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The Journal of British topographical mineralogy

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Aims and Scope

The Journal publishes articles and reviews by both amateur and professional mineralogists dealing with all aspects of mineralogy. Contributions concerning topographical mineralogy are particularly welcome.

In addition to full articles, short notes (up to 1000 words) may be submitted. Book reviews and correspondence will also be accepted with a view to publication. Notes for contributors can be found at the back of the Journal.

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COVER: Strunzite and beraunite,
Gravel Hill Mine, Perranporth, Cornwall. Photo: M.P. Cooper.

EDITORIAL

Considerable time has passed between publication of the last part of the Journal of the Russell Society and this present issue. This unfortunate lapse relates partly, as will already be known to many Members of the Society, to a change in the Editorship of the Journal, and partly also to a change in production methods. This issue has been printed from text which was computer typeset. The hope is that by using such modern techniques more rapid production of future issues will be guaranteed. In future, as papers are received, they will undergo the normal refereeing procedures, and then assuming they are accepted for publication, will be typed directly onto disc. When sufficient papers have been accepted the disc can then be simply passed to the typesetter for formatting prior to printing.

This issue contains no advertising, but advertisements will be incorporated in subsequent issues. Anyone wishing to advertise in the Journal should contact the Journal Manager, Nigel Moreton.

We hope that the new format finds general acceptance. It is to be emphasised that future issues rely on the submission of sufficient papers of suitable quality, and we call for such submissions as a matter of urgency.

Richard E. Bevins
Journal Editor

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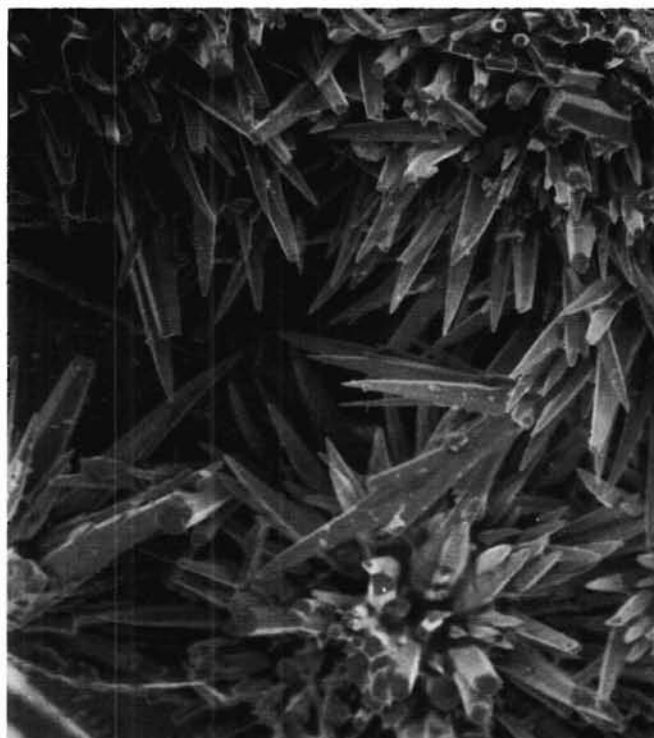
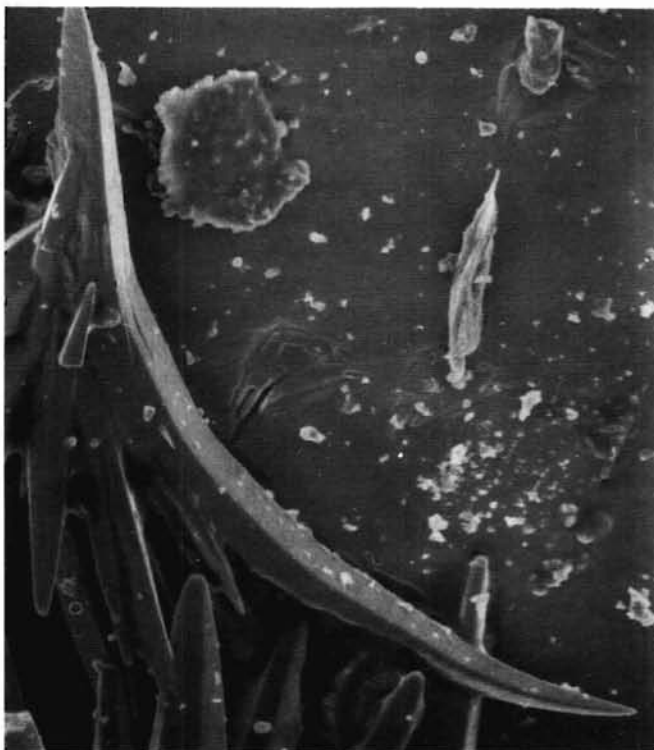
A**B**

FIGURE 1. Scanning electron microscope secondary electron images of strontianite crystals on celestine. Note curved crystals in (a), magnification X500. The scale of (b) is X200.

contents of celestines from the Leechpool area as only 0.05% - 0.09%. Partitioning data for calcium between water and celestine seem to be lacking, although Udowski (1973), and Butler (1973) discuss Sr partitioning between Ca sulfates and waters. Their results cannot be extrapolated to this study however, as anhydrite and celestine are not isostructural, and Ca substitution in celestine is probably non-ideal (Church, 1979).

Where calcite is the late carbonate it is likely that lower Sr/Ca ratios prevailed, as this would result in the crystallisation of the rhombohedral carbonate. Such low Sr/Ca ratios might be expected in "normal" groundwaters which had not equilibrated with celestine. Thus, according to this model, most of the late carbonates in the celestine rocks of the Yate area grew from an influx of groundwaters with low Sr concentrations, low Sr/Ca ratios and high CO₂ contents. Only where and when these waters had time to equilibrate with celestine was strontianite precipitated.

The association of late carbonates with pseudomorphs after pyrite suggests that the waters responsible contained reduced ionic sulfur species. This suggests the possibility of another mechanism of strontianite formation. Chamberlain *et al.* (1986) describe the occurrence of witherite on altered barite from Devonian rocks in New York State. They found that the carbon isotopes of the late carbonate showed enrichment of the heavy ¹³C component. Such heavy carbon isotopic signatures are normally ascribed to bacterial reduction of groundwaters involving the production of methane. Bacterial reduction of barite with subsequent formation of witherite has been observed in the laboratory (Romer and Schwartz, 1965), and similar reactions involving celestine and strontianite are likely (Chamberlain *et al.*, 1986). Testing of this hypothesis as a mechanism for the origin of the Yate strontianite must await the provision of appropriate isotopic data.

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STRONTIANITE FROM NEAR YATE (AVON)

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Strontianite is recorded from the Yate celestine deposits for the first time. Calcian strontianite has been found encrusting blue celestine crystals found near Leechpool Farm, Yate. X-ray diffraction and electron probe microanalysis both indicate a composition of $\text{Sr}_{0.8}\text{Ca}_{0.2}\text{CO}_3$. An origin by reaction of celestine with late calcium carbonate-rich groundwaters seems likely.

INTRODUCTION

The area around Yate, in Avon, has long been famous for the large deposits of celestine which occur near the Carboniferous/Triassic unconformity. The deposits are thought to have originated by interaction of sabkha evaporites with groundwaters enriched in strontium by dolomitization of the underlying Carboniferous Limestone (Wood and Shaw, 1976). A general account of the geology, mineralogy and genesis of the deposits can be found in Nickless *et al.* (1976). Minerals previously recorded from the deposits are celestine, gypsum, quartz, anhydrite, and calcite.

OCCURRENCE

During the summer of 1984, specimens of celestine were collected from a field about 200m east of Leechpool Farm, on the north side of Tanhouse Lane (ST 7095 8530). According to M. Hall (unpublished B.Sc. report, University of Leicester, 1980) this area has been strip mined for celestine in the past, and has since been reclaimed. The country rocks, not at present exposed, are Lower Coal Measures sandstones and shales, just below the Triassic unconformity (Hall, *op. cit.*). Blocks of white and pale blue celestine are common in this field, particularly in the south-west corner, where an old dump of celestine blocks is present.

Several specimens of pale blue celestine showed small white encrustations on crystal lining vughs; these proved to be strontianite. No such encrustations were seen on white or pink celestine. The strontianite occurs as tiny (<0.5 mm) radiating clusters of acicular, colourless or white crystals. They fluoresce a pale blue under long-wave UV light, and show a weak greenish phosphorescence. Under high magnification, the crystals are steep pseudo-hexagonal bipyramids, probably with the forms {110}, {010} and {hhl}; some are curved (Figure 1). Similar habits are recorded by Speer (1976).

Small spheroids of goethite, commonly clustered, are often associated with the strontianite. Scanning electron microscope photographs show these spheroids to be hollow. These are probably pseudomorphs after pyrite.

Examination of celestine specimens from other localities around Yate failed to reveal any strontianite, although thin calcite encrustations were seen on several vughy celestine specimens.

COMPOSITION OF THE STRONTIANITE

Steep pyramidal forms are often typical of calcian strontianites (Palache *et al.*, 1951, p 197). Speer and Hensley-Dunn (1976) proposed the use of the position of the d_{132} lattice parameter to determine Ca content of strontianites, according to the relationship $\text{SrCO}_3(\text{mol } \%) = -2116.24 + 1162.84(d_{132})$ where d_{132} is measured in angstroms. The value was measured using a diffractometer pattern as 1.887 angstroms. Use of the above relationship gives the composition as $\text{Sr}_{0.78}\text{Ca}_{0.22}\text{CO}_3$. As a check on this result, several strontianite crystals were analysed by electron microprobe, using energy-dispersive spectrometry. Systematic zoning was not seen in any crystal. The mean composition was found to be $\text{Sr}_{0.80}\text{Ca}_{0.20}\text{CO}_3$ with a range from $\text{Sr}_{0.77}$ to $\text{Sr}_{0.82}$ (7 analyses). Thus the agreement between the two methods is very good. No metals other than Ca and Sr were above detection limits.

DISCUSSION

The association of late Sr,Ca,Ba carbonates with primary Sr,Ba sulfates is not uncommon (Mitchell and Pharr, 1961; Speer, 1976; Chamberlain *et al.*, 1986; Baldasari and Speer, 1979). In most cases these have been ascribed to the reaction of primary sulfates with low temperature, carbonate-rich groundwaters. Given the occurrence of late calcite in other celestine specimens from the Yate area, this seems quite likely. The distribution coefficient, D , for the incorporation of Sr into orthorhombic Ca,Sr carbonate is approximately 1 (e.g., Vezier, 1983). Thus the Sr/Ca ratio of the water from which the strontianite crystallized was probably similar to that of the mineral *i.e.*, a molar Sr/Ca ratio of about 4. Such a high ratio must be due to at least partial equilibration of the groundwaters with celestine-rich rocks.

Whether equilibration with celestine would produce waters with molar Sr/Ca = 4 is very doubtful; Wood and Shaw (1976) give the Ca

MILLERITE FROM THE CUMBRIAN COALFIELD

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Crystals of nickel sulfide (NiS) within clay-ironstone nodules in the Coal Measures (Westphalian) of the South Wales Coalfield were first recognised as a new mineral by Miller (1842) and named millerite in his honour by Haidinger (1845). The mineral has subsequently been found at numerous localities throughout the coalfield where its paragenesis is consistent with a diagenetic origin (North and Howarth, 1928). Heddle (1901, p. 25) reported millerite in a similar

paragenesis in clay-ironstone from localities in the Lanarkshire and Ayrshire Coalfields. Millerite has been noted as a minor constituent of low temperature hydrothermal veins at several British localities. These include Combe Martin, Devon, and several Cornish mines (Greg and Lettsom, 1858, p. 296), Glen Sanda, Highland (formerly in Argyllshire; Heddle *op. cit.*, p. 24), Hilton Mine, Cumbria (Bridges, 1982), and at several localities in north-east England (Dearman and Jones, 1967).

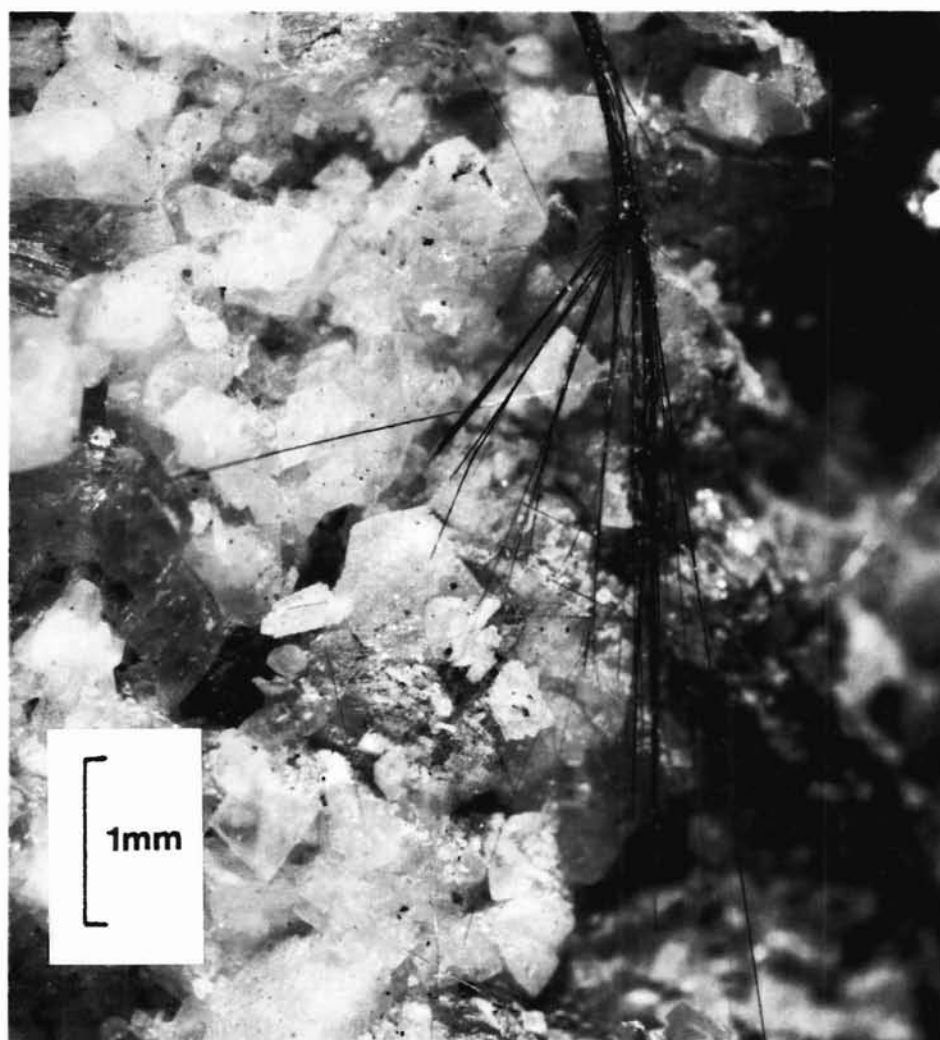


FIGURE 1. Acicular millerite crystals on white calcite and grey siderite; BGS Photo No. MNS 4766.

