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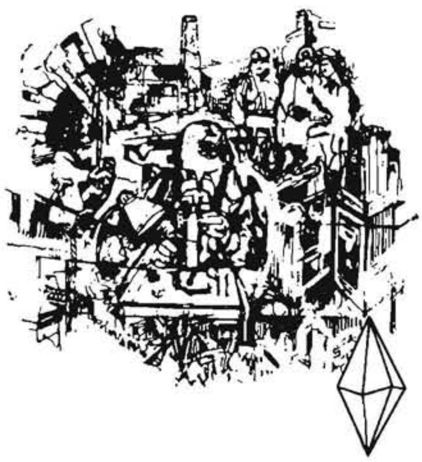

COVER PHOTO Cerussite with malachite from Redburn Mine, Weardale, Durham.

Collection of J.A.Jones.

EDITORIAL

This journal has set out to provide a medium whereby dedicated amateurs and professional mineralogists might set down topographical data of great value to the advancement of that branch of mineralogy, data possibly unacceptable to most professional journals unless accompanied by systematic mineralogical data.

From the type of article submitted in parts one to three it would appear that it is fulfilling that role, howbeit slow to gain momentum. There seems to be little need to worry about that aspect, a slow build up of momentum being better than a dramatic beginning and a steady decline.

The journal is in effect at least a hundred years behind the times, for topographical mineralogy, especially in the discovery of new macroscopic deposits, is facing, in Britain in particular, a steady decline. This is a course running parallel to the mining industry, where taxation and mining laws, high labour costs, etc. means the inevitable lack of development of old deposits and the discovery of new.

In spite of the almost day by day rate of mineralogical discovery of the 18th and 19th centuries, no doubt the number of authors would not have increased much in number beyond the present day level, for topographical mineralogists appear to be a shy breed of people, not too happy to appear in print or to share their findings with others.

The divulgence of mineralogical topographical data is a very real and topical issue and presents a serious problem to the geological sciences in general. Should data be made freely available or restricted to a few?

Although the problems are more acute in mineralogy, other geological disciplines face the same problem. They have attempted to meet it in several ways, not least by building a computer-based storage and retrieval of data system at the provincial museum level. In this it is assumed that museum personnel are responsible people, and allow such data to be made available only to bona fide and trustworthy recipients. But such responsibility places the keeper of such data in an unenviable position for he becomes the assessor of character, a notoriously difficult thing to do. Sadly also the keeper himself is human, as comparatively recent history demonstrates.

While it is vital that representative material and its accompanying data from new occurrences, described or not, should be lodged in a national museum where there is a tradition of conservation, the same assurance cannot be given at the provincial museum level. The collector is of course at liberty to lodge at both levels, but he should remember that safe lodgement in provincial or university musuems is often at the whim of the director or head of department. It is therefore a dangerous supposition that data storage and retrieval should be in the hands of such bodies.

What can be done to rationalise the situation?

In 1949 the Nature Conservancy was established by Royal Charter, with the conservation of our natural history heritage as its sole aim. It was eventually to become the Nature Conservancy Council as we know it today. From is earliest beginnings geologists have figured strongly in its organization and sterling work has been done in the field of geological conservation. By providing grant aid and expert advice, land owners, lessees and interested parties have been enabled to protect sites of scientific value and thus allowed the continuation or promotion of scientific research. Tickow Lane mine in Leicestershire is a good example. Sites of prime scientific value have been so designated and local authorities and land owners made to realise the value of the sites into the foreseeable future. The Council's system of data storage is second to none and its methods of data retrieval is practically efficient and lacking the personality bias so liable to occur in a musuem or private individual situation. Perhaps it is unnecessary to duplicate data storage systems at the level advocated by the Geological Curators' Group, but allow the Nature Conservancy Council to do the job it was created to do in full.

What can the Russell Society do with regard to conservation?. Items in its constitution state:

3B. To preserve mineralogical sites and material.

C. To develop mineralogical sites in the cause of mineralogical research.

While both items are admirable, both may unfortunately be loosely interpreted.

In the case of 3B., the preservation of mineralogical material implies the safe storage of specimens and field data, either in a personal well-organized collection, or by donation of representative material to an institution competent to look after it, or preferably both.

Within the Society framework as it now stands, the preservation of mineralogical material implies the work of an individual. There is no Society collecting policy. He finds himself in the unfortunate position of having to sort out his personal dedication, i.e. his order of priorities, either to his own collection or to science.

While certain individuals have already come to grips with the problem and have deposited representative material, and its accompanying field data, in the National Museums, there is no strong general dedication along these lines within the Society.

The ultimate fate of material held in private hands, though perhaps relevant to this discussion, is beyond its brief and will be discussed subsequently in the form of an article in the journal.

There is no doubt how 3C. has been interpreted. The development of mineralogical sites has often been conveniently and loosely interpreted to mean the collection, sometimes by desperate and illegal techniques, of a rare mineralogical association to promote, not the science, but personal greed. As a responsible society, which should be showing the way, there is much to do towards putting our own house in order.

A first occurrence of laumontite in Wales

R.E. BEVINS AND J.M. HORÁK

Bevins, R.E. & Horák, J.M. 1985. A first occurrence of laumontite in Wales. *J. Russell Soc.*, 1, 78-79.

ABSTRACT. Laumontite has been identified at Llanelwedd Quarry, Builth Wells, Wales, occurring in thin, 2-3cm veins in association with calcite. The presence of laumontite questions earlier interpretations of metamorphic grade in the Builth Inlier, suggesting that it may lie in the zeolite facies and not, as previously suggested, in the prehnite-pumpellyite facies. This occurrence of laumontite is the first reported in Wales.

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Introduction

Laumontite, $CaAl_2Si_4O_{12}.4H_2O$, a member of the zeolite group of minerals, has not previously been reported from Wales. In this paper a first occurrence of laumontite from Llanelwedd Quarry, Builth Wells, Powys (Nat. grid ref. SO 051 521) is described.

Laumontite typically occurs in low-grade metamorphic rocks filling veins or vesicles in lavas. In these environments much of the calcium is probably released by albitization of original calcium-rich feldspars. Laumontite is an index mineral for the upper part of the zeolite facies (Turner, 1981), but also occurs in areas of hydrothermal alteration where it commonly forms thick veins, in close association with heulandite. Recently Evans and Schiffman (1983) have reported the presence of laumontite 'mounds' from the Del Puerto Ophiolite, of Jurassic age, exposed in the Coast Ranges, California. These mounds are interpreted as representing precipitates from sea-floor emanations of calcium-rich hydrothermal fluids.

Laumontite has long been known to occur in Britain. Greg and Lettsom (1858) described numerous occurrences in Scotland, particularly in the Carboniferous lavas near Dumbarton, and in the Tertiary lavas of the Inner Hebrides. More recently Van de Kamp (1969) reported the presence of laumontite in Silurian volcanic rocks at Moon's Hill Quarry, Somerset. However, to date, no report of laumontite in Wales is known to the authors and zeolite group minerals as a whole are relatively rare in Wales. Analcime has been identified in limestones in the contact zone of the Plas Newydd Dyke, Anglesey (Greenly, 1919), and is known to exist in altered dolerite at Gimlet Quarry, near Pwllheli. In addition, harmotome has been identified from Cwm Orog, Llangynog, Powys while Williams (1924) reported the presence of thompsonite in dolerite dykes of Tertiary age in Snowdonia. The rarity of zeolites in Wales is related to the metamorphic grade of Lower Palaeozoic rocks, which generally lie in the prehnite-pumpellyite or greenschist facies (Bevins and Rowbotham, 1983), i.e. above the stability field of the zeolite group minerals.

Occurrence of laumontite at Llanelwedd Quarry

Laumontite has been identified in association with calcite in veins cutting altered Ordovician basic lavas at Llanelwedd Quarry, Builth Wells, Powys. The occurrence of pumpellyite and prehnite at Llanelwedd Quarry has been known for some time (Nicholls, 1958). Bevins and Rowbotham (1983) presented microprobe data of both prehnite and pumpellyite from Llanelwedd Quarry and suggested that metamorphic grade in the area lies in the prehnite-pumpellyite facies. More recently, Bevins (*in press*) has described the particular occurrence of pumpellyite-dominated metadomains at Llanelwedd Quarry and suggests that they possibly result from submarine hydrothermal alteration. The identification of laumontite raises questions concerning the metamorphic history of the area (see below).

The presence of laumontite was first brought to the attention of the authors by P. Sheldon (University College, Cardiff). He presented a self-collected specimen, labelled 'pink heulandite, Lower Spilite, Builth' to the National Museum of Wales, now registered as NMW 83.47G.M1. However, subsequent X-ray diffraction study (NMW - X149) has revealed that the so-called heulandite is, in fact, laumontite. The mineral is pink and massive and appears to be stable, as no signs of alteration to leonhardite have so far been observed. It occurs in thin veins (c. 20-30mm thick) cutting the volcanic rocks, in association with calcite. Further specimens of laumontite have been collected subsequently by the authors from the upper levels of the quarry (registered specimens NMW 84.46G.M1 and NMW 84.46G.M2). Field evidence suggests that the veins invaded at a relatively late stage in the alteration history of the volcanic rocks.

Discussion

The presence of laumontite at Llanelwedd Quarry raises certain questions concerning previous interpretations of the alteration history of the volcanic rocks of this part of Wales. The presence of prehnite and pumpellyite has been taken to indicate prehnite-pumpellyite facies; however both prehnite and pumpellyite are known to occur, albeit rarely, in zeolite facies terrains, in association with laumontite, as in Central Chile (Levi *et al.*, 1982), Takitumu, New Zealand (Houghton, 1982) and the Del Puerto Ophiolite, California (Evarts and Schiffman, 1983). It might, therefore, be that the metamorphic grade in the Builth Wells area is in the zeolite facies; certainly it would appear that in part the prehnite and pumpellyite at Llanelwedd Quarry is related to hydrothermal alteration (Bevins, in press) and, as such, should not be taken as indicative of regional metamorphic grade. Further support for a zeolite metamorphic grade in the Builth Wells area is provided by illite crystallinity studies (D. Robinson and R.E. Bevins, unpublished data), which suggest very low grades, in the zone of 'diagenesis'. Alternatively it might be that the laumontite-calcite veins are related to the effects of burial superimposed on the early hydrothermal alteration effects or even related to a late-stage retrogressive event. As yet the significance of laumontite at Builth Wells is equivocal. It is hoped that further study on the alteration of the volcanic rocks in the Builth area will help elucidate which of the above possibilities is correct.

Acknowledgements

We thank Peter Sheldon for first bringing the presence of laumontite at Builth Wells to our attention.

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Langite and Posnjakite from the Lake District

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Young, B. and Johnson, E.W. 1985. Langite and Posnjakite from the Lake District. *J. Russell Soc.*, 1, 80.

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Langite and posnjakite are respectively the orthorhombic and monoclinic dimorphs of $Cu_4(SO_4)(OH_6).H_2O$. Since its first description as a new mineral species by Maskelyne (1865) from Cornwall, langite has been reported from only a few British localities. The more recently described dimorph, posnjakite (Komkov and Nefedov, 1967) was first recorded in Britain by Knight and Barstow (1970, p.740) from Drakewalls Mine, Gunnislake, Cornwall where it occurs as a post-mine encrustation associated with langite and brochantite. Livingstone, *et al.* (1976) have since identified posnjakite from the dumps of West Blackcraig Mine, Newton Stewart, Kirkcudbrightshire where too it is associated with langite and other secondary minerals, and it is also reported from Britannia Mine, Gwynedd (R.E. Bevins, P.A. Williams and K. Jeffries, pers. comm.). These two apparently rare minerals are reported here for the first time from the Lake District, at two separate localities.

At Paddy End Mine, Coniston (Nat. Grid Ref. SD 284 988) langite is found as bright turquoise-blue, finely crystalline encrustations (Ph 7102)* on the walls of old stopes in the Middle Level section of the mine. Associated minerals are brochantite, malachite and gypsum. Specimens of massive tennantite collected from the dumps here contain small (1mm) spherules of turquoise-blue posnjakite (Ph 7165) locally associated with malachite and brochantite.

In Spothow Gill, Eskdale, the dumps from the upper level of a small copper mine (NY 205 004) have yielded a few specimens of heavily weathered chalcopyrite-quartz veinstone on which occur vivid turquoise-blue microcrystalline crusts which consist of a mixture of posnjakite and langite (Ph 6933, 6966).

At both these localities langite and posnjakite appear to be of recent, post-mine formation, as was suggested by Knight and Barstow (1970) for the Drakewalls Mine minerals. Despite their apparent rarity, suggested by the few reported occurrences, both of these minerals are likely to be of very widespread occurrence in old workings and dumps where copper sulphides are undergoing oxidation.

Mineral determinations by X-ray powder photography by B. Skilton and P.H.A. Nancarrow of the British Geological Survey are gratefully acknowledged.

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* Figures shown thus are BGS X-ray film numbers.

Pyromorphite in the Northern Pennines

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Introduction

Published references to pyromorphite from the northern Pennines are few. Jamieson (1816, p.397) recorded the mineral from Grasshill Mine, Teesdale and Greg and Lettsom (1858, p.405) noted its presence here as well as at "....Netherdale and Allendale in Durham....". As will be discussed below Grasshill Mine remains a notable locality for specimens of pyromorphite though the reference to the two latter localities is unsatifactory as both lack precise details. The whereabouts of the former has not been traced and the latter is in Northumberland and not County Durham. Dunham (1948, p.113) briefly comments on the occurrence of pyromorphite as "....small green hexagonal crystals....at Grasshill, Aglionby Beck, Closehouse and elsewhere...." though the other localities are not named.

In a recent review of secondary minerals in the northern Pennines the writer has examined all of these previously described pyromorphite localities and has located several new occurrences. In general pyromorphite is an uncommon mineral in the area though at a handful of localities it is present in some abundance. Throughout the area the mineral displays a variety of habits with each occurrence exhibiting a characteristic form.

Samples of pyromorphite from each locality described below have been examined by XRD-analysis and all have been shown to be very close to end member pyromorphite. No examples of mimetite or of minerals of near mimetite end member composition have been found. All occurrences of pyromorphite are listed below together with brief descriptions of the form of the mineral at each of these.

Pyromorphite occurrences in the northern Pennines

a) Hard Rigg Edge, Melmerby Fell (NY 6552 3876):

On the hillside east of Aglionby Beck the dumps from old workings on Knapside Vein, in beds beneath the Single Post Limestone, show abundant pyromorphite. Much of the pyromorphite here is well-crystallized as bright to dark green elongate prisms up to 3mm long scattered on limonite-stained quartz crystals. Crusts of small bright green crystals locally cover areas up to 100mm across on both quartz and shale. A few lumps of pure compact crystalline pyromorphite up to 70mm across also occur here. Cubic epimorphs in quartz up to 15mm across may represent original crystals of galena. This locality is also of interest for the abundance of quartz pseudomorphous after coxcomb baryte. A few small quartz pseudomorphous after a cubic mineral, locally with interpenetrant twinning, may represent original fluorite or galena. Goethite pseudomorphous after 'nail head' calcite have also been observed.

