JOURNAL
OF
The Russell Society

Volume 5, Part 2 1994

JOURNAL OF THE RUSSELL SOCIETY

The journal of British Isles topographical mineralogy

EDITOR:

George Ryback, 42 Bell Road, Sittingbourne, Kent ME10 4EB, U.K.

JOURNAL MANAGER:

Harry W. Day, 83 Hollywood Lane, Frindsbury, Rochester. Kent ME3 8AT, U.K.

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.

Subscription rates: The Journal is free to members of The Russell Society. Subscription rate for two issues £15. Enquiries should be made to the Journal Manager at the above address. Back copies of the Journal may also be ordered through the Journal Manager.

Advertising: Details of advertising rates may be obtained from the Journal Manager.

Typeset by Poole Typesetting (Wessex) Ltd, Bournemouth, Dorset.

Published by The Russell Society. Registered charity No. 803308.

ISSN 0263 7839

FRONT COVER: Fluorite, pale green octahedron (7 cm across) with calcite, galena and pyrite. Glengowla East mine, Oughterard, Co. Galway, Eire. Sir Arthur Russell specimen (BM 1964R,4904) in the Natural History Museum, London. Photograph by Harry Taylor.

JOURNAL OF THE RUSSELL SOCIETY

CONTENTS

VOLUME 5, PART 2, 1994

NOTES

JOURNAL OF THE RUSSELL SOCIETY
LIST OF PUBLISHED ISSUES

ISSUE No	COVER DATE	PAGINATION
Vol.1, No.1	1982	1-54
Vol.1, No.2	1983	1-77
Vol.1, No.3	1985	78-113
Vol.1, No.4	1986	114-168 With index for vol.1
Vol.2, Part 1	1988	1-35
Vol.2, Part 2	1989	1-54
Vol.3, Part 1	1990	1-42
Vol.3, Part 2	1990	43-94
Vol.4, Part 1	1991	1-42
Vol.4, Part 2	1992*	43-92 With index for vols 1-4
Vol.5, Part 1	1993	1-68
Vol.5, Part 2	1994	69-132

(*Vol.4, Part 2 was published in April 1993)

Back-numbers of most issues are available from the Journal Manager

Harry W. Day, 83 Hollywood Lane, Frindsbury, Rochester, Kent ME3 8AT

J. Russell Soc., 5(2), 71-75 (1994).

THE STORY OF A MINERAL COLLECTION
(Part 2)

The late R.D.S. SHRIMPTON

As he described in Part 1, Robert Shrimpton caught the mineral bug as a boy while on holiday in Cornwall in 1917. Though he spent his working life as an accountant with I.C.I., his enthusiasm for collecting, characterising and caring for minerals stands out from these reminiscences. In this second and last instalment, he mentions personalities that many readers will recognize – Bill Davidson of Penrith, noted for the minerals he collected in the Lake District; Arthur Scoble, from whose collection specimens have been offered for sale recently by several dealers; Reg Parkinson, after whom parkinsonite has just been named; Dr Jamie Nelson, who still remembers Robert Shrimpton with warm affection and regard: and Richard Barstow, a prodigious collector (especially underground) who inspired many of his contemporaries. The collection of over 500 registered specimens which Shrimpton donated to Tonbridge School contains examples of nearly 200 species from Britain and abroad, though none of outstanding quality; many of these acquisitions are mentioned in his story. Among good British material, for example, are stout, terminated translucent quartz prisms up to 8 cm across from Carrock mine, Cumbria, collected in 1943. I also spotted one novelty - tiny needles of dufrenoysite in a vugh, from Wheal Boys in Cornwall, collected by Shrimpton in 1938. They were later identified for him by Dr Nelson, using XRD, and the species does not appear to have been recorded hitherto from Britain. I should explain that this collection came to light through the South Eastern Museums Service, called in for advice by Tonbridge School. Simon Timberlake, their Travelling Geology Curator whose post is funded by British Gas and the Geologists' Association, inspected the collection, wrote a report, and suggested a plan for further curation work – hence my involvement, for which I am grateful to Simon. The various Area Museum Services in Britain perform a valuable task in locating and helping to conserve and document geological collections of all kinds. Members of the Russell Society are encouraged to lend support to these activities.

Editor

FELLOW COLLECTORS

It had been obvious for some time that the cabinet I had purchased in Exeter was quite inadequate even to store the collection, let alone display it. It so happened that I.C.I. had another subsidiary, the Paper Goods Manufacturing Co. in London, that made cardboard boxes. I bought 100 boxes with close-fitting lids (15 × 10 × 7 cm), and 100 white trays in three different sizes. The trays would be used to display specimens on velvet cushions, but display cabinets were out of the question while we were temporary residents in Northwich so, having wrapped each specimen in old newspaper, and having numbered and indexed them, I stored them in the cardboard boxes. I had already decided eventually to prepare a card index of the collection, and the Chief Accountant agreed to sell me a disused card index cabinet on behalf of the Company for 5 shillings.

In the meantime war had ended and I.C.I. was anxious to resume operations in Malaya. I was sent out there for the whole of 1946. On the journey out our ship called at Aden to refill its bunkers with coal, and to escape the noise and clouds of coal dust I elected to climb Jebel Shamsham (1723 ft), the highest of a range of volcanic hills above the town. On the return journey I crossed a flat, sandy plain littered in places with chalcedony, and I collected several pieces of this mineral. While in Singapore I drove out one Sunday to some waterfalls near Kota Tinggi in Johore, which I had visited before the war. To escape the crowds of British soldiers and local girls by the waterfalls, I went up the valley and came across the dumps of what had been a small iron mine, where I collected specimens of dark grey massive hematite. The best additions to my collection during 1946 arose from a chance meeting with an employee of the shipping agents for the arsenic, antimony and mercury mines in Sarawak, from whom I obtained specimens of stibnite, cinnabar and native arsenic.

Eventually, in 1947, I returned to England by flying boat – much the most enjoyable form of aerial transport – and became Chief Accountant of the Paints Division in Slough until my retirement in 1964. I rejoined the Geologists' Association and also applied for membership of the Mineralogical Society of London. My application was accepted and in April 1947 I took part in a Field Meeting in the North of England. There were about 30 of us, and I was the only member of the party who was not in some way connected with geology or mineralogy in a professional capacity.

For me the meeting was both absorbing and fruitful. On our first day we went to Egremont in west Cumbria, and were taken down Florence iron mine where I was able to pick up good specimens of hematite from the floor of one of the levels. In addition, the manager gave me a cluster of thin tabular crystals of hematite with metallic lustre, and an excellent specimen of intergrown curved crystals of pinkish-white dolomite. We spent the second day in the Caldbeck Fells where we visited Carrock and

Brandygill mines, and then climbed north over the fells to Driggeth lead mine which had recently been reopened. From a trench driven across the outcrop of a lead-bearing vein, I collected a good specimen of pyromorphite in small bright green crystals emplanted on dull white massive baryte. On our third day we visited Hilton mine in the morning and Silverband mine in the afternoon. Hilton mine is well-known owing to the fact that the fluorspar here is amber in colour, whereas elsewhere in the north of England it is found in colours varying from pale lilac to deep purple. The waste dumps are extensive and very rewarding to the collector. Silverband mine near Appleby, originally worked for lead, had recently been reopened for barytes. We were taken along a level driven into the hillside and from the floor of this I obtained a good translucent tabular crystal of baryte. On our last day we visited Stamp Hill mine, a mile or so NW of Kirkby Thore. This was a drift mine worked for gypsum, and I obtained good specimens of this mineral.

Before I leave the North of England I must mention Mr W.F. Davidson, a young shoemaker in Penrith who had developed quite a passion for minerals. During a period of only three or four years he had systematically ransacked the extensive waste dumps left by the miners in the Caldbeck Fells and had also visited many of the mines in the Northern Pennines. He had built up a very fine collection of minerals from the North of England and we were all impressed by the quality of his specimens. Later he sent me good specimens of galena and fluorite crystals from Weardale, molybdenite from Carrock mine, and three excellent specimens of colourless to white crystalline baryte from the old Cow Green mine in Teesdale. In exchange I sent him jamesonite and other antimony minerals from Cornwall.

During my years of membership of the Mineralogical Society I met only one other member who was not a 'professional' of one kind or another. He was Arthur Scoble and he owned a small farm near Moretonhampstead on the eastern edge of Dartmoor. When in 1951 we drove to St Ives in Cornwall for our holiday, we were able to accept an invitation to visit him and his charming wife on the way. The farm house was a veritable Aladdin's Cave, with a number of enormous glass-framed cabinets displaying wonderful specimens, mainly from the North of England where Scoble had worked for a few years sinking shafts and driving levels in some of the old lead mines which had been reopened for fluorspar. Every spring he and his wife took a week's holiday, which they spent searching for minerals in Devon and Cornwall. During the next few years Scoble sent me various specimens, mainly from Devon and Cornwall, including several from the Meldon quarries on the north-western edge of Dartmoor. When I last saw him in 1956 he had sold the farmhouse and the mineral collection the latter to an American for £1000.

On this holiday I also met John Curnow, a delightful old Cornishman, a miner in bygone years but now superintendent of a water pumping station on the outskirts of St Ives. On three occasions we drove in the evening to the old Botallack mine near St Just-in-Penwith. Here we would crack stones from a very large dump which was being carted away for road metal, so that on each occasion we had access to fresh material. I collected many specimens, but none of display potential. When I said goodbye to John Curnow at the end of our holiday he presented me with a fine piece of massive cassiterite.

In June 1952 I attended a week-end Field Meeting of the Geologists' Association, based at Hope in Derbyshire. In Smalldale, at the bottom of a shallow trench, I found a fine, large specimen of honey-coloured intergrown cubes of fluorite containing purple inclusions, and in Bradwell Dale I found, in the limestone cliff immediately west of the road, a thin vein containing white intergrown crystals of fluorite. After the meeting I drove to Barnard Castle and visited some of the northern mines. I returned home with specimens of fluorite from Stotfield Burn mine (lilac-coloured cubes emplanted on pale blue translucent quartz); black sphalerite from Nenthead mine; and fluorite and calcite from Rotherhopefell mine, all in upper Weardale. At Coldberry mine in Teesdale I obtained a good cubic crystal of pink fluorite on which were emplanted clusters of tiny crystals of galena. At Hilton mine, Scordale, I discovered a dump high up on the north-west side of Hilton Fell which was missed during the Mineralogical Society visit in 1947. Here I obtained good specimens of amber fluorite cubes associated with galena and baryte, and from the main dumps on the valley floor, specimens of nodular radiating witherite.

CORNWALL REVISITED

In August, on the way to visit my mother who was still living in her cottage at Port Isaac, I called at the old Treburland tin mine on the north-eastern border of Bodmin Moor. This mine was unusual in that it has produced not only tin but also, from a separate vein, manganese - two metals which never occur together in the same vein. What remained of the old mine dumps were on a small farm, and the farmer was not pleased to see me, but eventually allowed me in and I secured a reasonably good specimen of rhodonite. I also wanted to find Roughtor copper mine which I had once visited in the 1920s. I could not find the dumps, but in a corner of a field just west of Newpark farm was a mound of earth, partly covered with grass, and on top – just waiting for me to pick it up – was a lump of pale yellow earthy material covered with a mosaic of bright green tetragonal scaly crystals of torbernite.

From Port Isaac I revisited Castle-an-Dinas mine. Sir Arthur Russell had recently noted in the Mineralogical Magazine that he had discovered bismuthinite on the old mine dumps, and I decided to try my luck. After a long search I found a piece of white vein quartz with a tiny bunch of acicular bismuthinite in a small cavity, and also a better specimen of wolframite than any I had previously collected.

By this time I had accumulated a considerable number of specimens and the time had come to have a cabinet made for them. I gave the job to a local cabinet maker, who created a massive piece of furniture for me. At its base was a large cupboard with two doors. Above were twelve large drawers in two sets of six – one set on each side. In the drawers I arranged the best of my specimens, placing them on cushions of velvet in cardboard trays fastened to the drawer floors with drawing pins. In the cupboard I stored the cardboard boxes with specimens which were not good enough for display.

One of the perks of being a Division Chief Accountant was attendance at annual meetings of Chief Accountants, usually held in large hotels somewhere in the north of England. One day would be 'free', and on several occasions I was able to visit mining areas in central and northern England. In 1955 I visited Settlingstones mine near Haydon Bridge in Northumbria, which had the distinction of being the largest producer of witherite in the world. The manager was friendly and co-operative, and told me to help myself to specimens of baryte from a small heap outside his office, and to witherite from the ore trucks. He also gave me a small specimen of niccolite which had been found in the mine. On another occasion I revisited the old Ecton copper mine on the borders of Derbyshire and Staffordshire, but instead of searching the dumps at the foot of Ecton Hill, I climbed to the summit. Here I found an old shaft, heavily boarded over, and a small dump, from which I secured specimens of baryte and aggregates of pale biscuit-coloured cubes of fluorite, some of which were encrusted with crystals of the beautiful blue-green mineral aurichalcite.

During the next three years we went abroad for our holidays and it was not until 1960 that I visited any more mine dumps. In September of that year my wife and I went to Cornwall, and I was able to spend a day searching the dumps of the long abandoned South Terras uranium mine for uranium minerals, but without success. However, I did find quite good specimens of grey massive arsenopyrite. On our way back I made a detour to visit R.F.D. Parkinson, a family business situated on the outskirts of Doulting in Somerset, which sold minerals and geological specimens. I was impressed with the range of their stock and during the next few years I made several purchases from them, including a specimen of wiry native silver from British Columbia and specimens of natrolite, chabazite, apophyllite and other zeolites from Northern Ireland.

In 1962 I had received a letter from Mrs Hummel of Leeds. Her husband, the Professor of Mining whom I mentioned earlier, had died a year or two previously, and she now offered to give me a box of mineral specimens and a few fossils that she had found amongst her late husband's effects. The minerals included native bismuth from Bolivia, orange-yellow globular mimetite, and brassy metallic marcasite in chalk. That year my wife and I went on holiday in Scotland – a week at Lochinver on the west coast and a week at Killin at the western end of Loch Tay. While at Killin I visited Corrycharmaig mine, a few miles north-west of Killin, which had been worked for chromium in bygone years. The extensive dumps provided me with reasonably good specimens of black massive chromite. Although I did not know it at the time, these were to be the last mine dumps which I visited. The next year we were at Aiguebelle on the south coast of France. I knew of no mines or other sources of minerals in the area but, quite by chance, I discovered in the hills behind Aiguebelle an outcrop of bare rock which contained many crystals of brownish-black staurolite, specimens of which I brought back for my collection.

LEISURE YEARS

I retired from I.C.I. in June 1964, and we bought a flat in Eastbourne. It had been designed in such a way that every room had a window looking south-west over the grounds of what had been the Duke of Devonshire's estate to the South Downs beyond. On the other side of the flat was a long corridor into which the front door opened. It was obvious from the start that my mineral cabinet could not be accommodated in the flat, but the answer to my problem was provided by one of the directors of a furnishing firm from whom we were buying carpets and curtains. Why not have a line of cabinets for the collection ranged along the south-west wall of the corridor into which the front door opens? I could have the upper shelves of the cabinet illuminated by strip lights and display my best specimens on these shelves. Below these shelves the less showy specimens could be stored in drawers, and below the drawers there would be cupboards for the cardboard boxes containing specimens which were not of display quality. This seemed the obvious solution and I arranged for a local skilled carpenter to make the cabinets for me, and then an electrician to install the lines of strip lights.

Retirement brought me one very considerable bonus – the leisure to do things which I had never been able to do while I was working. In particular, I was able to fill gaps in my collection so that it would represent more effectively the whole of the mineral kingdom. I had earlier acquired small shareholdings in a number of mining companies, including the Rio Tinto-Zinc Corporation, the Anglo-American Corporation of South Africa, and the Messina (Transvaal) Development Co. I now wrote to these companies, explaining that I had been a shareholder for so many years, that I had been collecting minerals since 1917, and that I should very much appreciate good specimens of the various minerals which occurred in their mines. These requests produced valuable additions to my collection. I also bought a number of specimens from a 'rock shop' in Holborn, and one excellent specimen of malachite from a jeweller's shop in Hatton Garden.

A former colleague in Malaya, Jimmy Giles, had retired from I.C.I. in the late 1950s and went to live in Rhodesia (now Zimbabwe). When I discovered that Jimmy was a keen philatelist, I arranged for the British Post Office Philatelic Bureau in Edinburgh to send him at my expense the First Day Covers of all new issues of British stamps. In return he sent me parcels of Rhodesian minerals, supplies of which were continually becoming available through the activities of the numerous prospectors. In fact, all the specimens in my collection from Zimbabwe (with one small exception) were sent to me by Jimmy Giles, including good examples of sphalerite, magnetite, chromite, agate, amethyst, corundum, malachite, beryl, tourmaline and many other minerals.

In September 1965 I joined a Field Meeting of the Geologists' Association in the North of England. I cannot remember that we visited any mines but I obtained from High Force quarry in Teesdale a nice specimen of greenstone with rosettes of white, radiating pectolite. In the following year we took our car to Europe, touring the Alpine regions of Austria and Switzerland. About ten days were spent in Seefeld near Innsbruck, and in the tiny town of Mittenwald, across the border in Germany, I discovered a small shop which sold minerals. Here I purchased good specimens of andradite garnet and the efflorescent variety of aragonite known as 'flos ferri', both from localities in Austria.

In 1967 we left Eastbourne and moved to a bungalow in Beaconsfield in Buckinghamshire, within easy reach of our younger daughter and her family. For me our new home had the great advantage that there was a small third bedroom, with a window at the far end, which provided an ideal home for my mineral collection. My four illuminated cabinets were arranged along the side walls, two on each side, and the table which I used for 'office' work and as a base for my typewriter was placed under the window at the far end. A seven-foot long cupboard with sliding glass doors, originally in the kitchen, was installed above the cabinets on one wall, where it provided an excellent home for my larger specimens, and on the wall opposite I attached a long open bookcase.

About 1970 I met Mr J.B. Nelson, a director of a small engineering company in north London, and a recent recruit to the very small body of amateur mineral collectors in Britain. I was able to give him a large number of specimens from my cardboard boxes, and in return he gave excellent specimens of graphite from Sri Lanka, azurite from Mexico, and the relatively rare mineral ulexite from the United States.

In 1972 we moved back to Eastbourne, into a flat on the sea front with a third bedroom which was almost an exact replica of my mineral room at Beaconsfield, except that it was slightly larger. This became my study with the mineral cabinets arranged along the sides of the room exactly as they had been at Beaconsfield. Shortly after our return to Eastbourne I was introduced to Arthur Carter, who knew of a shop in Hastings (called 'The Stone Corner') which sold mineral specimens. During the next few years Carter and I paid several visits to the Stone Corner and my collection benefited accordingly. In addition to collecting minerals, Carter was a keen amateur archaeologist. Every summer he would go away, usually to the Mediterranean, to visit places of archaeological interest. On one of these holidays he picked up a nice specimen of magnesite from Greece, which he gave me on his return home. On another occasion he stopped off at Yate near Bristol, where there are large deposits of celestite, and Carter obtained a good specimen of this mineral for my collection. Eastbourne was not entirely lacking in opportunities for collecting minerals. There are chalk cliffs immediately west of the town in which there are occasional narrow bands of pyrite nodules. As the cliffs are gradually eroded, these nodules are deposited on the beaches where they acquire a dull black tarnish. I collected a few of these nodules, but the best specimen in my collection was given to me by Arthur Carter. It was a piece of brassy metallic pyrite about the size of a tennis ball, which he had prized out of the chalk of Beachy Head.

THE STORY ENDS

In 1974 my wife and I spent a holiday near Penzance. We travelled by train and I visited no mine dumps during the holiday. I did, however, visit the home of a young Cornishman, Richard Barstow, on the outskirts of St Just-in-Penwith. Until recently he had been a miner at Geevor (a working mine not far from St Just) but he had given up mining in favour of selling minerals. He had a good selection of specimens, one of which I purchased there and then, and I bought several more later through the post.

By this time I had, in addition to the specimens in the mineral cabinets, 88 boxes containing specimens which were not of good enough quality to deserve positions in the mineral cabinets. Each specimen was wrapped in newspaper and numbered, and the contents of each box were recorded on an index card. It had been my original intention to use these specimens for testing purposes but I had never got around to it and I now realized that I never would. So I decided to give them to Camborne School of Mines, where they might be useful for the tuition of pupils in blowpipe analysis, etc. David Binns from the School of Mines very kindly undertook to take the boxes and the relevant index cards to Camborne.

My collecting days were now over. None of my family were interested in minerals and I knew that, unless I did something about it, the collection would gradually disintegrate after my death. And so, in 1980, having received a letter of acceptance from the Headmaster, and with the invaluable help of my dear wife, I transferred the collection and all the paraphernalia associated with it – binocular microscope, fluorescent lamp, streak plate, test tubes, reagents, card index, etc. – to my old school, Tonbridge. There the collection is housed in a small room (adjacent to the library) which is virtually identical in shape and size with my study at Eastbourne. Compared with my study, however, it has one great advantage. There is a window at the far end which looks out across the 'quad' to the School Chapel, and the view from this window forms a perfect background to the collection which has given me so much pleasure for over 60 years.

NOWAK PACKARD MINERALS

W. John Nowak F.G.A.
A. Vicki Packard

GEMSTONES
A large selection
— Fine and rare for collectors.
— Most gemstones required for the study of gemmology.
— And for jewellery makers.

CRYSTALS
A Worldwide selection
— Fine and rare for collectors.
— All basic crystals required for teachers and students of crystallography, gemmology & geology.

MINERALS — We hold a selective stock

71, Glenhurst Avenue, Bexley, Kent, DA5 3QH, ENGLAND Telephone (0322) 523825 Fax (0322) 523825

We attend all UK shows
Visitors by appointment

MICROSCOPES

We specialise in the postal supply of microscopes for the dedicated amateur, for education and for research applications.

The **MEIJI** research standard stereo microscopes offer very high-performance, with a very wide choice of instruments and accessories, including trinocular zoom microscopes for photomicrography and video applications.

The **WESSEX** range of stereos are compact instruments for the beginner and where budgets are more limited.

We would be pleased to show you our range at our shop in Sutton Scotney, near Winchester.

Full details and price-list on request

Hampshire Micro

The Microscope Shop, Oxford Road,
Sutton Scotney, HANTS, SO21 3JG
Tel: 0962 760228 FAX: 0962 760652

COUNTY MAPS AND MINERALS

22, River Street, Truro, Cornwall.
Tel. (0872) 72972

Complete selection of
British Geological Survey maps,
geological accessories
and mineral books;
plus an extensive range of Cornish,
British and foreign mineral specimens

Opening hours: 10 am to 5.15 pm
Monday to Saturday

ORDNANCE SURVEY MAIN STOCKIST

BRITISH GEOLOGICAL SURVEY
MAIN AGENT

MINERALOGICAL SOCIETY

The Mineralogical Society was instituted in 1876. The general object is to advance the knowledge not only of Mineralogy but also of Crystallography, Geochemistry and Petrology, together with kindred subjects. This is done by publishing scientific journals, books and monographs, and by arranging or supporting scientific meetings. The Society speaks for Mineralogy in Great Britain linking with British science in general through the Royal Society and cooperating closely with the Geological Society. It maintains liaison with European mineralogists as a member Society of the European Mineralogical Union, and it is the body which nominates British representatives to the International Mineralogical Association.

The four interest groups within the Society are very active in arranging more specialised meetings and technical discussions in the following fields: Clay Minerals, Applied Mineralogy (study of industrial and ore minerals, including coal) Geochemistry (including cosmochemistry), and Metamorphic Studies.

The **Clay Minerals Group** promotes the advancement of clay science and clay technology as applied to all aspects of pure and applied research and industrial uses. Interests of its members cover a wide spectrum, including mining and mineral processing, soils and plant nutrition, crystallography, sedimentary geology, ceramics, petroleum engineering and medicine. Regular meetings are held two or three times a year. The group publishes reference monographs on specific aspects of clay science, and is responsible for the journal Clay Minerals.

The **Applied Mineralogy Group** aims to encourage study and research in applied aspects of mineralogy, such as ore mineralogy and ore microscopy, industrial mineralogy and petrology (including mineralogical aspects of refractories, slags, ceramics, concretes and other building materials), mineral fuels (including nuclear minerals and coals), environmental mineralogy (e.g. toxic and nuclear waste, minerals and health problems such as asbestosis), and fluid inclusion studies (in relation to ores and hydrothermal systems in particular). The group organises meetings and short courses and facilitates publication of conference proceedings and monographs.

The **Geochemistry Group** is the largest and most important specialist group to represent all aspects of this subject in Britain. In addition to the conventional areas of igneous, metamorphic and sedimentary geochemistry, and cosmochemistry, the group's activities encompass such interdisciplinary research areas as environmental, bio- and hydro-geochemistry. The group also promotes exchange of knowledge on the applications and development of relevant new techniques as they arise. Thematic meetings are held each year, which are sometimes international or in collaboration with other specialist groups; an annual research meeting is also held for informal presentations, particularly from research students. The group is developing its educational role through geochemical workshops and short field study meetings.

The **Metamorphic Studies Group** is a joint specialist group of the Mineralogical Society and the Geological Society, and was inaugurated in 1981 to promote all aspects of field and laboratory studies relating to metamorphic rocks. Meetings on particular themes are held each year, and field excursions are organised periodically. In March, an annual meeting is held (usually at Burlington House, London WI) on 'research in progress' when short papers on all aspects of metamorphism are invited, and research students are particularly encouraged to participate.

Publications

Three scientific journals and a newsletter are published quarterly by the Society. Mineralogical Magazine is a major international journal covering mineralogy, geochemistry and petrology. Mineralogical Abstracts, with its separate annual index, is an essential research tool containing informative abstracts which cover mineralogy, petrology, geochemistry, crystallography, gemmology, meteoritics and allied subjects. Clay Minerals is the journal of the European Clay Groups. The Bulletin is sent to all members. It contains details of Society and other meetings, Society news, and European and international items. Other Recent publications include: *Geochemistry of Clay Pore Fluid Interactions* edited by D.A.C. Manning, P.L. Hall and Hughes, C.R.; and *Stability of Minerals* edited by G.D. Price and N.I. Ross, both from the Mineralogical Society–Chapman and Hall Series.

Membership

Applicants may be elected as Ordinary Members who may receive any two or all three of the Society Journals, or as Associate Members, who may take any one Journal, or none at all. Associate members may not take a full part in the management of the Society, but otherwise have the same privileges as Ordinary Members. Full time students may join as Ordinary Members at a reduced rate. A limited number of distinguished mineralogists may be elected as Honorary Members.

Awards

The Society presents two medals annually: the Mineralogical Society-Schlumberger Award to a scientist to recognise scientific excellence in mineralogy and its applications; and the Mineralogical Society-Max Hey Medal which is awarded to a scientist under the age of 35 in recognition of research of excellence.

The Society also has a postgraduate student bursary, a senior bursary and a student award scheme. The bursaries are awarded for attendance at meetings appropriate to the interests of the Society, for fields or site visits or to further the research aims of the individuals involved. The student award scheme grants two years' of membership to the best undergraduate students in the second year of a three-year degree or third year of a fourth year degree course in each of the geology departments in the British Isles.

Further details about the Society are available from the General Secretary, Mineralogical Society, 41 Queen's Gate, London SW7 5HR, UK. Tel. +44 (0)71 584 7516, Fax +44 (0)71 823 8021, e-mail k_murphy@minersoc.demon.co.uk.

J. Russell Soc., **5**(2), 77–81 (1994).

JOHN HENRY VIVIAN (1785–1855): THE PROBABLE EPONYM OF VIVIANITE

PETER G. EMBREY
19 Edith Road, London W14 0SU

Evidence presented in this paper indicates that Werner named the mineral vivianite after John Henry Vivian (1785–1855), F.R.S., F.G.S., M.P for Swansea, and not an unidentifiable J.G. Vivian as stated in numerous reference works.

INTRODUCTION

It is unusual for a considerable number of reference works to agree on a particular matter, and all be wrong; but such is the case for the eponym of the mineral vivianite. Greg and Lettsom (1858); Collins (1871); Dana's *System of Mineralogy*, 5th, 6th and 7th editions (Dana, 1868, 1892; Palache *et al.*, 1951); Chester (1896); the *Encyclopædia Britannica* (11th edn, 1910/11; 14th edn. 1950): the *Oxford English Dictionary* (1933 edn): and others all assert that vivianite was named by Werner after J.G. Vivian, some adding that the latter was an English mineralogist who discovered the specimens in Cornwall. Unfortunately, their unsupported testimony appears to be the only evidence for the existence of an English mineralogist named J.G. Vivian. I know of no independent, primary reference to anyone of that name in the many indices to mineralogy and its literature - but this, of course, does not preclude the possibility of an amateur collector of that name. For a long time I believed Greg and Lettsom (1858) to be the first authors to have referred to J.G. Vivian; but an earlier mention is by von Kobell (1853). A surreal note was struck by Huot (1841), who claimed the naming to be "En honneur de M. Viviani, professeur de chimie et de minéralogie à Gènes [= Genoa]"; Domenico Viviani (1772–1840) had nothing whatever to do with the name vivianite.

When all else fails, we are advised to go back to the beginning and read the instruction manual - in this case, Werner's Letztes Mineral-System (1817), where the name vivianite was first published. Note 35 (by Freiesleben) reads: "Vivianit. ... Das Vaterland dieses Fossils ist Cornwall. ... Der Name ist vom Hrn. BR. [= Bergrath] Werner zu Ehren des Hrn. J. Vivian aus Truro in Cornwall, dem Er die Kentnis [sic] des Fossils verdankt. gebildet." (Loosely translated: The locality of this mineral is Cornwall. ... The name is given by Mining Councillor Werner in honour of Mr J. Vivian of Truro in Cornwall, to whom he is indebted for bringing the mineral to his notice).

THE VIVIANS

J. Vivian is not an uncommon name, but the circumstances suggest only two possible candidates for eponym: John Vivian (bapt. 1749–1826), Vicewarden of the Stannaries and with extensive interests in copper mining, smelting. and banking; and his (second) son, John Henry Vivian (b. 9 Aug. 1785, d. 10 Feb. 1855). Whereas John Henry's elder brother, Richard Hussey (b. 1775), and their father had received part of their education in France (Griffiths, 1988, p. 32), the Napoleonic Wars prevented him from doing the same; so he went instead to Germany to study languages and business methods at Marburg, and in 1803 enrolled at the Freiberg Mining Academy in Saxony, near Dresden, to study under Werner. He also toured the mining regions of Austria and Hungary, as well as those of Germany, before returning to Cornwall in the following year.

Copper smelting had long been carried on in South Wales because of its plentiful supplies of coal, and most of the Cornish copper ores were smelted there. In 1810, having bought a suitable site at Hafod, beside the river Tawe to the north of Swansea. John Vivian Sr set up a smelter of his own in the names of his two sons. John Henry, having managed another smelter (Penclawdd) for his father since 1806, became the managing partner; while his brother Richard Hussey was fighting with distinction in the Napoleonic Wars.

Despite his responsibilities at Hafod, John Henry found time for travel. In 1815, after visiting Napoleon in temporary captivity on Elba, he made another trip to Germany, in the course of which he revisited Freiberg. He described the work of the Academy, and of that at Schemnitz, in a paper read before the members of the newly-founded Royal Geological Society of Cornwall in May, 1817 (Vivian, 1818). In it (p. 73), he said of Freiberg that "At the time I studied there in 1804, there were Frenchmen, Spaniards, Poles, Prussians, Bavarians, and one Englishman, Mr Chenevix. In addition to the public lectures, I had a private course with Mr. Werner, and I shall ever feel gratified for the great attentions I received from him as well during my former residence at the academy, as at my late visit in 1815." It seems beyond doubt that it was on this visit that he gave to Werner the specimens that were later to be called vivianite.

FIGURE 1. Parts of John Henry Vivian's enrolment application at the Freiberg Academy, 1803. Vivian's signature is at the bottom right corner. From a photocopy kindly supplied by Prof. Rösler.

The RGSC minutes of this meeting record that he promised to give the Society his "mineralogical collection formed at Freyberg immediately under the eyes of Werner", conditionally on the founding of a Mining Academy and the establishment of a Professor's Chair in Cornwall. This did not come about; but earlier minutes record that Vivian had already made various gifts to the Society, including a model of an ore dressing machine used in Saxony, original drawings and plans illustrative of German mine hoists and ore dressing, "together with several Models and a complete dress of the Saxon Miner." I do not know if any of these have survived the ravages of time.

Werner and his pupils, from time to time, issued a tabular synopsis of his Mineral System, revised to the time of publication, on folio sheets, or published them in other works (see Dana, 1868, p. xlv; 1892, p. lx; Palache *et al.*, 1944, p. 83). On his return from Freiberg, John Henry Vivian presented a manuscript copy of Werner's current (1815) mineral system to the Geological Society of London: that the handwriting (in German script) is Vivian's own can be shown by comparison with that on his 1803 Freiberg enrolment application, fortunately still extant (Fig. 1). I have two further examples of his signature, on the title pages of his copy of the catalogue of the Pabst von Ohain cabinet (Werner, 1791–92), which I obtained from the late Dr L.J. Spencer's effects.

