

## JOURNAL OF THE RUSSELL SOCIETY

The journal of British Isles 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 the topographical mineralogy of the British Isles are particularly welcome. Notes for contributors can be found at the back of the Journal.

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**FRONT COVER**: Strontianite, Strontian mines, Highland Region, Scotland. 100 mm x 55 mm. From an old collection. Specimen and photo: John Hall.

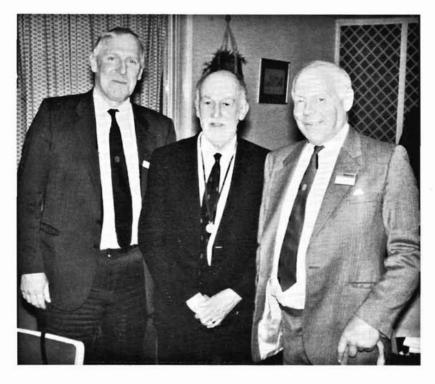
# JOURNAL OF THE RUSSELL SOCIETY

# **CONTENTS**

**VOLUME 4, PART 2, 1992** 

Supergene copper mineral assemblages at Botallack, St Just, Cornwall R.J. Bowell	45
The composition of stolzite from Wanlockhead and wulfenite from various Scottish localities  A. Livingstone	55
An unusual occurrence of mottramite from Peldar Tor, Leicestershire  John W. Faithfull and Francis Ince	59
NOTES	
Connellite from Colvend, Kirkcudbrightshire, and brochantite from Auchencat Burn, Dumfriesshire S. Moreton and P. Aspen	63
Barium-pharmacosiderite and symplesite from Caldbeck Fells, Cumbria B. Young, E. Hyslop and D. Millward	64
Cuprosklodowskite from Geevor mine, Cornwall  N.J. Elton, J.J. Hooper and L. Coggon	66
Growth of acanthite on native silver from the Clyde Plateau Lavas, Scotland T.K. Meikle	67
Conference Reports	71
Book Reviews	77
Index for volumes 1-4 (1982-92)	81

# THE RUSSELL MEDAL



Dr Bob King, recipient of the first Russell Medal, with Dr Bob Symes, President of the Russell Society (left) and Prof. Bob Howie. Honorary Member (right). Photograph taken at the Society's conference weekend at Loughborough University, April 1992.

## EDITORIAL

This tenth issue of the Journal of the Russell Society also marks the tenth anniversary of its publication, and the twentieth anniversary of the Society itself. The Society celebrated the anniversary by establishing a new international award for outstanding services to mineralogy, The Russell Medal. It is most appropriate that the first recipient of this medal was a protégé of the late Sir Arthur Russell — Dr R.J. King, founder of the Society, the first editor of its Journal, and acknowledged expert on the topographical mineralogy of Britain and the conservation of mineral collections.

Bob King became fascinated by rocks as a result of his father's interest in natural history. As a lad he took enquiry specimens to Leicester museum where he was inspired by the late H.H. Gregory, Keeper of Geology, and later attended his extramural classes. Under Gregory's direction he began reading geology at London University. He joined the army in 1941, and even became involved in repatriating mineralogical specimens under fire during service in Europe! Back home, he returned to his farming roots, but still dealt with enquiry specimens passed to him at the local museum. Bob later joined the Department of Geology at Leicester University, playing a major part in the subsequent success and development of that institution, and remaining on the staff for over 30 years. The teaching collection he built stands today as a model for all establishments teaching geology. In addition, Bob worked for more than 50 years to assemble one of the finest and most extensive contemporary private collections of British minerals, which now forms the core of the collection at the National Museum of Wales in Cardiff. Now settled in Tewkesbury and curator of the John Moore Countryside Museum, he is building a second collection of minerals...

Like children, successful journals grow, mature, and become respected members of the establishment. When the time came to pass on the editorship, the Society was fortunate in choosing Richard Bevins to nurture its Journal to full adulthood. Richard and his co-editor Peter Williams put in a great deal of unstinting effort to produce the Journal in its current glossy, professionally typeset format, and to ensure the continued publication of interesting, important and, above all, scientifically reliable information in its pages. In taking over as editor, I am conscious of the high standards set by my predecessors, and will aim to maintain these so that the Journal remains a real asset to the reputation of the Society — even though I have already fallen at the first hurdle, in respect of the late appearance of this particular issue!

For most people, writing scientific papers is an acquired skill and becomes easier with practice. Not surprisingly, therefore, many of our contributions are written by professional mineralogists. However, as Brian Young pointed out in a guest editorial not long ago, those who, with no previous experience of scientific writing, have taken up the challenge to commit their records to print, have almost always found the process to be much less daunting than they imagined. If there is something significant to report, it is worth the effort to place it on permanent record. This Journal would like to see more contributions from the 'amateur' sector, and the Editor and Editorial Board will be delighted to give any help necessary.

George Ryback

# SUPERGENE COPPER MINERAL ASSEMBLAGES AT BOTALLACK, ST JUST, CORNWALL

#### R.J. BOWELL

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Native gold has been found associated with chlorargyrite, gypsum, natron, and a suite of secondary chlorides and sulphates in an underground level of Botallack mine. Kröhnkite is present and this is believed to be the first reported occurrence of the mineral in the British Isles. This assemblage differs from the secondary copper mineral assemblages observed in material from the mine tailings around Botallack mine and Wheal Cock. The supergene mineral assemblage examined from the underground section is thought to represent seawater alteration of the hypogene copper lodes.

#### INTRODUCTION

Botallack mine (SW 363 336) in the St Just mining district, Cornwall (Fig. 1), although not renowned for substantial metal production, is still one of the most famous of Cornish mines. The area contains the type localities for botallackite and stokesite and is known for good specimens of axinite, almandine, connellite, cuprite, hematite, goethite, paratacamite and phenakite.

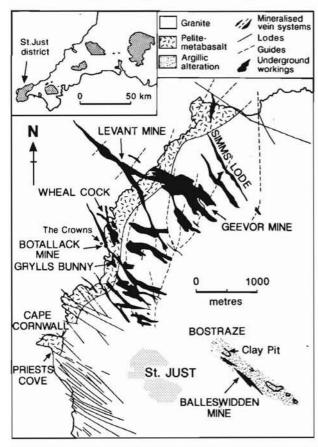


FIGURE 1. Schematic geology of the St Just district (after Jackson et al., 1982).

The origin of the mine is uncertain but mining operations are known from 1721, although organised mining did not start until the building of the first engine house on The Crowns rocks between 1795 and 1801 (Noall, 1972). Wheal Cock and other nearby mines were later incorporated into the Botallack sett. Tin and

copper were the main products of the mine but from 1875 onwards arsenic was also recovered. The remains of the kilns used to roast the sulphide ore can still be seen today. In 1894 the mine closed because of severe flooding but opened briefly betwen 1906 and 1914.

The Botallack mines were eventually bought by Geevor Tin Mines Ltd and the Allen shaft was refitted with new headgear in 1986 as part of an expansion programme at Geevor. But with the closure of Geevor mine in 1990 the mine is once again abandoned.

#### **GEOLOGY**

Geologically, the St Just district can be divided into two units (Fig. 1): an eastern unit, formed by the Land's End granite pluton, and a western unit of basalts and sedimentary rocks in the contact aureole. The northern part of the pluton consists of medium to coarse-grained two-mica granites. Hydrothermal alteration has taken place leading to sericitization of feldspars and chloritization of biotite. The contact aureole consists of an interbedded sequence of sediments and basalt lavas of possibly Devonian age (Miller and Mohr, 1964). Laminated argillites are the most abundant rocks but calcareous, tuffaceous and fine-grained argillites, cherts, and arenites are also present. Deformation of the volcano-sedimentary sequence during the Hercynian orogeny resulted in the formation of northeast-trending, north-plunging major and minor folds. During emplacement of the granites, the host rocks were thermally metamorphosed in the albite-actinolite and hornblende hornfels facies. The production of skarns rich in magnetite and garnet occurred early in the mineralizing sequence, with boron in these fluids producing axinite and tourmaline (Jackson et al., 1982). Extensive fracturing of both the pluton and the hornfels envelope produced conduits which were subsequently utilized by hydrothermal fluids. Veins and replacement deposits were developed in the roof and contact zones of the pluton and up to 2 km into the aureole. Five styles of mineralization have been recognised (Jackson et al., 1982). In chronological order these are: metasomatism, barren pre- and post-joint pegmatites, mineralized sheeted vein systems, mineralized fissure systems, and irregularly shaped replacement bodies. The major ore minerals in the hypogene quartz veins at Botallack are,

in order of decreasing abundance, chalcocite, arsenopyrite, bornite, chalcopyrite, cassiterite, hematite, scheelite, and bismuthinite. The mineralogy of the hypogene lodes and the country rocks has been described in detail elsewhere (Carne, 1822; Greg and Lettsom, 1858; Collins, 1892; Russell, 1920; Russell and Vincent, 1952; Couper and Barstow, 1977; Couper and Clarke, 1977; Embrey and Symes, 1987; Wolloxall, 1989).

#### SAMPLE COLLECTION AND ANALYSIS

Samples were collected *in situ* in 1989 from the 100-fathom level in the Wheal Hazard section of the Crowns lode. At this locality the stope was breached by the sea in the late 1970s and was subsequently infilled by precipitates. Additional material was collected in 1989 and 1990 from the cliffs (SW 3625 3405) and the Skip shaft dumps at Wheal Cock (Fig. 2).

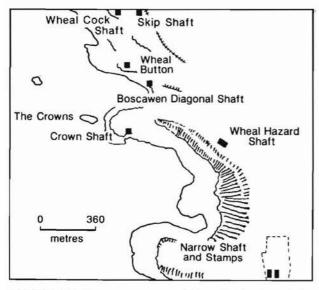


FIGURE 2. Location map of Botallack mine (after Noall, 1972).

Mineral identification was carried out in hand specimens and polished thin sections. The identifications were confirmed by X-ray diffraction (Phillips PW1390, using Ni-filtered CuK<sub>a</sub> radiation) and Fourier transform infrared spectroscopy (Perkin-Elmer 1700B, using KBr pellets). The minerals described in this study are now in the collections of the Natural History Museum, London, and the Department of Geology, Southampton University.

#### SUPERGENE MINERALS

The extensive supergene alteration of the Botallack copper lodes has produced a wide range of secondary chlorides, hydroxides, oxides, phosphates, arsenates and sulphates. In the descriptions below, minerals marked with an asterisk have not been described previously from the Botallack area, and kröhnkite is also new to the British Isles. A summary of the

supergene minerals found at each of the three studied localities is given in Table I.

**TABLE I.** Supergene mineral assemblages described in this paper. The minerals are listed in order of decreasing abundance.

Wheal Hazard	Botallack Cliff	Wheal Cock
(100 fathom leve	el)[SX 3625 3405]	(Skip shaft dump)
Quartz	Quartz	Quartz
Limonite	Limonite	Limonite
Gypsum	Gypsum	Chalcocite
Cuprite	Goethite	Cuprite
Jarosite	Cuprite	Goethite
Brochantite	Chalcocite	Scorodite
Chalcophyllite	Scorodite	Copper
Paratacamite	Jarosite	Pharmacosiderite
Natron	Paratacamite	Jarosite
Atacamite	Botallackite	Olivenite
Botallackite	Antlerite	Libethenite
Connellite	Connellite	Paratacamite
Woodwardite	Gold	Pseudomalachite
Antlerite	Chlorargyrite	Chalcophyllite
Chalcanthite	Woodwardite	Malachite
Kröhnkite	Atacamite	Connellite
Langite	Copper	Digenite
Devilline		Djurleite
Gold		Cornwallite
Chlorargyrite		Cornubite
Scorodite		Erythrite
Cyanotrichite		Manganite
		Clinoclase
		Bismuth
		Liroconite
		Silver

#### ANTLERITE, \* Cu, SO4(OH)4

This occurs as green coatings on gypsum and limonite in the Wheal Hazard section, associated with other copper sulphates, chlorargyrite, gold and botallackite (Fig. 6); occasional crystals measured up to 0.1 mm. Antlerite is also present as a coating on jarosite and limonite in material from the cliff section.

#### ATACAMITE, Cu<sub>2</sub>Cl(OH)<sub>3</sub>

Although thought at one time to be the dominant copper hydroxychloride at Botallack (Church, 1865b), more recent work showed that all the 'atacamites' from Botallack mine in the Natural History Museum collections are the more stable polymorph paratacamite (Frondel, 1950: Bannister et al., 1950). In this study all three polymorphs were found (atacamite, botallackite, and paratacamite). Atacamite occurs as dark green rhombohedra up to 1.6 mm in size, associated with botallackite, brochantite, chalcanthite, chlorargyrite, connellite, cuprite, gold, jarosite, kröhnkite, langite and limonite (Fig. 6). Atacamite was observed only in the vicinity of the sea breach underground.



**FIGURE 3**. Botallackite crystals associated with other copper minerals on a quartz-limonite matrix. Botallack cliff exposure. SEM photograph, scale bar 0.032 mm.

#### BISMUTH, Bi

Small rhombohedral crystals of bismuth have been recorded from Allen shaft (Greg and Lettsom, 1858; Wolloxall, 1989). In this study similar samples to those reported by Wolloxall (1989) were found on the Skip shaft dump, with bismuth wires up to 3 mm long associated with chalcocite, copper, silver and connellite on a chert-gossan matrix.

#### BOTALLACKITE, Cu2Cl(OH),

Botallackite was decribed by Church (1865b) as a new mineral from Botallack mine; the actual locality was the 20-fathom level of Wheal Cock, out under the sea (Kingsbury, 1964). The mineral is trimorphous with atacamite and paratacamite, and slowly recrystallised to the more stable polymorph paratacamite (Pollard et al., 1989a). In this study botallackite was observed as small pale green needles on a limonite matrix, associated with atacamite, paratacamite, copper sulphates, and gold, in the Wheal Hazard section and at the cliff exposure (Fig. 3).

#### BROCHANTITE, Cu<sub>4</sub>SO<sub>4</sub>(OH)<sub>6</sub>

Brochantite occurs as acicular crystals up to 0.3 mm long, associated with antlerite, atacamite, botallackite, chalcanthite, chlorargyrite. connellite, cyanotrichite, devilline, gold, jarosite, kröhnkite, langite, and limonite, in the Wheal Hazard section close to the sea breach (Fig. 7).

#### CHALCANTHITE, CuSO<sub>4</sub>.5H<sub>2</sub>O

A blue coating of chalcanthite on limonite, closely associated with antlerite, atacamite, botallackite, brochantite, chlorargyrite, chalcophyllite, connellite, cyanotrichite, devilline, kröhnkite and woodwardite, occurs in the Wheal Hazard underground section.

#### CHALCOCITE, Cu,S

This mineral is common in the cliff exposure and in material from the dumps at Wheal Cock. No chalcocite was observed underground in the Wheal Hazard section, although chalcocite was the main ore mineral in this part of the Crowns lode. The most common habit is as a granular aggregate, but occasionally prismatic crystals were found. One exceptional specimen, now in the collection of Southampton University, carried a pseudohexagonal twinned crystal 30 mm in size.

# CHALCOPHYLLITE,\* $Cu_{1x}Al_2(AsO_4)_3(SO_4)_3(OH)_{27}$ .-33H<sub>2</sub>O

Blue-green to emerald-green crystals of chalcophyllite (average size 0.02-1.1 mm) occur in vugs associated with other copper sulphates in the Wheal Hazard section. Chalcophyllite flakes (0.05-4 mm) were also found on a quartz-limonite matrix, associated with cornwallite, cornubite, erythrite. liroconite, paratacamite, and pharmacosiderite, from the dumps at Wheal Cock (Fig. 4).

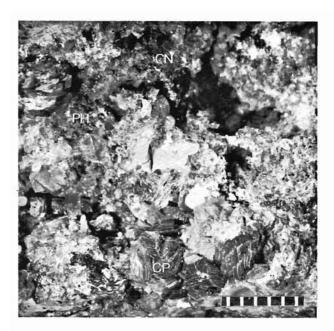


FIGURE 4. Chalcophyllite (CP), cornwallite (CN), and pharmacosiderite (PH) on a quartz-limonite matrix. Skip shaft dump. Scale divisions 1 mm.

#### CHLORARGYRITE, AgCI

In the Wheal Hazard assemblage, honey-yellow to brown crystals (up to 0.2 mm) of chlorargyrite are present (Fig. 6). Additionally, chlorargyrite is associated with gold on material collected from Botallack cliffs. Here the grains are larger (average 0.5 mm, with one grain 4 mm in size).

#### CLINOCLASE,\* Cu, AsO4(OH)3

This occurs as blue-green fibrous crystals (average size 0.03-0.06 mm, with one crystal 5.5 mm long) coating limonite and associated with copper arsenates and sulphates, erythrite, and pharmacosiderite, on the Skip shaft dumps at Wheal Cock.

#### CONNELLITE, Cu<sub>19</sub>Cl<sub>4</sub>SO<sub>4</sub>(OH)<sub>32</sub>.3H<sub>2</sub>O

In the Wheal Hazard section, connellite forms a light blue to turquoise-blue crust consisting of small crystals (0.5 mm) associated with atacamite, botallackite and copper sulphates (Fig. 6). Connellite also occurs as a light blue crust on chalcocite associated with copper in material collected from the Botallack cliffs, and with copper and bismuth in material from the Skip shaft dumps. Tallingite, described by Church (1865a) as a new mineral from Botallack mine, has been shown to be a carbonatian variety of connellite (Pollard et al., 1989b), but infrared traces of connellite from Botallack collected in this study showed no trace of carbonate.

#### COPPER, Cu

Brown-red tetrahedrons of copper up to 3 mm in size, associated with bismuth, chalcocite, connellite and silver, were found in surface material from the Skip shaft and from Botallack cliffs. Additionally, a moss-

like aggregate of copper 12 mm long was found on the Skip shaft dumps.

#### CORNUBITE, Cu<sub>5</sub>(AsO<sub>4</sub>)<sub>2</sub>(OH)<sub>4</sub>

This occurs as dark green coatings up to 1 mm thick, associated with chalcophyllite, clinoclase, cornwallite, erythrite, liroconite, paratacamite, pseudomalachite, and pharmacosiderite, on quartz-limonite matrix from the Skip shaft dump.

#### CORNWALLITE, Cu<sub>5</sub>(AsO<sub>4</sub>)<sub>2</sub>(OH)<sub>4</sub>.H<sub>2</sub>O

Cornwallite forms a light green coating on quartz-limonite matrix and is associated with chalcophyllite, clinoclase, cornubite, erythrite, liroconite, paratacamite and pharmacosiderite (Fig. 4). Cornwallite is also associated with cuprite. erythrite. libethenite, pseudomalachite, pharmacosiderite. olivenite, and scorodite, again on a quartz-limonite matrix. Both associations were found only on the Skip shaft dump.

#### CUPRITE, Cu2O

Lustrous complex aggregates of dodecahedral and octahedral crystals of cuprite, with individual crystals up to 6 mm across, were found in the Wheal Hazard section. intergrown with limonite, gypsum, jarosite, natron and quartz and coated by secondary copper sulphates and chlorides, chlorargyrite, and gold (Fig. 5). Cuprite was also found associated with copper, copper arsenates, libethenite, and pseudomalachite on a quartz-limonite-chalcocite matrix in material from the Skip shaft dump, and with copper in quartz-limonite matrix from the cliff section.

#### CYANOTRICHITE,\*Cu<sub>4</sub>Al<sub>2</sub>SO<sub>4</sub>(OH)<sub>12</sub>.2H<sub>2</sub>O

This occurs as blue acicular aggregates (up to 0.05 mm) on limonite, associated with copper sulphates, in the Wheal Hazard section.

#### DEVILLINE, CaCu<sub>4</sub>(SO<sub>4</sub>)<sub>2</sub>(OH)<sub>6</sub>.3H<sub>2</sub>O

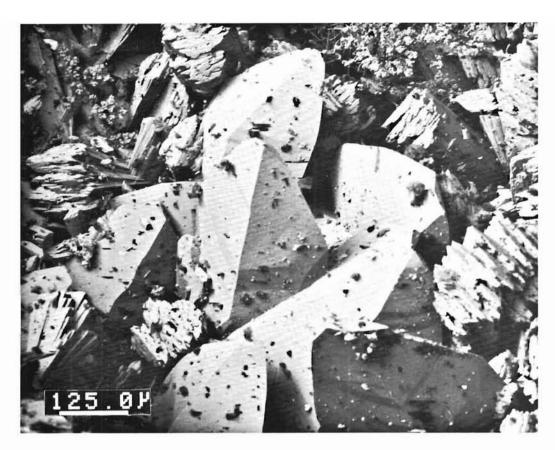
Dark green to turquoise coloured crusts and aggregates of small needles (up to 0.7 mm), associated with other copper sulphates, from the Wheal Hazard section.

#### DIGENITE (Cu<sub>2</sub>S<sub>5</sub>) AND DJURLEITE (Cu<sub>31</sub>S<sub>16</sub>)

These copper sulphides are present as microscopic grains associated with chalcocite replacing bornite in one sample from the Skip shaft dump, although both have been reported as being fairly common at Botallack (P.C. Tandy. personal communication).

#### ERYTHRITE, Co<sub>3</sub>(AsO<sub>4</sub>)<sub>2</sub>.8H<sub>2</sub>O

Radiating pinkish-red fibres on limonite associated with libethenite, pharmacosiderite, pseudomalachite, scorodite, and secondary copper arsenates, occur in material from the Skip shaft dump.



**FIGURE 5.** Cuprite crystals partly coated by antlerite, atacamite, brochantite, chalcanthite, chlorargyrite, connellite, devilline, gypsum, langite and woodwardite. Wheal Hazard, 100 fathom level. SEM photograph, scale bar 0.13 mm.



**FIGURE 6**. Gold (AU) associated with antlerite (AN), atacamite (AT), brochantite, botallackite (BO), chlorargyrite (CH), connellite (CO), cuprite, (CU) and limonite (I.). Wheal Hazard, 100 fathom level. SEM photograph, scale bar 0.29 mm.

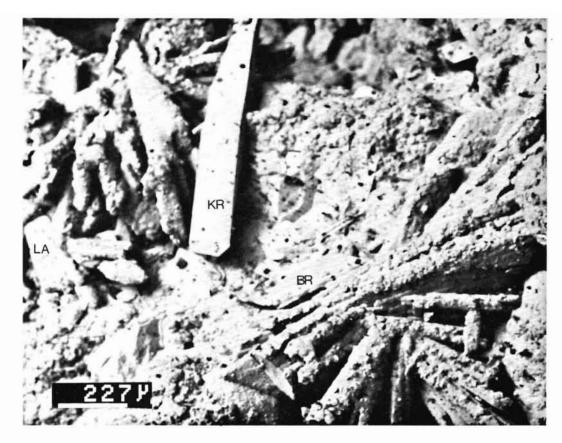


FIGURE 7. Kröhnkite (KR) fibres partly coated by cyanotrichite, devilline, gypsum and jarosite, associated with brochantite (BR) and langite (LA) on a cuprite-limonite matrix. Wheal Hazard, 100 fathom level. SEM photograph, scale bar 0.23 mm.

