WHITESIKE & BENTYFIELD MINES: Geology and mineralogy

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INTRODUCTION

The Whitesike and Bentyfield Mines site lies astride the Garrigill Burn and includes the remnants of mine entrances, surface buildings and related structures, and spoil heaps of the former Whitesike and Bentyfield mines (Figure 1).

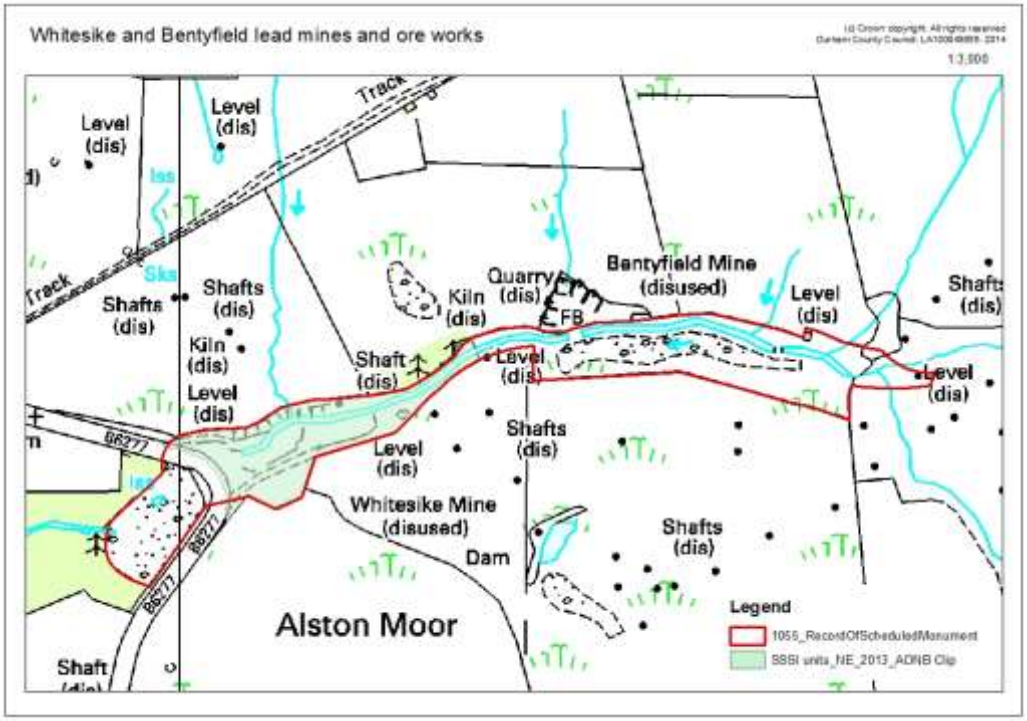


Figure 1.
WHITESIKE & BENTYFIELD MINES: boundary of SAM.

OREsome PROJECT: SURVEY HISTORY & PERSONNEL

Geological examinations of the site were undertaken by Brian Young and the following volunteers: Valdis Stals, Jane Norris.

PREVIOUS DESCRIPTIONS

The geology of this site and the area of veins worked was geologically mapped on the 1:10 560 scale between 1875 and 1877 and published on Geological Survey 1:10 560 scale County Sheets Cumberland 34SW, 34SE, 42NW, 42NE. An abridged version of this mapping was published on British Geological Survey 1:63 360 scale Sheet 25 (Alston) in 1883. Revisions to the geology, mainly resulting from mineral investigations undertaken during World War II led to a revised 1:63 360 sheet published in 1965. This mapping was re-issued at the 1:50 000 scale in 1973.

Unlike many areas of Great Britain, the Geological Survey mapping of the Alston area was not followed by the publication of an associated Sheet Memoir. However, outline descriptions of the geology of this part of Alston Moor were included in Geological Survey Memoir on the lead and zinc ores of Northumberland and Alston Moor (Smith, 1923), though no specific references were made in this text to either Whitesike or Bentyfield mines.