His marriage to Sarah Jones, in 1816, led him to lease and then purchase Marino, a house which he rebuilt in 1837 and renamed Singleton Abbey (or Hall/Park/Lodge). Much later, and after a serious fire in 1896, the Vivian family sold Singleton in 1919 and the newly-formed University College of Swansea moved in and remains in occupation to this day.

The problem of dealing with heavy pollution from the 'copper smoke' emitted by the smelter engaged his attention, and his account of smelting and practices adopted at Hafod (published in the *Annals of Philosophy*, 1823, vol. 113–114, and privately reprinted) led to his election to Fellowship of the Royal Society in 1823. He was visited at the Hafod works by many eminent scientists, including Sir Humphry Davy and Michael Faraday. Although elected to Parliament in 1832, to be returned uncontested as the Member for Swansea until his death in 1855, he found time to be a member of Council of the Geological Society of London from 1834 to 1836: and was a founder member of the Royal Institution of South Wales. Material on the Vivian family and John Henry can be found in many sources, among them Boase and Courtney (1878), Grant-Francis (1881), Vivian (1887), Jones (1974), and Griffiths (1988). A portrait is reproduced as Fig. 2.

He was an eminent man, and prominent memorials survive. Alongside those to other members of the Vivian family, there is a tablet to his memory in Truro Cathedral, high on the west wall of the north transept. Although opera glasses would be required to read it, a transcription is thoughtfully provided in *Lake's Parochial History* (Polsue, 1872, p. 257); "in lapidary inscriptions a man is not upon oath" (Johnson), but the sentiments expressed by it may well be not too far removed from truth:

"Sacred to the memory of John Henry Vivian ... He was educated in Germany, and became the favourite pupil and friend of the famous geologist Werner; Sir Humphry Davy, Faraday, Buckland, and other distinguished scientific men, were his personal friends. At the age of 21 he quitted Cornwall for Wales, where the remainder of his active and useful life was spent. He was humble-minded and gentle, though firm and far-sighted, and his life was a model of such charity as St. Paul discribes [*sic*], 1 Cor. XIII. ... A public funeral, attended by thousands of all classes, marked the deep grief of his constituents and neighbours, who have since testified their affection for him, and perpetuated the memory of his many virtues by the erection of his statue in bronze, opposite the Town Hall at Swansea. His remains are deposited in the church of St. Paul's, Sketty, which was built and endowed by himself and his eldest son Henry Hussy [*sic*] Vivian, M.P. ..."

The bronze statue, large and formerly standing outside the Old Guildhall in Swansea, was moved to the Victoria Park in 1933; more recently, it has been removed to Ferrara Square, off the marina in Swansea (Fig. 3). The inscription on the granite plinth is transcribed by Grant-Francis (1881, p. 138); but the year of birth that he gives (MDCCLXXIX) is wrong. Notices of his death appeared in the press; but he died before the Royal Society began the practice of publishing obituaries of its Fellows. It may also be noted that John Henry has no entry in the *Dictionary of National Biography*, an omission that needs attention in the revised edition that is now being prepared. Minerals, as may be expected, were among the many objects that he collected. There were cabinets of specimens, arranged on Wernerian principles, at Singleton; he gave another cabinet to University College, London (Griffiths, 1988, p. 34). I have inquired, some time ago, but do not know what became of them nor whether any of his original vivianite specimens have survived. Professor Rösler has assured me (1981) that none at Freiberg can be identified as those given by Vivian.

CONCLUSIONS

I first started work on this note in the late 1970s, but laid it aside on account of objections from several people whose views I respect. They were of the opinion that John Vivian Sr was more likely than his son, John Henry, to have been the "J. Vivian of Truro" for whom the mineral was named. No firm evidence has come to light in support of

FIGURE 2. Portrait of John Henry Vivian, in the possession of Lord Swansea. Painted by Sir George Hayter, signed and dated 1835.

either view. My support for John Henry Vivian, stronger after some years, is based on the following circumstantial considerations*:

a) Werner gave the name for the J. Vivian (of Truro) who had brought the mineral to his attention. This was almost certainly his "favourite pupil and friend", J.H. Vivian, in 1815.

b) I know of no evidence that J. Vivian Sr ever visited Freiberg or met Werner; nor even that his was the original suggestion that J.H.V. should go there I would guess that J.H.V. formed the idea when at Marburg.

c) It is held that John Vivian Sr was known as "John Vivian of Truro", whereas John Henry was known as being "of Singleton" (e.g. Vivian, 1887). But this was at a very much later period, after Singleton entered the picture in 1837. John Henry was undoubtedly "of Truro" in 1803, when he first met Werner; Werner would surely have continued to regard him as such; and he was still specifically described as "of Truro" in the Royal Geological Society of Cornwall minutes of 1816 (March 1, May 17).

FIGURE 3. Statue of John Henry Vivian in Ferrara Square, Swansea. Photograph by Ms Anna Ratcliffe.

NOTE ON THE TYPE LOCALITY

What is the type locality for vivianite? Werner did not say where in Cornwall his specimens were from and, as stated above, his original specimens (with or without locality labels) cannot now be identified. At around that time, however, many good specimens of crystallized 'phosphate of iron' were being mined at Wheal Kind, St Agnes. An advertisement offering them for sale appeared in the Royal Cornwall Gazette for 26th September 1818 (reproduced in Embrey and Symes, 1987, p. 52); and there is no reason to suppose that none had been found earlier. Wheal Kind is the only Cornish locality mentioned by Phillips (1823, p. 239), and my instinct is to let the matter rest there. I cannot, however, avoid noting that L.J. Spencer's short article on vivianite, in the 11th edition of the *Encyclopædia Britannica*, states quite definitely that the locality

---

*Note added in proof: Mr Courtenay Smale has just told me of, and lent me, a recently-published book about the Vivian family, which contains (p. 50) the statement: "It was during this period also that the mineral named after John Henry – Vivianite ... was identified. Indeed its identity and description was first noticed in the scientific literature in 1817 by John Henry's old teacher, Werner." Supporting evidence is not given, and the text appears to conflate the 1815 visit and the student days. (Stanley Vivian, *The Story of the Vivians/A Cornish Family through Seven Centuries at Home and Abroad.* Published privately by Stanley Vivian, Truro, 1989).

was Wheal Jane, near Truro; and I know of no instance where Spencer made such a statement unthinkingly! It may be noted that specimens from Wheal Kind (and later ones from Wheal Jane), in common with many fine foreign specimens, were associated with pyrrhotine or pyrite or both, and so, with their labels, have seldom escaped damage from 'pyrite rot' (and from treatments intended to curb it).

ACKNOWLEDGMENTS

I am grateful to many people for their generous help, mostly given around 1980, and I apologize to them for my delay in producing this note: Mr H.L. Douch, of the Cornwall County Museum, Truro; Professor D.T. Donovan, University College, London; Mr Courtenay V. Smale, past President of the Royal Geological Society of Cornwall; Lord Swansea, the 4th Baron; Professor Dr H.-J. Rösler, of the Bergakademie Freiberg; Dr David Painting, Honorary Librarian, Royal Institution of South Wales; Dr R.O. Roberts, Department of Economic History, University College, Swansea; and Mr B. Thomas, County Librarian, Swansea, West Glamorgan. Dr Geraint Owen, Department of Geography, University College of Swansea, kindly supplied the recent photograph of Vivian's statue.

REFERENCES

Boase, G.C. and Courtney, W.P. (1878). *Bibliotheca Cornubiensis*, vol. **2** (P-Z), pp. 832–833. London. [The paper on vivianite, listed on p. 833, is irrelevant.]

Chester, A.H. (1896). *A Dictionary of the Names of Minerals including their History and Etymology*. New York and London.

Collins, J.H. (1871). *A Handbook to the Mineralogy of Cornwall and Devon*. Truro and London. [Ref. to J.G. Vivian on p. 35; ditto in 2nd edn of 1892. My own copy, inscribed A. Pendarves Vivian, Novr 1871, (3rd son of J.H.V.), contains no note correcting this.]

Dana, E.S. (1892). *The System of Mineralogy of James Dwight Dana*, 6th edn. New York.

Dana, J.D. (1868). *A System of Mineralogy*, 5th edn. New York.

Embrey, P.G. and Symes, R.F. (1987). *Minerals of Cornwall and Devon*. British Museum (Natural History), London.

Geological Society of London. *Werner's Mineral System* (1815), ref. E Tracts 4. Manuscript presented by J.H. Vivian (and in his handwriting), 20th Oct. 1815; see *Transactions of the Geological Society*, **3**, 424 (1816).

Grant-Francis, G. (1881). *The Smelting of Copper in the Swansea District of South Wales, from the Time of Elizabeth to the Present Day*, 2nd edn. London and Manchester. [Small limited 1st edn, 1867.]

Greg, R.P. and Lettsom, W.G. (1858). *Manual of the Mineralogy of Great Britain and Ireland*. London.

Griffiths, Ralph A. (1988). *Singleton Abbey and the Vivians of Swansea*. Gomer Press, Llandysul, Dyfed.

Huot, J.J.N. (1841). *Nouveau Manuel Complet de Minéralogie*, p. 266. Paris.

Jones, Sally (1974). The Vivian Family. *Transactions of the Port Talbot Historical Society*, No. 3, vol. **2**, 5–17.

Kobell, F. von (1853). *Die Mineral-Namen und die Mineralogische Nomenklatur*, p.25. Munich.

Palache, C., Berman, H. and Frondel, C. (1944, 1951). *The System of Mineralogy of James Dwight Dana and Edward Salisbury Dana*, 7th edn, vol. **1**, 1944, and vol. **2**, 1951. New York.

Phillips, W. (1823). *An Elementary Introduction to Mineralogy*, 3rd edn. London.

[Polsue, J.] (1872). *A Complete Parochial History of the County of Cornwall*, vol. **4**. William Lake, Truro. [Usually known as *Lake's Parochial History*.]

Vivian, J.H. (1818). A sketch of the plan of the Mining Academies of Freyberg and Schemnitz. *Transactions of the Royal Geological Society of Cornwall*, **1**, 71–77.

[Vivian, J.L.] (1887). *The Visitations of Cornwall, ... with additions by Lieut.-Col. J.L. Vivian*. Exeter. [Pp. 538–539, family tree of Vivian of Truro.]

Werner, A.G. (1791–92). *Ausführliches und sistematisches Verzeichnis des Mineralien-Kabinets des ... Herrn Karl Eugen Pabst von Ohain*, vol. **1**, 1791 and vol. **2**, 1792 (usually bound together). Freiberg and Annaberg.

Werner, A.G. (1817). *Abraham Gottlob Werner's Letztes Mineral-System*. Freiberg and Vienna. [Edited by J.K. Freiesleben after the author's death in 1817. Note 35, pp. 41–42.]

ENDSLEIGH NATURE COMPANY

Suppliers of Mineralogical Books and Accessories

Reference Books and Encyclopedia

Large Range of Hand Lenses for Mineralogy

Large Range of Geological Hammers

Mineral Specimen Storage Boxes

Ultra Violet Lamps

Mineral Collection Labels

Send for a full price list to

ENDSLEIGH NATURE COMPANY
Endsleigh House, 50 Daniell Road, Truro
Cornwall TR1 2DA Tel/Fax 0872 223227

M.J. Minerals
Proprietor Margaret Johnson
130 Moat Street, Wigston
Leicestershire, LE18 2GE
Tel. 0533-880600

MAIL ORDER CATALOGUE AVAILABLE

Large stocks of minerals - about 600
on display in the shop at any one time
plus large reserves

* * * * * * * * * * * * * * * * *

Mayes Minerals
Proprietor Margaret Johnson
130 Moat Street, Wigston
Leicestershire, LE18 2GE
Tel. 0533-880600

Mineral Specimens - Basketware - Jewellery
Jewellery Findings - Candles - Pottery
Lapidary & Silversmithing Supplies

Opening times: Mon. Thurs, Fri 10.30-5.30
Wed 10.30-1.30 Sat 10.00-5.30
Private viewing by appointment

DIAMOND SAW BLADES

We carry extensive stocks of both continuous rim and notched diamond blades, from 4" to 24" diameter.

PERSONAL SERVICE-SAMEDAY DESPATCH

EXAMPLE

Continuous Rim	6"	**£52**
Continuous Rim	10"	**£86**
Continuous Rim	14"	**£182**

For more details and Price List contact Bob or Pat Jones at:

MALVERN LAPIDARY
39 Broadlands Drive,
Malvern,
Worcs. WR14 1PW.
Fax/Tel: (0684) 561537

5% discount when quoting this advert

BROADSTONE MINERALS

Quality Minerals — British, European, World-wide.

Lists on request from

Mike Brooke
The Courtyard Centre
Lytchett Minster
Poole
Dorset. BH16 6BA
Tel. (0202) 696523
(evenings)

THE RUSSELL SOCIETY

Enquiries about membership to:
F.K.Werner
12 Martinshaw Lane,
GROBY,
Leics LE6 0BJ

J. Russell Soc., **5**(2), 83–90 (1994).

NATIVE SILVER FROM HILDERSTON MINE, WEST LOTHIAN, SCOTLAND

T. KEMP MEIKLE
13 Tassie Place, East Kilbride, Glasgow, G74 3EB

The occurrence of silver in Scotland is reviewed and historical details are given of 17th century silver mining at Hilderston mine, Bathgate, West Lothian. Here there are two metallogenic assemblages: (1) galena, pyrite, chalcopyrite, sphalerite, solid hydrocarbon (albertite?), and quartz, where the vein cuts limestone: (2) silver, nickel and cobalt minerals, with minor galena, pyrite, chalcopyrite and sphalerite, adjacent to basalt dykes and a dolerite sill. The gangue is baryte with minor calcite. Native silver occurs rarely, as minute grains, but one specimen of wiry silver was also found. Other minerals described are acanthite, amalgam, cinnabar, mercury, nickeline, maucherite, an unidentified Ni–As–S phase, annabergite, erythrite, magnetite, barytocalcite, witherite, and harmotome.

INTRODUCTION

Native silver is extremely rare in Scotland. Recent literature records small amounts of silver associated with native copper in prehnite in the Clyde Plateau Lavas at Boyleston quarry, Loanhead quarry and Hartfield Moss (Meikle, 1989a, 1989b, 1990), and as minor occurrences with sphalerite and galena, loose on Law Hill and Nutberry Hill near Lesmahagow, Lanarkshire, presumably originating from Devonian or Silurian sediments (Todd and McMullen, 1991). Heddle (1901) refers briefly to minor occurrences near Abriachan, Loch Ness; at Craigsoales, Glen Esk; in Islay; and possibly also in Mull. He also records that it was mined in quantity at Hilderston in the Bathgate Hills, West Lothian, in the early 17th century; and also in the Ochil Hills near Stirling, at Tillicoultry and more notably at Alva, in the early 18th century. Specimens of native silver have been recovered by the author and others in recent years from old mine dumps in Silver Glen, Alva, and a very fine 18th century specimen (M953) is held in the Hunterian Museum, Glasgow University; another, larger specimen which was in the Smith Collection, Stirling, in 1974 has since been stolen. Other Alva silver specimens from the early 19th century collection of Cochran Patrick (senior) are now in the private collections of J.G. Todd and the author. No specimens of native silver from Hilderston were known hitherto, although specimens of other species, related to later mining there, are held in both the Royal Museum of Scotland in Edinburgh and in the Hunterian Museum, Glasgow University.

This paper describes the history of Hilderston mine, recent investigations of the surface remains, and the minerals that occur there.

HISTORY

The Hilderston silver vein was discovered accidentally in 1606 by a local coalminer, Sandy Maund, prospecting on his own account in the area for a new coal seam. The discovery is recorded by Atkinson (1619) and referred to by later writers (Aitken, 1893; Heddle, 1901; Cadell, 1925; Stephenson, 1983). Atkinson, who had "good cause to be well acquainted with that silver Myne, being there imployed from the begininge till the going out thereof, as a refiner of the same, and a longer time then any others of England, Scotland, or Germany", refers to Maund as follows: "And this Scotsman, by means of digging in the ground hitt upon the heavy peece of redd-mettle; no man thereabout ever saw the like. It was raced with many small stringes, like unto haiers or threads. It had descended from a vaine thereof where it had engendered with sparr-stone, which in foraine provinces is called ... cacilla. And he sought further ... and found a peece of brownish sparr-stone, and it was mossie. He broke it with his mattocke and it was white and glittered within like unto small white copper-keese which is to be found in many common free-stones." Maund's 'redd-mettle' was presumably nickeline and the 'haiers and threads' filiform native silver. The material was so unusual that it was taken to Sir Bevis Bulmer, then engaged in mining and prospecting for gold at Leadhills, who made several assays of it, "and it proved wondrous rich" (Atkinson, 1619).

The landowner, Sir Thomas Hamilton, the King's Advocate in Scotland, hearing of the discovery, took a lease from the King in January 1607 on all minerals in the district, and mining was commenced with Sir Bevis Bulmer in charge assisted by Atkinson as his refiner. According to Atkinson (1619), "After the full discoverie he [Bulmer] rested not untill he named them, calling one pitt or shafte there God's Blessing because of the wonderful works of God that he had seene. ... Shortly after I was brought thither, the silver Myne being sett open, I was stricken down into the shaft called God's Blessing and I brought up with me a most admirable peece of the Cacilla stone, a menerall stone, one which me thought came from one of God's treasure houses; parte whereof I kept still, and parte thereof I sent for a token to my uncle Atkinson of Foster Lane. It was much admired by many Goldsmiths of London, who saw it, proved it, tryed and commended it. ... The manner how it

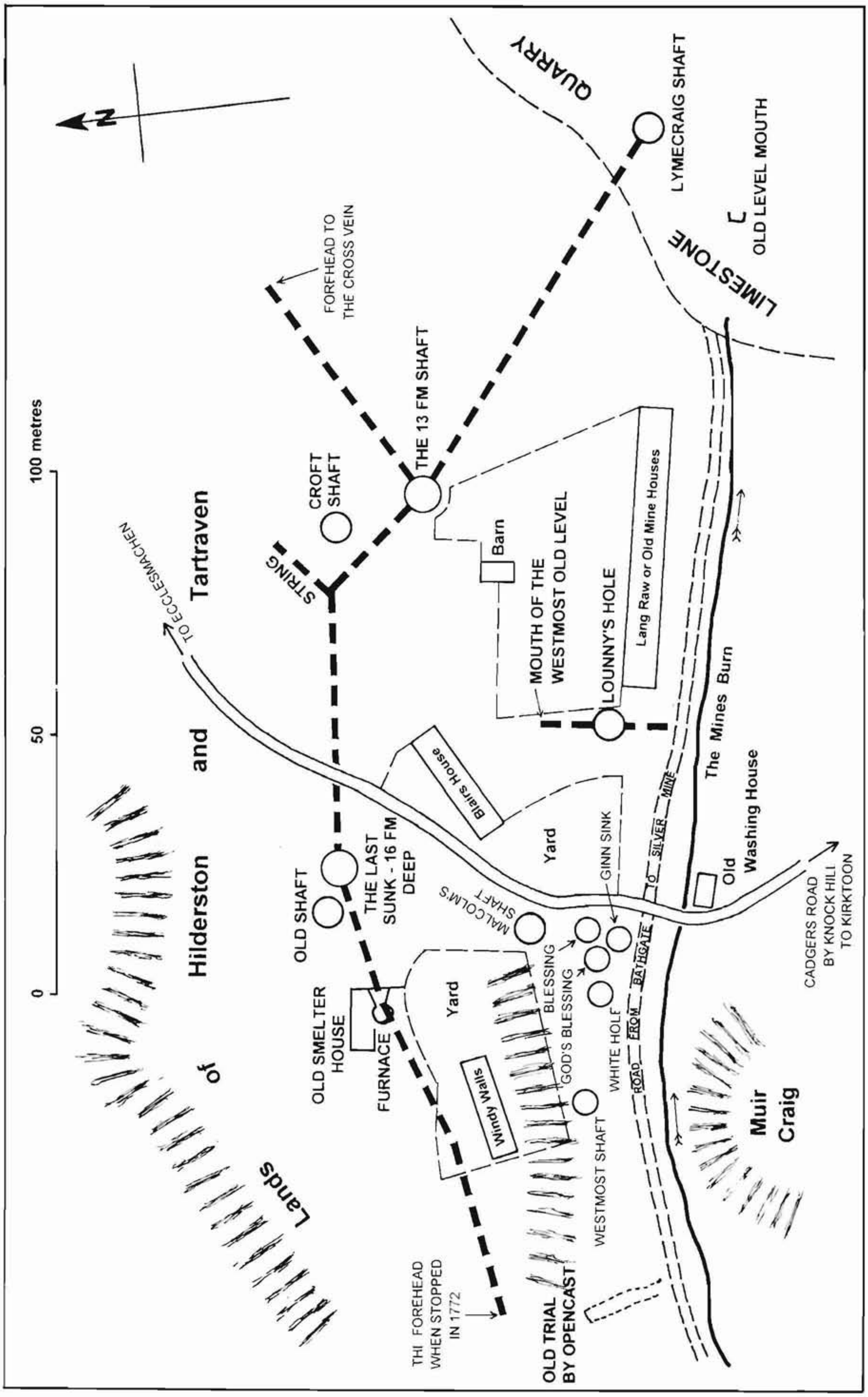

FIGURE 1. Plan of Hilderston mine showing 17th century features. Redrawn from *Plan of the Works of Silver Mine of Hilderston and Tartraven, Surveyed and Delineated 14th July 1772* by Joseph Udny (1 inch = 40 feet) in the Scottish National Records Office.

grew was like unto the haire of a man's head, and the grasse in the fielde. And the vaine thereof, out of which I had it was once two inches thicke ... the mettle thereof was both malliable and toughe. It was course silver, worth 4s 6d the ounceweight. ... The greatest quantity of Silver ... was raised and fined out of the redd-mettle. ... And much of the same redd-mettle, by assay, held twelve score pounds starling per ton weight. ... And when I wrought on the first sorte of red-mettle for Mr Bulmer and my Lord Advocate of Scotland, sundry times I refined it; and commonly for the space of three dayes weekly I made an hundred starling each day ... But this was the strangest of all others ... Untill the same redd-mettle came unto 12 faddomes deep, it remained still good; from thence unto 30 fathome deep it proved nought."

The vein initially proving to be very rich, the mine showed every sign of prosperity and the Scottish Privy Council was persuaded by the King's Advisers to rescind Hamilton's lease, with the mineral rights reverting to the Crown in May 1608 on payment to Hamilton of £5000 compensation. Unfortunately for the King, the mine's profitability began to fall almost immediately through increased production costs and falling silver content of the ore, aggravated by pilfering by the workforce. In 1612 a Proclamation by the Privy Council declared "That thair hes bene a grite quantitie of siluer vre with workloomes and vther prouisiouns embazelled and stollin away fra his Majesteis siluer mynes of Hilderstoun and fra the fyre workis and stamping workis belonging thairvnto", and demanded surrender within 20 days or "be perseuit and pvnist as commoun thevis and ressetairis of thift without favour or mercy" (Cochran Patrick. 1878). By 1613 the mine was showing little return, and was let to a private company for a royalty, before silver mining eventually ceased in about 1616. Towards the end of the 17th century mining rights were acquired by the Earl of Hopetoun, whose family had been operating the lead mines at Leadhills, and galena continued to be mined at Hilderston until 1772 despite having little or no silver content.

No further mining operation took place until about 1870, when exploration of the old workings proved them to be virtually worked out. A shaft was sunk to over 67 metres where the vein almost vanished, and a borehole put down a further 61 metres was unable to prove any values. The old mine wastes, mostly baryte, filling the old workings were, however. found to contain considerable quantities of nickel ore, the value of which was unknown to the early miners since nickel was not recognised as a new metal until the 1750s. These, along with similar but oxidised material from the surface dumps, were recovered and sold. although they were found to contain neither galena nor silver (Aitken, 1893). In 1896 one of Bulmer's original shafts was again cleared for further exploration of the old workings, though still without success, and final abandonment took place in 1898.

A mine plan surveyed by Joseph Udny on cessation of mining in July 1772, now in the Scottish National Records Office, Edinburgh. shows original site details including the positions and names of all of Bulmer's early shafts, mine buildings, washing house, smelter and furnace, etc. (see Fig. 1). Also, a British Geological Survey Record Plan labelled "Hilderston Silver Mine (Silver & Barytes)", but otherwise untitled and undated, marks several trial trenches and pits – some dated June/July '71 (presumably 1871) – and this is assumed to relate to the late 19th century investigations.

GEOLOGY AND MINERALISATION

The Bathgate Hills are comprised of Lower Limestone Group sedimentary and volcanic strata of Carboniferous Viséan Age, the mine being associated with thin E W trending much altered quartz-dolerite or basalt dykes which cut the Lower Petershill Limestone to the east, and an adjacent. wide, N–S trending dyke-like outcrop of a transgressive dolerite sill. The early records and the 1772 mine plan (Fig. 1) suggest two mineralised areas: a distinct vein trending E W along the northern side of the valley, with a small dump in the field east of the road; and an area west of the road in the valley centre, indicated by the old shaft craters near the N–S dyke-like feature. The former appears to intersect the valley immediately west of this area as indicated on Udny's plan (Fig. 1). The mineralisation is comprised principally of baryte with minor carbonates. There are two separate and distinct metallogenic assemblages: (1) galena, pyrite, chalcopyrite, sphalerite, solid hydrocarbon (albertite?), and quartz to the east where the vein cuts the limestone; (2) silver, nickel and cobalt minerals, with minor galena, pyrite, chalcopyrite and sphalerite, adjacent to the E–W basalt dykes and N–S dolerite sill to the west (Stephenson, 1983).

SURFACE REMAINS

Hilderston mine (NGR NS 990 715) is situated about 3 km NE of Bathgate, in a low, relatively narrow valley which rises from derelict and flooded old limestone quarries towards the low col of Hilderston Hills to the west, with Cairnpapple Hill and its Bronze Age henge and cairn forming the northern flank, and the basaltic bluff of Muir Craig the southern. Today it betrays little of its early mining history. Three small, crater-like depressions, in an area of lush water-meadow traversed by a small meandering watercourse, indicate the location of Bulmer's original shafts, to the west of the twisting, hilly, N–S country road. Also on the northern flank are the unobtrusive remains of a low building near the site of the original smelter and furnace. East of the road, at a lower level, lie two small grassed-over dumps derived from the later operations, and old level mouths exist in the abandoned quarries. The levels are difficult of access and have not been investigated. The ruins of a row of miners' cottages, and what may be the manager's house, may also be observed in this area.

The recent site investigations (1993) have been confined to opening a few shallow excavations in the water-meadow area, where the growth obscures the actual surface configuration, in the supposed vicinity of one of the original shafts (Ginn shaft) which is believed not to have been disturbed since the 17th century; and also in an area where original waste or re-excavated backfill material may have been temporarily dumped during the 19th century. Mineralised, frequently altered, hand and fist-size specimens were recovered, along with earthy balls of pale-yellow to greenish annabergite. In addition, several larger, smooth-surfaced, buried 'cobbles' of mineralised quartz-dolerite, displaying a striking purplish-brown outer impregnation, were collected. A dump of weathered cobbles was found adjacent to the ruins near the old smelter site, no doubt deriving partly from farming field-clearance of the higher ploughland, but partly also perhaps from the early mining or smelting operations. These tough cobbles may have been used to break up the ore in some form of drum mill prior to smelting, or simply in the construction of the mine road.

MINERALS

Heddle (1901) listed nine species occurring in a baryte vein at Hilderston: silver, nickeline, annabergite, erythrite, sphalerite, galena, pyrite and dolomite. Stephenson (1983) added calcite, quartz, chalcopyrite, bravoite, an unknown nickel arsenide (Ni_2As_2S), and a hydrocarbon (probably albertite), all from the baryte vein. The minerals identified during the present investigation, also considered to originate from the baryte vein, are described below. Examination of the 'cobbles' of altered quartz-dolerite, thought to come from one of the E-W dykes, revealed pyrite, quartz, feldspar, pyroxene and amphibole, along with highly titaniferous magnetite and possibly maghemite. This study involved the use of various techniques including transmitted light examination of grains and thin sections; reflected light examination of polished sections; powder X-ray diffraction (XRD); and semi-quantitative microprobe analysis by energy-dispersive X-ray spectroscopy (EDX).

ACANTHITE, Ag_2S

This species occurs on the faces of microfractures in calcite as dull black, sometimes lustrous metallic plates (up to 4 mm x 0.6 mm) displaying rounded crystal forms, and is shiny and malleable when scratched. An initial but imperfect XRD photograph indicated it to be a silver phase (either sulphide or selenide) and further EDX examination confirmed the sulphide (probably acanthite), closely associated with native mercury which seems to be concentrated as a surface coating. EDX examination of a cross-section of such a veinlet revealed a discrete grain of amalgam within the acanthite.

Acanthite also occurs on calcite as small individual crystals or groups (<1.4 mm) of similar appearance, and also displaying complex rounded faces (Fig. 2); they are closely associated with annabergite-coated galena and nickeline crystal aggregates, along with tiny aggregates of cinnabar.

ALBERTITE

Small lustrous, black, isolated globules (<3 mm) of solid hydrocarbon occur in the baryte/dolomite/calcite gangue, often accompanying small crystals of galena. Stephenson (1983) suggests that this is probably albertite and reports it only from vein material adjacent to the limestone, but it is also present in both baryte and carbonate breccia adjacent to the dolerite intrusion. On one specimen it is associated with silver, acanthite, amalgam, mercury, cinnabar, nickeline, annabergite, galena, and minor pyrite. Another specimen displaying many black globules in association with pyrite, annabergite and erythrite was weakly radioactive, and EDX examination of earthy red material from this showed Fe and probably U.

AMALGAM, (Ag,Hg)

A phase containing only Ag and Hg was detected by EDX examination as a short discrete platy section of infill in a microfracture in calcite adjoining mercury-coated(?) acanthite (Fig. 3). It is malleable and bright metallic in appearance, and consequently difficult to distinguish from the coated

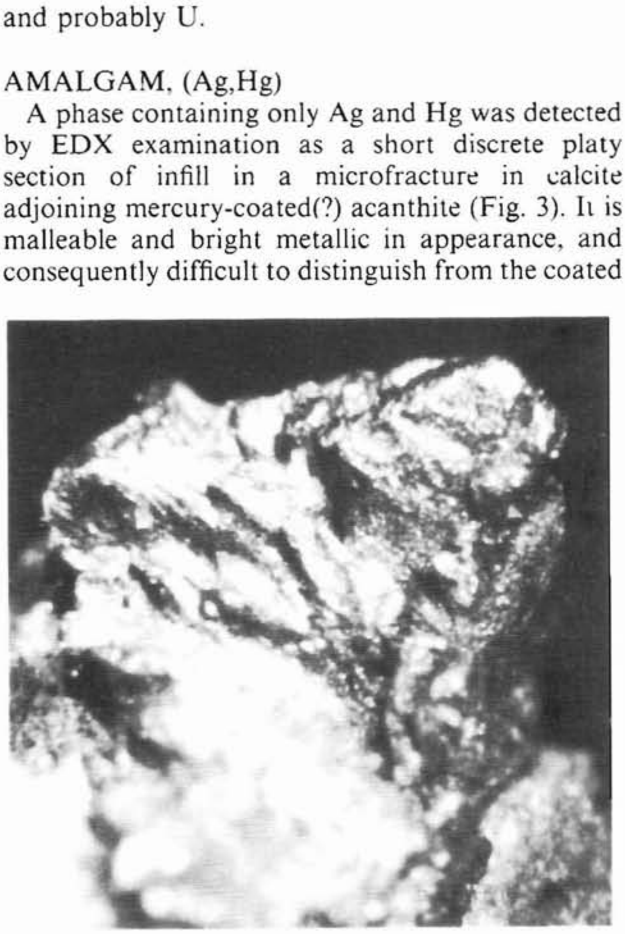

FIGURE 2. Acanthite, rounded crystal coated with native mercury. Field of view 0.8 mm.

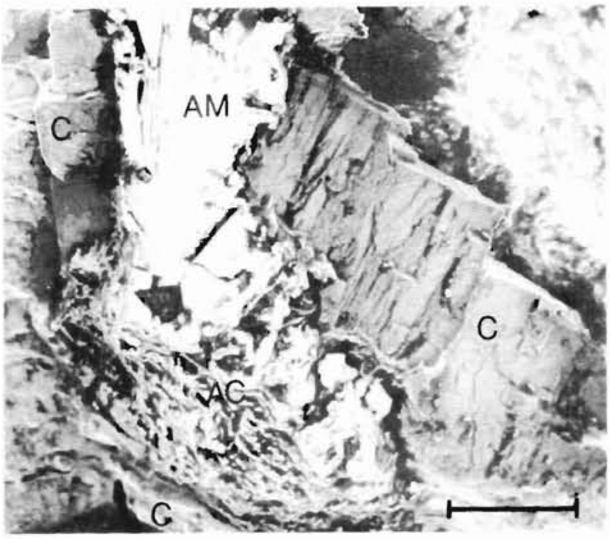

FIGURE 3. Acanthite (AC) veinlet with a discrete grain of amalgam (AM), in calcite (C). Composite electron and backscattered electron image. Scale bar 0.2 mm.

acanthite. Although this grain is referred to as amalgam (mercurian silver) in this paper, it is interesting that a very approximate EDX analysis indicated a composition of Ag 29, Hg 71 wt %, or $Ag_{2.2}Hg_{2.8}$, which is close to that of moschellandsbergite (Ag_2Hg_3). Further work is needed, however, to determine the exact nature of this phase.

