

Minerals in Britain

Past production . . .
Future potential

Nickel and Platinum



British
Geological
Survey

dti

Drilling to investigate PGE-bearing mineralisation
in the Loch Borralan alkaline complex, north-west
Scotland

Nickel and Platinum in Britain

Although nickel mining in Britain has been limited to a few small deposits, exploration has been carried out in several areas since the nickel boom of the late 1960s. The search for the platinum-group elements (PGE)* began in the 1980s, in response to increased industrial demand and long-term supply uncertainties. Exploration has identified a number of prospects, several of which merit further investigation.

In Britain both nickel and PGE concentrations with economic potential are associated with mafic and ultramafic rocks. Worldwide the principal sources of nickel are magmatic sulphide deposits related to rocks of this type. They occur in various tectonic settings and some contain copper and PGE. The most important PGE deposits are orthomagmatic in origin, occurring in layered mafic-ultramafic intrusions, primarily as stratabound bodies associated with magmatic sulphide or chromite bands known as 'reefs'.

Recent advances have widened the range of known settings for PGE mineralisation to include ophiolite complexes, zoned mafic-ultramafic Alaskan-type complexes, and various alkaline igneous intrusions including carbonatites. Epigenetic hydrothermal PGE mineralisation has also been recognised in veins with copper sulphides, with gold and uranium in redox unconformity-related settings and with gold in carbonaceous shales. Similarly, new genetic models and exploration criteria for magmatic nickel sulphide mineralisation have been developed, especially since the discovery of the Voisey's Bay deposit in Labrador. Application of these models has led to the identification of new prospective targets in Britain.

Much of the exploration work carried out in Britain by private- and public-sector organisations since the 1960s is either published in summary form or held on open file at the BGS. Most of the public-sector work was carried out by the BGS under the Mineral Reconnaissance Programme (MRP), funded by the Department of Trade and Industry (DTI). The results from this work are contained in the MRP Report Series and much of the data collected are available in digital form. Some of the private-sector exploration was carried out under the terms of the Mineral Exploration Investment Grants Act 1972 (MEIGA) in the 1970s and most of these data are now available on open file. Some, particularly airborne geophysical data for north-east

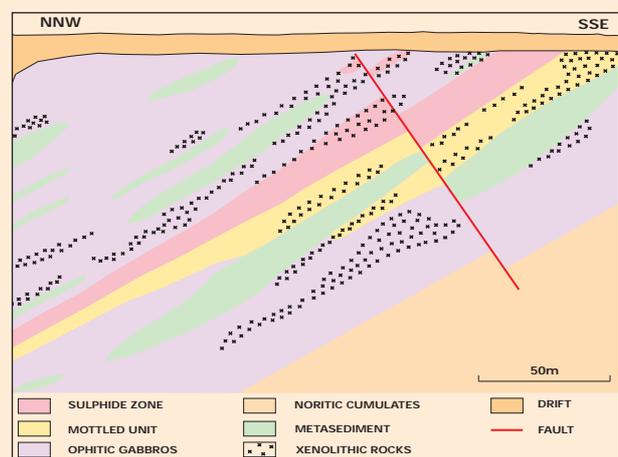
Scotland, have been converted to digital form and can be purchased in user-specified formats.

Layered intrusions

North-east Scotland

One of the principal targets for magmatic nickel-copper and PGE deposits in Britain has been the Caledonian synorogenic layered mafic-ultramafic intrusions of north-east Scotland, commonly known as the Aberdeenshire gabbros. These tholeiitic Ordovician intrusions, emplaced near the peak of regional metamorphism around 470 Ma ago, post-date the regional deformation but have undergone local high-temperature deformation along major shear zones.