The most recent and comprehensive accounts of the geology, mineralisation and mining activity at Whitesike and Bentyfield is that by Dunham (1990). Whereas more recent descriptions of Northern Pennine geology and mineralisation (e.g. Symes and Young, 2008, Stone et al, 2010) give useful insights into more recent interpretations of the geology and mineralisation, they make no specific references to these mines.

GEOLOGY AND MINERALOGY

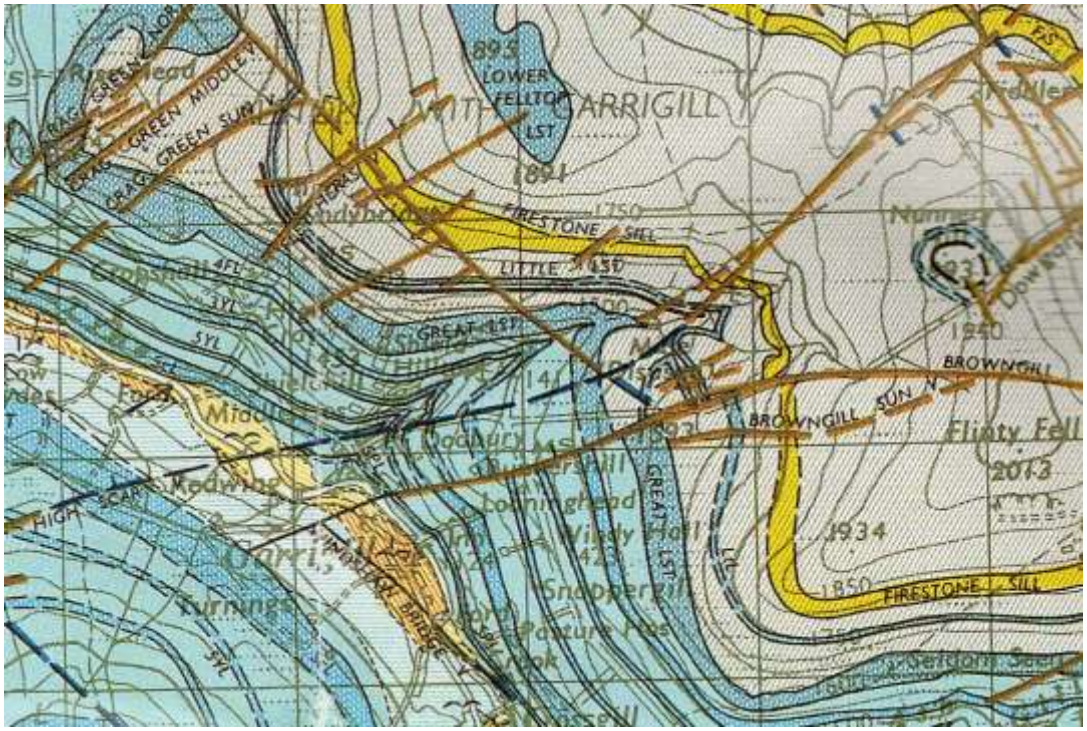


Figure 2.
WHITESIKE & BENTYFIELD MINES: Site geology

Figure 2 is an extract from the BGS 1:50 000 scale map, published in 1973. The colours and symbols employed on this map are shown on Figure XX of the General Introduction to this suite of reports.

From Figure 2 it can be seen that the surface geology of the site includes beds from the Four Fathom Limestone up to strata above the Little Limestone. General descriptions and observations on these strata, as they relate both to this site and to the wider area of the Northern Pennines studied within

this project, are given in Section ZZ of the General Introduction to this suite of reports. Details of key exposures of these beds on and in the vicinity of this site are given below.

Crucial to understanding metalliferous mining here is an appreciation of the mineral veins worked or explored from mine openings on the site. Although these are depicted on Figure 2, for greater clarity individual veins, without details of host rock geology, are depicted on Figure 3.

