**Table S1.** *Description of the most important studied nonsulphide deposits from UK and Ireland with their historical background (\*).*

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| **Locality** | | **Ore** | **Historical details** |
| **United Kingdom** | | | |
| Somerset | Whatley Quarry, Mendip Hills  East Harptree Mine, Mendip Hills  Merehead Quarry, Mendip Hills | Veins and impregnations in Carboniferous limestone and Triassic conglomerate  Ba>Pb>Zn-Fe-Mn  nonsulphides>sulphides | The Carboniferous Limestone hosts several lead-rich mineral deposits that have been worked since ancient times.. Mining in the region was not just limited to lead, but ochre, copper, zinc and manganese were all mined from the 13th century. It has been estimated that about 100,000 tons of lead have been obtained from the Mendips while most of the zinc was obtained from the region around Shipham and Rowberrow. Several supergene minerals have been extracted from this mining district, including mendipite (Pb3Cl2O2). The Whatley Quarry is one of the largest quarries in the Mendips and although quarrying had been undertaken for many years, the area was historically been mined for lead, whose main ore is galena. A wide range of other minerals has also been found in the rocks quarried. The East Harptree Lead Works Company was formed in 1867 by a group of Cornish engineers to rework the old lead mines and to re-smelt the slag heaps. Largely unsuccessful, the operation closed in 1875. In 1566, calamine was discovered in the same area of the Mendip Hills and extraction continued until the 19th century. |
| Higher Pitts mine, Priddy, Mendip Hills | Veins and impregnations in Triassic conglomerate  Ba>Pb>Zn-Fe-Mn  sulphides>>nonsulphides | The Higher Pitts mine is near to the village of Priddy in the Mendip Hills. Lead mining was carried out from Roman times, or even earlier. This activity peaked during the 17th century, but mining for lead continued on an ever-decreasing scale until the middle of the 19th century. The Mendip Hills ("the Mendips") consist of a number of domes disposed along a sickle-shaped structural axis. The cores of the domes consist of Devonian sandstones and shales, overlain by shales and limestones of Carboniferous age. Denudation during the Triassic period resulted in the formation of thick deposits of scree breccia and conglomerates that have been subjected to widespread dolomitization, and locally replaced by hematite, silica or barite. The conglomerates were host rocks for large deposits of sphalerite and pyrite/marcasite, which were subsequently oxidized to smithsonite and "limonite". Beds of iron and manganese minerals are also contained in this lithotype. A rich association of supergene, also rare minerals has been detected in this mine, as in several other areas of the Mendips. |
| Cumbria | Hilton Beck, Appleby, Westmoreland | Carboniferous rocks, Pb>>Ba>>Zn  sulphides>>>nonsulphides | Located along the western margin of the North Pennines, the Hilton mine near Scordale was first worked for lead (galena) and then for barium. The host of the mineralization was mainly Carboniferous limestone and sandstone, cut by numerous faults. Not too many supergene minerals have been detected. |
| Silvertop quarry, Hallbankgate, Brampton | Veins in Carboniferous sediments  Ba>Pb>Zn  sulphides>>>nonsulphides | A former coal and lead mining area consisting mostly of Carboniferous limestone. The mineralization occurs both as joints filling and as patchy replacements of carbonate rocks. Barite is prevailing and rare galena occurs locally. Adjacent to mineralization the limestone is replaced by dark brown goethite and fine-grained calcite. Curved rhombic crystals represent original siderite or ankerite. The altered limestone locally contains 'dry bone' smithsonite. Cavities are commonly filled with turquoise-blue aurichalcite. Cinnabar is in close association with supergene zinc minerals, suggesting that a small amount of Hg may have been present in sphalerite. |