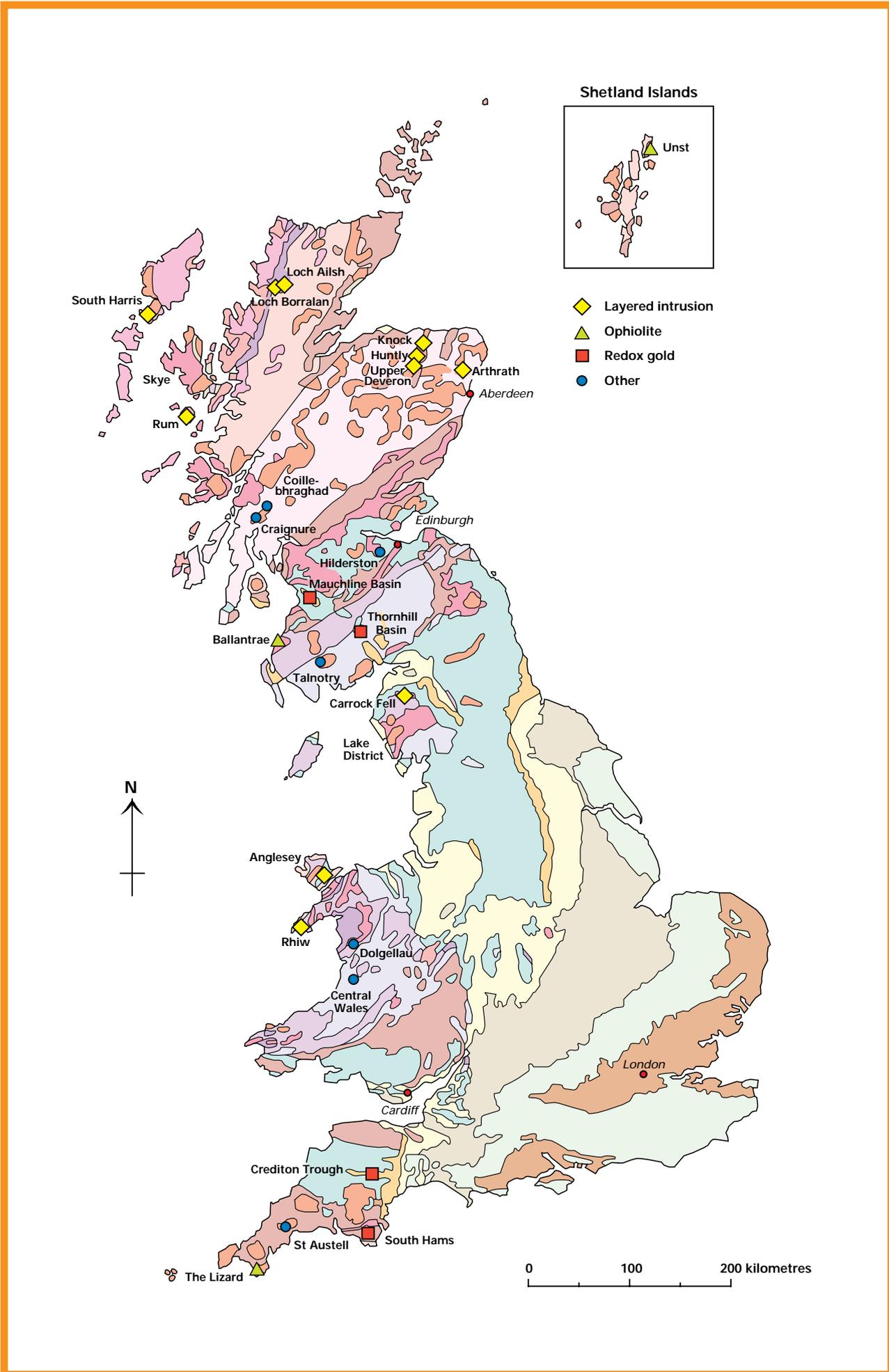
Exploration for copper-nickel mineralisation involving ground and airborne geophysical surveys, geochemical studies and drilling at several localities resulted in two principal discoveries. Drilling in the south-eastern part of the *Knock* intrusion outlined a 'geological reserve' of 3 Mt grading 0.52% Ni and 0.27% Cu in two sub-parallel zones dipping north-west. Copper and nickel occur in massive and sub-massive discontinuous lenticular sulphide bodies within a structurally complex contact zone at the edge of the intrusion. The sulphide zone, up to 20 m thick at Littlemill, is roughly conformable with the banding in the enclosing olivine cumulates. Pyrrhotite, chalcopyrite and pentlandite form the main ore assemblage, which displays some magmatic textures although intense deformation and hydrothermal reworking are commonly evident. Later work identified elevated precious-metal concentrations in these ores, up to a



Cross-section through the Ni-Cu sulphide zone at Littlemill, Knock.

