Force Crag Mine, Cumbria

[NY 200 216]

Introduction

Force Crag Mine, at the head of Coledale, approximately 3 km WSW of the village of Braithwaite, Cumbria, formerly worked the roughly east-west Force Crag Vein. The mine was accessed from a number of adit-levels driven into the vein along a strike length of almost 1 km and over a vertical interval of at least 350 m. The vein appears to be a member of the widespread suite of Lake District lead-zinc veins for which a Carboniferous age of mineralization has been proposed (Stanley and Vaughan, 1982a). There are excellent exposures of mineralization in underground workings, and abundant surface spoil-heaps contain good representative examples of veinstone.

Although there is evidence that lead mineralization at the head of Coledale was known as early as 1578 (Adams, 1988), reliable documentary records of mining at Force Crag appear to date from as recently as 1848. Since that time, and under a variety of owners, lead, zinc and some manganese ores, together with substantial tonnages of barite, have been mined intermittently. The last attempts at mining at Force Crag ended in the early 1990s.

Descriptions of the mine's geology and mineralization have been given by Eastwood (1921, 1959), and by Young and Cooper (1988). Young (1987a) provided a comprehensive list of all minerals then recorded from the site. Details of the mine's history include those by Shaw (1970), Adams (1988), and Tyler (1990). The building that housed the main ore-treatment plant, together with some machinery, are today preserved as a heritage feature.

Description

The Force Crag Vein occupies a roughly E–W-trending fault that cuts cleaved mudstones, siltstones and greywacke sandstones of the Kirkstile Formation, part of the Skiddaw Group of Ordovician age, at the head of Coledale, approximately 3 km WSW of Braithwaite (Figure 2.24). The vein runs parallel to, and a short distance to the north of, the gradational northern boundary of the Crummock Water thermal aureole. This elongate metasomatic aureole within Skiddaw Group rocks corresponds with a Bouguer anomaly, interpreted as being due to an elongate granitic body emplaced along the northern margin of the Lake District Batholith. The metasomatism has been dated at 401 ± 3 Ma (Cooper, D.C. *et al.,* 1988).

The vein generally hades to the north at about 75°, but in places it is vertical. The amount of throw cannot be reliably established (Young and Cooper, 1988). Throughout the worked portions of the vein, between Force Crag and the floor of the Coledale Valley, the vein is said to have averaged 1.5 m in width, although widths of up to 6.1 m have been recorded locally. In the lower levels of the mine, the vein divided into two parallel fractures separated by up to 4.6 m of unmineralized ground. Several small strings diverge from the vein locally, but these were found to be mineralized only near their junction with the main vein. Young and Cooper (1988) suggested that the vein could be identified in Gasgale Gill [NY 1834 2146], approximately 3 km to the west, although subsequent mapping by the British Geological Survey has not confirmed this connection.

Force Crag Vein is rather unusual amongst Lake District veins in exhibiting a marked vertical variation, or zonation, of its constituent minerals.

At the western end of the workings, above the High Force Level, barite is the main vein-filling. This is typically coarsely crystalline with individual crystals commonly up to 15 cm across. Much of it is white, although locally pale-pink shades are present. Large tabular barite crystals have been found in vugs. Much of the mine's commercial output of barite was obtained from these upper workings. Although the underground workings at this level are no longer safely accessible, representative examples of veinstone, abundantly present on the dumps, reveal that barite is accompanied here by a little quartz and abundant manganese and iron oxides. Hard dark-grey manganese oxides, generally referred to as

'psilomelane', are common as massive, reniform or stalactitic masses. 'Psilomelane' also occurs here as reniform nodules within siltstone and mudstone wall-rocks. Softer, black manganese oxides, referred to as 'wad' in some accounts, are locally abundant. Young and Cooper (1988) report that at least some of this material has been identified as todorokite ($Mn^{+2}.Ca,Mg)Mn_3{}^{+4}O_7.H_2O$). Goethite ($\alpha$-$Fe^{+3}O(OH)$) is also abundant in dark-brown massive form and locally as reniform masses with an internal radiating fibrous crystalline structure. Galena and sphalerite are almost absent from this level of the vein.

Below the High Force Level, the vein becomes barren of almost all except massive white quartz which is exposed intermittently at the surface in the gully on the north side of Force Crag. Underground exploration failed to find economic mineralization of any sort at this level.

As the vein is traced down the hillside below Force Crag, economic mineralization re-appears at the Number 3 Level. Here, and in the lower levels, sphalerite and galena are the main economic minerals, with barite usually present in only subordinate amounts. Sphalerite appears to be the most abundant sulphide. It typically occurs as dark-brown to almost black coarsely crystalline bands, although numerous large vugs are lined with well-formed large lustrous black crystals up to 2 cm across. These are commonly partially encrusted with pale-brown curved rhombic crystals of siderite. Striking specimens of black sphalerite crystals accompanied by pale-brown siderite from Force Crag Mine are to be seen in many museum collections (Figure 2.25).

