UK Critical Minerals Intelligence Centre

MINERALS FOR THE UK'S NET ZERO TRANSITION

# The potential for nickel in the UK

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## Introduction

Nickel is a silvery-white, lustrous metallic element, which belongs to the transition metals and is relatively abundant in the Earth's crust. An area of significant growth for nickel, and as such a driving force in the development of new nickel deposits worldwide, is its use as a cathode material in electric vehicle batteries.

Despite the challenges faced by the mining industry during the pandemic, the production of nickel increased in 2020 relative to 2019, with global production in 2020 reaching almost 2.5 million tonnes (metal content from mine production of nickel) (Idoine et al., 2022). The leading world nickel producers are Indonesia (32% of total), the Philippines (13%), Russia (9%), New Caledonia (8%), Australia (7%) and Canada (7%). Approximately 66 per cent of world nickel production was derived from laterite deposits in 2020, with the remainder from magmatic sulfide deposits.

More than three quarters of global nickel production is used to produce stainless steel (Nickel Institute, 2022). It is also used in other forms of steel and non-ferrous alloys and in plating, catalysts, and magnets. Eleven per cent of global nickel production was used in lithium-ion batteries in 2020 (Nickel Institute, 2022), and other sources suggest this has increased to thirteen per cent in

*This profile provides an overview of the geological potential for nickel in the UK. It forms part of a series on the minerals the UK requires to transition its economy in the coming decades to net-zero emissions. It was produced by the British Geological Survey for the Department for Business, Energy and Industrial Strategy as part of the UK Critical Minerals Intelligence Centre.*

BGS British Geological Survey

2021 (Garside, 2022). Nickel is traded in a variety of forms with the most important forms for the UK being mattes and sinters, scrap, ferro-nickel, unwrought metal, and unwrought alloys. UK imports of nickel in all forms were valued at £500 million in 2020, with a corresponding export value for nickel of all forms being £588 million (Bide, 2022). Global demand for nickel for use in clean energy technologies is expected to increase by as much as 21 times in 2040. However, this projection will be influenced by the rate of uptake of electric vehicles, grid-scale energy storage systems and future battery chemistries (IEA, 2021). Most nickel-containing materials are fully recyclable at the end of the product's useful life; indeed their high value encourages recycling (Nickel Institute, 2022).

Most economic nickel deposits occur either in magmatic sulfide deposits within mafic-ultramafic igneous intrusions, or in laterites formed by tropical weathering of magmatic deposits. Numerous nickel-bearing minerals are found in nickel ore deposits. In magmatic sulfide deposits, the most important nickel-bearing minerals are pentlandite and pyrrhotite, while others such as millerite, nickeline and siegenite are of local significance. In laterite deposits, garnierite (nickel-rich serpentine), nickeliferous limonite and nickeliferous goethite are the most important hosts of nickel. Significant concentrations of nickel also occur on the sea floor in iron-manganese-rich nodules and crusts, although to date no nickel has been extracted from these on a commercial scale (Lusty and Murton, 2018).

## UK mineral occurrences, exploration and production

There is currently no mine production of nickel in the UK, and there are no deposits that have nickel resources or reserves, which are compliant with international reporting standards. Nickel has historically been produced in small to very small quantities at a few localities in the UK, such as the Coille-Bhràghad mine which produced over 400 tons of nickeliferous mineralisation between 1854 and 1867 (Colman and Cooper, 2000). Small amounts of nickel-bearing ore were also extracted at several mines in Cornwall, commonly associated with the production of a range of other metals including cobalt, bismuth, lead, zinc, silver, iron, antimony and uranium (Dines, 1956). The UK does have nickel refining capacity. The Vale nickel refinery at Clydach in South Wales produces around 40 000 tpa of high purity nickel metal and other products from nickel matte imported from Vale's mining operations in Canada and Indonesia (Vale, 2022).

