

Minerals in Britain

Past production . . .
Future potential

Lead and Zinc

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Lead and zinc ores have been mined in Britain since prehistoric times. The main period of activity was in the eighteenth and nineteenth centuries, when total production exceeded 6 Mt lead and 1 Mt zinc. Production was predominantly from carbonate-hosted vein-style deposits, notably in the Northern and Southern Pennine Orefields and North Wales. There was also significant production of silver-rich lead-zinc ores from the mining fields of central Wales and south-west England.

Past mining was mostly from small-tonnage, high-grade deposits, typically of vein style. Increased geological understanding and the capabilities of present-day exploration technology have widened the range of deposit types and areas considered prospective for lead and zinc in Britain.

In addition to the former mining fields, several areas in Britain have been identified by mineral exploration carried out by the BGS and mining companies in recent years as being prospective for the discovery of new lead and zinc deposits. The greatest potential for significant mineralisation is for sedimentary exhalative (Sedex) style targets in the Dalradian (Neoproterozoic) and in Lower Carboniferous basins, but there are also areas with potential for mineralisation with volcanogenic massive sulphide (VMS), volcanogenic stratabound and Mississippi Valley type (MVT) affinities.

Much of the exploration work carried out 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 DTI-funded Mineral Reconnaissance Programme (MRP). The results from this work are contained in the MRP Report Series and much of the data collected are available in digital form. Much of the private-sector exploration work was carried out under the terms of the Mineral Exploration Investment Grants Act 1972 (MEIGA) in the 1970s, and most of the data are now available on open file for inspection. Some, particularly airborne geophysical data, have been converted to digital form and can be purchased in user-specified formats.

