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Mineralization at Seathwaite Tarn, near Coniston, English Lake District: The first occurrence of wittichenite in Great Britain

C. J. STANLEY

Department of Geological Sciences, University of Aston in Birmingham, Gosta Green, Birmingham B4 7ET

AND

A. J. CRIDDLE

Department of Mineralogy, British Museum (Natural History), Cromwell Road, London SW7 5BD

SUMMARY. Ore specimens from the abandoned copper mine at Seathwaite Tarn, Cumbria, were studied in polished section by reflected light microscopy. The mineral paragenesis is described and related to current views on Lake District ore genesis. A common origin with the neighbouring deposit at Coniston is proposed. Wittichenite was identified in the ore, and is the first authenticated occurrence in Great Britain.

COPPER mineralization in the Lake District is best seen at Coniston, the centre of mining activity in this area in the late nineteenth century. The mineralization here has been reasonably well documented (Dewey and Eastwood, 1925; Wheatley, 1971 and 1972; Dagger, 1977; Firman, in press), but the small workings near the head of Seathwaite Tarn to the north west of Coniston have received little attention.

Four quartz veins containing small amounts of sulphide mineralization course east-west across rugged, mountainous terrain at 1250-1750 feet OD. The veins dip steeply to the north and average two feet in width (Eastwood in Dewey and Eastwood, 1925), cutting through Seathwaite Tarn andesites and coarse tuffs and agglomerates assigned to the Tilberthwaite Group (Mitchell, 1963) of the Ordovician Borrowdale Volcanic Series (see fig. 1).

The two northernmost veins have been worked from an adit driven 100 fathoms NNW (Eastwood in Dewey and Eastwood, 1925); this is marked on the OS six-inch sheet SD 29 NE as Upper Level (SD 2662 9975). The adit is now collapsed and sulphide mineralization was not found *in situ* at the surface outcrop of the veins. The small spoil heap derived from the adit has yielded a variety of copper sulphides and the rare copper bismuth sulphide, wittichenite. This is the first confirmed occurrence of wittichenite in the British Isles.

Previously, Garby (1848, p. 86) reported that 'cupreous bismuth was found at Huel Buller (Cornwall) in perfect hexagonal prisms'. These crystals 'were tin white and lustrous' but the lustre was soon lost on exposure. Collins (1871, p. 106) mentioned this occurrence, and others from Botallack and Levant, and suggested that Garby's cupreous bismuth 'may possibly have been' wittichenite.

It is also possible that the klaprotholite (klaprothite) observed in polished section from Redruth, Cornwall (Krieger, 1940) was wittichenite, for in Nuffield's (1947) X-ray study of klaprothite, which included an examination of some of Krieger's material (from Wittichen, not Redruth) he concluded that klaprothite was identical to wittichenite. However, Springer and Demirsoy (1969) found that klaprothite from Wittichen had the same chemistry as emplectite but was different optically: they concluded that klaprothite is identical with cuprobismutite, a dimorph of emplectite.

Mineralogy. The only previous description of the mineralogy of Seathwaite is by Eastwood (in Dewey and Eastwood, 1925) who found 'in addition to copper pyrites, an appreciable quantity of copper glance'. The mineralogy of the Seathwaite vein material reported here was studied in polished section by reflected light microscopy. The main sulphide assemblage consists of digenite, djurleïte, and bornite, with smaller amounts of wittichenite, chalcopyrite, blaubleibender covelline, covelline, arsenopyrite, cobaltite, and pyrite in a hematitized quartz-chlorite matrix. Wittichenite, usually associated with microcrystalline hematite, occurs along grain boundaries, fractures, and structural planes