The date of these workings is unknown and although gravel tailings give evidence of former hand-dressing operations, no galena has been observed at this locality.

b) Smittergill Head Mine (NY 672 389):

The dumps from old opencast workings on the Great Sulphur Vein to the west of Gale Sike show much limonite-stained quartz veinstone. On some blocks of this occur small patches of deep green pyromorphite both as scattered prisms <1mm long and as rounded wart-like aggregates up to 2mm across. Other secondary minerals present in this oxidized veinstone include cerussite, malachite and linarite. The vein here occupies a fault which downthrows beds from the Five Yard to the Scar Limestone on the north against the quartz dolerite of the Whin Sill to the south.

c) Windy Brow Vein, Tynehead (NY 770 381):

One small (5mm) patch of pale dull green crystalline pyromorphite on limonitic quartz veinstone has been collected from the dumps of an old level driven on Windy Brow Vein in the beds beneath the Great Limestone. The limonitic veinstone here commonly contains small pockets of aurichalcite (Young *et al.* in press). Well crystallized galena, partly altered to grey cerussite, is common here on the site of an old dressing floor.

d) Grasshill Mine, Teesdale (NY 819 355):

Pyromorphite was first recorded from here by Jamieson (1816, p.397) and its occurrence here has also been noted by Greg and Lettsom (1858, p.405) and Dunham (1948, p.113 and 288). Several dumps from old workings known as Highfield Hushes on Black Leader Vein, contain abundant pyromorphite. The mineral here exhibits a very distinctive appearance and occurs as bright to yellowish-green cellular masses up to 200mm across in which roughly concentric bands of pyromorphite locally alternate with brownish-black earthy 'limonite'. Poorly developed stubby hexagonal crystals 1mm long are present in cavities. In some specimens concentric bands of pyromorphite surround cores of galena which is in an advanced stage of alteration to cerussite. Pyromorphite is more abundant at this locality than at any other known to the writer in the north Pennines, though its distribution in the dumps suggests that it was present in very local concentrations in oxidized portions of the vein in shale wall rock.

e) Whitfield Brow Mines, Weardale (NZ 008 341):

Dumps from workings in Rain's Vein in beds above the Upper Felltop Limestone contain some pyromorphite in addition to small quantities of quartz and fluorite. Much of the pyromorphite occurs as finely crystalline crusts, up to 2mm thick, on shale and quartz, and is mainly of a dull green colour though in places it is pale yellow. Thin crusts of green pyromorphite also occur on galena some of which shows advanced alteration to cerussite.

f) Healeyfield Mine, Consett (NZ 071 488):

This mine worked Healeyfield Vein in wallrocks of the "Millstone Grit" and Coal Measures. Parts of the dump contain blocks of coarse grained sandstone, joint surfaces of which are in places encrusted with finely crystalline to crudely mammillated bright green pyromorphite up to 2mm thick. Other blocks of sandstone display veinlets of well crystallized galena in cubes up to 3mm across.

g) Closehouse Mine, Lunedale (NY 850 228):

The occurrence of pyromorphite here was first noted by Dunham (1948, p.113). The mineral is relatively common here as deep grass green tapering prisms up to 3mm long which form thin encrustations on fracture surfaces of baryte, and in places on altered dolerite wallrock. A few specimens have been found which show minutely crystalline pyromorphite encrusting galena.

h) Yorkshire Silverband Mine, Cronkley Fell (NY 834 274):

A little pyromorphite is present on a small area of dumps alongside workings on Silverband Vein in beds between the Robinson and Peghorn Limestones. The mineral here occurs as dull green cellular botryoidal masses mainly up to 15mm across, though rarely pure masses up to 50mm have been found. The pyromorphite is generally free of matrix but in a few specimens it encrusts baryte.

Origin of the pyromorphite

There is little doubt that all pyromorphite in the northern Pennines is of secondary origin: no evidence has been found to suggest formation by deposition from primary mineralizing fluids as has been advocated by Strens (1964) for some, at least, of the pyromorphite group minerals in the Caldbeck Fells. In the northern Pennines pyromorphite occurs as encrustations coating fracture surfaces of other vein minerals or wall rock, and in places surrounds cores of galena.

The pyromorphite has clearly developed by alteration of galena in the presence of phosphate-bearing solutions percolating through the upper weathering zone of the deposits. Phosphate ions were probably supplied by leaching of primary vein minerals as well as wall rocks. Siderite and ankerite, which are so widespread in the veins of the area, commonly contain small amounts of phosphorous (e.g. Dunham, 1948, p.237) and such wall rocks as shales, limestone and Whin Sill dolerite also have a small phosphorous content (Dunham, *op. cit.* p.104). The apparent scarcity of pyromorphite in the secondary assemblages of the orefield no doubt reflects the low levels of available phosphorous. Only in a very few localized centres where relatively high phosphate concentrations occurred have groundwater conditions allowed pyromorphite to form. Although such sulpharsenide minerals as gersdorffite and glaucodot have been shown by Ixer *et al*. (1979) and Vaughan and Ixer (1980) to be widespread in very small amounts in the sulphide mineral assemblages throughout the area, it is perhaps surprising that no specimen of mimetite or of a pyromorphite group mineral near mimetite has yet been discovered. It may be noted that at Closehouse Mine, where Vaughan and Ixer (1980) described small amounts of arsenopyrite in the sulphide assemblage, pyromorphite of near end member composition is plentiful. Other secondary minerals commonly associated with pyromorphite in the north Pennines include cerussite and goethite.

Acknowledgements

X-ray diffraction analyses of pyromorphite specimens by B.R. Young of BGS London are gratefully acknowledged. This article is published by permission of the Director, British Geological Survey (NERC).

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Siegenite in clay-ironstone nodules from the South Wales Coalfield

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Bevins, R.E. & Horák, J.M. 1985. Siegenite in clay-ironstone nodules from the South Wales Coalfield. *J. Russell Soc.*, 1, 83-85.

ABSTRACT. Quantitative energy-dispersive analysis of small, silver, metallic, octahedral crystals occurring in clay-ironstone nodules from the South Wales Coalfield shows that they are siegenite and not linnaeite, as previously reported. The analyses compare favourably with siegenite from other localities. The presence of linnaeite in Wales is thus highly doubtful.

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Introduction

The occurrence of nickel- and cobalt-bearing sulphide minerals in clay-ironstone nodules from the Coal Measures strata of the South Wales Coalfield has been known for a long time. Miller (1842) first reported the presence of a nickel sulphide mineral in the area which, a few years later, was named millerite in his honour (Haidinger, 1845). In 1880 des Cloizeaux described a specimen belonging to 'Mr. Terrill of Swansea', which was collected from the coal-bearing strata of the 'Rhonda Valley, Glamorganshire'. On this specimen were small (between 0.25 and 0.75 mm diameter), silvery- white, octahedral crystals with a brilliant metallic lustre, which des Cloizeaux identified as the mineral linnaeite. North (1916) remarked on these observations, but noted that there was some doubt about the true identity of the mineral, as des Cloizeaux (*op. cit.*) had reported a cobalt-nickel-iron percentage of 40 and a copper percentage of 3 for the specimen. North (*op. cit.*) commented further that the described specimen 'does not appear to have been preserved'. During the course of a study concerned with the distribution of millerite in the South Wales Coalfield, Howarth (1928) remarked that linnaeite had been identified at six separate localities. A similar reference is made by North and Howarth (1928), but there is no mention in either paper of its dubious identity. Some time later, Howarth (1954) noted that, in fact, the specimen described by des Cloizeaux (*op. cit.*) was in the collections of the National Museum of Wales, having been acquired as part of a large donation by Mrs. Terrill in 1937. This specimen has the registered number NMW 37.239.GR1. Little attention has been paid subsequently to the sulphide mineralogy of the South Wales Coalfield, although Firth (1971) referred to the presence of possible linnaeite at three localities, all different to those reported by Howarth (1928). More recently, Macpherson (1981), in a reference list of British mineral species, suggested that the 'linnaeite' from South Wales is, in fact, siegenite (based on a personal communication from Mr. A. Dean). This paper is based on investigations aimed at establishing the identity of small, silver, metallic, octahedral crystals associated with millerite in clay-ironstone nodules from spoil tips at Wyndham Colliery, Ogmore Vale, Mid Glamorgan, identical to those originally described by des Cloizeaux (*op.cit.*). During the course of the work it proved necessary, for comparative purposes, to re-investigate the original specimen described by des Cloizeaux (*op.cit.*).

Mineralogy of the clay-ironstone nodules of the South Wales Coalfield

A wide range of minerals occurs in cavities in the clay-ironstone nodules of the South Wales Coalfield. The cavities are generally lined by siderite and commonly contain exceptionally well-formed, sometimes doubly-terminated quartz crystals (the so-called 'Merthyr diamonds'). Millerite is the most common sulphide mineral present, but variable amounts of galena, blende, chalcopyrite and (rare) pyrite also occur, along with the sulphide mineral discussed in this paper. Firth (1971) reported the possible presence of pyrrhotite in a nodule from Parc Colliery, Cwm Parc, Aberdere, but this has yet to be verified. Because of their growth in cavities, all of the above-mentioned minerals may be well-formed. Also of considerable interest is the occurrence of organic mineral in many of the nodules (Conybeare, 1821), which Firth and Eglinton (1972) identified as hattchetine. Alteration of millerite, possibly to morenosite, is a common feature, whilst Firth (*op.cit.*) records the presence of malachite coating chalcopyrite in a nodule from Llanwynno Tips, Tylorstown. The sulphide mineral described in this paper appears to have a relatively widespread distribution in the South Wales Coalfield.

Present investigations

In the clay-ironstone nodules from Wyndham Colliery, examined during the course of this study, small, silver, metallic, octahedral crystals occur most commonly in close, although typically not direct, association with millerite, chalcopyrite and, less frequently, galena. The crystals are comparatively rare, being observed in only 16 specimens, representing approximately 10% of the total number examined. The crystals are generally well-formed (Figure 1), reaching a maximum size of 0.75 mm.

Analysis of one crystal from Wyndham Colliery (registered specimen NMW 83.42G.M3)

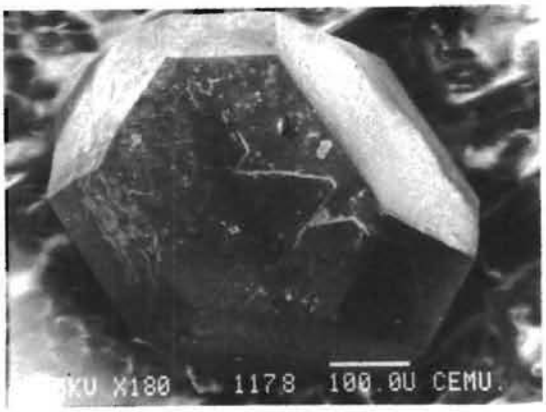

FIGURE 1. Scanning electron micrograph of siegenite crystal from Wyndham Colliery, Ogmore Vale, Mid Glamorgan (specimen number NMW 83.42G.M3).

and of a small crystal of similar character taken from the original Terrill specimen described by des Cloizeaux (*op. cit.*) was performed using a Jeol 35 CF scanning electron microscope (operating at 21 kV) in the energy dispersive mode at the Department of Metallurgy and Materials Science, University College, Cardiff. Calibration was made by analysing metal standards. Ni : Co : Fe : Cu cation ratios, based on the ideal formula A_3S_4 (where A = Ni, Co, Fe, Cu) for the Linnaeite Group of minerals, are presented along with comparative data in Table 1. More correctly, the ratios should be based on an ideal formula $A^{+2}B_2^{+3}S_4$, where A^{+2} = Co, Cu, Fe, Ni and B^{+3} = Co, Fe, Ni, but this was not possible because of the inability of the analytical technique to differentiate between divalent and trivalent cations. Consequently, there may be slight differences between the true cation ratios and those reported here.

TABLE 1. *Cation ratios of siegenites from the South Wales Coalfield along with comparative (recalculated) data from Palache et al., (1944).*

	1	2	3	4	5
Ni	1.59	1.57	1.65	1.62	1.62
Co	1.31	1.32	1.26	1.35	1.05
Cu	0.03	0.02	n.d.	n.d.	0.15
Fe	0.08	0.09	0.09	0.03	0.17

n.d. = not detected

1 = NMW 83.42G.M3, Wyndham Colliery, Ogmore Vale, Mid Glamorgan.
2 = NMW 83.42G.M3, Wyndham Colliery, Ogmore Vale, Mid Glamorgan.
3 = NMW 37.239.GR1, 'Rhonda Valley, Glamorganshire' (Ex Terrill Collection).
4 = Littfeld, Westphalia.
5 = Mine la Motte, Midison Co., Missouri.

Both the crystal taken from the Wyndham Colliery specimen and that from the original Terrill specimen are siegenites, and compare favourably with analyses of siegenites reported by Palache *et al.*, (1944) from Mine la Motte, Missouri and from Littfeld, Westphalia. The analyses from the two Welsh localities show close comparison. In the Wyndham Colliery specimen Fe and Cu are noticeably low, whilst in the Terrill specimen Cu was not detected at all. This offers contrast with the relatively high Cu content of the original analysis reported by des Cloizeaux (*op. cit.*).

Paragenesis

All of the sulphide minerals in the clay-ironstone nodules examined occur in siderite-lined cavities, and, although in a few cases siderite can be seen to enclose scattered millerite crystals, for the most part it is the earliest mineral to have precipitated. Generally siegenite is observed growing on millerite needles, and would appear to have grown slightly later; in some cases, however, the reverse is seen, with siegenite acting as a nucleus for radiating aggregates of millerite. It is clear that the two phases are intimately related and are close in the paragenetic sequence. Chalcopyrite is present in many of the siegenite-bearing specimens, but, typically, is not in contact with either millerite or siegenite. In one studied sample, however, siegenite is seen growing on chalcopyrite and clearly, in this case, grew after chalcopyrite.

Conclusions

Energy dispersive analysis of two silver, metallic, octahedral crystals from clay-ironstone nodules of the South Wales Coalfield confirms the presence of siegenite and demonstrates that the original identification of this mineral as linnaeite by des Cloizeaux (*op.cit.*) was in error. On the basis of the present findings, it is unlikely that linnaeite occurs in Wales.

The correct identification of the crystals as siegenite, a nickel- and cobalt-bearing sulphide, and not linnaeite, a sulphide which contains only cobalt, is not at all surprising in view of their close association with the nickel sulphide millerite.

Acknowledgements

The authors wish to thank Mr. C.T. and Mrs I. Taylor for the donation of the millerite- and siegenite-bearing clay ironstone nodules from Wyndham Colliery, upon which this study was based. Professor B. Ralph kindly made available analytical facilites in the Department of Metallurgy and Materials Science, University College, Cardiff and Mr R. Jones and Mr. P. Caceres assisted with the analyses.

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A microcomputer based mineral identification package

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ABSTRACT. A scheme has been developed at the Camborne School of Mines to meet the need for a simple, low cost, reliable method of mineral identification. The scheme has been tested, in its basic form, and found to be very successful. This article describes the basic scheme and the refinements made to it, particularly in the method of data storage and correlation. A software package has been developed, called "MINSEARCH" requiring an Apple IIe microcomputer equipped with a disc drive. The program has been written in Applesoft BASIC, and utilises a data file of reference data for over 200 minerals (user updatable). An implementation of the software has subsequently been developed for the BBC model B microcomputer. Total cost of the package, including computer, printer, and the requisite laboratory apparatus, is under £1500. The program can be used to create and variously manipulate disc files of mineral data, and to correlate these with test results. The time taken to perform the practical part of the scheme is about 15 minutes and that for the computer correlation less than 1 minute.

