Coniston Copper Mines, Cumbria

[SD 281 991]–[SD 290 985]

Introduction

Coniston Copper Mines comprise an extensive group of workings in and around the Copper Mines Valley at the head of Church Beck, southeast of Levers Water. Large tonnages of copper ores, together with smaller amounts of lead, zinc, nickel and cobalt ores, have been mined over a long period from two principal veins and a number of minor veins.

Coniston was one of the major centres of copper production within the Lake District. Copper mining here may be traced back over many centuries. It has been suggested that the earliest workings may be Roman or even earlier. It is known that some of the workings were already abandoned when the major revival of metal mining in the Lake District took place in Elizabethan times. Since then the mines were worked intermittently until the 19th century when they were developed on a large scale. A rapid decline in production from about 1874 culminated in the closure of the mines in 1889. Attempts to revive mining in the early years of the 20th century failed and the mines were abandoned in 1908. An unsuccessful attempt was made between 1912 and 1914 to recover copper from the dumps. Underground exploration and rehabilitation of some of the workings in 1954 did not lead to a resumption of mining. Important histories of mining at Coniston include those by Dewey and Eastwood (1925), Shaw (1970), Holland (1986), Flemming (1992), and Donald (1994).

The Coniston deposits occur as veins within rocks of the Ordovician Borrowdale Volcanic Group. There are two principal veins, although a number of associated veins have also been worked. Copper ore was the main product. The main ore mineral was chalcopyrite, although minor amounts of tennantite and bornite are locally present. Much smaller amounts of lead, zinc, nickel and cobalt ores were also raised. In addition to these, the veins contain a great variety of other minerals including arsenopyrite, pyrite, pyrrhotite and traces of rare bismuth-, tellurium- and selenium-bearing minerals. Substantial quantities of magnetite occur locally. The geology of the Coniston deposits has been described by Postlethwaite (1913), Dewey and Eastwood (1925), Wheatley (1971a), Dagger (1977), and Millward *et al.* (1999, 2000). The mineralogy has been the subject of work by Russell (1925), Stanley and Vaughan (1982a,b), Young and Johnson (1985), and Young (1987a).

Parts of the underground workings are accessible and are regularly visited by mine explorers. Important exposures of mineralization are available in parts of these workings. Holland (1981) provided a detailed guide to some of these. There are limited surface exposures of mineralization *in situ,* although huge quantities of veinstone on the extensive spoil-heaps provide abundant material for study.

Description

The geology and principal veins of the Coniston area are shown in (Figure 2.6). The roughly NW–SE-trending I3onser Vein is one of the area's two main veins. Over the western part of its course, from Levers Water to Kernal Crag, it is referred to on contemporary plans and reports by its alternative name of Thriddle (or Triddle) Vein'. East of Kernal Crag the vein is displaced about 80 m sinistrally by a NNE–SSW-trending fault belt, here in the form of a narrow horst, known as the 'Great Cross-course'. Over much of its course between Levers Water and Kernal Crag, and within the Great Cross-course horst, the vein at outcrop cuts ignimbrites of the Paddy End Member. In most surface outcrops the vein consists of up to 1.5 m of quartz-veined brecciated wall-rock. However, in a large cavelike excavation, known as the 'Glory Hole' [SD 2840 9917], the vein is up to 2.7 m wide and consists of quartz, chlorite, pyrite and chalcopyrite in crude bands parallel to the vein walls. Abundant dark-brown 'gossany' iron oxides encrust much of the outcrop. East of the Great Cross-course the vein passes into volcaniclastic sandstones of the Low Water Formation and immediately narrows to a belt of hematite-stained fractures with very little mineralization. Little information is available on the wall-rocks in the underground workings, although it seems likely that ignimbrites formed the walls in the most productive sections.

Bonser Vein, or a parallel branch from it, was tried beneath Levers Water in a branch from Hospital Level. Millward *et al.* (1999) described a section of the vein in the forehead of these workings which is here within andesitic tuffs of the Duddon Hall Formation of the Borrowdale Volcanic Group. Well-developed cleavage within the tuff wall-rocks is refracted through the vein. A similarly strong wall-rock cleavage fabric passes through the South Vein exposed in Courtney's Cross-cut, near the entrance to Hospital Level.