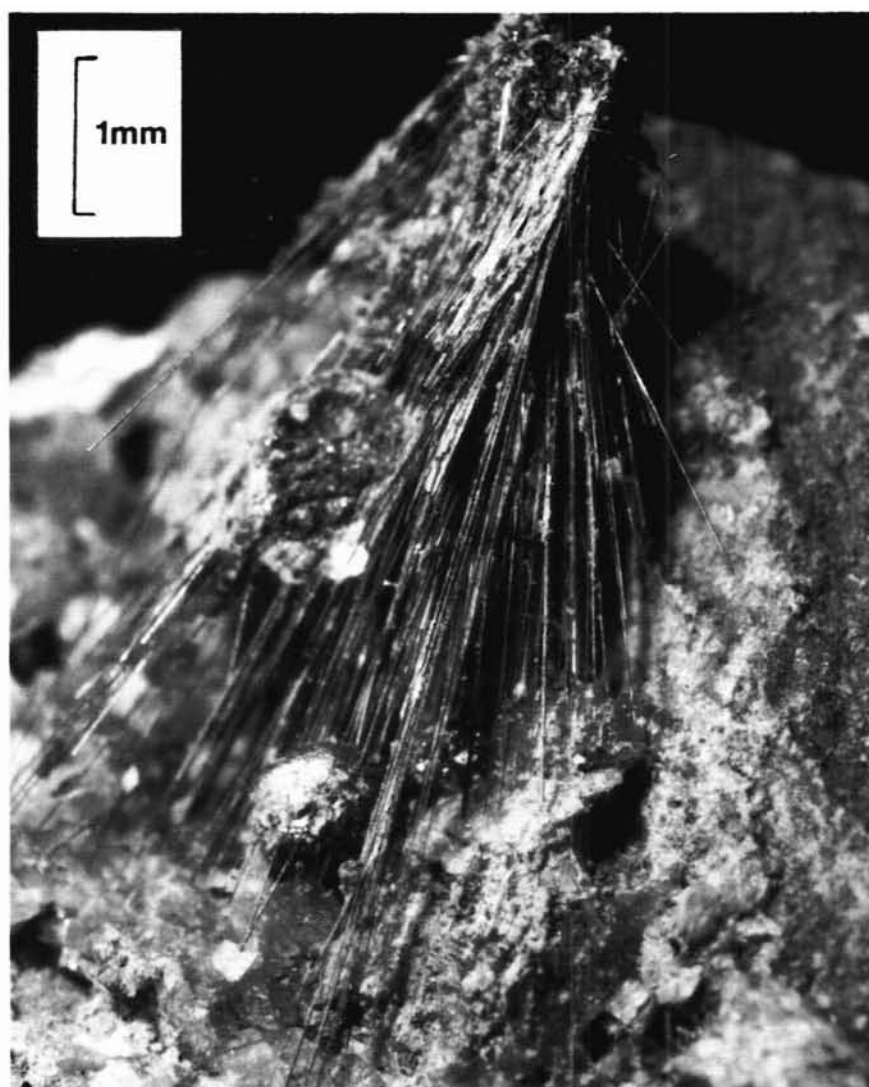


FIGURE 2. Radiating spray of acicular millerite crystals on clay ironstone. Rounded aggregates of pyrite locally overgrow the millerite; BGS Photo No. MNS 4764.

Although some of these vein occurrences are hosted by Coal Measures sediments they are almost all of clearly epigenetic origin. To date, records of diagenetic millerite within clay-ironstone nodules appear to be restricted to South Wales and central Scotland.

Millerite is described here from clay-ironstones within the Middle Coal Measures of Cumbria in a paragenesis which closely resembles that of South Wales.

At Oughterside Opencast Coal Site, near Aspatria, Cumbria [NY 110 398] the interval between the Rattler and Ten Quarters Seams comprises some 6 to 7 m of grey mudstone in which beds of closely spaced, roughly tabular clay-ironstone nodules are common. Several of these nodules exhibit septarian structure with the cracks lined with pale fawn rhombic crystals of siderite

(Ph7355^{*}), small crystals of pyrite and locally white scaly kaolinite (Ph7358). One bed of nodules approximately 4 m beneath the Ten Quarters Seam is up to 0.3 m thick and contains numerous siderite-lined cracks in which millerite (Ph7406) is locally common as characteristic brass-coloured capillary crystals. These occur as plumes of radiating crystals up to 8 mm long and as randomly oriented crystals forming felted masses up to 10 mm across. Individual crystals up to 10 mm long occur grown on, and scattered between, siderite crystals (Fig. 1). Electron microprobe analysis by the energy-dispersive method confirmed the composition as near-pure NiS (above a detection limit of about 0.2 wt%) with very minor Fe (up to about 1.4 wt%) in some analyses, probably due to adjacent pyrite. Analytical totals were low due to the very fine nature of the crystals which mostly

^{*}Numbers shown thus are BGS X-ray numbers.

ranged from 2 to 6 microns in diameter, rarely to 10 microns, in the sample extracted for analysis. The best analysis, obtained on a clean crystal face, totalled 96.87 wt% (62.2% Ni, 34.67% S) giving a formula of $\text{Ni}_{0.98}\text{S}$.

Other sulfides within the millerite-bearing nodules include pyrite, chalcopyrite and, rarely, sphalerite. Of these the commonest is pyrite which commonly forms rounded crystalline aggregates up to 2 mm across. At least some of the pyrite post-dates millerite as several specimens have been obtained in which millerite crystals are clearly overgrown by pyrite (Fig. 2). Chalcopyrite and sphalerite occur as small separate crystals less than 1 mm across encrusting siderite but neither has been seen in contact with millerite. Although several nodule beds in the exposed sections contained pyrite and traces of chalcopyrite, and despite a careful search, millerite was obtained from only this one bed. Neither septarian clay-ironstone nodules nor millerite have been found in any other sections through this horizon elsewhere in Cumbria.

Whereas many of the faults in the Cumbrian Coalfield are locally mineralised with calcite, in places accompanied by pyrite, millerite and other sulfides described here exhibit no obvious connection with any epigenetic mineralisation. Indeed their relationships and occurrences are consistent with a diagenetic origin. The millerite and associated sulfides in the South Wales occurrences have been regarded as the products of diagenesis by North and Howarth (1928). These authors have suggested that the small amounts of nickel, accompanied locally by traces of cobalt, in the South Wales Coal Measures sediment may have been derived from a clastic provenance within older Palaeozoic or Precambrian basic or ultrabasic igneous bodies, perhaps in the SW England province. No obvious source can be suggested for the nickel in the Cumbrian occurrence though it is perhaps worth noting that basic volcanic rocks are present in the lowest Carboniferous sequences of Cumbria and southern Scotland. It is conceivable therefore that erosion of such earlier formed materials could have supplied nickel-bearing sediment.

ACKNOWLEDGEMENTS

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ALUMOHYDROCALCITE FROM SCARBOROUGH, NORTH YORKSHIRE, AND WESTON FAVELL, NORTHAMPTONSHIRE

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Old museum specimens labelled 'scarbroite', from Scarborough, North Yorkshire, were examined by infrared spectrophotometry and found to be, variously, massive scarbroite, massive basaluminite, or massive allophane containing patches of powdery alumohydrocalcite which formed aggregates of thin needles *ca.* 0.06 mm long. Alumohydrocalcite was also identified on modern specimens from Weston Favell, Northamptonshire, occurring between nodules of scarbroite in the infill of solution pipes in Middle Jurassic sandstone. Alumohydrocalcite has not been previously recorded from the British Isles.

INTRODUCTION

Old mineral collections in provincial museums represent a valuable scientific resource, and their preservation and study should be encouraged. Interesting results can emerge from such work, as the example reported here shows. During the current cataloguing of the extensive mineral collection in the Museum and Art Gallery, Maidstone, Kent, several specimens, at least 65-110 years old, of supposed scarbroite from the type locality near Scarborough, North Yorkshire, were checked using an infrared spectrometer. This led to the discovery, on two of the specimens, of the rare mineral alumohydrocalcite, $\text{CaAl}_2(\text{CO}_3)_2(\text{OH})_4 \cdot 3\text{H}_2\text{O}$, which has not been previously recorded from the British Isles. The powdery alumohydrocalcite, which is intimately mixed with allophane and associated with an unidentified carbonate, forms patches in veins of allophane in a ferruginous sandstone. Scarbroite and basaluminite were also identified, but on separate specimens; two specimens in the suite consisted of earthy massive scarbroite, and two others of earthy massive basaluminite.

Subsequently, alumohydrocalcite in a much purer state was also identified on a scarbroite-bearing specimen collected by Dr. R.J. King in 1972 from Weston Favell, Northamptonshire, a new locality for scarbroite described recently (King, 1982).

ALUMOHYDROCALCITE, UNIDENTIFIED CARBONATE, AND ALLOPHANE FROM SCARBOROUGH

Alumohydrocalcite forms irregular white powdery slightly lustrous patches up to several mm across, on and embedded in massive allophane, which varies in appearance from white or cream, opaque and earthy to colourless, subtransparent and vitreous. On specimen No. 169.A*, which is *ca.* 3 x 3 x 2 cm in size, the two minerals form a sharply defined vein 4 mm thick in a fine grained

ferruginous sandstone, with allophane predominating. Specimen No. 168 is essentially similar but with matrix on one side only. Under high magnification the purer samples of alumohydrocalcite are seen to consist largely of particles <0.08 mm across, with a parallel or slightly divergent fibrous structure. The individual fibres are extremely thin, on average 0.06 mm long, and show approximately straight extinction.

Since infrared spectra of this material did not match those of available reference minerals, a sample (off No. 168) was kindly examined by X-ray diffraction at the British Museum (Natural History) and identified as alumohydrocalcite containing some impurities of uncertain nature (X-ray No. 3966F). An authentic sample of fibrous alumohydrocalcite from Chitral, Pakistan (Parr and Ruschka, 1977) made it possible to compare its infrared spectrum with that of the material from Scarborough.

The infrared absorption spectrum of alumohydrocalcite from Chitral is quite distinctive (Fig. 1, spectrum D), and shows absorption bands due to O-H and H_2O (3360, 3140, 2930, 1670 cm^{-1}), CO_3 (1545, 1520, 1420, 1400 cm^{-1}), and characteristic but unassigned OH, CO_3 and Al-O vibrations below 1200 cm^{-1} . The powdery material from Scarborough on specimens 168 and 169.A exhibits the absorption bands of alumohydrocalcite superimposed on broad absorption bands in the 3300-3500, 1500-1600, 900-1100, and 500-700 cm^{-1} .

1 regions, which are consistent with the presence of admixed allophane (Fig. 1, spectrum B). No material tested gave a spectrum of pure alumohydrocalcite, and further sampling revealed another complication, in that some samples of superficially similar material showed a different infrared absorption pattern (Fig. 1, spectrum A). While resembling in some respects that of alumohydrocalcite, the new spectrum showed marked differences (especially in the 3000-3600,

*Numbers refer to the new Maidstone Museum catalogue of minerals.

1600-1700, 1400-1550, and 1000 cm^{-1} regions) suggesting that the mineral may have a higher $\text{CO}_3:\text{OH}$ ratio than alumohydrocalcite. Such spectra, some showing admixed allophane, were observed on samples taken from specimens Nos. 168 (on which alumohydrocalcite had already been identified), 169.B (very similar to 169.A, above), and 170 (matrix-free slightly iron-stained white earthy mass, *ca.* 4.5 x 3 x 1 cm in size, containing subordinate patches of allophane). This mineral, or perhaps a mixture, remains unidentified at present.

The unidentified carbonate is more fine grained than the alumohydrocalcite but otherwise resembles it in microscopic appearance, consisting of parallel aggregates of very thin fibres <0.02 mm long.

Embedded in the white powdery material and attached to fracture surfaces in allophane, especially on specimen No. 169.A, are scattered bunches and rosettes of pure white silky fibres up to 0.2 mm long. These are perhaps alumohydrocalcite in larger crystals, but the amounts were too small for positive identification.

Allophane was identified by its amorphous appearance and low refractive index under the microscope, density *ca.* 1.88 (by flotation), and an infrared spectrum showing broad rounded absorption bands matching those of earthy allophane from Charlton, Greenwich, London (Whitaker, 1889). It does not effervesce in dilute hydrochloric acid.

