the Mineralogical Record

Volume Twenty-seven, Number Four
July–August 1996
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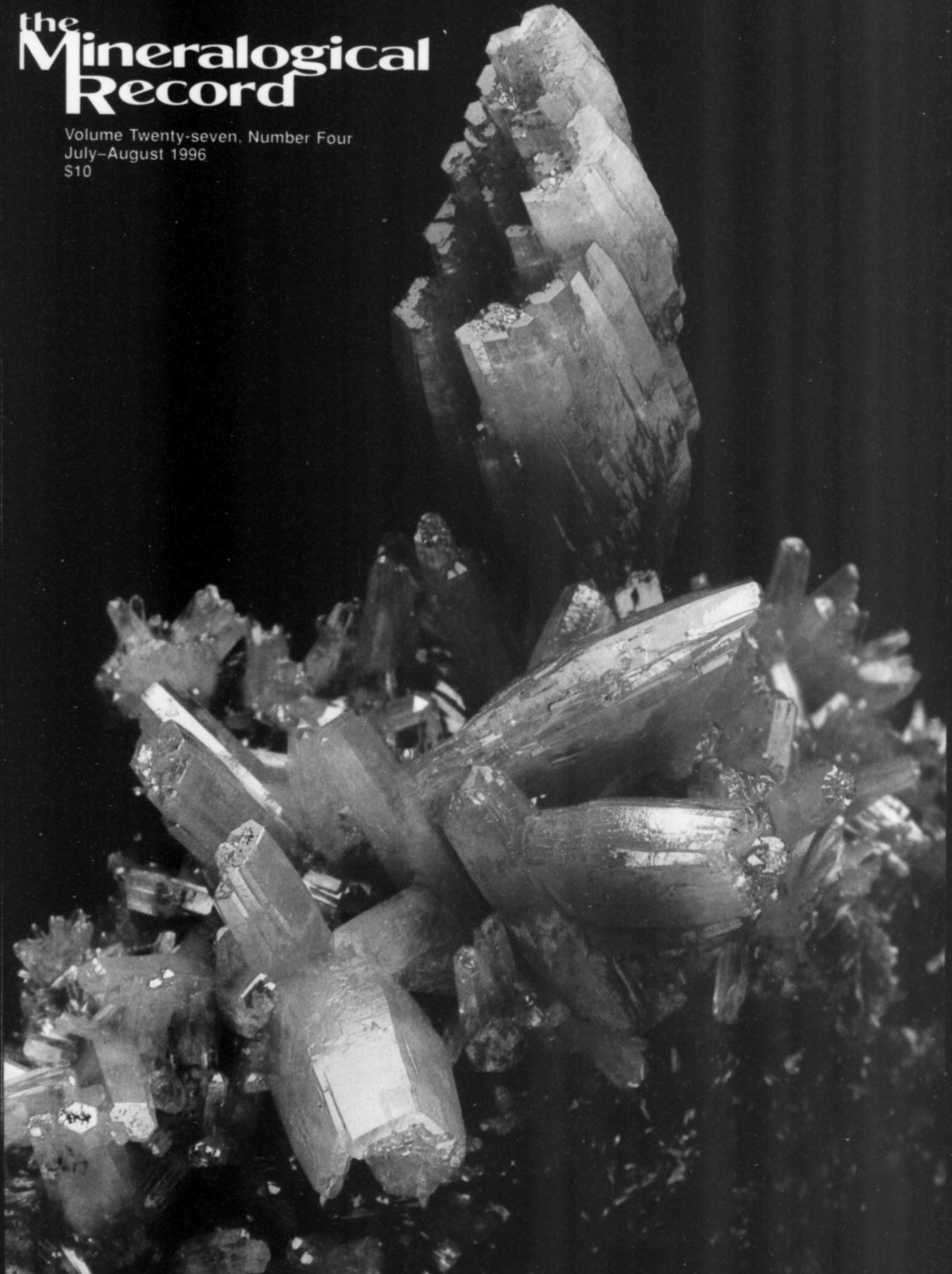

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*Continued on p. 319

THE
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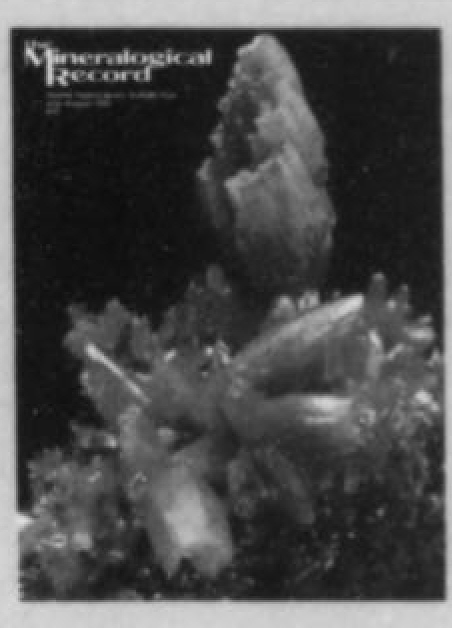
Articles

Columns



COVER: PYROMORPHITE crystal group, 6 cm tall, from the Bunker Hill mine, Kellogg, Idaho. James and Dawn Minette collection; photo by Jeffrey A. Scovil.

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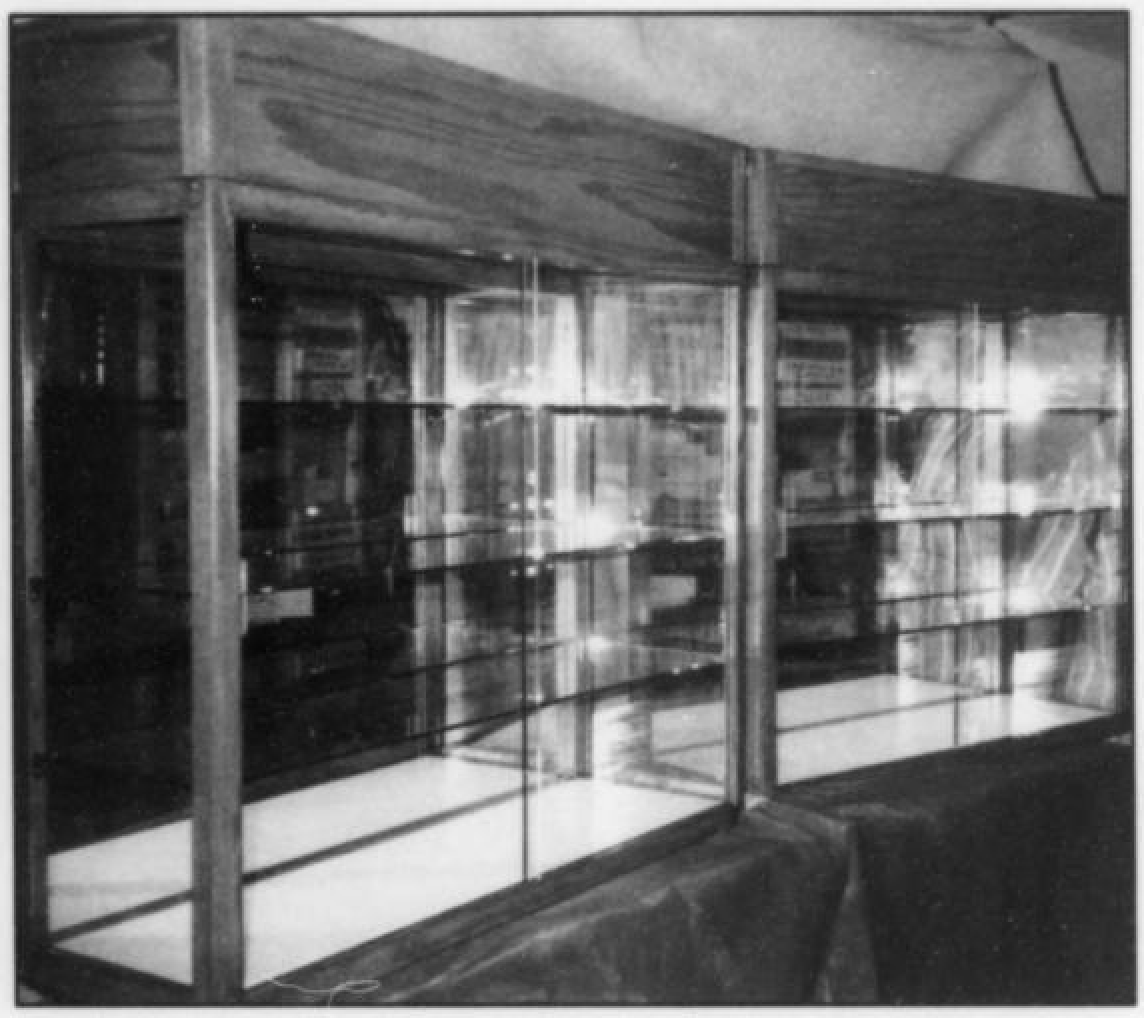
notes from the EDITOR

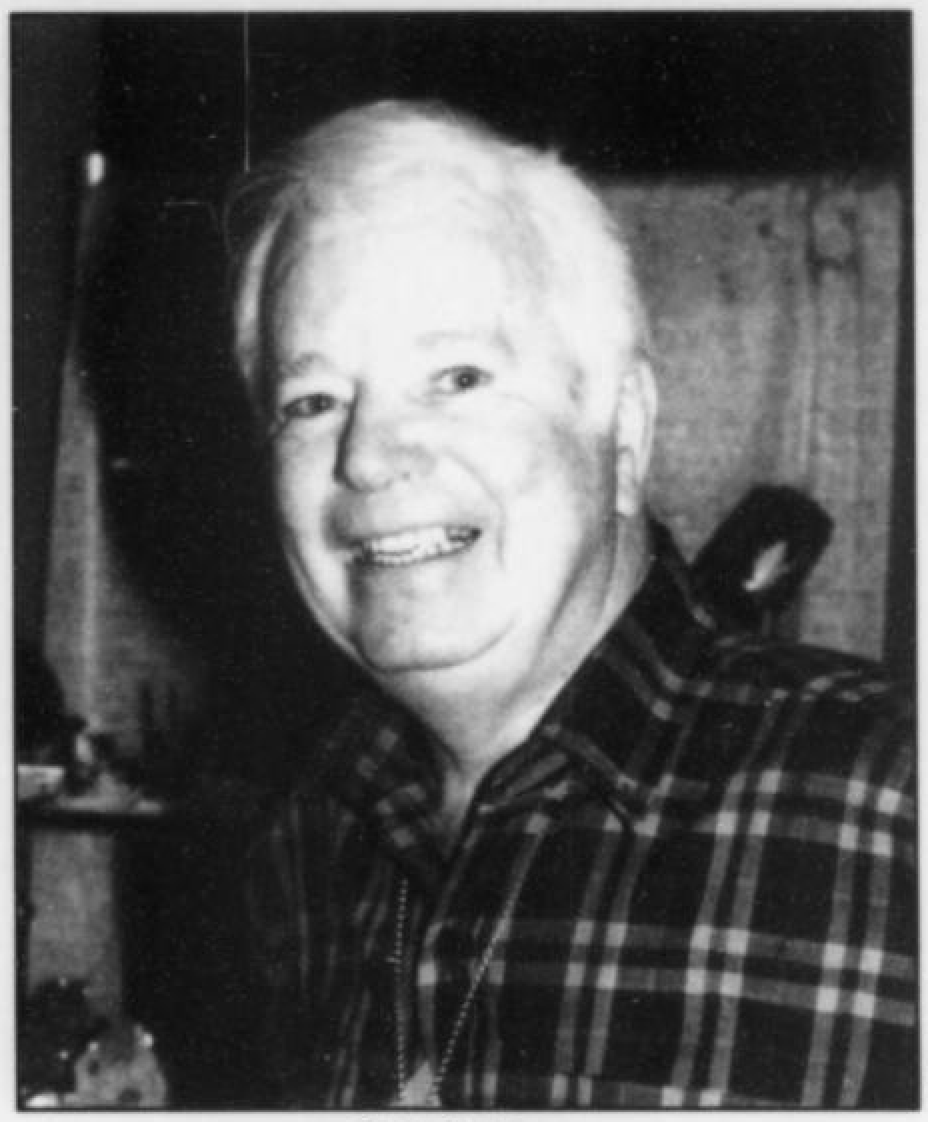


MINERAL CASES (II)

Our featured source for exhibit cases this time is **Tom Hales** of *The Case Place* (1317 South Socorro St., Deming, NM 88030-4926. Tel: (shop) 505-524-4096, (office) 505-546-9468), who is also a gem and mineral specimen dealer under the name of *Hale's Gems*. Tom produces a line of vertical glass-fronted wall cases with fluorescent or incandescent lighting, on/off switches, adjustable plate-glass shelves, sliding front glass doors and handfinished solid oak frames with your choice of stain colors. Many sizes are available, with varying numbers of shelves from 3 to 12 inches in depth. Prices for lighted cases range from about $80 for the 15 x 20-inch "extra small" wall case to $525 for the 53 x 42-inch "extra large" case, and $1,295 for the 76 x 48-inch "Large Floor Case." He also makes thumbnail cases. The workmanship on these is very nice, and Tom can add some traditional Southwestern design elements if that would suit your decor. Send for his new brochure.

NOTICES

Died, Robert (Bob) James Sullivan, 77, in Tucson, Arizona. Bob Sullivan was known to many people as a mineral dealer and former columnist for the *Mineralogical Record*. He was an Engineering graduate of Worchester Polytechnic Institute, conducted Research and Development for the Massachusetts Institute of Technology and for Cambridge Air Force Labs, served in Europe as Technical Advisor to NATO for the United States, and later was Director of Fairchild Controls Corporation. He operated a mineral business from 1971 until illness overtook him in 1995, and wrote a "What's New" column ("Letter from Europe") for the *Mineralogical Record* from 1977 until 1982. Bob and his wife, Maudine, moved to Tucson, Arizona, in 1978, but continued traveling extensively for many years. They could always be found during the Tucson Show at the Convention Center and, later, at the Desert Inn show.

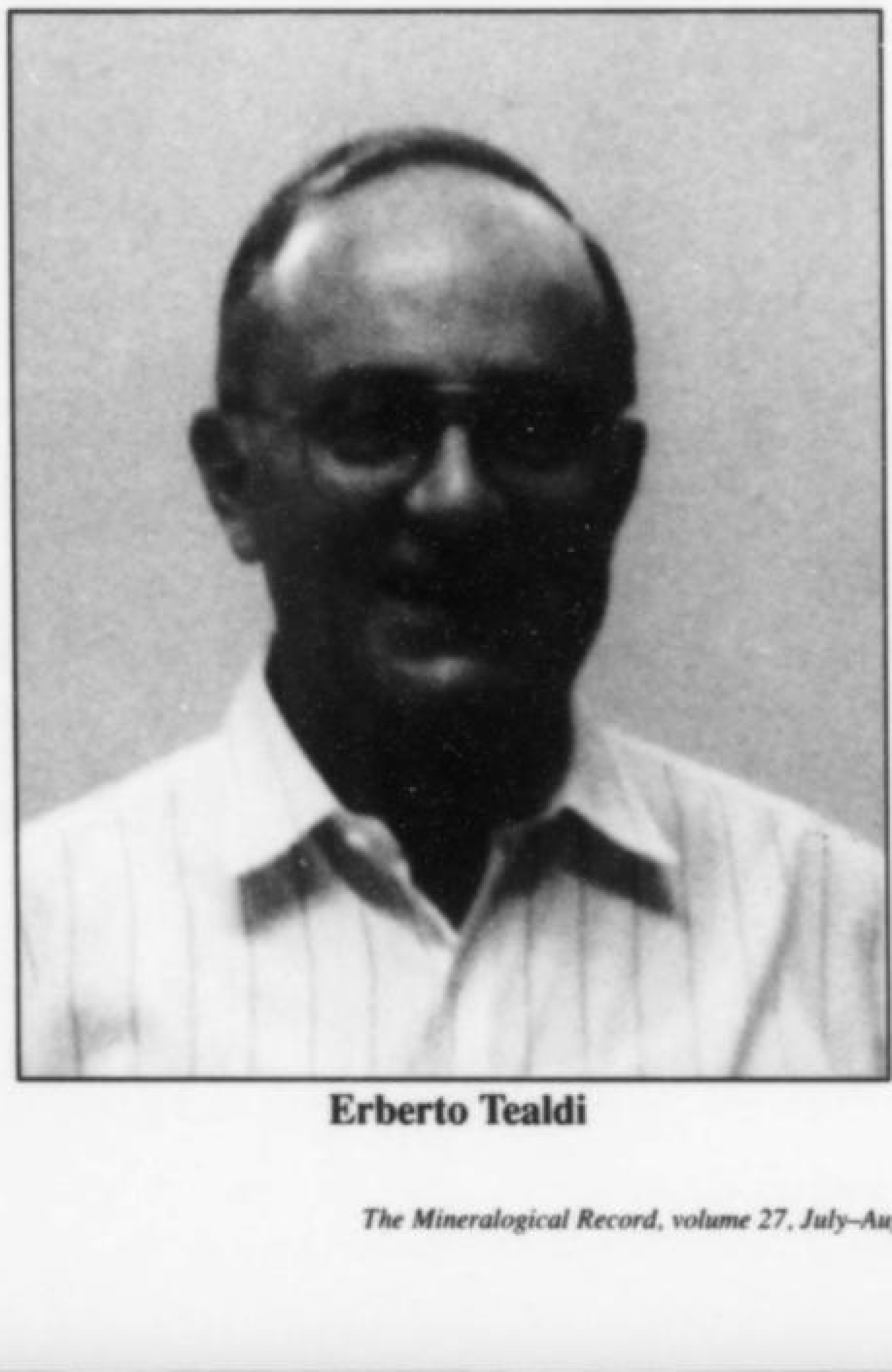

K. England

Bob Sullivan

Died, Erberto Tealdi, 61, editor of *Rivista Mineralogica Italiana*, a prominent personality in the international community of mineral collectors, and a friend to the *Mineralogical Record* and many of its readers.

Tealdi was born in Florence, Italy, in 1934 and completed his education in Milan, where he graduated with a PhD in Civil Engineering. He served as Assistant Professor at the Polytechnic Institute of Milan, and as a professional engineer involved in the management of several construction companies until the onset of his brief illness in the Fall of 1995.

His interest in minerals began in the mid-1960's, and he soon became a member of the Lombardy Mineral Club. He eventually built a collection of about 6,000 specimens, specializing in systematic mineralogy (about 2,400 species), and U.S. minerals, especially Colorado pegmatite minerals. As is often the case among the



Erberto Tealdi

more sophisticated mineral collectors, his love for minerals broadened to include a keen interest in mineralogical culture, and brought him into contact with mineral publications such as *Rivista Mineralogica Italiana*, of which he became editor in 1984. His experience with technical publishing as an engineer served him well, and he was able to develop *Rivista* from a local mineral club newsletter into a multi-lingual, beautifully illustrated and professionally sound periodical with an international circulation of 2,000 copies. More than an editor, Tealdi was also a fine graphic designer and illustrator; his specimen sketches appeared frequently in *Rivista* and other publications.

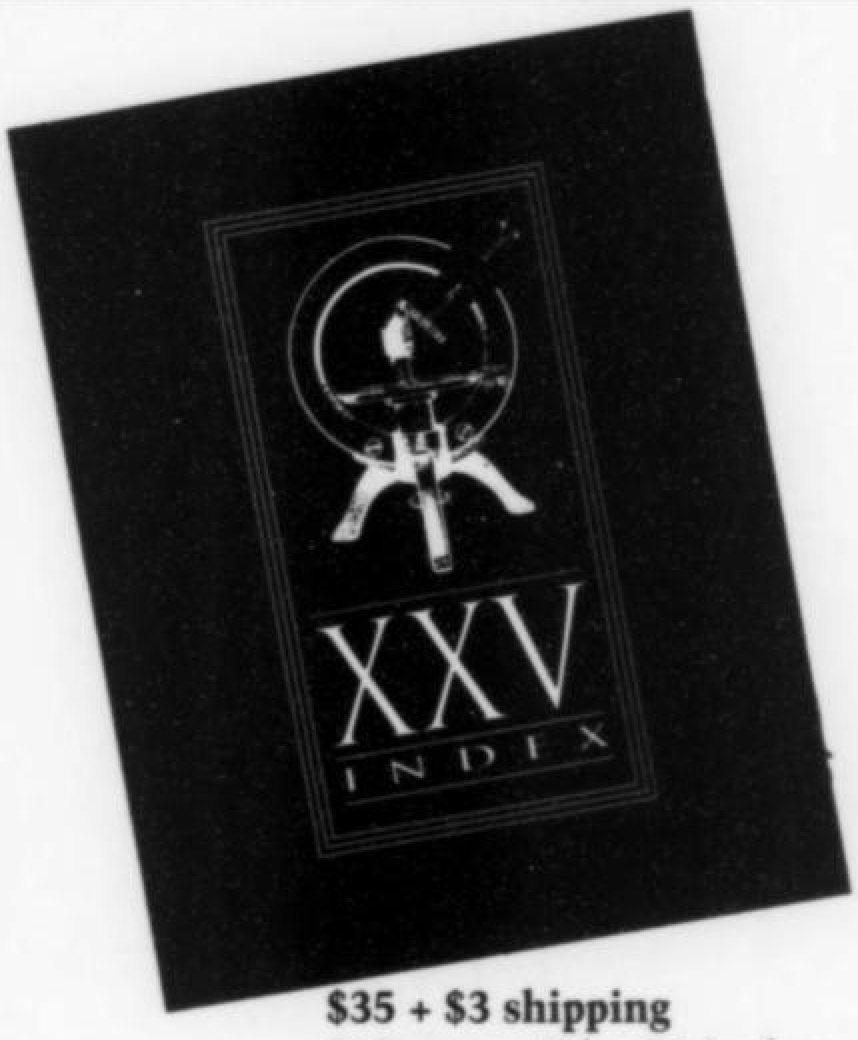
Tealdi's personal bibliography (listed in his recent *General Index* to *Rivista*, 1967–1994, compiled with A. Berti) includes the special issue of *Rivista* on Franklin and Sterling Hill, New Jersey (1993), a series of articles on North American zeolites written with Rudy Tschernich (1984–1985), his international statistical survey *Investigation on Mineral Collecting* (1987–1988), a book on technical terminology entitled *Mineralogia e Geologia: Vocabolario* (1991), and other works.

Erberto Tealdi was a man of many warm friendships (including Americans; he spoke English fluently) and good relations with authors, photographers, collectors and coworkers. He leaves his wife, Camilla, always very close to his cultural and social life, and two children, Fabio and Thea. His friends and readers wish great success to the Editorial Board of *Rivista* which must now take up the task of continuing the work of this many-faceted man.

Renato Pagano

CURATORS!

Our two-page *Museum Directory* in each issue, listing basic contact information for mineral museums worldwide, has proven to be popular and appears to be about filled up. However, we will be pleased to expand it to three pages in order to accommodate more listings. The annual fee is quite low, and your institution will receive year-round exposure to scientists, future visitors, and potential donors. Write or fax the editor for immediate inclusion in the *Directory*, and an invoice will be sent to you.



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Famous Mineral Localities

THE HIGHER PITTS MINE MENDIP HILLS, SOMERSET ENGLAND

Peter S. Burr
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Until the much larger deposits of mendipite were discovered at Merehead quarry, the Higher Pitts mine at Priddy was the main source of specimens of this mineral in the Mendip Hills. The mine is the type locality for the minerals chloroxiphite and diaboleite, and has also produced some of the largest known crystals of hydrocerussite and crednerite. Recently, plattnerite and kentrolite have been identified in old specimens from the locality.

INTRODUCTION

The Higher Pitts mine is situated near to the village of Priddy in the Mendip Hills, Somerset, England, 25 km south of the city of Bristol and 4 km north of the city of Wells. It is a picturesque spot at the edge of the steep southern escarpment of the Mendip Hills plateau, with wide views out across the Somerset Levels (alluvial plains) some 240 meters below. The shallow, dry valley in which the mine workings are located leads via Dursdon Wood to Ebbor Gorge, which cuts through the escarpment and descends to the famous Wookey Hole cave at its base. The gorge was presented to the National Trust in 1967 by Mrs. G. W. Hodgkinson, and is now a national nature reserve, but this does not include the Higher Pitts mine workings.

The area surrounding the Higher Pitts mine has long been used for sheep and cattle grazing, and there was an estate there in Saxon times called "Aebbewyrth" [Saxon = Aebbe's farmstead], which has given its name to Ebbor ("Ebber" in older documents) Gorge.

Lead mining was carried out in the immediate vicinity of the Higher Pitts mine from very early times. This activity peaked during the 17th century, but mining may have taken place during Roman times, or perhaps even earlier; there is a prominent Bronze-Age tumulus (burial mound) situated directly between two of the largest lead veins in the region, approximately 1 km to the east of the Higher Pitts mine. Mining for lead continued on an ever-decreasing scale throughout the 18th century, but had died out by the middle of the 19th century.

Indications of iron mining in the area date from 1752 when the shallow, dry valley at Dursdon Wood was known as "Iron Pits Bottom" (Gough, 1930). Around 1856, trials for iron, manganese, lead and copper were made in the area, but with little success. In 1890, the "Somerset Manganese and Iron Ore Company" was formed, and worked the Higher Pitts mine until 1893. The venture was a financial disaster for the shareholders, but it exposed a number of deposits of great mineralogical interest.

During 1992, the last remaining pit and dump at the Higher Pitts mine were obliterated during the construction of a new house at the Higher Pitts Farm. All that now remains at the site is a small underground working leading off from an old quarry pit at the edge of Dursdon Wood. Now is therefore an appropriate time, 100 years

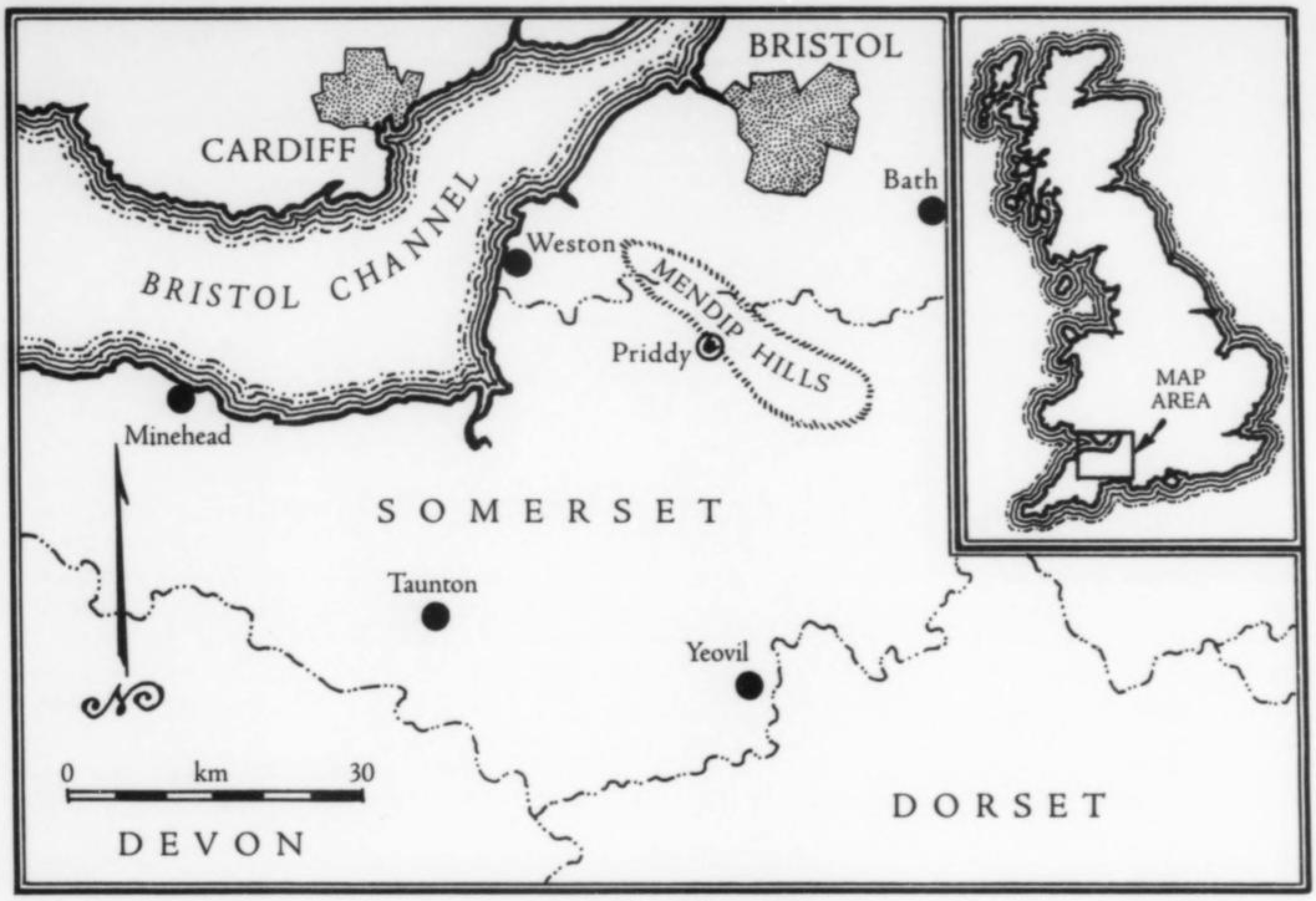

Figure 1. **Location map.**

after it was last worked, to look back at the history, geology and mineralogy of this interesting locality where the minerals chloroxiphite and diaboleite were first discovered.

HISTORY

Mining for iron and manganese was carried on in the Mendips possibly as early as Roman times, and manganese ores from the region were recorded by Christopher Merret (1614–1695), the author of one of the first lists of English minerals (Merret, 1666), and by John Woodward (1665–1728), the author of perhaps the most famous early catalog of English minerals (Woodward, 1729).

The deposits of iron in the rocks of the Dolomitic Conglomerate at the Higher Pitts mine crop out at the edge of Dursdon Wood, and must have been recognized at a very early date. As mentioned above, iron mining probably started here in "Iron Pit Bottom" before 1752.

Around 1856, there was again interest in the mineralization near Dursdon Wood. Information on the subsequent activities there is given in numerous reports in *The Mining Journal* and in *The Wells Journal*, by Gough (1930), and by Brooke (1971). In November, 1856, the "Little Down and Ebber Rocks Mineral Mining Company" was formed with the supposed intention of mining for iron, manganese, lead, copper and limestone (for the production of lime) on the "Little Down and Ebber Rocks" estate which had been purchased by Charles Crawford and two others from John William Wrey. The estate consisted of about 86 acres on what is now the Higher Pitts Farm, and was purchased for £7,000 in cash and £8,000 in shares.

The flotation of this company (with an excessive share capital of £50,000) would seem to have been an attempt (probably conceived by J. W. Wrey) to fleece shareholders. It was condemned at the time by Nicholas Ennor (1798–1874). Ennor was a celebrated and controversial mining consultant, promoter and correspondent who was involved in mines in Cornwall, Devon, Somerset and abroad, and who also produced an annual list of mines to invest in (*The Mining Journal*; Atthill, 1964; Gough, 1930; Stanton and Clarke, 1984). Ennor stated that, although there was good iron ore and poor manganese ore on the property, its value was too low even to pay carriage costs. One of the purchasers of the estate (Greaves) subsequently made an unsuccessful attempt to sue J. W. Wrey for the recovery of the purchase price on the grounds that a wall of ore had been built in one of the levels, and that this had been done to provide a distorted view of the richness of the ore deposit. There were also doubts about the title to the minerals. As a result of these disputes the company was reformed as the "Little Down and Ebber Rocks Mineral *and* Mining Company" at the end of 1858, and J. W. Wrey became a director of this new company in 1859. The prospectus of the new company stated that the company was to have exclusive rights over an estate of 325 acres and that the estate contained "variegated and fossil marbles of great beauty" in addition to the profusion of mineral products listed above (*The Mining Journal*, January 1, 1859).

Parts of the prospectus of the first company were quoted by Horace Bolingbroke Woodward (1848–1902), geologist and later Assistant Director of the Geological Survey, in 1876 (Woodward, 1876). Manganese was stated to occur "in the Dolomitic Conglomerate in the form of per-oxide," and analyses of lead ore and copper ore by John W. Perkins were quoted. The galena showed "the presence of silver to the extent of 7 per cent," and the copper ore was described as "green carbonate of copper, sulphuret, and grey copper; fine copper, 21.3 per cent."

The above information was evidently intended to mislead prospective shareholders in the company. The silver content of "7 per cent" was perhaps a (deliberate?) misprint for "7 ounces" (per ton of lead) as printed in the version of the prospectus published in *The Mining Journal* on February 14, 1857, but lead from the Mendips typically contains much less than this (about 0.009% Ag). While the content of copper in the copper ore might have been correct, such ore would only have been present in very small amounts. An analysis of the "pyrolusite" from the Higher Pitts mine by Bucknell (1924) showed the presence of about 0.26% copper, together with about 0.86% lead.

The "Little Down and Ebber Rocks Mineral and Mining Company" went bankrupt in 1859 with very little mining having been done (Gough, 1930). J. W. Wrey absconded and fled abroad. *The Wells Journal* for July 16, 1859, announced the sale of: "The Little Down and Ebber Rocks Agricultural and Mineral Estate." The estate, "of about 87 acres," was "considerably enhanced by about 30 acres having been proved to contain large deposits of the ores of manganese and iron." Further particulars could be obtained from the auctioneers, or from "Messrs. Vandercom, Cree, Law, and Comin" solicitors (attorneys) of London. The company was finally struck off the company register in 1882 (Brooke, 1971).

It would seem that the company had been mainly interested in iron and manganese ores (if it had been interested in mining at all), but Horace B. Woodward quoted Robert Etheridge (1819–1903; geological surveyor to the mining company, paleontologist of the Geological Survey, and later Assistant Keeper of Geology at the British Museum, London) as saying that galena and "calamine" (smithsonite) occurred "in horizontal veins, interstratified with beds of the Dolomitic Conglomerate" (Woodward, 1876; see also *The Mining Journal*, and Etheridge, 1870). In 1890, Prof. Conwy Lloyd Morgan (1852?–1936; Professor of Geology and Zoology at Bristol University) also recorded the occurrence of small strings of galena at the Higher Pitts mine (Morgan, 1890). The quantities of these ores in the conglomerates must have been very small; Arthur Kingsbury (1906–1968; see below) found no galena on the old dumps during his extensive collecting in the 1930's (Kingsbury, 1935, 1941). There was, however, one narrow, elongated pit on the northern edge of the conglomerates which may have been dug for galena; large deposits of galena occurred in the limestones nearby. However, the pit may have been the prospecting trench referred to below which only exposed a "vein, or fissure, spotted with galena, and containing also some carbonate of lead."

With respect to workings for limestone for the production of lime, it should be noted that there are indications of lime works 1 km northwest of the Higher Pitts Farm. The 1:10,560 Ordnance Survey map shows two shafts there, and I have found traces of coal and coke at the site. There are also indications of lime works at the Pitts Farm, 2 km to the north of the Higher Pitts Farm (see below).

In 1889, Mr. H. B. Crouch of Cardiff, South Wales, purchased the Higher Pitts Farm and, in the spring of 1890, the "Somerset Manganese and Iron Ore Company" was formed to work the iron and manganese deposits there, apparently on the advice of a Mr. Forster Browne. Forty men were employed, eight of them working underground. The mine was managed by Thomas Willcox (1850–1945; see below) who was, at the same time, the manager of the nearby St. Cuthbert's Lead Works, where ancient lead slags and slimes were being reprocessed.

The production of the company was approximately as follows (Burt *et al.*, 1984; Gough, 1930):

Year	*Production*	*Tonnes*	*Value (£)*
1890	Iron-ore	15.2	7.50
	Manganese-ore	30.0	59.00
1891	Iron-ore	0.0	0.00
	Manganese-ore	50.8	75.00
1890–1891	Total	96.0	141.50

This small amount of ore was produced at enormous cost: £9,000 had been spent on the property, and about £3,000 on general expenses. More detailed information on the finances of the company, based on information provided by T. Willcox, has been published by Gough (1930). By the spring of 1891 the company was in great difficulties, and *The Wells Journal* for May 7, 1891, reported on a meeting to wind up the company that had been held at Bristol the previous week. The chairman of the company was James Inskip, a Bristol solicitor (attorney), and another director was A. H. Baily. *The Wells Journal* for August 20, 1891, announced the sale on August 29 of the farm, which had been "recently in the occupation of Mr. Alfred Hann." No mention was made of the mineral deposits.

At this time there were about 1,500 tonnes of iron ore and 250 tonnes of manganese ore stockpiled (probably of low quality), and some of this was evidently sold after 1891 (Burt *et al.*, 1984; Gough, 1930). The company closed in 1893, and nothing has been done since. The formation of the "Somerset Manganese and Iron Ore Company" would seem to have been a genuine attempt to work the ore deposits; more than one-third of the share capital had been held by the directors and their "immediate connections."

The name "Higher Pitts" seems to have originated from the name of a farm 2 km to the north called Pitts Farm. The farm on which the Higher Pitts mine is located, and which is situated at a slightly higher elevation than the Pitts Farm, later became known as the Higher Pitts Farm. There is no evidence that the name of this farm has anything to do with "pits," but there are remains of some old quarry workings near the farmhouse of the Pitts Farm (these seem to have been for limestone, and there is an old lime kiln there which probably dates from the first half of the 19th century); and "pits" is often spelled as "pitts" in old documents, as for example, on Day and Masters' map of Somerset which was published in 1782, and which, incidentally, does not show either of the farms.

GEOLOGY

The following is a very brief and simplified description of the most important aspects of the local geology; for more detailed information, the reader is referred to the publications of the Geological Survey.

The Mendip Hills ("the Mendips") consist of a number of domes disposed along a sickle-shaped structural axis stretching some 50 km from Frome in the east to the Bristol Channel in the west. The domes are elongated in an east-west direction and have steep or over-thrust northern arcs. The cores of the domes consist of sandstones and shales of Devonian age, overlain by shales and limestones of Carboniferous age. At the eastern end of the Mendips volcanic rocks of Silurian age are also present in the core of the Beacon Hill dome.

Denudation of the rocks during the Triassic period resulted in the formation of thick deposits of scree breccia and conglomerate filling ancient river valleys and other depressions. The conglomerates consist of rounded to sub-angular fragments of limestone and sandstone, ranging from a few centimeters up to 1 meter or more in size, set in a matrix of sandy marl or fine-grained limestone debris. They have been subjected to widespread (but not universal) dolomitization, and more locally are replaced by hematite, silica or (locally) barite. In the area around Shipham, to the northwest of Priddy, the conglomerates, which as a group are known as the Dolomitic Conglomerate, reach maximum thicknesses of about 100 meters. They were the host rocks for large deposits of sphalerite and pyrite/marcasite which were subsequently oxidized to smithsonite and "limonite."