ANNABERGITE, $Ni_3(AsO_4)_2.8H_2O$

This occurs as apple green and pale green to yellow and whitish spherules and coatings on baryte with calcite, and in carbonate breccia, often accompanying minor nickeline and occasional pale pink erythrite and/or small lustrous irregular spots and patches of the unidentified Ni–Co–As–S phase described below.

It occurs also as pale-yellow earthy balls up to 8 cm across. These were disintegrated in water, then panned to remove silt and fines, and the residues were dried, separated on graded sieves, and examined under the microscope. (This useful technique has been regularly used by the author for specimen wash-water). The residues contained grains and tiny crystals of green annabergite on nickeline; magnetite or possibly maghemite; galena; sphalerite; tiny crystals of scalenohedral calcite and doubly-terminated quartz; rare, blackened grains of silver: and one tiny spherule of interlocking crystal plates of specular hematite. Excepting much of the magnetic material, sphalerite and galena, nearly all these grains were below 1 mm in size.

BARYTE, $BaSO_4$

The literature records baryte as the principal vein material throughout the old workings, and it is also the main component of much of the recently recovered material. It is opaque white to pale pink, mainly massive, and rarely lamellar. It also occurs as small (0.2–0.3 mm), sharp, transparent to translucent, randomly oriented platy crystals covering areas up to about 3 cm wide over the surface of much-altered carbonate breccia. The matrix is a breccia vein of intimately mixed baryte, calcite and altered carbonates, some being stained dark grey to black, and with small intermixed aggregates and crystals of chalcopyrite and pyrite. The degraded outer surfaces often show a pale green annabergite coating along with the black platy unidentified Ni–Co–As–S mineral discussed below.

BARYTOCALCITE, $BaCa(CO_3)_2$

This species has been identified previously from the site by infrared spectrometry and XRD (S. Moreton, *personal communication*). It has now been found as small, sharp, well-terminated colourless crystals (<1 mm), with witherite and harmotome, on one of the grassed-over dumps east of the road, and confirmed by infrared spectrometry.

CINNABAR, HgS

Cinnabar occurs as lustrous, bright coccineal-red aggregates (<0.18 mm) dispersed randomly in the annabergite–galena–nickeline aggregate referred to under acanthite and galena. The identification was confirmed by EDX analysis.

ERYTHRITE, $Co_3(AsO_4)_2.8H_2O$

This is noted as small, deep to pale pink to whitish spherules and coatings on baryte and calcite, frequently accompanying and bordering earthy black platy alteration products of Co–Ni arsenides. On some specimens it is often associated with annabergite as a pale pink coating on baryte, and it is also present in one of the weathered quartz-dolerite cobbles from near the smelter site, which suggests that this cobble is derived from the old workings.

GALENA, PbS

Galena occurs frequently in both baryte and calcite, as individual small cube-octahedral crystals up to 10 mm in size, often with a dull grey to blackish coating, but occasionally bright grey to silvery in appearance where modified by dissolution. Very small cubic crystals occur with acanthite, nickeline, cinnabar, etc., as already described. A small aggregate of galena adjacent to nickeline was seen in a polished section (Fig. 4) to contain a number of inclusions; most were sphalerite, but some tiny bright silvery inclusions of an unidentified Ni–As–S phase were also present (see below).

HARMOTOME, $(Ba,K)_{1-2}(Si,Al)_8O_{16}.6H_2O$

This species occurs as well-formed, closely packed but randomly oriented, colourless and highly transparent cruciform twinned crystals (up to 0.12 mm x 0.6 mm) on fracture surfaces in the highly altered carbonate breccia vein material. Two similar but

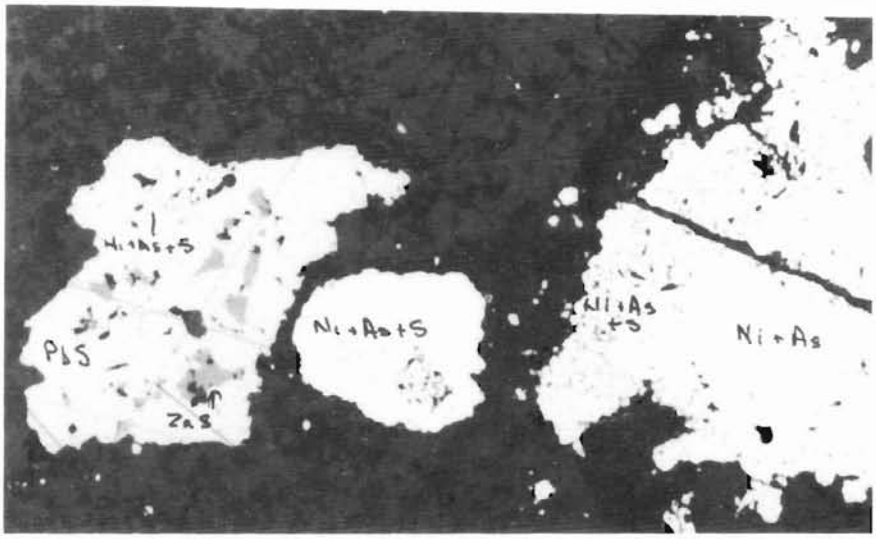

FIGURE 4. Polished section of ore in reflected polarised light, showing nickeline (Ni+As) with rim of Ni–As–S phase, and galena (PbS) with inclusions of sphalerite (ZnS) and Ni–As–S phase, in a matrix of calcite and baryte (dark). Field of view 1.35 mm.

larger crystals, with grey surface impregnations, occur in what appears to be a dissolution cavity. These all display prism re-entrants and terminations indicative of complex Marburg twinning. Such crystals, associated with witherite and barytocalcite in baryte vein matrix, were also collected from the grassed-over dump east of the road by N. Hubbard (*personal communication*) and subsequently by the author.

MAGNETITE, Fe_3O_4

Magnetite occurs as fresh, well-formed, lustrous black octahedra up to about 1.5 mm in size, as a major component of the quartz-dolerite cobbles recovered from the excavations. Pale to dark brown, highly magnetic octahedral crystals of similar size occur in the weathered cobble from the smelter site area and may be magnetite or possibly maghemite; EDX partial analysis of one such crystal indicates a relatively high titanium content. Much highly magnetic material was also recovered from the annabergite-ball residues.

MAUCHERITE, $Ni_{11}As_8$

Pale copper-coloured, possibly tetragonal crystals occur with galena and annabergite, and also as individual similar crystals (<1 mm) in the matrix. Cleavage surfaces suggest that these may be maucherite rather than nickeline. One specimen exhibits tiny threads up to 0.09 mm long in association with native silver. Similar threads collected by S. Moreton have been confirmed as maucherite by P. Aspen, University of Edinburgh, using XRD (S. Moreton, *personal communication*).

MERCURY, Hg

During SEM examination of acanthite, very tiny (micrometre-sized) particles were noted in close association with the acanthite, and were analysed as native mercury. The silvery coating on some of the acanthite is also considered to be mercury, although attempts to confirm this were inconclusive.

NICKELINE, NiAs

Nickeline (niccolite) occurs in baryte or calcite and is often associated with random crystals and small aggregates of galena and, rarely, with small black lustrous globules of albertite. It forms closely packed, copper-coloured, sometimes tarnished or blackened radiating hexagonal prisms in banded concentric growths up to 5 mm in diameter, or aggregates up to 15 mm in length, both of which often display a silvery rim (Fig. 5a). EDX analysis confirmed the radial material as nickeline and the silvery rim as a Ni–Co–As–S phase (see below). One specimen showed an unusually bright and striking rainbow tarnish.

SILVER, Ag

Silver occurs only rarely, as small isolated irregular grains (up to 0.25 mm x 0.16 mm) in baryte associated with small octahedral crystals of galena. A unique specimen exhibits over forty randomly grown, relatively bright, curved and twisted filiform crystals of silver (confirmed by EDX), up to 0.25 mm long and 0.02 mm wide at the base (Fig. 6). They are square in section and have tapering, longitudinally grooved faces, suggestive of complex cruciform twinning or parallel growth. The wires cover an area of 4 mm x 1.6 mm on the surface of nickeline coated lightly by pale annabergite, in a matrix of calcite, and other associated species are acanthite, mercury, amalgam, cinnabar, galena, and albertite.

SPHALERITE, ZnS

Sphalerite is recorded from the Ag–Ni–Co mineralised zone (Heddle, 1901), but is not evident on the

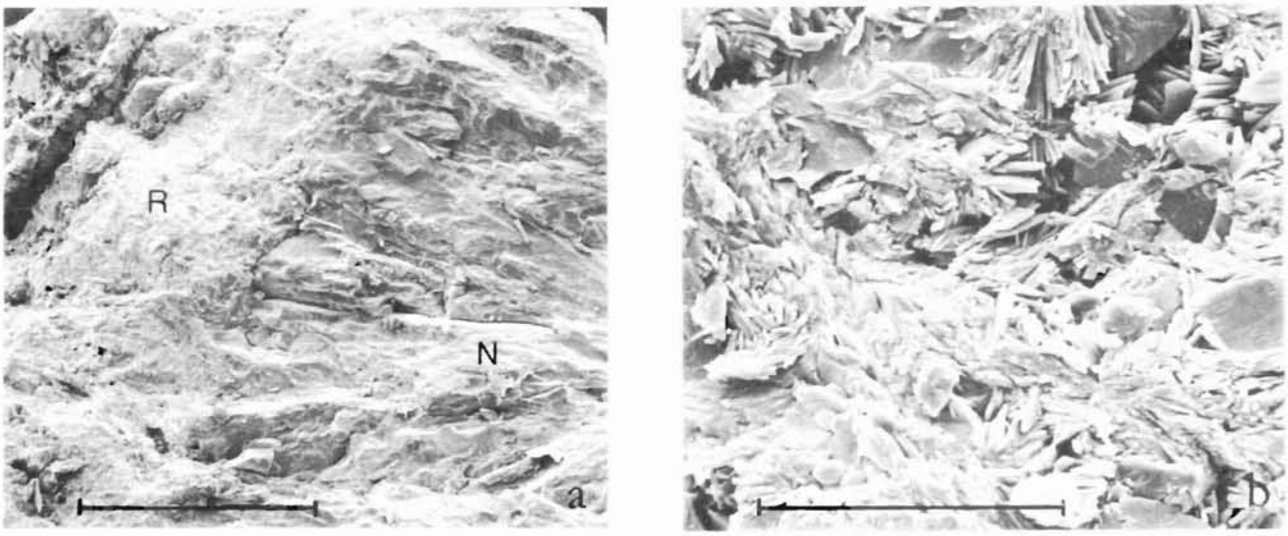

FIGURE 5. (**a**) Radiating nickeline (N) with rim of Ni–As–S phase (R); scale bar 0.2 mm. (**b**) The rim at higher magnification, showing microcrystalline structure; scale bar 0.02 mm. Both are backscattered electron images.

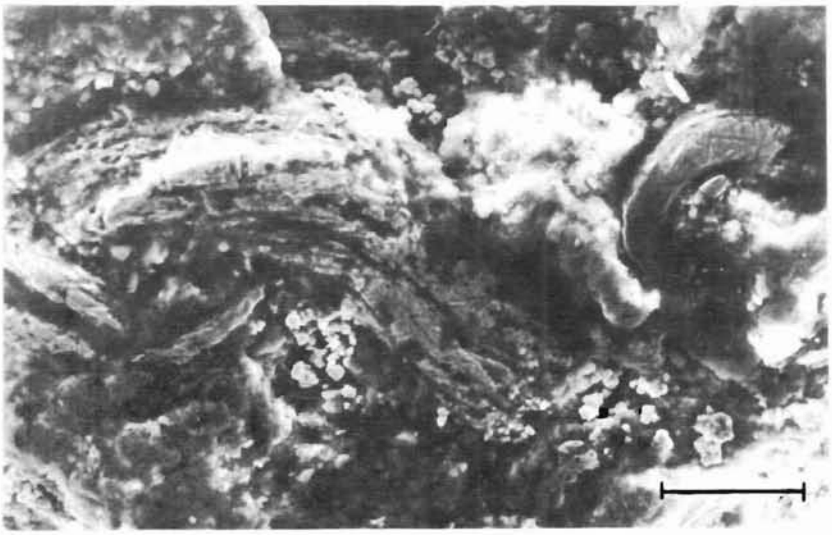

FIGURE 6. Filiform native silver crystals on nickeline with annabergite. Backscattered electron image. Scale bar 0.02 mm.

Royal Museum of Scotland specimens nor on the hand-specimens recently collected by the author. However, reddish-brown well-crystallised sphalerite is abundant in the annabergite-ball residues, both as cleavage fragments and as entire crystals up to 4 mm in size; sphalerite is about three times more abundant than the accompanying galena fragments. Sphalerite also occurs as microscopic inclusions in galena accompanying nickeline, as already mentioned.

UNIDENTIFIED NICKEL-COBALT ARSENIDE-SULPHIDES

Stephenson (1983) refers to an unknown pale metallic phase approximating to Ni_2As_2S which forms rims around nickeline on a Heddle specimen in the Royal Museum of Scotland (No. 1894.212.158 713) from Cairn Naple [*sic*], Hilderston Hills. EDX partial analysis of the rims associated with the recently collected nickeline (Fig. 5a) confirms the presence of Ni, As and S along with minor Co. At higher magnification (Fig. 5b) an apparently microcrystalline structure is revealed. In reflected light the rim is white and nearly isotropic, with variations in brightness which may relate to a variation in composition. The same Ni–As–S phase appears to occur as tiny, bright silvery inclusions in galena adjacent to the rimmed nickeline.

Heddle (1901) refers to the 'redd-mettle' of Atkinson (1619) as containing approximately 30% Ni and 2% Co, and cobalt is a common constituent of black, probably secondary material accompanying nickeline and erythrite. EDX analysis of some of the earthy black cleavage plates indicates a high arsenic content varying from about 60 to 70 wt %, with Co about 11–24, Ni about 7–11, and S about 6–11%. The associated small black lustrous patches contain much manganese along with Co, Ni, As, S, Al and Si.

WITHERITE, $BaCO_3$

Witherite was found at Hilderston in 1991 by Neil Hubbard (*personal communication*) and is now noted from the baryte-carbonate material recovered along with harmotome from one of the grassed-over dumps east of the road. Witherite forms platy, elongated, transparent to whitish, well-terminated crystals (<4 mm x 1.4 mm) in parallel growth, or in groups of transparent to whitish pseudohexagonal bevelled tabular crystals (<1 mm), and is closely associated with barytocalcite.

DISCUSSION

The native silver wires on the single recovered specimen, though very small, so fittingly match the description of a piece of ore by Atkinson (1619): "It was raced with many small stringes like unto haiers or thredds ... The manner how it grew was like unto the haire of a man's head and the grasse in the fielde." Since the same specimen carries black malleable acanthite, mercury, amalgam and cinnabar, this seems worthy of special note.

Although the 'redd-mettle' (red metal) of the 17th century miners (Atkinson, 1619) was most likely to have been nickeline, the exact nature of the silver-bearing ore remains uncertain. Contemporary records referred to by Cochran Patrick (1878) indicate considerable difficulties and variable results in assaying the ore at the Mint in the Tower of London, and elsewhere, for the King's valuation assessments in 1608. Likewise, no records exist concerning the smelting procedures used. A curious and as yet unexplained observation is that EDX examination of slag recovered from the site showed only silicates of Ca, Al and Mg, and no silver, copper, lead, zinc or nickel.

The presence of mercury, amalgam and radioactive hydrocarbon at Hilderston, and of amalgam and tiemannite with pyrobitumen at Silver Glen, Alva (Livingstone, 1993), suggests a similarity in the mineralisation. This similarity appears not to extend to the silver itself, however, since no specimens of filiform silver are known from Alva. All examined Silver Glen specimens exhibit either reticulated cubic, or branching arborescent octahedral, growth forms. This difference of form between the two sites may point to differing modes of formation of silver primary at Hilderston and perhaps secondary at Silver Glen.

ACKNOWLEDGEMENTS

Thanks are due to Dr Alec Livingstone (Royal Museum of Scotland), Dr Allan Hall and Peter Ainsworth (University of Glasgow), and Dr Mike Rothwell (Unilever Ltd, Port Sunlight), for X-ray diffraction, EDX analyses and SEM photographs, and for their helpful discussions and comments during the preparation of this paper. Thanks are also due to Alex Herriott (East Kilbride) for his expertise in thin section and polished section preparation and interpretation, and consequent useful discussion of vein composition: and also to Norman Thomson (Carlisle) for the IR confirmation of barytocalcite. Acknowledgement is made of discussions with Dr Stephen Moreton on Alva and Hilderston silver mines, his presence and observations during a visit to Hilderston, and subsequent useful comments during the paper's preparation.

REFERENCES

Aitken, H. (1893). The Hilderstone Silver Mine, near Linlithgow. *Transactions of the Federated Institution of Mining Engineers*, **6**, 193–198.

Atkinson, S. (1619). *The Discoverie and Historie of the Gold Mynes in Scotland, written by Stephen Atkinson in the year MDCXIX*, pp. 47–50. Taken from the original, prefaced by Gilbert Laing Meason, and presented to the Bannatyne Club, Edinburgh. Printed by James Ballantyne & Co., Edinburgh, 1825.

Cadell, H.M. (1925). *The Rocks of West Lothian*, pp. 359–378. Oliver and Boyd, Edinburgh.

Cochran Patrick, R.W. (1878). *Early Records Relating to Mining in Scotland*, pp. 135–166. David Douglas, Edinburgh.

Heddle, M.F. (1901). *The Mineralogy of Scotland* (ed. by J.G. Goodchild), vol. **1**, pp. 25–27. David Douglas, Edinburgh.

Livingstone, A. (1993). Glossary of Scottish mineral species – an update. *Scottish Journal of Geology*, **29**, 87–101.

Meikle, T.K. (1989a). The secondary mineralogy of the Clyde Plateau Lavas, Scotland. Part 1: Boyleston Quarry. *Journal of the Russell Society*, **2**, pt 2, 11–14.

Meikle, T.K. (1989b). The secondary mineralogy of the Clyde Plateau Lavas, Scotland. Part 2: Loanhead Quarry. *Journal of the Russell Society*, **2**, pt 2, 15–21.

Meikle, T.K. (1990). The secondary mineralogy of the Clyde Plateau Lavas, Scotland. Part 3: Hartfield Moss. *Journal of the Russell Society*, **3**, pt 2, 43–47.

Stephenson, D. (1983). *Hilderston Mine, West Lothian: Mining History and the Nature of the Vein Mineralisation as Deduced from Old Records*. British Geological Survey, Report No. NL 83/84.

Todd, J.G. and McMullen, M.J. (1991). Vein minerals of Mannoch Hill, Scotland. *UK Journal of Mines and Minerals*, No. 9, 35–38.

J. Russell Soc., **5**(2), 91–102 (1994).

MINERALOGY OF THE ALDERLEY EDGE – MOTTRAM ST ANDREW AREA, CHESHIRE, ENGLAND

RICHARD S.W. BRAITHWAITE
Chemistry Department, University of Manchester Institute of Science and Technology, Manchester M60 1QD

The mineral deposits in the Trias at Alderley Edge and Mottram St Andrew in Cheshire are briefly described and discussed, and details are given of the minerals found in and reported from the area. The doubtful and erroneous records of minerals, so persistent in the extensive literature on the subject, are discussed, as well as the probable source of the type material of mottramite.

INTRODUCTION

Alderley Edge and Mottram St Andrew are villages in an area of scenic beauty some 20 km south of the centre of Manchester. The Edge itself is a set of NW-trending fault scarps rising to about 200 m above sea level. These are part of a faulted complex of Triassic New Red Sandstones, the surface of resistant Helsby Sandstone (Lower 'Keuper') conglomerates and sandstones resting on softer Wilmslow ('Bunter') Sandstone, which is exposed below the scarp, i.e. to the north-east. Some 3 km further to the ENE the N-S Kirkleyditch fault brings the Helsby Sandstone series to the surface again at Mottram St Andrew.

The copper-rich deposits in this area, being exposed at the surface and colourful, were probably worked in very early times. Clearly substantiated evidence for this is lacking, however, though a considerable number of stone hammers, which might have been used for mining, have been unearthed in copper-mineralised surface pits (Boyd-Dawkins, 1875, 1876). The first documentary evidence of mining relates to 1693, from when the mines were worked intermittently to 1919. The most intensive operations were conducted between 1857 and 1877, at which time the copper was being extracted by an acid leaching process. Smaller amounts of concentrates of lead, cobalt, and vanadium minerals were also produced (Dewey and Eastwood, 1925). For a detailed account of the history of these mines, as well as a description of the surface remains and underground workings, see Carlon (1979) and also Warrington (1981) and Thompson (1991).

MINERALISATION

With the exception of baryte fault in-fillings, which penetrate all the beds, the mineralisation is mainly confined to the Helsby Sandstone series at the top of the Edge and at Mottram St Andrew, with only a little in the topmost part of the Wilmslow Sandstone. Within the Helsby Sandstone series the mineralisation tends to be restricted to the more porous conglomeratic and arenaceous horizons, in what look like syngenetic green bedding-plane disseminations, mainly of malachite, which may extend to a considerable distance from the mineralised faults, but are associated with them. Some faults are richly mineralised within this series, galena being a major constituent in some; an isotope date of 210 ± 60 million years for galena from the Engine Vein fault (Moorbath, 1962) is now considered doubtful. These Triassic beds are exposed over a wide area in the Welsh borderland counties, including Salop (Shropshire), Staffordshire and Worcestershire as well as Cheshire. Similar mineralisations on a smaller scale occur at many scattered places throughout this area, for example at Clive, Grinshill, Hawkstone Park, Pim Hill and West Felton in Salop, and Peckforton in Cheshire (Holmes *et al.*, 1983; Naylor *et al.*, 1989).

The major mines and mineralised localities at Alderley Edge are named on the map (Fig. 1), and a full list with grid references is given in Table I.

The mechanism of the mineralisation is controversial, having been described as syngenetic (e.g. Rudler, 1905; Dewey and Eastwood, 1925), or mixed (Mohr, 1964; Ixer and Vaughan, 1982), but is generally regarded nowadays as epigenetic (e.g. Taylor *et al.*, 1963; Warrington, 1965) and originating from saline basin brines (Naylor *et al.*, 1989).

The mines have been described in a number of publications, covering mainly the geological and mining aspects of the area, with mineral species usually being dealt with as lists (Higgs, 1858; Greenwell, 1864; Hull, 1864; Hull and Green, 1866; Dewey and Eastwood, 1925; Paxton, 1951; Eagar and Broadhurst, 1959; Jones, 1961; Taylor *et al.*, 1963; Mohr, 1964; Warrington, 1965; Thompson, 1970; Carlon, 1979; Warrington, 1981; Thompson, 1991). The only systematic mineralogy, albeit confined to the primary sulphides, is that of Ixer and Vaughan (1982).

MINERALS

Despite their fame, these mines are not known for

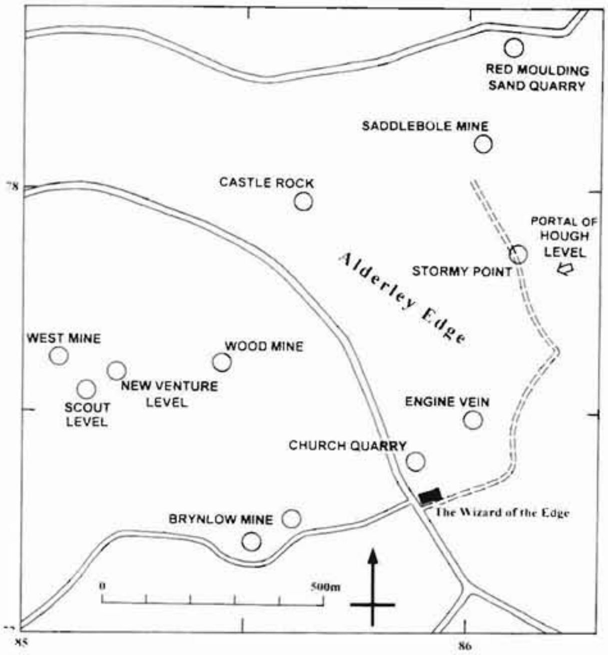

FIGURE 1. Outline map showing the main mineral localities at Alderley Edge. Mottram St Andrew mine is 1.25 km east of Saddlebole mine.

TABLE I. List of mines and other mineral localities, with National Grid References in square SJ.

Brynlow (Brinlow) mine	855 772 & 856 773
Castle Rock	856 779
Church quarry	859 774
Doc mine, Stormy Point	861 778
Engine Vein (NW–SE)	860 775
Hough level	from 862 778 to near 852 775
Kirkleyditch quarry, Mottram (now built over)	875 784
Mottram St Andrew mine	873 783
New Venture mine and level	852 776
Opencast mine	861 777 or 855 773
Pillar mine, Stormy Point	861 778
Red Moulding Sand quarry	861 783
Saddlebole mine, Stormy Point	860 782
Scout level	runs west from 852 775
Stormy Point	86 77
Twin shafts, Stormy Point	860 779
West mine	851 776
The Wizard of the Edge (hotel)	859 773
Wood mine	855 776
Yard mine, Alderley Edge	unplaced, 85 77 or 86 77?

spectacular mineral specimens, for although many colourful, attractive and rare species occur, they are mostly found as fine-grained disseminations and tiny sub-millimetric crystals between the grains of sandstones, and well-crystallised hand specimens are quite exceptional. Detrital minerals (the normal sedimentary rock constituents) have been excluded from this account.

A significant problem when listing minerals from this area is that a number of species have been reported in the past on the basis of dubious and unconfirmed identifications. An example is the assumed presence of copper arsenates in impregnations on the basis of colour and chemical detection of copper and arsenic in the *bulk specimen*. Similarly, langite and copper-stained gypsum on museum specimens have been labelled 'caledonite' from visual identifications. Prior to any analysis, *pure* material must be isolated from the specimen, and this is often difficult to do when dealing with impregnations such as those in this area.

Sulphide ore minerals are almost completely confined to the fault-veins and, although galena is common, especially in Engine Vein, other sulphides are much less so, even those of copper, iron and zinc, partly through having been oxidised. The ore mineralogy has been studied in detail by Ixer and Vaughan (1982), and its minerals are believed to be the precursors to the numerous secondary minerals. Supergene minerals, in fact, dominate the mineralogy, and include a number of rare species.

Some specimens from the area, when stored, are peculiarly prone to develop dark mossy-looking corrosion growths on highly specific patches. Their formation may be connected with the presence of native sulphur with the galena, and is probably accelerated by damp conditions. Some of the growths look like covelline and may well be so, as covelline has been detected among growths of similar appearance on specimens from Red Gill, Cumbria (M. Wirth, *personal communication*).

THE MOTTRAMITE QUESTION

The only species for which the area has been claimed to provide the type locality is mottramite, $PbCuVO_4(OH)$ (Roscoe, 1876), which is named after Mottram St Andrew, and the type material of which may have been collected from the processing plant dumps there. This plant, however, processed ore from other localities, too, including Pim (Harmer) Hill (SJ 486 201), 8.5 km north of Shrewsbury, Salop, and Kingsbury (1956) pointed out that the sandstone matrix of the type material is more like that from Pim Hill than that from Mottram or Alderley Edge. Sir Arthur Russell had found similar material *in situ* at Pim Hill (Bannister, 1933).

More recently, arsenatian mottramite in the form of thick dark brown botryoidal crusts on sandstone has been found *in situ* underground at Mottram. This appears to be the only mottramite available now that can be assigned with certainty to Mottram St Andrew. It does not resemble the type material in mineral appearance, matrix or composition (e.g. specimens RSWB 91–11, GR 82–3 and 82–4, collected by P. Ward and passed on by R.W. Barstow and N. Hubbard; and similar specimens in the NHM). The site of this find, in the northern part of the Mottram mine, is described by Ward (1982), though when his article was written, vanadium minerals had not yet been detected there.

Roscoe's papers (1868, 1876) on vanadium minerals are somewhat ambiguous; in the 1868 paper he suggested vanadinite as the source of the vanadium "in some of the copper bearing beds of the Lower Keuper Sandstone of the Trias, worked at Alderley Edge and Mottram St. Andrew"; in the 1876 paper he describes the source of the vanadium as a new mineral, which he named mottramite, forming an "incrustation on Keuper Sandstone found at Alderley Edge and at Mottram ... and at other localities". The author has a specimen (RSWB 65-46) from an old bottle labelled 'Vanadium ore from Alderley Edge' found in the Chemistry Department at Manchester, where Roscoe was Professor of Chemistry, which displays a thin crust of olive-green mottramite on a pale sandstone matrix resembling that from Pim Hill, and which is probably part of Roscoe's original (i.e. cotype) material. So *is* Mottram the type locality, or merely the name locality?

The infrared spectra of these mottramites (Fig. 2) fall into two groups: those of Roscoe's material (off RSWB 65–46) and of a sample from Pim Hill (off GR 58–72, donated by A.W.G. Kingsbury) are virtually identical with each other, and agree with the published spectrum of mottramite (Von Rahden and Dicks, 1967); those of the recent material from Mottram (off GR 82–3 and RSWB 91–11) are distinctly different, and agree with spectra of samples from elsewhere known to be intermediates between mottramite and the arsenate analogue, α-duftite (R.S.W. Braithwaite and G. Ryback, *unpublished work*). Arsenate and vanadate absorptions appear in the same regions of the spectrum, and are difficult to distinguish from each other. However, the strong shoulder near 767 cm $^{-1}$ on the side of the V-O stretching absorption at 723 cm $^{-1}$ in spectrum 2 (Fig. 2) can be assigned to As-O stretching, and corresponds to the strong absorption near 760 cm $^{-1}$ in spectra of α-duftite.

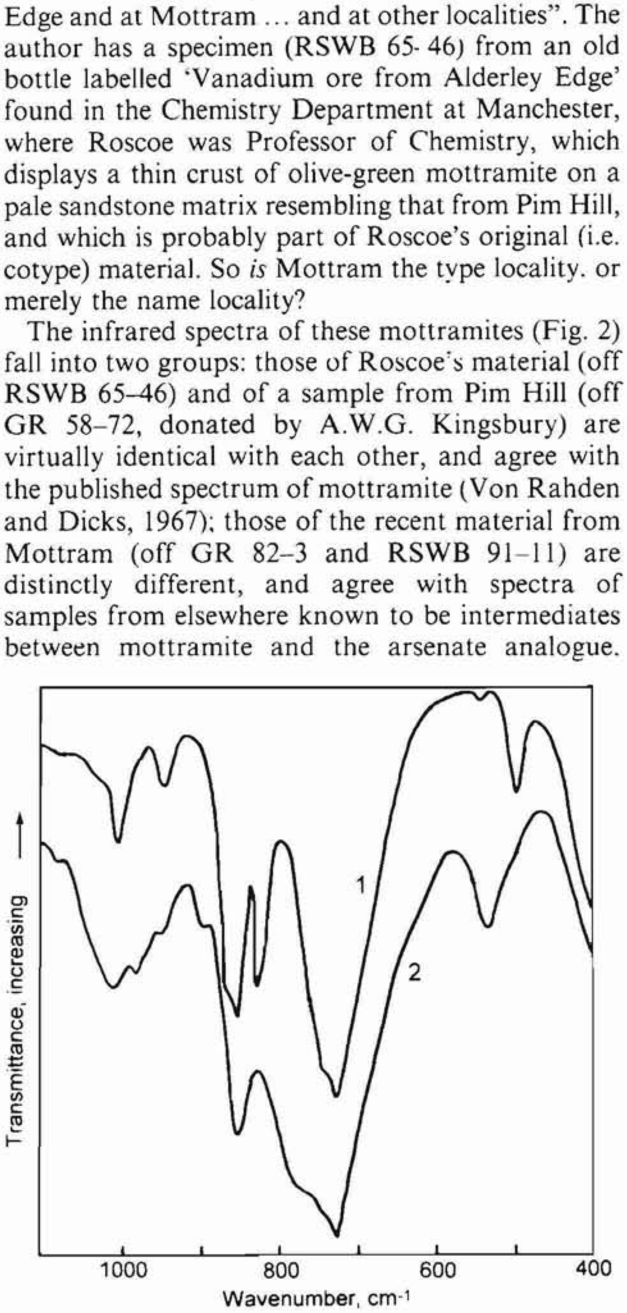

FIGURE 2. Infrared spectra of mottramites. **1:** Dark olive-green crust off RSWB 65–46, from Roscoe's laboratory. **2:** Dark brown crust off RSWB 91–11, collected *in situ* from Mottram mine. (Fourier Transform spectra, measured on Nujol mulls between KBr plates).