#### GOETHITE, FeO(OH)

Botryoidal massive goethite with well-developed colour banding on fresh surfaces is common in the Botallack area. Fine splays of acicular goethite crystals (up to 1.5 mm) occur in druses in massive goethite, and in a quartz-limonite matrix. in material from Botallack cliffs and Skip shaft dump.

#### GOLD, Au

Platelets and wires of gold are present in the quartz-limonite-cuprite matrix of the Wheal Hazard section, associated with copper sulphates and chlorides, chlorargyrite, jarosite, gypsum, and natron (Fig. 6). The grain size was 0.15-5 mm. Six grains were located in polished sections and their composition ranged from 96 to 97 wt% Au and 2 to 3 wt% Ag, with minor Cu and Fe (Bowell, 1992). Additionally, four gold grains were found in similar material from the cliff exposure. ranging in size from 0.1 to 0.3 mm. These grains occurred largely in fine-grained quartz or a chert type matrix, and have a slightly greater gold content than the gold from the underground exposure (Bowell, 1992). In both cases inclusions of cuprite. goethite, gypsum, jarosite, and scorodite are common in the gold grains.

#### GYPSUM, CaSO<sub>4</sub>.2H<sub>2</sub>O

Gypsum forms massive grey translucent aggregates, occasionally with slightly corroded crystals up to

25 mm in size. Much of the gypsum is intermixed with limonite and quartz and is coated by secondary copper minerals. Gypsum is present in the underground and surface exposures.

#### JAROSITE, KFe3(SO4)2(OH)6

Jarosite was found at all the sites examined and forms yellow to brown earthy masses which partly coat goethite. Material collected from the cliff site had trace quantities of Pb and Ag (by semi-quantitative EDX analysis), but elsewhere has a composition close to the ideal formula.

#### KRÖHNKITE,\* Na2Cu(SO4)2.2H2O

Kröhnkite was found only in material from the Wheal Hazard section and this is its first reported occurrence in the British Isles. The identification was confirmed by XRD and IR spectroscopy. The mineral occurs as blue interpenetrating fibres (Fig. 7) associated with antlerite, atacamite, brochantite, botallackite, chalcanthite, chlorargyrite, connellite, cyanotrichite, devilline, gold, goethite, gypsum, jarosite, langite, limonite, paratacamite, quartz, and woodwardite.

#### LANGITE, Cu<sub>4</sub>SO<sub>4</sub>(OH)<sub>6</sub>.2H<sub>2</sub>O

This occurs as blue globular aggregates associated with

other secondary copper minerals, particularly brochantite, on quartz, cuprite, gypsum and jarosite, in the Wheal Hazard section.

#### LIBETHENITE, Cu<sub>2</sub>PO<sub>4</sub>(OH)

Libethenite forms dark green crusts up to 1 cm across on a quartz-limonite-chalcocite matrix from the Skip shaft dump. It is intergrown with pseudomalachite, pharmacosiderite, olivenite, and scorodite, and is associated with cornwallite and cornubite.

#### LIROCONITE,\* Cu2AlAsO4(OH)4.4H2O

This mineral was found as a light blue granular aggregate (up to 0.05 mm grain size), associated with chalcophyllite, cornwallite, cornubite, olivenite, paratacamite, pharmacosiderite, and pseudomalachite, on a quartz-limonite matrix in material from the Skip shaft dump.

#### MALACHITE, Cu<sub>2</sub>CO<sub>3</sub>(OH)<sub>2</sub>

Malachite occurs as a green coating on a quartzjarosite-limonite matrix in material from the Skip shaft dump.

#### MANGANITE, MnO(OH)

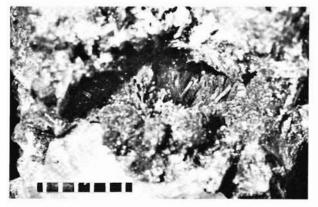
Although manganite is reported as being common at Botallack (Wolloxall, 1989), in this study only one splay of black needles was found in a vug in quartz-limonite matrix from the Skip shaft dump. The longest needle measured 1.2 mm.

#### NATRON, Na.CO<sub>3</sub>.10H<sub>2</sub>O

Natron occurs as a white precipitate intergrown with gypsum and jarosite in the Wheal Hazard section. This confirms a recent uncertain record of this mineral at Botallack mine (Ryback and Tandy, 1992).

#### OLIVENITE, Cu<sub>2</sub>AsO<sub>4</sub>(OH)

An olive-green coating of olivenite, associated with other secondary arsenates and phosphates, was found



**FIGURE 8.** Druse of olivenite crystals in quartzlimonite matrix associated with other copper arsenates. Skip shaft dump. Scale divisions 1 mm.

on a quartz-limonite matrix in material from the Skip shaft dump (fig. 8).

#### PARATACAMITE, Cu, Cl(OH),

The most common copper hydroxychloride polymorph at Botallack is paratacamite. Rhombohedral crystals up to 1.1 mm in size occur in the Wheal Hazard section and the Botallack cliff exposure, associated with other secondary copper minerals, chlorargyrite, and gold. Additionally, paratacamite occurs intergrown with chalcophyllite, copper arsenates and phosphates, erythrite, and pharmacosiderite on a quartz-limonite matrix in material from the Skip shaft dump.

PHARMACOSIDERITE. KFe<sub>4</sub>(AsO<sub>4</sub>)<sub>3</sub>(OH)<sub>4</sub>.6-7H<sub>2</sub>O This mineral occurs as small reddish brown crystals (up to 0.5 mm) intergrown with erythrite and scorodite, replacing arsenopyrite in material collected from the Skip shaft dump (Fig. 4). It is also associated with secondary copper minerals in a quartz-limonite-chalcocite matrix.

#### PSEUDOMALACHITE, Cu<sub>5</sub>(PO<sub>4</sub>)<sub>2</sub>(OH)<sub>4</sub>

A botryoidal aggregate of pseudomalachite, 3 mm in size, partly coated by copper phosphates and arsenates and resting on a quartz matrix, was found on the Skip shaft dump. Pseudomalachite also occurred here intergrown with chalcophyllite. clinoclase. cornwallite, cornubite, erythrite, libethenite, liroconite, olivenite, paratacamite, and pharmacosiderite, on quartz-limonite-chalcocite matrix.

#### SCORODITE,\* FeAsO4.2H,O

Scorodite forms a yellowish-brown to brownish-green coating associated with erythrite and pharmacosiderite, replacing arsenopyrite in material from the Skip shaft dump. Additionally, scorodite is associated closely with gold, and occurs in the cliff exposure as free grains and inclusions in gold, and in the Wheal Hazard section as inclusions in gold and jarosite.

#### SILVER, Ag

A single 0.6 mm-long wire of silver was found on the Skip shaft dump associated with bismuth, chalcocite, copper, and connellite.

#### WOODWARDITE, Cu<sub>4</sub>Al<sub>2</sub>SO<sub>4</sub>(OH)<sub>12</sub>.2-4H<sub>2</sub>O(?)

Woodwardite occurs as a green coating associated with other copper sulphates in the Wheal Hazard section, and as individual grains up to 0.07 mm at the Botallack cliff exposure.

#### DISCUSSION

The supergene leaching of copper in south-west England has been recorded in numerous studies, although no detailed investigation has been made of the supergene mineralogy (Henwood, 1843; Spargo, 1865; Church, 1865b; Dewey, 1923; Dines, 1956; Kingsbury, 1964). Supergene alteration of the copper lodes probably started in the post-Armorican early Mesozoic period when south-west England was approximately 200 300 miles from the equator (Tarling, 1979). The climate was that of a semi-arid desert with minor volcanic activity and deposition of sandstones and marls in a fresh-water environment. Under a hot arid environment, sulphides such as arsenopyrite would oxidize to form a series of more stable secondary phases. Although sphalerite and galena are present in the hypogene ore, no secondary zinc or lead minerals have been found. Present-day alteration of the copper lodes occurs dominantly by the action of sea-water either on the cliffs or at breaches in the mine, such as in the assemblages from Botallack cliff and Wheal Hazard decribed here (Table I).

This may explain the abundance of otherwise rare phases such as chlorargyrite, some of the copper sulphates, natron, and even gold. Although the effects of post-Armorican weathering cannot be ruled out, the presence of metastable phases such as atacamite and botallackite suggest that their deposition is relatively recent. With time these phases will alter into the more stable polymorph paratacamite (Pollard et al., 1989a), as probably happened on museum specimens collected from Botallack in the 19th century (Bannister et al., 1950; Frondel, 1950). The original botallackite (Church, 1865b) was collected from a submarine level in Wheal Cock into which sea-water had seeped for some 30 years through a plugged breach (Kingsbury, 1964), and was accompanied by what were described as 'tallingite' (carbonatian connellite) and atacamite. Thus the conditions were probably similar to those in the Wheal Hazard section studied here.

Both native bismuth and silver have been reported previously from Botallack (Wolloxall, 1989), but gold has not been recorded. Bismuth and silver may be resistant hypogene phases which have been preserved in the supergene assemblages, rather than products of supergene alteration, and the same could be said of the gold. However, the presence of cuprite, goethite, gypsum, jarosite and scorodite inclusions in the gold grains, and the lack of a gold-enriched rim on the grains (a common feature of hypogene gold subjected to supergene alteration), point to a supergene origin. The concentration of gold in sea-water is 0.002-48.7 µg/l (Goldberg, 1987; Koide et al., 1988; McHugh, 1988), the gold occurring as a complex with many of the dissolved species present in sea-water, such as chloride, bromide, iodide, thiosulphate, ammonia, and anions of organic acids (Koide et al., 1988). In groundwaters, the average concentration of gold is 0.002 µg/l but locally, where high concentrations of suitable ligands occur (e.g. from admixed sea-water), gold solubility may increase by four orders of magnitude (Mann, 1984; Stoffregan, 1986; McHugh, 1988). However, because of the limited Eh-pH environment under which these gold complexes are stable and the limited availability of

suitable ligands, extensive leaching of gold is unlikely so precipitation occurs. In the case of gold-thiosulphate complexation the breakdown of the complex ion  $\operatorname{Au}(S_2O_3)_2^{3}$  produces sulphate ions, which could explain the presence of jarosite and gypsum as inclusions in the precipitated gold.

Consequently the supergene copper assemblage at Botallack represents the product of supergene alteration of the copper lodes from the Permian to the present day, producing a suite of arsenates, halides, phosphates, sulphates, sulphides, and oxides which, along with the hypogene ore, has been extensively modified and overprinted by sea-water infiltration.

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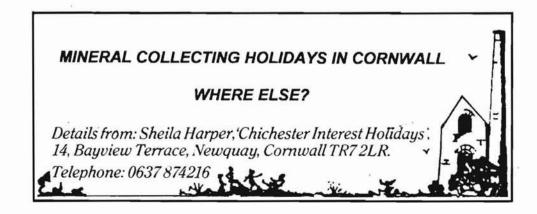
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# THE COMPOSITION OF STOLZITE FROM WANLOCKHEAD AND WULFENITE FROM VARIOUS SCOTTISH LOCALITIES

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Twenty-two electron probe microanalyses are presented for wulfenite, and one for scheelite, from various Scottish localities. Little chemical variation is apparent, in keeping with wulfenite analyses (from worldwide localities) throughout the literature. Wulfenite from granitic environments is higher in tungsten than that from lead-zinc deposits. Two tabular crystals from Wanlockhead, however, exhibit a wide range in molybdenum-tungsten substitution: one crystal is molybdenian stolzite, the second a tungstenian wulfenite.

#### INTRODUCTION

Wulfenite is a rare mineral throughout Scotland although Green (1986) pointed out that its readily recognisable characteristics under the stereomicroscope have led to it being identified from numerous localities. Heddle (1901) reported wulfenite from only one locality (Lauchentyre mine, Kirkcudbrightshire), whereas Dudgeon (1890) tentatively identified stolzite from Girthon (3.2 km south of Gatehouse of Fleet, Kirkcudbrightshire). Lauchentyre mine remained the only known Scottish locality for wulfenite until Russell (1946) added a second occurrence at Struy mines, Inverness-shire. Green (1986) noted that wulfenite may be found on Broad Law dumps, Leadhills, and at Pibble mine, Kirkcudbrightshire. Wulfenite has also been reported from the Susanna mine dumps, Leadhills (Rust, 1963). Within the Royal Museum of Scotland Scottish Mineral Collection wulfenite is additionally known from Pass of Ballater and Abergairn, Aberdeenshire.

#### MORPHOLOGY AND COLOUR

Morphologically, Scottish wulfenite is commonly tabular or displays a combination of prism with various pyramids. Rare cases of the acute bipyramidal form {111} are found at Struy mines, Inverness-shire, and Gairnshiel, Aberdeenshire. The colour ranges from golden yellow, orangy-red, browny-red to smoky purplish-grey, the last being found only at Gairnshiel. Pure synthetic PbMoO<sub>4</sub> is colourless whereas natural wulfenite displays a range of colours from the characteristic yellowy-orange and deep reddish hues to smoky blue-grey, white and grey to black. Bideaux (1990) demonstrated that chromium was responsible for the red colouration, the chromium tenor being 0.18% in the deepest red varieties from Iran.

#### CHEMISTRY

Scottish wulfenite has not been previously quantitatively analysed. A reluctance to sacrifice aesthetic material may be one reason, combined with analytical

difficulties with tiny grains (e.g. 0.4 mm long). For this study Mr T.K. Meikle has generously donated material collected over a number of years from numerous Scottish localities where he has identified wulfenite. Both bipyramidal and tabular forms (the former more abundant) were present on minute, imperfect crystals found on pyromorphite-quartz specimens or on greisen.

Wulfenite theoretically contains 60.79% PbO and 39.21% MoO<sub>3</sub>; the high content of the latter might imply the presence of a primary molybdenum phase in most wulfenite-bearing deposits. However, Bideaux (1990) intimated that the source of the molybdenum is enigmatic, for most deposits containing wulfenite are devoid of primary molybdenum minerals.

Within the Leadhills-Wanlockhead orefield, wulfenite from Raik, Margaret's and Susanna veins, and from Whyte's Cleuch, have been analysed. Drumruck, Struy and Lauchentyre mines provided specimens from additional lead-zinc deposits. Wulfenite from granitic environments came from Pass of Ballater and Gairnshiel. In order to prevent unnecessary duplication of wulfenite and scheelite analyses, which show little variation within individual localities, average compositions are reported in Table I (analyses 1-9). All analyses were undertaken on polished grains using a Camebax Cameca microprobe utilizing metals, galena and wollastonite standards. Salient features from Table I are the higher tungsten values in wulfenite from granitic parageneses (analyses 3, 4 and 7), but even at Gairnshiel they are surprisingly low in spite of locally abundant hübnerite (MnWO4) in the greisen from which the wulfenite was extracted. Molybdenite (MoS<sub>2</sub>) and koechlinite (Bi<sub>2</sub>MoO<sub>6</sub>) are also present in the greisen, and it is noteworthy that the wulfenite from granite environments shows greater site occupancy, 0.993 0.999 atoms of (Mo + W) per mole, than wulfenite from small lead-zinc deposits. Substitution of tungsten by molybdenum in the Gairnshiel scheelite lattice has not occurred in spite of molybdenum availability (analysis 9).

Backscattered-electron imaging of a  $60 \times 60 \mu m$  crystal from Whyte's Cleuch revealed higher peripheral tungsten levels compared with core concentrations.

TABLE I. Electron-microprobe analyses (weight %) of wulfenite, scheelite, stolzite and tungstenian wulfenite.

Analysis	1	2	3	4	5	6	7	8	9
MoO <sub>3</sub>	38.34	38.05	38.92	38.16	38.67	37.09	39.08	38.54	0.00
FeO	0.09	0.11	0.06	0.07	0.04	0.09	0.00	0.09	0.12
PbO	61.15	62.41	60.72	61.36	62.40	62.70	61.09	62.15	0.05
CaO	0.01	0.01	0.01	0.06	0.00	0.00	0.02	0.00	20.51
MnO	0.03	0.04	0.02	0.13	0.05	0.03	0.00	0.02	0.00
WO,	0.07	0.07	0.67	0.65	0.04	0.04	0.30	0.02	77.64
Total	99.69	100.69	100.40	100.43	101.20	99.95	100.49	100.82	98.32
FORMUL	A ON 4 OX	YGENS							#2
Pb	1.021	1.041	0.995	1.019	1.028	1.066	1.003	1.028	-
Mo	0.991	0.985	0.988	0.982	0.991	0.979	0.995	0.991	-
W	-	===	0.011	0.011	19	- 1000 Held	0.003	***	0.977
Ca	$(-1)^{n}$	-	-	entententen	-		=	-	1.067
Analysis	10	11	12	13	14	15	16	17	
MoO <sub>3</sub>	10.79	14.52	14.35	7.34	7.38	15.33	15.57	9.49	
FeO	0.06	0.05	0.06	0.04	0.05	0.01	0.06	0.02	
PbO	53.48	53.29	54.37	52.04	51.62	54.99	54.47	52.28	
CaO	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	
MnO	0.02	0.01	0.04	0.04	0.01	0.01	0.03	0.00	
WO,	33.81	29.27	29.13	38.49	38.77	28.26	27.94	35.84	
Total	98.16	97.15	97.95	97.95	97.83	98.61	98.07	97.63	
FORMUL	A ON 4 OX	YGENS							
Pb	1.177	1.038	1.060	1.054	1.044	1.058	1.049	1.045	
Mo	0.369	0.438	0.433	0.231	0.230	0.457	0.464	0.295	
W	0.719	0.547	0.548	0.751	0.754	0.523	0.518	0.688	
Analysis	18	19	20	21	22	23			
MoO <sub>3</sub>	24.75	23.20	22.75	33.70	18.94	21.78			
PbO	57.29	55.88	55.74	60.71	54.42	54.53			
CaO	0.02	0.03	0.02	0.01	0.02	0.03			
$WO_3$	17.37	20.63	20.07	6.17	25.40	22.13			
Total	99.43	99.74	98.58	100.59	98.78	98.47			
FORMUL	A ON 4 OX	YGENS							
Pb	1.026	0.999	1.014	1.033	1.009	0.992			
Mo	0.689	0.643	0.643	0.889	0.544	0.614			
W	0.301	0.356	0.350	0.098	0.451	0.386			

<sup>1.</sup> Wulfenite, Struy lead mines, near Cannich. Inverness-shire [NH 375 380]. Average of 4 analyses, single spot per grain. 2. Wulfenite, Lauchentyre lead mine, near Anwoth, Kirkcudbrightshire [NX 558 571]. Average of 5 analyses from two grains. 3. Wulfenite from greisen, Gairnshiel, Gairnshiel Bridge, near Ballater, Aberdeenshire [NJ 292 009]. Average of 5 analyses from 5 grains. 4. Wulfenite from granite, Pass of Ballater, Aberdeenshire [NO 365 969]. Average of 2 analyses from one grain. 5. Wulfenite, Drumruck lead mine, near Gatehouse of Fleet, Kirkcudbrightshire [NX 582 635]. Average of 3 analyses from two grains. 6. Wulfenite, Raik vein, Leadhills, Lanarkshire [NS 889 157]. Average of 5 analyses from 5 grains. 7. Wulfenite, smoky purplish-grey from greisen, Gairnshiel, Gairnshiel Bridge, near Ballater, Aberdeenshire [NJ 292 009]. Average of 3 analyses from 3 grains. 8. Wulfenite, Susanna vein, Leadhills, Lanarkshire [NS 880 158]. One analysis. 9. Scheelite from greisen, Gairnshiel, Gairnshiel Bridge, near Ballater, Aberdeenshire [NJ 292 009]. Average of 3 analyses from three grains. 10-17. Molybdenian stolzite, Whyte's Cleuch, Wanlockhead, Dumfriesshire [NS 867 137]. Single grain. 18-23. Tungstenian wulfenite, Margaret's vein, Wanlockhead, Dumfriesshire [NS 875 130]. Single grain.

Analyses 10-17 of this grain demonstrate tungsten dominance over molybdenum, and the crystal is therefore a molybdenian stolzite with a compositional range  $Pb(W_{0.75}Mo_{0.23})O_4$  to  $Pb(W_{0.52}Mo_{0.46})O_4$ . A crystal of tungstenian wulfenite from Margaret's vein also exhibits wide compositional variation within the single crystal, from 0.1 to 0.45 W atoms per mole (analyses 18-23). As far as the author is aware tungsten or molybdenum minerals apart from wulfenite have not been reported before from the Leadhills-Wanlockhead area. Specimens of supposed 'eosite' (a vanadomolybdate of lead) from Leadhills (Heddle, 1901) have been examined and do not contain molybdenum; the 'eosite' is vanadinite. Jaeger and Germs (1921) demonstrated, for synthetic material, that a complete solid solution series exists between tetragonal PbWO4 (stolzite) and PbMoO<sub>4</sub> (wulfenite). It is remarkable that two single crystals, in toto, demonstrate the wide range of solid solutions in natural material whereas 28 other analyses (from which analyses 1-8, Table I, were computed) reveal little variation. Similarly, Williams (1966) found that only three of sixty-four analyses of wulfenite from numerous localities displayed appreciable deviation.

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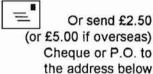
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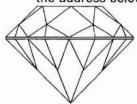
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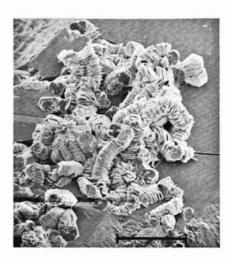
#### INTRODUCTION

Springhill quarry (also known as Peldar Tor quarry; SK 449 158), at Peldar Tor, Whitwick, north-west Leicestershire, is working late Precambrian porphyritic dacite (the 'Peldar Tor porphyroid' of Watts, 1947) associated with the intrusive Whitwick Complex. This complex may be contemporaneous with bedded tuffs in part of the Mapplewell Group of the Charnian Supergroup (Moseley and Ford, 1985). The dacite contains phenocrysts of K-feldspar, plagioclase and quartz in a fine-grained matrix of epidote, chlorite, feldspar and iron oxides. Secondary, finely divided hematite is widespread. Thrust belts, which are obvious features in the quarry, carry vein quartz, chlorite, specular hematite and, very rarely, gold (King and Ford, 1968). Quartz veins with a range of orientations are widespread in the quarry; only one has been found to contain mottramite.

#### MINERALISATION

The minerals described below occurred in one of a number of quartz-rich veins (dipping at about 50° to the north-west), located in the south-western face of the lowest level (1983-1986) in the quarry. Quarrying operations during 1986-1987 removed the exposures, but they may well reappear when lower levels are developed. The mottramite-bearing vein, up to 20 cm wide, consists mainly of white to colourless quartz. In addition to the massive white quartz which forms the bulk of the veins, colourless and transparent prismatic crystals (to 4 cm) occur in cavities. Many of the quartz crystals have small chlorite inclusions. The cavities are often filled with brown calcite, a red-brown clay, and green earthy chlorite. A few crystals appear to be freegrowing in the calcite clay, and are doubly terminated, displaying parallel growth and a flattened habit. This latter is typical of many quartz crystals from Charnian rocks (R.J. King, personal communication).