### *Scotland*

The most important occurrences of magmatic nickel-copper mineralisation in the UK are associated with a suite of Caledonian syntectonic layered mafic-ultramafic intrusions in north-east Scotland, commonly referred to as the 'Younger Basics'. Prompted by the booming nickel market and the discovery of large economic deposits in Western Australia, Rio Tinto Zinc and Consolidated Goldfields undertook major programmes of exploration for nickel mineralisation in the Caledonian layered mafic intrusive complexes of north-east Scotland between 1967 and 1973. From 1969 onwards they formed a joint venture partnership known as Exploration Ventures Limited (EVL). EVL carried out extensive multidisciplinary surveys (geology, geophysics and geochemistry) and associated diamond drilling of some targets (Gunn, 2007). Although no resource or reserve estimates that are compliant with international reporting standards were produced, 'geological reserves' for the two principal discoveries were reported. At Knock, near Huntly, an estimated 3 million tonnes at 0.52% Ni and 0.27% Cu was defined; and at Arthrath, near Ellon, about 30 km north of Aberdeen, an estimated ~17 million tonnes of ore grading 0.21% Ni and 0.14% Cu was reported (Fletcher et al., 1997). The basis for these estimates and their equivalence to modern reporting standards are not known. Subsequent exploration in the area in the late 1970s by Amax Exploration UK Ltd, and Alba in the mid-2000s did not lead to the publication of any new resource data. Exploration of the Arthrath Intrusion for nickel-copper-cobalt (±PGEs) mineralisation is ongoing (Aberdeen Minerals Limited, 2022).

Low tenor nickel-iron sulfide mineralisation, up to 1–2% per volume, is widespread in both the chromitites and silicate rocks in the Unst ophiolite in Shetland, associated with podiform chromite ores, which were worked between 1820 and 1945 (Gunn, 1989; Gunn et al., 1985).

A small body of arsenic-rich nickel-copper ore occurs at Talnotry located about 9 km north-east

of Newton Stewart in the Southern Uplands of Scotland. The mineralisation is located near the base of a sheet-like diorite intrusion emplaced in Ordovician metasedimentary rocks in the aureole of the Cairnsmore of Fleet granite (Stanley et al., 1987). Geophysical surveys by BGS indicated that the deposit is small, 20 m in length and up to 4 m wide (Parker, 1977). The mineralisation was discovered in about 1885 and trial working continued until 1890. About 100 tons of ore were raised but none left the site (Wilson and Flett, 1921).

Nickel is reported from the Hilderston mine, near Linlithgow in West Lothian, central Scotland, where it is associated with cobalt and silver, and hosted by Lower Carboniferous sedimentary rocks (Stephenson et al., 1983). Low tenor nickel-bearing mineralisation has been reported from a small (500 m x 200 m) body of metamorphosed and altered ultramafic rocks at Corrycharmaig near Killin in Perthshire (Power and Pirrie, 2000).

## *England*

Small amounts of nickel-cobalt mineralisation have been recorded with copper ores in the Bonser vein and in the Paddy End section of the mines near Coniston in the Lake District (Young, 1987), 1987). Russell (1925) reported the production of 3 tons of nickel and cobalt ore in 1855 and further sales of smaller quantities of nickel ore in 1873.

Minor occurrences of nickeline and several other nickel-bearing minerals have been recorded at four disused mines in the North Pennine orefield (Ixer, 1986; Young et al., 1985). At the Lady's Rake lead mine near Harwood in Upper Teesdale a magnetite-rich ore containing nickel and other base metals has been described. At the Settlingstones lead mine near Hexham a varied suite of nickel-bearing minerals has been found, together with minor amounts of cobalt minerals, in association with the lead ores (Ixer, 1986; Young et al., 1985). At the Hilton mine, near Appleby, the lead mineralisation is accompanied by nickel, with a final phase comprising fluorite, lead and nickel (Bridges, 1982; Ixer, 1986). Young et al., (1985) concluded that the nickel-bearing assemblages at Settlingstones, Lady's Rake and Hilton may have been produced by skarn-type alteration accompanying the emplacement of the Whin Sill which itself may have been the source of the nickel.

