

Technical Report WF/90/6
MRP Report 114

The Mineral Reconnaissance Programme 1990

H W Haslam, D G Cameron
and A D Evans

Technical Report WF/90/6

Mineral Resources Series

The Mineral Reconnaissance Programme 1990

*A continuing programme of mineral exploration in the
United Kingdom carried out by the British Geological
Survey on behalf of the Department of Trade and Industry*

Cover illustration

Blasting in the open pit at the Foss baryte mine, near Aberfeldy. The white dust comes from the baryte deposit, the darker dust from the graphitic-schist wall rock.

Photo courtesy of MI Great Britain Limited.

This report was prepared for the
Department of Trade and Industry

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Maps and diagrams in this report use
topography that is based on Ordnance
Survey mapping

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Mineral Reconnaissance Programme Report 114

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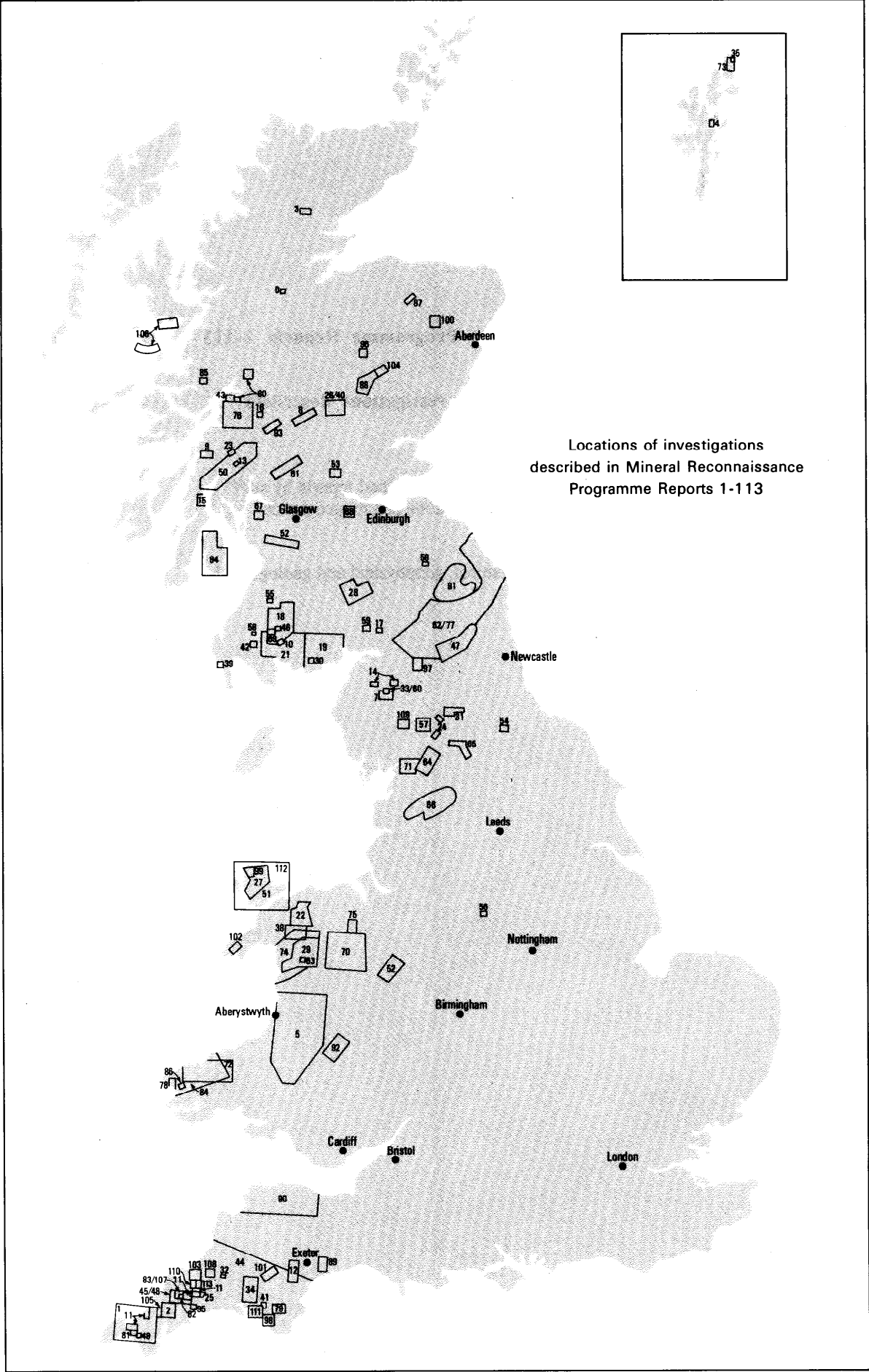
This report relates to work carried out by the British Geological Survey on behalf of the Department of Trade and Industry. The information contained herein must not be published without reference to the Director, British Geological Survey.

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Locations of investigations described in Mineral Reconnaissance Programme Reports 1-113

Introduction

The background

Mining for non-ferrous metals, which in the past had occupied an important position in the British economy, had, by the 1960s, declined to a very low level. Towards the end of that decade, however, the industry was showing some signs of recovery, with exploration for copper and gold in North Wales, development work at a few sites, notably in the north of England, and the opening of the Wheal Jane tin mine in Cornwall. However, mining companies had little or no experience of prospecting in this country, and the complexities of land and mineral-rights ownership meant that access was more difficult than in the overseas territories where they were accustomed to working.

Against this background, and in order to encourage exploration and mining for the non-ferrous metals and related commodities, three schemes were initiated, funded by the British government's Department of Trade and Industry, which together have done much to facilitate the revival of the industry. The British Geological Survey's Mineral Reconnaissance Programme (MRP) is a nationwide programme of mineral exploration and investigation. Its purpose is to stimulate private-sector exploration by identifying new areas with potential for metalliferous and associated minerals. At the same time, the Geochemical Survey Programme, also operated by the the British Geological Survey, is systematically collecting geochemical data from the whole country, based on high-density sampling of stream sediments. Together, these two programmes are establishing a database of national importance both for mineral exploration and for environmental studies. Additionally, from 1972 to 1984 the Department of Trade and Industry provided financial assistance to industry through the Mineral Exploration and Investment Grants scheme.

The Mineral Reconnaissance Programme

The Mineral Reconnaissance Programme began in 1972. From the start it has been multidisciplinary, drawing on the wide range of geochemical, geophysical and geological expertise available in the Survey, in a way not previously used in this country. Tried and tested field techniques have been adapted to local conditions and have been complemented by newly developed high-technology methods of chemical and mineralogical analysis and data handling, interpretation and presentation.

Three factors, particularly, give the British Geological Survey an advantage over other organisations in implementing an exploration programme on this scale: first, the size of the organisation, with the wide range of expertise that can be called upon to contribute to the programme; secondly, the comprehensive databases and archives in its possession, unequalled in this country; and, thirdly, the statutory remit of the Survey to carry out geological investigations throughout the country, which enables its staff to operate without the access difficulties that might be experienced by a commercial organisation.

Initially the emphasis within the MRP was on base metals, but in response to changes in national and market requirements, effort later became focused on strategic metals such as manganese and tungsten and on other commodities such as baryte, gold and the platinum-group metals. Increasingly, the intention is to keep ahead of the market in the search for resources for which a demand can be anticipated, or for which security of supply might be required.

The success of the MRP can be measured by the amount of private-sector exploration and development that has followed from its initiatives. A large number of the prospects identified by the Programme have merited further investigation, and it is estimated that between 30% and 50% of the investigations reported by the MRP have attracted commercial interest.

Through the work of the MRP, a world-class deposit of stratabound baryte and base metals was discovered near Aberfeldy in the Scottish Highlands. This deposit is currently being mined with an annual output of some 50 000 t of baryte. More recent work in the

southwest of England has revealed unexpected possibilities for gold mineralisation over a wide area and in a variety of geological environments. Here the careful application of geochemical, mineralogical and geophysical techniques has, in an area of poor natural exposure, provided sufficient positive indications to attract exploration companies to the area. In North Wales, MRP data have been used as a basis for strategic planning in exploration for base metals. Other MRP investigations that have stimulated further work on the part of the private sector include those at Vidlin in Shetland (for base metals), in near-shore waters off the island of Rhum, northwest Scotland (for chromite), at Kilmelford in the Scottish Highlands (for copper and gold), at Foreburn in southwest Scotland (for gold) and in the Craven Basin in northern England (for base metals).

Reports and publications

The results of the Programme are published in a series of reports, the Mineral Reconnaissance Programme Report Series. By early 1990, 113 of these reports had been issued. The locations of the investigations covered by each report are shown on the map facing page 1.

These MRP Reports are summarised in the pages that follow. The summaries are adapted from compilations first published in 1982, 1987, 1988 and 1989 in the *Transactions of the Institution of Mining and Metallurgy (Applied earth science section)*.

Copies of the reports are available through the Book Sales section of the British Geological Survey. Staff employed on the MRP are available to discuss the investigations described in the reports and to offer whatever assistance is required to those interested in taking investigations further. The database of information that has been assembled during the course of the Programme, together with the wealth of practical experience, offers invaluable assistance to any mining company undertaking mineral reconnaissance in Britain. Enquiries should be made in the first instance to Dr J A Plant or J H Bateson, British Geological Survey, Keyworth, Nottingham, NG12 5GG, UK (telephone: 06077 6111; telex: 378173 BGSKEY G; fax: 06077 6602).

In addition to the MRP Reports, a large number of papers and reports have been written describing investigations, methods and results pertinent to the MRP. The selection listed towards the end of this volume gives an impression of the range of skills and experience acquired in BGS over the past twenty years in the fields of mineral deposit studies and exploration techniques.



Summaries of Mineral Reconnaissance Programme Reports 1-113

1 The concealed granite roof in south-west Cornwall

K E Beer, A J Burley and J M C Tombs (1975)

This report outlines the results of gravity surveys and drilling to locate cusps in the concealed granite roof north and west of the Carnmenellis granite outcrop. The results are plotted as Bouguer anomaly maps. Three other maps are presented that show the results of similar surveys to the north of the St. Austell granite. The surveys around the Carnmenellis granite show that shallower-depth prolongations of outcropping granites can be defined, but that smaller or more deeply buried rises in the roof are not easily recognisable. The relationships between mineralisation, porphyry intrusion and granite eminences are considerably more complex than had been postulated previously. A borehole at Bosworgy penetrated greisenised granite. A hole at Parbola failed to reach a postulated granite cusp but found cassiterite in some narrow quartz-chlorite veins and a complex Cu-Pb-Zn lode. It is concluded that the location of concealed cupolas is likely to define areas of future mineral potential.

2 Geochemical and geophysical investigations around Garras Mine near Truro, Cornwall

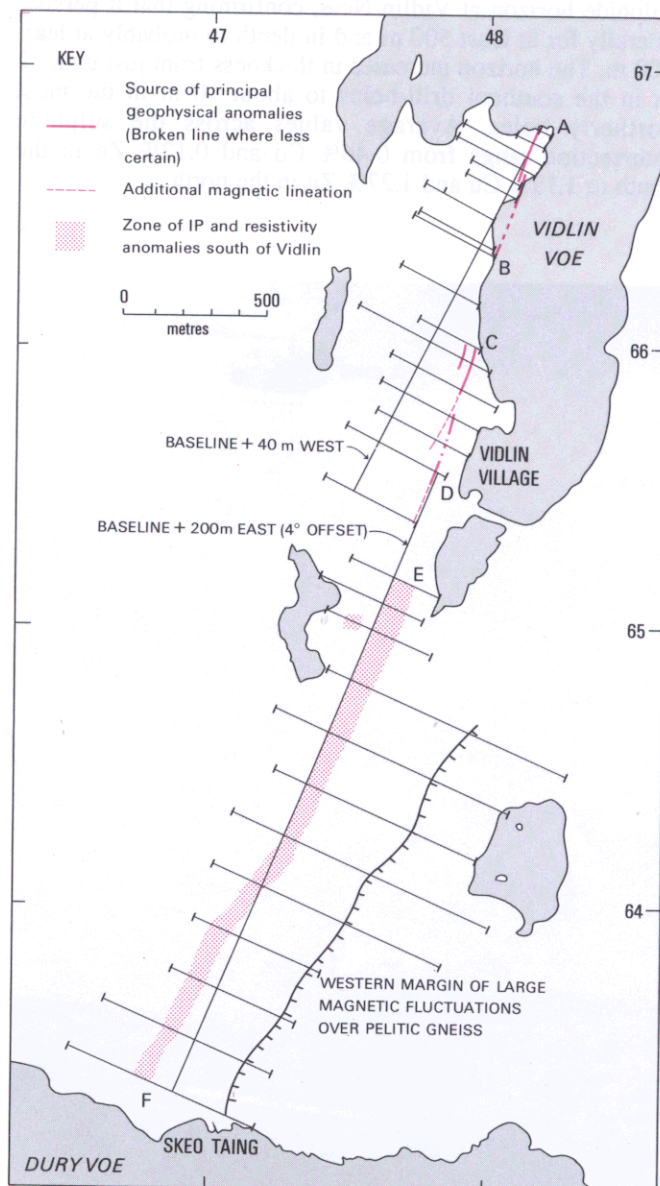
R C Jones and J M C Tombs (1975)

Detailed geochemical and geophysical surveys indicated that only very limited extensions exist to the Pb-Ag lodes in Devonian sediments previously worked at Garras.

3 Molybdenite mineralisation in Precambrian rocks, near Lairg, Scotland

M J Gallagher and R T Smith (1976)

Low-grade molybdenite mineralisation is intermittently exposed in Moinian and Lewisian rocks intruded by Caledonian granites to the west of Lairg in Sutherland. Molybdenite occurs with pyrite in thin post-foliation quartz veins and as coatings to joints and foliation planes in the schists and gneisses. Chalcopyrite, fluorite and bismuth minerals sometimes occur as accessories. Galena, baryte and sphalerite are also present in narrow brecciated zones and small veins. Sampling of sparse rock exposures and of cores from a series of shallow boreholes drilled through peat and glacial deposits shows the Mo and Cu concentrations to average less than 100 ppm. The regional distribution of mineralisation appears to be related to the presence of small late-Caledonian granites that contain traces of molybdenite, but the local controls are mainly structural and include zones of thrusting associated with the Moine-Lewisian boundary.



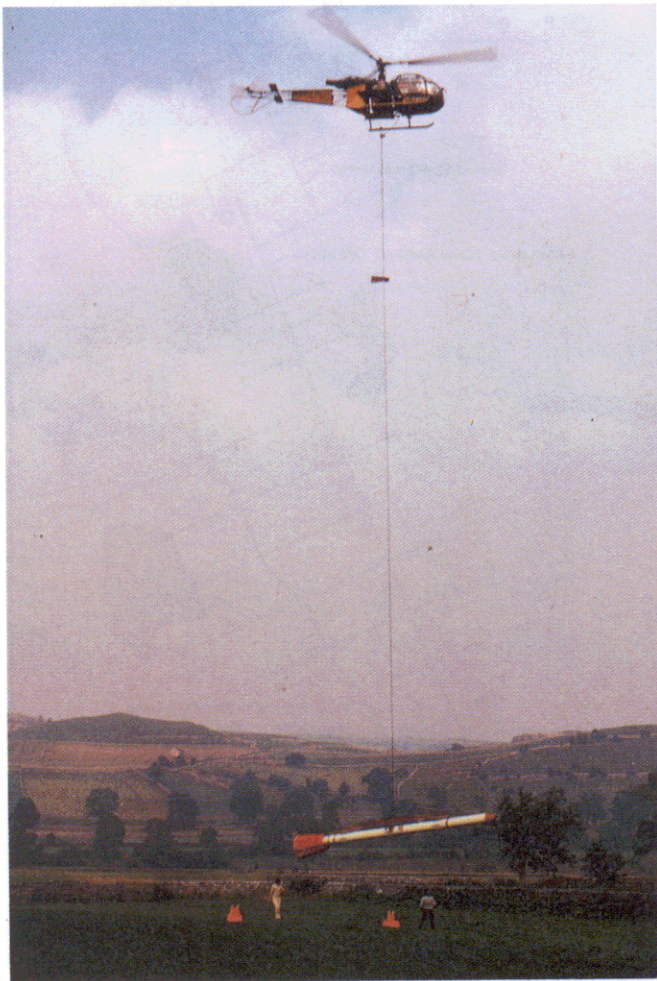
Geophysical anomalies associated with sulphide mineralisation, Vidlin, Shetland (Report No. 4)

4 Investigation of copper mineralisation at Vidlin, Shetland

M S Garson, F May and others (1976)

The mineralisation occurs in an amphibolitic belt (possibly metamorphosed tholeiitic lavas) and consists of a strata-bound sulphide horizon outcropping at four localities at Vidlin Ness within a Dalradian succession of dominant calcisilicate granulites and minor marbles and semi-pelitic gneisses. The massive sulphides comprise mainly pyrrhotite and interesting amounts of chalcopyrite, sphalerite and galena, associated with sulphide-bearing quartz rock and

tremolite rock. A southern extension of the mineralisation is indicated by linear geophysical anomalies and occasional outcrops of sulphide-bearing amphibolite. At the northern end, well-defined EM and magnetic anomalies suggest that the belt of massive sulphides at Vidlin Ness has a strike length of at least 1000 m. Six drill-holes penetrated the sulphide horizon at Vidlin Ness, confirming that it persists laterally for at least 500 m and in depth to probably at least 100 m. The horizon increases in thickness from just under 2 m in the southern drill-holes to about 10 m in the most northerly holes. Average values across the sulphide intersection range from 0.46% Cu and 0.12% Zn in the south to 1.19% Cu and 1.27% Zn in the north.



Techniques of mineral exploration. Helicopter magnetic, EM and radiometric survey

5 Preliminary mineral reconnaissance of Central Wales (also published as *Rep. Inst Geol. Sci.*, No. 75/14)

T K Ball and M J C Nutt (1975)

Numerous lodes in the Lower Palaeozoic mudstones, shales and sandstones of Central Wales have been worked, principally, for Cu, Pb, Zn and Ag. This report presents 1:100 000 geochemical maps for Cu, Zn and Pb in stream waters, Mn, Cu, Zn, Sn, Ba and Pb in stream sediments, and

Zn, Ba, Ce and Pb in panning concentrates for the Central Wales mining field, together with a geological map and a list of named mines. It is concluded that future potential lies in the extension, under cover and at depths greater than 130 m, of known base-metal lodes.

6 Report on geophysical surveys at Struy, Inverness-shire

A J Burley (1976)

Geophysical surveys carried out over two veins containing Pb and Zn mineralisation in Moine schists and granulites in Strath Glass showed that resistivity lows coincide with both veins, and also that the adits are probably located in the areas of most concentrated mineralisation. There was an indication that one of the veins may extend to the west, but the size and ore content of the exposed deposits are insufficient to make them of economic importance.

7 Investigation of tungsten and other mineralisation associated with the Skiddaw Granite near Carrock mine, Cumbria

J D Appleton and A J Wadge (1976)

The W mineralisation at Carrock mine is closely associated with a greisenised cupola of the Caledonian Skiddaw granite, and in the investigation described in this report similar cupolas were tested for W veins. Analyses of stream sediments, panned concentrates and rock samples indicate anomalous W and As values from an area west of the mine, and further exploration is suggested. Analytical data are presented for Ti, Mn, Fe, Cu, Zn, As, Mo, Sn, Ba, W, Au, Pb and U.

8 Investigation of stratiform sulphide mineralisation in parts of central Perthshire

C G Smith and others (1977)

Detailed geological mapping in the area north and west of Loch Tay confirmed the presence of a weak but persistent zone of pyritic mineralisation, and subsequent reconnaissance surveys showed it to have considerable lateral extent. It was found, however, to contain only minor amounts of chalcopyrite and no other base-metal sulphides. Chemical analyses of rock samples showed that Cu, the most abundant base metal, seldom averages more than 60 ppm, though locally it exceeds 1000 ppm. A limited number of Au analyses failed to confirm a previous report of anomalously high concentration.

9 Investigation of disseminated copper mineralisation near Kilmelford, Argyllshire, Scotland

R A Ellis and others (1977)

Geological and geophysical surveys and geochemical sampling (drainage, soil, deep till and rock) showed the

presence of low-grade Cu and Mo mineralisation over an area of approximately 1500 m x 800 m associated with a Caledonian dacitic porphyry. The sulphide mineralisation shows features characteristic of porphyry-style mineralisation. It is in the form of blebs and veinlets associated with quartz-carbonate vein stockworks and is accompanied by pervasive hydrothermal alteration. Two boreholes were drilled, and maximum assays of 0.34% Cu over 2.15 m and 0.04% Mo over 1.80 m were obtained. Further drilling is recommended.



Banded baryte, Teign Valley (Report No. 12)

10 Geophysical surveys around Talnoy mine, Kirkcudbrightshire, Scotland

M E Parker (1977)

Magnetic field and VLF electromagnetic surveys were performed to investigate the Ni-Co lode at the contact between a diorite and Silurian greywackes in the aureole of the Cairnsmore of Fleet intrusion. No significant anomalies were found in the area, except over the small amount of mineralisation already known.

11 A study of the space form of the Cornubian granite batholith and its application to detailed gravity surveys in Cornwall

J M C Tombs (1977)

A three-dimensional computer model of the Cornubian granite batholith, defined by polygonal contours, was created so that its calculated gravity field matched the observed Bouguer anomaly field both onshore and offshore. The model was used to define a background ('regional') field in three areas where detailed gravity surveys had been undertaken in the search for shallow granite. Maps of depth to granite were produced from the residual field by an iterative technique. Geological interpretations of the batholith model and of the depth maps are included in the report.

12 Mineral investigations in the Teign Valley, Devon. Part 1—Barytes

K E Beer and T K Ball (1977)

Geochemical studies in the Teign Valley, carried out on stream sediment and soil samples, have indicated extensions of baryte mineralisation some 2.5 km north and 1.2 km south of the formerly mined strike length in Upper Palaeozoic sediments. Ba-Pb-Zn mineralisation is now known to extend over a total length of 12.3 km and over a width rarely less than 0.5 km, though orebodies large enough to be worked occur only intermittently within this belt. Part of the southern extension was investigated by deeper sampling, a percussive drill being used to obtain powdered rock samples for assay. To the south of Hennock village a baryte-rich zone has been defined, some 1.2 km long and 260 m wide.

13 Investigation of stratiform sulphide mineralisation at McPhun's Cairn, Argyllshire

C G Smith and others (1977)

A small stratiform occurrence of massive sulphide, apparently over 2 m thick, occurs in the Dalradian schists at McPhun's Cairn beside Loch Fyne. At outcrop it contains 3.5% Zn, 3.0% Pb, 6 ppm Ag and 0.75 ppm Au. Geological, geophysical (IP, magnetic, resistivity) and geochemical (soil, stream sediment, panned concentrate) surveys and shallow drilling indicate the presence of only sporadic weak mineralisation. Regional structural analysis and examination of the mineralisation suggest that local concentration of sulphides occurred at the nose of a steeply plunging small fold system. A borehole to investigate the outcrop occurrence proved the extension of mineralisation down the fold axis.

14 Mineral investigations at Woodhall and Longlands in north Cumbria

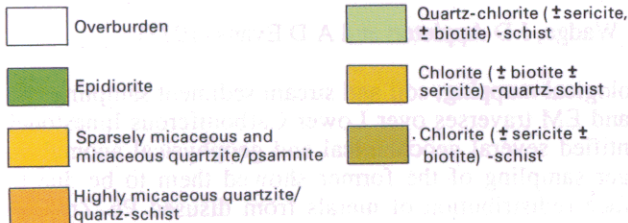
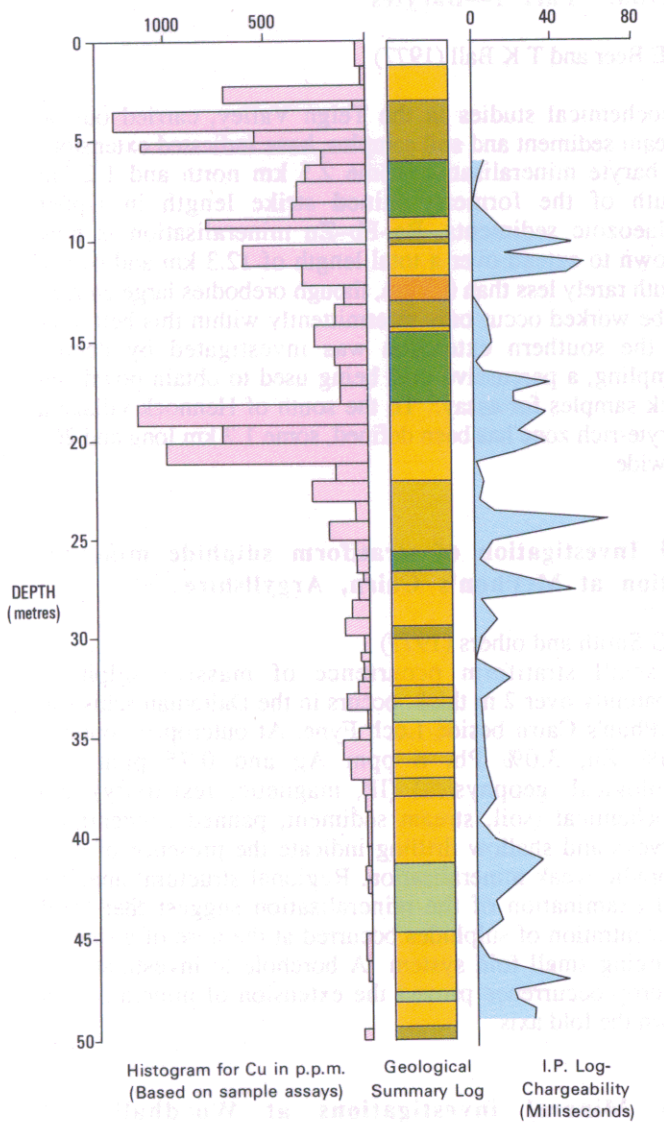
A J Wadge, J D Appleton and A D Evans (1977)

Geological mapping, soil and stream sediment sampling and IP and EM traverses over Lower Carboniferous limestones identified several geochemical and geophysical anomalies. Auger sampling of the former showed them to be due to surface redistribution of metals from disused Pb-Zn-Cu-baryte mines, whereas the weak geophysical anomalies in themselves do not constitute viable drilling targets.