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Introduction

Accurate mineral identification is essential in mineral exploration, mining geology and mineral processing. In the past, many geologists and mineral processors were familiar with simple, inexpensive physical and chemical tests for mineral identification, which could be carried out in the field or in modestly equipped mine laboratories. However, in recent years, mineral identification has relied increasingly on elaborate instrumental methods, requiring complex, costly machines and highly skilled operators.

Techniques for mineral species identification have progressed from the earliest elementary observation of external form and character, through the physical and chemical reactions of minerals in the test tube and before the blowpipe, to the sophisticated X-ray powder diffraction and scanning electron microscope technology of the present day.

Traditional methods, such as blowpipe analysis, are attractively simple and quick, but rely on rather subjective observations and become less dependable when the obscurer minerals are encountered. In contrast, accurate and reliable though modern techniques may be, they require machines which are bulky, laboratory-bound and both costly to purchase and run. Furthermore, they may only be operated by highly skilled personnel. In consequence, access to these facilities is not widespread.

Therefore, there is a need for a ready method of mineral identification which combines the merits of the older methods - rapidity, portability, simplicity and economy - with those of the new methods - accuracy, reliability and objectivity - while excluding their demerits, in particular, their common need for skilled operatives.

With the objective of fulfilling this requirement, an identification scheme has already been developed and tested over a period of years with significant success: A series of tests have been established which rely on the observation of simple physical properties of the mineral concerned and its chemical reactions with a variety of reagents. The most elementary of apparatus is used and a small sample of the mineral is sufficient for the tests to be performed. Reference to textbooks is not required. The results may be observed easily and their nature is essentially non-subjective, obviating the attendant risk of erroneous interpretation. Thus, the scheme may be used with confidence by both the inexperienced and semi-skilled.

The characteristic results of some 200 minerals have already been determined; the 15 different tests produce a permutation of results which, for most minerals, is unique.

The mineral identification scheme

1. Equipment and reagents required.

The only relatively high cost item required for the determinative scheme, is a stereomicroscope having a maximum magnification of x80 to x100 and a working distance of about 100mm. It should be equipped with both transmitted and oblique incident illumination and should have some form of crossed polarizers. The microscope serves not only its natural function for sample selection and observational tests, but also forms a 'micro-laboratory' on which to perform and observe the results of physical and microchemical tests. An automatic micropipette, with disposable tips and a capacity of 10 microlitres, is used for all transfer of liquids. Its use completely avoids contamination and also enables semi-quantitative assessments to be made in certain microchemical tests. Some items of equipment, for example the specific gravity cell (Fig. 1) and the hardness standard (Fig. 2), are easily fabricated; all other apparatus is readily available at nominal cost through laboratory suppliers. Many of the chemicals used in the scheme are expensive, but since they are consumed in extremely small quantities operating costs are effectively negligible.

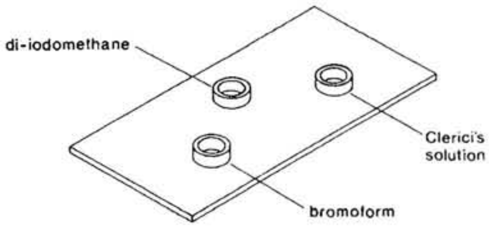

FIGURE 1. Specific gravity cell.

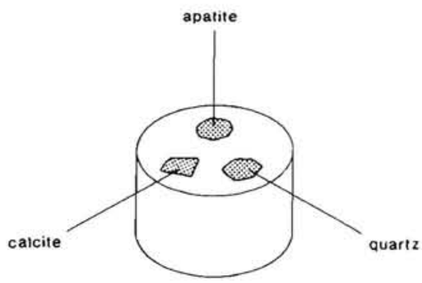

FIGURE 2. Hardness standard.

2. Procedure

The scheme comprises 15 tests: 8 of them diagnostic; 2 non-diagnostic or supplementary; and 5 confirmatory. An outline of the procedure, originally devised by Bromley (1983), is given below.

Sample preparation: Select 10-20 grains, approximately 1mm diameter (or equivalent). Grains should be liberated and free from inclusions or alteration.

Test 1. Colour (diagnostic).

Observe colour in incident light, and categorise it with one of the following standardised groups:

White/light
Coloured >yellow
>orange
>red
>blue
>green
>brown
Black/dark

Test 2. Opacity/Isotropy (diagnostic).

Determine whether the unknown mineral is opaque or transparent/transluscent; determine the isotropic or anisotropic character of transparent or translucent grains. Hence, categorise the mineral as one of the following:

Opaque
Translucent >isotropic
>anisotropic

Test 3. Refractive Index (non-diagnostic).

Using a triple cavity biological microscope slide to contain the liquids, determine by the half-shadow method whether the mineral has a greater or lesser refractive index than that of iodobenzene and then, respectively, a greater or lesser refractive index than either di-iodomethane or bromobenzene. Hence, categorise the mineral's refractive index as one of the following:

Non-refractive (opaque)
1.56>RI
1.62>RI>1.56
1.74>RI>1.62
RI>1.74

Test 4. Specific Gravity (diagnostic).

Using the specific gravity cell, determine whether the mineral is less or more dense than di-iodomethane and then, respectively, less or more dense than either bromoform or Clerici's solution. Hence, categorise the mineral's specific gravity as one of the following:

2.9>SG
3.2>SG>2.9
4.2>SG>3.2
SG>4.2

Test 5. Hardness (diagnostic).

Using the hardness standard, determine whether the scratch hardness of the mineral is greater or lesser than that of apatite and then, respectively, greater or less than that of either quartz or calcite. Hence, categorise the mineral's hardness (on Moh's scale) as one of the following:

3>H
5>H>3
7>H>5
H>7

Test 6. Streak (diagnostic).

Grind approximately half of the sample (5-10 grains) to a fine powder and observe the colour under the microscope in incident light. Hence, categorise it as one of the standard colour groups (see Test 1, above).

Test 7. Magnetic Permeability (non-diagnostic).

Determine the magnetic properties of the unknown mineral by testing the behaviour of both grains and powder towards a bar magnet, one end of which is covered by a plastic sheath. Hence, categorise the mineral's magnetic permeability as one of the following:

None (grains unaffected by magnet)
Low (powder adheres to uncovered magnet)

Moderate (powder adheres to covered magnet)
High (grains adhere to covered magnet)

Test 8. Solubility (diagnostic).

Attempt to dissolve the mineral in progressively stronger solvents. Hence, determine its solubility category as one of the following:

(a) Dissolves in water
 if insoluble perform (b)
(b) Hydrochloric acid (hot, concentrated)
 Dissolves with strong effervescence
 Dissolves quietly
 Decomposes; precipitate forms
 if mineral is unattacked perform (c)
(c) Nitric acid (hot, concentrated)
 Dissolves quietly
 Decomposes; precipitate forms
 if mineral is unattacked perform (d)
(d) Sulphuric acid (hot, concentrated)
 Dissolves quietly
 Decomposes; precipitate forms
 Mineral unattacked; perform (e)
(e) Microfusion with sodium carbonate + potassium nitrate and leaching with hydrochloric acid, to bring into solution.

Test 9. Ammonium hydroxide - complex (diagnostic).

Observe the complexing action of ammonium hydroxide upon the acid solution formed in test 8, above. Hence, categorise it as one of the following:

Colourless solution formed			
Yellow-brown	"	"	(indicates Ca)
Green	"	"	(" Ni)
Dark blue	"	"	(" Co)

Test 10. Ammonium hydroxide - precipitate (diagnostic).

Observe the precipitative action of the ammonium hydroxide in test 9 and categorise it as one of the following:

No precipitate formed	
White precipitate	(indicates As,Bi,Pb,Sn,Ti Zr,Th,Al,Be,Mo,V)
Yellow precipitate	(indicates U)
Brown "	(" Fe)
Black "	(" Hg)

The above sequence of tests serves to limit the identity of an unknown mineral to a small number of possibilities; usually one or two, always less than five. Confirmation in the former case, and final identification in the latter, is carried out by the use of microchemical tests.

A microchemical test is defined as one where a reagent reacts with a particular ion in the acid solution of a mineral to form a precipitate of characteristic crystal form or colour. Reagents fall into two groups: General reagents, which give a characteristic reaction with a range of ions; specific reagents, which give a characteristic reaction with one ion and are free from interferences.

Test 11. Ammonium oxalate - precipitate (confirmatory).

Observe the precipitative action of ammonium oxalate on the acid solution and categorise it as one of the following:

No precipitate
White precipitate (indicates Ca,Sr,Ba)

Test 12. Ammonium phosphate - precipitate (confirmatory).

Observe the precipitative action of ammonium phosphate on the acid solution and categorise it as one of the following:

No precipitate
White precipitate (indicates Mg,Mn)

Test 13. Ammonium molybdate - precipitate (confirmatory).

Observe the precipitative action of ammonium molybdate on the acid solution and categorise it as one of the following:

No precipitate
White precipitate (indicates phosphate, arsenate, vanadate)

Test 14. Hydrochloric & nitric acid - precipitate (confirmatory).

Observe the precipitative action of hydrochloric plus nitric acids on the acid solution and categorise it as one of the following:

No precipitate
White precipitate (indicates Pb,Ag,Hg)

Test 15. Barium chloride - precipitate (confirmatory).

Observe the precipitative action of barium chloride on the acid solution (omit if sulphuric acid) and categorise it as one of the following:

No precipitate
White precipitate (indicates sulphate)

One or two microchemical tests are usually sufficient to confirm an identification. Other microchemical test reagents include: Caesium chloride, bromide, and iodide; rubidium chloride and iodide; potassium mercury thiocyanate; acridine + potassium thiocyanate; and quinoline + potassium thiocyanate.

Reactions are performed under the stereomicroscope and require only microlitre quantities of sample solution and microgram quantities of reagent. Reagents are added either as solid fragments in the case of alkali metal halides (Fig. 3) or in solution for thiocyanate complexes etc. (Fig. 4).

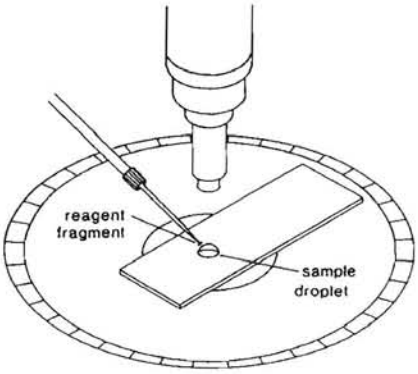

FIGURE 3. Application of solid reagents.

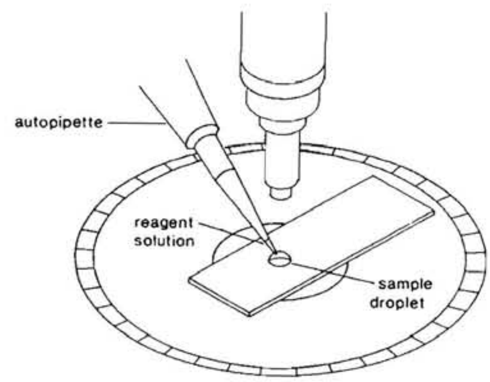

FIGURE 4. Application of liquid reagents.

The results to all the above tests may be recorded on an observation sheet (Fig. 5). This also accommodates other data which the user may wish to record, for example crystal shape, cleavage and habit, occurrence and associated minerals.

The time taken to complete the practical part of the scheme varies from about 20 minutes for an inexperienced user, to less than 10 minutes for the practised worker. Final identification is made by correlation of the observations with reference data.

Refinement of the scheme

The scheme embraces the attributes of speed and ease of testing, accuracy, reliability, portability and economy (after initial purchase of equipment, running costs are negligible). However, its simplicity, having performed the tests, was faulted by the method of correlating the results obtained with the reference list of mineral characteristics. Comparison with lists, mineral by mineral and result by result was laborious and unreliable. Alternative approaches had been tried but found wanting.

To appreciate the need for a computerised scheme a brief discussion of these former systems is given below.

A 'tree search' system, wherein the tests are performed in a specific order, was developed. The tests are categorised as diagnostic if they define a branching point in the search system and supplementary if they provide useful information, but where their outcome may be ambiguous when performed by a semi-skilled operator. The first diagnostic test result branches the user to its respective half of the determinative tables which contains all the minerals which may exhibit that result. The next diagnostic result branches the search to the section within those tables which lists all minerals exhibiting this second characteristic, in addition, of course, to the first. Similarly, further branching progressively reduces the number of possible identities which the mineral may have.

This system worked reasonably well, but it was inflexible; the tests had to be carried out in their proper sequence if the correct series of branches was to be taken and a successful identification made. Suppose a mineral processing engineer recovers a gravity concentrate from a beach sand and wishes to identify the minerals comprising this heavy fraction. If the system were flexible he could immediately isolate all those minerals in the table with high specific gravities and then proceed with the other tests appropriately. Another disadvantage of this system was that many minerals, with variable characteristics, would appear more than once in the tables. This was inefficient and hindered the revision of the existing mineral entries and the inclusion of new ones.

A more flexible and efficient approach was developed by Randall (1978), using a punched card system. Each mineral was given an individual index card upon which was written details of composition, habit, etc. Around the perimeter of the card its characteristic test results were encoded as slots and holes. For any particular test the cards for all those minerals which may exhibit a certain result could be drawn from the stack of cards, and so on.

This system had the flexibility of access required. Furthermore, the data cards could hold more information about individual minerals than was possible with tables, and new minerals could easily be added to the data file. However, the cards were rather laborious to make up initially, and to subsequently reproduce or update.

The punched card system probably represented the best approach possible using printed forms of data storage with retrieval by hand. However, the advent of widely available and cheap microcomputers and their growing acceptance in educational and technical fields, prompted the consideration of a computer based system.

No.	Date	Description
Locality		
Type of occurrence		Associated minerals

		1. Colour	6. Streak
White/light:	W	___	___
Coloured: yellow	Y	___	___
orange	O	___	___
red	R	___	___
blue	L	___	___
green	G	___	___
brown	B	___	___
Dark/black:	D	___	___

2. Opacity/Isotropy

Opaque:	O	___
Transparent:		
Isotropic	I	___
Anisotropic	A	

3. Refractive index

Opaque	O	___
1.56 > RI	1	___
1.62 > RI > 1.56	2	___
1.74 > RI > 1.62	3	___
RI > 1.74	4	___

4. Specific gravity

2.9 > SG	1	___
3.2 > SG > 2.9	2	___
4.2 > SG > 3.2	3	___
SG > 4.2	4	

5. Hardness

3 > H	1	___
5 > H > 3	2	___
7 > H > 5	3	___
H > 7	4	

7. Magnetic permeability

None	N	___
Low	L	___
Moderate	M	___
High	H	

8. Solubility

(a) Water: dissolves	1	___
insoluble then (b)		
(b) Hydrochloric acid:		
effervesces	2	___
dissolves	3	___
decomposes	4	___
insoluble then (c)		
(c) Nitric acid:		
dissolves	5	___
decomposes	6	___
insoluble then (d)		
(d) Sulphuric acid:		
dissolves	7	___
decomposes	8	___
insoluble	9	

9. Ammonium hydroxide - complex

Colourless	C	___
Yellow/brown	Y	___
Green	G	___
Dark blue	L	

10. Ammonium hydroxide - precipitate

None	N	___
White	W	___
Yellow	Y	___
Brown	B	___
Black	K	

11. Ammonium oxalate

No precip.	N	___
Precipitate	Y	

12. Ammonium phosphate

No precip.	N	___
Precipitate	Y	

13. Ammonium molybdate

No precip.	N	___
Precipitate	Y	

14. Hydrocloric & Nitric

No precip.	N	___
Precipitate	Y	

15. Barium chloride

No precip.	N	___
Precipitate	Y	

Other

IDENTIFICATION

FIGURE 5. Package record sheet.