There was no evidence of the presence of any substantial amounts of kaolinite group silicates, gypsum, calcite, or gibbsite, all of which have been noted as associates of alumohydrocalcite at other localities. The appearance of the Scarborough specimens suggests that alumohydrocalcite was here formed by the alteration of allophane, as has been proposed for some of its other occurrences (e.g. Kautz, 1968; Srebrodolskii, 1974). This would have involved addition of Ca and CO_2 and removal of silica. Although allophane has not been recorded at Scarborough, irregular masses of allophane occur in similar situations elsewhere, e.g. at or near the junction between Eocene sandstones and Chalk at localities in S.E. England

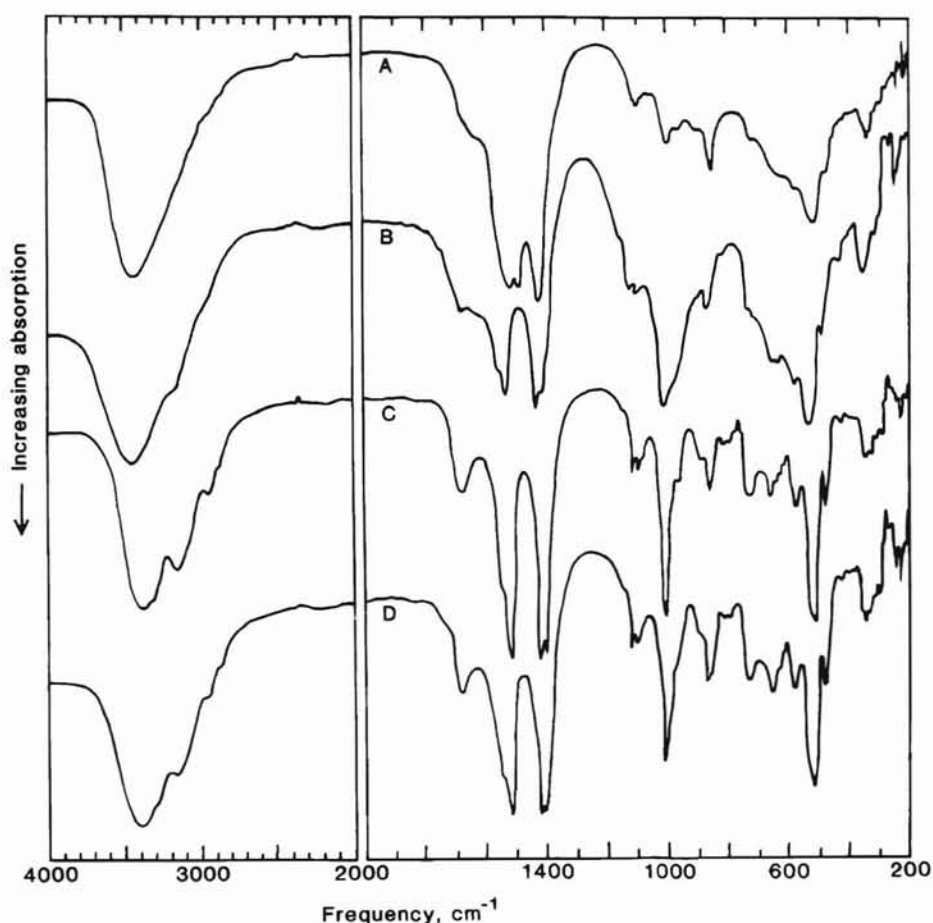


FIGURE 1. Infrared spectra (CsI pressed discs; successive spectra are displaced vertically). A: unidentified carbonate, Scarborough (Maidstone Museum specimen No. 169 B); B: mixture of alumohydrocalcite & allophane, Scarborough (Maidstone Museum specimen No. 168); C: alumohydrocalcite, Weston Favell (R.J.King Collection specimen No.K8183-72, now National Museum of Wales specimen NMW 83.41G.M9413); D: alumohydrocalcite, Chitral, Pakistan (*ex* W.H.Paar).

(Whitaker, 1889; Chandler, 1909; and specimens in the British Museum (Natural History)).

SCARBROITE AND BASALUMINITE FROM SCARBOROUGH

Two of this series of specimens proved to be scarbroite (Nos. 166 and 167). Both are matrix-free, pure white and opaque, compact, chalk-like irregular masses with knobbly iron-stained surfaces, and are clearly portions of veins or flattened nodules of maximum thickness *ca.* 18 mm. Small fragments of this scarbroite indicated a density of *ca.* 2.01 (by flotation), dissolved almost completely in dilute hydrochloric acid with effervescence, and gave infrared spectra matching those of authentic scarbroite from Weston Favell, Northamptonshire, supplied by Dr. R.J. King. There seemed to be no gibbsite or other identifiable impurities, although the infrared method would probably not detect these in amounts of less than a few percent. When heated at 195°C for one hour, both the Maidstone Museum sample and the reference sample showed the same characteristic change in the infrared spectra. In the range 1100-4000 cm^{-1} these spectra of unheated and heated samples were similar to the spectra of scarbroite and of scarbroite heated to 248°C, respectively, published by Duffin and Goodyear (1960). However, below *ca.* 1100 cm^{-1} , the scarbroite spectrum of Duffin and Goodyear, which extends only to *ca.* 715 cm^{-1} , is less detailed while that of the heated scarbroite shows a broad blanketing absorption not observed in this study.

Basaluminite on the Maidstone Museum specimens is also white, opaque, earthy, and unaccompanied by other minerals. On specimen No. 171 it forms a sharply defined vein 6-9 mm thick in a medium to coarse ferruginous sandstone; abundant tiny patches of apparently the same mineral occur interstitially in the sandstone. Specimen No. 172 consists of three fragments of a 1-4 mm thick basaluminite vein with some adhering fine grained ferruginous sandstone. Basaluminite was identified by comparison of its infrared spectrum with those of reference material from Newhaven, Sussex (kindly provided by Mr. B. Young; see Wilmot and Young, 1985) and Chickerell, Dorset (Clayton, 1980). On being dehydrated at 195°C for 1 hour, samples from all three localities exhibited the same characteristic change in infrared absorption pattern.

Basaluminite is another mineral not previously observed at Scarborough, but one that could readily occur in such an environment. When aluminium-bearing solutions percolate into underlying strata, which of the aluminium oxides, sulfates or carbonates is precipitated would depend on the exact chemical and physical

conditions at the time of deposition, and these could vary over short distances (cf. Clayton, 1980; King, 1982; Wilmot and Young, 1985).

FURTHER COMMENTS ON THE SPECIMENS FROM SCARBOROUGH

The historical information on these specimens is unfortunately fragmentary. Old handwritten labels stuck to specimen Nos. 166, 167, 168, 169.A, 170, and 171 are worded either "Scarbroite. Scarbro." or "Scarbroite. Hyd. Sil. Aluma. White Nab, Scarbro." (Scarbro is an abbreviation for Scarborough). No. 169.B and the three pieces comprising No. 172 are unlabelled but clearly belong to the suite. Specimens 168 and 169.A bear numbers matching entries in a catalogue of Maidstone Museum minerals compiled in the 1880's, and No. 168 carries an additional number matching an entry in a catalogue compiled in 1876. These catalogues give only the locality and the donor. Specimen No. 171 was donated in 1910.

All these were presented by Corbet Stacey Catty, Esq., of Southsea, Hampshire, who had family connections in Maidstone and was a keen collector of natural history objects, especially minerals. He was a regular donor of minerals to Maidstone Museum from before 1876, and finally presented his entire extensive collection, which included one cabinet of specimens formerly belonging to Professor Arthur Connell of St. Andrews University, to the museum in 1921. The labels referred to above vary in shape and style but are all in the handwriting associated with other Catty specimens. It is unfortunately not known whether Catty collected the "scarbroite" specimens himself or acquired them, whether they were collected all at the same time or on different occasions, or indeed whether they came from the same cliff section.

A further search in Maidstone Museum has produced a group of Catty specimens labelled "Websterite, Newhaven" [Sussex] two of which, donated before 1876, proved to consist of earthy basaluminite associated with gypsum and calcite. Basaluminite was not, in fact, known to occur at this locality until recently (Wilmot and Young, 1985). It is significant that these specimens are quite different from the basaluminite specimens from Scarborough in appearance and associations.

Thus it is possible that the specimens described in this paper did come from the type locality for scarbroite (King, 1982), and the appearance of those with matrix does not contradict their origin, but some uncertainty must remain. Suppliers of specimens for collectors' "cabinets" sometimes filled a demand for desirable rare species by using any similar-looking material, from any locality.

And there is evidence that as a mineralogist Catty was at times incompetent or gullible, in spite of possessing a very fine collection. Thus a specimen of crocoite in his collection is labelled "Crystallised Realgar", one of manganite as "Antimonite" [stibnite], and one of columnar diopside (from the Alps?) as "Bacillary Diopside. Emerald Copper. Kirghese Steppes, Tartary.". Furthermore, we are seeing these specimens at least 65 to 110 years after collection, and they may have undergone changes during storage, e.g. reaction with atmospheric carbon dioxide or vapours from storage cases, in addition to dehydration. In view of this and the lack of data on their exact occurrence further work does not seem to be warranted, although a re-examination of the exposures at Scarborough could prove fruitful. It is fortunate, therefore, that a second, modern occurrence of alumohydrocalcite can now be reported.

ALUMOHYDROCALCITE FROM WESTON FAVELL

The occurrence near Weston Favell, Northamptonshire, of scarbroite nodules in solution pipes in Middle Jurassic sandstone unconformably overlain by Pleistocene boulder clay was reported recently (King, 1982); the paper included a photograph of a large scarbroite-bearing specimen (R.J. King No. K8183-72, now National Museum of Wales No. NMW 83.41G.M9413). Dr R.J. King kindly provided samples of material occurring between the prominent scarbroite nodules on this figured specimen, and some were found to contain alumohydrocalcite.

One sample consisted of a loose powdery aggregate of almost pure alumohydrocalcite (see Fig.1, spectrum C) with small amounts of other material which could be readily removed under the microscope. The alumohydrocalcite formed small (<1 mm) pure soft white masses with a silky lustre, and under high magnification resembled the Scarborough material described above, the visible ultimate structural units being extremely thin fibres 0.01-0.02 mm long. Other samples were more heterogeneous and the components included, in addition to alumohydrocalcite, a grey opaque dull earthy mineral tentatively identified as halloysite. It is interesting that the less hydrated form, metahalloysite, is sometimes found in infilled solution pipes, e.g. near Brassington, Derbyshire (Ford, 1963), and that associations of alumohydrocalcite with metahalloysite and other clay minerals (kaolinite, dickite) have been reported (e.g. Kautz, 1968; Parr and Ruschka, 1977; Popov, 1972).

Further work on the minerals accompanying scarbroite at Weston Favell, and their relationships, is in progress.

ACKNOWLEDGEMENTS

I am grateful to the authorities of Maidstone Museum and to Mr E. Philp, Curator of Natural History, for access to the museum collection; to Miss E. Fejer, British Museum (Natural History) for the X-ray identification; to Dr R.J. King, Professor W.H. Parr, and Mr B. Young for supplying specimens; and to Shell Research Ltd. for the use of a spectrophotometer.

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COPPER(II) PHOSPHATE MINERALS FROM THE MIGUEL VACAS MINE, ALENTEJO, PORTUGAL.

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INTRODUCTION

The Miguel Vacas mine is situated to the south-east of Vila Viçosa in the Alentejo region of Portugal (Fig. 1), some 200 km east of Lisboa (Lisbon). Although the region is well-known for its current marble production, it is less generally appreciated that it also plays host to a large number of small copper deposits and prospects which have been worked sporadically in the past. Elsewhere in the Alentejo, copper mining represents a major industrial activity. Locations of copper prospects and abandoned mines to the south-east of Vila Viçosa are also marked on Fig. 1. These are erroneously referred to as iron deposits on the geological survey map of the area (Perdigão, 1976). Bugalho and Mocissos were the most important centres apart from Miguel Vacas itself.

Secondary copper phosphate minerals are particularly pronounced in the oxide zone of the Miguel Vacas mine. In particular the individual crystals and groups of libethenite found towards the base of the zone represent some of the most magnificent examples of that mineral which have ever been found.

GEOLOGICAL SETTING

The Miguel Vacas deposit is located in Silurian schists and phyllites close to the contact with a lenticular outcrop of the Vila Viçosa Group of Cambrian rocks chiefly composed of schists, quartzites and calcareous members. Concerning the latter, which are particularly prominent just to the west of the mine, metamorphism has led to the formation of large bodies of marble which are now extensively exploited. The main axis of the lenticular Cambrian unit coincides with the crest of a major anticline striking N25°W and whose flank in the vicinity of the mine dips subvertically. Parallel to this structure, in both easterly and westerly directions, successive synclines and anticlines are developed.

While the general geological setting has been described elsewhere (see Perdigão, 1976), little information is available concerning the Miguel Vacas mine. We rely here on our own observations and on an internal report prepared by the company which has most recently undertaken mining operations.

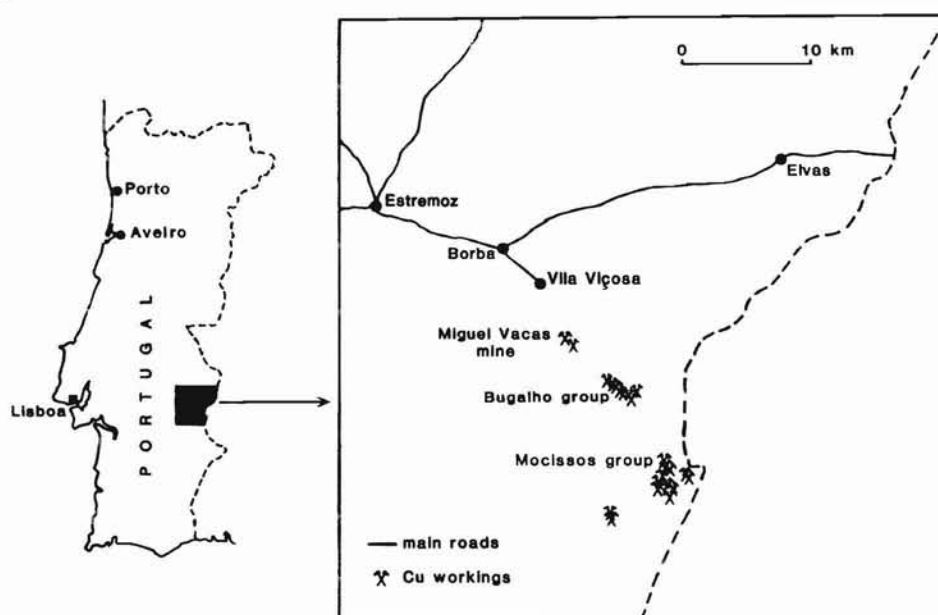


FIGURE 1. Location of the Miguel Vacas Mine and other copper prospects in eastern Portugal.

In the immediate vicinity of the deposit, the Silurian host rocks dip at about 80°E and are composed of grey schists, heavily graphitized schists, and black cherts. Mineralisation is essentially confined to an extensive and well-developed vein system approximately 25 m thick, striking about N-S and dipping 70°E. It may be traced on the surface for over 2000 m. This mineralized zone is structurally complex and consists of the main vein referred to above with an imbricate aspect in certain sections, together with separate parallel tabular veins. Structural elaboration is more pronounced in the hanging wall. At depth, the main shear zone does not intersect the Cambrian rocks lying parallel to the outcrop of the vein and some 70 m distant, as revealed by a drilling programme.

The shear zone is filled with a schist and quartz breccia. In the primary ore zone encountered at a depth of about 80 m from the surface, sulfides are largely confined to the quartz breccia which also contains silicified dolomite from time to time. Only chalcopyrite and pyrite have been observed as primary sulfides, the latter not being very abundant. No sulfides are exposed in the present open cast or are present in the surface dumps. Minor Pb and Zn grades have been recorded in bulk samples of oxide zone ore, but no discrete minerals of these elements have been noted in any section of the deposit.

