Smallcleugh Mine, Cumbria

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Introduction

The underground workings of Smallcleugh Mine provide some of the most extensive and clearest available exposures of lead- and zinc-rich metasomatic replacement flat deposits in limestone within the Northern Pennines. Outcrops of exactly similar deposits, in the banks of the River Nent about 100 m north-west of Smallcleugh Mine entrance, are the finest surface exposures of such deposits in the Northern Pennines.

Smallcleugh Mine is one of a large number of closely spaced and interconnected workings within the upper part of the Nent valley. Driving of Smallcleugh Horse Level, the principal access for the mine, seems to have begun in about 1770, although the main development of the mine seems to date from the London Lead Company's commencement of operations here in about 1787. The first of the flat deposits are understood to have been discovered in 1796 (Wallace, 1861), and it was these extensive and rich deposits which were to be the mainstay of the mine for many years. Production figures for Smallcleugh Mine during the London Lead Company's long tenure are incomplete. Dunham (1990) recorded a figure of 4999 tons of lead concentrates for the period 1848–1882, but commented that this figure probably represents only a fraction of the yield from these extensive deposits. During subsequent years the mine was worked by the Nenthead and Tynedale Zinc Company and their successors the Belgian Vieille Montagne Zinc Company, under whose tenure significant quantities of zinc, in addition to lead, concentrates were raised, although figures for Smallcleugh Mine alone are not available. Underground mining at Smallcleugh ended in the early years of the 20th century, although considerable amounts of zinc concentrates were recovered by reprocessing parts of the Smallcleugh and other dumps during World War II. Historical accounts of mining at Smallcleugh and nearby mines include those by Almond (1977), Critchley (1984, 1998), and Fairbairn (1993).

Smallcleugh Mine, like so many of the Nenthead mines, is connected at various levels with neighbouring mines, in the complex group of vein and related deposits for which this area was once extensively worked. The principal interest of this site lies in the extensive group of large replacement flat deposits, known as the 'Smallcleugh Flats' or 'Handsome Mea Flats', which are associated with a number of major veins and faults within the Great Limestone (Namurian) (Figure 3.3). Within the underground workings in the central and northernmost portions of the mine, the stratigraphical and structural relationships of the orebodies and their mineralogical composition and textures are clearly visible in extensive exposures of very fresh mineralized rock. In the southernmost parts of the mine, several orebodies were worked from a number of generally NE–SW-trending veins. Whereas some mineralization is still exposed here, these workings present few features of particular note, except locally where some rare supergene minerals have been reported. Post-mining alteration processes have led to the formation of a variety of supergene minerals throughout many parts of the Smallcleugh workings.

The structure and primary mineralization of the Smallcleugh Flats deposits have been described by Wallace (1861), and more recently by Dunham (1948, 1990). The supergene mineralization within the mine has been discussed by Dunham (1948, 1990), Bridges (1983, 1987), Livingstone (1991), and Bridges and Young (1998).

Description

In the upper part of the Nent valley, around Nenthead, the Carboniferous rocks are cut by a series of roughly parallel NNW–SSE-trending faults, known to the local lead miners as 'cross veins'. Whereas elsewhere in the orefield faults with this trend are characteristically barren or only poorly mineralized, within the Nenthead area they locally yielded payable quantities of lead and zinc ore. Their chief economic importance, however, lay in the extensive areas of metasomatic alteration of the limestone adjacent to many of them. These large flat deposits commonly carried an abundance of both galena and sphalerite, large quantities of which were mined from them. Perhaps the most celebrated of these flats, and the most extensive still accessible for study today, are those worked at Smallcleugh Mine and known as the 'Smallcleugh

Flats' or 'Handsome Mea Flats'.