15 Investigation of stratiform sulphide mineralisation at Meall Mor, South Knapdale, Argyll

C G Smith and others (1978)

A geochemical-geophysical-geological investigation of Cu mineralisation in the Meall Mor area was followed by the drilling of six shallow holes. The mineralisation occurs in a zone of weak stratiform sulphide mineralisation (the pyrite zone) with a strike length of 10 km in the Upper Erins



Graphic log of Borehole 1, Meall Mor (Report No. 15)

Quartzite of the Middle Dalradian. A geochemical drainage survey showed the existence of a strongly anomalous distribution of Cu and Sb in the Abhainn Srathain, which drains south from Meall Mor. Detailed soil and basal till sampling over the pyrite zone outlined a broad area enriched in Cu, and a coincident IP anomaly was found that stretched from Meall Mor south to the old mine workings on Abhainn Srathain and had probably been caused by a local enrichment of pyrite and chalcopryrite within the pyrite zone. Cu values range up to 0.24% Cu over 4.27 m in the first two holes and up to 1.06% Cu over 2.67 m in the third. This enrichment

may be related to a later remobilisation of the disseminated chalcopryrite.

16 Report on geophysical and geological surveys at Blackmount, Argyllshire

C G Smith and G R Marsden (1977)

The underlying Precambrian Moine psammite at Blackmount, on the southern fringe of Rannoch Moor, contains granitic veins that probably stem from the adjacent Moor of Rannoch granite. These veins are generally pyritiferous and, at one locality, carry small amounts of molybdenite. Blackmount is also traversed by the Ericht-Laidon Fault, which, in theory and by analogy with the Tyntrum Fault, could be a site of significant sulphide mineralisation. Magnetic, VLF-EM, Slingram EM and induced polarisation measurements which were carried out in the area of the veins suggest that the mineralisation has little or no lateral or depth continuation. Similar surveys were successful in locating the Ericht-Laidon Fault beneath drift, but suggest that to the greatest depth that was investigated no associated mineralisation is present.

17 Lead, zinc and copper mineralisation in basal Carboniferous rocks at Westwater, south Scotland

M J Gallagher and others (1977)

A zone of Pb, Zn and Cu mineralisation is developed over a minimum of 4 km of strike of basal Carboniferous cementstone group sediments and immediately underlying Birrenswark Lavas at Westwater, near Langholm. Grades in sparse rock exposures and shallow boreholes are usually 0.1–0.3% of combined metals over 1–2 m of thickness, but a fissure vein of higher grade and a relatively thick zone of disseminated sulphides were also located. Galena, sphalerite, chalcopryrite and baryte occur mainly in thin dolomite veins, but disseminations of galena are also present in sandstone units. The mineralisation is of low-temperature type and was emplaced along northeasterly-trending normal faults and cross faults regarded as late Carboniferous in age. Mineralisation was controlled by faulting, regional facies variation and local lithological variation, as well as by stratigraphic position. The heavy mineral fraction of stream sediment is the optimum sampling type in reconnaissance exploration of areas of calcareous rocks, such as the Lower Carboniferous of south Scotland, and basal till sampling is the most effective method of follow-up exploration in those areas where glacial deposits are widespread and often thick.

18 A mineral reconnaissance survey of the Doon-Glenkens area, south-west Scotland

J Dawson and others (1977)

Geological, geophysical and geochemical surveys were carried out over the Loch Doon and Carsphairn granites and the surrounding Lower Palaeozoic sediments. Geochemical drainage surveys led to the discovery of several occurrences of

Cu, Pb, Zn, Mo, W and Au. Airborne electromagnetic and magnetic surveys showed prominent anomalies associated with belts of black shales.

19 A reconnaissance geochemical drainage survey of the Criffel–Dalbeattie granodiorite complex and its environs

R C Leake, M J Brown, A R Date and T K Smith (1978)

Regional geochemical maps, compiled from multi-element analysis of stream sediments (Li, Be, B, MgO, K₂O, CaO, TiO₂, V, Cr, Mn, Fe₂O₃, Co, Ni, Cu, Zn, Ga, Rb, Sr, Zr, Mo, Sn, Ba, Pb, U) and panned concentrates (Ca, Ti, Mn, Fe, Ni, Cu, Zn, Y, Zr, Nb, Sn, Sb, Ba, Ce, Pb, Th, U) show patterns of element distribution related to geology and mineralisation of the region. Broad-scale patterns in the distribution of some elements reflect compositional variations in both the Lower Palaeozoic turbidite sequence and the Criffel–Dalbeattie granodiorite complex, both of which may be sub-divided into specific units on the basis of the geochemical data.

The follow-up of Cu anomalies in drainage samples from the Black Stockarton Moor area led to the discovery of porphyry-style Cu mineralisation (Report No. 30) and related disseminated Cu mineralisation at Screel Burn. The area to the west of the Criffel–Dalbeattie plutonic complex is also characterised by relatively high B levels in stream sediments, which reflect the widespread occurrence of tourmaline both in association with and peripheral to the Cu mineralisation. Vein mineralisation, usually containing baryte in addition to base metals, is identifiable from the drainage survey at the eastern margin of the Criffel–Dalbeattie granodiorite, in association with the Lower Carboniferous rocks along the Solway coast, and within the Lower Palaeozoic turbidites in the west of the area.

20 Geophysical field techniques for mineral exploration

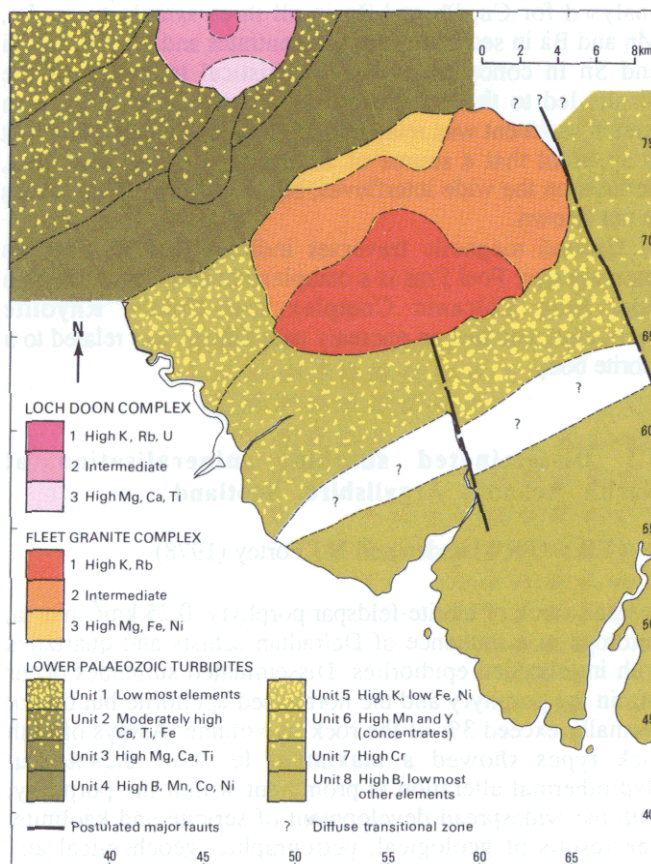
A J Burley, J D Cornwell and J M C Tombs (1978)

Details are given of the geophysical equipment and methods used in airborne and ground surveys for the Mineral Reconnaissance Programme. Airborne surveys employ magnetic, electromagnetic and radiometric equipment. Ground surveys use electromagnetic (Slingram, Turam and VLF), resistivity and induced polarisation, magnetic and gravity methods. Borehole logging methods are also described and six case histories are given.

21 A geochemical drainage survey of the Fleet granitic complex and its environs

R C Leake, M J Brown, T K Smith and A R Date (1978)

Data from multi-element analysis of stream sediments and heavy mineral concentrates are presented in geochemical maps. (The elements are the same as in Report No. 19, except that Sn is not considered in sediments.) Broad-scale patterns exhibited by some elements make possible the



Interpretation of the geology of the Fleet granitic complex and the surrounding area based on drainage geochemistry (Report No. 21)

division of the sedimentary rocks into eight distinct geochemical units, each characterised by different element distribution patterns. The Fleet and Loch Doon plutons are sub-divided on the same basis.

Follow-up investigations of drainage anomalies led to the discovery of both structure-controlled and disseminated base-metal mineralisation in the Penkiln drainage basin within the southern aureole of the Loch Doon granite. The distribution of Cu, Pb and Zn, to the south and southwest of the Fleet granite suggests a zonation of vein mineralisation, with Cu prominent adjacent to the granite contact and Pb and Zn having a wider dispersion away from the granite. Other anomalies delineate a mineralised lineament following the regional strike of the Lower Palaeozoic sediments, southeast of the Fleet granite.

22 Geochemical and geophysical investigations north-west of Llanrwst, North Wales

D C Cooper and K E Rollin (1978)

Anomalous Zn values had been found in previous regional-scale stream sediment surveys over Ordovician volcanic and sedimentary rocks northwest of the former Llanrwst mining field. To find the source of these anomalies stream sediment, panned concentrate and stream water samples were collected from 28 sites in the Afon Dulyrn and Llyn Eigiau areas and

analysed for Cu, Pb and Zn in all three sample types, Fe, Mn and Ba in sediments and concentrates and Ce, Ca, Ni, Ti and Sn in concentrates only. Statistical treatment of the results led to the conclusion that most of the high Zn in stream sediment was related to hydrous oxide precipitates. It is apparent that a source of Zn exists in the general area, perhaps on the wide interfluvies, but the nature of this source is not known.

Ground magnetic traverses indicate that an airborne anomaly over Foel Fras is a complex anomaly caused by the Foel Fras Volcanic Complex and Conwy Rhyolite Formation, and that an anomaly near Drosgl was related to a diorite body.

23 Disseminated sulphide mineralisation at Garbh Achadh, Argyllshire, Scotland

R A Ellis, G R Marsden and N J Fortey (1978)

A small stock of biotite-feldspar porphyry, 0.25 km² in area, outcrops in a sequence of Dalradian schists and quartzites with interbedded epidiorites. Disseminated sulphides occur within the porphyry and the hornfelsed epidiorite but do not normally exceed 3% of the rock by volume. Assays of both rock types showed a maximum level of 0.24% Cu. Hydrothermal alteration is prominent within the porphyry, with the widespread development of sericite and kaolinite. The results of geological, petrographic, geochemical and geophysical studies demonstrate the presence of several features characteristic of porphyry-style mineralisation, but the small surface area and low grade of the deposit, combined with a lack of encouraging geophysical responses at depth, suggest that there is little chance of discovering an economic orebody. Several small strata-bound lenses of massive sulphide within the metasediments were recorded, but were not investigated in detail.

24 Geophysical investigations along parts of the Dent and Augill Faults

J D Cornwell, D J Patrick and J M Hudson (1978)

Airborne electromagnetic (AEM), radiometric and magnetic surveys were conducted over selected parts of the Dent and Augill Faults, followed, at the most promising anomalies, by ground EM surveys employing VLF, Turam and Slingram methods and by detailed geological mapping. A gravity survey was undertaken to provide Bouguer anomaly data typical of the margins of the Lower Carboniferous blocks in the northern Pennines. Five AEM anomalies were attributed to conductive shale or mudstone horizons in the Carboniferous sequence. The VLF and Turam methods produced anomalies at Kitchen Gill and Birkett Common, which correlate with faults and mudstone outcrops. Anomalies at Long Rigg and Dowgill are thought to be due to conductive boulder clay. The regional gravity survey indicated that the main faults are characterised by weak Bouguer anomaly highs. Other anomalies probably reflect variations in the basement. Such changes may be generally useful in defining the boundaries of uplifted blocks of basement rocks.



Techniques of mineral exploration. Drainage survey: collection of minus 100 mesh stream sediment and panned concentrate

25 Mineral investigations near Bodmin, Cornwall. Part 1—Airborne and ground geophysical surveys

J M C Tombs (1978)

Airborne magnetic and electromagnetic surveys and ground follow-up showed that airborne geophysical methods are unsuited to this area. No significant new mineralised areas were located.

26 Stratabound barium-zinc mineralisation in Dalradian schist near Aberfeldy, Scotland: Preliminary report

J S Coats, C G Smith and others (1978)

See summary of Final Report (Report No. 40)

27 Airborne geophysical survey of part of Anglesey, North Wales

I F Smith (1979)

An airborne magnetic, electromagnetic and radiometric survey was carried out over most of the northwestern half of Anglesey. The EM and radiometric results show little of interest, but the magnetic results, presented as an aeromagnetic map, show prominent anomalies associated with the Carmel Head Thrust, with Tertiary dykes and with various hornfels bodies. Possible extensions of known ultrabasic bodies and areas where other such potentially mineralised bodies may be concealed are indicated, in particular near Llandyfydog and near the coast south of Valley.

28 A mineral reconnaissance survey of the Abington-Biggarr-Moffat area, south-central Scotland

J Dawson, J D Floyd and P R Phillip (1979)

Panned heavy mineral concentrates from an area underlain mostly by Lower Palaeozoic sedimentary rocks were examined for heavy detrital minerals and analysed for Ca, Ti, Cr, Mn, Fe, Ni, Cu, Zn, As, Mo, Sn, Sb, Ba, Ce and Pb. Numerous new occurrences of Pb, Zn, Cu and Ba minerals were found, and nine areas are recommended for further investigation. Minor amounts of baryte and traces of cuprifera pyrite were identified in the basal breccia of the New Red Sandstone deposits in Annandale. The Hg mineral, cinnabar, was identified for the first time in Scotland. Chromiferous spinel is a major constituent in the majority of panned samples. Corundum is widely dispersed in trace amounts. Historical references to a wide distribution of particle gold were confirmed and many new occurrences found. Some placer concentration of gold and chromiferous spinel is likely in the alluvium of the valleys of the River Tweed and the Megget Water. Six greywacke formations were mapped in the project area, each distinguished by a characteristic lithology and heavy mineral content.

29 Mineral exploration in the Harlech Dome, North Wales

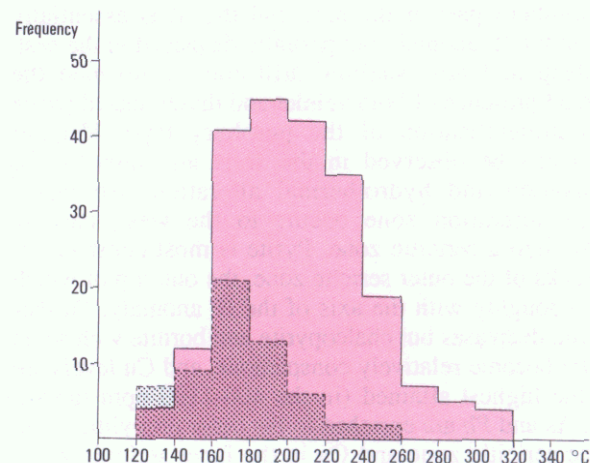
P M Allen, D C Cooper and I F Smith (1979)

This report presents the results of an airborne geophysical (electromagnetic, magnetic and radiometric) survey of the eastern part of the Harlech Dome and the consequent geological, geochemical and geophysical investigations carried out on the ground and in the laboratory. The area is underlain predominantly by Lower Palaeozoic sedimentary and volcanic rocks.

The airborne magnetic and EM results show a complex pattern of anomalies, but little variation is apparent from the aeroradiometric data. Ground studies of aeromagnetic anomalies demonstrated that they are related either to magnetite present in some sandstones and igneous rocks, or, more importantly, to pyrrhotite enrichments in several lithologies. Mineralogical studies showed that, whereas some enrichments in siltstones and mudstones are probably syngenetic in origin, others are possibly related to epigenetic concentrations produced during vein mineralisation. A study of the EM anomalies showed that many of them are related to comparatively low concentrations (<3%) of carbonaceous material or non-commercial quantities of sulphides in the dark mudstones of the Dolgellau Member and Clogau Formation. An interpretation of the radiometric data confirmed that the only indications of uraniferous enrichment occur in the black mudstones of the upper Cambrian Dolgellau Member.

A rock geochemistry study indicated that statistical treatment of rock analysis could be used to distinguish intrusions associated with porphyry-style mineralisation. It also showed that the porphyry-style mineralisation at Coed-y-Brenin is probably cogenetic with the end-Tremadoc magmatism that gave rise to both the volcanic pile on

Rhobell Fawr and intermediate intrusions in the Cambrian, and therefore is quite distinct from the end-Silurian quartz-sulphide vein mineralisation. Intrusion breccias, which are also linked to the Rhobell Fawr volcanism, were recognised in the area for the first time. One of them contains the worked-out Glasdir Cu deposit. Fluid inclusion studies showed differences between quartz veins associated with the vein and disseminated styles of mineralisation, which may be useful in exploration.



Homogenisation temperatures of primary inclusions for vein (coloured) and disseminated (shaded) styles of mineralisation (Report No. 29)

Ground follow-up work showed indications of mineralisation in many of the areas examined. Among these, the possibility of vein and strata-bound Pb and Zn mineralisation was found at Hengwrt Uchaf and Benglog. At Bryn Coch, Tyddyn Gwladys and Hafod Fraith possible associated but separate bodies or extensions to the proved porphyry-type Cu deposit at Coed-y-Brenin were identified, as was, also, modest vein mineralisation.

In three areas—Mynydd Foel Uchaf, Hafod-y-fedw and Y-Gors—dispersed epigenetic sulphide mineralisation in bedrock was found, mainly pyrrhotite with sub-economic base-metal sulphides. Similar metalliferous concentrations were tentatively identified in a number of other areas, which included Garth Gell, where pilot studies were carried out on coincident EM and magnetic anomalies. At Mynydd Bach, Craiglaseithin and Dol Haidd there are indications of either new veins or extensions to known veins containing Cu, Pb and Zn and, at Craiglaseithin and Dol Haidd, feeble disseminated Cu mineralisation also; here, too, the metal concentrations are considered sub-economic. Ffridd Dol-y-moch and Waun Hir are both drift-covered areas that may conceal mineralisation, but exploration is hampered by contamination problems. At Nannau, slight Cu enrichment was found in volcanic rocks which are believed to be cogenetic with the Coed-y-Brenin porphyry Cu deposit.

Recommendations are made for further work at Glasdir, in the Coed-y-Brenin area, at Hengwrt Uchaf and Benglog, at Ffridd Dol-y-moch and Nannau. Further investigations are also recommended on the nature and extent of the sulphide concentrations in the Clogau Formation.

30 Porphyry style copper mineralisation at Black Stockarton Moor, south-west Scotland

M J Brown, R C Leake, M E Parker and N J Fortey (1979)

A Caledonian multiphase subvolcanic complex intruding Lower Palaeozoic turbidites to the west of the Criffel granodioritic plutonic complex has been mapped. An induced polarisation survey delineated an arcuate anomaly about 6 km long, and a geochemical soil survey showed that there is a zone with anomalous levels of Cu (from 140 to 5500 ppm) in the southern part of the area and that it is essentially parallel to the IP anomaly but partially displaced to the east. Three deep and nine shallow drill-holes confirmed the widespread presence of both veinlet and disseminated pyrite and Cu mineralisation of the porphyry type. Regular zonation can be observed in the style and intensity of mineralisation and hydrothermal alteration. An outer, propylitic alteration zone occurs to the west, passing eastwards into a sericitic zone. Pyrite is most conspicuous within rocks of the outer sericitic zone, the outcrop of which coincides roughly with the axis of the IP anomaly. Further east, pyrite decreases but chalcopyrite and bornite with some chalcocite become relatively conspicuous, and Cu levels are among the highest attained (in the 400-1100 ppm range). Mn, Zn, As and Pb are enriched in the outer propylitic zone, Ba in the sericitic zone and Cu in the inner sericitic zone, whereas As, Sb and Au are concentrated with Cu and Mo in isolated brecciated sections.



Techniques of mineral exploration. Measurement of gravity. The theodolite is for accurate determination of station elevation

31 Geophysical investigations in the Closehouse-Lunedale area

J D Cornwell and A J Wadge (1980)

The area around the Lunedale Fault and the Closehouse baryte mine, at the northern edge of a deep Carboniferous sedimentary basin, was investigated by an airborne magnetic, EM and radiometric survey. The Whin dolerite gives rise to pronounced magnetic features, some of which indicate previously unknown intrusions. The Closehouse baryte

deposit is related to the distribution and alteration of the Whin dykes, and ground investigation of the aeromagnetic anomalies is recommended. Ground follow-up of EM anomalies was incomplete, but the four areas that were studied show no indications of mineralisation.

32 Investigations at Polyphant, near Launceston, Cornwall

M J Bennett, K Turton and K E Rollin (1980)

Geological examination, shallow boreholes and geochemical soil sampling over the Polyphant ultrabasic igneous mass indicate a marked variation in composition, with at least two types of peridotite and two of gabbro. The distribution of Ni, Co and Cr in overlying soil gives an impression of macro-layering within the peridotite, but the concentration levels of these metals, and of Cu, are normal or low for peridotite and gabbro and offer little prospect of layered base-metal orebodies being found. No significant mineralisation was indicated by the investigations, but high IP values at the southern margin of the complex may be due to minor sulphide concentrations.

33 Mineral investigations at Carrock Fell, Cumbria. Part 1—Geophysical survey

D J Patrick (1980)

A geophysical survey was conducted in the vicinity of the Carrock tungsten mine to establish an optimum geophysical exploration procedure for the location of the style of mineralisation known at Carrock. The VLF-EM method proved to be the best tool for this environment. It recorded only weak or indistinct anomalies over much of the known mineralisation, but a weak anomaly coincident with the Emerson vein was traced northwards for 1 km. Several similar linear features were recorded in the area on trends favourable for mineralisation, and two, at Poddy Gill in the east and Arm o'Grain in the west, are coincident for part of their strike with exposed mineralisation. These three anomalies appear to warrant investigation by drilling.

Resistivity measurements indicated that most fault structures have coincident low-resistivity zones; a detailed traverse across the Emerson vein showed a minor high-resistivity peak within the low zone.

Induced polarisation, magnetic and self-potential anomalies were recorded only within the gabbro on the extrapolated positions of the Smith and Wilson lodes. It is concluded that these anomalies are caused by discontinuous near-surface lenses of pyrrhotite (which have little VLF response).

34 Results of a gravity survey of the south-west margin of Dartmoor, Devon

J M C Tombs (1980)

A gravity survey (station density 4-6 per km²) of the southwestern margin of Dartmoor, including the Hemerdon stockwork, was interpreted with the aid of computer

techniques to indicate the depth to buried granite. The results show that the Hemerdon Ball granite is an isolated block that does not extend to depth and that no vertically continuous shallow granite occurs at any distance from the known outcrop. Various computer-graphics presentations of the data are given.

35 Geophysical investigation of chromite-bearing ultrabasic rocks in the Baltasound-Hagdale area, Unst, Shetland Islands

C E Johnson, C G Smith and N J Fortey (1980)

Economic deposits of chromite in Unst were worked intermittently until exhaustion of the known near-surface deposits in 1945. Since it is likely that further comparable deposits exist at shallow depth, detailed geophysical surveys employing gravity, magnetic and electrical methods were carried out over 1 km² of the area of known mineralisation to test the feasibility of detecting and delineating them. Seven of 16 small positive gravity anomalies were tested by shallow boreholes, but only two were attributed to chromite concentrations and the efficacy of geophysical techniques in the detection of chromite concentrations is unproven.

36 An appraisal of the VLF ground resistivity technique as an aid to mineral exploration

R D Ogilvy (1980)

A study of the VLF ground resistivity method confirmed that it is well suited to the mapping of broad mineralised zones, flat-lying conductors of limited lateral extent, or abrupt changes in conductivity associated with geological contacts. In resistive terrains the method offers distinct operational advantages over galvanic resistivity methods. The principal disadvantages of the technique relate to interpretational ambiguities associated with the complex behaviour of surface impedance at VLF and the fact that the operator has no effective control over the depth of investigation.

37 Compilation of stratabound mineralisation in the Scottish Caledonides

G S Johnstone and M J Gallagher (1980)

This report forms part of the United Kingdom contribution to the International Geological Correlation Programme Project 60, 'Correlation of Caledonian strata-bound sulphides'. Details of seven deposits are presented in tabular form, accompanied by a geological map of Scotland.

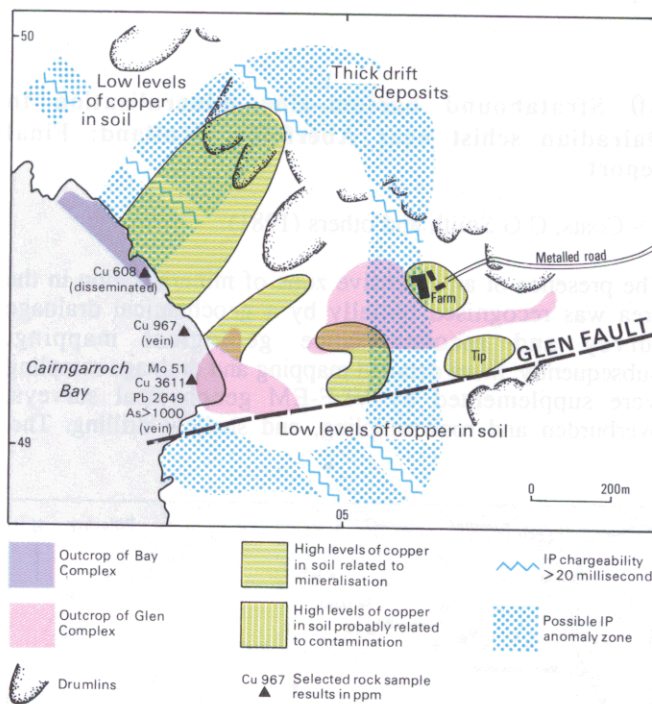
38 Geophysical evidence for a concealed eastern extension of the Tanygrisiau microgranite and its possible relationship to mineralisation

J D Cornwell, D J Patrick and R J Tappin (1980)

A Bouguer anomaly low near Blaenau Ffestiniog in North Wales, in an area of Lower Palaeozoic sedimentary and

igneous rocks, is interpreted as being due to a concealed eastward extension of the Tanygrisiau microgranite. The magnetite-bearing granite is also thought to be responsible for a pronounced aeromagnetic anomaly, which has a form that supports the gravity evidence for the eastward extension of the granite body but requires the extension of a magnetic body down to a depth of 15 km.

The mineralisation in the area consists of sulphide-bearing quartz veins. The veins occupy faults trending chiefly to the northeast, their distribution appearing to be mainly coincident with the southern flank of the concealed granite.