In all exposed sections, every trace of sulfides has been obliterated and only oxidized ore remains. Secondary copper minerals are found in both the quartz and schist breccias, as well as impregnating adjacent zones of the host rocks. At depths of less than about 30 m little copper

mineralization is present, being confined to staining on exposed sections and a few patches of poorly crystalline malachite. Copper phosphate minerals are confined to depths greater than about 30-35 m and are prominent in the deepest levels developed in the open cast. It has been reported that malachite, libethenite, chrysocolla, atacamite and covellite are present in the oxide zone, but of these we have observed only the former two with any certainty. Iron and manganese oxyhydroxides are common in the oxidized zone and a well-developed gossan is exposed (Fig. 2) after massive sulfide veins contained within the main fault.

HISTORY

Legend has it that the Romans worked copper in the district, but no evidence to prove this contention is available. Indeed, copper mining may go back to even earlier dates. However, remains of ancient mining activity in the area have been reported (Cerveira, 1972). Concerning more recent activity, the only information that has been uncovered is contained in internal company reports, now in the archives of the Direcção Geral de Geologia e Minas in Lisbon (Metello, 1925; Cerveira, 1972; da Silveira, 1986).

A lease on the deposit was taken up by one J. Norton Nogueira in 1922 and transferred to G.F. Norton and Co., in 1923. An active exploration and development programme was commenced entailing the development of a 508 m crosscut adit to the lode at the 42 m level. About 75 m of driving on the lode was carried out with crosscuts to the hanging and footwalls of the main structure. Three shafts for ventilation and extraction purposes were

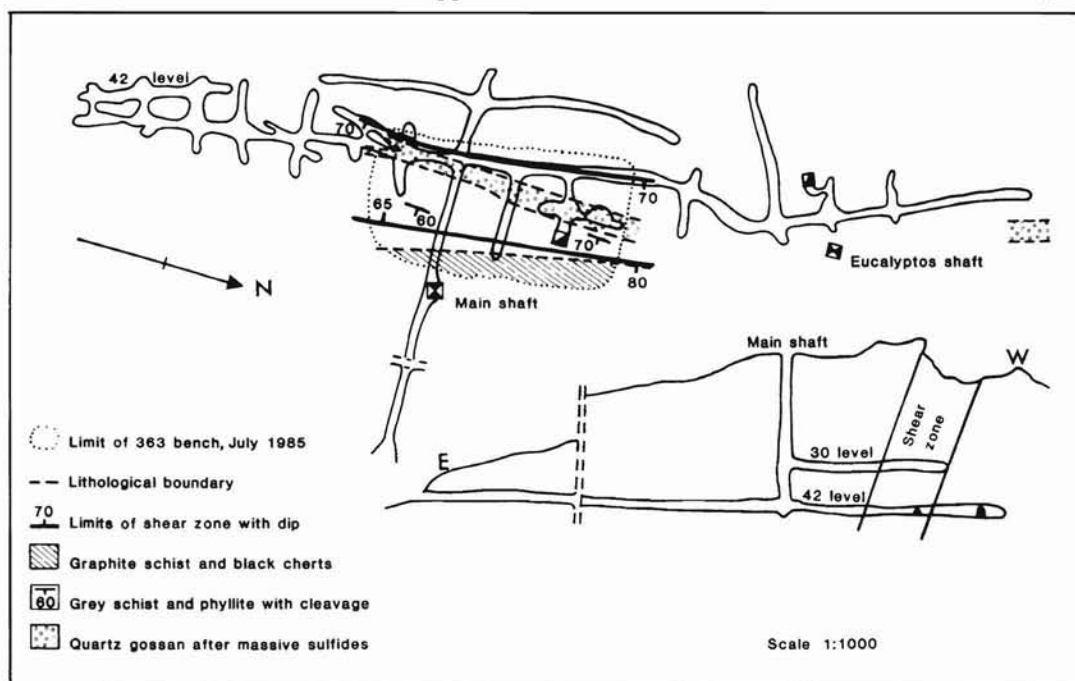


FIGURE 2. Geology of the 363 bench open cast, Miguel Vacas, July 1985. This bench intersects the workings of the 42 m level which are projected onto the plan.



FIGURE 3. Libethenite crystals (L) to 5 mm with later botryoidal pseudomalachite (P) masses, Miguel Vacas Mine. National Museum of Wales specimen NMW 85.46G.M19.

also developed and some driving was commenced at the 30 m level. Little and irregular production was recorded until the venture ceased operations in 1940 and the mine was declared abandoned in 1943. Adriano Domingos Galo took up the lease in 1948 and the American Smelting and Refining Co. carried out limited exploratory work. Between 1950 and 1953 minor amounts of concentrates were produced and the lease was transferred to EMIL (Empresa de Mineração SARL) in 1956. Irregular exploration and evaluation of the deposit continued, some of which was carried out by the Canadian firm Mining Exploration International. In 1979 the lease was acquired by MINARGOL (Complexo Mineiro de Arcozelo) which carried out further exploration in and around the deposit. As a result, open cast operations were commenced in the oxide zone with a view to leaching the richer oxide zone ore. Operations are currently suspended.

SECONDARY COPPER MINERALS

Little secondary copper mineralization is found above the 42 m level developed by G.F. Norton and Co., in the 1920's (Fig.2). In July 1985, the lowest bench in the open pit (363 bench) intersected the 42 m level workings. Figure 2 shows the geology of the bench together with a projection of the workings on the 42 m level. A well-defined shear-zone striking N-S and dipping variably, but about 70-80°E, is exposed. The footwall is clearly defined; shear gouging grades off into the hanging wall. Pre-existing sulfides are represented by a prominent quartz-rich gossan which clearly outlines the former position of a

massive sulfide vein. Its location in a higher bench is also marked on the plan. The sulfide vein branches at the south end of the 363 bench. Secondary minerals are not confined to this vein but are widely dispersed in the shear zone and impregnate sections of the graphite schists and cherts in the hanging wall.

LIBETHENITE, $\text{Cu}_2\text{PO}_4(\text{OH})$

Libethenite is the earliest secondary copper mineral to form. The largest crystals were found at the southern end of the 363 bench. Here, the grey schists have been thoroughly shattered in the fault zone and gaps up to 3 cm wide remain in the phyllites/schists over the area between the gossan and the hanging wall contact. This brecciated mass has been coated with goethite, hematite and unidentified manganese oxyhydroxides on exposed surfaces. Subsequently, libethenite has crystallized on these surfaces. Magnificent crystals up to 1 cm in the form of tetragonal bipyramids may occur alone (Fig. 3), but are sometimes accompanied by small blue spherules and coatings of later pseudomalachite.

Smaller crystals of libethenite are found in the graphite schists at the northern end of the bench. At this site a well-defined zone about 2 m wide yielded brilliant drusy crusts of almost black crystals up to 2 mm coating the schists along cleavage planes.

The occurrence represents some of the finest examples of the mineral that have ever come to light. The quality of the crystals ranks with other notable cases such as the Rokana mine, Zambia (Korowski and Notebaart, 1978) and the Burra mine, South Australia (Bywater, 1984).

PSEUDOMALACHITE, $\text{Cu}_3(\text{PO}_4)_2(\text{OH})_4 \cdot \text{H}_2\text{O}$

At least two generations of pseudomalachite are present on the 363 bench. Single crystals have not been observed, but the mineral is certainly crystalline and gives a sharp X-ray diffraction pattern. The mode of occurrence, as noted above, is as small spherules up to 2 mm which merge to form botryoidal masses and sheets. Much pseudomalachite is present in the N end of the 363 bench especially in the quartz gossan and breccia. Occasionally, a second generation of small spherules is seen to overlie the first, particularly when the latter have merged into sheet-like masses. The later material is somewhat paler in colour. However, the most handsome specimens, of micro size, are found in the southern end of the bench associated with the earlier libethenite. Particularly beautiful specimens are found here comprising balls of pseudomalachite perched on transparent flawless quartz crystals.

MALACHITE, $\text{Cu}_2\text{CO}_3(\text{OH})_2$ and AZURITE, $\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$

Malachite patches and stains are found above the 363 bench. On this level, it frequently is seen to replace pseudomalachite, but never libethenite (*vide infra*). Radiating bands of malachite after pseudomalachite are common and complete replacements have been observed. Azurite is confined to the northern end of the 363 level in the schist breccia adjacent to the graphite schist. Crystals are small, rarely exceeding 3 mm, and are implanted on hematite and goethite coatings on breccia fragments. Early libethenite is found together with azurite in the zone, both minerals presenting bright, reflecting crystal faces, but azurite is clearly the younger phase; a few libethenite bipyramids have single crystals of azurite perched on faces. Minor alteration of azurite to malachite has been noticed on a number of specimens.

MINERAL CHEMISTRY

The chemistry of formation of copper (II) phosphate minerals has been described (Magalhães *et al.*, 1986). Some additional solubility experiments have been carried out for libethenite, pseudomalachite and cornetite, and results are given in Table 1. Equilibrium calculations such as those which have been carried out here can be useful for an understanding of the chemical conditions under which certain mineral assemblages can form. The standard Gibbs free energy of formation of any species at a given temperature is a measurement of its overall stability with respect to the elements of which it is composed. Values of this parameter for minerals and ions may be related to give conditions under

which certain minerals will be stable with respect to others. The overall standard free energy charge for a reaction at a given temperature may be related to the equilibrium constant for that process. This information may be used in turn to indicate whether or not a particular reaction will take place under certain conditions (e.g. of concentrations of reactants and products, including, in this case, $\text{H}^+(\text{aq})$, $\text{H}_2\text{PO}_4^-(\text{aq})$, $\text{Cu}^{2+}(\text{aq})$ ions).

Calculations using the data were performed in exactly the same way as previously and lead to further refined values for $\Delta fG^\circ(298.2\text{K})$ for libethenite, pseudomalachite and cornetite of -1224.4 ± 3.2 , -2832.8 ± 5.0 and -1603.0 ± 2.8 kJ mol⁻¹, respectively.

None of the conclusions reached in our previous account are altered by this additional new work. We have chosen a more reasonable value for $\Delta fG^\circ(298.2\text{K}, \text{Cu}_3(\text{PO}_4)_2, \text{s})$ equal to -2051.3 kJ mol⁻¹ (Wagman *et al.*, 1969), and a slightly modified stability field diagram for the phosphate minerals is shown in Figure 4.

In connection with the Miguel Vacas deposit, libethenite was the earliest copper(II) phosphate formed. It crystallized under reasonably acidic conditions. Hydrogen ions generated by the oxidation of sulfides (principally pyrite) and the hydrolysis of Fe(III) ions to produce, ultimately, goethite were subsequently neutralized. The elevation of pH gave rise to conditions which permitted the later crystallization of pseudomalachite.

A rather interesting situation arises when the effects of carbon dioxide on the system are considered. This has some bearing on other occurrences of copper phosphate mineralization.

TABLE 1

Experimentally determined solubilities^a of libethenite, pseudomalachite and cornetite at 298.2K in $8.736 \times 10^{-4}\text{M}$ aqueous HClO_4 .

Mineral	10^4 Solubility/ mol dm ⁻³	pH
libethenite	2.428	4.23
	2.437	4.54
	2.536	4.37
	2.405	4.68
pseudomalachite	0.893	4.21
	0.915	4.31
	0.905	4.32
	0.822	4.36
	0.913	4.31
	0.911	4.17
cornetite	1.483	4.27

^aIn addition to values already reported in Magalhães *et al.* (1986).

In order to take these effects into account values for the solubility products of azurite and malachite, and free energies of formation of appropriate solution species at 298.2K have been taken from critical compilations (Smith and Martell, 1976; Robie *et al.*, 1978), as have equilibrium constants for the interchange of carbonate species in solution and of $\text{CO}_2(\text{g})$.

We have chosen to compute phase boundary changes in terms of the activity of $\text{H}_2\text{CO}_3^0(\text{aq})$. The activity of this species is pH-independent and with $\text{pH} < 7$ no problems arise with respect to total dissolved carbonate concentrations. Figure 5 shows stability fields for the relevant minerals between pH 3 and 7 (H_2PO_4^- is the predominant aqueous phosphate species over the range) and for an activity of $\text{H}_2\text{PO}_4^- = 10^{-4}$ to 10^{-8} . In terms of these diagrams it is worth pointing out that libethenite will only crystallize from solutions containing comparatively elevated concentrations of phosphate species. This fact is inherent in the diagram of Figure 4, but it is not necessarily obvious. It is immediately apparent from the diagrams as to why neither azurite nor malachite is seen to replace libethenite. Under no conditions does this mineral share a boundary with either carbonate. With reference to Figure 5, it should be noted that the greatest partial pressure of $\text{CO}_2(\text{g})$ achievable is 10^5 Pa (1 atm) and this corresponds to an activity of $\text{H}_2\text{CO}_3^0 = 10^{-1.46}$. As phosphate levels fall, carbonate species encroach on the stability fields of the phosphates. Pseudomalachite may alter to azurite directly or to malachite, *via* cornetite, but over a range of solution conditions which change only a little. On the other hand, the alteration sequence pseudomalachite to azurite to malachite is a thermodynamically simple course. Furthermore libethenite cannot alter directly to a carbonate. It must dissolve completely or alter to pseudomalachite prior to subsequent replacement by azurite or malachite. However, if the crystals of libethenite are large, as in the Miguel Vacas deposit, this re-equilibration might be expected to occur quite slowly, thus permitting the occurrence of azurite, malachite and libethenite in the same environment, but under kinetic control. This being the case, it is clear from a chemical point of view as to why the libethenite crystals are preserved with such pristine forms as found in the Miguel Vacas deposit and elsewhere (Palache *et al.*, 1951) even when they have been in obvious contact with groundwaters charged with carbonate.