Reproduced courtesy of T A Fletcher

*platinum (Pt), palladium (Pd), rhodium (Rh), ruthenium (Ru), osmium (Os) and iridium (Ir).



maximum of 574 ppb Au+Pt+Pd. Exploration stimulated by reports of nickel toxicity in crops led to the discovery of five zones of disseminated Fe-Ni-Cu sulphide mineralisation in the *Arthra* intrusion. Diamond drilling intersected widespread disseminated sulphides (5 – 20%), together with local net-textured and rare sub-massive intersections, hosted by xenolithic and non-xenolithic norites. A geological reserve of 17 Mt grading 0.21% Ni and 0.14% Cu was outlined, and PGE values up to 201 ppb Pt and 138 ppb Pd have been reported from analysis of sulphide-rich samples from one borehole.

New genetic models developed since the Voisey's Bay discovery indicate further potential in the Grampian region. These models predict that the mafic-ultramafic intrusions are prospective where they contain olivine-rich rocks and evidence of extensive assimilation of metasediments. Feeder zones which acted as conduits for large volumes of magma are particularly favourable targets.

A different style of PGE mineralisation is found in the *Huntly* intrusion. Irregular discordant bodies, up to a few metres wide, of graphite- and sulphide-bearing orthopyroxene-rich pegmatites occur in olivine cumulate rocks. In the western part of the intrusion these bodies are enriched in precious metals, up to about 700 ppb Au+Pt+Pd. Occurrences in the Bin Quarry, about 4.5 km north-west of Huntly, were drilled but no significant continuity at depth was identified.

Deformed mafic-ultramafic intrusions that occur along a major regional shear zone known as the Portsoy Lineament, in the *Upper Deveron* valley have also been investigated. Above background PGE levels occur in the clinopyroxene-bearing ultramafic rocks of the Succoth – Brown Hill intrusion, and drilling in one zone revealed Pt+Pd values up to about 270 ppb. Local enrichment of palladium relative to platinum is accompanied by gold (up to 370 ppb). About 8 km to the south-west, near Kelman Hill, drilling into the Craigs of Succoth deformed ultramafic body revealed PGE enrichment up to 280 ppb Pt+Pd. Nearby, at Bridgend, a zone of PGE enrichment in basal overburden was identified close to the sheared margin of another lenticular body of sheared serpentinite, but no significant PGE values were reported in bedrock. The precious-metal enrichments observed in these intrusions along the Portsoy Lineament are believed to be of hydrothermal origin, possibly related to serpentinisation.

North-west Scotland

Attention has been drawn to the alkaline complexes along the north-west margin of the Scottish Caledonides by analogy with PGE-mineralised alkaline intrusions in Canada. High

levels of PGE (up to 859 ppb Pt) and gold were recorded in drainage samples over the *Loch Ailsh* complex, and PGE concentrations (up to 300 ppb Pt+Pd) were found in pyroxenites at the south-eastern margin of the complex. A range of complex tellurides and platinum-group minerals, including sperrylite and isomerteite ($\text{Pd}_{11}\text{Sb}_2\text{As}_2$), were identified in bedrock. Similar results were obtained from pyroxenite at the south-western margin of the *Loch Borrulan* complex. Widespread low-tenor enrichment in PGE, up to 878 ppb Pt + Pd, was found in association with copper and minor gold enrichment. A late-magmatic origin with possible subsequent hydrothermal upgrading at lower temperatures has been proposed for the PGE mineralisation in these intrusions.

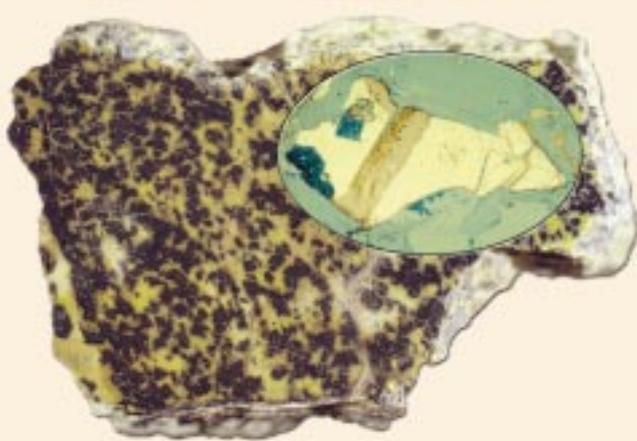
The main intrusive bodies forming the Lower Proterozoic *South Harris* intrusive complex have low sulphide and PGE levels, but Pd enrichment, up to 210 ppb, has been recorded in ultramafic rocks and in a pyritic vein in metasediment along shear zones marginal to the intrusions. Analyses of metamorphosed basic and ultrabasic rocks in the Lewisian Archaean basement by the MRP revealed minor PGE enrichments, but no evidence of primary magmatic sulphide concentrations was recorded.