Summary of geological, geochemical and geophysical data for Cairngaroch Bay area (Report No. 39)

39 Copper-bearing intrusive rocks at Cairngaroch Bay, south-west Scotland

P M Allen and others (1981)

Two intrusion complexes, the Bay and the Glen, which probably represent an early phase of the Devonian magmatic episode, and a number of dykes are emplaced within a folded succession of Silurian sedimentary rocks at Cairngaroch Bay. The Bay Complex consists of microtonalite and granodiorite. The Glen Complex comprises quartz porphyry, porphyritic quartz microdiorite and quartz microdiorite. Local high-chargeability zones were identified along three geophysical traverse lines. Soil samples were collected on a 50-m grid over an area of IP anomalies. In addition, water, base of stope talus and rock samples were chemically analysed.

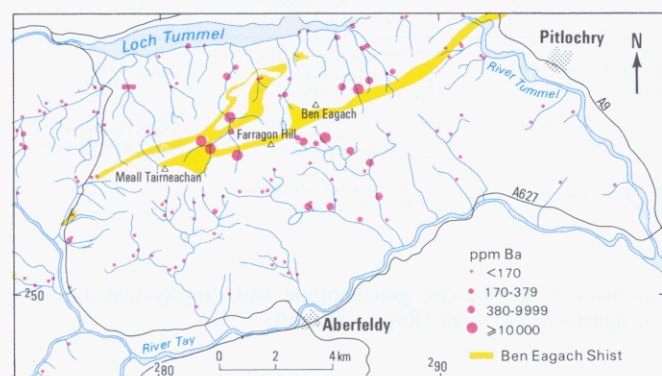
Both the intrusion complexes and some of the sedimentary rocks show locally intense hydrothermal alteration. In the Bay Complex narrow zones of bleached rock are rich in calcite, chlorite and pyrite and contain minor chalcopyrite and pyrrhotite. The Glen Complex displays

network fracturing, brecciation and locally intense alteration to sericite or calcite. There is locally abundant pyrite in veins and disseminated and rare chalcopyrite. Arsenopyrite is present in wallrock adjacent to the Bay Complex. Rock geochemistry indicates a pervasive but patchy Cu-Fe-As-Mo mineralisation in all rock types, with Cu values up to 600 ppm. The mineralisation is accompanied by irregular Ba, K and Sr enrichment. The K/Rb ratios suggest that the hydrothermal liquors were not entirely late magmatic. The mineralisation and alteration have some characteristics of a porphyry system and it is conceivable that Cu enrichment might increase with depth.

40 Stratabound barium-zinc mineralisation in Dalradian schist near Aberfeldy, Scotland: Final report

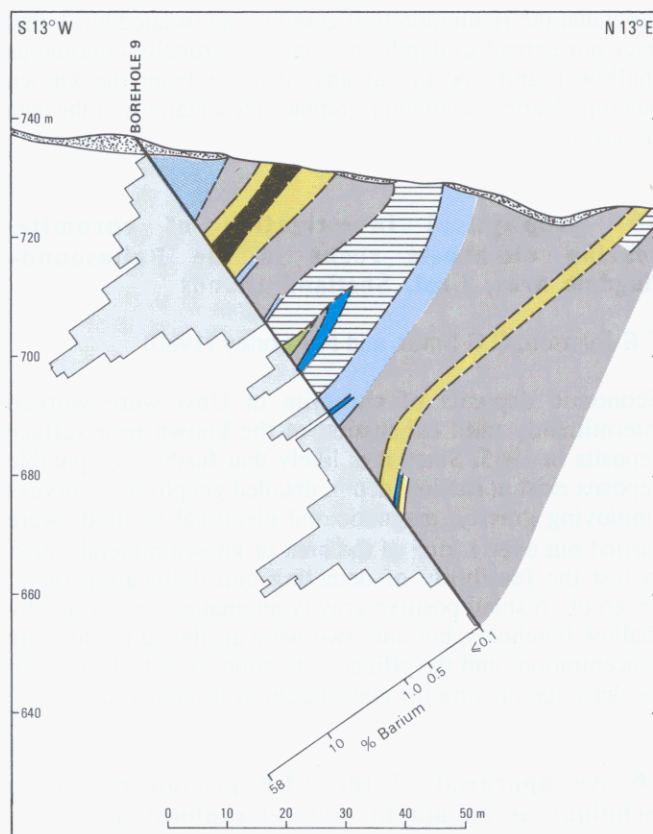
J S Coats, C G Smith and others (1981)

The presence of an extensive zone of mineralisation in the area was recognised initially by a geochemical drainage survey and reconnaissance geological mapping. Subsequently, more detailed mapping and drainage sampling were supplemented by VLF-EM geophysical surveys, overburden and rock sampling, and shallow drilling. The



Ba in panned concentrate samples in the area north of Aberfeldy (Report No. 40)

VLF-EM technique successfully delineated resistive rocks within the generally conductive graphitic schists and proved a valuable mapping aid in areas of poor exposure. The mineralised zone is defined by the presence of bedded baryte, sulphide concentrations, quartz-celsian rock and micaceous schists in which the muscovite is barium-rich. It varies in thickness from about 60 m to 110 m and extends, at least intermittently, over 7 km of strike and through a vertical interval of 370 m. Individual baryte bands are 2.3–15.5 m thick and may extend along strike for up to 1.8 km. The greatest sulphide concentration is in carbonate rock and assays 8.5% Zn and 3.6% Pb over 4.3 m. Other unusual constituents of the mineralised zone are the barium silicates, hyalophane and cymrite, and the chromian muscovite, fuchsite. It is concluded that the mineralisation is of syndimentary origin and involved the introduction of metal-rich hydrothermal brine into an euxinic basin.



Section through Borehole 9, Creag an Chanaich, Aberfeldy (Report No. 40)

41 Metalliferous mineralisation near Luton, Ivybridge, Devon

K E Beer and others (1981)

Localised U and base-metal mineralisation in Devonian slates and volcanics was traced by radiometric and geochemical soil surveys. The mineralisation is confined to two narrow structures in a fault zone trending northwest-southeast, and at surface it has a strike length of no more than 200 m. Percussive drilling down to the shallow water-table indicated persistence of the secondary metalliferous minerals, but cored drilling failed to intersect any recognisable well-mineralised structure. It remains uncertain whether a small ore shoot exists below the surface anomalies; if so, it must be presumed to pitch southeastwards. Only oxidised, and possibly enriched, mineralisation was sampled; this yielded a little cassiterite, sphalerite, pyrite, pyrrhotite and covellite, abundant hydrated iron and manganese oxides with adsorbed U, Pb, Bi, Zn, Cu and As, and flakes of secondary U and Ag minerals. Radiometry confirmed gross U disequilibrium.

42 Mineral exploration in the area around Culvennan Fell, Kirkcowan, south-western Scotland

M E Parker, D C Cooper, P J Bide and P M Allen (1981)

Reconnaissance geochemical and geophysical surveys were concentrated on the west of the Culvennan diorites, where numerous dykes, mainly of intermediate composition, and three small bodies of intrusion breccia intrude folded greywacke, quartz wacke, silty mudstone, siltstone and calcareous mudstone of the Silurian Gala Group. A zone of high chargeability was defined, within which there are areas of low resistivity and narrow magnetic anomalies. The cause of these anomalies is most likely to be strata-bound concentrations of sulphides within the sedimentary succession and the dykes, and there is no evidence to show that the high chargeability is associated with porphyry-style mineralisation. The results of the geochemical survey substantiate this, though minor secondary concentrations of metals and weak, local Cu-As-Fe-Pb mineralisation were indicated.

43 Disseminated copper-molybdenum mineralisation near Ballachulish, Highland Region

H W Haslam and G S Kimbell (1981)

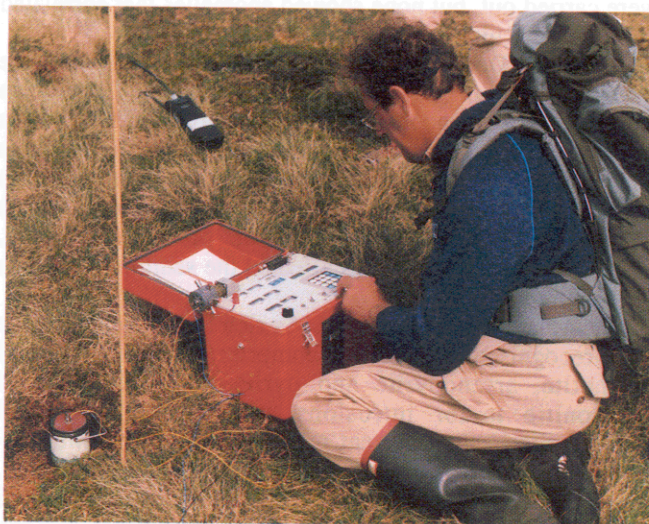
Chalcopyrite-pyrite-molybdenite mineralisation, with minor scheelite, occurs in disseminated, veinlet and fracture-filling forms in microadamellite and surrounding adamellite in the Ballachulish igneous complex. The mineralisation is best developed in and around the eastern part of the microadamellite over an area of about 250 m x 450 m, where it was observed over a vertical interval of 250 m from the highest exposure to the base of a borehole. An IP survey showed that chargeability values are slightly higher in this area. In 3 m lengths of core the maximum Cu content was 260 ppm and the maximum Mo content 500 ppm, but the average tenor over the mineralised area is not more than 50-100 ppm Cu and 10-30 ppm Mo. Selected mineralised outcrop samples gave values of up to 2400 ppm Cu, 9200 ppm Mo, 2400 ppm W, 0.31 ppm Au and 8 ppm Ag. It is thought that the ore minerals were introduced by a hydrothermal system, which, compared with those of classic porphyry models, was small in extent and weak in intensity. Sericitic alteration is generally associated with the mineralisation, but no potassic alteration is evident and the standard zonation of porphyry copper deposits is absent. There is very little K or Rb metasomatism, the best defined chemical change being a loss of Sr in altered rocks. Anomalously low Rb and high K/Rb values in the unaltered microadamellite are attributed to the separation of a Rb-rich aqueous fluid from the microadamellite before or at the time of consolidation of the rock.

44 Reconnaissance geochemical maps of parts of south Devon and Cornwall

R C Jones (1981)

These geochemical maps cover, in four sheets at a scale of 1:50 000, the area bounded by National Grid lines ¹70 and ²90E and ⁰40 and ¹00N. The data presented are for Cr, Mn,

Fe, Co, Ni, Cu, Zn, Zr, Mo, Sn, Ba, Pb and U in stream sediments and Ti, Mn, Fe, Ni, Cu, Zn, Sn, Sb, Ba and Ce in panned concentrates.



Techniques of mineral exploration. Digital recording of induced polarisation and resistivity data

45 Mineral investigations near Bodmin, Cornwall. Part 2—New uranium, tin and copper occurrences in the Tremayne area of St Columb Major

B C Tandy and others (1981)

Investigations of radiometric anomalies in slates and calc-silicate rocks of Devonian age 2 km northeast of St Columb Major indicate that at the main (Tremayne) occurrence a body containing 600-1000 t of U at a grade of 0.2% U may exist within 60 m of the surface. A Sn stockwork, similar to those of the nearby Mulberry and Prosper mines, may be indicated, but Sn values are erratic.

Radiometric reconnaissance and gridding outlined three main groups of surface anomalies greater than 15 μ R/h in an area 1.2 km x 0.7 km. They probably represent separate but related mineralised zones located where northerly-orientated structures intersect the easterly-trending boundary between calc-flintas and slates.

Two inclined boreholes were drilled to examine the largest radioactive structure. Meta-autunite and meta-torbernite occur at true depths of 34-38 m in the first borehole and at 18-29 m and 34-36 m in the second. Analytical and gamma log data indicate broad zones of moderate-grade U, which reach a grade of at least 0.2% U over 3 m in the second borehole. Cu, Zn, Co and Sn values are also high, and further drilling is recommended.

46 Gold mineralisation at the southern margin of the Loch Doon granitoid complex, south-west Scotland

R C Leake, H A Auld, P Stone and C E Johnson (1981)

Following the identification of native gold and arsenopyrite in the area, geochemical soil sampling of the southern margin and aureole of the Loch Doon plutonic complex found several As anomalies with levels in excess of 1000

ppm within the pluton and its aureole. Seven shallow boreholes were drilled to test their source. Geophysical surveys by magnetic, Slingram EM, VLF and IP methods were carried out, but none showed anomalies that correlated with zones of high As in soil.

The Loch Doon plutonic complex in this area is intrusive into a sequence of graded turbidites of probable Caradocian age. Swarms of concordant minor intrusive rocks of quartz monzonite and granodiorite, which predate the pluton, have been encountered in its aureole. Major differences in chemistry exist between these minor intrusions and the composition of the margin of the plutonic complex. Pervasive metasomatism has affected the sedimentary rocks throughout the area.

Two phases of Au-bearing, As-rich mineralisation have been recognised. The earlier comprises disseminations of pyrrhotite, arsenopyrite and pyrite in the margins of monzonitic minor intrusions and disseminations of arsenopyrite in the adjacent metasediments. This mineralisation occurs in zones of thickness up to at least 18 m, within which As levels reach 3000 ppm and Au levels 0.16 ppm in samples of c. 1 m of core. It is probable that the majority of soil As anomalies originate from this type of mineralisation. Superimposed upon this is a series of discordant quartz veins and stringers, which trend roughly south, cutting all rock types, and which may be richly mineralised with arsenopyrite and some pyrite and may also contain minute grains of native gold. Individual veins range up to 30 cm in thickness, but thicker stockwork zones also exist. Arsenic levels in 200–300 g samples of veined material exceed 3.5% and Au assays up to 8.8 ppm have been obtained. A separate, minor phase of sphalerite and galena mineralisation also occurs within the area, usually in association with carbonate veinlets.



Techniques of mineral exploration. Panning a stream sediment sample to obtain a heavy mineral concentrate

47 An airborne geophysical survey of the Whin Sill between Haltwhistle and Scots' Gap, south Northumberland

A D Evans and J D Cornwell (1981)

The survey, conducted with magnetic, electromagnetic (VLF-EM) and radiometric equipment, covered the outcrop of the

Whin Sill (a dolerite sill in Lower Carboniferous limestones and associated detrital sediments), its downdip extension, and the Haydon Bridge mining district. Maps are presented of the magnetic and VLF results. The aeromagnetic map shows a clear correlation between the distribution of anomalies and the mapped outcrops of the sill, and in drift-covered areas allows more accurate delineation of the subcrop of the sill. The magnetic data also indicate that the outcrop pattern consists of a series of linear segments, and it is suggested that the form of the sill was subject to control by the pre-existing joint or fault system during intrusion, as well as to extensive modification by later faulting. In the Settlingstones mine area the magnetic anomalies show a clear spatial relationship to the known veins and have been used to guide the search for vein extensions; elsewhere, comparable anomalies suggest new sites to be considered for detailed exploration.

48 Mineral investigations near Bodmin, Cornwall. Part 3—The Mulberry and Wheal Prosper area

M J Bennett and others (1981)

The results of geochemical soil sampling and geophysical surveys (gravity, VLF-EM and IP) in an area of Lower Devonian sediments north of the St Austell granite, between the former opencast tin workings of Mulberry and Wheal Prosper, suggest that the most promising ground for future mineral exploration lies to the south of the latter workings. Geochemical and geophysical evidence points to the presence of a previously unrecognised mineralised zone sub-parallel to the Prosper vein sheets and some 200 m south of them. The presence of Sn, Cu, Zn and a little W is indicated. Traced westwards, the Prosper mineralisation becomes more tenuous and, as seen in core from shallow boreholes, uneconomic.

49 Seismic and gravity surveys over the concealed granite ridge at Bosworgy, Cornwall

K E Rollin, C F O'Brien and J M C Tombs (1982)

An attempt to define the form of the concealed granite ridge by seismic surveys carried out at a station separation of 20 m was unsuccessful, and it was concluded that if the seismic method were to be effective a more intensive coverage would be needed, possibly with a 2 m station separation. The detailed gravity survey was useful in providing an approximate shape for the granite ridge and an order of magnitude to the actual depths.

50 Geochemical drainage survey of central Argyll, Scotland

J S Coats, B C Tandy and U McL Michie (1982)

A reconnaissance geochemical drainage survey of 720 km² of Dalradian outcrop in central Argyll is described, and geochemical maps are presented to show the distribution of

Cu, Pb, Zn, Ni, U and Mo in stream sediments and of Cu, Pb, Zn, Ni, Ba, Sb, Sn, Fe, Ce, Ca, Mn and Ti in panned concentrates. The survey identified base-metal anomalies in the Pyrite Zone, Ardrishaig Phyllites, Loch Tay Limestone and the Green Beds. The distribution of metal content within these formations has been modified by faulting and igneous intrusion. Resampling and the investigation of anomalous stream courses defined parts of Glen Fyne, the Garabal Hill–Glen Fyne igneous complex, the southerly outcrop of the Pyrite Zone and the Loch Tay Limestone as zones of base-metal mineralisation in which further investigation is recommended.

51 A reconnaissance geochemical survey of Anglesey

D C Cooper, M J C Nutt and D J Morgan (1982)

A reconnaissance field survey identified three groups of mineral occurrences, (a) copper, (b) copper (lead, zinc) and (c) baryte (lead), of which (b) is the most important. Drainage samples were collected from 440 sites, and soil samples were collected from three areas of poor drainage and thin drift cover. Cu, Pb, Zn, Ba, Fe, Mn, Co, Ni and Mo were determined in sediment samples and Cu, Pb, Zn, Ba, Fe, Mn, Ti, Ni, Sn, Sb and Ca in panned concentrates. Cu, Pb and Zn were determined in soil and water samples. The geochemical drainage survey encountered major difficulties from the lack of surface drainage, contamination, subdued topography, variable background geology and extensive drift deposits.

The comparison of statistical analyses and mineralogical observations indicated that all high Sn and Sb levels were related to contamination and that factor analysis was an effective means of discrimination between anomalies caused by contamination and those due to mineralisation. Eighteen anomalous areas related to sulphide or baryte mineralisation were delineated. Six of these—at Carmel Head, Llandyfydog, City Dulas, Llanbadrig, Cerrigceinwen and Lligwy—were the subject of further study.



Techniques of mineral exploration. Determining Cu in a panned concentrate sample using a portable X-ray fluorescence analyser

52 Geochemical reconnaissance in the Cheshire Basin (pages 1-13)

J H Bateson (1982)

Geochemical maps are presented to show the distribution of anomalous values of Cu, Pb and Co in soil samples from five areas on the outcrop of the Triassic Helsby Sandstone and Tarporley Siltstone formations. In each area the soil geochemistry identified the known area of mineralisation. Several other small areas with anomalously high soil values are presumed to reflect local, hitherto unknown mineralisation, but none of them appears to have the areal extent necessary for economic deposits. Suitable porous host rocks and fault structures appear to be common factors in the final location of the mineralisation.

52 Titanium dioxide in the Ayrshire Bauxitic Clay (pages 14-18)

I B Cameron (1982)

TiO₂ contents range from 1.2% to 14.17%, with a mean of 4.68%. The TiO₂ is thought to come from the Carboniferous Passage Group lavas from which the clay is derived, the process of residual concentration being responsible for upgrading it. Extraction of Ti from bauxite has not yet proved possible, even at much higher grades.

52 The Marl Slate (Kupferschiefer) in the Southern North Sea Basin (pages 19-26)

H W Haslam (1982)

Samples of the Permian Marl Slate from borehole cores in the Southern North Sea Basin were analysed for Cu, Pb, Zn, Ag, V, Ni, Co, Sb, As, Cr, Mo, Sn and Mn. The geochemical characteristics are similar to those described in Germany and northeast England. Maximum values of 7000 ppm Cu, 1.3% Zn and 340 ppm Pb were recorded.

53 Investigation of polymetallic mineralisation in Lower Devonian volcanics near Alva, central Scotland

I H S Hall, M J Gallagher, B R H Skilton and C E Johnson (1982)

Boreholes drilled on three known occurrences of fracture-controlled mineralisation in the Lower Devonian Ochil Volcanic Formation intersected mineralised structures which contain only minor amounts of baryte and geochemical enrichments of Cu, As and U. Earlier Ag–Co mineralisation appears to have been followed by Cu–Ba mineralisation. Differential fracturing within the volcanic sequence and increased brecciation at fault intersections are the principal controls.

54 Copper mineralisation near Middleton Tyas, North Yorkshire

A J Wadge and others (1982)

Geochemical soil sampling outlined an area of 6 km² of anomalous Cu values to the south of the mined area at Middleton Tyas. The drift in this area is thick, and the cause of the anomalies is not known. Examination of the known mineralisation in the area, which occurs in Lower Carboniferous limestones, suggest that it originated from metalliferous brines migrating from the Stainmore Trough or a similar Lower Carboniferous sedimentary basin to the east. The possibility that the mineralisation is syngenetic is now discounted, and shallow holes into the Permian succession showed that no Kupferschiefer facies is present, which eliminates the Permian as a source for the Cu. The primary Cu sulphides were enhanced in grade by supergene enrichment under arid conditions in early Permian times.



Techniques of mineral exploration. Collection of overburden samples, using power auger

55 Mineral exploration in the area of the Fore Burn igneous complex, south-western Scotland

P M Allen and others (1982)

The Fore Burn igneous complex consists mainly of quartz microdiorite, tonalite and feldspar porphyry forming semi-concordant or concordant bodies in early Devonian volcanic and sedimentary rocks, just north of the Southern Upland

Fault, 24 km east of Girvan. Several small bodies of intrusion breccia occur within the complex and the country rock and there is a zone of monolithological breccias along a fault followed by the Fore Burn itself. Alteration to sericite, carbonate and chlorite is widespread, and tourmaline is also widely distributed. The most intensely altered rocks occur in the breccia zone along the Fore Burn. There the breccias contain locally abundant disseminated sulphides and are cut by veins rich in sulphides.

Drainage and rock geochemistry and detailed mineralogical study showed that arsenopyrite, pyrite and chalcopryite occur in the breccia zone, with smaller quantities of tennantite, tetrahedrite and cobaltite. Cu, As, Mo, Au, Sb, Bi, Co, Ni, Pb, and Zn were all enriched in mineralised rock. Native gold was identified in a quartz-tourmaline vein, with chalcopryite and other sulphides. Geophysical surveys located three small areas of low resistivity, one of which is in the breccia zone. The induced polarisation chargeability levels do not indicate any widespread, significant, near-surface disseminated sulphide mineralisation.

56 Geophysical and geochemical investigations over the Long Rake, Haddon Fields, Derbyshire

M J Brown and R D Ogilvy (1982)

Geophysical and geochemical investigations were undertaken over the Long Rake, a major mineralised vein in Dinantian limestones, to establish which methods show the best response to the mineralisation. The mineralised structure carries high concentrations of fluorite with associated lead and zinc minerals and the gangue minerals barite and calcite.

Gravity and magnetic anomalies such as those obtained over the Long Rake could have limited applications for the indirect location of veins whose approximate position is known. Induced polarisation, resistivity and electromagnetic measurements failed to produce anomalies that could be directly attributed to the mineralisation or its host structure. However, reconnaissance mapping with very low-frequency electromagnetic and Radiohm methods showed that, over a large section of the survey area, the fluorspar vein could be mapped by its association with the sub-drift shale-limestone contact.

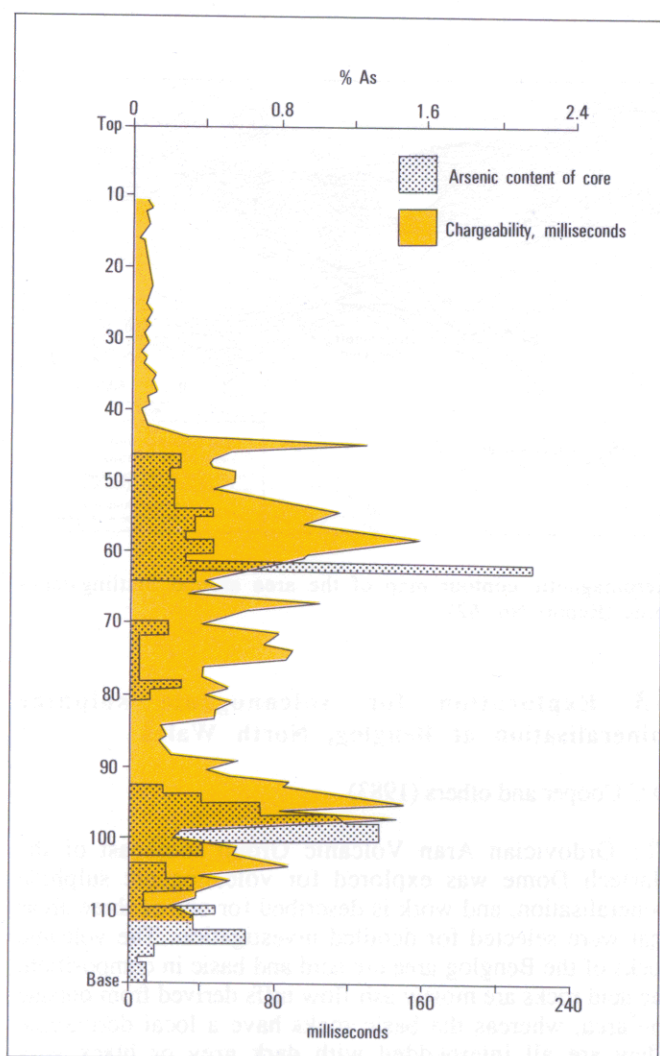
The determination of a wide range of elements in soils and tills showed that the more mobile elements, such as F and Zn, are particularly useful in detecting mineralisation over broad areas. Less mobile elements tend to exhibit localised dispersion patterns, which have applications for the precise location of an orebody. Pb, Ba, Sr, Ca, Zn, Rb and Th are enriched in soils above the Long Rake in areas of thin overburden, but only Ba, Sr and Pb maintain significant contrast in thickening cover towards the west. The use of basal till samples was found to have no advantage over subsurface soil samples, as geochemical contrast was not improved.