Chlorite is found as loose, green, earthy aggregates of small (<0.5 mm) flakes or vermicular stacks (Fig. 1),



**FIGURE 1.** SEM photograph showing 'books' and vermicular stacks of ferroan clinochlore on, and partly included in, a quartz crystal. LEIUG 113864. Scale bar 0.2 mm.

filling cavities in the quartz, and sometimes included in it. King (1973) analysed similar earthy material from elsewhere in the quarry and identified it as 'pycnochlorite', or ferroan clinochlore.

Hematite occurs in two main forms: as plates of specular hematite (<1 cm) associated with pale-green. fine-grained muscovite in quartz, and as reddish or brown finely divided material on joint planes in the dacite, and included in early calcite within the quartz veins. Specimens from the veins which show specular hematite do not show baryte, pyrolusite or mottramite.

Muscovite (2M<sub>1</sub> polytype) forms aggregates of small (<0.5 mm) greenish yellow flakes, associated with specular hematite, filling cavities in quartz.

Calcite is present in two distinct settings. The earliest is as brown or reddish brown (due to associated hematite) irregularly crystallised material coating quartz. In many places this grades into pale brown to colourless scalenohedral crystals, the most abundant form of calcite in the veins. This calcite partly fills most

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of the cavities in the quartz veins. The crystals are singly or sometimes doubly terminated scalenohedra up to 1 cm long, frequently with curved faces.

A late generation of dolomite forms small (up to 1 mm) white or colourless rhombohedra, set on baryte, pyrolusite or mottramite.



FIGURE 2. SEM photograph showing pyrolusite crystals, some with stepped terminations, with dolomite rhombs. LEIUG 113864. Scale bar 0.3 mm.

Pyrolusite occurs as black films on chlorite aggregates, or on joints, and as lustrous or sooty black acicular crystals (Fig. 2) on quartz. calcite or dolomite (rarely included in dolomite), or baryte. It is often associated with baryte which occurs as small (<2 mm) white to pink crystals, in typical cockscomb groups.

#### **MOTTRAMITE**

The mottramite crystals show a number of different habits. Small tabular crystals (0.1-1 mm), occurring individually or in groups, are the most common. Many of the faces are noticeably curved (Fig. 3). These crystals are similar to those described by Wilson (1971) from Apache mine, Gila County, Arizona. When small, such crystals are translucent to opaque, olive-green to black, with a vitreous lustre, and are usually found on quartz. Larger crystals of this type are opaque and dark-brown to black in colour, sometimes with a submetallic olive-green coating, and occur on quartz or calcite in cavities with baryte and pyrolusite.

Much larger crystals also occur. These tend to show more complex forms. Several habits are seen: almost globular interpenetrant clusters, cogwheels, elongated blades and spear-like bundles. The last are the largest crystals seen (up to 7 mm), and are probably the largest recorded from any British locality. Most of these large crystals are dark-brown to black in colour, although a few have a green powdery surface which also seems to be composed of mottramite. Unfortunately, these large crystals have proved remarkably difficult to photograph!

Semi-quantitative EDAX analyses of a small brown tabular crystal indicated the presence of major Pb, Cu



FIGURE 3. SEM photograph showing mottramite crystal with composite faces, resulting in development of curved faces and edges. An etched dolomite rhomb can be seen on the tip of the mottramite crystal. LEIUG 113865. Scale bar 0.2 mm.

and V, and traces of Ca, Fe and Mn. The analysed crystal appeared to be homogeneous. Zinc was not detected; thus the mottramite is very close to the pure end-member composition. A fragment of the analysed crystal gave an XRD pattern very similar to that of mottramite in the JCPDS index.

#### **PARAGENESIS**

An approximate paragenetic sequence is given in Fig. 4. The middle and later parts of the sequence are somewhat conjectural given the paucity of unambiguous relationships observed. The onset of hematite crystallisation seems to mark a change in the chemistry of the solutions. Before this, oxygen fugacity was relatively low — the chlorite analysed by King (1973) has a Fe<sup>2+</sup>/Fe<sup>3+</sup> ratio of more than 5. After this point, no Fe<sup>2+</sup> minerals are seen and all ionic species are highly oxidised (Mn<sup>4+</sup>, Fe<sup>3+</sup>, SO<sub>4</sub><sup>2-</sup>, VO<sub>4</sub><sup>3-</sup>).

Other vanadate minerals occur in small quantities at several places in Leicestershire (e.g. King and Dixon,

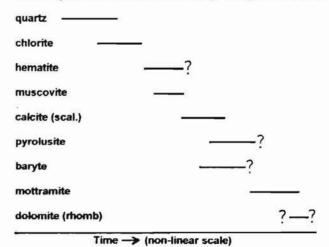


FIGURE 4. Paragenetic sequence of mineralisation.

1971; King and Wilson, 1976). All these occurrences are either in Triassic sediments, or near the Triassic unconformity. Such 'red-bed' vanadate occurrences are common elsewhere in the world. Members of the mottramite-descloizite series are also found in the oxidised zones of Pb-Cu-Zn deposits, for example in the Leadhills-Wanlockhead area (Brown, 1926) and the Caldbeck Fells (Young, 1987). An occurrence at Judkins quarry, Nuneaton, Warwickshire, is described by Ince et al. (1990). Here mottramite and vanadinite are fairly abundant as secondary minerals in thin veins cutting late Precambrian tuffs. Lead and copper sulphides are also found here, together with other secondary copper minerals.

The Springhill quarry occurrence, some 80-100 m below the Triassic unconformity, is clearly distinct from these. There are no associated copper or lead minerals. The early quartz-chlorite-muscovite-hematite assemblage in the veins, together with the secondary epidote, hematite and chlorite common in the groundmass of the dacite, suggest an origin during lower greenschist facies conditions. It is likely that the veins are similar in age to the pervasive low-grade metamorphism of the Charnian rocks. It is not entirely clear that the hematite-pyrolusite-mottramite mineralisation immediately followed on from the quartz-chlorite deposition. It may be related to a distinct later event which utilised the same fractures. However, there does not seem to be much evidence for brecciation of pre-existing vein material, nor for cross-cutting relationships, which might be expected if this were the case.

Whether the quartz-chlorite and the later assemblages are approximately coeval, or whether they are significantly separated in time, they represent significantly different fluid chemistries. The quartz-chlorite episode represents 'normal' low-grade metamorphic fluids. Many rocks in Britain and around the world have suffered such low-grade metamorphism. A large proportion of these contain quartz-chlorite veins. None, to our knowledge, has been recorded as containing mottramite. There seem to be no published data on the pressure-temperature-compositional stability of mottramite, or on vanadium ionic speciation in Fe-Ca-Ba-Mn-Pb-Cu-SO<sub>4</sub><sup>2</sup>-CO<sub>3</sub><sup>2</sup>-bearing solutions. It is not possible, therefore, to make more than rather general statements about solution chemistry. The mottramite must have crystallised from mildly alkaline solutions, as calcite seems to have been stable during deposition of mottramite. Under such conditions, VO<sub>4</sub><sup>3-</sup> ions may be stable at relatively low Eh (Evans and Garrels, 1958). Prior to crystallisation of the calcite, a lower pH would be required to maintain Fe and Mn in solution. It is notable that hematite forms before or with the calcite, and pyrolusite soon after (Fig. 4). This is the sequence one would expect with increasing pH (and/or Eh) in a Fe2+-Mn2+ solution (Krauskopf, 1957). Oxidising conditions are required to form pyrolusite rather than rhodochrosite, or to prevent Mn being incorporated in calcite. Lead and copper did not precipitate as carbonates, as one might expect in a calcite-saturated oxidising

solution, presumably because of high VO<sub>4</sub><sup>3-</sup> activity and or low abundances of Pb<sup>2+</sup> and Cu<sup>2+</sup>.

The source of the metals is unclear but, given the tiny total mass of Pb, Cu and V involved, suitable leaching of almost any rock would be capable of providing the quantities observed. An origin from downward percolating Triassic groundwaters cannot be ruled out, although most of the field evidence suggests that the mottramite is associated with pre-Triassic low-grade metamorphism. Oxidation of magnetite under such conditions might release small quantities of vanadium. Mottramite (especially when black or brown) is not the most conspicuous of minerals — it may be commoner than has been supposed in altered volcanic rocks.

Representative specimens, including those figured here, have been deposited in the collections of Leicester University Geology Department (LFIUG 95051-55, 113864-67).

#### **ACKNOWLEDGEMENTS**

Thanks are due to Mr D.G. Steeples, the ARC area manager, and Mr S. Chambers, the quarry manager, for permission to visit the quarry. Photographs were taken using the Hitachi S-520 Scanning Electron Microscope facility at Leicester University Geology Department, and are secondary electron images.

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## NOTES

# CONNELLITE FROM COLVEND, KIRKCUDBRIGHTSHIRE, AND BROCHANTITE FROM AUCHENCAT BURN, DUMFRIESSHIRE

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The secondary copper minerals connellite, Cu<sub>19</sub>Cl<sub>4</sub>(SO<sub>4</sub>) (OH)<sub>32</sub>.3H<sub>2</sub>O. and brochantite, Cu<sub>4</sub>(SO<sub>4</sub>)(OH)<sub>6</sub>, are rarely encountered in Scotland. They have both been reported as occurring in uranium-bearing veins near Dalbeattie, Kirkcudbrightshire (Miller and Taylor, 1966; Braithwaite and Knight, 1990) and brochantite occurs with other basic copper sulphates at West Blackcraig mine, near Newton Stewart, Kirkcudbrightshire (Livingstone et al., 1976). Heddle (1901) reported brochantite from Sandlodge mine, Shetland and from Rassal mine, Loch Kishorn, Ross-shire, but that from Sandlodge was, in fact, malachite (Macpherson and Livingstone, 1982). The National Museum of Scotland has identified brochantite in several Heddle specimens from the Leadhills and Wanlockhead area (B. Jackson, personal communication). At all these localities connellite and brochantite appear to be scarce. This note describes an occurrence of connellite at Colvend mine, near Rockcliffe, Kirkcudbrightshire and of brochantite at Auchencat Burn, near Moffat, Dumfriesshire. In each case the mineral is locally abundant and good specimens may be readily obtained.

#### **COLVEND MINE**

Colvend mine [Grid ref. NX 868 527] is described by Wilson (1921, p.126) who states that the deposit, which was worked around 1770, consisted of a vein along a north-east trending fault in porphyritic felsite. The ores were chalcopyrite, malachite and azurite in a gangue of calcite, quartz and crushed rock. In an adit driven three fathoms along the vein, just above the high water mark, Wilson records encrustations of 'soft oxides of iron, together with azurite and malachite.'

The mine may be reached by following the coastal path from Rockcliffe. The only workings visible now are an infilled shaft beside the path and the aforementioned adit in a narrow sea inlet immediately below a small monument. Connellite occurs abundantly on the east wall of the adit, near the entrance. It forms deep blue encrustations up to 1 mm thick over areas up to  $10 \times 20$  cm, which often exhibit a rippled appearance resembling the so-called 'flow-stone' found in caves. Identification was by X-ray diffraction and infrared spectroscopy.

Accompanying the connellite are encrustations of a pale blue, powdery material. Chemical tests show this to contain chloride, sulphate and copper but it was found to be amorphous by XRD. Malachite occurs as green stains and as minute (ca 0.2 mm) green spherules in fractures in the wall rock. Orange and brown hydrous iron oxides cover much of the floor of the adit and, towards the end of the level, well-formed gypsum crystals up to 1 cm in size coat the roof and walls. Contrary to Wilson's description, no azurite was observed in this adit. It is possible that Wilson may have mistaken connellite for azurite.

#### **AUCHENCAT BURN**

Little is recorded about this copper trial [NT 090 110] next to the Auchencat Burn, below Hartfell Spa, near Moffat. Wilson (1921, p.131) makes only a brief mention of it. Approximately 1 km below the spa, on the south side of the burn, an adit has been driven southwards in copper-stained Silurian shales. This can be followed for some tens of metres before it is partially blocked by a small roof fall. Near the entrance a branch goes eastwards for a few metres before terminating.

The shales at the entrance and up to about 3-4 m west of the adit mouth are heavily stained and impregnated with malachite and brochantite. Malachite is the more common and occurs as bright green, finely mamillated films and coatings up to 1 mm thick along cleavage planes and fracture surfaces in the shale. It also forms rosettes up to 4 mm in diameter with a fibrous radiating structure and sometimes showing concentric banding. Brochantite occurs as emerald green, minutely crystallised films, up to 0.5 mm thick and 4 cm across, on cleavage planes and fracture surfaces of the shale. Identification was by X-ray diffraction.

#### DISCUSSION

The connellite, malachite, gypsum and iron oxide assemblage at Colvend mine undoubtedly formed on the walls of the mine after it was abandoned. It may be assumed that the chloride in the connellite was derived from sea-water. Connellite of post-mine origin has been

observed before in mine adits in sea-cliffs (e.g. Moreton, 1991), and is probably to be expected whenever copper mineralisation occurs on the sea-shore. The original Scottish connellite locality (Miller and Taylor, 1966) is also a coastal one.

The malachite and brochantite at Auchencat Burn are not of post-mine origin but are most likely the result of the oxidation of disseminated sulphides in the shales where they outcrop. The shales are slightly pyritiferous, although no copper sulphides can be detected visually. No doubt it was the presence of copper staining in these shales that first drew the attention of the miners.

#### **ACKNOWLEDGEMENTS**

Thanks are extended to Mr Brian Jackson of the National Museum of Scotland for helpful comments during the writing of this note and for IR spectroscopy of connellite.

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# BARIUM-PHARMACOSIDERITE AND SYMPLESITE FROM CALDBECK FELLS, CUMBRIA

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#### **BARIUM-PHARMACOSIDERITE**

Whereas pharmacosiderite, KFe<sub>4</sub><sup>3+</sup>(AsO<sub>4</sub>)<sub>3</sub>(OH)<sub>4</sub>.6-7H<sub>2</sub>O, has long been known as beautiful, well-crystal-lised specimens from several localities on Caldbeck Fells (e.g. Young, 1987; Cooper and Stanley, 1990), the barium analogue barium-pharmacosiderite, BaFe<sub>8</sub><sup>3+</sup> (AsO<sub>4</sub>)<sub>6</sub>(OH)<sub>8</sub>.14H<sub>2</sub>O, has not hitherto been reported from the area. To date we have been able to trace only two references to the occurrence of this mineral in the British Isles. A partial analysis of a specimen described simply as from 'Cornwall,

England' was given by Peacor and Dunn (1985), and it has been identified from Tynagh mine, Co. Galway, Eire (see Ryback and Tandy, 1992).

Barium-pharmacosiderite was first described as a new mineral from the Clara mine, Black Forest, Germany, by Walenta (1966) and, in addition to the occurrences noted above, it has been reported from Czechoslovakia (Čech et al., 1975), from Schramberg, Germany (Walenta, 1980), and from Aschaffenberg, Germany; Liebenschlehen mine, Neustaedtel-Schneeberg, Germany; Tintic district, Utah, USA; and

Robinson's Reef, Port Phillip, Victoria, Australia (Peacor and Dunn, 1985). Barium-pharmacosiderite is described here from two localities on Caldbeck Fells, Cumbria.

#### DUMPY STONE LEVEL [NY 3268 3641]

This small trial working is situated at the northeastern mapped extremity of the SW-NE trending Low Pike vein, one of the longest mineralised faults which cut the Eycott Volcanic Group. The only exposure of the vein at the Dumpy Stone today consists of a few centimetres of barren quartz in the roof of the collapsed adit portal. The small dump at the level mouth is almost completely overgrown but has yielded samples of such supergene minerals as beaverite and beudantite (Kingsbury and Hartley, 1957a; Hartley, 1984).

X-ray diffraction of recently collected material from here has revealed the presence of barium-pharmacosiderite (BGS powder photograph XE 719). The mineral occurs as pale greenish brown cellular earthy to finely crystalline crusts in porous cellular quartz. Apart from quartz and brown earthy iron oxides no other minerals have been identified on the few specimens bearing barium-pharmacosiderite which have been collected.

#### SANDBEDS MINE [NY 329 358]

A wide variety of minerals has been described from the veins worked for lead and barytes at Sandbeds mine (e.g. Young, 1987; Cooper and Stanley, 1990). The veins were worked opencast as well as underground though there are very few good exposures of mineralised ground at Sandbeds today. The most important vein worked here was the SW-NE trending Roughtongill South vein, the outcrop of which may be traced south-westwards from Sandbeds through a series of collapsed opencuts and old shafts. An isolated exposure in one of these opencuts shows an irregular rib up to 1 m wide of highly oxidised vein material composed principally of quartz and arsenopyrite with traces of galena, and abundant pale green to brown and reddish brown cellular, crystalline beudantite, some of which may be pseudomorphous after carminite. The field relations of this vein exposure are not clear. It may be a faulted portion of the main Roughtongill South vein or, perhaps more likely, a branch vein on the footwall side of this vein.

Locally within this vein the joint surfaces carry distinctive radiating aggregates up to 5 mm across composed of a pale green to greenish white rather dull earthy mineral. X-ray powder photography has identified this as barium-pharmacosiderite (XE 725). Closer examination of these rosettes suggest that they may be pseudomorphs after a mineral of radiating, bladed habit. The precise form of the original mineral cannot now be distinguished on the few specimens obtained, though cerussite or anglesite are considered most likely.

#### SYMPLESITE

Within the Lake District symplesite, Fe<sub>3</sub><sup>2+</sup>(AsO<sub>4</sub>)<sub>2</sub>.8H<sub>2</sub>O, has been reported from Wanthwaite mine, St John's in the Vale (Young, 1987). Cooper and Stanley (1990) referred to an undifferentiated member of the symplesite-metavivianite series found in dump material from the old trial level [NY 323 370] at the foot of Nether Row Brow. Symplesite has been identified by X-ray powder photography on samples collected recently from a temporary exposure of the vein in the track immediately south of the collapsed level portal. The mineral occurs as crusts of greenish-white to pale brown spherules up to about 0.5 mm across composed of very delicate radiating fibrous crystals (XE 708) coating joint surfaces of compact quartz, and as apparently structureless bluish-grey coatings (XE 709) up to about 10 mm across, also on quartz. A large variety of rare supergene minerals have been reported of the dumps this trial These include arseniosiderite (Kingsbury and Hartley. 1957b); beudantite, carminite and pharmacosiderite (Kingsbury and Hartley, 1960); mottramite (Kingsbury and Hartley, 1956); and plumbojarosite and beaverite (Kingsbury and Hartley, 1957a). Recent detailed mapping by one of us (D.M.) has shown that this trial is situated on a SW-NE trending vein and not, as Kingsbury and Hartley believed, on the same vein as that tried in the Dumpy Stone level.

#### ACKNOWLEDGEMENTS

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# CUPROSKLODOWSKITE FRÖM GEEVOR MINE, CORNWALL

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Cuprosklodowskite,  $(H_3O)_2Cu(UO_2)_2(SiO_4)_2.2H_2O$ , is a supergene mineral typically found in the oxidised zone of copper and uranium deposits. The mineral was originally described by Vaes (1933) from specimens found at the Kolongwe mine, Shaba (Katanga), Zaire, where it occurred as thick encrustations of pale to dark

green acicular crystals up to about 1 cm long. Associated minerals included vandenbrandeite, kasolite, malachite and rarely becquerelite and soddyite (Gauthier et al., 1989). It has also been discovered at other deposits in the Shaba region (Deliens et al., 1981) and at many localities worldwide (Frondel, 1958;

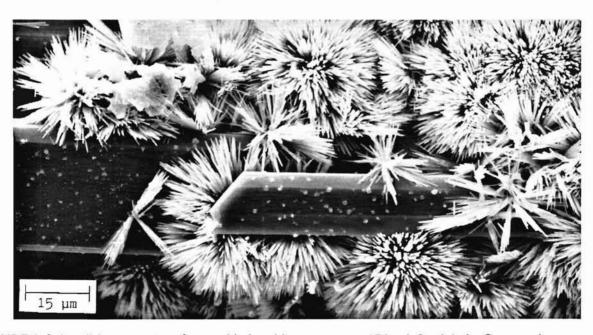


FIGURE 1. Spherulitic aggregates of cuprosklodowskite on gypsum, 17 level, Peeth lode, Geevor mine.

Smith, 1984; Roberts et al., 1990). The first British specimens of cuprosklodowskite, which were identified in 1991, were collected from a backfilled stope in the Cargodna section of West Wheal Owles, St Just, Cornwall. The mineral here occurred as pale to dark green botryoidal crusts and silky coatings composed of small radiating acicular crystals (see Ryback and Tandy, 1992).

A second British occurrence of cuprosklodowskite has now been confirmed at Geevor mine, St Just, Cornwall [Grid ref. SW 37 34]. Only one specimen is known to the authors and was collected in situ from the wall of a drive on 17 level in the Peeth lode. The specimen is composed of quartz spotted with chalcopyrite which is accompanied by small brown wartlike deposits of manganese and iron oxides. Crystallised gypsum and a thin deposit of fine sand cover parts of the surface. Cuprosklodowskite forms a thin, pale green crust of about 1 cm2, composed of tiny spherulitic aggregates and divergent groups of acicular crystals up to about 0.01 mm long (Fig. 1), covering gypsum and intergrown with it. The identity of the cuprosklodowskite was confirmed by XRD at the Natural History Museum, London (powder diffraction photograph 8848F). Sodium-zippeite is the only other uranium mineral identified on the specimen with cuprosklodowskite and occurs as a tiny powdery aggregate among the gypsum crystals.

Other supergene uranium minerals recorded from 17 level in the Peeth lode include the sulphate, johannite; the sulphate-carbonate, schröckingerite; and the carbonate, andersonite (Elton and Hooper, 1992 and in press). Cuprosklodowskite is the only uranyl silicate identified to date from this locality and is much rarer than the other uranium supergene minerals.

The larger portion of the Geevor specimen has been lodged with the Natural History Museum, London.

#### **ACKNOWLEDGEMENTS**

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# GROWTH OF ACANTHITE ON NATIVE SILVER FROM THE CLYDE PLATEAU LAVAS, SCOTLAND

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Specimens of native silver in and on prehnite were collected between 1967 and 1972 from mineralised joints and cavities in basalt at Boyleston quarry, Barrhead, Renfew District, Strathclyde Region (Meikle, 1989a). In 1983, black platelets, up to 0.15 x 0.04 mm in size, were observed to have grown on the native silver crystals and, locally, directly on the prehnite of one specimen. No ready explanation was

apparent for this but they were photographed then for their aesthetic appearance. In 1987 similar growths were observed on further Boyleston specimens, only a year after collection, while other specimens of both collecting periods remained bright and apparently unaffected. All the specimens had been stored under identical conditions (initially as large specimens in boxes in a garage, then broken up to reveal the silver

and housed in plastic or cardboard display boxes indoors); only the time intervals between collection, exposure of the silver, and appearance of growths varied.

Scanning electron microscope (SEM) examination of the specimens revealed that clusters of platy crystals occurred both on the apparently untarnished areas of individual silver crystals and on the areas blackened by obvious secondary growths, more being present on the blackened surfaces (Figs 1 and 2). The size and concentration of the platelets appeared to be greater on the edges and terminations of the silver crystals. Similar growths were also observed directly on the prehnite matrix (Fig. 3). It is remarkable that some specimens showed growths on both blackened and bright silver faces, while others showed none at all, and some as yet undefined surface conditions may control the formation of growths.