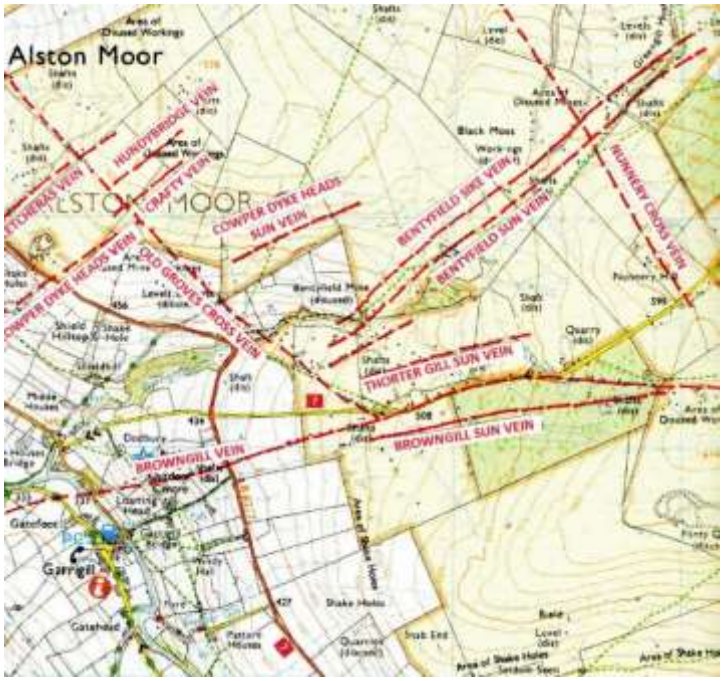


Figure 2.
WHITESIKE & BENTYFIELD MINES: Vein outcrops

The vein outcrops depicted on Figure 3 are derived from the original 1:10 560 scale geological field mapping together with information compiled by the late Sir Kingsley Dunham, mainly during his World War II investigations of the area. Faults depicted on the published geological mapping, but that are understood to be unmineralised within the area of this map are omitted.

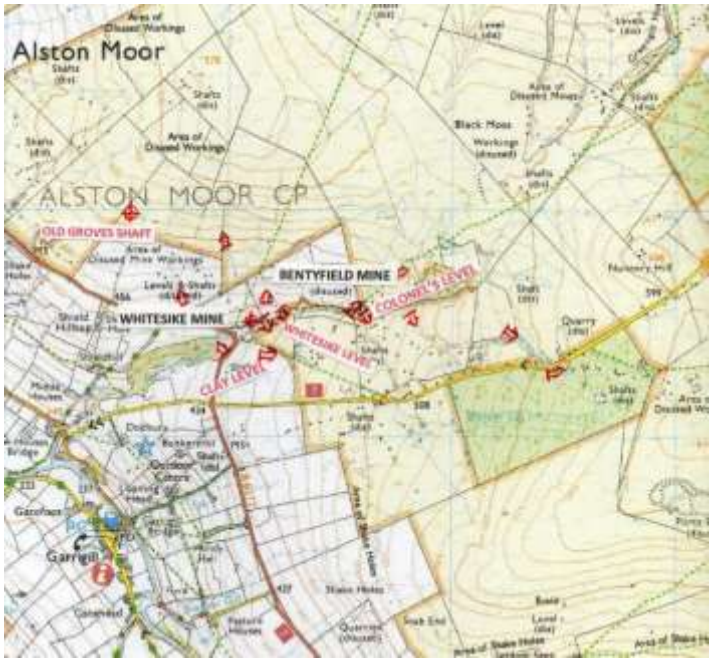


Figure 4.
WHITESIKE & BENTYFIELD MINES: Mine openings

In order to understand the working of the several veins worked, or explored, at this site, the position of key mine openings, with their names where known, are shown on Figure 4. These have been derived primarily from Dunham's manuscript maps and notes in which he summarised key features of significance to understanding these deposits from original mine plans and related archival documents.