57 Mineral exploration in the Ravenstonedale area, Cumbria

J H Bateson and A D Evans (1982)

Following stream-sediment and soil sampling, four areas of anomalous Cu, Pb and Zn in soils were recognised in an area

of Lower Carboniferous rocks close to the Silurian unconformity: at Stennerskeugh Clouds, Birkett Common, Crosby Garrett Fell and Windy Hill. VLF-EM and IP surveys at Stennerskeugh Clouds and Crosby Garrett Fell showed anomalies attributed to the presence of shale bands in the Carboniferous succession. Previous geophysical surveys at Birkett Common had suggested the presence of small mineralised structures, but the present geochemical and geophysical results do not indicate the presence of mineralisation of economic significance in the area.



Arsenic distribution and IP log of Borehole 2, Glendinning (Report No. 59)

58 Investigations of small intrusions in southern Scotland

D C Cooper, M E Parker and P M Allen (1982)

Sixteen small Caledonian intrusions, ranging from granite to diorite, were examined for indications of disseminated mineralisation. Stream-sediment and panned concentrate

samples were collected from streams crossing some of the intrusions, and reconnaissance geophysical surveys were conducted over Priestlaw, Cockburn Law and Lamberton Moor. Rock samples from some of the intrusions were analysed for major and trace elements. Hydrothermal alteration—in places with associated pyrite—was recorded at Mains of Dhuloch, Mochrum, Priesthope, Lamberton Moor, Broad Law, Glenluce, Priestlaw, Cockburn Law and Mull of Galloway. Cu enrichments were recorded locally, but it was concluded that in no case is there a likelihood of appreciable porphyry copper mineralisation at or near the surface.

59 Stratabound arsenic and vein antimony mineralisation in Silurian greywackes at Glendinning, south Scotland

M J Gallagher and others (1983)

Stratiform and disseminated pyrite–arsenopyrite concentrations are overprinted by fracture-controlled polymetallic mineralisation, including stibnite, in Silurian sediments at Glendinning, near Langholm. Three shallow boreholes were drilled on an anomaly defined by VLF-EM and IP surveys and by Sb values >20 ppm in thin, B–C horizon soils. A parallel conductive zone with an accompanying soil anomaly but lacking an IP response was investigated by a fourth hole. The stratabound sulphides form disseminations and bands parallel to the bedding and are particularly concentrated in intraformational breccia units regarded as debris flows, which, together with the presence of small-scale slump folds in the greywackes, testify to the existence of an unstable slope during sedimentation. The thickest such unit has a true thickness of 4 m and, together with 8 m of adjoining greywackes, grades 0.7% As and 0.07 ppm Au.

Phases of fracture-controlled Fe–As–Sb–Pb–Zn–Cu–(?)Hg mineralisation associated with widespread dolomite and quartz veinlets and narrow breccia veins are superimposed on the strata-bound mineralisation. Their spatial association with the strata-bound mineralisation and the presence of up to 0.33% Sb in the stratiform arsenopyrite and as much as 5% As in the stratiform pyrite favour a common source for the As and Sb. This source was probably a synsedimentary metal accumulation in a mid or lower fan environment in which euxinic conditions developed periodically.

(After publication of this report most of the drill cores were analysed for Au by BP Minerals International Ltd: maximum values were 0.4 ppm Au over 3.7 m true thickness of breccia vein and fractured siltstone.)

60 Mineral investigations at Carrock Fell, Cumbria. Part 2—Geochemical investigations

M J Brown (1983)

Soil samples were collected from an area of 5 km² around the tungsten veins at Carrock. New areas of mineral potential to the northeast of the mine were identified from the coincidence of geochemical anomalies with strong linear VLF features. High levels of W, Cu, Zn, As, Rb and Pb and low levels of Sr are evident in the soils above the worked veins. These elements, with the exception of As, constitute

a broad zone of anomalously high values to the north and east of the vein system, accompanied by low Sr values extending up to 1 km east of the worked veins over a distance of 1.2 km north-south. A broad As halo is apparent for some 800 m west of the main vein system. The distribution patterns of some elements unrelated to mineralisation reflect bedrock lithological variation. Gamma spectrometry demonstrates a distinct increase in the K/Th ratios over the main veins and delineates a potential area of mineralisation to the west of the mine, coincident with a strong VLF anomaly. Qualitative, contoured maps of the count rate for the U and K channels delineate the sub-outcrop of the granite. The geochemical results and previously reported geophysical results (Report No. 33) enabled three areas to be recommended for further, detailed exploration.

61 Mineral reconnaissance at the Highland Boundary with special reference to the Loch Lomond and Aberfoyle areas

W G Henderson, N J Fortey, C E Johnson and A Grout (1983)

The chromite geochemistry and hornblende-schist mineralogy of the serpentinite-spilite-black-shale-chert assemblage tend to confirm its ophiolitic character. Relict textures indicate that the serpentinites were derived from peridotitic precursors, but one unaltered ultrabasic sample comprises mainly chromian diopside. Magnetic and VLF traverses across the Highland Boundary Fault near Helensburgh identified several anomalous zones. One may be due to a concealed serpentinite sheet. The most mineralised serpentinite body showed Cr values in the range 1000-3035 ppm. Such concentrations, though not economically significant, may indicate that larger, unaltered serpentinites elsewhere at the Highland Boundary merit investigation.

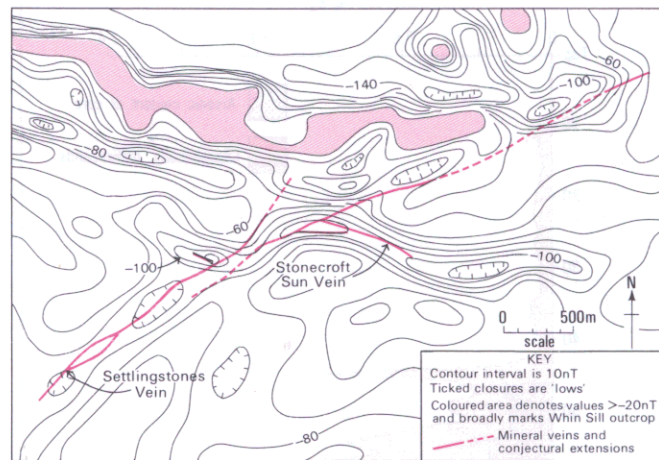
62 Mineral reconnaissance in the Northumberland Trough

J H Bateson, C C Johnson and A D Evans (1983)

A reconnaissance geochemical drainage survey across Lower Carboniferous sediments identified not only the known mining areas but also a number of other areas with anomalously high metal values. Ba in stream sediments and panned concentrates is a reliable indicator of mineralisation and identifies the Whinnetley-Settlingstones-Fallowfield area. High Ba values in concentrates were obtained from an area to the south of Rothbury (Ewesley Farm); subsequent soil sampling also revealed high levels of Ba, and it is considered that unexposed Ba mineralisation exists in the area, probably associated with a fracture cutting dolerite of the Whin Sill.

A number of linear magnetic anomalies were identified from the results of a detailed low-level airborne geophysical survey over the part of the basin underlain by the Whin Sill at shallow depth. Several of these can be equated with known fault structures or their probable extensions, some of which have carried significant mineralisation. Selected anomalies were further examined by geochemical (soil sampling) and ground geophysical techniques, but the soil samples contained generally low values of ore elements.

Four boreholes were drilled on a magnetic anomaly that indicates an eastward extension of the Sun Vein near Newbrough, to test the fault structure affecting the Whin Sill as interpreted from the magnetic data. Considerable variations in the texture and alteration of the quartz dolerite sill were evident from the cores. Base-metal mineralisation was identified associated with this alteration and in some of the carbonate sediments. Chemical analyses of samples from the Whin Sill quantify the changes in composition effected by the hydrothermal alteration. Magnetic susceptibility values determined on the Whin Sill core show great variability, consistent with the variation in the degree of alteration.



Aeromagnetic contour map of the area around Settlingstones mine (Report No. 62)

63 Exploration for volcanogenic sulphide mineralisation at Benglog, North Wales

D C Cooper and others (1983)

The Ordovician Aran Volcanic Group southeast of the Harlech Dome was explored for volcanogenic sulphide mineralisation, and work is described for one of three areas that were selected for detailed investigation. The volcanic rocks of the Benglog area are acid and basic in composition; the acid rocks are mostly ash-flow tuffs derived from outside the area, whereas the basic rocks have a local derivation. They are all interbedded with dark grey or black silty mudstone and were probably erupted in a submarine environment. Contemporaneous dolerite sills were intruded into the wet sediment. This environment was suitable for the formation of volcanogenic exhalative sulphide deposits, and indications of a metallogenic horizon were found at the top of the Y Fron Formation in the form of abundant pyrite, minor pyrrhotite and minor base-metal enrichment. Soil samples were collected for Cu, Pb and Zn determination, and geophysical surveys were conducted along 11 east-west traverse lines 300 m apart across the succession. Indications were found of minor vein mineralisation at dolerite intrusion margins and locally along faults. Very high chargeability and low resistivity anomalies over mudstones do not coincide spatially with geochemical anomalies in soil, which in many cases may be transported. Geochemical drainage data, in

conjunction with rock analyses, show strong Ba enrichment in mudstones, which could be volcanogenic in origin and related to two separate eruptive episodes.

64 A mineral reconnaissance of the Dent-Ingleton area of the Askrigg Block, northern England

J H Bateson and C C Johnson (1983)

The western margin of the Askrigg Block of Lower Carboniferous sediments was investigated by reconnaissance geochemical drainage survey. In addition, following identification of a moss-like plant with tolerance to high levels of base metals, a soil survey was carried out on Tow Scar, 3 km northwest of Ingleton. The drainage survey revealed no new major mineralisation, though minor mineral shows were located following investigation of some anomalous sites. The soil survey led to the discovery of minor mineralisation, which suggests that similar occurrences might exist adjacent to the Craven Fault system east of Ingleton.

65 Geophysical investigations in Swaledale, North Yorkshire

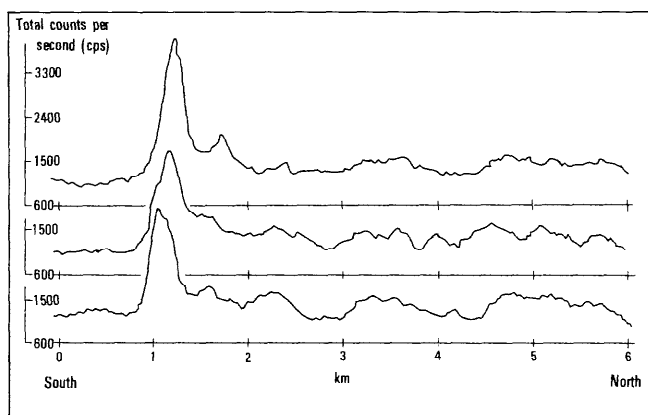
A D Evans and others (1983)

An airborne geophysical survey was carried out over part of upper Swaledale and the adjacent moorland, where the Lower Carboniferous geology and the style of mineralisation are representative of the Northern Pennine Orefield. Magnetic, electromagnetic and radiometric methods were employed to assess their applicability in this environment. Eleven airborne EM anomalies were followed up with detailed ground surveys. Drilling targeted on anomalies at Oxnop Gill revealed no evidence of significant mineralisation. Further promising anomalies at Whirley Gill were not drilled and remain unexplained. Of the other airborne anomalies, some were not detectable on the ground and others were considered to reflect stratigraphical or artificial conductors. It is concluded that the airborne EM system employed is not effective in exploration for Pennine-type mineral veins.

66 Mineral reconnaissance surveys in the Craven Basin

A J Wadge and others (1983)

A geochemical drainage survey indicated the presence of anomalously high Cu, Pb and Zn in stream sediments and panned concentrates over Lower Carboniferous limestones and mudstones in various parts of the Craven Basin. An airborne geophysical survey (magnetic, electromagnetic and radiometric) over the Craven Faults, at the northern margin of the basin, identified 25 localities that gave an anomalous EM response; ground EM surveys showed that five of these merited more detailed examination. High radiometric readings were obtained over several limestone reefs. Seismic traverses over the South Craven Fault provided information about the stratigraphy on either side of it, and regional gravity data provided information about the major structures.



Airborne radiometric profiles (total counts) east of Settle, showing an anomaly over a Carboniferous reef limestone along the Craven Fault. The U which is responsible for the radiometric anomaly is associated with Pb-Zn mineralisation (Report No. 66)

Detailed geophysical, geochemical and geological investigations were carried out in 16 areas where the geological environment or the results of reconnaissance work suggested that mineralisation might be present. Sulphide mineralisation associated with limestones of reef facies was proved—notably at How Hill and Cow Ark—and evidence was found of a continuation of the mined Bycliffe vein, but on present evidence none of the areas appears to contain deposits of ore grade. Many of the minerals appear to have been emplaced by the concentration of brines in structural or stratigraphical traps in which limestones have acted as host rocks. Comparison with the important sulphide deposits in the Lower Carboniferous of Ireland suggests that the most promising area for mineralisation is near the northern boundary of the Craven Basin, possibly at depths of 300–400 m.

67 Baryte and copper mineralisation in the Renfrewshire Hills, central Scotland

D Stephenson and J S Coats (1983)

Baryte veins are concentrated in massive, open-jointed rocks of the Misty Law trachytic complex, where they occupy a variety of fracture directions within the limits of a northwest-southeast swarm of Tertiary dolerite dykes. Outside the trachytic complex—in the less massive basaltic sequence—barite veins are confined to major ESE to ENE trending fault zones and the margins of the ENE trending late Carboniferous quartz dolerite dykes, with which they are probably contemporaneous. Several new discoveries of isolated, wide veins of pure baryte could be economic if worked on a small scale, and areas are recommended in which follow-up geochemical work may reveal more extensive deposits. It is suggested that baryte mineralisation occurred at intervals from the late Carboniferous onwards during tensional stress regimes when increased heat flow circulated low-temperature, Ba-rich brines, which combined with sulphurous groundwaters in near-surface, oxidising conditions.

Cu mineralisation occurs in a wide variety of environments, which range from replacement of plant debris by malachite in sandstones to veins of chalcocite, chalcopyrite and malachite on the margins of quartz dolerite

dykes. Mineralised rocks include basal Carboniferous to Lower Limestone Group sediments and volcanics and late Carboniferous dykes. Some of the Cu has a direct, late-stage hydrothermal association with the basaltic magmas and it is suggested that cupriferous veins were deposited by later, possibly late-Carboniferous, hydrothermal fluids which leached Cu from the basalt pile.

68 Polymetallic mineralisation in Carboniferous rocks at Hilderston, near Bathgate, central Scotland

D Stephenson, N J Fortey and M J Gallagher (1983)

Five boreholes in the vicinity of the ancient Ag–Ni–Pb mine at Hilderston yielded new stratigraphic, mineralogical and geochemical information. Stratabound Zn–Pb mineralisation occurs in the lower, argillaceous part of the Petershill Limestone, which was deposited in an anaerobic lagoon on the edge of a volcanic landmass during the Lower Carboniferous (Lower Limestone Group, Viséan stage). The best intersection shows 8 m of mineralised limestone, with underlying carbonaceous mudstone (1 m) and tuffaceous seat rock (2 m), which has an average concentration of 0.14% Pb and 0.66% Zn and maximum values of 0.6% Pb and 3.1% Zn in the carbonaceous mudstone.

Late Carboniferous hydrothermal veins occur within the Petershill Limestone and in immediately overlying clastic sediments, where they are cut by east–west faults and quartz dolerite dykes. At Hilderston mine two assemblages are recognised in the vein: Ba–Fe–Ni–Co–Ag–As on a dyke margin adjacent to the clastic sediments and Fe–Pb–Zn–S at lower levels adjacent to the limestone. Zones of alteration in the dolerite dykes carry hydrocarbons and weak Ba–Fe–Cu–F mineralisation. No potentially valuable vein deposits were discovered.

69 Base metal mineralisation associated with Ordovician shales in south-west Scotland

P Stone and others (1984)

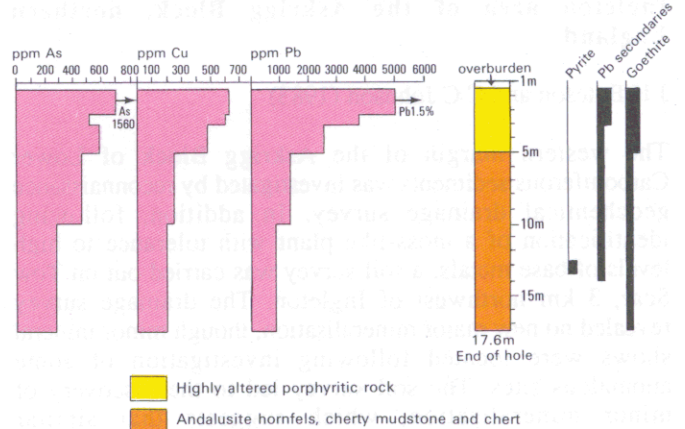
Base-metal anomalies in drainage and overburden are associated with a belt of hornfelsed black cherty mudstone and siltstone (the Moffat Shales) in the Penkiln Burn area, 13 km NNE of Newton Stewart, which is host to weakly disseminated and epigenetic Pb–Zn–Cu mineralisation.

Three varieties of mineralisation have been recognised, the earliest of which is probably syngenetic, whereas the latter two are structurally controlled. The first phase consists of fine disseminations, chiefly of sphalerite and pyrite, in mudstone and chert or stratiform pyrite laminae in mudstone. It is characterised by Zn levels averaging 500–1000 ppm over several metres of drill core; Pb levels rarely exceed 300 ppm.

The second phase of the mineralisation occurs in thin quartz veinlets, which contain accessory sphalerite, galena and pyrite. Where the veining is intense Pb reaches 7000 ppm and Zn 1500 ppm, but these values persist over only a few tens of centimetres of core.

Finally, a low-temperature mineral assemblage in which plumbogummite is dominant is associated with the altered

margins of dykes and gossan-like zones occupying a north–south fault system. Pb levels in the dyke margins range up to 1.5% in zones that are generally less than 0.5 m thick, but 4.5% Pb has been recorded in one specimen from the exposed gossan.



Graphical log of Borehole 2, Penkiln Burn (Report No. 69)

70 Regional geochemical and geophysical surveys in the Berwyn Dome and adjacent areas, North Wales

D C Cooper, K E Rollin and J D Cornwell (1984)

A gravity survey across the Berwyn Dome confirmed a broad, regional Bouguer anomaly low in the central part of the dome with smaller, irregular highs and lows, some of which may reflect small igneous bodies. The Bryneglwys Fault coincides with a 4.5 mGal anomaly, but, southwards, the two features diverge, suggesting that the density interface is related either to a splay fault or to the eastern margin of the Lower Palaeozoic Montgomery trough. The Bouguer anomalies probably reflect such factors as variation in the Precambrian basement and changes in the lithology and thickness of Lower Palaeozoic sedimentary rocks. There is no evidence for a large granitic body in Lower Palaeozoic rocks underlying the mineralisation at Llangynog.

A drainage geochemical survey provided evidence of hydrous oxide precipitation processes; contamination from human activities; base-metal and baryte mineralisation; the presence of monazite nodules; hitherto unrecorded Au mineralisation; and lithological variations. The latter were related principally to shale-sandstone variation, but geochemical signatures attributable to basic intrusions, phosphatic rocks, coal measures, sandstones, limestones and volcanics were also discerned.

A few geochemical anomalies deserve further investigation, notably those associated with (1) Au mineralisation in the northwest of the area; (2) baryte, perhaps accompanied by base-metal mineralisation associated with Caradocian volcanics and phosphatic rocks; (3) mineralisation associated with Llandeilian limestones and volcanic rocks north of Llanrhaeadr; and (4) Cu mineralisation associated with intrusives near the eastern margin of the dome.

71 A regional geochemical soil investigation of the Carboniferous Limestone areas south of Kendal (south Cumbria and north Lancashire)

J H Bateson and C C Johnson (1984)

The soils of four areas were sampled and analysed for Cu, Pb, Zn, Ba and Mn. The few significant soil-geochemical anomalies can be related either to contamination or to association with minor iron mineralisation or the reefal limestones that occur in the south of the area. The latter are the most significant in view of the similarities with areas along the Craven Fault to the east and the association of economic mineralisation with Carboniferous reefs in Ireland.

72 A geochemical drainage survey of the Preseli Hills, south-west Dyfed, Wales

D G Cameron and others (1984)

The main sources of variation in the geochemical drainage data were found to be bedrock lithology, mineralisation, contamination and hydromorphic processes. Strong geochemical signatures are shown by dolerite intrusions and by acid volcanics of the Ordovician Fishguard Volcanic Group. Dark mudstone of the *Didymograptus murchisoni* Beds and Sealyham Volcanic Series also show characteristic geochemical features. Over most of the area abundant monazite nodules give rise to high background levels of rare-earth elements and uranium in the panned concentrates, particularly over Llandeilo–Ashgill sedimentary rocks. Anomalies detected in three areas may be due to hitherto unrevealed mineralisation: (1) Cu, Pb, Zn and Ba near Llanfyrnach, which may represent an extension of the known Pb–Ag mineralisation of the area; (2) Ba and base metals near Crosswell–Crymmych, associated with the Fishguard Volcanic Group and overlying pyritiferous dark mudstones of the *D. murchisoni* Beds, with potential for massive sulphide deposits; and (3) minor native gold and chalcopyrite occurrences near Minas Dinas and Pentre Ifan.

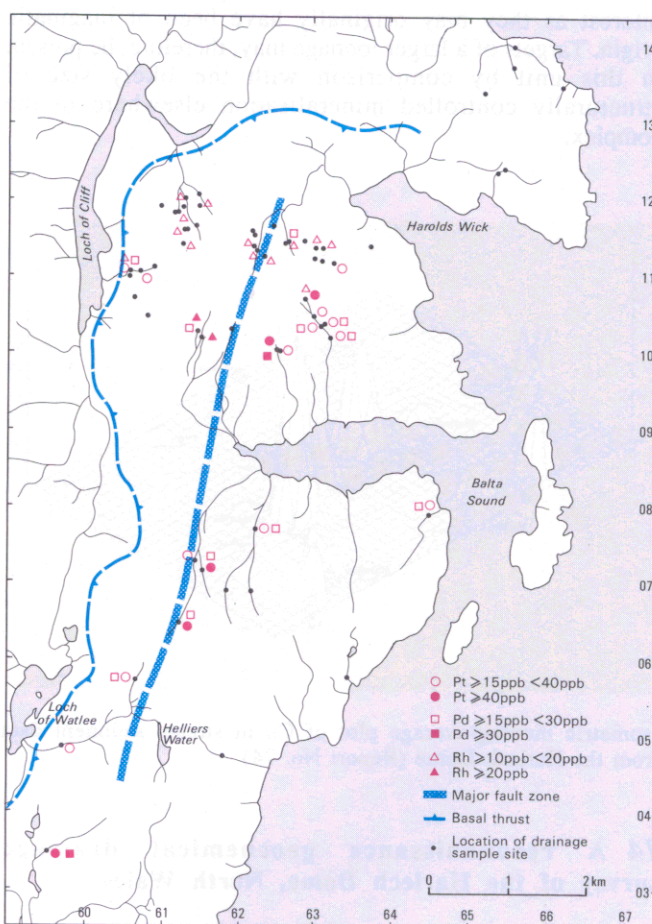
73 Platinum-group element mineralisation in the Unst ophiolite, Shetland

A G Gunn, R C Leake and M T Styles (1985)

The ophiolitic basic and ultrabasic rocks of Unst comprise a sequence of harzburgite, dunite, clinopyroxene-rich cumulates and gabbro. Concentrations of chromite are found in the harzburgite and dunite and, to a small extent, in the pyroxene cumulate rocks. Five alteration or hydrothermal events have been recognised in the ultrabasic rocks. Exploration for platinum-group element (PGE) mineralisation was conducted by drainage, overburden and rock sampling and up to 20 other elements were determined in the samples.

Low-amplitude Ir anomalies are present in drainage samples from three discrete areas in the harzburgite, but the maximum level of 210 ppb Ir is derived from a prominent north–south zone of faulting and hydrothermal activity. This discordant zone, which extends for at least 7 km, is also marked by enrichments in Fe, Co, Ni, Cu and As. The highest Cr levels are associated with an area in the north of

the harzburgite with no previous history of chromite working but where many locally derived pieces of chromite float have been discovered. Systematic collection of panned heavy-mineral concentrates from overburden samples in the Cliff area outlined a zone of coincident Pd, Pt and Rh enrichment near to, but separate from, the chromite workings known to be enriched in PGE. The distribution of Ru was entirely different, with scattered, low-amplitude anomalous zones and a maximum anomaly 300 m from the chromite-rich zone. Low-amplitude Pd and Pt anomalies were detected at other locations within the dunite unit, especially in a traverse at Helliers Water across the trace of the prominent north–south fault zone adjacent to the outcrop of the cumulate unit.

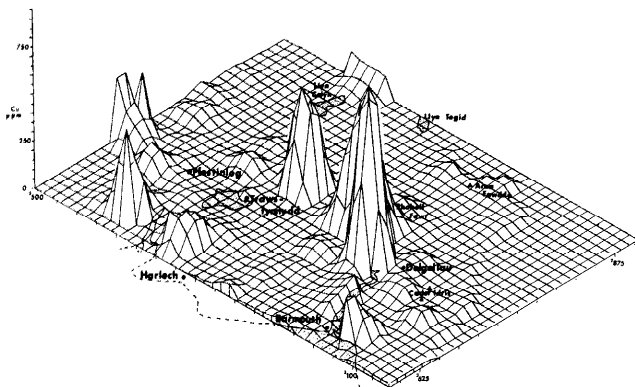


Distribution of Pt, Pd, and Rh in panned drainage samples over the Unst ophiolite (Report No. 73)

Very high levels of all PGE occur in rock samples from chromitite, chromite-rich dunite and dunite in the Cliff area. The proportions of the PGE—with strong relative enrichment in Pd and Pt—are similar to those in deposits in major layered basic/ultrabasic complexes and completely different from the Ru–Ir–Os-dominant assemblage typical of ophiolitic rocks. There is no correlation with Cr, and some samples of chromitite from the Cliff area contain only background levels of PGE. High to moderate levels of PGE with the same proportions of elements as the Cliff samples also occur in samples of chromitite and serpentinised dunite from the dunite unit and in samples of pyroxenite from the

cumulate unit. In contrast, PGE-rich samples of chromitite from the harzburgite unit near Harold's Grave have proportions of PGE that closely resemble the pattern found in typical ophiolites. In samples from the Cliff area the platinum-group minerals sperrylite, stibiopalladinite, hollingworthite, laurite and, possibly, irarsite have been identified, mostly as grains less than 10 μm in size. A hydrothermal origin for the PGE mineralisation is proposed, probably related to the second phase of serpentinisation. Pre-existing concentrations of chromite may have acted as a precipitation barrier, causing rich platinum-group mineral deposition in the alteration haloes around chromite grains.