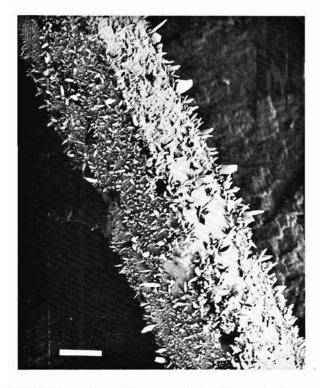


FIGURE 1. Acanthite crystals on silver, Boyleston quarry. SEM photograph. Scale bar 0.02 mm. (Specimen LEIUG 98894).

Energy-dispersive (EDAX) examination of the silver from Boyleston quarry showed no detectable Cu or Au, and it is therefore essentially pure, while examination of the platelet-covered surfaces showed the presence of sulphur. Sulphides do occur relatively close to the silver at Boyleston quarry (Meikle 1989a), but none were detected on these specimens, and the most likely source of the sulphur is considered to be atmospheric. EDAX analyses of the platy crystals (Table I) were performed directly on specimens such as those shown in Figs 1 and 2, and detection of Si, Al, Fe, Ca, Mg and K is presumably due to excitation of the surrounding matrix. If these elements are subtracted, analysis 1 is consistent



FIGURE 2. Acanthite crystals on silver, Boyleston quarry. SEM photograph. Scale bar 0.02 mm. (Specimen LEIUG 98894).

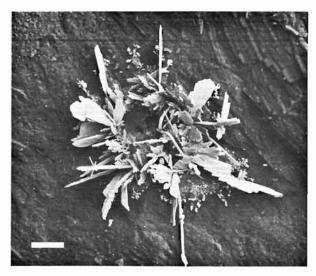


FIGURE 3. Acanthite crystals on prehnite, Boyleston quarry. SEM photograph. Scale bar 0.03 mm. (Specimen LEIUG 98892).

with the composition Ag<sub>2</sub>S, and the low temperature of formation, apparently under atmospheric action, together with the elongated platy habit, suggest that the growths are acanthite. Acanthite of similar appearance was reported from Mammoth mine, Tiger, Arizona, partially encrusting silver wires and crystals embedded in leadhillite and also as crystals on and in the leadhillite (Bideaux, 1980). The acanthite crystals were described as having bristling and sharply angled terminations, indicating primary low-temperature crystallisation. Analysis 2 (Table I) indicates the additional presence of chlorine and would fit a mixture of Ag<sub>2</sub>S with some AgCl. More detailed analyses are required to localise and identify the phases present.

Similar growths have been observed on specimens of native silver, in and on prehnite, collected in 1987 from Loanhead quarry, Beith, Cunninghame District, Strathclyde Region (Meikle, 1989b). In this case a prehnite specimen was only recently broken, and showed bright silver crystals along with native copper crystals on one face, while the opposing fracture face showed only darkened silver crystals bristling with acanthite growths. On this latter face, the silver wires

**TABLE I.** Energy-dispersive microprobe analyses of acanthite crystals on silver, Boyleston quarry.

	Analysis 1		Analysis 2		
	wt %(a)	atoms(b)	wt %(a)	atoms(b)	
Ag	75.3	1.98	84.8	2.19	
S	11.3	1.00	11.5	1.00	
Ag S Cl	n.d.		2.7	0.21	
Si	4.4		n.d.		
A1	3.0		n.d.		
Fe	< 0.5		n.d.		
Ca	4.7		1.0		
Mg	< 0.5		n.d.		
K	< 0.3		n.d.		

<sup>(</sup>a) Normalised to 100%. Elements below Na not measured. n.d. = not detected.

(0.01-0.02 mm thick) were surrounded by curious haloes (up to 0.05 mm wide) consisting of bright silvery films on the prehnite matrix, with acanthite growths on the outer edges. On the other hand, silver specimens collected in 1988-89 from Hartfield Moss, Renfew District, Strathclyde Region, were bright and without any obvious tarnish although they had apparently lain undamaged and partly embedded in peaty ground for upwards of 100 years (Meikle, 1990). SEM examination of one such specimen at high magnification showed only surface pitting, while EDAX analysis indicated the presence of sulphur, and very high SEM magnification was necessary to reveal localised areas of small clusters of tiny plates.

The occurrence of acanthite on these specimens seems worthy of record, although further work is needed to define the conditions required for its growth. Specimens from Boyleston quarry and Hartfield Moss have been deposited in Leicester University Geology Department (LEIUG 98892-98895). Acanthite that is not formed from argentite is very rare. Only one occurrence, as an interstitial form associated with cosalite and koechlinite at Gairnshiel, near Ballater, Grampian Region, has been recorded in Scotland (Tindle and Webb, 1989; P.C. Webb, personal communication).

#### ACKNOWLEDGEMENTS

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<sup>(</sup>b) Calculated after subtracting Si, Al, Fe, Ca. Mg and K (anal. 1) or Ca (anal. 2).

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## CONFERENCE REPORTS

#### CONSERVING BRITAIN'S MINERALOGICAL HERITAGE. 31 MARCH – 1 APRIL 1992. UNIVERSITY OF MANCHESTER.

This conference, the first of its kind to be held in the UK, was organised jointly by the Geological Society of London, the Mineralogical Society, and the Joint Nature Conservation Committee. Convenors were Dr R.E. Bevins (National Museum of Wales), Dr R.F. Symes (Natural History Museum, London), Mr B. Young (British Geological Survey, Newcastle upon Tyne), Dr D. O'Halloran (JNCC), and Dr C. Stevens (English Nature).

The meeting attracted more than 80 delegates, and 27 papers, from a very broad cross-section of earth science, mining history and conservation bodies, including a significant number of mineral collectors and dealers. The proceedings were organised into six discrete sessions, each focussing on a particular theme.

Brian Young (BGS) opened the first session, MIN-ERAL COLLECTING: AMATEUR, PROFESSIONAL AND COMMERCIAL INTERESTS, with a thought provoking address on 'The collector as conservationist'. There are many more people collecting today than ever before. They are more mobile, many have stereo microscopes and commonly have access to analytical facilities via contacts, workplaces, etc. In short, the amateur collector is now better equipped than ever to do a worthwhile job in mineral conservation. In particular, collectors active at working mine and quarry sites undoubtedly salvage material which would otherwise be lost to the crusher. The situation is different in non-exploited areas, for example outcrops and stream sections. Here, commercial gain, greed and sheer ignorance can lead to serious damage and loss of information to science. On the other hand, where finds of importance are made, it is imperative that proper records are published in reputable scientific journals. Indeed, were it necessary to obtain a licence to collect minerals, he suggested that failure to record occurrences properly should lead to withdrawal of a licence to collect.

Lyndsey Greenbank (Kendal) gave an interesting account of 'Professional mineral collecting in the Northern Pennines'. This was a personal account of some 25 years' development of the green fluorite deposits at Rogerley quarry near Stanhope. The ongoing programme of development had included negotiation in Weardale with land owners, mineral rights owners, mines and quarries inspectorate, local police, planning authorities, and so on. An explosives licence had been obtained, and both rent and royalties are paid on the operation. In spite of the commercial pressures of trying to cover costs, the policy has been to allow visitors to view material in situ for a nominal charge. Mr Greenbank concluded by reminding the audience that mining is a hazardous pursuit, both financially and physically.

Roy Starkey (Russell Society) focussed on the conflicts which exist between land or mineral rights owners and the mineral collector. In his talk entitled 'Mineral collectors - friend or foe?', emphasis was placed on the problems of gaining permission for access, partly as a result of restrictive Health and Safety legislation. This can lead to land or mine and quarry owners being reluctant to expose themselves to possible legal action in the, albeit unlikely, event of an accident. The question of exactly when it is or is not appropriate to ensure that permission has been granted was discussed in some detail, together with proposals for ways in which the amateur may seek to improve his image. It seems in some instances that bodies such as the National Trust and Lake District Special Planning Board seek to restrict access as an end in itself, rather than as part of a coordinated conservation strategy. Meaningful dialogue between representatives of the mineral collecting fraternity and such bodies will be essential in order to establish a sensible compromise position.

In summary, Mr Starkey suggested that mineral collectors are foes when they destroy property in working premises; don't get permission; do not follow the Country Code; and do not curate material properly. By way of contrast, 'friendly' activities include rescue of material from temporary exposures; careful study leading to new discoveries; publication of discoveries; proper curation of material for posterity; and organisation into societies dedicated to research, education and conservation. If the ultimate effect of conservation policies is severely to restrict or prevent the carrying on of legitimate recreational collecting, then in a relatively short space of time interest in the subject will dwindle, exposures and dumps will become overgrown and mine workings inaccessible, and there will be no-one left to appreciate that which has been conserved. Science and the institutions will be deprived of material, and the already low priority given to display space for earth science material may ultimately result in the total withdrawal of geological specimens from public display.

Brian Jackson (National Museums of Scotland) brought Session 1 to a close with a talk entitled 'Working with others — the experience of the National Museums of Scotland'. Building on the contributions of the previous three speakers, Mr Jackson gave an encouraging account of several areas of joint action and liaison. Prior to the early 1960s specimen acquisition had been mainly by purchase or donation, but now the Museum was seeking to fill gaps by field collecting involving members of staff. This work is striving to balance breadth and depth of the collection, and relies heavily on information culled from recreational collectors, fellow professionals, and the conservation agencies. The Museums encourage a symbiotic relationship with amateur collectors. Joint rescue action at Leadhills-Wanlockhead, negotiations with the former

operators of Strontian mines to preserve access for collecting after restoration of the site, and a planned programme of work at Alva silver mines, all pointed to a healthy situation 'north of the Border'.

Session 2 sought to examine the RESEARCH POTENTIAL OF MINERALOGICAL SITES. Geoff Warrington (BGS) illustrated the importance of the uniquely accessible deposits at Alderley Edge in Cheshire, emphasising the need to preserve an *in situ* record so that material can be studied in its true context.

Richard Pattrick (University of Manchester) in his talk entitled 'Tyndrum: mineralogical research on an abandoned mine site' showed how many years of research had unravelled an elegant paragenetic story in an area still of considerable commercial interest. The work had led to the discovery of cadmium tetrahedrite. An understanding of the mechanism of so-called 'chalcopyrite disease' has also been helped by research on material from Tyndrum.

Bob King (John Moore Museum, Tewkesbury) gave an enlightening account of the battle to preserve the Tickow Lane lead mine at Shepshed, Leicestershire. A BGS specimen described by Moorbath led to the original interest in the locality, and resulted in an extensive digging and underground excavation project by the Russell Society. Over a period of several years, various measures to control access by provision of secure doors and shaft caps were violated by local youngsters. Eventually the Society decided that the site could no longer be adequately protected, and filled the shaft with concrete. Regrettably very little of the orebody now remains in situ, but good specimens are preserved in the collections of the National Museum of Wales.

David Jenkins (University of Wales, Bangor) concluded the session with a review of the research interests of various localities in North Wales. His talk 'Abandoned mines: unique geochemical and mineral environments' drew attention to the various factors which contribute to the importance of underground workings: abnormal concentrations of trace elements, extreme environments (pH and Eh), and the resulting unique microbial populations. Areas of interest included erythrite from Great Ormes Head; pedogenic chalcopyrite on spoil surfaces; lanthanite-Ce; manganese nodules of up to 2 cm size forming on an adit floor in only 100 years; and mine waters with a pH of 1.5 at Parys Mountain. The interelationship of these factors with biological populations has considerable importance for biotechnological applications. In spite of entirely honourable intentions, it has been impossible even for bona fide researchers to obtain permission from the Forestry Commission for work underground. Sites are now being sealed at an alarming rate possibly never to be reopened.

THE BOTANICAL POTENTIAL OF MINERAL SITES was addressed in Session 3, by three speakers. **John Hopkins** (JNCC) gave a fascinating account of 'The conservation value of metalliferous plant communities'. The stress tolerance of such species is of great

interest, and John advocated that a policy of 'wall-towall green' countryside is not necessarily appropriate in all areas.

William Purvis (NHM) continued this theme with an impassioned plea on behalf of the lichenology interest. We have over 1,600 lichen species in the UK, and these exhibit astonishing longevity and tolerance of extreme environments, and function as sensitive bio-indicators. There is a need to define criteria for grading of sites, and serious threats exist from both weedkillers and mineral collectors.

Roy Perry (National Museum of Wales) echoed the sentiments of the previous speakers, in relation to mosses and liverworts. The presence in the UK of three bryophyte species which are unique in the world highlights the need for conservation.

In Session 4 the discussion moved on to address MINING HISTORY, EDUCATIONAL AND TOUR-ISM ROLES. The opening speaker, Simon Timberlake (Southeast Area Museums Council) described many years of work in and around the Cwmystwyth area east of Aberystwyth. This most spectacular of mining landscapes has a history extending back to the Bronze age. As a result of recent survey work and on-site research a very complex historical interpretation is now emerging.

David Jenkins (University of Wales, Bangor) gave a most interesting account of 'The archaeological potential of abandoned mines', with particular reference to the Great Orme mines, Llandudno. Bronze age workings have been discovered to a depth of 200 feet. Stone hammers or 'mauls' and also bone tools have been excavated from the workings, and carbon-14 dating suggests an age of about 3,500 years for at least some of the mining. The policy of the research and exploration team has been to leave material undisturbed underground until there is a convincing reason to remove it to surface for analysis. Studies have shown that the morphology of soot deposits on passage roofs can be related to the fuel burnt, e.g. pig fat, alder, etc.

Mike Bamlett (Centre for Extra Mural Studies, University of London) gave an entertaining account of 'Selfishness, prestige and heritage protection — a view from adult and continuing education'. In attempting to quantify the pressures upon sites, Mike had estimated that around 11,500 people-days had been spent in the field on formally organised events. The attendees could be categorised broadly into groups ranging from ardent collectors, through non-collectors, to social attendees and dogs! Material collected would end up variously in the dustbin, in junk collections, some perhaps as well catalogued and curated specimens, and even fewer as donations to institutions. The collecting culture is well established in the UK, in the earth sciences as in other areas. Good amateur work is still being carried on, as evidenced by the centenary volume of the Proceedings of the Geologists' Association, which comprises contributions exclusively by amateur authors.

David Thompson (Department of Education, University of Keele) highlighted the growing pressures on

sites for educational fieldwork as a result of the National Curriculum. In 1985 about 40,000 students and 4,000 teachers participated in subjects requiring field work. Now 250,000 primary teachers and 30,000 secondary school teachers are responsible for science. Fieldwork is now a key part of attainment targets in predicting and testing hypotheses, and controlling variables. Alderley Edge in Cheshire has been developed to be used as a field resource, with structured trails, workbooks and exercises. Access has been negotiated with the owners (National Trust and Mr Paul Sorenson), and skills taught include the need for conservation - e.g. not removing specimens from dumps, not hammering outcrops, etc. Ecton Hill in Staffordshire has also been put to good use in the same connection, but here maintenance costs for the five mines are high, and problems are being encountered with insurance.

Tony Hammond (Great Orme Mines Ltd, Llandudno) described 'The tourist potential of abandoned mine sites', with particular reference to his project at Llandudno. The team has been successful in opening up prehistoric workings, after many problems involving planning authorities, tourism sub-committees, the Welsh Development Agency, and others. The scheme enjoyed 45,000 visitors in the first six months, and this year a special subsidiary company is to handle bookings and conference visits. The site will develop into a major world resource for the study of prehistoric mining.

Ian Standing (The Historical Metallurgy Society Ltd) brought this session to a close, describing the 'Forest of Dean: problems and strategies of conserving mineralogical sites in afforested areas'. A multi-disciplinary approach has been adopted, embracing cavers, industrial historians, archaeologists, wild life and botanical enthusiasts, and so on. A RIGS scheme has been established together with a geological teaching trail. Given that more than 60% of UK forestry is privately owned, and that many owners are keenly interested in conservation, Ian argued that there is ample scope for effective lobbying at local level, without waiting for legislation or statutory protection. A multi-disciplinary approach is essential for successful conservation.

Session 5 embraced PLANNING POLICIES AND SAFETY CONCERNS, starting with a most informative address by John Leigh (Civil Service Occupational Health Service). In his talk 'Taking care — the practice of underground safety and mine stability' John summarised the statistics and legislation surrounding safety in mines. On average there is one fatal accident every five years in disused mines. He suggested that a code of practice should be prepared, covering training; protective clothing; obtaining permission; minimum of four in a party; leaving information with a responsible person; capability; signposting; climbing techniques; stacked rock; fooling around; knowledge of the environment and hazards underground; actions to be implemented in an emergency.

John Palmer (Richards, Moorehead and Laing Ltd) spoke on 'Resolving conflicts: reclamation and management options'. The key aims of reclamation are prevention of pollution, making the site 'safe', removal of visual scars, putting the land to beneficial use, and conservation of valuable attributes. Actions to be taken range from 'do nothing', through minimal treatment and fencing off, to alternative clean-up techniques. As a working principle, reclamation should only be carried out where there is a clear need, a feasibility study should be undertaken prior to any action, and the impact of any reclamation should be minimised.

Ken Smith (Peak District National Park) reviewed the integrated approach adopted in the Peak District National Park. Since the Park's establishment in 1951, priority has been given to preserving public access, and safeguarding the ecology and conservation. The Park Authority is responsible for all planning matters and extractive operations. The Park covers about 555 square miles, has 35,000 inhabitants — many of whom derive their livelihood within the Park area — and endures 20 million visitor-days per annum. Through an integrated approach involving ecology, geology, archaeology and planning, the Park Authority has successfully balanced the apparently conflicting demands on this National Park.

Brian Marker (Minerals and Land Reclamation Unit, DOE) explained the role of central government in relation to 'Greening the environment and access to mineralogical sites: conflicts and opportunities'. Many initiatives are underway, trying to embrace site reclamation more sensitively, taking account of RIGS schemes and SSSI status. Two key issues for future success are availability of information, and awareness. Information must be in the public domain, and awareness must tackle the problems of adult education groups and school.

David Cranstone (consultant archaeologist representing English Heritage) described recent work to update the list of scheduled monuments, with particular reference to the lead industry. Priorities have been developed for types of site, regions, mines, smelters, etc. A system of classification based on county, parish, features, landscape, published data, etc., has been developed. Identification and cataloguing of sites is the first requirement for effective conservation.

final session of the meeting covered CONSERVATION ISSUES as a general theme. Tim Badman (Centre for Environmental Interpretation) spoke on 'Interpreting mining sites for the public', showing how a structured approach could lead to better understanding by visitors. There are many tried and tested techniques which can be borrowed from other areas of conservation - guided walks, nature trails, leaflets, display boards, visitor centres, etc. All of these have a role to play if a clear message is developed, aimed at a specific audience and using effective communication media. As a general rule it is necessary to start in a modest way and build up to more sophisticated approaches. Finance tends to follow enthusiasm, and in this regard attention was drawn to the COPUS grant scheme, administered by the Royal Society. This offers

financial support for the public interpretation of science — including geology.

Des O'Halloran (Joint Nature Conservation Committee) gave an explanation of the structure and organisation of the JNCC and its constituent bodies, moving on to report on 'Mineralogical sites and the Geological Conservation Review (GCR) — a network for statutory protection'. The GCR is designed to protect the 'best' sites, based on an assessment of 3,000 GCR sites and 2,000 SSSIs between 1979 and 1990. A methodical basis has been adopted, evaluating national and international value, research value, thematic and time subdivisions, and establishment of 'Networks' of sites. The GCR is intended to be an ongoing process, and will eventually lead to publication of 50 volumes, as public justification, to ensure upkeep, to offer transcountry communication and to serve as a comprehensive database. The first volume (Quaternary of Wales) is already published and two further volumes are due for publication during 1992. Two separate networks have been developed for mineralogy species/chemistry, and metallogenesis/processes, covering a total of about 170 sites throughout the UK.

Alan McKirdy (Scottish Natural Heritage) presented a talk entitled 'Re-assessing the conservation value of mine dumps and spoil heaps in Scotland', setting out the relationships which exist between the various agencies responsible for wildlife protection, land management, planning controls and so on. Site management briefs (SMBs) are to be prepared for all sites in Scotland, detailing the scientific interest, a photographic dossier (to establish a 'base line' condition), site management plan, threats such as removal for hardcore, afforestastion, excessive collecting, etc. So far 46 mineralogical sites have been identified for action within Scotland.

Tom Moat (English Nature) provided the final contribution to the formal proceedings: 'Threats to England's mineralogical heritage — conflict or conciliation'. English Nature is seeking to establish a highly interactive approach to site conservation by increasing awareness of the importance of sites amongst owners and users, alerting people to potential threats — industry, forestry, landfill activities, farming, etc. Promotion of good collecting practice is another key aspect to ensure that the public at large know how to look after the resource.

Richard Bevins (National Museum of Wales), on behalf of the organising committee, summarised some conclusions and recommendations arising out of the discussions over the two days of the meeting. As with most events of this kind, the attendees tend to be likeminded individuals with converging views and sympathetic appreciation of others' interests. There were notable absences in the audience as unfortunately not all interested parties agreed or were able to participate. Mineralogical sites embrace both surface and underground environments, covering a very wide range of interests: collecting, research, botanical, industrial archaeological, archaeological, etc. The approach to

conservation must therefore be multi-disciplinary. Current practice tends to be compartmentalised, and this perhaps is the most important lesson to come from the Conference. We must find ways to integrate usage of sites with protection, to provide a stronger lobby by a multi-faceted, almost novel approach to conservation.

A lot of work remains to be done, both at national and local level. Health and Safety issues must be addressed at government level, involving discussion with major land owners, JNCC and other government agencies. Information must be disseminated to potential users and local planners. At a local level, user groups and societies must act in tandem to reach local access and preservation agreements with land owners. A programme of actions covering collation of data. prioritisation and feeding of data to decision makers must be established. The JNCC with its regional constituents is happy to take on a coordinating role, but believes itself to be unable, because of limited resources, to become an effective executive authority. The most pressing need is to develop a mechanism for collation of information to ensure that data are available for submission before any given site comes under threat.

The meeting provided a most interesting two days of discussion, and certainly provided some new perspectives on how the activities of mineral collectors impinge on other parties, and vice versa. Perhaps the most enduring impression was that if you are unable to remove all the lichen from a specimen — don't worry, find out what species is present and write out a second label. Collectors and collections can be multi-disciplinary, too!

A copy of the abstracts of the meeting will be housed in the Society library.

Two excellent field trips were held before and after the formal sessions. The first, to the Alderley Edge area, was led by **Dr Geoff Warrington** (BGS, Keyworth), and access to the underground sites of Alderley Edge was provided in collaboration with the Derbyshire Caving Club. This is an excellent area of underground and surface mineralisation and mining features. The post-conference field trip to the Coniston area was led by **Dr Chris Stanley** (Natural History Museum). Again, a most interesting full day was spent in the field examining aspects of mineralisation and discussion of conservation principles with, among others, representatives of the Lake District Special Planning Board.