MINING HISTORY AND OUTPUT

Whitesike Mine

In his detailed description of the Northern Pennine mines Dunham (1990, p 128) discusses the workings on Old Groves Vein and related veins (Figures 3 & 4) and, although he offers no dates for these workings, he refers to comments made on them by Wallace (1861).He further adds that "…*there is no reason to think that much lead ore was obtained from any of these workings*…".

The mine's main production appears to have been derived from workings in the Browngill Vein accessed mainly via the Whitesike Level (or Whitesike Low Level), the Clay Level and Colonel's Level (Figure 4). from which significant stoping is understood to have been undertaken in the Great Limestone and overlying beds (Dunham, 1990, p 144). Some ores is also believed to have been raised from the Thorter Gill Syke Vein and the Browngill Sun Vein within the Great Limestone. According to Dunham the main minerals present in these deposits were, in addition to galena, quartz, siderite, purple fluorite and a small amount of sphalerite.

Dunham (1990) records an output of 7322 tons of lead concentrates by the London Lead Company between 1848 and 1882. Silver recovery from the Browngill Vein ore between 1861 and 1870 amounted to around 7.0 ozs per ton of lead.

Bentyfield Mine

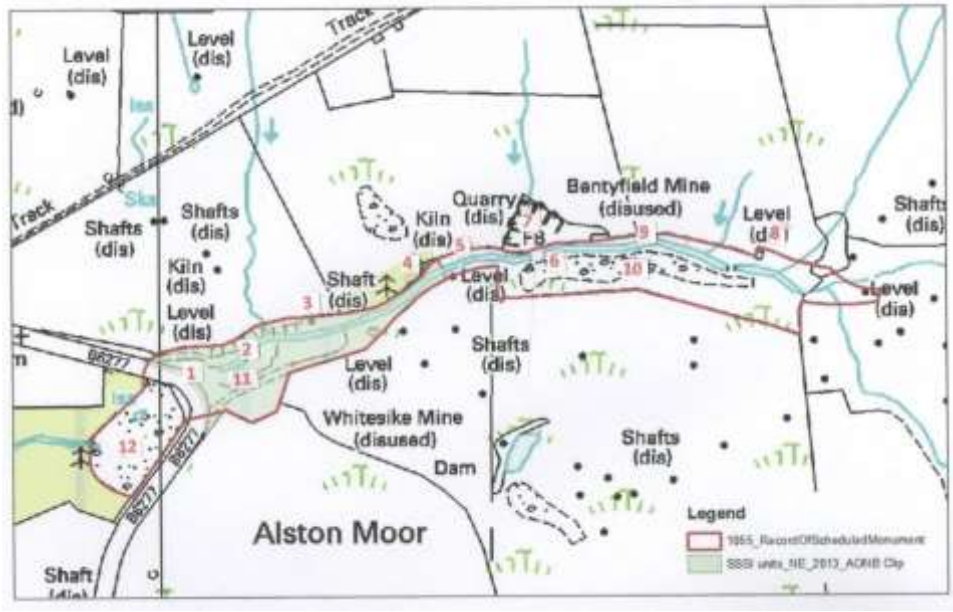
Dunham (1990, p 141) gives details of the workings of Bentyfield Mine in the Bentyfield veins. In this account he refers to the main Bentyfield level being driven on top of the Great Limestone for 282 m along a vein he names as Taylor's Sike Vein, before turning to join the main Bentyfield Vein (named Bentyfield Sike Vein on Duham's maps and on Figure 3). Taylor's Sike Vein is not shown, or named, on BGS Sheet 25 Alston and was not noted on Dunham's field maps from which Figure 3 has been complied: it is likely that it lies so close to the Bentyfield Vein as to be difficult to depict on maps of this scale. Dunham also notes that from this level oreshoots were worked in the Great Limestone, Coal Sills and Little Limestone with quartz, purple fluorite, galena and sphalerite as the veins' main constituents.