Analytical data are summarised in Table II. Roscoe's chemical analysis of his mottramite (analysis 2) indicates the presence of a small amount of zinc, but only traces of arsenate (Roscoe, 1876). More recent chemical and microprobe analyses of mottramites from Pim Hill (analyses 5–6) and of the material from Roscoe's laboratory (analysis 4) are very similar, with little arsenate, and some zinc. An EDX analysis of the recent material from Mottram (analysis 7) shows appreciable arsenate to be present, with a corresponding reduction in the proportion of vanadate, and negligible zinc: this confirms its identification as arsenatian mottramite by infrared spectrometry.

Seven XRD patterns at the NHM, three early ones of samples off BM 52314 from Roscoe's 'Mottram' material (presented by Roscoe in 1879), the others from 'Pim Hill', 'Harmer Hill', and 'Shrewsbury', are all listed as 'mottramite' as distinct from 'near mottramite' or 'mottramite-duftite'. A ticket with specimen BM 52314 indicates that a qualitative analysis in 1929 of a sample of the crust found Pb, Cu and V to be present, and Cr and phosphate to be absent, and the sample was concluded to be 'psittacinite' (i.e. mottramite, see below).

Thus Roscoe's mottramites from 'Mottram' are very similar to those from Pim Hill in terms of physical appearance, matrix, infrared spectra and composition, whereas the material recently found *in situ* at Mottram is clearly different in all these respects. The evidence so far favours Kingsbury's (1958) suggestion that Roscoe's type material is more likely to have come from Pim Hill than from Mottram St Andrew.

The argument is further complicated by the fact that, although Roscoe's material is generally accorded type status, the same mineral had been reported earlier (and even analysed reasonably well) from several foreign localities, and published under various names, e.g. 'vanadate of lead and copper' in 1848, renamed 'chileite' in 1853; 'psittacinite' analysed in 1876 (published one month after Roscoe's); and, less well characterised, 'cuprovanadinite' in 1869 and the later 'vesbine' in 1879 (for details, analyses and references see Dana, 1892). All were subsequently shown to be identical with mottramite (e.g. Bannister, 1933). Note that Greenwood (1919) reports psittacinite as well as mottramite from the Alderley Edge area.

In his 1876 paper Roscoe describes another new mineral, a vanadium mica subsequently named

TABLE II. Analyses of mottramites, recalculated to wt % elements.

	1	2	3	4	5	6	7
Pb	51.5	47.3	52.1	50.9	50.5	Major	Major
Cu	15.8	15.3	16.8	15.8	15.4	Major	Major
V	12.7	9.6	10.6	13.8	12.1	Major	Major*
H_2O	2.24	3.6	4.0	n.d.	2.2	n.d.	n.d.
As	–	Trace	–	**	Nil	n.f.	Minor
Zn	–	Minor	–	0.14	0.56	Trace	n.f.
P	–	n.d.	–	n.d.	–	n.f.	n.f.

n.d. = not determined. n.f. = not found.
* = major, but less than in analysis 6.
** = a small amount of As detected in analysis 4. not quantifiable with the equipment available.
1. Theoretical for $PbCuVO_4(OH)$.
2. Roscoe (1876). average of two analyses, as determined (other minor constituents omitted).
3. Roscoe (1876), analysis 2 after deduction of impurities.
4. Microprobe analysis by D. Plant of sample off RSWB 65–46 (specimen from Roscoe's laboratory).
5. Mottramite, Pim Hill, Salop. Chemical analysis by M.H. Hey in Bannister (1933), after deducting Si and Fe attributed to admixed sandstone.
6. Mottramite, Pim Hill, Salop; off GR 58–72 ex A.W.G. Kingsbury. EDX analysis by R.N. Pillinger.
7. Mottramite, Mottram St Andrew; off GR 82–3, ex R.W. Barstow. EDX analysis by R.N. Pillinger.

roscoelite, from California, with no suggestion that it occurred in Britain. Nevertheless roscoelite has appeared in lists of Mottram and Alderley Edge minerals!

LIST OF MINERALS

The following is a catalogue of minerals that occur, or have been claimed to occur, at Alderley Edge and Mottram St Andrew. In each case, only the earliest of the references found is normally quoted, in the interests of simplicity. The following abbreviations are used in this section:

AE	= From unspecified localities at Alderley Edge.
M	= From Mottram St Andrew.
EV	= From Engine Vein, Alderley Edge.
SP	= From unspecified localities in the Stormy Point area, Alderley Edge.
XRD	= Powder X-ray diffraction.
IR	= Infrared spectrometry.
EDX	= Microprobe analysis by energy-dispersive X-ray spectroscopy.
NHM	= Natural History Museum, formerly British Museum (Natural History).
(RSWB, *year*)	= Identified by the author in the year specified. and usually quoted in various publications.

ANGLESITE, $PbSO_4$ (Rare)

First reported by Eagar and Broadhurst (1959) from EV, where it is found as colourless elongated blades (RSWB, 1960): from Wood mine. with wulfenite (RSWB, 1972).

ANTLERITE, $Cu_3SO_4(OH)_4$ (Very rare)

A greenish crust from a baryte gozzan near the surface at the north-west end of the Engine Vein rift, associated with posnjakite and langite (RSWB, 1967) was shown to contain antlerite by XRD at the NHM and subsequently also by IR.

ASBOLANE, $(Co,Ni)_{1-y}(MnO_2)_{2-x}(OH)_{2-2y-2x}.nH_2O$ (Common)

Black, sooty-looking patches of manganese oxides, frequently carrying cobalt, etc., occur sporadically throughout the mineralised parts of the area. and are said to be particularly abundant in an old level recently excavated near The Wizard of the Edge. Reported from AE, M, EV, SP, New Venture mine, Opencast mine, West mine, and Wood mine. First recorded from AE in 1811 by Sowerby as 'black oxide of cobalt', by Holland as 'cobalt ore', and by Farey as 'cobalt'; as 'asbolane' from AE by Greg and Lettsom (1858); and from M as 'cobalt ore' by Hull (1864) and as 'asbolite' by Warrington (1965). A qualitative EDX analysis of a black shiny botryoidal sample from M, accompanying arsenatian mottramite, indicates the presence of major Mn and Co, and minor Fe, Cu, Pb, Ba, and possibly Ni (G. Ryback, *personal communication*).

AURICHALCITE, $(Zn,Cu)_5(CO_3)_2(OH)_6$ (Very rare)

Tiny amounts of typical pearly blue-green radiating blades, containing zinc, copper and carbonate were found, with hemimorphite, in Wood mine (RSWB, 1974).

AZURITE, $Cu_3(CO_3)_2(OH)_2$ (Common)

Deep blue impregnations of azurite, and occasionally small crystals, less than 1 mm long and often in rounded aggregates, are common in the mineralised parts of the area. Azurite is associated with malachite, and can be seen in outcrops. Recorded from AE (Greg and Lettsom, 1858); M (Hull, 1864); EV and SP (Eagar and Broadhurst, 1959); Doc mine (RSWB, 1962); New Venture mine and West mine (Warrington, 1965); Opencast mine (Thompson, 1970); and Wood mine (RSWB, 1960; Mohr, 1964). Blue nodules up to 1 cm across occur in a marl band at EV (Dewey and Eastwood, 1925), and are rich in azurite (see under chrysocolla).

BARYTE, $BaSO_4$ (Common)

Ubiquitous throughout the area, as colourless to pinkish (iron-stained) vein fillings and small platy crystals: recorded from AE, M, EV, SP, Castle Rock, Church quarry, Doc mine, New Venture mine, Opencast mine, Red Moulding Sand quarry, Twin shafts, West mine and Wood mine. The first record found is that from AE by Holland (1811); mentioned in most relevant publications.

BEAVERITE. $Pb(Cu,Fe^{3+},Al)_3(SO_4)_2(OH)_6$ (Rare)

A number of specimens in the NHM from AE, presented by Professor F. Hodson, have been shown to contain beaverite by XRD over the period 1966–1972 (J.G. Francis, *personal communication*).

BEUDANTITE, $PbFe^{3+}{}_3(AsO_4)(SO_4)(OH)_6$ (Very rare?)

A specimen from AE was identified by XRD at the NHM as '*near* beudantite' in 1972. Beudantite is reported by M.S. Skwarnecki in a Newsletter of the Peak District Mines Historical Society (March 1980) as a pale greenish-yellow to brownish-yellow coating on iron-stained barytic sandstone: this was collected in 1976 from SP and identified by XRD.

BITUMINOUS MINERALS

Mohr (1964) describes a 'dark carbonaceous sandstone' from SP containing high concentrations of ten different metals. Brownish-black oily stains are not uncommon on specimens from Doc mine.

BORNITE, Cu_5FeS_4 (Common)

This was first reported from AE by Mohr (1964). The Manchester Museum holds specimens labelled 'bornite with galena' without evidence of identification. Listed from EV and SP by Warrington (1965) and Thompson (1970). Confirmed from AE by Ixer and Vaughan (1982) as an alteration product of chalcopyrite.

BRAVOITE (nickeloan pyrite), $(Fe,Ni)S_2$ (Uncommon?)

Bravoite occurs with other sulphides at EV, SP and Wood mine, sometimes in crystals up to 0.08 mm across (Ixer, 1978; Ixer and Vaughan, 1982).

BROCHANTITE, $Cu_4SO_4(OH)_6$ (Uncommon)

This was first identified, by IR (RSWB, 1964), in green crusts on material collected from EV by Don Hyde: good crystals, up to 0.2 mm in size, were found there subsequently. Minute crystals were found with wulfenite in Wood mine (RSWB, 1972), and rich impregnations of good bright green crystals were found by the author and Nigel Hoppe in Doc mine in 1979 (Fig. 3).

CALCITE, $CaCO_3$ (Rare?)

Noted from a sandstone bed at AE by Hull (1864) and from EV by Dewey and Eastwood (1925).

CALEDONITE, $Pb_5Cu_2(CO_3)(SO_4)_3(OH)_6$ (Doubtful)

Caledonite was reported from EV by Eagar and Broadhurst (1959). Two supposed caledonite specimens in Manchester Museum, presented by W.D.

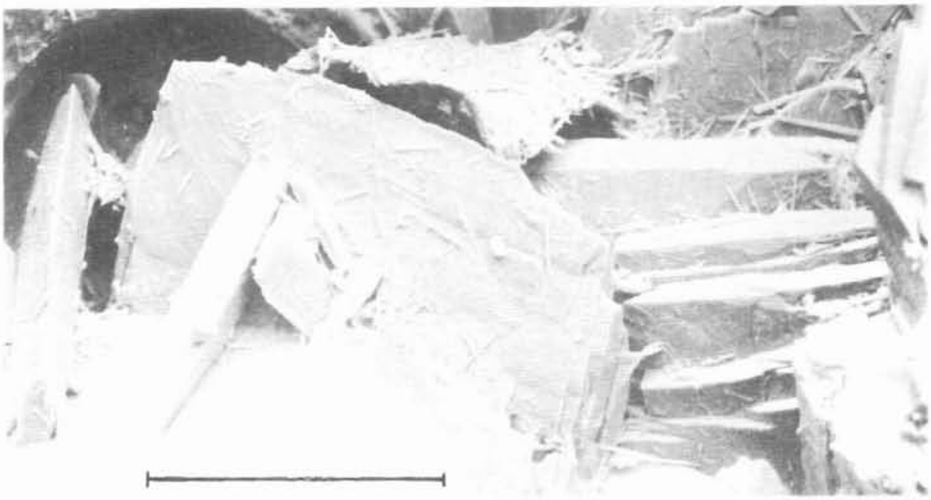

FIGURE 3. Brochantite crystals on and between rounded sandstone grains; the needles are malachite. Doc mine. Stormy Point. (RSWB 79–123). SEM photograph by D. Plant. Scale bar 0.1 mm.

Prince, were examined by the author in 1967: N.2499 has light blue, very soft, inhomogeneous impregnations with gypsum, and so is probably copper-stained gypsum; N.2503 has light blue crystals of langite, associated with linarite and anglesite.

CERUSSITE, $PbCO_3$ (Common)

First recorded from AE as 'white ore' (Farey, 1811), and from M as 'carbonate of lead' (Hull, 1864). Cerussite occurs at EV (Eagar and Broadhurst, 1959), occasionally in good crystals of various habits, including tabular, quartz-like prismatic, and silky rod-like, occasionally up to 7 mm long (RSWB, 1960); also at SP (Mohr, 1964). Pea-sized nodules of 'carbonate of lead' were found at the mouth of New Venture level (Dewey and Eastwood, 1925). From Opencast mine in conglomerate (Thompson, 1970). Listed from West mine (Eagar and Broadhurst, 1959) and Wood mine (Mohr, 1964).

CHALCOCITE, Cu_2S (Uncommon)

This was first reported from AE by Greenwood (1919); it is listed from EV by Warrington (1965). Chalcocite has been confirmed at Wood mine (R.A. Ixer, *personal communication*, 1971), but djurleite is more common in the area (Ixer and Vaughan, 1982).

CHALCOPYRITE, $CuFeS_2$ (Common)

Reported from AE as 'towanite' by Hall (1868), from EV by Eagar and Broadhurst (1959), from SP by Warrington (1965), from West mine (RSWB, 1975), and from Wood mine (Ixer and Vaughan, 1982).

CHRYSOCOLLA, $(Cu,Al)_2H_2Si_2O_5(OH)_4.nH_2O$ (Common)

Reported as 'silicate of copper' in rounded azuritic nodules from EV by Dewey and Eastwood (1925); these blue nodules, up to 1 cm across and embedded in a marl band, were examined by Chesworth (1960), and found to contain only silica, azurite and malachite. Green crusts from EV were found to be chrysocolla by IR (RSWB, 1960). Chrysocolla is listed from AE by Mohr (1964) and from SP by Warrington (1965). At one place in an underground level in Wood mine a wall is coated with a magnificent bright green rippled crust of chrysocolla, confirmed by IR (RSWB, 1960; listed by Warrington, 1965). From West mine (RSWB, 1975). It is also a common alteration product of tyrolite (see below).

COBALT MINERALS, unspecified

Farey (1811) mentions 'cobalt' from AE, and Hull (1864) mentions 'cobalt ore' from M. These and other references to cobalt ore normally denote asbolane, although other cobalt minerals also occur in the area.

COBALTITE, (Co,Ni)AsS (Unconfirmed)

A mineral similar in composition to nickeliferous cobaltite is reported from AE, EV and SP by Ixer and Vaughan (1982).

CONNELLITE, $Cu_{19}Cl_4(SO_4)(OH)_{32}.3H_2O$ (Very rare, unconfirmed)

Tiny, royal blue, silky, radiating spherules with the typical appearance of connellite were found, associated with langite, in a baryte gozzan near the surface at the NW end of the EV rift (RSWB, 1969).

COPPER, Cu (Rare)

Farey (1811), Neil (1908) and others have reported 'copper' from AE, but probably meant copper ore rather than the native metal. Beautiful arborescent native copper in clusters up to about 3 mm in size was found in a baryte gozzan at the NW end of the EV rift, with cuprite, langite and other species (RSWB, 1967; listed by Thompson, 1970; see Fig. 4).

COPPER ARSENATES, unspecified

Dewey and Eastwood (1925) quote a bulk analysis of copper ore from EV and conclude that it is a mixture of 'arseniate' and other copper compounds. Chesworth (1960) notes that a specimen in Manchester Museum was labelled 'copper arsenate' on the strength of Cu and As having been detected in it before donation. Copper arsenates, "probably olivenite and enargite", are also referred to by Warrington (1965), while Eagar and Broadhurst (1959) note "a mixture of cerussite and copper arsenate, or a mixture of arsenates" in the West mine opencast. See also under liroconite.

COPPER MINERALS, unspecified

'Copper' or 'copper ore' has been reported from the AE and M areas since the earliest publications (e.g. Farey, 1811; Holland, 1811). Malachite is the main copper ore.

COVELLINE, CuS (Common)

Found as blue films on galena, with characteristic reflection pleochroism, from EV (RSWB, 1964); confirmed by XRD at the NHM in 1971. It is common in coatings on sulphides throughout the area (Ixer and Vaughan, 1982).

CUPRITE, Cu_2O (Rare)

Listed by Thompson (1970) from EV, having been found there by P. Robinson. Beautiful crystals, including octahedra up to 0.5 mm across, were found with and on the native copper from the NW end of the EV rift (RSWB, 1967; see Fig. 5).

CYANOTRICHITE, $Cu_4Al_2SO_4(OH)_{12}.2H_2O$ (Very rare, unconfirmed)

A thin sky-blue gel from the footwall at the NW end of the EV opencast has radiating crystals in places with the appearance of cyanotrichite, and similar to it in optical properties. An infrared spec-

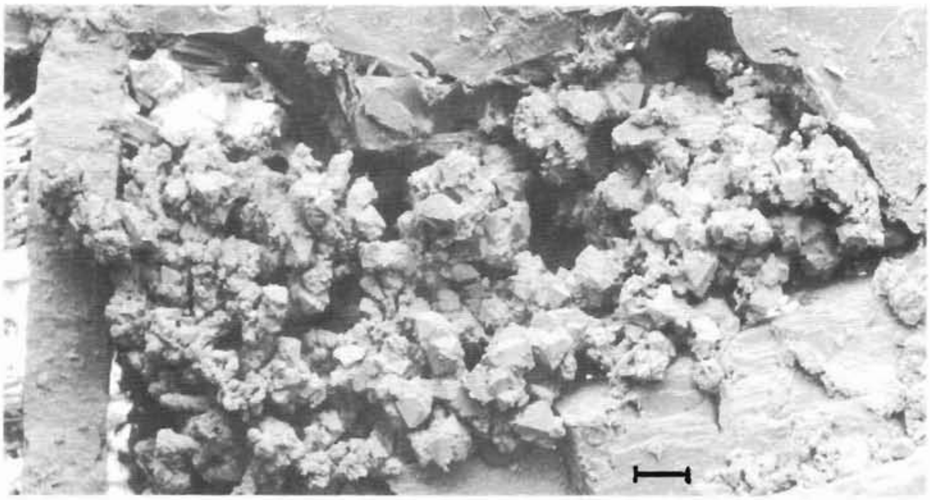

FIGURE 4. Native copper, bushy mass partly encrusted with cuprite crystals, in cavity bounded by baryte blades. Engine vein. (RSWB 67–78). SEM photograph by D. Plant. Scale bar 0.1 mm.

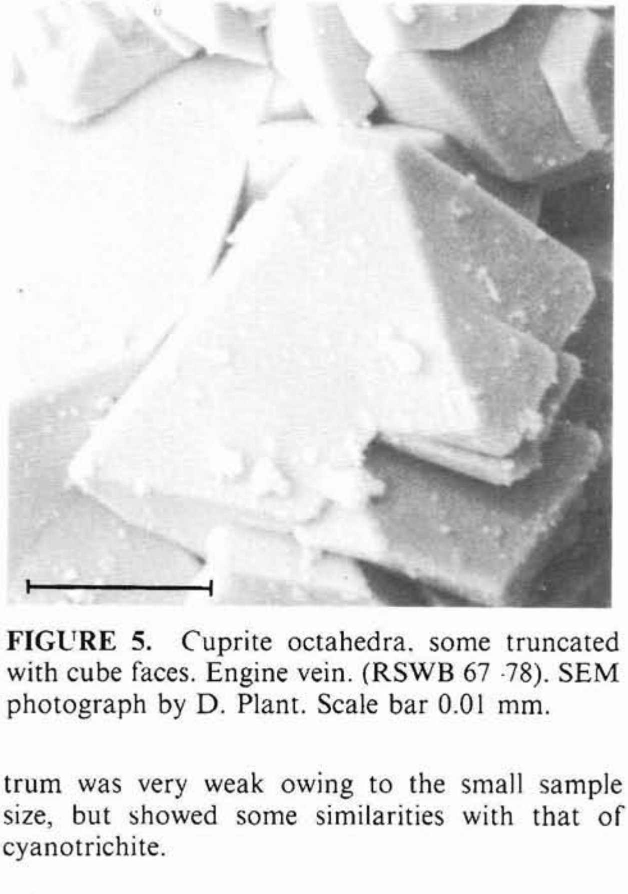

FIGURE 5. Cuprite octahedra, some truncated with cube faces. Engine vein. (RSWB 67–78). SEM photograph by D. Plant. Scale bar 0.01 mm.

trum was very weak owing to the small sample size, but showed some similarities with that of cyanotrichite.

DJURLEITE, $Cu_{31}S_{16}$ (Common)

This is the main secondary copper sulphide at AE, chalcocite being minor (Ixer and Vaughan, 1982).

ENARGITE, Cu_3AsS_4 (Probable error)

AE ores are a mixture containing arsenates and other copper compounds, according to Dewey and Eastwood (1925), who report a bulk analysis. Warrington (1965) quotes this as "copper arsenates, probably olivenite and enargite". (Enargite is not even an arsenate!)

ERYTHRITE, $Co_3(AsO_4)_2.8H_2O$ (Very rare)

First suggested by Sowerby (1811) as 'cobalt bloom of a crimson cast', betraying 'black oxide of cobalt'. 'Cobalt bloom' was noted from AE by Taylor *et al.* (1963) and erythrite was specifically listed by Mohr (1964). Specimens of erythrite from Wood mine were presented to the NHM by W.D. Prince in 1958 (e.g. BM 1958,759), and it can be found in the workings as small radiating aggregates of pink blades. Listed from EV and SP by Warrington (1965) and Thompson (1970).

GALENA, PbS (Common)

'Lead' or 'lead ore', presumably galena, was reported from AE by Farey (1811) and Holland (1811). Galena was listed from M by Warrington (1965), and first reported from EV and West mine by Eagar and Broadhurst (1959), from SP and New Venture mine by Warrington (1965), from Opencast mine by Thompson (1970) and from Wood mine by Mohr (1964). A specimen in the former Geological Museum collection (now in the NHM) is labelled as from Yard mine.

GERSDORFFITE, NiAsS (Uncommon?)

Optically zoned gersdorffite with variable contents of Ni, Co and Fe, and enclosing bravoite, occurs at AE (EV and SP assumed) (Ixer and Vaughan, 1982).

GOETHITE, FeO(OH)

Only present as limonite, q.v.

GYPSUM, $CaSO_4.2H_2O$ (Common)

Efflorescences and coatings of gypsum are not uncommon at AE, and were noted by Mohr (1964). Listed from EV (Thompson, 1970), and identified from EV by IR (RSWB, 1967).

HEMIMORPHITE, $Zn_4Si_2O_7(OH)_2.H_2O$ (Very rare)

Small radiating sheaves of blades collected in 1965 from EV were confirmed as hemimorphite by IR (RSWB. 1972); colourless sheaves were also found in Wood mine, with aurichalcite (RSWB, 1974).

HETEROGENITE, $CoO(OH)$ (Unconfirmed)

A single specimen of black botryoidal heterogenite on sandstone, collected in 1963 from AE by A.W.G. Kingsbury, is in the NHM and has been mentioned recently (Ryback and Tandy, 1992). No similar material has been reported since, and there is some doubt about the locality.

IDAITE, Cu_3FeS_4(?) (Rare)

At AE chalcopyrite sometimes alters to "a brown anisotropic mineral with properties close to those of 'idaite'" (Ixer and Vaughan, 1982).

JAROSITE, $KFe^{3+}_3(SO_4)_2(OH)_6$ (Uncommon)

Yellow to brownish microcrystalline to powdery jarosite was found in conglomerate associated with galena from the EV rift, and identified by IR (RSWB. 1971). Probably widespread in admixture with other minerals.

LANGITE, $Cu_4SO_4(OH)_6.2H_2O$ (Rare)

Langite sometimes accompanies the linarite from EV, and has been confused with caledonite; it has been confirmed by IR and by XRD. A few crystals, remarkably fine for the species, let alone for this locality, were found as deep blue-green, transparent, equant pseudohexagonal twins and twin-clusters of blades up to 3 mm long, in baryte gozzan near ground level at the NW end of the EV rift, accompanied by other species (RSWB, 1967).

LAVENDULAN, $NaCaCu_5(AsO_4)_4Cl.5H_2O$ (Very rare, unconfirmed)

Traces of microscopic needles in clusters, similar in appearance and associations to lavendulan, were found with erythrite in Wood mine in 1963 (RSWB). It requires confirmation.

LEADHILLITE, $Pb_4(SO_4)(CO_3)_2(OH)_2$ (Very rare)

Colourless to very pale greenish, pearly, hexagonal short prismatic crystals up to 0.4 mm across, often in complex aggregates, were found with cerussite, anglesite and pyromorphite in altered galena at EV (RSWB, 1964); confirmed by IR.

LIBETHENITE, $Cu_2PO_4(OH)$ (Doubtful)

'Phosphate of copper' was reported from EV by Berruti (in Hull and Green, 1866), and Dewey and Eastwood (1925) quote an analysis of bulk ore from AE, concluding that it is a mixture containing, among other things, arsenate and phosphates of copper. Greenwood (1919) was the first to list libethenite (one of the many known copper phosphates), and this has been copied by later authors. The occurrence must be considered doubtful until confirmed.

LIMONITE (Common)

Ubiquitous throughout the mineralised parts of the area, usually in the gozzan resulting from the oxidation of iron-bearing sulphides. Seemingly first reported as 'oxide of iron' by Hull (1864) and as 'limonite' by Mohr (1964).

LINARITE, $PbCuSO_4(OH)_2$ (Rare)

First reported by Eagar and Broadhurst (1959) from EV, and from Wood mine by Thompson (1970). Royal blue blades up to 0.5 mm long, and occasionally tabular crystals, have been found by the author from 1960 onwards, associated with altering galena, cerussite, anglesite, pyromorphite, brochantite and langite, from EV and also from Wood mine.

LIROCONITE, $Cu_2AlAsO_4(OH)_4.4H_2O$ (Doubtful)

A specimen from AE, presented by A. Russell, used to be on display in the Economic Minerals gallery in the Geological Museum, London, labelled "Conglomerate impregnated with azurite and malachite. Arsenic is probably present as liroconite"; the corresponding catalogue card (11501) states "sandstone impregnated with azurite and arsenates of copper", without mentioning liroconite, or any analytical evidence. This specimen is the source of the liroconite said to be from EV given in Warrington (1965). Even if copper arsenates are present, liroconite is only one of many possibilities.

MALACHITE, $Cu_2CO_3(OH)_2$ (Common)

Ubiquitous throughout the mineralised parts of the area; green disseminations, mainly following bedding planes, are common in outcrops, and normally consist of malachite. It is the main copper ore. First specified from AE by Greg and Lettsom (1858), and from M as late as 1965 (Warrington), though Hull (1864) notes 'green carbonate of copper' there. Eagar and Broadhurst (1959) report it from EV and West mine, Mohr (1964) from SP and Wood mine, Warrington (1965) also from New Venture mine, and Thompson (1970) from Opencast mine. The author has confirmed it additionally from specific localities at SP: Doc and Pillar mines (1962), Twin shafts (1971). The best specimen material comes from cavities in EV (see Fig. 3); even disseminations can be attractive, especially when azurite is also present.

MANGANESE MINERALS, unspecified

The first records of 'manganese' from AE seem to be those of Farey (1811) and Sowerby (1811). See also asbolane and wad.

MARCASITE, FeS_2 (Very rare)

Traces were found with other sulphides at EV and SP (Ixer and Vaughan, 1982).

MASSICOT, PbO (Doubtful)

Reported by Greenwood (1919) from AE, and the locality specified as EV by Thompson (1970). Must be considered as doubtful until confirmed.

MELANTERITE. var. pisanite, $(Fe,Cu)SO_4.7H_2O$ (Uncommon)
Found as blue-green efflorescences on old workings at EV (Eagar and Broadhurst, 1959).

MIMETITE, $Pb_5(AsO_4,PO_4)_3Cl$
See below under pyromorphite.

MINIUM, Pb_3O_4 (Very rare)
Recorded from EV by Thompson (1970). Specimens from here are preserved in the Arthur Russell Collection in the NHM.

MOTTRAMITE, $PbCu(VO_4,AsO_4)(OH)$ (Rare)
The occurrence of mottramite in the area was discussed in an earlier section.

OLIVENITE, $Cu_2AsO_4(OH)$ (Very rare)
Recorded from AE by Warrington (1965), who refers to Dewey and Eastwood's (1925) report of mixtures containing copper arsenate. Listed from EV and Wood mine by Thompson (1970). Specimens of olivenite from Wood mine. associated with erythrite and tyrolite, were presented to the NHM in 1958 by W.D. Prince.

OSARIZAWAITE, $PbCuAl_2(SO_4)_2(OH)_6$ (Very rare?)
This has been identified by XRD at the NHM in 1970 on an enquiry specimen from AE, consisting of a yellowish-green crust on, and impregnations in, sandstone.

PARARAMMELSBERGITE, $(Ni,Co)As_2$ (Rare?)
A nickel diarsenide with approx. 5 wt % Co, and with the optical properties of pararammelsbergite, was detected as inclusions in the probable nickeliferous cobaltite from AE (EV and SP assumed from the context) (Ixer and Vaughan, 1982).

PHARMACOSIDERITE,
$KFe^{3+}{}_4(AsO_4)_3(OH)_4.6\text{–}7H_2O$ (Very rare)
Orange-brown cubes up to 0.2 mm across (confirmed by XRD at the NHM) were found near surface level at the NW end of the EV rift. in a baryte gozzan with antlerite, langite, posnjakite, native copper and cuprite (RSWB. 1967).

PLANCHEITE, $Cu_8Si_8O_{22}(OH)_4.H_2O$ (Very rare)
A single, matrix-free, sky-blue, compact radiating broken spherule of plancheite several mm across, collected in 1963 from AE by A.W.G. Kingsbury, is in the NHM. A similar but less compact matrix-free specimen, 3 mm x 3 mm x 2 mm in size, was collected by Stuart Clark from the SE end of the EV rift in 1976 and was presented to the author (specimen RSWB 76–149).

POSNJAKITE, $Cu_4SO_4(OH)_6.H_2O$ (Very rare)
Thin blue crusts containing posnjakite (identified by XRD at the NHM), antlerite, langite, pharmacosiderite, copper and cuprite, were found in a baryte gozzan near surface level at the NW end of the EV rift (RSWB, 1967).

PYRITE, FeS_2 (Uncommon?)
Recorded from AE (Mohr, 1964), EV and SP (Warrington, 1965), and from Wood mine (Ixer and Vaughan, 1982). See also bravoite.

PYROMORPHITE, $Pb_5(PO_4,AsO_4)_3Cl$ (Common)
First reported from AE in Rudler (1905), then by Chesworth (1960) and Mohr (1964); from EV by Mohr (1964); from SP and M by Warrington (1965). The author and George Ryback have studied the IR spectra of many specimens from the area from 1960 onwards, and have found that a wide range of compositions in the pyromorphite-mimetite series occurs, from virtually arsenate-free pyromorphite (e.g. RSWB 71–60 from Doc mine) to phosphatian mimetite with a P:As ratio near 1:3 (RSWB 60–77 from EV, associated with wulfenite), with wide variations within individual localities. As yet no end-member or near end-member mimetite has been detected. No correlation between composition and appearance, including colour, is evident. Thompson (1970) mis-quotes the author by reporting 'As pyromorphite' from Wood mine instead of EV.

A wide range of appearance is found. in colour from bright green to yellowish to colourless, and in habit from short prismatic crystals to needles to off-white cauliflower-like masses to smooth rounded knobbly crusts. These last are sometimes grey-green, and then superficially resemble scorodite.

Material giving IR spectra similar to those of calcian pyromorphite was found in Wood mine. Arsenate-free, calcian pyromorphite also forms thin white shells around smooth spherules of yellow phosphatian and probably calcian mimetite from M (the same collecting site as for the arsenatian mottramite already discussed).

SCORODITE, $FeAsO_4.2H_2O$ (Unconfirmed)
Carlon (1979) lists scorodite from EV, but the occurrence requires confirmation.

SIDERITE, $FeCO_3$ (Unconfirmed)
Thompson (1970) lists 'sparry iron ore', presumably siderite, from EV; not confirmed.

SILVER, Ag (Very rare)
Minute dendritic crystal aggregates of silver in limonite gozzan have been found at EV (J.R. Knight, *personal communication*. 1971).

SMITHSONITE, $ZnCO_3$ (Very rare)
Reported among alteration products of the AE sulphides by Ixer and Vaughan (1982).

SPHALERITE, ZnS (Uncommon)

Sphalerite is not common in the area. Reported from AE, EV (Dewey and Eastwood, 1925) and SP (Warrington, 1965). The occurrence of sphalerite is discussed by Ixer and Vaughan (1982).

SPIONKOPITE, $Cu_{39}S_{28}$ (Rare?)