With these points in mind it is worth recalling the observations of Baywater (1984) on pseudomorphs in the libethenite zone at Burra, South Australia. Azurite as sharp royal-blue crystals or as massive vein replacements after libethenite was reported as was malachite after libethenite "as deep green replacements to 5 mm, frequently intermingled with azurite in the same

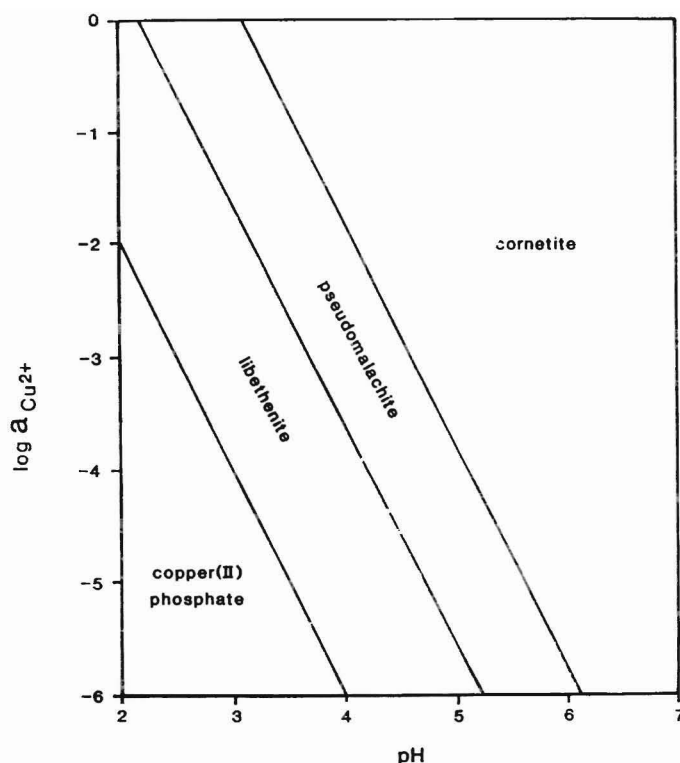


FIGURE 4. Stability field diagram for the copper phosphate minerals.

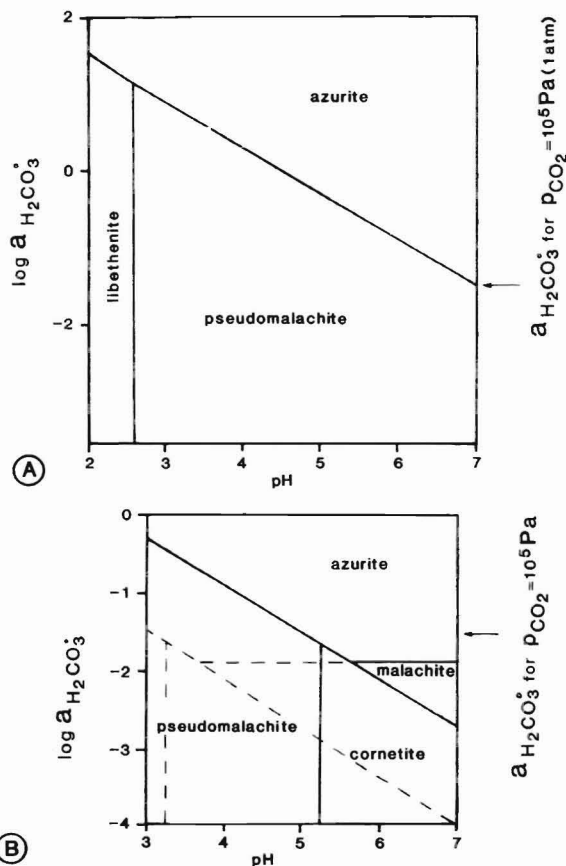


FIGURE 5. Effect of $\text{H}_2\text{CO}_3^0(\text{aq})$, or the partial pressure of $\text{CO}_2(\text{g})$, on the relative stabilities of the copper phosphate minerals. A: dihydrogen phosphate activity = 10^{-4} ; B: dihydrogen phosphate activity = 10^{-6} (firm lines) and 10^{-8} (dashed lines).

crystal. Pseudomalachite is also believed to have pseudomorphically replaced libethenite, however, this remains unsubstantiated." The chemical studies and calculations reported above point to the fact that the last comment is most probably true and that these pseudomorphs represent replacements not of libethenite directly, but of pseudomalachite after libethenite.

ACKNOWLEDGEMENTS

We wish to thank the staff of MINARGOL for permission to study the deposit at Miguel Vacas. Special thanks are also due to Eng. N. M. da Silva of the Direcção Geral de Geologia e Minas, Lisbon, for his help in locating historical material. We would also like to thank INIC (Centro de Química do Meio Aquático da Universidade de Aveiro) for financial support.

MATERIAL FOR STUDY

A suite of the minerals from the Miguel Vacas mine has been deposited in the Department of Geology, National Museum of Wales, and in the Department of Geosciences, University of Aveiro.

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ROSASITE FROM BUTE QUARRY, MID GLAMORGAN. THE FIRST REPORTED OCCURRENCE IN WALES.

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INTRODUCTION

During the recent resurvey of the Brigend Sheet by the British Geological Survey, secondary copper minerals were identified within calcite-lined vugs at Bute Quarry (Grid ref. ST 0525 8150). These were identified by X-ray diffraction and chemical analysis as rosasite $(\text{Cu,Zn})_2\text{CO}_3(\text{OH})_2$, aurichalcite $(\text{Zn,Cu})_5(\text{CO}_3)_2(\text{OH})_6$, and zincian malachite. Subsequently the same assemblage was encountered at a depth of 35 m in a borehole at Locks Common, Porthcawl (Grid ref. SS 8168 7648). Both mineral localities are contained within Carboniferous Limestone (Dinantian).

The majority of the known metallic mineralization in the Vale of Glamorgan is found either in veins cutting the Carboniferous Limestone or in interstitial cements and replacements in the overlying Triassic and Jurassic conglomerates, breccias and limestones. In both cases the dominant mineralogy is galena-calcite-barite, with little or no copper or zinc mineralization. This may suggest that the copper/zinc occurrences at Bute Quarry and Porthcawl are the result of a separate phase of mineralization or that there is some form of zonation within the ore field.

GEOLOGY OF THE LOCALITIES

Both mineral localities occur within the Carboniferous Limestone (Dinantian) sequence of the Vale of Glamorgan. Samples have been donated to the National Museum of Wales, Bute Quarry registration number NMW 86.28G.M1 and Locks Common borehole registration number NMW 86.28G.M2.

Bute Quarry is an abandoned limestone quarry which has been partially filled with colliery waste; however the main faces are still well exposed. The limestones belong to the Hunts Bay Oolite (Waters and Wilson, 1983) of Holkerian age, which forms part of a well defined shelf-carbonate sequence (Figure 1). To the north the Carboniferous Limestone is unconformably

overlain by Triassic conglomerates and breccias of the Mercia Mudstone Group.

The Hunts Bay Oolite consists of approximately 185 m of well bedded pale grey, fine to coarse-grained oolitic packstone-grainstones and grainstones, locally interbedded with micrites and thin pellety or bioclastic limestones (Waters and Wilson, 1983). Although there is no pervasive dolomitization, some of the beds appear to be preferentially dolomitized.

The sequence is cut by a series of NNW-trending normal faults, one of which is situated just to the east of Bute Quarry (Figure 1). Most of these faults have limited throws, although the Miskin Fault, lying to the west, has a throw in excess of 200 m. Some of the faults are associated with base-metal mineralization.

The secondary copper minerals are associated with a series of calcite-lined vugs which occur at distinct levels within the dolomite beds. The vugs may attain 50 cm across, but the majority are much smaller (Figure 2). The shapes of the vugs appear to have been controlled by bedding and subvertical fractures. Their margins are rather diffuse with saccharoidal dolomite interfingering with the calcite of the vugs. Galena, sphalerite and chalcopryrite are concentrated along these marginal zones, together with secondary zincian malachite and rosasite. Crystalline aurichalcite is concentrated mainly between the larger calcite crystals within the central part of the vugs.

The vertical boreholes at Locks Common, Porthcawl, intersected sub-horizontal Oxwich Head Limestone of Asbian/Brigantian age (Davies, 1982). The sequence consists of skeletal packstone units separated by palaeokarst surfaces. Between 33.63 and 36.06 m the limestones are dolomitized, brecciated and veined by wide subhorizontal calcite veins, and at around 47 m there is a narrow subvertical calcite vein. The margins of these veins contain sphalerite and chalcopryrite together with secondary zincian malachite, rosasite, and azurite. Crystalline aurichalcite again occurs in the voids between the calcite crystals.

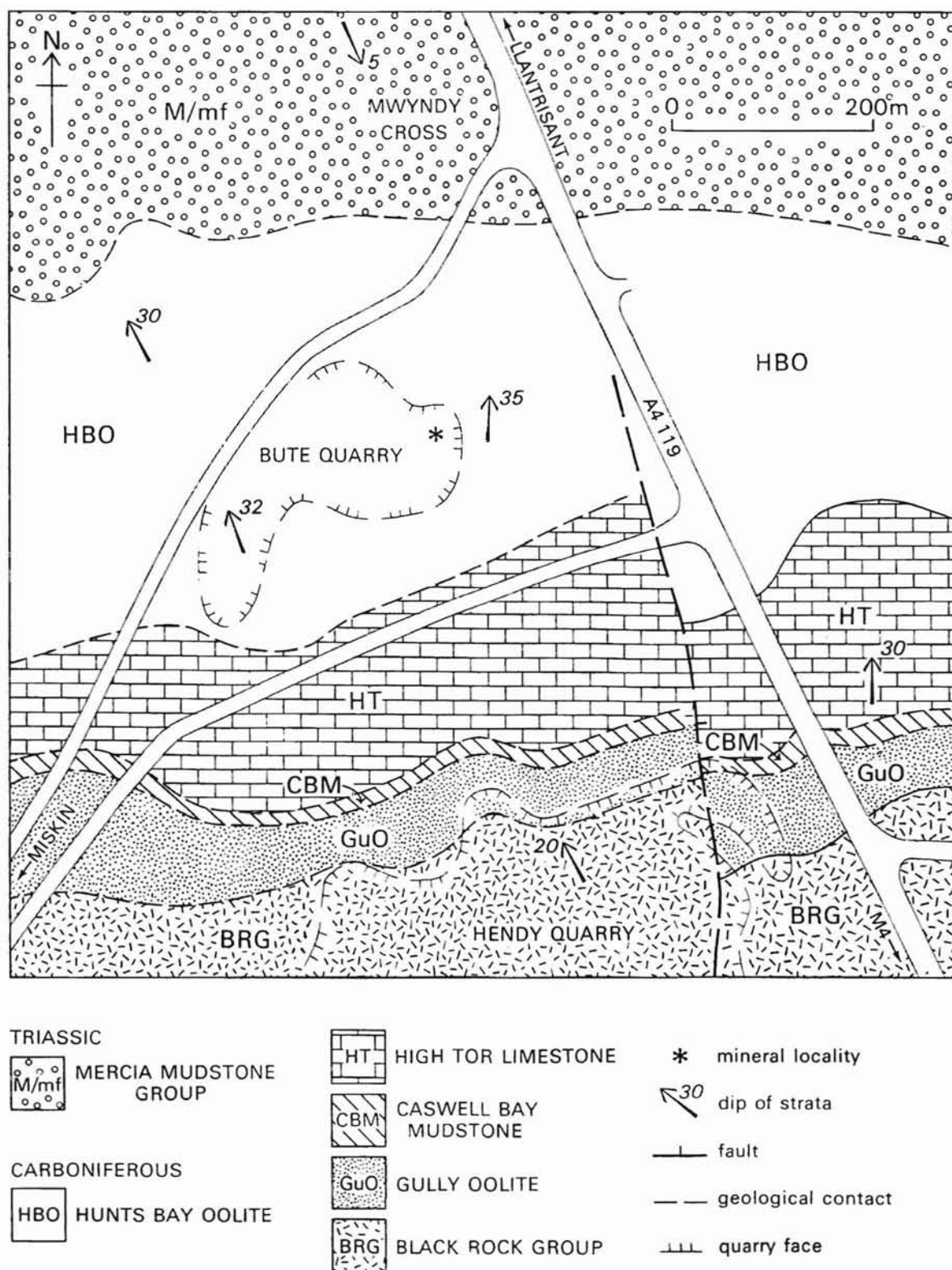


FIGURE 1. Geological sketch map of the area around Bute Quarry, Mid Glamorgan (after Wilson, 1983).

The borehole also intersected Triassic fissure-fill deposits similar to those now exposed on the foreshore at Porthcawl, where Triassic breccias are associated with N-trending normal faults. Between Irongate and Porthcawl Points sulfide mineralization is present in a calcite vein system cutting the Carboniferous Limestone (Grid. ref. SS 8168 7648) and in the overlying Triassic breccias (Davies, 1982).

MINERALOGY

At Bute Quarry the primary sulfide mineralogy consists of galena cubes, up to 1 cm across, and composite crystals of sphalerite and chalcopyrite. The latter crystals are composed of irregular chalcopyrite cores with subhedral sphalerite rims and range in size from 3 mm to less than 0.2 mm. Their composition appears to vary from 50% chalcopyrite to almost pure sphalerite. Nearly all



FIGURE 2. Calcite-lined vughs and thin calcite vein developed parallel to bedding within dolomitized limestone of Hunts Bay Oolite. Bute Quarry. Scale 20p piece.



FIGURE 3. Sheaf of acicular aurichalcite crystals in calcite-lined vugh. Locks Common borehole. Field of view 6 mm x 9.5 mm. Registration number NMW 86.28G.M2.

the composite crystals are associated with secondary alteration to platy pale green copper-zinc carbonates. A similar mineralogy has been found in the Locks Common borehole, except that no galena was identified.

ROSASITE

It is impossible to distinguish malachite, zincian malachite, and rosasite in the field, and even the X-ray powder diffraction patterns are virtually identical. This has been attributed to the mutual substitution of Cu^{2+} and Zn^{2+} in the crystal lattice (Jambor, 1976). However recent single crystal work (Nickel and Berry, 1981) has shown that malachite and rosasite are not isostructural or isomorphous, although malachite can accommodate some Zn^{2+} into its structure. The exact chemical distinction between these mineral species has yet to be determined and therefore without detailed and careful single crystal X-ray work the final positive identification of rosasite is impossible. However the published Zn:Cu ratios of rosasite vary between 0.40 to 0.68 (Dana, 1951; Jambor, 1976) which can be used as a guide to the presence of rosasite. Four small grains from different parts of a specimen from Bute Quarry were analysed by electron microprobe (Table 1). The analyses were carried out on powders, and the percentages may therefore be slightly low, though, since Cu and Zn are next to each other in the periodic table the Cu:Zn ratio should be reliable.