Galena, which is less abundant than sphalerite, occurs as coarsely crystalline masses; freely grown crystals are rare. Eastwood (1921) reported around 30 oz of silver per ton of lead in samples of Force Crag galena. Microscopic inclusions of bournonite ($CuPbSbS_3$) and native antimony (Sb) have been described from Force Crag galena by Stanley and Vaughan (1981). Chalcopyrite and pyrite are minor constituents of the vein at these lower levels.

Within the lowest levels of the mine, fluorite was found sparingly as pale-yellow cubes up to 5 mm across, coating siderite crystals within vugs in mudstone breccia cemented by siderite, or as bands a few millimetres thick on the margins of the vein adjacent to the wall-rock.

A number of supergene species have been reported from the Force Crag workings. Included with these are almost certainly the manganese oxides, abundantly present in the upper levels of the mine. Greg and Lettsom (1858) reported the first British occurrence of stolzite ($PbWO_4$) from Force Crag, a record that has been repeated by several subsequent authors cited by Young (1987a). However, in view of the mineralogy and chemistry 9f the Force Crag deposit, the occurrence of this species here seems improbable. Young (1987a), and Young and Cooper (1988) provided persuasive arguments for regarding this record as erroneous. More recently, Green and Briscoe (2002) have commented briefly on the presence of well-formed crystals of pyromorphite and small amounts of native silver at Force Crag.

The features described above are best examined *in situ* in the underground workings. For some time after the last workings were abandoned in the 1990s fine sections of vein and adjacent wall-rock could be examined in levels and stopes accessed from the lowest, Number 0 and Number 1, levels (Figure 2.26). Although safe access to these underground workings is not possible at the time of writing (March 2008), it is hoped that access for *bona fide* researchers may be possible in the future. In the meantime, substantial quantities of veinstone remain available for examination on the substantial spoil-heaps.

Interpretation

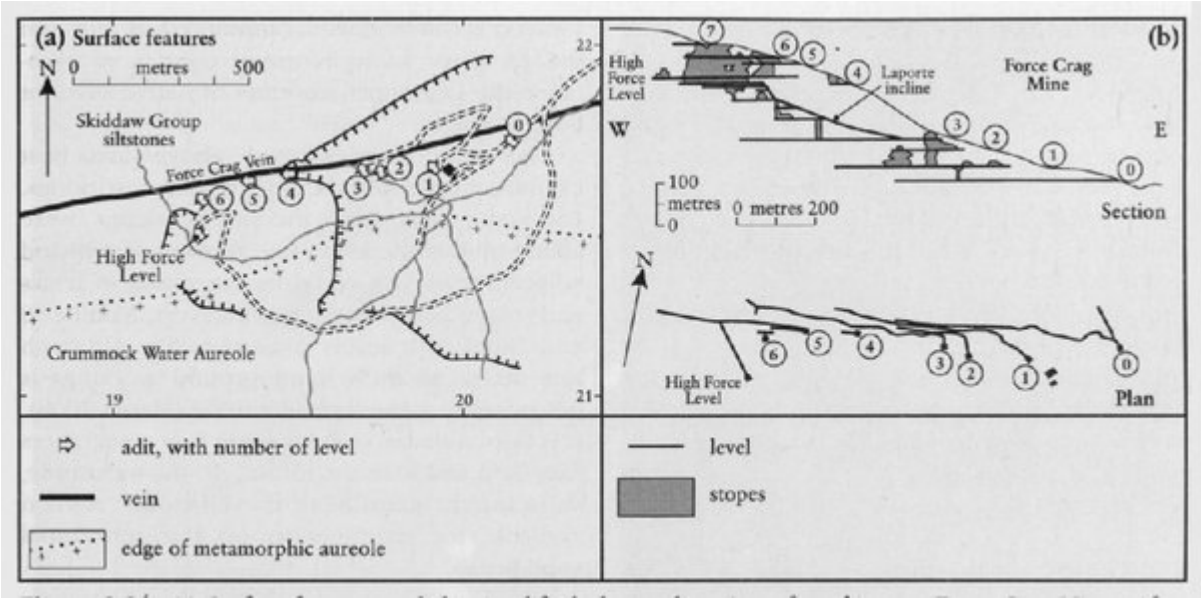
Force Crag Vein is one of a number of Lake District veins characterized by the abundance of lead and zinc mineralization within a gangue of barite, quartz and, at this location, siderite and minor fluorite. In their genetic classification of Lake District mineralization, Stanley and Vaughan (1982a) assigned an early Carboniferous age to these deposits, though the admittedly rather tenuous grounds for this age invite revision. Certainly these lead-zinc-barite veins do appear to comprise a recognizable suite of deposits that clearly post-date the early copper-rich mineralization that is so widespread in the Lake District and for which Millward *et al.* (1999) have demonstrated a pre-Acadian date of emplacement. However, these Lake District lead-zinc veins bear a number of similarities to the lead-zinc-barite-fluorite mineralization of the Northern Pennines, a similarity that is arguably re-inforced by the local presence within them of small quantities of