This was reported as 'blaubleibender covelline' from AE (Ixer and Vaughan, 1982).

SULPHUR, S_8 (Common?)

Very pale yellow, small rounded crystals of native sulphur are not uncommon in partly oxidised galena at EV (RSWB, 1961). When powdered samples of fine-grained. compact massive galena from EV were extracted with hot acetone or cold carbon disulphide, the filtered solution on evaporation deposited sulphur amounting to 1.8 wt % of the original sample (G. Ryback, *personal communication*). Of scientific interest as an intermediate oxidation state of sulphur between those in galena and in anglesite.

TETRAHEDRITE, $(Cu,Fe)_{12}Sb_4S_{13}$ (Rare)

Tetrahedrite with a high silver content (~14 wt %) and significant zinc (~8%) forms microscopic inclusions in galena at EV and SP (Ixer and Vaughan, 1982).

TYROLITE, sulphatian,
$CaCu_5(AsO_4)_2(SO_4,CO_3)(OH)_4.6H_2O$ (Very rare)

Specimens from Wood mine containing tyrolite (checked by XRD on material off BM 1958,759) were presented to the NHM in 1958 by W.D. Prince. Specimens collected by the author from there from 1967 onwards (e.g. RSWB 67–81 and 74–130) gave IR spectra similar to those of tyrolite from Brixlegg, Tyrol. Austria. and displaying absorption at 1120, 1088 and 1032 cm^{-1} ascribed to the presence of $(SO_4)^{2-}$, with only weak absorption near 1400 cm^{-1} due to $(CO_3)^{2-}$. Some of the tyrolite is altered or partly altered to an amorphous copper silicate, presumably chrysocolla (see Fig. 6). One small specimen was collected by the author in West mine in 1981.

VANADINITE, $Pb_5(VO_4)_3Cl$ (Doubtful)

The validity of the vanadinite listed among "specimens found while mapping" at AE (Chesworth, 1960). and of the 'vanadinite or vanadiferous sandstone (Dr. H.G. Harwood)' from West mine (Thompson, 1970), cannot be judged in the absence of any evidence of identification. Mohr (1964) failed to find any vanadium minerals at AE "despite many protracted searches". Roscoe's (1868) initial suggestion that vanadinite is probably the source of the vanadium at Mottram (and AE?) remains the only first-hand record from there.

WAD

Black sooty impregnations of manganese oxides are common throughout the mineralised parts of the area. At least some are cobaltiferous (see asbolane). Probably the 'manganese' from AE of Farey (1811) and Sowerby (1811), and the 'black oxide of manganese' from M of Hull (1864). Mohr (1964) refers to 'pyrolusite (wad)' from AE. Reported from AE. M EV, SP. Opencast mine. West mine. Wood mine.

FIGURE 6. Tyrolite, a fan of blades, largely pseudomorphosed by copper silicate. Wood mine. (RSWB 73-74). SEM photograph by D. Plant. Scale bar 0.1 mm.

WITHERITE, $BaCO_3$ (Doubtful)

Recorded as barium carbonate from AE by Greenwood (1919) on the basis of the detection of a trace of carbonate in one of a number of analyses of baryte-containing *strata*! Listed from EV by Warrington (1965).

WULFENITE, $PbMoO_4$ (Very rare)

First found in the EV rift as tiny yellow tabular crystals, sometimes associated with arsenatian pyromorphite (RSWB, 1965); confirmed by XRD at the NHM. Subsequently found in Wood mine. as tiny bipyramidal orange-yellow crystals (RSWB, 1972), and as tiny orange-yellow tabular to rectangular prismatic crystals in West mine (RSWB, 1975).

ACKNOWLEDGEMENTS

The author wishes to record his thanks to Dr George Ryback for his help with this project over many years; to Mr D. Plant of the Geology Department, University of Manchester, for SEM photography and for some of the analyses; to Mr R.N. Pillinger, Shell Research Ltd. for EDX analyses; to Mr Paul Sorensen for permission to investigate West mine; and to the colleagues who have helped with field work, including Tim Greenland, Don Hyde, Jim Knight and George Ryback.

REFERENCES

Bannister, F.A. (1933). The identity of mottramite and psittacinite with cupriferous descloizite. *Mineralogical Magazine*, **23**, 376–386.

Boyd-Dawkins, W. (1875). On the stone mining tools from Alderley Edge. *Proceedings of the Literary and Philosophical Society of Manchester*, **14**, 74–79.

Boyd-Dawkins, W. (1876). On the stone mining tools from Alderley Edge. *Journal of the Anthropological Institute of Great Britain and Ireland*, **5**, 2–5.

Carlon, C.J. (1979). *The Alderley Edge Mines*. John Sherratt & Son, Altrincham.

Chesworth, W. (1960). *Geochemical Prospecting at Alderley Edge, Cheshire*. Unpublished M.Sc. thesis. University of Manchester.

Dana, E.S. (1892). *The System of Mineralogy of James Dwight Dana*, 6th edn, pp. 791, 792, 1051. New York.

Dewey, H. and Eastwood, T. (1925). *Copper Ores of the Midlands, Wales, the Lake District and the Isle of Man*, pp. 5–18. Memoirs of the Geological Survey: Special Reports on the Mineral Resources of Great Britain, vol. **30**.

Eagar, R.M.C. and Broadhurst, F.M. (1959). Alderley Edge, Cheshire. In: *Geologists' Association Guide No. 7: The Area around Manchester*, pp. 18–22.

Farey, J. (1811). *General View of the Agriculture and Minerals of Derbyshire*, vol. **1**, pp. 252, 354. London.

Greg, R.P. and Lettsom. W.G. (1858). *Manual of the Mineralogy of Great Britain and Ireland*. London.

Greenwell, G.C. (1864). On the copper sandstone of Alderley Edge, Cheshire. *Proceedings of the South Wales Institute of Engineers*, **4**, 44–50.

Greenwood, H.W. (1919). The Trias of the Macclesfield district with notes on its relation to the adjacent Carboniferous rocks and to the Trias of the Midlands. *Proceedings of the Liverpool Geological Society*, **12**, 325–338.

Hall, T.M. (1868). *The Mineralogist's Directory*. p.31. London.

Higgs, S. (1858). Notice of the copper mines, at Alderley Edge, Cheshire. *Mining Magazine*, October 16th, 692. (Also *Transactions of the Royal Geological Society of Cornwall*, **7**. 325–326).

Holland, H. (1811). A sketch of the natural history of the Cheshire rock-salt district. *Transactions of the Geological Society of London*, **1**, 38–61.

Holmes, I., Chambers, A.D., Ixer, R.A., Turner, P. and Vaughan, D.J. (1983). Diagenetic processes and the mineralisation in the Triassic of Central England. *Mineralium Deposita*, **18**, 365–377.

Hull, E. (1864). On the copper-bearing rocks of Alderley Edge. *Geological Magazine*, **1**, 65–69.

Hull, E. and Green, A.H. (1866). *The Geology of the Country around Stockport, Macclesfield, Congleton and Leek*, pp. 37–39. Memoir of the Geological Survey.

Ixer, R.A. (1978). The distribution of bravoite and nickeliferous marcasite in central Britain. *Mineralogical Magazine*, **42**, 149–150.

Ixer. R.A. and Vaughan, D.J. (1982). The primary ore mineralogy of the Alderley Edge deposit, Cheshire. *Mineralogical Magazine*, **46**, 485–492.

Jones, W.F. (1961). *Copper Mines of Alderley Edge*. Privately published.

Kingsbury, A.W.G. (1956). Note on the origin of mottramite from Mottram St. Andrew. In: Kingsbury, A.W.G. and Hartley, J., New occurrences of vanadium minerals (mottramite, descloizite and vanadinite) in the Caldbeck area of Cumberland. *Mineralogical Magazine*, **31**, 289–295.

Mohr, P.A. (1964). On the copper-mineralised sandstones of Alderley Edge, England, and of Chercher, Ethiopia, and the problem of their genesis. An essay on red bed copper deposits. *Contributions from the Geophysical Observatory, Haile Sellassie I University, Addis Ababa*, **A 4**, 1–59.

Moorbath, S. (1962). Lead isotope abundance studies on minerals in the British Isles and their geological significance. *Philosophical Transaction of the Royal Society of London*, **A 254**. 295–360.

Naylor, H., Turner, P., Vaughan, D.J., Boyce, A.J. and Fallick, A.E. (1989). Genetic studies of red bed mineralization in the Triassic of the Cheshire Basin, northwest England. *Journal of the Geological Society*, **146**, 685–700.

Neil, J.S. (1908). *British Minerals and Where to Find Them*. Thomas Murby, London.

Paxton, R.A. (1951). Alderley Edge mines. Cheshire. *Cave Science*, **3**, 71–82.

Roscoe, H.E. (1868). Researches on vanadium. *Philosophical Transactions of the Royal Society of London*, **158**, 4–6.

Roscoe, H.E. (1876). On two new vanadium minerals. *Proceedings of the Royal Society of London*, **25**, 109–112.

Rudler, F.W. (1905). *A Handbook to a Collection of the Minerals of the British Islands, mostly selected from the Ludlam Collection in the Museum of Practical Geology*. H.M.S.O., London.

Ryback. G. and Tandy. P.C. (1992). Eighth supplementary list of British Isles minerals (English). *Mineralogical Magazine*, **56**, 261–275.

Sowerby, J. (1811). *British Mineralogy: or coloured* *figures intended to elucidate the mineralogy of Great Britain*, vol. **4**, p. 69. Published by the author, London.

Taylor, B.J., Price, R.H. and Trotter, F.M. (1963). *Geology of the Country around Stockport and Knutsford.* Memoir of the Geological Survey of G.B.

Thompson, D.B. (1970). Alderley Edge. In: *Geologists' Association Guide No. 7: The Area around Manchester*. revised 1st edn, pp. 39–51.

Thompson, D.B. (1991). Alderley Edge. In: *Geologists' Association Guide No. 7: The Area around Manchester*, 2nd edn, pp. 59–74.

Von Rahden, H.V.R. and Dicks, L.W.R. (1967). Descloizite, mottramite, and vanadinite from South West Africa: an infrared and X-ray study. *American Mineralogist*, **52**, 1067–1076.

Ward, P. (1982). Mottram mine, Cheshire. *Mineral Realm*, **2**, No. 2, 11–13.

Warrington, G. (1965). The metalliferous mining district of Alderley Edge, Cheshire. *Mercian Geologist*, **1**, 111–129.

Warrington, G. (1981). The copper mines of Alderley Edge and Mottram St. Andrew, Cheshire. *Journal of the Chester Archaeological Society*, **64**, 47–73.

J. Russell Soc., 5(2), 103–107 (1994).

FLUORITE AT HAMPSTEAD FARM QUARRY, CHIPPING SODBURY, AVON: A NEW BRITISH OCCURRENCE

MICHAEL F. BROOKE
138 Lower Blandford Road, Broadstone, Dorset BH18 8NZ

Fluorite is known from a number of quarries in the Mendips and Bristol district but the occurrence at Hampstead Farm quarry, Chipping Sodbury, Avon, differs in that it is an example of vein mineralisation. Specimens show a range of colours, and some display green fluorescence under short-wave ultraviolet light. Associated minerals include baryte, pyrite and goethite. Paragenesis is difficult to establish and the origin of mineralising fluids is still open to debate.

INTRODUCTION

Hampstead Farm quarry (NGR ST 728 843) has been operated by A.R.C. since the late 1970s or early 1980s. Situated on the eastern side of the B4060 Chipping Sodbury to Wickwar road (Fig. 1), the quarry has been developed within a N–S trending outcrop of Carboniferous limestone, the detailed geology of which was described by Alabaster (1990).

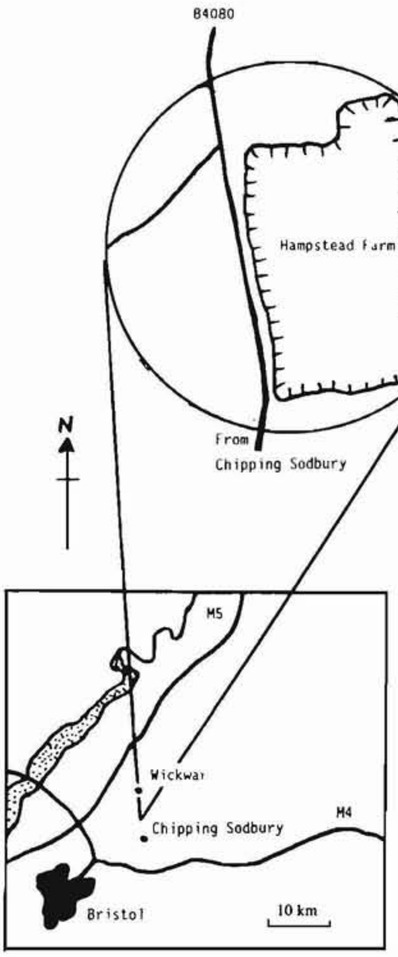

FIGURE 1. Location of Hampstead Farm quarry.

By 1984 work had only just commenced on the second level but even then evidence existed for the presence of significant mineralisation. During 1985, as the working face was extended southwards, a major mineral vein containing baryte, sphalerite, pyrite and calcite was exposed. This vein was described in detail by J. Jones in Russell Society Newsletter No. 14 (1985), and is similar in mineralogy to those described by Curtis (1981) from the adjacent Southfields quarry. It had been completely worked through by the end of October 1987, except for a galena-rich stringer traceable across the quarry floor. Like many of the mineralised veins in the quarry, this trended NW–SE (Fig. 2). Subsequent working has extended both northern and southern faces and in doing so has revealed numerous other mineralised veins, including one containing fluorite crystals. A list of minerals recorded from the quarry is given in Table I. A third level is now being developed; consequently, access is restricted. Permission must be obtained from the Quarry Manager.

TABLE I. List of minerals reported from Hampstead Farm quarry.

Allophane[1]
Baryte
Basaluminite[1]
Calcite
Dolomite[2]
Dundasite[1]
Fluorite
Galena
Gibbsite[1]
Goethite
Gypsum
Hematite
Iron sulphate[3]
Limonite
Marcasite
Para-alumohydrocalcite[1]
Pyrite
Quartz
Scarbroite[1]
Sphalerite

1. Reported by Alabaster (1990).
2. Part of the Black Rock Limestone host rock. Not identified as a separate mineral within the mineralisation.
3. Species undetermined.

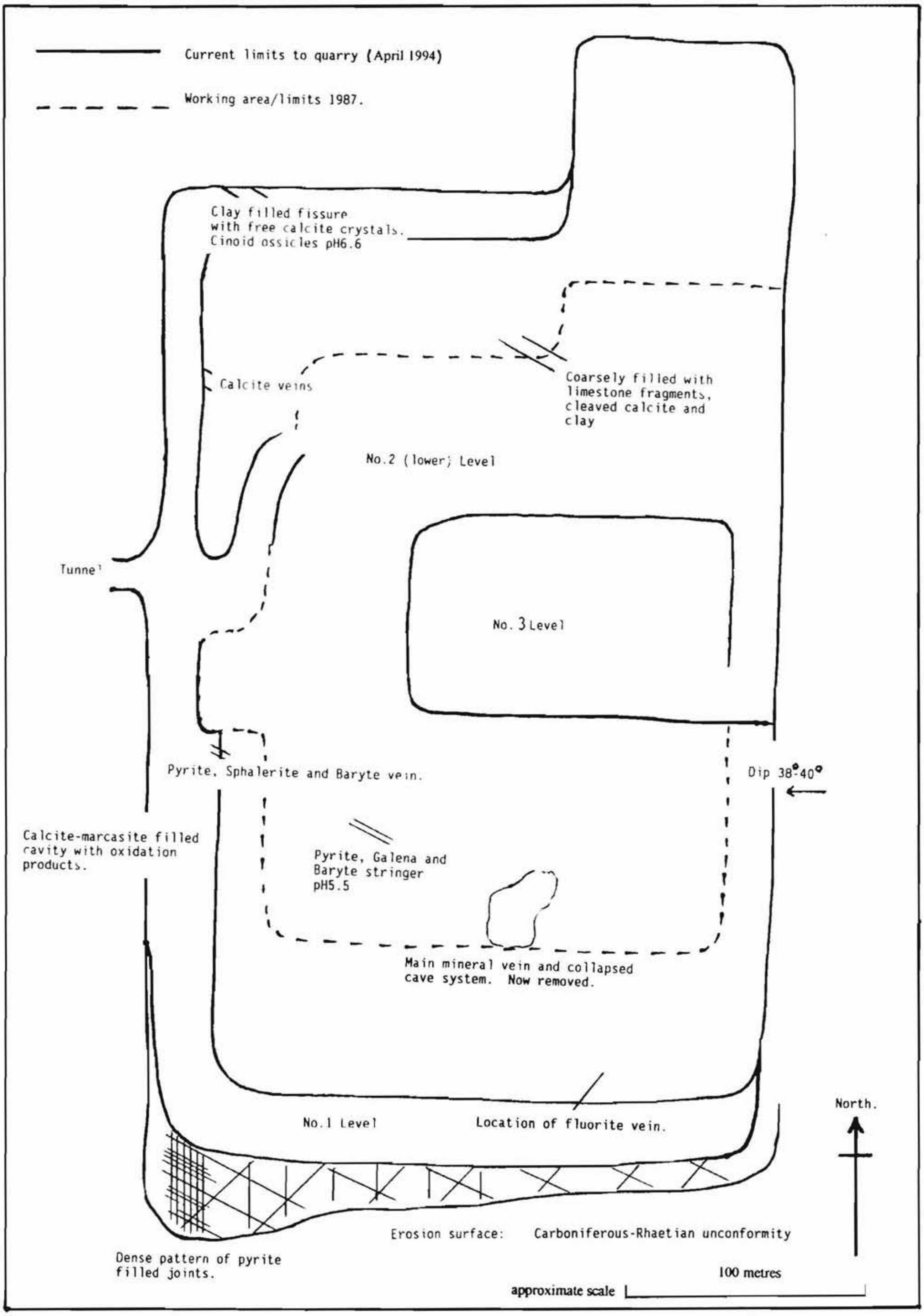

FIGURE 2. Sketch map of Hampstead Farm quarry.

FLUORITE

The discovery of fluorite at Hampstead Farm quarry in September 1991 was reported by the author in Russell Society Newsletter No. 23 (1992). The first samples were obtained from freshly blasted material at the floor of the south face, second level (Fig. 3). Evidence from these pointed to vein mineralisation, which was confirmed in November 1992 when specimens were found *in situ*. A thorough search of the south face located only one fluorite-bearing vein among a series of veins which trend NE–SW and dip at 60–70° to the east. These veins cut through Black Rock Limestone and intersect the NW–SE mineralised veins at approximately 90°. The fluorite-bearing vein varies in width from less than 1 cm to 20 cm, and consists of brecciated limestone fragments trapped within massive pink and white calcite. Vugs are quite common and within these fluorite crystals may be found investing calcite scalenohedra.

It is a little surprising that fluorite was apparently not noticed until 1991, since the Black Rock Limestone hosts several other occurrences within the area, though these differ considerably in character. At Whatley quarry, Frome (ST 728 482), Halecombe quarry, Leigh-on-Mendip (ST 701 475), and Stancombe Lane quarry, Flax Bourton (ST 504 684). fluorite is found within calcite/dolomite-filled replacement cavities. Such cavities are less common at Hampstead Farm quarry, are smaller, and appear to be devoid of fluorite.

A new find (in late 1993) of colourless fluorite within a mineralised thrust plane at the northern end of the quarry (Dr N. Hollingsworth, *personal communication*) suggests that the occcurrence of fluorite within the quarry may be more extensive than at first thought.

Fluorite from Hampstead Farm quarry occurs as individual crystals up to 3 mm across, though 1 mm or less is more usual. It also exists as thin crystalline crusts and surface coatings. The colour of the original specimen was pale yellow and the crystals, less than 0.5 mm in size, were also opaque. Subsequent specimens have produced a range of colours, the most striking being deep golden yellow and completely transparent.

Several forms have been identified. The most common is the simple cube. This may be colourless, pale to golden yellow, deep purple, or pale mauve; yellow/purple and purple/colourless zoned crystals are also found. Considerably less common are bevelled edged cubes (Fig. 4a) which, like the even rarer tetrahexahedral form (Fig. 4b), appear to be restricted to deep purple coloured specimens. Interpenetrant twins exist, but they are less common.

Some of the specimens fluoresce in short-wave ultraviolet light. The colour and intensity varies from very pale greenish-cream to strong green, and tends to be associated only with yellow coloured specimens. Intensity of fluorescence appears to correspond with depth of colour: the more golden yellow the crystal the stronger the fluorescence. Europium (Howie *et al.*, 1982) is not the cause since qualitative analysis by A.D. Hart of the Natural History Museum, using a Hitachi Probe S2500 electron microprobe, showed the fluorite to be free of rare earth elements.

FIGURE 3. Southern face of Hampstead Farm quarry, showing steeply dipping calcite veins. The arrow points to the fluorite vein, and the straight lines delimit the area within which fluorite specimens may be found.

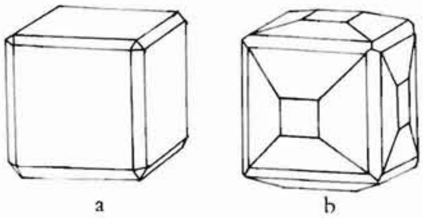

FIGURE 4. Modified habits of Hampstead Farm quarry fluorite: **a)** with bevelled edges; **b)** tetrahexahedron.

ASSOCIATED MINERALS

BARYTE

Baryte is relatively common. Two habits have been identified: (1) small (<2 mm) pink lenticular plates in parallel growth on pink sugary calcite; (2) white to whitish-pink opaque tapering bladed crystals up to 5 cm long with goethite on white calcite scalenohedra.

CALCITE

Calcite is ubiquitous. Early growths show opaque pink sugary and massive formations which develop into colourless to white scalenohedra up to 2 cm long. This transition can lead to the formation of pink 'phantoms' within the crystals.

GALENA

Galena is extremely rare. The crystals are generally less than 1 mm in size and are usually found on or within the sugary calcite. Only rarely has it been found on fluorite. Several forms have been identified: cube. cube-octahedron and octahedron.

GOETHITE

This is by far the most common mineral, after calcite, and occurs as black spherules up to 1 mm across, and occasionally as radiating fans of needles up to 1 mm long growing from the spherules (Fig. 5).

PYRITE

Pyrite occurs as minute composite clusters and single modified cubes up to 0.5 mm across. They often have iridescent surfaces.

SPHALERITE

This forms very tiny, transparent pale brown gemmy crystals in contact with limestone, and is very rare.

Very rarely do more than three of these minerals occur together within any one vug. The most common associations are: i) calcite + yellow fluorite; ii) calcite + yellow fluorite + goethite; iii) calcite + colourless fluorite + pyrite; iv) calcite + baryte +

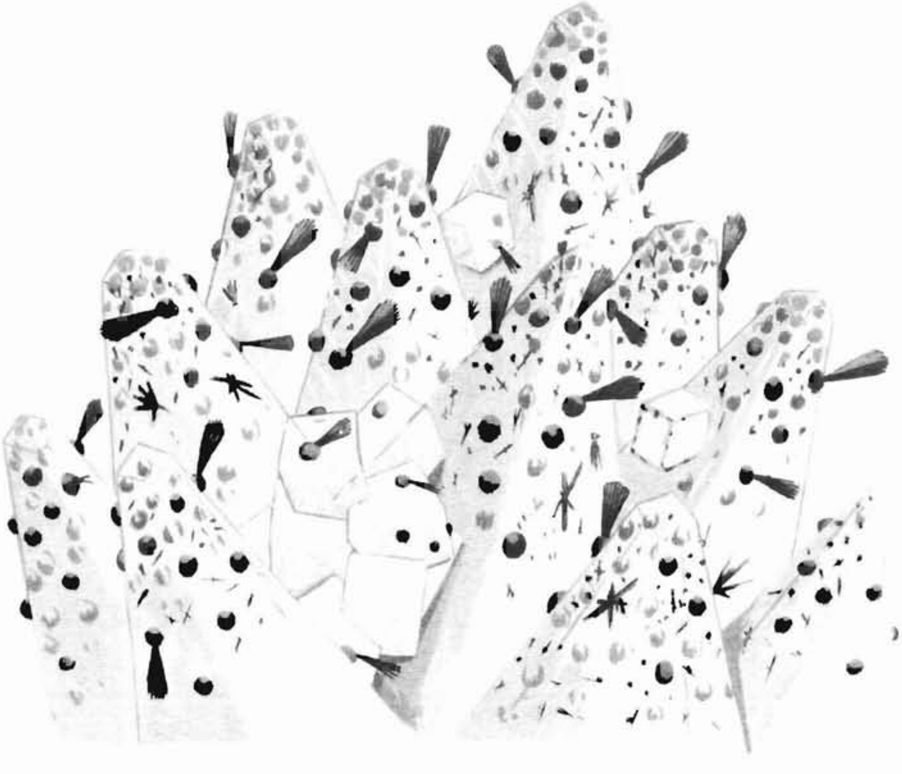

FIGURE 5. Typical association of fluorite (yellow cubes up to 1.5 mm in size) and goethite (black spherules and bunches of acicular crystals) on scalenohedra of calcite. From an original painting by Jim Goulding. Specimen in the Jim Goulding collection.

goethite; v) calcite – purple fluorite. No single specimen possesses all the minerals listed above, and only one has been found which carries purple fluorite. colourless fluorite. yellow fluorite. pyrite, galena and calcite. Apart from goethite, which occurs both overgrown by and overgrowing fluorite, the minerals tend to be spatially separated.

PARAGENESIS

Close scrutiny of numerous specimens suggests the paragenesis shown in Fig. 6. The initial mineralisation involved traces of sphalerite together with purple fluorite. Crystallisation took place either within or on the limestone adjacent to the joint plane. Contemporaneous with this was the crystallisation of calcite. The fluorite appears to have been deposited in a series of stages during which purple varieties gave way to colourless and yellow varieties. The spatial separation of the purple, colourless and yellow varieties is indicative of distinct generations of crystals, but the occurrence of colour-zoned crystals suggests some overlap or repetition in the sequence of deposition.

The precise sequence of crystallisation of baryte, galena, pyrite and goethite is more difficult to establish and will require both a wider range of specimens and further research. The origin of the mineralising solutions is also open to debate. The most probable source is hydrothermal brines forced upwards or laterally (King, 1983, 1993; Alabaster, 1990) during earth movements associated with late Carboniferous to Permian tectonism. But the role of meteoric waters carrying dissolved salts from the Coal Measures and Westbury Shales downwards into the limestone has not been ruled out, nor has migration of Permo-Triassic basin brines. The fluorite occurrence at Hampstead Farm quarry is somewhat enigmatic and demands further research.

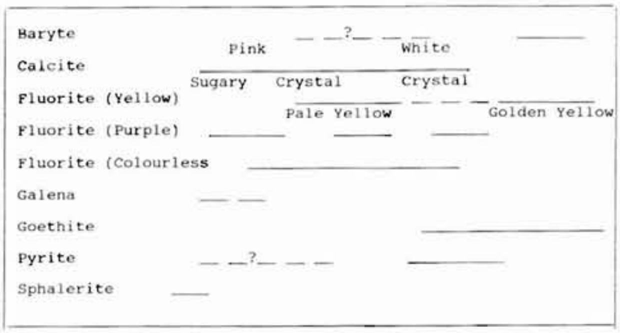

FIGURE 6. Proposed paragenesis of fluorite vein. Hampstead Farm quarry.

ACKNOWLEDGEMENTS

I am grateful to the management of ARC Southern, especially Mr Richard Webb, for permission to visit the quarry and to publish this paper; to Dr R.J. King for his helpful comments during the preparation of the text; to the Natural History Museum, London, for the analyses; and to Jim Goulding for permission to use the illustration for Fig. 5.

REFERENCES

Alabaster, C. (1990). New occurrences of secondary aluminium minerals from the Bristol district. *Journal of the Russell Society*, **3**, pt 2, 49–59.

Curtis, M.T. (1981). The mineralization of Southfields quarry, Chipping Sodbury, Avon. *Proceedings of the Bristol Naturalists' Society*, **40**, 36–44.

Howie, R.A., Pegram, E. and Walsh, J.N. (1982). The content of rare earth elements in English fluorites: a preliminary study. *Journal of the Russell Society*, **1**, No. 1, 22–25.

King, R.J. (1983). The occurrence of galena in Leicestershire. *Journal of the Russell Society*, **1**, No. 2, 27–47.

King, R.J. (1993). The occurrence of sphalerite in Leicestershire, England. *Journal of the Russell Society*, **5**, pt 1, 15–21.

J. Russell Soc., 5(2), 109–113 (1994).

AN UNUSUAL OCCURRENCE OF ARSENATE MINERALS AT GWAITH-YR-AFON MINE, DYFED, WALES

STEVE A. RUST
7 Dulverton Court, Linslade, Bedfordshire LU7 7UG
JOHN S. MASON
Rhiwlwyfen, Forge, near Machynlleth, Powis, Wales

An unusual and significant assemblage of secondary copper, iron and lead arsenate minerals, the most abundant of which is tyrolite, is described from Gwaith-yr-Afon mine in the Central Wales Orefield. The primary sulphides present include gersdorffite and ullmannite. This assemblage contrasts with those typical of the Central Wales Orefield.

INTRODUCTION AND HISTORY

Gwaith-yr-Afon or Gwaithyrafon mine (NGR SN 691 839) is located 6 km SE of Talybont and 11 km ENE of Aberystwyth, in Trefeirig parish, Dyfed (Fig. 1). The workings are on a wooded hillside on the north side of the Nant Silo stream. This small mine explored, and worked to a limited extent, the area of intersection between the E–W Cwmsymlog North lode and the NE–SW trending Darren (Daren) lode. The junction was evidently complex, the scattered small trial adits on various branch veins being testimony to this.

The earliest date of working is not clear. John Taylor, active at Cwmsymlog (East Darren) mine, commented in 1847 that some work had been undertaken at an old group of workings, known as the Copper Work, on the Darren lode. Over the following half-century, the mine was included either with the Cwmsymlog mines or with Cwmdarren and Cerrig-yr-wyn, and enjoyed at least sixteen different names, including West Cwmsymlog, North Cwmsymlog, Cwmsymlog United, Black mine, and Gwaithyrafon (Hughes, 1990).

In 1909 the mine was re-examined by the Lery Mining Company and the two minor workings on the south side of the Nant Silo stream date largely from this period. The mining consultant Henry Francis (son of Absalom Francis) was involved and, when the project ended, continued to promote the site, but it does not appear that any further work took place after about 1922. The workings apparently reached a depth of just over 40 fathoms (73 m) below shallow adit level although reliable details are scarce; the same comment applies to production figures which give, under the name Gwaithyrafon, a total for 1863 and 1867-68 of 18 tons (18,300 kg) of lead concentrate yielding 435 oz (13.5 kg) of silver. Other production was probably absorbed into the figures for adjacent mines, particularly Cwmsymlog (Hughes, 1990).

The mineralogical interest in Gwaith-yr-Afon mine arose from a chance conversation in 1985 between one of us (J.S.M.) and Simon Hughes, who in the early 1970s had worked for the Cambrian Exploration Company and had undertaken sampling programmes at a number of sites in the area. He mentioned a very wet adit downstream from the Engine shaft at Gwaith-yr-Afon, at the end of which was a small but rich copper lode carrying a good deal of 'colour', and this seemed worth investigating. The results of a study of the minerals of this lode by the authors during the following years are reported in this paper.

GEOLOGY AND MINERALISATION

The mineralisation at Gwaith-yr-Afon mine is hosted by greenish-grey mudstones of the Cwmsymlog Formation on the eastern limb of the Coed Dipws anticline (Cave and Hains, 1986). A number of fractures traverse the mine area; these consist of subvertical quartz veins and quartz-cemented breccias carrying a variety of ore minerals. The assemblage is typical of the early, complex polymetallic phase of mineralisation in Central Wales (J.S. Mason, *unpublished work*). The area from which the samples described here were collected is reached via a crosscut adit ~30 m west of the large Engine shaft dump, the adit portal being marked by a long trench. The adit is flooded to a maximum depth of 1 metre for the first 20 m; 10 m beyond this the lode is intersected, and a drift has been driven eastward for about 40 m to a flooded winze from which water is often seen to be rising. Significant secondary mineralisation is restricted to the first 10 m of this drivage, where a quartz–chalcopyrite vein is exposed in the roof of the level. This vein rarely exceeds 0.5 m in thickness and may be a minor branch; masses of quartz-cemented breccia on the Engine shaft dumps, however, suggest a much larger vein structure.