The central portion of the hills around Priddy consists of a flat plateau about 240 meters above sea level and 8 km wide. To the north, and especially to the south, the surface descends rapidly. The limestone rocks immediately to the north of the southern escarp-

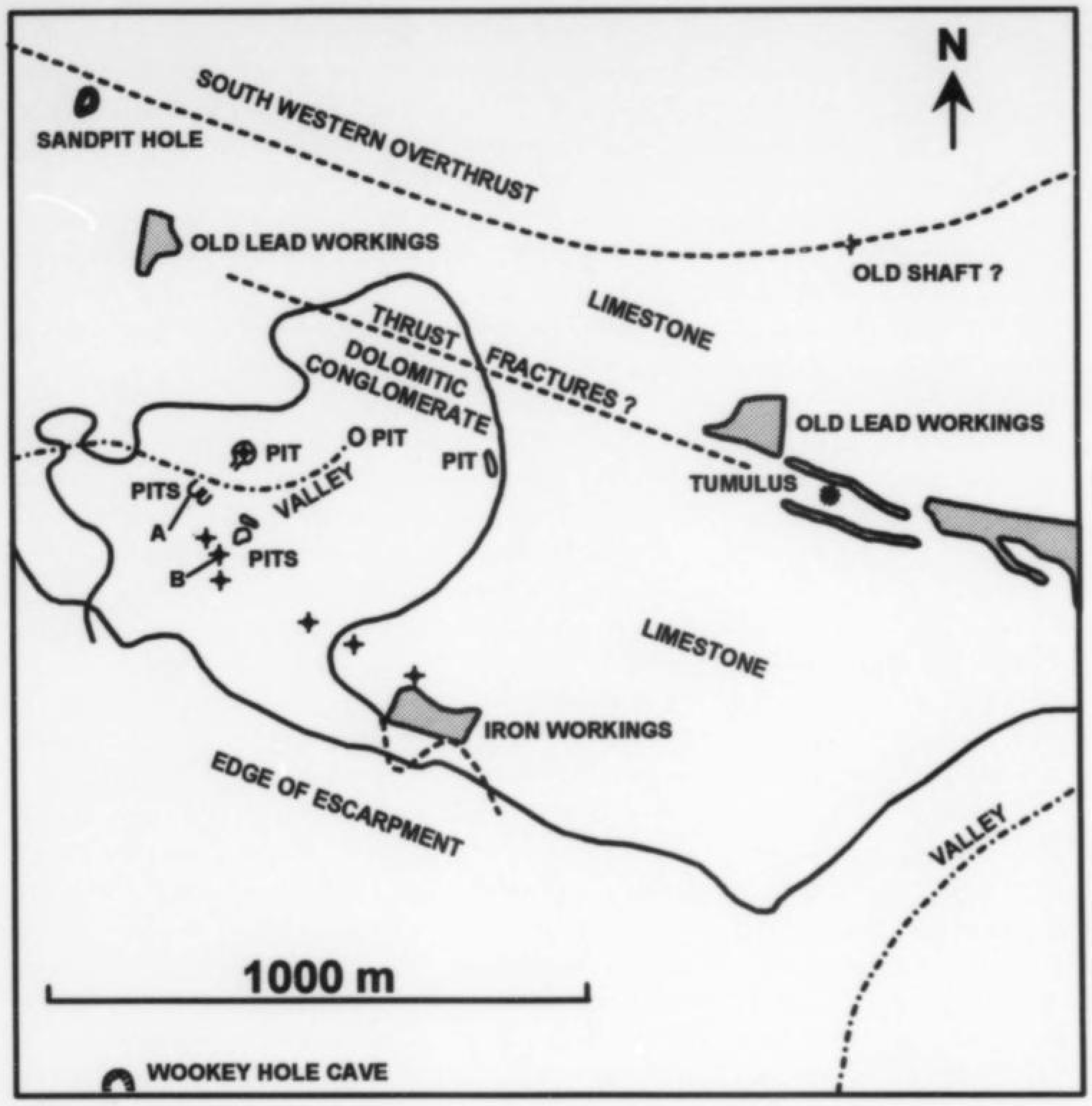

Figure 2. **Geological sketch map of the Higher Pitts mine.**

ment were subjected to northeasterly thrust forces during Armorican times which resulted in the formation of a major northwest-southeast thrust fault, the South-Western Overthrust (Green and Welch, 1965). This low-angle fault is not known to be mineralized, but the contorted limestones to the southwest were heavily mineralized with galena.

The limestone countryside around Priddy shows typical karst features: barren outcrops of limestone, shallow dry valleys, and cave systems. There is a large, steep-sided dolina approximately 50 meters in diameter and 20 meters in depth, called Sandpit Hole, situated about 800 meters to the north-northwest of the Higher Pitts mine near the South-Western Overthrust fault. The few surface streams in the area are small, and disappear underground on reaching limestone, then reappear at the large Wookey Hole resurgence cave at the foot of the southern escarpment.

In the area near the Higher Pitts mine there is a localized deposit of conglomerate (Dolomitic Conglomerate) filling an ancient hollow in the limestones, and this conglomerate is mineralized with iron and manganese. Similar deposits occur throughout the Bristol region. The iron and manganese mineralization seems to occur mainly at the junction of the conglomerates with the underlying limestones, and is also concentrated at the fringes of such conglomerates. A deposit very similar to that at the Higher Pitts mine is found about 4 km to the north at the Priddy Hill Farm, and this has also produced specimens of mendipite.

The deposit of conglomerate at the Higher Pitts mine is more or less cut off to the south by the southern escarpment, so that it is best visualized as a roughly saucer-shaped mass some 500 meters in diameter and up to 25 meters in thickness, with iron and manganese mineralization at its edges. The deposit (in particular the northern edge) probably also hosts lead mineralization where the conglomerates are underlain by contorted limestones associated with the South-Western Overthrust fault.

The iron and manganese mineralization consists largely of horizontal beds of oxides and hydroxides intermixed with much calcite; these beds give the appearance of being interstratified with the conglomerates, and probably represent weathering products of Coal Measure strata during the Triassic period. The lead, zinc, silica and barite mineralization in the area would seem to be mainly of Jurassic age and telethermal in nature, and not derived directly through the erosion or oxidation of older mineral deposits as assumed by many authors (Dewey, 1921; Green, 1958; Stanton, 1981).

The origin of the rare lead and copper minerals within the beds of iron and manganese oxides and hydroxides is still unclear, but it seems to be related to the remobilization and modification of earlier Triassic deposits of iron and manganese oxides and hydroxides by lead and copper-bearing brines released during later Jurassic mineralizing episodes (cf. Symes and Embrey, 1977).

THE WORKINGS

The best contemporary account of the ore deposits and early mine workings was published in *The Mining Journal* on August 1, 1857. The account was prepared as part of the evidence to be presented at the legal hearing of the dispute between Greaves and Wrey (see above). It must have originally been accompanied by a plan but, despite considerable efforts, I have not been able to trace the legal documents presented at the hearing. The account is the defendant's view of the ore deposits, and it may be somewhat distorted, but it is nevertheless worth presenting in full:

> From pit Nos. 17 to 18, as well as from No. 1 to 17, the vegetable soil was everywhere loaded with fragments of ore, and stained of a deep red colour; and at the pit No. 18, which I went down, I found an excellent deposit of oxide of manganese, at a depth of about 10 feet from the surface which was laid bare, but had not been worked. Pits Nos. 19 and 11 were also both of them sunk in ore ground, and ore had been

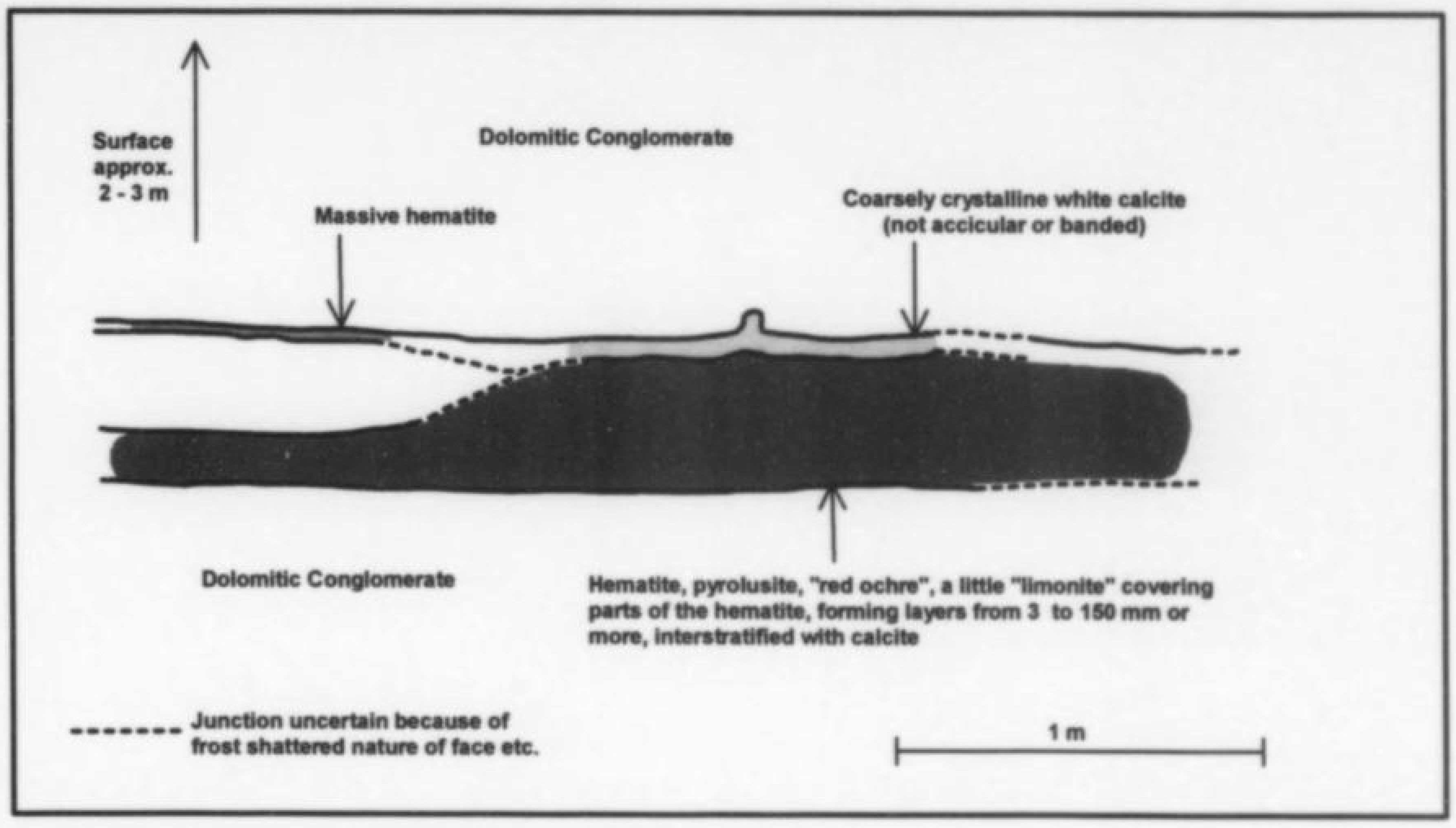

Figure 3. **Cross-section through "Pit A" (surveyed in 1965).**

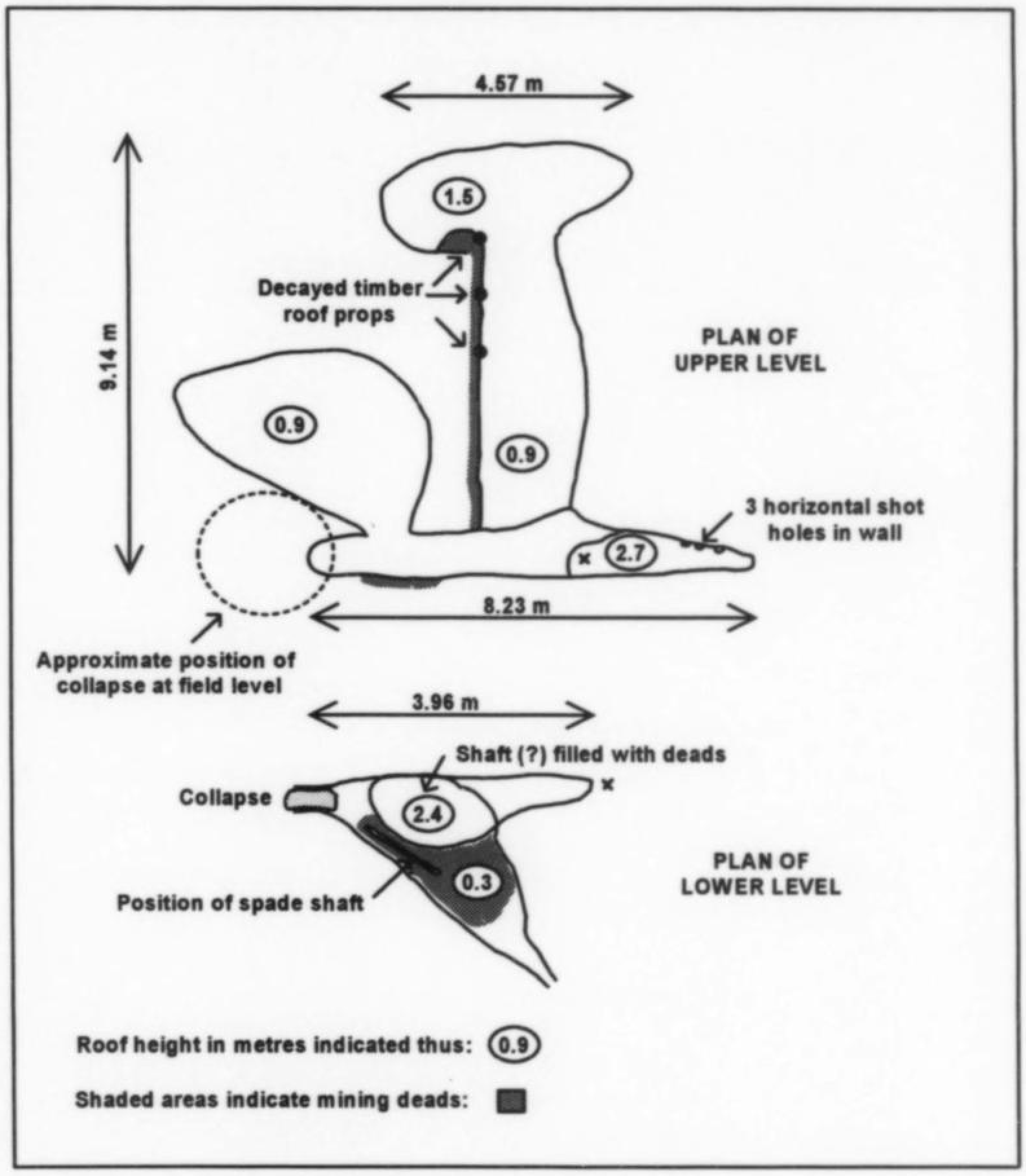

Figure 4. **Plan of "Pit B" (surveyed in 1971).**

raised from them. The deposits opened in the pits marked Nos. 7, 17, 18, 19, and 11, respectively, appear to be distinct from one another, and in fissures, more or less, nearly parallel to each other; the remaining pits, with three exceptions, form a distinct group, and are those already referred to as being the most worked. Pits Nos. 10 and 13 have been worked together, and are within a few yards of each other. No. 10 is sunk 7 fathoms into a valuable bed of manganese ore, of extreme purity, which has been partially removed, but is still left standing in the walls and end. There is a level driven a few fathoms to the north-west through this deposit, and another to the south-west, into a large mass of iron ore, only partly filling a cavity, or fissure, in the limestone. The level has been driven near the top of this cavity, so that the mass of ore is seen separated from the roof. It has, however, been proved downwards 3 fathom below this level by a sink, and continues to bear hematite. The actual depth of ore is not at present proved at a greater depth than in this pit in any part of the property.

Figure 5. **The Higher Pitts Farm, 1994.**

From the principal level there is a holing to the shaft No. 13, and above (close to the surface) manganese ore has been removed. A large quantity of rich hematite could be immediately raised from this pair of pits. The pit No. 8, holed to No. 9 by a short level at 4 fathoms depth, appears to reach a deposit of ore a little to the west of that last described. At the depth of 13 feet is an irregular level, driven about N.N.E., into a mass of the purest hematite, about 4 feet thick. Near the end the miners have broken into an old working, probably from pit 15, but the ore is solid in the end. Manganese has been obtained from this pit, above the hematite, and is of fine quality. The extent of the works is very small, but I observed considerable piles of ore, almost entirely manganese at the surface. The group of pits, Nos. 2, 3, 4, and 5, are about 50 yds. to the north; they are sunk only a few yards, and all of them communicate, but there appear to be two deposits. In No. 5, the deposit assumes the character of a lode, being about 12 feet wide, with defined walls, nearly vertical and corresponding in bearing with the other deposits. The manganese ore is here at least 4 feet thick, of solid ore, and there are also several feet of hematite. About 50 yards to the east of this group of pits are three others, sunk on a parallel deposit; No. 6 contains good ores, both of manganese and iron, but it is now walled up. Some distance to the north-west is the costeaning pit (No. 21), which proves the existence of a similar deposit. Still further off, and more towards the north, is a pit sunk several fathoms, and also some length of costeaning on a vein, or fissure, spotted with galena, and containing also some carbonate of lead. In addition to the ores of manganese and iron, and the indications of lead just mentioned, I observed calamine (carbonate of zinc) at various places, and occasional stains of copper. Excellent red and yellow ochres occur on the estate.

Following a visit, Prof. C. L. Morgan (1890) described the deposits as follows:

> The deposits are very irregular, and occur mainly in the Dolomitic Conglomerate. But they are also described as passing down into the underlying Mountain Limestone, whether as lodes or as infillings of cracks from the surface is uncertain. I incline to the latter view. There are also sparry veins containing little strings of galena. The locality is well worth a visit, and I have to thank Col. Harcourt and the secretary of the company, Mr. J. Bicknell, for kindly giving me the opportunity of examining it.

Horace B. Woodward and the Rev. H. H. Winwood (1830–1920; a local geologist) described the deposits following a visit of the Geologists' Association in 1890 as follows (Woodward and Winwood, 1891):

> Deep trenches have been excavated in the Dolomitic Conglomerate, and a shaft had been sunk at one point to a depth of 62 ft in this rock. Near the surface the rock was seen to contain nests of manganese-ore, and associated with this a little copper-ore had been found, and what was of especial interest the mineral mendipite (oxy-chloride of lead) had also been obtained. In the present instance it was associated with cerussite (carbonate of lead). Haematite was also found in veins and pockets of the Dolomitic Conglomerate at these works.

The following description of the workings at the Higher Pitts mine is based on other published descriptions, old maps, personal observations and notes I have made over the last 30 years, and on information provided by John Edwards, the present owner of the Higher Pitts Farm, by Geoffrey Fitton of Brent Knoll, Somerset, and by Richard Ivens of Weston-super-Mare, Somerset.

Figure 6. **The entrance to underground workings in "Pit A" by Dursdon Wood, 1994.**

Figure 7. **Inside the flooded underground workings off of "Pit A," 1994. Note bed of manganese oxides at lower left.**

The workings consisted of a number of pits, shafts, and minor underground excavations around the fringes of the conglomerates, reaching to a maximum depth of 20 to 25 meters. There were three major pits near the old Higher Pitts farmhouse (this consists of two of the eight cottages originally built at the mine) on the northwestern edge of the conglomerates. These pits were of irregular outline and up to about 6 meters in depth. The hematite and "wad" had evidently occurred as horizontal beds giving the appearance of being interstratified with the conglomerates, and as irregular fissure fillings in the conglomerates and the underlying limestones. The largest of the pits was about 10 to 12 meters in diameter and 6 meters deep. It had three horizontal levels about 1.4 meters high, 1.5 meters wide, and about 6 meters long connected to it, and a central shaft about 4 meters deep (this was perhaps the shaft which originally reached to a depth of "62 ft"). The pit also had a tramroad entering it. One section of the tramroad led from the pit to the main tip heap or dump alongside, and another section curved around to end by the mine cottages. This part of the tramroad was probably for loading the ore onto carts. The carts would have been drawn by horses along the track to Priddy, and from there to Wells, from where the ore would have been sent (at great cost) by railway and ship to South Wales. Some of the ore may also have been sent to the smelting works at Ashton Vale, near Bristol.

On the edge of Dursdon Wood there were two excavations into the hillside. The larger of these, which still exists, connects to a small underground working. This consists of an entrance level about 1.5 meters high, 2.5 meters wide, and 3 meters long, connected to a circular excavation about 1.5 meters high and 5 meters in diameter. Beds of hematite are well-exposed in the working. In 1984, a trench was excavated near the entrance to aid drainage, and this also exposed deposits of hematite. Unfortunately, no pockets of manganese ore (with which the rarer minerals are usually associated) were exposed. There was also a small shaft in this area which was investigated by B. S. Roach in 1957 (Roach, 1964).

At the northern edge of the conglomerates there was a long, narrow excavation about 2 meters wide, 10 meters long and at least 2 meters deep (now filled with rubbish), trending in a north-northwesterly direction. This excavation was quite unlike any of the others, and was most likely dug for galena rather than for iron or manganese, although the direction of the excavation was somewhat unusual for a lead working (see above).

Along the southern edge of the conglomerates there was a series of shafts, and some of these were evidently connected to underground workings. In February, 1971, one of these underground workings was explored by G. Fitton, R. Ivens and J. Edwards, the present owner of the Higher Pitts Farm, whose tractor had broken through into it. These workings were found to consist of a series of irregular, horizontal excavations, 0.9 to 1.5 meters in height, covering an area about 9 by 11 meters in size. These excavations were only a few meters below ground level. There was also a further small excavation, 3 to 4 meters lower down, in the center of which there appeared to be an infilled shaft. Mr. Fitton found a Cornish-style spade (with a curved blade and a long handle) at the side of this shaft. The excavations were very irregular in shape, and Mr. Fitton, an experienced caver, commented that the "minerals" appeared to have infilled karst cavities in the conglomerates. This description is consistent with the reference to a partly open ore-filled cavity in limestone referred to above.

In 1964, the whole area was covered with excavations and heaps of waste material, in particular an area in the southeast corner, but during the last 30 years the dumps have been systematically removed, and the pits filled. The area is now largely green fields with few indications that mining once occurred there. Mr. Edwards has agreed to preserve the last remaining workings at the edge of Dursdon Wood, but attempts to add Dursdon Wood to the Ebbor Gorge nature reserve, and hence guarantee the preservation of the workings, have so far been unsuccessful.

MINERALS

The minerals occurring at the Higher Pitts mine, and the minerals occurring in similar deposits at other localities nearby, have been described in detail by other authors, so that a detailed description of all the minerals is not required here (Alabaster, 1975, 1977, 1978, 1985a, 1985b, 1989, 1990; Berzelius, 1824; Burr, 1992; Eastwood, 1983; Haidinger, 1824; Kingsbury, 1935, 1941; Spencer and Mountain, 1923; Symes, 1977; Symes and Embrey, 1977; Symes *et al.*, 1994; Woodward, 1729). Information on the thermodynamic stability of several of the lead oxy-chloride compounds has also been published by a number of authors (Abdul-Samad *et al.*, 1981, 1982; Humphreys *et al.*, 1980; Williams, 1990).

The most interesting of the minerals known from the Higher Pitts mine (see Table 1) are described below. The uncommon lead minerals for which the locality is famous occurred in small nodules dispersed irregularly through the beds of manganese ore.

Aragonite $CaCO_3$

Aragonite has been found as nodules within the manganese ore. It is quite rare at the Higher Pitts mine, and much less common than calcite. It generally forms compact aggregates of large white prisms altering to calcite, but also forms small groups of needle-like crystals in association with hydrocerussite. I have also found one small group of what appear to be aragonite crystals enclosed within a quartz crystal. Aragonite has also been found at numerous other localities in the area.

It is an interesting fact that most of the specimens of wulfenite from the Higher Pitts mine were found in close association with nodules of aragonite. No explanation can be given for this strange association, except to note that some of the aragonite from the Higher Pitts mine contains a small quantity of lead in solid solution.

In contrast to calcite, the more compact crystal lattice of aragonite seems unable to accommodate manganese ions. This probably causes the different responses of the two minerals to shortwave ultraviolet radiation; the calcite from the Higher Pitts mine fluoresces very strongly brilliant orange, whereas the aragonite fluoresces very weakly pale blue, if at all.

Calcite $CaCO_3$

Calcite was found filling and lining cavities within the iron ore and manganese ore, and also filling veins within the conglomerates and limestones. It was very common, and formed the main gangue mineral of the ores. Crystals lining cavities are nearly always rhombohedral in form, but scalenohedral and prismatic forms also occur. The rhombohedral and scalenohedral crystals are up to about 5 cm in size, but the prismatic crystals (which are very rare) are not more than 3 mm in size. The rhombohedral crystals sometimes occur as overgrowths on scalenohedral crystals.

Cerussite $PbCO_3$

Cerussite was common, both as compact, crystalline masses (up to 600 g in weight) embedded in the manganese ore, and as loose, reticulated groups (up to about 5 cm in diameter) of corroded crystals within cavities in the manganese ore. It also formed thin alteration layers on hydrocerussite around nodules of mendipite, epitaxial growths on hydrocerussite crystals, and complete pseudomorphs of hydrocerussite crystals. The largest cerussite crystal found is about 2.5 x 3.5 cm across and 4 mm thick. Some of the cerussite from the Higher Pitts mine contains a small quantity of strontium in solid solution.

Chloroxiphite $Pb_3CuCl_2(OH)_2O_2$

Higher Pitts mine chloroxiphite was described as a new species by Spencer and Mountain in 1923. It forms dull, olive-green, blade-like crystals penetrating the mendipite, and very rarely occurs as corroded crystals in hydrocerussite (A. W. G. Kingsbury collection, No. M13, Bristol Museum, Bristol). The name was derived from the Greek ("chloros" = "green," and "xiphos" = "blade"). The blades are completely embedded in the mendipite, but the crystallographic orientations of the two minerals are seldom coincident. Thin fragments of chloroxiphite crystals are transparent, and very similar to epidote in overall appearance. The largest crystals known measure about 1 x 3 cm and 1 mm thick; these occur in the largest specimen of mendipite from the Higher Pitts mine (BM 1923, 212; see below). Kingsbury found a chloroxiphite crystal 1 x 2 cm and 4 mm thick in the 1930's. Chloroxiphite has also been found at other localities in the area.

Crednerite $CuMnO_2$

Crednerite has usually been found as fan-like groups and hemispherical masses of thin, bright black plates on nodules of cerussite, hydrocerussite and mendipite in Mn ore. It also occurred as groups of thin plates in close association with masses of well-crystallized pyrolusite, as thin plates penetrating nodules of hydrocerussite, and as small spheres up to 2 mm embedded in mendipite. Although it often appears quite fresh, the crednerite is always more-or-less decomposed (X-ray studies of similar material from Merehead quarry have shown it to consist of a mixture of copper and manganese oxides), and the remnant crystals are often coated by films and tufts of malachite crystals. The decomposed nature of the crednerite makes analysis difficult, and it was originally thought to contain only about half as much copper as indicated by the presently accepted formula. The largest crystal of crednerite found at the Higher Pitts mine was 3.5 x 4 x 6 cm in size, and at the time of its discovery by Kingsbury in 1940, was thought to be one of the finest specimens of the mineral in existence. It is now in the Natural History Museum, London. Crednerite has also been found at other localities in the area.

Diaboleite $Pb_2CuCl_2(OH)_4$

Higher Pitts mine diaboleite was described as a new species by Spencer and Mountain in 1923. It occurs as bright, sky-blue, tabular crystals (occasionally showing a square outline) embedded in hydrocerussite or cerussite, and as dull, sky-blue, granular aggregates of minute crystals in close association with chloroxiphite, probably having resulted from its alteration. The name, diaboleite, was chosen for the mineral to distinguish it (Greek "dia" = "apart") from the similar mineral, boleite. Diaboleite from the Higher Pitts mine seldom occurs in well-formed crystals, and the largest crystals showing distinct crystal faces are not more than 2 mm in

Table 1. **Minerals known to occur at Higher Pitts mine.**

Oxides		
Crednerite	$CuMnO_2$	Uncommon; largest crystal 3.5 x 4 x 6 cm
Goethite	$\alpha\text{-}Fe^{3+}O(OH)$	Common
Hematite	$\alpha\text{-}Fe_2O_3$	Common; main iron-ore
Manganite	$Mn^{3+}O(OH)$	Common in small amounts
Plattnerite	PbO_2	Rare
Pyrolusite	$Mn^{4+}O_2$	Common; main manganese-ore ("wad")
Quartz	SiO_2	Common in small amounts
"Limonite"	Fe oxides	Common; ill-defined
"Psilomelane"	Hard Mn oxides	Rare; ill-defined
"Wad"	Soft Mn oxides	Common; main manganese-ore; ill-defined
Carbonates		
Aragonite	$CaCO_3$	Uncommon
Azurite	$Cu_3^{2+}(CO_3)_2(OH)_2$	Rare
Calcite	$CaCO_3$	Common; main gangue mineral
Cerussite	$PbCO_3$	Common in small amounts; largest nodule 0.628 kg; largest crystal 2.5 x 3.5 cm x 4 mm
Dolomite	$CaMg(CO_3)_2$	Uncommon in the iron-ore and manganese-ore
Hydrocerussite	$Pb_3(CO_3)_2(OH)_2$	Common in small amounts; largest nodule 0.486 kg; largest crystal 6 x 6 x 1 cm
Malachite	$Cu_2^{2+}(CO_3)(OH)_2$	Common in small amounts
Rhodochrosite	$Mn^{2+}CO_3$	Common in small amounts
"Manganocalcite"	Manganiferous calcite	Common in small amounts; ill-defined
Oxy-chlorides		
Chloroxiphite	$Pb_3Cu^{2+}Cl_2(OH)_2O_2$	Rare; largest crystal 1 x 3 cm
Diaboleite	$Pb_2Cu^{2+}Cl_2(OH)_4$	Rare; largest crystal 2 x 2 x 1 mm
Mendipite	$Pb_3Cl_2O_2$	Uncommon; largest nodule 3.640 kg (with matrix)
Phosphates and Arsenates		
Mimetite	$Pb_5(AsO_4)_3Cl$	Uncommon
Pyromorphite	$Pb_5(PO_4)_3Cl$	Rare
Sulfates		
Barite	$BaSO_4$	Rare
Molybdates		
Wulfenite	$PbMoO_4$	Rare; largest nodule 1 x 2.5 x 4 cm
Silicates		
Kentrolite	$Pb_2Mn_2^{3+}Si_2O_9$	Rare
Melanotekite	$Pb_2Fe_2^{3+}Si_2O_9$	Rare
Sulfides		
Chalcocite	Cu_2S	Rare; listed in prospectus ("grey copper"); unconfirmed
Chalcopyrite	$CuFeS_2$	Rare; listed in prospectus ("sulphuret"); unconfirmed
Galena	PbS	Rare
Tetrahedrite	$(Cu,Fe,Ag,Zn)_{12}Sb_4S_{13}$	Rare

size. Dull aggregates and films of minute crystals may cover areas up to about 5 x 30 mm in association with chloroxiphite. The best specimens known are those from the Perceval collection which are now in the Natural History Museum, London. Diaboleite has also been found at other localities in the area.

Hydrocerussite $Pb_3(CO_3)_2(OH_2)$

Hydrocerussite was fairly common. It occurred as nodules, and as masses (up to 486 g in weight) of corroded crystals within the manganese ore, and occasionally as fairly well-formed crystals within cavities in the manganese ore. It also formed thin alteration layers around nodules of mendipite. The hydrocerussite crystals are of two habits: thick, tabular crystals up to 3 cm across, and 1 cm in thickness, and large, lenticular crystals up to about 6 cm across and 1 cm in thickness. At the time of their discovery, these were thought to be the largest hydrocerussite crystals in existence. Cerussite and hydrocerussite have also been found at numerous other localities in the area.

Kentrolite-Melanotekite $Pb_2(Mn,Fe)_2Si_2O_9$

Members of the kentrolite-melanotekite series were first reported from the Bristol area by Alabaster (1985). He identified the yellow iron-rich end member, melanotekite, in specimens from a number of localities in the area (Merehead quarry, Coombe Farm quarry, and Wesley mine), and reported on the identification (by the Natural History Museum, London) of the black manganese-rich end member, kentrolite, in a specimen from the Higher Pitts mine (Kingsbury collection, No. 1048, Natural History Museum, London). The minerals only occur in small amounts, and are often decomposed.

Mendipite $Pb_3Cl_2O_2$

Mendipite occurred as nodules embedded in the manganese ore. Typically a single crystal will occupy the whole nodule, but sometimes up to three irregularly grouped individuals occupy the nodule. When the nodules are broken open, the pronounced prismatic cleavages of the crystals are seen to extend right across

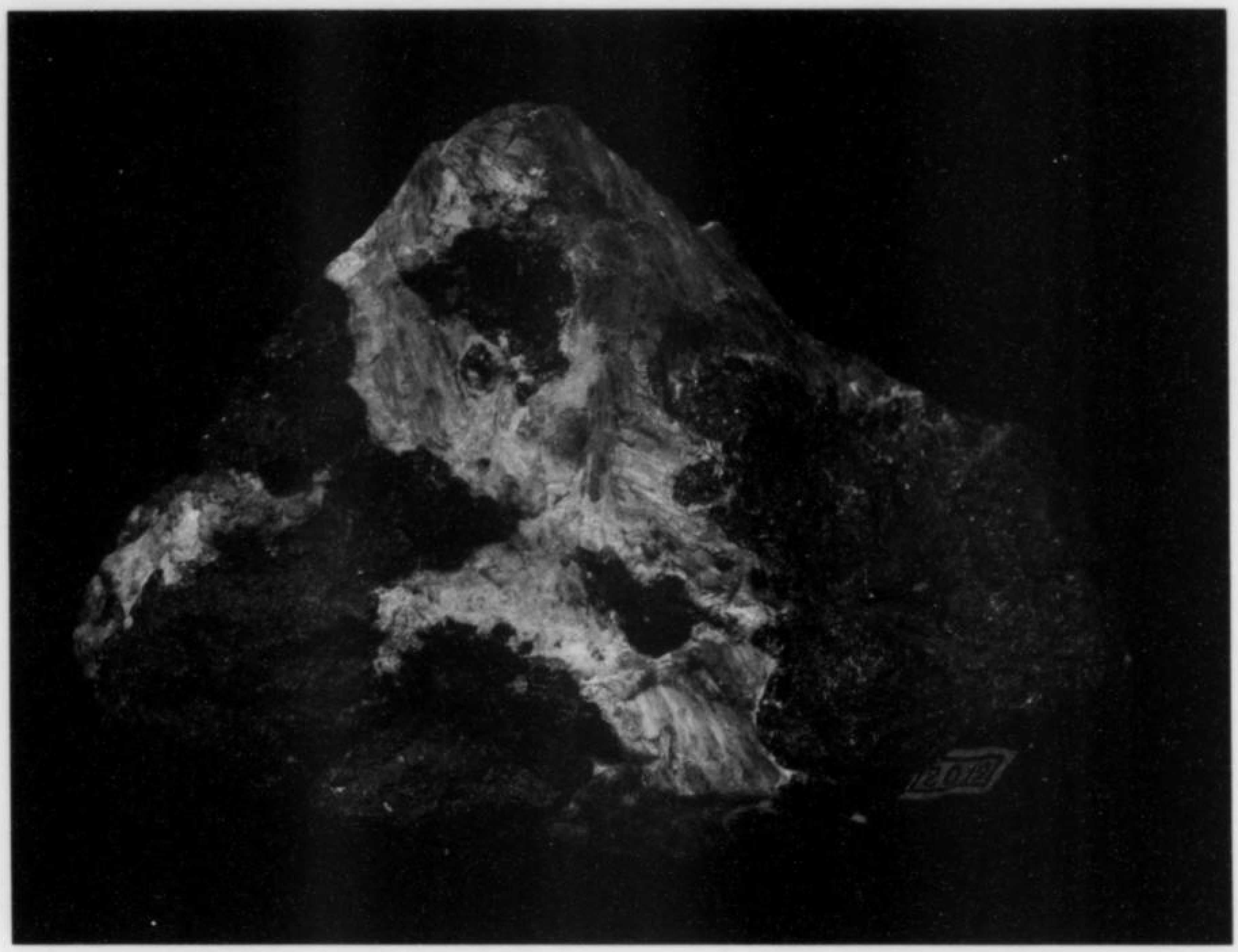

Figure 8. **Mendipite (white) in matrix, 10 cm, from the Higher Pitts mine. Purchased by Sir Arthur Russell in the 1920's from London mineral dealer Samuel Henson (1848–1930). Specimen and photo: Natural History Museum, London, R2012.**

Figure 9. **Chloroxiphite (olive-green), diaboleite (blue), mendipite (cream-white to pale brown), crednerite (black) and hydrocerussite (white) in matrix, 4 cm, from the Higher Pitts mine. Sir Arthur Russell collection. Specimen and photo: Natural History Museum, London, R2014.**

the nodules and to end abruptly at the surface. The surface of the mendipite is generally partly altered into hydrocerussite and cerussite, and thin layers of these minerals enclose the nodules. In such cases, the boundary between the mendipite and the enclosing manganese oxides is usually rather corroded. More rarely, the mendipite nodules are enclosed in pink rhodochrosite and are then less corroded.

The vast majority of the nodules of mendipite found were less than 3 cm in diameter. The largest specimen of mendipite from Higher Pitts mine is some 8 x 12 cm across the exposed area of mendipite, has a weight of 3.6 kg with matrix, and came originally from the collection of Spencer Perceval (1838–1922; see below). It is now in the Natural History Museum, London (BM 1923, 212). Arthur Kingsbury found a nodule of mendipite with a weight of 1.1 kg in the 1930's. Mendipite has also been found at numerous other localities in the area.

In recent years, the occurrence of mendipite at the Higher Pitts mine has become rather overshadowed by the occurrence at Merehead quarry, Cranmore, Somerset (about 15 km to the east-southeast). It is probable that the Higher Pitts mine produced no more than about 200 specimens of mendipite, whereas the Merehead quarry has produced many thousands of specimens during the last 30 years. The mendipite from the Higher Pitts mine is distinct from that of the Merehead quarry, being more often of a dirty gray color, less often of a pure white/cream/pink color, more fibrous and splintery in nature, and generally of an inferior specimen quality. The boundary between the mendipite and the enclosing manganese oxides is also generally much more corroded than is the case with similar nodules from the Merehead quarry.

Because most specimens from the Higher Pitts mine now preserved in collections were obtained many years ago, the broken surfaces of the mendipite are now generally coated with a thin gray/brown alteration layer. This alteration of mendipite to unknown products becomes noticeable after about 100 years (T. Willcox collection, Wells Museum, Wells), and would appear to

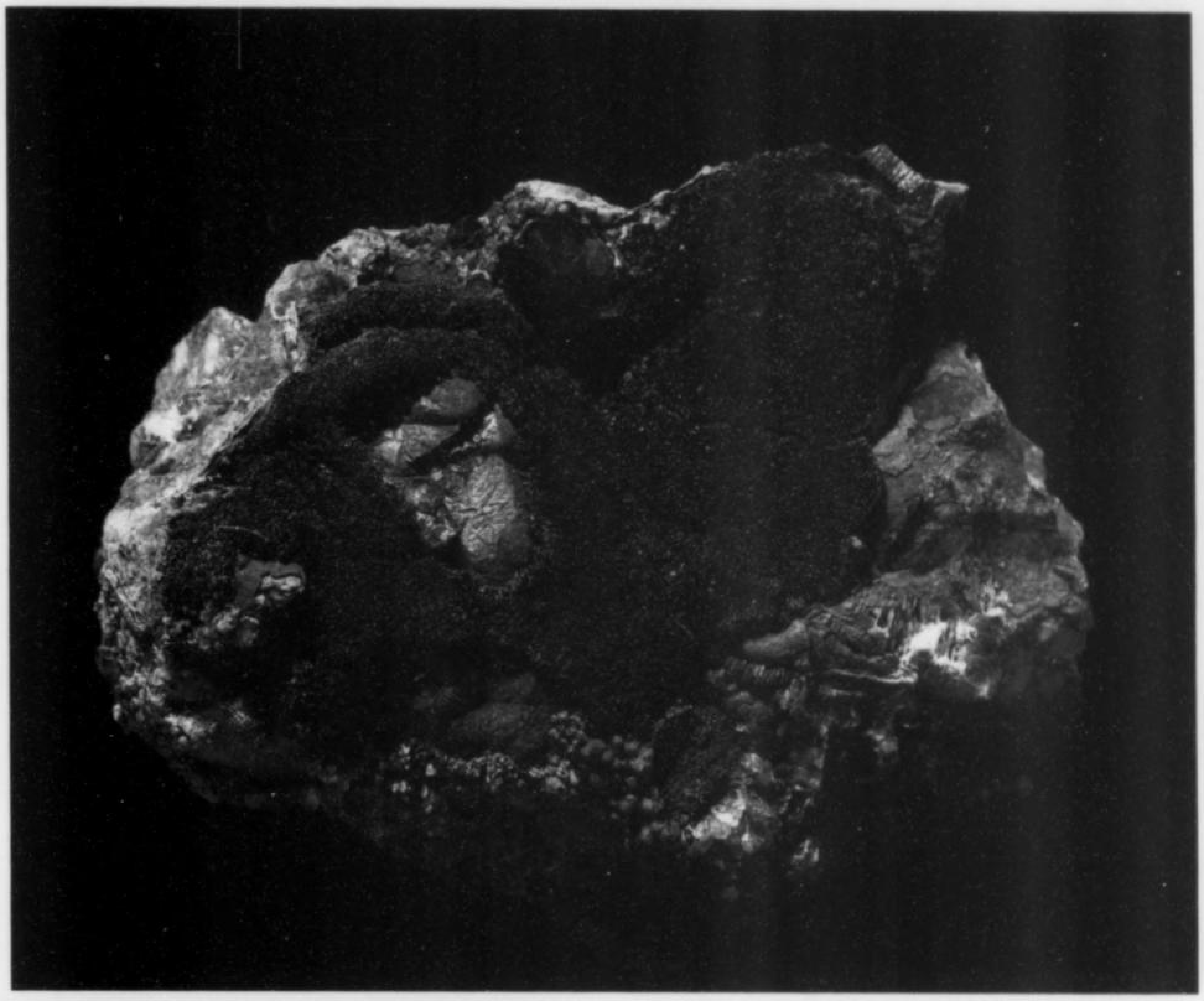

Figure 10. **Goethite (black) with calcite and quartz, 9 cm, from the Higher Pitts mine. Collected by Sir Arthur Russell in August 1928. Specimen and photo: Natural History Museum, London, R3344.**

Figure 11. **Goethite (black) with calcite and quartz, 5 cm, from the Higher Pitts mine. Collected by Sir Arthur Russell in August 1928. Specimen and photo: Natural History Museum, London, R3344.**

progress over the next 200 years (J. Woodward collection, Sedgwick Museum, Cambridge). It is believed to be accelerated by high humidity and exposure to light; keep your specimens dry and in the dark!