Bonser Vein has been worked from outcrop down to at least 457 m below the surface over a strike length of about 0.5 km. When followed downwards the hade of the vein changed from southwards at the surface to a northerly hade in the lowermost workings. Throughout the underground workings vein widths varied from 0.3 m up to several metres. Dewey and Eastwood (1925) recorded that in the lower levels the vein was about 1.0 m wide with nearly half of the filling being copper ore.

Chalcopyrite is the main copper ore mineral in the Bonser Vein. It is accompanied by abundant arsenopyrite, some pyrite and marcasite and a little pyrrhotite, galena and sphalerite. Magnetite, at least some of which appears to replace earlier hematite, is an important constituent of the vein, especially in the deeper levels where it became progressively more abundant, apparently at the expense of chalcopyrite (Shaw, 1970) (Figure 2.7). Other metallic minerals, commonly associated with the magnetite, are native bismuth, bismuthinite, josëite, cosalite and laitakarite. The nickel and cobalt minerals niccolite, nickel skutterudite, rammelsbergite and safflorite were found locally in the Bonser Vein or in a branch of it (Russell, 1925; Stanley, 1979; Young, 1987a). Non-metalliferous gangue minerals include quartz, chlorite, stilpnomelane, calcite and dolomite.

Dewey and Eastwood (1925) recorded a vein carrying galena and sphalerite in an exploratory drive from the Bonser Deep Level. The exact position of this is unknown, although Eastwood (1959) suggested that these minerals were found in the easterly parts of the mine. Firman (1978a) noted that the Coniston copper veins are cut and shifted by barren cross-courses or by lead-bearing cross-veins which strike north–south or north-east–south-west.

Sections of Bonser Vein with abundant iron sulphides are exposed in workings accessible via Bonser Deep Level, and the large dumps adjacent to the Bonser Deep Level entrance contain abundant examples of apparently typical chalcopyrite-bearing veinstone, much of it rich in magnetite. Small concentrations of veinstone distinguished by carrying abundant galena and sphalerite, in association with arsenopyrite and chalcopyrite, may be seen locally on parts of the old dressing floors. This material may have been derived from one or more of the lead-bearing cross-veins.

Roughly parallel to Bonser Vein, and approximately 300 m to the south-west, lies the Paddy End Vein, the second major vein of the Coniston area, and said to have yielded richer ores (Dewey and Eastwood, 1925). The surface geology of the Paddy End Vein resembles that of the Bonser Vein (Figure 2.8). At its western extremity, near Levers Water, the vein splits into a number of roughly parallel branches. These have been worked out to surface within ignimbrites of the Paddy End Member in a series of ancient, deep open stopes known as the 'Back Strings'. One of these open workings on Paddy End Vein forms the prominent gully known as 'Simon's Nick'. The wall-rocks adjacent to these veins show considerable metasomatism to a relatively soft clay-rich rock. A branch vein, known as 'Belman Hole Vein', diverges north from Paddy End Vein near Levers Water. According to Dewey and Eastwood (1925) the vein was particularly rich at the junction which was referred to by the miners as the 'Californian Bunch'. Whereas there are few records of the wall-rock in the underground workings at Paddy End, Millward *et al.* (1999) concluded that payable mineralization is likely to have been concentrated within ignimbrite wall-rocks. According to Dewey and Eastwood (1925) muchof Paddy End Vein has been removed by stoping down to about 110 m below the Grey Crag Level.

As at Bonser the main copper ore mineral at Paddy End was chalcopyrite, although small amounts of tennantite were present locally. Arsenopyrite and pyrite are also common. Traces of native bismuth and bismuthinite have also been found (Stanley and Criddle, 1979). Stanley (1979) recorded traces of gold associated with a bismuth telluride tentatively identified as wehrlite. Ores of nickel and cobalt were also reported (Russell, 1925). Gangue minerals include quartz, chlorite, calcite and dolomite. In contrast to the Bonser workings, those at Paddy End contain a number of supergene species. Russell (1925) noted the occurrence of erythrite on the dumps. The mineral remains comparatively common here today and, in addition, is locally common in some sections of the underground workings. Young and Johnson (1985) recorded langite and posnjakite in crusts of post-mining origin in some of the upper stopes.

Limited sections of the underground workings which remain accessible provide sections of veinstone *in situ.* Representative examples of vein material are, however, very abundant on the extensive dumps along the course of Paddy End Vein, especially adjacent to the entrances of Grey Crag and Hospital levels.