Samples from the vein underground and from the Engine shaft dump show that chalcopyrite is the dominant sulphide present. Galena occurs as small

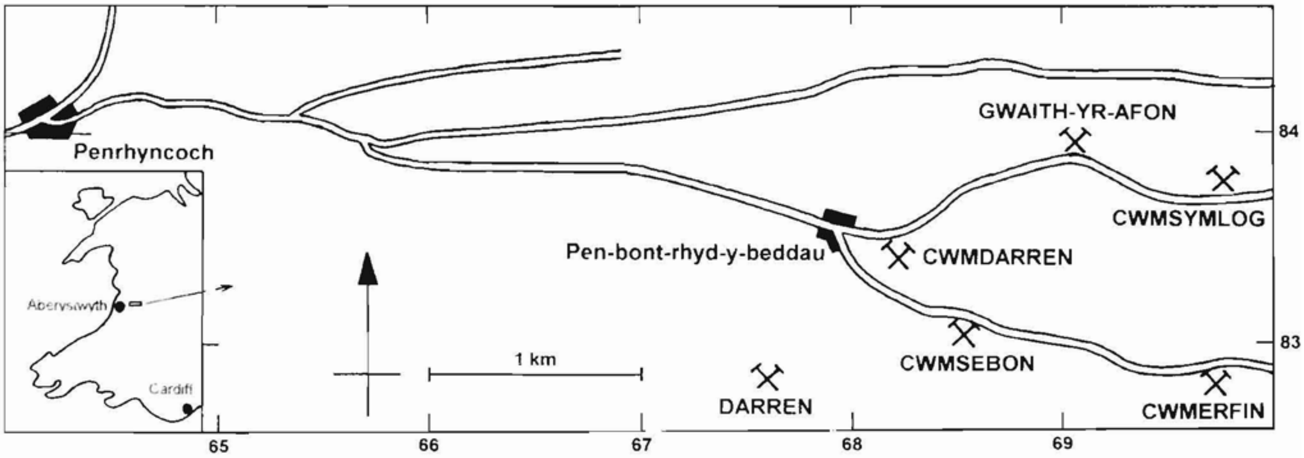

FIGURE 1. Location map showing Gwaith-yr-Afon and neighbouring mines.

veinlets and infills in quartz cavities and is occasionally associated with small amounts of tetrahedrite and bournonite (confirmed by powder XRD, J.S. Mason, *unpublished data*). Examination of the veinstuff in polished section shows that the galena contains numerous inclusions of tetrahedrite and bournonite as well as small (mainly <20 μm) grains of ullmannite and gersdorffite (confirmed by energy dispersive analysis, R.E. Bevins, *personal communication*). Although petrological studies have been limited, the paragenetic sequence chalcopyrite–ullmannite/gersdorffite–tetrahedrite–bournonite–galena is evident, and is compatible with those at similar sites in the area. Open cavities in quartz are occasionally filled with minor amounts of late red sphalerite, ferroan dolomite, and calcite. Well-developed crystals of the primary sulphides have not been observed.

The secondary mineralisation comprises an intense original alteration of vein material along cracks, and post-mining copper sulphates formed on exposed surfaces of chalcopyrite. The former is particularly well developed in a restricted area where the vein intersects a small low-angle fault; although the fault is demonstrably pre-mineralisation in origin, it has evidently been reactivated at some later stage causing shattering and local cataclasis of the quartz and chalcopyrite. The creation of this small, relatively permeable zone has permitted greater access to meteoric waters, with consequent relatively intense oxidation of the sulphides and development of the supergene assemlage. In this area tyrolite, malachite and chrysocolla are clearly visible to the naked eye, while microscopic examination reveals a variety of minor species.

Representative suites from Gwaith-yr-Afon mine have been deposited in the Natural History Museum, London (NHM) and the National Museum of Wales (NMW).

SUPERGENE MINERALS

AGARDITE-(Y), $(Y,Ca)Cu_6(AsO_4)_3(OH)_6.3H_2O$

This was identified at the National Museum of Wales by XRD (No. X-846) and energy-dispersive analysis. Agardite-(Y) forms scattered, lustrous, pale to mid-green groups of minute (<0.5 mm) acicular crystals on black to brown iron oxide on shattered, friable quartz. The associated minerals are minor malachite, chrysocolla and traces of mimetite. This represents the first confirmed occurrence of Y-dominant agardite in the British Isles (Bevins, 1994).

BAYLDONITE, $PbCu_3(AsO_4H)_2O(OH)_2$

Bayldonite forms thin, minutely crystalline crusts up to 1.5 cm² in area, on quartz containing chalcopyrite and minor galena. The colour is apple green and very similar to that of material from Brandy Gill, Caldbeck Fells, Cumbria. The few specimens were found on the overgrown dumps beyond the flooded adit portal; it has not so far been found underground. Confirmation was by XRD (NMW No. X-941), and this represents the first occurrence of bayldonite in Wales.

BROCHANTITE, $Cu_4(SO_4)(OH)_6$

Brochantite is not uncommon as thin emerald-green platy crystals on chalcopyrite, covering areas of up to several cm², and was confirmed by XRD (NHM). Additionally, divergent bladed groups (≤1 mm) and parallel prismatic groups of similar size are occasionally found on malachite spherules. Much, if not all, of the brochantite is interpreted as being of post-mining origin.

CHALCOPHYLLITE.
$Cu_{18}Al_2(AsO_4)_3(SO_4)_3(OH)_{2\text{-}}.3H_2O$

Chalcophyllite has been observed rarely as minute (<0.5 mm) emerald-green hexagonal plates aggregated together in small cavities in quartz associated with tyrolite. Chalcophyllite is extremely rare in Wales, the only other occurrences being at Dylife mine, Machynlleth. Powys (in the Central Wales Orefield) and at a trial level near Bontddu, Gwynedd (Saich and Rust, 1987; Bevins, 1994).

CHRYSOCOLLA, $(Cu,Al)_2H_2Si_2O_5(OH)_4.nH_2O$

A very common mineral, representing an estimated 40% of the total supergene content of the vein. It occurs as resinous masses up to several cm^3 in volume within the veinstuff. and varies in colour from shades of brown through green to blue. There appear to be two generations present: an early one replacing chalcopyrite, often forming opaque brown-black 'copper pitch', and a minor later phase (possibly post-mining) in which chrysocolla coats and replaces tyrolite and malachite and also forms epimorphs after mimetite and brochantite crystals. Chrysocolla was confirmed by infrared spectrometry.

CONNELLITE. $Cu_{19}Cl_4(SO_4)(OH)_{32}.3H_2O$

Connellite (confirmed by XRD, NHM) is very localised and forms minute (<0.5 mm) blue to deep blue acicular crystal sprays, usually aggregated together into radially-textured spherules. Occasionally these form crusts covering areas up to 10 mm x 5 mm. Associated minerals are brochantite, chrysocolla, malachite, langite and, rarely, parnauite. Connellite is very localised in Wales; it was confirmed from Britannia mine. Snowdon, Gwynedd (Pollard *et al.*, 1989) and has since been found in the Central Wales Orefield at Geufron mine, Llanidloes, Powys and at Lodge Park copper trial near Tre'r-ddol, Dyfed (Bevins, 1994). In both these other Central Wales occurrences, connellite is closely associated with cuprite.

COPPER (Cu) and CUPRITE (Cu_2O)

These minerals are typically intimately intergrown, as at most other Central Wales localities. Copper forms tiny metallic particles within cuprite masses; the cuprite occurs as masses up to 3 mm across but is very rare. Thin drusy crusts of cuprite octahedra have recently been noted on late-formed, filmy calcite with. possibly. aragonite.

ERYTHRITE(?), $Co_3(AsO_4)_2.8H_2O$

Thin pink coatings on quartz and breccia clasts from the Engine shaft dump have been tentatively identified as erythrite; the amounts are too small for analytical confirmation. The occurrence of erythrite is supported by the fact that some gersdorffite grains contain up to 6 wt % Co (S. Chambers, *personal communication*).

JAROSITE(?), $KFe^{3+}{}_3(SO_4)_2(OH)_6$

A yellow-brown to golden-yellow mineral forming thin drusy crusts of platy crystals on heavily corroded chalcopyrite has been tentatively identified as jarosite. It is occasionally overgrown by later langite and brochantite.

LANGITE/WROEWOLFEITE(?),
$Cu_4(SO_4)(OH)_6.2H_2O$

Small, blue. tabular crystals associated principally with brochantite have been identified from their appearance as belonging to the langite group of minerals; similarly-coloured, poorly-formed prismatic crystals are probably wroewolfeite. Their occurrence on broken chalcopyrite is typically post-mining.

LINARITE, $PbCu(SO_4)(OH)_2$

Linarite occurs as a sporadic coating of poorly-formed bladed crystals (<1 mm) on joint faces within the veinstuff, particularly in areas adjacent to galena. It is associated with cerussite, malachite, minor brochantite and, locally, mimetite.

MALACHITE, $Cu_2(CO_3)(OH)_2$

Malachite (confirmed by XRD, NHM) is a very common mineral at Gwaith-yr-Afon mine, where it forms thin botryoidal crusts covering veinstuff in areas of up to several cm^2, and occasionally displaying a drusy surface. Rarely it is found as epimorphs after tyrolite and associated with all the other species.

MIMETITE, $Pb_5(AsO_4)_3Cl$

Mimetite has been confirmed by XRD (NHM) as colourless to yellow, and occasionally pale green, prismatic to blocky crystals. Typically, it forms quite extensive coatings on joint surfaces in the veinstuff, and in particular in masses of mudstone within the vein. Infrared spectrometry of the yellow prisms shows that they are phosphatian mimetite with a molar P:As ratio of about 1:4. Zoned colourless to brown crystals are observed rarely, and some specimens show a secondary parallel growth of acicular crystals on the pinacoid faces of the more prismatic forms. The crystals range up to 1.5 mm in size; the associated minerals are principally malachite and cerussite, and more rarely tyrolite, chrysocolla, linarite and brochantite. Mimetite has also been confirmed from the nearby Darren mine. and from Dylife mine. Machynlleth, Powys, and Hendrefelen mine, Ysbyty Ystwyth, Dyfed (Bevins, 1994).

OLIVENITE, $Cu_2(AsO_4)(OH)$

Olivenite has been found on two specimens only and was confirmed by XRD (NHM). It occurs as the variety 'leucochalcite', forming aggregated, silky-white radial crystal groups up to 0.75 mm across, covering areas of up to 1.5 cm^2 on goethite-coated quartz. Olivenite is associated with an unidentified greenish botryoidal mineral.

PARNAUITE, $Cu_9(AsO_4)_2(SO_4)(OH)_{10}.7H_2O$

Parnauite has been recorded previously from localities in Cornwall and Devon, and from Tynagh mine, Eire (Ryback and Tandy, 1992). At Gwaith-yr-Afon mine, the first Welsh occurrence, it was confirmed by XRD (NHM) as pale blue-green thin drusy crusts lining small (<3 mm) cavities in quartz, and as thin crusts on corroded chalcopyrite. It is rarely observed forming scattered groups of tiny lath-like crystals in groups up to 0.75 mm across. Parnauite is associated with chrysocolla, brochantite, malachite, tyrolite and connellite.

PHARMACOSIDERITE,
$KFe^{3+}_4(AsO_4)_3(OH)_4.6\text{-}7H_2O$

Pharmacosiderite forms tiny cubic crystals (<0.25 mm), from almost colourless to pale green or yellowish in colour, and occurs principally as thin drusy crusts on goethite and quartz, with heavily corroded chalcopyrite; scorodite(?) is the only associated supergene mineral. Pharmacosiderite was confirmed by XRD (NHM), and this represents its first Welsh occurrence.

ROSASITE, $(Cu,Zn)_2(CO_3)(OH)_2$

Rosasite forms minute groups of green acicular crystals (<0.5 mm) and fragile epimorphs of laths of possibly serpierite, sparsely scattered over drusy malachite, and was identified by XRD (NHM).

SCORODITE(?), $FeAsO_4.2H_2O$

Greyish to pale yellow, very sparsely scattered crystal aggregates (<0.75 mm), and scattered single crystals (<0.3 mm) which appear to show major development of the faces [111] and [210], are identified from their appearance as scorodite. They are associated with limonite and pharmacosiderite on quartz.

SERPIERITE/DEVILLINE(?),
$Ca(Cu,Zn)_4(SO_4)_2(OH)_6.3H_2O$

Pale blue, pearly, lath-like crystals up to 0.5 mm long, scattered over veinstuff with tiny brochantite crystals, on two specimens, are tentatively identified as either serpierite or devilline.

TYROLITE (sulphatian),
$CaCu_5(AsO_4)_2(SO_4,CO_3)(OH)_4.6H_2O$

Tyrolite is very abundant at Gwaith-yr-Afon mine compared with the other arsenate minerals, forming bright blue (or occasionally greenish or whitish) radial groups of lath-like crystals which are very sectile: they tend to line cracks in altered quartz-chalcopyrite veinstuff. Tyrolite sometimes forms spherical masses of compact platy crystals in cavities in quartz. The crystal groups reach 4 mm in diameter but are usually only 1–2 mm across. When richly scattered on matrix they provide some excellent small cabinet specimens. Tyrolite is most commonly associated with chrysocolla and malachite. Confirmation was by XRD (NHM), while infrared spectrometry showed that this is a low-carbonate, sulphatian tyrolite.

UNIDENTIFIED MINERALS

No.1: The X-ray powder pattern of the green botryoidal mineral associated with olivenite matches that of a partly characterised mineral from Chile (NHM).

No.2: Groups of light blue-green, platy, six-sided crystals (<0.15 mm), covering areas of up to 3 mm^2, give an X-ray powder pattern near that of schulenbergite (NHM).

DISCUSSION

The Central Wales Orefield, compared with areas such as Cornwall and the Caldbeck Fells, is a much under-investigated area that is gradually becoming better known for its wide range of rare secondary minerals (see Bevins, 1994, for references). While suites of basic sulphate minerals from various localities, e.g. Eaglebrook (or Nant-y-Cagal) and Esgairhir mines, Ceulanymaesmawr, as well as display specimens of pyromorphite and cerussite from Bwlchglas mine, Ceulanymaesmawr, and from Frongoch and Logaulas mines near Ysbyty Ystwyth, are found in many public and private collections and are characteristic of the area, occurrences of arsenate minerals are very limited. In this context Gwaith-yr-Afon mine is an exception. The reason for this clearly lies in the arsenic-bearing primary assemblage, which is unusual for Central Wales, where primary hydrothermal assemblages are Pb-Cu- and Pb–Zn-dominated with subordinate Fe, Ag, Sb, Co, Ni and Au (J.S. Mason, *unpublished data*). The scarcity of arsenic in these assemblages is curious, particularly as minor occurrences of antimony-bearing minerals are widespread. Arsenopyrite and cobaltite occur both to the north, in the Dolgellau gold-belt, and to the south, in the gold-bearing orebodies at Dolaucothi, although the geneses of these deposits are quite different from those of the veins in Central Wales.

According to Raybould (1976), arsenopyrite is widespread as inclusions in galena in Central Wales. However, re-examination of Raybould's polished ore sections by one of us (J.S.M.) has revealed that the 'arsenopyrite' is tetrahedrite, bournonite or ullmannite; these identifications are supported by XRD and microprobe analyses. Several analyses of tetrahedrites and ullmannites revealed low arsenic contents (2–3 wt %). However, the finding of gersdorffite at Gwaith-yr-Afon mine represents the first analytically confirmed primary arsenic mineral from the orefield. A series exists between gersdorffite (NiAsS) and ullmannite (NiSbS) and, not surprisingly, some grains revealed an intermediate composition (J.S. Mason, *unpublished work*). Whether these represent a discrete phase cannot be ascertained from the limited data available.

Recent fieldwork has indicated the presence of a second, though weaker, occurrence of secondary arsenate mineralisation, at Darren mine on the same lode; the fact that this particular lode is richer in arsenic that other nearby contemporaneous lodes is yet another problematic feature of the early polymetallic mineralisation of Central Wales.

ACKNOWLEDGEMENTS

The authors would like to thank the staff of the Natural History Museum, London, for XRD identifications; Sara Chambers and Richard Bevins of the National Museum of Wales for identifying the gersdorffite, agardite-(Y) and bayldonite; George Ryback for infrared spectrometry; Simon Hughes for the original lead that initiated this work; and Francoise Curtis and Bernard Moore for assistance during fieldwork.

REFERENCES

Bevins, R.E. (1994). *A Mineralogy of Wales*. National Museum of Wales, Geological Series No. 16, Cardiff.

Cave, R. and Hains, B.A. (1986). *Geology of the Country between Aberystwyth and Machynlleth*. Memoir of the British Geological Survey.

Hughes, S.J.S. (1990). *The Darren Mines*. British Mining No.40, Memoirs of the Northern Mine Research Society.

Pollard, A.M., Thomas, R.G., Williams, P.A., Bevins, R.E. and Turgoose, S. (1989). Carbonatian connellite. a new variety. from the Britannia Mine, North Wales, and from the Botallack Mine, Cornwall. *Journal of the Russell Society*, **2**, pt 2, 23–27.

Raybould, J.G. (1974). Ore textures, zoning and paragenesis in the lead-zinc veins of Mid-Wales. *Transactions of the Institution of Mining and Metallurgy (sect. B)*, **85**, 112–119.

Ryback, G. and Tandy, P.C. (1992). Eighth supplementary list of British Isles minerals (English). *Mineralogical Magazine*, **56**, 261–275.

Saich, D.A. and Rust, S.A. (1987). Micro minerals from a trial level in Wales. *UK Journal of Mines and Minerals*, No. 3, 3–4.

J. Russell Soc., 5(2), 114–115 (1994).

NOTES

TYUYAMUNITE FROM ST JUST, CORNWALL, ENGLAND

NICHOLAS J. ELTON
Tregears. Little Treviscoe, St Austell, Cornwall PL26 7QL
JEREMY J. HOOPER
48 St Julitta, Luxulyan, Bodmin, Cornwall PL30 5ED

Uranyl vanadate minerals are found chiefly in the oxidised zone of sandstone-type uranium deposits, notably in the Colorado plateau region of the USA (Frondel, 1958; Roberts *et al.*, 1990). Carnotite, $K_2(UO_2)_2V_2O_8.3H_2O$, tyuyamunite, $Ca(UO_2)_2V_2O_8.5\text{-}8H_2O$, and metatyuyamunite, $Ca(UO_2)_2V_2O_8.3H_2O$, are the more common members of the group and are sufficiently abundant in some sedimentary deposits to be the major ore minerals (Frondel, 1958; Smith, 1984). The formation of tyuyamunite rather than carnotite requires an abundance of Ca^{2+} ions and the mineral occurs predominantly in limestones (e.g. at the type locality, Tyuya Muyun, Fergana, Uzbekistan), or in regions of calcite or gypsum mineralisation. Members of the uranyl vanadate group may also be found in other supergene environments and three. carnotite, metatyuyuamunite and francevillite, have been reported previously in Britain.

Metatyuyamunite was reported by Wyley (1961) in uraniferous-vanadiferous concretions from Budleigh Salterton, Devon. Embrey (*personal communication* in King and Dixon. 1971: also Embrey, 1977) cast some doubt on the identification. suggesting that the mineral may have been pascoite misidentified. However, an X-ray diffraction study of concretions from the same locality by Durrance and George (1976) provided confirmation of the presence of metatyuyamunite. Durrance and George considered that the original mineral was tyuyamunite, the lower hydrate having formed subsequent to collection. The only other previously recorded location for uranyl vanadate minerals in Britain is South Terras mine, St Stephen, Cornwall. Francevillite (Embrey, 1977; Natural History Museum specimen BM 1936,32) and carnotite (Gramaccioli, 1954; see also Ryback and Tandy, 1992) have been reported from this locality, although the carnotite was identified only on the basis of qualitative chemical analysis.

Tyuyamunite has now been found *in situ* in disused mine workings on the Cargodna section of Wheal Owles. St Just, Cornwall (NGR SW 362 329). Identification was by energy-dispersive X-ray analysis and X-ray powder diffraction (NHM film No. 9053F). Tyuyamunite is present in very small quantities at Wheal Owles and occurs as earthy crusts and small, canary yellow, microcrystalline aggregates on one wall of a backfilled stope. The aggregates are formed of sheaves and fan-like groups of acute petaline crystals flattened on {001} and showing the form {110} in typical tyuyuamunite habit (e.g. Frondel, 1958). Individual crystals are of the order of 5-10 μm in length, but the aggregates may cover several mm^2. Zeunerite is intimately associated with the tyuyamunite. The cool, moist conditions within the mine are evidently appropriate for the existence of the higher hydrates of both minerals. Small amounts of uranophane also occur on the specimens.

At Wheal Owles. tyuyamunite is found in cavities within quartz containing minor chalcopyrite. In one example tyuyamunite is found on the surface of earthy limonite encrusting quartz. The Cargodna section of Wheal Owles lies in mafic hornfels which, in places, contains inclusions of potassium-feldspar. The presence of compreignacite (Elton *et al.*, 1994) provides evidence for the leaching and transport of K^+ ions by meteoric waters. In the presence of potassium salts, tyuyamunite is readily converted to carnotite by cation-exchange, the reverse reaction being very slow (Frondel, 1958). Only limited substitution of K for Ca may take place before structural changes occur. The presence of tyuyamunite at Wheal Owles is probably attributable to a small and localised patch of aragonite in the roof of the stope above the area where the tyuyamunite was found. Uranophane is concentrated around and below the aragonite.

Vanadium has a much lower geochemical mobility than uranium and is an effective precipitant for the uranyl ion (Dongarra, 1984). No carnotite has been identified within the mine and this suggests that the source of vanadium may also be localised. No other vanadium minerals have been identified to date.

A sample of tyuyamunite from Wheal Owles has been deposited at the Natural History Museum, London.

ACKNOWLEDGEMENTS

The authors are indebted to Mr J.G. Francis of the Natural History Museum, London, for the X-ray powder photography, and to Mr J.F. Wyley for providing references and other information on metatyuyamunite from Budleigh Salterton.

REFERENCES

Dongarra, G. (1984). Geochemical behaviour of uranium in the supergene environment. In: De Vivo, B., *et al.* (eds), *Uranium Geochemistry, Mineralogy, Geology, Exploration and Resources*, pp. 18–22. Institution of Mining and Metallurgy, London.

Durrance, E.M. and George, M.C. (1976). Metatyuyamunite from the uraniferous-vanadiferous nodules in the Permian marls and sandstones of Budleigh Salterton. *Proceedings of the Ussher Society*, **3**, 435–440.

Elton, N.J., Hooper, J.J. and Ryback, G. (1994). Compreignacite: a second occurrence, from St Just, Cornwall. *Mineralogical Magazine*, **58**, 339–341.

Embrey, P.G. (1977). Fourth supplementary list of British minerals. Appendix to facsimile edition of Greg, R.P. and Lettsom, W.G. (1858), *Manual of the Mineralogy of Great Britain and Ireland* (Lapidary Publications, Kent, 1977). Also *Mineralogical Magazine*, **42**, 169–177 (1978).

Frondel, C. (1958). Systematic mineralogy of uranium and thorium. *U.S. Geological Survey Bulletin* **1064**.

Gramaccioli, C. (1955). [Presence of a uranium vanadate identifiable as carnotite – in the English mine of South Terras (Cornwall).] *Natura (Milano)*, **46**, 30–32. (In Italian)

King, R.J. and Dixon, J.A. (1971). A new occurrence of vanadium minerals in Leicestershire. *Mineralogical Magazine*, **38**, 488–492.

Roberts, W.L., Campbell, T.J. and Rapp, G.R. (1990). *Encyclopedia of Minerals*, 2nd edn. Van Nostrand Reinhold, New York.

Ryback, G. and Tandy, P.C. (1992). Eighth supplementary list of British Isles minerals (English). *Mineralogical Magazine*, **56**, 261–275.

Smith, D.K. (1984). Uranium mineralogy. In: De Vivo, B. et al. (eds), *Uranium Geochemistry, Mineralogy, Geology, Exploration and Resources*, pp. 43–88. Institution of Mining and Metallurgy, London.

Wyley, J.F. (1961). Exhibit: metatyuyuamunite from the Permian, Budleigh Salterton, Devon. [Title only.] *Mineralogical Society Notice* No. 112. Also *Mineralogical Magazine*, **33**, xlvi (1962).

J. Russell Soc., **5**(2), *115–118 (1994).*

BARYTOCALCITE AND WITHERITE FROM RORRINGTON MINE, CHIRBURY, SALOP, ENGLAND

ROY E. STARKEY
15 Warwick Avenue, Bromsgrove, Worcestershire B60 2AH
NEIL HUBBARD
30 Thirlmere Road, Barrow-upon-Soar, Leicestershire LE12 8QQ
BRIAN YOUNG
British Geological Survey, Murchison House, West Mains Road, Edinburgh EH9 3LA

Barytocalcite was first described by Brooke (1824). Whereas no precise details of the locality were given, Blagill mine near Alston is likely to have been the source of the specimens (Young, 1985). Although since found at other localities, both in the northern Pennines (Dunham and Wilson, 1985, p. 93; Dunham, 1990, p. 78) and elsewhere in the world, barytocalcite remains a rare mineral. Young (1985, 1993) described barytocalcite from some twenty localities in the northern Pennines; Alabaster (1990) reported new occurrences in the Mendips and south Wales; and Moles (1985) noted inclusions of the mineral in pyrite in a sample of manganoan calcite and baryte from the stratabound Ba–Zn mineralisation near Aberfeldy, Perthshire. The identification of barytocalcite at Rorrington mine reported in this note is the first from Salop, although Richards (1992, p. 12) hinted at its possible but unconfirmed presence at Snailbeach mine.

The West Shropshire mining region, now in the administrative county of Salop, has a long and varied history, some workings dating back to Roman times (Dines, 1958; Brook and Allbutt, 1973). Originally the region was principally a producer of lead ore, but in later years small amounts of zinc ore were raised, and subsequently baryte, witherite and calcite, enabling a few of the mines to remain active into the early part of the present century.

At Rorrington mine (also known as West Snailbeach mine) four east—west veins, described by Dines (1958), cut mudstones and siltstones of the Ordovician Weston Flags Formation. According to Dines (1958) only two of these veins are known to have been worked. The vein fillings consist predominantly of baryte and calcite with some quartz, witherite and fluorite, and scattered crystals and patches of sphalerite and galena. The spoilheaps contain representative examples of veinstuff. Records of output indicate that the mine has never been a great success: in the years 1850 to 1890 the yield of lead ore totalled only 293 tons. Baryte output was also modest, amounting to only 347 tons between 1889 and 1893. The mine was reopened in 1916, producing 16 tons of baryte until mining finally ceased in 1920 (Dines, 1958).

From the spoilheaps around Engine shaft (NGR SO 305 997) blocks of veinstone have recently been collected in which barytocalcite is comparatively common. Representative specimen material has been deposited in the collections of the Natural History Museum, London (NHM), the National Museum of Wales, Cardiff, and the University Museum, Oxford.

BARYTOCALCITE

Barytocalcite occurs at Rorrington mine mainly as compact creamish-white crystalline masses up to 50 mm across within baryte—witherite—calcite veinstone which in places also contain fluorite and fragments of mudstone wall-rock. Small isolated crystals of chalcopyrite less than 1 mm across occur scattered through the barytocalcite masses in some specimens. Within this veinstone occur small cavities which, although mostly less than 5 mm across, locally exceed 100 mm. Within these, barytocalcite is present as slender, colourless to pale creamish-white, terminated monoclinic prisms up to 7 mm long (Fig. 1). In most examples barytocalcite crystals line cavities in apparently pure crystalline barytocalcite, but in a few instances the mineral encrusts pale pink calcite or shale clasts. Identification of barytocalcite was confirmed by XRD (NHM No. 9761F) and infrared spectrometry.

So far as could be determined from the available samples, barytocalcite appears to post-date the crystallisation of most of the primary constituents of the vein. In a few blocks barytocalcite is encrusted with a layer, up to 5 mm thick, of white baryte composed of small (mainly <1 mm) ill-formed crystals, exactly similar to those noted by Dunham (1990, p. 91) as characterising supergene baryte in witherite-bearing veins in the Northern Pennines. A few blocks show barytocalcite coated with a thin (<2 mm) layer of dull white rather earthy baryte, probably formed by weathering processes within the dump.

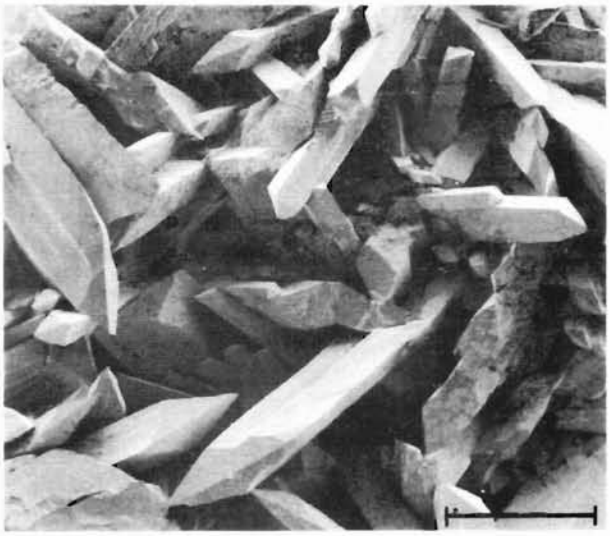

FIGURE 1. SEM photograph of barytocalcite crystals from Rorrington mine. Scale bar 1 mm.

WITHERITE

Witherite is common on the Engine shaft spoilheap. It occurs as white to pale cream-coloured, coarsely crystalline masses with, in places, cavities up to 50 mm across lined with lustrous white to pale cream-coloured pseudohexagonal crystals, which typically exhibit prism and pyramid faces. A crudely radial orientation of crystals is present in a few specimens. A few rather rounded tuberose crystalline masses of witherite up to about 50 mm across have been collected. The identification of representative specimens of witherite was confirmed by infrared spectrometry and simple wet chemistry.

Witherite is also common as coarsely crystalline masses which, from the abundance of flat tabular cleavage surfaces, superficially resemble baryte; indeed, it is easy to confuse these two minerals in hand specimens. Pale green coarsely crystalline fluorite is commonly intergrown in this veinstone. When digested in 10% hydrochloric acid this 'tabular' witherite leaves a residue of irregular tabular plates of baryte. From the limited studies so far conducted it appears likely that witherite has here partially replaced original baryte, and that the tabular habit of the witherite is pseudomorphous after original baryte, some of which remains unaltered. Exactly similar replacements of original baryte by witherite were reported from the Northern Pennines by Hancox (1934). More recently, Dunham (1990, p. 265) has described bands of primary minerals passing through cavities in witherite formed from original baryte at Settlingstones mine. Northumberland. A few samples of veinstone from Rorrington mine contain small irregular cellular cavities in witherite into which small crystalline masses of fluorite project.

OTHER MINERALS

Baryte is common at Rorrington mine in several forms. Coarse masses of white anhedral to subhedral tabular crystals are common. Many of these show varying degrees of pseudomorphous replacement by witherite as described above. Baryte is also common as sharply-pointed 'tombstone'-shaped crystals up to 5 mm long in which the dominant faces are (110), combined with (001). This morphology is characteristic of much of the baryte present within witherite-rich veins in the Northern Pennines (Dunham, 1990, p. 77). Thin crusts of rather powdery white baryte commonly encrust the outer surface of witherite and barytocalcite blocks. It is likely that this baryte results from weathering processes within the dump.

Fluorite is locally common as colourless or green coarsely crystalline masses and veins up to 30 mm across within baryte, witherite and calcite. Two specimens of crystallised fluorite from Rorrington mine, showing simple cubes up to 10 mm across associated with baryte, were collected by Sir Arthur Russell in 1911 and are now in the Russell Collection in the NHM. Rorrington and Snailbeach are the only mines in the West Shropshire orefield in which fluorite has been recorded (Dines, 1958).

Calcite is possibly the most abundant mineral in the spoilheaps and occurs as tapering terminated hexagonal prisms, simple rhombs, and more complex lustrous transparent crystals up to 4 mm across, sometimes containing inclusions of galena and other sulphides.

Galena is present as fresh crystalline masses up to 15 mm across, embedded within the non-metallic minerals.

Sphalerite occurs both as lustrous, transparent, yellow-orange crystals (<2 mm) in white quartz, and as fine-grained crystalline material enclosing euhedral galena crystals up to 10 mm across. A small amount of sphalerite-rich veinstone has been collected. and this shows a 50-mm band of fine-grained sphalerite bordered by siliceous cherty material, with included clasts of wall rock and coarse calcite cleavages. Cavities in the sphalerite are lined with euhedral sphalerite and quartz crystals up to 3 mm across. Thin white crusts, probably of hydrozincite, are common on sphalerite-bearing blocks. Small vivid yellow crusts of an undetermined cadmium sulphide were observed on the cleavage surfaces of a few sphalerite specimens.

Marcasite has been found in a few specimens, forming fan-like aggregates of spear-shaped tarnished crystals 2.5 mm long on coarse bladed baryte crystals.

DISCUSSION

Hancox (1934) presented evidence that much of the witherite in the Northern Pennines was produced by hydrothermal alteration of previously deposited baryte by reaction with fluids carrying an abundance of carbonate ions. More recently Dunham (1990) has cited Northern Pennine localities at which witherite is clearly pseudomorphous after original baryte. The textural relationships of witherite and baryte in many examples of veinstone from Rorrington mine clearly resemble closely those at such Northern Pennine occurrences. It is probable therefore that, as in the Pennines, at least some of the witherite in the Shropshire orefield may have been produced during a phase of carbonate ion activity late in the history of filling.