| Farnberry mine, Alston | Veins in Carboniferous sedimentary rocks.  Pb>Ba>Zn  sulphides>>>nonsulphides | The Carboniferous sediments are cut by a network of mineralised faults. The ENE-WSW trending Dowgang, Scaleburn and Rampgill veins were economically important. Late cross-fractures with lead and zinc mineralisation are typically associated with extensive replacement bodies only in the Nent valley. Ankeritization (saddle-shaped rhombic crystals) is the main hydrothermal alteration. Masses of coarsely crystalline galena and brown sphalerite are also present. Quartz is also common; calcite is occasionally seen lining vugs as white rhombic crystals. Supergene alteration is only very weakly developed and large concentrations of oxidised lead and zinc ores are not common in the Northern Pennine orefield. However, smithsonite locally coats brown sphalerite masses as thin crusts, and occur also as ‘dry bone ore’. Cerussite has been reported from the Hudgill Burn Mine. |
| Alston Block | sulphides>>nonsulphides | The comparatively thin successions of Carboniferous rocks on the Alston Block are cut by an extensive suite of veins and related deposits, which collectively make up the Northern Pennine Orefield. The orefield coincides with the uplands of the northern Pennines, but extends eastwards to include parts of the Durham Coalfield. A group of mineralised faults close to the southern margin of the Northumberland Trough in the Haydon Bridge area are generally regarded as being part of an outlying portion of the orefield. The deposits exhibit many characteristics of the worldwide ‘Mississippi Valley’ mineralisation type, though they are considered as a fluoritic subtype. Since at least the 12th century, the orefield has been a significant producer of lead and iron ores; minor amounts of copper have been produced and a little silver was the by-product of lead smelting. The peak years of metal production were during the 18th and 19th centuries. More recently zinc mining was important, together with fluorspar, barite and witherite. Hard, competent wallrocks such as limestone, sandstone or dolerite of the Whin Sill-swarm provided clean open fissures favourable for the deposition of wide mineralised veins. In addition to hundreds of fissure veins, the Northern Pennine Orefield is noted for extensive replacements of limestone wallrock (“flats”). Adjacent to many veins, the original limestone has been wholly or partly replaced by variable assemblages of quartz, ankerite, siderite, fluorite, barite, witherite, galena and sphalerite. Ore minerals such as galena and sphalerite are commonly more abundant in the ‘flats’ than in the parent veins. Most of the galena is silver-bearing with silver values of between 4 and 8 oz per ton of lead (112 to 223 ppm). The sphalerite normally carries some cadmium and a little mercury. Chalcopyrite is common in small amounts throughout the orefield. Small, but significant concentrations of nickel minerals are known at Scordale. |
| Stanhopeburn mine, Co. Durham Pennine Orefield | Veins in Carboniferous sedimentary rocks.  Pb-F>Ba>Zn  sulphides>>>nonsulphides | This mine is located along the Crawelyside Bank at the eastern end of the Red Vein, which runs the length of Rookhopeburn to the west. The mine was worked for veins of lead ore by the London Lead Company and then by Lord Carlisle in the 18th century. Lead concentrates were poor but contained a lot of fluorspar. At the beginning of the 20th century the mine was opened again and started extracting also the fluorspar. Most of the ore came from in or above the Great Limestone, but some workings did reach the Firestone Sill below the Great Limestone. |
| Roughton Gill Caldbeck Fells | Mostly lead and copper>>>>zinc  sulphides & nonsulphides | The Roughton Gill Mines worked the Gill South Vein, the Silver Gill Vein and other smaller veins. The South Vein was exploited in the 18th century, and for the whole 19th century. The ores were near the boundary between extrusive igneous rocks of the Eycott Volcanic Group (Ordovician) and intrusive rocks of the Carrock Fell Complex. Roughton Gill was one of the biggest mines in the Caldbeck Fells, producing large amounts of lead and copper ores. The primary minerals were galena, chalcopyrite and sphalerite in a quartz/carbonate gangue. Oxidation of the primary sulphides was extensive, resulting in malachite, pyromorphite, hemimorphite and cerussite. The supergene alteration of the deposit is exceptional, because its scale and depth surpasses that of any other deposit in northern England. |