fluorite. It may be significant that the Force Crag Vein exhibits a downward passage from barite-dominated mineralization to a lower zone characterized by the abundance of sulphides and the incoming of fluorite, albeit in comparatively modest amount. A similar zonal transition from barite to fluorite mineralization is characteristic of the veins of the Northern Pennines (see Chapter 3). Further support for this comparison might be adduced from the suggestion of Crowley *et al.* (1997) that $\delta^{34}S$ in barite from both the northern Lake District and northern margins of the Northern Pennine Orefield appears to have been derived from Lower Carboniferous evaporites from the Solway Basin. If, as seems reasonable, a case may be advanced for regarding these Lake District veins as sharing a similar age and origin to those of the Northern Pennines, a late Carboniferous or early Permian age would be implied.

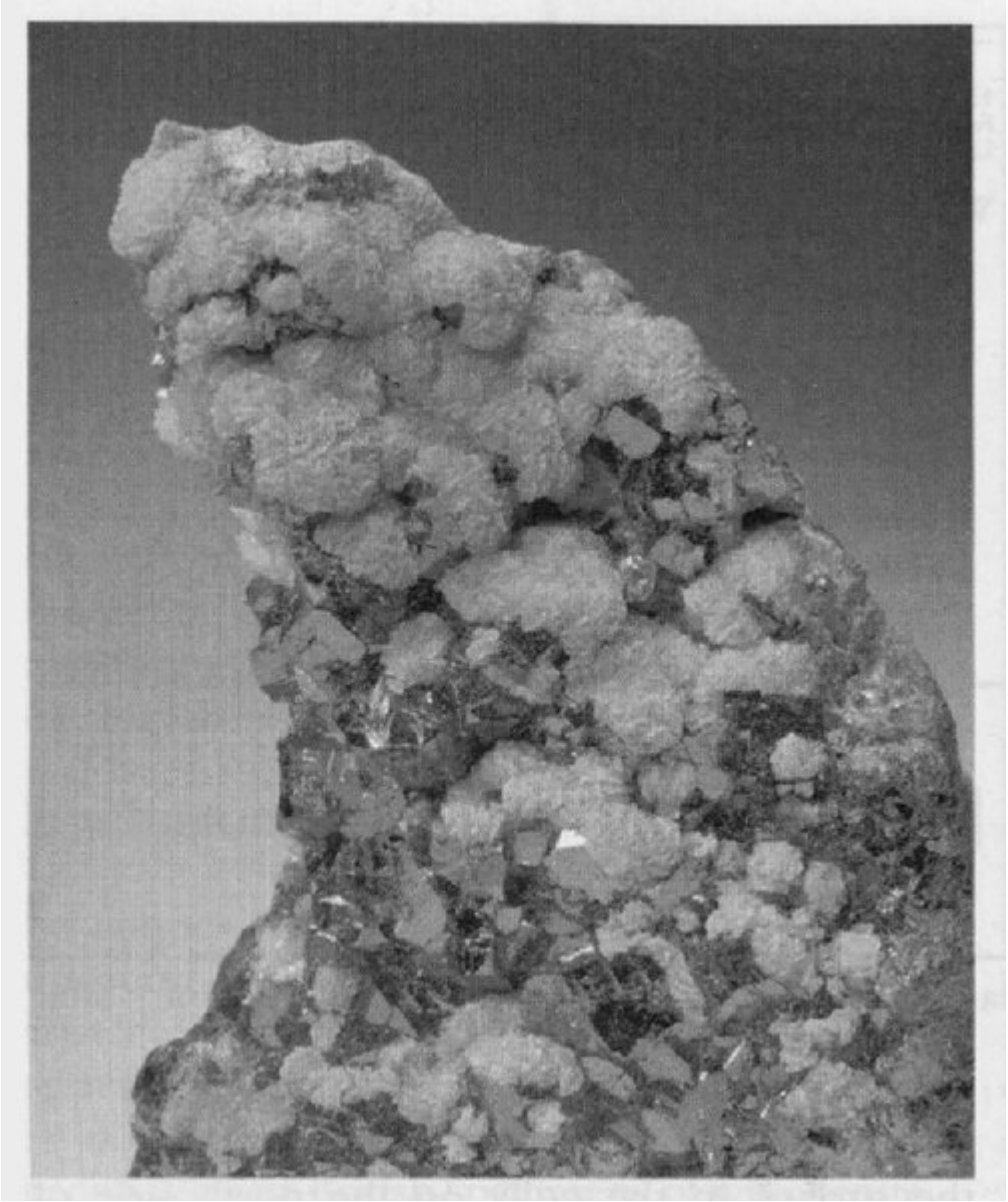
Conclusions