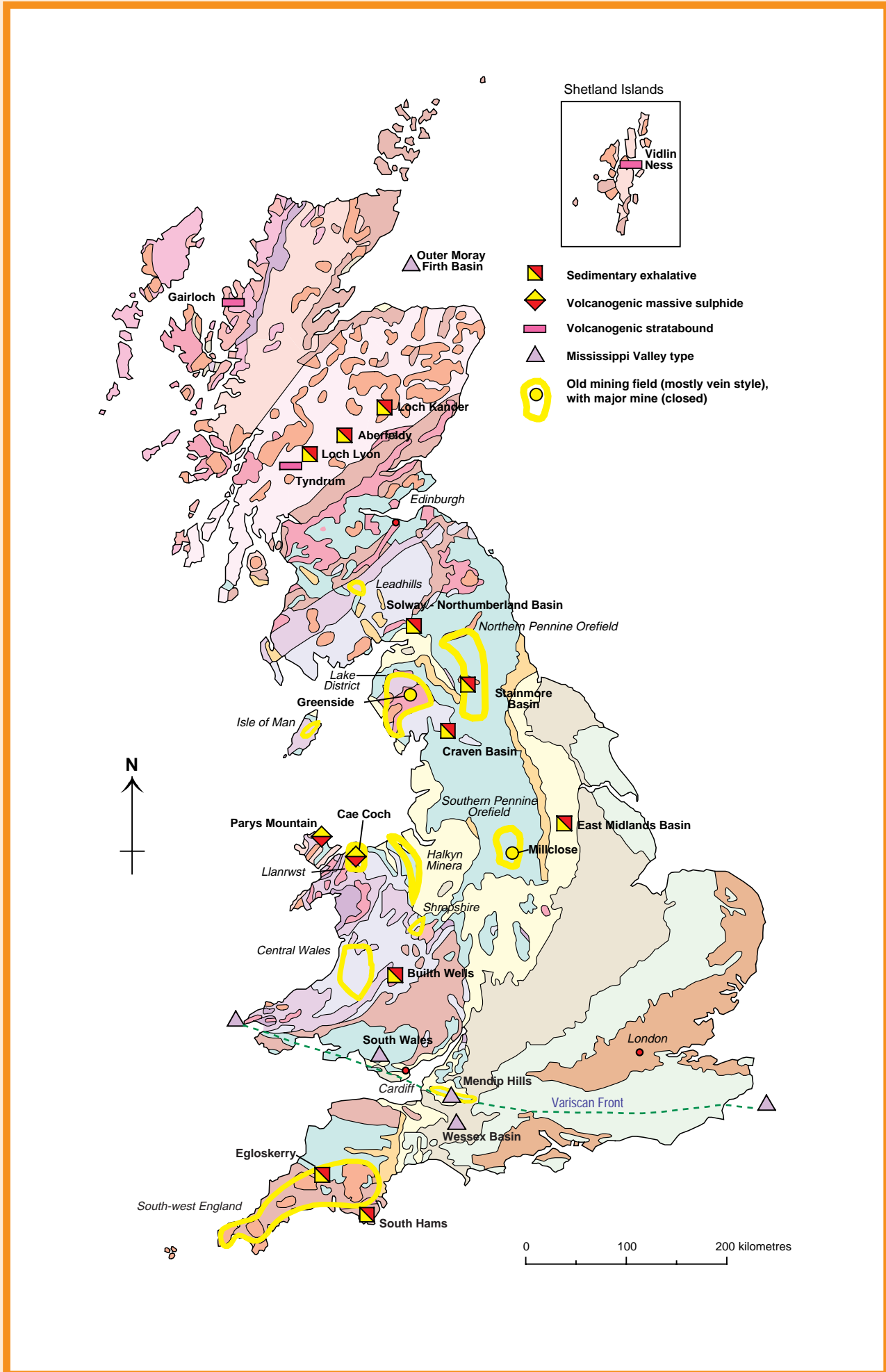
Sedimentary exhalative (Sedex) deposits

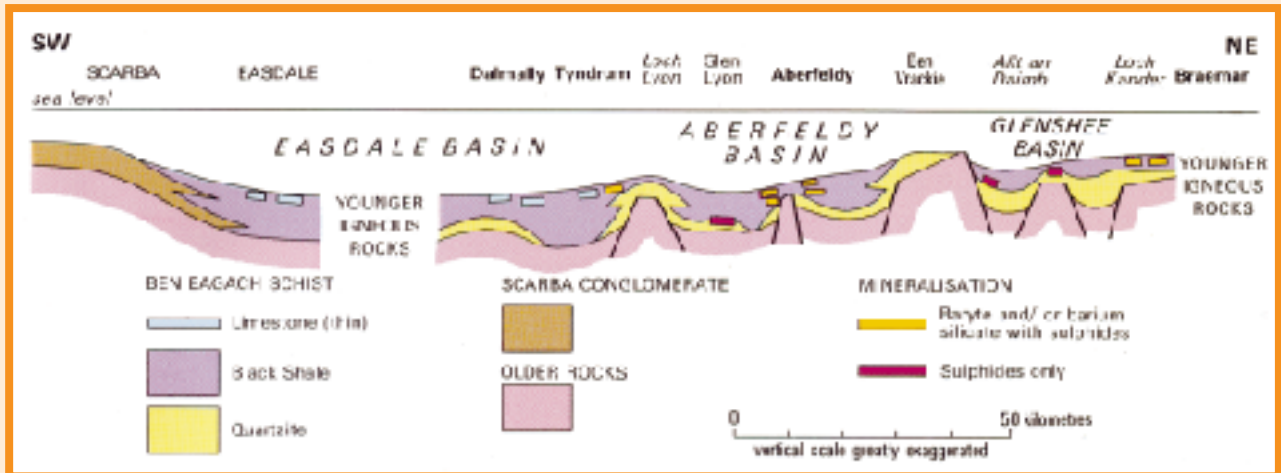
There are several highly prospective areas for Sedex base-metal and baryte mineralisation in the Middle Dalradian (Argyll Group) sequence of the Scottish Highlands, over a 200 km strike length from Portsoy in the north-east to Islay in the south-west. The world-class *Aberfeldy* baryte deposits in the central Highlands