The high levels of PGE and the evidence of widespread occurrence of the Cliff-type PGE enrichment are favourable indications of economic mineralisation. The PGE enrichments found in the cumulate complex are of potential interest as they may originally have been of magmatic origin. Targets of a larger tonnage may, therefore, be present in this unit by comparison with the likely size of structurally controlled mineralisation elsewhere in the complex.



Isometric moving-average plot of Cu in stream sediment data from the Harlech Dome (Report No. 74)

74 A reconnaissance geochemical drainage survey of the Harlech Dome, North Wales

D C Cooper and others (1985)

The results of a geochemical drainage survey show that the Harlech Dome area is metalliferous, containing large anomalies for a wide range of metals. Strong regional patterns are caused by bedrock lithology, hydromorphic processes, mineralisation and contamination. Geochemical signatures characteristic of the following metalliferous concentrations were identified: (1) disseminated Cu 'porphyry-style' mineralisation; (2) 'gold-belt' vein-style mineralisation in Cambrian rocks; (3) mineralisation in Ordovician volcanic and sedimentary rocks; (4) bedded Mn deposits in the Cambrian; (5) Mn vein-style mineralisation in Ordovician volcanic rocks; (6) granite-related mineralisation; and (7) dark mudstones.

Eleven areas or styles of mineralisation were identified where it was considered that further work might lead to the

recognition of deposits of economic or supply significance. These targets include base-metal anomalies in Ordovician volcanic rocks where there is some potential for volcanogenic stratiform mineralisation; Cu and Au anomalies in Cambrian rocks indicating the presence of further gold-belt, vein-style mineralisation; As anomalies over Ordovician acid volcanic rocks whose Au potential merits investigation; Mn and Ba anomalies related to Mn–Ba vein mineralisation in Arenig volcanic rocks; and metalliferous concentrations in dark mudstones marginal to the Rhobell volcanic centre.

75 Geophysical surveys in part of the Halkyn–Minera mining district, north-east Wales

J D Cornwell and G S Kimbell (1985)

Induced polarisation surveys were carried out over Carboniferous limestones and sandstones at four localities in the Halkyn–Minera area. The first covered the Llandegla Moor area, but failed to produce any evidence for a northwestward continuation of the rich Minera lode system. Gravity data subsequently demonstrated a Bouguer anomaly low over the western margin of the Cefn-y-Fedw Sandstone Group, including the Llandegla Moor area, suggesting that these rocks thicken rapidly eastwards, perhaps along a concealed northerly-trending fault.

Trial IP surveys were conducted at three sites in an attempt to locate this fault and test its mineral potential, but with negative results. The Bouguer low is interpreted as probably due to the presence of high-porosity and rapidly thickening sandstones in the Cefn-y-Fedw Sandstone Group. For these reasons the area where the low was discovered is not strongly recommended for any future exploration for extensions of the mineral veins.

76 Disseminated molybdenum mineralisation in the Etive plutonic complex in the western Highlands of Scotland

H W Haslam and D G Cameron (1985)

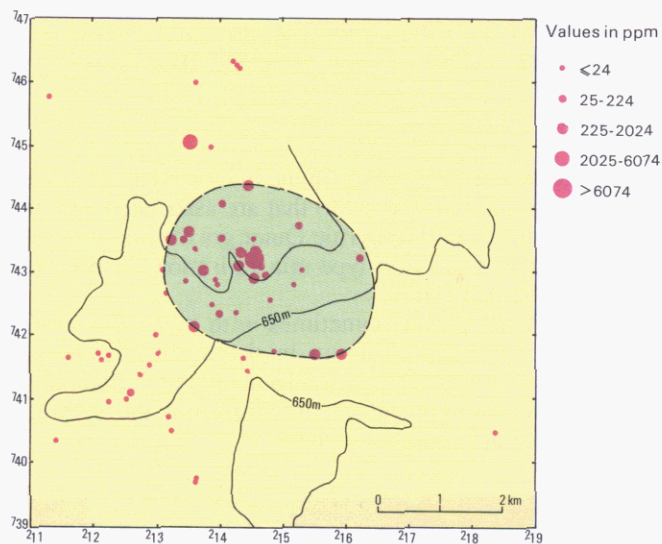
A drainage geochemical survey covering most of the Etive plutonic complex, of Caledonian age, found the highest concentrations of Mo in stream sediment (40–120 ppm) to be in streams draining an area about 5 km in diameter within the Central Starav granite. Within this area molybdenite occurs sporadically, mainly in quartz veinlets. Although selected samples of mineralised rock have been shown to contain up to 0.9% Mo, the incidence of sulphide mineralisation is too sparse for a meaningful estimate of tenor to be given. Molybdenite is usually accompanied by pyrite. Chalcopyrite and scheelite are also widespread, though less common.

Mild hydrothermal alteration accompanies the mineralisation, but there is no pervasive or zoned alteration, nor is there any K or Rb metasomatism. It is suggested that the ore minerals were deposited from hydrothermal fluids, which, in the absence of any structural or physico-chemical constraints, circulated freely throughout a large volume of rock, with the consequence that the ore minerals are widely dispersed.

77 Follow-up mineral reconnaissance investigations in the Northumberland Trough

J H Bateson, C C Johnson and A D Evans (1985)

A regional mineral reconnaissance of the Carboniferous sediments of the Northumberland Trough (Report No. 62), including detailed airborne geophysical coverage, enabled several areas to be defined for further investigation, largely on the basis of magnetic data. At Todridge Fell, Wheathill and Brown Moor, soil geochemical data indicate that faulting in the Whin Sill is accompanied by mineralisation. The amount and type of such mineralisation are, however, not determinable—except at Brown Moor, where a short drilling programme indicated alteration of the Whin Sill accompanied by Mn, Ba and Pb mineralisation. At Ewesley a linear zone of Ba enrichment in soils was identified, with associated Pb and Zn. A weak linear magnetic feature does not coincide with the surface geochemical 'highs'. The source of the geochemical anomalies can only be determined by drilling; mineralisation associated with a fault structure or a strata-bound concentration is possible. The work in these four areas provides further evidence of the value of magnetic methods in identifying fault structures affecting the Whin Sill, with which alteration and mineralisation may be associated.



Mo in rock samples from the inner part of the Central Starav granite. The central mineralised area is shown in deeper colour (Report No. 76)

78 Exploration for porphyry-style copper mineralisation near Llandeloy, southwest Dyfed

P M Allen, D C Cooper and others (1985)

Geological, geochemical and geophysical surveys followed by drilling in the area around Llandeloy have located disseminated Cu mineralisation of porphyry type associated with intermediate intrusive rocks masked by thick overburden.

Geological examination combined with a stream-sediment survey revealed the presence of weak polymetallic sulphide



Techniques of mineral exploration. Collecting a sample of estuarine sand containing precious metals

mineralisation associated with the margin of a tonalitic intrusion at Middle Mill. Six traverse lines, totalling 10.5 km in length, were surveyed by IP, VLF-EM and magnetic methods. Soil samples were collected at 25 m intervals along the same lines and analysed for Cu, Pb and Zn. Few anomalies were located, and it was concluded that no substantial body of disseminated Cu mineralisation is present at or near the surface in this area. The mineralisation found in Middle Mill quarry is thought to be minor epigenetic mineralisation associated with the intrusion.

At Llandeloy traverses totalling 37 line km in length were surveyed by IP, VLF-EM, magnetic and radiometric methods. Soil samples were collected at 50 m intervals along all traverses and analysed for Cu, Pb and Zn. Gravity data were also collected from some traverses and sites. Several strong soil Cu and geophysical anomalies were identified. Nine boreholes were drilled to investigate their cause. Disseminated Cu mineralisation was intersected, occurring principally within a concordant or semi-concordant sheeted complex of dioritic and tonalitic rocks, believed to be latest Cambrian or early Arenig in age, whose composition is consistent with emplacement within a volcanic-arc setting.

The intrusions and their host rocks have suffered a two-phase, pervasive, hydrothermal alteration which is inseparable from the sulphide mineralisation and which was recorded in boreholes over an area of 1 km². The alteration shows features common to porphyry Cu systems, consisting of an early, patchy and irregularly developed, porphyritic and potassic alteration overprinted by widespread and locally intense, late propylitic alteration.

Cu-Fe-S mineralisation accompanied the alteration. Cu levels are generally modest, the best intersection being 0.1 wt% over 3.4 m. Cu, and particularly the Cu/S ratio, are generally highest in the most altered rocks, but locally high levels of Cu may be found in weakly altered rocks. Mo enrichment is weak and erratic, and high levels of Cu and Mo show only a weak correlation. There are localised, very weak enrichments of As, Pb and Zn.

It is suggested that the present erosion level cuts a deep section through a Cu porphyry deposit, thus explaining the imperfectly developed zonation, low Cu content and abundant magnetite. The richest material has probably been removed by erosion, and some of it may be represented in the overlying lacustrine sediments, which contain abundant magnetite, clay, feldspar and up to 640 ppm Cu.



Techniques of mineral exploration. Using a concentrator to up-grade panned heavy mineral concentrates of overburden for mineral examination in the field

79 Volcanogenic and exhalative mineralisation within Devonian rocks of the South Hams district of Devon

R C Leake and others (1985)

Soil samples collected across the outcrop of the Devonian volcanic rocks between the River Yealm and Tonnes in the South Hams district display several geochemical anomalies, the most extensive and highest-amplitude of which comprise: Ba with smaller amounts of other elements in the Burraton area; Ba and other elements in the Higher Ludbrook area and further northeast; Sb in the Ladywell area; As in the extreme west of the area; Cu in association with a diabase body near Weeke; and Zn and Pb around Willing Cross.

In the Burraton and Higher Ludbrook areas resistivity/IP, VLF-EM, VLF-R and some detailed gravity surveys were conducted. Around Burraton resistivity anomalies were generally coincident with soil Ba anomalies, but there was no coincident gravity anomaly. In the Higher Ludbrook area a massive carbonate horizon found by drilling is responsible for a zone of high apparent resistivity and a residual Bouguer anomaly high; IP anomalies indicate that disseminated pyrite-rich mineralisation may be extensive, although the results of EM and resistivity surveys suggest that the massive pyrite intersected in one of the boreholes is of limited lateral extent.

Geophysical surveys were also carried out near Ba anomalies around Whetcombe Cross and near Fursdon in an area of diffuse geochemical anomalies. A small-amplitude IP anomaly in the Fursdon area indicates a possible zone of disseminated, pyrite-rich mineralisation.

In the Higher Ludbrook area the drilling proved a sequence of massive ankeritic-carbonate-quartz rock about 25 m thick, underlain by massive pyrite up to 7 m thick resting on highly altered tuffaceous volcanic rocks; the sequence is interpreted to be of exhalative origin. Associated with the carbonate rock are high Zn, minor baryte and veinlets

containing pyrite, tetrahedrite and chalcopyrite. The carbonate rock also contains some inclusions of highly altered schistose tuff with more than 5 wt% Ba. In this rock, and also in similar volcanic rocks beneath the pyrite, Ba appears to be accommodated chiefly in muscovite. The massive pyrite is lensoid in shape, with very minor chalcopyrite. Pyrite in layers up to 0.25 m thick and as rich disseminations also occurs in the upper part of the volcanic rocks beneath the pyrite rock. The tuffaceous volcanics are highly altered basic rocks enriched in potassium. They contain minor amounts of discordant tetrahedrite, chalcopyrite and Co-Ni mineralisation.

In the Burraton area argillaceous sedimentary rocks were the dominant rock type in the drill-holes, a 10-m volcanic horizon also being present. Quartzite and baryte occur within a 2-m zone, which may be similar to the massive, layered baryte float seen in the vicinity.

The Ladywell borehole intersected an inverted sequence of volcanic rocks similar to those from the Higher Ludbrook area. No significant Sb mineralisation was intersected, and the source of the surface anomalies remains uncertain.

The extensive exhalative mineralisation and disseminated sulphide in altered volcanic rocks in South Hams suggest the activity of large, convective hydrothermal cells. The geochemistry suggests that enrichments of Au may also occur in the region.

80 Mineral investigations in the Ben Nevis and Ballachulish areas of the Scottish Highlands

H W Haslam (1986)

A drainage geochemical survey of the Ben Nevis area revealed above-background levels of Mo that are associated with the outer margins of the Porphyritic Outer granite and probably related to small-scale vein-type mineralisation, such as that exposed in the Allt Daim.

Disseminated pyrite, sometimes with pyrrhotite and/or chalcopyrite, is quite common in the dioritic, appinitic, trondhjemitic and ultrabasic rocks near the Ballachulish igneous complex. Cu values are low, and the sulphide disseminations are probably primary.



Techniques of mineral exploration. Trenching

81 Investigations for tin around Wheal Reeth, Godolphin, Cornwall

K E Beer and others (1986)

Recognition of greisenisation associated with worked Sn lodes in granite near Wheal Reeth suggest the possibility of unrecorded mineralisation of stockwork or vein-sheet type. Geophysical methods were unable to define either greisenised or mineralised ground, and a line of shallow, percussive boreholes was drilled to examine the distribution of Sn, associated base metals and F in solid rock below surface soils, which may have been highly contaminated by former mining.

No economic mineralisation was revealed by the investigation nor was any broadly disseminated metallisation indicated. Not all of the worked tin-bearing structures could be identified from vertical percussive holes, but one new vein was located by vertical and inclined drilling and trenching. The drill-holes outlined at least four more stanniferous veins or vein zones south of the Lady Gwendolen workings. Heavy-mineral concentrates from the drilling samples revealed the ubiquitous enrichment of cassiterite at the base of the regolith cover.

82 Mineral investigations near Bodmin, Cornwall. Part 4—Drilling at Royalton Farm

K E Beer, K Turton and T K Ball (1986)

Fourteen percussive drill-holes showed that weak Sn mineralisation persists for a distance of at least 50 m into the Devonian slates that form the hanging-wall of the Royalton elvan. Anomalous Sn values are recorded along the full strike length of the former opencast workings of Old Castle-an-Dinas mine, but the richest concentrations are found near the circular, western pit. Even there the grades rarely reach economically interesting levels—and then only over intervals of 1.5 m.

Immediately east of the open works there is a marked enrichment in Cu and Ni, but at levels well below those of economic significance.

83 Mineral investigations near Bodmin, Cornwall. Part 5—The Castle-an-Dinas Wolfram Lode

K E Beer, T K Ball and M J Bennett (1986)

A soil survey over Devonian slates to the south of Castle-an-Dinas wolfram mine produced anomalies indicative of at least two sub-parallel zones of W veining and a broad area of anomalously high Sn values. Percussive drilling confirmed widespread Sn mineralisation beneath the soil anomaly, but the *in situ* W mineralisation was confined almost entirely to one zone, which can be correlated with the Wolfram Lode in the mine.

To the north of the former workings three sets of traverses were also sampled from percussive drill-holes. Two zones of W-Sn mineralisation—sometimes with Cu—were located, one correlatable with the Wolfram Lode and the other sub-parallel and some 90 m to the west.

Close to the surface these lode extensions are sub-economic, but it appears that viable ore grades are located in the metamorphosed slates within about 200 m of the contact with the small granite outcrop at Castle-an-Dinas. The ore potential south of the old workings can be estimated at about 1000 t of recoverable tungsten. To the north the strike length of possible mineralisation is less predictable, but there is little doubt that this area offers the better target for exploration.



Techniques of mineral exploration. Gas sampling to detect CO₂ and O₂ over gold-bearing arsenopyrite-pyrite veins

84 An airborne geophysical survey of part of west Dyfed, South Wales, and some related ground surveys

J D Cornwell and R Cave (1985)

A detailed airborne geophysical survey was made of part of west Dyfed with magnetic, electromagnetic (VLF-EM) and radiometric equipment mounted in a helicopter. The 670 km² area includes the Precambrian anticlines of St David's and Hayscastle, the Ordovician Fishguard, Sealyham and Treffgame volcanic groups and the adjacent Lower Palaeozoic sediments and basic intrusions.

Ground geophysical surveys were carried out at 33 localities to confirm the nature and the sources of the airborne anomalies, and a geological examination was also made at selected localities. Rock samples were collected for petrographic examination and the determination of physical properties. A regional gravity survey was also conducted.

The aeromagnetic data show clearly the distribution of the Precambrian rocks, the numerous dolerite intrusions and some of the pillow lavas associated with the Fishguard Volcanic Group. This distribution generally confirms the outcrop pattern observed in geological mapping. The magnetic data are likely to be more reliable for mapping on a more detailed scale on account of the extensive drift cover that hinders geological mapping in many places, and they have also revealed some large-scale structures, including a previously unrecorded dyke at least 40 km long. The VLF data indicate the presence of many conductive horizons, mostly within Lower Palaeozoic sediments.

85 Geophysical surveys near Strontian, Highland Region

G S Kimbell (1986)

Reconnaissance VLF-EM and magnetic surveys were carried out over Ba-Pb-Zn prospects near Strontian. Rather than attempting to detect the economic minerals directly, which is unlikely to be practicable by geophysical methods, the trials concentrated on exploration for the crush zones and associated Permo-Carboniferous basic dykes that act as hosts to mineralisation. The VLF-EM method proved effective in delineating crush zones, whereas magnetic traverses detected the basic dykes. To the east of Bellsgrove mine a crush zone and dyke extend eastwards along the strike of the Strontian Main Vein. Several crush zones and associated dykes were identified in the Corrantee-Whitesmith area. Probable extensions are indicated to a number of known veins near Fee Donald mine.



Techniques of mineral exploration. Digital geophysical equipment for the simultaneous recording of total magnetic field and vertical gradient, and VLF-EM data

86 Volcanogenic mineralisation in the Treffgarne area, south-west Dyfed, Wales

M J Brown and others (1987)

An integrated programme of geological, geochemical and geophysical investigations in the Treffgarne area identified a zone of intense hydrothermal alteration associated with disseminated and vein pyrite within acid volcanic and sedimentary rocks of the Roch Rhyolite Group. Reconnaissance geophysical surveys revealed a 6 km zone of high chargeability coincident with rocks of the Roch Rhyolite Group.

Following geological mapping and reconnaissance soil sampling, three boreholes were sited to investigate the geophysical anomalies. The acid volcanic rocks are all highly altered, characterised by exceptionally low total $\text{Na}_2\text{O} + \text{CaO} + \text{K}_2\text{O}$ and high Al_2O_3 , Fe, S and, locally, Sr and Ba. This is reflected mineralogically by the presence of corundum, baryte and abundant pyrite. The associated altered sedimentary and pyroclastic rocks are intensely sericitised and contain

numerous veins and stringers of quartz and pyrite. Some samples of highly pyritiferous dark mudstone contain enhanced levels of gold.

Evidence from geological mapping, litho-geochemistry and palaeontological studies suggests that the rocks of the Roch Rhyolite Group are of Lower Ordovician (Arenig) age—not Precambrian as previously documented. An Ordovician age enhances the mineral potential of the Roch Rhyolite Group because of the known association of Ordovician igneous activity with volcanogenic mineralisation in the southern Caledonides.

87 Exploration for stratabound mineralisation in Middle Dalradian rocks near Huntly, Grampian Region, Scotland*

J S Coats and others (1987)

Test drilling on geochemical and geophysical anomalies associated with very poorly exposed Middle Dalradian metasedimentary rocks of the Portsoy Group at Wellheads Farm, 4 km WSW of Huntly, has revealed intraformational breccias, sulphidic graphitic chert and stratabound pyrite in graphitic quartzite—features that are favourable for the occurrence of stratabound base metals in the area. Adjacent basic-ultrabasic rocks, although not examined, are favourable for platinum and chromite investigation.

Initial Zn anomalies in stream sediment were followed up by shallow and deep overburden sampling and by geophysical surveys (VLF-EM, IP and magnetic) along 5.2 km of across-strike traverses over an area of 2.5 km². Metal dispersion is hydromorphically controlled in overburden (up to 30 m thick) and probably also in biotite-muscovite schist—the principal bedrock type in boreholes 1–5, which is decomposed and leached to at least 30 m below surface. A final, southernmost, borehole (no. 7) proved fresher rocks, including breccias and pyritic quartzites, chert and limestones. Further geochemical and geophysical surveys, followed by drilling with improved core recovery, are needed in this area, and deeper drilling is required further north to intersect unaltered mica schists.

* Available only in the form of a data package

88 Mineral exploration for zinc, lead and baryte in Middle Dalradian rocks of the Glenshee area, Grampian Highlands

J S Coats and others (1987)

Drainage surveys and airborne geophysical surveys of a 600 km² area from Blair Atholl to Braemar identified several targets near Glenshee within the Ben Eagach Schist, the host formation of the Aberfeldy deposits 30 km along strike to the southwest. Integrated geological, geochemical and geophysical surveys were carried out over these targets. The extensive cover of peat and glacial overburden, particularly over the softer lithologies of the formation, hinders geological mapping, and near-surface leaching has destroyed most of the sulphide. The presence of base metals and baryte is best shown by detailed drainage sampling, and the sulphide-bearing graphitic schist can be traced through drift-

covered ground by VLF-EM, IP and SP surveys. Six shallow boreholes were drilled on the basis of the geochemical and geophysical anomalies and mapping of the available outcrop.

Zinc-lead mineralisation was found in the clastic lower member of the Ben Eagach Schist as well as in the upper member of graphitic schist. Vein baryte with minor base metals is present in the Ben Lui Schist, a higher Middle Dalradian formation, in southern Glenshee.

89 Geochemical and geophysical investigations of the Permian (Littleham Mudstone) sediments of part of Devon

J H Bateson, C C Johnson and A D Evans (1987)

New geophysical and geochemical data are presented from three deep, cored boreholes drilled through the Littleham Mudstone sequence. Also included are chemical data for a number of the uraniferous nodules that are scattered throughout the mudstones and which have long been known to be enriched in a variety of metals besides U and V. The borehole geophysical data provide new information on the character of the sediments and the distribution of the nodules in an area where there are few alternative sources of this information.

90 Geochemical and geophysical investigations in Exmoor and the Brendon Hills

R C Jones, K E Beer and J M C Tombs (1987)

Drainage geochemical surveys over Exmoor and the Brendon Hills indicated areas of anomalous metal concentrations in stream sediments which call for further investigation. Some of these anomalies undoubtedly relate to vein-style mineralisation, but others probably reflect a stratiform distribution of ore metals. Ba anomalies were also recognised and indicate previously unrecorded veins of baryte.

Investigation of an aeromagnetic anomaly trending WNW-ESE over the upland areas indicates that it comprises components of both deep and shallow origin. The source of the more deep-seated magnetic anomaly remains uncertain, but two drill-holes showed the shallow source to be pyrrhotite mineralisation in the form of disseminations and veinlets. Detailed soil-geochemical studies were conducted over some of the aeromagnetic anomalies.

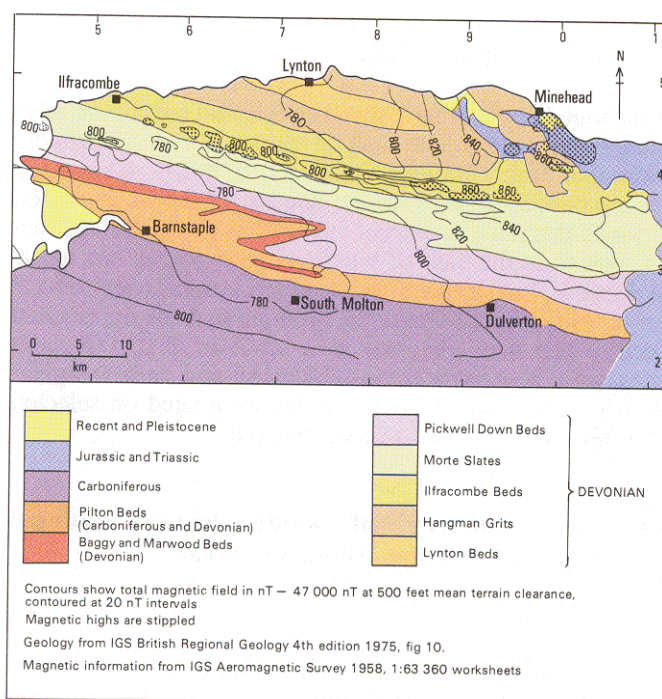
91 A geochemical survey of part of the Cheviot Hills and investigations of drainage anomalies in the Kingsseat area

D G Cameron and others (1988)

A reconnaissance geochemical drainage survey in the Cheviot Hills of northern England identified anomalous concentrations of metals, which are, in general, related to (i) known mineral occurrences, (ii) hydrous oxide precipitation and scavenging processes, (iii) the relatively widespread

occurrence of baryte, (iv) contamination, (v) tourmalinisation and other hydrothermal activity and (vi) high background levels in unmineralised rocks. Some anomalies may reflect hitherto unknown mineralisation. Anomaly groupings and regional variation patterns in the data are influenced by major structures such as the Gyle-Harthope fracture zone.

In the Kingsseat area, rocks previously mapped as extrusive mica felsites are reinterpreted as a high level intrusion complex, named the Cock Law Complex, which contains five distinct types of porphyry. Many of the intrusive and extrusive rocks are highly altered. Metal enrichments were recorded in many of the analysed rocks. The greatest enrichments, for the widest range of elements, occur in samples taken from a gossanous structure, where the mineralisation has features in common with the epithermal precious-metal style of mineralisation associated with sub-aerial volcanism.



Generalised geology of the Exmoor area, and aeromagnetic anomalies (Report No. 90)

92 A mineral reconnaissance survey of the Llandrindod Wells/Builth Wells Ordovician inlier, Powys

T R Marshall, R C Leake and K E Rollin (1987)

A reconnaissance drainage geochemical survey, supplemented by soil sampling, located several Pb and Zn anomalies, many of which appear to be associated with the outcrop of the main volcanic unit of the area. Samples collected from an area of old lead workings in the west of the inlier failed to provide evidence of further vein mineralisation beyond the limits of the workings. Elsewhere the biggest concentration of Pb and Zn anomalies and the greatest amplitude of anomaly (2000 ppm Pb) were located over the northern outcrop of the main unit of tuffaceous volcanic rocks, particularly in the vicinity of the farm Pen Rhiw Frank.

