LEAD MINERALISATION WITHIN THE STUBLICK FAULT SYSTEM AT CHURCH BURN AND WOLF HILLS, HALTWHISTLE, NORTHUMBERLAND

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Two hitherto unreported small clusters of lead-bearing veins and associated workings at Church Burn and Wolf Hills, south of Haltwhistle, described here, add to the group of mineral deposits within the main Tyne Valley, sometimes collectively referred to as the Haydon Bridge Orefield. Long regarded as an outlying portion of the Northern Pennine Orefield, with which they share close structural and mineralogical similarities, these deposits are separated by approximately 15 km of barren ground from the nearest mineralisation in the orefield and lie adjacent to the Stublick Fault, part of the Maryport-Gilcrux-Stublick-Ninety Fathom Fault System. This major fault belt acted as a syn-sedimentary 'hinge zone' during Carboniferous times resulting in the accumulation of substantially greater thicknesses of Carboniferous sediments in the Northumberland-Solway Basin than on the Alston and Lake District blocks to the south. Similar base metal-barium mineralisation is common within a narrow belt along this structural line from coast to coast. It is suggested that the Church Burn and Wolf Hills mineralisation adds further weight to the hypothesis that this belt of mineralisation is both structurally and genetically related to the development of this major Carboniferous fault line.
Also reported here is the first reliable record of plumbojarosite from a Pennine location.

INTRODUCTION

Substantial tonnages of galena, witherite and subordinate amounts of sphalerite and baryte have been worked from veins in Carboniferous and Whin Sill wallrocks at several mines in the Tyne Valley between Haltwhistle and Hexham. Most prominent of these were those at Langley Barony, Stonecroft, Greyside, Settlingstones, and Fallowfield, the latter two being most celebrated as major world sources of witherite. Very much smaller quantities of these minerals were also raised from a handful of smaller mines and trial workings. The geology and mineralisation of all of these deposits have been well documented by Wilson et al. (1922), Smith (1923) and Dunham (1990).

The workings and explorations for lead ore at Church Burn and Wolf Hills south of Haltwhistle (Figures 1, 2 and 10), described here, are remarkable for having hitherto escaped published description despite, in the case of Church Burn, being comparatively conspicuous within the local landscape. The sole reference to lead mineralisation at Church Burn is the depiction of a single NNE-

SSW trending lead-bearing vein on the 1:50 000 scale BGS sheet 19 (Hexham) (British Geological Survey, 1975). No evidence of mineralisation at Wolf Hills is depicted on this map.

The mineralised veins of the Tyne Valley downstream from Haltwhistle have traditionally been regarded as an outlying expression of Northern Pennine mineralisation, referred to by Dunham (1990) as the Haydon Bridge portion of this orefield. However, this cluster of deposits is separated from the main concentrations of Northern Pennine mineralisation by at least 15 km of ground in which mineralisation is conspicuously absent and it is notable that these lie close to, and mostly within, the hangingwall zone of the Stublick-Ninety Fathom Fault System of fractures which, together with its westerly extension in Cumbria, the Maryport-Gilcux Fault, defines the boundary between the structural units of the Lake District and Alston blocks and the Northumberland-Solway Basin. The Church Burn and Wolf Hills deposits lie within the footwall of this fault zone.

Drawing upon the few surviving historical documentary sources and the results of recent field surveys and mineralogical investigations, the geology and mineralisation of the Church Burn and Wolf Hills veins are described and their relationship with the deposits of the main body of the Northern Pennine Orefield are discussed. As these deposits add to the numerous known mineralised sites along the full length of the Maryport-Gilcrux-Stublick-Ninety Fathom Fault System the hypothesis that this belt of mineralisation may be structurally and genetically related to this major Carboniferous fault line is also explored.

Within the following text reference will be made to the individual sections of the Maryport-Gilcrux-Stublick-Ninety Fathom Fault System relevant to the area being discussed: use of the structure's full name will be reserved for discussion of the full regional context.

GEOLOGICAL SETTING

Church Burn and Wolf Hills lie on the northern flanks of the Alston Block, a major structural unit composed of Lower Palaeozoic rocks, including the granite of the Caledonian North Pennine Batholith, which is overlain unconformably by a comparatively thin cyclothemic succession of Carboniferous sediments. The block is separated from the Northumberland-Solway Basin on its northern side by the E-W trending Stublick-Ninety Fathom Fault System, a complex fault zone which was active during Carboniferous times allowing the accumulation of very much greater thicknesses of similar Carboniferous cyclothemic sediments in the basin than on the adjoining block (Figure 1).

The sites described here lie on the outcrop of the succession of Carboniferous rocks formerly known and depicted on the current 1:50 000 Hexham Sheet, as the Upper Limestone Group (British Geological Survey, 1975), but today classified as the Stainmore Formation of the Upper Carboniferous Yoredale Group (Stone et al., 2010). Here, as in much of the Northern Pennines, these comprise a cyclothemic succession of mudstone, siltstone and numerous sandstones with a few thin and generally impure limestones and locally some thin coals. South of Haltwhistle, these rocks dip gently towards the south and east within the footwall zone of the Stublick Fault.

Within the Stublick Fault System and approximately 4 km northwest and 2 km north of Church Burn and Wolf Hills respectively, small E-W elongated fault-bounded outliers of Upper Carboniferous Coal Measures rocks, which comprise the Midgeholme and Plenmeller coalfields, reflect post-Carboniferous movement of this fracture system.

An extensive mantle of superficial deposits, mainly of Quaternary age, conceals substantial parts of the bedrock geology, though low scarp features which locally mark the outcrops of sandstones within the Stainmore Formation constrain the main geological features.

CHURCH BURN MINE

Church Burn Mine comprises a series of long-abandoned workings on a set of mineralised faults within Stainmore Formation rocks on Agarshill Fell, on the south side of the Tyne Valley approximately 6 km southeast of Haltwhistle, centred around old dressing floors at NY7532 5869.