contain more than 10 Mt of high-grade baryte and are currently worked in the Foss mine. Lenses of lead and zinc sulphides, containing up to 10% Pb + Zn, with associated barium-rich metasedimentary rocks have been discovered at Aberfeldy and at other localities in the Argyll Group outcrop, notably at *Loch Kander* and *Loch Lyon*. Helicopter EM surveys have been flown over extensive areas of the Middle Dalradian, but only limited ground follow-up has taken place. Data from the surveys are available on open file.

Prospective areas for carbonate-hosted Sedex mineralisation all contain early Carboniferous (Tournaisian) sediments in geological settings that are generally similar to those of the world-class Irish zinc-lead deposits. The *Craven Basin* is the most prospective, being heavily tectonised with carbonate debris-flows and minor stratabound zinc-lead mineralisation near surface in the Clitheroe area in the north-west of the basin. Geophysical data indicate that suitable depositional and tectonic environments for Sedex mineralisation could occur at reasonable depths (< 200 m) in this area. A large amount of data are available from extensive exploration by the BGS and BP Minerals, as well as core from some 40 boreholes. Other areas with some potential include the early Carboniferous sediments in the *East Midlands* and *Stainmore basins*, but here the target horizons are mainly at depths exceeding 1 km. To the north, in the *Solway-Northumberland Basin*, the early Carboniferous rocks are mainly shallow-water, thin-bedded deltaic sandstones, mudstones and carbonates, which are unlikely to be suitable hosts for the preservation of exhaled sulphides. Replacement-type deposits, however, may occur in the more massive sandstones. Many geochemical anomalies in this area remain inadequately explained, partly because of the extensive superficial deposits.

Stratabound lead-zinc-barium mineralisation occurs in folded and faulted Middle and Upper Devonian sedimentary and volcanic rocks in south-west England. A 1–2 m thick black-shale horizon with about 2% Pb + Zn (but 10% Pb over 4 m of drill core in a fold nose) was found by RioFinex at *Egloskerry* near Launceston in Cornwall, and the BGS Mineral Reconnaissance Programme drilled 7 m of massive stratabound pyrite mineralisation, with associated high-grade baryte float, in the *South Hams* area of Devon. The whole Devonian and Lower Carboniferous (Hercynian) volcano-sedimentary belt in south-west England has considerable exploration potential for Sedex mineralisation of the baryte-base-metal type, similar to the Meggen and Rammelsberg deposits of similar age in Germany.





Schematic section of the Dalradian basin at the time of deposition of the Ben Eagach Schist, showing location of stratabound mineralisation

The south-eastern margin of the back-arc Lower Palaeozoic Welsh Basin near *Builth Wells*, where it abuts the continental margin of the Midlands Microcraton along the line of the Church Stretton Fault, is a promising setting for stratabound mineralisation of Sedex style. Compaction and dewatering of the thick Ordovician–Silurian succession would provide mineralising fluids, and the basinal Lower Silurian shales to the west of the carbonate shelf facies form a suitable depositional environment. No significant mineralisation is recorded from the area but there has been very little exploration for this style of mineralisation.

Volcanogenic massive sulphide (VMS) deposits

The largest VMS deposit known in Britain occurs at *Parys Mountain* on the island of Anglesey in North Wales, where an estimated 300 000 t of copper metal was produced from 3 Mt of ore between the mid-eighteenth and late nineteenth centuries from quartz-chalcopyrite veins, stockworks and disseminations. There was only minor production from the fine-grained zinc- and lead-rich ‘bluestone’ massive sulphides which accompanied the copper mineralisation. The deposit, which occurs in Ordovician or early Silurian altered rhyolites, basalts and volcanoclastic sediments, has been investigated from the 1960s to the present. Recent exploration work by Anglesey Mining plc has shown that additional reserves are present at depth. In its 1997 Annual Report the company gave the identified geological resource as about 6.5 Mt grading 5.3% Zn, 2.7% Pb, 2.3% Cu, 39 g/t Ag and 0.32 g/t Au. Exploration for additional resources is continuing, based on a new model which suggests that the mineralisation formed on the flanks of an en-echelon series of rhyolite domes. Ordovician volcanic rocks and associated mudstones occur elsewhere in Wales, providing potential target areas for deposits of this type.