The Smallcleugh Flats occur within the Great Limestone (Namurian) within a horst structure up to 213 m wide between the Smallcleugh and Handsome Mea cross veins (Figure 3.4). Dunham (1990) recorded that the flats extend over a total length of 1.1 km within this up-faulted area, and recalled that Wallace (1861) estimated that not less than 5 000 000 cubic feet (3.5 x 10^6 m^3) of limestone had undergone metasomatic alteration during their formation. Numerous small fractures, which cross the horst at right-angles to the bounding faults and which may be seen as small mineralized strings or leaders within the flats, appear to have, in part, controlled the form and extent of the deposits. The majority of the flats at Smallcleugh occur at the level within the Great Limestone known to the former lead miners as the 'Low Flat'.

Within the Smallcleugh Flats the Great Limestone has been extensively replaced mainly by ankerite, siderite and some fine-grained silica, giving an intensely hard, generally medium- to dark-grey crystalline rock, well seen in clear unweathered sections in the walls of the workings throughout the mine. Alteration is most intense in certain beds or posts. Shaly partings within the limestone locally separate beds which have suffered intense mineralization from beds in which alteration is much less conspicuous. In the most intensely mineralized beds, vugs or cavities, typically lined with curved rhombic crystals of cream-coloured ankerite, in places accompanied by quartz, calcite, and ore minerals are extremely common (Figure 3.4). Altlhough mainly less than 30 cm across, vugs over 1 m across have been encountered in many places. Galena and sphalerite occur as coarsely crystalline lenses and bands within the altered limestone and are common as well-crystallized masses within many vugs. Crystals of galena up to several centimetres across are common in many parts of the flats; sphalerite crystals are typically smaller (mainly < 1 cm). Other sulphides, present in very small amounts, include pyrite and in places chalcopyrite. Dunham (1990) noted a silver recovery from galena equivalent to 7 oz of silver per ton of lead, although commented that this may represent an average figure for the London Lead Company's Nenthead mines, as Cameron Swan (in discussion of Nall, 1904) reported that the galena from the Smallcleugh Flats was non-argentiferous.

Extraction of the Smallcleugh Flats has created an extensive series of wide open workings, the extent of which gives a clear indication of the limits of payable mineralization. Throughout large areas of the mine, flat mineralization remains exposed in the walls of the workings.

The true extent of the metasomatic alteration is thus greater, perhaps substantially greater, than revealed by the extent of the workings.

Surviving portions of the Handsome Mea and Smallcleugh cross veins mainly comprise brecciated wall-rock cemented by ankerite, galena and sphalerite. The numerous small stringers or leaders which cross the flats, at right-angles to their bounding faults, are typically filled with ankerite.

Part of a small flat deposit, also at the Low Flat horizon of the Great Limestone, is exposed at the surface on the east bank of the River Nent, below the waterfall, approximately 100 m northwest of the entrance to Smallcleugh Mine. Although this outcrop shows some discolouration due to slight surface oxidation of ankerite, most of the features described from the flats displayed underground in Smallcleugh Mine may be seen here in fresh condition. Lenses .of coarsely crystalline galena greater than 10 cm across are particularly conspicuous. The flat exposed here is not part of the Smallcleugh or Handsome Mea suite of flats. It occurs on the western side of the Carr's Cross Vein, which mapping and plans of adjoining workings show to lie a few metres east of the present outcrop. A few metres downstream from this exposure the lowest several metres of the Great Limestone are well exposed. The presence here of some ankerite replacement along joints and bedding planes is betrayed by pale-brown discolouration. The section is also notable for the spectacular development of the sponge and coral-rich bed known as the '*Chaetetes* Band' a few metres above the base of the limestone.