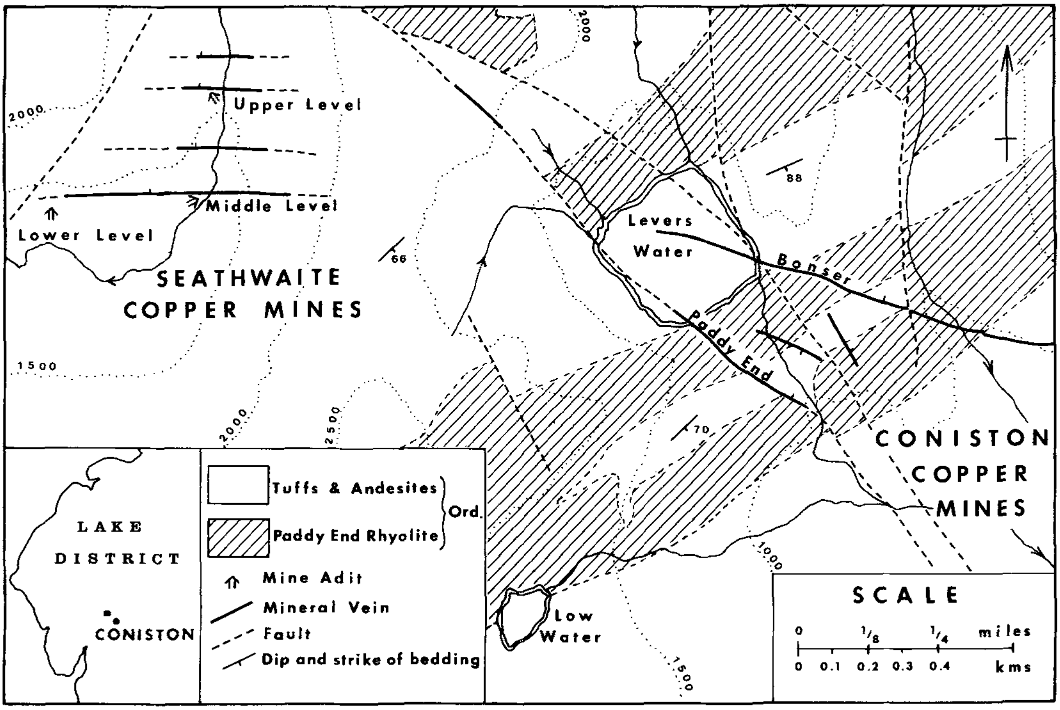