Also in North Wales, a small Kuroko-style massive pyrite deposit occurs in Ordovician volcanic and sedimentary rocks at *Cae Coch*, just within the Snowdonia National Park north-east of Snowdon. It produced over 200 000 t of pyrite from a 2-m-thick bed during the First World War. The area is prospective for VMS base-metal mineralisation.

Volcanogenic stratabound deposits

The Middle to Upper Dalradian Tayvallich Formation in western Scotland is a thick (up to 5 km) series of submarine basic tholeiitic lavas and high-level intrusions associated with the development of the Dalradian extensional basin. The formation has potential for base- and precious-metal mineralisation in various environments and deposit styles. Zinc-copper-lead mineralisation in pyritic quartzites up to 20 m thick with a strike length of several kilometres in the *Tyndrum* area has been attributed to hydrothermal systems associated with the development of basic intrusive rocks at shallow depth forming a possible Besshi-style deposit.

A stratabound copper-zinc deposit occurs in Dalradian volcanic and sedimentary rocks at *Vidlin Ness* in the Shetland Islands. Drilling by the MRP and a mining company proved massive and disseminated sulphides grading up to 1.19% Cu and 1.27% Zn in zones up to 10 m thick over a strike length of 4 km. No mining has taken place here, but the deposit is similar in style to several small deposits exploited in Scandinavia.

Besshi-style copper-zinc-gold mineralisation occurs in supracrustal Lewisian rocks of the Loch Maree Group (Proterozoic) near *Gairloch* in north-west Scotland. The host rocks are mafic volcanics and associated sedimentary rocks with exhalite units. A 4-m-thick horizon of quartz-carbonate schist, grading about 1% Cu, 0.5% Zn and 1 g/t Au, extends for over 1 km. The sub-economic deposit has been extensively drilled by Consolidated Goldfields and the data, including some drill core, are available. Another exhalative horizon, which extends intermittently over 6 km, consists mainly of iron sulphides.

Mississippi Valley type (MVT) deposits

Along the trace of the *Variscan Front* in southern England, Dinantian limestones are unconformably overlain by Mesozoic rocks on the northern margins of the *Wessex Basin*, while to the west Dinantian strata outcrop in the *Mendip Hills* and in *South Wales*. In some of these areas, especially in the Mendip Hills, the limestones contain vein, replacement and disseminated lead-zinc MVT mineralisation of Mesozoic age. Base-metal mineralisation also occurs in several boreholes in the Wessex Basin at the Mesozoic–Dinantian unconformity. There are several major Jurassic growth faults in the area, providing a focus for mineralising fluids from the Wessex Basin. A concealed Tournaisian Waulsortian reef complex (similar in age to those hosting some of the Irish zinc-lead deposits) occurs some 30 km south-west of the Mendip Hills, near Bridgwater. There is thus potential for concealed lead-zinc mineralisation in structural and stratigraphical traps in both Carboniferous and Jurassic rocks along the line of the Variscan Front.



MRP drilling for MVT replacement-style mineralisation in the Southern Pennine Orefield.

Lead-zinc-iron sulphide and baryte mineralisation occurs in several Jurassic oil reservoirs in the *Outer Moray Firth Basin*. The mineralisation is found mainly in structural highs and adjacent to faults within the Upper Jurassic Piper Formation. All the observations have been in offshore oil exploration drill holes, but there may be suitable targets for base-metal mineralisation closer inshore, and at shallower depths, than those considered for oil.