The computerised system

An Apple IIe microcomputer was selected for this purpose; it is a well established model in the United Kingdom higher educational and technical fields. Apart from the normal monitor and printer peripheral hardware, the need for a disc drive was readily apparent. The alternative conventional audio cassette machines were far too unreliable and slow in access, reading and writing times. This expedient was particularly necessary because the storage system was not to be used just to save the computer program itself, but also to hold the scheme's database of mineral characteristics.

The reference data of the established scheme was transferred into a disc file. This contains a number of records, each comprising a mineral name and its characteristic test results. Minerals often exhibit a range of results to a particular test and therefore each of the 15 prescribed tests was allocated an equal series of disc file bytes (a byte of memory will hold one character or numeral) to permit complete mineral characterisation. For a full development of the disc filing principles utilised in the software, the reader is referred to Kantaris (1983).

The Apple II software developed by Barton (1983) provides two programs which the user may select: A limited menu program offers the basic data correlation facility together with data print outs and disc storage of test observations, while a master program provides a fuller menu, including facilities to create, extend and edit files of reference data. The smaller size of the former requires commensurately less RAM (random access memory), permitting the entire data file to be loaded into machine memory. This enables searches to be performed more rapidly - approximately 30 seconds - than by the disc based master program.

The software is written in a 'friendly' interactive form; information and commands required of the user are typed in response to prompts and questions from the microcomputer. Thus a search of the reference data is initiated by simply selecting this function from the program menu and then typing in the results as obtained. The observation sheet (Fig. 5) is designed to assist encoding these results; single letters or numerals indicate the particular outcome of a test.

Once entered the microcomputer then searches its reference mineral data (either in memory or disc file), comparing in sequence each coded test result obtained with the respective possible code or codes for each mineral. Those which correlate successfully are displayed on screen or printed out as required. The user may choose to perform all 15 tests and then carry out a search. However, often it is easier to perform, say, the first eight tests, search the data file to see which minerals fit and then proceed accordingly: Often a unique identification is made immediately; otherwise the user can simply inspect the remaining test results of those minerals found, to determine which will differentiate between them.

The number of mineral species currently characterised and stored in the package data file is being extended to over 220, and further expansion is being considered. It is thought that the natural limit of the scheme is around 350 to 400 species, which is within the limitations imposed by the present hardware of available RAM and disc storage capacity.

The authors gratefuly acknowledge the assistance given to them in the development of the package software by Dr. N. Kantaris, Head of Computing, Camborne School of Mines.

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Thenardite (Na_2SO_4), a mineral new to Britain, from Sussex and Cumbria

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Young, B.R., Young, B. & Raine, A.T. 1985. Thenardite (Na_2SO_4), a mineral new to Britain, from Sussex and Cumbria. *J. Russell Soc.*, 1, 92-93.

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Introduction

Post-mine efflorescences on mudstone from the workings of Mountfield Mine, Mountfield, Sussex have been identified as thenardite (Na_2SO_4). This mineral, together with thaumasite has also been identified from gypsum workings at Kirkby Thore, Cumbria. Thenardite has not previously been described from this country though its occurrence at Mountfield has been briefly recorded (British Geological Survey, 1984).

Mountfield Mine, Sussex

Gypsum is mined here from seams interbedded with laminated limestones, argillaceous limestones, dolomite rocks and mudstones at the base of the Purbeck Beds (Upper Jurassic). Recent descriptions of these beds include those by Howitt (1964), Anderson and Bazley (1971), Holliday and Shephard-Thorn (1974), Lake and Holliday (1978) and Holliday (1978). At depth, under areas of thick cover, the evaporite beds consist mainly of anhydrite with minor amounts of dolomite. Calcite and silica, both as quartz and chalcedony, and rare traces of celestite have been identified in core specimens from the Broadoak Borehole (Nat. Grid Ref. TQ 6195 2214) (Holliday and Lake, 1978). Celestite, as clear, colourless tabular crystals up to 10mm long, was also found by one of us (A.T.R.) in a cavity (TQ 7060 1980) cut in the lowest (No. 4) gypsum seam in Mountfield Mine in 1982.

Extensive areas of finely crystalline efflorescence up to 80mm thick on mudstones exposed in the roof and sides of mine roadways between No. 1 and No. 3 gypsum seams were noticed in 1983. X-ray diffraction analysis showed that much of this material consisted of thenardite (Na_2SO_4). The mineral from the No. 1 seam workings (TQ 57155 11920) comprises colourless to white loosely aggregated crystalline aggregates which proved to be pure thenardite (X8526*). White, rather powdery material from the No. 3 seam workings (TQ 57170 11915) was found to be a mixture of thenardite, gypsum and calcite (X7746). In both cases the thenardite occurred in slightly damp areas of the workings in areas of still air: the delicate efflorescences were readily dislodged by the slightest air movement.

* Figures shown thus are BGS X-ray film numbers

Kirkby Thore, Cumbria

The hydrated sodium sulphate mineral mirabilite ($Na_2SO_4.10H_2O$) was recorded by Trechmann (1901) from a gypsum quarry in the Eden Shales (Upper Permian) near Kirkby Thore, Cumbria. The precise location of the quarry is unknown though gypsum was worked from several small pits in the area and is now mined underground on a large scale. Mirabilite was described here as a clear colourless layer up to 16mm thick on grey coarse-grained gypsum. Examination of a specimen of this material in the mineral collection of the Geological Museum which had been presented to the Museum by Trechman in 1901 (Registration No. MI 7855) revealed that the mineral had altered to a white powder which proved on X-ray diffraction examination (X8533) to be thenardite with some intermixed thaumasite which has a theoretical formula ($Ca_3Si(OH)_6.12H_2O$) $(SO_4)(CO_3)$.

No mirabilite was found on the specimen. Trechmann (1901, p.73) noted that the mirabilite locally exhibited dehydration to a white powder and it appears likely that the whole of the specimen in the Geological Museum collection has suffered similar dehydration.

In Britain thaumasite has previously been recorded from County Down and Embleton near Cockermouth, Cumbria (Knill 1960), and from the north side of Colla Firth, North Mainland, Shetland (Geological Survey, 1960).

Acknowledgements

We thank Mr S.P.G. Court for first drawing our attention to the efflorescences at Mountfield which proved to be thenardite. This note is published by permission of the Director, British Geological Survey (N.E.R.C.).

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The care of minerals

Section 3A: The curation of minerals

R.J. KING

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Abstract

This paper, the third in the series on the Care of Minerals, is the first of two parts on the Curation of Minerals. Written with the amateur in mind, it sets out a procedure of curatorial practise commencing with in-field curation.

In this context it examines the vital need to maintain a field note book and provides an order for the acquisition of field data based on the use of a unique numbering system for both note book and specimens.

Post field curation involves First Stage curatorial techniques, principally the slow drying of material, followed by the provisional identification of material and the recognition of metastability. The latter is examined under the headings: deliquescence, efflorescence, hydration, non metallic oxidation, the effects of changes of temperature, shrinkage, hydrolysis, the influence of light and radioactive metastability. The author advocates the creation of enforced microclimates for the control of chemical metastability.

Second stage curatorial techniques involve cleaning and development of minerals a.d the reader is referred back to previous work under the Care of Minerals (King, 1982 and 1983).

The correct method of handling mineral specimens is demonstrated, though the maxim: as little as possible, should be employed. A routine is set out for the repair of mineralogical material. The use of water-based or "permanent" adhesives, such as polyesters or epoxies is condemned.

Finally an interim storage system is described, based on the field numbering system for rapid retrieval for accessioning, the techniques of which are to be described in a subsequent number of the Journal.

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Contents

Introduction

Everywhere at this present time our natural heritage is threatened. Geological materials, including minerals, are part of this natural heritage. Minerals have become endangered species. It is no longer acceptable that minerals are collected for purely aesthetic reasons. Mineralogy as a science suffers. The mantlepiece and the shoe-box under the bed should no longer be associated with mineralogy. No-one should have the right to collect minerals without having the skill, means or desire to curate them properly.

For many people curation has a low priority, and the curation of their mineral collections is a task which "will be done one day". In fact this task can be the most rewarding aspect of their collecting activity - a task which can prove to be a pleasure and which will teach them more about their subject than listening to erudite expositions or watching other people during practical exercises. More than just a task, curation is a duty, and in the following pages the author hopes that he may be able to persuade those same people that it can be a pleasurable duty. For many people curation is a way of life and it is certain that many professional curators are born, their way of thinking governed almost by instinct. This same instinct may be present in people who for some reason or other do not become professional curators. Nevertheless this inborn curatorial ability will show through. Should they become mineral collectors, this ability will be obvious to anyone fortunate enough to examine their collections.

Not everyone can be born a curator. Many people find curation difficult although they may be dedicated collectors. While commiseration may be in order here, something positive must be done to help these people, not only for their own sakes, but above all for the material they have collected. This article is an attempt to provide a step-by-step curatorial procedure for the non-curatorially minded to follow.

Collectors should remember that by curating their collections, not only will they have built a memorial to themselves, but they will have produced something of lasting scientific value. A well curated collection is a valuable collection.

A In Field Curation

Curation does not begin in the home, laboratory or office. CURATION BEGINS IN THE FIELD. Poor or non-existent field curation greatly reduces the value of any later work to the point of rendering the collection valueless. The amount of data associated with a specimen also decides its future scientific value. Frequently such data is scientifically more valuable than the specimen itself. A good curator's field note books are precious documents.

In the following pages the author has provided a set of guide lines to assist the collector when in the field. Many of the observations made are based on personal experience and all complement what has already been said elsewhere (King, 1978).

It is not within the brief of this article to describe the techniques of collecting minerals. Much depends on common sense, the availability of tools and the expertise to use them. Basically, collecting should be achieved by skill not brute force.

Before embarking on field work, the collector should come to grips with the ethics of collecting. Conservation of mineral sites should figure strongly in a collector's mind. He should consider himself to be acting as a guardian of the natural heritage he is enjoying. Restraint should figure strongly in his collecting policy. In the case of a mineral body destined to go through a crushing mill, however, collection and preservation are the best form of conservation.

In addition, the collector should also consider the ethical and related problems associated with the collection, storage and (particularly) dissemination of data. Is he prepared to share that data with others or does he wish to place restraints on its dissemination? The complications are such that each case must be judged on its merits. It is in the author's experience that, if the data are made available only in the scientific press, there is less likelihood that it will fall into the wrong hands. Thus, the specialists, to whom it is aimed will benefit, the site will be protected and the state of knowledge will advance. We are left with the unfortunate necessity of accumulating data but not knowing how to safeguard them for the future. Hopefully as education in conservation takes effect, we shall be followed by a more enlightened generation. We can only work with this end in mind.

A1 The Field Note Book

The collector may say to himself: "It is inconvenient to stand here making notes, it is pouring with rain. I shall remember what I have collected here in the form of specimens and data. I will write it up in the warmth and convenience of my home". The temptation to do this must be strongly resisted. It is impossible for the average human brain to accurately remember sufficient detail even for a single locality, let alone a complete day in the field. Observations and data <u>must</u> be recorded on site at the time they <u>are</u> made.

The collector will thus need a good quality notebook. It should preferably be small enough to fit into a coat pocket yet large enough to accommodate sketches. Its covers should be waterproof and the pages preferably ruled on one side and either blank or squared on the opposite. Notebooks used by surveyors are ideal. These usually have alternate squared pages which will enable the collector to make more accurate scale sketches and diagrams. Each square can become a unit of measurement, and be marked accordingly on the sketch as in Fig. 1.

All relevant data should be written in waterproof ink, but in exceptionally bad weather, it may be impracticable to do so and the collector may have to resort to the use of a soft pencil. Most ballpoint pens are useless on damp paper. Once the notebook has been dried out, the pencil-written data should be written over in waterproof ink.

The collector should bear in mind that what he has written may well be read by a future worker, and must therefore be legible. If the data has been written in some form of speed writing, it should be readily translatable. A well presented notebook is an indication of the stature of the collector.

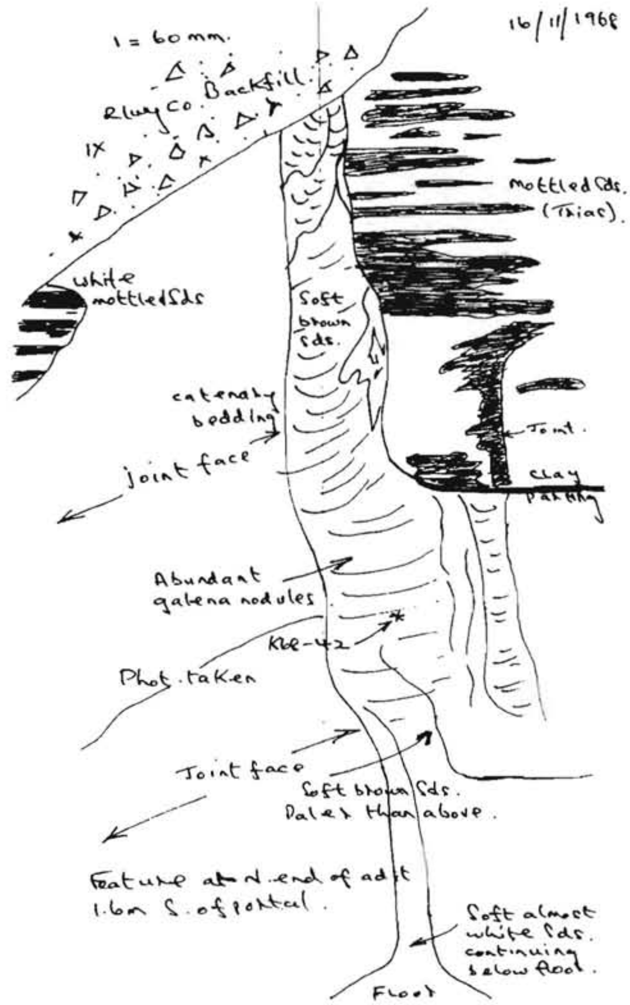

Figure 1. Facsimile of a page from the author's field notebook, showing a sketch of a mineralised body at the north end of Tickow Lane Mine, Leicestershire. Each square equals 60 mm.

A2 Field Data

The identification of a specimen has relatively little importance at the time of collection. Identifications in the field should be tentative and take up little time. It is sufficient to know a broad outline of the composition of the mineral body. Locality data is, however, of paramount importance and if not specified immediatly and accurately noted is lost for all time.

As much locality data as can be gleaned should therefore be entered into the notebook. The data should provide, not only accurate topographical data, but also geological data, including as much as the collector knows about the localised stratigraphy and the lithologies present at the site.

It is sound policy for the collector to establish a set procedure which may be unique to him but which he follows at each locality.