Interpretation

The copper-bearing veins at Coniston belong within the widespread chalcopyrite-pyrite-arsenopyrite-type suite of Lake District veins described by Stanley and Vaughan (1982a). These authors proposed a Lower Devonian age for the emplacement of these deposits, based in part on K-Ar isotopic dating of veinstone samples by Ineson and Mitchell (1974).

A dose relationship between vein productivity and wall-rock lithology has long been recognized in the Coniston veins where economic copper mineralization appears, in most places, to have been restricted to veins within ignimbrite wall-rocks (the rhyolites of Mitchell, 1940). Dewey and Eastwood (1925) noted that the 'slates' worked in the Coniston area effectively limit the area of productive mineralization within the veins. In his structural study of these veins Dagger (1977) explained this relationship in terms of the greater tendency of the hard ignimbritic rocks to form open fractures in response to faulting than the associated volcaniclastic sandstones. Whereas there are few contemporary descriptions of vein wall-rocks, and most sections of the mines are now inaccessible for study, Millward *et al*. (1999, 2000) suggested that there are good grounds for accepting this relationship.

Work by several authors (e.g. Dagger, 1977; Stanley and Criddle, 1979; Stanley and Vaughan, 1982a,b) on the parageneses of these veins has suggested that many may be the result of several mineralizing episodes. It has been claimed that the Coniston veins exhibited a vertical zonation of constituent minerals, with pyrite and chalcopyrite at higher levels, and arsenopyrite increasing in abundance with depth and being progressively replaced by magnetite at even deeper levels (Dagger, 1977). This suggestion must, however, be viewed with some caution as only the Bonser and Paddy End veins have been systematically explored by mining over a significant vertical interval and in neither instance are reliable mineralogical observations known to have been recorded during mine development. Whereas magnetite seems to be present only at depth in the Bonser Vein it occurs at high levels in the Long Crag Vein in the nearby Greenburn Valley. In the Bonser Vein, magnetite, together with specular hematite, which it appears to replace, occupy an early position in the vein's paragenesis and may not be a reliable indicator of increasing depth.

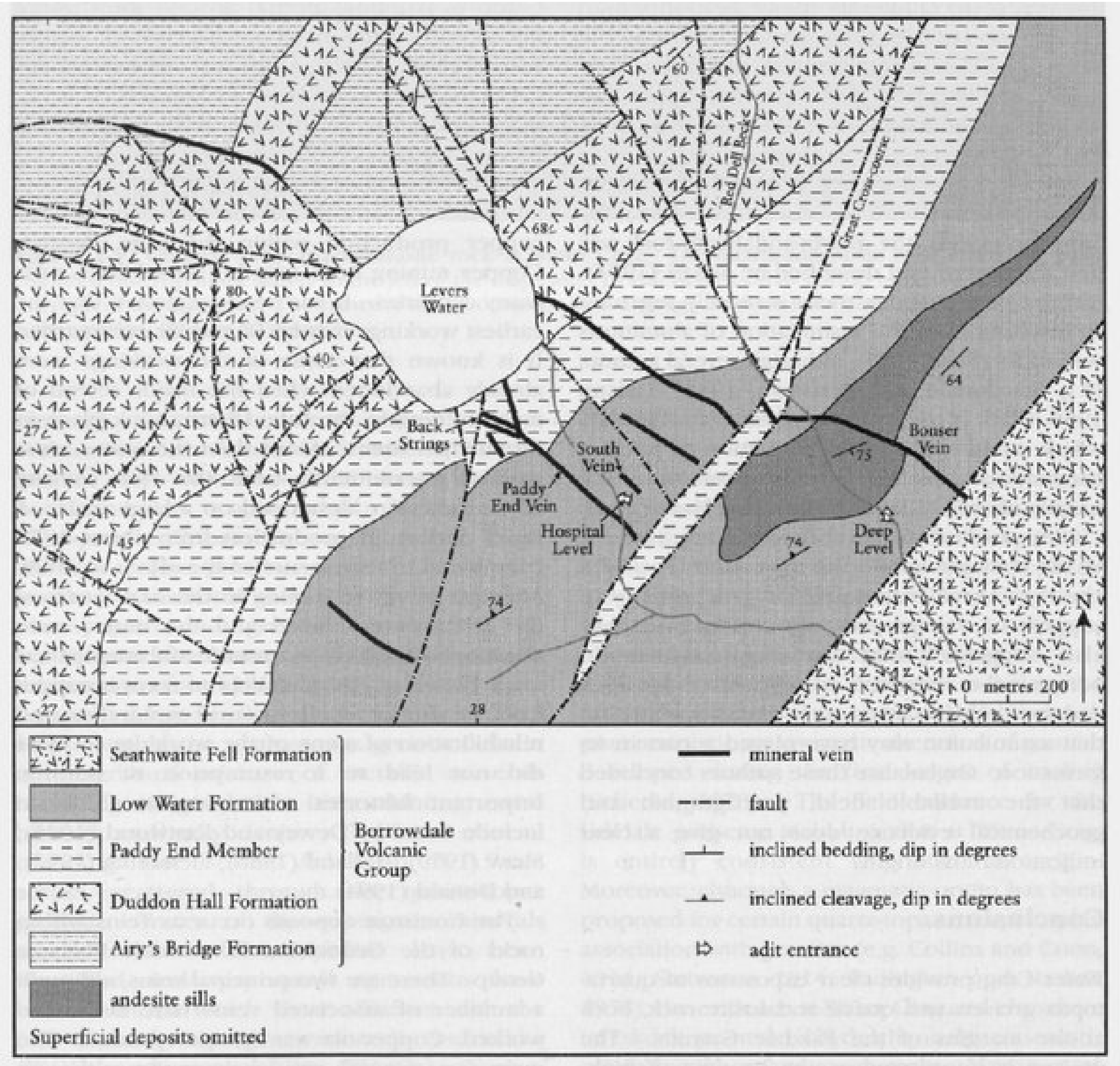
Stanley and Vaughan (1980, 1982a,b) have provided data for the likely formation temperatures of minerals within the Lake District copper veins and on the composition of the fluids from which they were deposited. For the Bonser Vein they suggested (1982b) that replacement of the original hematite by magnetite, and deposition of early arsenopyrite, which post-dates magnetite, may have occurred at 350°–400°C. Quartz, chlorite, stilpnomelane, calcite, dolomite, pyrrhotite, chalcopyrite, sphalerite and late arsenopyrite were probably deposited at about 240°C. Later minerals, including pyrite, native bismuth, bismuthinite, laitakarite, josëite, galena and cosalite are considered to have formed at temperatures as low as 200°C.