Mapping within the headwaters of the Church Burn reveals a limestone, tentatively correlated with the Lower Felltop Limestone, on both sides of the burn, overlain and underlain by a series of sandstones that form prominent ridges, interbedded with siltstones. These rocks are cut by three roughly N-S to NNE-SSW trending faults (Figure 2). The two western fractures exhibit small throws of only a few metres to the east: the easternmost fault throws down a few metres to the west. In addition to the comparatively conspicuous displacement of surface features, the course of the two western faults is traceable on the ground from the position of collapsed adit levels and several small spoil heaps from surface shafts sunk on, or close to, their outcrops. It is clear from material remaining on the small adjacent dumps that the two western faults carry lead mineralisation. For convenience of description the mineralised faults are identified here as the Church Burn West and Church Burn East veins. No signs of working are associated with the easternmost fault and there is no evidence of any mineralisation associated with it.

Three mine plans dating from 1854 and 1884 held by the North of England Institute of Mining and Mechanical Engineers record levels driven on both the West and East veins in beds beneath the sandstone that immediately underlies the Lower Felltop Limestone and which, on the plan of the workings in the East Vein, is identified as the 'High Slate Sill', a local name for this sandstone unit. In addition, both plans depict a roughly WNW-ESE trending vein, identified on the 1854 plan as the 'Principal Vein' and which for convenience of description in this account we refer to as the South Vein. This vein has no obvious surface expression.

The following descriptions of the Church Burn veins are derived from these plans together with recent field observations of surface features. As none of the veins is exposed at the surface and all of the underground workings are inaccessible, the descriptions of the content of the veins are necessarily based upon material present on the numerous small, though much overgrown, spoil heaps.

Church Burn West Vein

A plan entitled '*Plan of Church Burn Lead Mines in the Parish of Whitfield belonging to William Ord Esq., surveyed by John Nevin in September 1854*', shows a level driven south towards this vein from the southern bank of the burn [NY7525 5863]. However, as substantial parts of the plan covering this part of the workings are missing, it is unclear how extensive these workings may have been at that time. A later plan entitled '*Church Burn Lead Mine. Whitfield, County of Northumberland*', attributed to the Church Burn Mining Co. Ltd. and dated July 1884, is complete and shows this level driven 267 m south to its intersection with the South Vein. Neither plan contains any indication of the throw of the vein or of its width, wall-rock or contents. However, a small rise of unknown height at 60 m from the portal, depicted on the 1884 plan, may indicate some exploration of the vein above the level at this point. A small area of stoping of unrecorded, but almost certainly very small, extent is also recorded between 84 and 108 m inbye from the portal. The plan also notes a small roughly E-W orientated 'string', though without further description, at 144 m inbye.

Dumps from the level lie on both sides of the burn and are likely to include material derived from both the West and South veins (Figure 3). They are composed mainly of grey fissile siltstone and sandstone accompanied by fragments of coarse-grained crystalline galena up to several centimetres across associated with some of which are rare anhedral grains of chalcopyrite up to a few millimetres across. One block of the distinctive 'steel ore' variety of galena, indicative of post-mineralisation shearing, was found.

Supergene minerals are present in small amounts. Most abundant of these is cerussite ($PbCO_3$), which typically occurs as greyish white compact crystalline or earthy crusts on galena fragments and may, at least in part, be of post-mining origin (Figure 4). A few specimens of such deeply altered galena, in which tiny chalcopyrite grains are also present, exhibit thin crusts of microcrystalline vivid deep blue linarite ($PbCu^{2+}(SO_4)(OH)_2$) and bright green malachite ($Cu_2^{2+}(CO_3)(OH)_2$) up to a few millimetres across (Figures 5a and 5b).

Yellowish buff earthy coatings, up to several centimetres across, on galena from this dump were identified by X-ray diffraction as the rare lead-iron sulphate hydroxide mineral plumbojarosite ($PbFe^{3+}_6(SO_4)_4(OH)_{12}$) (D.I. Green, personal communication) (Figure 6). The sole previous record of this mineral from a Pennine location is that from Grassington Moor, Yorkshire (Kingsbury, 1965; Dunham and Wilson, 1985). However, in view of serious doubts over the true provenance of many of Kingsbury's records, including those at Grassington, (Ryback et al., 1998, 2001; Green and Briscoe, 2002) the presence of this mineral at Grassington cannot be reliably confirmed. The identification of plumbojarosite at Church Burn Mine may therefore be regarded as the first reliable record of this mineral from a Pennine location.

Apart from a few coatings of compact crystalline baryte up to about 3 mm thick on sandstone, and rarely some similarly thin coatings of quartz, no gangue minerals were noted in this spoil. None of the baryte or quartz was found in association with sulphides. Gangue minerals thus appear to be extremely rare in these veins.

Whereas recent mapping identified the presence of several old shafts along the length of this vein (Figure 2), their associated small dumps are overgrown and most reveal no evidence of any of the rocks or minerals penetrated. A single shaft near the access track north of the burn [NY7523 5873] almost certainly marks an unsuccessful trial of this vein.

Church Burn East Vein

The 1854 plan depicts a level [NY7552 5869] driven south on this vein from the southern bank of the burn for 362 m to its intersection with the South Vein. Apart from a single note stating that the level is driven beneath the High Slate Sill, the plan provides no information on the nature of the vein or its wall-rocks. From its intersection with the South Vein the level turns to follow that vein for around 20 m, whence it returns to its roughly NNE-SSW bearing, presumably following the continuation of the East Vein, suggesting that this vein may be displaced westwards by around 20 m by the South Vein. The drive appears to terminate after a further 100 m after passing through a cross vein of unrecorded throw and two closely-spaced veins recorded as the Sun No. 1 and 2 veins, though the plan records no other information on these. No stopes are shown on any of these drives.