Force Crag Vein offers the finest opportunity within the Lake District to examine a lead-zinc-barite vein which exhibits vertical zonation of its constituent minerals. In addition, the vein gives some evidence in support of a genetic link between Lake District lead-zinc-barium veins and those of the Northern Pennines.

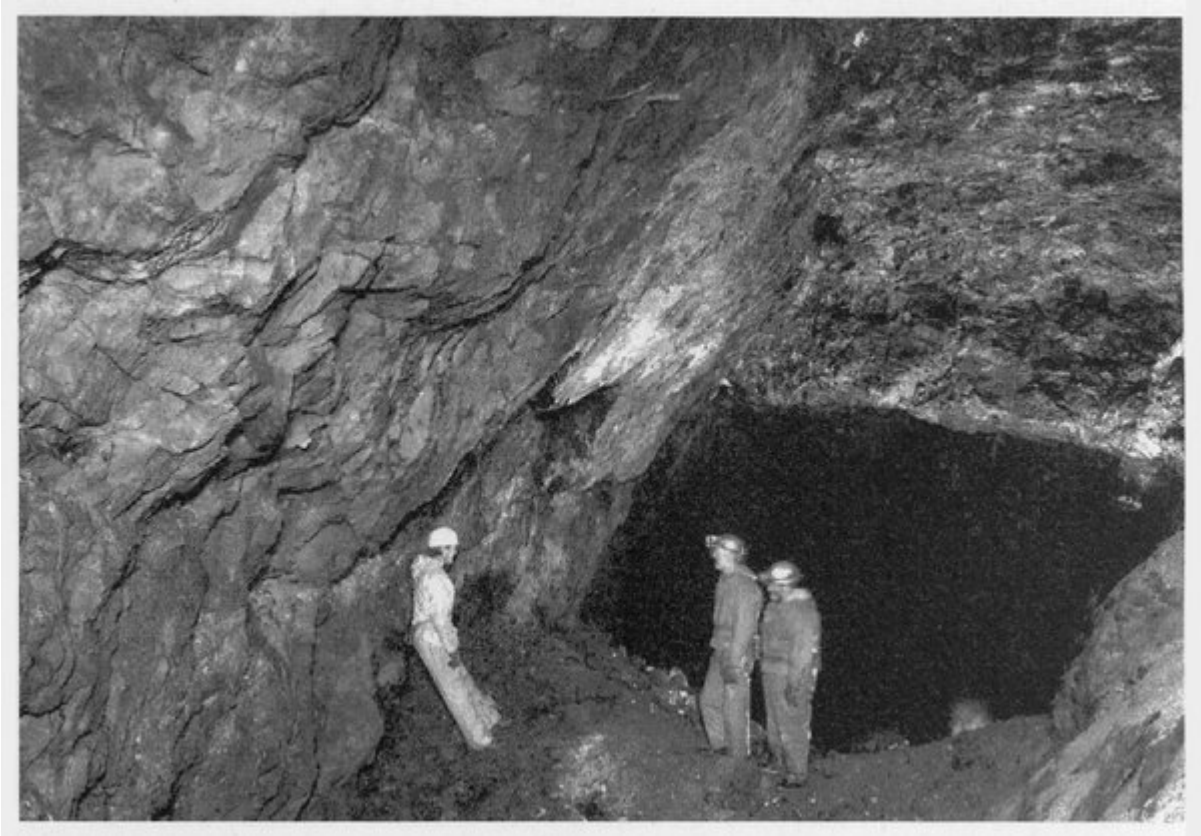
References



(Figure 2.24) (a) Surface features and (b) simplified plan and section of workings at Force Crag Mine. Oct-Young and Cooper (1988).



(Figure 2.25) Group of large black sphalerite crystals up to 1 cm across partially encrusted with pale brownish-yellow siderite, from Force Crag Mine. (Photo: BGS No. MNS 4491, reproduced by permission of the British Geological Survey, © NERC. All rights reserved. IPR/105–15CX.)



(Figure 2.26) Number 1 Level, Force Crag Mine. The vein here is unusually wide and contains an abundance of sphalerite with a conspicuous band of white barite near the right of the picture. (Photo: BGS No. D4794, reproduced by permission of the British Geological Survey, © NERC. All rights reserved. IPR/105–15CX.)