Mimetite $Pb_5(AsO_4)_3Cl$

Mimetite was once fairly common at the Higher Pitts mine. It occurred as small, rounded aggregates and thin crusts of minute (typically 250 µm, but up to 2 mm), confusedly aggregated, orange-red to orange-yellow prismatic crystals on and in calcite, cerussite and hydrocerussite. Sometimes the crystals form subparallel groupings giving rise to sheaf-like aggregates.

Plattnerite PbO_2

Plattnerite was first reported from the Bristol area by Christopher Alabaster in 1985. He identified 29 specimens from three different localities (Merehead quarry, Higher Pitts mine and Wesley mine) in a number of collections. Since then I have identified a further 5 specimens in my own collection. These came from the Merehead quarry and from the Higher Pitts mine. It is very difficult to distinguish the plattnerite from the various black manganese oxides with which it occurs, and it is probably much more common than suggested by the few specimens known. At Merehead quarry it occurs as a replacement of mendipite, at the edges of the nodules of this mineral, and along the divisional planes of the fibers. It forms dark brown, resinous masses (to 1 cm) and groups (to 5 mm) of bright black, sub-millimeter-size, distorted crystals. Some specimens of mendipite have a streaked, blackish violet appearance resulting from widespread replacement of the mendipite by plattnerite.

Pyromorphite $Pb_5(PO_4)_3Cl$

Pyromorphite, unlike mimetite, was always very rare at the Higher Pitts mine, and only a few specimens are known. It occurred in small rounded aggregates and thin crusts of minute, yellow-green crystals on and in calcite and cerussite.

Wulfenite $PbMoO_4$

Wulfenite was very rare at the Higher Pitts mine, and only about 15 specimens are known today. However, some of these specimens are the largest specimens of wulfenite that have been found in the British Isles (Rothwell and Mason, 1992). Most of these specimens were found in close association with nodules of aragonite embedded in manganese ore. The wulfenite, which is a very pale wine-yellow color, and is easily confused with cerussite, forms nodules up to 4 cm in size, and rough crystals up to 3 cm across and 5 mm thick. The majority of the specimens were found on the outside of a single nodule of aragonite. One specimen (a 1-cm patch of 5-mm crystals) was found embedded in black calcite on the outside of another nodule of aragonite; another specimen (a 2-mm crystal) was found embedded in hydrocerussite; and yet another specimen (a 3-mm patch of minute crystals) occurred in association with cerussite. Wulfenite has also been found at other localities in the area.

DISCOVERY of CHLOROXIPHITE and DIABOLEITE

Leonard James Spencer (1870–1959), the discoverer of chloroxiphite and diaboleite, joined the British Museum (Natural History), London, as an assistant in the Department of Mineralogy in 1894. He was greatly interested in minerals, and spent his holidays visiting mines and collecting specimens. In June of 1898 he visited Priddy in the Mendips, and was given a large specimen of hydrocerussite from the Higher Pitts mine (although he did not know the source at the time), and some specimens of ancient (Roman?) lead slags from the St. Cuthbert Lead Works at Priddy. These specimens were probably given to him by Thomas Willcox who had been manager of the lead works up until 1897, and had also been manager of the Higher Pitts mine.

The slags proved to contain cerussite, anglesite and leadhillite, and Spencer reported on these at the meeting of the British Association for the Advancement of Science at Bristol in 1898 (Spencer, 1899). He did not report on his investigations of the hydrocerussite at this time because he did not know where it had come from.

In November of 1898, the British Museum (Natural History), London, acquired a few small specimens (including specimens of chloroxiphite) from the collection of Spencer Perceval by way of the London mineral dealer J. R. Gregory (1832–1899), and in March of 1922 obtained the remainder of his mineral collection by bequest. The collection contained a very fine suite of minerals from the Higher Pitt mine.

In April of 1923, Spencer paid another visit to the Mendips and visited the Higher Pitts mine, where he collected specimens of hydrocerussite and wulfenite. He also visited the old iron workings at the Priddy Hill Farm to the north, which had been worked around 1870 and again around 1914 (Gough, 1930). One of his daughters found a small specimen of mendipite there, and I have also found mendipite at this locality, together with cerussite, hydrocerussite, pyrolusite ("wad"), hematite, goethite, calcite, aragonite and quartz.

Spencer published the results of his investigations in 1923 and, together with Edgar Donald Mountain of the British Museum (Natural History), London, who had performed the chemical analyses, described the new minerals chloroxiphite and diaboleite (Smith, 1982; Spencer and Mountain, 1923). The specimens used had come from the Perceval collection.

It is of interest to note that the famous American collector Washington Augustus Roebling (1837–1926) had acquired specimens of mendipite, chloroxiphite, diaboleite and crednerite from the Higher Pitts mine as early as 1894 (in London from the German mineral dealer Oscar Penzig). Roebling was prompted to re-examine them after Spencer published his descriptions in 1923 (Roe, 1990).

MINERAL COLLECTIONS

Although it was possible to collect small specimens of many of the minerals described above up until very recently, by far the best specimens (with the possible exception of those of goethite) are to be found in collections made before 1940. The most important collections of minerals from the Higher Pitts mine are the following:

Thomas Willcox Collection

Thomas Willcox (1850–1945) was born at Leek, Staffordshire, about 10 km west of the famous Ecton copper mine, and died at Wells, Somerset (*The Wells Journal*, January 4 and January 11, 1946). He had two sons, Thomas Henry Charles and Alfred John, by his first wife, Elizabeth, and a daughter, Kathleen Mary (1899–1987?) and son, Stanley, by his second wife, Mary (born Chegwidden).

On leaving school he joined his grandfather's civil engineering company at Manchester, and took charge of the company's work on the reconstruction of the Cumberland Basin at Bristol docks. Afterwards he formed his own company, sinking shafts in the South Wales collieries, but moved to Somerset in 1880 to become manager of the St. Cuthbert's Lead Works at Priddy. He visited Germany to study ore dressing, and as a result greatly improved the lead works at Priddy. The works continued to operate until 1908, but Willcox resigned his position in 1897, moved to Wells, and again formed his own company, this time to work the Underwood limestone quarry (then a new quarry). He retired from business in 1918, and sold the quarry to the local authorities. Willcox was also manager of the Higher Pitts mine from its beginning in 1890 until work ceased in 1891.

Apart from being concerned with geology as part of his job as a civil engineer, Willcox was also greatly interested in geology as a hobby, and he accumulated a large collection of geological specimens. He was also a pioneer in the exploration of the caves and ancient mines of the Mendips (together with Bert Willcox, Harry Willcox, Harold Hiley, Reginald Troup, Herbert Balch, James McMurtrie and others), and is well-known for having carved his initials in one of the chambers of the Lamb Leer cave (a practice that was more acceptable then than now!). There is a photograph of him in Herbert Ernest Balch's book, *Mendip: Its Swallet Caves and Rock Shelters* (Balch, 1948).

Willcox's geological collection consisted of minerals, rocks and fossils from various parts of the British Isles and abroad. A fairly large number of specimens from the Higher Pitts mine, and one or two specimens from other Mendip Hills localities were included in the collection.

During his lifetime, Thomas Willcox donated geological specimens to the British Museum (Natural History), London, in particular in 1923 and 1935, coinciding with the investigations of L. J. Spencer, and A. W. G. Kingsbury, and to the Bristol Museum, Bristol. In 1946, his daughter Kathleen presented the Wells Museum (which had been founded by H. E. Balch in 1893, and greatly improved in 1945 through a Carnegie grant), with the oak (not recommended for mineral specimens!) cabinet that had housed her father's geological collection. It is probable that most of the specimens remaining in the collection were transferred to this museum at that time, although I have found no record of this, and it is possible that specimens were transferred to the museum at earlier times.

The collection in Wells Museum contains 108 specimens from the Higher Pitts mine, about half of which are loose masses of corroded cerussite crystals (up to about 5 cm in diameter) without matrix. The remainder of the specimens from the Higher Pitts mine consists of one or more of the following minerals: cerussite, hydrocerussite, mendipite, crednerite, malachite, chloroxiphite, diaboleite, mimetite and wulfenite (?), together with calcite, hematite, pyrolusite ("wad") and "limonite." The original collection had no catalog, and many of the specimens are without labels. Labels were added to some of the specimens in 1964 and 1983. The specimens from Higher Pitts mine are listed below with my reference numbers:

Specimen	*Size (cm)*	*Minerals*
001–048	<5	Loose masses of cerussite crystals
049–055	—	Hydrocerussite, cerussite, "wad"
056–060	<5	Mendipite
061–067	<5	Mendipite, chloroxiphite, diaboleite
068	<5	Mendipite, chloroxiphite, diaboleite
069	<5	Mendipite
070–074	—	Hydrocerussite
075–076	—	Cerussite
077–078	—	Cerussite
079	—	Cerussite
080	—	Cerussite
081–083	<5	Mendipite
084	<5	Mendipite
085	—	Cerussite
086	—	Crednerite, diaboleite
087–092	<5	Mendipite, chloroxiphite, diaboleite
093	—	Cerussite
094–098	—	Cerussite
099–101	<5	Mendipite
102–103	—	Cerussite
104	—	"Wad"
105	—	Cerussite
106	<5	Mendipite
107	—	Crednerite
108	—	Crednerite (very fine)

Only a few of the above specimens are on display. Permission to view the collection must be obtained from the museum curator.

The distribution of the various minerals agrees with the observations of Spencer and Kingsbury: groups of cerussite crystals and nodules of hydrocerussite were much more common than nodules of mendipite, and only a small number of the nodules of mendipite contained chloroxiphite or diaboleite, with diaboleite being much rarer than chloroxiphite.

Spencer Perceval Collection

Spencer George Perceval (1838–1922) was born at Langford Budville, Somerset, and was buried at Henbury, near Bristol (Spencer, 1924; *The Times,* March 14 and July 27, 1922; Venn, 1953). He was the grandson of Spencer Perceval (1762–1812), Prime Minister of England, who was assassinated in 1812. There was a long tradition of mineral collecting in his uncle's family; his uncle Sir Walter C. Trevelyan (1797–1879), an amateur geologist, and his uncle's father Sir John Trevelyan both had collections; the Trevelyan family had large estates in Cornwall, Devon, Somerset and Northumberland, and also had mining interests. When his family moved to Chapel Cleeve on the west coast of Somerset in 1847 he also became interested in geology and mineralogy. He graduated from Cambridge University in 1862, and became an amateur geologist and bibliophile. He was a gentleman of private means, and was of a very retiring and nervous disposition.

For many years Spencer Perceval lived at Severn House, Henbury and at Longwitton Hall, Northumberland, and collected minerals and fossils extensively in Devon, Somerset and South Wales. He was particularly interested in the Mendips. He published several short papers on British mineralogy (see *Catalogue of Scientific Papers,* The Royal Society, London), and produced a manuscript list of the minerals found in west Somerset which was used by Horace B. Woodward in compiling a list of Somerset minerals which he published in 1872 (Woodward, 1872). Spencer Perceval added to Woodward's list in a note in *The Geological Magazine* in 1873.

During his lifetime Spencer Perceval made occasional donations of geological specimens to the British Museum (Natural History), London, and shortly before his death he transferred his geological and other collections to Cambridge University on loan. On his death, the British Museum (Natural History), London, received his mineral collection by bequest, and many of the specimens, including most of those from the Higher Pitts mine, were transferred to that museum. The remainder of the specimens, including seven specimens from the Higher Pitts mine, were transferred to the Sedgwick Museum, Cambridge. As mentioned above, the British Museum (Natural History), London, had also purchased specimens from Spencer Perceval's collection in 1898. His collections of books, manuscripts, pictures and art objects were bequeathed to the Fitzwilliam Museum, Cambridge. Spencer Perceval's mineral collection contained most of the best known specimens from the Higher Pitts mine.

Arthur Kingsbury Collection

Arthur William Gerald Kingsbury (1906–1968) was born in East Meon, Hampshire (Embrey, 1973a, 1973b; *The Times,* August 8, 1968). There was a long tradition of mineral collecting in his family (his grandfather William Joseph Kingsbury, 1825–1904, and his great grandfather Thomas Kingsbury, 1777–1854, both had collections), and in 1927 he also became interested in mineralogy as a hobby. In 1929 he took his final legal examinations and began practicing as a solicitor (attorney) at Sherborne and later at Crewkerne, Somerset, both about 35 km south of the Mendips. He later moved to Bath, 25 km northeast of the Mendips. During the period 1929–1941 he undertook a systematic investigation of the mineralogy of the Mendips in continuation of the work of Spencer, and published four papers describing his finds there (Kingsbury, 1935, 1939, 1941; Kingsbury and Friend, 1939).

In 1947 he was appointed research assistant to the Reader in Mineralogy at Oxford University, and remained at this post for the rest of his life. He collected extensively throughout the British Isles, became one of the foremost authorities on British minerals, and published a number of papers on British mineralogy. The mineral arthurite was named for him and his friend Sir Arthur Russell (1878–1964).

During his lifetime Arthur Kingsbury donated specimens to a number of museums, including the British Museum (Natural History), London, and the Wells Museum, Wells. On his death, his mineral collection was donated by his family to the British Museum (Natural History), London. Arthur Kingsbury's collection contained a fine set of specimens from the Higher Pitts mine, including the best known specimens of wulfenite and crednerite and some of the best known specimens of mendipite and chloroxiphite.

FINAL COMMENTS

I hope that the above information will serve as a fairly comprehensive record of the Higher Pitts mine, all traces of which may well disappear forever in the not-too-distant future. Although there is, even now, not much left to be seen, the area makes a very pleasant venue for a lazy walk on a hot summer's afternoon; the public footpath from Priddy to Wookey Hole passes immediately by the last remaining workings. However, the footpath is well-used and many people stray from it and damage the farm; permission to leave the public footpath and visit the workings must be obtained from Mr. J. Edwards, the present owner of the Higher Pitts Farm.

I have been unable to trace the documents relating to the Higher Pitts mine that were once in the possession of Thomas Willcox, nor was I able to trace any of his relatives. I was also unable to trace the mineral collections of Mr. William H. Janes and Mr. Wilkins of Wookey-Hole (which existed about 1900–1930, and apparently contained material from the Higher Pitts mine), nor any of their relatives. Furthermore, I was unable to trace any old photographs of the mine, nor of similar mines (as distinct from smelting works) in the Mendips. I would be most grateful for any additional information or copies of old photographs that readers might have.

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THE ENGINEER MINE
TAGISH LAKE, BRITISH COLUMBIA

Mark H. F. Mauthner, **Lee A. Groat** and **Mati Raudsepp**
Department of Geological Sciences
University of British Columbia
Vancouver, British Columbia V6T 1Z4

The Engineer mine is a Dana locality for classic, botryoidal "allemontite" (stibarsen and native arsenic). Several other minerals of interest to the collector are also found, including crystallized auriferous silver ("electrum"). The site is currently being mined for gold, but the operators are also setting aside specimens specifically for the collector market.

INTRODUCTION

The Engineer mine is located on the east shore of the Taku Arm of Tagish Lake, about 32 km (20 miles) west of Atlin, British Columbia. Whitehorse, Yukon, is about 137 km (85 miles) north. National Topographic Series Map Sheet 104 M/8E covers this area. Access to the mine is either by boat or float-equipped aircraft.

HISTORY

As with so many mines in British Columbia, the Engineer mine's history is one of high hopes and dreams, fancy financial footwork, success and disaster. The story began in 1899, when Charles A. Anderson, an engineer with the White Pass and Yukon Railway, paddled south along the eastern shore of Taku Arm. He found visible gold in large quartz veins in bluffs at the water's edge. Anderson staked the Hope claim on July 8, recorded it in Atlin, then returned with Henry C. Diers, another company engineer, to stake another twelve claims which became known as the Engineer Group. These men then organized the Engineer Mining Company of Skagway, Alaska, and began development work on the property, which continued for several years They also began construction of a small mill, but did not complete it. The Company's money had run out and the results had not been encouraging enough to attempt more fund-raising. As a result, the claims were allowed to lapse in 1906. A group of local men led by Edwin Brown restaked the claims, then in 1907 sold them to Captain James Alexander, John Dunham, Ben G. Nichol and K. Wawrecka of the Northern Partnership Syndicate.

The new owners began by prospecting the neighboring ground, which resulted in the staking of the Northern Partnership Numbers 1, 2, 3, 4 and 5 claims. The construction of the mill was also completed and several tons of high-grade ore were treated by amalgamation methods.

Minimal work was done between 1910 and 1912 due to pending litigation. After acquiring the interests of his partners, Captain Alexander continued more comprehensive and systematic prospecting and development than had been previously undertaken and, for the next 6 years, work continued sporadically. It slowed down when engineers and consultants visited during attempts to sell the mine. When asked about the origin of the mine's name Alexander was reported to have replied, "Because it has been 'engineered' to death!"

In 1918, Wayne Darlington, a well-known New York engineer, managed to secure an option on the mine from Alexander, with a total purchase price of $1,000,000. This option was passed on to the Mining Corporation of Canada. One of the Corporation's

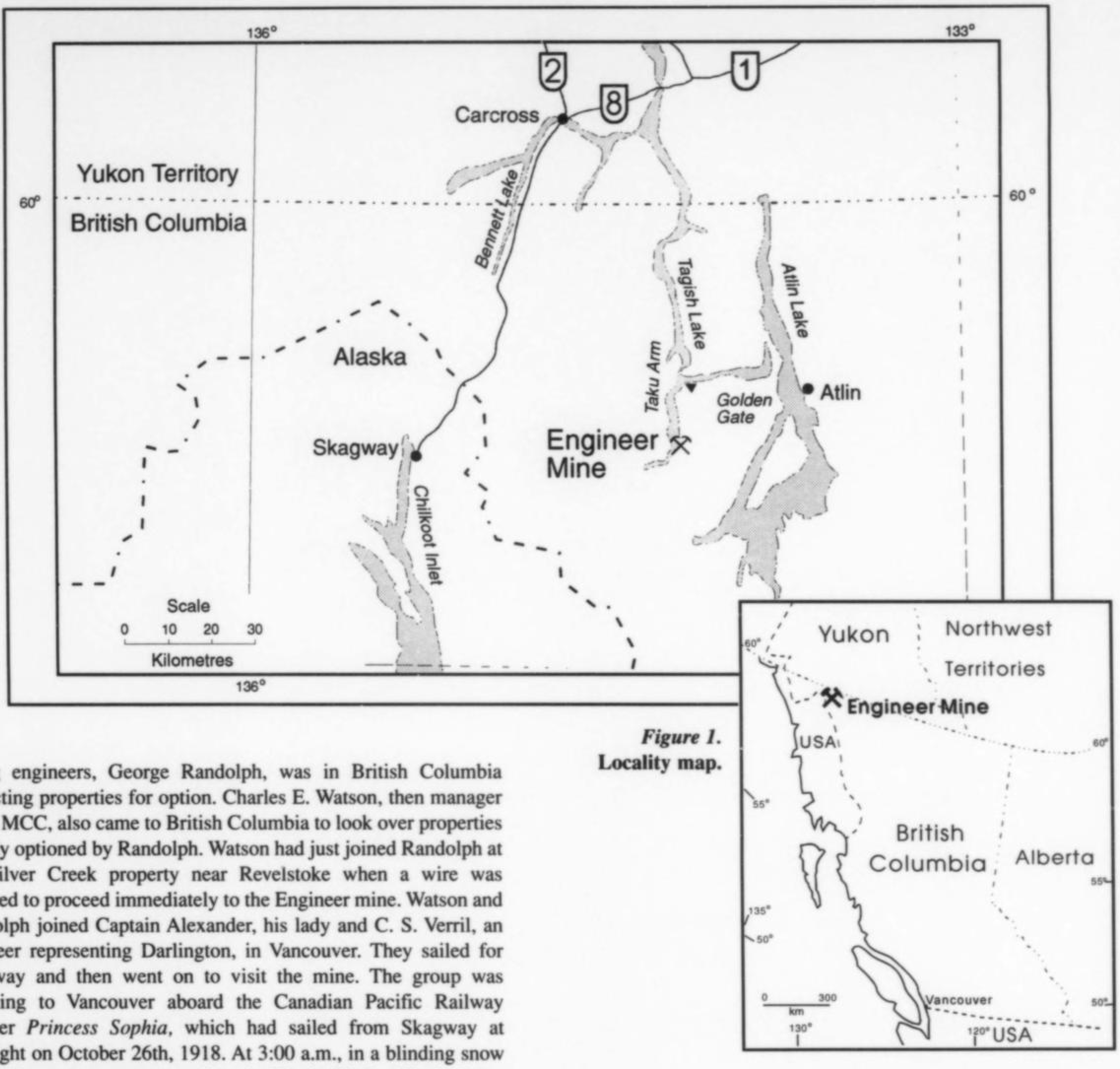

***Figure 1.* Locality map.**

young engineers, George Randolph, was in British Columbia inspecting properties for option. Charles E. Watson, then manager of the MCC, also came to British Columbia to look over properties already optioned by Randolph. Watson had just joined Randolph at the Silver Creek property near Revelstoke when a wire was received to proceed immediately to the Engineer mine. Watson and Randolph joined Captain Alexander, his lady and C. S. Verril, an engineer representing Darlington, in Vancouver. They sailed for Skagway and then went on to visit the mine. The group was returning to Vancouver aboard the Canadian Pacific Railway steamer *Princess Sophia,* which had sailed from Skagway at midnight on October 26th, 1918. At 3:00 a.m., in a blinding snow storm, the steamer ran aground on the Vanderbilt Reef in the Lynn Canal. At dawn, the tide was low, leaving the boat high and dry on the reef. For more than a day the ship was perched atop the reef. It had been decided that if an attempt were made to bring the passengers ashore during the storm, many would surely perish. Just after dark on October 28th, the *Princess Sophia* finally plunged off the rocks, taking everyone on board into the icy depths. A pet dog was the only survivor (Greene, 1969).

For several years after Alexander's death, little work was done at the mine due to litigation regarding the ownership. It turned out that the woman accompanying Alexander in British Columbia was not his wife as people had assumed. Apparently Mrs. Alexander and their 16-year-old daughter were still living in England when they learned of his demise. Litigation arose when their claim as heirs was countered by a claim made by Alan Smith of Philadelphia. Smith claimed that he had grubstaked Alexander and the two had an agreement that in the event of the death of one partner, the other was to receive the deceased's share of the Engineer mine. The mine was held under bond by Ecla Copper Company, a Nevada mining corporation. Repair and development work done during this time was headed by Reggie Brooks, a long-time friend of Captain Alexander.

The property was examined and bonded by Andrew Sostad for New York interests in the fall of 1923. Extensive work began again in 1924, when Engineer Gold Mines, Limited, was incorporated in the State of Delaware, with the British Columbia head office in Vancouver. With a capitalization of $1,000,000, the Company made the mine a major operation by building a power plant and transmission lines and installing a 50 tons-per-day concentrator near the 5th level portal. The concentrator was started in November of 1925 and within two months had milled 1,700 tons of ore yielding 1,814 ounces of gold and 843 ounces of silver. The high mining and milling rate outpaced the development of reserves and after the summer of 1926, having produced 7,757 ounces of gold that year, the mine and mill were shut down for the winter to let ore reserve development catch up. After a short period of milling during the summer of 1927, developed reserves were once again exhausted and the mine was closed. Exploration and development continued until 1931 when all work in the mine was ceased even though reserves had been established in the lower levels. Reggie Brooks stayed on as a caretaker for Engineer Gold Mines for the next two years. Although he was not a paid employee, he was permitted by the company to hand-mine the surface showings.

In 1934 the mine was sold at a Sheriff's sale to representatives of the Mining Corporation of Canada, Limited, for $25,000 cash in

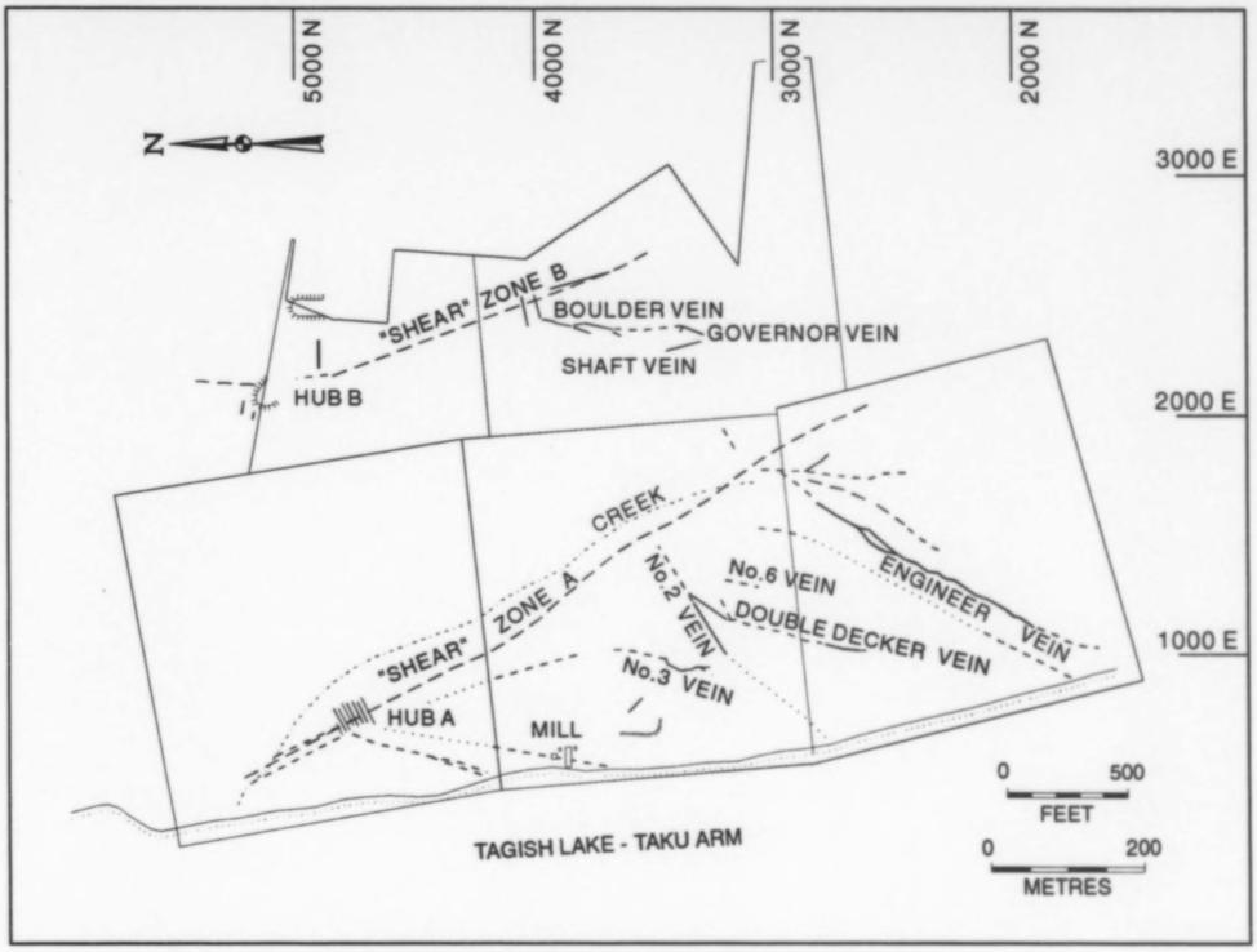

Figure 2. **Surface plan of the Engineer mine showing outcrops of the major veins. (Computer drawn by Arne Toma after Smith, 1990.)**

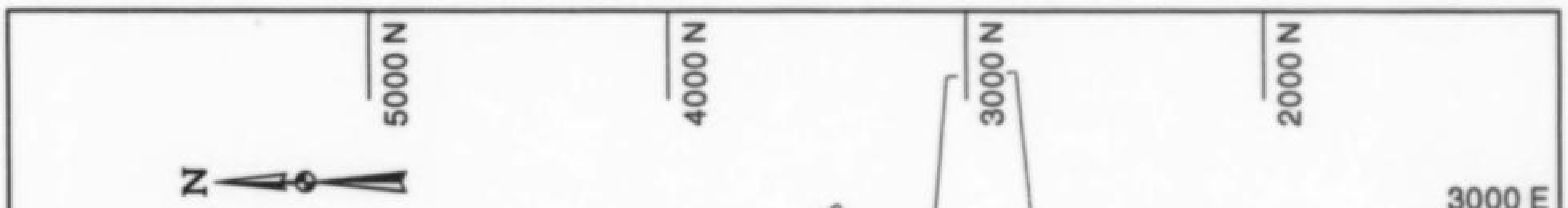

Figure 3. **Underground workings at the Engineer mine. (Computer drawn by Arne Toma after Smith, 1990.)**

Figure 4. **Engineer mine camp on the eastern shore of Tagish Lake. Photo by Mark Mauthner.**

satisfaction of judgments against the mine: over $8,700 to a C. L. Hershman, over $4,000 to a Louis Schulz and $207,431.18 in favor of John G. Harris. In his memoirs, Reggie Brooks relates how the latter came to have a claim against the mine. Apparently, someone who knew Harris well had informed Brooks that the claim was transferred to Stewart Hamilton, then treasurer of Engineer Gold Mines in New York, by C. V. Bob, an earlier president of the company, in exchange for an estate in the West Indies which Hamilton had acquired. Hamilton, in turn, transferred the loan indebtedness to Jack Harris, his brother-in-law because, as an executive officer of the company, Hamilton could not very well sell the mine and satisfy his judgement for the debt.

The Mining Corporation of Canada made no attempt to reopen the mine. John E. Hammell arranged for an option on the mine from the Corporation in 1936. The engineer he had hoped would run the operation died after falling down a shaft at a gold mine in the Philippines, and Hammell consequently turned down the option. In May of 1944, Neil Forbes, Tommy Kirkwood and Pete Brandes of Atlin bought the mine from the Mining Corporation for $5,000 plus about $1,500 in back taxes. These miners highgraded the property off and on through the 1940's until 1952. Walter Sweet, also of Atlin, joined the group in 1945, after obtaining Pete Brandes' interest.

There has been no production from the mine since 1952, although several companies have made efforts to explore the property further. The property was bought by Tagish Gold Mines Limited in the early 1960's. Nu-Energy Resources Limited merged with Tagish Gold Mines in 1975 and in the same year conducted an exploration program. In 1979, Nu-Lady acquired the right to the property and continued exploration for the next couple of years. Total Erickson Resources Limited carried out magnetometer aerial and ground geophysical surveys in 1987 (Smith, 1990). The Engineer mine is presently being worked by Warren Arnholtz and Swede Martensson of Ampex Mining.

One story about the Engineer mine relates a curse put on the mine in its early days. The curse proclaims that "nothing but death and disaster would be the lot of Alexander and anyone else who had anything to do with the property" (Fairlie, 1940). Perhaps it is still in effect. With their operation shut down for the season, Warren and Swede were heading home across Tagish Lake in October of 1993 when a sudden storm capsized the boat. They, along with the boat's owner and captain, Rob Cumming, hung on for over an hour in the icy water before being rescued. Most of that season's gold lies at the bottom of the lake. The tale is not yet ended.

GEOLOGY

Several investigators made cursory observations in the Tagish Lake area from 1899 to the mid-1950's. A map of the area was drawn by R. L. Christie in 1957. The most significant work relevant to the Taku Arm (in particular, to the east of the lake) was done by Bultman (1979) and by the British Columbia Geological Survey (Mihalynuk and Mountjoy, 1990). The Engineer mine area was also studied as part of the Bennett Project conducted by the BC Geological Survey (Schroeter, 1986).

The Engineer mine claims are situated within the Whitehorse

Figure 5. **Engineer mine mill on Tagish Lake. Photo by Mark Mauthner.**

Trough, which is a synclinorium underlain by the Late Triassic Stuhini Group. The center of the trough is dominated by the Jurassic Laberge Group. The Whitehorse Trough is structurally controlled to the west by the Llewellyn Fault, which separates it from the Coast Plutonic Complex, and to the east by the Nahlin Fault which separates the trough from the Atlin terrane.

The orebodies of the Engineer mine are part of an epithermal vein system situated in the sedimentary rocks of the Inklin Formation. This formation is one of two comprising the Laberge group of rocks, which are a northwest-trending linear belt of Early Sinemurian to Late Pliensbachian muddy turbidites, graywackes and conglomerates (Johannson, 1993).

Several workers have made comments about the mineralization history, or aspects thereof (for example, Mihalynuk and Mountjoy, 1990, and Schroeter, 1986), but a more comprehensive hypothesis than the one presented in this article has not yet been put forward or tested. Smith (1990) points out that two types of mineralization exist: the low-grade, finely disseminated mineralization of the "shear zones" and "hubs," and that of the "erratically distributed pockets of high-grade gold ore that occur in the numerous narrow quartz veins throughout the property."

Two nearly vertically dipping and northwest-trending zones of dilatant quartz veins ("shear zones" in previous literature) cut the Inklin rocks. These have been interpreted as splays of the Llewellyn Fault system (Schroeter, 1986). Smith (1990) also compares the "shear zone" quartz veins with the type of quartz veins found in the California Motherlode belt on the basis of the presence of graphitic horizons parallel to the quartz zones. The last major motion along the Llewellyn Fault has been dated at about 132 Ma (million years) by potassium-argon dating of sericite from the fault zone (Mihalynuk, personal communication, 1993), and an early period of gold mineralization could have taken place during this time. Each of these zones hosts a large, oval stockwork or "hub" from which some subsidiary, though clearly epithermal, veins seem to radiate.

Schroeter (1986) suggests that "mineralization in the vicinity of Engineer Mountain and Bee Peak may be genetically related to a hydrothermal event associated with intrusive activity." Mihalynuk (personal communication, 1993) has obtained dates of 55 Ma and 62 Ma for the Sloko volcanics, which he feels are coeval with the Engineer Mountain plutons. An epithermal event associated with this activity could well have followed older structural weaknesses such as the "shear" zones and created offshoots. The distinct clastic nature of some of the electrum/roscoelite mineralization suggests that the epithermal event was at least a lengthy one, if not multi-episodic with earlier mineralization having been brecciated and redeposited by a later episode of the same event. Furthermore, a specimen of the epithermal material (in the University of British Columbia collection) exhibiting a slickensided surface with the gold smeared across it supports the idea of an extended or multi-episodic epithermal event. The feature is too small to suggest post-epithermal tectonic movement in the area, and no large-scale, post-mineralization faulting was observed by the author who visited the mine (MM).

MINERALS

Allemontite mixture of stibarsen + arsenic or antimony

The occurrence of "allemontite" at the Engineer mine was the first in Canada (Walker, 1921). Because allemontite is a discredited species, further description of the material is given under **arsenic** and **stibarsen**.

Ankerite Ca(Fe,Mg,Mn)(CO_3)

Ankerite occurs as fine-grained masses up to several centimeters in calcite veinlets in the cockscomb quartz/calcite veins.

Antimony Sb

The occurrence of native antimony at the Engineer mine is first mentioned by Thomson (1937) and Walker (1921). It occurs as lumpy nodules up to 5 cm wide in cockscomb quartz. These specimens are quite different from the banded, colloform "allemontite" in that they appear homogeneous. A polished cut through a specimen in the University of British Columbia collection does not show banding like that in similarly cut "allemontite." Native antimony has also been found as rhombohedral crystals to 2 mm in calcite veinlets on level 5 of the "E" vein.

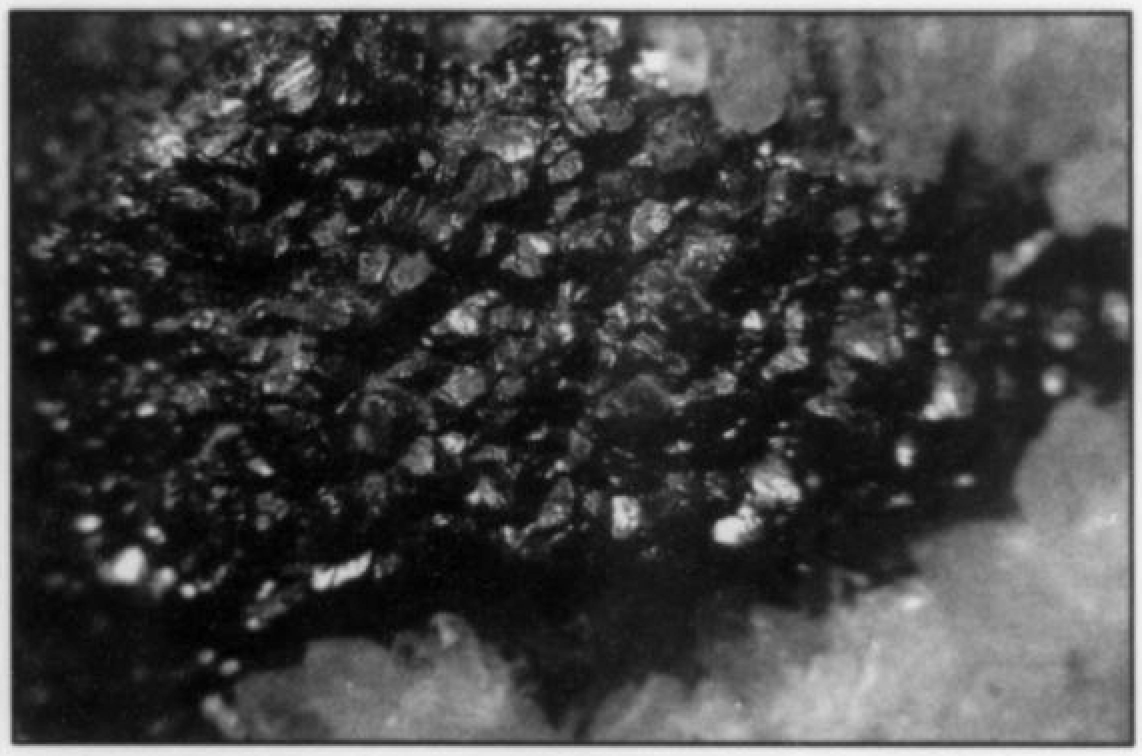

***Figure 6.* Arsenic crystal group, 7 mm. Mark Mauthner collection and photo.**

Arsenic As

Native arsenic occurs as bright silvery bands interlayered with stibarsen ("allemontite"). After being collected and exposed to air, these bands soon alter to a sooty black color. Reniform masses up to 30 cm wide are the largest known. The surface of these aggregates can vary from being smooth to pimply to drusy with crystals up to 1 mm visible. [See also **stibarsen**.]

***Figure 7.* Arsenopyrite crystal, 0.8 mm, with löllingite. Mark Mauthner collection and photo.**

Arsenopyrite FeAsS

Arsenopyrite occurs as euhedral prisms associated with the roscoelite/electrum nodules and as freestanding crystals in quartz vugs of the calcite/quartz veins. Crystals up to 5 mm are known. Some interesting arsenopyrite crystals with a coating of löllingite and more tiny, irridescent arsenopyrite crystals sprinkled over the löllingite also occur in the quartz vugs. The arsenopyrite samples analyzed contain 0.55 to 4.49 % antimony. Values for iron remain fairly constant, whereas the sulfur and, to a lesser degree, the arsenic values fluctuate correspondingly with the antimony values. This suggests that the antimony is substituting for sulfur and possibly arsenic in the structure.