The small and much overgrown dump on the southern side of the burn, derived from the level, contains much sandstone and fissile siltstone together with small fragments of compact crystalline pale grey cerussite, some of which have residual cores of unaltered galena. A few fragments of brecciated sandstone on this heap contain coatings of scaly white kaolinite though, as none of this is associated with ore or other gangue minerals, it is not clear whether this is a minor gangue or an authigenic mineral within the sandstone and thus unrelated to the metalliferous mineralisation. No other gangue minerals have been seen here.

There is no evidence of any trials on this vein north of the burn.

The small dumps from several shafts along this vein, south from the level dump are completely overgrown (Figure 7) and, except for the dump at NY7547 5843 where fragments of galena much altered to cerussite are common together with traces of malachite and linarite: no wall-rock or vein minerals can be seen.

A small cluster of old shafts centred on NY7542 5832 appears to coincide with the intersection of the East and South veins and may indicate that some ore was obtained hereabouts from unrecorded workings above the level. Spoil on what appears to be an old sorting area here contains abundant small fragments of galena, much of it considerably altered to cerussite. A few fragments of brecciated sandstone exhibit small patches of scaly white kaolinite but, as in the previously mentioned level dump, it is unclear whether this was part of a meagre gangue assemblage or an authigenic mineral. A few blocks of sandstone breccia cemented by brown-weathering calcite here contain rare scattered anhedral grains of chalcopyrite up to around 2mm across (Figure 8). Apart from this, no other gangue minerals have been observed here suggesting that, as with the West Vein, gangue minerals are extremely rare. A few blocks of pale buff, dark brown-weathering limestone in which crinoid and shell fragments are conspicuous, incorporated into a wall surrounding the shaft, may indicate that the shaft reached or penetrated the Lower Fell Top Limestone. These blocks offer the only convincing evidence that this limestone was reached in any part of the Church Burn workings.

Church Burn South Vein

This vein is known only from the mine plans and has no obvious surface expression. Its position and extent on the geological maps (Figures 1 and 2) are based on subsurface data and must be considered in this light.

Whereas the vein was encountered in the level driven on the East Vein, as noted above, there is no evidence of any development or significant exploration of it from that point.

The 1884 plan shows drivages of up to 168 m northwest and 108 m southeast along the vein from the head of the level on the West Vein, though no indication of its throw, width, wall-rock or mineral content are recorded. The westerly bend in the level that follows the East Vein, and the displacement of the East Vein that this implies, suggests a southerly throw for the South Vein, though in the absence of conclusive evidence in this regard, no direction of movement for the south Vein is indicated on the geological maps (Figures 1 and 2). The plan also depicts the positions of internal shafts and sumps and shows a sub-level approximately 4 m below the main level, reached by a 6 m deep sump sunk in the South Vein. A section on this plan shows small stopes up to 111 m long and up to 3 m high in this vein northwest of its intersection with the West Vein above both the main level and sub-level (Figure 9). Although the section includes no guide to the notation used, the blue colouring used for the lowest levels may follow the convention of some northern Pennine plans and indicate that it was driven in limestone, which in this instance would be the Lower Felltop Limestone, though insufficient information is contained in the plans to be confident of this. It is likely that most of the mine's modest recorded output of lead ore was obtained from these stopes. A small area of surface subsidence above these stopes, indicated on the plan, is not obvious at the surface today.

Mining history and output

Apart from the mine plans discussed above and a single record of output for the years 1854 and 1884, we have been unable to trace any other references to working at Church Burn.

The 1854 plan shows a 'shop' adjacent to the level entrances on both the East and West veins though without any indication of sorting or dressing facilities. The 1884 plan depicts only the first 140 m of the East Vein level, suggesting that by then it was impassable beyond that point and was not considered worthy of reopening or of further exploration. It seems probable that the mine lay unworked between 1854 and 1884, though the extent or date of any exploration between those years is unknown. However, the surface arrangements for ore dressing depicted on the 1884 plan, including a 12 bay set of bouse teams, adjoining sorting area with knock stone, bingstead, dressing house with waterwheel and settling pits and buddles, appear to indicate an optimistic view of the enterprise that was plainly not realised.

Whereas the plans record horizontal drivages on all three veins the few modest attempts to explore the veins in beds both above and below the levels suggest that they offered little incentive for further exploration at other horizons.

The only records of production from Church Burn Mine in the documents seen are a return of 16.25 tonnes of lead ore for 1854 and one of 35.56 tonnes for 1884. With such a meagre output the mine must be seen as a short-lived and unsuccessful venture.

WOLF HILLS WORKINGS

Whereas the occurrence of lead mineralisation in a single vein at Church Burn was recorded by the Geological Survey on 1:50 00 scale geological sheet 19 (Hexham), albeit without further description, no indication of any mineralisation is recorded on that map at Wolf Hills [NY7286 5876] which lies approximately 2.5 kms west of Church Burn Mine (Figure 1). Whereas in common with Church Burn, neither Smith (1923) nor Dunham (1990) make any reference to mineralisation at Wolf Wills, documents held by the Northumberland Archive (NRO) refer to exploration for, and perhaps some small scale working of, lead ores at Wolf Hills during the 18th century.

These records indicate that lead minerals were known here from at least the early 18th century for, in 1733, a tacknote was granted for lead mines at Wolf Hills for one seventh duty (NRO 324/W.2/4). Twenty years later, in 1753, the London Lead Company, one of the major mining enterprises responsible for developing the Northern Pennines as a major lead producer, was granted a 31 year lease for lead and copper ores, but not coal, for the whole manor of Coanwood, in which Wolf Hills lies (NRO324/W.2/8). The reference here to copper is interesting as it was not standard practice in the Northern Pennine leases to mention copper in such agreements, perhaps indicating some hope or expectation of copper ores at this location, though the grounds for this are not known. The traces of chalcopyrite and copper supergene minerals at Church Burn are much too small to have given grounds for suspecting the presence of workable copper ores in this area.