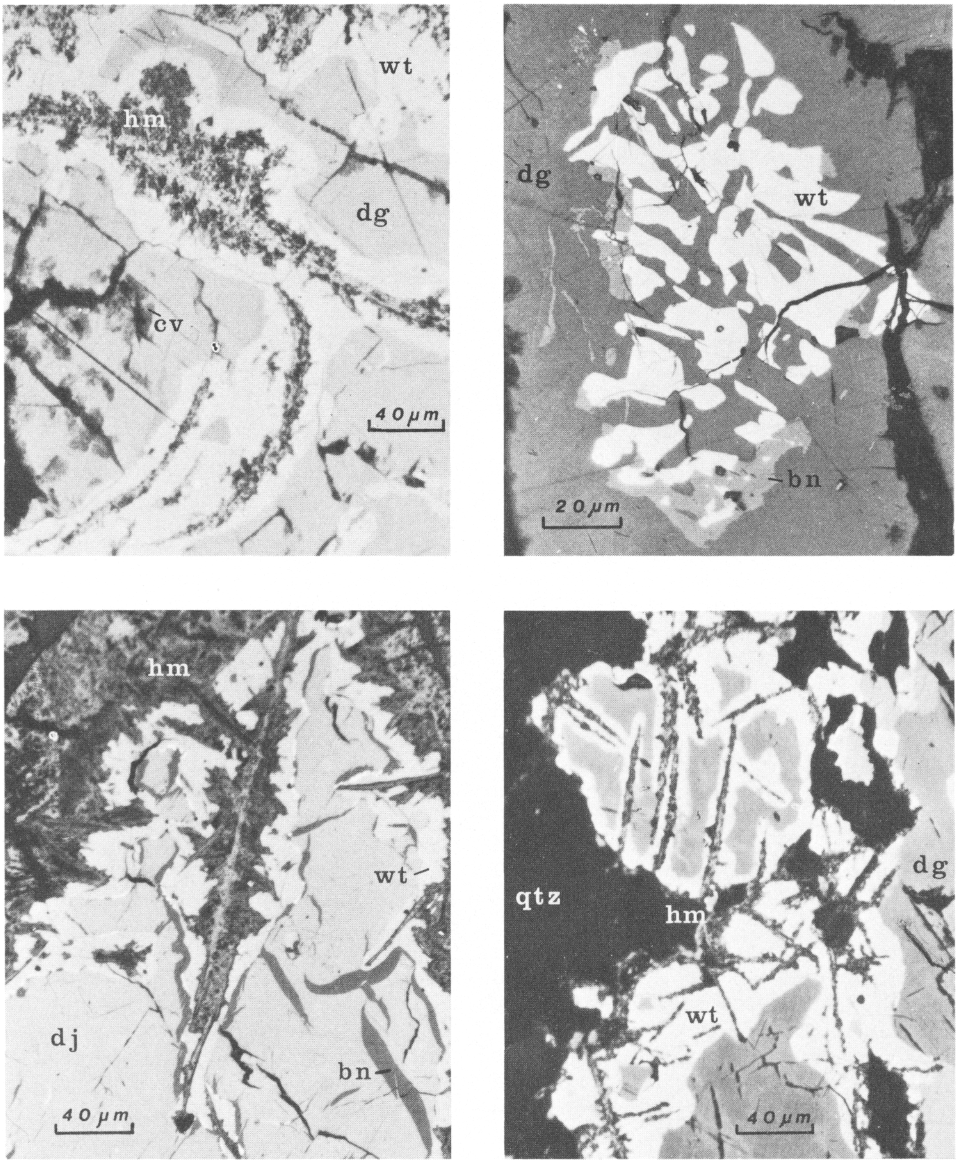