TABLE 1

Electron microprobe analyses of secondary copper minerals from a sample from Bute Quarry. Registration Number NMW 86.28G.M2.

	Rosasite		Zincian malachite	
Grain No.	1	2	3	4
CuO	43.70	60.13	55.74	56.32
ZnO	20.26	6.54	9.41	11.12
FeO	0.23	n.d.	0.23	n.d.
Total	64.19	66.67	65.38	67.44
Zn:Cu	0.46	0.11	0.16	0.19

n.d.; not detected; Analyst: P.H.A.Nancarrow.

Grain 1, which has a Zn:Cu ratio of 0.46, was examined by X-ray powder diffraction after it had been probed and gave a pattern of malachite. No other mineral was detected, and it is considered that this grain is rosasite. Grains 2, 3 and 4 have lower Zn:Cu ratios but similar combined totals suggesting they are zincian malachites. The range in Zn:Cu ratios may either be due to zonation or

variation in the original composition of the sulfide crystal. There appears to be no morphological or colour difference between any of the analysed grains.

No analyses have been undertaken on the Locks Common borehole specimens, but the similar mineral morphologies and modes of occurrence would suggest the presence of rosasite and/or zincian malachite. Some samples contain dark green botryoidal growths within small voids between the calcite crystals. These do not have the form of aurichalcite and may also be rosasite or zincian malachite.

Single-crystal X-ray work is currently in progress on all these specimens, which hopefully will confirm the presence of rosasite.

AURICHALCITE

At Bute Quarry aurichalcite occurs as radiating acicular needles developed within small cavities between the larger calcite crystals that form the lining of the vughs. The needles are up to 2 mm in length and range in colour from medium bluish green in the centres of the radiating aggregates to nearly white at the outer ends of the crystals. X-ray powder photography has confirmed the aurichalcite identification.

In the Locks Common borehole aurichalcite also occurs within the voids between the calcite crystals (Figure 3).

ORIGIN OF MINERALIZATION

All the known mineralization in the Carboniferous Limestone of the Vale of Glamorgan is of hydrothermal origin; there is no evidence that exhalative base metal ore bodies are present within the sequence. The mineralization is restricted to narrow vein systems generally related to faults. All the dolomitization within the Hunts Bay Oolite is of epigenetic origin (Waters and Lawrence, 1987) and adjacent to fault and joint systems the limestones were dolomitized by percolating hydrothermal fluids, some of which contained dissolved base metals.

The Bute Quarry mineralization appears to have formed in distinct phases. First a permeable horizon within the carbonate sequence was selectively dolomitized, resulting in the formation of cavities due to volume reduction of the alteration process. The size of the cavities may have been increased by subsequent solution. Dolomitization was followed by the introduction of sulfide-bearing solutions which initially crystallized galena, sphalerite, and chalcopyrite close to the margins of the cavities and finally the coarse calcite of the vughs.

The secondary alteration of the copper and zinc sulfides to form zincian malachite, rosasite and aurichalcite probably took place during the Triassic when the Carboniferous Limestone was

subaerial and the percolation of ground water would have facilitated the development of the hydrated mineral species. The proximity of the Triassic unconformity (Figure 1) would support this view.

ACKNOWLEDGEMENTS

The authors would like to thank Mr P.H.A. Nancarrow and Mr H.J. Evans for analysing the mineral specimens. We are grateful to Dr S.D.G. Campbell, who first suggested that the acicular mineral was aurichalcite, and Dr R.A. Waters for discussion about dolomitization within the area. This paper is published with the permission of the Director of the Geological Survey (N.E.R.C.).

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COFFINITE FROM GIPSY LANE BRICKPIT, LEICESTER

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Coffinite, $U(SiO_4)_{1-x}(OH)_{4x}$, has been found as a major constituent of black spheroids scattered through gypsum beds in the Mercia Mudstone Group (Triassic) at Gipsy Lane Brickpit, Leicester.

INTRODUCTION

Gipsy Lane Brickpit (SK 620 071), on the northern outskirts of Leicester (Fig.1), is working calcareous mudstones of the Mercia Mudstone Group, formerly known as the Keuper Marl. Within the mudstones at this locality at least three gypsum beds occur. These main gypsum beds are from 0.2 m - 1 m thick, and fairly continuous where exposed, although they have irregular top and bottom contacts, and have a nodular structure with abundant included marl. Thinner layers of discontinuous nodular gypsum also occur in the pit.

Scattered through the mudstone sequence are thin lensoid and irregular sandy beds. These are often dolomite-rich, and minor amounts of galena are sometimes found on fracture planes. These sandstones often show beautiful halite "pseudomorphs" (preserved in sandstone), together with raindrop pits, and ripples on the upper surfaces.

GENERAL MINERALOGY

Where the top surfaces of the gypsum beds are exposed in the pit, green copper staining is not uncommon. Most of this is malachite. Some older accounts (e.g. Anon, 1973) mention bornite and djurleite occurring as metallic films on the top of gypsum beds, but these have not been found recently.

Celestine, $SrSO_4$, has recently been found in one rather dolomitic layer in the marl, as cavernous, roughly crystallised, pink masses.

Black, vanadium-rich areas, up to 1 cm across, also occur scattered through the marl. These are made more conspicuous by the green "reduction spots" surrounding each one, where the organic-rich vanadium spots have reduced the Fe^{3+} in the surrounding mudstone. These vanadium-rich spots are well known in many parts of the British Triassic.

COFFINITE

The gypsum beds, particularly the upper one, contain small sub-spherical black masses, up to 8 mm in diameter. These occur in a variety of environments: (a) on the top surfaces of gypsum beds; (b) in greenish clay films within nodular gypsum, sometimes partially enclosed in adjacent gypsum; (c) enclosed entirely within massive gypsum, in the outer portions of gypsum nodules; and (d) rarely, in greenish clay a few mm from gypsum nodules.

These spheroids may be encrusted by efflorescences of malachite (common), erythrite (fairly common) or lavendulan (rare). A very rare deep blue efflorescence may be azurite. Usually only one of these minerals is present in any quantity on any one spheroid.

The spheroids are quite distinct in occurrence and appearance from the vanadium-rich "spots", which tend to have rather diffuse boundaries, and which are not associated with the gypsum beds.

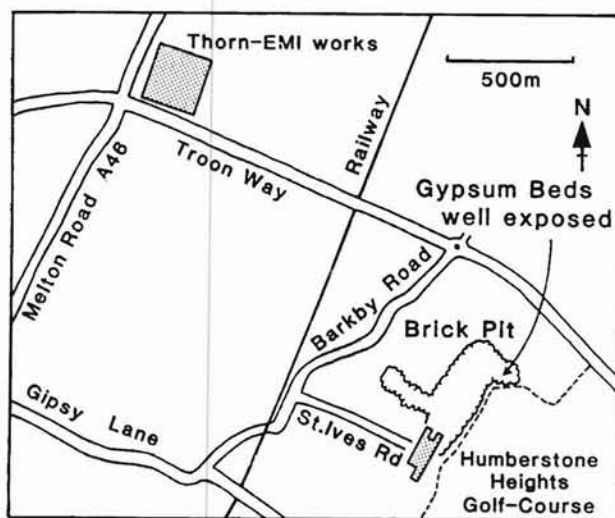


FIGURE 1. Sketch map showing the location of Gipsy Lane Brickpit.

TABLE 1X-ray diffraction data for powdered spheroid sample.^a

D(angstroms)	I	Minerals	JCPDS coffinite main peaks
7.67	10	gypsum	
4.63	5	coffinite (chernovite)	4.64(I = 95)
4.29	5	gypsum	
3.98	4	^b	
3.82	4	gypsum ^b	
3.48	7	coffinite(chernovite)	3.48(I=100)
3.35	3	^b	
3.08	4	gypsum	
2.97	<1	^b	
2.88	<1	gypsum	
2.78	2	gypsum + coffinite	2.789(I=45)
2.69	1	gypsum	
2.62	2	coffinite	2.636(I=95)
2.54	4	^b	
2.45B	1	coffinite?(chernovite?)	2.463(I=25)
2.16B	1	coffinite?(chernovite?)	2.177(I=30)
1.98B	2	coffinite?	1.996(I=30)
1.906	1	^b	
1.875	4	^b	1.849(I=35)
1.793B	1	coffinite?	1.803(I=70)
1.67B	1	^b	

^a Intensities estimated visually; B: broad. Some lines have not yet been ascribed to known minerals, but are probably due to admixed arsenides/sulfides. ^b Agreement with lines in the JCPDS powder file index is not perfect.

The identification of the spheroids has been a subject of some conjecture. For a time, they were identified as djurleite, $\text{Cu}_{31}\text{S}_{16}$, (e.g. Anon, 1973), and later as chernovite, YAsO_4 (Embrey, 1978), the latter on the basis of X-ray diffraction and unspecified "spectrographic" determination.

Three of these spheroids have been examined by X-ray diffraction. Whole spheroids, apparently free from alteration products, were ground under acetone and spread on glass slides. Diffractometer traces were taken from these samples. The patterns were similar for all samples. The peaks and estimated intensities are given in Table 1. Among these peaks those for gypsum stand out, suggesting adhering gypsum that was not removed from the spheroids during sample preparation.

Careful scanning of the JCPDS index indicated that coffinite was a likely constituent of the spheroids. However chernovite (which has a similar zircon-type structure) could not be ruled out on this basis alone (Table 1). To provide compositional constraints on the mineralogy, the powder from one of the diffraction slides was examined by X-ray fluorescence. The results are shown in Table 2. This is not a quantitative

analysis, but the relative values shown are probably correct to within 10% (N. Marsh, pers. comm.). It is clear that yttrium and the rare earth elements are very minor components; thus the

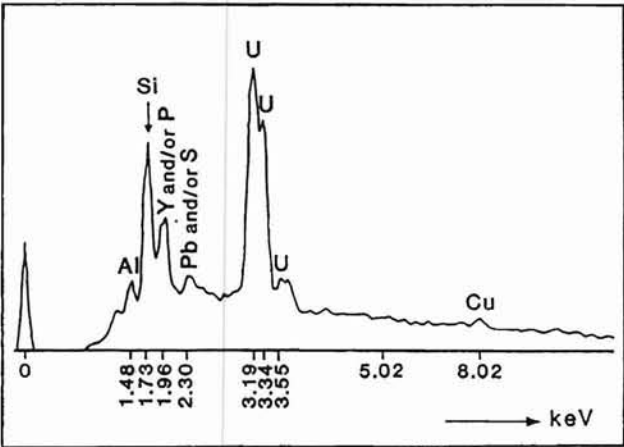


FIGURE 2. Edax spectrum of coffinite. 15kV electron beam. Uncoated polished section. Elements responsible for the peaks are shown. This technique cannot distinguish between lead and sulfur, or yttrium and phosphorus.

TABLE 2

Semi-quantitative X-ray fluorescence analysis^a of crushed spheroids

Element	Concentration(%)	Element	Concentration(%)
U	7.9	Ni	4.1
Th	0.2	Co	8.4
Pb	0.35	Fe	2.75
Zr	0.05	Mn	0.17
Y	0.60	V	0.02
Sr	0.46	Ti	0.45
Rb	0.07	Ca	7.75
As	34.9	S	25.0
Cu	5.0	P	0.5
		Si	1.25

^aSame powder as used for diffraction investigations. The elements analysed sum to 100%. This analysis ignores elements such as carbon, oxygen, and hydrogen which are probably major components. The absolute values given may thus be wildly inaccurate, however the relative abundances of the elements are probably accurate to within 10% or so (N. Marsh, pers. comm.).

presence of chervonite can be ruled out. Uranium and silicon are however present in roughly the proportions one would expect in coffinite. Cobalt, nickel, copper, sulfur, and arsenic are also present in significant quantities but the mineralogical expressions of these elements are not clear from the diffraction patterns.

Polished sections of several spheroids show a total of four phases to be present. Many of the spheroids consist only of soft, grey, low-reflectance coffinite. Analysis of this material by energy dispersive analysis shows peaks for U, Si, Pb or S, Al, and, interestingly a peak at 1.96 keV, which is either Y or P (Fig. 2). Yttrian coffinites are known (e.g. PDF no 17-460, JCPDS Index), and this might account for the Y detected spectroscopically by the British Museum (Natural History)(Embrey, 1978). Analysis of many points in three different spheroids showed almost constant compositions. It should be noted that the X-ray diffraction pattern does not fit yttrian coffinite 17-460, but it is very close to synthetic coffinite 11-420 (JCPDS Index).

The other minerals present have not yet been identified with certainty, but include a grey copper sulfide, a pink nickel arsenide, and a grey/white cobalt-nickel-copper arsenide-sulfide. These may form between 0% and 50% of the volume of the spheroids. Work on these phases is continuing.

The spheroids are only moderately radioactive, suggesting that they are never pure coffinite. The spheroids undergo partial combustion when heated in air, thus appreciable quantities of organic material are probably present. So far no uranium-free low-reflectance material has been found associated with the coffinite. It seems likely therefore that coffinite is homogeneously dispersed on a fine scale in an organic matrix. The coffinite/organic mixture seems to be homogeneous at magnifications at least up to 1000X.

This is not the first record of coffinite from the British Triassic. A similar suite of minerals with coffinite and Cu-Co-Ni-As mineralisation occurs in Permo-Triassic rocks at Budleigh Salterton, Devon (Harrison, 1975). Pb-Cu-Co-Ni-As-V mineralisation, without uranium, is well-known in Triassic sandstones at Alderley Edge, Cheshire (Ixer and Vaughan, 1982).

Recently, Holmes *et al.*, (1983) have argued for a diagenetic origin for metalliferous concentrations in the Triassic. Following Walker (1976) they hold that the reddening of red-beds is a secondary, diagenetic feature, and that during this diagenetic oxidation, elements such as Cu, Co, Ni, As, V, and U are released from rock-forming minerals. Once in solution, they are deposited at sites where reducing conditions prevail, such as on trapped hydrocarbons.

The metallic content of the Gipsy Lane spheroids must be an early feature, as coffinite + arsenide spheroids occur completely enclosed in massive nodular gypsum. This gypsum is thought to have grown in the sediment interstices in inter- and supra-tidal sabkha flats around the Triassic shoreline. If diagenetic oxidation was occurring simultaneously with the formation of the gypsum, it is feasible that any organic material present (e.g. broken-up algal mats) would scavenge elements such as U, Co, Ni, Cu, and As before being enclosed by the growing gypsum nodules.