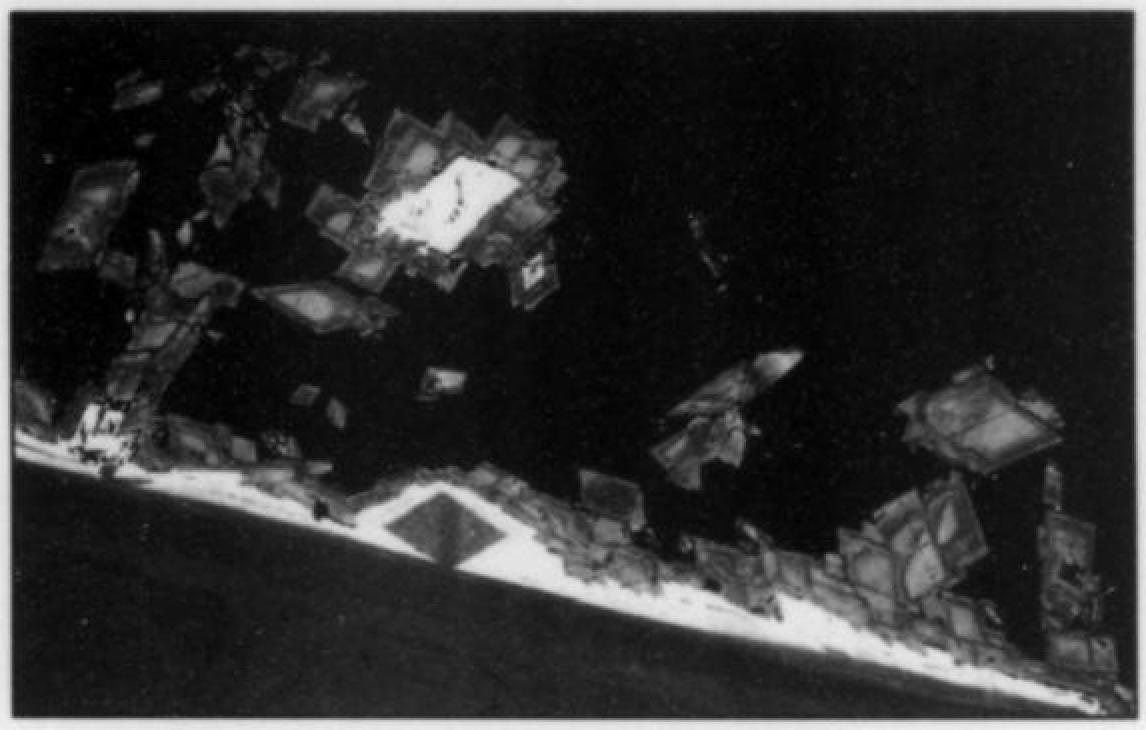

***Figure 8.* Arsenopyrite crystals (gray) with löllingite (white) in polished section back-scatter electron image 250 μm across, by M. Raudsepp. U.B.C. collection.**

***Table 1.* Five analyses of various zones within an arsenopyrite crystal. Analysis #6 was made on the lighter grey core of the arsenopyrite crystal seen on the far right, center of BSE photo 3. See also BSE photo 2.**

	1	*2*	*3*	*5*	*6*
Weight % Concentration					
Fe	35.08	35.74	35.66	35.71	32.98
S	19.53	21.20	20.82	20.95	16.60
As	43.52	41.70	43.09	40.79	41.23
Sb	2.51	2.12	1.26	3.38	9.49
TOTAL	100.64	100.76	100.83	100.83	100.30
Normalized Atomic Concentration					
Fe	34.16	34.13	34.09	34.29	34.01
S	33.13	35.26	34.66	35.03	29.81
As	31.59	29.68	30.70	29.19	31.69
Sb	1.12	0.93	0.55	1.49	4.49
TOTAL	100.00	100.00	100.00	100.00	100.00

Berthierite $FeSb_2S$

Berthierite was identified by X-ray analysis in a sample collected by the British Columbia Geological Survey. It occurs as fine needles up to 1 cm long in a quartz-lined vug (Schroeter, 1986).

Bismuth Bi

Bismuth was first mentioned from the Engineer mine by Cairnes (1911), but no analyses or documentation of specimens were given. No bismuth was detected in any samples analyzed by the current authors.

Calaverite $AuTe_2$

[See under **Tellurides.**]

Calcite $CaCO_3$

Calcite is a gangue mineral in the epithermal, vuggy quartz veins. Aesthetic rhombs and blades up to several centimeters in size and coated with iron oxides are found in the vugs of many of the same veins. Clear, colorless prisms with rhombic terminations also occur throughout the mine.

Chalcopyrite $CuFeS_2$

Chalcopyrite was reported to occur in a quartz vug in the quartz/calcite veins (*B.C. Mines Annual Report*, 1927). This is the only mention of any copper-bearing mineral occurring in this mine.

Fluorite CaF_2

Fluorite occurs as pale green masses and small, clear, colorless cubes in the epithermal veins. The cubes (up to 1 mm on an edge) are associated with arsenopyrite and calcite crystals in quartz-lined vugs.

Gold Au

[See under **Silver**.]

Table 2. **Five analyses of different points within a löllingite overgrowth on an arsenopyrite crystal. See BSE photos 2 and 3.**

Analysis	*8*	*9*	*10*	*12*	*13*
Weight % Concentration					
Fe	28.50	28.16	29.36	28.84	28.72
S	1.17	0.84	4.49	2.16	1.96
As	67.72	67.92	62.31	66.27	66.76
Sb	2.56	2.42	3.67	2.53	2.26
TOTAL	99.95	99.34	99.83	99.80	99.70
Normalized Atomic Concentration					
Fe	34.66	34.61	34.42	34.68	34.63
S	2.47	1.79	9.17	4.53	4.12
As	61.42	62.24	54.45	59.40	60.00
Sb	1.43	1.36	1.97	1.39	1.25
TOTAL	99.98	100.00	100.01	100.00	100.00

Löllingite $FeAs_2$

Löllingite was identified as a coating and as tiny crystals on arsenopyrite crystals in quartz vugs. These coated arsenopyrite crystals have a bizarre, spiky appearance and could be considered as löllingite encrustation pseudomorphs after arsenopyrite with some smaller arsenopyrite and pyrite crystals sprinkled on the löllingite. Electron microprobe analyses showed the presence of 1.26 to 1.97 % antimony.

Pyrite FeS_2

Pyrite occurs as cubes and pyritohedrons up to 2 mm in small quantities near and along the vein/country rock contacts. These are probably the result of country rock alteration and scavenging as the hydrothermal fluids were intruding. Pyrite was also found as extremely small (5–10 microns) crystals on löllingite/arsenopyrite crystals. Sulfide mineralization is very poor throughout the mine.

Pyrrhotite $Fe_{1-x}S$ ($x = 0$–0.17)

Massive pyrrhotite occurs intimately associated with the arborescent electrum and roscoelite, and as small blebs and streaks in clasts of the sedimentary host rocks within the quartz/calcite veins. As with other sulfides, pyrrhotite is a very minor constituent in the veins.

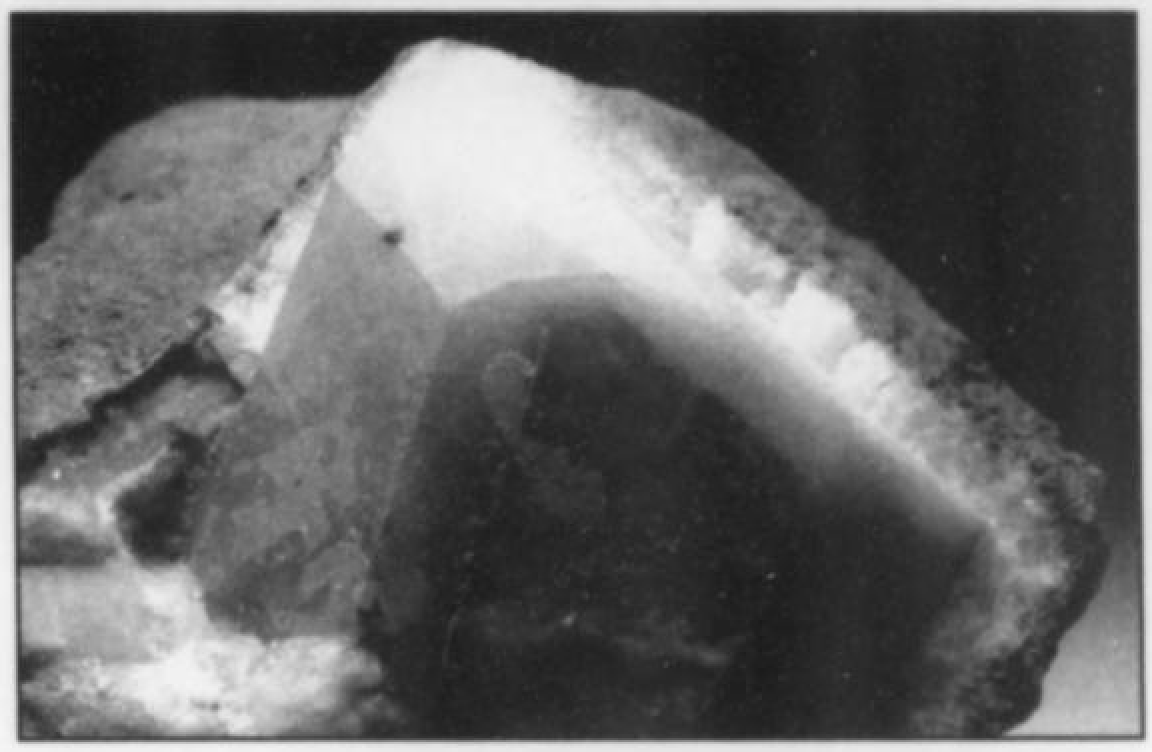

Figure 9. **Quartz pseudomorph after a calcite crystal, 6 cm. Mark Mauthner collection and photo.**

Quartz SiO_2

Quartz is the main gangue mineral in the Engineer vein system. Most is of a drusy, "cockscomb" habit and while not really notable on its own, often provides a beautiful matrix for other, more "collectible" species. Of interest to the collector, though, are the drusy quartz pseudomorphs after calcite and the pseudomorphous specimens in which the calcite has been replaced by quartz producing "quartz pseudomorphs after pseudomorphs after calcite."

Roscoelite $K(V,Al,Mg)_2(AlSi_3)O_{10}(OH)_2$

Dark green to black roscoelite occurs as a radiating, micaceous coating (up to several millimeters thick) surrounding electrum in the epithermal veins. This association is sometimes enclosed in calcite which can be etched away to reveal the arborescent nature of the electrum and roscoelite. All green micaceous minerals analyzed by the authors have been identified as roscoelite. No chromium was found in any sample. References to "mariposite" in previous literature are probably references to the roscoelite due to their similar appearance and because mariposite is perhaps more commonly associated with gold veins.

Siderite $FeCO_3$

Siderite was identified as dark brown, earthy or sparry masses and as paler brown, crusty crystal aggregates up to several centimeters in diameter. It is associated with clear, colorless calcite in quartz vugs.

Silver (Auriferous) (Ag,Au)

Highly auriferous silver (40–42% Au) occurs as dendritic crystals, plates and wires in the quartz/calcite veins. Auriferous silver from the "E," Double Decker and adjacent veins is most often enclosed in roscoelite. This association is found as distinct clasts and as irregular nodules, both up to several tens of centimeters in size. Auriferous silver occurs alone in cockscomb quartz, particularly in the Shaft and Governor veins. A number of superbly crystallized specimens, ranging in size from micromounts to miniatures (5 cm), were collected from the Governor vein during the 1994 season. Habits of these crystals vary from centimeter-sized single sheets (flattened octahedra) to millimeter-scale, highly modified cuboctahedra. The sheet-like crystals commonly have raised, triangular growth hillocks on them. Quartz crystals often "pierce" the sheet-like crystals, which then have overgrowths of more equant crystals collaring the quartz. This is the first noted occurrence of well-crystallized auriferous silver ("electrum") in Canada. (Note: the "E" vein is also referred to as the "Engineer" or "No. 8" vein.)

Figure 10. **Bright electrum in dark roscoelite, 8 cm across. U.B.C. specimen #6724; Mark Mauthner photo.**

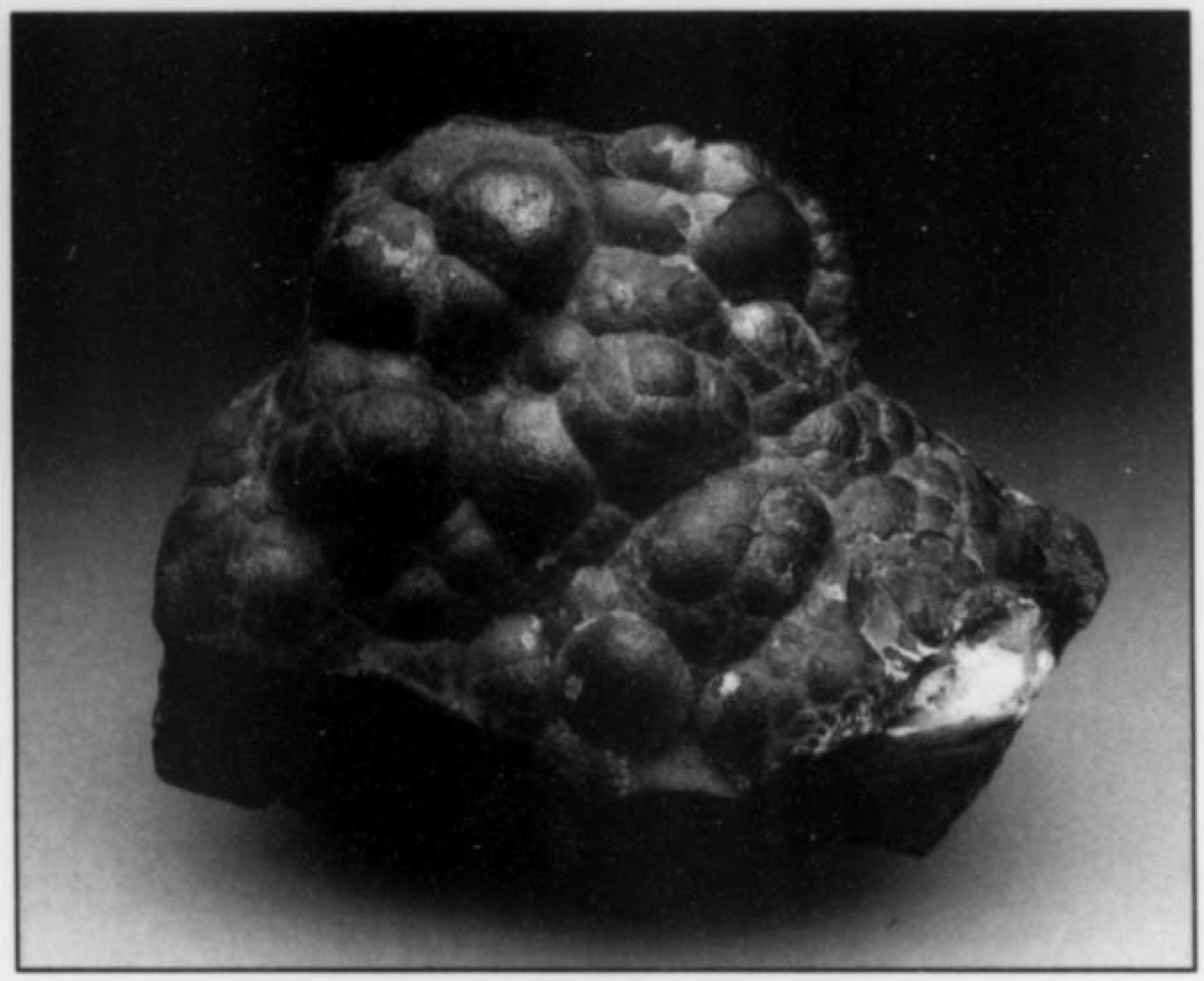

Figure 11. **Botryoidal, layered stibarsen with minutely intergrown arsenic, 5.8 cm across. Canadian Museum of Nature specimen #35193; Jeffrey Scovil photo.**

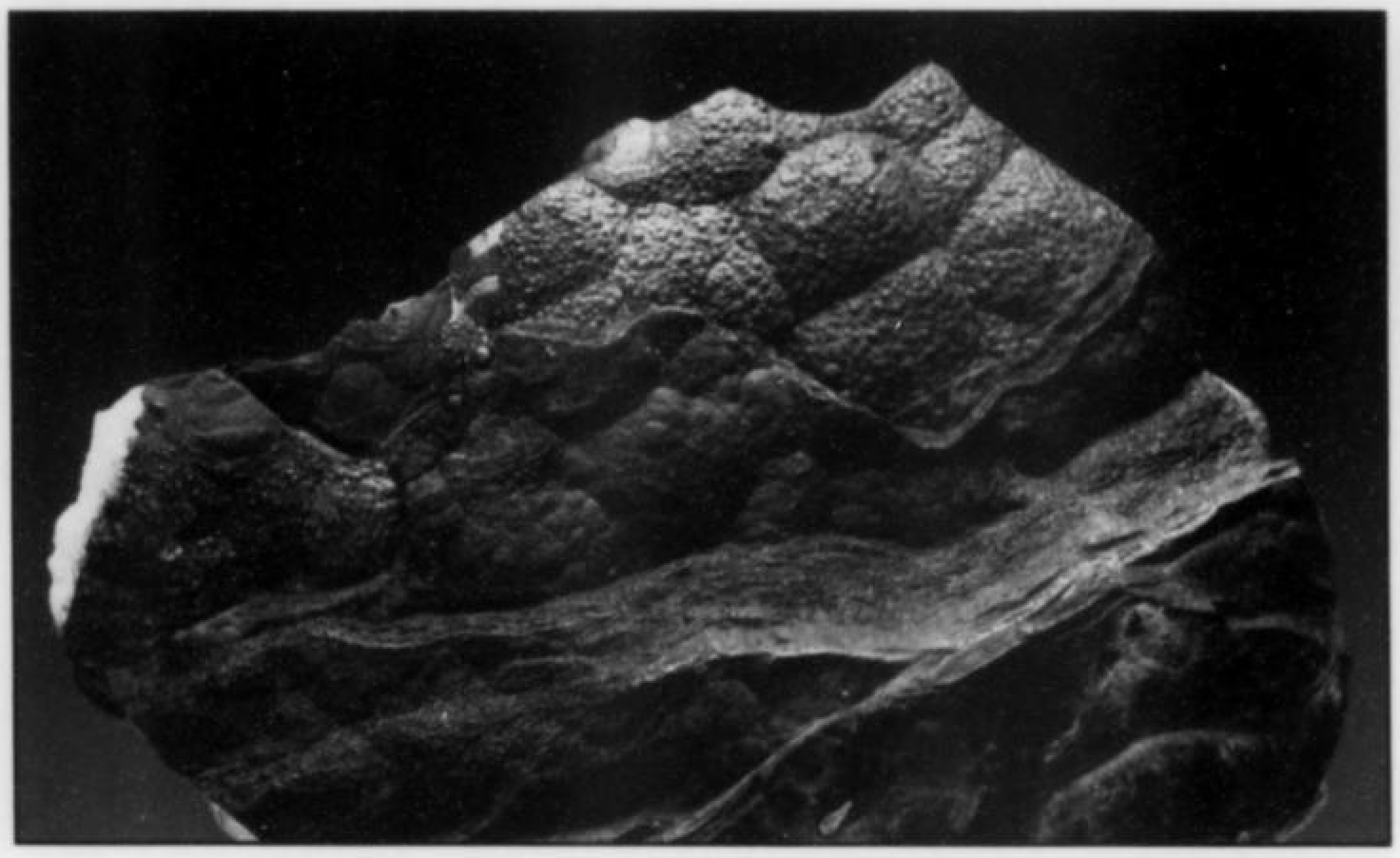

Figure 12. **Botryoidal, layered stibarsen with minutely intergrown arsenic, 8 cm across. U.B.C. specimen #44; photo by Mark Mauthner.**

Figure 13. **Botryoidal stibarsen with minutely intergrown arsenic, 13 cm across. U.B.C. specimen #2252; Mark Mauthner photo.**

Figure 14. **Cut and polished specimen of banded stibarsen/arsenic ("allemontite"), 5.5 cm across. U.B.C. specimen #43; Mark Mauthner photo.**

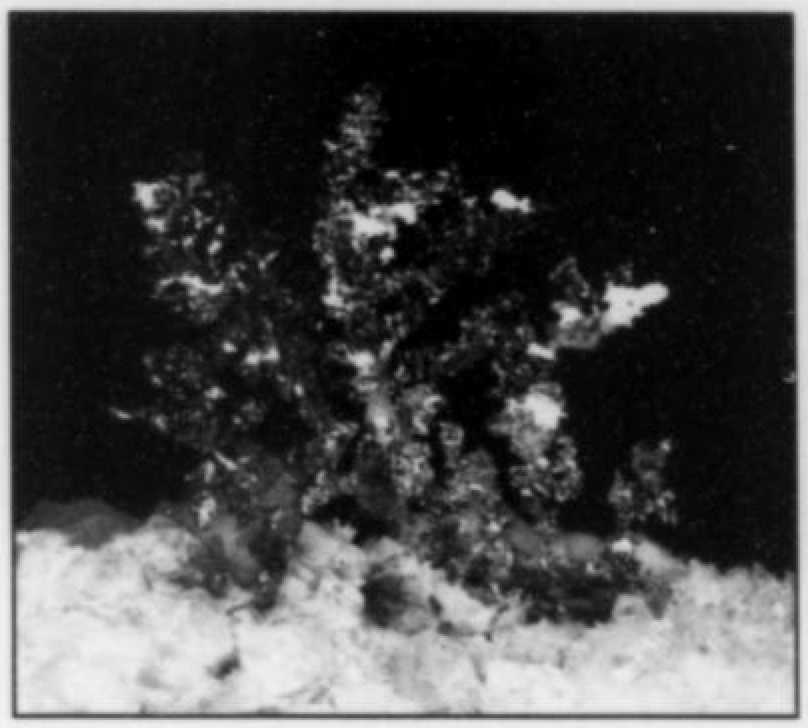

Figure 15. Arborescent auriferous silver crystal group, 1 cm. U.B.C. collection; Mark Mauthner photo.

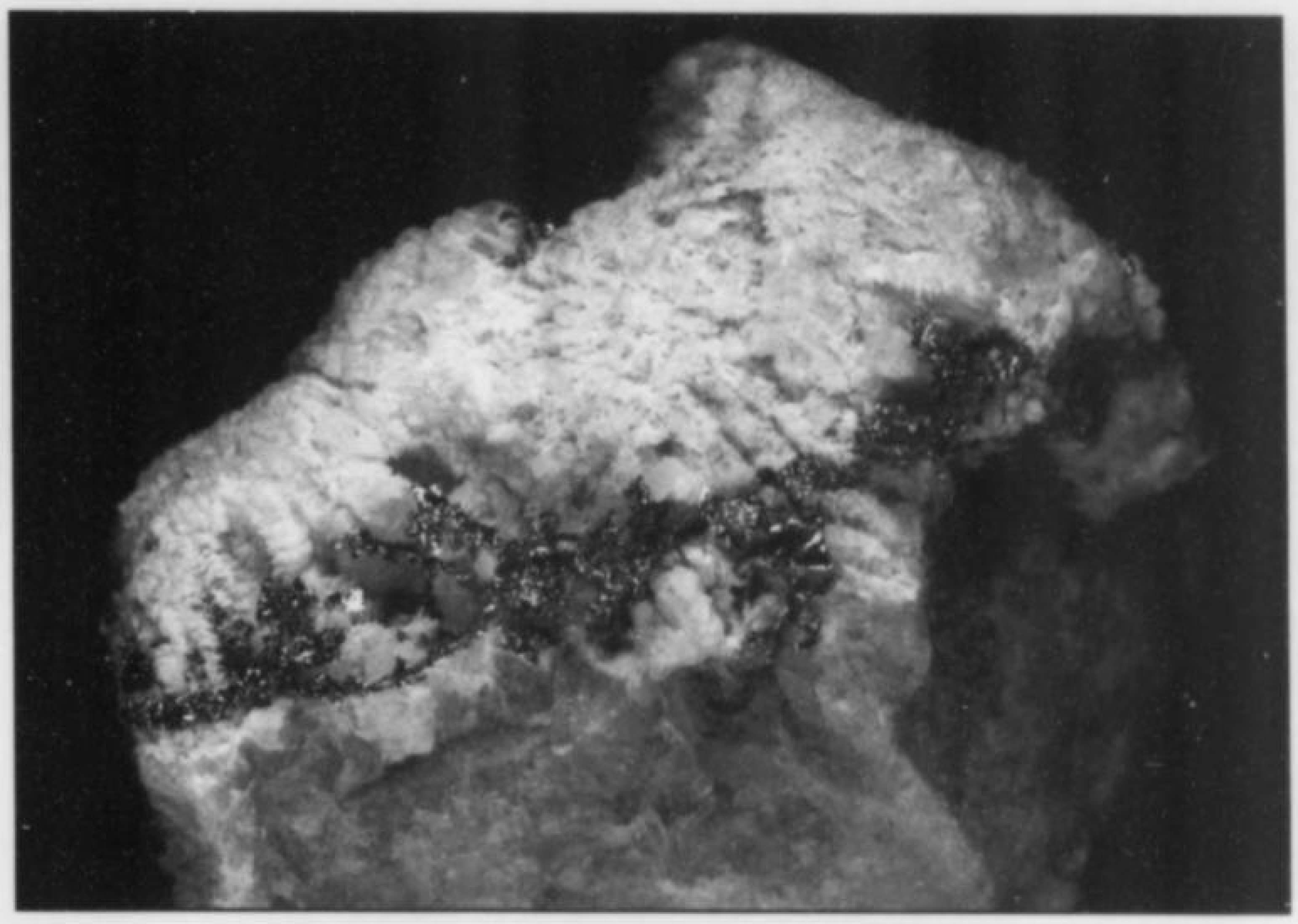

Figure 16. (right) Arborescent auriferous silver crystals in quartz, 3.5 cm. U.B.C. collection; Mark Mauthner photo.

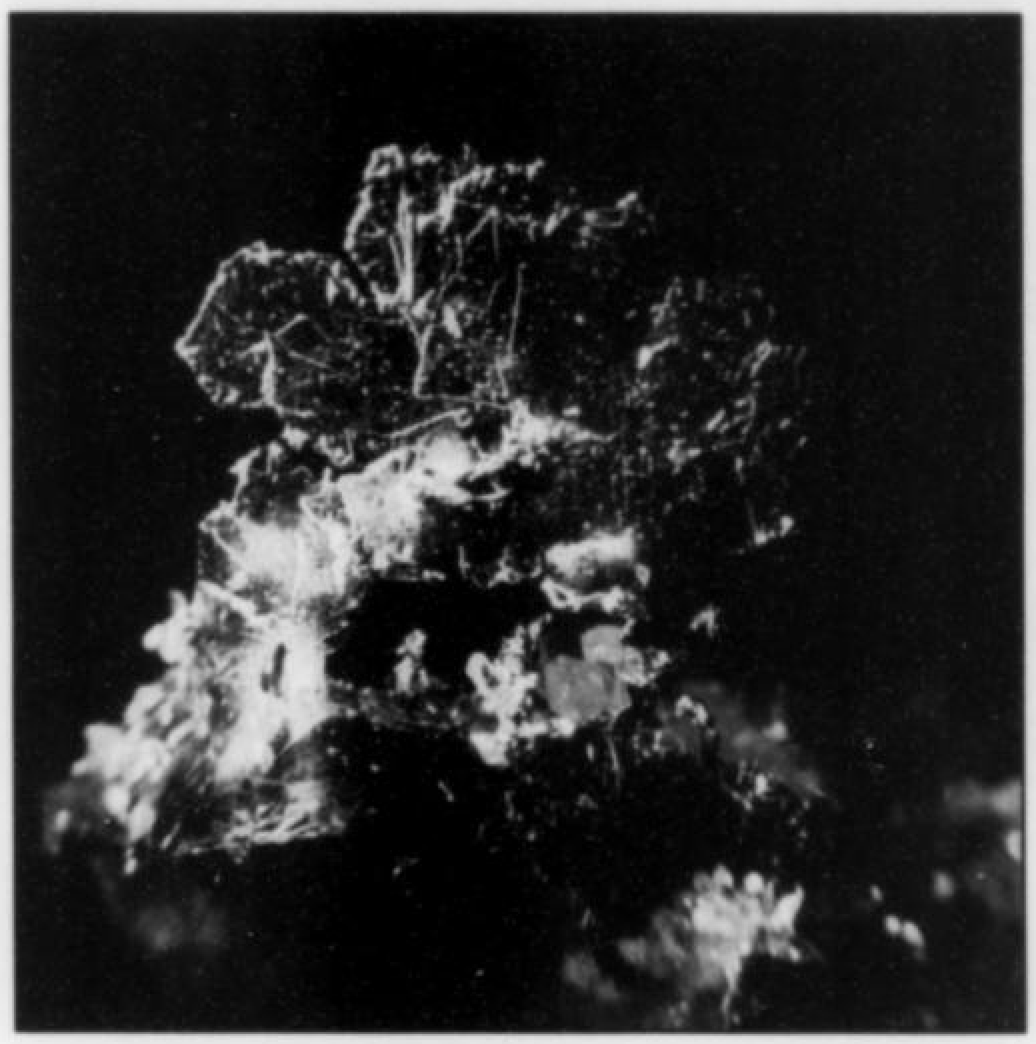

Figure 17. Auriferous leaf silver, 7 mm. Mark Mauthner collection and photo.

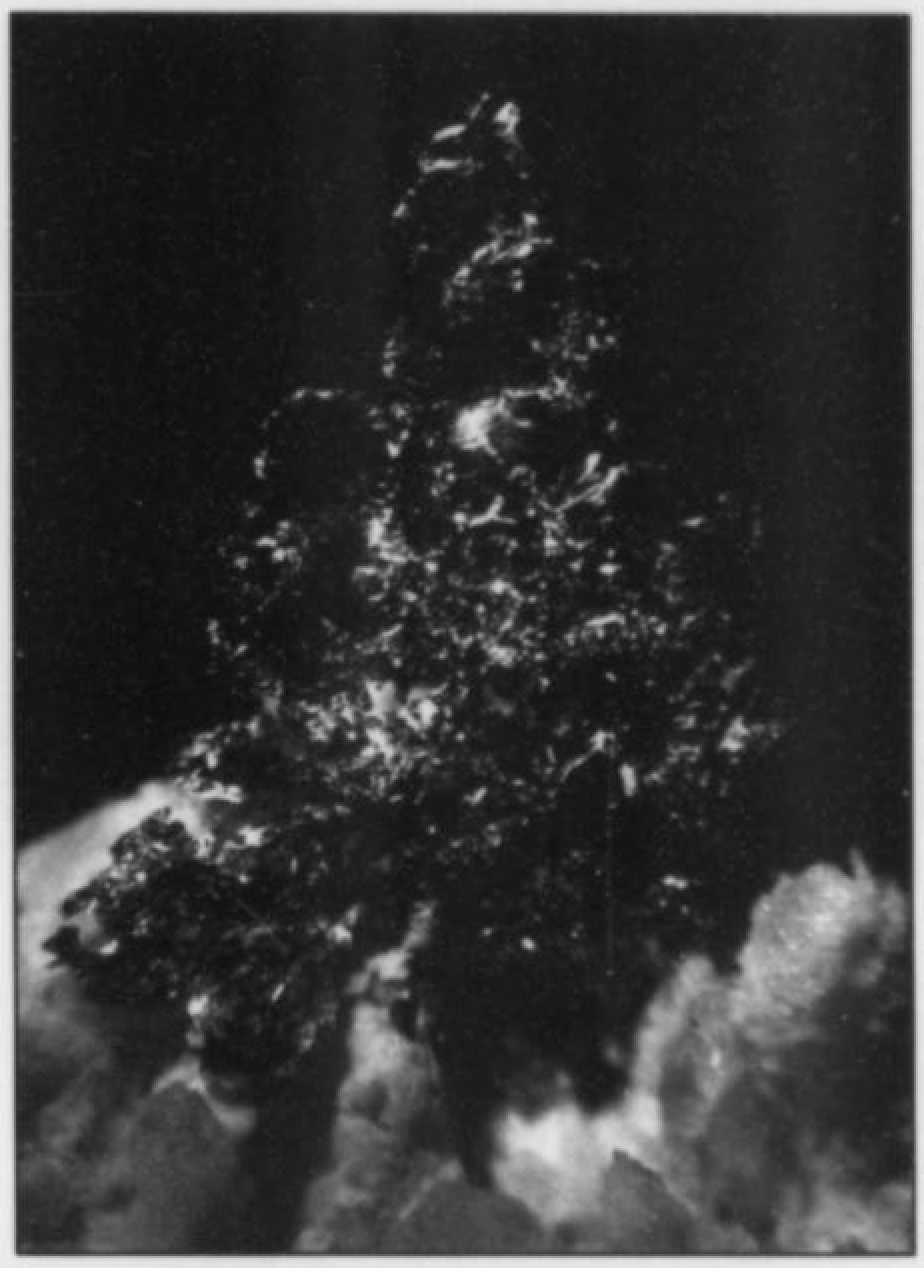

Figure 18. Auriferous silver, 7 mm. Mark Mauthner collection and photo.

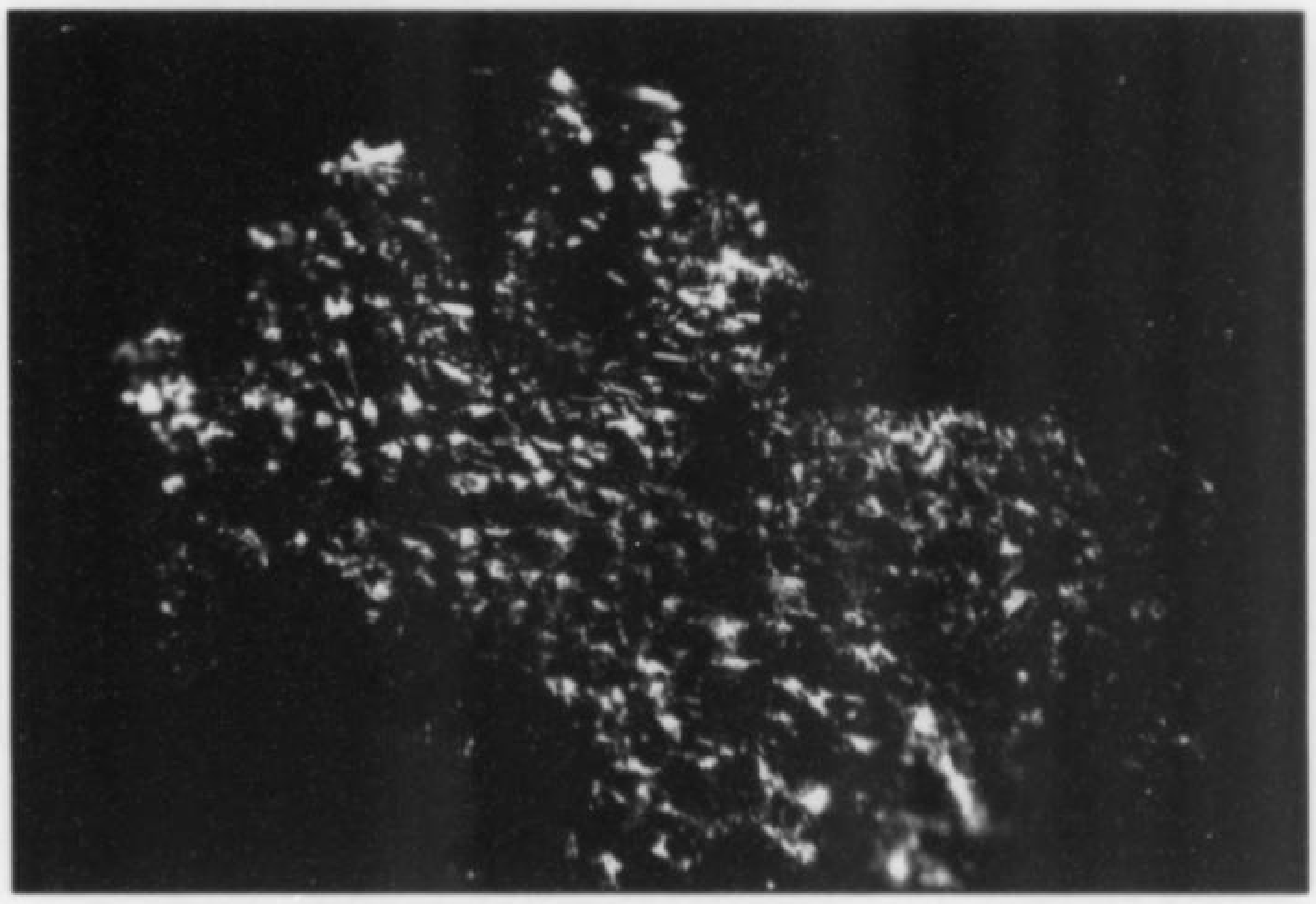

Figure 19. Auriferous silver crystal leaf, 3 mm. Mark Mauthner collection and photo.

***Table 3.* Analyses of two silver samples. Copper and mercury were analyzed for but were not detected.**

	ENG2-M12	*ENG3-M10*
Weight % Concentration		
Au	57.04	54.27
Ag	42.02	43.96
Sb	0.92	1.13
TOTAL	99.98	99.36
Normalized Atomic Concentration		
Au	42.17	39.80
Ag	56.73	58.87
Sb	1.10	1.33
TOTAL	100.00	100.00

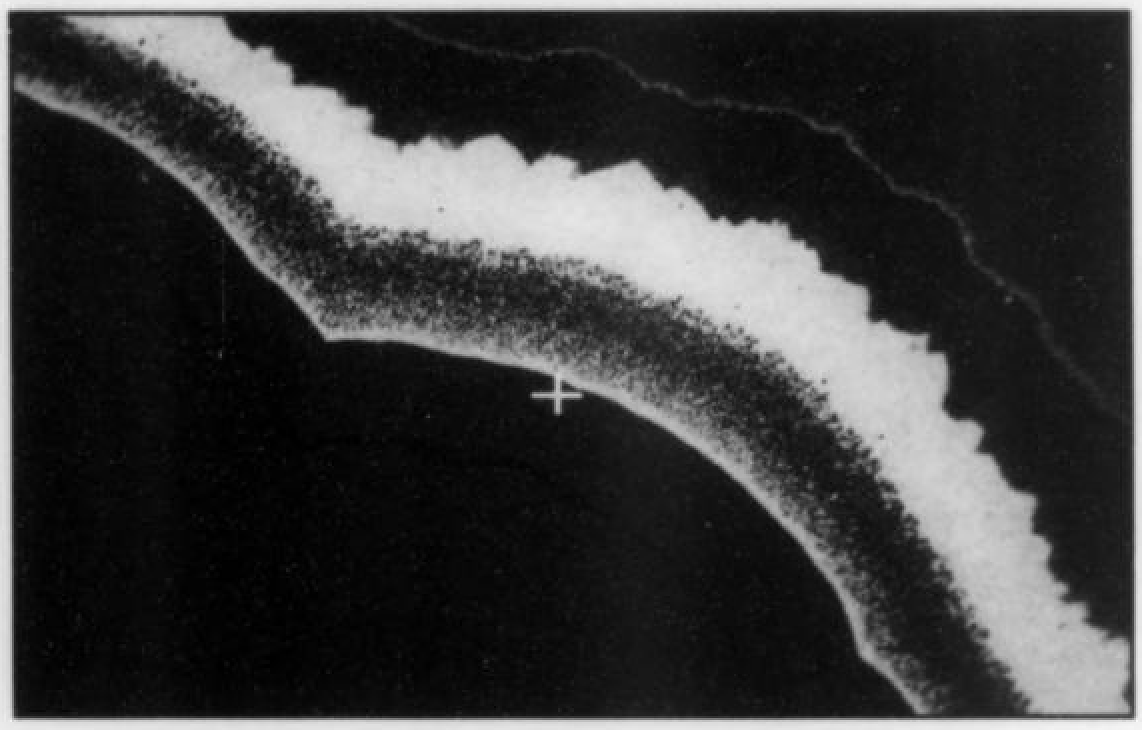

***Figure 20.* Back-scatter electron image of "allemontite" consisting of an intimate intergrowth of 95% stibarsen and 5% arsenic in the light-colored bands and 50% stibarsen/50% arsenic in the gray bands. U.B.C. collection; Mark Mauthner photo.**

Stibarsen SbAs

Stibarsen occurs with arsenic as an intimate, layered mixture ("allemontite") which forms reniform masses up to 30 cm in breadth. Analyses of the layers have shown them *not* to be pure stibarsen interlayered with pure arsenic, as one might intuitively guess by looking at a polished sample. Most layers are some mixture of both minerals with the layer boundaries generally being defined by changes in grain size. Occasionally, a layer of relatively pure stibarsen or arsenic occurs, but this seems to be the exception. Most of this material was found in the upper levels of the mine and discarded during hand-cobbing of the ore. It is still being found on the fifth level (Bonanza Shoot) of the "E" vein.