A detailed geological, geochemical and geophysical survey of this area was carried out. The geophysical work revealed a zone of high resistivity with roughly coincident low amplitude chargeability maxima and a VLF crossover over part of the zone. There was a general association of this zone with Pb in soil anomalies and the presence of significant amounts of weathered pyrite in the limited outcrops. The Pb in soil anomalies broadly follow the local strike of the rocks. Four boreholes were drilled to test the down dip extension of apparently stratabound surface soil anomalies. Secondary Pb minerals occur within a soft clay-rich section 5.8 m thick near the top of one of the holes. Lead levels up to 0.52% over 3.4 m were found in this zone, which is located at the interface between a dacitic tuff and an andesitic lava.

93 Stratabound base-metal mineralisation in Dalradian rocks near Tyndrum, Scotland

C G Smith and others (1988)

Stratabound zones of base-metal enrichment (sphalerite, with subordinate galena and chalcopyrite) occur in the Middle Dalradian Ben Challum Quartzite, a newly recognised horizon occurring between the Ben Lawers Schist, at the top of which there is a horizon of cupriferous pyrite, and the Ben Lui Schist, at the base of which a chromiferous horizon is developed. The distribution of mineralisation over some 9 km of strike length between Tyndrum and the upper Glen Lochay has been mapped at a scale of 1:10 000, and integrated geophysical, geochemical and mineralogical studies carried out. Four boreholes were sited on selected anomalies and the resultant core analysed.

94 Geochemistry of some heavy mineral concentrates from the island of Arran

K E.Beer (1988)

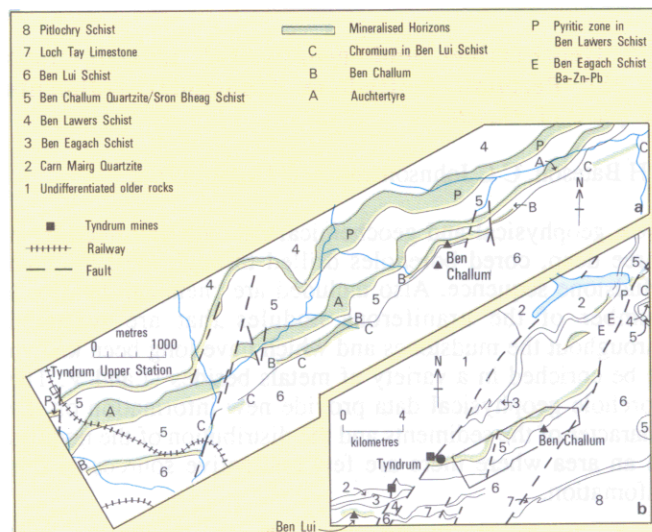
Chemical analysis of panned concentrates has identified areas of possible mineralisation that merit further study. Moderate values of Sn and W in the Tertiary Goatfell granite suggest the possibility of disseminated low grade mineralisation. A cluster of anomalous values near the southern margin of the northern granite holds out some hope of zones of quartz-molybdenite veining associated with the marginal areas of the granite. Anomalous values for Ag are quite widely spread in the southern half of the island and appear to be associated with some of the basic minor intrusives. There are high Ba values in samples from the environs of the northern granite and over the Palaeozoic sediments east of Machrie Bay. Occasional very high values for Cu and Pb occur in lithologies which might well host sulphide mineralisation.

95 Mineral reconnaissance at Menear, St Austell, Cornwall

K E Beer, B C Tandy and G S Kimbell (1988)

Geochemical soil sampling shows no evidence for a continuation of the Menear stockwork Sn mineralisation

beyond the eastern rim of the old openwork, though there may be some extension westwards below areas of recent housing development. Elevated levels of Sn in soils are indicated to the north of Wheal Eliza, with above average values of Cu and Zn immediately to the south, over the site of that mine; VLF-EM anomalies delineate several possible mineral veins in this area. None of these metals is present at concentrations likely to be of economic interest.



Stratabound mineralisation in the Dalradian of the Tyndrum-Ben Challum area (a); and its spatial relationship with the Loch Lyon horizons and the Tyndrum mines (b) (Report No. 93)

96 Geochemistry of sediments from the Lui drainage, Braemar, Grampian

K E Beer and M J Bennett (1988)

Stream sediments from the western headwaters of the Lui Water all contain markedly high amounts of Nb and some bear anomalous levels of Ce, Y, Th or Zr. Most of this composition is attributable to the presence of a refractory mineral suite presumed to be derived from nearby granitic rocks. The tenor of these elements, however, offers little prospect of any significant concentrations of industrial or ore minerals.

97 Magnetic and geochemical surveys in the area between Geltsdale, Cumbria, and Glendue Fell, Northumberland

A D Evans, P D Roberts and J H Bateson (1989)

A magnetic survey over the northwest corner of the Lower Carboniferous Alston Block revealed anomalies en-echelon along the line of an aeromagnetic feature. These may represent part of a major NE-SW structural feature extending to the northeast across Northumberland. The magnetic data indicate that the Whin Sill may be more extensive than suggested on the geological map, and additional evidence for

this is provided by the geochemical data from the Thinhope Burn and Glendue Burn catchments immediately west of the River South Tyne. Geochemical stream and soil sampling confirm Pb-Zn mineralisation in the area.

98 Exploration for gold between the lower valleys of the Erme and Avon in the South Hams district of Devon

R C Leake and others (1988)

A geochemical drainage survey within a poorly understood belt of Lower Devonian rocks, using panned concentrates, revealed gold anomalies which were subsequently followed up by overburden sampling, geophysical surveys and drilling. The geophysical data suggest that the upper crustal structure of the area and its relationship with the Start Complex to the south require re-interpretation.

The multivariate statistical procedures of principal component analysis and cluster analysis, applied to the drainage geochemical data, facilitated recognition of geochemical patterns reflecting major geological boundaries and mineralization of different types.

Comparison of the analyses of different size fractions of the concentrate samples proved useful in detecting anomalies likely to be derived from contamination and in classifying anomaly types. The drainage data strongly suggest the presence of a major fault, trending around WNW, separating two entirely different sequences in the northeast of the area.

The use of panned overburden samples from shallow pits in exploration for gold is described and compared with the results of conventional sieved soil samples. Mineralogical examination and chemical analysis of mineral grains from overburden concentrate samples led to the discovery of the very rare mineral potarite (Pd + Hg) and the recognition of several types of iron oxide, cassiterite and some secondary base-metal minerals.

On average the diameter of gold grains in drainage is three times that in overburden grains, whether from background or anomalous sites. To account for this it is suggested that gold grain growth has occurred in head and perhaps in more recent alluvium in valley bottoms.

The chemical composition of overburden gold grains from a number of sites has been determined by electron microprobe. Many grains have relatively silver-rich rims while the bulk of the grain is silver-poor, frequently containing a few percent Pd. Other grains are pure gold to the detection limit of the analytical procedure employed.

99 Base-metal and gold mineralisation in north-west Anglesey, North Wales

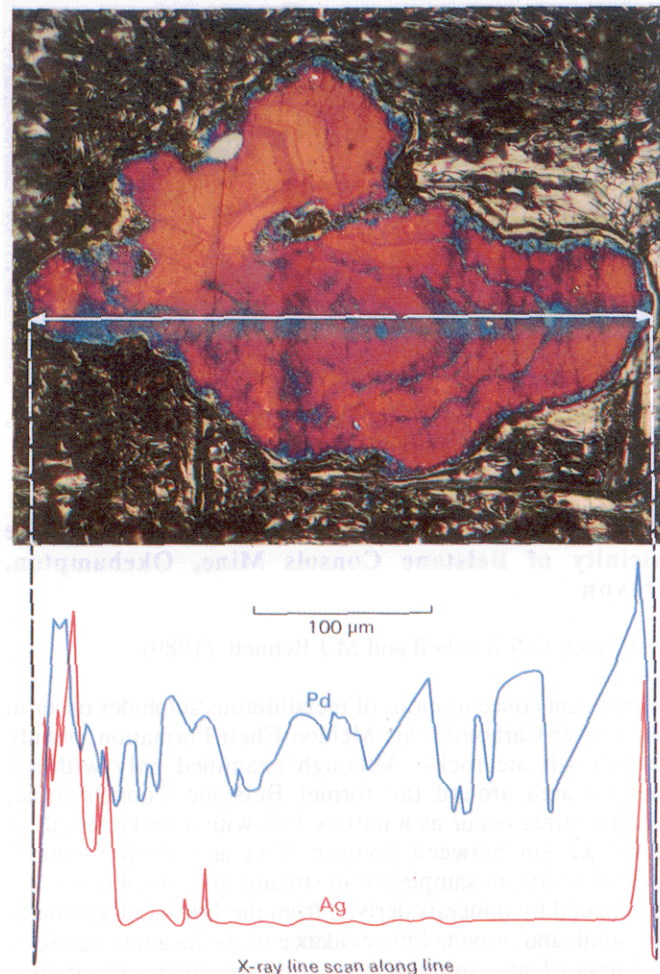
D C Cooper and others (1990)

Mineral exploration in northwest Anglesey, an area of complex geology with rocks ranging from Precambrian to Ordovician, has indicated the presence of hitherto unknown base-metal mineralisation, accompanied locally by gold. Very low frequency electromagnetic ground survey data contain strong features related to mapped fault lines and

steeply dipping geological boundaries. IP and soil survey data indicate the presence of anomalies related to mineralisation and more detailed surveys were carried out in the area between Carmel Head and Llanfairynghornwy.

The sources of seven of the geophysical anomalies were investigated by fifteen boreholes ranging in depth between 32 and 122 m. These boreholes showed that the anomalies were related to buried base-metal sulphide (Cu, Zn, Pb) mineralisation, locally accompanied by gold. The mineralisation is polyphase: syngenetic/diagenetic pyrite and disseminated pyritisation (possibly associated with sericitic alteration) events are followed by hydrothermal mineralisation characterised by quartz \pm carbonate \pm chalcopyrite \pm sphalerite \pm galena \pm pyrite veins and impregnations. This mineralisation occurs in at least five separate structures.

Geochemical and geophysical anomalies not investigated by drilling suggest the presence of further mineralised structures and extensions to those intersected by drill-holes.



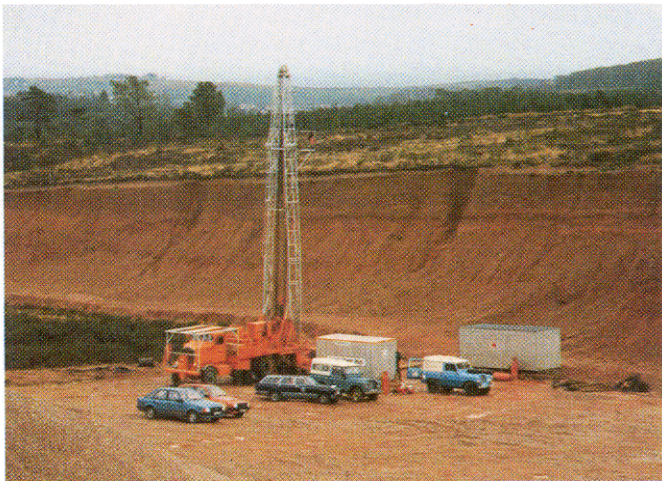
Silver and palladium concentrations along an electron microprobe scan of an overburden gold grain showing colour zoning (Report No. 98)

100 Molybdenum mineralisation near Chapel of Garioch, Inverurie, Aberdeenshire

T B Colman and others (1989)

Molybdenum and tungsten mineralisation in quartz veins is associated with the Caledonian Middleton granite, a small stock apparently rooted in the buried roof of the large Bennachie pluton. The granite is emplaced in Dalradian schists. The veins are usually in granite, which is intensely sericitised (greisenised?); the alteration and mineralisation are believed to be coeval.

Geophysical surveys were used to define the granite stock, an epidiorite body (a sill?) which caps the hill, and a late (Tertiary?) east-west basic dyke. Four short inclined boreholes were drilled in the Dalradian schists to the east of the granite stock and three into the granite itself. The drilling intersected minor quartz-molybdenite mineralisation in both schist and granite. Exposure is poor and neither the drilling nor base-of-drift geochemical sampling were effective in defining the distribution of the mineralisation.



Techniques of mineral exploration. Core drilling, accompanied by geophysical logging

101 Skarn-type copper mineralisation in the vicinity of Belstone Consols Mine, Okehampton, Devon

K E Beer, G S Kimbell and M J Bennett (1989)

Significant concentrations of metalliferous sulphides occur in the Lower Carboniferous Meldon Chert Formation, mainly in calc-silicate rocks. Although examined only within a limited area around the former Belstone Consols mine, similar strata occur as a narrow belt with a strike length of some 22 km between Sourton Tors and Drewsteignton. Stream sediment samples from streams crossing this belt are dominated by minerals derived from the Dartmoor granite to the south and provide little evidence of the location, nature or richness of any sulphide ores. Soil geochemical surveys, however, do indicate clearly the presence and general composition of near-surface mineralisation, even when sited on steep valley slopes or over rather narrow ore beds.

Surface geophysical surveys immediately west of Belstone Consols mine detected and traced horizons of

contrasting resistivity and chargeability and provide a new insight into the geological structure. Most of the geophysical markers do not relate directly to potentially economic mineralisation, although higher chargeability values were observed over the principal mineralised zones revealed by subsequent drilling. Magnetic surveys indicate that pyrrhotite is no more than a minor constituent of the mineralisation in the vicinity of the mine.

Drilling proved the presence of significant Cu and As mineralisation, with little Zn. Co is not important as an accessory metal, but high values of Bi are quite common. Sn is well developed in most calc-silicate lithologies but is present mainly in the garnets. Metal values locally exceed 3%. The worked ore beds were not identified with certainty, but it seems that a previously unknown mineralised horizon can be recognised higher in the Meldon Chert Formation.

102 Geophysical and geochemical investigations of the manganese deposits of Rhiw, western Llyn, North Wales

M J Brown and A D Evans (1989)

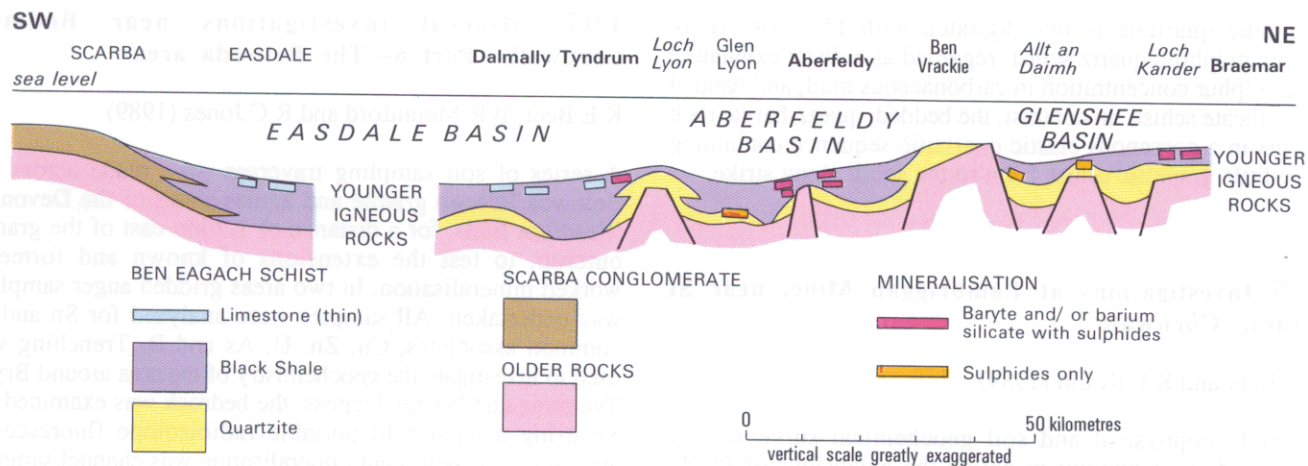
Detailed magnetic surveys were carried out southwest from the old Benallt Mn mine as far as the old Nant mine, and northwards from Benallt towards Sarn. Rocks in the area are of Arenig and Llanvirn age (Lower Ordovician) and consist of mudstones, siltstones and sandstones with interbedded basic lavas and sills. The Mn deposits occur in a structurally complex setting in Arenig sediments, between a basic sill and a dolerite or basalt lava. That part of the Mn mineralisation which is of ore grade is unique within the British Isles because of its strong magnetisation, caused by the presence of the Fe-Mn oxide jacobsonite. Soil samples from across-strike traverses proved of limited value for exploration purposes, mainly because of the variable depth of drift cover. Ti and V were useful in areas of limited drift cover as an aid to mapping the sub-crop of the basic igneous rocks.

The more extensive magnetic anomalies mark the sub-crop of a basic sill (the Footwall Sill), which occurs below the sediments that host the manganese mineralisation. In addition, several very localised magnetic anomalies were identified, three of which were investigated by drilling. Two of them were found to be due to stratabound ironstones of very limited lateral extent and of particularly high magnetic susceptibility. These ironstones contain up to ~70% Fe₂O₃ and show a marked depletion in Mn compared with the enclosing sediments and basic igneous rocks. It is thought that other anomalies may be due to discrete bodies of Mn ore.

103 Exploration for volcanogenic mineralisation in Devonian rocks north of Wadebridge, Cornwall

R C Leake and others (1989)

Reconnaissance overburden sampling across the main outcrops of Middle Devonian volcanic rocks clearly showed the position of the contacts between volcanic and



Schematic section of the Dalradian basin at the time of deposition of the Ben Eagach Schist, showing location of stratabound mineralisation (Report No. 104)

sedimentary rocks, either as sharp increases in elements like Ti or in the value of principal component 1 derived from a principal component analysis of the geochemical data. Follow-up overburden sampling delineated several types of anomaly, some of which were investigated with ground geophysical surveys. Finally eight diamond drill holes were collared to test the source of five overburden anomalies. Forty horizons of basic igneous rock were intersected in the drill holes, some clearly volcanic and others clearly intrusive, varying in inclined thickness from a few cm to over 50 m. Four compositional groups of basic igneous rock were recognised on the basis of relative concentrations of the immobile elements Ti, Y, Zr and Nb.

Two varieties of quartz vein were found as loose blocks during the overburden sampling, one containing boulangerite + galena and the other with arsenopyrite + pyrite. A significant amount of Au (up to 1.0 ppm) is associated with the arsenopyrite-bearing veins. No veins corresponding exactly to these two varieties were intersected in the drill holes, though quartz veins and veinlets with either manganian siderite or ankerite are common. Associated with some of these veins and with chloritic veins are pyrite, arsenopyrite, chalcopyrite, sphalerite and galena in varying proportions and minor amounts of tetrahedrite, some of which is richly argentiferous. A second variety of mineralisation, consisting of minor amounts of bournonite, jamesonite and stibnite, is closely associated with intrusive greenstone bodies and their immediate aureoles. Stibnite and secondary products of its alteration in association with siderite is a third type of mineralisation.

104 Stratabound barium and base-metal mineralisation in Middle Dalradian metasediments near Braemar, Scotland

MJ Gallagher and others (1989)

Stratabound mineralisation comprising baryte, Ba silicates, sphalerite, galena and other sulphides has been discovered in the upper part of the Ben Eagach Schist Formation 11–13 km SSE of Braemar. This Formation forms part of the

Middle Dalradian (late Precambrian to Cambrian) sequence of metasedimentary and meta-igneous rocks. The new mineralisation occurs at the same stratigraphical position as the Aberfeldy and Loch Lyon deposits, 45 km and 90 km southwest respectively along the regional strike in the Grampian Highlands. Up to 10% Zn + Pb is present in Coire Loch Kander in quartzite which also contains hyalophane and armenite, the rare hydrated Ba–Ca aluminosilicate. Bedded quartz-baryte rock, some 5 m thick, is exposed in the headwaters of Allt an Loch, 1–2 km south of Loch Kander. A Ba anomaly in the overburden extends over 1.6 km along the strike of the bed. The mineralisation was found as a result of integrated geochemical–geophysical–geological investigations northeastwards along the presumed strike of the Ben Eagach Schist from the Glenshee district. Overburden sampling and geophysical (VLF-EM, magnetics, IP and SP in part) measurements were conducted along 40 km of across-strike lines running for 11 km from Glen Brighty in the south, across the mountains of Glas Maol and Cairn of Claise to the Allt an Loch district and Coire Loch Kander.

Host-rocks are graphitic schists and quartzites, regionally metamorphosed to amphibolite grade, lying at or within a few tens of metres of the top of the Ben Eagach Schist against a thick, sill-like amphibolite body incorporated into the Ben Lawers Schist Formation. Sharp variation in the thickness of the Graphitic Schist Member from 0 m to 300 m may be partly attributable to folding but along-strike facies variation is probably of greater significance. Younger igneous rocks include a stock-like diorite which has contact metamorphosed both the bedded sulphide mineralisation and a thin baryte-galena vein unaffected by the regional metamorphism. The geochemical and geophysical information provides an excellent guide to the bedrock geology which is very poorly exposed except in Coire Loch Kander.

The Zn-Pb sulphide enrichment in quartzite is accompanied by pyrite, actinolite and diopside as well as by armenite, hyalophane and traces of baryte, while the massive fine-grained quartz component of this rock is rich in fluid inclusions. The precursor assemblage may have been a hydrothermally altered sediment or a chemical exhalite. The

sulphidic quartzite is interdigitated with 15 m of highly pyritic graphitic quartz schist, regarded as a distal exhalative iron-sulphur concentration in carbonaceous mud, and banded calc-silicate schist. In contrast, the bedded, quartz-baryte rock occurs in a gossanous clastic quartzitic sequence containing very little graphitic schist 1 km to the south along strike.

105 Investigations at Lambriggan Mine, near St Agnes, Cornwall

K E Beer and K E Rollin (1989)

Ground geophysical and soil geochemical surveys were employed in an attempt to define the extensions of Pb-Zn mineralised veins, in Devonian slates, formerly exploited in the Lambriggan mine. The geochemical surveys did not indicate any extensions to known mineralisation nor any new mineral veins. Of the geophysical methods used, only the IP method offered any promise and even that yielded a somewhat speculative interpretation. It seems unlikely that a significant body of Pb or Zn ore awaits discovery in the immediate area of the Lambriggan mine.

106 Marine deposits of chromite and olivine, Inner Hebrides of Scotland

M J Gallagher, I R Basham and others (1989)

A reconnaissance survey was carried out of near-shore marine deposits considered to have been derived from Tertiary ultrabasic rocks in southwest Skye and southern Rhum, rocks known to be enriched in chrome spinel and forsteritic olivine. Dive sampling close to the rocky coastlines supplemented grab sampling at surveyed locations in water depths of 50 m or less.

In the bay off Harris, southern Rhum, a heavy mineral sand deposit 3 km² in area occurs within 2 km of the coast in waters of 20–25 m average depth. A 1 km² deposit is present up to 1 km off Dibidil, also in southern Rhum, in an average water depth of about 20 m. Using a wet density of 2.2 g.cm⁻³ some 9 million t of sand are calculated to be present in the topmost 1 m of the deltas. Shell calcite forming about 20% was removed prior to chemical analysis.

The analytical results indicate that the surficial 1 m of sand contains some 70 000 t of chrome spinel averaging 32% Cr₂O₃ at a grade of nearly 1%. Also present are 1.5–2 million t of olivine averaging 47% MgO at 25% grade. Accompanying minerals are ilmenite and vanadiferous magnetite, and traces of platinum-group elements have been detected. The minerals occur in sand-size fractions (125–500 μm), from which concentrates of 86% chromite and 78% olivine at recoveries of 60% and 50% respectively have been achieved in the laboratory.

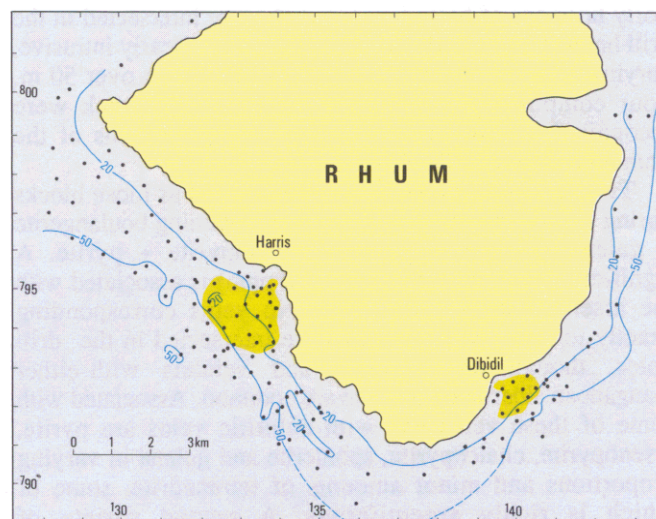
Most of the 63 seabed samples from Loch Scaivaig and the Soay Sound, southwest Skye, are grey glacial sandy clays averaging only 0.5% Cr₂O₃ and 2% Mg after carbonate dissolution. Heavy mineral sands derived from the Cuillins igneous centre may nevertheless underly the glacial deposits. Geophysical surveys and profile sampling are required to determine the thickness and grade of the heavy mineral sands.

107 Mineral investigations near Bodmin, Cornwall. Part 6—The Belowda area

K E Beer, B R Mountford and R C Jones (1989)

A series of soil sampling traverses were made across the Belowda Beacon granite and across slates of the Devonian Meadfoot Beds, for a distance of 1.7 km east of the granite outcrop, to test the extensions of known and formerly worked mineralisation. In two areas gridded auger sampling was undertaken. All samples were analysed for Sn and its common associates, Cu, Zn, U, As and B. Trenching was used to investigate the geochemistry of the area around Brynn Tye mine and Wheal Tregoss: the bedrock was examined for Sn using a hand-held portable radioisotope fluorescence analyser, and significant mineralisation was channel sampled for laboratory assay.

Anomalous Sn values in one of the two gridded areas indicate extensions to two veins which may have been previously worked. Trenching at Brynn Tye mine demonstrated that Sn mineralisation is associated most commonly with quartz-tourmaline veining and alteration of the slates. Two wide zones of low-grade ore were defined by the sampling, one of which was recognised in two trenches, thus defining a limited strike length, but two inclined diamond drillholes failed to find depth continuation to the veining or the cassiterite distribution.



