

interfere with the analysis. Experiments have shown that fast cutting of the blocks causes rupturing of the inclusions adjacent to the sawn face. To minimize this sub-surface damage a cutting rate of  $\leq 9$  mm/min using a 150 mm diameter fine diamond blade at 2000 r.p.m. is recommended for routine preparation.

All grinding and polishing processes are carried out using a basic Speedfam 12 lapping machine, with ancillary discs and felt lap designed by the authors. The former ensure that only the slices are in contact with the laps, and afford greater support than the retaining rings supplied by the manufacturer. This avoids any tendency for the thinned slices to warp or shatter.

When thinning and polishing the second face of the specimens, glass discs are substituted for the duralumin discs, allowing rapid visual monitoring of the thickness.

Water is employed as the abrasive vehicle in preference to the recommended oils, which tend to dissolve the Lakeside adhesive. During grinding it was also found that carborundum coarser than 600-mesh (9  $\mu$ m average particle size) settled out in the screw feed of the Speedfam, resulting in an unpredictable grinding rate. 600-mesh carborundum was therefore selected as the best compromise in that it provided an adequate removal of material whilst requiring the use of only one finer grade before polishing.

Assuming a maximum of 9 slices per disc, loaded

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with a 5 kg weight, an adequate polish is achieved in approximately 1 hour. The Speedfam 12 will accept 4 discs simultaneously, and it is therefore possible to process 32 samples per run. However, this number may be increased by using smaller moulds, or by increasing the number of specimens per block. Without these refinements, an average of 12 doubly polished slices per day may be prepared.

Process time could be reduced further by employing an automatic surface grinding machine. However, these are relatively expensive, whereas the method described utilizes a modestly priced and compact machine, which can be used by an unskilled operator.

It is anticipated that future requirements will be of slices  $< 150$   $\mu$ m which will necessitate a more controlled method of thinning such as that provided by an automatic surface grinder.

A list of manufacturers and suppliers may be obtained from the authors.

*Acknowledgement.* We wish to thank Dr. A. H. Rankin, Imperial College, London, for providing technical data on polyester resins. This note is published by permission of the Director, Institute of Geological Sciences.

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[*Manuscript received 15 November 1977*]

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MINERALOGICAL MAGAZINE, JUNE 1978, VOL. 42, PP. 298-300

## A new wulfenite locality, near Bristol

WULFENITE has been found at a new locality, at Henbury, near Bristol (Coombe Farm quarry, G.R. 1" sheet 156. 562778). The quarry, now disused, is opened in steeply dipping Lower Carboniferous limestone, and is notable for the occurrence of a small, podiform, replacement deposit consisting of both Mn and Fe oxides, developed in a narrow north-south-trending rubble-filled fissure in the limestone. This deposit is typical of the type of low-temperature secondary Mn-Fe mineralization found scattered throughout the Bristol district (Spencer and Mountain, 1923; Alabaster, 1975). East-west-trending calcite veinlets, carrying galena

and chalcopyrite, cut the mineralized fissure. To the east of the quarry these veins thicken up and have been worked for lead in the past.

The manganese ore varies in texture, from massive, locally coarsely crystalline (pyrolusite), to soft and cindery. Colloform banding and shrinkage cracks are visible in both ore types. Polished sections of the ore suggest that much of the crystalline pyrolusite has been derived from manginite. The 'pod' is differentiated into a Mn-rich core and a Fe-rich margin.

Wulfenite is found in two distinct environments in this deposit. It is sparingly distributed through-

out the Mn ore where individual crystals are usually very small (seldom exceeding 1 mm longest dimension), poorly formed, and frequently corroded. Most specimens consist of aggregates of tabular  $\{001\}$  pale lemon-yellow to orange-yellow crystals, which form patchy encrustations on the walls of small cavities (usually  $< 2 \text{ cm}^3$  volume) in the Mn ore. These aggregates resemble cockscomb baryte in appearance. Less commonly, a large, single tabular crystal may be developed in place of the drusy encrustations usually found. The large crystals commonly have a slightly lensoid appearance in cross-section. Many of the cavities contain cerussite or baryte or both in addition to wulfenite. Wulfenite is found growing on both the baryte, where this mineral forms cavity linings, and less commonly on the cerussite. Small wulfenites, occasionally showing perfect crystal form, are often seen projecting into the cerussite from the cavity wall or lining. No intergrowth between the wulfenite and either baryte or cerussite has been seen. It appears that the wulfenite, baryte, and cerussite are all of the same generation. XRD analysis as well as the crystal form suggest that some of the cerussite has been derived from hydrocerussite. Wulfenite associated with baryte, hydrocerussite, cerussite, aragonite, and a number of rarer secondary Pb and Cu minerals has been described from similar Mn-Fe replacement deposits in the Mendip hills (Spencer and Mountain, 1923; Symes and Embrey, 1977).