Silver-nickel-cobalt mineralisation has been described from the disused lead mine at Tynebottom, Garrigill, near Alston in the North Pennine Orefield (Ixer and Stanley, 1987). In south-west England small quantities of nickel ore have been recorded in several old mines commonly associated with cobalt and bismuth in late-stage, low temperature, discordant veins. Dines (1956) notes production of small tonnages (<10 ton) of nickel ore in the St Austell district at St Austell Consols and Fowey Consols, and from East Pool Mine in the Camborne and Redruth mining district. Small quantities of nickeliferous ores were also recorded in the St Ives district, the Carn Brea area, and the Helford-Falmouth area (Dines, 1956). In addition, mixed nickel and cobalt ores were reported to have been produced in the St Austell district at St Austell Consols and Dowgas Mine.

## *Wales*

In the Central Wales Orefield nickel occurs in a variety of minerals, commonly with cobalt, as a minor component of polymetallic vein mineralisation which was previously mined for lead, zinc, copper and silver (Mason, 1997). Most of these old mines are located near Tal-y-bont in Ceredigion (National Museum Wales, 2019). Nickel minerals are also found as trace constituents of the copper ores at the Great Orme mine near Llandudno (National Museum Wales, 2019d and 2019b). Cobalt-nickel-bearing mineralisation occurs at the Foel Hiraddug mine (also known as Moel Hiraddug) near Dyserth, located about 30 km east of Llandudno. In addition to working for hematite and pyrite, cobalt and nickel were also produced at this site. Mine production of cobalt ore is estimated to have been 264 tons between 1878 and 1880 (North, 1962). Foster (1882) reported assays of ore parcels containing between 1.0–1.8% Co and 0.4–1.1% Ni.

In the Upper Carboniferous Coal Measures of South Wales claystone-ironstone nodules are widespread in mudstones adjacent to the coal seams (Bevins and Mason, 2010). Within these concretionary nodules, a suite of sulfide minerals is commonly developed along septarian cracks lined with siderite. Most notable is the presence of the nickel sulfide mineral, millerite. There is no consensus on the origin of these nodules or the included sulfides.