In Britain, the county (or equivalent administrative area), the nearest town and in certain cases the parish should be recorded for each locality. National Grid Reference numbers should be given to at least 6 figures, preferably 8 (Remember that Grid letters are an integral part of the reference). Elsewhere in the world co-ordinates are often more difficult and compass bearings and distances from landmarks are often the only criteria available.

If the collector is working in a mine, then he should record the name of the lode, and his position on it. In a working mine the plan co-ordinates and distances from them or other survey points will all accurately locate a working site.

Use metric measurements: the kilometre, the metre, and the millimetre being the only units used. If the measurements are only approximate or estimates, it is important to say so. An estimate is better than no measurement at all.

If a compass is available, bearings on the disposition of an ore body are valuable. The expression of bearings should follow the set convention, namely that strike should be expressed as three figures degrees east of north. For example: a lode striking at 040 with a dip of 15° west should read: 040/15° west. It should be noted that the readings taken are either magnetic or true, and care should be taken that they are not influenced by the possible magnetic nature of the rocks present, steel rails or nearby machinery. The use of a simple clinometer will quickly establish the dip of a lode or mineralised body.

An oriented sketch of the mineralised body is valuable, and will help record where specimens were collected. In short, an annotated sketch should be diagrammatic and yet bear as much data as possible. A collector need no longer be a skilled photographer to be able to augment his field sketches with good quality photographs of the locality. It must be emphasised however that augment is the operative word. A sketch is still a vital necessity, especially if the mineralised body has been placed in a complicated geological perspective.

Each specimen as it is collected should be given a unique number in accordance with the collector's standard, so that specimen and field data can be cross-related.

A survey of such numbering systems shows that they are many and varied, often relating to the personal character of the collector. There is nothing wrong with such individuality providing it is efficient and readily understood by another worker in that field.

The numbering system recommended by the author consists of the last two digits of the year of collection followed by the specimen's number (85-1, 85-2, etc.). This starts again each year. This makes a useful memory prompter and an aid to finding the appropriate field note book entries. In addition it provides the framework for an interim storage system for the specimens.

If the collector prefers, a locality indicator may be used in the form of a prefix letter(s); for example, a specimen collected from Newhurst Quarry could appear as: NH85-24, i.e. the 24th specimen collected from Newhurst Quarry in 1985.

It is also sound practise to add a further prefix letter(s) indicating the identity of the collector, e.g.: K/NH85-24.

It is useful to list localities, and the group of numbers related to them, in the form of an index at the back of the notebook. As the notation commences with No. 1 each year, localities are readily referred to.

Finally, the collector should ensure that his name and address is obviously marked in the front cover of his notebook. The addition of words "reward to finder" could ensure its safe return to the loser.

A3 The Specimens

The unique field reference number given to a specimen and entered in the notebook must also appear on the specimen itself. There are several methods of doing this.

The first and best method uses adhesive medical dressing strip/tape. 20 mm lengths of 12 mm wide tape are cut and pressed onto a plastic sheet (such as xylonite or celluloid) glued into the back of the notebook. This is done before going into the field. The field number is written onto the strip of plaster, peeled off the plastic sheet and stuck firmly onto the specimen. Should the tape leave any adhesive behind when subsequently removed, especially after a long delay, it may be readily removed using a small swab of lint soaked in acetone. The only limitation to the use of this method of field labelling is if the specimen is wet. The tape may then not adhere properly.

A second method is to use felt-tipped marker pens. The ink should be instant drying and water-proof and the felt tip must be reasonably fine. The principal objection to using these pens is the virtual impossibility of removing the ink from the specimens once it is applied, especially if the specimen is at all porous. Prolonged soaking in a solvent may help, but this may do nothing for the stability of the specimen. It is often difficult to mark a specimen lacking plane surfaces or that is wet with any degree of legibility.

For collecting wet specimens, it is perfectly reasonable to write field numbers on the dry wrapping paper, providing it is recognised that this is only a temporary expedient. The specimens should be numbered more permanently when they have dried out.

Each specimen should be individually wrapped. If the specimen was broken while being collected, each piece should be wrapped separately. Much unnecessary damage is done to specimens and parts of specimens as they are being transported out of the field.

Newspaper is the ideal packing material, being absorbent and easily removed from wet material. Cellulose wadding is also good but once it is wet it can mould itself into voids and cracks on a specimen and be difficult to remove.

Large-paged newspapers are ideal for size and absorbence. The size of its double page (780 x 390 mm) will cope with large specimens, while small specimens may be wrapped in single pages, either double thickness or single. The specimen should be wrapped so that the most delicate area of the specimen is protected by the bulk of the packing medium. The specimen is placed, delicate side upwards in the corner of the sheet of newspaper. The left and right-hand sides of the sheet of newspaper are then folded onto the specimen. It is then gently rolled along the length of the paper, becoming increasingly protected as it goes, until the collector is left with a package ready for transportation.

If the specimen is to be carried out of the field in a pack of some kind, a layer of screwed-up newspaper should be placed at the bottom of the pack and a layer of specimens placed on it. Another layer of screwed-up newspaper should then be placed on the specimens and this procedure of paper-specimens-paper-specimens should continue until the pack is filled or can still be lifted and carried. In this way a pack full of high quality specimens may be carried great distances without detriment to the specimens.

The author has mixed feelings about the use of polythene bags. In their favour: they are quick and easy to use in the field; they are light and easy to transport; it is possible to write on them with a suitable felt-tipped pen; and they carry wet and loosely aggregated material well. Against them: they are not too kind to delicate material and such a specimen must be pre-wrapped in another medium prior to bagging; in spite of their permeability to water vapour (Thomson, 1978, p.223), if wet material is left in them for too long, metastability problems may be promoted. For example, some carbonates, if collected from a wet clay environment and allowed to remain in polythene bags for too long, will continue to grow. The growth, though in optical continuity, does not develop as a continuation of a mega crystal, but produces microscopic vicinal faces in the form of a "frosting" effect.

Old newspapers may cost nothing, whereas polythene bags can be expensive, especially the more practical thicknesses. There may be some advantage in carrying a few polythene bags, just to meet all eventualities.

The safe arrival of collected material into the laboratory should see the end of the first stage of curating.

B Post Field Curation

This section may conveniently be divided into the following headings:

1. First Stage Curatorial Techniques.
2. Provisional identification and recognition of metastability.
3. Second Stage Curatorial Techniques and Interim Storage.

B1 First Stage Curatorial Techniques

A well-equipped and climate-controlled laboratory is usually denied to a collector and sometimes even to a professional curator. He must improvise, and normally this is not difficult. A working surface, reasonably dry conditions and tapped hot and cold water supply are usually adequate for first stage curatorial work.

Upon arrival at the "laboratory" the specimens must be unpacked immediately and allowed to dry slowly. Place the specimens on several thicknesses of newspaper, replacing it as necessary. It is essential that the field number remain with the specimen. Ensure that it is still legible and firmly attached to the specimen. If the number is loose, attach it e.g. with an elastic band.

Oven-drying can do great harm to a specimen, either promoting latent metastability in the specimen, or drying out adhered clay which then can be difficult to de-flocculate and remove.

Once the material is dry, re-affix loose field reference numbers to the specimens using additional tape strips. Do not leave wet specimens in polythene bags. Once it is dry disaggregated material may be placed in another bag, or bottle.

The collector may now proceed.

B2 Provisional identification and recognition of metastability

In most cases an experienced collector will have a shrewd idea of what species he has collected. It may be sufficient at this stage to identify the chemical group in which the mineral belongs, and assume that metastability may be a problem - prevention being better than a doubtful cure. As the collector's experience grows so does his ability to assess metastability.

If there is a sulphide present, for example, prevention of metastability should follow as a matter of course. Amongst sulphides such problems are more pronounced and, in certain cases, irreversible as in iron, nickel and cobalt sulphides. If there is any doubt about the physical nature of a specimen or whether there is a possibly metastable mineral associated with something known to be stable, then the collector should not hesitate to ask advice of an experienced mineralogist.

In almost every case a mineral once collected has been taken from its benign natural environment into a hostile unnatural one.

The onset of metastability problems may often be attributed to inappropriate relative humidity levels (RH). At least 10% of known mineral species can undergo complete phase transitions when subjected to unnatural RH conditions. Others may face complete chemical disintegration. Ideally it is necessary to establish, in the first place, the complete identity of the mineral assemblage and, secondly, to establish the stability limits of the mineral or minerals involved and preserve them accordingly.

It is, in practise, impossible for most collectors to determine the equilibrium vapour pressures of their material and to be able to accurately preserve each specimen according to its indivdual needs. Thus the techniques described below have attempted to meet these practical difficulties. Some preservation is better than none.

Some minerals are notoriously difficult to preserve and if there should be any doubt in his mind, the collector should ask for advice.

There is an enormous amount of literature available on the prevention and control of metastability in minerals. Much of it is inconclusive and, in certain cases, describes techniques actually detrimental to the minerals themselves. Techniques include coating minerals with lacquers to act as vapour barriers, refrigerating them and storing them in sealed containers at elevated, intermediate or reduced levels of RH. Waller (1980) has provided a valuable and comprehensive list of metastable species and much of his data has been used here.

The several problems may be treated under the following headings:

2a. Deliquescence.
b. Efflorescence.
c. Hydration.
d. Non-metallic oxidiation.
e. Temperature changes.
f. Shrinkage.
g. Hydrolysis.
h. Influence of light.
i. Miscellaneous metastabilities.
j. Radioactive metastability.

2a Deliquescence

Deliquescence is the spontaneous solution of a mineral by atmospheric moisture. Many water soluble salts such as halite ($NaCl$) readily draw in moisture from the air forming a solution when the RH of the air is higher than the water activity of a saturated solution of the salt. The speed of this reaction is dependent on the physical characteristics of the mineral and the duration of the exposure of the mineral to high RH factors. The effects vary from etching and rounding of crystal faces, to complete disintegration of hydration.

It is also possible that chemical decomposition may accompany deliquescence. The mineral butschliite ($K_6Ca_2(CO_3)_5.6H_2O$ is susceptible to this action, high RH causing K_2CO_3 as the end product (Pabst, 1974).

A further complication can occur with the onset of deliquescence, namely hydrolysis. The mineral molysite ($FeCl_3$) occurs as a sublimation product in fumaroles. Here, following deliquesence, it hydrolises rapidly leaving stains of hydrous iron oxide. Certain occurrences of paratacamite ($Cu_2(OH)_3Cl$) (e.g. Broken Hill, New South Wales) may well be the end products of oxidation processes following the deliquescence of nantokite (CuCl). An often repeated story which loses nothing by the re-telling was that told by Lane in 1926 (p.82). A specimen of minasragite ($(VO)_2H_2(SO_4)_3.15H_2O$) stored in a damp basement for several months, when next examined had changed, through deliquescence from its blue massive state to a green spot in the card tray.

It is of great importance therefore that the collector recognises potentially deliquescent material in his collection. The unfortunate loss of a specimen through deliquescence may become even more disastrous if the metastability has not been noticed and liquid phases are allowed to react with accompanying specimens in store.

Table 1 lists the better known minerals likely to come into a collector's hands which are known to be metastable and deliquesce or hydrate in conditions of high RH.

TABLE 1. *Minerals Liable to Deliquesce*

Antarcticite-$CaCl_2.6H_2O$

Bischofite (of Ochsenius)-$MgCl_2.6H_2O$

Bütschliite (of Milton & Axelrod)-$K_6Ca_2(CO_3)_5.6H_2O$

Carnallite-$KMgCl_3.6H_2O$

Carobbiite-KF

Chlormanganokalite-K_4MnCl_6

Chlorocalcite-$KCaCl_3$

Carobbiite-KF

Darapskite-$Na_3NO_3SO_4.H_2O$

Douglasite-$K_2FeCl_4.2H_2O$

Erythrosiderite-$K_2FeCl_5.H_2O$

Gerhardtite-$Cu_2NO_3(OH)_3$

Halite-NaCl

Hisingerite-$Fe_2Si_2O_5(OH)_4.2H_2O$

Huantajayite-(Na,Ag)Cl

Kainite-$KMgSO_4Cl.3H_2O$

Kremersite-$(K,NH_4)_2FeCl_5.H_2O$

Langbeinite-$K_2Mg_2(SO_4)_3$

Lawrencite-$FeCl_2$

Matteuccite-$NaHSO_4.H_2O$

Melanterite-$FeSO_4.7H_2O$

Minasragite-$(VO)_2H_2(SO_4)_3.15H_2O$

Molysite-$FeCl_3$

Nantokite-CuCl

Nesquehonite-$MgCO_3.3H_2O$

Nitratine-$NaNO_3$

Nitre-KNO_3

Nitrobarite-$Ba(NO_3)_2$

Nitrocalcite-$Ca(NO_3)_2.nH_2O$

Nitromagnesite-$Mg(NO_3)_2.6H_2O$

Rinneite-$K_3NaFeCl_6$

Scacchite(of Adam)-$MnCl_2$

Sylvine-KCl

Tachhydrite-$CaMg_2Cl_6.12H_2O$

Thermonatrite-$Na_2CO_3.H_2O$

The Prevention of Deliquescence

The prevention of deliquescence in minerals has caused problems for curators for many years, especially where there is little opportunity to control the climate in the stores where the minerals are kept. The problems may be even greater for the average amateur collector whose storage facilities in a domestic scene may be even more limited. The collector is usually forced to create special microclimates for individual specimens. Although much has been written about deliquescence the problems it causes in mineralogy have still not been completely resolved.

The use of lacquers

Bannister (1937, p.470) recommended the use of a 10% solution of vinyl acetate solution in equal volumes of acetone and toluene. There are other similar recipes, and even hair sprays have been recommended. Nevertheless, no lacquer, however well applied to a specimen, can form a perfect barrier to water vapour, the infiltration being in proportion to the level of RH and length of time of exposure to it. In addition a lacquer frequently adds an unnatural glassy appearance to a mineral, and can alter the shade of colouring.

Although Bannister's solution may not be the answer to deliquescence, it does have its uses for consolidating material already decomposing by deliquescence. The use of lacquers for the control of deliquescence is not recommended here.

Refrigeration

The use of refrigeration in the control of deliquescence cannot be recommended to the amateur collector. Unless the stability range of the specimens and the climatic conditions in the refrigerator are accurately known, stabilization by refrigeration can be at best fortuitous. In addition instability may also be introduced by the introduction of a low temperature phase in material under refrigeration (Waller, 1984, p.139).

Microclimates

The creation of microclimates at the single specimen level was described as far back as 1922 when Parsons was writing his papers on the preservation of minerals. He proposed for the first time that sealed containers should be used to store metastable material, either by itself or accompanied by a suitable liquid which the material could not absorb. He also pointed out the importance of temperature and RH of the ambient atmosphere in the study of metastability in mineralogy.

Bannister (1937, p.470) added the refinement of using sealed rectangular-shaped glass jars in which it was possible to effect a better seal.

Waller (1984) examined the current state of knowledge concerning the control of deliquescence, efflorescence and hydration in minerals, giving scientific explanation for much of what had been written before. He regarded the use of microclimates as the only efficient means of long-term control of metastability.

King, V. (1982, p.245) set out the complete procedure for creating microclimates for the control of deliquescence using glass jars and wax impregnated cork seals.