No fluid-inclusion data are available for the Coniston veins. However, inclusions in quartz from Castle Nook Vein in the Vale of Newlands, and likely to be a member of the same suite of deposits as those at Coniston, suggest that the mineralizing fluids were moderately saline brines (T. Shepherd, pers. comm. in Stanley and Vaughan, 1982a). The Borrowdale Volcanic Group has been proposed as a source of the introduced metals, the remobilization and redistribution of which may have been brought about by heat flow from the batholith (Firman, 1978b; Stanley and Vaughan, 1982a). Lowry *et al.* (1991) demonstrated from sulphur isotope studies that Skiddaw Group rocks were the most likely source of sulphur. These authors have attempted, although with some difficulty, to relate the distribution of copper mineralization to features in the underlying batholith. However, Millward *et al.* (1999) have noted that at least some of the faults now occupied by mineralized veins at Coniston may have been active during volcanism. In addition, they have described cleavage fabrics within the wall-rocks passing through the veins, indicating that at least some of the mineralization pre-dates the Acadian cleavage-forming event. They have further pointed to similarities, including the local abundance of magnetite within the veins, with broadly contemporaneous copper deposits in North Wales (see Chapter 5), which Reedman *et al.* (1985) regarded as being genetically related to hydrothermal activity late in the process of caldera evolution. There are thus grounds to suggest that copper mineralization here may be genetically linked with the final phase of Ordovician magmatism.