(\*) Literature quoted in text

**Table S1.** *(continued).*

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| **Locality** | | **Ore** | **Historical details** |
| **United Kingdom** | | | |
| Derbyshire | Brassington | Carboniferous Limestone, Pb>>Zn-Ba-F  sulphides>>nonsulphides | Brassington was for centuries dependent on lead mining. The deposits were hosted in Carboniferous limestone, as veins and cavity fillings and as replacement “flats”. Mineralized palaeokarst is limited to a few pipe veins, some in contemporary solution pits in the limestones. In the area an extensive hydrothermal dolomitization preceded mineralization. The ore minerals were mainly galena, but also sphalerite, fluorite and barite.  Around Castleton has been found and exploited the so-called Blue-John: a decorative form of fluorspar, with banded purple and colourless spar, to be used from the 18th century onwards for ornamental objects. Supergene alteration has produced anglesite, cerussite, smithsonite and other secondary minerals. |
| Matlock | Carboniferous Limestone, Pb>>Zn>>F  sulphides>>>nonsulphides | Matlock Bath, just a short distance down the Derwent valley, was a well-established spa resort, famous for its thermal waters. In the older times (still from the Roman time), there was also a fair amount of lead mines, where sphalerite, marcasite and several gangue minerals were detected and exploited from veins and “flats”. These mines were active at least until the 19th century, and they produced also abundant calamine ore derived from supergene weathering. In the Matlock site excellent hemimorphite with fluorite, banded aragonite, smithsonite, cerussite and calcite have been found. |
| Ball Eye Quarry | Carboniferous Limestone, Pb>>Zn-Ba-F  sulphides>>nonsulphides | In this site the ore minerals occurred in veins and as cavity fillings exploited in Carboniferous limestone. At the southern end of the Pennine hills several lead deposits have been worked since Roman times and possibly before. Lead mining has been an important part of the local economy. Most recently fluorite and baryte have been worked, by opencast methods, with localised workings for calcite. Supergene alteration was quite important locally. In the Ball Eye Quarry dark blue fluorite, barite, malachite, cerussite, smithsonite and anglesite have been exploited. |
| Cobbler mine | Carboniferous Limestone, Pb>>Zn-Ba-F  sulphides>>nonsulphides | The majority of the lead-bearing mineralisation is confined to the Carboniferous Limestone at the centre of the Peak District. The primary mineralisation (5%) is most commonly found in near-vertical veins roughly east/ west. The larger veins are a few kilometres long and several metres wide. Another type of deposit was identified as “flats”, which follow the near-horizontal bedding of the limestone. The commonest lead ore found in the Peak District is galena that was altered to cerussite and pyromorphite as a result of strong weathering processes. Other ores occur (commonly sphalerite and secondary smithsonite), copper (commonly chalcopyrite, malachite, azurite and aurichalcite) and iron. As gangue minerals are common: fluorite, barite and calcite. |
| Hopping mine, Matlock | Carboniferous Limestone, Pb>>F-Ba>>Zn  sulphides>>nonsulphides | This mine was first exploited for lead (galena), and then mined during the 40s and 50s mainly for fluorite. The ore was hosted in Carboniferous limestone, as in the whole Derbyshire. Supergene minerals have been sporadically exploited, but were never economically important. |
| Grinton Moor, Swaledale, Yorkshire | Carboniferous succession, mostly Pb>>>>Zn  sulphides>>>nonsulphides | The geology of Swaledale is dominated by the Yoredale series of rocks (Carboniferous), clearly visible as a repeating pattern of banded rock outcrops or steeper slopes of hard limestone and gritstone alternated by more gentle slopes formed by the less resistant shales. The Millstone Grit lies on top of the Yoredales and comprises a series of coarse sandstones with intervening shales and occasional coals. The ore occurred in narrow veins. Lead mining was practised in Swaledale since Roman times. In the 9th century, Swaledale produced half the lead mined in Yorkshire. |