Stibnite Sb_2S_3

Gwillim (1900) notes that the Engineer orebody "carries values in free gold, also some stibnite." However, no Engineer mine stibnite specimens are currently known, and it is suggested that the usage of "stibnite" may be synonymous with "antimony (stibnium)." Most of the work done at the time would have been in the allemontite-rich upper levels, and this source of antimony would have been the most obvious.

Tellurides

Telluride occurrences at the Engineer mine were first mentioned by Gwillim (1900). However, he states that none were found in the Geological Survey of Canada's samples. All other references to tellurides date back to this first document, which is at best secondhand, unsubstantiated information. Calaverite was first mentioned by Cairnes (1911), who referred to Gwillim's "gold telluride" as "telluride, apparently calaverite." The 1900 report of the Minister of Mines quotes from a prospectus from the Engineer Mining Company of Skagway that indicates the presence of tellurides. It is further explained in the report that the Provincial Assayer did not find any tellurium in any of the samples. These samples were selected by the Company as representative of those which had been giving unfavorable fire assay results, due the "great presence of tellurides" compared to cyanide tests performed after the ore had been roasted. It is our opinion that the roasting effect was probably due to the presence of arsenic which, like tellurium, volatilizes readily upon roasting.

CONCLUSIONS

The occurrence of several minerals for which there is no physical evidence in the form of analyses or specimens would suggest that they were originally misidentified. These minerals include native bismuth, stibnite and tellurides, reports of the occurrence of which have unfortunately persisted in the literature.

Two distinct periods of mineralization are seen in the Engineer mine orebodies. The first produced low-grade dilation veins and may well have been related to Cretaceous movement along the Llewellyn Fault. The second period was clearly an epithermal event, possibly related to Tertiary magmatic activity, during which mineralizing fluids followed pre-existing structural weaknesses. Clastic textures of some of the gold/roscoelite mineralization, and minor faulting within the epithermal veins makes it apparent that more than a single episode was involved in this event. Most of the minerals of interest, ore as well as specimens, were emplaced during this period.

COLLECTING

The Engineer mine is currently being worked for gold by Ampex Mining. The operators, Warren Arnholtz and Swede Martensson, are setting aside material for the specimen market. It may also be worthwhile, from a collector's point of view, to sift through the 100-level dump material for "allemontite." A few nice pieces were found by one of us (MM) within a few hours of combing the surface of the dump.

ACKNOWLEDGMENTS

We thank Warren Arnholtz and Swede Martensson for their information, specimens, access to the property and exemplary northern hospitality. Discussions with Gary Johannson, Tom Schroeter and Mitch Mihalynuk are much appreciated, as were the review and comments on the initial draft by Joe Nagel. Thanks also go to George Robinson for providing specimen information, and to Jeff Scovil for photographing the C.M.N. specimen.

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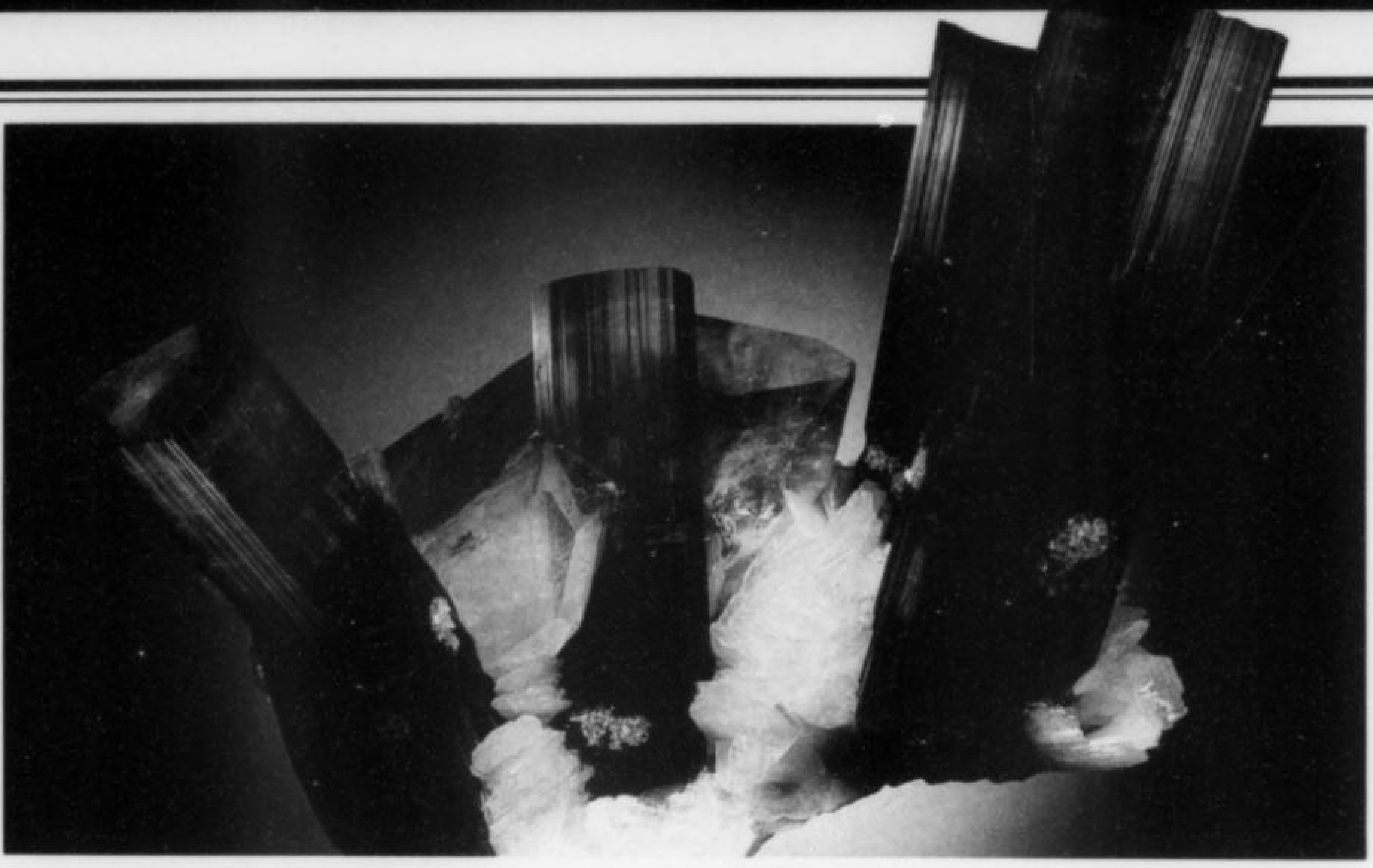

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Famous Mineral Localities

THE RÍO TINTO MINES
HUELVA, SPAIN

Gonzalo García García
Grupo Mineralogista de Madrid
E. T. S. de Ingenieros de Minas
C/Ríos Rosas, 21
28003 Madrid, Spain

Río Tinto, perhaps the oldest major mine in the world, exploits huge massive pyrite orebodies and their associated gossans. Fine native copper, large barite crystals, gratonite crystals, spectacular formations of post-mining sulfates, and the world's finest voltaite are among the features of this historic deposit.

INTRODUCTION

The famous Río Tinto mines are located in Huelva province in extreme southwestern Spain. They represent probably the oldest major mining area in the world, and were for many years the leading producer of copper in Europe. A variety of interesting archeological and mineralogical specimens have also come from the mines since the 19th century, and can be seen in museums throughout Europe. The name Río Tinto ("Red River") comes from the iron-stained local river of the same name.

HISTORY

Mining in the Río Tinto area seems to have begun during the Phoenician period (before the 10th century B.C.). Archeological evidence is extensive regarding ancient work for the recovery of gold, silver and copper. Many Roman-period mining and metallurgical artifacts are regularly brought up with the ore and come tumbling out into the dumpers. As might be expected, the quantity and quality of these historical treasures have placed archeologists at odds with the mining company; if allowed, archeologists would quite cheerfully bring a complete halt to gossan production and rope off the entire space of the mine for the purpose of detailed archeological excavations. Consequently, in order to remain in operation, the mining company has felt compelled to place limits on archeological access, and has set aside a small area as an archeological reserve. But, in my experience, the areas of potentially greatest archeological interest are much larger.

As an indication of the scope of ancient mining, sixteen million tons of Roman slag have been identified, with a high silver and copper content. It was not until 1873, however, that large-scale modern mining began in the district. British companies set up a colonial-style system of operation and commenced open-cast mining. This was a major departure from the traditional operations involving numerous small-scale pits and shallow underground workings; metal production of the district began to increase.

An industrial complex grew up around the district, making it

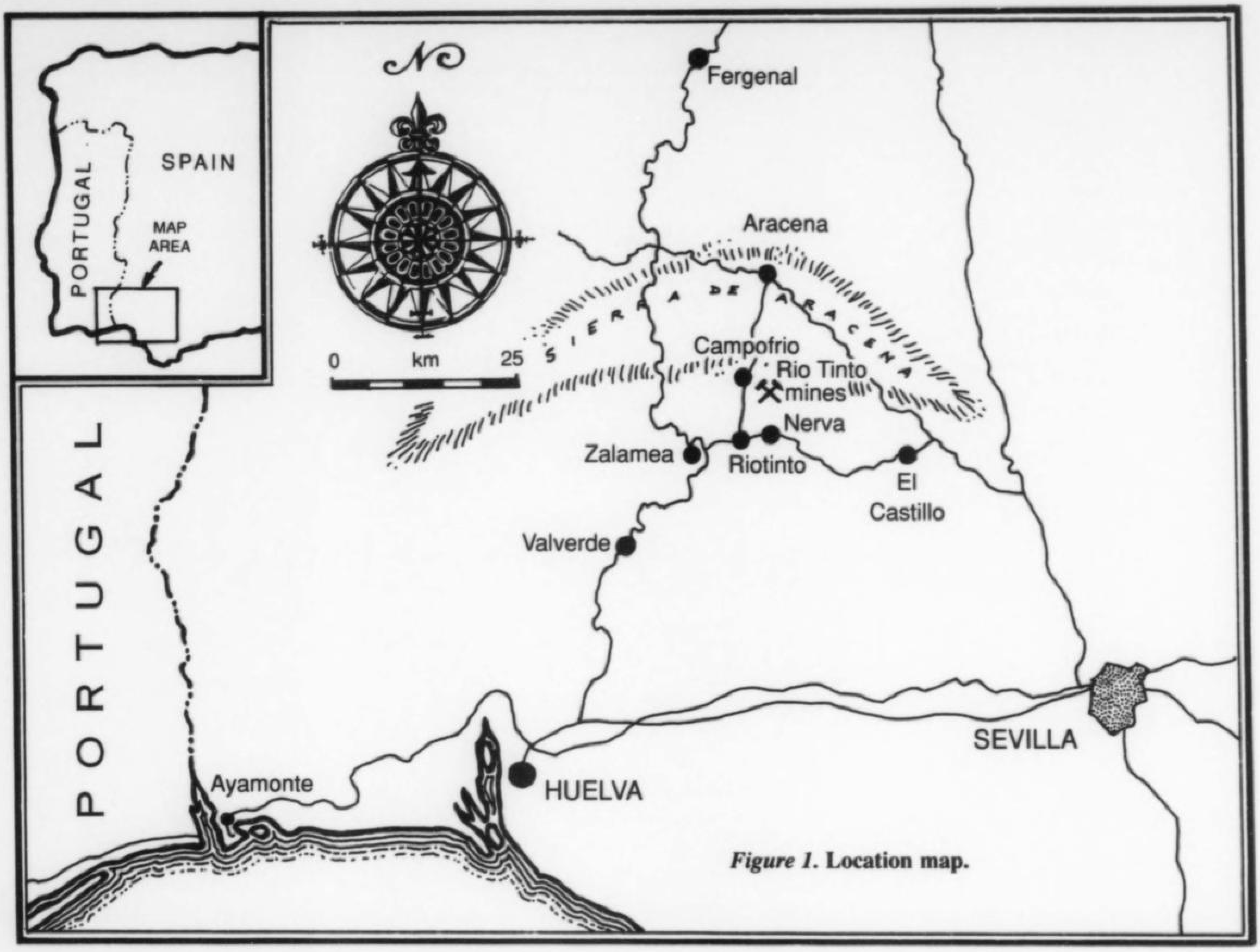

Figure 1. **Location map.**

increasingly self-sufficient. A foundry, electric power station, workshops of all kinds and railway connections to the company-owned port facilities at Huelva were constructed. Eventually over 14,000 workers were employed, utilizing 300 km of railway track, 2,000 ore wagons and 150 locomotives, all within the 23-square-km concession.

In 1954 the mines came under Spanish ownership, and Río Tinto Company Ltd. later merged with the Zinc Corporation in 1962 to form the London-based Río Tinto Zinc Corporation. Meanwhile the Spanish-owned Compañia Española de Minas de Ríotinto, S.A., continued to operate the mines, modernizing the facilities and improving working conditions. Over the years the company has changed its name several times (e.g. Río Tinto Patiño, then Unión Explosivos Río Tinto). Technical improvements have continued, particularly the construction of a new gossan concentrator for gold and silver extraction in 1970.

In 1977 the Río Tinto Minera, S.A., was founded. Under this company the Cerro Colorado workings were expanded and the Alfredo shaft was modernized, including the installation of conveyor belts for ore transport.

In 1987 falling copper prices precipitated a crisis. Work at the Alfredo shaft was halted and the Cerro Colorado operation was restricted to the mining of gossan only; this, however was accompanied by increased production (30 million tons annually), yielding 5,000 to 6,000 kg of gold per year.

The final product of the Río Tinto operation today is bullion (98% silver, 1% gold, plus minor Cu, Pd, Hg, etc.). The Atalaya open pit, which produced crude pyrite only, was shut down in 1992. Gold reserves are expected to run out in January of 1996, at which time mining may cease at Río Tinto after over 3,000 years of activity. However, a project turning again to copper extraction is currently being developed under the direction of Professor Pla Ortiz de Urbina, and may extend the life of the mine.

GEOLOGY

Spain has long been a major world producer of pyrite, due almost entirely to production from mines along the Hispano-Portuguese pyrite Belt in Huelva Province. This belt extends for some 230 km, from Sevilla Province to the Atlantic Coast; over this distance it is estimated to have contained over 1 billion tons of ore containing 39–43% Fe, 2–6% Cu+Pb+Zn, 5–40 ppm Ag and 0.2–1.5 ppm Au. Of this total, roughly 300 million tons have been mined to date.

The pyritic deposits are associated with Lower Carboniferous marine volcanic rocks and intercalated slate, quartzite, sandstone and limestone. These rocks are overlain by the Carboniferous Culm Formation (conformable slates and graywackes), and rest upon Upper Devonian slates, quartzites, sandstones, limestones and conglomerates. The entire stratigraphic sequence was folded and metamorphosed during the Hercynian Orogeny, the major Late Paleozoic orogeny in Europe (Vázquez Guzmán, 1989).

The most important mines on the Pyrite Belt are the Tharsis, the La Zarza and the Río Tinto. The several pyrite orebodies exploited at Río Tinto are related to an anticline within the so-called Río Tinto Syncline; they are located on the eastern extremity of the anticline. Individual workings include the San Dionisio, Filón Sur [South Lode], Planes-San Antonio, Filón Norte [North Lode] and the Cerro Colorado. These deposits are thought to have originally formed a single, continuous stratum 5 km long by 750 meters wide and about 40 meters thick, containing half a billion tons of ore. But

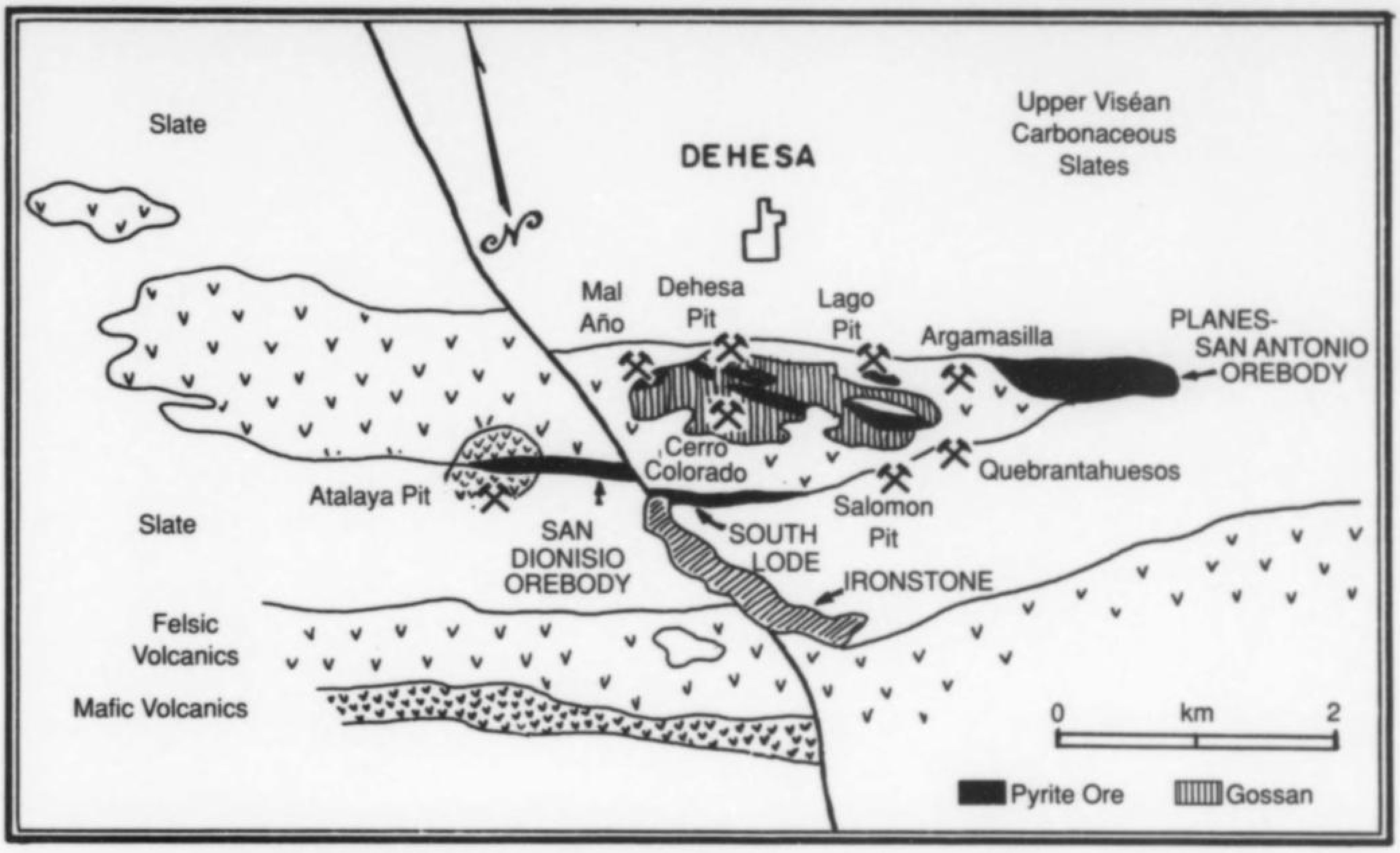

Figure 2. **Geologic map of the deposits in the Rio Tinto area (Williams *et al.*, 1975).**

much of it has weathered away leaving an extensive gossan still rich enough to be mined, at least in part.

The largest of the Río Tinto orebodies, the San Dionisio, was exploited by the Atalaya open pit and also the Alfredo shaft which served the underground workings. The Cerro Colorado workings are in the gossan where copper may be mined in the future. Except for the small Masa Valle deposit (in carbonaceous slates and rhyolitic ash), all of these orebodies occur associated with pyroclastic felsic rocks penetrated by chimneys, pipes and a multitude of small sulfide veins forming stockworks.

The pyritic orebodies occur as massive, stratabound deposits near volcanic centers, either overlying volcanic rocks or intercalated with shales and tuffs (Strauss and Madel, 1974). The mineralization is considered to be of volcanic-sedimentary origin intimately associated with felsic volcanic rocks, primarily sodic to potassic rhyolites and spilitized dacites (Schermerhorn, 1970). Some authorities believe the origin is related to a zone of subduction and associated island arc formation (Williams *et al.*, 1975), whereas others see the volcanicity as representing magmatic activity in an intra-continental basin (Munhá, 1979). In any case, all agree that the massive pyritic beds formed as the result of submarine metalliferous volcanic exhalations.

WORKINGS

Corta Atalaya

The Corta Atalaya (= Atalaya open pit) was opened in 1907 on the San Dionisio orebody. It currently has an elliptical or ovoid shape measuring 1,200 meters on the long axis, 906 meters across and 325 meters deep. Atalaya, with 26 bench levels at 12.5-meter intervals, is one of the most spectacular open pits in the world. In recent times it yielded 1 million tons of pyrite a year, but is now closed.

Pozo Alfredo

The Pozo Alfredo (= Alfredo shaft) is reached via a connecting tunnel and access ramp at the bottom of the Atalaya open pit. The workings are extensive, reaching a depth of 562 meters in the porphyritic portion of the San Dionisio orebody. Initially operated around the turn of the century, it employed the room-and-pillar method but later switched to cut-and-fill. The Alfredo workings consist of 45 levels at 12.5-meter intervals, with access down to level 32 via a headframe shaft, as well as the ramp from the 23rd level in the Atalaya pit.

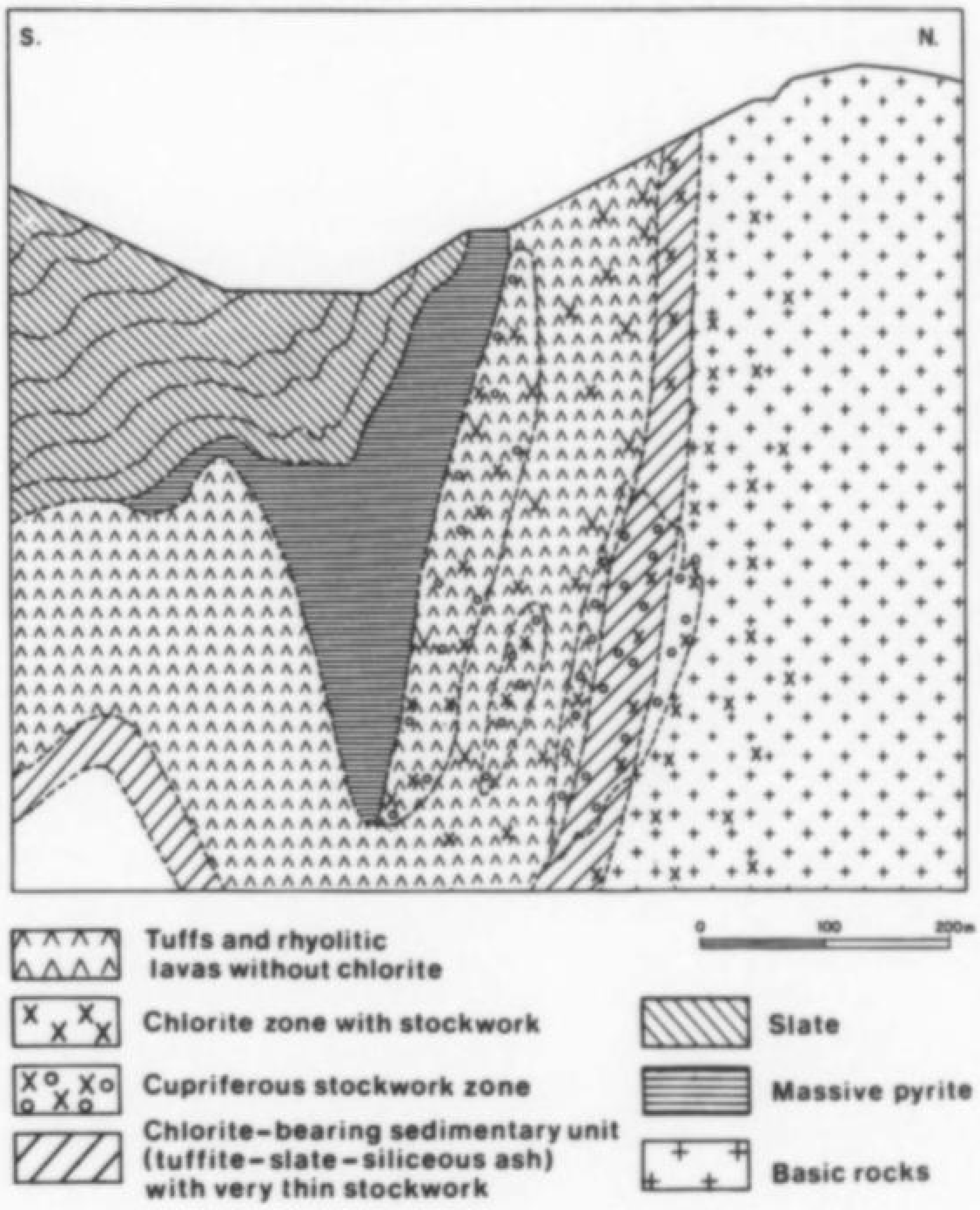

Figure 3. **Geologic cross-section through the San Dionisio orebody (IGME, 1982).**

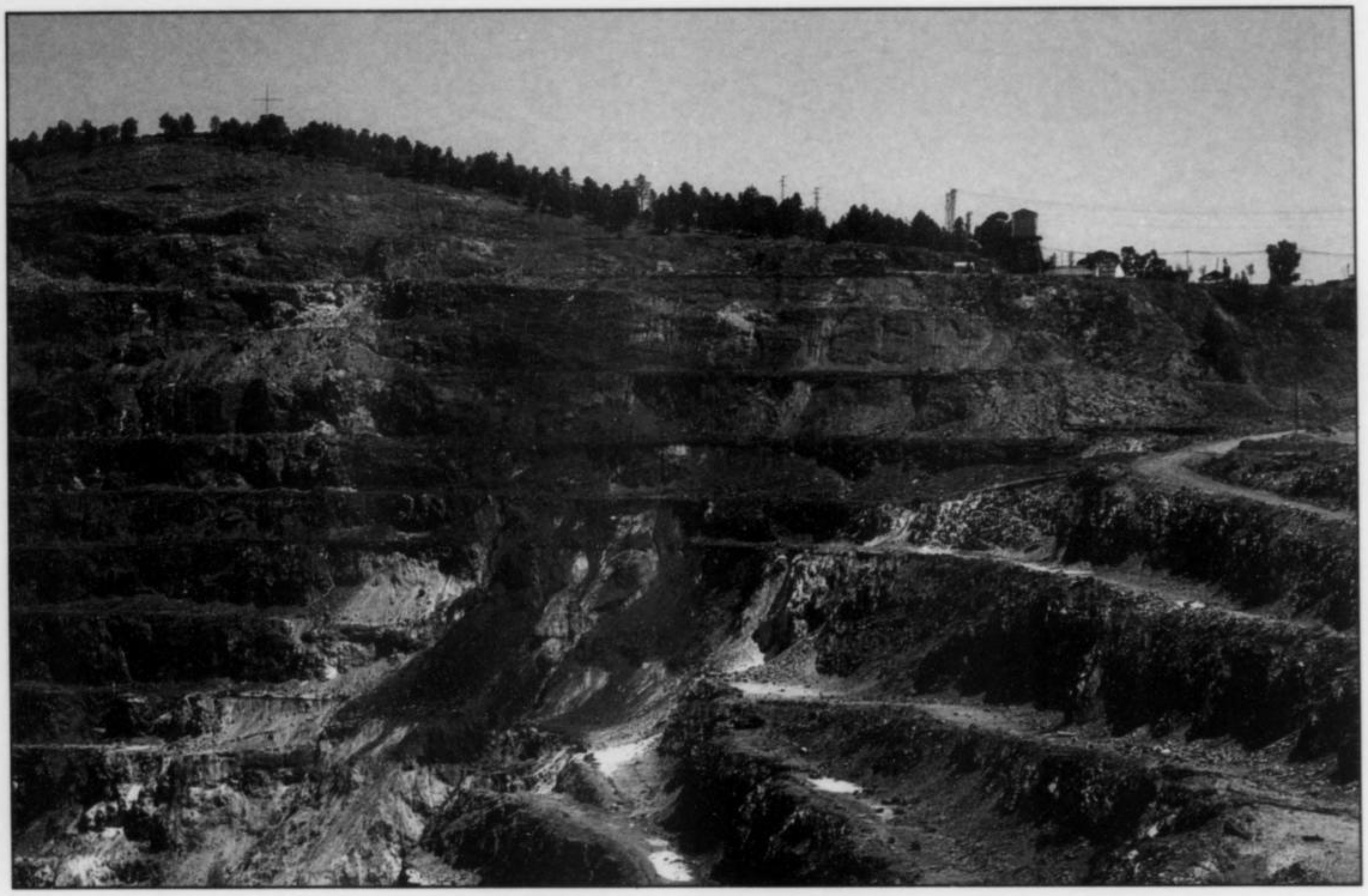

Figure 4. **The Atalaya open pit. Gonzalo García García photo.**

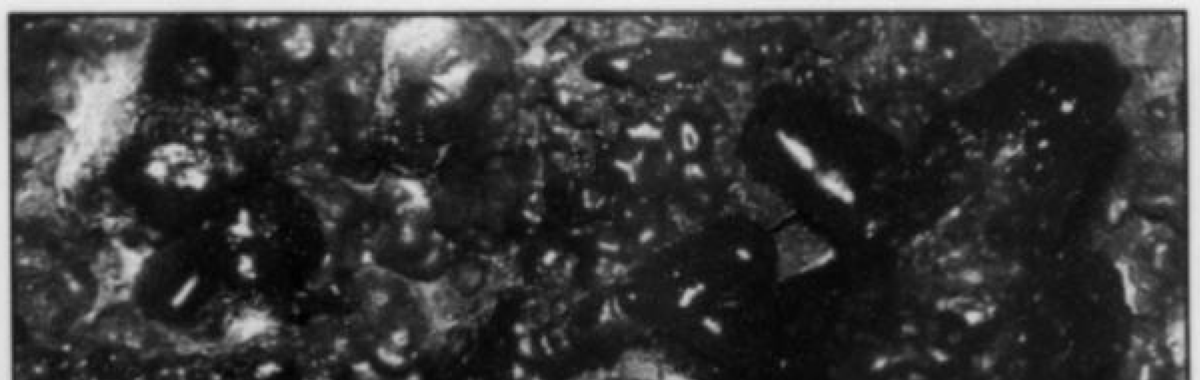

Figure 5. **Botryoidal chalcanthite on level 33 of the Alfredo shaft. Gonzalo García García photo.**

Figure 6. **Chalcanthite stalagmites on level 33 of the Alfredo shaft. Photo by Francisco Piña Miró.**

Figure 7. **Room 18 on level 33 of the Alfredo shaft; chalcanthite stalagmites. Gonzalo García García photo.**

Figure 8. **Chalcanthite stalagmite, 20 cm, in place on level 33 of the Alfredo shaft. Francisco Piña Miró photo.**

Figure 9. **Chalcanthite stalactites to 50 cm in length, on level 33 of the Alfredo shaft. Gonzalo García García photo.**

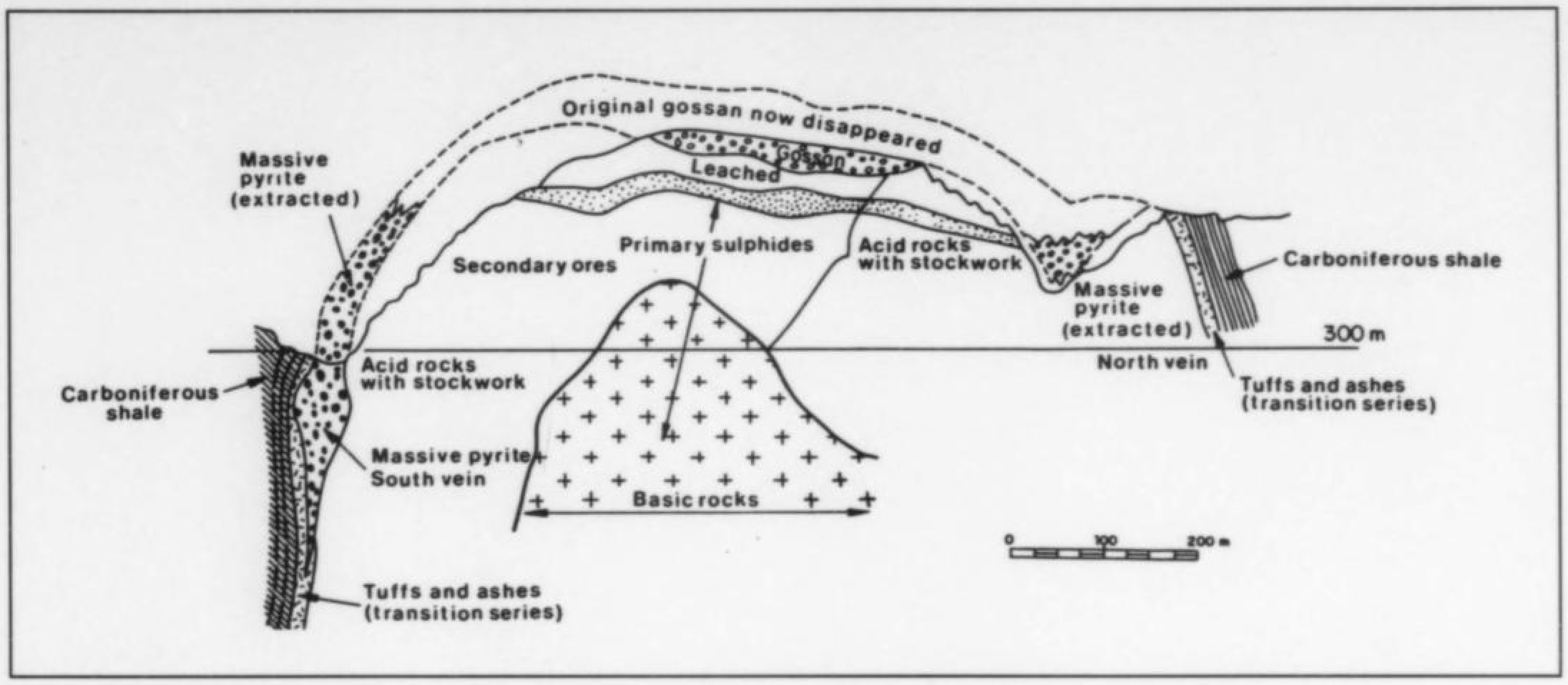

Figure 10. **Cross-section through the Cerro Colorado orebody (IGME, 1982).**

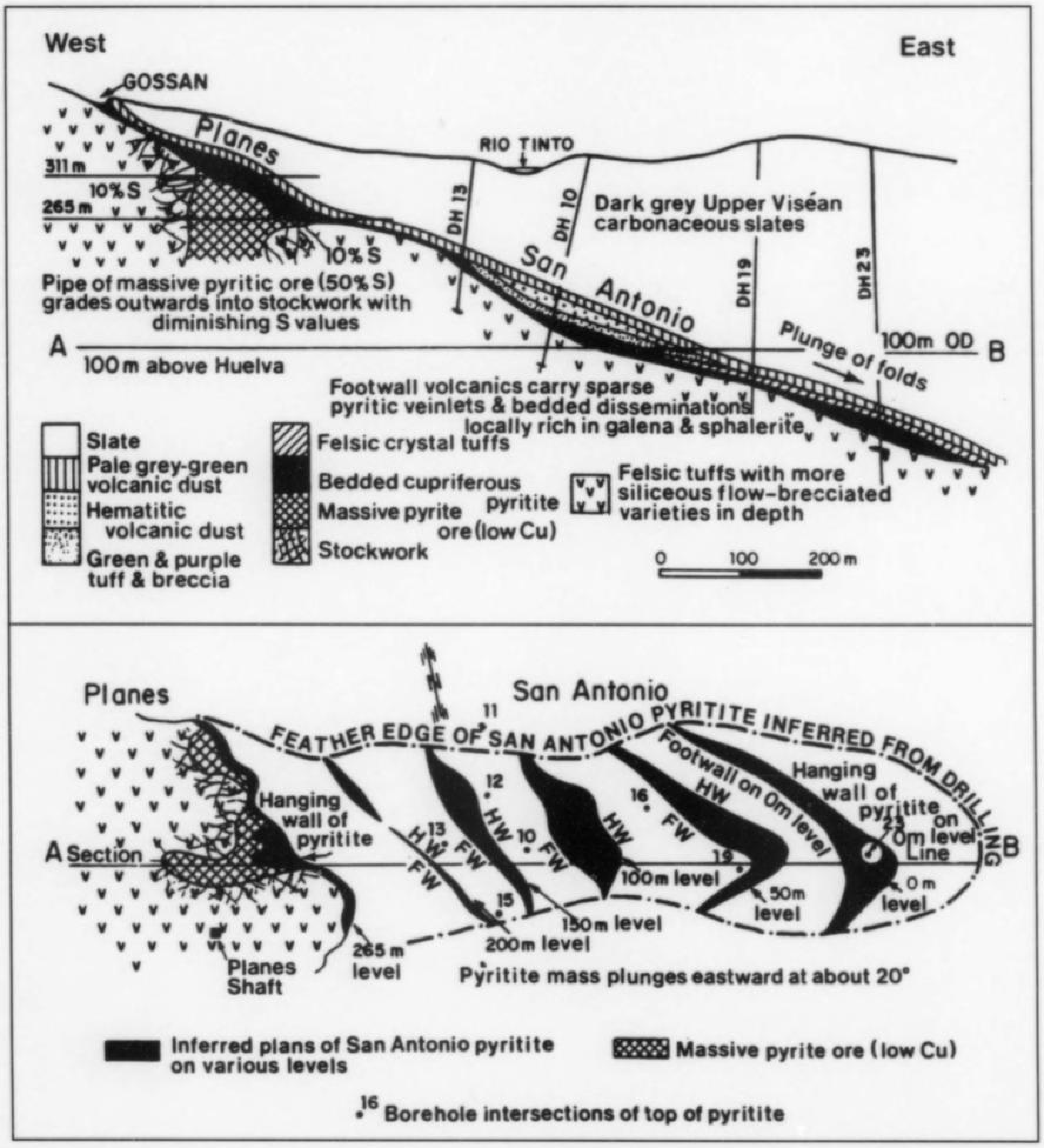

Figure 11. **Longitudinal section *(top)* and plan of the Planes-San Antonio deposit showing the spatial relationship between the Planes stockwork pipe or chimney (left) and the Planes-San Antonio strataform sheet (Williams *et al.*, 1975).**

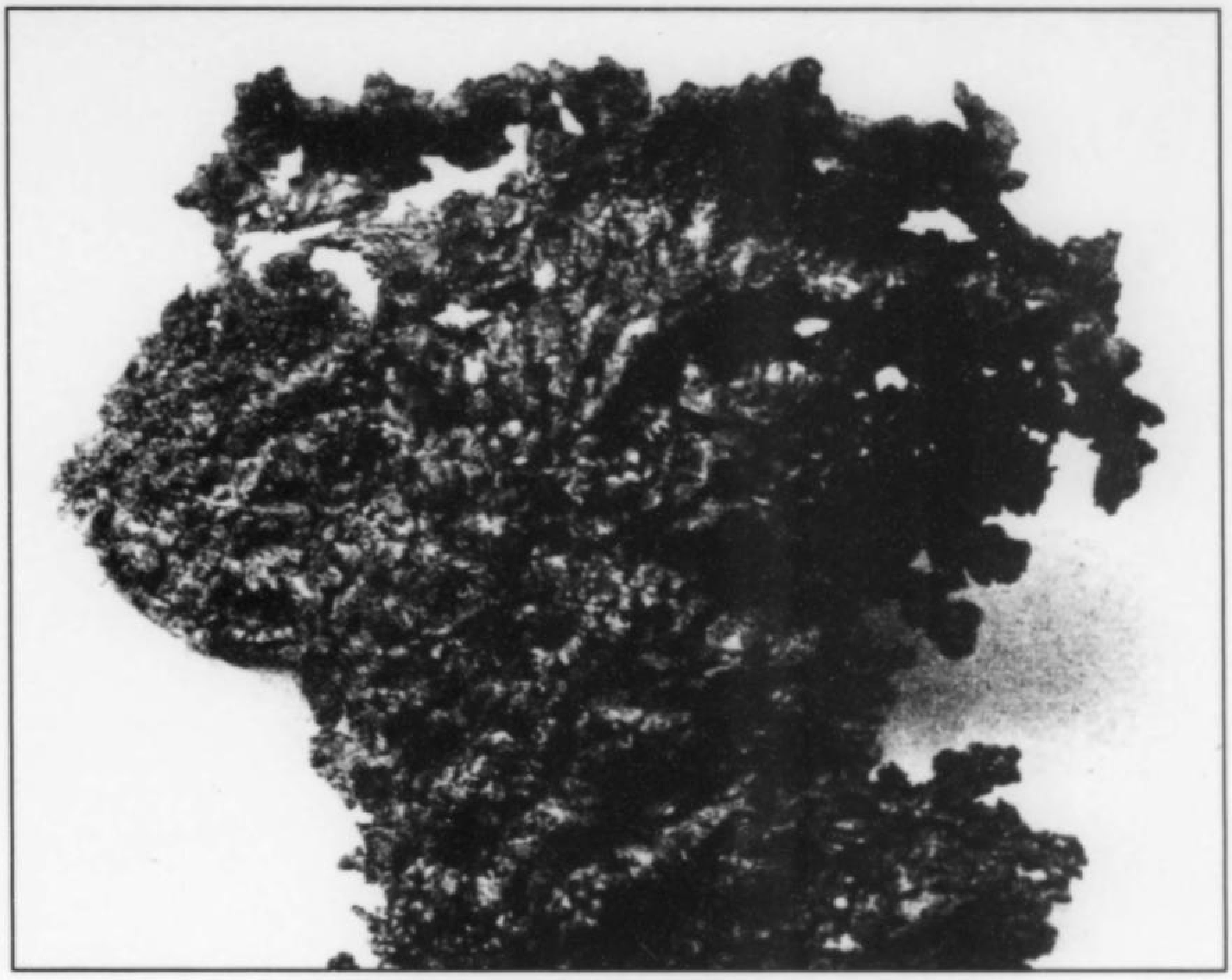

Figure 12. **Arborescent native copper specimen from Rio Tinto illustrated in Calderón (1910).**

Mine water has become quite acidic (pH = 2 or less) due to reaction with the sulfide ore. In 1987 and 1989 temporary flooding below level 33 literally dissolved a power substation, a mandibular crusher and several hundred meters of transport belts. The Pozo Alfredo is currently closed.