It is clear from these documents that the London Lead Company's main focus of interest was Wolf Hills where reference is made to up to four named veins, though the only known document illustrating the position of these is an extremely crude sketch plan (NRO324/W.2/6) dated 1754 which related to a contemporary dispute over the ownership of mineral rights. The plan lacks any indication of scale and orientation and, apart from the approximate position of 'Wolf Hills House', contains no topographical reference points identifiable on the ground today. Moreover, very considerable caution must be applied to its reliability as it is reported to have been drafted by agents of the aggrieved party who had no access to the London Lead Company's records or workings and who relied heavily upon anecdotal information from miners employed by the company, combined with some meagre surface observations. Nevertheless, the plan depicts two roughly parallel W-E or NW-SE trending veins a short distance north of Wolf Hills Farm named as the North and Level veins which appear to be crossed by N-S to NNW-SSE trending veins identified as the Son (presumably Sun or South) and Snab veins.

It is impossible to reconcile with any confidence the position of any of these veins with Geological Survey mapping, the most recent versions of which are incorporated into Figure 10. Like Church Burn, Wolf Hills lies on the outcrop of Stainmore Formation rocks but is separated from the former by a series of NE-SW trending sub-parallel faults that throw down towards the northwest. Stream sections around Wolf Hills expose the Lower and Upper Felltop limestones, along with an intervening thin coal, and over and underlying sandstones. In this area, the Upper Felltop Limestone is sufficiently well-developed to form conspicuous landscape features, and is mapped as a separate unit. A prominent W-E to SSW-ENE trending fault, which comprises part of the Stublick Fault System crops out roughly 150 m north of Wolf Hills Farm and displaces the strata to the north. Two closely spaced shafts [NY7278 5893] on the west side of Wolf Hills Burn, roughly 150 m north of Wolf Hills Farm, lie on the outcrop of this fault close to the outcrop of the Lower Felltop Limestone. This fault may coincide with the North Vein depicted on the sketch plan and referred to in the London Lead Company documents (NRO324/W.2/6) as being worked on the west side of the burn. These documents also report that pieces of galena could be found in the burn at the point where it crosses the vein outcrop and add that the vein continued east of the burn where it was described as "…*very promising*...". An overgrown spoil heap from a shaft immediately east of the burn, and also on the outcrop of this fault, [NY7284 5893] may relate to these workings (Figure 11). During the present investigation no exposure of a fault or vein was seen in the burn and no traces of galena or of any other mineralised material was found either here or in the modest and almost wholly overgrown spoil heaps adjacent to these shafts: only a few fragments of grey fissile siltstone and sandstone were seen.

A line of three closely-spaced shafts with adjacent spoil heaps [NY7286 5877] lies on the east side of the burn immediately south of the road at Wolf Hills Farm (Figures 10 and 12). Although a coal seam is mapped hereabouts beneath the Upper Felltop Limestone, the shafts lie north of its outcrop and in an obvious NNW-SSE linear alignment, and are thus extremely unlikely to relate to workings in that seam. However, their alignment, together with evidence of surface features consistent with the presence of a minor roughly N-S trending fault in nearby sandstone outcrops on the east side of the burn approximately 450 m south of Wolf Hills (C.Vye-Brown, personal communication), may mark the position of the vein identified on the sketch plan as the Son (or, more likely, Sun) Vein. For the purposes of this description, the position of this vein has been tentatively included on Figure 10, though in the absence of adequate information no attempt has been made to suggest the direction or amount of throw on this. Like the previously mentioned shafts, the accompanying spoil heaps here are small and overgrown and reveal only fragments of fissile siltstone and sandstone without any trace of mineralisation.

The Northumberland Archive documents refer to a shaft lying in the enclosed ground at East Wolf Hills, which was being sunk in '*hard sill*' (sandstone) between depths of 11.9 m and 17.7 m with a comment that the miners were expecting to "…*be through it and into plate* (fissile siltstone) *within two or three days…*". Insufficient information is contained in these records either to identify the position of this shaft or the stratigraphical horizons of the beds penetrated by it. None of these records for Wolf Hills includes any descriptions of the veins or their contents and it is uncertain in which vein or veins any workable ore may have been encountered.

No evidence has been found on the ground to give any clue to the presence or position of the other veins depicted on this plan.

The only record of any commercial output of ore from Wolf hills is contained in a letter dated December 1757 (NRO324/W.2.6) which states that "… *the men have got 15 bings* (6 tonnes) *of ore out of that vein and expected to have 20 by Christmas*...". From these records it is likely that the Sun Vein was the source of this ore. No further reports of any production are known from here and it must be concluded that the workings amounted to little more than unsuccessful trials.

DISCUSSION

In addition to the veins at Church Burn and Wolf Hills, similar mineralisation was encountered in the nearby Plenmeller Opencast Coal Site [NY735 605]. Here, a small pocket of barium mineralisation was encountered as lenses of massive baryte up to 0.3 m wide in the fissile siltstone gouge of splinter faults off the main Stublick Fault exposed, in 1997, in the 'Area A East' workings, approximately 2 km north of Church Burn. Turner (1997) also noted the occurrence here of unspecified sulphides coating fault planes and minor fractures and in 1996 one of the present authors (B.Y.) found well-crystallised pyrite, locally accompanied by white kaolinite, coating joint surfaces in sandstone here. As the veins at Church Burn, Wolf Hills and Plenmeller share close structural and mineralogical similarities with those of the main Northern Pennine Orefield they may reasonably be seen as being additional members of the Haydon Bridge group of deposits regarded by Dunham (1990) as part of that field.