R.E. Starkey

#### COLLECTING MINERALS. 4 APRIL 1992. LOUGHBOROUGH UNIVERSITY

This symposium was held during the Russell Society's AGM weekend, on the occasion of its 20th anniversary, and was a day marked, above all, by the excellence of the speakers both in presentation and erudition. Congratulations are due to Council for organising such a galaxy.

A broad and entertaining spectrum of the concepts and ethics of collecting was presented, opened by **Dr**  Hugh Torrens of Keele University, who set the standard of the meeting with an exhilirating discourse on the historical aspects of geological collecting. Hugh called for a shift in values in our attitudes to the Arts and Sciences, in an attempt to reverse the decline in the care of geological collections, especially in museums.

Miss Monica Price of the University Museum, Oxford, also looked at the role played by museums in the ultimate care of geological collections. Monica focussed on the changes facing museums. New standards, prompted at Government level, are being imposed, using such words as registration, and these, together with financial restraints, affect acquisition policies.

Dr Tom Moat of English Nature discussed the disastrous role played by some mineral dealers in the acquisition of material, often employing destructive techniques. Tom wondered whether it might be necessary to invoke repressive legislation to prevent or contain the trend. While such measures were currently not in favour with English Nature, it was obviously necessary that some restraint was essential and hoped that a voluntary code of ethics could be formulated.

Roy Starkey, a Vice-president of the Society, stepped out of the ranks to augment Tom's theme. Roy, too, called for a reversal of the present trend of avaricious collecting and hoped that, if such a reversal could not be achieved, we should not lose mineral sites to the detriment of the growing army of young people taking up an interest in mineralogy.

Our final speaker of the day was **Brian Young** of the British Geological Survey. In a highly controversial talk Brian made a case for the removal of a mineralised body into 'safe custody', from where it could be examined by *bona fide* research workers. The vocal reaction from the floor was expected and we were not disappoined.

The message which came through clearly from every speaker was the need for the collector to exercise restraint in collecting. Unfortunately, we are dealing with human nature which is difficult to assess and where covetousness can be the dominant emotion. It is difficult to imagine how such restraint may be imposed. Before the age of the motorways and the family car, when access to formerly remote and sensitive sites was physically difficult, there was no problem. The limitation to collecting then was one's back. The answers to the problems are elusive — we cannot change human nature. Shall we be faced with the ultimate loss of in situ mineralogy and its imprisonment in museums where we have a poor record of subsequent care, or shall we reach a saturation point on our roads so that the car is no longer viable and access to sites once again becomes difficult? Perhaps we should have left minerals in the ground in the first

In this symposium we have barely scraped the surface of the problems. I look forward to the next.

R.J. King

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### **BOOK REVIEWS**

Knell, S.J. and Taylor, M.A. Geology and the Local Museum. HMSO, London., 1989, xii + 150 pp. Price £9.95. ISBN 0-11-290459-9.

At the end of a favourable and perceptive review of Guidelines for the Curation of Geological Material in 1986, Stephen Locke (then Executive Director of the Area Museum Council for the South West, now Director of Hampshire County Museums) pointed to the need for a less technical distillation of the fundamental requirements for the responsible care and use of geological collections, aimed specifically at the nongeological, 'lay' curator. Guidelines had been published for the Geological Curators' Group (GCG) by the Geological Society in 1985 and it remains today the geological curator's indispensable and definitive guide to best professional practice. Guidelines represents the fulfilment of one of the original aims of the GCG and is a testament to the efforts of many Group members, particularly the coordinating authors, Howard Brunton, Tristram Besterman and John Cooper. (It is still, incidentally, the only such curator's manual covering a single specialist museum discipline in depth — notwithstanding the Museums Association's Manual of Curatorship which, despite its title, is not a practical manual.)

But producing a rigorous guide to best curatorial practice is one thing, making it accessible to the majority of curators responsible for geological collections is quite another. As Stephen Locke recognised in 1986, Guidelines doesn't emphasise the really fundamental problems commonly faced by lay curators; it neither reduces such a curator's sense of isolation and inadequacy, nor provides any explicit motivation to improve geological curation by ameliorating the worst kinds of physical neglect. The sheer scale of this problem had already been highlighted by another GCG initiative: a survey of collections held by UK museums carried out for the Group by Phil Doughty (Keeper of Geology, Ulster Museum). The resulting 'Doughty Report' had appeared in 1981 as The State and Status of Geology in UK Museums. It documented an appalling state of neglect and, crucially, revealed that the great majority of museum collections were not in the care of geologists.

The 'Doughty Report' was an important catalyst in convincing several of the nine Area Museum Councils — regional organisations funded through a government quango, the Museums and Galleries Commission, which provide much needed support to non-national museums — that urgent action was required, through the preferred medium of peripatetic curators/conservators. The Area Museum Council for the South West (AMCSW) led the way with the appointment of Michael Taylor as their roving geologist in 1983; the South East followed suit in 1985 with Simon Knell. Their trail-blazing work in southern England is carried

on today by AMCSW's Geology Conservation and Advisory Service (operated as an agency by the Geology Section of Bristol City Museums and Art Gallery), while Timberlake has replaced Knell as the Simon covering the South East region, now grant-aided by the Curry Fund of the Geologists' Association and British Gas.

Clearly, if Stephen Locke's plea for a practical guide aimed at the lay curator was to be written, who better to undertake the task than the two pioneers of peripatetic curation/conservation, Michael Taylor (now an Assistant Keeper of Earth Sciences for Leicestershire Museums Service) and Simon Knell (now Keeper of Natural Sciences for Scunthorpe Museum)? They had, after all, spent six man-years between them advising museums from Cornwall to Norfolk on how to improve standards of collection storage, documentation, conservation and interpretation. Geology and the Local Museum succeeds admirably in translating their combined experience into a practical, 'how to do it' manual, which is just what the busy curator needs.

Assuming only a will on the part of curators to improve the lot of material in their care, Knell and Taylor guide the reader through every stage necessary to realize the full potential of a geological collection, in terms of both its care and its use. The book is divided into four major units: an introductory section, 'Geology and Museums'; a guide to looking after geological specimens in 'how to do it' format, 'Care of Collections'; a basic look at how a museum might begin to approach the provision of a geological service to the visitor, 'Using Collections'; and a series of useful appendices devoted mainly to the various classification systems considered most appropriate by the authors for systematically arranging geological collections in the local museum (in the case of minerals, a system devised specifically for the book by Monica Price of Oxford University Museum). In other words, the authors tell you how to find out what you've got, how to ensure it survives in future, and how to use it today for the public

A grant from the Museums and Galleries Commission has ensured that all nine Area Museum Councils received enough copies to give one to every museum in the UK known to contain geological material — so lay curators can no longer claim ignorance of what should be done to safeguard their collections (although procuring the resources actually to do anything is another matter . . .). And, as with so many of the exciting developments in geological conservation of recent years, whether specimen or site related, the Curry Fund of the Geologists' Association also provided grant-aid.

But is there anything here for geologists not involved with museum collections? Most certainly there is! Just take a look at the topics covered in what I consider to be the real 'meat' of this book — 'Care of Collections'. In a down-to-earth, 'everything you wanted to know but never dared to ask' look at collection care, Knell and Taylor comprehensively cover Taking Action,

Approaches to New and Old Material, Documentation, Storage, Organising Collections, Storage and Display Environment, Conservation Problems, Security, Hazards, and Transferring or Destroying Geological Material. Now, most of these topics will have given pause for thought to any serious collector of minerals, rocks or fossils, whether museum-based or not. By aiming the text at the lay curator, the book is preadapted to a role as the amateur collector's guide to the curation of their own material, with all its practical tips on storage and basic documentation procedures. And let's face it, adequate storage and documentation is often all that separates the collection of permanent value — both intellectual and financial — from so much hard-core.

The quality of printing is high, as befits a publication from HMSO, and at £9.95 it is not expensive. If you are a collector (amateur, professional, academic, or whatever) and have ever wondered how best to ensure that your material retains a lasting value to the science which fascinates us all, it could be the most important book you ever buy.

Peter R. Crowther

Klein, C. Minerals and Rocks. Exercises in Crystallography, Mineralogy and Hand Specimen Petrology. Wiley and Sons, 1989, 402 pp. Price £22.95. ISBN 0-47-162207-9.

The title says it all — this book, every page of which is perforated so that it can be removed, completed and submitted, or photocopied, as need be, contains enough material for any first year course in crystallography plus a course, perhaps to run in tandem, in mineralogy and hand specimen recognition of minerals and rocks. There are even chapter-exercises that would fit usefully into many second year courses. Truly this is one of the few books that would justify the old cliche — Teach Yourself Mineralogy/Hand Specimen Petrography — for it has sufficient worked examples, all of which are fully explained, to allow self-tuition. The only obstacle to true independence is that the answers for the student exercises are not given.

The first sixteen exercises teach crystallography from elementary symmetry, via stereographic projections, Miller Indices, and axial ratio calculations, to space groups. Unfortunately, some of the proof-reading in this section is inadequate, especially as regards Miller Indices, some of which are mislabelled both in text and diagrams: exercise 6 (Stereographic Projections) has the greatest concentration of errors and could well confuse a struggling student. In addition, the method of plotting poles to crystal faces taught in exercises 6 and 9 is different from the method normally used in British universities. Chapters 14 to 16 concentrate on the determination of an unknown mineral using the x-ray powder camera technique and x-ray diffractometer trace, and finally on the determination of the unit cell of an isometric mineral. These are among the best of the

exercises (i.e., the most enjoyable for me) and could easily be incorporated into a second or even third year course.

The second section (Mineralogy) includes exercises explaining atomic packing, coordination numbers and valency, and exercises on tetrahedral linking in silicates; on hand specimen properties of minerals; and on relationships between chemical analyses, mineral formulae and triangular diagrams. Three chapter-exercises on common non-silicates complete the section. It is all very well done. The final five chapter-exercises include one on elementary economic geology and one each on classification and identification of common igneous, metamorphic and sedimentary rocks.

The exercises have been written exclusively with North American students in view, and there is almost no reference to non-USA text books — Deer, Howie and Zussman are first mentioned on page 450. But, notwithstanding the caveat about exercises 6 and 9, this book would be an excellent supplementary and cheap text for the first year. Were I ever to teach these courses again, I would use this book a great deal.

R.A. Ixer

Peckett, A. *The Colours of Opaque Minerals*. Wiley and Sons, 1992, 471 pp. Price £95. ISBN 0-47-193347-3.

This excellent book has been written by Andrew Peckett based upon notes by Roy Phillips and Norman Henry, who for many years were the doyens of scientific ore microscopy and who had the longstanding aim of writing the definitive book on reflected light optics. Sadly their deaths have prevented them from seeing this ambition fulfilled, and fulfilled splendidly well. In this they were lucky to have someone with the required patience and attention to detail to realize their dream. Projects that stretch over a long time often become spoiled or at least blemished before completion — but not here.

The book is divided into two unequal parts; the first 172 pages deal with the theory of reflected light and its interaction with opaque minerals, while the longer second half systematically outlines mineral data for many of the natural metals, alloys, sulphide-type minerals, sulphosalts and oxides — the 'opaque minerals'. Finally there is a twenty-two page appendix of the mathematics needed to help with proofs given in the optics chapters, followed by indexes of formulae, mineral names and subjects, and an extensive reference list.

The book is not for light reading. The initial chapter outlining the nature of light, colour, and colour vision and its defects, does have a couple of lighter moments— the use of the CIE chromaticity diagram with beetroot and chocolate as examples is mouthwatering, while the stern warning that 'excessive consumption of alcohol and tobacco has been cited as causes of defective colour vision' inevitably brings back memories of Roy Phillips who had superb colour vision. The

next two chapters are the main theoretical ones. 'Light and Crystals' is a very thorough treatment of bonding within materials, discussing the merits and problems of classical chemical, molecular orbital, ligand field and band theories and how these models can be used to explain the results of the interaction of light and opaque minerals. 'Reflected Light' is a lengthy exposition of reflectance, extinction angles and anisotropy colours—it is here that the mathematical appendices are required and even with them most of us will have to take the chapter on trust.

The rest of the book, I suspect, will be used far more often than the first half, as the mineral data are up to date and some are even presented for the first time. The chapters, one on metals and alloys, six on 'sulphides', one on sulphosalts and one on oxides, all follow a similar pattern: an introduction, a listing of the main mineral species in structural groupings, and a discussion of each mineral. Each mineral is given its formula, crystallographic data, colour data, colour description, a discussion of colour and reflectance in terms of the structure of the mineral, and finally some selected recent references.

The book is essentially free of typographical errors—there may be one on page 199 and there is certainly one on page 200—but for a book as complex as this all the production team are to be congratulated. It is expensive, but if you *must* know why native silver is white and bright and hematite pale blue and dull, or if you want a modern, thoroughly reliable source of references and mineral data that is more accessible than Criddle and Stanley's *Quantitative Data File for Ore Minerals*, then this is the book.

R.A. Ixer

Chambers, Bryan (editor). Men, Mines and Minerals of the North Pennines. The Friends of Killhope, 1992, 94 pp. Price £7.50. ISBN 0-95-189390-4. (Also from W. Grigg, 6 East Blackdene, St John's Chapel, Bishop Auckland, Co. Durham DL13 1RE. £8.50 incl. postage).

The all-embracing title of this book will, without doubt, ensure its being picked up from a bookstand by anyone with an interest in the oldest traditional industry of the Northern Pennines. The ninety or so pages represent a fine example of the relatively new art of desk-top publishing, applied in this case to a memorial volume to the late Eric Ryan who did so much to establish the now famous Killhope Lead Mining Centre.

Between the covers of this A4 paperback are collected 13 'articles', many by authors eminent in their own fields. The authors' approaches to these are as varied as the topics selected. Any collection of this sort must give prominence to an account of the geological basis for the mining industry. Who else could present this but Sir Kingsley Dunham, whose name is inextricably linked with this orefield and who is now President of the Friends of Killhope? There follow chapters devoted to personal views of the world of

metalliferous mining both here and elsewhere, and to the details of one of the area's fluorspar plants and smelt mills. More anecdotal contributions give interesting insights into former lifestyles and old stories, as well as details of a nineteenth century mine lease for mining historians with an antique legal bent. A lengthy discussion of hushing from an archaeologist's viewpoint is included. Perhaps most unexpected is a short but fascinating piece of detective work which identifies a little known drawing by L.S. Lowry as an immediately recognisable portrayal of Killhope Wheel, prior to the advent of today's museum.

The book has been compiled in a generally workmanlike fashion. Half-tone photographs mostly reproduced well though some of the line drawings would have benefitted from fair-drawing; the manuscript versions do, in my view, spoil the appearance. The Friends of Killhope deserve congratulations for producing this entertaining miscellany of essays. In recommending the book to anyone with an interest in the area I would only add my hope that at some time they may offer us further texts on this most interesting part of England.

Brian Young

Hutchison, R. and Graham, A. Meteorites: The Key to Our Existence. Natural History Museum Publications, London, 1992, 60 pp., 89 illustrations, including 41 coloured photographs. Price £5.95. ISBN 0-565-01124-3.

This is the fifth in the current most admirable and attractive series of booklets on the Earth Sciences published by the Natural History Museum. The credentials of the authors, both professional meteoriticists, are impeccable, and the text is accurate, informative and very readable. Meteorite falls are newsworthy events, and finds are sufficiently rare to excite interest. The authors manage to convey the dramatic qualities of their subject in the process of explaining the important scientific insights obtained from the study of meteorites ('the poor man's space probe' and 'the key to our existence'). The story is up to date: It includes accounts of the first British fall for 22 years (in May 1991), and finds in Antarctica which have increased the number of known meteorites from about 2000 to 3500 in the last two decades, including rocks ejected from the Moon and from Mars. Some apparently curious facts are clearly explained (e.g., more meteorites fall in the tropics than at higher altitudes; most meteorites arrive in the afternoon and evening).

Technical terms are kept to a minimum; when they are necessary they are defined both within the text and in a glossary. The copious illustrations, a pleasing mix of colour and black and white photographs and diagrams, carry extensive captions which elaborate on the text. The book's designer is to be congratulated. The 'landscape' format of the series has been criticized on the grounds that an A5 format would sit more comfortably on a book shelf, but the latter would preclude the use of some of the more attractive illustrations.

This publication is excellent value for money and is thoroughly recommended to a wide readership, from the schoolchild with an enquiring mind to the grizzled mineral collector or other specialist who wants to expand his or her knowledge of the solar system. One is left with a sense of wonder that so much information about our origins can be obtained from such a small sample of exotic fragments.

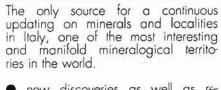
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### JOURNAL OF THE RUSSELL SOCIETY

## INDEX

### VOLUMES 1-4 (1982-92)

Names of authors are in CAPITALS, subjects and minerals in lower case, and localities in *italics*. References are to Volume(Part), First page of each article. Articles or pages carrying mineral photographs are marked (P).

Counties in England and Wales were reorganised in 1974, with some changes in names and boundaries; in Scotland, Regions were introduced in 1975. The old county names, if different from the current names, have been added here in square brackets to the locality entries, to aid correlation with older literature and specimen labels.

Abbey Wood, London: Quartz in flint 1(2),21.

Acanthite: Growth on silver specimens, Boyleston quarry, Hartfield Moss & Loanhead quarry, Strathclyde 4(2),67 (P).

Adularia: Hartfield Moss, Strathclyde (?) 3(2),43.

Agabeg, Richard: Obituary 1(2),4.

ALABASTER, C.: Alstonite & barytocalcite, South Wules & Mendip Hills 3(1),1. Alumohydrocalcite, Bristol district, Avon 2(2),5. Pb oxychloride minerals, Wesley mine, Avon 2(2),29. Secondary Al minerals, Bristol district, Avon 3(2),49.

Albert Village, Ashby Woulds, Leicestershire: Galena, sphalerite 1(2),27.

Albion pit, Ashby Woulds, Leicestershire: Galena, 1(2),27.

Albite: Boyleston quarry, Strathclyde 2(2),11.

ALDERTON, D.H.M.: Book review by 3(1),35. Stannite etc (Review) 4(1),17.

Aleksite: Clogau - St David's mine, Gwynedd 3(2),67 (P).

Allophane: East Harptree, Avon 3(2),49. Hampstead Farm quarry, Avon 2(2),5 (P); 3(2),49. Scarborough, North Yorkshire 2(1),9. Woodleaze quarry, Avon 2(2),5.

Alstonite: *Llantrisant*, *Mid Glamorgan* 3(1),1 (P). Aluminium minerals, secondary: *Bristol district* 3(2),49.

Alumohydrocalcite: Chitral, Pakistan 2(1),9.

Hampstead Farm quarry, Avon (?) 3(2),49 (P).

Scarborough, North Yorkshire 2(1),9. Weston Favell,
Northamptonshire 2(1),9. Woodleaze quarry, Avon
2(2),5 (P).

Amphibole: Loanhead quarry, Strathclyde 2(2),15. Analcime: Boyleston quarry, Strathclyde 2(2),11. Hartfield Moss, Strathclyde 3(2),43. Loanhead quarry, Strathclyde 2(2),15.

Analyses: Acanthite 4(2),67. Aleksite 3(2),67. Canfieldite (Cu analogue) 4(1),17. Celsian 2(2),1. Chromite & Cr-Ti mineral 3(1),15. Coffinite 2(1),25. Connellite 2(2),23. Hyalophane 2(2),1. Kësterite 4(1),17. Ktenasite (Zn analogue) 4(1),13. Kuramite 4(1),17. Malachite (zincian) 2(1),19. Millerite 2(1),5. Mottramite 2(2),11. Namuwite 3(1),23. Philipsburgite 3(1),25. Rare earth elements in

fluorite 1(1),22. Rosasite 2(1),19. Russellite 4(1),3. Scarbroite 1(1).9. Scheelite 4(2),55. Schulenbergite 3(1),23. Siegenite 1(2),83. Stannoidite 4(1),17. Stolzite 4(2),55. Strontianite 2(1),1. Wulfenite 4(2),55.

Andradite: Loanhead quarry, Strathclyde 2(2),11.

Anglesite: Ball Eye quarry (near), Derbyshire 1(2),48.
Clevedon, Avon 1(4),125. Greystone quarry,
Cornwall 1(2),23. Hilton mine, Cumbria (?) 1(1),33.

Machen quarry, Gwent 3(2),85. Newporth beach,
Cornwall 1(1),40. Penrhyn Du mine, Gwynedd
4(1),35. Wapping mine, Derbyshire 4(1),25. Wheal
Friendship, Devon 1(4),123.

Ankerite: Brownley Hill mine, Cumbria 4(1),13 & 36. Smallcleugh mine, Cumbria 4(1),13.

Annabergite: Hilton mine, Cumbria 1(1),33. Smallcleugh mine, Cumbria 1(2),18.

Antimony oxides: Machen quarry, Gwent 3(2),85.

Antlerite: Botallack, Cornwall 4(2),45 (P).

Aragonite: Colemans quarry, Somerset 3(1),1. Hilton mine, Cumbria 1(1),33. Llantrisant, Mid Glamorgan 3(1),1 (P). Wapping mine, Derbyshire 4(1),25.

Arizona: see Melissa mine.

Arsenopyrite: Mulberry openwork, Cornwall 1(4),119. Sandbeds mine, Cumbria 4(2),64. Wheal Friendship, Devon 1(4),123.

Ashby de la Zouch, Leicestershire: Galena, sphalerite 1(2),27.

ASPEN, P.: see MORETON, S.

Asphaltum: *Staunton Harold*, *Leicestershire* 1(2),27. Cf. hydrocarbons.

Atacamite: Botallack, Cornwall 4(2),45 (P). Knockmahon, Waterford 4(1),36. Newporth beach, Cornwall 1(1),40.

ATKINS, B.: Book review by 4(2),79.

Auchencat Burn, Moffat, Dumfries & Galloway District [formerly Dumfriesshire]: Brochantite 4(2),63.

Augite: Scawgill Bridge, Cumbria 3(1),15.

Aurichalcite: Bute quarry, Mid Glamorgan 2(1),19. Greystone quarry, Cornwall 1(2),23. Porthcawl, Mid Glamorgan 2(1),19 (P). Wapping mine, Derbyshire 4(1),25. Windy Brow vein, Cumbria 1(3),81.

Australia: see Broken Hill.