ACKNOWLEDGEMENTS

Thanks are due to the Nottingham Brick Company for allowing access to the their pit, and particularly to Mr. Mitchell, the pit manager. Nick Marsh performed the XRF analysis, and Rod Branson assisted with EDAX work.

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RETGERSITE, $\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$: A NEW BRITISH OCCURRENCE FROM WARWICKSHIRE

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In October, 1980 a mineralised septarian nodule collected from Newdigate Colliery, near Bedworth, southwest of Nuneaton, Warwickshire, was taken to the City of Birmingham Museum for identification.

The sulfide minerals present in this typical Coal Measures clay ironstone septarian nodule, which included millerite and galena, were readily identifiable, but an associated green oxidation product warranted a more detailed examination. Accordingly a portion of the nodule, bearing the unknown green material, was sent to the British Museum (Natural History). The tetragonal hydrated nickel sulfate phase retgersite was subsequently identified.

Retgersite is a rare mineral, first fully described by Frondel and Palache (1949, p.188). To the writer's knowledge the occurrence described here is only the second known in Britain, the first being reported by Macpherson and Livingstone (1982, p.32) from "Menimuir Burn" near Cassencarie, Kirkcudbrightshire, where it occurs associated with niccolite and annabergite.

The horizon at which the septarian nodules occur is approximately 6 m above the Two Yard Coal in the Lower *similis-pulchra* zone of the Middle Coal Measures (Ammanian) of the Warwickshire Coalfield (Mitchell, 1954; Ramsbottom *et al.*, 1978). The mineralised nodule was collected approximately 2 km west of Newdigate Colliery Shafts.

The principal sulfide present in the material brought to the museum is millerite which takes the form of acicular or capillary crystals up to 24 mm in length radiating out from a common centre. The crystal groups are dispersed on the microcrystalline surfaces (dominantly rhombohedra) of the chalybite-covered septa voids, and are commonly associated with galena. The colour is dark brass but there are degrees of tarnish producing darker shades. The acicular crystals are commonly coated with minute single and groups of retgersite crystals, sometimes investing single crystals of millerite completely. Also associated with millerite are thin films of yellow-green zaraitite, $\text{Ni}_3(\text{CO}_3)(\text{OH})_4 \cdot 4\text{H}_2\text{O}$.

The galena is always crystallised as aggregated cubes, sometimes elongate parallel to {100}. Rare

cubo-octahedra have been observed. The largest crystal observed was 4 mm in length. Sphalerite is present as thin blackish-brown films, but precedes the chalybite-millerite phase.

Chalcopyrite is late in the paragenesis and is present as single or compound tetragonal crystals dispersed on the chalybite surfaces, but all are tarnished or show a development of limonite and specks of malachite.

The retgersite is always associated with millerite and isolated crystalline masses betray the former presence of millerite. Its most common form is that of minute crystalline masses in and around the focus of radiate groups of millerite crystals. The single crystals, observed along the lengths of millerite crystals, show tetragonal faces, although the crystals are only minute fractions of a millimetre in prismatic length. Both crystalline masses and single crystals are emerald-green in colour with a vitreous lustre. They are transparent and frequently show marked cleavage traces.

It would appear that the retgersite has been formed by normal oxidation processes under essentially atmospheric conditions.

ACKNOWLEDGEMENTS

The writer would like to acknowledge the help he has received from Mr J. Francis of the British Museum (Natural History) for the identification of zaraitite and the retgersite by X-ray diffraction techniques.

A specimen from this occurrence has been deposited in the collections of the Department of Mineralogy in the British Museum (Natural History) under accession No. X20482. Other material from the occurrence is lodged in the mineral collection of the City of Birmingham Museum under accession No. G.4.82.

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CONFERENCE REPORT

MINERALOGY AND MUSEUMS, 5-6 JULY 1988 BRITISH MUSEUM (NATURAL HISTORY), LONDON

This international conference sought to address the many issues facing mineral curators and administrators in museums, and attracted over 100 delegates from 18 countries. Many museums are going through a period of unprecedented and particularly rapid change as their functions are challenged and their resources are coming under increasing pressure. **Dr Clive Bishop** (British Museum (Natural History), London) in his opening address pointed out that in the UK alone, the number of museums had increased annually by 10% every year since the 1950's. This stiffens the competition both for resources, and customers. Museums must, he said, decide what kind of business they are in, define their mission, identify the needs of their customers and decide priorities concerning the use of their finite resources. Museums must display and encourage imagination and curiosity - otherwise they would become merely warehouses.

The conference was separated into 4 discrete sessions - Acquisition and Curation, Communication and Displays, Research Directions and Needs, and an Open Session.

Each session was introduced by a Keynote Speaker, and the first of these was **Mr John S. White** (Smithsonian Institution, Washington). His paper, entitled 'Some aspects of modern mineral collection curation,' highlighted the many pressures on curators, in particular the conflict that can occur between one curatorial activity *e.g.* training and education, and the perceived importance of others, *e.g.* collection building or research. Curators in the USA have experienced an explosion of interest from collectors and dealers and this has altered the perception of the curator's job. Previously he was concerned to satisfy his boss within the museum organisation, but now the emphasis has shifted towards satisfying the customer. This change has in general been welcomed by curators.

Specimen security represents a major headache and many museums are now adopting control procedures for accessioning and de-accessioning material similar to those used by art museums. The role of volunteer workers, and the growing importance of computers in collection management were explored. Collection utilisation by non-museum staff, *e.g.* collectors, has been shown to offer many benefits such as the recognition of gaps in the collection, wrongly labelled specimens, or has resulted in donations of material which the museum would not otherwise have had the opportunity to obtain.

Dr Tony Kampf (Natural History Museum of Los Angeles County) described the establishment of a public support group to provide supplementary resources and funding for the mineralogy department. This involved providing a wide range of activities for members to participate in, on a 'privileged' basis, *e.g.* visits to working mines, viewing of private collections not normally available to the public, exhibit openings within the museum, and lectures. Membership costs \$100 US per annum, and has grown to 150 in 3 years. The group now has surplus capital of \$30,000 and supports the museum through provision of equipment, sponsoring travel fees, specimen purchases and exhibitions.

Dr Bill Birch (Museum of Victoria, Australia) gave an entertaining account of 'Australian Museums and Mineralogy' against the background of the Australian bicentenary. He hinted that he was looking for some birthday gifts at the museum level! Mineralogy got off to a poor start in Australia and it was not until 1869 that a valid new mineral species, maldonite, was described from the country. Periods of classical mineralogical studies on Australian specimens in museum collections were few and shortlived, but perhaps exemplified by the contributions of George Ulrich in Victoria in the 1860's, and Charles Anderson in New South Wales in the early 1900's. In 1985 the Museum of Victoria was formed by the merger of the Sydney, Melbourne and Geological Survey collections, but in other states mineralogical collections are in a depressing condition. It is surprising that a country so rich in mineral deposits and mining history is so poorly documented or researched. Ulrichite, a calcium-copper-uranium-phosphate, has recently been described from a granite quarry in New South Wales - the first new mineral species from Australia for 80 years.

Dr Lydie Touret (Teyler Museum, Netherlands) gave a fascinating insight into mineralogy in the late 18th century. Her paper described the remarkable collections of the Teylerian Museum, dating from 1783, where specimen material and associated records have been preserved in their original state. The first director of the museum, Martinus Van Marum (1750-1837) assembled over 12,000 specimens, and since his death these have lain untouched and unattended to the present day. At that time the records show that the average price of a mineral specimen was 100 Guilders, much more than a small Michaelangelo painting. The situation is rather different today!

Mr Paul Hicks (formerly of the British Museum, Natural History) gave an over-view of the problems resulting from the decision to merge the collections of the BM (NH) and the Geological

Museum. The simple logistics of how to accomplish such a massive task led to the use of computer-based systems for cataloguing and mapping the collections. Over 250,000 specimens are involved, stored in 6000 drawers. The whole project is likely to take 20 years to complete. In the course of this work much useful experience has been gained using PC software, and also concerning paper and ink types with regard to permanence of records and labels.

The afternoon session entitled 'Communication and Displays' opened with a second Keynote Speaker - **Mr Hubert Bari** (Musée de Mineralogie, Strasbourg). Mr Bari introduced his talk by explaining that Strasbourg was in the Alsace district, and that the history of the area was rather like toilets - always occupied! His paper, 'Bijoux Cailloux Fous,' described how a project which began as an idea for "winning a lot of money with crystals" became a major touring exhibition attracting over 400,000 visitors so far, being viewed in Strasbourg, Bourg d'Oisans, Lille and Paris. All of the finance required for the exhibits has been raised through bank loans and at the end of the operation £400,000 will be available for the purchase of minerals and gems by the museum. A special collection of visually stunning specimens was assembled, together with spectacular visual effects and display areas. The aims of the project were to examine mineralogy in 3 ways - What is a Crystal?, Crystals and Science Fiction and Crystals in Nature. It is hoped that the exhibits will be seen in London in 1989.

Mr Ian Mercer (Geological Museum, London) delivered a paper entitled 'Communication and Treasures.' This was a detailed account explaining the technical issues addressed when designing museum exhibits, with particular reference to the new 'Treasures of the Earth' exhibition for the Geological Museum.

Dr Graham Durant (Hunterian Museum, Glasgow) described his ambitious project to design, construct and fund the Crystal Pavilion for the Glasgow Garden Festival. The theme of the exhibit, 'we live on a crystal ball,' is brought to life through a variety of exciting and novel displays. The pavilion seems likely to attract over 1 million visitors and provides a major opportunity for the public to investigate the way in which minerals influence the way we live.

Dr Peter Keller (Natural History Museum of Los Angeles County) gave an interesting account of how his museum had approached 'Teaching the natural history of gemstones through exhibitions'. Darkened galleries, large location maps, thematic divisions within the displays and dramatic lighting had all been used to good effect. In order to convey the pressures within the earth's crust a new unit, the 'elephant' had been introduced, and by this means a visual appreciation of increasing pressure

with depth had been achieved. Seating had been incorporated into the display areas to combat the physical fatigue of visitors. Future developments include a laser-disc, touch-screen video presentation detailing the properties of 20 common gemstones, and allowing interactive interrogation by visitors.

Dr Jacques Deferne and **N. Engel** (Museum d'Histoire Naturelle, Geneva) described three examples of original animations for explaining mineralogy. The first, using mirrors and fluorescent balls, provided a striking impression of the infinite dimensions of atomic structure. Mirrors positioned to represent planes of symmetry within the crystal structure replicated, again and again, images of the balls within the model. A second model illustrated the double refraction of calcite using a rotating crystal section and polariser. The final model used an array of six modified slide projectors and polished thin sections of rocks to simulate the operation of a polarising microscope. The controls are operated by the visitor who may rotate the stage, insert or remove the analyser, or select a new thin section. Design drawings of the various models are available from Dr Deferne upon request.

The afternoon session was concluded with a general discussion chaired by **Mr F.W. Dunning** (Geological Museum, London). **Dr Joe Mandarino** (Royal Ontario Museum, Canada) advised curators not to be afraid of gadgetry in the gallery. He recounted 13 years experience of such animated displays in the ROM and suggested that the secret of success was to anticipate and protect against every possible abuse by the public. Surveys of visitors to assess what they think about displays may be useful, and he also questioned the purpose of the systematic display. There was general agreement that curators should go for aesthetic displays and reduce the systematic content. **Dr Hubert Bari** (Musée de Mineralogie, Strasbourg) suggested that the first thing the public thinks about is "how much does it cost to get it?" Provision for short-term private collector displays was discussed and both the Geological Museum, London and the Royal Museum of Scotland, Edinburgh, have space available for this. In the first instance amateurs are encouraged to display recent fossil finds as part of the British Fossils exhibit, and the latter is for varied mineralogical topics.

It was suggested that with around 50 major mineralogical museums in Europe, each might prepare a touring exhibit to fit a standard display area, and these could then circulate around the institutions to provide an element of change and variety at low cost.

The question of how best to measure the effectiveness of a display prompted considerable debate, but it was agreed that 'numbers through

the door', alone, was not an adequate measure. Other factors such as educational impact, re-visits, entertainment *etc.* must be addressed. Visitor surveys should also incorporate 'non-visitors' and 'potential visitors', both within the immediate environs of the institution and also those further away but within travelling distance. Such investigations should ask 'have you ever been?' and 'if you did visit, what would you like to see?'

In the evening delegates were entertained to a wine reception in the Gemstone Gallery of the Geological Museum, London, and this provided a welcome opportunity to relax and discuss the day's events with colleagues from around the world.

The second day of the conference began with a Keynote Address by **Dr Joe Mandarino** (Royal Ontario Museum, Canada) entitled 'Mineralogical Research in Museums'. **Dr Mandarino** outlined the need for clear research policy documents, and compared this to the current situation where few museums have written guidelines. The need is not only to guide curators, but also as a protection measure against research funds being redirected to other needs. He went on to explain Mandarino's Law of Ethics, which is, that when faced with a question of whether something is ethical or not, if it takes you more than 30 seconds to reach a decision, it is non-ethical. If the museum mineralogist is to be considered equal to his peers in industry, universities, and Survey workers, he must show the ability to carry out research and publish the results. Other workers, and museum administrators tend to see the life-sciences as being more important, and therefore good, high-profile research could help to raise the image of mineralogy. When one considers that there are only around 3300 known mineral species, compared to the number of insects or plants, the description of 60-80 new mineral species *per annum* is very significant. Also, only in mineralogy are new species subject to internationally agreed approval procedures prior to publication. **Dr Mandarino** then went on to suggest areas for research appropriate to the role of museums, *e.g.* conservation and preservation techniques, production and improvement of data for non-silicate minerals, taxonomic works and topographical mineralogy publications.