The Grupo Mineralogista de Madrid opposed the closing of the Pozo Alfredo, proposing instead that the shaft be reconditioned as a tourist attraction. As at other important mines in Spain, however, support from the general public and the mining companies was lacking. Nevertheless, many people still hope that the Río Tinto mine will someday be transformed into a mining museum and tourist site.

Cerro Colorado

The Cerro Colorado (= Red Hill, named for its huge ferruginous gossan) carried many ancient workings but was reopened as an open pit operation for copper in 1966. As copper prices fell, however, the higher-grade portions of the oxidized copper zone were extracted, leaving much of the remainder uneconomical to mine. Gold and silver values in the gossan now support the operation, the only one still active at Río Tinto.

Others

Numerous other less important workings exist in the area, including the Planes-San Antonio orebody (worked intermittently from Roman times up until 1950), and the Filón Sur and Filón Norte. For the mineral collector and historian there are many fascinating remains including Roman furnaces, abandoned processing facilities, shunting yards for steam engines, and an incredible Railway Museum.

MINERALS

The list of minerals which have been found at Río Tinto over the years is extensive (see Table 1). Most of them are associated with the gossan and supergene zones of the orebodies which, being the richest in copper, have been heavily exploited. In old collections and museums it is possible to see specimens of azurite, malachite, cuprite, tenorite, native copper and other typical species from Río Tinto. With the exception of native copper, however, specimens of these minerals are now almost impossible to find on the market.

The zone of secondary enrichment commonly carried chalcocite, bornite and covellite, but only in massive specimens of little interest to the collector. A large suite of complex sulfates occurs in a contact zone between the pyrite orebody and chlorite. The deeper, unaltered portions of the orebodies are occasionally crossed by thin veins containing sulfides and sulfosalts including sphalerite, galena, tetrahedrite and gratonite.

The following descriptions will deal only with those species which, because of their rarity or quality, are of particular interest to collectors. Nevertheless, this discussion is surely incomplete. Mineral collectors in southwestern Spain have never been particularly active or interested in documenting the minerals from important occurrences, so the available source material is sparse regarding earlier finds. Calderon (1910) mentioned a number of species from Río Tinto but gave practically no descriptive information.

Barite $BaSO_4$

A plumbian variety of barite has been found at Río Tinto, in tabular to prismatic-looking crystals up to 5 cm long. The smaller crystals tend to have complex terminations. Many crystals are stained brown by iron oxides, but some excellent colorless, transparent specimens have also been recovered. The lead-rich variety was also quite abundant at the nearby Cerro Salomón area.

Copper Cu

Native copper has been found in large dendritic masses and crystalline arborescent growths; one is illustrated in Calderón's (1910) *Los Minerales de España*. The individual crystals are

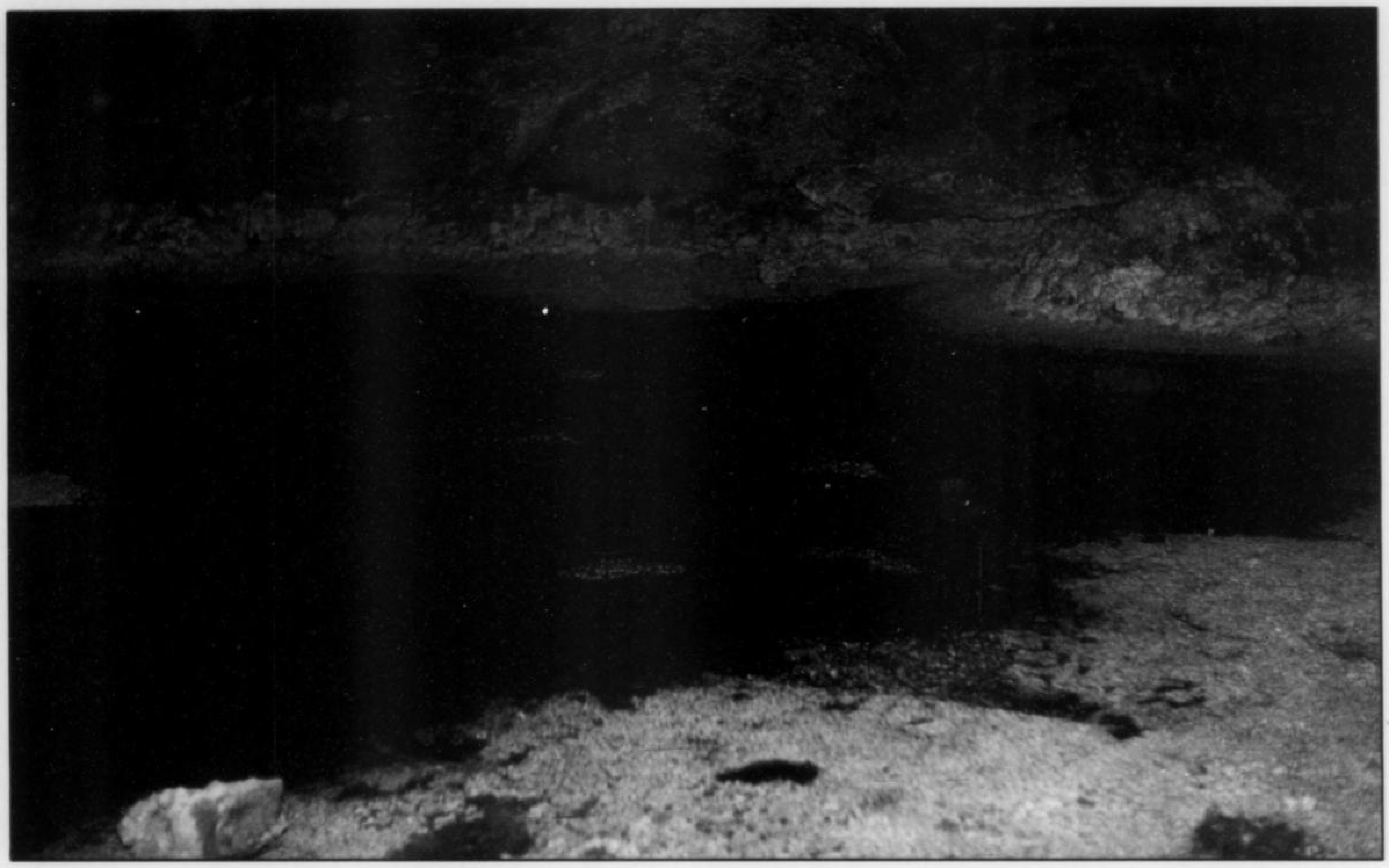

Figure 13. **Sulfate-rich pool on level 33 of the Alfredo workings. Gonzalo García García photo.**

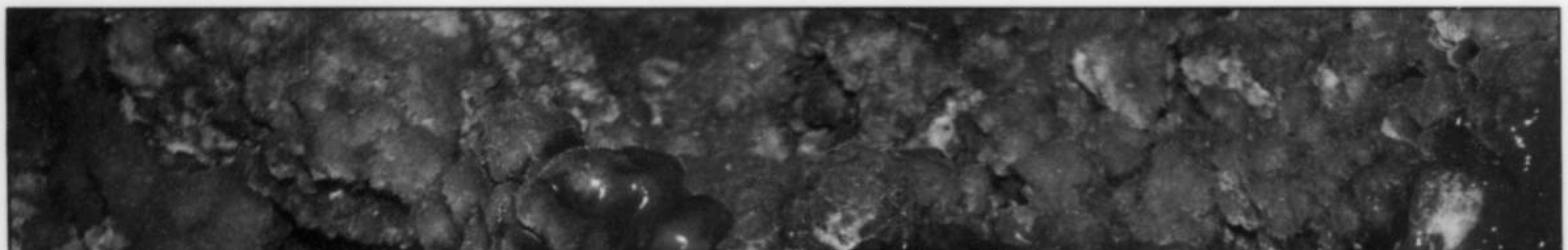

Figure 14. **Cuprian melanterite and chalcanthite growths surrounding a sulfate-rich pool in room 6, level 33 of the Alfredo shaft. The view is 50 cm across. Gonzalo García García photo, December 1993.**

Figure 15. Lead-rich barite crystal, 1.5 mm, from Cerro Colorado. Gonzalo García García collection and photo.

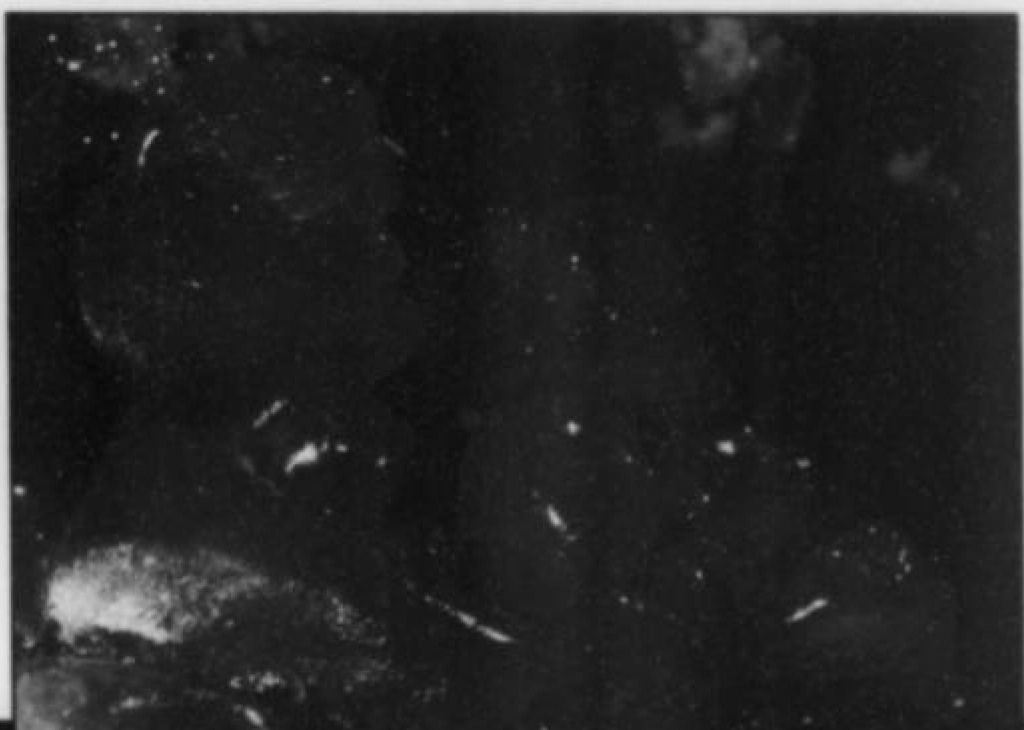

Figure 16. Cuprian melanterite in place on level 33 of the Alfredo shaft; the view is about 25 cm across. Francisco Piña Miró photo.

Figure 17. (below) Yellow copiapite with red botryogen, 6 cm, from level 33 of the Alfredo shaft. Gonzalo García García collection; Francisco Piña Miró photo.

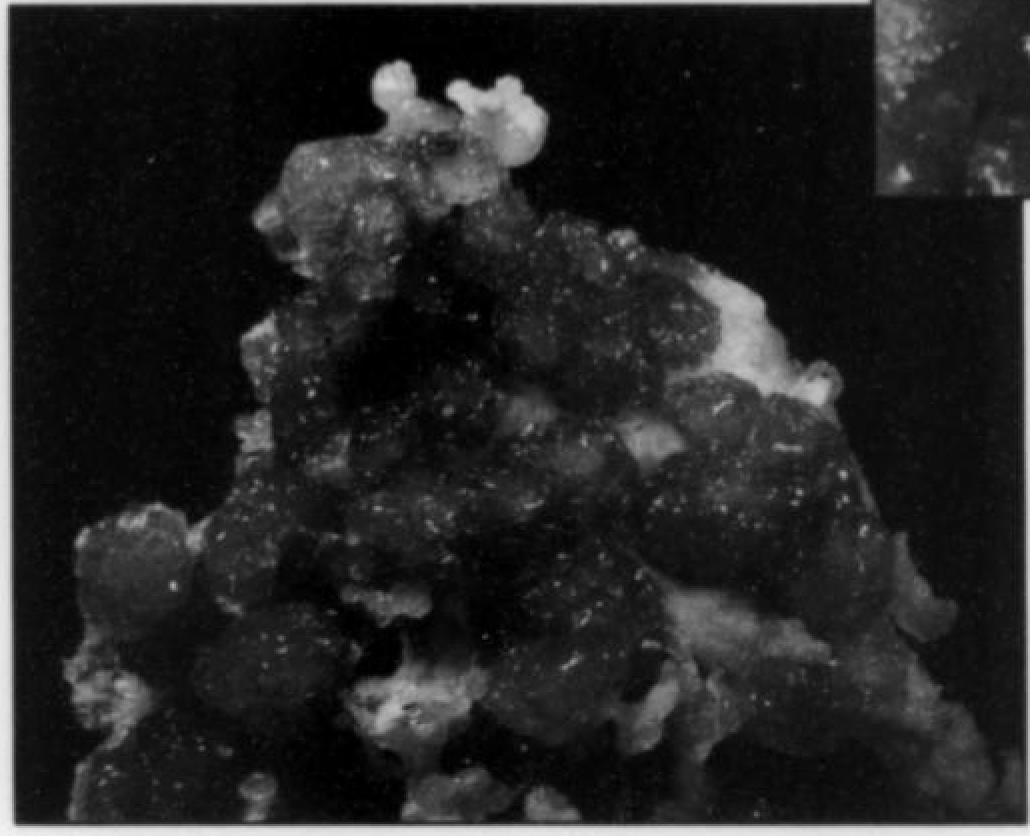

Figure 18. Pink coquimbite with halotrichite, 5 cm, from level 33 of the Alfredo shaft. Gonzalo García García collection; Francisco Piña Miró photo.

Figure 19. (right) Superb, 3-mm cuboctahedral-dodecahedral voltaite crystal on matrix from level 29 of the Alfredo shaft. Gonzalo García García collection; Francisco Piña Miró photo.

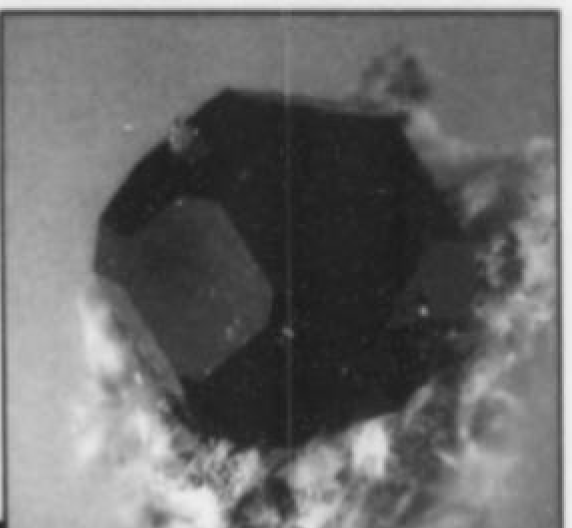

Figure 20. Voltaite crystals to 7 mm from level 33 of the Alfredo shaft. James Catmur collection; Francisco Piña Miró photo.

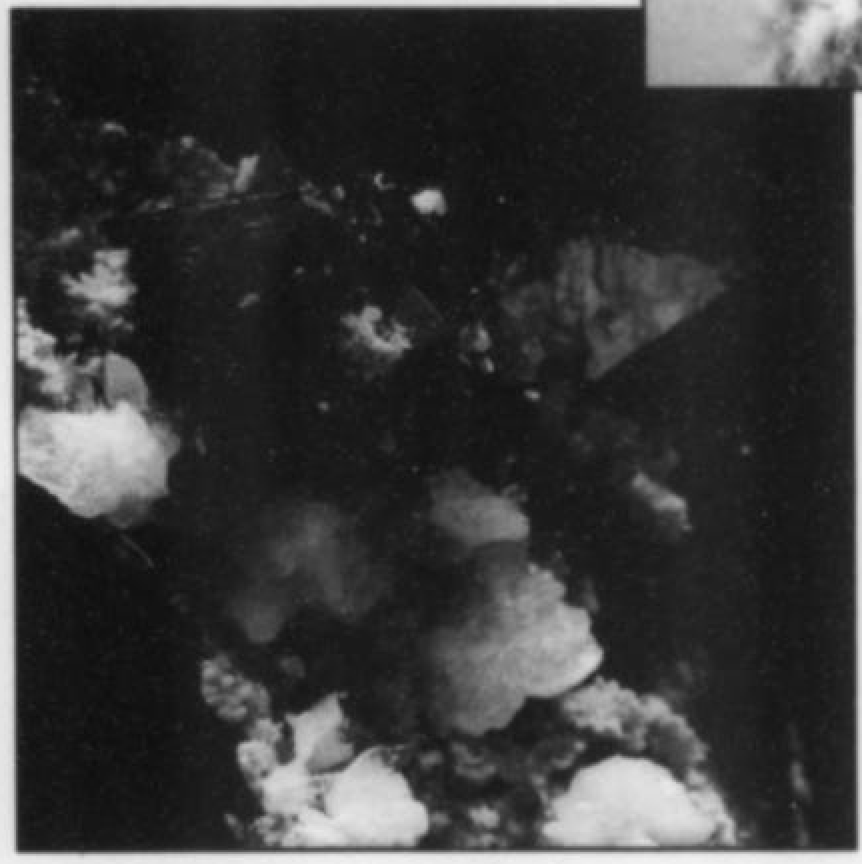

Figure 21. Voltaite octahedrons to 5 mm on matrix from level 33 of the Alfredo shaft. Gonzalo García García collection; Francisco Piña Miró photo.

generally cuboctahedral in habit, sometimes coated with black tenorite. At Cerro Colorado it is still possible to find specimens, although in many cases they are hidden by surface oxides.

Goethite FeO(OH)

Beautiful iridescent goethite is very common at Cerro Colorado, as in most of the other mines in the Pyrite Belt. (Fantastic specimens have come from the Tharsis mine in particular.) It occurs in botryoidal to stactitic habits with beautiful colors and luster. Some exceptionally large cavities lined with goethite have been found in the gossan.

Figure 22. **Prismatic gratonite crystals to 2 mm on pyrite from level 23 of the Atalaya open pit. Gonzalo García García collection; Francisco Piña Miró photo.**

Gratonite $Pb_9As_4S_{15}$

Gratonite, which collectors usually associate with the mines at Cerro de Pasco, Peru, was found at Río Tinto in the 1980's. Only a single short-lived occurrence on level 23 of the Atalaya open pit has been encountered, extending to the same level of the Alfredo shaft. Unfortunately, although hundreds of specimens were found, they were nearly all badly damaged in transport.

The gratonite forms carpets and druses on massive pyrite, as steel-gray prismatic crystals with three-faced rhombohedral terminations. Most of the crystals are small, not exceeding 3 mm.

Specimens of gratonite are usually overvalued in the Río Tinto area, and can be purchased more economically in Madrid.

Table 1. **Metalliferous minerals reported from the Río Tinto mines. Mineral names in bold have been confirmed during the course of the current study. Starred* minerals were reported by Calderón (1910). Double starred** minerals were reported by Galan y Mirete (1979).**

Arsenopyrite*	FeAsS
Azurite*	$Cu_3(CO_3)_2(OH)_2$
Barite*	$BaSO_4$ [+ Pb]
Bornite*	Cu_5FeS_4
Botryogen	$MgFe(SO_4)_2(OH)\cdot 7H_2O$
Chalcanthite*	$CuSO_4\cdot 5H_2O$
Chalcopyrite*	$CuFeS_2$
Chalcocite*	Cu_2S
Copiapite	$Fe^{2+}Fe_4^{3+}(SO_4)_6(OH)_2\cdot 20H_2O$
Copper*	Cu
Coquimbite	$Fe_2^{3+}(SO_4)_3\cdot 9_2O$
Covellite*	CuS
Cuprite*	Cu_2O
Epsomite	$MgSO_4\cdot 7H_2O$
Galena*	PbS
Goethite (Limonite*)	FeO(OH)
Goslarite	$ZnSO_4\cdot 7H_2O$
Gratonite	$Pb_9As_4S_{16}$
Gypsum	$CaSO_4\cdot 2H_2O$
Halotrichite	$Fe^{2+}Al_2(SO_4)_4\cdot 22H_2O$
Hematite*	Fe_2O_3
Jarosite	$KFe_6^{3+}(SO_4)_4(OH)_{12}$
Magnetite*	Fe_3O_4
Malachite*	$Cu_2(CO_3)(OH)_2$
Mallardite	$MnSO_4\cdot 7H_2O$
Melanterite*	$Fe^{2+}SO_4\cdot 7H_2O$
Metavoltine**	$K_2Na_6Fe^{2+}Fe_6^{3+}(SO_4)_{12}O_2\cdot 18H_2O$
Parabutlerite**	$Fe^{3+}(SO_4)(OH)\cdot 2H_2O$
Pyrite*	FeS_2
Sphalerite*	(Zn,Fe)S
Sulfur	S
Tenorite*	CuO
Tennantite*	$(Cu,Ag,Fe,Zn)_{12}As_4S_{13}$
Tetrahedrite*	$(Cu,Fe,Ag,Zn)_{12}Sb_4S_{13}$
Voltaite	$K_2Fe_5^{2+}Fe_4^{3+}(SO_4)_{12}\cdot 18H_2O$

Melanterite $FeSO_4\cdot 7H_2O$ and
Chalcanthite $CuSO_4\cdot 5H_2O$

The typical sulfates of copper and iron occur abundantly in the Alfredo shaft area, especially in rooms 6 and 18 on level 33. Spectacular formations of stalactites and stalagmites there reach several meters in length. Nearby acidic pools contain druses of magnificent, 1-cm, transparent, blue-green crystals of cuprian melanterite. Sadly, their conservation is almost impossible because of their strong tendency to oxidize and dehydrate if removed. Many visitors have come down to see the fantastic sulfate formations, including a television crew.

Voltaite $K_2Fe_5^{2+}Fe_4^{3+}(SO_4)_{12}\cdot 18H_2O$

The finest voltaites in the world are probably those from levels 29 and 33 in the Pozo Alfredo workings. Brilliant black crystals to 1.5 cm show a complex combination of cube, octahedron and dodecahedron. They have grown in a pyrite-chlorite matrix with capillary white halotrichite and fibroferrite (?). On level 33 it is extremely common in octahedral crystals to 3 mm on halotrichite, pink coquimbite, red botryogen, blue chalcanthite, brown jarosite, yellow copiapite and many other complex sulfates . . . a colorful assemblage. These specimens have unfortunately never been made available on the mineral market, despite efforts to convince the miners of their value to collectors.

VISITORS INFORMATION

The Río Tinto mines offer the visitor a rich mix of historic sites and facilities, local culture, and minerals. The description given here has been necessarily brief, omitting much more information of archeological and historical interest. Visitors will also enjoy seeing the Río Tinto Mining Museum, with its extensive exhibits devoted to mining archeology, and may even have the opportunity to take an underground tour. For further information contact the Fundación Río Tinto, El Valle, Minas de Ríotinto, 21660 Huelva, Spain.

ACKNOWLEDGMENTS

I would like to thank all of my friends at Ríotinto and Río Tinto Minera, S.A., in particular my companions in the Pozo Alfredo, and above all Pablo Fernández Diaz, who took me on a tour, during an unforgettable month, of the best treasures of the Alfredo mine. My friend Francisco Piña took the photographs, and my friends James R. Catmur and Paloma Fradejas translated my original manuscript into English.

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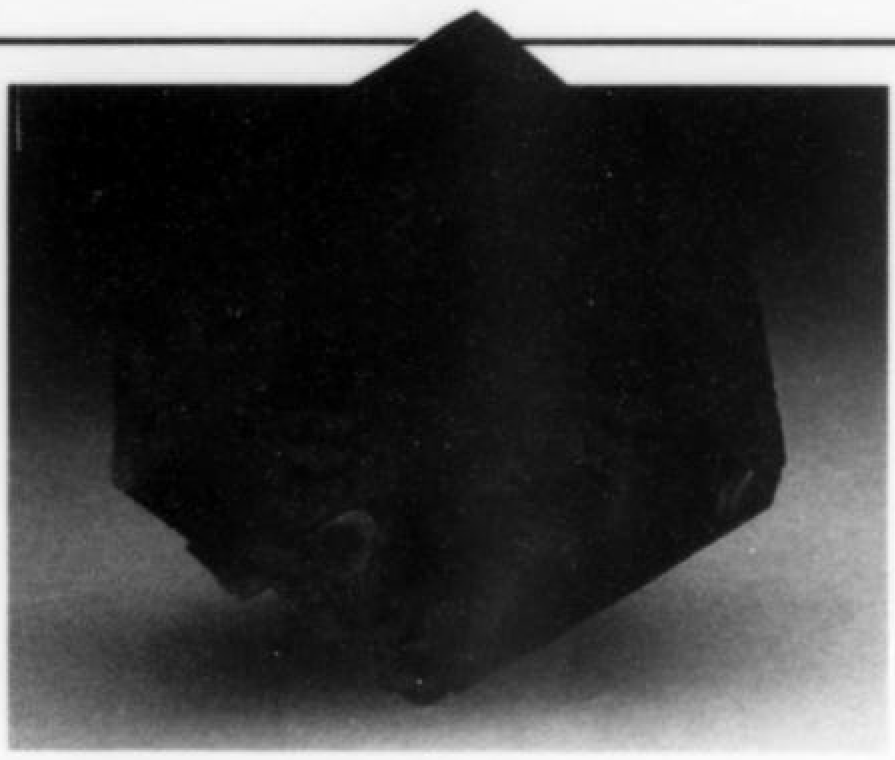

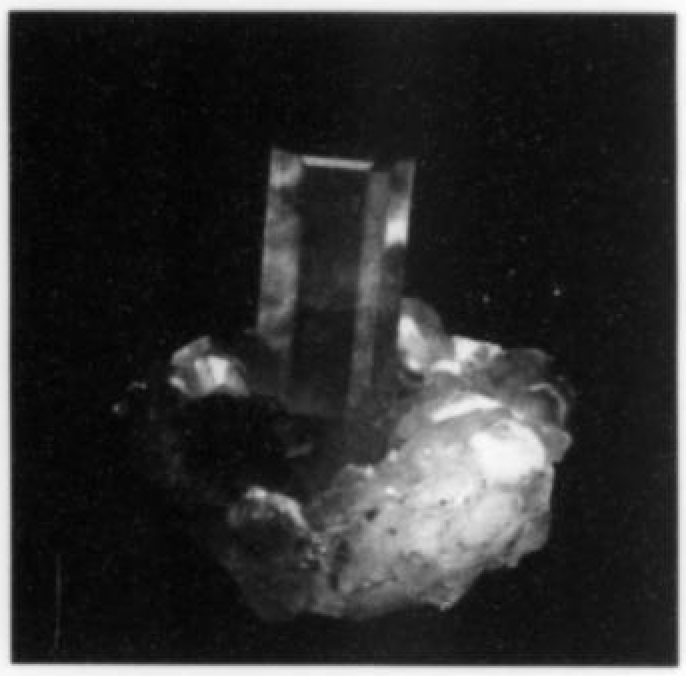

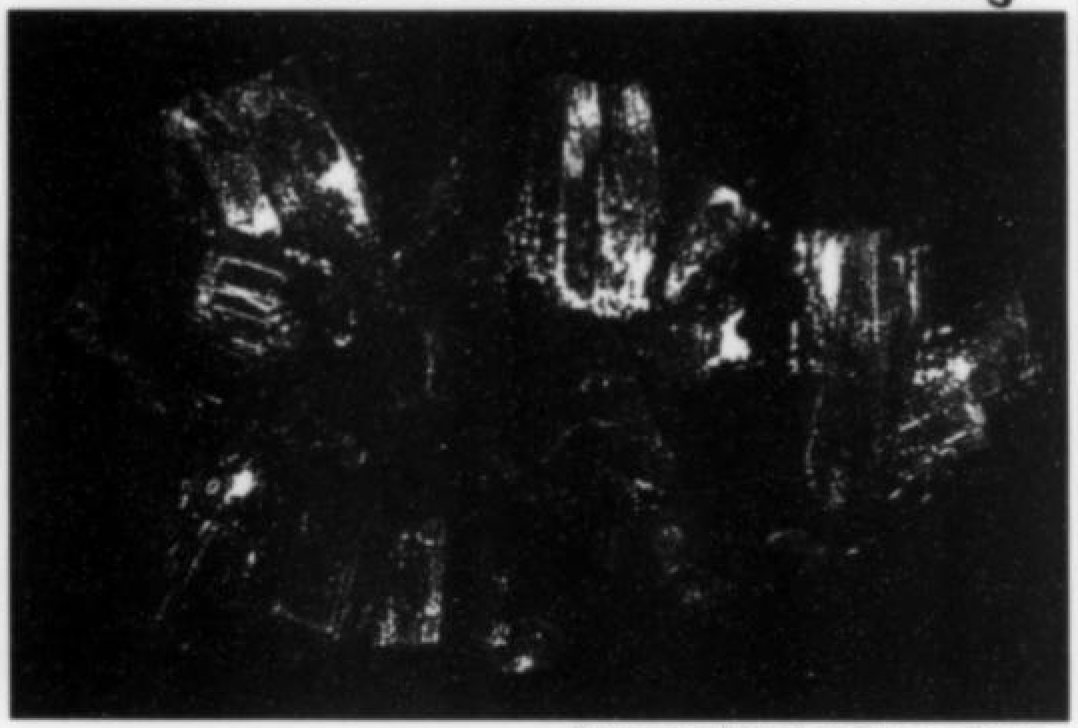

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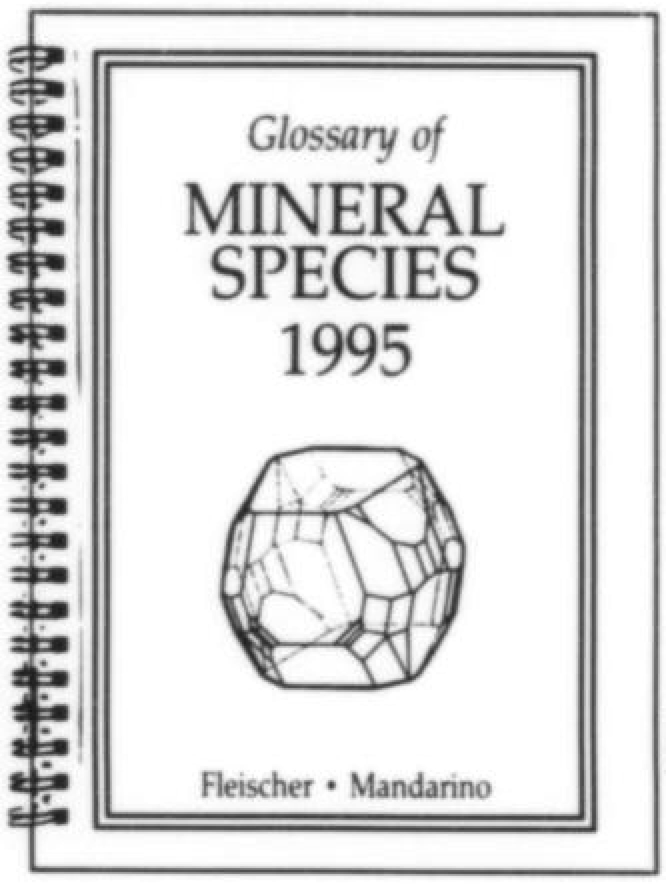

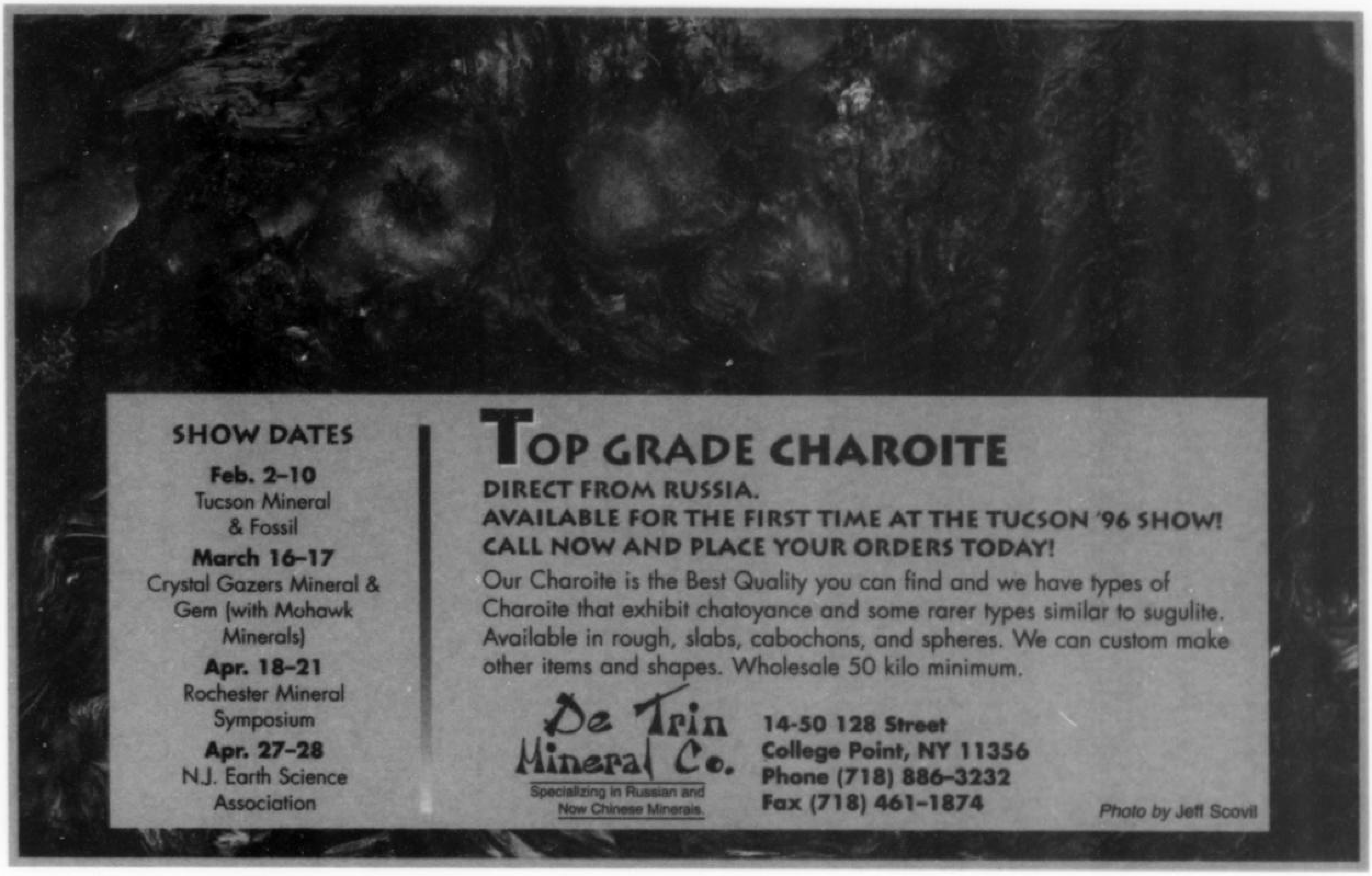

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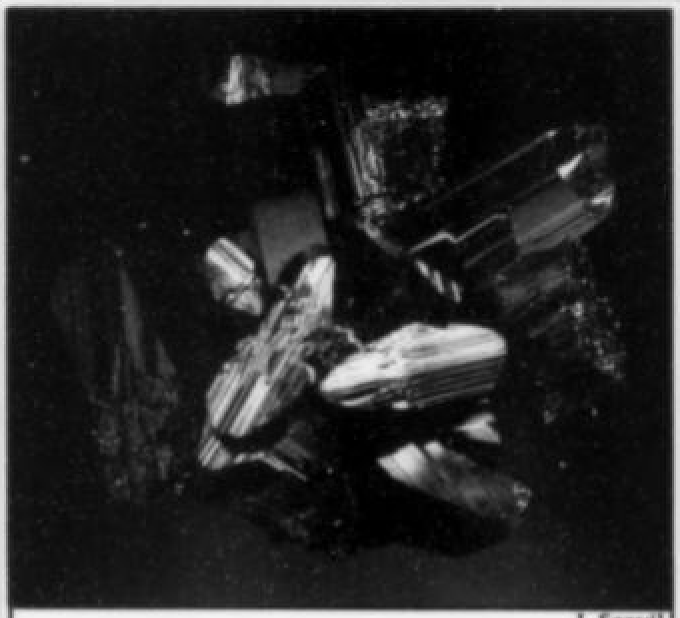

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PUMPELLYITE AND CLINOZOISITE

FROM THE
McKINNEY MINE
SPRUCE PINE DISTRICT
NORTH CAROLINA

Keith Y. Wood
Department of Geological Sciences
4044 Derring Hall
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

Richard N. Abbott, Jr.
Department of Geology
Appalachian State University
Boone, North Carolina 28608

Pumpellyite, clinozoisite and chlorite are the principal minerals of a lower-temperature assemblage not ordinarily found in a pegmatite environment. Euhedral crystals of these minerals occur in cavities lined by albite crystals. This is the first report of an occurrence of pumpellyite in North Carolina.