- Azurite: Gipsy Lane brickpit, Leicestershire (?) 2(1),25. Miguel Vacas mine, Portugal 2(1),13.
- Bage mine, Wirksworth, Derbyshire: Phosgenite & matlockite 1(2),7 (P).
- Ballater (Pass of), Ballater, Grampian Region [formerly Aberdeenshire]: Bertrandite 3(1),31. Wulfenite 4(2),55.
- Ball Eye quarry (near), Matlock Bath, Derbyshire: Wulfenite, anglesite, sulphur 1(2),48.
- Barium feldspars: Broken Hill, Australia 2(2),1.
  Barium-pharmacosiderite: Dumpy Stone level & Sandbeds mine, Cumbria 4(2),64.
- BARSTOW, R.W.: see LLOYD, D.
- Barstow, Richard William: Obituary 1(2),4.
- BARTON, L.R. & BROMLEY, A.V.: Computeraided mineral identification 1(3).86.
- Baryte: Boyleston quarry, Strathclyde 2(2).11. Breedon quarry, Leicestershire 4(1),9 (P). Brownley Hill mine, Cumbria 4(1),35. Cleator Moor, Cumbria 4(1),cover (P). Clevedon, Avon 1(4),125 (P). Colemans quarry, Somerset 3(1),1. East Harptree, Avon 3(2),49. Fall Hill quarry, Derbyshire 1(1),26. Hampstead Farm quarry, Avon 3(2),49. Hartfield Moss, Strathclyde 3(2),43. Llantrisant, Mid Glamorgan 3(1),1 (P). Loanhead quarry, Strathclyde 2(2),15. Low Pike, Cumbria 3(1),25. Machen quarry, Gwent 3(2),85. Peldar Tor, Leicestershire 4(2),59. Sheppey, Kent 1(1),5. Wapping mine, Derbyshire 4(1),25. Wesley mine, Avon 2(2),29. Woodleaze quarry, Avon 2(2),5. Wyndham pit, Cumbria 3(1),29.
- Barytocalcite: Colemans quarry, Somerset 3(1),1 (P). Llantrisant, Mid Glamorgan 3(1),1.
- Basaluminite: Hampstead Farm quarry, Avon 3(2),49
   (P). Newhaven, East Sussex 2(1),9. Scarborough, North Yorkshire 2(1),9.
- Batts Combe quarry, Cheddar, Somerset: Wulfenite etc. 1(2).25.
- Bayldonite: Low Pike, Cumbria 3(1),25.
- Beaverite: Brownley Hill & Smallcleugh mines, Cumbria 4(1).13.
- Beraunite: Gravel Hill mine, Cornwall 2(1), cover (P). Bertrandite: Pass of Ballater, Grampian 3(1), 31.
- Beryl: Pass of Ballater, Grampian 3(1),31.
- BETTERTON, J.: Birnessite, Penberthy Croft mine, Cornwall 2(2),48.
- Beudantite: Clevedon, Avon 1(4).125 (P). Low Pike, Cumbria 3(1).25. Sandbeds mine, Cumbria 4(2),64.
- BEVINS, R.E.: Book reviews by 3(1),37; 3(2),88-89; 4(1),40. Editorials 2(1); 2(2); 3(1). See also POLLARD, A.M.; LIVINGSTONE, A.
- & HORÁK, J.M.: Laumontite, Llanelwedd quarry, Powys 1(3),78. Siegenite, South Wales Coalfield 1(3),83.
- O'BRIEN, P., TURGOOSE, S. & WILLIAMS,
   P.A.: Nickeloan hydrozincite, Parc mine, Gwynedd 1(1),19.
- & STANLEY, C.J.: Aleksite, Dolgellau, Gwynedd 3(2),67.
- BICK, D.E.: Mines & minerals, Newent, Gloucestershire 1(4),114.

- Bigrigg mine, Egremont, Cumbria [formerly Cumberland]: Calcite 3(1) cover (P). Bindheimite: Newporth beach, Cornwall 1(1),40.
- Birnessite: Penberthy Croft mine, Cornwall 2(2),48. Bismuth, native: Botallack, Cornwall 4(2),45.
- Bismutoferrite: Buckbarrow Beck, Cumbria 4(1),3. Blackheath, London: Quartz in flint 1(2),21.
- Bonhiva lode, Knockmahon, Co. Waterford: Langite, connellite 4(1),36.

### Book reviews:

- Adams, 'Mines of the Lake District Fells' 3(1),33.
- Anthony, Bideaux, Bladh & Nichols, 'Handbook of Mineralogy, vol.1' 4(1).40.
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- Young, 'Glossary of the Minerals of the Lake District and Adjoining Areas' 2(2),53.
- Bornite: Boyleston quarry, Strathclyde (?) 2(2),11. Loanhead quarry, Strathclyde 2(2),15. Newhurst quarry, Leicestershire 1(2),27.
- Borstall Woods, Abbey Wood, London: Quartz in flint 1(2),21.
- Botallack, St Just, Cornwall: Supergene Cu minerals & gold 4(2),45 (P).
- Botallack mine, St Just, Cornwall: Carbonatian connellite (tallingite) 2(2),23.
- Botallackite: Botallack, Cornwall 4(2),45 (P).
- Bournonite: Newporth beach, Cornwall 1(1),40.
- BOWELL, R.J.: Supergene Cu minerals, *Botallack*, *Cornwall* 4(2).45.
- Boyleston quarry, Barrhead, Strathclyde Region [formerly Renfewshire]: Growth of acanthite on silver specimens 4(2),67 (P). Secondary minerals in basalt 2(2),11.
- BRAITHWAITE, R.S.W.: Infrared spectroscopic investigation of minerals (Review) 3(2),71.
- Breedon quarry, Breedon on the Hill, Leicestershire: Pb-Mo mineralisation 4(1),9 (P).
- BRIDGES, T.F.: Annabergite, Smallcleugh mine, Cumbria 1(2),18. Cinnabar, Machen quarry, Gwent 3(2),85. Nickel minerals, Hilton mine, Cumbria 1(1),33. Wulfenite etc, near Ball Eye quarry, Derbyshire 1(2),48. See also LIVINGSTONE, A.
- & SMITH, M.E.: Phosgenite & matlockite, Derbyshire 1(2),9.
- Bristol district, Avon: Alumohydrocalcite etc 2(2),5. Pb oxychloride minerals 2(2),29. Secondary Al minerals 3(2),49.
- Britain's Mineralogical Heritage (Conference, 1992) 4(2),71.
- Britannia mine, Snowdon, Gwynedd [formerly Caernarvonshire]: Carbonatian connellite 2(2),23 (P).
- Brochantite: Auchencat Burn, Dumfries & Galloway 4(2),63. Botallack, Cornwall 4(2),45. Buckbarrow Beck, Cumbria 4(1),3. Clevedon, Avon 1(4),125. Coniston, Cumbria 1(3),80. Low Pike, Cumbria 3(1),25. Mulberry openwork, Cornwall 1(4),119. New East Wheal Russell, Devon 1(4),121. Penberthy Croft mine, Cornwall 2(2),48. Wheal Friendship, Devon 1(4),123.
- Broken Hill, New South Wales, Australia: Barium feldspars 2(2),1.
- BROMLEY, A.V.: see BARTON, L.R.
- BROOKE, M.F.: Devilline etc, Wheal Friendship, Devon 1(4),123.
- Brownley Hill mine, Nenthead, Cumbria [formerly Cumberland]: Strontianite, 4(1),35. Zn analogue of ktenasite 4(1),13.
- Buckbarrow Beck veins, Corney Fell, Cumbria [formerly Cumberland]: Russellite etc 4(1),3 (P).
- Bute quarry, Llantrisant, Mid Glamorgan [formerly Glamorganshire]: Rosasite etc 2(1),19.

- Buttgenbachite, carbonatian: *Likasi, Zaire* 2(2),23. Cadmium sulphide: *Wapping mine, Derbyshire* 4(1),25.
- Calcite: Batts Combe quarry, Somerset, manganoan 1(2),25. Bigrigg mine, Cumbria 3(1),cover (P). Boyleston quarry, Strathclyde 2(2),11. Brownley Hill mine, Cumbria 4(1),35. Bute quarry, Mid Glamorgan 2(1),19. Colemans quarry, Somerset 3(1),1. Fall Hill quarry, Derbyshire 1(1),26. Hampstead Farm quarry, Avon 3(2),49. Hartfield Moss, Strathclyde 3(2),43. Hilton mine, Cumbria 1(1),33. Llantrisant, Mid Glamorgan 3(1),1. Loanhead quarry, Strathclyde 2(2),15. Peldar Tor, Leicestershire 4(2),59. Porthcawl, Mid Glamorgan 2(1),19. Sheppey, Kent 1(1),5. Wapping mine, Derbyshire 4(1),25. Woodleaze quarry, Avon 2(2),5. Wyndham pit, Cumbria 3(1),29.
- Canfieldite (Cu analogue of): Gunheath pit, Cornwall 4(1),17.
- Carbonate-cyanotrichite: New East Wheal Russell, Devon 1(4),121.
- Carrock Fell, Caldbeck Fells, Cumbria [formerly Cumberland]: Magnetite misidentified as chromite 3(1),15.
- Cassiterite: Mulberry openwork, Cornwall 1(4),119.
- Celestine: Ecton, Staffordshire 1(2),17 (P). Gipsy Lane brickpit, Leicestershire 2(1),25. Mountfield mine, Sussex 1(3),92. Yate, Avon 2(1),1.
- Celsian: Broken Hill, Australia 2(2),1.
- Cerussite: Ball Eye quarry (near), Derbyshire 1(2),48.
  Batts Combe quarry, Somerset 1(2),25. Breedon
  quarry, Leicestershire 4(1),9 (P). Cloud Hill quarry,
  Leicestershire 1(2),27. Colemans quarry, Somerset
  3(1),1. Grasshill mine, Durham 1(3),81. Greystone
  quarry, Cornwall 1(2),23. Hilton mine, Cumbria
  1(1),33. Machen quarry, Gwent 3(2),85. Newporth
  beach, Cornwall 1(1).40; 1(2).19. Penrhyn Du mine,
  Gwynedd 4(1),35. Redburn mine, Durham 1(3) cover
  (P). Smittergill Head mine, Cumbria 1(3),81.
  Wapping mine, Derhyshire 4(1),25 (P). Wesley mine,
  Avon 2(2),29 (P). Wheal Friendship, Devon 1(4),123.
  Whitfield Brow mines, Durham 1(3),81. Windy Brow
  vein, Cumbria 1(3),81.
- Chabazite: Boyleston quarry, Strathclyde 2(2),11. Loanhead quarry, Strathclyde 2(2),15 (P).
- Chalcanthite: Botallack, Cornwall 4(2),45. Knockmahon, Waterford 4(1),36.
- Chalcedony: In flint 1(2),21.
- Chalcoalumite: New East Wheal Russell, Devon 1(4),121.
- Chalcocite: see chalcosine.
- Chalcophyllite: Botallack, Cornwall 4(2),45 (P). Mulberry openwork, Cornwall 1(4),119.
- Chalcopyrite: Boyleston quarry, Strathclyde 2(2),11.
  Brownley Hill mine, Cumbria 4(1),13 & 35.
  Buckbarrow Beck, Cumbria 4(1),3. Bute quarry, Mid Glamorgan 2(1),19. Greystone quarry, Cornwall 1(2),23. Llantrisant, Mid Glamorgan 3(1),1.
  Loanhead quarry, Strathclyde 2(2),15. Mulberry openwork, Cornwall 1(4),119. Newdigate colliery,

Warwickshire 2(1),29. New East Wheal Russell, Devon 1(4),121. Newent, Gloucestershire (?) 1(4),114. Newhurst quarry, Leicestershire 1(2),27. Newporth beach, Cornwall 1(1),40. Oughterside coalpit, Cumbria 2(1),5. Porthcawl, Mid Glamorgan 2(1),19. Scawgill Bridge, Cumbria, accessory in microdiorite 3(1),15. Smallcleugh mine, Cumbria 4(1).13. Spothow Gill, Cumbria 1(3),80. Ty Gwyn mine, Gwynedd 1(1),cover (P). Wapping mine, Derbyshire 4(1),25. Wesley mine, Avon 2(2),29. Wheal Friendship, Devon 1(4),123. Wyndham colliery, Mid Glamorgan 1(3),83.

Chalcosiderite: Gunheath pit, Cornwall 1(4),127 (P). Chalcosine (chalcocite): Botallack, Cornwall 4(2),45. Boyleston quarry, Strathclyde 2(2),11. Loanhead quarry, Strathclyde 2(2),15. New East Wheal Russell, Devon 1(4),121. Newhurst quarry, Leicestershire 1(2),27.

Childrenite: New East Wheal Russell, Devon 1(4),121. Chitral, Pakistan: Alumohydrocalcite 2(1),9.

Chlorargyrite: Botallack, Cornwall 4(2),45 (P).

Chlorite: Buckbarrow Beck, Cumbria 4(1),3. Hartfield Moss, Strathclyde 3(2),43. Loanhead quarry, Strathclyde 2(2),15. Peldar Tor, Leicestershire 4(2),59 (P). Scawgill Bridge, Cumbria 3(1),15.

Chloroxiphite: Colemans quarry, Somerset 3(1),1. Wesley mine, Avon 2(2),29.

Chromite: Carrock Fell, Cumbria, error for magnetite 3(1),15. Scawgill Bridge, Cumbria, accessory in microdiorite 3(1),15.

Chrysocolla: Boyleston quarry, Strathclyde 2(2),11.

Buckbarrow Beck, Cumbria 4(1),3. Hartfield Moss,
Strathclyde 3(2),43.

Chrysotile: Wesley mine, Avon 2(2),29.

Cinnabar: Machen quarry, Gwent 3(2),85.

Clayton adit, Ecton, Staffordshire: Millerite 1(2),17 (P).

Cleaning of minerals: 1(1),42.

Cleator Moor, Cumbria [formerly Cumberland]: Baryte 4(1),cover (P).

Clevedon, Avon [formerly Somerset]: Beudantite etc 1(4),125 (P).

Cligga Head, Perranzabuloe, Cornwall: Stannite, kësterite, ferrokësterite, stannoidite 4(1),17. Zeunerite 2(2),cover (P).

Clinochlore, ferroan: *Peldar Tor*, *Leicestershire* 4(2),59 (P).

Clinoclase: Botallack, Cornwall 4(2),45.

Clinozoisite: Loanhead quarry, Strathclyde 2(2),15.

Clogau mine, Dolgellau, Gwynedd [formerly Merionethshire]: Aleksite 3(2),49 (P).

Closehouse mine, Lunedale, Durham [formerly Yorkshire]: Pyromorphite 1(3),81.

Cloud Hill quarry, Breedon-on-the-Hill, Leicestershire: Galena 1(2),27.

Cobaltite: Scawgill Bridge, Cumbria (?) 3(1),15.

Coffinite: Gipsy Lane brickpit, Leicestershire 2(1),25.

COGGON, L.: see ELTON, N.J.

Colemans quarry, Holwell, Mendip Hills, Somerset: Barytocalcite etc 3(1),1 (P). Collecting Minerals (Conference, 1992): 4(2),74.

Colvend mine, Rockcliffe, near Dalheattie, Dumfries & Galloway [formerly Kirkcudbrightshire]: Connellite 4(2),63.

Computers: Mineral identification package 1(3),86.

Conference reports: Collecting Minerals (Loughborough 1992) 4(2),74. Conserving Britain's Mineralogical Heritage (Manchester 1992) 4(2),71.

Mineralogy & Museums (London 1988) 2(1),31. Coniston, Cumbria [formerly Luncashire]: Langite, posnjakite 1(3),80.

Connellite: Synthetic 2(2),23. Botallack, Cornwall 4(2),45 (P). Botallack mine, Cornwall & Britannia mine, Gwynedd, carbonatian (tallingite) 2(2),23 (P). Colvend mine, Dumfries & Galloway 4(2),63. Knockmahon, Waterford 4(1),36. Penberthy Croft mine, Cornwall 2(2),48. Perran St George mine, Cornwall 2(2),23.

Conserving Britain's Mineralogical Heritage (Conference, 1992): 4(2),71.

COOPER, M.P.: see YOUNG, B.

Copper, native: Botallack, Cornwall 4(2),45. Boyleston quarry, Strathclyde 2(2),11. Cloud Hill quarry, Leicestershire 1(2),27. Hartfield Moss, Strathclyde 3(2),43. Loanhead quarry, Strathclyde 2(2),15. New East Wheal Russell, Devon 1(4),121.

Cornubite: Botallack, Cornwall 4(2),45.

Cornwall: Rare earth elements in fluorite 1(1),22. Stannite etc (Review) 4(1),17.

Cornwallite: Botallack, Cornwall 4(2),45 (P). Low Pike, Cumbria 3(1),25.

Coulsonite pseudomorphs: Newhurst quarry, Leicestershire 1(2),27.

Covellite: Boylestone quarry, Strathclyde 2(2),11.
Buckbarrow Beck, Cumbria 4(1),3. Hartfield Moss,
Strathclyde 3(2),43. Loanhead quarry, Strathclyde
2(2),15. Mulberry openwork, Cornwall 1(4),119.

Crednerite: Colemans quarry, Somerset 3(1),1. Wesley mine, Avon 2(2),29 (P).

Cromford level, Cromford, Derhyshire: Matlockite & phosgenite 1(2),7

CROWTHER, P.R.: Book review by 4(2),77.

Cumberland Cavern, Matlock Bath, Derbyshire: Minerals 4(1),25.

Cumengeite: Newporth beach, Cornwall 1(1),40.
Cuprite: Botallack, Cornwall 4(2),45 (P). Boyleston quarry, Strathclyde 2(2),11. Cloud Hill quarry, Leicestershire 1(2),27. Colemans quarry, Somerset 3(1),1. New East Wheal Russell, Devon 1(4),121. West Caradon mine, Cornwall 3(2).81.

Cuprosklodowskite: Geevor mine, Cornwall 4(2),66 (P). Cuprotungstite: Buckbarrow Beck, Cumbria 4(1),3.

Curation of minerals: 1(3),94; 1(4),129.

Cyanotrichite: *Botallack*, *Cornwall* 4(2),45. *Mulberry openwork*, *Cornwall* 1(4),119. See also carbonate-cyanotrichite.

Cyrilovite: Gunheath pit, Cornwall 1(4),127 (P). DEAN, A.C.: Cumengeite, phosgenite, Newporth beach, Cornwall 1(1),40; 1(2),19. Derbyshire: Phosgenite & matlockite 1(2),7.

Descloizite: Wesley mine, Avon 2(2),29 (P).

Developing mineral specimens: 1(2),54.

Devilline: Botallack, Cornwall 4(2),45. Wheal Friendship, Devon 1(4),123.

Devon: Stannite etc (Review) 4(1),17.

Diaboleite: Batts Combe quarry, Somerset (?) 1(2),25. Colemans quarry, Somerset 3(1),1. Wesley mine, Avon (?) 2(2),29.

Diaspore: Hartfield Moss, Strathclyde 3(2),43.

Digenite: Botallack, Cornwall 4(2),45.

Diopside: Loanhead quarry, Strathclyde 2(2),15.

Djurleite: Botallack, Cornwall 4(2),45. West Caradon mine, Cornwall 3(2),81.

Dolgellau gold belt, Gwynedd [formerly Merionethshire]: Aleksite 3(2),49.

Dolomite: Breedon quarry, Leicestershire 4(1),9. Brownley Hill mine, Cumbria 4(1),13. Llantrisant, Mid Glamorgan 3(1),1. Peldar Tor, Leicestershire 4(2),59(P). Smallcleugh mine, Cumbria 4(1),13.

Drumruck mine, near Gatehouse of Fleet, Dumfries & Galloway Region [formerly Kirkcudbrightshire]: Wulfenite 4(2),55.

Duftite: Low Pike, Cumbria 3(1),25.

Dumpy Stone level, Caldbeck Fells, Cumbria [formerly Cumberland]: Barium- pharmacosiderite 4(2),64.

Dundasite: East Harptree, Avon 3(2),49. Greystone quarry, Cornwall 1(2),23. Hampstead Farm quarry, Avon 2(2),5; 3(2),49 (P).

DUNHAM, Sir Kingsley: Book review by 4(1),40.

Dylife mine, Penegoes, Powys [formerly Montgomeryshire]: Minerals 1(1),8 (P).

Earl Ferrers' mine, Staunton Harold, Leicestershire: Galena 1(2),27 (P).

East Harptree, Mendip Hills, Avon [formerly Somerset]: Secondary Al minerals 3(2).49 (P).

EASTWOOD, N.J.: Wulfenite, Batts Combe quarry, Somerset 1(2),25.

Ecton Hill, Ecton, Staffordshire: Millerite 1(2),17 (P). Editorials: see BEVINS, R.E.; KING, R.J.; RYBACK, G.; YOUNG, B.

Eire: see Ireland.

ELTON, N.J., HOOPER, J.J. & COGGON, L.: Cuprosklodowskite, *Geevor mine*, *Cornwall* 4(2),66. Endellite: see halloysite-10Å. *England*:

- Avon: see Bristol district; Clevedon; East Harptree; Hampstead Farm quarry; Leechpool Farm; Tytherington quarries; Wesley mine; Woodleaze quarry; Yate.
- Cornwall: see Botallack; Botallack mine; Cligga Head; Geevor mine; Gravel Hill mine; Greystone quarry; Gunheath pit; Hensbarrow pit; Mulberry openwork; Newporth beach; Penberthy Croft mine; Perran St George mine; St Michael's Mount; West Caradon mine; Wheal Cock; Wheal Gorland; Wheal Trehane.
- Cumbria: see Bigrigg mine; Brownley Hill mine;
   Buckbarrow Beck veins; Carrock Fell; Cleator
   Moor; Dumpy Stone level; Eskdale; Florence mine;
   Haggs mine; Hard Rigg Edge; Hilton mine; Kirkby

- Thore; Low Pike; Nether Row Brow; Oughterside coalpit; Paddy End mine; Red Gill mine; Roughton Gill mine; Sandbeds mine; Scawgill Bridge; Smallcleugh mine; Smittergill Head mine; Spothow Gill; Windy Brow vein; Wyndham pit.
- Derbyshire: see Bage mine; Ball Eye quarry;
   Cromford level; Cumberland Cavern; Fall Hill
   quarry; Ladywash mine; Millclose mine; Treak Cliff;
   Wallclose mine; Wapping mine.
- Devon: see Hope's Nose; Meldon; New East Wheal Russell; Wheal Friendship.
- Durham: see Closehouse mine; Grasshill mine; Healyfield mine; Heights mine; Redburn mine; Weardale; West Pasture mine; Whitfield Brow mines; Yorkshire Silverband mine.
- Gloucestershire: see Newent.
- Kent: see Herne Bay; Oldhaven Gap; St Margaret's Bay; Sheppey (Isle of); Warden Point.
- -- Leicestershire: see Albert Village; Albion pit; Ashby de la Zouch; Breedon quarry; Cloud Hill quarry; Gipsy Lane brickpit; Lount; Measham; Mountsorrel; Newhurst quarry; Peldar Tor; Ravenstone; Sheethedges Wood quarry; Staunton Harold; Tickow Lane mine.
- London: see Abbey Wood; Blackheath; Borstall Woods.
- Northamptonshire: see Weston Favell.
- Somerset: see Batts Combe quarry; Colemans quarry.
- Staffordshire: see Clayton adit; Ecton Hill; Waterbank mine.
- Sussex (East): see Mountfield mine; Newhaven.
- Warwickshire: see Newdigate colliery.
- Wiltshire: see Salisbury Plain.
- Yorkshire (North): see Pateley Bridge; Scarborough.

Eosite: *Leadhills*, *Strathclyde*, error for vanadinite 4(2),55.

Epidote: Loanhead quarry, Strathclyde 2(2),15. Scawgill Bridge, Cumbria 3(1),15.

Erythrite: Botallack, Cornwall 4(2),45. Gipsy Lane brickpit, Leicestershire 2(1),25. Hilton mine, Cumbria 1(1),33.