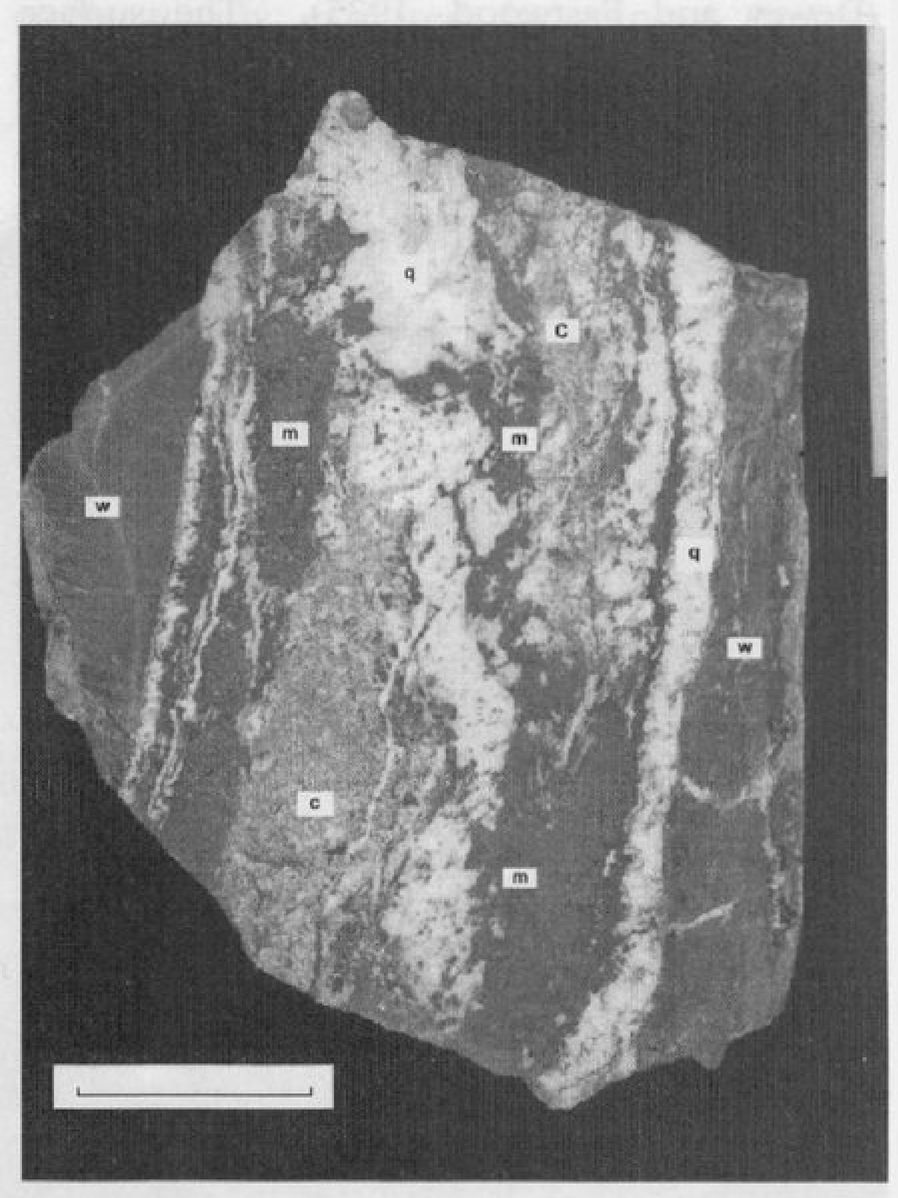
Conclusions

The copper deposits at Coniston are important examples of the chalcopyrite-pyrite-arsenopyrite suite of Lake District veins. Limited surface and underground exposures of veins and an abundance of mine spoil provide excellent opportunities to study the mineral parageneses. The relationships of the veins, and their economic mineral content, to wall-rock lithology may also be demonstrated. Recently described cleavage fabrics within the veins give evidence of pre-Acadian emplacement for at least part of the mineralization, perhaps linked to the final stages of Ordovician magmatism. The local abundance of magnetite suggests similarities with the caldera-related mineralization in North Wales.

[References](#)



(Figure 2.6) Geological sketch map of Coniston Copper Mines. After Millward et al. (2000).



(Figure 2.7) A cut section of a large specimen from Bonser Vein, Coniston Copper Mines, showing crude bands of white quartz (q), magnetite (m), and chalcopyrite (c), between Borrowdale Volcanic Group wall-rock (w). The scale bar is 10 cm. (Photo: T. Bain, BGS No. MNS 5932, reproduced by permission of the British Geological Survey, © NERC. All rights reserved. IPR/116–33CY.)

(Figure 2.8) View of the Paddy End workings at Coniston Copper Mines. The large dumps in the foreground adjoin Hospital (H) and Grey Crag (G) levels. Dumps from higher levels may be seen to the left of the stream. Ancient surface workings, including Simon's Nick, are visible on the skyline above these dumps. The modem buildings are part of a water-treatment plant. (Photo: B. Young.)