FIG. 1. Sketch map showing the location of Seathwaite and Coniston mines; the geology is based on Mitchell (1940 and 1963).

in the digenite and djurleïte (fig. 2). It is also found as graphic intergrowths with digenite and bornite (fig. 3). Descriptive and analytical data for Seathwaite wittichenite (BM 1977, 172), and for a specimen from Wittichen, Wolfach, Baden (Criddle and Stanley, 1979), are presented and compared later in this journal.

Paragenesis. Chalcopyrite-pyrite-arsenopyrite mineralization in the Lake District occupies normal faults with a predominantly E-W trend, which are assigned to earth movements associated with the Caledonian Orogeny (Strens, 1962; Dagger, 1977). This 'typical' mineral association, which is well developed at Coniston, is also seen at Seathwaite. However, this study has shown that the assemblage at Seathwaite is more varied and the paragenesis, particularly of the copper sulphides, more complex, than has been shown for the Coniston assemblage (Dagger, 1977).

The earliest mineralization at Seathwaite appears to have been of quartz with chlorite and minor amounts of hematite. The main sulphide assemblage was deposited after brecciation of these quartz-chlorite veins. In the ore-mineralized parts of the veins the quartz fragments are rarely more than a few cm across. Minor amounts of euhedral pyrite (< 0.8 mm), arsenopyrite (< 0.1 mm) and euhedral to subhedral cobaltite (< 0.5 mm) were introduced into the breccia before cementation by copper sulphides. Digenite and djurleïte are interpreted as the first formed copper sulphides. Both replace early quartz and hematite and, to a lesser extent, pyrite and arsenopyrite. Digenite and djurleïte were contiguous in none of the polished mounts in which both minerals were found. For this reason it was not possible to determine their age relationships with any certainty. Sillitoe and Clark (1969) suggest that digenite may be formed by the oxidation of djurleïte, and that further oxidation may lead to the formation of covelline and blaubleibender covelline. Both these minerals have replaced digenite at Seathwaite, but their position in the paragenetic sequence as a whole is uncertain. Digenite and djurleïte have been replaced by most of the later minerals: bornite replaces digenite extensively and, less commonly, forms sigmoidal replacement textures with djurleïte (fig. 4). Wittichenite occurs as discrete areas (0.2 mm) in graphic intergrowths with digenite and bornite (fig. 3), but is more commonly associated with microcrystalline hematite. Together they separate digenite and djurleïte from early quartz, and occupy fractures within these phases; they also replace digenite along its octahedral cleavages (fig. 5), and grain boundaries. It was not possible to determine whether the wittichenite was contemporaneous with, or introduced before, the microcrystalline hematite. A thin margin (< 0.5 μm) of bornite, or chalcopyrite, or both, often separates wittichenite from digenite and djurleïte. One irregular grain of gold (*c.* 20 μm) found in bornite may have been introduced at this stage of mineralization. Exsolution textures of chalcopyrite in bornite occur, but are less common than the replacement of bornite by chalcopyrite and covelline. In such instances the replacement proceeded



FIGS. 2–5: FIG. 2 (*top left*). Covelline replaced digenite along cleavages and fractures. Wittichenite and hematite also replace digenite. FIG. 3 (*top right*). Graphic intergrowth of wittichenite and digenite. FIG. 4 (*bottom left*). Djurleïte replaced by bornite and wittichenite. Wittichenite is separated from djurleïte by a thin margin of chalcopyrite (white) and bornite. Hematite and wittichenite are closely related. FIG. 5 (*bottom right*). Wittichenite and hematite replace digenite at grain boundaries and along structural planes.

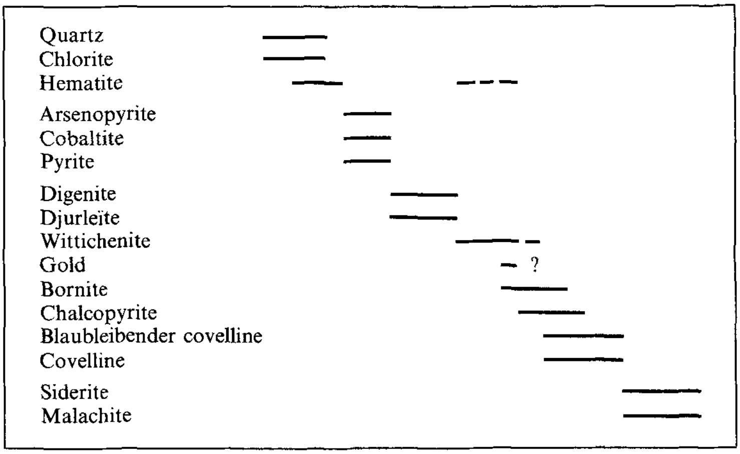


FIG. 6. Paragenetic relationships of vein minerals at Seathwaite.

along fractures and structural planes in the bornite. Covelline also defines cleavages in digenite and has sometimes replaced it more extensively. Similarly, blaubleibender covelline, in replacing digenite, utilized the host's structure, and, as with covelline, diffuse and more extensive replacements spread out from the earlier linear features. Many of these textures are characteristic of shrinkage of the earlier phases followed by infill and replacement.

Later minerals include botryoidal hematite, siderite, and small amounts of malachite. These observations are summarized in the paragenetic diagram (fig. 6).

Genesis. The major Coniston copper veins, Paddy End and Bonser, besides having the usual chalcopyrite-arsenopyrite-pyrite assemblage, carry small amounts of native bismuth and bismuthinite. In the Bonser vein, native bismuth and bismuthinite are more abundant in material derived from deep levels in magnetite-rich portions of the vein, whereas in the Paddy End vein they occur mainly as minute inclusions in chalcopyrite.