Eskdale, Cumbria [formerly Cumberland]: Langite, posnjakite 1(3),80.

- FAITHFULL, J.[W.]: Strontianite, Yate, Avon 2(1),1 & erratum 2(2).
- & HUBBARD, N.: Coffinite, Gipsy Lane brickpit, Leicestershire 2(1),25.
- & INCE, F.: Mottramite, Peldar Tor, Leicestershire 4(2),59.

Fall Hill quarry, Ashover, Derbyshire: Minerals 1(1),26.

Feldspar: Broken Hill, Australia, barium feldspars 2(2),1. Hartfield Moss, Strathclyde 3(2),43. Loanhead quarry, Strathclyde 2(2),15.

Ferberite: Buckbarrow Beck, Cumbria 4(1),3.

Ferrokësterite: Cornwall 4(1),17.

Field curation of minerals: 1(3),94.

FLETCHER, C.J.N. & YOUNG, B.R.: Rosasite, Bute quarry, Mid Glamorgan 2(1),19.

Flint: Secondary silica in 1(2),21.

Florence mine, Egremont, Cumbria [formerly

Cumberland: Rare earth elements in fluorite 1(1),22.

Fluorite: Rare earth elements in 1(1),22. Ball Eye quarry (near), Derbyshire 1(2),48. Colemans quarry, Somerset 3(1),1. Fall Hill quarry, Derbyshire 1(1),26. Hilton mine, Cumbria 1(1),33. Pass of Ballater, Grampian 3(1),31. Wapping mine, Derbyshire 4(1),25 (P).

FORTEY, N.J.: Book review by 3(2),91. See also YOUNG, B.

— & NANCARROW, P.H.A.: Chromian oxide minerals, Lake District 3(1),15.

FRANCIS, J.G.: see YOUNG, B.

Fuller, John P.: Obituary 1(4).

Gairnshiel, Gairnshiel Bridge, near Ballater, Grampian Region [formerly Aberdeenshire]: Scheelite, wulfenite 4(2),55.

Galena: Ball Eye quarry (near), Derbyshire 1(2),48. Breedon quarry, Leicestershire 4(1),9 (P). Bute quarry, Mid Glamorgan 2(1),19. Clevedon, Avon 1(4),125. Fall Hill quarry, Derbyshire 1(1),26. Clogau - St David's mine, Gwynedd 3(2),49 (P). East Harptree, Avon 3(2),49. Gipsy Lane brickpit, Leicestershire 1(2),27; 2(1),25. Greystone quarry, Cornwall 1(2),23. Hampstead Farm quarry, Avon 3(2),49. Healeyfield mine, Durham 1(3),81. Hilton mine, Cumbria 1(1),33. Llantrisant, Mid Glamorgan 3(1),1. Loanhead quarry, Strathclyde 2(2).15. Machen quarry, Gwent 3(2),85. Newdigate colliery, Warwickshire 2(1),29. Newent, Gloucestershire 1(4),114. Newporth beach, Cornwall 1(1),40. Parc mine, Gwynedd 1(1),19. Penrhyn Du mine, Gwynedd 4(1),35. Sandbeds mine, Cumbria 4(2),64. Wapping mine, Derbyshire 4(1),25 (P). Wesley mine, Avon 2(2),29. Wheal Friendship, Devon 1(4),123. Windy Brow vein, Cumbria 1(3),81. Woodleaze quarry, Avon 2(2),5. Wyndham colliery, Mid Glamorgan

Garnet: Loanheud quarry, Strathclyde 2(2).15 (P). Geevor mine, St Just, Cornwall: Cuprosklodowskite 4(2),66 (P).

Georgeite: Britannia mine, Gwynedd 2(2),23.

Gersdorffite: Hilton mine, Cumbria 1(1),33. Scawgill Bridge, Cumbria (?) 3(1),15.

Gibbsite: East Harptree & Hampstead Farm quarry, Avon 3(2),49. Woodleaze guarry, Avon 2(2),5.

Gipsy Lane brickpit, Leicester, Leicestershire: Coffinite 2(1),25. Galena 1(2),27.

Goethite: Botallack, Cornwall 4(2),45. Colemans quarry, Somerset 3(1),1. Fall Hill quarry, Derbyshire 1(1),26. Loanhead quarry, Strathclyde 2(2),15. Newent, Gloucestershire 1(4),114. Newporth beach, Cornwall 1(1),40. Wapping mine, Derbyshire 4(1),25. Wesley mine, Avon 2(2),29. Yate, Avon 2(1),1.

Gold, native: Botallack, Cornwall 4(2),45 (P). Hope's Nose, Devon 3(2), cover (P). Newent, Gloucestershire (?) 1(4),114.

Grasshill mine, Teesdale, Durham: Pyromorphite 1(3),81.

Gravel Hill mine, Perranzabuloe, Cornwall: Strunzite, beraunite 2(1), cover (P).

GREEN, D.I.: see YOUNG, B.

Greenockite: Fall Hill quarry, Derbyshire (?) 1(1),26. Loanhead quarry, Strathclyde 2(2),15.

Greystone quarry, Lezant, Cornwall: Aurichalcite, hemimorphite 1(2).23.

Grossular: Loanhead quarry, Strathclyde 2(2),11. Gunheath pit, St Austell, Cornwall: Cyrilovite, chalcosiderite 1(4),127 (P). Kuramite, stannoidite, stannite 4(1),17.

Gypsum: Botallack, Cornwall 4(2),45. Brownley Hill mine, Cumbria 4(1),13. Colvend mine, Dumfries & Galloway 4(2),63. Coniston, Cumbria 1(3),80. Geevor mine, Cornwall 4(2),66. Gipsy Lane brickpit, Leicestershire 2(1),25. Hampstead Farm quarry, Avon 3(2),49. Sheppey, Kent 1(1),5. Smallcleugh mine, Cumbria 3(1).23; 4(1),13. Wapping mine, Derbyshire 4(1),25 (P). Wheal Friendship, Devon 1(4),123.

Haggs mine, Nenthead, Cumbria [formerly Cumberland: Rare earth elements in fluorite 1(1),22.

Halloysite-10Å (endellite): East Harptree, Avon 3(2),49. Weston Favell, Northamptonshire 2(1),9.

Hampstead Farm quarry, Chipping Sodbury, Avon [formerly Gloucestershire]: Scarbroite etc 2(2),5. Secondary Al minerals 3(2),49 (P).

HARDING, R.R.: Book reviews by 3(2),87; 4(1),39. Hard Rigg Edge, Melmerby Fell, Cumbria [formerly Cumberland: Pyromorphite 1(3),81.

Harker, Dr Roger Stuart: Obituary 1(2),5.

Harmotome: Hartfield Moss, Strathclyde 3(2),43. Loanhead quarry, Strathclyde 2(2),15.

HART, A.D. & SYMES, R.F.: Arthur Russell (Minibiography) 4(1),1.

Hartfield Moss, near Neilston, Strathclyde Region [formerly Renfewshire]: Secondary minerals in basalt 3(2),43.

Hausmannite: Colemans quarry, Somerset 3(1),1. Wesley mine, Avon 2(2),29. Wyndham pit, Cumbria 3(1).29 (P).

Hawleyite: Fall Hill quarry, Derhyshire 1(1),26. Healeyfield mine, Consett, Durham [formerly Yorkshire]: Pyromorphite 1(3),81.

Heddle, Matthew Forster: Biography 3(2),61. Heights mine, Weardale, Durham: Rare earth elements in fluorite 1(1),22.

Hematite: Boyleston quarry, Strathclyde 2(2),11. Colemans quarry, Somerset 3(1),1. Hartfield Moss, Strathclyde 3(2),43. Loanhead quarry, Strathclyde 2(2),15. Newent, Gloucestershire 1(4),114. Peldar Tor, Leicestershire 4(2).59.

Hemimorphite: Greystone quarry, Cornwall 1(2),23. Wapping mine, Derbyshire 4(1),25 (P).

Hensbarrow pit, St Austell, Cornwall: Stannite, stannoidite, mawsonite 4(1),17.

Herne Bay, Kent: Quartz in flint 1(2),21.

Heulandite: Hartfield Moss, Strathclyde 3(2),43. Loanhead quarry, Strathclyde 2(2),15.

HICKS, R.P.: Radioactive minerals, storage & handling 1(2).52.

Hilton mine, Scordale, Cumbria [formerly Westmorland]: Nickel minerals 1(1),33.

HOOPER, J.J.: see ELTON, N.J.

Hope's Nose, Torquay, Devon: Gold 3(2), cover (P).

HORÁK, J.M.: see BEVINS, R.E.

Hornblende: Scawgill Bridge, Cumbria 3(1),15.

HOWIE, R.A.: Book reviews by 2(1),35; 2(2),53; 3(1),33; 3(2),87; 4(1),39.

— PEGRAM, E. & WALSH, J.N.: Rare earth elements in fluorite 1(1),22.

HUBBARD, N.: Phosgenite, Penrhyn Du mine, Gwynedd 4(1).35. See also FAITHFULL, J.W.

Hyalophane: Broken Hill, Australia 2(2),1.

Hydrobasaluminite: *Hampstead Farm quarry*, Avon (?) 3(2),49.

Hydrocarbons: *Fall Hill quarry*, *Derbyshire* 1(1),26. Cf. asphaltum.

Hydrocerussite: Batts Combe quarry, Somerset 1(2),25. Colemans quarry, Somerset 3(1),1. Wesley mine, Avon 2(2),29.

Hydroscarbroite: East Harptree & Hampstead Farm quarry, Avon 3(2),49. Weston Favell, Northamptonshire (?) 1(1),9.

Hydrotalcite: East Harptree, Avon 3(2),49 (P).

Hydrozincite, nickeloan: Parc mine, Gwynedd 1(1),19.

HYSLOP, E.: see YOUNG, B.

Ilmenite: Scawgill Bridge, Cumbria 3(1),15.

INCE, F.: Cyrilovite, chalcosiderite, Gunheath pit, Cornwall 1(4),127. Minerals, Wapping mine, Derbyshire 4(1).25. See also FAITHFULL, J.W.

Infrared data: Alumohydrocalcite 2(1),9. Atacamite 3(2),71. Botallackite 3(2),71. Buttgenbachite 2(2),23. Connellite 2(2),23. Ktenasite (Zn analogue of) 4(1),13. Paratacamite 3(2),71. Pseudomalachite 3(2),71.

Infrared spectroscopy: For mineral investigation (Review) 3(2),71.

Ireland (Republic of):

— Co. Waterford: see Bonhiva lode; Knockmahon mines; Tankardstown mine.

Iron mines: Newent, Gloucestershire 1(4),114.

IXER, R.A.: Book reviews by 3(1),35; 4(2),78.

Jarosite: Botallack, Cornwall 4(2),45. Wheal Friendship, Devon (?) 1(4),123.

JOHNSON, E.W.: see YOUNG, B.

Kaolinite: East Harptree, Avon 3(2),49. Oughterside coalpit, Cumbria 2(1),5.

Kent: Quartz & chalcedony in flint 1(2),21.

Kentrolite: Colemans quarry, Somerset 3(1),1.

Kësterite: Cornwall 4(1),17.

KING, R.J.: Award of Russell Medal to 4(2),43. Cleaning minerals 1(1),42. Conference report (Collecting Minerals, 1992) 4(2),74. Curating minerals 1(3),94; 1(4),129. Developing minerals 1(2),54. Editorials 1(1); 1(2); 1(3); 1(4). Galena, Leicestershire 1(2),27. Pb-Mo mineralisation, Breedon quarry, Leicestershire 4(1),9. Scarbroite, Scarborough, North Yorkshire & Weston Favell, Northamptonshire 1(1),9.

Kirkby Thore, Cumbria [formerly Westmorland]: Thenardite 1(3),92.

Knockmahon mines, Knockmahon, Co. Waterford: Cu secondaries 4(1),36.

Kröhnkite: Botallack, Cornwall 4(2),45 (P).

Ktenasite, Zn analogue of: Brownley Hill & Smallcleugh mines, Cumbria 4(1),13.

Kuramite: Gunheath pit, Cornwall 4(1),17.

Ladywash mine, Eyam, Derbyshire: Rare earth elements in fluorite 1(1),22.

Langhorn quarry, Egremont, Cumbria [formerly Cumberland]: see Wyndham pit.

Langite: Botallack, Cornwall 4(2),45. Coniston & Eskdale, Cumbria 1(3).80. Knockmahon, Waterford 4(1),36. New East Wheal Russell, Devon (?) 1(4),121. Wheal Friendship, Devon 1(4),123.

Lauchentyre mine, near Gatehouse of Fleet, Dumfries & Galloway Region [formerly Kirkcudbrightshire]: Wulfenite 4(2),55.

Laumontite: Hartfield Moss, Strathclyde 3(2),43. Llanelwedd quarry, Powys 1(3),78. Loanhead quarry, Strathclyde 2(2),15.

Laurionite: Wesley mine, Avon 2(2),29.

Lavendulan: Gipsy Lane brickpit, Leicestershire 2(1),25.

LAWRENCE, J.A.: Djurleite, West Caradon mine, Cornwall 3(2),81.

Leadhills, Strathclyde Region [formerly Lanarkshire]: Wulfenite, eosite (misidentified) 4(2),55.

Leechpool Farm, Yate, Avon [formerly Gloucestershire]: Strontianite 2(1),1 (P) & erratum 2(2).

Leicestershire: Galena 1(2),27.

Libethenite: Botallack, Cornwall 4(2),45. Miguel Vacas mine, Portugal 2(1),13 (P).

Likasi, Katanga, Zaire: Carbonatian buttgenbachite 2(2),23.

Linarite: Smittergill Head vein, Cumbria 1(3),81. Wheal Friendship, Devon 1(4),123.

Liroconite: Botallack, Cornwall 4(2),45. Wheal Gorland, Cornwall 1(2),cover (P).

LIVINGSTONE, A.: Matthew Forster Heddle (Biography) 3(2),61. Stolzite, Wanlockhead, Strathclyde & wulfenite, Scotland 4(2),55. Zn analogue of ktenasite, Brownley Hill & Smallcleugh mine, Cumbria 4(1),13.

 BRIDGES, T.F. & BEVINS, R.E.: Schulenbergite & namuwite, Smallcleugh mine, Cumbria 3(1),23.

— THOMAS, R.G. & WILLIAMS, P.A.: Mineral identification by X-ray diffraction (Review) 3(1),7.

Llanelwedd quarry [formerly in Radnorshire]; Builth Wells, Powys: Laumontite 1(3),78.

Llantrisant, Mid Glamorgan [formerly Glamorganshire]: Alstonite & barytocalcite 3(1),1 (P).

LLOYD, D. & BARSTOW, R.W.: Aurichalcite & hemimorphite, Greystone quarry, Cornwall 1(2),23.

Loanhead quarry, Beith, Strathclyde Region [formerly on Ayrshire-Renfewshire border]: Growth of acanthite on silver specimens 4(2),67. Secondary minerals in basalt 2(2),15 (P).

Locks Common borehole, Porthcawl, Mid Glumorgan

[formerly *Glamorganshire*]: Rosasite, aurichalcite, etc 2(1),19 (P).

Lount, Staunton Harold, Leicestershire: Galena 1(2),27.

Low Pike, Caldbeck Fells, Cumbria [formerly Cumberland]: Supergene Cu & Pb minerals 3(1),25.

Machen quarry, Machen, Gwent [formerly Monmouthshire]: Cinnabar 3(2),85.

MAGALHÃES, M.C.F., PEDROSA DE JESUS, J.D. & WILLIAMS, P.A.: Copper phosphates, Miguel Vacas mine, Portugal 2(1),13.

Magnetite: Loanhead quarry, Strathclyde 2(2),15.

Malachite: Auchencat Burn, Dumfries & Galloway 4(2),63. Batts Combe quarry, Somerset 1(2),25. Botallack, Cornwall 4(2),45. Boyleston guarry. Strathclyde 2(2),11. Britannia mine, Gwynedd 2(2),23. Brownley Hill mine, Cumbria 4(1),13. Buckbarrow Beck, Cumbria 4(1),3. Bute quarry, Mid Glamorgan, zincian 2(1),19. Cloud Hill quarry, Leicestershire 1(2),27. Colemans quarry, Somerset 3(1),1. Colvend mine, Dumfries & Galloway 4(2),63. Coniston, Cumbria 1(3),80. Gipsy Lane brickpit, Leicestershire 2(1),25. Greystone quarry, Cornwall 1(2),23. Hartfield Moss, Strathclyde 3(2),43. Knockmahon, Waterford 4(1), 36. Loanhead quarry, Strathclyde 2(2),15. Low Pike, Cumbria 3(1),25. Miguel Vacas mine, Portugul 2(1),13. New East Wheal Russell, Devon 1(4),121. Newporth beach, Cornwall 1(1),40. Porthcawl, Mid Glamorgan, zincian 2(1),19. Redburn mine, Durham 1(3), cover (P). Smallcleugh mine, Cumbria 4(1),13. Smittergill Head mine, Cumbria 1(3),81. Ty Gwyn mine, Gwynedd 1(1),cover (P). Wheal Friendship, Devon 1(4),123.

Manganite: Botallack, Cornwall 4(2),45. Colemans quarry, Somerset 3(1),1. Wesley mine, Avon (?) 2(2),29. Wyndham pit, Cumbria 3(1),29.

Manganocalcite: Batts Combe quarry, Somerset 1(2),25.

Marcasite: Fall Hill quarry, Derbyshire 1(1),26.

Hampstead Farm quarry, Avon 3(2),49. Parc mine,
Gwynedd 1(1),19. Wapping mine, Derbyshire 4(1),25.

Matlockite: Derbyshire 1(2),7 (P).

Mawsonite: Cornwall 4(1),17.

Measham, Leicestershire: Galena 1(2),27.

MEIKLE, T.K.: Acanthite, growth on silver specimens, Boyleston quarry, Hartfield Moss & Loanhead quarry, Strathclyde 4(2),67. Secondary minerals in basalt, Boyleston quarry, Strathclyde 2(2),11; Hartfield Moss, Strathclyde 3(2),43; Loanhead quarry, Strathclyde 2(2),15.

Melanotekite: Colemans quarry, Somerset 3(1),1. Wesley mine, Avon 2(2),29.

Meldon, Devon: Rare earth elements in fluorite 1(1),22.

Melissa mine, Silver District, La Paz Co., Arizona, USA: Wulfenite 2(2), back cover (P).

Mendipite: Colemans quarry, Somerset 3(1),1. Wesley mine, Avon 2(2),29.

'Mereheadite': Colemans quarry, Somerset (?) 3(1),1. Wesley mine, Avon 2(2),29.

Miguel Vacas mine, Alentejo, Portugal: Copper phosphates 2(1),13 (P).

Millclose mine, Darley Dale, Derbyshire: Phosgenite 1(2).7.

Millerite: Ecton, Staffordshire 1(2),17
(P). Fall Hill quarry, Derbyshire 1(1),26.
Hilton mine, Cumbria 1(1),33. Newdigate
colliery, Warwickshire 2(1),29. Newent,
Gloucestershire 1(4),114. Oughterside coalpit,
Cumbria 2(1),5 (P). Wyndham colliery, Mid
Glamorgan 1(3),83.

MILLWARD, D.: see YOUNG, B.

Mimetite: Colemans quarry, Somerset 3(1),1. Low-Pike, Cumbria 3(1),25.

Mineral & Gem Show, London, 1989 (Report): 2(2),51.

Mineralogy & Museums (Conference, 1988): 2(1),31. Minerals: Cleaning of 1(1),42. Computer-aided identification 1(3),86. Curation of 1(3),94; 1(4),129. Development of 1(2),54. Identification by X-ray diffraction (Review) 3(1),7. Infrared spectroscopic investigation (Review) 3(2),71. Radioactive, storage & handling 1(2),52. Toxic & radioactive hazards 1(4),129.

Mirabilite: Kirkby Thore, Cumbria 1(3),92. MONK, P.K.: Baryte etc, Sheppey, Kent 1(1),5. Secondary silica in flint 1(2),21.

Morenosite: Ecton, Staffordshire (?) 1(2),17.

MORETON, N.J.M.: Dylife, Powis 1(1),8.

MORETON, S.: Cu secondaries, Knockmahon, Waterford 4(1),36.

— & ASPEN, P.: Connellite, Colvend & brochantite, Auchencat Burn, Dumfries & Galloway 4(2),63.

Mottramite: Loanhead quarry, Strathclyde 2(2),15. Low Pike, Cumbria 3(1),25. Peldar Tor, Leicestershire 4(2),59 (P).

Mountfield mine, Battle, East Sussex [formerly Sussex]: Thenardite 1(3),92.

Mountsorrel, Leicestershire: Galena 1(2),27.

Mulberry openwork, Lanivet, Cornwall: Cyanotrichite, 1(4),119.

Muscovite: Hartfield Moss, Strathclyde 3(2),43. Loanhead quarry, Strathclyde 2(2),15. Peldar Tor, Leicestershire 4(2),59.

Natrolite: Hartfield Moss, Strathclyde 3(2),43. Loanhead quarry, Strathclyde 2(2),15 (P).

Natron: Botallack, Cornwall 4(2),45.

Namuwite: Brownley Hill mine, Cumbria 4(1),13. Smallcleugh mine, Cumbria 3(1),23 (P); 4(1),13.

NANCARROW, P.H.A.: see FORTEY, N.J.; YOUNG, B.

Natrolite: Hartfield Moss, Strathclyde 3(2),43. Loanhead quarry, Strathclyde 2(2),15.

Nether Row Brow, Caldbeck Fells, Cumbria [formerly Cumberland]: Symplesite 4(2),64.

Newdigate colliery, Nuneaton, Warwickshire: Retgersite 2(1),29.

New East Wheal Russell, Tavistock, Devon: Carbonate-cyanotrichite 1(4),121.

Newent, Gloucestershire: Mines & minerals 1(4),114.

Newhaven, East Sussex [formerly Sussex]: Basaluminite 2(1),9.

Newhurst quarry, Shepshed, Leicestershire: Galena etc 1(2),27.

Newporth beach, Falmouth, Cornwall: Cumengeite etc 1(1),40. Phosgenite 1(2),19.

Niccolite: see nickeline.

Nickeline & nickel minerals: *Hilton mine*, *Cumbria* 1(1),33.

O'BRIEN, P.: see BEVINS, R.E.

Offretite: Hartfield Moss, Strathclyde (?) 3(2),43. Oldhaven Gap, Herne Bay, Kent: Quartz in flint 1(2),21.

Oligoclase: Hartfield Moss, Strathclyde 3(2),43. Olivenite: Botallack, Cornwall 4(2),45 (P).

Olivine: Scawgill Bridge, Cumbria 3(1),15.

Orthoclase: *Hartfield Moss, Strathclyde*, adularia (?) 3(2),43.

Oughterside coalpit, near Aspatria, Cumbria [formerly Cumberland]: Millerite 2(1),5 (P).

Paddy End mine, Coniston, Cumbria [formerly Lancashire]: Langite, posnjakite 1(3),80.

Pakistan: see Chitral.

Para-alumohydrocalcite: Hampstead Farm quarry, Avon 2(2),5; 3(2),49 (P).

Paralaurionite: Colemans quarry, Somerset 3(1),1. Wesley mine, Avon 2(2),29.