Dunham (1990, p141) notes that the mine was worked both by the London Lead Company and the Alston Moor Mining Company, the latter presumably after the former company surrendered its lease here. He records that, between 1848 and 1882 the mine returned an output of 4868 tons of lead concentrates with 40 tons of zinc concentrates in 1874. Silver production between 1854 and 1875 indicated a silver recovery of 7.6 ozs per ton of lead. Productyion figures for other years are not known.

The very substantial, and potentially unstable, tailings dump containing waste from the treatment of ore at both mines, which lies astride the Garrigill Burn west of the B6277 road was estimated by Dunham to contain not less than 60 000 tons of material containing 1.89% lead and 1.32% zinc.

DESCRIPTIONS OF INDIVIDUAL GEOLOGICAL FEATURES

The positions of features of geological and/or mineralogical interest are indicated by numbers on Figure 5. Individual descriptions of these features follow. Illustration (sketches & photos to be added as appropriate).



Location 1.
Bed and banks of Garrigill Burn immediately west and east of culvert carrying burn beneath B6277 road
Up to 3 m of Four Fathom Limestone exposed, comprising dark grey thickly bedded bioclastic limestone in beds, or posts, up to 1 m thick.

Location 2.
South bank of Garrigill Burn
Topmost beds of Four Fathom Limestone. Here comprises typical thickly bedded dark grey bioclastic limestone with very prominent rectilinear jointing with joints approximately 1 to 1.5 m appart giving striking blocky appearance, especially when viewed from top of the bank on the north side of the burn. The topmost few centimetres of the exposed limestone are here very clay-rich, giving a marked shale-like appearance. Shell fragments up to 3 cms across are locally common and conspicuous on bedding planes. These are mostly indeterminate but one specimen of *Productus* sp. has been noted.

Location 3.
Open shaft surrounded by low stone wall and steel framed capping.
This narrow (approximately 1.5 m diameter) vertical shaft exhibits a dry stone lining, apparently to its full depth. The shaft was plumbed to a depth of 40 m. The nature of the base is not known: it may be collapsed rumble, indicating that it was sunk to a greater depth, or the base seen may represent its full final excavated depth. At the time if its measurement (October 2017) it did not hold water.

The shaft is not mentioned by Dunham in his descriptions of either Whitesike or Bentyfield mines. From the available geological mapping the shaft has been shaft sunk on the outcrop of the Old Groves Cross Vein from a position a few metres above the Four Fathom Limestone. From its measured depth of 40 m the shaft may be assumed to have been sunk to the level of the Three Yard Limestone. Its purpose is not known, though it may indicate an attempt to explore the Old Groves Cross Vein at that horizon.

No records of workings of this, or any other vein, at this horizon are known here and it may therefore be assumed that any trial of the vein at this level proved unsuccessful or at least L

It is interesting to note that, despite its position so close to the Garrigill Burn, the shaft was free of water.

Location 4.
Old limekiln on north side of Garrigill Burn
The remains of this kiln indicate the burning of Great Limestone obtained from the quarry (Location 7) a few metres to the east. The former tramway linking the kiln with the quarry is today seemn as a grass-covered bench.

Location 5.
Rock exposures on the north side of the footpath on the north bank of Garrigill Burn

Intermittent exposures if thickly-bedded massive medium-grained pale fawn sandstone in bed up to 0.75 m thick.
Above the highest of these sandstone exposures is an unexposed interval of approximately 3 m, above which the lowest beds of the Great Limestone are clearly visible in the bank. This sandstone may therefore be confidently correlated with the Tuft Sandstone of the Alston formation sequence.