Post-mining supergene alteration of the Smallcleugh mineralization is conspicuous in many parts of the underground workings. In common with most of the zinc-rich deposits of the Northern Pennines, parts of the Smallcleugh workings carry abundant stalactitic and stalagmitic crusts of white hydrozincite, which is clearly being deposited today in many parts of the mine. Efflorescent crusts of colourless acicular gypsum crystals are common. These are easily confused with crusts of epsomite which in places coat large portions of the workings. Both of these minerals are also clearly forming today. The abundance of epsomite within parts of the mine appears to be controlled to a large extent by humidity levels within the mine atmosphere. Crystalline masses of melanterite are commonly associated with oxidizing pyrite in the flats cut by Hetherington's Crosscut and elsewhere in the mine (Dunham, 1990). Post-mining encrustations on the walls of old stopes in Middlecleugh Second Sun Vein have yielded specimens of serpierite (Bridges, 1987), namuwite and schulenbergite (Livingstone *et al.,* 1990), ktenasite (Rust, 1991), and brianyoungite (Livingstone and Champness, 1993). Other supergene minerals recorded from the mine include an as yet un-named zinc analogue of ktenasite (Livingstone, 1991), devilline (Bridges and Young, 1998), and beudantite and erythrite (Young *et al.,* 2005).

Interpretation

The exposures of mineralized ground in Smallcleugh Mine clearly demonstrate the structural and stratigraphical relationships of flat mineralization which occurs here mainly within the 'Low Flat Horizon' of the Great Limestone. The Smallcleugh (or Handsome Mea) Flats which represent the most extensive development of flat mineralization within the Nenthead area occur within the horst of Great Limestone which lies between the Smallcleugh and Handsome Mea cross veins. The smaller development of flat mineralization, exposed near the waterfall, is closely associated with the Carr's Cross Vein.

Throughout much of the Northern Pennine Orefield, NNW-trending faults or cross-veins carry little or no workable mineralization. In the Nenthead area these veins have proved to be workable locally, including within Smallcleugh Mine. However, these veins have been of prime importance as major channels, along which flowed the mineralizing fluids responsible for the widespread metasomatism within the Great Limestone. Within the Smallcleugh horst it seems very likely that numerous minor cross-fractures, or leaders, which cut the limestone at right-angles to the bounding faults, also acted as important mineralizing channels. Parts of the flats, as revealed by their worked-out extent on mine plans, clearly show an elongation along these leaders.

The Great Limestone has proved to be one of the most important host-rocks within the ore-field for mineralization. Not only have many of the field's veins been at their most productive in this wall-rock, but the limestone has been one of the principal beds in which metasomatic flats have been developed. It has long been appreciated by the local miners that three main levels within the limestone have been preferentially mineralized in this way. These were known locally as the 'High', 'Middle' and 'Lower' flat horizons (Dunham, 1948). The predominance of flat mineralization at any one of these levels varies from place to place across the field. At Smallcleugh, and the nearby Carr's Cross Vein, flat mineralization occurs mainly at the 'Low Flat' horizon.

The reasons for the preferential development of flat mineralization at one or more of these three distinct levels are not fully understood. It is, however, worth recalling that individual beds or 'posts' within the Great Limestone exhibit a remarkable persistence across much of the Alston Block (Fairbairn, 1978). Factors such as original composition or texture within certain limestone beds may have exercised a profound influence on their susceptibility to metasomatism. The role of interbedded shale partings within the Great Limestone in presenting barriers to the upward or downward passage of mineralizing fluids is clearly apparent in many sections exposed within the Smallcleugh workings (Figure 3.4). In these sections the intensity of metasomatism varies considerably between beds, even within the overall thickness of the flat deposit. It has also been observed that flat mineralization is only widely present within the Great Limestone where the limestone is overlain by shaly beds: where sandstones directly overlie the limestone, flats are normally absent (Dunham, 1990). Shales overlie the Great Limestone at Nenthead.