Paratacamite: Botallack, Cornwall 4(2),45.

Parc mine, Llanrhychwyn, Gwynedd [formerly Caernarvonshire]: Nickeloan hydrozincite 1(1),19.

'Parkinsonite': Colemans quarry, Somerset (?) 3(1),1. Wesley mine, Avon 2(2),29.

Pass of Ballater, Ballater, Grampian Region [formerly Aberdeenshire]: Bertrandite 3(1),31. Wulfenite 4(2),55.

Pateley Bridge, North Yorkshire [formerly Yorkshire]: Rare earth elements in fluorite 1(1),22.

PEDROSA DE JESUS, J.D.: see MAGALHĀES, M.C.F.

PEGRAM, E.: see HOWIE, R.A.

Peldar Tor, Whitwick, Leicestershire: Mottramite 4(2),59 (P).

Penberthy Croft mine, St Hilary, Cornwall: Birnessite 2(2),48.

Pennines (Northern): Pyromorphite 1(3),81.

Penrhyn Du mine, Abersoch, Gwynedd [formerly Caernarvonshire]: Phosgenite 4(1),35.

Perran St George mine, Perranzabuloe, Cornwall: Connellite 2(2),23.

Pharmacosiderite: *Botallack*, *Cornwall* 4(2),45 (P). See also barium- pharmacosiderite.

Philipsburgite: Low Pike, Cumbria 3(1),25.

Phosgenite: Clevedon, Avon 1(4),125 (P). Derbyshire 1(2),7. Newporth beach, Cornwall 1(2),19. Penrhyn Du mine, Gwynedd 4(1),35. Wesley mine, Avon 2(2),29 (P).

Plattnerite: Wesley mine, Avon 2(2),29.

PLIMER, I.: Barium feldspar rocks, *Broken Hill*, *Australia* 2(2),1.

Plumbogummite: Roughton Gill mine, Cumbria 1(4),cover (P).

POLLARD, A.M., THOMAS, R.G., WILLIAMS, P.A., BEVINS, R.E. & TURGOOSE, S.:

Carbonatian connellite, Botallack mine, Cornwall & Britannia mine, Gwynedd 2(2),23.

Porthcawl, Mid Glamorgan [formerly Glamorganshire]: Rosasite etc 2(1),19.

Portugal: see Miguel Vacas mine.

Posnjakite: Coniston & Eskdale, Cumbria 1(3),80.

Prehnite: Boyleston quarry, Strathclyde 2(2),11. Hartfield Moss, Strathclyde 3(2),43. Loanhead quarry, Strathclyde 2(2),15.

Pseudomalachite: Botallack, Cornwall 4(2),45. Low Pike, Cumbria 3(1),25. Miguel Vacas mine, Portugal 2(1),13 (P).

Pumpellyite: Loanhead quarry, Strathclyde 2(2),15.

Pyrite: Buckbarrow Beck, Cumbria 4(1),3. East Harptree, Avon 3(2),49. Ecton, Staffordshire 1(2),17. Fall Hill quarry, Derbyshire 1(1),26. Greystone quarry, Cornwall 1(2),23. Hampstead Farm quarry, Avon 3(2),49. Hilton mine, Cumbria 1(1),33. Llantrisant, Mid Glamorgan 3(1),1. New East Wheal Russell, Devon 1(4),121. Newent, Gloucestershire 1(4),114. Newporth beach, Cornwall 1(1),40. Oughterside coalpit, Cumbria 2(1),5. Scawgill Bridge, Cumbria, accessory in microdiorite 3(1),15. Sheppey, Kent 1(1),5. Wesley mine, Avon 2(2),29. Wheal Friendship, Devon 1(4),123. Woodleaze quarry, Avon 2(2),5.

Pyrolusite: Colemans quarry, Somerset 3(1),1. Peldar Tor, Leicestershire 4(2),59 (P). Wesley mine, Avon 2(2),29. Wyndham pit, Cumbria 3(1),29.

Pyromorphite: Colemans quarry, Somerset 3(1),1. Fall Hill quarry, Derbyshire 1(1),26. Greystone quarry, Cornwall 1(2),23. Northern Pennines 1(3),81. Roughton Gill mine, Cumbria 1(4),cover (P). Wapping mine, Derbyshire 4(1),25.

Pyrrhotine: Dylife mine, Powis 1(1),8 (P). Newporth beach, Cornwall 1(1),40.

Quartz: In flint 1(2),21. Fall Hill quarry, Derbyshire 1(1),26. Hard Rigg Edge, Cumbria, pseudomorphs 1(3),81. Hartfield Moss, Strathclyde 3(2),43. Hilton mine, Cumbria 1(1),33. Llantrisant, Mid Glamorgan 3(1),1. Loanhead quarry, Strathclyde 2(2),15. Pass of Ballater, Grampian 3(1).31. Peldar Tor, Leicestershire 4(2),59. Wapping mine, Derbyshire 4(1),25.

Radioactive minerals: storage & handling 1(2),52; 1(4),129.

Raik vein, Leadhills, Strathclyde Region [formerly Lanarkshire]: Wulfenite 4(2),55.

RAINE, A.T.: see YOUNG, B.R.

Ramsdellite: Wyndham pit, Cumbria (?) 3(1),29.

Rare earth elements: In fluorite 1(1).22.

Ravenstone, Coalville, Leicestershire: Galena 1(2),27. Redhurn mine, Weardale, Durham: Cerussite,

edhurn mine, Weardale, Durham: Ceru malachite 1(3),cover (P).

Red Gill mine, Caldbeck Fells, Cumbria [formerly Cumberland]: Silver 2(2),49.

Retgersite: Newdigate colliery, Warwickshire 2(1),29. Rhodochrosite: Batts Combe quarry, Somerset 1(2),25.

- Colemans quarry, Somerset 3(1).1. Wesley mine, Avon 2(2),29.
- Rhondda Valley, Mid Glamorgan [formerly Glamorganshire]: Siegenite 1(3),83.
- Rosasite: Bute quarry & Portcawl, Mid Glamorgan 2(1),19. West Pasture mine, Durham 2(2),50.
- Roughton Gill mine, Caldbeck Fells, Cumbria [formerly Cumberland]: Pyromorphite, plumbogummite 1(4),cover (P).
- Russell, Sir Arthur: Mini-biography 4(1),1.

Russell Medal: 4(2),43.

Russellite: Buckbarrow Beck, Cumbria 4(1),3 (P).

Rutile: Scawgill Bridge, Cumbria, accesory in microdiorite 3(1),15.

- RYBACK, G.: Alumohydrocalcite, Scarborough, North Yorkshire & Weston Favell, Northamptonshire 2(1),9. Editorial 4(2),43.
- St David's mine, Dolgellau, Gwynedd [formerly Merionethshire]: Aleksite 3(2),67 (P).
- St Margaret's Bay, Dover, Kent: Quartz in flint 1(2),21.
- St Michael's Mount, Marazion, Cornwall: Stannite, stannoidite, kësterite 4(1),17.
- Salisbury Plain, Wiltshire: Quartz in flint 1(2),21.
- Sandbeds mine, Caldbeck Fells, Cumbria [formerly Cumberland]: Barium-pharmacosiderite 4(2),64.
- Scarborough, North Yorkshire [formerly Yorkshire]: Alumohydrocalcite 2(1),9. Scarbroite 1(1),9.
- Scarbroite: East Harptree, Avon 3(2),49 (P).

  Hampstead Farm quarry, Avon 2(2),5; 3(2),49 (P).

  Scarborough, North Yorkshire 1(1),9; 2(1),9. Weston Favell, Northamptonshire 1(1),9 (P). Woodleaze quarry, Avon (?) 2(2),5 (P).
- Scawgill Bridge, High Lorton, Cumbria [formerly Cumberland]: Chromian oxide minerals 3(1),15 (P).
- Scheelite: Buckbarrow Beck, Cumbria 4(1),3. Gairnshiel, Grampian 4(2),55.
- Schulenbergite: *Brownley Hill mine, Cumbria* 4(1),13. *Smallcleugh mine, Cumbria* 3(1),23; 4(1),13.
- Scorodite: Botallack, Cornwall 4(2),45. Mulberry openwork, Cornwall 1(4),119.

### Scotland:

- Dumfries & Galloway Region: see Auchencat Burn; Colvend mine; Drumruck mine; Lauchentyre mine.
- Grampian Region: see Gairnshiel; Pass of Ballater.
- Highland Region: see Sgurr nam Boc; Strontian; Struy mines.
- Strathclyde Region: see Boyleston quarry; Hartfield Moss; Leadhills; Loanhead quarry; Raik vein; Straitstep vein; Susanna vein; Whyte's Cleuch.

Serpentine: Wesley mine, Avon 2(2),29.

- Serpierite: Brownley Hill mine, Cumbria 4(1),13. Wheal Friendship, Devon (?) 1(4),123. Smallcleugh mine, Cumbria 3(1),23; 4(1),13.
- Sgurr nam Boc, between Loch Brittle & Loch Eynort, Skye, Highland Region [formerly Inverness-shire]: Stilbite 3(2),61 (P).
- Sheethedges Wood quarry, Groby, Leicestershire: Galena (?) 1(2).27.
- Sheppey, Isle of, Kent: Baryte etc 1(1),5.

- Siderite: Ashby de la Zouch, Leicestershire 1(2),27.

  Newdigate colliery, Warwickshire 2(1),29.

  Oughterside coalpit, Cumbria 2(1),5. Wapping mine,
  Derhyshire 4(1),25.
- Siegenite: South Wales Coalfield 1(3),83. Wyndham colliery, Mid Glamorgan 1(3),83 (P).
- Silver, native: Botallack, Cornwall 4(2),45. Boyleston quarry, Strathclyde 2(2),11. Hartfield Moss, Strathclyde 3(2).43. Loanhead quarry, Strathclyde 2(2),15. Red Gill mine, Cumbria 2(2),49. Growth of acanthite on 4(2),67 (P).
- Smallcleugh mine, Nenthead, Cumbria [formerly Cumberland]: Annabergite 1(2),18. Schulenbergite & namuwite 3(1),23 (P). Zn analogue of ktenasite 4(1),13.
- SMITH, M.E.: Minerals, Fall Hill quarry, Derbyshire 1(1),26. See also BRIDGES, T.
- Smithsonite: Brownley Hill mine, Cumbria 4(1),13. East Harptree, Avon 3(2),49. Fall Hill quarry, Derbyshire 1(1),26. Smallcleugh mine, Cumbria 4(1),13. Wapping mine, Derbyshire 4(1).25 (P). Woodleaze quarry, Avon 2(2),5.
- Smittergill Head mine, Alston, Cumbria [formerly Cumberland]: Pyromorphite etc 1(3),81.
- Sodium-zippeite: Geevor mine, Cornwall 4(2),66.
  Sphalerite: Ashby de la Zouch, Leicestershire 1(2),27.
  Bute quarry, Mid Glamorgan 2(1),19. Fall Hill
  quarry, Derbyshire, 1(1),26. Greystone quarry,
  Cornwall 1(2),23. Hampstead Farm quarry, Avon
  3(2),49. Hilton mine, Cumbria 1(1),33. Llantrisant, Mid
  Glamorgan 3(1),1. Newdigate colliery, Warwickshire
  2(1),29. Newent, Gloucestershire 1(4),114. Oughterside
  coalpit, Cumbria 2(1),5. Parc mine, Gwynedd 1(1),9.
  Staunton Harold mine, Leicestershire 1(2),27.

Sphene: see titanite.

Spothow Gill, Eskdale, Cumbria [formerly Cumberland]: Langite, posnjakite 1(3),80.

Springhill quarry, Peldar Tor, Whitwick, Leicestershire: Mottramite 4(2),59 (P).

STANLEY, C.J.: see BEVINS, R.E.

Woodleaze quarry, Avon 2(2),5.

Stannite: Cornwall 4(1),17. Mulberry openwork, Cornwall 1(4),119.

Stannoidite: Cornwall 4(1),17.

STARKEY, R.E.: Bertrandite, Pass of Ballater, Grampian 3(1),31. Beudantite, Clevedon, Avon 1(4),125. Carbonate-cyanotrichite, New East Wheal Russell, Devon 1(4),121. Conference reports: Mineralogy & Museums (1988) 2(1),31: Conserving Britain's Mineralogical Heritage (1992) 4(2),71. Cyanotrichite, Mulberry openwork, Cornwall 1(4),119. Millerite, Ecton, Staffordshire 1(2),17. Mineral & Gem Show report (1989) 2(2),51.

Staunton Harold, Leicestershire: Galena 1(2),27 (P). Stilbite: Hartfield Moss, Strathclyde 3(2),43. Sgurr

nam Boc, Skye, Highland 3(2),61 (P).

Stolzite: Wanlockhead, Strathclyde 4(2),55.

Storage of radioactive minerals: 1(2),52.

Stored silver specimens: Growth of acanthite on 4(2),67.

- Straitstep vein, Wanlockhead, Strathclyde Region [formerly Dumfriesshire]: Wulfenite 4(2),55.
- Strontian, Loch Sunart, Highland Region [formerly Argyllshire]: Strontianite 4(2),cover (P).
- Strontianite: Brownley Hill mine, Cumbria 4(1),35. Strontian, Highland 4(2),cover (P). Yate, Avon, calcian 2(1),1 (P).
- Strunzite: Gravel Hill mine, Cornwall 2(1),cover (P).
- Struy mines, Struy, Highland Region [formerly Inverness-shire]: Wulfenite 4(2),55.
- Sulphur, native: Ball Eye quarry (near), Derbyshire 1(2),48.
- Susanna vein, Leadhills, Strathclyde Region [formerly Lanarkshire]: Wulfenite 4(2),55.
- SYMES, R.F.: see HART, A.D.
- Symplesite: Nether Row Brow, Cumbria 4(2),64.
- Talc: Boyleston quarry, Strathclyde 2(2),11.
- Tallingite: see connellite, carbonatian.
- Tankardstown mine, Knockmahon, Co. Waterford: Atacamite, chalcanthite 4(1),36.
- Tellurobismuthite: Clogau St David's mine, Gwynedd 3(2),49 (P).
- Tennantite: Coniston, Cumbria 1(3),80.
- Tenorite: West Caradon mine, Cornwall 3(2),81.
- Tetrahedrite: Newporth heach, Cornwall 1(1),40; 1(2),19.
- Thaumasite: Kirkby Thore, Cumbria 1(3),92.
- Thenardite: Kirkby Thore, Cumbria & Mountfield mine, East Sussex 1(3),92.
- THOMAS, R.G.: see LIVINGSTONE, A.; POLLARD, A.M.
- Thomsonite: Hartfield Moss, Strathclyde 3(2),43. Loanhead quarry, Strathclyde 2(2),15 (P).
- Tickow Lane mine, Shepshed, Leicestershire: Galena etc. 1(2),27.
- Titanite: Hartfield Moss, Strathclyde 3(2),43. Scawgill Bridge, Cumbria, accessory in microdiorite 3(1),15.
- Tourmaline: Mulberry openwork, Cornwall 1(4),119. Toxic minerals: 1(4),129.
- Treak Cliff, Derbyshire: Rare earth elements in fluorite 1(1),22.
- TURGOOSE, S.: see BEVINS, R.E.; POLLARD.
- Ty Gwyn mine, Great Ormes Head, Llandudno, Gwynedd [formerly Caernarvonshire]: Malachite, chalcopyrite 1(1),cover (P).
- Tytherington quarries, Tytherington, Avon [formerly Gloucestershire]: Alumohydrocalcite etc 2(2),5 (P).
- Unidentified aluminium carbonates: Scarborough, North Yorkshire 2(1),9. Woodleaze quarry, Avon 2(2),5.
- Unidentified amorphous copper sulphate: Colvend mine, Dumfries & Galloway 4(2),63.
- Unidentified bismuth-tellurium sulphides: Clogau St David's mine, Gwynedd 3(2),67.
- Unidentified blixite-like mineral: Wesley mine, Avon 2(2),29.
- Unidentified copper mineral: Wheal Friendship, Devon 1(4),123.
- Unidentified sulphides: Gipsy Lane brickpit,

- Leicestershire 2(1),25. Scawgill Bridge, Cumbria 3(1),15.
- Unnamed Cr-Ti-rich oxide: Scawgill Bridge, Cumbria 3(1),15 (P).
- Unnamed Cu analogue of canfieldite: Gunheath pit, Cornwall 4(1),17.
- Unnamed Zn analogue of ktenasite: Brownley Hill & Smallcleugh mines, Cumbria 4(1),13.
- USA: see Melissa mine.
- Vanadiferous nodules: Gipsy Lane brickpit, Leicestershire 2(1),25.
- Vanadinite: Leadhills, Strathclyde, 'eosite' 4(2),55. Loanhead quarry, Strathclyde 2(2),15. Wesley mine, Avon 2(2),29.
- Wad: Batts Combe quarry, Somerset 1(2),25. Breedon quarry, Leicestershire 4(1),9. Wapping mine, Derbyshire 4(1),25.
- Wales: Siegenite, South Wales Coalfield 1(3),83.
- Glamorgan (Mid): see Bute quarry; Llantrisant;
   Locks Common borehole; Porthcawl; Rhondda
   Valley; Wvndham colliery.
- Gwent: see Machen quarry.
- -- Gwynedd: see Britannia mine; Clogau mine; Dolgellau gold helt; Parc mine; Penrhyn Du mine; St David's mine; Ty Gwyn mine.
- Powys: see Dylife mine; Llanelwedd quarry.
- WALKER, D.R.G.: Retgersite, Newdigate colliery, Warwickshire 2(1),29.
- Wallclose mine, Wirksworth, Derbyshire: Phosgenite & matlockite 1(2),7.
- WALSH, J.N.: see HOWIE, R.A.
- Wapping mine, Matlock Bath, Derbyshire: Minerals 4(1),25 (P).
- Warden Point, Isle of Sheppey, Kent: Baryte etc 1(1),5. Waterbank mine, Ecton, Staffordshire: Millerite 1(2),17.
- Weardale, Durham: Rare earth elements in fluorite 1(1),22.
- Wesley mine, Westbury on Trym, Bristol, Avon [formerly Gloucestershire]: Pb oxychloride minerals 2(2),29 (P).
- West Caradon mine, St Cleer, Cornwall: Djurleite 3(2),81.
- Weston Favell, Northampton, Northamptonshire: Alumohydrocalcite 2(1),9. Scarbroite 1(1),9 (P).
- West Pasture mine, Stanhope, Weardale, Durham: Rosasite 2(2),50.
- Wheal Cock, St Just, Cornwall: Supergene Cu minerals 4(2),45 (P).
- Wheal Friendship, Mary Tavy, Devon: Devilline etc 1(4),123.
- Wheal Gorland, Gwennap, Cornwall: Liroconite 1(2), cover (P).
- Wheal Hazard, Botallack mine, St Just, Cornwall: Supergene Cu minerals 4(2),45 (P).
- Wheal Trehane, Menheniot, Cornwall: Rare earth elements in fluorite 1(1),22.
- Whitfield Brow mines, Weardale, Durham: Pyromorphite 1(3),81.
- Whyte's Cleuch, Wanlockhead, Strathclyde Region [formerly Dumfriesshire]: Stolzite 4(2),55.

- WILLIAMS, P.A.: Book review by 2(2),53. See also BEVINS, R.E.; LIVINGSTONE, A.: MAGALHÃES, M.C.F.; POLLARD, A.M.
- Windy Brow vein, Tynehead, Cumbria [formerly Cumberland]: Pyromorphite 1(3),81.
- WIRTH, M.: Native silver, Red Gill mine, Cumbria 2(2),49.
- Witherite: Llantrisant, Mid Glamorgan 3(1),1.
  Wolframite: Mulberry openwork, Cornwall 1(4),119.
  See also ferberite.
- WOOD, M.: Strontianite, Brownley Hill mine, Cumbria 4(1),35.
- Woodleaze quarry, Tytherington, Avon [formerly Gloucestershire]: Alumohydrocalcite etc 2(2),5 (P).
- Woodwardite: Botallack, Cornwall 4(2),45. Penberthy Croft mine, Cornwall 2(2),48.
- Wroewolfeite: Penberthy Croft mine, Cornwall 2(2),48.
  Wulfenite: Rall Five quarry (near), Derhyshire 1(2) 4
- Wulfenite: Ball Eye quarry (near), Derbyshire 1(2),48.
  Batts Combe quarry, Somerset 1(2),25. Breedon
  quarry, Leicestershire 4(1),9 (P). Drumruck mine,
  Dumfries & Galloway 4(2),55. Gairnshiel, Grampian
  4(2),55. Lauchentyre mine, Dumfries & Galloway
  4(2),55. Leadhills, Strathclyde 4(2),55. Melissa mine,
  Arizona, USA 2(2),back cover (P). Pass of Ballater,
  Grampian 4(2),55. Struy mines, Highland 4(2),55.
  Wanlockhead, Strathclyde 4(2),55. Wesley mine,
  Avon 2(2),29.
- Wyndham colliery, Ogmore Vale, Mid Glamorgan [formerly Glamorganshire]: Siegenite 1(3),83 (P).
- Wyndham pit, Egremont, Cumbria [formerly Cumberland]: Hausmannite 3(1),29 (P).
- X-ray diffraction: For mineral identification (Review) 3(1),7.

- X-ray diffraction data: Coffinite 2(1),25. Connellite 2(2),23. Djurleite 3(2),81. Philipsburgite 3(1),25.
- Yate, Avon [formerly Gloucestershire]: Strontianite 2(1),1 (P).
- Yorkshire Silverhand mine, Cronkley Fell, Durham [formerly Yorkshire]: Pyromorphite 1(3),81.
- YOUNG, B.: Book reviews by 3(1),33; 3(2),89-90; 4(2),79. Guest editorial 3(2). Pyromorphite, Northern Pennines 1(3),81. See also YOUNG, B.R.
- COOPER, M.P., NANCARROW, P.H.A. & GREEN, D.I.: Supergene Cu & Pb minerals, Low Pike, Cumbria 3(1).25.
- FORTEY, N.J. & NANCARROW, P.H.A.: Russellite etc, Buckbarrow Beck, Cumbria 4(1),3.
- & FRANCIS, J.G.: Rosasite, West Pasture mine, Durham 2(2),50.
- HYSLOP, E. & MILLWARD, D.: Bariumpharmacosiderite & symplesite, Caldbeck Fells, Cumbria 4(2),64.
- & JOHNSON, E.W.: Langite, posnjakite, Lake District, Cumbria 1(3),80.
- & NANCARROW, P.H.A.: Hausmannite, Wyndham pit, Cumbria 3(1).29. Millerite, Oughterside coalpit, Cumbria 2(1),5.
- YOUNG, B.R.: see FLETCHER, C.J.N.
- YOUNG, B. & RAINE, A.T.: Thenardite, Mountfield mine, East Sussex & Kirkby Thore, Cumbria 1(3),92.
- Zaire: see Likasi.
- Zaratite: Ecton, Staffordshire (?) 1(2),17. Newdigate colliery, Warwickshire 2(1),29.
- Zeunerite: Cligga Head mine, Cornwall 2(2), cover (P). Zippeite group: see sodium-zippeite.

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