Location 6.
Upstream end of culvert on Garrigill Burn
The vertical sides of the burn on its north side expose up to 1.5 m of thickly bedded grey limestone. Approximately 0.5 m above water level at the time of this visit (October 2017) is a conspicuous bed, approximately 6 cm thick, composed of colonies of the colonial coral *Siphonodendron* sp. (? *S. junceum*. About 5 – 10 cm beneath this are roughly parallel undulating bands up to 3 cm thick composed of the sponge *Chaetetes* sp. Approximately 30 cm of *Chaetetes*-bearing limestone are exposed in the bank here.

This is a good section through the *Chaetetes* band, a widespread and important stratigraphical marker which typically lies around 1- 2 m above the base of the Great Limestone.

N.B. This exposure is commonly partly or wholly submerged beneath the Garrigill Burn. Although a fine section it is typically difficult to examine in detail.

Location 7.
Old limestone quarry
This large long-abandoned quarry is excavated entirely within the Great Limestone.
Grey massive bioclastic limestone forms a very prominent massive bed up to 2 m thick in the lowest faces of the quarry. This is overlain by similar grey limestone in beds, or posts, up to 0.75 m thick separated by generally poorly exposed mudstone partings typically up to around 2 cm thick. The wavy bedding that characterises the Great Limestone throughout the Northern Pennines is conspicuous.

Up to around 12 m of limestone are exposed in the quarry faces. As the Great Limestone is typically around 20 m thick in this part of Alston Moor, it is clear that the full thickness of this unit is not exposed here.

From examination of the surrounding ground it is clear that the base of this quarry coincides very closely with the base of the Great Limestone, though the underlying beds are nowhere exposed in the thickly grass-covered quarry floor.

Location 8.
Bentyfield Level
The drystone-arched portal of this level lies at the foot of a prominent linear topographic hollow which marks the outcrop position of the vein along which the level was driven. As noted above Dunham (1990) records that the first 282 m of this level was driven on the Taylor's Syke Vein, though also remarked above, this may lie very close to the parallel position of the Bentyfield or Bentyfield Sike Vein depicted on Figure 3.

Location 9.
Dumps from Bentyfield Level
The spoil heaps which lie between the footpath and Garrigill Burn contain material derived mainly from the Bentyfield Level (Location 8).

Much of the spoil comprises blocks of unmineralised limestone and sandstone, though blocks of partially sideritised limestone, brecciated sandstone and quartz-rich veinstone are also comparatively common. Within these occur small concentrations of galena and dark brown sphalerite. Conspicuous on these dumps are blocks of waste rock, mainly limestone, which exhibit superficial coatings < 1 mm thick of a white mineral. Preliminary examination of these, together with similar coatings on blocks of sphalerite-rich veinstone, suggest that these are crusts of hydrozincite. This mineral is common throughout the orefield both on spoil heaps and in underground workings where it has been deposited from zinc-rich groundwaters resulting from the ready oxidation and mobilisation of zinc from oxidising sphalerite. It seems likely that precipitation of this mineral from zinc-rich waters percolating through the spoil heaps is an ongoing process here.

Gravel-sized tailings comprise part of this heap, suggesting that some dressing or ores took place near the mine entrance.

It is noteworthy that, despite Dunham's report of fluorite as a constituent of the veins worked here, little if any trace of this mineral can be seen on this spoil heap.

Location 10.
Large spoil heap derived from either Whitesike Level or Colonel's Level
The large size of this spoil heap clearly indicates its derivation from extensive underground workings. Whereas much of the heap is thickly vegetated with grass, a few areas of bare spoil are accessible, particularly at its western extremity immediately above the exposure of the *Chaetetes* band at location 6.

Spoil examined at the latter location resembles that seen at location 9. Here again limestone and sandstone fragments appear to comprise the majority of the spoil together with white to colourless quartz, typically as small pyramidal crystals up to around 3 mm across, commonly cementing brecciated frasgments of sandstone. Sideritised limestone is also common and small concentrations of both galena and sphalerite are also present. A little white calcite as small white cleavable masses also occurs. As at location 9, little or no fluorite was observed.