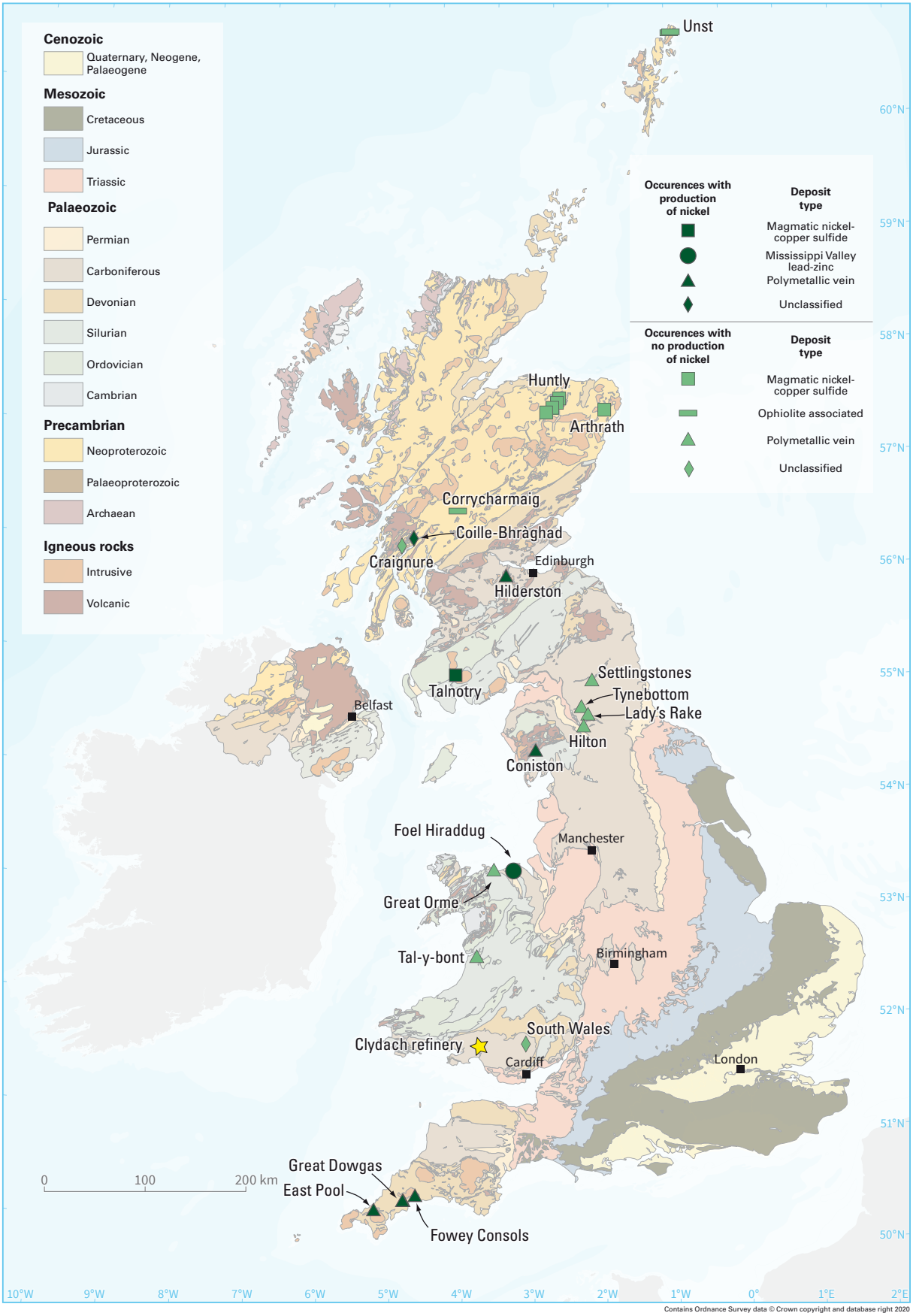


Figure 1 Location of the principal occurrences of nickel in the United Kingdom.

## *Northern Ireland*

In Northern Ireland high nickel concentrations in the Tellus survey geochemical data, characterise the Palaeogene volcanics. Elevated nickel concentrations occurs in several other areas, some times associated with Palaeogene dykes (GSNI, 2018). There is potential for the occurrence of platinum group metals (PGM) with associated nickel in the Palaeogene Antrim Lava Group (Andersen et al., 2002). Karelian Diamond Resources currently holds two mineral prospecting licences (active from 2022 for six years) for Ni-Cu-PGM mineralisation in the Fermanagh-Tyrone area.

## Resource potential

A considerable amount of research has identified high concentrations of nickel, and the occurrence of a wide range of nickel-bearing minerals, in several areas of the UK (Colman and Cooper, 2000; British Geological Survey, 2020). However, it should be noted that in many cases these metals are minor constituents of polymetallic ores and are unlikely to constitute anything more than a minor by-product of the extraction of another metal. Nevertheless, further research into the abundance and distribution of nickel (and associated cobalt) in some of the polymetallic ores worked in historic mining districts in Wales, Cornwall, the Lake District and the north Pennines is warranted as few modern systematic studies have been undertaken in these areas.

The most attractive targets for nickel exploration, with possible by-product cobalt and PGM, are located in the Caledonian layered mafic-ultramafic intrusions in north-east Scotland. Although the geology of the north-east Grampians is complex and bedrock exposure is sparse, experience from past commercial exploration has demonstrated the efficacy of soil geochemistry (Hashmi et al., 2022; Hashmi et al., 2021) and electromagnetic surveys (King, 2007) for locating deposits of this type in the region (Gunn, 2007). The application of these or similar techniques based on modern conceptual models for deposits of this type provide a sound basis for undertaking further exploration.

In Northern Ireland there is potential for the occurrence of magmatic nickel-copper-PGM mineralisation associated with the Palaeogene Antrim Lava Group (Andersen et al., 2002). Although there is little published information on metal contents in these rocks, their geological setting and the presence of elevated PGM concentrations in regional geochemical data suggest that there is potential for magmatic nickel-copper-PGM deposits associated with the Antrim Lava Group and their underlying feeder zones (Lusty, 2016).

The nickel-bearing claystone-ironstone nodules in south Wales are a potential target for further research. Although the nodules have a significant lateral extent, no assessment of their potential as a source of metals appears to have been undertaken (Bevins and Mason, 2010). Geochemical studies to elucidate metal contents are recommended, followed by an investigation of the controls on their distribution and abundance.

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