However, although substantial parts of the area south of the Tyne Valley are mantled by superficial deposits, mainly of Quaternary origin, exposure of bedrock geology is sufficient to conclude that this group of deposits is separated by around 15 km of un-mineralised ground from the main body of the orefield. It is also important to note that they lie within an E-W elongated belt close to and parallel with the Stublick Fault, adjacent to which similar mineralisation is common along most of its length throughout Northumberland and Cumbria. It is therefore appropriate to consider the possible relationships of these deposits to that structure.

East of Haydon Bridge, Smith (1923) referred to a trial working for lead in a vein in the Thornbrough Limestone and adjacent beds at Thornbrough, near Corbridge [NZ0094 6490] as well as to an 18th century report of an attempt to work a lead vein at Dilston Park, also near Corbridge, though he offered no descriptions of the mineralisation at either location. No remnants of mineralisation are visible at Thornbrough today and the exact location of the Dilston trial is not known. Land (1974) described lead-zinc-barium mineralisation within the Ninety Fathom Fault System in both Coal Measures and Permian rocks on the North Sea coast at Cullercoats [NZ3668 7107].

Approximately 18 km west of Church Burn and Wolf Hills, Young et al. (1989) reported lead-zinc-copper-barium-mercury mineralisation in the Four Fathom Limestone within the Stublick Fault Zone at Silvertop Quarry, near Brampton [NY586 606].

The fault zone is concealed for approximately 15 km west of Brampton beneath an almost complete mantle of thick superficial deposits overlying Permo-Triassic rocks. Where it re-emerges as the Maryport-Gilcrux Fault System in Carboniferous rocks in the country between Caldbeck and Cockermouth, it is closely associated with numerous local concentrations of mineralisation, dominated by barium accompanied by some copper and lead, within a belt up to 5 km wide (Cooper et al., 1991; 1992). At least two small workings for baryte are known from such concentrations at Gilcrux, near Maryport [NY090 374] (Eastwood, 1930) and at Ruthwaite, near Ireby [NY090 374] (Eastwood, 1959) together with a trial working in chalcopyrite-galena-baryte mineralisation within the Gilcrux Fault at Threapland, near Plumbland [NY1619 3942] (Eastwood et al., 1968).

Crowley et al. (1997) identified close similarities between sulphur isotope ratios obtained from baryte samples collected from locations along the Maryport-Gilcrux-Stublick-Ninety Fathom Fault Zone in Cumbria and Northumberland and Lower Carboniferous anhydrites penetrated in deep boreholes within the Northumberland-Solway Basin to the north. From this they concluded that these were the likely source of sulphur in the baryte deposits of both the Northern Pennines and northern Lake District which have since been considered as possible expressions of the same mineralising episode (Stone et al., 2010).

A study by Young et al. (1992) reviewed the nature, distribution and possible origins of mineralisation along the full length of the Maryport-Gilcux-Stublick-Ninety Fathom Fault System and highlighted structural similarities between the geological setting of these deposits and those of Ireland, such as Tynnagh.

Whilst not ruling out a genetic connection between the Haydon Bridge mineralisation and the main body of North Pennine mineralisation, Young et al. (1992) speculated on the possible role of the Stublick-Ninety Fathom Fault system in the emplacement of these deposits, including the possibility that the fault system may have acted as a major conduit for mineralising fluids that may have, at least in part, remobilised certain components from syngenetic mineralisation within the Carboniferous rocks at depth, a situation comparable with the southern Irish deposits.

Whereas there is insufficient evidence to propose a definitive model for the nature and origins of this mineralisation, we suggest that there are valid grounds for speculating both on the possible presence of syngenetic mineral deposits at depth as well as the role that this fault zone may have played in the emplacement of both those deposits so closely associated with it and perhaps those of the Northern Pennines and northern Lake District.

A similar situation may exist along the Lunedale-Butterknowle Fault System, the hinge fault that bounds the southern edge of the Alston Block. Here substantial baryte deposits are emplaced within the fault itself at Closehouse Mine in Lunedale [NY850 228] (Dunham, 1990). Further east extensive low-grade baryte-fluorite-galena and localised copper mineralisation in the Ferryhill area was interpreted by Hirst and Smith (1977) as evidence of the fault having acted as a conduit for upwelling mineralising brines. This is consistent with the conclusions of Bott et al. (1972) who interpreted the high heat flows reported from the Woodland Borehole [NZ0910 2770], drilled approximately 2 km north of the surface outcrop of the Lunedale-Butterknowle Fault, as due to the upward convection of geothermal brines in the fault system and its associated fracture zones.

ACKNOWLEDGEMENTS

Staff of Allendale estates are thanked for allowing access and providing information on this site. Peter Tandy, formerly of the Natural History Museum, London, and David Green, formerly of Manchester University, are thanked for undertaking X-ray identifications of minerals collected at Church Burn Mine. We are also grateful to the North of England Institute of Mining and Mechanical Engineers for access to plans of Church Burn Mine, The Northumberland Archives for documents relating to Wolf Hills and to Liz Sobell for alerting us to these. Charlotte Vye-Brown is also thanked for information on her geological mapping of the Wolf Hills area.