The Creation of a Microclimate (King, V., 1982)

1. Ensure that the specimen is thoroughly dry using a radiant heat source such as a lamp.

2. Oven dry the glass jar to temperatures of 100° C for one hour.

3. Allow jar to cool to 30°C and temporarily seal.

4. Oven dry the cork stopper to temperatures of 100°C for one hour.

5. Soak hot cork in melted paraffin wax. Wipe off excess wax.

6. Prepare baked self-indicating silica gel and pack either in a loosely sealed polythene, or muslin bag.

7. Place specimen and silica gel packet into jar.

8. Paint neck of jar with melted paraffin wax, re-dip the cork and press home into neck of jar.

9. Paint the whole of the exterior of the neck of the jar and the cork with melted wad and allow to cool slowly.

10. Wrap adhesive medical tape around the seal to protect it.

11. Clearly label the jar with name, locality, accession number of specimen and when the sealing operation was done.

The limitations of the technique are apparent in King's article. Glass jars do not fit well into storage systems such as drawers, and inevitably a separate space has to be arranged for jarred microclimates.

To overcome the limitations imposed by the use of jars, it is desirable to seek a container, suitably transparent and flexible and yet which provides the means of enforcing and maintaining a microclimate.

All thicknesses of polythene were found to be valueless for creating microclimates. Thomson (1978, p.223) demonstrated categorically that polythene film was not a barrier to water vapour.

Experiments with plastic boxes with so-called air-tight lids (the type used to maintain freshness in foods) suggest that these too are no good for creating RH control microclimates, though Horie and Francis (1984, p.13), recommended their use for enforcing the RH control around archaeological materials.

The use of Kapak polyester pouches for the conservation of geological materials was examined by Splettstoesser and Hoyer (1983). These pouches were originally designed for the preservation of forensic and medical materials. They consist of an inner layer of polyolefin (Polypropylene) bonded to an outer film of polyester and are available in a range of thicknesses and sizes. The author has found the thickness of 4.5 mil. (0.0045 ins.) and the range of sizes 165 x 205mm, 205 x 305mm, and 240 x 410mm to be most versatile.

In Britain the pouches are available under the agency of Messrs. Guest Medical Ltd., under the name of G-PAK (see Appendix).

Controlled experiments in the use of these pouches for the enforcement of microclimates has met with encouraging results, the 4.5 mil. pouch giving better control. Over a period of nine months, using baked silica gel as a visual indicator, the RH values in the pouches and the room have not equalised and there is no sign of deliquescence on the specimens in the pouches. It seems likely that the period will extend to 12 months.

The achievement of 9 months of stability represents a breakthrough in the control of deliquescence. Specimens liable to deliquesce represent a small proportion of most collections maintained by the amateur collector. This fact and the relative cheapness of the pouches makes the technique a realistic proposition for the collector. The necessary heat-sealing press is also relatively inexpensive, particularly if it could be bought by a society or some such group of people. The annual unsealing, replenishment of baked silica gel, and re-sealing of the pouches represents no insurmountable duty.

The problems caused by the lack of control of lacquers and sprays, and the impracticability of the use of wax-sealed jars, could all be resolved by the use of G-PAK. The study has obviously not been exhaustive and accurate records from as many sources as possible are desirable.

2(b) Efflorescence

Efflorescence is the spontaneous loss of essential water of crystallisation from a hydrate. Many minerals are hydrates, but in some the water present exerts a strong vapour pressure at room temperatures. Should the partial pressure of water vapour in the air fall below that of the water of crystallisation of the mineral, that water will leave the mineral and a state of efflorescence will develop.

As far as the mineral specimen is concerned efflorescence, like deliquescence, is irreversible, e.g. dark blue chalcanthite ($CuSO_4.5H_2O$), dehydrates to a mass of white powder of bonattite ($CuSO_4.3H_2O$), which is quite impossible to re-constitute by hydration. Other species may become pseudomorphs without loss of original form, but have a marked change of colour.

In certain cases chemically purer material such as chalcanthite ($CuSO_4.5H_2O$) may resist efflorescence, while other minerals possessing additional elements, such as pisanite ($(Fe,Cu)SO_4.7H_2O$) may be at much greater risk. Table 2 lists the efflorescent minerals a collector is liable to encounter.

TABLE 2. *Some minerals liable to Effloresce*

Albrittonite-$CoCl_2.6H_2O$

Antarcticite-$CaCl_2.6H_2O$

Bianchite-$(Zn,Fe)SO_4.6H_2O$

Bieberite-$CoSO_4.7H_2O$

Bischofite (of Ochsenius)-$MgCl_2.6H_2O$

Bonattite $CuSO_4.3H_2O$

Boothite-$CuSO_4.7H_2O$

Boracite (of Werner)-$Mg_6B_{14}O_{26}Cl_2$-only when massive (Spencer, 1943, p.152)

Borax-$Na_2B_4O_7.10H_2O$

Boussingaultite-$(NH_4)_2Mg(SO_4)_2.6H_2O$

Brushite-$CaHPO_4.2H_2O$

Carobbiite-KF

Chalcanthite-$CuSO_4.5H_2O$

Coquimbite-$Fe_2(SO_4)_3.9H_2O$

Cyanochroite-$K_2Cu(SO_4)_2.6H_2O$

Epsomite-$MgSO_4.7H_2O$

Eriochalcite-$CuCl_2.2H_2O$

Gay-lussite-$Na_2Ca(CO_3)_2.5H_2O$

Goslarite-$ZnSO_4.7H_2O$

Halotrichite (of Glocker)-$FeAl_2(SO_4)_4.22H_2O$

Hexahydrite-$MgSO_4.6H_2O$

Hydromagnesite (of Wachtmeister)-$Mg_4(CO_3)_3(OH)_2.3H_2O$

Inyoite-$Ca_2B_6O_{11}.13H_2O$

Jokokuite-$MnSO_4.5H_2$

Kernite-$Na_2B_4O_7.4H_2O$

Lansfordite-$MgCO_3.5H_2O$

Lanthanite-$(La,Ce)_2(CO_3)_3.9H_2O$

Mallardite-$MnSO_4.7H_2O$

Melanterite-$FeSO_4.7H_2O$ (McCaughey, 1918, p.162)

Mendozite-$NaAl(SO_4)_2 11(?)H_2O$

Meta-vanuralite-$Al(UO_2)_2(VO_4)_2(OH).8H_2O$

Minasragite-$(VO)_2H_2(SO_4)_3.15H_2O$

Mirabilite-$Na_2SO_4.10H_2O$

Morenosite-$NiSO_4.7H_2O$

Natron-$Na_2CO_3.10H_2O$

Pentahydrite-$MgSO_4.5H_2O$

Phospho-rosslerite-$MgHPO_4.7H_2O$

Picromerite-$K_2Mg(SO_4)_2.6H_2O$

Pintadoite-$Ca_2V_2O_7.9H_2O$

Pirssonite-$Na_2Ca(CO_3)_2.2H_2O$

Pisanite-$(Fe,Cu)SO_4.7H_2O$

Probertite-$NaCaB_5O_9.5H_2O$

Quenstedtite-$Fe_2(SO_4)_3.10H_2O$

Rhomboclase-$HFe(SO_4)_2.4H_2O$

Rösslerite-$MgHAsO_4.7H_2O$

Rossite-$CaV_2O_6.4H_2O$

Sanderite-$MgSO_4.2H_2O$

Starkeyite-$MgSO_4.4H_2O$ syn. leonhardtite

Struvite-$NH_4MgPO_4.6H_2O$

Szmikite-$MnSO_4.H_2O$

Szomolnokite-$FeSO_4.H_2O$

Thermonatrite-$Na_2CO_3.H_2O$

Trona-$Na_3H(CO_3)_2.2H_2O$

Tschermigite-$NH_4Al(SO_4)_2.12H_2O$

Tyuyamunite-$Ca(UO_2)_2(VO_4)_2.10H_2O$

Voltaite-$HK_2Fe_4(Fe,Al)_3(SO_4)_{10}.13H_2O$

The collector will note that the names of some species appear on both Tables 1 and 2. The reason for this apparent anomaly is that those species have a narrow stability range and are likely to deliquesce at one end of the range and effloresce at the other.

The prevention of efflorescence

The techniques described under the prevention of deliquescence apply equally well in this section, with the important exception that, in the case of inforced microclimates, pre-conditioning of the silica gel used must be such that it maintains a suitable high RH in the cell.

The use of lacquers

This technique is not recommended here but the solution used by Bannister (1937, p.470) does have its uses in the strengthening of the base of specimens prior to enclosure in a microclimate.

Use a 10% Vinyl acetate solution in equal volumes of toluene and acetone. Never use shellacs; they have a limited life and are difficult to remove.

The use of alcohol

Walther (in Gordon, 1922, p.45) described the use of ethyl alcohol in the preservation and stability of copper and iron sulphates. The author has used this technique which involves the brushing or spraying on of ethyl alcohol and allowing the specimens to dry as slowly as possible. It gives a measure of success. The technique seems to be particularly efficacious in the preservation of stalactites of chalcanthite.

Refrigeration

The author sees little value in the application of techniques involving refrigeration in the control of efflorescence, although it does have a marked effect on the prolongation of low RH factors in G-PAK pouches stored under such conditions.

Microclimates

In the use of glass storage jars and G-PAK pouches, the physical techniques are identical to those used for deliquescence, except the pre-conditioning of the silica gel used is totally different. Instead of baked, dark blue, silica gel, slightly moistened, and therefore pink, silica gel should be enclosed in the cell with the specimen. The enforced microclimate has now produced a vapour pressure greater than that of the specimen and its loosely bonded water of crystallisation remains bonded in the mineral structure.

Much depends on the size of the specimen, the amount of silica gel enclosed and the amount of air in the pouch. As experience develops and experimentation continues, figures hopefully will emerge and a set procedure be established. At this point it is hoped that other workers will come into this field of study and add to the data.

2(c) Hydration

Hydration is the opposite of efflorescence, being the spontaneous intake of water of crystallisation from the atmosphere to form higher hydrates. For example hexahydrite ($MgSO_4.6H_2O$) readily hydrates to epsomite ($MgSO_4.7H_2O$). Minerals susceptible to hydration are listed in Table 3.

TABLE 3. *Some minerals liable to hydrate*

Anhydrite-$CaSO_4$

Betafite-$(Ca,Na,U)_2(Ti,Nb,Ta)_2O_6(OH)$

Bonattite-$CuSO_4.3H_2O$

Chalcolamprite-$(Ca,Na,Ce)_{1.5}(Nb,Si,Zr)_{2.25}O_{5.46}(OH,F)_{1.54}$

Ellsworthite-$(U,Ca,Ce)_2(Nb,Ta)_2O_6(OH,F)$

Endeiolite-$(Na,Ca,Ce)_{1.10}(Nb,Si,Sr)_{2.24}O_{5.36}(OH)_{1.64}$

Euxenite-$(Yt,Er,Ce,La,U)(Nb,Ti,Ta)_2(O,OH)_6$

Fairchildite-$K_2Ca(CO_3)_2$

Fergusonite-$(Yt,Er)(Nb,Ta)O_4$

Ferrinitrite-$Na_3Fe(SO_4)_3.3H_2O$

Formanite-$(Yt,Er)(Ta,Nb)O_4$

Hanksite-$Na_{22}K(SO_4)_9(CO_3)_2Cl$

Hatchettolite-$(Ca,Fe,U)_2(Nb,Ta,Ti)_2(O,OH,F)_7$

Hexahydrite-$MgSO_4.6H_2O$

Hjelmite-$(Y,Ca)(Ta,Nb)_2O_6(OH)$

Hydrocyanite-$CuSO_4$

Kieserite-$MgSO_4.H_2O$

Koppite-$(Ca,Ce,Na,K)_2(Nb,Fe)_2(O,OH,F)_7$

Leonite-$K_2Mg(SO_4)_2.4H_2O$

Lyndochite-var of euxenite

Metatyuyamunite-$Ca(UO_2)_2(VO_4)_2.5\text{-}7H_2O$

Meta-vanuralite-$Al(UO_2)_2(VO_4)_2OH.8H_2O$

Microlite-$(Ca,Na)_2(Ta,Nb)_2(O,OH,F)_7$

Monetite-$CaHPO_4$

Neotantalite-$(Fe,Mn,Na)_2(Ta,Nb)_2(O,OH,F)_7$

Pentahydrite-$MgSO_4.5H_2O$

Plumbonioliite-var, of samarskite

Poitevinite-$(Cu,Fe,Zn)SO_4.H_2O$

Polycrase-$(Yt,Er,Ce,La,U)(Ti,Nb,Ta)_2(O,OH)_6$

Pyrochlore (of Wöhler)-$(Ca,Na,Ce)_2(Nb,Ti,Ta)_2(O,OH,F)_7$

Risörite-$(Yt,Er)(Nb,Ti,Ta)(O,OH)_4$

Samarskite-$(Yt,U,Fe,Th)(Nb,Ta)_2O_6$

Sanderite-$MgSO_4.2H_2O$

Starkeyite-$MgSO_4.4H_2O$

Tanteuxenite-var. of euxenite

Triplite-$(Mn,Fe)_2PO_4F$

Voltaite-$HK_2Fe_4(Fe,Al)_3(SO_4)_{10}.13H_2O$

Wiikite-Columbotantalite of Ti etc.

The control of hydration

This is not so straight forward as the control of deliquescence, but if the collector uses the same techniques employed when dealing with the control of deliquescence, good control should be obtained.

2(d) **Metastability resulting from non-metallic oxidation**

These are perhaps the most unpleasant and least understood of the metastability problems confronting a collector, and include so-called "pyrite rot" or "disease". This involves the oxidation of sulphides (and some sulpharsenides) a process promoted by high RH. During this process iron sulphide is converted to ferrous sulphate ($FeSO_4$) and sulphuric acid. The smell of the latter is distinctive and characterises the "disease", but it should not be the first intimation to the collector that he has such a problem. It may well then be too late to solve the problem. Some mineralogists believe that "pyrite rot" is infectious and will not retain such decayed material in their collections. It is more likely that the presence of sulphuric acid is itself promoting the chemical deterioration of specimens nearby.

It is a known fact that sulphur reducing bacteria play an important role in the oxidation processes of weathering mineral bodies (Ehlich, 1964), a fact made use of in the beneficiation of ore deposits. It was thought at one time that such bacteria were largely responsible for the oxidation process, especially in the decay of the dimorphs, pyrite and marcasite. Many preventative measures were taken to control the activities of these bacteria, including the use of alcoholic solutions of the cationic bactericide Cetrimide BP. (Postgate and Butlin, 1955). The problems remained.

It now seems likely from Howie's work (1978), that bacteria do not promote the initial oxidation of pyrite and marcasite, though they may play an active role subsequently.

In a valuable piece of experimental work Howie (1977) was able to prove that the upper level of the stability range for pyrite at room temperature was 60%RH, but that ideally the RH should not exceed 55%. This suggests that most British geological storage areas, not possessing a controlled climate, are unsuitable places for the storage of sulphides.

The collector must store such material where the RH neither exceeds 55% nor varies dramatically above or below that figure. Alternatively he may do this by creating a microclimate where he may dictate the required humidity level, in a similar manner to that he employed in the control of deliquescence.

Not all pyrite and marcasite is equally metastable. Bannister (1937, p.465) listed localities where metastable pyrite and marcasite occurred, but this valuable listing is not conclusive. For example both stable and metastable pyrite may occur at the same locality, sometimes even in the same lode. The most important factor determining stability, is crystal morphology, since oxidation begins at exposed surfaces and inter-crystalline boundaries. Thus stability is related to the genetic environment of the material and therefore to locality. Large crystals from metamorphic or hydrothermal situations are less likely to be affected by oxidation than fine-grained polycrystalline material, such as sedimentary pyrite or marcasite nodules.