Location 11.
The old dressing floors of Whitesike Mine
The old dressing floors are partially strewn with gravel-sized debris remaing from ore processing operations. The spoil shows a remarkably small diversity of mineral content: quartz is common, locally accompanied by traces of galena and a little dark brown sphalerite. More rarely, a few specks of chalcopyrite and pyrite can be seen in quartz-rich veinstone. A few mall specimens of malachite are known to have been collected here in the 1980s, though none was seen at either Whitesike or Bentyfield mines during the present investigation.

The local occurrence of copper mineralisation here is of interest as the spoil here supports an abundance of thrift (*Armeria maritima*), a metallophyte species known to be associated with copper-

rich mineralisation at a number of UK locations. This site is understood to be scheduled as an SSSI for its metallophyte plant communities.

Location 12.
Tailings dumps
West of the B6277 road, and lying astride the Garrigill Burn which is partially carried through a culvert beneath them, are the extensive tailings dumps derived from both the Whitesike and Bentyfield workings. As already noted these dumps have been estimated to contain at least 60 000 tons of tailings in which small but significant concentrations of both lead and zinc minerals remain. Substantial parts of these dumps are unstable and cannot be safely accessed. However, examination reveals that, as might be expected, they contain a mineral assemblage closely similar to that seen on the dumps at locations 9, 10, and 11, though with small amounts of pale purple fluorite.

NOTABLE GEOLOGICAL AND MINERALOGICAL FEATURES
Whereas most of the geological features noted above may be regarded as representative of many comparable sites across the orefield, one location deserves to be highlighted.

This is the exposure of the *Chaetetes* band at location 6. Although this bed is widely present across the Northern Pennines, good and accessible exposures are rather few. Even allowing for its rather awkward position in the stream here, in view of its location alongside a public footpath it is considered appropriate to ensure both its protection and its employment in any interpretation initiatives devised to include the mines at this site.

EXISTING CONSERVATION STATUS OF GEOLOGICAL FEATURES
No features of geological interest at or in the immediate vicinity of Whitesike and Bentyfield mines are covered by any form of statutory or non-statutory protection.

Whereas the present study has revealed no features that might realistically be deemed worthy of such notification, it should not be assumed that the site is devoid of interest or that geological features of interest might be ignored or overlooked in any future management or conservation strategies.

OPPORTUNITIES
The site offers significant potential for further research in at least two areas of interest.

1. Whereas supergene development of hydrozincite and other related species is common in sphalerite-rich mine spoil and vein exposures both at the surface and in abandoned underground mine workings, sites at which these processes appear to be directly associated with surface mine water discharges are less common. The spoil heaps of Bentyfield Level (Location 9, above) appear to be one such location. This site may therefore offer a valuable opportunity at which to investigate the chemistry of such current supergene processes.

In addition, as the relationship of zinc mobility and precipitation in surface waters to the ecology of bryophytes and higher plants is comparatively poorly understood, sites such as this may offer ideal locations for such studies.

2.
As noted above the old dressing floors at Whitesike Mine (Location 11) are notified as an SSSI for their rich calaminarian flora. A notable feature of this site is the abundance of thrift (Armeria maritma), a plant which has a rather restricted distribution within such communities in this orefield. In addition to the site's calaminarian importance, it offers significant potential for multidisciplinary studies into the distribution and relationship between individual calaminarian species such as thrift, and the content and concentration of specific metals within the mine spoil and soils derived from it. The possible relationship here between thrift and concentrations of copper mineralisation may be of partuclar interest.

THREATS
This site has already been subject to significant archaeological investigation and conservation and is likely to attract further work of this sort. Moreover, its accessible location and aesthetic appeal may invite its development as site for a way-marked trails and allied interpretation.

In view of its significant inter-related mineralogical, geological and ecological interest, it is essential to safeguard those features of importance should any further archaeological conservation or trail creation activities be planned.