Figures 1, 2 and 10: Maps created using BGS▪SIGMA 2015 digital geological mapping software (https://www.bgs.ac.uk/research/sigma/home.html) with cultural data derived from OS Open Map – local [SHAPE geospatial data], Scale 1:10000, Tiles: NY, Updated: 11 October 2019, Ordnance Survey (GB), Using: EDINA Digimap Ordnance Survey Service, https://digimap.edina.ac.uk, Downloaded: 2020-04-10 12:12:42.774; and OS Terrain 5 [SHAPE geospatial data], Scale 1:10000, Tiles: NY75NE/NW, Updated: 3 December 2019, Ordnance Survey (GB), Using: EDINA Digimap Ordnance Survey Service, https://digimap.edina.ac.uk, Downloaded: 2020-04-10 10:40:10.904

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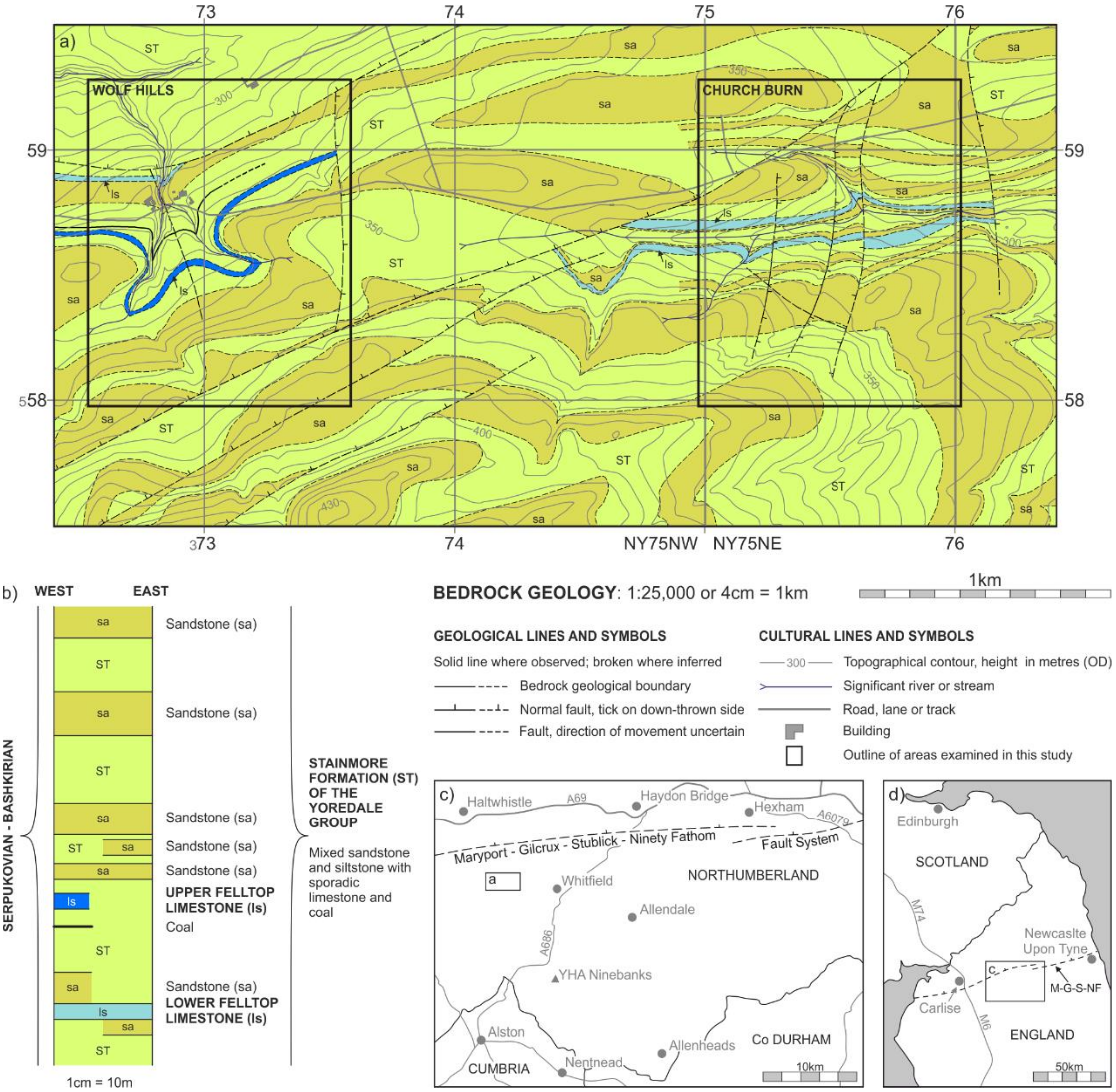

Figure 1.

a) Bedrock geological map showing key faults and veins. The locations of the two studied areas of Church Burn (Figure 2) and Wolf Hills (Figure 10) are indicated. b) Generalised vertical section for the map shown in (a). Note the relative positions of the Lower and Upper Felltop limestones. c) Index map showing key towns and position of the geological map shown (a) with respect to the Maryport-Gilcrux-Stublick-Ninety Fathom Fault System. d) The position of the index map shown in (c) with respect to the UK. M-G-S-NF = Maryport-Gilcrux-Stublick-Ninety Fathom Fault System.

Bedrock geology based on mapping by S.M.Clarke and C.Vye-Brown (2004) with modifications by the present authors. Some veins and workings derived from mine plans.