| Cornwall | Penberthy Croft mine, St. Hilary Mount’s Bay | Cu-(Sn)-Pb-Zn veins  sulphides>>nonsulphides | 3,000 tons of copper ore were exploited toward the end of the 18th century. Mixed copper and tin mining took place at depth at a later date, but the mine closed around 1840. The mineralisation is situated in Devonian metasediments consisting of lower-grade-greenschist facies (killas) slates between the Land's End and Godolphin granite masses. The main Penberthy lode strikes east-west and dips to the south. The lode is associated with a rhyolite porphyry dyke and is probably related to a shear zone. The mineralisation is of a multi-stage, polymetallic and hydrothermal character. The deposit consists of several, but distinct overlapping assemblages. There is lower-temperature epithermal Pb-Zn sulphide mineralisation; and a late-stage, low-temperature Fe-Mn mineralisation. Subsequent supergene oxidation and weathering of lodes resulted in the formation of complex gossans with oxides and supergene enrichment zones. |
| Wales | Holywell, Flintshire,  Holywell Clwyd  Talargoch mine, Dyserth, Rhyl, Clwyd  Halkyn mine, Jamaica mine, Flintshire | Lead-zinc veins in the Carboniferous Limestone in South Wales.  The limestone outcrops around the South Wales coalfield. Pb>>Zn  sulphides>>nonsulphides | The mineralisation is not only confined to the Carboniferous, but does extend into the unconformably overlying Trias and Lower Jurassic sediments as minor veins and disseminations. Some sub-horizontal ‘flats’ also occur, as in the Jamaica mine, which may have infilled solution cavities in the limestone. The veins have a simple mineralogy with calcite, sphalerite and galena (dominant) with up to 550 mg/kg Ag. Quartz, fluorite and barite occur sporadically. Substantial amounts of chalcopyrite and malachite were reported from the veins in the Talargoch mines. Secondary minerals occur in the shallower parts of most veins, where smithsonite and cerussite are common.  The mining industry in Flintshire dates from at least the Roman times, but the earliest records of lead mining near Holywell and Halkyn are between 1300 and 1320. In the 18th and 19th century, the Flintshire has been the largest producer of lead ore in Wales. |
| Shropshire | Ladywell Mine, Shelve, Shrewsbury | Carboniferous Limestone and Ordovician shales  Pb>Zn sulphides>>>nonsulphides | This mine was part of a group that included Grit Mine and it was intensely exploited in the 19th century, where the production of lead reached its peak. In the same area there were several coal mines, as well as ironstone ones. The Ladywell mine exploited copper, silver and lead, contained both in the Carboniferous limestone, as well as in Triassic sediments. Supergene ore minerals were very limited, mostly consisting of cerussite. |
| Scotland | Leadhills, Strathclyde Region | Cu-Pb-Zn, Sulphides>>>>Nonsulphides | Leadhills is in the Southern Upland Terrane, comprising rocks of Ordovician age, where the ores occur in veins. The mineral veins within the Leadhills orefield generally lie between the Leadhills Fault to the northwest and the Fardingmullach Fault to the southeast. The primary ore mineralisation is related to the Caledonian Orogeny resulting in minerals veins with ores consisting mainly of galena, chalcopyrite and other minor ore minerals. The Portpatrick Formation consists of volcaniclastic sandstone, which forms the host country rock for the lead-zinc mineral veins. Larger scale lead mining commenced during the late 18th century and was working until the 1930s. |

**Table S1.** *(continued).*

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| **Locality** | | **Ore** | **Historical details** |
| **Ireland** | | | |
| Co. Kilkenny | Galmoy | Carboniferous Limestone (calcite, dolomite)  Irish type, Pb-Zn-Ag, sulphides>nonsulphides | The sulphide ore is located on the northern margin of a Lower Palaeozoic inlier adjacent to the E–W trending Silvermines fault system. The ore is mostly stratabound, but also concentrated on faults and in a dolomite breccia. Sphalerite, galena and barite were the primary ore minerals. Nonsulphide ore consists of smithsonite and hemimorphite, and was exploited intermittently from the 17th Century up until 1953. Four significant deposits occur in the area: three of them (G-Zone, K-Zone and Ballygown South) have been found in the hanging wall of the Silvermines fault, while a fourth zone (Cooleen) is some distance from the fault. |