Lead-zinc-fluorite-baryte veins have been worked in most Dinantian shelf limestone areas. The most productive have been the *Northern* and *Southern Pennine Orefields* (lead-fluorite-baryte) and the *Halkyn–Minera* area (lead and zinc). Fluorite and baryte are now the main economic minerals in the Pennines, but lead and

zinc are produced in small quantities as by-products. Extraction is now largely confined to the Southern Pennine Orefield. The silver content of the galena is generally low, but ranges from 10 g/t in the Southern Pennines up to 550 g/t in the Halkyn–Minera area.

Mineralisation occurs in oreshoots within major veins up to 20 km long and 10 m wide, as well as in stratabound replacement orebodies (flats) adjacent to veins and in numerous minor veins. The largest single mine, *Millclose* in the Southern Pennine Orefield, produced 450 000 t of lead and zinc concentrates. The major Red Vein in the Northern Pennine Orefield produced more than 100 000 t of lead concentrates and over 1.9 Mt of fluor spar from several mines over its length of 14 km. Substantial (in excess of several hundred thousand tonnes of fluorite) replacement orebodies have recently been mined in the Southern Pennine Orefield, adjacent to major veins. They appear to represent domal collapse structures forming mineralised breccias similar to those in the Tennessee zinc deposits. Mineralisation is

thought to have commenced in early Permian times and continued into the Triassic — and into the early Jurassic in the Mendip Hills. The source of the mineralising fluids is generally thought to lie in Carboniferous shale basins adjacent to the carbonate platforms which host the mineralisation. Fluid movement occurred during the Variscan orogeny, aided by seismic pumping from the over-pressured basins along listric faults.

Lower Palaeozoic vein-style deposits in greywackes and volcanic rocks

The main producing areas for these deposits were *Central Wales*, *Shropshire*, the *Llanrwst* area in North Wales, the *Lake District*, the *Isle of Man* and *Leadhills* in the Southern Uplands of Scotland. One of the largest lead mines in Britain, the *Greenside* mine in the Lake District, produced over 200 000 t of lead concentrates before closure in 1962. Some of the mines in central Wales also produced substantial amounts of zinc. Mineralisation shows some spatial association with underlying granitic intrusions in the Lake District and the Isle of Man, and with volcanics at Llanrwst, but in central Wales and the Southern Uplands there is no indication of magmatic influence. The galena in the Lower Palaeozoic deposits generally contains more silver than that in the carbonate-hosted mineralisation: the silver content of galena from the central Wales orefield, for example, varies from 100 to 1000 g/t.

Vein-style deposits associated with Hercynian granitic intrusions

The main production of lead and zinc in the predominantly tin-copper mining area of *South-west England* was from north-south 'crosscourse' veins cutting the earlier major east-west tin-copper veins. Total production from the area was around 250 000 t of lead and 50 000 t of zinc. The lead and zinc tend to occur on the margins of the main mineralised districts. The galena is generally silver-rich, averaging around 1200 g/t. Few of the major east-west tin-copper veins produced lead or zinc, but zinc was produced as a co-product of tin production at the Wheal Jane mine at the rate of 6000 t per year until the mine's closure in 1991.



Sphalerite breccia vein from the Cwmystwyth mine in the central Wales orefield, showing angular fragments of black mudstone wallrock cemented by quartz and honey-brown sphalerite.

Data Holdings

A substantial amount of information relating to lead and zinc 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:

- Reports, maps and other data provided under the terms of the Mineral Exploration and Investment Grants Act 1972 (MEIGA). Some, particularly airborne geophysical data, have been converted to digital form and can be purchased in user-specified formats. Hard-copy data and reports may be photocopied.
- Mineral Reconnaissance Programme Reports and Data Releases.
- 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 and legislative matters, planning constraints.
- 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.

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