Dr Pete Williams (University College Cardiff, Wales) in his paper 'Museum collections - varied and valuable research resources' enumerated the many ways in which museum collections can be of value to the mineralogist. The 'comprehensive' nature of collections, both in terms of different species, and the range of variation within a given species is invaluable. Museum collections often provide access to material which can no longer be obtained *in situ*, and also allows the opportunity to re-study material which was described perhaps 100 or 200 years ago. Specimen labels and associated

data can allow the piecing together of the 3-dimensional relationships within an orebody or mine, and this is of great importance in paragenetic and chemical studies. Perhaps the most valuable resource however is the people looking after the curated material - a curator who knows his collection well, can guide the research worker to specimens or data in answer to specific requests or needs. **Dr Paul Henderson** (British Museum (Natural History), London) went on to discuss 'Mineralogical research in national museums', and, following **Dr Mandarino's** lead, expressed the view that museums are primarily centres of scholarship, and that when they cease to fulfil this function, they cease to be museums. A number of different forces act upon museums - both internal and external. The BM (NH) is used as a centre for advice, and this must therefore be of the very highest scientific quality. It is in fact the principal national research and advisory centre for mineralogy in the UK. **Dr Henderson** then described the great diversity of activities within the BM (NH). Amongst these, collaboration with other institutions, including universities was seen as very important. **Dr Henderson** pointed out that governments are unlikely to create the right climate for national and international collaboration. It is therefore up to all of us to ensure that such collaboration flourishes for our mutual benefit and the benefit of mineralogy.

Dr Ian Freestone (British Museum, London) described 'Applied mineralogy in an archaeological museum' where physical and chemical techniques are used to investigate the collections. For example, problems of classification sometimes arise, such as Egyptian 'alabaster' which is in fact all calcite. The petrology of stone implements or building facades can be used to trace the origin of the material, either for demographic studies or repair work.

Dr David Smith (Musée National d'Histoire Naturelle, Paris) gave a detailed account of 'Museological applications of Raman microspectrometry: mineralogical characterisations.' This technique utilises visible radiation generated by a laser to investigate non-destructively transparent mineral materials. Reflected and refracted radiation is detected and analysed using a spectroscope where the position of a peak is diagnostic for an element or compound and the intensity of the peak is roughly proportional to the quantity present. No vacuum or specimen coating is required for operation unlike the electron microprobe or most scanning electron microscopes. The laser beam can be focussed at different depths in the sample, and can even be directed through the sample, for example at a fluid inclusion to provide an analysis of the solution. Spectra are calibrated against EMP analyses, but no software is yet available for processing spectra.

This technique is clearly ideally suited to museum studies where removal of specimen material for analysis may be undesirable or impracticable.

Dr Werner Quellmalz (Staatliches Museum für Mineralogie und Geologie zu Dresden, East Germany) in his paper 'Mineralogy and art - tradition and the future of mineralogical research in Dresden, GDR' described various new X-ray techniques which have been developed to 'fingerprint' precious stones. This enables a particular diamond for example to be recognised even after re-cutting. Other techniques using inclusion studies have enabled tracing of materials to their original source, and this ability is invaluable when faced with problems of replacement or repair work on artefacts.

The final session of the conference had been designated as an 'Open Session', and this began with a brief review of the IMA Museums Commission by **Prof. Hans Stalder** (Natural History Museum Berne, Switzerland). A current project of great importance is the preparation of a computerised index of type mineral specimens and the museums or institutes where they are preserved. This should be completed by the end of 1988.

Next, **Mr Roy Starkey** (Redditch, UK) presented a paper entitled 'The role of museums and the amateur mineralogist'. This explored the relationship which exists between the professional and the amateur communities and reviewed the relative strengths and weaknesses of the amateur collector. The policies followed by museums were compared to the needs of the collector from the 'customer viewpoint'. Proposals put forward for consideration and possible future development included improving accessibility to reference material, making provision for temporary displays from amateurs, and encouraging curators, particularly in provincial museums, to enlist the help of knowledgeable amateurs. It was clear from the general response that most museum curators do appreciate the worth of the contribution made by amateur collectors, and that in some countries this has been developed to a very considerable extent.

Dr Andrew Clark (British Museum (Natural History), London) reviewed the progress made on a new edition of *Hey's Index of Mineral Species* and explained how a computer-based classification had been developed which will allow interrogation of a computer file to provide indices sorted in various different field categories *e.g.* chemical composition, localities, structure *etc.*

The file currently holds around 15,000 records, of which some 3000 refer to valid mineral species. Publication is envisaged in about 3 years' time.

The establishment of a national topographical mineralogy database in Hungary was described by **Dr Tamas Weiszberg** (Eotvos Lorand University, Budapest). Work began in 1984 with a thorough review of published literature and national museum collections. It has become clear that many records are erroneous, and that specimens of some described species do not exist in national collections.

A fascinating account of the discovery, protection and subsequent conservation of an alpine fissure at the Grimsel, Ct. Berne was given by **Prof. Hans Stalder**. The occurrence was discovered during the construction of a pumped storage HEP scheme, and the mineralized cavity, measuring 1.5m x 1.5m x *ca.* 13m has now been permanently preserved. Quartz crystals up to 70cm occur together with chlorite, large calcite plates and pink fluorite octahedra up to 1cm on edge.

The final contribution of the conference was an interesting pair of films depicting the minerals of Minas Gerais, Brazil and the Gem Gravels of the Far East by **Prof. H.J. Schubnel** (Musée National d'Histoire Naturelle, Paris.).

Prof. David Vaughan (President, Mineralogical Society) brought the conference to a close by thanking the supporters, sponsors and organising committee for making this a worthwhile and memorable occasion. He reminded delegates of the important role which museums have in providing what is for many young people their first contact with mineralogy. With regard to research activities he believed that museums must enhance their performance in this area, making full use of the collections in their care, to provide databases, characterizations of new species and so on. As for the UK, the re-structuring of our university earth science departments is forcing radical change in the way we approach geology and mineralogy, and this too will demand determination and commitment if collaborative projects are to succeed.

This had, he said, been the first international conference on mineralogy and museums, but there was enthusiasm for more, and it was clear, from comments already made, that it would not be the last.

R.E. Starkey

BOOK REVIEWS

Embrey, P.G. and Symes, R.F. *Minerals of Cornwall and Devon*. London (British Museum [Natural History]) and Tucson, Arizona (Mineralogical Record), 1987. vi + 154 pp., 36 figs., 114 colour photos., 8 maps. Price: Hardback £19.95, Paperback £9.95.

The first half of this well-illustrated book deals with the geology, mines and mining in this classic area, with numerous maps, black-and-white photographs of mining operations in the last century and details of the development of special skills and techniques to deal with the difficulties of mining such refractory material. These innovations were later carried throughout the world by pioneering Cornishmen. There is also a fascinating section on collectors and mineral dealers - including a facsimile of part of a letter from Philip Rashleigh to John Hawkins in which Rashleigh writes "The expense of procuring specimens has increased to such extravagance that if my collection was not considerable at present, I should not have begun now" - "now" being 1802! The authors point out that most dealers had a wholly different main source of livelihood, often of a kind likely to bring them into contact both with possible customers and with the main source of specimens, the miner and his family. Richard Talling of Lostwithiel is described as, beyond question, the greatest Cornish dealer of all time, flourishing in the years 1844-1883 when mining activity was at its peak in Cornwall.

In the second part of the book the minerals themselves are presented, with brief descriptions of each with an account of the paragenesis and locality and some 80 truly magnificent colour photographs. Most of the specimens are selected from the collections of the British Museum (Natural History), now augmented and enriched by the incorporation of the collections of the Geological Museum.

There was undoubtedly a need for such an illustrated account of both mining and minerals in the southwest of England. The maps of the localities of the various old mines long-closed are invaluable. The authors kindle the imagination with details of old and rich tin mines and collectors and dealers of bygone days. Devon unfortunately gets condensed into three pages, but reference to its mines and minerals are included in the 1100 entries given, together with annotations and selective bibliography.

This is a marvellous book at an extremely reasonable price, which all mineralogists, amateur or professional, throughout the world will want to have on their own shelves.

R.A. Howie

Laforet, C., Monchoux, P., Oudin, E. and Tollon, F. *Ariège: T2. Bassin versant de l'Ariège* (Inventaire minéralogique de la France, No. 12). Orléans (B.R.G.M.), 1986. 176pp, 25maps. Price 86FF.

This second volume in this series to deal with the Ariège region covers the mineralogy of the east of the Department. This includes an area of Palaeozoic rocks showing varying grades of metamorphism associated with Hercynian granites. Extensive mineralization has resulted in veins with lead, zinc, copper, and particularly iron minerals developed. In the style of this useful series, there are twenty-two locality sketch-maps, each with several 'indices' of either mine workings or outcrops and full directions on how to reach them. The later Mesozoic Tarascon basin in the centre of the region produces gypsum and anhydrite, with rutile and brown tourmaline.

R.A. Howie

Woodward, C. and Harding, R. *Gemstones*. London (British Museum [Natural History]), 1987. 60pp., 150 colour photos. Price £4.95.

This beautifully produced and illustrated booklet features many of the cut and rough stones displayed in the Gemstones Exhibition at the Geological Museum and also some of the fine crystals and cut gems on view in the Mineral Gallery of the British Museum (Natural History), as well as famous gems from other world collections. There is a useful and authoritative text and in addition to the photographs there are several colour diagrams.

R.A. Howie

NOTES FOR CONTRIBUTORS

TYPESCRIPTS

Papers should be typed, preferably on A4 paper, on one side only, with double spacing and wide margins (about 2.5cm) on good quality paper and submitted in triplicate to the Editor. Each paper will be read by two designated reviewers. Submission of a paper to the Journal is taken to imply that it has not been considered for publication elsewhere. Material accepted for publication can not be published elsewhere in the same form without the consent of the Editor.

Both full articles, covering all aspects of mineralogy including topographical mineralogy, and notes (up to 1000 words) are accepted for publication. Each full length paper should contain an abstract of up to 250 words summarizing the significant points of the paper. No abstract is required for notes.

The first sheet of the typescript should give, in order, the title of the paper, the names and addresses of the authors, and the name and address of the author for correspondence and to whom proofs are to be sent. Text pages should be numbered serially. Papers should be submitted in the style and format of the Journal.

FORMAT

The manuscript should be presented under various headings such as abstract, introduction, experimental results, discussion, references, etc. Not all sections will be necessary in any given paper and others may be appropriate. In these sections, the headings should be typed in capitals over to the left. Subheadings in the experimental, results and discussion sections should be typed in lower case, beginning with a capital and underlined, also to the left of the page.

PRESENTATION

Authors should present their material with clarity and conciseness. Experimental work should be accurately set out in sufficient detail to allow reproduction of results by other workers. When unusual new minerals are identified, sufficient proof of the nature of the mineral (X-ray diffraction data, analyses, etc.) must be supplied (along with analysis reference numbers), and should be compared with published data. Full lists of such data might not be necessary in the text, but should be supplied to the Editor if required by the referees in the course of their assessment. For mineral occurrences of particular note (eg. new occurrences in the U.K. or from a particular locality) authors are strongly encouraged to provide a note of the specimen number and a record of the institution or collection where the

specimen is lodged. Specific localities should be referred to by National Grid references together with the 100 kilometre square letters (*e.g.*, SM 928476). Ordinarily, results and discussion should not be intermingled.

FIGURES

All figures should be numbered with consecutive arabic numbers. They should be mentioned in the text and must have a descriptive caption. A list of figure captions should be typed on a separate sheet and included with the manuscript.

All figures should be of a quality suitable for direct reproduction. Original line drawings, crystal diagrams, maps etc., should be prepared with black (india) ink on white art paper or tracing paper. All lettering and symbols should be included on the diagrams. The size of the lettering (not typed) should be appropriate, if the diagrams are to be reduced in size. For example, if a figure is to be reduced by one half, lettering 4mm high should be used. Where relevant, a metric scale should be provided, along with National Grid reference or co-ordinates of latitude or longitude.

Photographs, where necessary, should be submitted as good, glossy original prints of maximum possible contrast. Each figure should be labelled on the reverse side with the author's name and the figure number. The tops of all figures and photographs should be marked as appropriate. Originals of photographs should be supplied at the time of manuscript submission. Only photocopies of figures, however, should be sent initially with the manuscript; the Editor will request originals once the manuscript has been accepted for publication.

TABLES

Tables should be numbered consecutively with Roman numbers. No vertical lines should be used. A clear title should be provided separated from the bulk of the information by a horizontal line. Another line should mark the end of the tabulated data, and beneath this any footnotes, referred to in the table by superior case letters, should be included. Footnotes, however, should be kept to a minimum. Each table should be typed on a separate page, continuing as necessary to further pages.

MATHEMATICS

Where possible any mathematical equations (or chemical equations) should be typewritten with subscripts and superscripts clearly shown. Equations referred to in the text should be

numbered consecutively by arabic numbers in parenthesis at the right hand margin.

MINERALOGY

Nomenclature and terminology of the International Mineralogical Association must be adopted. If the authors are uncertain about any aspect of these rules, the Editor should be consulted. As a guide to correct mineral names, Fleischer's most recent compilation should be used (at present this is M. Fleischer, Glossary of Mineral Species (Fifth Edition), Mineralogical Record Inc., Tucson, 1987).

If varietal names are employed in the text, these should appear underlined (for italics) after the formal definition and should be referred to in the same way throughout the text. Chemical formulae for minerals, wherever appropriate, should be included.

CHEMISTRY

Nomenclature should be that adopted by the International Union of Pure and Applied Chemistry. If authors are in doubt, they should consult the Editor.

Crystal structure studies should be reported in the manner outlined by the International Union of Crystallography (*Acta Crystallographica*, **22**, 45 (1967)). Tables of anisotropic thermal parameters and observed and calculated structure factors

should be deposited with the Editor.

REFERENCES

References and notes should be indicated in the text by the author and year of publication, thus: (Brown, 1967) or, "as stated by Brown (1967)". If two authors are involved, both should be named: (Green and Brown, 1985), and if more than two authors: (Green *et al.*, 1986). When more than one reference is quoted, each should be separated by a semicolon thus (Brown, 1969; Green *et al.*, 1986).

A list of references should be provided in alphabetical order. References should be given in full. Some examples are given below.

- Manning, D.A.C. and Henderson, P., 1984. The behaviour of tungsten in granitic melt-vapor systems. *Contributions to Mineralogy and Petrology*, **86**, 286-293.
- Pankhurst, R.J., Sutherland, D.S., Brown, G.C. and Pitcher, W.S., 1982. Caledonian granites and diorites of Scotland and Ireland. In: Sutherland, D.S. (ed.) *Igneous Rocks of the British Isles*. Wiley, London, 149-190.
- McGarvie, D.W., 1985. Volcanology and Petrology of mixed-magmas and rhyolites from the Torfajökull Volcano, Iceland. Unpublished Ph.D. thesis, University of Lancaster.
- Ramsay, J.G., 1967. *Folding and Fracturing of Rocks*. McGraw-Hill, New York.