| Co. Galway | Tynagh | Carboniferous Limestone, calcite, dolomite, Irish type, Pb-Zn-Cu, sulphides/nonsulphides | Opened in the 1960s, Tynagh was an important source of lead and zinc concentrates at that time and was closed in 1981. The sulphide orebody was in the hanging wall of an E–W trending normal fault in Waulsortian limestone. The mineral association comprises galena, sphalerite, barite and pyrite with minor chalcopyrite and tennantite. The supergene mineralization in the “Residual Orebody” consisted of a mixture of detrital as well as supergene sulphides, together with smithsonite, hemimorphite, cerussite and minor Cu-carbonates. |
| Co. Clare | Sheshodonnell, Burren | Carboniferous Limestone (calcite, dolomite)  Irish type. Pb-Zn(Cd)-F  sulphides/nonsulphides | Victorian lead(>zinc) mine in vein from about 30 to 45 cm in width. The sphalerite in the vein has been altered to green, yellow, grey and white botryoidal smithsonite (Cd-rich). The vein was worked on a very small scale from about 1862-1863 by a shallow trench over a distance of about 100m. The smithsonite was originally left in the spoil as a gangue mineral. |
| Co. Kerry | Ross Island Mine (Blue Hole), Killarney | Carboniferous Limestone (calcite, dolomite)  Irish type (mainly in veins), Cu-Pb-Zn  sulphides>>nonsulphides | The mine is located in Carboniferous limestone containing stratabound chalcopyrite and tennantite. The deposit is bordered on the eastern side by a vein-type structure (the Blue Hole). The mineralisation has a significant silver content extracted in the past. The periods of greatest mining activity is from 1804 to 1810, and from 1825 to 1829, and then regular mining ceased. |
| Co. Wicklow | Glendalough | At the contact between the Leinster Granite (Devonian) and Silurian schists, Pb>Zn>Ag, sulphides>>>nonsulphides | Vein lead ores hosted in fractures and faults in granite; the mineral association consists of galena, sphalerite, pyrite, minor chalcopyrite with quartz and calcite gangue. Clear evidence of brecciation and hydrothermal alteration of the granite host rock.  Mining in Glendalough dates back to the 1790’s, when lead, zinc and silver were mined, but main exploitation was in the 19th century. |
| Co. Tipperary | Silvermines | Carboniferous Limestone (calcite, dolomite)  Irish type, Zn-Pb-Ba-Ag, sulphides/nonsulphides | Artisanal exploitation started in 1289, but was short-lived. Mining resumed in the 17th century and continued intermittently until 1874. It restarted in 1949, and shortly after barite was exploited from 1963 in Magcobar. Soon after a multi-million tonne orebody grading about 11% combined lead and zinc was also discovered and worked from 1968 to 1982. The Magcobar mine closed in 1992. |
| Co. Limerick | Cloghatrida mine, Rathkeale | Carboniferous Waulsortian Limestone (calcite, dolomite)  Irish type,Pb-Zn, sulphides>>>nonsulphides | Coarse massive galena, dolomite with galena-chalcopyrite veins and crinoidal limestone with minor calcite-galena veins.  The area includes several old 18th or 19th century mine trials. There are no production records but the largest at Cloghatrida may have had a small commercial production. Modern exploration in the area began in 1960, but economic production was never reached. |
| Co. Clare | Kilbricken mine, Ennis | Carboniferous Waulsortian Limestone (calcite, dolomite)  Irish type, Pb-Zn-Ag, sulphides>>nonsulphides | Victorian era lead-zinc mine worked from 1834-1854. The mine reached a maximum depth of 54m where considerable technical difficulties with groundwater were met. The Kilbricken project is a new high-grade Zn-Pb-Ag-Cu discovery. Early, massive-textured, fine-grained pyrite, galena and sphalerite cross-cut by coarse-grained sphalerite and galena, resembling sulphides found in the overlying veins. It differs from most other Irish zinc/lead prospects, because it is silver-rich in the galena-containing zones. |