The barytocalcite described here from Rorrington mine bears several similarities to that present in the Northern Pennines. It exhibits a strikingly similar crystal morphology and, as at some of the Pennine occurrences, it is commonly associated with very small amounts of chalcopyrite. As in the Pennine veins, the Rorrington barytocalcite post-dates most, if not all, of the primary constituents of the vein: the limited evidence available from the specimens collected indicates that barytocalcite here post-dates witherite. In the Pennine occurrences Young (1985) recognised a strong relationship between the double calcium barium carbonates barytocalcite and alstonite and the presence of limestone wall-rocks. In the absence of limestone wall-rock no such relationship occurs at Rorrington mine, though it may be significant that, unlike the Pennine veins, those at Rorrington contain an abundance of early calcite. If, as suggested by Young (1985), a nearby source of calcium carbonate is needed to form barytocalcite, the abundant calcite at Rorrington may have provided it.

ACKNOWLEDGEMENTS

Thanks are due to the Department of Mineralogy, Natural History Museum, London. for providing X-ray confirmation of barytocalcite. G. Ryback provided infrared confirmation of barytocalcite and witherite. M. Rothwell of Unilever Research kindly provided the SEM photomicrograph. B. Young publishes with the approval of the Director, British Geological Survey (N.E.R.C.).

REFERENCES

Alabaster, C. (1990). Alstonite and barytocalcite from Llantrisant, South Wales, and barytocalcite from Holwell, Mendip Hills, England. *Journal of the Russell Society*, **3**, pt 1, 1–6.

Brook, F. and Allbutt, M. (1973). *The Shropshire Lead Mines.* Moorland Publishing Co., Buxton.

Brooke, H.J. (1824). On baryto-calcite. *Annals of Philosophy*, ser. 2, **8**, 114.

Dines, H.G. (1958). The West Shropshire mining region. *Bulletin of the Geological Survey of Great Britain*, No. 14, 1–43.

Dunham, K.C. (1990). *Geology of the Northern Pennine Orefield: Volume 1. Tyne to Stainmore*, 2nd edn. Economic Memoir, British Geological Survey.

Dunham, K.C. and Wilson, A.A. (1985). *Geology of the Northern Pennine Orefield: Volume 2, Stainmore to Craven*. Economic Memoir, British Geological Survey.

Hancox, E.G. (1934). Witherite and barytes. *Mining Magazine*, **51**, 76–79.

Moles, N.R. (1985). *Geology, Geochemistry and Petrology of the Foss Stratiform Barite-Base Metal Deposit and adjacent Dalradian Metasediments, near Aberfeldy, Scotland*. Unpublished Ph.D. thesis, University of Edinburgh.

Richards, L. (1992). Snailbeach Lead Mine — reclamation and conservation. *Earth Science Conservation*, No. 31, 8–12.

Young, B. (1985). The distribution of barytocalcite and alstonite in the Northern Pennine Orefield. *Proceedings of the Yorkshire Geological Society*, **45**, 199–206.

Young, B. (1993). Some new occurrences of barytocalcite in the northern Pennine orefield. *Transactions of the Natural History Society of Northumbria*, **56**, 61-64.

J. Russell Soc., **5**(2), 118–119 (1994).

WITHERITE FROM SCALEBURN VEIN, NENTHEAD, CUMBRIA, ENGLAND

ROBERT BUNTING
12 Cavendish Road, Matlock, Derbyshire DE4 3GY

The zonal distribution of minerals, particularly gangue minerals, within the deposits of the Alston Block portion of the Northern Pennine Orefield has long been recognised (e.g. Smythe, 1922; Dunham, 1934, 1937, 1990). Within this area a central zone of deposits dominated by a fluorite gangue is surrounded by an outer zone in which barium minerals, mainly baryte and witherite, are characteristic. Save in a very few deposits there is an almost mutually exclusive relationship between the fluorite and barium zones. Deposits with significant quantities of both fluorite and barium minerals are comparatively rare: the Hilton and Murton mines near Appleby are perhaps the best known examples.

This marked segregation of gangue minerals in the Alston Block contrasts strikingly with the orefields of the Yorkshire Pennines and Derbyshire, where fluorite and baryte are commonly interbanded. In a few places within the orefield, notably around Nenthead and parts of Teesdale, an intermediate zone in which neither fluorite nor barium minerals are abundant is apparent. Whereas present levels of erosion give an impression of the zonation being lateral, a handful of deposits are known in which fluorite-dominated veins pass vertically upwards into barium-dominated assemblages (Dunham, 1990; Young, 1985, 1991, 1993).

Scaleburn vein is one of the most prominent SW–NE trending veins of the Nenthead area and is generally regarded as lying within the fluorite zone close to its outer limit with the relatively gangue-free intermediate zone of the Nenthead area. Dunham (1990, p. 142) comments on the presence of purple fluorite on the spoil heaps from the shafts along the outcrop of Scaleburn vein. To the SE of Scaleburn vein, the sub-parallel Rampgill vein contained abundant fluorite in the Firestone level workings: this mineral was apparently rare in the Great Limestone though epimorphs in quartz point to its former abundance (Dunham, 1990, p. 144). This is one of the few veins in the orefield where an upward passage into the barium zone may be recognised: Wallace (1861, p. 143) reported the presence of barytocalcite at the horizon of the Gridstone Sill, although Young (1985) was unable to confirm this.

Recent exploration of underground workings in Rampgill mine (NGR NY 782 435) has revealed the presence of witherite in Scaleburn vein in the Great Limestone. The mineral is present in some abundance along a 3-metre length of the vein approximately beneath surface grid reference NY 787 444. The vein at this point is ~5 m wide with a rib of witherite and baryte up to 0.5 m across situated in a stope 5 m above the Horse level. The stope is at least 50 m long, 10 m high, and 3-5 m in width. There is a collapse at the southern end. The witherite occurs on the hanging wall of the vein. No fluorite has been observed in the vein hereabouts, though some quartz and a little sphalerite were noted in the adjacent limestone wallrock. The witherite occurs as coarsely crystalline, white to pale cream-coloured masses up to 75 mm across. Incomplete crude pseudohexagonal crystals up to 15 mm long are present locally in small cavities. They are coated with thin encrustations of small baryte crystals. Baryte is also common as crusts of lustrous white crystals up to 2 mm long lining small vugs along fractures within the witherite. These baryte crystals exhibit the distinctive morphology characteristic of baryte when developed secondarily after a barium carbonate mineral, as described by Dunham (1990, p. 77). This form is common both in supergene baryte found in the upper oxised portions of witherite- and barytocalcite-bearing veins, and in witherite orebodies lying well beneath the present-day oxidation zone such as that formerly worked at Settlingstones mine.

The presence of witherite on Scaleburn vein is one of the very few occurrences of this mineral in a vein in the central part of the orefield. The witherite here is present at depth in the vein: spoil from the shafts above theis level indicate that fluorite is present at higher levels. This occurrence, like that reported from Eastgate quarry (Young, 1985), indicates that barium-rich fluids clearly were able to gain access, at least locally, to the central parts of the orefield. The widespread partial alteration of the witherite to baryte indicates that sulphate-rich waters, unrelated to the present oxidising groundwater zone, were active at some stage in the vein's paragenesis.

ACKNOWLEDGEMENTS

I would like to express my appreciation to B. Young for help in compiling this article, and to J. Lawson without whose help it would not have been possible to locate this occurrence.

REFERENCES

Dunham, K.C. (1934). The genesis of the north Pennine ore deposits. *Quarterly Journal of the Geological Society of London*, **90**, 689-720.

Dunham, K.C. (1937). The paragenesis and color of fluorite in the English Pennines. *American Mineralogist*, **22**, 468–479.

Dunham, K.C. (1990). *Geology of the Northern Pennine Orefield: Volume 1. Tyne to Stainmore*, 2nd edn. Economic Memoir, British Geological Survey.

Smythe. J.A. (1922). Minerals of the north country. III. Barium minerals. *The Vasculum*, **8**, 90–93 and 113–116.

Wallace, W. (1861). *The Laws which Regulate the Deposition of Lead Ore in Veins; illustrated by an examination of the geological structure of the mining districts of Alston Moor*. E. Stanford, London.

Young, B. (1985). The distribution of barytocalcite and alstonite in the Northern Pennine Orefield. *Proceedings of the Yorkshire Geological Society*, **45**, 199-206.

Young. B. (1991). An occurrence of witherite in Weardale, Co. Durham, Northern Pennines. *Transactions of the Natural History Society of Northumbria*, **55**, 206-207.

Young, B. (1993). Some new occurrences of barytocalcite in the Northern Pennine Orefield. *Transactions of the Natural History Society of Northumbria*, **56**, 61-64.

J. Russell Soc., **5**(2), 119–120 (1994).

VIVIANITE FROM SOUTH HUMBERSIDE AND YORKSHIRE, ENGLAND

MICHAEL E. SMITH
7 Orchard Close, Pocklington, York YO4 2EQ

Vivianite, $Fe^{2-}{}_3(PO_4)_2.8H_2O$, was first recorded from Wheal Kind, St Agnes in Cornwall and named for J.G. Vivian*. It occurred here as crystals in the oxidised portion of a metalliferous vein (Collins, 1892; Rudler, 1905; Embrey and Symes, 1987).

Vivianite is more commonly found in an earthy form in a sedimentary environment and is often associated with organic debris of recent origin, such as wood or bone. Vivianite requires a source of phosphate and iron to be readily available; such conditions are common in many waterlogged sediments. Greg and Lettsom (1858) record vivianite within alluvial deposits at Clifton, Bristol; Toxteth Park, Liverpool; Bury St Edmunds, Suffolk; and the Isle of Dogs, Kent. They also describe it encrusting bones and horns from Ballagh, Isle of Man, and in the interior of antlers of an Irish Elk of unknown provenance. Birley and Young

---

*But see P.G. Embrey, *this issue*, pp. 77–81. – Editor.

(1993) describe vivianite on wood, metal, bone and other artifacts of Roman origin at Vindolanda, Northumberland. A small specimen of blue earthy vivianite on clay from Chellaston, near Derby, is on display at Sheffield City Museum (accession No. 1971.644). Vivianite has not been previously described from Yorkshire; reported here are four occurrences of vivianite within the former county of Yorkshire, one at Howden (now in South Humberside), two in the City of York, and a fourth on the Yorkshire Wolds.

At Howden, vivianite has been found in a borrow pit excavated in alluvial clay for use in bunding works along the adjoining river banks (NGR SE 740 258). The pit, which is now flooded, exposed up to two metres of grey, slightly silty clay, near the base of which organic debris, including numerous wood fragments, was abundant. Vivianite occurred as bright cobalt-blue earthy encrustations on much of this wood. The mineral degenerates to a paler powdery blue colour on prolonged exposure. Some of the wood is in part impregnated with finely divided pyrite. Acicular efflorescences of gypsum were present on some specimens, no doubt derived from the breakdown of the pyrite. The vivianite at Howden all exhibited the characteristic blue colour. The colour change noted by Birley and Young (1993) at Vindolanda was not observed here. A representative sample from Howden has been deposited in the collection of the Yorkshire Museum, York (registration No. YORYM 1993.719).

Vivianite has been found at two sites in York City Centre, excavated by the Environmental Archaeology Unit of the University of York. These sites are the General Accident Insurance Co. site at Lendal Bridge (SE 601 519), and the Jorvik site at 16-22 Coppergate (SE 601 517). At this latter site vivianite occurred as a lining of worm tubes or possibly root casts as well as coatings on other organic material. The deposits on both sites date from the 9th to 11th centuries (O'Connor, 1989).

Two small specimens of vivianite have been located recently in the collection of the Yorkshire Museum (Nos. YORYM 1994.1781 and 1782). They were found in the early 19th century during archaeological excavation of a barrow on Huggate Wold, Pocklington (SE 86 57). The vivianite is pale blue, and intermixed with a grey chalky clay.

The first three localities from which vivianite is here recorded are all within the prehistoric flood plain of the river Ouse, and all within 100 metres of the present river banks. It is probable that occurrences of vivanite in anaerobic organic-rich deposits are more common than the few published records would suggest.

ACKNOWLEDGEMENTS

The assistance given during preparation of this note by Mr P. Ensom, The Yorkshire Museum; Mr D. Hall, Environmental Archaeology Unit, University of York; and Mr B. Young, British Geological Survey, Newcastle, is gratefully acknowledged.

REFERENCES

Birley, R. and Young, B. (1993). Vivianite of post Roman origin from Vindolanda, Northumberland. *Transactions of the Natural History Society of Northumbria*, **65**, 65–67.

Collins, J.H. (1892). *A Handbook to the Mineralogy of Cornwall and Devon*, 2nd edn. Facsimile reprint, Bradford Barton, Truro, 1969.

Embrey, P.G. and Symes, R.F. (1987). *Minerals of Cornwall and Devon*. British Museum (Natural History) and Mineralogical Record Inc., Tucson, Arizona.

Greg, R.P. and Lettsom, W.G. (1858). *Manual of the Mineralogy of Great Britain and Ireland*. Facsimile reprint, Lapidary Publications, Broadstairs, Kent, 1977.

O'Connor, T.P. (1992). *Bones from Anglo Scandinavian Levels at 16-22 Coppergate*, vol. 15, fasc. 3. The Yorkshire Archaeological Trust: Council for British Archaeology.

Rudler, F.W. (1905). *A Handbook to a Collection of Minerals of the British Islands, mostly selected from the Ludlam Collection, in the Museum of Practical Geology*. London.

LEADHILLITE FROM THE NORTHERN PENNINE OREFIELD, ENGLAND

BRIAN YOUNG
British Geological Survey, Murchison House, West Mains Road, Edinburgh EH9 3LA
TREVOR F. BRIDGES
10 Springfield, Ovington, Northumberland NE42 6EH
EWAN K. HYSLOP
British Geological Survey, Murchison House. West Mains Road, Edinburgh EH9 3LA

Although long known from its widespread occurrence in small quantity in the oxidised zones of many of the veins in its type area, Leadhills, Strathclyde Region (Wilson, 1921, p. 17), leadhillite ($Pb_4(SO_4)(CO_3)_2(OH)_2$) remains a comparatively uncommon British mineral. It is present at Drumruck mine, Gatehouse of Fleet. Dumfries and Galloway Region (Russell, 1936), and locally as a member of the supergene assemblage in several of the lead-bearing veins of the Caldbeck Fells, Cumbria (e.g. Greg and Lettsom, 1858, p. 399; Young, 1987, p.67; Cooper and Stanley, 1990, pp. 101-102). Leadhillite has been reported, though without description, from Nether Stowey and Dodington near Holford, Somerset (Woodward. 1872) and from an old lead mine at Kingston near Taunton, also in Somerset (Greg and Lettsom, 1858), and has also been described from numerous localities in the central Wales mining district (Braithwaite, 1982; Rust and Rust, 1987; Bevins, 1994). The only records of leadhillite from Pennine localities are those of Bertrand (1878), who described the mineral from the Matlock area. Derbyshire, though without more specific locality details; Flindall and Hayes (1976, p. 14), who noted its presence in Rutland Cavern, also in the Matlock neighbourhood; and Rust (1983), from Waterbank mine, Ecton, Staffordshire.

Leadhillite has now been identified in one large, recently quarried block of veinstone from Closehouse mine, Middleton-in-Teesdale. Co. Durham (NGR NY 850 228). The mineral here occurs sparingly in small cavities in oxidised galena-baryte veinstone as lustrous, white to colourless, hexagonal prismatic crystals up to 0.75 mm across and 1.0 mm long. Identification was by X-ray powder photography (BGS X-ray No. XE 790). The line characteristic of the polymorph susannite as described by Livingstone and Russell (1985) was not found. Associated minerals include abundant cerussite, mostly as reticulated crusts of very thin tabular white crystals. In a few specimens lenticular, platy, off-white to pale buff crystals closely resembling hydrocerussite have been noted. Examination of these by X-ray powder photography reveals them to be cerussite, though the presence of a few lines suggestive of hydrocerussite, and their morphology, indicate that these are almost certainly cerussite pseudomorphs after original hydrocerussite. Clusters of well-formed terminated prisms of colourless anglesite together with traces of malachite and linarite are also present locally in this veinstone.

Closehouse open pit mine works baryte from vein and associated replacement deposits in an altered dolerite dyke of the Whin Sill suite, emplaced in the Lunedale Fault which here cuts Lower Carboniferous limestones, sandstones and shales that range from the Melmerby Scar Limestone up to beds above the Smiddy Limestone (Hill and Dunham, 1968; Dunham, 1990). Baryte is overwhelmingly the most abundant primary mineral of the Closehouse deposit. Galena is present in minor amounts only with, in places, traces of sphalerite and pyrite. Other primary constituents include calcite, aragonite and a little quartz. In addition to those mentioned above, supergene minerals recorded from Closehouse mine include aurichalcite. rosasite and pyromorphite (Young. 1985; Young *et al.*, 1985; Dunham, 1990).

In common with most Pennine lead veins, the most abundant lead supergene mineral at Closehouse is cerussite, though with local concentrations of anglesite. In an oxidising environment in a deposit of this sort the formation of cerussite, hydrocerussite, anglesite or leadhillite depends upon groundwater pH and the availability of carbon dioxide. In such an environment, pH is usually controlled by a balance between the availability of calcium carbonate from calcareous wall-rock and vein minerals, and sulphuric acid from the oxidation of pyrite and other sulphides. The reaction between the sulphuric acid and calcium carbonate releases carbon dioxide. Figure 1 (solid lines) shows the stability field relationships between cerussite, hydrocerussite, leadhillite and anglesite at $p(CO_2) = 10^{-3.82}$ (0.015% v/v). Under these conditions, which can arise if rainwater percolating through the veinstuff dissolves small quantities of calcium carbonate without free access to air, cerus-

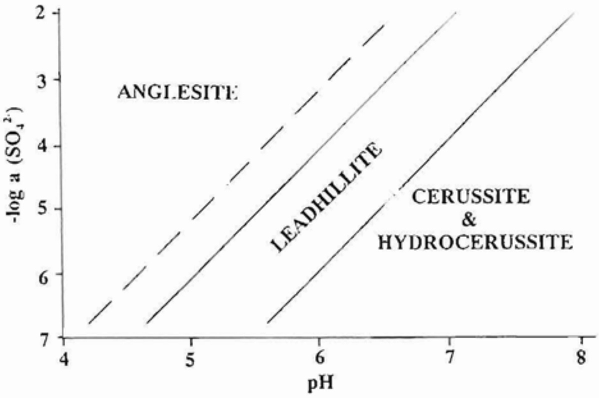

FIGURE 1. Stability field diagram at 25°C and 1 atmosphere total pressure for cerussite, hydrocerussite, leadhillite and anglesite, at $p(CO_2) = 10^{-3.82}$ (solid lines) and $10^{-2.45}$ (broken lines). The necessary thermochemical data are taken from Robie *et al.* (1978) and Smith and Martell (1976) excepting cerussite and hydrocerussite (Taylor and Lopata, 1984) and leadhillite (Abdul-Samad *et al.*, 1982).

site and hydrocerussite can form in equilibrium with each other and with leadhillite. At lower partial pressures of carbon dioxide hydrocerussite is the stable lead carbonate phase. At higher partial pressures cerussite is stable. Under these conditions leadhillite occupies a narrow field between the carbonates and anglesite. However, as the level of carbon dioxide increases, the leadhillite field moves to lower pH and narrows until at a $p(CO_2)$ of $10^{-2.45}$ (0.35% v/v) it is eliminated (Fig. 1, broken line), and at higher carbon dioxide levels cerussite and anglesite are the only stable minerals that coexist in equilibrium. The above is a relatively low level of carbon dioxide for an oxidising mineral vein. For example, smithsonite is by far more common than hydrozincite in oxide zones, and smithsonite requires a $p(CO_2)$ at or above $10^{-1.41}$ (3.9% v/v) before it becomes stable (Williams, 1990).

We conclude that during supergene alteration within the baryte-dominated Closehouse orebody, the groundwater pH has locally fallen to levels at which anglesite has formed and, in rare instances, reached the comparatively restricted conditions favourable to leadhillite and hydrocerussite formation. The unusual chemical conditions under which leadhillite and hydrocerussite can form will be attained only exceptionally in veins with the mineralogical content and wall-rock composition typical of most Pennine veins. Such conditions may be expected to occur rather more commonly in relatively carbonate-poor (though not carbonate-free) veins and wall-rocks such as those found in the Leadhills, Caldbeck Fells and central Wales orefields, the British localities in which leadhillite and hydrocerussite is most commonly found.

ACKNOWLEDGEMENTS

The management of Closehouse Minerals Ltd are thanked for allowing access to Closehouse mine. B.Y. and E.K.H. publish with the permission of the Director, British Geological Survey (NERC).

REFERENCES

Abdul-Samad, F., Thomas, J.H., Williams, P.A., Bideaux, R.A. and Symes, R.F. (1982). Mode of formation of some rare copper(II) and lead(II) minerals from aqueous solution, with particular reference to deposits of Tiger, Arizona. *Transition Metal Chemistry*, **7**, 32-37.

Bertrand, E. (1878). Sur la leadhillite de Matlock. *Compte Rendu de l'Academie des Sciences, Paris*, **86**, 348-350.

Bevins, R.E. (1994). *A Mineralogy of Wales*. National Museum of Wales, Geological Series, No. 16. Cardiff.

Braithwaite, R.S.W. (1982). Wroewolfeite in Britain. *Mineralogical Record*, **13**, 167-170 & 174.

Cooper, M.P. and Stanley, C.J. (1990). *Minerals of the English Lake District: Caldbeck Fells*. Natural History Museum Publications, London.

Dunham, K.C. (1990). *Geology of the Northern Pennine Orefield. Vol. 1. Tyne to Stainmore*, 2nd edn. Economic Memoir, British Geological Survey.

Flindall, R. and Hayes, A. (1976). *The Caverns and Mines of Matlock Bath. 1. The Nestus Mines: Rutland and Masson Caverns*. Moorland Publishing Co., Ashbourne, Derbyshire.

Greg, R.P. and Lettsom, W.G. (1858). *Manual of the Mineralogy of Great Britain and Ireland*. John van Voorst, London. Reprinted 1977 by Lapidary Publications, Broadstairs, Kent.

Hill, J.A. and Dunham, K.C. (1968). The barytes deposits at Closehouse, Lunedale, Yorkshire. *Proceedings of the Yorkshire Geological Society*, **36**, 351-372.

Livingstone, A. and Russell, J.D. (1985). X-ray powder data for susannite and its distinction from leadhillite. *Mineralogical Magazine*, **49**, 759-761.

Robie, R.A., Hemingway, B.S. and Fisher R.R. (1978). Thermodynamic properties of minerals and related substances at 298.15 K and 1 bar (10^5 pascals) pressure and at higher temperatures. *U.S. Geological Survey Bulletin* No. 1452.

Rust, S. (1983). Notes on micro-specimens found at the Waterbank mine, Ecton, Staffordshire. *Mineral Realm*, **3**, No. 2/3, 29–32.

Rust, S. and Rust, D. (1987). Micro minerals from Dyfngwm mine. *UK Journal of Mines and Minerals*, No. 2, 28–32.

Russell, A. (1936). Wulfenite at Brandy Gill, Cumberland, and leadhillite at Drumruck mine, Kirkcudbrightshire. *Mineralogical Magazine*, **24**, 321–323.

Smith, R.M. and Martell, A.E. (1976). *Critical Stability Constants*, Vol. **4**. Plenum Press, New York.

Taylor, P. and Lopata, V.J. (1984). Stability and solubility relationships between some solids in the system PbO-CO_2-H_2O. *Canadian Journal of Chemistry*, **62**, 395-402.

Williams, P.A. (1990). *Oxide Zone Geochemistry*. Ellis Horwood Series in Inorganic Chemistry.

Wilson, G.V. (1921). *The Lead, Zinc, Copper and Nickel Ores of Scotland*. Memoir of the Geological Survey, of G.B.: Special Reports on the Mineral Resources of Great Britain, vol. **17**.

Woodward, H.B. (1872). List of minerals found in Somersetshire. *Geological Magazine*, **9**, 129.

Young, B. (1985). Pyromorphite in the northern Pennines. *Journal of the Russell Society*, **1**, No. 3, 81–82.

Young, B. (1987). *Glossary of the Minerals of the Lake District and Adjoining Areas*. British Geological Survey, Newcastle upon Tyne.

Young, B., Pettigrew, T. and Bridges, T.F. (1985). Rosasite and aurichalcite from the northern Pennine orefield. *Transactions of the Natural History Society of Northumbria*, **54**, 31.

J. Russell Soc., **5**(2), 123-124 (1994).

CINNABAR FROM THE CALDBECK FELLS, CUMBRIA, ENGLAND

TIMOTHY NEALL
Greenside, Kirkbride, Cumbria CA5 5JH
MICHAEL LEPPINGTON
1 Harrot Hill, Cockermouth, Cumbria CA13 0BL

Cinnabar is well known from the Pennine orefields (Braithwaite *et al.*, 1963; Young *et al.*, 1989) but is rare in the Lake District. The first confirmed occurrences of cinnabar in the Lake District were in panned concentrates from streams to the north and west of Cockermouth where it is widespread in small amounts (Cooper *et al.*, 1991, 1992). The only record of cinnabar from the Caldbeck Fells is a rather unsatisfactory reference by Goodchild (1882, p. 105) to an unconfirmed report in an unnamed local newspaper. A precise locality was not given and Goodchild himself doubted the occurrence.

Cinnabar has now been identified at Potts Gill baryte mine (NGR NY 320 366) and at Dry Gill mine (NY 322 345). Identification was originally by means of microchemical tests and was confirmed by energy-dispersive X-ray analysis.

At Potts Gill mine cinnabar occurs as very thin, bright crimson to brick-red, earthy or glistening granular coatings in tiny (<2 mm) cavities in highly cellular quartz. The cellular nature of the quartz appears to arise from the leaching of sulphides, traces of which survive. The residual sulphides consist of sphalerite and smaller quantities of chalcopyrite. White laminar baryte is a minor primary constituent of the assemblage. The cinnabar is associated with a suite of supergene minerals of which adamite, hemimorphite and philipsburgite are the most abundant, though olivenite and agardite are locally common. The cinnabar-bearing quartz has a very restricted distribution, being confined to a small area of dumps in and immediately west of Gill Beck, below the track to the Deer Hills trial. The source of this material is not known, but it is possible that it came from a small trial level a little upstream from the main Potts Gill mine levels but at approximately the same elevation. This level was possibly a trial on the outcrop of a minor east-west vein known as 'Rainbow lode'.

At Dry Gill mine cinnabar occurs as bright red earthy coatings in 2-5 mm diameter voids in coarsely granular quartz. A little residual sphalerite or a formless, earthy iron manganese oxide is often associated with the cinnabar, and the quartz is often partly encrusted with black manganese oxide and the campylite variety of mimetite. The cinnabar-bearing quartz was found amongst loose spoil from the floor of the gill, but the occurrence of campylite on some of the specimens strongly suggests that the source was the Dry Gill lead vein.

ACKNOWLEDGEMENT

The authors wish to thank M. Rothwell of Unilever Research for the energy-dispersive X-ray analyses.

REFERENCES

Braithwaite, R.S.W., Greenland, T.B. and Ryback, G. (1963). A mercury mineral from the British Isles. *Nature*, **200**, 1004.

Cooper, D.C., Cameron, D.G., Young, B., Cornwell, J.D. and Bland, D.J. (1991). *Mineral Exploration in the Cockermouth Area. Part 1: Regional Surveys*. British Geological Survey, Mineral Reconnaissance Programme Report **118**.

Cooper, D.C., Cameron, D.G., Young, B., Chacksfield, B.C. and Cornwell, J.D. (1992). *Mineral Exploration in the Cockermouth Area. Part 2: Follow-up Surveys*. British Geological Survey, Mineral Reconnaissance Programme Report **122**.

Goodchild, J.G. (1882). Contribution towards a list of the minerals in Cumberland and Westmorland. *Transactions of the Cumberland Association for the Advancement of Literature and Science*, **7**, 101–126.

Young, B., Ineson, R.R., Bridges, T.F. and Smith, M.E. (1989). Cinnabar from the northern Pennines, England. *Mineralogical Magazine*, **53**, 388–390.

J. Russell Soc., **5**(2), 124–126(1994).

ANALYSES OF CALCIAN PHOSPHATIAN VANADINITE, AND APATITE HIGH IN LEAD, FROM WANLOCKHEAD, SCOTLAND

ALEC LIVINGSTONE
Department of Geology, Royal Museum of Scotland, Chambers Street,
Edinburgh EH1 1JF

A recent investigation (Livingstone, 1994) into white, chalky, fluorine-bearing carbonate-apatite associated with globular vanadinite from Belton Grain vein, Wanlockhead*, revealed that it contained 22-23 wt % PbO. The plumboan apatite appears to post-date vanadinite formation. Frenzel (1881) published an analysis of a Wanlockhead vanadinite which contained 3.25 wt % CaO and 2.93 wt % P_2O_5. Consequently the composition of the vanadinite became of interest. Polished sections were prepared using globules of vanadinite, which ranged in colour from the characteristic orange-brown to, rarely, cream. Utilising a Camebax Cameca electron-microprobe, with wollastonite, apatite, fluorite, halite, lead and vanadium standards, the significant calcium and phosphorus values previously reported have been confirmed.

Table I shows that the vanadinite contains appreciable calcium and phosphorus (maximum 4.8% P_2O_5 in analysis 10). Low V is associated with high P levels, suggesting structural replacement; calcium probably replaces lead. A plot of Ca atoms against P atoms in the vanadinite (Fig. 1) reveals an unexpected coupled substitution of Ca and P, with an average Ca/P ratio of 0.36. This ratio is too low for the Ca and P content to be explained by the presence of diffused, sub-micrometre inclusions of (plumboan?) apatite; for apatite, $Ca_5(PO_4)_3F$, the Ca/P ratio would be 5:3 or 1.67, and somewhat lower for plumboan apatite. One vanadinite globule contained a 10-20 μm band of calcian pyromorphite (with 0.16% V_2O_5), close and parallel to two crystal faces. A consistent pattern of phosphorus distribution globule-to-globule did not emerge; some exhibited a fairly uniform content whereas others showed a slight increase towards the rim.

*A colour photograph of one such specimen (NMS G 1991.31.85) is reproduced on the cover of the last issue of this Journal (vol. **5**, part 1, 1993).

TABLE I. Electron-microprobe analyses (wt %) of calcian phosphatian vanadinite from Belton Grain vein, Wanlockhead.

Analysis	1	2	3	4	5	6	7	8	9
PbO	79.95	80.26	80.47	80.24	79.23	79.91	79.75	79.77	78.45
CaO	0.38	0.06	0.89	0.04	0.47	0.30	0.27	0.53	1.37
V_2O_5	17.70	18.47	15.33	18.60	17.45	18.16	18.39	16.68	15.04
P_2O_5	1.25	0.40	2.98	0.31	1.52	0.92	0.75	1.95	3.76
Cl	2.30	2.28	2.28	2.29	2.27	2.30	2.27	2.25	2.23
Total	101.58	101.47	101.95	101.48	100.94	101.59	101.43	101.18	100.85
O≡Cl	0.53	0.52	0.52	0.52	0.52	0.53	0.52	0.51	0.51
Total	101.05	100.95	101.43	100.96	100.42	101.06	100.91	100.67	100.34
ATOMS ON BASIS OF 12 OXYGENS									
Pb	4.80	4.89	4.79	4.89	4.75	4.80	4.79	4.79	4.58
Ca	0.09	0.01	0.21	0.01	0.11	0.07	0.06	0.13	0.32
V	2.61	2.76	2.24	2.78	2.57	2.68	2.71	2.46	2.15
P	0.24	0.08	0.56	0.06	0.29	0.17	0.14	0.37	0.69
Cl	0.87	0.87	0.86	0.88	0.86	0.87	0.86	0.85	0.82
Analysis	10	11	12	13	14	15	16	17	18
PbO	79.67	80.11	79.44	79.41	81.07	79.25	79.19	80.22	79.47
CaO	1.42	1.19	0.73	0.72	0.91	1.21	0.46	0.20	0.35
V_2O_5	13.21	14.00	16.01	15.67	14.26	15.32	18.23	17.67	17.00
P_2O_5	4.79	4.13	2.64	2.63	3.15	3.32	0.83	0.95	1.57
Cl	2.28	2.27	2.27	2.37	2.33	2.29	2.21	2.23	2.18
Total	101.37	101.70	101.09	100.80	101.72	101.39	100.92	101.27	100.57
O≡Cl	0.52	0.52	0.52	0.54	0.53	0.52	0.51	0.51	0.50
Total	100.85	101.18	100.57	100.26	101.19	100.87	100.41	100.76	100.07
ATOMS ON BASIS OF 12 OXYGENS									
Pb	4.68	4.73	4.73	4.79	4.94	4.66	4.76	4.88	4.83
Ca	0.33	0.28	0.17	0.17	0.22	0.28	0.11	0.05	0.08
V	1.91	2.03	2.34	2.32	2.13	2.21	2.69	2.64	2.53
P	0.89	0.77	0.49	0.50	0.60	0.61	0.16	0.18	0.30
Cl	0.84	0.84	0.85	0.90	0.89	0.85	0.84	0.85	0.84

1-4. Brown vanadinite, NMS G 552.9, single spot per grain. **5-7.** Orange vanadinite, NMS G 552.19, two grains. **8-11.** Brown vanadinite, NMS G 552.6, 8-9 core, 10-11 rim of one grain. **12-13.** Brown vanadinite, NMS G 552.6, 12 core, 13 rim. **14-15.** Brown vanadinite, NMS G 1991.31.84, 14 core, 15 rim. **16-17.** Brown vanadinite, NMS G 1991.31.84, two spots on same grain. **18.** Cream vanadinite on plumboan apatite, NMS G 552.9.