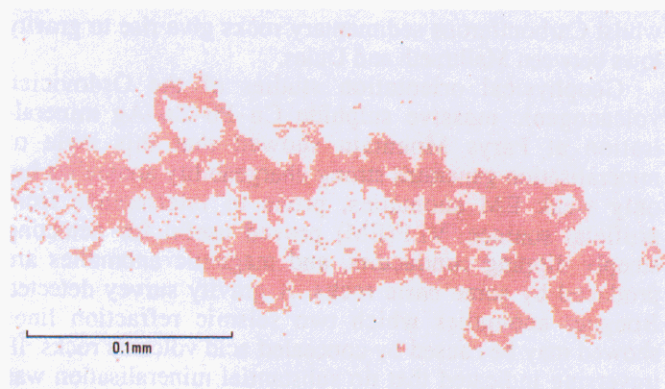
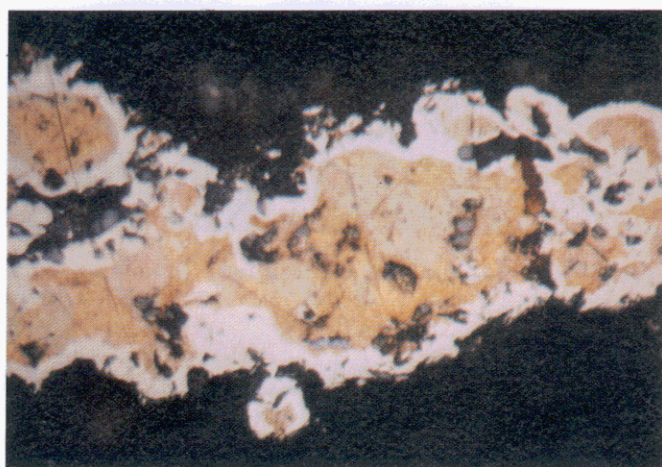
Sample locations and bathymetric observations off southern Rhum, showing the approximate positions of the heavy mineral sands off Harris and Dibidil (Report No. 106)

108 Geochemical investigations around Trewalder, near Camelford, Cornwall

K E Beer and R C Jones (1989)

Stream sediment geochemistry over Devonian slates to the north of St Teath revealed two Zn anomalies, suggestive of an apparently unexplored extension to the Pb lode of Trewalder mine. More detailed stream sampling confirmed these findings, with a significant length of the River Allen

reporting anomalous Zn levels in sediments and panned concentrates. There is no correlation with either Pb or Ag. 150 soil samples were collected for analysis from six lines across the strike of the Trewalder Lode and its possible extensions to the north. Log-probability plots failed to show any significant correlation between the distribution populations and the mapped lithology and mineralisation. Traverse profiles for Pb, Zn and Ba, on the other hand, can be interpreted as showing both particulate and hydromorphic anomalies, suggesting that there may be more than one mesothermal lode in the Trewalder area, extending north of that hamlet for some distance, and that to the north of the River Allen, near Helland, the lode may change in character to become essentially baryte. It appears from the low tenor of the anomalies that the prospects for significant economic ore concentrations must be extremely small. Some previously unexplored Pb-Zn-Ba mineralisation seems to be indicated on the slopes to the west of the River Allen.



Reflected light photomicrograph of detrital gold-platinum grain; and microchemical map, obtained by electron microprobe, showing area of high Pt. The composition of the core is 96% Au, 4% Pd; that of the rim is 60% Pt, 35% Au, 5% Hg (Report No. 111)

109 Copper and molybdenum distribution at Shap, Cumbria

K E Beer and G S Kimbell (1989)

Examination of rock outcrops in and around the Shap granite and percussion drilling behind the Pink Granite Quarry confirmed that Cu and Mo are present over a wide area, though in amounts which everywhere are subeconomic. IP surveys did not provide any evidence of anomalously high concentrations of sulphide mineralisation, although a VLF-EM anomaly indicates a possible northward extension of a fracture zone which is mineralised where exposed in the quarry face. A model suggesting a more deeply buried porphyry-type deposit is not wholly disproved, but the evidence obtained from drillholes and geophysical surveys is not encouraging.

110 Mineral investigations near Bodmin, Cornwall. Part 7—New uranium occurrences at Quito and Higher Trenoweth

T K Ball, B C Tandy and K Turton (1990)

Radiometric anomalies over Devonian slates near Quito and Higher Trenoweth were investigated to determine their subsurface continuity and their potential for associated concentrations of elements such as Co and Ni.

Surface geochemical investigations and drilling indicate that the individual surface anomalies at Quito are too isolated to offer significant targets for further exploration. The low levels of Cu, Pb and Zn suggest that there is little likelihood of this structure being of any significance for mineralisation. Although the anomaly at Higher Trenoweth is traceable for a strike length of at least 300 m it still presents too small a structure to merit further attention. Some high surface Sn and B values are indicated at the southern end of the structure, where kaolinised elvan is known to occur, but although the values reflect the mineralisation they are considered too low to warrant further investigation.

111 Gold and platinum group elements in drainage between the River Erme and Plymouth Sound, South Devon

R C Leake, D G Cameron, D J Bland and M T Styles (1990)

Significant amounts of gold have been found in drainage sediment at several localities in the area of south Devon bounded on the east by the estuary and the lower part of the River Erme and on the west by Plymouth Sound. Gold is particularly abundant at a site about 2 km to the southwest of Holbeton, where many of the grains are dendritic or otherwise extremely irregular in shape. The dendritic gold shows internal zonation in Pd abundance very similar to that seen in material in carbonate veins in limestone at Hope's Nose, Torquay. Other grains show incomplete rims rich in Pd (up to 13%) or are close to pure gold in composition. Grains with silver-rich rims are much less common than in drainage and overburden samples from east of the River Erme.

Associated with the dendritic gold from southwest of Holbeton are dendritic, elongate knobbly and subrounded grains rich in either Pt or Pd or both, forming around 5% of the total. Though some grains are either pure potarite (PdHg)

or Au-bearing potarite without significant internal compositional variation, the majority, including all those containing a significant amount of Pt, show very complex compositional zonation. Six PGE-bearing compositional types have been distinguished. The cores of grains are generally Au-rich: either Au with only small contents of other metals, or Au with significant Pd and Hg. Rims are generally Pt-rich, often with a significant Au or Cu content which may be recognisable as a distinct thin marginal zone. Other compositions include Pt with a significant Hg content, and a combination of roughly equal amounts of Pd, Hg, Au and Pt. Some grains show clear concentric zonation and there may be very large compositional differences between zones only a few microns thick.

Cinnabar occurs in small amounts in several drainage samples from the area but is particularly abundant (up to 2000 ppm Hg) in samples derived from an area underlain by Middle Devonian rocks, chiefly mafic volcanics, in the northeast of the area. The distribution of Mg, Ca, Ti, Mn, Fe, S, Ni, Cu, Zn, As, Rb, Zr, Sn, Sb, Ba, W, Pb and Bi in drainage samples is also discussed. Au concentrations show greatest positive correlation with Mn and Fe but a correlation with Sn is also significant.



Techniques of mineral exploration. Determination of Mo concentration in stream sediment sample, using field-laboratory technique

112 Geophysical and geochemical investigations on Anglesey, North Wales

D C Cooper, I F Smith, M J C Nutt and J D Cornwell (1990)

This report describes a number of surveys carried out on Anglesey and not covered by previous reports in the series.

A gravity survey of the island identified two large amplitude lows: one is associated with volcanic rocks and granite cropping out southeast of the Menai Strait Fault; the



Techniques of mineral exploration. Examining bore-hole core

other is centred off the northwest coast and is possibly caused by a concealed granite. If of Caledonian age, such a granite would have influenced the distribution of base-metal mineralisation on the island. Positive anomalies are associated with metabasic rocks in the southeast of the island whilst Carboniferous sedimentary rocks give rise to gravity lows between Malltraeth and Dulas.

Geophysical orientation studies of the Ordovician volcanogenic massive sulphide Cu-Pb-Zn-Ag mineralisation at Parys Mountain showed that this style of mineralisation generates strong chargeability anomalies but only weak EM anomalies, prone to interference from artificial sources. VLF(EM) proved useful for detecting steeply dipping conductors, and magnetic anomalies are produced by some basic rocks. A gravity survey detected Bouguer anomalies which two seismic refraction lines showed may be caused by concealed acid volcanic rocks. IP traversing indicated that no substantial mineralisation was associated with the Bouguer anomalies.

Ground geophysical surveys confirmed airborne EM and magnetic anomalies at Bodewryd, Rhosbeirio, Treferwydd and Tyntywyn. At Rhosbeirio and Tyntywyn the cause of the EM ground anomalies remains uncertain whilst at Bodewryd and Treferwydd basic dykes are the probable source of magnetic and EM anomalies.

Soil sampling was carried out around Cerrigceinwen, City Dulas, Llanbadrig, Llandyfydog and Lligwy to investigate promising indications of mineralisation arising from earlier regional surveys. In addition, geochemical groundwater surveys were carried out around Cerrigceinwen and Llanbadrig, geophysical traversing at Llanbadrig and City Dulas, and rock sampling at Llandyfydog.

Anomalous results related to mineralisation, possibly of similar style to that found at Parys Mountain or Carmel Head, were recorded at Llanbadrig. Geochemical and geophysical anomalies probably caused by hitherto undiscovered mineralisation were also found at City Dulas.

At Llandyfydog large base-metal anomalies in soils were ascribed to metal-rich water, derived from the Parys Mountain mine, flooding across and percolating into superficial deposits. Some smaller anomalies are probably derived from weak base-metal vein mineralisation. In the Cerrigceinwen area stream sediment and groundwater survey data suggest that mineralisation might be associated with spilitic rocks within the Mona Complex and the basal Carboniferous succession, but limited soil sampling across these lithologies only located a few isolated base-metal anomalies. The single soil traverse sampled across the basal Carboniferous at Lligwy produced similar results.

113 Mineral investigations at Tredaule, near Launceston, Cornwall

R C Jones and K E Beer (1990)

Five sediment samples from the two small streams east of Tredaule yielded panned concentrates with anomalous

contents of Sn and W, suggestive of local mineralisation. A single soil sampling traverse was sited parallel to the main stream and in the analyses of 34 soils from this line a small group of coincident Sn and W anomalies were reported, as well as a marked pair of Ag anomalies farther south.

In an endeavour to determine the source of these anomalies a gridded pattern of soil samples was collected. A total of 379 samples were analysed for a range of ore metals and associated elements. For some elements the results were combined with those from the adjacent traverse line prior to statistical treatment. From these results it is possible to recognise several soils anomalous in Sn, usually with associated elevated levels of W, and a different set anomalous in Ag. The latter are sometimes associated with anomalous levels of Cu, but there is a separate grouping of Cu anomalies which may have a closer relationship either to the Sn anomalies or to the volcanic rocks over which they are located.

It remains an open question as to whether the anomalies have been fully defined in this restricted geochemical programme or whether they continue to the east of the Tredaule stream. The correlation between W and Sn, and the location of their anomalies relative to those of Cu and to the mapped geology, suggests the presence of an east-west hypothetical vein.

	Ag	As	Au	Ba	Bi	Co	Cr	Cu	F	Hg	Mn	Mo	Ni	Pb	PG	Rn	Sb	Sn	Ti	U	V	W	Zn	multi- element	
1 The concealed granite roof in south-west Cornwall	◆	◆	.	.	.	◆	◆	.	
2 Geochemical and geophysical investigations around Garras Mine, near Truro, Cornwall	◆	◆	◆	◆	◆
3 Molybdenite mineralisation in Precambrian rocks near Lairg, Scotland	◆	◆
4 Investigation of copper mineralisation at Vidlin, Shetland	◆	◆	◆	◆
5 Preliminary mineral reconnaissance of Central Wales	◆
6 Report on geophysical surveys at Struy, Inverness-shire	◆	◆	.
7 Investigation of tungsten and other mineralisation associated with the Skiddaw Granite near Carrock Mine, Cumbria	.	◆	◆	◆	◆	.	◆	.	◆	.	◆
8 Investigation of stratiform sulphide mineralisation in parts of central Perthshire	.	.	◆	◆	◆	◆	◆
9 Investigation of disseminated copper mineralisation near Kilmelford, Argyllshire, Scotland	.	◆	◆	.	.	.	◆	.	◆	◆	◆
10 Geophysical surveys around Talnoy Mine, Kirkcudbrightshire, Scotland	◆	◆
11 A study of the space form of the Cornubian granite batholith and its application to detailed gravity surveys in Cornwall
12 Mineral investigations in the Teign Valley, Devon. Part 1—Barytes	.	.	.	◆	◆	◆	◆
13 Investigation of stratiform sulphide mineralisation at McPhun's Cairn, Argyllshire	◆	.	◆	◆	◆	◆
14 Mineral investigations at Woodhall and Longlands in north Cumbria	.	.	.	◆	.	.	.	◆	◆	◆	.
15 Investigation of stratiform sulphide mineralisation at Meall Mor, South Knapdale, Argyll	◆	◆	.	.	◆	◆	◆
16 Report on geophysical and geological surveys at Blackmount, Argyllshire	◆
17 Lead, zinc and copper mineralisation in basal Carboniferous rocks at Westwater, south Scotland	◆	◆	◆	◆
18 A mineral reconnaissance survey of the Doon-Glenkens area, south-west Scotland	.	.	◆	◆	.	.	.	◆	.	◆	◆	◆	◆
19 A reconnaissance geochemical drainage survey of the Criffel-Dalbeattie granodiorite complex and its environs	.	.	.	◆	.	.	.	◆	◆	◆	.	.	.	◆	◆
20 Geophysical field techniques for mineral exploration
21 A geochemical drainage survey of the Fleet granitic complex and its environs	◆	◆	◆	◆
22 Geochemical and geophysical investigations north-west of Llanrwst, North Wales	◆	◆	◆
23 Disseminated sulphide mineralisation at Garbh Achadh, Argyllshire, Scotland	◆	.	.	.	◆
24 Geophysical investigations along parts of the Dent and Augill Faults	.	.	.	◆	◆	◆	◆
25 Mineral investigations near Bodmin, Cornwall. Part 1—Airborne and ground geophysical surveys	◆	.	.	.	◆	.	◆

Report number	Style and type of occurrence							Geological and geochemical techniques reported							Geophysical techniques reported					Other studies							
	Stratabound	Volcanogenic	Granite-related	Vein or stockwork	Ultrabasic	Porphyry	Placer	Regional survey	Geological mapping & interpretation	Photogeology	Drainage geochemistry [1]	Soil geochemistry	Overburden geochemistry	Rock geochemistry	Drilling	Soil-gas geochemistry	Radiometry [2]	Sea-bed sampling	Airborne [3]	Gravity [3]	Magnetic	Electromagnetic	IP and resistivity	Borehole logging [4]	Seismic	Mineralogy & petrology	Fluid inclusion studies
1	.	.	◆	◆	◆	◆	.	.	◆
2	.	.	.	◆	◆	◆
3	.	.	◆	◆	◆	.	◆	◆	◆
4	◆	◆	◆	◆	◆	◆	◆	◆	◆	.	.	.	◇	.	◆	◆	◆	.	.	◆	.
5	◆	◆	◆
6	.	.	.	◆	◆	.	◆
7	.	.	◆	◆	◆	.	.	◆	◆
8	◆	◆	◆	.	◆	.	◆	◆	◆	.	◆	.	.	◆	.
9	◆	.	.	◆	◆	◆	◆	◆	◆	◆	◆	.	◆	◆	.	◆	.
10	.	.	◆	◆	◆
11	.	.	◆	◆	◆	◆
12	.	.	.	◆	◆	.	◆	◆	◆	◆	◆	◆
13	◆	◆	.	◆	◆	◆	◆	◆	◆	◆	◆	.	.	◆	.	◆	◆	.	.	.
14	.	.	.	◆	◆	.	◆	◆	◆	◆	◆
15	◆	◆	.	◆	◆	◆	◆	◆	◆	.	◆	◆	.	◆	.
16	.	.	◆	◆	◆	◆	◆
17	.	.	.	◆	◆	.	◆	◆	◆	◆	◆	◆	.	◆	◆	.	◆	.
18	◆	.	◆	◆	◆	.	◆	.	.	◆	◆	◆	◆	◆	◆	.	.	◆	.
19	.	.	◆	◆	.	◆	.	◆	◆	.	◆
20	◆	◆	◆	◆	◆	.	.	.
21	◆	.	◆	◆	.	.	.	◆	◆	.	◆	◆	◆	◆	.	.	.
22	.	◆	◆	.	◆	◇	.	◆	◆
23	◆	.	.	◆	◆	◆	◆	◆	◆	◆	.	◆	.	.	◆	.
24	.	.	.	◆	.	.	.	◆	◆	◆	◆	.	◆
25	.	.	◆	.	.	◆	.	◆	◆	.	◆	◆	◆

	Ag	As	Au	Ba	Ri	Co	Cr	Cu	F	Hg	Mn	Mo	Ni	Pb	PG	Rn	Sb	Sn	Ti	U	V	W	Zn	multi- elem- ent	
26 Stratabound barium-zinc mineralisation in Dalradian schist near Aberfeldy, Scotland; Preliminary report	.	.	.	◆	◆	◆	
27 Airborne geophysical survey of part of Anglesey, North Wales	◆	◆	
28 A mineral reconnaissance survey of the Abington-Biggarr-Moffat area, south-central Scotland	.	.	◆	◆	.	.	.	◆	.	◆	.	.	.	◆	◆	◆
29 Mineral exploration in the Harlech Dome, North Wales	.	.	◆	◆	◆	
30 Porphyry style copper mineralisation at Black Stockarton Moor, south-west Scotland	.	.	◆	◆	◆	
31 Geophysical investigations in the Closehouse-Lunedale area	.	.	.	◆	◆	◆	
32 Investigations at Polyphant, near Launceston, Cornwall	◆	◆	◆	◆	
33 Mineral investigations at Carrock Fell, Cumbria. Part 1—Geophysical survey	◆	.	.	
34 Results of a gravity survey of the south-west margin of Dartmoor, Devon	
35 Geophysical investigation of chromite-bearing ultrabasic rocks in the Baltasound-Hagdale area, Unst, Shetland Islands	◆	
36 An appraisal of the VLF ground resistivity technique as an aid to mineral exploration	
37 Compilation of stratabound mineralisation in the Scottish Caledonides	◆	
38 Geophysical evidence for a concealed eastern extension of the Tanygrisiau microgranite and its possible relationship to mineralisation	◆	
39 Copper-bearing intrusive rocks at Cairngaroch Bay, south-west Scotland	.	◆	◆	.	.	.	◆	◆	
40 Stratabound barium-zinc mineralisation in Dalradian schist near Aberfeldy, Scotland; Final report	.	.	.	◆	◆	
41 Metalliferous mineralisation near Luton, Ivybridge, Devon	◆	◆	.	.	◆	.	.	◆	◆	.	◆	.	.	.	◆	.	.	.	◆	
42 Mineral exploration in the area around Culvannan Fell, Kirkcowan, south-western Scotland	◆	◆	◆	
43 Disseminated copper-molybdenum mineralisation near Ballachulish, Highland Region	◆	.	.	.	◆	◆	
44 Reconnaissance geochemical maps of parts of south Devon and Cornwall	◆	
45 Mineral investigations near Bodmin, Cornwall. Part 2—New uranium, tin and copper occurrences in the Tremayne area of St Columb Major	◆	◆	.	◆	.	.	.	
46 Gold mineralisation at the southern margin of the Loch Doon granitoid complex, south-west Scotland	.	◆	◆	◆	
47 An airborne geophysical survey of the Whin Sill between Haltwhistle and Scots' Gap, south Northumberland	◆	
48 Mineral investigations near Bodmin, Cornwall. Part 3—The Mulberry and Wheal Prosper area	◆	◆	.	.	◆	◆	◆	

	Style and type of occurrence	Geological and geochemical techniques reported	Geophysical techniques reported	Other studies
26	Report number			
27	◆ Stratabound ◆ Volcanogenic ◆ Granite-related ◆ Vein or stockwork ◆ Ultrabasic ◆ Porphyry ◆ Placer	◆ Geological mapping & interpretation ◆ Photogeology ◆ Drainage geochemistry [1] ◆ Soil geochemistry ◆ Overburden geochemistry ◆ Rock geochemistry ◆ Drilling ◆ Soil-gas geochemistry ◆ Radiometry [2] ◆ Sea-bed sampling	◆ Airborne [3] ◆ Gravity [3] ◆ Magnetic ◆ Electromagnetic ◆ IP and resistivity ◆ Borehole logging [4] ◆ Seismic	◆ Mineralogy & petrology ◆ Fluid inclusion studies
28	◆	◆		◆
29	◆	◆	◆	◆
30		◆	◆	◆
31	◆	◆	◆	
32		◆	◆	
33	◆		◆	
34	◆		◆	
35	◆		◆	◆
36	◆		◆	
37	◆		◆	
38	◆		◆	
39	◆	◆	◆	◆
40	◆	◆	◆	◆
41	◆	◆	◆	◆
42	◆	◆	◆	
43		◆	◆	◆
44		◆	◆	
45	◆	◆	◆	
46	◆	◆	◆	◆
47	◆	◆	◆	
48	◆	◆	◆	

Report number	Style and type of occurrence								Geological and geochemical techniques reported								Geophysical techniques reported				Other studies						
	Stratabound	Volcanogenic	Granite-related	Vein or stockwork	Ultrabasic	Porphyry	Placer	Regional survey	Geological mapping & interpretation	Photogeology	Drainage geochemistry [1]	Soil geochemistry	Overburden geochemistry	Rock geochemistry	Drilling	Soil-gas geochemistry	Radiometry [2]	Sea-bed sampling	Airborne [3]	Gravity [3]	Magnetic	Electromagnetic	IP and resistivity	Borehole logging [4]	Seismic	Mineralogy & petrology	Fluid inclusion studies
49	.	.	◆	◆	.	.	.	◆	.	.	
50	◆	◆
51	◆	◆	◆	◆	◆	.
52
	◆	◆	.	.	.	◆
	◆	◆	◆
	◆	◆	◆
53	.	◆	◆	◆	◆	◆	◆	.	◆	.	◆	◆	.
54	.	.	.	◆	.	.	.	◆	.	◆	◆	◆	.	◆	◆
55	◆	.	◆	.	◆	.	.	◆	◆	.	◆	.	.	◆	.
56	.	.	.	◆	◆	◆	.	◆	.	◆	.	.	.	◆	◆	◆	◆	◆	.	.	.
57	.	.	.	◆	◆	◆	◆	◆
58	◆	◆	◆	.	◆	.	◆	◆	◇	.	◆	◆	◆
59	◆	.	.	◆	.	.	.	◆	.	◆	◆	◆	◆	◆	◆	◆	◆	.	◆	.
60	.	.	◆	◆	◆	◆
61	◆	.	◆	◆	.	.	.	◆	◆	◆	.	.	.	◆	.
62	.	.	.	◆	.	.	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	.	◆	.	.	.
63	.	◆	.	◆	.	.	.	◆	.	.	◆	.	◆	◆	◆	◆
64	.	.	.	◆	.	.	◆	◆	◆	◆	◆
65	.	.	.	◆	.	.	◆	◆	◇	.	.	◆
66	◆	.	.	◆	.	.	◆	◆	.	◆	◆	◆	◆	◆	◆	◆	.	◆	◆	.	◆	.	.
67	.	.	.	◆	.	.	.	◆	.	◆	.	.	◆
68	◆	.	.	◆	.	.	.	◆	◆	◆	◆	◆	.
69	◆	.	◆	◆	.	.	◆	.	◆	◆	◆	◆	.	.	.	◆	.
70	◆	◆	◆	◇	◆	◆	◆	.

Report number	Style and type of occurrence								Geological and geochemical techniques reported								Geophysical techniques reported				Other studies							
	Stratabound	Volcanogenic	Granite-related	Vein or stockwork	Ultrabasic	Porphyry	Placer	Regional survey	Geological mapping & interpretation	Photogeology	Drainage geochemistry [1]	Soil geochemistry	Overburden geochemistry	Rock geochemistry	Drilling	Soil-gas geochemistry	Radiometry [2]	Sea-bed sampling	Airborne [3]	Gravity [3]	Magnetic	Electromagnetic	IP and resistivity	Borehole logging [4]	Seismic	Mineralogy & petrology	Fluid inclusion studies	
71	◆	.	.	◆	.	.	.	◆	.	.	.	◆
72	◆	◆	◆	◆	.	◆	◆	.
73	◆	.	.	.	◆	◆	◆	.	◆	◆	◆	.
74	◆	◆	.	◆	.	◆	.	◆	.	.	◆
75	.	.	.	◆	◆	.	.	◆
76	.	.	◆	◆	◆	.	◆	◆	◆	.
77	.	.	.	◆	◆	◆	◆	◆	◆	◆	◆	.	.	◆
78	◆	.	.	◆	.	◆	◆	◆	◆	◆	.	.	.	◇	◆	◆	.	◆	.	.	.	◆	.
79	◆	◆	◆	.	.	.	◆	.	◆	◆	◆	.	◆	◆	.	.	.	◆	.
80	.	.	◆	◆	◆	.	.	◆
81	.	.	◆	◆	◆	◆	◆	◆
82	.	.	◆	◆	◆	◆
83	.	.	◆	◆	◆	.	◆	◆
84	◆	◆	.	.	.	◆	.	◆	◆	◇	◆	◆
85	.	.	.	◆	◆	◆	◆
86	.	◆	.	.	.	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	.	.	◆	.
87	◆	◆	.	◆	◆	◆	◆	◆	◆
88	◆	.	.	◆	.	.	.	◆	.	.	◆	.	◆	◆	◆	◆	◆	◆	◆	.	.	.	◆	.
89	◆	◆	◆	.	◆	◆	◆
90	◆	.	.	◆	.	.	.	◆	.	.	◆	◇	.	◆	.	.	◆
91	.	◆	◆	◆	.	.	.	◆	.	.	◆	◆	.	◆	◆	.
92	◆	◆	.	◆	.	.	.	◆	.	◆	◆	◆	.	◆	◆	◆	◆
93	◆	◆	.	◆	◆	◆	◆	◆	◆	◆	.	.	.	◆	.