Layered intrusions of the Tertiary igneous province on the islands of *Skye* and *Rum* are also potentially favourable settings for stratiform PGE mineralisation. Little systematic exploration has been carried out over these areas, but low-tenor PGE enrichment in rocks and platinum-group minerals have been identified at several localities on Rum. The outstanding scenic beauty of much of this region is likely to conflict with development of its mineral resources.

Northern England and Wales

Investigation of gravity and magnetic anomalies over metamorphosed basic rocks in the Penmynydd zone of south-east *Anglesey* by the MRP suggested the possibility of a buried fault-bounded layered basic intrusion at depth, with potential for nickel and copper mineralisation.

Layered basic intrusions at *Carrock Fell* in the *Lake District* and at *Rhiw* in north-west Wales have been investigated briefly for some metal concentrations, though not for PGE. A commercial company briefly examined copper and nickel concentrations at Rhiw, while several scientific studies have been carried out at Carrock Fell which contains local concentrations of iron-titanium and vanadium. No significant Ni enrichment has been reported from these or other Caledonian basic intrusions in the same areas, but little mineral exploration has been carried out.



Main image: Chromite ore containing very high concentrations of Pt and Pd from the Cliff locality, Unst, Shetland. Inset image: Microphotograph of high-grade Pt-Pd chromite ore. Sperrylite ($PtAs_2$), pale yellow, intergrown with orcellite ($Ni_{5-x}As_2$), brown, and native copper, blue (reflected light, field of view 0.2 mm).

Ophiolites

Shetland

In the mid-1980s PGE enrichment was identified in the Unst ophiolite associated with podiform chromitite ores. Previously, it was generally thought that ophiolite complexes contained PGE mineralisation dominated by osmium, iridium and ruthenium, but the mantle section of the Unst complex yielded values exceeding 100 ppm of both platinum and palladium, accompanied by ppm levels of gold and the other PGE. The high-grade mineralisation occurs close to the basal thrust of the ophiolite in a zone of talc-carbonate alteration at the margin of a chromitite pod. Several platinum-group minerals have been identified, the most common being sperrylite ($PtAs_2$) and stibiopalladinite (Pd_5Sb_2). They occur as very small grains, mainly in chlorite halos around chromite grains and in the altered rims of chromite grains, associated with Ni, Ni-Fe and Ni-Co sulphides and arsenides. A hydrothermal origin related to serpentinisation localised by faulting has been proposed for this mineralisation. Lower-grade palladium-platinum-dominant mineralisation has been identified locally in the cumulate sequence in the upper part of the ophiolite complex. Elsewhere, PGE mineralisation more typical of ophiolites, dominated by osmium, iridium and ruthenium, occurs in chromite grains in chromitite. The prospect has attracted private-sector exploration, but the extent of the high-grade mineralisation remains unknown and reconnaissance data indicate potential for further discoveries in the complex.

Others

There are unsubstantiated historical reports of platinum-group minerals recovered from stream gravels on the *Lizard* ophiolite in Cornwall. Recent studies have identified a variety of PGE in bedrock, but the potential for economic PGE mineralisation remains untested. MRP work revealed no significant Ni or PGE concentrations in the *Ballantrae* complex in south-west Scotland.

Redox (unconformity-related) gold deposits

MRP surveys in several parts of Britain during the 1990s identified an association between gold and PGE related to the boundary between Permian red-bed basins, associated igneous rocks and older, more reduced, strata. Complex Au-Pd-Pt grains and discrete PGE are widespread in surficial media derived from the Lower Devonian and Permo-Triassic rocks in the *South Hams* and the *Crediton Trough* in south-west England, and the *Mauchline* and *Thornhill* basins of southern Scotland. Companies are investigating the bedrock sources of the gold and PGE.