Wulfenite is also found associated with the sulphide veins. Individual crystals are minute (average 0.15 mm longest dimension), usually very well formed, and show no obvious signs of corrosion. The greatest concentration of crystals is found along the sheared vein/wall-rock contacts. Lesser amounts, restricted to the immediate vicinity of the veins, occur along small cracks and joints in the partially replaced fissure-fill. In some areas small wulfenite crystals appear to have grown on the later muddy infillings to these fractures. Thin films and distorted crystals of wulfenite are also found along crystal boundaries in the vein calcite and encrusting corroded grains of galena. In this environment wulfenite is often intimately associated with malachite and less commonly azurite. Well-formed wulfenites are also found growing on these Cu minerals. The wulfenite thus appears to be, at least in part, contemporaneous with the malachite and azurite. In view of this lindgrenite might be expected, but a careful search failed to reveal any. Cerussite is rare in this environment.

Tabular crystals, often showing concentric zoning, are the habit most commonly exhibited by these wulfenites, but a wide variety of curved and prismatic crystals are also found. This contrasts

sharply with the wulfenite from the cavities in the Mn ore, which appear only to occur as tabular crystals. Here the prismatic, and especially the curved crystals, are not common. They are sparingly distributed both as single crystals and in small clusters amongst the more abundant tabular crystals. Most of the prismatic and tabular crystals are bright yellow to bright orange; the curved crystals are always bright orange. In view of the small size of the crystals, goniometry was not possible. The forms shown appear to be the common ones, prism  $\{010\}$ , pyramids  $\{011\}$  and  $\{021\}$ , and the base  $\{001\}$  (following the setting used in Dana's (1951) system, 7th edn.). Many of these crystals are similar to those figured by Deans (1961, p. 710) and Russell (1946, p. 151) from two other British wulfenite localities.

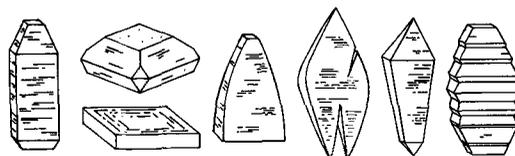


FIG. 1. Habits of wulfenite from Coombe Farm quarry.

Under high magnification, many crystals show fine striations and ridges parallel to  $\{001\}$ . These are especially noticeable in the curved crystals. On some specimens, repeated oscillations, probably between  $\{011\}$  and  $\{021\}$ , have imparted a concertina-like appearance to the crystals. Oscillatory combinations between  $\{011\}$  and  $\{021\}$  were also noted by Deans on crystals from the English Midlands. Such oscillations during growth are probably the cause of the fine striations and may also be responsible for the development of the curved crystals.

The lack of corrosion, difference in colour, abundance of well-formed crystals, variety of habits shown, apparent freshness, and differing mineral association strongly suggest that the wulfenite crystals associated with the sulphide veins are of a different and later generation from those in the Mn oxide. It is thus suggested that two generations of wulfenite are present in this deposit.

The age of the Mn-Fe mineralization is uncertain, but in view of its over-all similarity to other Triassic Mn-Fe deposits in the Bristol region a Triassic age for this mineralization seems likely. It thus follows that the Pb-Cu sulphide mineralization is of a later date. Pb-Zn-Cu sulphide mineralization that postdates the Rhaetic period occurs round Bristol, in the Mendip hills, and in South Wales (Hamilton, 1965; Dewey, 1921;

Alabaster, 1976; Moore, 1867). It seems likely that the sulphide mineralization at Henbury is of a similar age.

The immediate source of Mo for the wulfenite in both environments appears to be the Mn oxide. No molybdenum was detected in either the galena or chalcopyrite, but the Mn oxide contains up to 0.1% Mo, with high levels of many other heavy metals. Assuming a Triassic age for the Mn-Fe mineralization, the most likely source for the Mn and Fe are the Coal Measure shales. Although now largely obscured by a thick Mesozoic covering, the Coal Measure shales in the Bristol area probably formed extensive outcrops in Triassic times. These shales contain up to 20 ppm Mo. Leaching of these shales by Triassic ground waters would provide metal-bearing solutions which, under favourable Eh/pH conditions, would precipitate the Mn and Fe as hydrated oxide gels. The high levels of heavy metals in the Mn oxide can be accounted for by prolonged cation scavenging from the Triassic ground water. Subsequent compaction and crystallization of the gels would remobilize the Mo, Pb, and other adsorbed cations, leading to the formation of the baryte, wulfenite, cerussite, and hydrocerussite now found in the cavities in the Mn ore. It is further suggested that, subsequent to the introduction of the sulphide veins, circulating ground waters

leached Mo from the Mn oxide, which, on encountering the slowly oxidizing galena veins, gave rise to the second generation of wulfenite. A fuller account of the mineralization at this locality will be published elsewhere.

*Acknowledgements.* I would like to thank Mr. I. H. Ford and Dr. R. Bradshaw for their helpful comments and suggestions during the course of this work. The diagram was drawn by Mr. J. Simpson of this Department.

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[Manuscript received 25 May 1977;  
 revised 10 October 1977]

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