Report number	Style and type of occurrence							Geological and geochemical techniques reported							Geophysical techniques reported					Other studies							
	Stratabound	Volcanogenic	Granite-related	Vein or stockwork	Ultrabasic	Porphyry	Placer	Regional survey	Geological mapping & interpretation	Photogeology	Drainage geochemistry [1]	Soil geochemistry	Overburden geochemistry	Rock geochemistry	Drilling	Soil-gas geochemistry	Radiometry [2]	Sea-bed sampling	Airborne [3]	Gravity [3]	Magnetic	Electromagnetic	IP and resistivity	Borehole logging [4]	Seismic	Mineralogy & petrology	Fluid inclusion studies
94	.	.	◆	.	.	.	◆	.	.	◆
95	.	.	◆	◆	.	.	.	◆	.	.	◆	◆	◆
96	.	.	◆	◆
97	◆	.	.	◆	◆	◆	◆	◇	.	◆
98	◆	◆	.	.	◆	◆	◆	◆	◆	◇	◇	◆	◆	◆	.	◆	.	◆
99	◆	.	.	◆	.	.	◆	◆	.	.	◆	.	◆	◆	◆	◆	◆	.	.	.	◆
100	.	.	◆	◆	◆	◆	◆	◆	◆	◆	◆
101	◆	◆	.	◆	◆	.	◆	◆	◇	.	◆	◆	◆	◆	.	.	.
102	◆	◆	.	.	◆	.	◆	◆	◇	.	◆	.	.	◆	.	.	.
103	.	◆	◆	◆	.	.	.	◆	.	◆	◇	◇	◆	◆	◆
104	◆	◆	.	◆	◆	◆	◆	◆	◆	◆	◆	.	.	.	◆
105	.	.	.	◆	.	.	.	◆	.	.	◆	◆	◆	◆
06	◆	◆	◆	◆	◆
07	.	.	◆	◆	.	.	.	◆	.	.	◆	◆	◆	◆
08	.	.	◆	◆	◆	◆
09	.	.	◆	◆	.	.	◆	.	.	.	◆	.	◆	◆	◆	◆	◆
10	.	.	◆	◆	◆	.	.	◆	.	◆
11	◆	◆	◆	.	◆	◆
12	.	◆	.	◆	.	.	◆	◆	.	◆	◆	.	◆	◆	◆	◆	◆
13	.	.	◆	◆	◆	◆
14

1 Entries under drainage geochemistry denote stream-sediment and/or panned-concentrate and/or water sample.

2 Radiometric data are available separately for all detailed airborne surveys.

3 In the airborne and gravity columns, the symbol ◆ denotes a detailed survey; the symbol ◇ denotes use of

regional aeromagnetic or gravity data. Detailed airborne surveys comprise magnetic, electromagnetic and radiometric measurements.

4 Entries under borehole logging denote either in-hole geophysical logging or systematic measurements on core.

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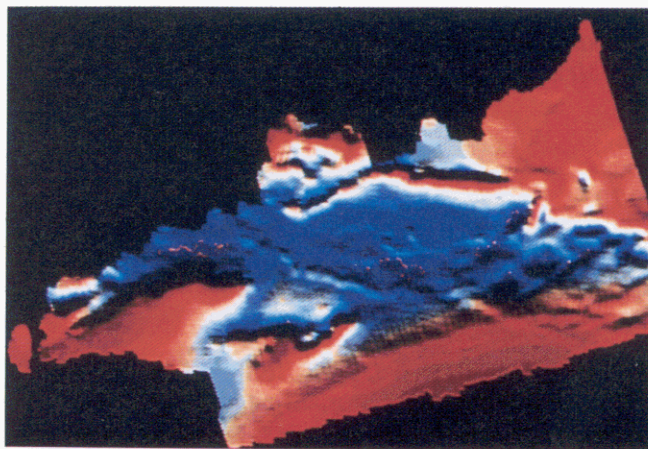
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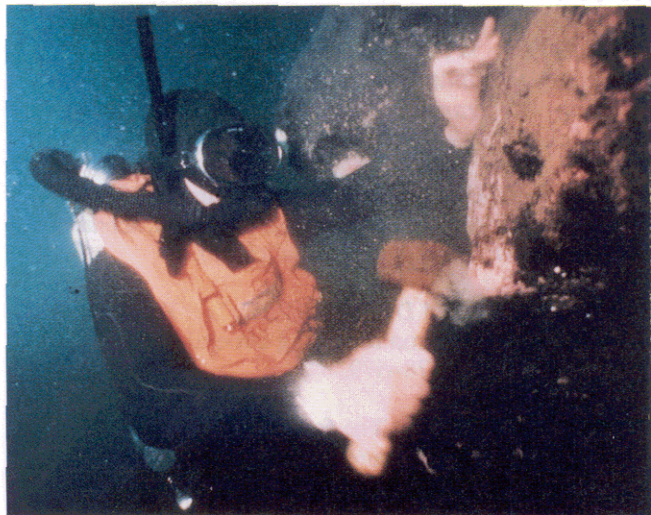


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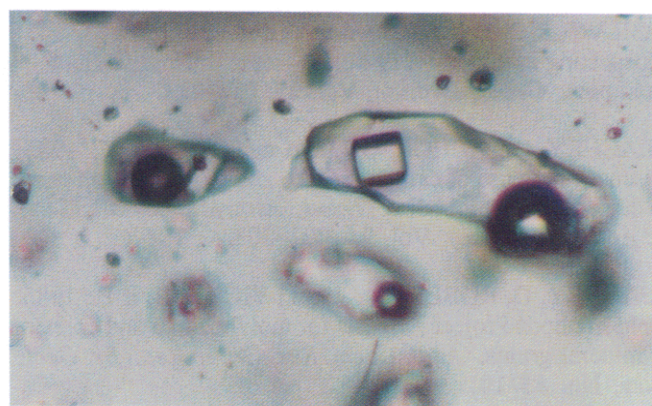
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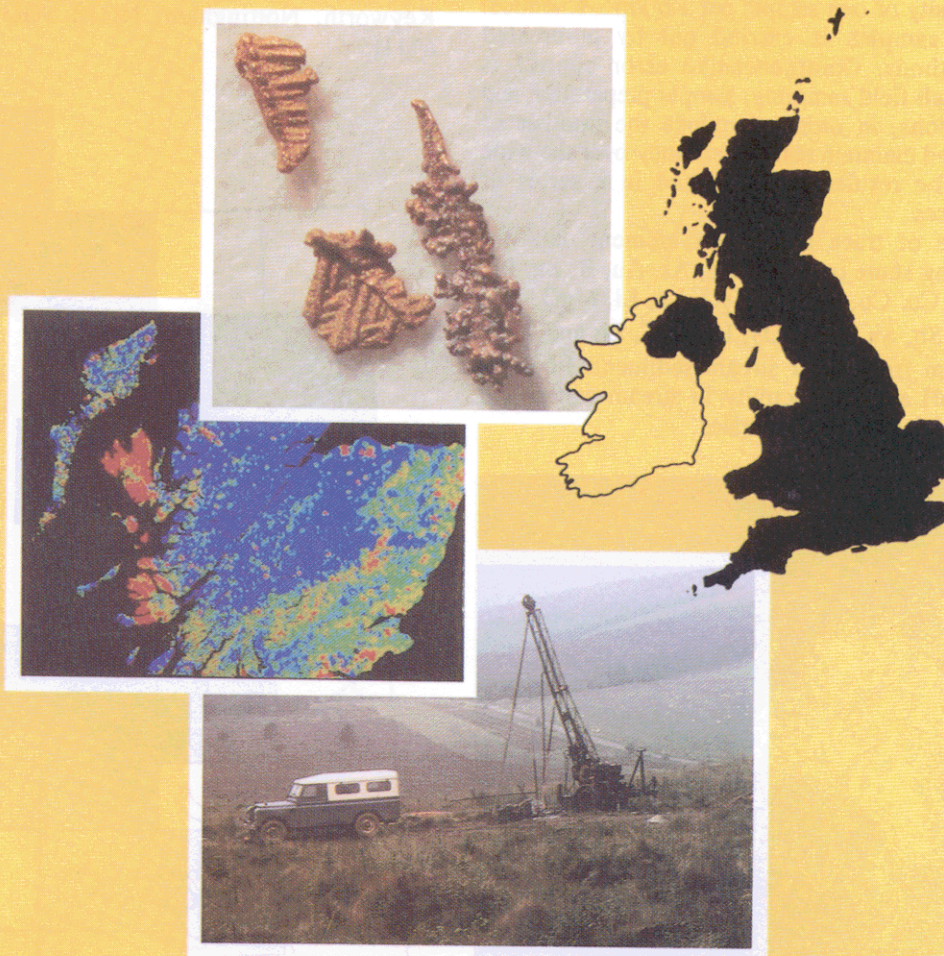
Collecting soil samples from shallow depth, using hand auger

Lower Old Red Sandstone sediments, Ousdale, Caithness, Scotland. *Mineral. Deposita*, Vol. 24, 117–123.

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Exploration for metalliferous and related minerals in Britain: a guide



BRITISH GEOLOGICAL SURVEY



COLMAN, T B. 1990. *Exploration for metalliferous and related minerals in Britain: a guide*. (Keyworth, Nottinghamshire: British Geological Survey)

This guide, published by the British Geological Survey under commission from the Department of Trade and Industry, is intended to assist and inform all those interested in exploring for minerals in Britain. It describes in broad terms the highly varied geology of the country and records the achievements of exploration and development work carried out by the public and commercial sectors over the past 25 years.

It describes the results of investigations based on modern metallogenic models, in particular the discovery of economic mineralisation in the Middle Dalradian rocks of the Scottish Highlands, and outlines a number of general areas considered to have potential for the discovery of economic mineralisation.

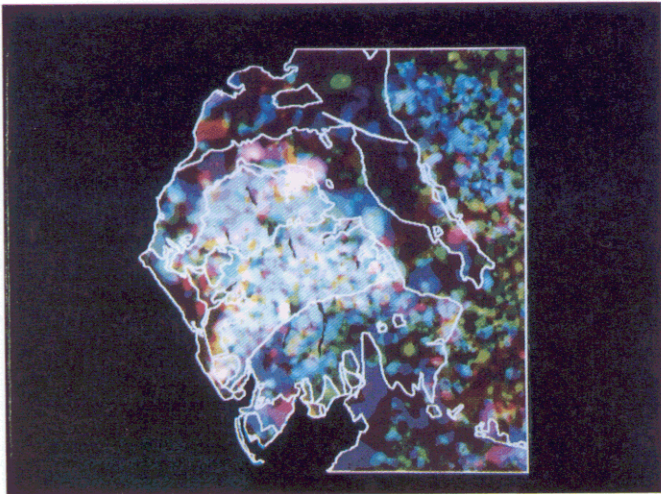
There are chapters describing the administrative and legal framework within which exploration can be undertaken, and the complex issues relating to land access, mineral rights ownership and the procurement of Local Authority planning consent.

Appendix Availability of regional geochemical, geophysical and geological data and maps

Regional geochemistry

The Geochemical Survey Programme (GSP), funded by the Department of Trade and Industry, is based on the collection of stream sediment and water samples from surface drainage at an average density of one sample per 1.5 km². Chemical analysis of the samples is carried out by automated instrumental methods. Comprehensive error control is incorporated into all field sampling, sample preparation and analytical operations, in order to reduce the number of spurious results and maintain data consistency over the wide areas covered. The results are published in a series of Geochemical Atlases.

A wide range of trace and major element data are available, including some or all of: Ag, As, Au, B, Ba, Be, Bi, CaO, Cd, Cr, Co, Cu, Fe₂O₃, K₂O, La, Li, MgO, Mn, Mo, Ni, Pb, Rb, Sb, Sn, Sr, TiO₂, U, V, Y, Zn and Zr in the minus 150 µm fraction of stream sediment; fluoride, bicarbonate, U, pH and conductivity in stream water; and gold observations in panned concentrates.

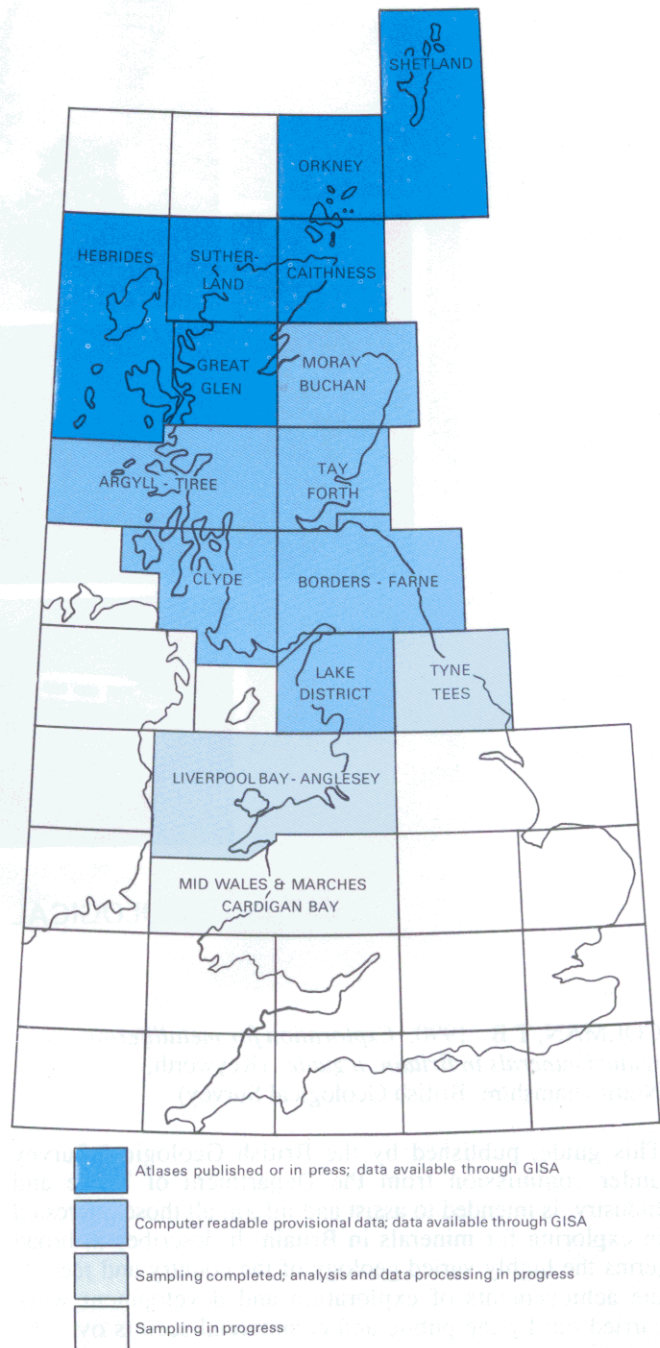


Example of the digital geochemical imagery available through the NGDB and GISA service, showing a combined ternary image prepared by image analysis techniques from the GSP's Geochemical Atlas of the Lake District. The image illustrates the regional distribution of gold pathfinder elements in minus 150 µm stream sediment: arsenic (red), bismuth (green) and antimony (blue). The lighter tones over the Skiddaw and Borrowdale volcanic groups reflect the enhanced potential for gold in these geological groups, while the white spots coincide in some instances with areas of known gold mineralisation.

Soon after the completion of chemical analysis, and before the publication of the Geochemical Atlases, the provisional locational and geochemical data are made available for sale through the National Geochemical Data Bank (NGDB) and through the Geochemical Interactive Systems Analysis (GISA) service. The GISA service is currently available at the Keyworth, Edinburgh and Wallingford offices of BGS and at the National Remote

Sensing Centre at Farnborough. A demonstration of the GISA service is available, based on geochemical, geophysical, geological and remotely sensed data covering the Lake District of northern England.

Enquiries about the availability of data should be directed to Dr J A Plant or P R Simpson, British Geological Survey, Keyworth, Nottingham, NG12 5GG (telephone 06077 6111).



Availability of regional geochemical data and Geochemical Atlases

Regional geophysics

The British Geological Survey is responsible for systematic gravity and aeromagnetic coverage of onshore UK, and the datasets from these surveys have been converted to digital form. The data are available in their raw form, as grids, or as monochrome or colour images. Grids and images can be provided to customer requirements. The data are also available as maps in the BGS 1:250 000 UTM Series (see key map overleaf).

Requests for data should be addressed to the Group Manager, Regional Geophysics, British Geological Survey, Keyworth, Nottingham, NG12 5GG (telephone 06077 6111).

Brief technical details for each of the datasets are as follows:

UK National Gravity Data Bank

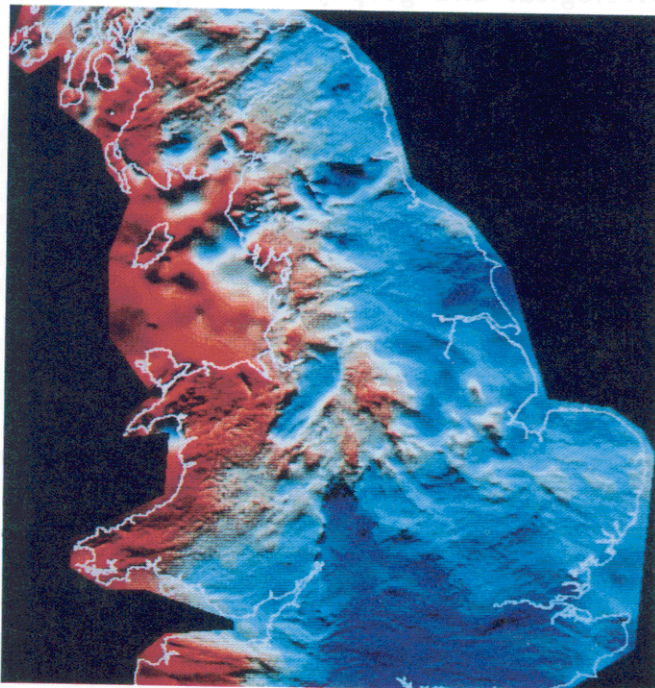
There are currently some 150 000 regional gravity stations onshore in the UK. These are linked to a national gravity base network and reduced to an agreed international datum. The station distribution is about one per km² in lowland areas and about one per 2.5 km² in upland areas. Some coastal areas exposed at low tide are also included. The majority of the gravity observations were made by the BGS (and its predecessors); supplementary data have been obtained from commercial and academic sources. The gravity stations are generally occupied at Ordnance Survey Bench Marks and spot heights, giving elevation control to better than 1 m and station location control to approximately 10 m. Gravity values have generally been read to approximately 0.01 mGal.

The digital dataset is held by BGS as the National Gravity Data Bank, and is administered by the Regional Geophysics Group.

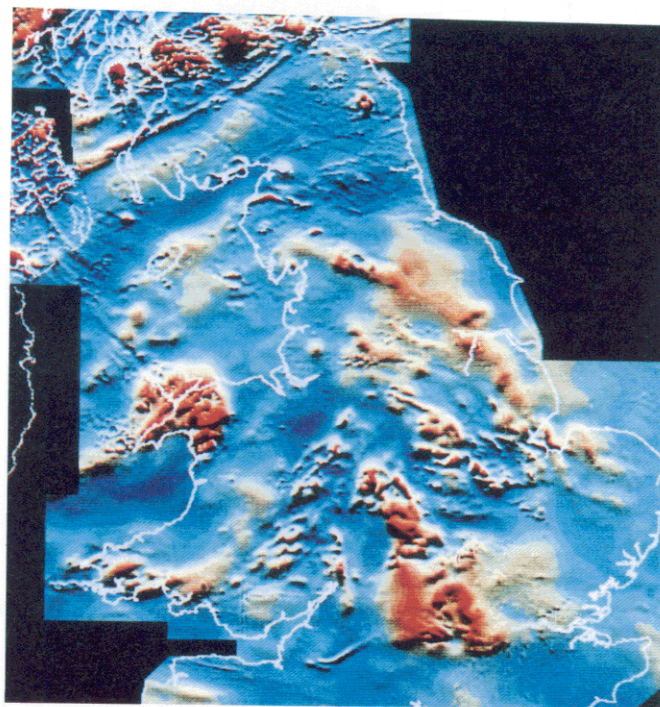
Aeromagnetic survey of the UK

The aeromagnetic dataset is the product of a series of aeromagnetic surveys carried out for the Geological Survey of Great Britain between 1955 and 1965. The whole of the land area and some adjacent sea areas are covered, approximately 490 000 km² in total. Flight lines are generally at a 2 km spacing, oriented either north-south or east-west. More detailed coverage (with a flight line spacing of 0.4 km) was provided over a large part of southwest England. Most of the country was covered at a terrain clearance of 1000 feet (305 m), with a terrain clearance of 500 feet for the detailed survey in southwest England. The flight records, which were analogue, were compiled onto worksheets at 1:63 360 scale, the anomaly values being referred to a planar reference field covering the UK, and contoured at an interval of 10nT.

The data were converted to digital form by digitising the intercepts between the flight lines and the contours on the worksheets. The data reduction that would have been required if the analogue flight records had been digitised was thus avoided, without significant loss of information. The digital dataset comprises a total of approximately 530 000 captured intercepts and is administered by the Regional Geophysics Group.



Colour shaded-relief presentation of digital gravity data for central and southern Britain.



Colour shaded-relief presentation of digital aeromagnetic data for central and southern Britain.

In the two presentations above, anomaly amplitude is represented by colour; shading simulates illumination of the anomaly surface from the north. Subtle lineaments are thus highlighted, providing considerably more information than a traditional contour map

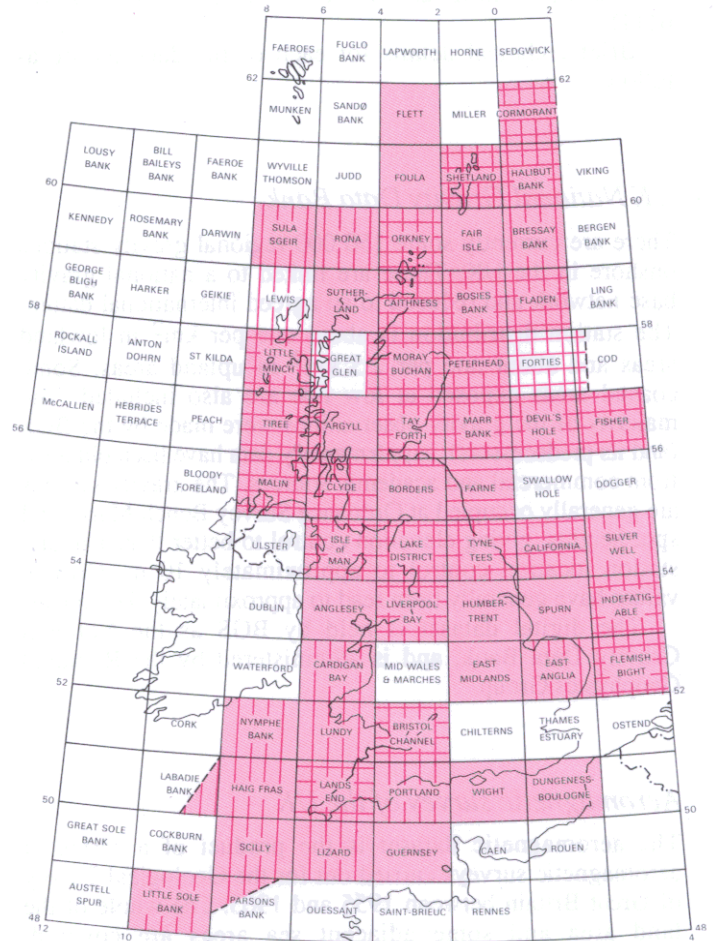
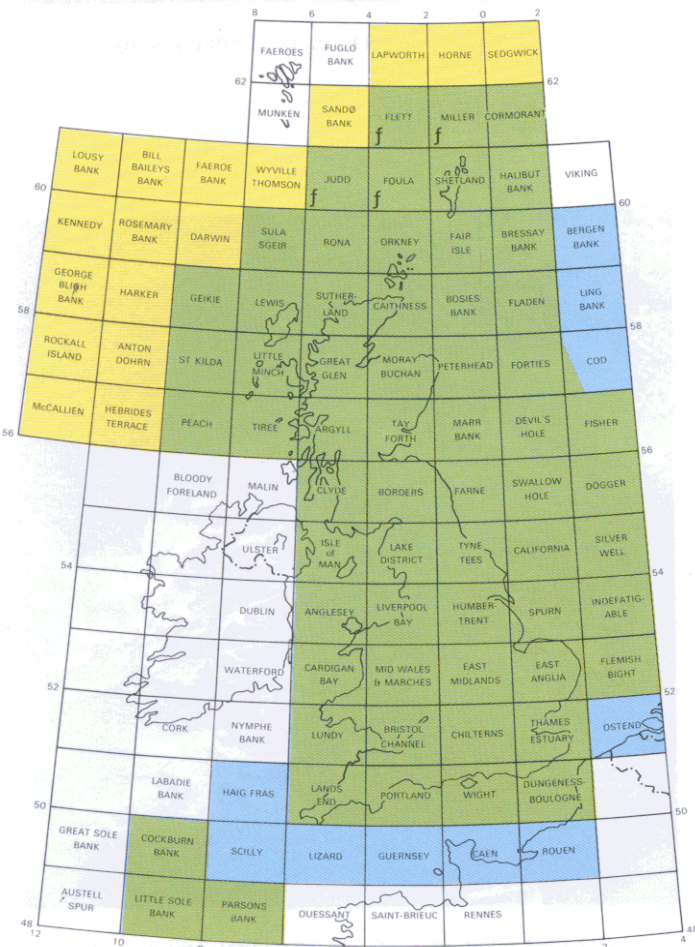
Geological and geophysical maps

Maps at 1:250 000

BGS publishes six series of maps at 1:250 000, three geological and three geophysical. They use the Universal Transverse Mercator (UTM) projection, and cover the UK landmass and its surrounding sea area. Each sheet covers 1° of latitude by 2° of longitude and is indexed by the coordinates of its southwest corner. For ease of reference the sheets are also named.

The three series of geological map published at this scale are solid geology, sea-bed sediments and Quaternary sediments (indicated on upper map by light colour, vertical lines and horizontal lines, respectively).

The three series of geophysical map show Bouguer gravity anomalies and aeromagnetic anomalies (blue and yellow, respectively, on the lower map; areas for which both maps are published are shown green), and also free-air gravity anomalies (designated by *f*).



Maps at 1:50 000 and 1:63 360 (opposite)

The Survey's main coverage of geological maps is at the scales of 1:50 000 and 1:63 360. Maps at 1:63 360 (blue in the index map) are being replaced by maps at 1:50 000 (pink). One 1:50 000 sheet, 255, is out of print (pale pink), as are many of the 1:63 360 sheets (pale blue). The Outer Hebrides are covered by four sheets at 1:100 000 (yellow).

Copies of out-of-print maps may be consulted in BGS libraries. Coloured photocopies or photographic prints of most out-of-print maps are available or can be produced on demand.