Exposures of the Smallcleugh deposits provide abundant evidence of the nature and origins of flat mineralization. Dunham (1990) has provided a detailed summary of the mineralogical processes involved in the development of flats within the orefield. The earliest event generally appears to have been the introduction, along mineralizing channels, of fluids which converted much of the limestone wall-rock into ankerite rock in which some siderite and silica is also common. More recently, Bouch *et al.* (2006) have highlighted the importance of increased porosity, resulting from dolomitization and ankeritization, in the development of these and similar flats throughout the orefield. It is likely that this alteration may have created an environment unfavourable to replacement by later fluids which carried lead and fluorine. In places, however, these later fluids were able to break through areas of earlier, ankerite-rich, alteration to affect replacement of limestone beyond with galena and fluorite. The sections remaining at Smallcleugh, and at the waterfall, clearly show that both galena and sphalerite generally postdate ankeritization and may also be the product of a later influx of lead- and zinc-rich mineralizing fluids, although without fluorite or barium minerals. The Smallcleugh deposits lie within an intermediate zone of Northern Pennine mineralization in which neither fluorite nor barium minerals occur within the gangue assemblage. Dunham (1990) also demonstrated that the replacement of limestone by the denser minerals of the metasomatic deposits should lead to a volume reduction within the affected rock mass. He suggested that within deposits of this sort the volume reduction may be accommodated either by the formation of cavities within the altered limestone or by the development of collapse breccias within the altered rock. At Smallcleugh replacement of the limestone has been complete, with bedding planes, joints and stylolites and even some fossils faithfully replaced, and the formation within the deposit of numerous cavities. Collapse breccias have not been observed within the Smallcleugh Flats.

The cavities within the Smallcleugh Flats have, like those of many other deposits within the orefield, yielded striking specimens of well-crystallized minerals, most notably galena, sphalerite and ankerite. Good examples of the latter mineral in many collections are incorrectly labelled as 'dolomite'. Dolomite appears to be absent or extremely rare within these deposits.