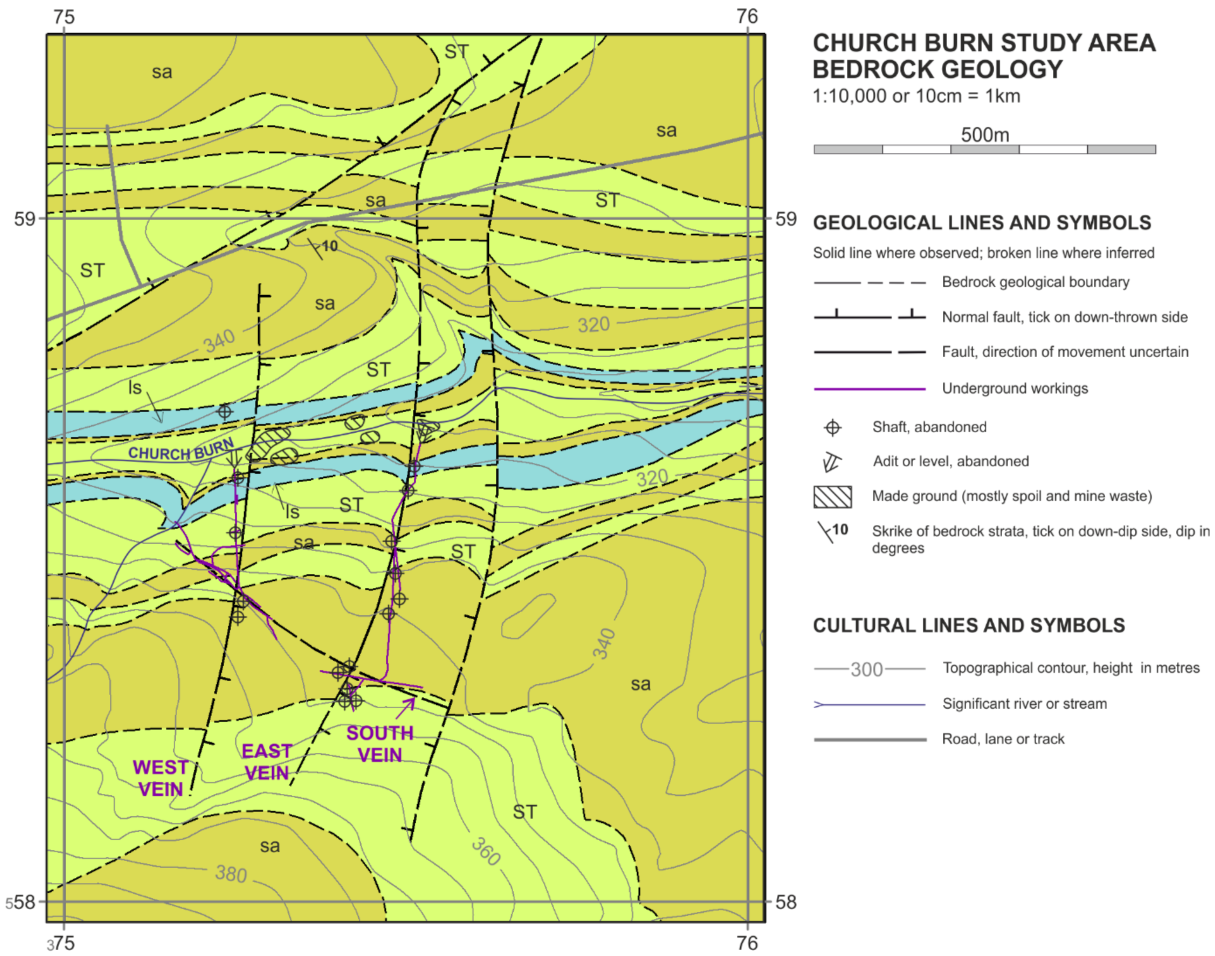

Figure 2.

Surface geology of Church Burn study area based on mapping by S.M.Clarke (2004) with underground workings derived from mine plans. For key to the bedrock geological colours see Figure 1.
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Figure 3.
The collapsed entrance to the level on the West Vein lies immediately to the right of the large boulder (centre left). Un-vegetated dumps from the level lie on both sides of the burn. The figure stands on the site of the dressing floors. *Photo. B. Young*

Figure 4.
Galena with superficial crusts of cerussite.
Specimen is 7 cm across. B. Young Specimen No. BY8055/A
Photo. Andy Hopkirk

Figure 5a.
Small crusts of microcrystalline blue linarite and green malachite on grey cerussite coating on galena.
Specimen is 7 cm across. B. Young Specimen No. BY8058/A. *Photo. Andy Hopkirk*

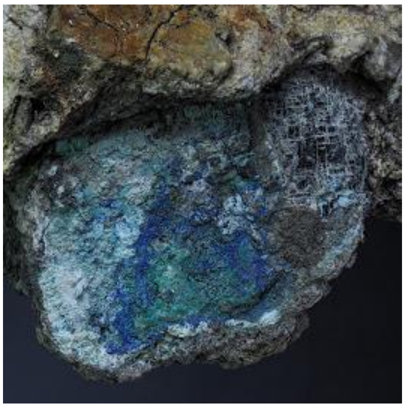

Figure 5b.
Detail of specimen shown in Figure 5a showing microcrystalline linarite with minor malachite coating cerussite on altered galena. A rectilinear network of pale grey cerussite, developed along cubic cleavage planes of galena, is conspicuous at the top right. Field of view 1 cm. B. Young Specimen No. BY8055/A. *Photo. Andy Hopkirk*

Figure 6.
Pale buff crusts of plumbojarosite on galena. Specimens are each 6 cm across.
B. Young Specimen No. BY8056/A & B.
Photo. Andy Hopkirk

Figure 7.
Looking north along the outcrop of the East Vein showing overgrown shaft dumps.
Photo. B. Young

Figure 8.
Calcite-cemented sandstone breccia. The cementing calcite contains a few tiny grains of chalcopyrite, though none is visible in this photograph. *Photo. B. Young*

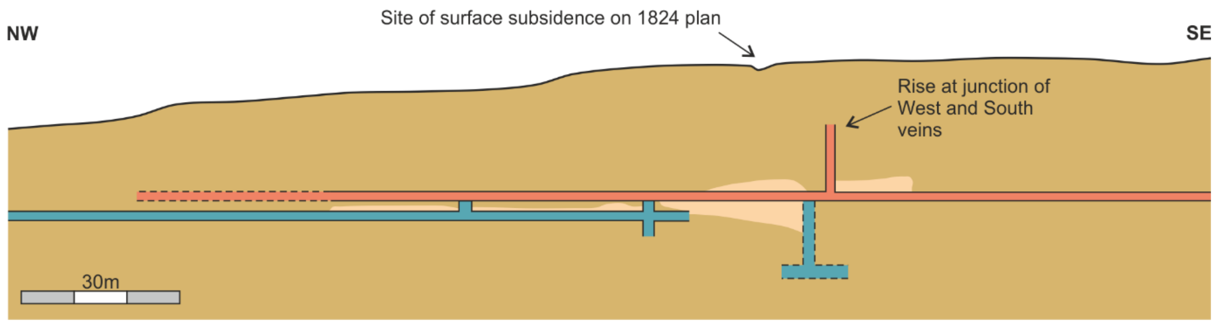

Figure 9.