Collectors should treat all sulphides as being potentially at risk under adverse conditions and should handle them accordingly (Carmichael, 1926, p.29). However most sulphides are stable under average conditions of temperature and RH. Some particularly susceptible species are listed in Table 4. The metastability may well lead to the complete disintegration of the specimen.

TABLE 4. *Some metastable sulphides, arsenides and elements*

Alabandite-MnS	Lead, Native - Pb
Arsenic, Native - As	Marcasite - FeS_2
Arsenopyrite - FeAsS	Pyrite - FeS_2
Gersdorffite - NiAsS	Pyrrhotine - FeS
Iron, Native - Fe	Safflorite - $CoAs_2$

Other sulphides betray oxidation processes by tarnish which is frequently iridescent in character. Tarnish is usually associated with high levels of atmospheric contamination, especially sulphur dioxide or hydrogen sulphide. Minerals stored in areas subject to airborn contamination from industrial sites are especially at risk, but it should be realised also that hydrogen sulphide is likely to be present in the atmosphere as a product of organic decay in rural situations. Tarnish may also develop in stores adjacent to chemical laboratories or photographic dark rooms.

Tobacco smoke (especially from cigarettes) rapidly causes tarnish in sulphides. Specimens on open display may suffer tarnish in this way. Even during curatorial preparation work specimens may tarnish. The process can be rapid.

Table 5 lists the common species known to tarnish rapidly under high risk conditions:

TABLE 5. *Minerals liable to tarnish*

Berthierite - $FeSb_2S_4$
Bismuth, Native - Bi
Bismuthinte - Bi_2S_3
Bornite - Cu_5FeS_4
Chalcocite - Cu_2S
Chalcopyrite - $CuFeS_2$
Cobaltite -CoAsS
Copper, Native - Cu
Domeykite - Cu_3As
Dyscrasite - Ag_3Sb
Enargite - Cu_3AsS_4
Galena - PbS
Silver, Native - Ag
Smaltite - $CoAs_2$
Stannite - Cu_2FeSnS_4
Stibnite - Sb_2S_3
Temiskamite - Ni_3As_2 (var. of maucherite)

The control of non-metallic oxidation

The decay of sulphides, especially pyrite and marcasite, has been known for centuries and the supposed reasons for the phenomena and suggestions for its control are many and varied.

A comprehensive account of the historical aspects of pyrite oxidation was produced by Howie in 197? (p.459), but there is little value in listing here the many techniques used over the long history of the conservator's largely fruitless struggle to combat this unpleasant "disease". No one technique can be recommended for all purposes.

The most recent technique uses ethanolamine thioglycollate (Cornish and Doyle, 1984), and this may ultimately prove to be not so efficaceous as first thought. Although this compound may be suitable for fossils, where form is the most important feature, it should not be used on mineral specimens, because it alters the lustre and colour of the mineral. In addition there are hazards in using it which in practise place it out of reach of the average collector.

At the present state of knowledge, it is recommended that the collector follow the procedures set out below:

Fresh unattacked specimens

1. Slowly dry the material by radiant heat. For an average sized specimen the heat from a 60 watt lamp for 1 hour at 200mm height is ideal.
2. Either (a): Store material in an area carefully monitored to maintain, without fluctuation, a RH of 50-55%.

   Or (b): Heat seal material in a suitably sized G-PAK pouch together with enough baked silica gel to maintain a low RH.

Material already attacked

1. Slowly dry the material by radiant heat as above.
2. Physically remove all traces of decomposition products (mainly ferrous sulphate). This may be done at first by dry dusting and the use of mechanical extraction.
3. If the material is still robust, flush away the less accessible decompositional material with de-ionised water from a wash bottle, but do not do this unless absolutely necessary. Return to stage 1.
4. Providing stages 1 and 2 have been thorough, a large measure of neutralisation can be effected by enclosing the specimen in a tightly sealed polythene bag containing a dish of 0.88 ammonia. The reaction is slow and can take weeks to be of any value.
5. Repair and consolidate, if necessary. Use a spirit based adhesive for repairs. Consolidate using a dilute solution of polyvinyl acetate, if possible under vacuum.
6. The material should be placed either in storage having a constant RH no higher than 55% or: in a sealed G-PAK pouch accompanied by an adequate supply of self indicating blue silica gel.

It must be stressed that any data accompanying a specimen being treated should be removed from the specimen and be placed in a sealed polythene bag, kept with the specimen during treatment, and be ultimately re-affixed to the specimen.

It should be pointed out that once "pyrite disease" has taken a firm hold on a specimen, the cure rate is low.

The restoration of tarnished material

It is often impossible to restore the lustre of tarnished material. Soaking specimens in dilute solutions of oxalic acid may be effective, but the collector should maintain close surveillance on the experiment. Never use concentrated acids, such as recommended by Bertrand and Bertrand (1962) and many other authors.

2(e) Metastability induced by temperature changes

Most minerals are relatively immune to changes of temperature and are not visibly affected by them. Others are notoriously difficult to handle or display for the same reasons. No mineral should be subjected to violent temperature changes.

Many minerals have low thermal conductivity and high thermal expansion factors, the classical example being that of native sulphur. Rapid changes of temperature can completely fracture the mineral, even when it is held in the hand. Some minerals with well developed cleavages are also liable to fracture with violent temperature changes. Fluorite should never be immersed in hot water following storage at room temperatures, nor be brought into a warm room suddenly after being brought out of unheated storage. Certain occurrences of baryte with well marked cleavage should be treated equally carefully.

Many efflorescent minerals are also sensitive to elevated temperatures since RH is temperature dependant. Hydrated minerals literally dissolve in their own water of crystallisation at comparatively low temperatures, an example being that of mirabilite ($Na_2SO_4.10H_2O$) which appears to melt at temperatures below 32°C.

Parsons (1922, p.63) reported the fact that sal-ammoniac (NH_4Cl) and Teschermacherite ($(NH_4)HCO_3$) can volatilise under normal storage conditions. They require special storage.

Frequently minerals contain abundant bubble-like inclusions of fluid. They are mostly invisible to the naked eye. Table 6 lists some of the more important minerals that contain such fluid inclusions.

TABLE 6. *Minerals which commonly contain fluid inclusions*

Beryl - $Be_3Al_2Si_6O_{18}$
Calcite - $CaCO_3$
Chalcedony - SiO_2
Fluorite - CaF_2
Gypsum, var. selenite - $CaSO_4$
Halite - NaCl
Olivine - $(Mg,Fe)_2SiO_4$
Quartz - SiO_2
Topaz - $Al_2SiO_4(OH,F)_2$

The species listed should never be subjected to sub-zero temperatures since the aqueous liquid contents of the inclusions might freeze and rupture the specimen. Collections housed in unheated buildings can therefore be at risk.

The preservation of minerals sensitive to temperature changes

This is a matter of common sense, but minerals are frequently and thoughtlessly subjected to rapid temperature changes, as when being transported to and from a display meeting. Collectors may find that their specimens are suffering long term deterioration and wonder why. It is a simple matter to insulate carrying boxes from temperature changes by wrapping or lining them with suitable material.

Changes of temperature can damage minerals in displays. Techniques to avoid this problem will be discussed in a future article.

2(f) Minerals at risk through shrinkage

The dehydration of some minerals following a drop in RH can cause problems which may involve shrinkage. This can appear merely as shrinkage cracks, or as complete structural failure. Minerals with a high water content are much more likely to be affected. Chrysocolla ($(Cu,Al)_2H_2Si_2O_5(OH)_4.nH_2O$) develops characteristic shrinkage cracks, but does not disintegrate while minerals of the autunite group ($Ca(UO_2)_2(PO_4)_2.12H_2O$), completely disintegrate.

The internal structure of opal (particularly precious opal), is such that a rapid drop of RH may cause shrinkage cracks. The seriousness of this problem is related to the original environment of the opal. Australian opal, being found in an arid environment, needs no post mining preservation, whereas that mined in the Virgin Valley of Nevada in the U.S.A. is re-buried in moist earth until required for lapidary work.

Many collectors preserve their opal under glycerin or mineral oils in order to maintain a high RH. Opal in the form of jewellery is relatively safe if worn from time to time as the natural oils in the wearer's skin are sufficient.

Once shrinkage has occurred, little can be done to heal cracks or other structural failure. All that can be done is to prevent complete structural failure in such dehydrated material, and this can be achieved by impregnating the specimen with polyvinyl acetate.

Table 7 is a list of minerals which may suffer due to shrinkage.

TABLE 7. *Minerals prone to shrinkage following dehydration*

Albertite - Hydrocarbon compound

Alunite - $KAl_3(SO_4)_2(OH)_6$

Amber - Hydrocarbon compound

Autunite - $Ca(UO_2)_2(PO_4)_2.12H_2O$

Chrysocolla - $(Cu,Al)_2H_2Si_2O_5(OH)_4.nH_2O$

Opal - $SiO_2.nH_2O$

Turquoise - $CuAl_6(PO_4)_4(OH)_8.5H_2O$

2(g) **Minerals at risk through hydrolysis**

There are some minerals, known to be hygroscopic, which under conditions of high RH react to produce new species. There are two well known often quoted species:

Chloraluminte ($AlCl_3.6H_2O$)

Molysite ($FeCl_3$)

Both are rare minerals originating in fumaroles in volcanic regions. In old collections they are usually preserved in sealed glass jars, but as the seals tend to fail in time, some hydrolysis will almost certainly have occurred and then breakdown products will also be present. Should a collector acquire a jarred specimen of a species such as molysite, he should not attempt to remove the specimen from its jar, but maintain the seal by adding melted paraffin wax to it and re-inforcing it with adhesive tape. Such jars are collectors items in their own right.

2(h) **Minerals at risk through the action of light**

Many minerals are affected by light, some change simply in colour, others decompose. This metastability can cause changes that are irreversible and very damaging. In addition effects on such photosensitive minerals can be cumulative.

The most serious risk occurs in displays where minerals are subjected to strong lighting over long periods of time. This aspect will be dealt with in a future article. Nevertheless the problems exist wherever minerals are exposed to light. Exposure to full sunlight should be avoided at all costs, though fluorescent lighting may be equally damaging. It is possible to acquire efficient light filters, designed to filter out the more harmful shorter wavelengths (Thomson, 1978, p.10) and lamp manufacturers are usually keen to advise on the strength and suitability of filters for specific requirements.

Tungsten lighting poses few problems and the preliminary examination of all species should be conducted under such lighting.

The reasons for light induced metastability are little understood, as are the reasons why the phenomenon is limited to certain groups of minerals.

Light induced colour change has long been known and is frequently employed by lapidarists, some dealers and others for often dubious and always unscientific reasons. The outcome is a mineralogist's nightmare. There is a great deal of literature concerning the colour of minerals and the technique used to change those colours (which besides light include heat, irradiation, etc.). This topic is beyond the brief of this paper. Burns (1983) gives a useful introduction to the subject.

The list of minerals affected by light is a long one, but the better known, gleaned largely from Bannister's work (1937, p.471) are listed below under two headings:

1. Minerals subject to colour change by light without decomposition. Table 8.
2. Minerals subject to decomposition by light (in oxygen). Table 9.

TABLE 8. *Minerals subject to colour change by light, without decomposition*

Anglesite - $PbSO_4$

Broken Hill, New South Wales; from pale brown to colourless (Bannister, 1937, p.473).

Anhydrite - $CaSO_4$

Heaselden's Mine, Cropwell Bishop, Nottinghamshire; from blue to white (Personal observation - RJK). Hanaoka and Kano Mines, Japan; from blue to colourless (Kinoshita, 1926). The mechanism hydration.

Apatite - $Ca_5(PO_4)_3F$

From several localities in Switzerland and the Austrian Tyrol (Bannister, 1937, p.473).

Azurite - $Cu_3(CO_3)_2(OH)_2$

Becomes darker (Parsons, 1926, p.81).

Baryte - $BaSO_4$

Mowbray Mine, Frizington, Cumbria; from pale yellow to blue (Sweet, 1930, p.265). Dirtlow Rake, Castleton, Derbyshire; from sky blue to chalky white in minutes of exposure to bright sunlight (M.E. Smith - personal communication). Hartsel, Park County, Colorado, U.S.A; pale to dark blue (Eckel, 1961).

*Celestine - $SrSO_4$

Aust Cliff, Avon; from dark blue to white on prolonged exposure (1-2 days) to strong sunlight. After a period in darkness the blue colour is restored (Alabaster, 1979, p.11).

Fayalite - Fe_2SiO_4

St. Peter's Dome, Colorado, U.S.A; from green to blue (Mohr, 1948, p.207).

Fluorite - CaF_2

Weardale, Durham; from green to purple (Sweet, 1930, p.266). Weardale, Durham; from purple to pink (Bannister, 1937, p.473), from coloured to colourless (Speckles, 1965, p.78). Cardiff Township, Haliburton County, Ontario, Canada; from purple to colourless (Pearl, 1980, p.75).

Colourless fluorites, especially those known to fluoresce strongly under ultraviolet light, should not be exposed to any form of lighting for any length of time. Marked colour fading will result (Personal observation - RJK).

*Hackmannite - $Na_8Al_6Si_6O_{24}(Cl_2,S)$

Towa Valley, Kola Peninsula; from pink to colourless (Borgstrom, 1901, p.563). Bancroft, Dungannon Township, Ontario, Canada; from pink to colourless (Walker and Parsons, 1925b, p.5 Lee, 1936, p.764).

Hisingerite - $Fe_2Si_2O_5(OH)_4.2H_2O$

Minnie Moor Mine, Blaine County, Idaho, U.S.A; from dark red to dark brown (Hewett and Schaller, 1925, p.33).

Ianthinte - $Ca_3(UO_2)_6U(CO_3)_2(OH)_{18}.H_2O$

From purple to greenish yellow (Spencer, 1928, p.312).

*Kleinite - $Hg_2N(Cl,SO_4).nH_2O$

Terlingua, Brewstar County, Texas, U.S.A; From canary-yellow to orange in daylight, reverting to the original colour in darkness (Palache, Berman and Frondel, 1951, p.88).

*Nepheline - $Na_3KAl_4Si_4O_{16}$

York River, Hastings County, Ontario, Canada; from colourless to pale pink (Spencer, 1937, p.473).

*Phenakite - Be_2SiO_4

From red to pale pink (Fersman, 1958, p.388).

Quartz, var. Amethyst - SiO_2

Most will fade in depth of colour if left in strong light for long periods (Speckels, 1965, p.78).

Quartz, var. Chrysoprase - SiO_2

Fades in sunlight (Pearl, 1980, p.74).

Quartz, var. Rose Quartz - SiO_2

Fades in sunlight (Pearl, 1980, p.74, Davidson, 1941, p.57). Holden (1924, p.102) had previously disputed the above two statements.

Quartz, var. Smokey Quartz - SiO_2

Generally turns colourless in the sun or strong lighting (Speckels, 1965, p.78).

*Rutile - TiO_2

Most natural crystals of rutile are too dark to show the effects described by Williamson (1940, p.513) as photosensitivity, but crushed rutile or bruised areas will show the colour range from cream coloured in daylight to white following a period in darkness.