INTRODUCTION

Pumpellyite [$Ca_2FeAl_2(SiO_4)(Si_2O_7)_2 \cdot H_2O$], occurring with clinozoisite [$Ca_2Al_3(SiO_4)(Si_2O_7)(O,OH)_2$] and chlorite, has recently been discovered at the McKinney mine in the Spruce Pine pegmatite district of North Carolina. The discovery is significant for several reasons, among which are the following: (1) Pumpellyite is not normally associated with pegmatites. (2) The associated clinozoisite crystals are of excellent quality, some showing double terminations.

The McKinney mine has long been known as one of the most mineralogically diverse pegmatites of the Spruce Pine district. Though originally mined for the feldspar used in Bon Ami scouring powder, it also produced many fine specimens of aquamarine, amazonite, samarskite and other typical pegmatite minerals. This mine is now operated as a mining museum where limited mineral collecting is permitted.

OCCURRENCE

In December of 1993, pumpellyite and clinozoisite were found in a single rock in a collapsed area located between the opening of one of the underground workings and a pond near the road. The rock was somewhat larger than a basketball and consisted almost entirely of small albite grains (3 to 10 mm) with some pyrite and muscovite. Vugs up to 8 cm lined with albite crystals occur throughout the rock. Pumpellyite was found in the vugs as both massive grayish green material filling parts of the cavities, and as small, clustered "wheat sheaves" of delicate acicular crystals with a similar color. The "sheaves" of pumpellyite range in size up to 5 mm. The acicular clinozoisite crystals, up to 2 cm long, are principally intergrown with pumpellyite clusters, but also occur on albite crystals lining the vugs. Yellowish gray color and well-formed wedge-like terminations typify the clinozoisite crystals. Chlorite was found entirely filling some vugs, and also formed as a

Figure 1. **Green pumpellyite sheaves clustered with slender clinozoisite crystals and white albite crystals from largest vug. Specimen is 2 cm long. K. Wood specimen and photo.**

fine green druse on albite crystals. Also found in the vugs were a few tiny, lustrous crystals of titanite and some small muscovite crystals.

On subsequent visits many more rocks (up to 10 or 15 cubic meters) were found in the same area which also contained vugs lined with albite crystals. Their fracture pattern, their position in the mine, and the attached country rock all indicate that these rocks are part of a collapsed overhang in the mine. The potential still exists for collection of nice micromount-size to miniature specimens of pumpellyite, clinozoisite and associated minerals.

IDENTIFICATION

X-ray powder diffraction analyses were conducted at the Department of Geology at Appalachian State University to identify both the pumpellyite and clinozoisite, both of which yielded excellent patterns. PCXRAY software (Simmons *et al.*, 1989) was used to match the twelve strongest peaks for each mineral and gave unique matches for pumpellyite and clinozoisite. Smaller peaks were subsequently indexed and compared with the JCPDS cards (Berry, 1974) for the two minerals, and again yielded excellent matches for each.

DISCUSSION

The occurrence of pumpellyite, clinozoisite and chlorite in a pegmatite is unusual. These minerals form in lower temperature environments than those normally associated with the formation of pegmatites. Also, pumpellyite is typically found in rocks of mafic composition. The presence of pumpellyite suggests a temperature of formation between 260° and 370° C (Liou *et al.*, 1987). Such conditions argue for crystallization from a late-stage fluid phase after the formation of the pegmatite. Rocks lacking iron-stained fractures also lack pumpellyite and prehnite, further suggesting that their deposition took place long after pegmatite formation. Pegmatites of the Spruce Pine district are thought to have formed during a period of relatively high-grade metamorphism which would have destroyed any pumpellyite present at the time, hence these minerals probably formed during the cooling of the rocks.

Figure 2. **Detail of pumpellyite sheaves. Note sharp terminations on clinozoisite crystals against background. Field of view is 1 cm in height. K. Wood specimen and photo.**

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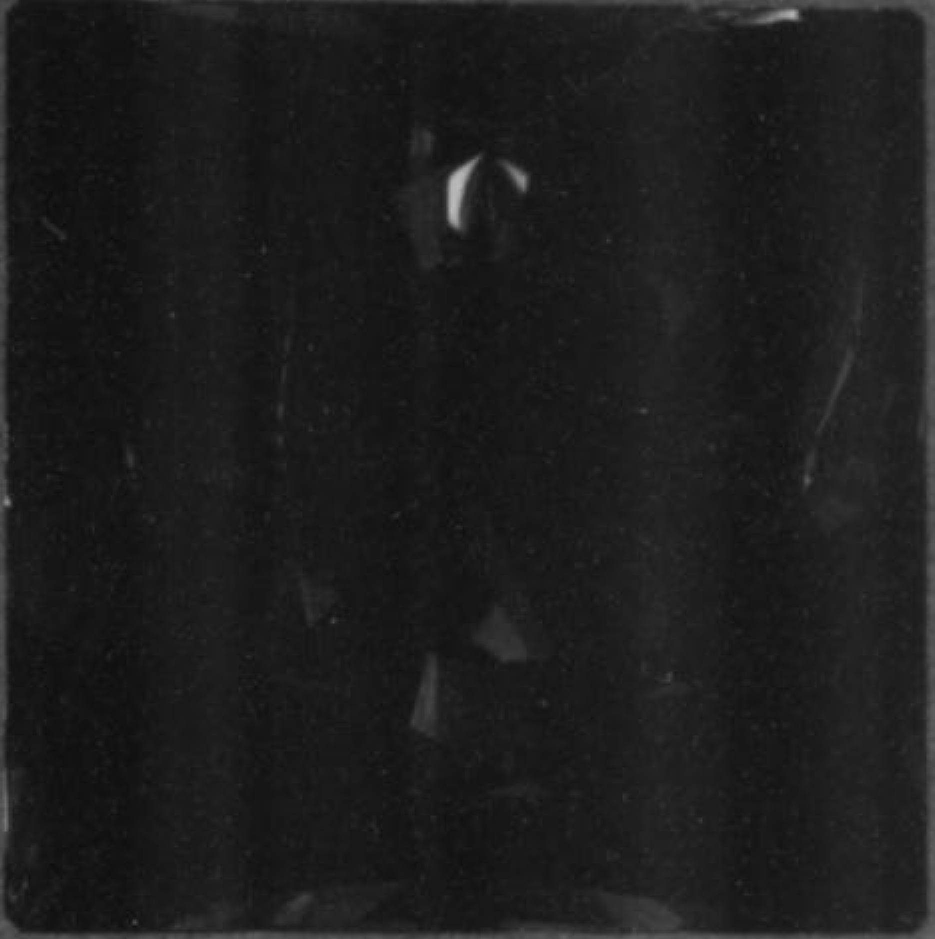

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CALCIOARAVAIPAITE
A NEW MINERAL

AND
ASSOCIATED LEAD FLUORIDE MINERALS FROM THE GRAND REEF MINE, GRAHAM COUNTY, ARIZONA

Anthony R. Kampf
Mineralogy Section
Natural History Museum of Los Angeles County
900 Exposition Blvd.
Los Angeles, California 90007

Eugene E. Foord
United States Geological Survey
Box 25046, Denver Federal Center, MS 905
Lakewood, Colorado 80225

The Grand Reef mine in southeastern Arizona, best known to collectors for superb crystals of linarite, is also the type locality for a unique suite of lead fluoride minerals. Grandreefite, pseudograndreefite, laurelite, aravaipaite, and artroeite have been found nowhere else; added to this group is calcioaravaipaite, described here for the first time.

INTRODUCTION

The Grand Reef mine is situated in Laurel Canyon, about 6 km northeast of Klondyke, in the Aravaipa mining district of Graham County, Arizona. Jones (1980) provided an overview of the history, geology and mineralogy of the deposit. The mineralogy was treated in greater detail in a thesis by Besse (1981). The mine exploits a small epithermal lead-copper-silver deposit hosted by a silicified breccia. The breccia is highly resistant to weathering and forms a precipitous cliff known as the "reef," from which the name of the mine is derived.

In 1969 a bench was blasted near the top of the reef just south of a vertical stope known as the "glory hole." Most of the mine's well-crystallized oxidized minerals, predominantly sulfates, have been recovered from this area. The fine linarite crystals up to 5 cm in length for which the mine is most famous were found here. This is also the source of six new lead fluoride minerals (Table 1). The first four, *grandreefite, pseudograndreefite, laurelite* and *aravaipaite,* were discovered on a single specimen (LACMNH 25414) recovered in 1980 during mining by Southwestern Mineral Associates

Figure 1. **The Grand Reef mine as viewed from the approach in Laurel Canyon. The new minerals were found near the "glory hole" opening about halfway up the face of the "reef" (center).**

Figure 2. **Location map.**

Table 1. **New lead fluoride minerals from the Grand Reef mine.**

Mineral	*Formula*
Grandreefite	$Pb_2F_2SO_4$
Pseudograndreefite	$Pb_6F_{10}SO_4$
Laurelite	$Pb_7F_{12}Cl_2$
Aravaipaite	$Pb_3Al(F,OH)_9$
Calcioaravaipaite	$PbCa_2Al(F,OH)_9$
Artroeite	$PbAlF_3(OH)_2$

(Richard Bideaux and Wayne Thompson). Two more, *artroeite* and *calcioaravaipaite*, were discovered on a specimen (LACMNH 39338) found in 1981 by Michael Shannon. The latter species is described for the first time in this study.

CALCIOARAVAIPAITE

Name and Deposition

Calcioaravaipaite is named for its relationship to aravaipaite; data imply that two of the three Pb atoms in aravaipaite are replaced by Ca atoms in calcioaravaipaite. The species and its name were approved by the Commission on New Minerals and Mineral Names, IMA, prior to publication. The type specimen has been deposited at the Natural History Museum of Los Angeles County.

Figure 3. **A portion of the type specimen of artroeite and calcioaravaipaite (LACMNH 39338). The white material in the vug is massive calcioaravaipaite covered with crystals of artroeite and calcioaravaipaite. Quartz layers with embedded fluorite surround the vug. The glassy, gray embedded crystal at the left is fluorite. The dark masses are galena partially altered to anglesite. The field of view is 1.5 cm across.**

Figure 4. **Calcioaravaipaite (lower left) and artroeite crystals (lower center) on the type specimen (LACMNH 39338). The field of view is 2.5 mm across.**

Occurrence

Calcioaravaipaite is found on a single specimen in a 5 x 15-mm quartz-lined vug in association with crystals of anglesite and artroeite (Figures 1 and 2). Layers of quartz with embedded crystals of fluorite completely surround the vug. Crystals and masses of galena partially altered to anglesite form a discontinuous envelope bordering and included within the quartz layers. Linarite and muscovite are present outside of the galena envelope.

X-ray Crystallography

X-ray powder diffraction data, including calculated *d* values, are given in Table 2. Precession single-crystal studies, employing Zr-filtered Mo radiation, showed that calcioaravaipaite is monoclinic with space group *A*2, *A*2/*m*, or *Am*. The refined cell parameters based upon all powder reflections except the broad ones at 1.593 and 1.451 Å are provided in Table 3. Also presented in this table are parameters for an alternate cell of triclinic geometry compared to data for the triclinic cell of aravaipaite.

Precession films of aravaipaite and calcioaravaipaite are so similar, both in reflection patterns and intensities, that a close structural relationship between these minerals appears to be a virtual certainty. The triclinic cell of calcioaravaipaite is appreciably smaller than the equivalent cell of aravaipaite, as is to be expected when Ca takes the place of two-thirds of the Pb. Note that the triclinic cell parameters *a* and *c* and the angle β between them for aravaipaite and calcioaravaipaite compare closely to parameters of planes in the cubic fluorite structure-type of β-PbF_2 ($a = 5.940$ Å) and CaF_2 ($a = 5.463$ Å), respectively. This suggests that these structures may consist of $(Pb,Ca)F_2$ layers parallel to {010}, with Al–(F,OH) octahedra between layers. Unfortunately, crystals of both aravaipaite and calcioaravaipaite provide broad multiple reflections and are inadequate for structure determination.

Physical Characteristics

Calcioaravaipaite crystals were measured on a two-circle optical goniometer. They are tabular elongate on [011], flattened on {100}, and exhibit the forms {100} and {011}. (If the space group is *A*2, the form $\{0\bar{1}\bar{1}\}$ is also present; if the space group is *Am*, the forms $\{\bar{1}00\}$ and $\{01\bar{1}\}$ are also present.) Twinning on {100} is ubiquitous. An orthographic projection of an idealized twinned crystal is shown in Figure 3. Maximum crystal dimensions are 0.05 x 0.3 x 0.7 mm. Calcioaravaipaite also occurs as a dense massive substrate for later-formed crystals of calcioaravaipaite and artroeite, and as tabular inclusions in artroeite reaching 10 microns in length.

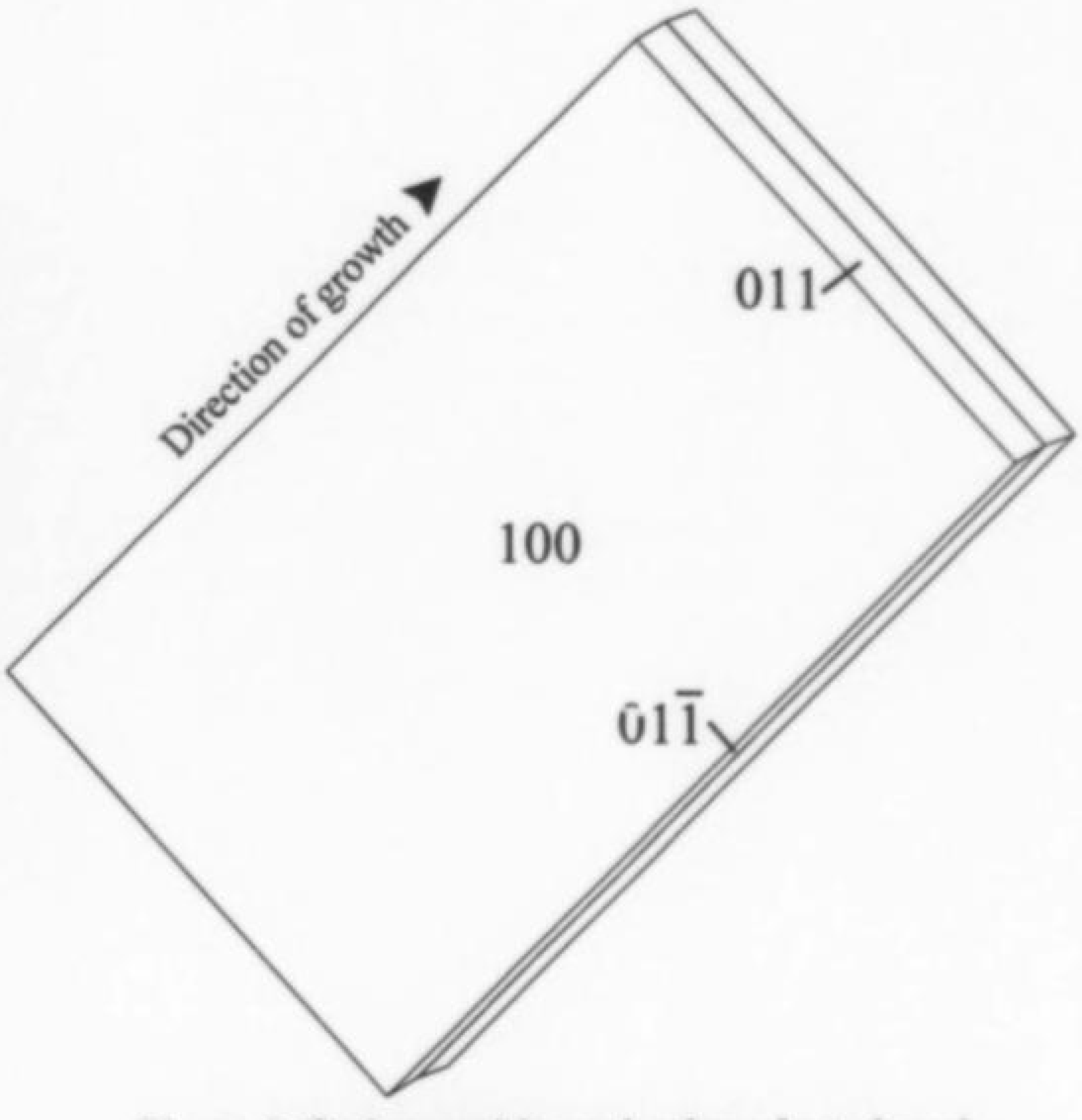

Figure 5. **Orthographic projection of a twinned crystal of calcioaravaipaite.**

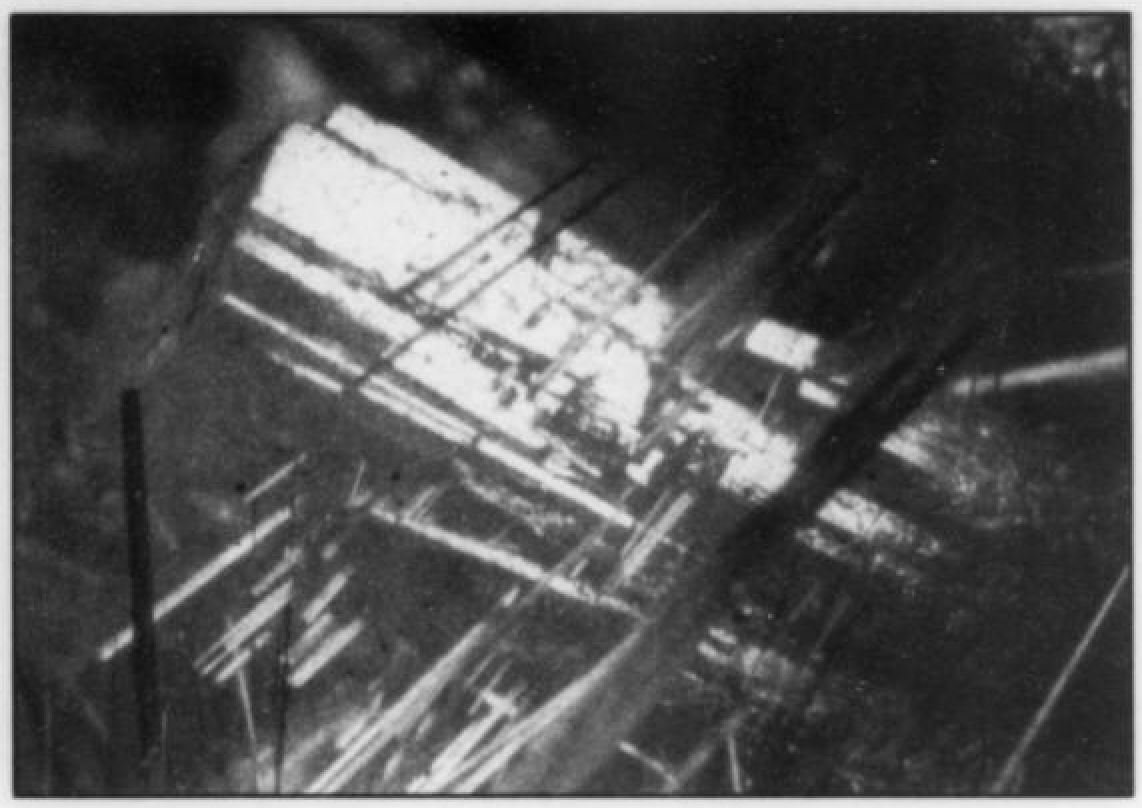

Figure 6. **Blocky crystal of pseudograndreefite with needles of laurelite on the type specimen of grandreefite, pseudograndreefite, laurelite and aravaipaite (LACMNH 25414). The field of view is 4 mm across.**

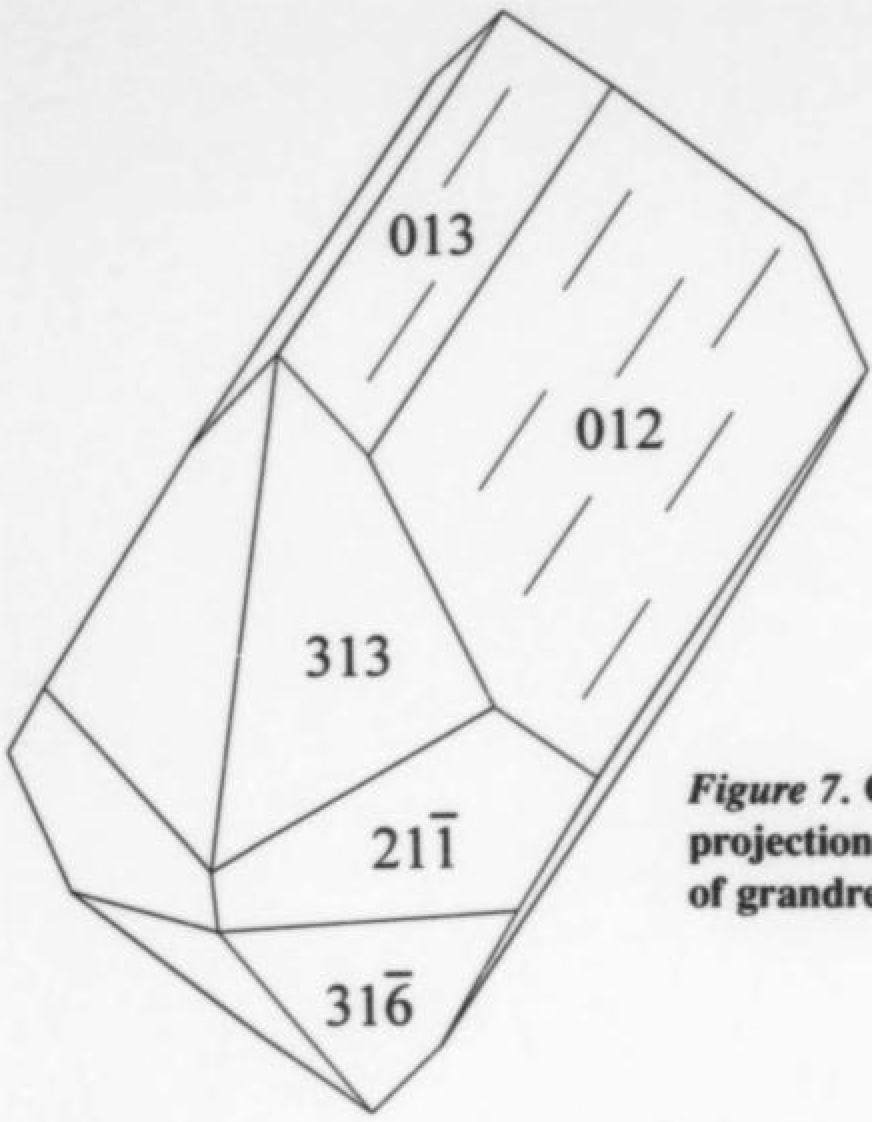

Figure 7. **Orthographic projection of a crystal of grandreefite.**

Crystals are colorless and transparent with a vitreous luster. The streak is white and the mineral is non-fluorescent. Crystals are brittle and possess a good {100} cleavage and conchoidal fracture. The Mohs hardness is about $2^1/_2$. The density determined by Berman balance on 2.4 mg is 4.85(5) g/cm^3. The calculated density assuming $Z = 8$ is 4.71 g/cm^3. Sample contamination with artroeite may be responsible for the higher measured density.

Optical Properties

The optical properties of calcioaravaipaite were determined by immersion using a Supper spindle stage. The mineral is optically biaxial (-). The indices of refraction measured in white light are $\alpha = 1.510(1)$, $\beta = 1.528(1)$, $\gamma = 1.531(1)$. The measured $2V$ is 36(2)°; the calculated $2V$ is 44°. Strong dispersion, $r > v$, was observed. The optical orientation is $Y = \mathbf{b}$, $Z \vartriangle \mathbf{c} = 73°$ in obtuse β.

Chemistry

Calcioaravaipaite was analyzed with an ARL-SEMQ electron microprobe at the U.S. Geological Survey in Denver, Colorado. The standards used were synthetic PbS, anhydrite, kyanite, and synthetic phlogopite for Pb, Ca, Al, and F, respectively. Water determination by moisture titration on 1.9 mg provided a value of 0.7 weight % H_2O. The accuracy of this value is questionable because of the very small sample size. The H_2O content obtained by difference (1.4 weight %) yields better stoichiometry and has therefore been used in the calculations below. The mean analytical results (and ranges) for five analyses are PbO = 46.4 (45.7–47.0), CaO = 23.5 (23.3–23.7), Al_2O_3 = 10.8 (10.7–10.9), F = 30.9 (30.8–31.1), H_2O = 1.4, sum 113.0, less O ≡ F 13.0, total 100.0 weight %.

The empirical formula based on 9 anions is $Pb_{1.02}Ca_{2.05}Al_{1.04}[F_{7.97}(OH)_{0.76}O_{0.27}]_{\Sigma 9.00}$. The simplified formula is **$PbCa_2Al(F,OH)_9$**, which with F:OH = 8.1 requires PbO = 46.17, CaO = 23.21, Al_2O_3 = 10.55, F = 31.45, H_2O = 1.86, sum 113.24, less O ≡ F 13.24, total 100.00 weight %. The mineral dissolves slowly in H_2O and 1:1 HCl.

BRIEF DESCRIPTIONS of the OTHER NEW LEAD FLUORIDES

Grandreefite $Pb_2F_2SO_4$

Grandreefite was originally determined (Kampf *et al.*, 1989) to have an orthorhombic cell. Subsequent atomic structure determination (Kampf, 1991) showed it to be monoclinic, space group *A*2/*a*, $a = 8.667(1)$, $b = 4.4419(6)$, $c = 14.242(2)$ Å, $\beta = 107.418(2)°$, $Z = 4$. It occurs as colorless prismatic crystals striated parallel to [100] (Figure 4). The luster is subadamantine. Grandreefite has a Mohs hardness of about $2^1/_2$. It has a measured density of 7.0(1) g/cm^3. It decomposes rapidly in cold H_2O. Grandreefite is optically biaxial (+) with a very small $2V$ and weak dispersion, $r > v$. The indices of refraction are $\alpha = 1.872(5)$, $\beta = 1.873(5)$, $\gamma = 1.897(5)$; orientation $X \approx \mathbf{a}$, $Y = \mathbf{b}$, $Z \vartriangle \mathbf{c} = 17°$. Grandreefite is similar in structure to $La_2O_2SO_4$, based on layer fragments of the β-PbF_2 (fluorite) structure parallel to (100) with SO_4 groups between layers.

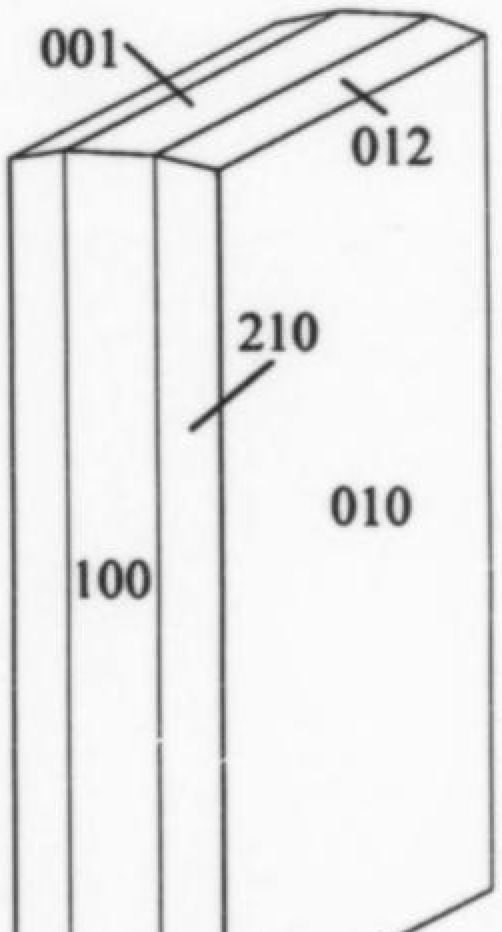

Figure 8. **Orthographic projection of a crystal of pseudograndreefite.**

Pseudograndreefite $Pb_6F_{10}SO_4$

Pseudograndreefite (Kampf *et al.*, 1989) is orthorhombic, space group *F*222, $a = 8.5182(5)$, $b = 19.5736(11)$, $c = 8.4926(5)$ Å, $Z = 4$. It occurs as colorless square crystals tabular on {010} (Figures 5 and 6). The luster is subadamantine. Pseudograndreefite has a Mohs hardness of about $2^1/_2$. It has a measured density of 7.0(1) g/cm^3. It decomposes rapidly in cold H_2O. Pseudograndreefite is optically biaxial (+) with $2V = 30(3)°$ and strong dispersion, $r > v$. The indices of refraction are $\alpha = 1.864(5)$, $\beta = 1.865(5)$, $\gamma = 1.873(5)$; orientation $X = \mathbf{c}$, $Y = \mathbf{a}$, $Z = \mathbf{b}$. The structure of pseudograndreefite has not been completely solved but is very similar to that of grandreefite, based on double layer fragments of the β-PbF_2 (fluorite) structure parallel to {010} with SO_4 groups between layers.

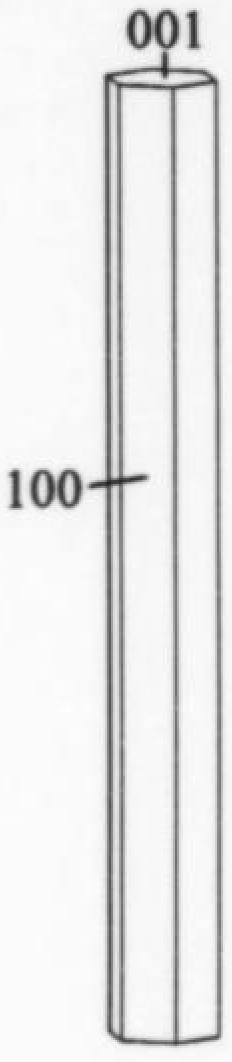

***Figure 9.* Orthographic projection of a crystal of laurelite.**

Laurelite $Pb_7F_{12}Cl_2$

Laurelite (Kampf *et al.*, 1989) is hexagonal, space group $P\bar{6}$, $a = 10.252(9)$, $c = 3.973(1)$ Å, $Z = 1$. Most typically it occurs as thin tapering needles grouped into parallel bundles. Rarely it occurs as colorless simple hexagonal prisms (Figures 5 and 7). Broken surfaces across densely packed crystal bundles provide a subadamantine luster; the surfaces of crystal bundles have a silky luster. Laurelite has a Mohs hardness of about 2. The original measured density of 6.2(1) g/cm³ was obtained using a pycnometer and a sample consisting of many small difficult-to-handle needles. Subsequently, three large crystal fragments weighing a total of 13 mg provided a better density measurement of 7.65 g/cm³ on a Berman balance. Laurelite decomposes rapidly in cold 1:1 HCl and dissolves very slowly in cold H_2O. It is optically uniaxial (+), with $\omega = 1.903(5)$, $\varepsilon = 1.946(5)$. The structure of laurelite (report by S. Merlino, M. Pasero, N. Perchiazzi and A. Kampf submitted for publication) is closely related to that of α-PbF_2 consisting of layers of nine-coordinated Pb parallel to {001}.

Aravaipaite $Pb_3Al(F,OH)_9$

Aravaipaite (Kampf *et al.*, 1989) is triclinic, space group $P1$ or $P\bar{1}$, $a = 5.842(2)$, $b = 25.20(5)$, $c = 5.652(2)$ Å, $\alpha = 93.84(4)$, $\beta = 90.14(4)$, $\gamma = 85.28(4)°$, $Z = 4$. It occurs as colorless, thin, flexible plates with perfect micaceous {010} cleavage (Fig. 8). Polysynthetic twinning on {010} is ubiquitous. The luster is vitreous to pearly. Aravaipaite has a Mohs hardness of about 2, and a calculated density of 6.37 g/cm³. Aravaipaite decomposes rapidly in cold 1:1 HCl and dissolves very slowly in cold H_2O. It is optically biaxial (-) with $2V = 70(3)°$ and strong dispersion, $r < v$. The indices of refraction are $\alpha = 1.678(2)$, $\beta = 1.690(2)$, $\gamma = 1.694(2)$; Euler angles are $\varphi = 67°$, $\psi = 60°$, $\theta = 76°$. As noted earlier, the structure of aravaipaite may be related to that of β-PbF_2 with layers of the β-PbF_2 structure parallel to {010} and Al–(F,OH) octahedra between layers.

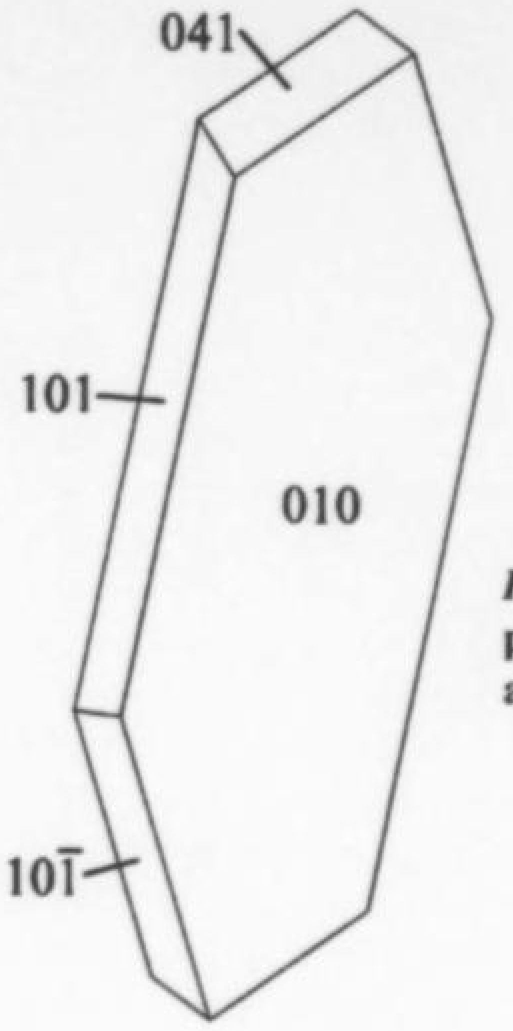

***Figure 10.* Orthographic projection of a crystal of aravaipaite.**

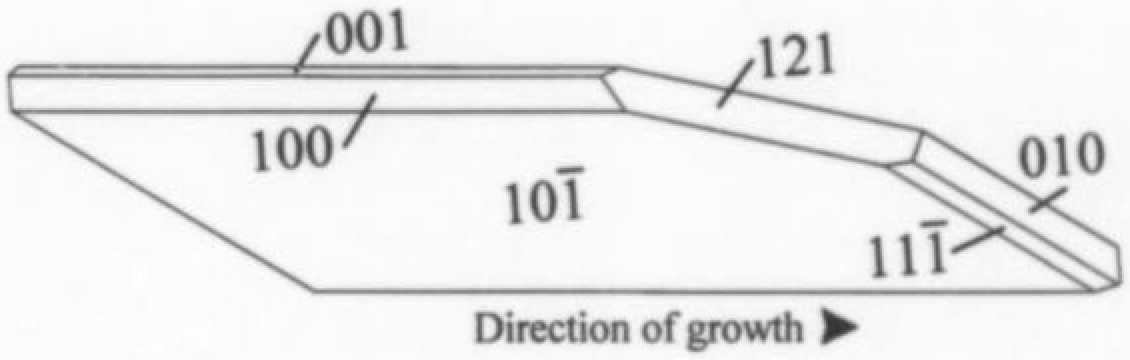

***Figure 11.* Orthographic projection of a crystal of artroeite.**

Artroeite $PbAlF_3(OH)_2$

Artroeite (Kampf and Foord, 1995) is triclinic, space group $P\bar{1}$, $a = 6.270(2)$, $b = 6.821(3)$, $c = 5.057(2)$ Å, $\alpha = 90.68(2)$, $\beta = 107.69(2)$, $\gamma = 104.46(2)°$, $Z = 2$. It occurs as colorless, bladed crystals (Figure 2 and 9) with perfect {100} cleavage and good {010} cleavage. The luster is vitreous. Artroeite has a Mohs hardness of about $2^1/_2$. It has a measured density of 5.36(2) g/cm³. Artroeite is optically biaxial (-) with $2V = 41°$ and strong dispersion, $r > v$. The indices of refraction are $\alpha = 1.629(1)$, $\beta = 1.682(2)$, and $\gamma = 1.691(2)$. The structure of artroeite consists of edge-sharing dimers of $AlF_3(OH)_3$ octahedra linked together via bonds to Pb atoms to form approximately close-packed layers parallel to {10$\bar{1}$}.

PARAGENESIS of the LEAD FLUORIDES

Observations

It is known that the specimens containing the new lead fluoride minerals were all recovered from the bench area that has produced most of the other well-crystallized oxidized minerals at the mine. Unfortunately, the details of the recovery of these specimens, including their specific contexts in this assemblage, are not known. To date the most complete picture of the surrounding assemblage is provided by a reconstructed block of matrix measuring about 15 x 25 x 27 cm that originally abutted the type specimen containing grandreefite, pseudograndreefite, laurelite and aravaipaite

(LACMNH 25414). The type specimen containing artroeite and calcioaravaipaite (LACMNH 39338) and other recovered specimens containing these new minerals have provided additional clues to the paragenesis of these unique minerals.

The aforementioned reconstructed block is typical of the mineralization found in the bench area of the Grand Reef mine. Veins of galena follow irregular fractures in the breccia, and minor amounts of copper sulfides associated with the galena are altered principally to linarite and caledonite. The galena shows lesser alteration to anglesite. Galena veins often border interstices between breccia blocks, and the gangue minerals fluorite and quartz commonly fill these interstices. The vug containing grandreefite, pseudograndreefite, laurelite and aravaipaite occupies the center of an interstice between breccia blocks. Although a portion of the rock surrounding the vug is missing, it is clear that the vug was completely surrounded by galena. An irregular and incomplete layer of fluorite is found inside the galena layer, followed by a complete layer of quartz surrounding the quartz-lined vug. Anglesite fills narrow fractures in the quartz. A few centimeters away from this vug, another interstice in the breccia is bordered by galena and completely filled by massive fluorite.

The type specimen containing artroeite and calcioaravaipaite is similar in character. An intergrowth of fluorite and galena completely envelops the quartz-lined vug. The galena is partially altered to anglesite. The artroeite and calcioaravaipaite are associated with anglesite crystals within the vug. Linarite and muscovite are present outside of the fluorite/galena envelope.

Laurelite appears to be the most widespread of the new minerals. Numerous specimens containing laurelite were examined in the course of this study. In general the laurelite occurs in quartz-lined vugs that are surrounded by galena. The laurelite is usually found growing on or in close proximity to fluorite. In some instances the fluorite shows evidence of dissolution. Anglesite crystals are commonly associated with laurelite, the anglesite clearly preceding the crystallization of the laurelite. In only two instances was linarite found in close proximity to laurelite.

The evidence suggests the following order of crystallization: galena → fluorite → quartz → anglesite → lead fluorides. Among the lead fluorides the order of crystallization based upon the first type specimen (LACMNH 25414) is: grandreefite → pseudograndreefite → laurelite → aravaipaite; the order based upon the second type specimen (LACMNH 39338) is: calcioaravaipaite → artroeite. Intergrowth relationships between the lead fluorides indicate significant overlaps in their periods of crystallization.

The secondary calcium fluoride minerals gearksutite and creedite were reported from the mine by Jones (1980) and Besse (1981). Besse reported gearksutite to be moderately common in the bench area as a very late-stage, chalky cavity filling. Besse (personal communication, 1988) also reported the occurrence of prosopite in an isolated vug in the bench area. None of these minerals were observed in association with the new lead fluoride minerals, although small amounts of gearksutite are present in the matrix surrounding the first vug.

Cerussite is a common supergene alteration product of galena at the Grand Reef mine, although it is less common than anglesite in the surface exposure of the vein (Jones, 1980). Notably, cerussite was not found on any of the specimens bearing the new lead fluoride minerals.

Chemical Considerations

The presence of Pb^{2+} in solution is clearly critical to the formation of the new minerals. Because of the strong tendency of this ion to combine with SO_4^{2-} or CO_3^{2-}, its mobility in systems dominated by these anions is very limited (*cf.* Garrels and Christ, 1965). Close proximity of galena to a source of F^- is seemingly necessary for the formation of the new minerals.