Section of stopes on Church Burn South Vein.

The colours are those shown on the surviving plans: the West Vein Level is depicted in deep pink and the sub-level and sumps beneath it in blue.

Although the mine plan from which this figure is derived gives no position for the end points on the section, it gives an indication of the modest area of stoping (pale pink) on the South Vein in the vicinity of its junction with the West Vein.

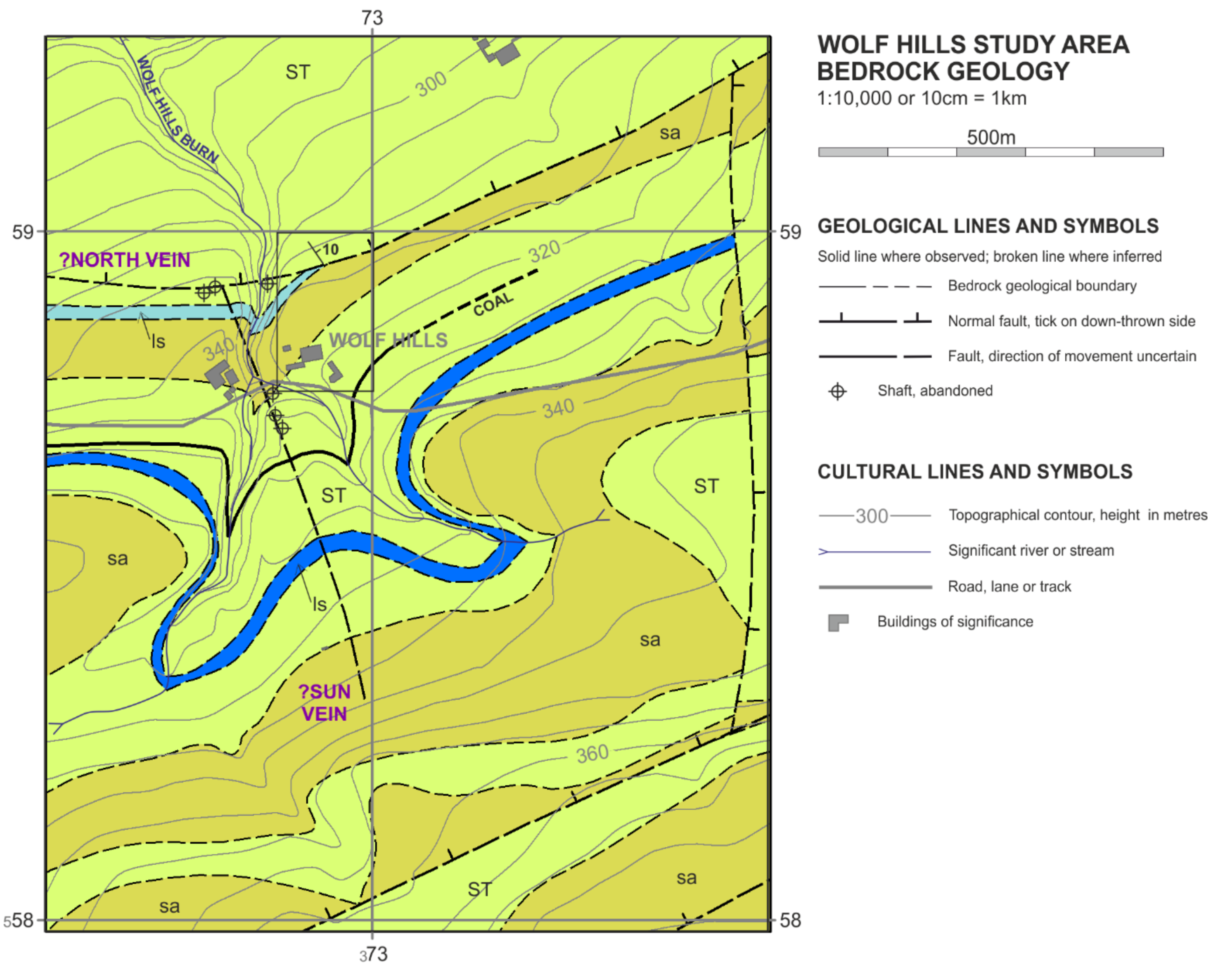

Figure 10.

Surface geology of Wolf Hills study area based on mapping by C.L.Vye-Brown (2004) with modifications by the present authors. Vein names and positions are derived, in part, from mine plans. For key to the bedrock geological colours see Figure 1.

Figure 11.
Overgrown spoil heap, probably on North Vein, on east side of Wolf Hills Burn.
Photo. B. Young

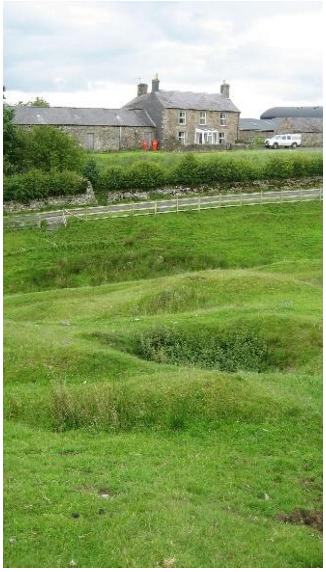

Figure 12.
Overgrown shaft dumps, probably on Sun Vein, south of Wolf Hills Farm.
Photo. B. Young