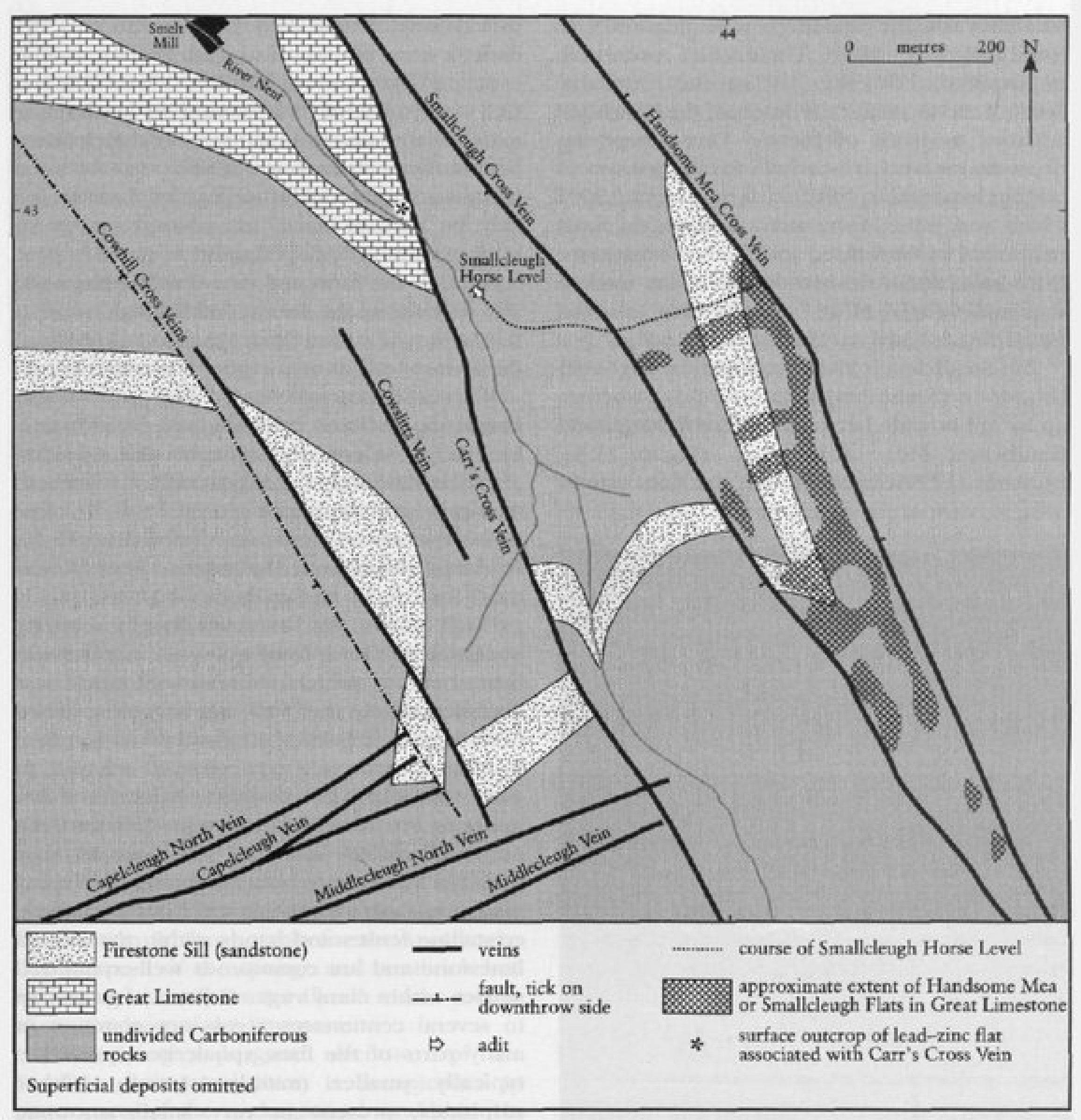
Although the flats exposed within Smallcleugh Mine mostly lie well below the present level of oxidation, and thus do not exhibit extensive natural supergene alteration, they locally exhibit assemblages of supergene minerals where oxygen-rich air has attacked the deposits since their opening by mining. Within the workings, oxidation of pyrite and other sulphides has provided sulphate-rich waters which, upon reaction with calcite and dolomite, have locally resulted in the formation of concentrations of gypsum and epsomite where air humidity and temperature have allowed them to crystallize. Efflorescent crusts of delicate, acicular epsomite crystals are common in several places, although the quantity present appears to fluctuate, apparently in response to variations in the temperature and humidity of the mine atmosphere. Reaction of sulphate-rich waters with further pyrite has produced local concentrations of melanterite. Precipitation of zinc from solution in mine waters has produced widespread stalactitic and stalagmitic coatings of hydrozincite widely throughout the mine. Soft, brown coatings of hydrated iron oxides are widespread. Supergene alteration of zinc, copper, and locally traces of nickel, within the flats, has given rise to local occurrences of the range of supergene minerals listed above.

The outcrop of the flat mineralization at the waterfall contains fresh galena and sphalerite and only very limited oxidization of the ankerite is apparent. This, like the outcrop of Old Moss Vein at the Killhope Head GCR site (see GCR site report, this chapter), is consistent with Dunham's (1990) observation that unoxidized primary minerals are found at outcrop in valley bottoms.