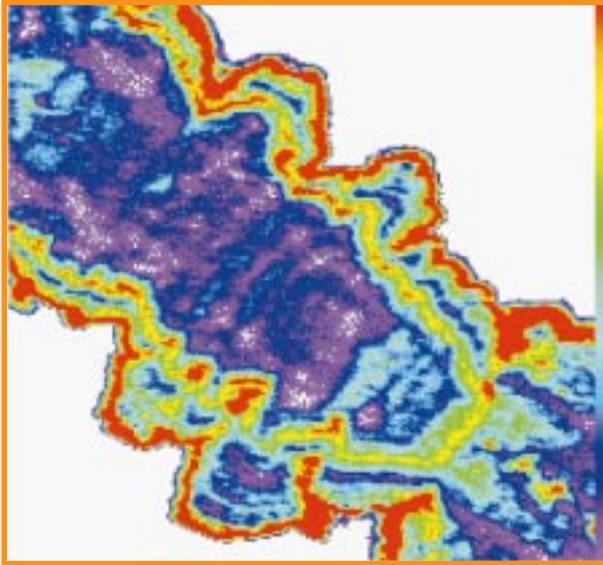
Other occurrences and prospects

Replacement deposits in Dalradian metasediments

Two former copper mines near Inverary in the south-west Highlands of Scotland produced small quantities of nickel. Between 1854 and 1867 more than 400 t of nickel ore, comprising pyrrhotite, chalcopyrite, pyrite and pentlandite, were produced from the *Coille-bhraghad* deposit. At *Craignure*, about 10 km to the south-west, similar nickel ores were initially discarded and later removed from the dumps. No modern studies have been conducted at these localities, but the ore seems to be a replacement of quartzitic bands within the predominantly pelitic Dalradian metasedimentary sequence. The extent of the mineralisation is unknown, but as the deposits occur at similar structural levels close to an extensive suite of metabasic intrusives, potential may exist for further occurrences along strike between the two bodies.

Magmatic deposit in diorite, south-west Scotland

Nickel-copper mineralisation at *Talnotry* was mined on a trial basis between 1885 and 1900. About 100 t of ore was raised but not taken away. The mineralisation, thought to be of magmatic origin, occurs at the base of an altered diorite sheet. The principal ore minerals are nickeline, gersdorffite, pyrrhotite, pentlandite and chalcopyrite, which are associated with local minor enrichments in platinum, palladium and gold. Geophysical surveys indicate that the mineralisation is restricted to a single lenticular body about 20 m in length.



Geochemical map of a gold grain from the South Hams, Devon. The core is almost pure gold (purple/white) and is surrounded by thin layers rich in potarite (PdHg, blue), PtAu alloy (yellow/red) and Pt₃Cu alloy (red).

Vein-style mineralisation

The granite-related vein-style mineralisation of south-west England locally contains small amounts of nickel, associated with cobalt and uranium in a relatively late-stage low-temperature mineralising event. Nickel occurs principally as millerite, niccolite, gersdorffite and chloanthite. Small amounts, a few tons, have been extracted and sold from mines primarily working other ores, notably in the *St. Austell* area.

At *Hilderston* near Edinburgh a worked vein structure carried native silver, argentiferous galena and niccolite where it cut Lower Carboniferous limestone. Erythrite, annabergite, calcite and baryte are also present. Oxidised nickel ores are said to have contained 30% nickel and 2% cobalt. Nickel mineralisation has also been recorded with copper mineralisation at Coniston in the *Lake District*, in the gold-bearing veins of the *Dolgellau* district, and in the lead-zinc-copper lodes of the *Central Wales* mining field, but amounts are very small.

Data Holdings

A substantial amount of information related to nickel and PGE mineralisation in Britain is either published or held on open file at the BGS. Increasingly, the data are held in digital form on databases fronted by a GIS (the BGS MINGOL system) and can be supplied under licence or as hard-copy products, in formats to match the user's requirements. Some of the principal data sources are:

- Mineral Reconnaissance Programme Reports and Data Releases.
- Reports, maps and other data provided under the terms of the Mineral Exploration and Investment Grants Act 1972 (MEIGA). Some data have been converted to digital form and can be purchased in user-specified formats. Hard-copy data and reports may be photocopied.
- Regional and local scale geochemical surveys.
- Regional and local scale ground and airborne geophysical data coverage.
- Geological mapping at various scales.
- Mineral occurrence and mineral workings databases.
- Drillcore and rock samples, thin sections.
- Licensing, legislative and planning constraint information.
- Minerals trade and production statistics in Britain and worldwide.
- Scientific publications on mineral deposits in Britain.

Staff of the BGS Minerals Programme act as a reference point for the supply of advice and information on minerals-related matters in Britain. They can provide detailed information on the above datasets.

Enquiries should be directed to:

*The Manager, BGS Minerals Programme, British Geological Survey,
Keyworth, Nottingham NG12 5GG*

**Tel 0115 936 3494 Fax 0115 936 3520 email minerals@bgs.ac.uk
Internet www.MineralsUK.com and www.bgs.ac.uk**