*Sodalite - $Na_4Al_3Si_3O_{12}Cl$

Kishangahr State, Rajputana, India; from colourless or pale blue to pink after being kept in the dark for up to 3 weeks (Vredenburg, 1904, p.43).

Topaz - $Al_2SiO_4(OH,F)_2$

Pike's Peak area, Colorado, U.S.A; from blue to colourless. Pearl (1980, p.74). Thomas Range, Utah, U.S.A.; from shades of brown to colourless (Parsons, 1926, p.81, Pearl, 1980, p.74) and from shades of brown to blue in daylight (Wada, 1904, p.91). Cairngorm, Grampian; from cinnamon-brown to pale blue in 70 years of good light-free storage (Sweet, 1930, p.266).

Turquoise - $CuAl_6(PO_4)_4(OH)_8.5H_2O$

Marked colour loss after exposure to sunlight (Pearl, 1980, p.74).

Tyuyamunite - $Ca(UO_2)_2(VO_4)_2.10H_2O$

From bright lemon-yellow to dirty greenish yellow in a few minutes of bright light (Parsons, 1926, p.81).

Vanadinite - $Pb_5(VO_4)_3Cl$

From bright yellow to dull brown in prolonged exposure to light (Pough, 1953, p.217).

Zircon - $ZrSiO_4$

Chanthaburi, Thailand; from flesh-colour to blue (Michel and Przibram, 1926, p.49).

Species marked with an asterisk in Table 8 are known to have some degree of reversible photosensitivity. Placing them in darkness for a limited period is usually sufficient to restore the first noted colour.

TABLE 9. *Minerals subject to decomposition by light (in oxygen)*

Acanthite - Ag_2S

Aguilarite - Ag_4SSe

alters to silver and cuprian stephanite

Alabandite - MnS

Alaskaite - $Pb(Ag,Cu)_2Bi_4S_8$

First stage decomposition is a bronze-coloured tarnish.

Anapaite - $Ca_2Fe(PO_4)_2.4H_2O$

Alters to the metacolloid mitridatite.

Andorite - $AgPbSb_3S_6$

Aramayoite - $Ag(Bi,Sb)S_2$

Argentite - Ag_2S:

High temperature cubic phase of Ag_2S. Most natural silver sulphide specimens are pseudomorphs of acanthite after argentite (Hey, 1962, p.10).

Argyrodite - Ag_8GeS_6

Baumhaurite - $Pb_3As_4S_9$

Berzelianite - Cu_2Se

Bromargyrite - AgBr

Alters to silver.

Canfieldite - $Ag_8(Sn,Ge)S_6$

Chalcocite - Cu_2S

A member of a metastable series, ending with loss of copper as digenite.

Chlorargyrite - AgCl

Alters to silver.

Cinnabar - AgS

Alters to mercury and sulphur (Cropp, 1923, p.259).

Crocoite - $PbCrO_4$

Cuprite - CuO_2

Diaphorite - $Ag_3Pb_2Sb_3S_8$

Dietzeïte - $Ca_2(IO_3)_2CrO_4$

Dufrenoysite (of Damour) - $Pb_2As_2S_5$

Eglestonite - Hg_4Cl_2O

Exsolves mercury.

Embolite - Ag(Cl,Br)

Alters to silver.

Erythrite - $CO_3(AsO_4)_2.8H_2O$

Fizélyite - $Ag_2Pb_5Sb_8S_{18}$

Freieslebenite - $Ag_5Pb_3Sb_5S_{12}$

Graftonite $(Fe,Mn,Ca)_3(PO_4)_2$

Hessite - Ag_2Te

Huantajayite - (Na,Ag)Cl

Hureaulite - $Mn_5H_2(PO_4)_4.4H_2O$

Hutchinsonite - $(Tl,Pb)_2AgAs_5S_{10}$

Iodargyrite - AgI

Alters to silver.

Iodembolite - Ag(Cl,Br,I)

Alters to silver.

Jalpaïte - Ag_3CuS_2

Alters to silver and silver sulphosalts.

Koninckite - $FePO_4.3H_2O$

Lengenbachite - $(Ag,Cu)_2Pb_6As_4S_{13}$

Lorandite - $TlAsS_2$

Marshite - CuI

Matildite - $AgBiS_2$

Miargyrite - $AgSbS_2$

Miersite - (Ag,Cu)I

Montroydite - HgO

Nantokite - CuCl

Alters to paratacamite.

Naumannite (of Haidinger) - Ag_2Se

Pearceite - $Ag_{16}As_2S_{11}$

Penroseite - $(Ni,Cu)Se_2$

Phoenicochroite - $Pb_3Cr_2O_9$

Polybasite - $Ag_{16}Sb_2S_{11}$

Alters readily to stephanite.

Polydymite - Ni_3S_4

Alters to erythrite and pitticite.

Proustite - Ag_3AsS_3

Readily alters to silver and acanthite.

Pyrargyrite - Ag_3SbS_3

Readily alters to silver and acanthite.

Pyrostilpnite - Ag_3SbS_3

Ramdohrite - $AgPbSb_3S_6$

Rathite - $Pb_{13}As_{18}S_{49}$

Alters to arsenical sulphides.

Realgar - As_4S_4

Alters quickly to orpiment and arsenolite.

Samsonite - $Ag_4MnSb_2S_6$

Sanguinite - Sulpharsenite of silver.

Sartorite - $PbAs_2S_4$

Smithite - $AgAsS_2$

Light red changing to orange in light with loss of form.

Stephanite - Ag_5SbS_4

Alters to silver and other silver sulphosalts.

Stibnite - Sb_2S_3

Stromeyerite - AgCuS

Sylvanite (of Necker) - $AgAuTe_4$

Symplesite - $Fe_3(AsO_4)_2.8H_2O$

Light green to indigo blue with loss of form.

Terlinguaite - Hg_2ClO

From sulphur yellow to olive green on exposure to light.

Trechmannite (of Solly) - $AgAsS_2$

Vivianite - $Fe_3(PO_4)_2.8H_2O$

Changes from colourless transparent to bluish-black with loss of form (Watson, 1918).

Vrbaite - $Tl(As,Sb)_3S_5$

Xanthoconite-Ag_3AsS_3

Many of the silver salts listed in Table 9 are highly photosensitive and are affected by light even in anaerobic conditions.

Prevention of metastability by light

The control and prevention of decomposition and changes of colour by light is largely a matter of common sense. Being aware of the danger to those species which are most susceptible to it a collector would not exhibit them in an open or illuminated glass-topped display case. Nor would he leave such material as the "ruby silvers" or silver halides in a cabinet of drawers unless he had deposited each individual specimen in a closed light-tight box within the drawers. Nor would he offer to show those species to an interested observer unless specifically asked. The effects of photosensitivity are cumulative - each time the mineral is exposed to light, the greater the decay factor.

Display techniques whereby a limited number of the species listed above may be used will be discussed in a future article. The recent development of light filters and other materials has made significant advances in display techniques.

2(i) **Miscellaneous metastabilities**

In a final miscellaneous group are included minerals that are very metastable for a variety of reasons. The causes of the metastability are not completely understood. Details are given in Table 10.

TABLE 10. *Minerals subject to miscellaneous metastabilities*

Arsenic, Native - As

Oxidises on exposure to a mixture of arsenic and arsenolite (AsO_3), or simply aresenolite. Should not be subjected to high RH. See also Table 4.

Chalcocite - Cu_2S

Chalcocite is not stable in air. Copper slowly exsolves from its surface by tarnish, phase by phase until the final phase digenite ($Cu_{1.8}S$ or Cu_9S_5) is reached without any apparent loss of form. Specimens of so-named chalcocite in excess of 43 years old, upon examination have proved to be exsolved phases of the series (Cook, 1972, p.15). See also Table 5.

Kröhnkite - $Na_2Cu(SO_4)_2.2H_2O$

Rapidly loses its sky-blue colour and transparency under high RH and becomes green or opaque. Should be kept under surveillance in low RH.

Lansfordite - $MgCO_3.5H_2O$

Speedily becomes dull and opaque (nesquehonite) on exposure, and in low RH efflorescences. Should be kept in a sealed pouch.

Laumontite - $CaAl_2SiO_4O_{12}.4H_2O$

Some occurrences dehydrate rapidly to the variant leonhardite with efflorescence without structural change. With the exception of those occurrences known to resist metastability, laumontite should be sealed in a pouch with moistened silica gel. Bannister (1937, p.471) described the preservation of laumontite sealed in a jar containing a bed of cotton wool soaked in water.

Löweite - $Na_2Mg(SO_4)_2.2.5H_2O$

Becomes dull and coated with a white encrustation in high RH. Should be stored under conditions of enforced reduction of RH.

Melanovanadite - $Ca_2(VO)_4V_6O_{21}$

Readily alters to pascoite.

Pararamellsbergite - $NiAs_2$

Readily alters to annabergite at most levels of RH. Should be sealed in a pouch.

Romeite, Titanian - $(Ca,Na)_2(Sb,Ti)_2(O,OH)_7$

Superficially but rapidly alters to a sulphur-yellow powder. Should be sealed from air.

Smaltite - $CoAs_2$

Readily alters to erythrite under moist conditions with earthy mixtures of Co, Ni and Fe oxides. Should be kept in storage of low RH (Walker and Parsons, 1925a, p.41).

Turquoise - $CuAl_6(PO_4)_4(OH)_8.5H_2O$
Can loose capillary water in low RH with corresponding loss of colour. Presents little problem when cut and worn as jewellery. Should never be left near heat sources.

Vivianite - $Fe_3(PO_4)_2.8H_2O$

Originally colourless and transparent, but quickly becomes green and finally bluish-black, due partly to oxidation, but possibly also as the result of shock. Parsons (1926, p.81) recalled that L.J. Spencer brought his attention to the fact that the destruction of equilibrium by rupturing of the crystal surfaces was responsible for the onset of colour change in vivianite.

2(j) **Radioactive metastability**

Finally, the collector must identify radioactivity in his material. The risks of induced radioactivity of other specimens stored in close proximity to radioactive sources in short term storage are slight. It is the collector himself who is at risk. All radioactive sources are potentially dangerous and should be handled as little as possible. Powdery efflorescences are particularly dangerous. Should the collector suspect that he has such material, he should ask for advice and heed it carefully. The personal risks themselves are examined in Section F.

B3 **Second stage curatorial techniques and interim storage**

3(a) **Cleaning minerals.** (See King, 1982, p.42).

3(b) **Development of minerals.** (See King, 1983, p.54).

Having recognised and dealt with any metastability problems either by stabilisation or prevention, the collector may wish to attempt more specialised cleaning and development of his material. The ethics and the techniques involved have been dealt with previously (King, 1982, and 1983) and will not be enlarged on here.

3(c) **The Handling of Minerals**

It may be useful here to examine the safe and correct way to handle mineral specimens. Minerals are not rocks. Minerals, though frequently heavy, like rocks, are nevertheless much more delicate. Their physical structure, frequently possessing such features as a marked cleavage, etc., and their sometimes loosely cemented mineralogical associations, etc., imply delicasy.

A specimen should be picked up so that its weight is distributed over the whole palm of the hand, and when returned to its place in the cabinet, should be placed down gently and in the exact position the owner had placed it. Should it be necessary to examine the base of the specimen, use both hands to rotate it safely. The golden rule should be, however, that the specimen should be handled as little as possible.

3(d) **The Repair of Minerals**

As soon as a specimen is damaged, its value in the eyes of a dealer is much reduced, no matter how skilfully a break is repaired. However, there is not necessarily any great loss of scientific value. Some breakages are inevitable, others are purely accidental. A skilful repair takes nothing from the specimen and gives praise to the repairer, but details of any repairs should form an integral part of the specimens records. The appearance of a specimen has been enhanced by the modification of a complicated break, but this amounts to faking, which is an entirely separate matter and is of course totally unacceptable. This will be dealt with in a subsequent article.

A specimen cannot be left unrepaired. Repair techniques can call for considerable mineralogical experience, and there are some people more gifted in manipulative skills than others. Rather than risk additional damage, it is often wise to seek help. Should the collector feel competent to effect a repair, the following steps should be taken. Make sure that any resins or adhesives used do not chemically react unfavourably with the mineral, and will not affect any subsequent optical or chemical work. The general procedure is as follows:-

1. Prepare a sand tray, by filling a tray or box with fine clean dry sand to a minimum depth of 80mm.
2. Have all materials ready to hand.
3. Ensure that the base or substrate of the specimen to be repaired is strong enough to handle.
4. If not, consolidate with a hardener, such as a polyvinyl acetate emulsion or an epoxy

resin. It is a refinement to make the impregnation under vacuum.

5. Should the break be an old one, ensure that all traces of any original adhesive are removed.

6. Coat each side of the break with a spirit based glue. A useful adhesive is made by dissolving celluloid chips in equal volumes of amyl acetate and acetone. It is unfortunate that the Rawlplug Company no longer produces its compound Durofix. Proprietary balsa wood cements may work. Never use water-based adhesive, which readily deteriorates in damp conditions, or "permanent" adhesives such as polyesters or epoxies. Bonds made from the latter are frequently stronger than the mineral itself. Should it be necessary to re-break the specimen, e.g. through bad manipulation, the bond will be too strong and the specimen will break elsewhere.

7. Place each half of the specimen, broken surface upwards in the tray and allow sufficient time for some of the solvent to evaporate.

8. Firmly embed the stronger half of the specimen in the sand, and bring the two pieces firmly together so that balance is achieved. Allow to dry. Remove all traces of excess adhesive.

9. The specimen should be clearly marked that it has been repaired, and details of the repair noted in the register.

3(e) Interim storage

Having cleaned, developed and repaired his material as necessary, the collector will now have to make some decisions. If he is certain of his identifications and wishes to retain the whole batch of field material before him, then he can proceed to accession it. On the other hand, if he needs time to work on the material, to identify it, or wishes to hold it at this stage pending a second opinion, or simply has no time to proceed, the material should be lodged in an efficient and simple storage system from whence it can be readily retrieved when time allows work to proceed.

Ideally the system should be housed in an adequately monitored equable climate, where the RH does not exceed 55%, or the temperature fall below 0°C. Where only unmonitored or unsuitable conditions are available, special provision must be made for metastable specimens (see above).

The ideal storage system for speed of retrieval and maximum vision must be a set of drawers. A stack of trays or boxes is perfectly adequate providing it is stable. Each drawer or tray should be labelled with the field numbers which will provide chronological order and rapid access to a specimen.

If space should be a serious problem specimens may have to be wrapped and be stored at a greater density, and, providing individual specimens receive their own field numbers clearly marked on the wrapping, little flexibility will have been lost. It is wise to extract delicate specimens and store them separately. There should be no reason why such interim storage cannot survive for years.

Section 3B on the Curation of Minerals will be concluded in number 4 of Volume One of the Journal of the Russell Society.

It will include:
- C The Identification of Minerals
- D Accessioning Techniques and Types of Collection
- E Data Retrieval
- F The Collector at Risk
- G Accommodation and Storage
- H The Transportation of Minerals

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Appendix

G-Pak pouches and G-Pak Sealer are available from:

Messrs. Guest (Medical & Dental) Ltd.,
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Pouch sizes: 2 Mil thickness
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205 x 240 mm
205 x 305 mm
240 x 410 mm

4 Mil thickness
165 x 205 mm
205 x 240 mm
205 x 305 mm
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Special sizes are available on request.

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