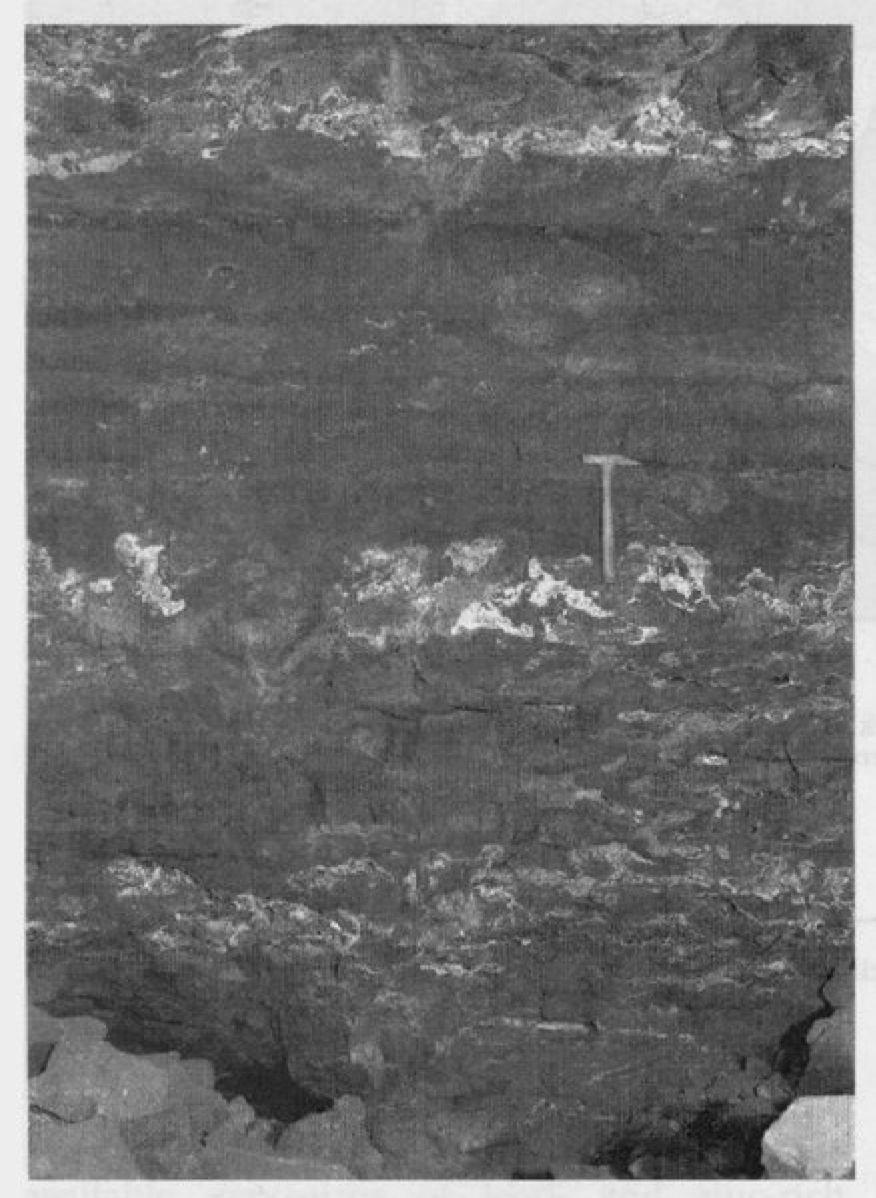
Conclusions

The underground workings of Smallcleugh Mine, together with the nearby exposures of similar mineralization at the waterfall in the River Nent, provide extremely important exposures of lead- and zinc-rich metasomatic replacement flat mineralization within the Great Limestone. These extensive sections demonstrate clearly the stratigraphical and structural relationships of the deposits. They also display the main constituent minerals and offer fine opportunities to study post-mine supergene alteration.

References



(Figure 3.3) Sketch map showing main veins and approximate extent of main flat deposits at Smallcleugh Mine.



(Figure 3.4) Metasomatized Great Limestone in the Smallcleugh (or Handsome Mea) Flats at Smallcleugh Mine. The limestone has been replaced mainly by ankerite and some silica. The most intensely altered limestone contains roughly horizontal bands of vugs lined with crystals of ankerite, galena and sphalerite. Above the hammer a limestone bed with numerous shaly partings has escaped intense alteration. (Photo: T.F. Bridges, BGS No. MNS 5565, reproduced by permission of the British Geological Survey, © NERC. All rights reserved. IPR/105–15CX.)