Vanadinite globules are sometimes rimmed by plumboan apatite (Table II), which increases in lead content as the vanadinite boundary is approached, the highest lead content found being 30-32% PbO (Table II, analyses 22 and 25). These high values are not attributable to grain edge effects, for V_2O_5 is no higher than that in plumboan apatite with less lead. On the basis of 10 cations, analysis 22 yields a cation composition of $(Ca_{8.05}Pb_{1.95})$, comparable with that previously obtained (Livingstone, 1994). The analyses in Table II show low totals because the apatite contains H_2O and carbonate (Livingstone, 1994); the variability of the totals is related to the observed differences in stability under the electron beam of the analysed samples.

REFERENCES

Frenzel, A. (1881). Vanadinit und Tritochorit. *Mineralogische und Petrographische Mitteilungen*, **3**, 504–516.

Livingstone, A. (1994). An apatite high in lead from Wanlockhead, Strathclyde Region, Scotland. *Mineralogical Magazine*, **58**, 159- 163.

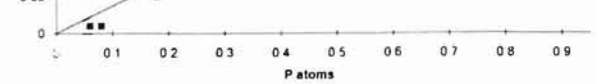

FIGURE 1 Plot of Ca atoms against P atoms per formula unit in Wanlockhead vanadinite (analyses 1-18).

TABLE II. Electron-microprobe analyses (wt %) of plumboan apatite from Belton Grain vein, Wanlockhead.

Analysis	19	20	21	22	23	24	25	26
CaO	46.23	43.37	45.37	34.84	38.93	44.69	34.90	43.63
PbO	13.73	19.37	13.61	33.63	27.78	16.44	30.22	18.50
P_2O_5	33.92	31.52	32.43	29.67	30.77	32.47	28.56	31.71
V_2O_5	0.04	0.04	0.03	0.06	0.05	0.06	0.05	0.05
Cl	0.04	0.09	0.03	0.67	0.36	0.10	0.30	0.09
F	2.96	2.54	2.03	1.99	2.60	2.52	2.25	2.44
Total	96.92	96.93	93.50	100.86	100.49	96.28	96.28	96.42
O≡Cl+F	1.26	1.09	0.86	0.99	1.17	1.08	1.02	1.05
Total	95.66	95.84	92.64	99.87*	99.32*	95.20	95.26	95.37

* When the sum is normalised to 95.5%, PbO becomes 31.96 and 26.4%, respectively.

19. Plumboan apatite, NMS G 1991.31.84. **20-21.** Plumboan apatite, NMS G 552.9. **22-24.** Plumboan apatite, NMS G 1991.31.83. **25-26.** Plumboan apatite, NMS G 1991.31.84.

J. Russell Soc., 5(2), 127–132 (1994).

BOOK REVIEWS

Klein, C. and Hurlbut, C.S., *Manual of Mineralogy (after James D. Dana)*. 21st edn. John Wiley & Sons. New York & Toronto, 1993. xii + 682 pp., 80 tables, 687 figs, 4 colour photographs. Price £22.95. ISBN 0-471-59955-7.

This book, the latest generation of a long ancestry, bears little resemblance to James Dwight Dana's original *Manual of Mineralogy* of 1848. Dana would surely be pleased with, as well as amazed at, this edition, which clearly illustrates how much our science has advanced in recent years.

This is quite a large book, of near-A4 format and 2.5 cm thick, with soft covers, and is profusely illustrated, including four excellent colour photographs of displays of gemstones. It is clearly written, well edited and well produced. There are lots of useful tables, and even the insides of the front and back covers are utilised, with extra tables of units, symbols, ionic radii and coordination, crustal abundances of common elements, a stereographic net, an interference colour chart, etc. An excellent table (4.8) of effective ionic radii is presented in the form of a periodic table of ions; the *negative* values for C^{4+} and N^{5+} in 3-fold coordination may puzzle some readers, and an explanatory footnote would have helped, mentioning their coordination with oxygen. In addition to the normal subject index, there is a mineral index which doubles as a table of the species mentioned in the book, with chemical formulae and physical data. There are also tables of minerals in order of increasing refractive index and specific gravity, though these are again restricted to the species discussed in the book. A large determinative table, of 32 pages, lists lustre, colour, streak, cleavage, hardness, and specific gravity; like most such tables, it looks very useful, but I have always found them disappointing when it comes to actual mineral identifications!

This will make a very useful textbook for students and from the point of view of the serious amateur is an excellent reference book, with well-written chapters to explain subjects such as crystallography, crystal classes, symmetry, crystal structures, crystal chemistry, petrology, gemmology, and determinative techniques. The techniques include X-ray diffraction, optical and other physical methods; X-ray fluorescence and electron microprobe methods are explained, but curiously not scanning electron microscopy. Other unfortunate omissions are infrared spectroscopy and simple microchemical tests. About half the book is devoted to explaining the principles of modern mineralogy, the other half to systematic mineralogy the description of mineral species. The range of species discussed is limited to about 200 of the more common ones. The choice of species displays the normal geologists' petrological bias and, not surprisingly, the localities show an American bias. A number of less common species are listed as 'similar species', but many of the rare minerals so interesting to amateurs as well as to professional mineralogists are missed out. Out of over 3200 known mineral species, about 850 contain silicate, but the description of silicates in this book occupies 118 pages, and of all other classes 106 pages, with the phosphates, arsenates and vanadates occupying only $7^{1}/_{2}$ pages. Chapter 14 (*Mineral assemlages: introduction to rock types and vein mineralization*) is excellent, and many readers will enjoy the final short chapter on *Gem minerals*.

R.S.W. Braithwaite

Blackburn, W.H. and Dennan, W.H., *Principles of Mineralogy*, 2nd edn. Wm C. Brown, Dubuque, 1994. 409 pp. Price £19.95.

The first edition of this text, which is aimed at junior North American undergraduates, has a copyright date of 1988. This edition, "incorporating many helpful and constructive comments", has a 1994 date, suggesting that there has been a significant market for this book and that the pace of American academic life be swift. The book falls securely into the seemingly endless number of American texts that concentrate on a rigorous exposition of crystallography, mineral chemistry and physics, phase equilibria, etc., to a depth that, I suspect, is no longer taught in most British earth science departments. These books are polymorphs — they have essentially the same content but differ in structure, hardness and habit. In this example the text follows the style and format of *Mineralogy* by Berry and Mason and, less closely, that of Rutley's *Elements of Mineralogy*, in that detailed mineral descriptions and determinative tables follow a set of general theoretical chapters.

The book is divided into three parts. Part one (160 pages) covers 'theoretical considerations' and is split into eight chapters on symmetry; crystallography; atomic and molecular bonding; mineralogic (*sic*) variations (a catch-all chapter of diverse subjects including triangular composition diagrams, exsolution, twinning and polymorphism); phase equilibria and crystal growth. All the chapters are illustrated very well with many line drawings. Phase equilibria, crystallization and habit are particularly clearly explained. The final chapter, entitled 'Geological Framework', deals with minerals as components of igneous, metamorphic or sedimentary rocks or as parts of mineral deposits. This is disappointing — it has a slightly dated feel and there is an over-emphasis on porphyry copper deposits.

Chapters 9-12 belong to the second part: 'Practical Mineralogy', fifty pages of techniques. Macroscopic properties are followed by optical properties and the use of the petrological microscope (too brief for most undergraduate courses) and then the full range of black boxes. This chapter concentrates on the principles behind each technique, describes in good detail the hardware, and then finishes with an introduction to statistics. The final chapter concentrates on all forms of X-ray diffraction. X-ray diffraction in a number of recent American texts is given equal space to optical petrography despite, I assume, the greater availability of microscopes.

The final part (chapters 13-21) is 150 pages long, describes 178 common minerals in detail (Berry and Mason give approximately 200) and mentions by name and formula a further 740. The chapters are divided chemically, beginning with native elements and ending with silicates which make up 40% of this final part. For each mineral the formula and etymology of the name is followed by crystallographic and structural data, physical properties (but not optical properties in polarized light), associations, occurrence, alteration, and finally variants and related minerals — hence the extra 740 names. Most minerals have a structural diagram assigned to them and many have a black and white photograph of a museum specimen.

There is a 24-page appendix comprising determinative tables. The first two are short; B1 lists minerals based on rock associations, B2 gives minerals that have very distinctive properties, for example being water-soluble or magnetic, but the main table, B3, is comprehensive and determinations are made based upon lustre, cleavage, hardness and colour.

However, what is the market and where are the classes for such texts? Whilst undergraduates could learn much from parts one and two of this book, I doubt many of them would use the final chapters. Undergraduates, serious mineral collectors and amateurs learn mineral identification by the oral tradition, by asking someone, or, if the species is obscure, by obtaining X-ray diffraction data or a microscopical identification. Like microscopy, macroscopic mineral identification is not a book art, it is a taught skill, and mineral lists giving hand specimen properties are, at best, there for the sake of completeness. In particular, repeating the litany of blowpipe tests for minerals has much the same value as the constant repetition of Egyptian King lists.

To summarize, this book is a good example of the genre; it is a useful undergraduate text and value for money. However, it is too complex for the amateur but not eclectic enough for the serious mineral collector, and many of the data could be obtained from a second-hand copy of Berry and Mason.

R.A. Ixer

Brocardo, G., *Minerals and Gemstones of the World*. David and Charles, Newton Abbot, Devon, 1994. 215 pp, 156 colour photographs. Price £10.99 (paperback). ISBN 0 7153 0197 7.

This handy identification guide (translated from Italian) comprises an excellent text in the first 43 pages, followed by 156 pages with colour plates of mineral specimens, together with a pictographic table below each which uses easily identified symbols to allow rapid selection from a mass of detailed information on the characteristics and properties used to classify and identify the mineral. The order of presentation of the minerals is by their overall colour.

The colour photographs are generally excellent, but the specimens to be shown were all selected from the Turin Museum of which the author is Director; there is thus a tendency to select rather rare species, e.g. buergerite, creedite and greenockite. Admittedly, we are told that these are rare or extremely rare, but with only some four percent of known mineral species on display the inclusion of such rare species must be questioned. Also, we are shown some unusually coloured varieties, e.g. violet-pink cobaltian calcite (though, no doubt by a slip, the formula is given beneath the plate as $CaCo_3$); similarly, we have a rather bilious yellow quartz, labelled prase. Another problem users may find is with the colour descriptions in the pictograms: it turns out that the colour indicated there is that of the mineral *powder* rather than the hand-specimen appearance — thus we have a representative picture of kyanite, we are told the name is for the blue colour, but the pictogram indicates merely white or pale. Under epidote, piemontite is mis-spelt and the selected sample of epidote is yellow-brown rather than the typical pistachio green.

Despite these reservations (colour giving a collector such an important clue), I would happily recommend this useful little book to a beginner.

R.A. Howie

Bevins, R.E., *A Mineralogy of Wales*. National Museum of Wales, Geological Series No. 16, Cardiff, 1994. 146 pp. Price £25. ISBN 0 7200 0403 9.

This book is the first comprehensive compilation of the mineral species occurring in Wales. It is essential reading for anyone with an interest in the mineralogy of the Principality. After a brief Foreword and Introduction, the latter giving lists of those minerals that were first described from Wales, and the first British Isles occurrences from Wales, the main body of the text is in two chapters.

The first chapter, titled 'Mineral Occurrences in Wales' (22 pp), outlines the geology, mineralogy and distribution of the occurrences. Rock forming minerals are not neglected and are covered under igneous, metamorphic and sedimentary headings. These are followed by comprehensive coverage of hydrothermal mineralisation and a final brief mention of superficial deposits. This chapter is very clearly written. There are brief outlines of basic mineral emplacement principles and unnecessary jargon has been avoided. Anyone with a modest knowledge of geology should have no difficulty in understanding the text. In addition to some photographs of sites, and thin sections to illustrate rock forming minerals. there are ten maps which show the distribution and position of the mineralogical sites. Map references are not included, so would-be visitors to the sites will have to do some further research in most cases.

The second main chapter, simply titled 'The Minerals' (97 pp), describes the 300-plus minerals noted from Wales at the time of going to press. Included are references to some occurrences which have since been discredited or are doubtful. but are nevertheless important in a historical context. For each mineral entry there is a brief outline of the normal mode of occurrence, with chemical formula and group affiliation. Then follows a detailed description of the Welsh localities where the mineral has been recorded. Full references for each locality are included and the depth of the literature search is exemplified by the fact that even newsletters of mineralogical societies are included. The final pages are devoted to the literature reference list and the index.

The presentation is similar to those of the BM(NH)/NHM books on Cornwall and Devon and on the Caldbeck Fells, except that historical chapters are not included. No attempt has been made to illustrate all minerals, but the pages contain many superb colour photographs which clearly show the beauty and range of specimens found within the Principality. Aficionados of typographical errors will find a few but, overall, like everything else about this book, the checking of the text has been done very well.

T.F. Bridges

Kelly, D., *The Red Hills.* Red Earth Publications, Ulverston, Cumbria, 1994. 176 pp, 52 photographs, 40 maps. Price £9.99. ISBN 0-9512946-7-9.

In common with many authors who have written about the west Cumbrian hematite mining field, I have over the years often been obliged to comment on the surprising lack of any comprehensive history of these mines. I was about to do so yet again when Red Earth Publications announced Dave Kelly's Book.

The book begins with a very brief introduction to the geology and mineralogy of the deposits, which is followed by almost equally brief outlines of the mine owners, the miners and the working of the mines. The main text chronicles the history of virtually every mine in the main orefield between Egremont and Lamplugh, with brief mention made of south Cumbrian mines including Hodbarrow. The Furness district is not included. Notes are given for a few hematite mines and trials in the adjoining fells of the western Lake District. Very brief chapters on ironworks and railways conclude the main text. An ample selection of photographs, mainly old ones, gives a welcome glimpse of several mines which have long been famous to the mineralogist as localities on specimen labels. The sites of mines and individual pits are a valuable aid to anyone not familiar with the area.

The author and publisher are to be congratulated on attempting to fill such a long-standing gap in the history of British mining. The layout is easy to follow, the photographs mostly reproduce well and the maps, though in manuscript form, are serviceable but almost universally lacking in scales. There are, however, some grounds for serious criticism. Even accepting that the book is primarily an historical account, the reader is entitled to a better introduction to the deposits than that offered in Chapter 1. A fundamental misunderstanding of even the most elementary of geological principles is apparent here. Amongst these the citing of Kendall's work dating from 1893 and even earlier as the accepted authority on the origin of Cumbrian hematite is frankly astonishing. Whereas the author cannot be expected to be a qualified geologist it would surely have been sensible for him, or his publisher, to seek a modicum of technical advice before committing this chapter to print.

The historical chapters which follow are distinguished by an economy of writing. Certainly this book is not burdened with the oppressive weight of irrelevant detail which characterises so many recent mining histories. However, there are clearly some factual errors. For example, Beckermet Mine is stated to have closed in 1973: Haile Moor Mine closed in 1973, Beckermet worked until 1980. Frequent reference is made to the dates of abandonment of mines. It is not clear, however, whether the dates given are the dates of *closure* when mining ceased or the date of *abandonment* when statutory abandonment plans were lodged with the Mining Records Office. Instances of several years separating these two events are by no means uncommon. One is left wondering whether the text's brevity is the result of careful sifting of data or the limit of the author's research.

A number of editorial idiosyncrasies are apparent. The main text is broken into three parts for no obvious reason. The maps, mostly lacking in scales, are collected together at the end of the book. They would function much better if included with their relevant section of text; one or two have their titles transposed. A final disappointment is the bibliography. A number of obvious important works are inexplicably absent, and most of those which are given are in such an abbreviated form as to render them untraceable.

The book is a *useful* addition to the literature of British mining history: had more care been taken in its preparation it could have been an *important* one. It can thus be recommended if only because there is no alternative text.

B. Young

Birch, W.D. and Henry, D.A. (eds), *Phosphate Minerals of Victoria*. Special Publication No. 3, Mineralogical Society of Victoria, Melbourne, 1993. viii + 182 pp., 215 figs. Price, Australian $40.00 (+ overseas postage $15.00 seamail, $26.00 airmail).

This well illustrated book describes forty-eight recorded phosphate minerals in their various associations and geological environments, including granites, sediments and cave deposits. The text is illustrated with photographs (115 in colour), maps, crystal drawings and SEM photographs.

After an introductory chapter, there are comprehensive reports on the phosphates in granites and in mafic igneous rocks, including microprobe analyses of fluorapatite, cyrilovite, kidwellite, leucophosphite, eosphorite, wardite and rockbridgeite, together with locality details and mouth-watering colour photographs of libethenite, sampleite, saléeite, torbernite, turquoise, ulrichite, eosphorite and wycheproofite. Turning to the phosphates from oxidised sulphide deposits, detailed descriptions, microprobe analyses and photographs are presented for green, brown and yellow pyromorphites. Sedimentary phosphate deposits are widespread in Victoria and are hosted by Palaeozoic black slates, sandstone/siltstone, Tertiary marine strata with phosphatic nodules, and terrestrial alluvial deposits. Wavellite, cacoxenite, fluellite, rockbridgeite, sasaite and turquoise are described from the black slate deposits, whereas vivianite is the dominant phosphate in the sandstone/siltstone-hosted deposits. Spectacular large blue or green vivianite crystals were also found in volcanic tuff at Wannon Falls. The detrital phosphates are mainly represented by monazite-(Ce), for which 18 analyses are given.

Guano deposits in the Skipton and Parwan cave systems contain significant suites of phosphate minerals; full descriptions are given for struvite, hannayite, newberyite, schertelite, sasaite and dittmarite from the Skipton lava cave and for montgomeryite, carbonate-hydroxyfluorapatite and gordonite from Parwan caves. The bibliography includes some 150 references.

This book is the third in a series published by the Mineralogical Society of Victoria, the first having dealt with minerals of the Maldon Goldfield, and the second with the zeolites of Victoria. This comprehensive book on phosphates fills an important gap, as little had been previously written on phosphate minerals and their localities within Victoria, and much of the material presented represents the results of detailed research by the senior editor. The high standard of the illustrations and the very complete locality details will make this book attractive to all interested in topographic mineralogy.

R.A. Howie

Regional Geochemistry of the Lake District and Adjacent Areas. British Geological Survey, Keyworth, Nottingham, 1992. A3 format, 98 pp, 32 colour images, 1:250,000 geological map. Price £50.

This substantial publication is the ninth in a series being prepared to provide a systematic picture of the geochemistry of the whole of Britain, starting in Shetland and progressing southwards. This issue follows the format and style of the previous volume covering the East Grampian area. Whilst adopting a more comfortable page size than the seven earlier volumes, the double A3 format still requires a good amount of space in which to open the book — certainly non-ideal when reading on a transatlantic crossing in a 747 as I did for this review! That apart, the book is nicely presented on good quality paper and well illustrated throughout.

The aim of the Geochemical Survey Programme is to identify new occurrences of metalliferous minerals and to provide quantitative data on natural element levels which may be used to assess environmental contamination. It seems likely that the environmental applications are set to become increasingly important in the future. Professor Charles Curtis in his foreword reviews the history of Lake District research and comments on basic geochemical processes. There are introductory comments on how primary sediment characteristics and composition may be affected by weathering processes and the composition and properties of surface and stream waters.

Considerable background information is given regarding sample collection methodology, chemical analysis, data and image processing, together with statistical analysis and data interpretation. Some 6200 sites were sampled over a three-year period, giving an average density of one sample every 1.6 km^2, the sites being situated, where possible, on first or second order streams. Explanation is given of the precautions taken to ensure repeatability and accuracy during the sampling and analytical operations.

A comprehensive review of the geology and mineralisation of the region occupies 15 pages, providing a thorough, up to date account of current knowledge, together with maps and photographs. The map of 88 selected mineralisation localities, with name, national grid reference, and principal ores, is slightly irritating to use in that the numbering of localities appears to follow no defined pattern in relation to the spatial distribution of points on the map.

A reference on page 19 to the reports by Ward (1876) and Postlethwaite of a mass of pure stibnite weighing up to 50 kg recovered from Troutbeck Station raises the intriguing possibility of a significant, but as yet undiscovered, antimony deposit concealed by drift.

The bulk of the atlas is, of course, given over to a series of 32 computer-generated, full-colour maps for specific elements in stream sediments. Each map includes a summary table showing key statistical data, together with a frequency distribution for elemental concentration. The page facing each map carries a description of the occurrence and the geochemistry of each featured element in turn. These accounts are rather repetitive and one is left with the feeling that almost all significant geochemical anomalies are the result of metallic or man-made contamination, rather than mineral deposits or geology; but this is perhaps as much as one might expect. There are, however, one or two interesting exceptions.

The previously unrecorded copper mineralisation in Dodd Wood might be worth following up: together with the occurrence of 200 ppm of lanthanum west of Walden Beck (perhaps raising the possibility of finding lanthanite), and a 20,000 ppm anomaly with Ba, Zn and other elements near Ireby, which may be due to a mineralisation site. The entries for manganese and molybdenum include interesting anomalies, and there is a significant uranium anomaly south of Cow Green Reservoir.

At the back of the volume, a new feature is the inclusion of combined anomaly maps which show well the association of related elements, e.g. Sr and Ba; Cd and Zn; Co and Mn; Pb, Zn and Ag; As, Sb and Bi.

Although the occurrence of gold in association with As, Sb and Bi is mentioned a couple of times, no map or data are given for gold in stream sediments — a surprising omission. Presumably gold data are commercially valuable and can be sold as specialised reports.

Overall I found the atlas an interesting read for 5 or 6 hours. As is perhaps inevitable with a publication of this nature, a sprinkling of typographical errors may be found throughout the text, but these do not detract from the value of the work. The book can be recommended as a standard work in its field, and will doubtless find a place in all good libraries associated with earth science. At £50, and given its specialist appeal, it is unlikely to be taken up to any great extent by the amateur mineralogist or collector. However, both of these groups would be well advised to browse through the pages, and especially the excellent list of 335 references, as a means of gaining new leads for field work and hopefully to increase their understanding of the geology and mineralisation of this area.

R.E. Starkey

Jones, G.C. and Jackson, B., *Infrared Transmission Spectra of Carbonate Minerals*. Chapman and Hall, London, 1993. xv + 234 pp. Price £75. ISBN 0-412-54650-7.

The lack of adequate collections of reference data, such as exist for X-ray diffraction patterns, has been a major obstacle in the development of infrared spectrometry as a relatively cheap and rapid technique for identifying minerals by matching their spectra with those of authentic reference samples. This book, the result of a collaboration between the Natural History Museum in London and the Royal Museum of Scotland in Edinburgh, is a welcome first step on the road to such a database, and covers the carbonate minerals. All the common species are here, as well as many rare species whose spectra are recorded for the first time. It is, of course, a book for the specialist; its very high price alone will ensure that, apart from some libraries, only the serious IR user will buy a copy.

The actual spectra (4000-300 cm^{-1}) of about 110 species are reproduced here, out of some 230 carbonate-containing species listed in *Hey's Mineral Index* — a very respectable proportion, considering that only samples of undoubted authenticity and purity were used, nearly all checked by XRD and some also analysed (and this distinguishes the book from most previous compilations of this type). Each facing page carries details of the specimen used, some comments, up to four literature references, and a table of measured absorption peak frequencies. This last is essential since the spectra, obtained with a Fourier Transform instrument and of excellent quality, are presented in the now familiar, user-unfriendly, computer-plotted form with scanty scale markings (and their machine can't even divide a range of 100 or 1000 cm^{-1} into five instead of the irritating four divisions!). But this is a trifling criticism, which the user can largely overcome by labelling the prominent peaks on his or her copy using the frequency tables provided. Overall the book is very well produced, on good thick paper, and the spine cleverly hides a spiral binding that allows it to open flat.

My only real disappointment is that the authors do not provide, or even discuss, any means of using this library of spectra for identifying an unknown from its spectrum. Most carbonates can be easily recognised as such from their spectra, and one can then simply leaf through this book to try to find a matching spectrum. But this is obviously not a general solution, and impractical for a larger collection of reference spectra (imagine attempting to use the Powder Diffraction File without the search manuals!). The problem needs to be addressed in any future extension of the authors' work. I have two more wishes: that this book should remain in print for a long time (previous compilations of IR spectra are now hard to obtain, even on loan); and, of course. that further volumes. on phosphates. arsenates. sulphates, etc., should follow.

G. Ryback

Wilson, M.J. (ed.), *Clay Mineralogy: Spectroscopic and Chemical Determinative Methods*. Chapman and Hall, London, 1994. x + 367 pp, 146 figs, 22 tables. Price £79. ISBN 0-412-53380-4.

In recent years, advances in spectroscopic techniques and their uses have contributed much to the detailed understanding of clay chemistry. This new book is essentially a compilation of spectroscopic and chemical methods with applications in clay mineralogy. The book is intended to be useful both to clay mineralogists and to scientists with no previous experience of clays, by striking a balance between introductory text and research compendium. The volume comprises nine chapters, each dealing with a specific chemical or spectroscopic technique, and most of the eleven authors, like the editor, are or have been associated with the Macaulay Land Use Research Institute in Aberdeen.

Following a general introduction to molecular spectroscopy, individual chapters deal with infrared methods, Mössbauer spectroscopy, nuclear magnetic resonance, electron paramagnetic spectroscopy, X-ray photoelectron spectroscopy, and X-ray fluorescence and microanalysis; the two final chapters deal with more traditional chemical methods and the investigation of poorly ordered minerals by selective chemical techniques. The chapters on infrared and chemical methods are updated from an earlier publication. Each chapter follows a broadly similar format, providing an introduction to the principles of the technique, a description of instrumentation and experimental practices, and an account of applications of relevance to clay mineralogy. The work is well illustrated and other minerals associated with clays are also discussed in some chapters.

The book is likely to prove a useful reference for those interested in clays and related mineralogical applications. Mineralogists using spectroscopic techniques should also find parts of the book helpful when confronted with clay minerals — for instance, the chapter in infrared methods contains a valuable collection of infrared spectra of clays and accessory species. The book is perhaps less successful as an introduction for non-specialists, and the reader seeking information on the individual spectroscopic methods will probably be better off with a standard introductory text.

In summary, this book is a useful and timely reference work, well produced, and reasonably well indexed and referenced. Most geological and mineralogical libraries will want a copy, but its regrettably high price surely means that very few researchers will have a copy on their personal bookshelf.

N.J. Elton

NOTES FOR CONTRIBUTORS

TYPESCRIPTS

Papers should be typed, preferably on A4 paper, on one side only, with double spacing and wide margins. All pages should be numbered. Three complete copies should be submitted to the Editor. Each paper will be reviewed by two referees. Submission of a paper to the Journal is taken to imply that it has not been considered for publication elsewhere. Material accepted for publication can not be published elsewhere in the same form without the consent of the Editor.

The submitted material should normally contain original observations or experimental results relating to mineral occurrences in the British Isles, although other suitable topics may be considered. Full articles should include an abstract of up to 250 words summarising the significant points of the paper; notes (up to 1500 words) do not require an abstract. Review articles, which are usually invited, are also published occasionally.

FORMAT AND PRESENTATION

Papers should be submitted in the style and format of the Journal, and divided into appropriate sections and subsections. A recent issue of the Journal should be consulted for examples. Words to be printed in italics should be underlined in the typescript. Titles of papers should be adequately informative.

Authors should present their material with clarity and conciseness. Results and discussion should not normally be intermingled. Identification of the less common minerals should be supported by sufficient proof (X-ray diffraction, analyses, etc.). It may not be necessary to reproduce such data in full in the text, but they should be supplied to the Editor if required by the referees in the course of their assessment. For mineral occurrences of particular note (e.g. new occurrences in the British Isles or at a particular locality) authors are strongly encouraged to record the specimen number and the institution or collection where the specimen is lodged. National Grid References should be given for localities described in the text (the format is, e.g.: ST 4015 7185, ST 401 718, ST 40 71).

FIGURES

All figures should be numbered with consecutive Arabic numbers, and referred to in the text as Fig. 1, etc. Figures must have descriptive captions, and a list of these is to be typed on a separate sheet of the typescript.

Line drawings, crystal diagrams, maps, etc., should be of a quality suitable for direct reproduction, with appropriate line thicknesses and letter sizes. The Editor will arrange artwork for authors who do not have access to such facilities. Photographs should be submitted as good, glossy, black-and-white original prints of maximum possible contrast. The scale must be indicated, either on the photograph or by specifying, e.g. frame width or crystal size in the caption.

Draft line diagrams and good photocopies of photographs will suffice for attachment to the submitted typescripts, but a set of original photographs must be supplied at the time of submission; fair-drawn line diagrams will be needed only after acceptance of the paper.

TABLES

Tables should be numbered consecutively with Roman numbers, and referred to in the text as Table I, etc. Each table should have a descriptive title, separated from the table by a horizontal line. Another horizontal line should mark the end of tabulated data; any footnotes should be placed below this.

TERMINOLOGY

Authors must adhere to the nomenclature and terminology of the International Mineralogical Association. The most recent *Glossary of Mineral Species* (at present the 6th edition, by M. Fleischer and J.A. Mandarino, 1991) can be used as a guide to mineral nomenclature, but where this conflicts with *Hey's Mineral Index* (1993) or *Mineralogical Magazine* and *Mineralogical Abstracts* usage, the Editor will advise on the preferred nomenclature. Chemical nomenclature should conform to the rules of the International Union of Pure and Applied Chemistry. Crystal structure studies should be reported in the manner outlined by the International Union of Crystallography (*Acta Crystallographica*, **22**, 45 (1967)).

ABBREVIATIONS

Except for common non-scientific abbreviations and those for standard units of measurement, abbreviations should be spelt out in full at their first mention in the article, e.g. 'platinum group mineral (PGM)'. If used, 'n.d.' in tables must be defined ('not determined' or 'not detected'). The following abbreviations may be used without explanation:

XRD = X-ray diffraction
XRF = X-ray fluorescence analysis
EPMA = electron probe microanalysis (electron microprobe analysis)
EDX = energy dispersive analysis (same as EDA, EDAX, EDS)
SEM = scanning electron microscope or microscopy
TEM = transmission electron microscope or microscopy
IR = infrared
UV = ultraviolet
NGR = National Grid Reference

REFERENCES

References should be indicated in the text thus: (Brown, 1967) or 'as stated by Brown (1967)'; (Green and Brown, 1985) for two authors; (Green *et al.*, 1986) for three or more authors. If two or more references would give rise to identical citations in the text, they may be distinguished by appending 'a', 'b', etc. to the publication year.

A list of references in alphabetical order should form the last section of each paper. Some examples of the style used are given below; note that journal names are given in full. References to Newsletters and similar publications will not normally be allowed. Papers *in press* may be included provided they have been accepted for publication and the journal name is given. Personal communications and unpublished work (except M.Sc. and Ph.D. theses) should not be included here but can be cited in the text, thus: (A. Brown, *personal communication* or *personal communication*, 1992), (B.C. Green, *unpublished work*).

Bannister, F.A., Hey, M.H. and Claringbull, G.F. (1950). Connellite, buttgenbachite and tallingite. *Mineralogical Magazine*, **29**, 280–286.

Dewey, H. (1923). *Copper Ores of Cornwall and Devon*. Memoirs of the Geological Survey: Special Reports on the Mineral Resources of Great Britain, vol. **27**.

Heddle, M.F. (1901). *The Mineralogy of Scotland* (ed. by J.G. Goodchild), vol. **1**, p. 25. David Douglas, Edinburgh.

Jackson, N.J. (1977). *The Geology and Mineralization of the St Just District*. Unpublished Ph.D. thesis, University of London.

King, R.J. (1973). Mineralization. In: Sylvester-Bradley, P.C. and Ford, T.D. (eds), *The Geology of the East Midlands*, pp. 112–137. Leicester University Press.

BACK COVER: Native copper, dendritic crystals coated with malachite (17 cm high). Botallack mine, St Just, Cornwall. Specimen BM 56520 in the Natural History Museum, London, purchased in 1886 from F.H. Butler. Photograph by Frank Greenaway.