The origin of the copper mineralization at Coniston has been interpreted by Dagger (1977) as resulting from redistribution of trace amounts of copper and other elements from the Borrowdale Volcanic Series, the heat source being the underlying basement granite. Firman (1978) speculates that pre-Bala volcanic exhalations contributed 'formation waters', which were later recirculated when the Lower Devonian granites were intruded. Eastwood has suggested (in Dewey and Eastwood, 1925) that the veins at Seathwaite are probably continuations of the Coniston veins, but field evidence for this is not entirely convincing because, although the northernmost part of the Bonser vein swings towards the Seathwaite veins E–W trend, most of the Coniston veins have a NW–SE trend (fig. 1). There are, however, broad similarities in the paragenesis of both groups of veins and, although we have identified more copper sulphides in one stage of mineralization at Seathwaite than have yet been found at Coniston, the presence of wittichenite at Seathwaite and native bismuth and bismuthinite at Coniston offers some support for Eastwood's suggestion.

It is apparent from the paragenetic diagram (fig. 6) that the mineralization at Seathwaite was discontinuous, and consisted of three main episodes: an early quartz–chlorite and hematite stage, which was subsequently brecciated; an arsenopyrite, pyrite, and cobaltite stage, and finally the main copper–bismuth sulphide stage. The relatively superficial late oxidation assemblage may be considered to constitute a fourth episode.

There are similarities between this sequence and the sequence advocated, for Coniston, by Dagger (1977). He regarded the quartz–chlorite phase as a 'rock alteration' phenomenon rather than an episode in mineralization, and concluded (p. 201) that the sequence there consisted of three episodes: an early hematite phase; a pyrite–chalcopyrite–arsenopyrite–magnetite 'main' phase; and a 'carbonate' phase. However, he also suggested (p. 198) that the 'primary mineralization' was a single phase and that this involved 'sequential deposition of minerals and only minor replacement textures . . .'. The order of deposition of this phase, namely magnetite, arsenopyrite, pyrrhotine, pyrite, marcasite, chalcopyrite, blende, galena, bismuth, and bismuthinite is similar to that at Seathwaite where this mineralization is divided into two separate episodes and where there is ample textural evidence of replacement.

We conclude that the Coniston and Seathwaite deposits, which share many of the characteristics of the classical hydrothermal sequences, also share a common genesis.

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REFERENCES

Collins (J. H.), 1871. *A handbook to the mineralogy of Cornwall and Devon.* Truro: Herd and Sons.
Dagger (G. W.), 1977. *Geol. Mag.* **114,** 195-202.
Dewey (H.) and Eastwood (T.), 1925. *Mem. Geol. Surv. Spec. Rep. Mineral Resour. G.B.* **30.**
Firman (R. J.), 1978. Ch. 15 of *The Geology of the Lake District* (ed. F. Moseley). Yorks. Geol. Soc. Occasional Publ. no. 3.
Garby (J.), 1848. *Trans. R. Geol. Soc. Cornwall,* **7,** 72-92.
Krieger (P.), 1940. *Econ. Geol.* **35,** 687-97.
Mitchell (G. H.), 1940. *Q.J. Geol. Soc.* **96,** 301-19.
—— 1963. *Liverpool and Manchester Geol. J.* **3,** 289-300.
Nuffield (E. W.), 1947. *Econ. Geol.* **42,** 147-60.
Sillitoe (R. H.) and Clark (A. H.), 1969. *Am. Mineral.* **54,** 1684-710.
Springer (G.) and Demirsoy (S.), 1969. *Neues Jahrb. Mineral. Monatsh.* 32-7.
Strens (R. G. J.), 1962. *Unpublished Ph.D. thesis,* Nottingham University.
Wheatley (C. J. E.), 1971. *Trans. Inst. Min. Metall.* **80,** 211-23.
—— 1972. *Unpublished Ph.D. thesis,* London.

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