Solution attack on fluorite, the obvious source of F^- in the system, would release Ca^{2+} as well. In this respect, the absence of the secondary calcium fluoride minerals gearksutite and creedite in the vugs with the new lead fluorides, and the presence of essential calcium in only one of the new lead fluorides, calcioaravaipaite, is notable. The Ca^{2+}, having a much greater mobility (solubility) than Pb^{2+} in solution in the presence of SO_4^{2-} and F^-, probably migrated away from the vicinity of the vug.

As evidenced by the abundance of supergene sulfate mineralization, acidic sulfate-rich solutions were apparently dominant during the formation of much of the secondary oxidized assemblage in the upper portion of the bench. The absence of cerussite on any of the specimens containing the lead fluoride minerals suggests at least a local dearth of CO_3^{2-} in the supergene solutions. Aside from the obvious requirement of SO_4^{2-} for the formation of grandreefite and pseudograndreefite (which contain essential SO_4^{2-}), the initial presence of SO_4^{2-} and absence of CO_3^{2-} in solution may also have been critical to the formation of all of the new lead fluoride minerals.

The selective incorporation of chloride in laurelite is probably attributable to the preference of chloride for the α-$PbF_2(PbCl_2)$ structural arrangement. The greater abundance of this mineral relative to the other new lead fluorides may also be related to its ability to accommodate chloride.

The aluminum essential to aravaipaite, calcioaravaipaite and artroeite was probably provided by the invading supergene solutions which had acquired the aluminum through reaction with silicates such as muscovite occurring in the breccia.

Interpretations

The new lead fluoride minerals are interpreted as resulting from the reaction of late-stage supergene solutions with galena and fluorite. This is suggested by the compositions of the new minerals, by their spatial proximity to galena and fluorite, by dissolution features noted in some fluorite, by alteration of the galena surrounding the vug, and by the formation of anglesite both as a fracture-filling in the quartz lining and as crystals in the vugs prior to the crystallization of the lead fluoride minerals.

The crystallization of anglesite before the lead fluorides and (in the first vug) the crystallization of grandreefite and pseudograndreefite before aravaipaite and laurelite, represent progressions from sulfate-rich to fluoride-rich phases. This is consistent with progressive crystallization under closed-system conditions within the vug and, together with the earlier presented evidence, suggests the following sequence of formation: (1) the incoming acidic sulfate-rich supergene solution reacts with galena and fluorite as it enters the open vug, (2) the F^- concentration of the solution trapped in the vug increases as SO_4^{2-} is preferentially incorporated into earlier crystallizing anglesite, (3) the new lead fluoride minerals form from the increasingly fluoride-rich solution, and (4) the galena-fluorite-quartz envelope around the vug isolates it from further interaction with aqueous solutions, thereby preserving the lead fluoride minerals.

Isolated vugs containing mineralization quite distinct from nearby vugs are typical of the Grand Reef mine (Wayne Thompson, personal communication, 1988). These may be attributed to the mode of emplacement of the orebody according to the following scenario. When the orebody was emplaced in the breccia, the interstices between breccia blocks were in-filled with layers of sulfides (mostly galena) and gangue minerals (mostly fluorite and quartz). During supergene alteration of the deposit, solutions entered the open vugs through fractures in the surrounding layers of galena, fluorite and quartz. Initial crystallization of supergene

***Table 2*. X-ray powder diffraction data for calcioaravaipaite.**

I/I_o	d_{obs}	d_{calc}	hkl_m	hkl_t
100	11.9	11.94	200	020
10	5.22	5.214	111	$\bar{1}10$, 011
20	4.85	4.853	211	$\bar{1}20$, 021
5	4.51	4.514	$\bar{3}11$	130, $0\bar{3}1$
20	4.40	4.400	311	$\bar{1}30$, 031
5	4.06	4.051	$\bar{4}11$	140, $0\bar{4}1$
10	3.93	3.942	411	$\bar{1}40$, 041
35	3.82	3.821	$\bar{1}02$	$11\bar{1}$
70	3.71	3.712	120	111, $1\bar{1}1$
5	3.62	3.621	$\bar{5}11$	150, $0\bar{5}1$
85	3.51	3.523	511	$\bar{1}50$, 051
		3.518	$\bar{3}02$	$13\bar{1}$
50	3.406	3.411	302	$\bar{1}31$
		3.399	320	131, $1\bar{3}1$
20	3.235	3.242	$\bar{6}11$	160, $0\bar{6}1$
20	3.157	3.158	611	$\bar{1}60$, 061
60	2.981	2.986	800	080
60	2.943	2.940	502	$\bar{1}51$
5	2.847	2.846	711	$\bar{1}70$, 071
50	2.692	2.688	022	200, 002
45	2.638	2.638	$\bar{2}22$	220, $0\bar{2}2$
5	2.509	2.504	702	$\bar{1}71$
30	2.390	2.389	10·0·0	0·10·0
5	2.331	2.331	231	$2\bar{2}1$, 122
15	2.274	2.278	$\bar{4}13$	$24\bar{1}$, $14\bar{2}$
		2.275	331	132, $2\bar{3}1$
5	2.223	2.226	$\bar{9}02$	$19\bar{1}$
		2.220	413	$\bar{1}42$, $\bar{2}41$
10	2.204	2.206	$\overline{10}$·1·1	1·10·0, 0·$\overline{10}$·1
		2.203	431	142, $2\bar{4}1$
5	2.164	2.168	920	191, $1\bar{9}91$
		2.161	10·1·1	$\bar{1}$·10·0, 0·10·1
5	2.144	2.145	902	$\bar{1}91$
5	2.109	2.107	$\bar{6}13$	$26\bar{1}$, $16\bar{2}$
60	2.028	2.026	$\bar{8}22$	280, $0\bar{8}2$
5	1.989	1.991	12·0·0	0·12·0
60	1.971	1.971	822	$\bar{2}80$, 082
25	1.926	1.924	$\overline{11}$·0·2	1·11·$\bar{1}$
		1.923	004	$20\bar{2}$
50	1.879	1.879	040	202
5	1.852	1.852	$\bar{4}04$	$24\bar{2}$
10	1.790	1.792	033	300, 003
		1.791	$\bar{1}33$	310, $0\bar{1}3$
5	1.758	1.759	$\bar{6}04$	330, $0\bar{3}3$
		1.759	$\bar{3}33$	$26\bar{2}$
40	1.686	1.686	$\bar{1}42$	311, $1\bar{1}3$
		1.686	$\bar{3}24$	$13\bar{3}$, $33\bar{1}$
15	1.657	1.657	$\bar{3}42$	331, $1\bar{3}3$
5	1.651	1.651	$\bar{6}33$	360, $0\bar{6}3$
10	1.622	1.621	$\overline{12}$·2·2	2·12·0, 0·$\overline{12}$·2
45b	1.593	1.595	11·3·1	1·11·2, 2·$\overline{11}$·1
		1.594	524	$\bar{3}51$, $\bar{1}53$
		1.593	$\bar{6}24$	$36\bar{1}$, $16\bar{3}$
		1.590	840	282, $2\bar{8}2$
		1.589	11·1·3	$\bar{1}$·11·2, $\bar{2}$·11·1
5	1.557	1.556	$\bar{8}33$	380, $0\bar{8}3$
5	1.539	1.539	$\overline{15}$·1·1	1·15·0, 0·$\overline{15}$·1
15	1.520	1.518	12·3·1	1·12·2, 2·$\overline{12}$·1
10	1.493	1.493	16·0·0	0·16·0
5	1.467	1.467	933	$\bar{3}90$, 093
5b	1.451	1.453	$\overline{10}$·3·3	3·10·0, 0·$\overline{10}$·3
		1.449	$\overline{16}$·1·1	1·16·0, 0·$\overline{16}$·1
5	1.414	1.415	10·3·3	$\bar{3}$·10·0, 0·10·3
10	1.369	1.369	10·2·4	$\bar{3}$·10·1, $\bar{1}$·10·3
		1.369	$\overline{17}$·1·1	1·17·0, 0·$\overline{17}$·1
10	1.344	1.344	044	400, 004
20	1.320	1.321	$\overline{16}$·2·2	2·16·0, 0·$\overline{16}$·2
		1.319	$\bar{4}44$	440, $0\bar{4}4$

hkl_m: indices based upon monoclinic cell, a = 23.905(5), b = 7.516(2), c = 7.699(2) Å, β = 92.25(2)°.

hkl_t: indices based upon alternate cell with triclinic geometry, a = 5.380(1), b = 23.905(4), c = 5.380(1) Å, α = 91.62(2)°, β = 91.38(2)°, γ = 88.38(2)°.

114.6-mm Gandolfi camera; Ni-filtered Cu$K\alpha$ radiation; intensities visually estimated.

***Table 3*. Comparison of crystallographic data for aravaipaite and calcioaravaipaite.**

		Aravaipaite	*Calcioaravaipaite*	
Chemical formula		$Pb_3Al(F,OH)_9$	$PbCa_2Al(F,OH)_9$	
Crystal system		triclinic	triclinic§	monoclinic
Space group		$P1$ or $P\bar{1}$		$A2$, Am or $A2/m$
Cell parameters	a	5.842(2) Å	5.380(1) Å	23.906(5) Å
	b	25.20(5) Å	23.905(4) Å	7.516(2) Å
	c	5.652(2) Å	5.380(1) Å	7.699(2) Å
	α	93.84(4)°	91.62(2)°	
	β	90.14(4)°	91.38(2)°	92.25(2)°
	γ	85.28(4)°	88.38(2)°	
	V	827(2) Å^3	691.1(2) Å^3	1382.2(4) Å^3
	Z	4	4	8

* Aravaipaite cell data from Kampf *et al.*, 1989

§ Alternate cell with triclinic geometery.

minerals sealed the entrance fractures, thereby isolating the vugs from further interaction with supergene solutions and creating individual micro-environments within the vugs. Small local variations in chemistry were then accentuated by progressive crystallization under closed-system conditions. Another example of a unique micro-environment mineral occurrence at the Grand Reef mine is shannonite, Pb_2OCO_3, recently described by Roberts *et al.* (1995).

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Reef mine. Larry L. Jackson of the U.S. Geological Survey in Denver conducted the moisture titration on calcioaravaipaite. Peter A. Williams of the University of Western Sydney Nepean, Australia, provided helpful comments regarding the paragenesis. The manuscript benefited from a review by Donald R. Peacor of the University of Michigan and suggestions by Dorothy Ettensohn of the Natural History Museum of Los Angeles County.

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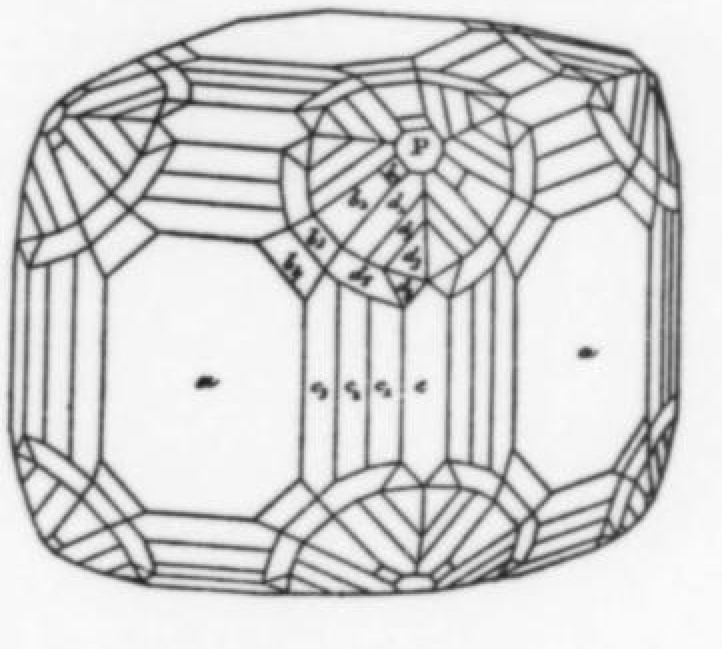
KAMPF, A. R., and FOORD, E. E. (1995) Artroeite, $PbAlF_3(OH)_2$, a new mineral from the Grand Reef mine, Graham County, Arizona: Description and crystal structure. *American Mineralogist,* **80**, 179–183.

MERLINO, S., PASERO, M., PERCHIAZZI, N., and KAMPF, A. R. (1996?) Laurelite: Its atomic structure and relationship to alpha-PbF_2. (manuscript submitted for publication)

ROBERTS, A. C., STIRLING, J. A. R., CARPENTER, G. J. C., CRIDDLE, A. J., JONES, G. C., BIRKETT, T. C., and BIRCH, W. D. (1995) Shannonite, Pb_2OCO_3, a new mineral from the Grand Reef mine, Graham County, Arizona, USA. *Mineralogical Magazine,* **59**, 305–310.

ABSTRACTS OF NEW MINERAL DESCRIPTIONS



J. A. Mandarino
Chairman Emeritus of the Commission on
New Minerals and Mineral Names
of the International Mineralogical Association
and
Curator Emeritus
Department of Mineralogy
Royal Ontario Museum
100 Queen's Park
Toronto, Ontario, Canada M5S 2C6

Altisite — Monoclinic

$Na_3K_6Ti_2Al_2Si_8O_{26}Cl_3$

Locality: In a drill core from the Oleny Stream apatite deposit in the southeastern part of the Khibina alkaline massif, Kola Peninsula, Russia.

Occurrence: In the interstices of pectolite crystals in a hyperagpaitic pegmatite. Associated minerals are: sodalite, nepheline, potassium feldspar, pectolite, aegirine, shcherbakovite, tinaksite, magnesium astrophyllite, nefedovite, villiaumite, natrite and rasvumite.

General appearance: Anhedral grains (up to 3 mm).

Physical properties: *Luster:* vitreous. *Diaphaneity:* transparent. *Color:* colorless. *Streak:* white. *Luminescence:* non-fluorescent. *Hardness:* 6. *Tenacity:* brittle. *Cleavage:* none. *Fracture:* conchoidal. *Density:* 2.64 g/cm³ (meas.), 2.67 g/cm³ (calc.). ***Crystallography:*** Monoclinic, C2/m, a 10.37, b 16.32, c 9.16 Å, β 105.6°, V 1493 Å³, Z 2, a:b:c = 0.6354:1:0.5599. Morphology: no forms observed. Twinning: none observed. ***X-ray powder diffraction data:*** 8.22 (71), 3.50 (42), 3.157 (35), 3.049 (100), 2.900 (71), 2.835 (84), 1.996 (29), 1.967 (29), 1.723 (29). ***Optical data:*** Biaxial (+), α 1.601, β 1.625, γ 1.654, 2V(meas.) 85°, 2V(calc.) 86°, dispersion r < v weak, X ≈ c, Y = b, Z ≈ a. ***Chemical analytical data:*** Means of three sets of electron microprobe data: Na_2O 9.3, K_2O 20.7, BaO 1.0, Al_2O_3 8.7, SiO_2 40.3, TiO_2 13.1, ZrO_2 0.1, Nb_2O_5 0.5, Cl 8.6, sum 102.3, less O = Cl 1.9, Total 100.4 wt.%. Empirical formula: $Na_{3.00}(K_{5.24}Na_{0.58}Ba_{0.08})_{\Sigma 5.90}(Ti_{1.95}Nb_{0.04}Zr_{0.01})_{\Sigma 2.00}Al_{2.03}Si_{7.99}O_{26.11}Cl_{2.89}$. ***Relationship to other species:*** It is structurally related to lemoynite. ***Name:*** For the elements Al, Ti and Si in the composition. ***Comments:*** IMA No. 93-055. Some of the data given in this abstract were taken from the original IMA proposal.

KHOMYAKOV, A. P., NECHELYUSTOV, G. N., FERRARIS, G., and IVALDI, G. (1995) Altisite $Na_3K_6Ti_2Al_2$-$Si_8O_{26}Cl_3$—a new mineral. *Zapiski Vsesoyuznyi Mineralogicheskoe Obshchestva* **123(6)**, 82–86. FERRARIS, G., IVALDI, G., and KHOMYAKOV, A. P. (1995) Altisite $Na_3K_6Ti_2[Al_2Si_8O_{26}]Cl_3$ a new hyperalkaline aluminosilicate from Kola Peninsula (Russia) related to lemoynite: crystal structure and thermal evolution. *European Journal of Mineralogy* **7**, 537–546.

Calcioburbankite — Hexagonal

$Na_3(Ca,REE,Sr)_3(CO_3)_5$

Locality: Mont Saint-Hilaire. Rouville County, Quebec, Canada

Occurrence: In two different modes of occurrence: (1) in a vent associated with ancylite-(Ce), calcite, a chlorite group mineral, donnayite-(Y), fluorapatite, natrolite, pyrite, rhodochrosite and rutile; (2) in a vug in a marble xenolith associated with aegirine, calcite, fluorite, galena, leucophanite, mangan-neptunite, microcline, molybdenite-*2H* and -*3R*, narsarsukite, pectolite, pyrite, schairerite, shortite, sodalite, sphalerite, thermonatrite and titanite.

General appearance: A subhedral prismatic crystal elongated parallel to [001] (2 x 1.8 x 2 cm) from which all of the following data were obtained. Also as nearly equant crystals up to 0.5 mm across.

Physical properties: *Luster:* vitreous. *Diaphaneity:* translucent. *Color:* deep orange; also silky white to light pink. *Streak:* white. *Luminescence:* non-fluorescent. *Hardness:* 3 to 4. *Tenacity:* brittle. *Cleavage:* {100} indistinct. *Fracture:* conchoidal. *Density:* 3.45 g/cm³ (meas.), 3.46 g/cm³ (calc.). ***Crystallography:*** Hexagonal, $P6_3mc$, $P6_3mmc$ or $P\bar{6}2c$, a 10.447, c 6.318 Å, V 597.23 Å³, Z 2, c:a = 0.6048. Morphology: forms, {100} and {001}. Twinning: none observed. ***X-ray powder diffraction data:*** 9.07 (2), 5.20 (4), 4.54 (2), 3.68 (3), 3.01 (5), 2.601 (10), 2.130 (6), 1.649 (3). ***Optical data:*** Uniaxial (-), ω 1.636, ε 1.631, nonpleochroic. ***Chemical analytical data:*** Means of three sets of electron microprobe data: Na_2O 15.17, CaO 11.81, SrO 7.65, BaO 0.46, La_2O_3 9.30, Ce_2O_3 14.38, Pr_2O_3 1.26, Nd_2O_3 3.76, Sm_2O_3 0.48, CO_2 (35.13), Total (99.40) wt. %. CO_2 was calculated. Empirical formula: $Na_{3.07}(Ca_{1.32}Ce_{0.55}$-$Sr_{0.46}La_{0.36}Nd_{0.14}Pr_{0.05}Ba_{0.02}Sm_{0.02})_{\Sigma 2.92}(CO_3)_{5.00}$. ***Relationship to other species:*** It is the calcium-dominant analog of burbankite. ***Name:*** For the relationship to burbankite. ***Comments:*** IMA No. 93-001.

VAN VELTHUIZEN, J., GAULT, R. A., and GRICE, J. D. (1995) Calcioburbankite, $Na_3(Ca,REE,Sr)_3(CO_3)_5$, a new mineral species from Mont Saint-Hilaire, Quebec, and its relationship to the burbankite group of minerals. *Canadian Mineralogist* **33**, 1231–1235.

Dozyite — Monoclinic

$(Mg_7Al_2)(Si_4Al_2)O_{15}(OH)_{12}$

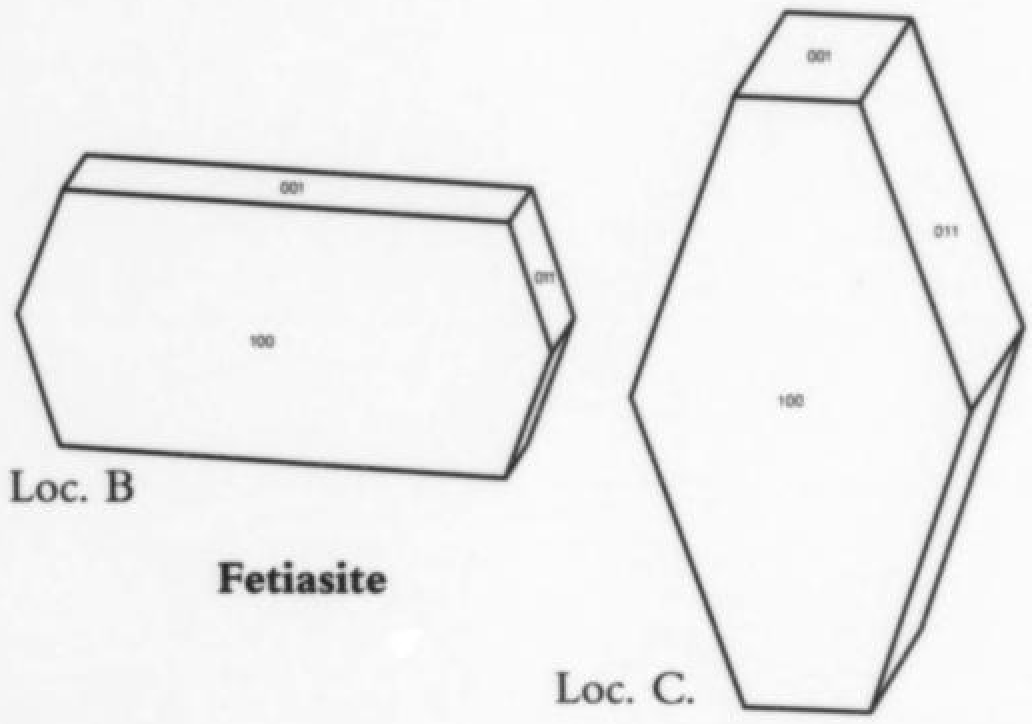
Locality: The Ertsberg East Complex (4200 m elevation), Carstensz Mountains, central Irian Jaya (the western half of the island of New Guinea), Indonesia. A second locality is the Wood Chrome mine, Lancaster Co., Pennsylvania, U.S.A. Most of the data given here are for the material from Indonesia.

Occurrence: The Indonesia material occurs in an altered skarn near a copper-gold-silver ore zone. Associated minerals are: lizardite, chrysotile, antigorite, amesite, clinochlore, other interstratified serpentine-chlorite phases, magnesite, dolomite, calcite, anhydrite, and chalcopyrite. The Pennsylvania material occurs in a Cr-rich serpentinite. Associated minerals are: chromian chlorite-II*bb*, chromian lizardite, and chromite.

General appearance: Crystals (up to 2.0 mm) intergrown with amesite, clinochlore and other interstratified serpentine-chlorite phases as tabular wedges, whorls and platelets in a tight network.

Physical properties: *Luster:* nacreous. *Diaphaneity:* translucent. *Color:* colorless. *Streak:* white. *Luminescence:* not mentioned. *Hardness:* about 2½. *Tenacity:* not mentioned. *Cleavage:* {001} perfect. *Fracture:* not mentioned. *Density:* 2.66 g/cm^3 (meas.), 2.68 g/cm^3 (calc.). ***Crystallography:*** Monoclinic, Cm, a 5.323, b 9.214, c 21.45 Å, β 94.43°, V 1049 Å^3, Z 2, a:b:c = 0.5777:1:2.3280. Morphology: no forms observed. Twinning: none mentioned. ***X-ray powder diffraction data:*** 7.1 (100), 4.61 (60), 3.560 (80), 2.557 (40), 2.427 (60), 1.536 (70). ***Optical data:*** Biaxial (+), α 1.575, β 1.575, γ 1.581, 2V(meas.) 0° to 5°, 2V(calc.) 0°, dispersion very weak, pleochroism X = Y = colorless, Z = very pale tan in thick crystals; Y = b, Z ^ c = 4° (in obtuse angle β). ***Chemical analytical data:*** Means of 19 sets of electron microprobe data: Na_2O 0.07, MgO 34.74, CaO 0.04, FeO 1.63, Al_2O_3 20.29, SiO_2 29.69, H_2O 12.20, Cl 0.18, sum 98.84, less O = Cl 0.04, Total 98.80 wt. %. Empirical formula: $(Mg_{7.39}Al_{1.64}Fe_{0.19})_{\Sigma 9.22}(Si_{4.23}Al_{1.77})_{\Sigma 6.00}O_{15.40}[(OH)_{11.60}Cl_{0.04}]_{\Sigma 11.64}$. ***Relationship to other species:*** A 1:1 regular interstratification of serpentine and chlorite. ***Name:*** For the locality. ***Comments:*** IMA No. 93-042. Some of the data given in this abstract were taken from the original IMA proposal. The empirical formula and calculated density given here are slightly different from those given in the paper.

BAILEY, S. W., BANFIELD, J. F., BARKER, W. W., and KATCHAN, G. (1995) Dozyite, a 1:1 regular interstratification of serpentine and chlorite. *American Mineralogist* **80**, 65–77.



Fetiasite

Fetiasite

Monoclinic

$(Fe^{2+},Fe^{3+},Ti)_3O_2[As_2O_5]$

Locality: Locality A: at about 3000 m above sea level at the eastern slope of Pizzo Cervandone, Italy. Localities B and C (C is about 5 m above B): about 4 km north of Locality A at Gorb (about 2000 m above sea level), Binntal, Switzerland.

Occurrence: In Alpine mineral fissures. Associated minerals are: clinochlore, quartz and anatase at the Italian locality; asbecasite, cafarsite and cervandonite at the Swiss localities, which produced spectacular anatase crystals early in the 20th century.

General appearance: Locality A: a single specimen consisting of minute tabular crystals (about 0.2 mm in diameter) forming globular aggregates of pine-cone shape, rarely exceeding 2 mm in diameter. Locality B: radial aggregates (up to 4 cm across) of flat, elongated crystals (up to 2 cm long). Locality C: boat-like crystals up to 1 cm long.

Physical properties: *Luster:* metallic to submetallic. *Diaphaneity:* opaque. *Color:* brown to black. *Streak:* light brown to ochre. *Luminescence:* non-fluorescent. *Hardness:* VHN$_{50}$ 430–494 kg/mm^2, Mohs ≈ 5. *Tenacity:* brittle. *Cleavage:* {100} perfect. *Fracture:* uneven to conchoidal. *Density:* 4.6 g/cm^3 (meas.) (low due to alteration), 4.74–4.80 g/cm^3 (calc.). ***Crystallography:*** Monoclinic, $P2_1/m$, a 10.625, b 3.264, c 8.990 Å, β 109.15°, V 294.5 Å^3, Z 2, a:b:c = 3.2552:1:2.7543. Morphology: forms, {100}, {001}, {011}. Twinning: none mentioned. ***X-ray powder diffraction data:*** 2.985 (67), 2.811 (94), 2.749 (100), 2.391 (85), 1.779 (48), 1.709 (35). ***Optical data:*** In reflected light: creamy white, anisotropism visible along grain boundaries, bireflectance not visible, nonpleochroic. $R_{min.}$ & $R_{max.}$: (15.4, 16.0 %) 470nm, (15.3, 15.8 %) 546nm, (14.8, 15.2 %) 589nm, (14.2, 15.0 %) 650nm. ***Chemical analytical data:*** Means of seven sets of electron microprobe data: FeO 23.12, MnO 1.25, Fe_2O_3 17.13, TiO_2 10.09, As_2O_3 46.95, Total 98.54 wt.%. Empirical formula: $(Fe^{2+}_{1.39}Fe^{3+}_{0.92}Ti_{0.54}Mn_{0.08})_{\Sigma 2.93}As_{2.04}O_{7.00}$. ***Relationship to other species:*** It is an arsenite. ***Name:*** For the chemical composition, FeTiAs. ***Comments:*** IMA No. 91-019. Some of the data given in this abstract were taken from the original IMA proposal.

GRAESER, S., SCHWANDER, H., DEMARTIN, F., GRAMACCIOLI, C. M., PILATI, T., and REUSSER, E. (1994) Fetiasite $(Fe^{2+},Fe^{3+},Ti)_3O_2[As_2O_5]$, a new arsenite mineral: Its description and structure determination. *American Mineralogist* **79**, 996–1002.

Jankovićite

Triclinic

$Tl_5Sb_9(As,Sb)_4S_{22}$

Locality: Crven Dol mine, Allchar, Macedonia.

Occurrence: In the Sb-poor, As- and Tl-rich zone of the orebody, which contains the following minerals: realgar, orpiment, pyrite, lorandite, vrbaite, raguinite, picotpaulite, rebulite, simonite and weissbergite. Minerals in the Crven Dol mine are: realgar, orpiment, As-bearing pyrite, marcasite, fangite and bernardite. Jankovićite is associated with realgar, stibnite and pyrite.

General appearance: Hypidiomorphic or tabular grains (less than 1 mm).

Physical properties: *Luster:* metallic. *Diaphaneity:* opaque. *Color:* black. *Streak:* brown-violet. *Hardness:* VHN$_{50}$ 97.7 kg/mm^2, Mohs about 2. *Tenacity:* brittle. *Cleavage:* galena-like {100}. *Fracture:* subconchoidal. *Density:* could not be measured, 5.08 g/cm^3 (calc.). ***Crystallography:*** Triclinic, $P\bar{1}$, a 7.393, b 8.707, c 17.584 Å, α 103.8°, β 91.79°, γ 109.50°, V 1028 Å^3, Z 1, a:b:c = 0.8491:1:2.0195. Morphology: no forms were observed. Twinning may be represented by a lamellar texture which was observed. ***X-ray powder diffraction data:*** 3.4590 (100), 3.3884 (64), 3.1774 (54), 3.0755 (65), 2.8019 (44), 2.5820 (35), 2.2868 (57), 1.7364 (38). ***Optical data:*** In reflected light: white to greyish-bluish white; distinct to strong anisotropism, with grey-blue to green-blue effects; low to medium bireflectance. $R_{min.}$ & $R_{max.}$: (34.0, 36.7 %) 470nm, (32.0, 34.9 %) 546nm, (30.5, 33.0 %) 589nm, (28.1, 29.7 %) 650nm. ***Chemical analytical data:*** Means of four sets of electron microprobe data: Tl 31.51, Sb 37.69, As 7.95, S 22.30, Total 99.45 wt. %. Empirical formula: $Tl_{4.87}Sb_{9.79}As_{3.35}S_{21.99}$. ***Relationship to other species:*** none apparent. ***Name:*** For Prof. S Janković (1925–) in recognition of his work on the mineralogy and geology of Allchar. ***Comments:*** IMA No. 93-050. It is not clear how a "galena-like" cleavage (i.e., cubic) can result from the {100} cleavage of this triclinic mineral.

CVETKOVIĆ, LJ., BORONIKHIN, V. A., PAVICEVIĆ, M. K., KRAJNOVIĆ, D., GRŽETIĆ, I., LIBOWITZKY, E., GIESTER, G. and TILLMANNS, E. (1995): Jankovićite, $Tl_5Sb_9(\underline{As},Sb)_4S_{22}$, a new Tl-sulfosalt from Allchar, Macedonia. *Mineralogy and Petrology* **53**, 125–131.

Kintoreite

Hexagonal (trigonal)

$PbFe^{3+}_3(PO_4)_2(OH,H_2O)_6$

Locality: The Kintore Opencut and the Block 14 Opencut, Broken Hill, New South Wales, Australia.

Occurrence: In the Kintore Opencut, as crusts lining cavities in goethite; associated minerals are: pyromorphite and mimetite. In the Block 14 Opencut, as encrustations on quartz and garnet-rich lode rocks; associated minerals are: pyromorphite, hinsdalite, libethenite, apatite and a phosphate resembling rockbridgeite or dufrenite.

General appearance: Clusters and coatings of "dog-tooth" crystals up to several mm high (Kintore Opencut) and globular crusts and hemispheres (Block 14 Opencut).

Physical properties: *Luster:* crystals vitreous to adamantine, globules greasy or waxy. *Diaphaneity:* crystals translucent, globules transparent to translucent. *Color:* cream to yellowish green and brownish yellow. *Streak:* pale yellowish green. *Luminescence:* not mentioned. *Hardness:* is about 4. *Tenacity:* brittle. *Cleavage:* {001} good. *Fracture:* rough. *Density:* could not be measured but is greater than 4.2 g/cm^3, 4.34 g/cm^3 (calc.). ***Crystallography:*** Hexagonal (trigonal), $R\bar{3}m$ (by analogy with segnitite), a 7.325, c 16.900 Å, V 785.3 Å^3, Z 3, c:a = 2.3072. Morphology: {112} is listed as the dominant form; no others are mentioned. Twinning: present, but not described. ***X-ray powder diffraction data:*** 5.96 (90), 3.67 (60), 3.07 (100), 2.971 (40), 2.818 (40), 2.538 (50), 2.257 (50), 1.979 (50), 1.831 (40). ***Optical data:*** Uniaxial (-), indices of refraction are between 1.955 and 1.935. Pleochroism is from light yellowish green to medium yellow. ***Chemical analytical data:*** Means of 6 sets of electron microprobe data: CuO 0.25, ZnO 1.58, PbO 31.37, BaO 0.09, Al_2O_3 0.02, Fe_2O_3 34.01, P_2O_5 13.30, As_2O_5 6.43, SO_3 2.02, CO_2 0.73, H_2O 9.0, Total 98.80 wt. % (given as 98.90). Empirical formula: $Pb_{0.97}(Fe^{3+}_{2.95}Zn_{0.13}Cu_{0.02})_{\Sigma 3.10}[(PO_4)_{1.30}(AsO_4)_{0.39}(SO_4)_{0.17}(CO_3)_{0.11}]_{\Sigma 1.97}$-$(OH)_{5.46}\cdot 0.73H_2O$. ***Relationship to other species:*** It is the Pb-Fe^{3+}-P analog of segnitite and is a member of the alunite-jarosite family. ***Name:*** For the locality. ***Comments:*** IMA No. 92-045. The empirical formula derived here is *very* slightly different from that given in the paper.

PRING, A., BIRCH, W. D., DAWE, J., TAYLOR, M., DELIENS, M., and WALENTA, K. (1995): Kintoreite, $PbFe_3(PO_4)_2(OH,H_2O)_6$, a new mineral of the jarosite-alunite family, and lusungite discredited. *Mineralogical Magazine* **59**, 143–148.

Kusachiite

Tetragonal

$CuBi_2O_4$

Locality: Fuka, Bitchu-Cho, Okayama Prefecture, Japan (Lat. 43°46′ N, Long. 133°26′ E).

Occurrence: On calcite crystals in a calcite vein (2 to 8 cm wide) which occurs along the boundary between gehlenite-spurrite skarn and crystalline limestone. Associated minerals are: henmilite, sillenite, bakerite, tenorite (given as "tenolite"), bultfonteinite, a member of the apophyllite group, cuspidine and thaumasite.

General appearance: Prismatic crystals up to 0.5 mm long and globular aggregates up to 2 mm in diameter.

Physical properties: *Luster:* metallic. *Diaphaneity:* opaque. *Color:* black. *Streak:* black. *Hardness:* VHN_{25} 292-357 kg/mm^2, Mohs 4½. *Tenacity:* not given. *Cleavage:* {110} perfect. *Fracture:* not given. *Density:* 8.5 g/cm^3 (meas.), 8.64 g/cm^3 (calc.). ***Crystallography:*** Tetragonal, P4/ncc, a 8.511, c 5.823 Å, V 421.8 Å^3, Z 4, c:a = 0.6842. Morphology: no forms are given, but {100} and {001} are listed in the IMA proposal. Twinning: not mentioned. ***X-ray powder diffraction data:*** 4.26 (17), 3.191 (100), 2.913 (16), 2.695 (18), 2.404 (13), 1.947 (18), 1.728 (12). ***Optical data:*** In reflected light: grey; weak to distinct anisotropism; bireflectance weak, but distinct; pleochroism colors, grey with a faint bluish tint and brownish grey;. $R_{min.}$ & $R_{max.}$: (19.0, 21.1 %) 482nm, (18.0, 20.2 %) 545nm, (17.6, 19.7 %) 589nm, (17.3, 19.5 %) 650nm. ***Chemical analytical data:*** Means of six sets of electron microprobe data: CuO 13.91, Bi_2O_3 86.00, Total 99.91 wt. %. Empirical formula: $Cu_{0.96}Bi_{2.03}O_{4.00}$. ***Relationship to other species:*** The natural analog of synthetic $CuBi_2O_4$. ***Name:*** For Dr. Isao Kusachi (1942–), of Okayama University in recognition of his work on the skarn minerals of the locality. ***Comments:*** IMA No. 92-024. Some of the data given in this abstract were taken from the original IMA proposal.

HENMI, C. (1995): Kusachiite, $CuBi_2O_4$, a new mineral from Fuka, Okayama Prefecture, Japan. *Mineralogical Magazine* **59**, 545–548.

Magnesiocoulsonite

Cubic

MgV_2O_4

Locality: In the Precambrian Slyudyanka Complex, Slyudyanka, southern Lake Baikal Region, Russia.

Occurrence: As an accessory mineral in Cr-V-bearing parametamorphic rocks. Associated minerals are: Cr-V-bearing tremolite and diopside, calcite, quartz, goldmanite, Cr-V-bearing chlorite and muscovite, vanadian magnesiochromite, karelianite, chromian karelianite, pyrite and a new Mg-Cr-V mineral with the preliminary formula $Mg(Cr,V)_4O_9$.

General appearance: Equant grains (0.2 to 0.3 mm).

Physical properties: *Luster:* metallic. *Diaphaneity:* opaque. *Color:* black. *Streak:* black. *Hardness:* VHN_{100} 969 kg/mm^2, Mohs 6½. *Tenacity:* brittle. *Cleavage:* none. *Fracture:* uneven. *Density:* could not be measured, 4.30 g/cm^3 (calc.). ***Crystallography:*** Cubic, Fd3m, a 8.385 Å, V 589.5 Å^3, Z 8. Morphology: Some sections resemble octahedra. Twinning: not mentioned. ***X-ray powder diffraction data:*** 4.84 (9), 2.52 (10), 2.093 (8), 1.612 (8), 1.482 (9), 1.092 (7), 1.048 (5). ***Optical data:*** In reflected light: light grey, no anisotropism, no bireflectance, nonpleochroic. R: (14.0 %) 470nm, (13.7 %) 546nm, (13.7 %) 589nm, (13.7 %) 650nm. ***Chemical analytical data:*** Means of ten sets of electron microprobe data: MgO 20.90, MnO 0.18, FeO 0.20, Al_2O_3 0.36, V_2O_3 50.07, Cr_2O_3 28.09, TiO_2 0.14, Total 99.94 wt. %. Empirical formula: $(Mg_{0.99}Fe_{0.01})_{\Sigma 1.00}(V_{1.28}Cr_{0.71}Al_{0.01})_{\Sigma 2.00}O_{4.00}$. ***Relationship to other species:*** The magnesium-dominant analog of coulsonite and a member of the spinel group. ***Name:*** For the relationship to coulsonite. ***Comments:*** IMA No. 94-034. Some of the data given in this abstract were taken from the original IMA proposal.

REZNITSKII, L.Z., SKLYAROV, E. V., and USHCHAPOVSKAYA, Z. F. (1995) Magnesiocoulsonite MgV_2O_4—a new mineral species in the spinel group. *Zapiski Vsesoyuznyi Mineralogicheskoe Obshchestva* **124(4)**, 91–98.

Magnesiodumortierite

Orthorhombic

$(Mg,Ti,\square)(Al,Mg)_2Al_4Si_3O_{18-y}(OH)_yB$ y = 2-3

Locality: Dora-Maira massif, western Alps, Italy.

Occurrence: In pyrope megablasts (up to 25 cm in diameter) in coesite-bearing quartz-phengite-kyanite schists. Other minerals in the pyrope megablasts are: bearthite, ellenbergerite, magnesiostaurolite (IMA No. 92-035), kyanite, talc, rutile, zircon, "monazite," dravite, wagnerite, clinochlore, an orthopyroxene, gedrite, corundum, sapphirine, "apatite," glaucophane, and vermiculite.

General appearance: Anhedral to subhedral inclusions up to 300 µm.

Physical properties: *Luster:* vitreous. *Diaphaneity:* transparent. *Color:* pink to red. *Streak:* probably white. *Luminescence:* non-fluorescent. *Hardness:* probably 7-8. *Tenacity:* not given. *Cleavage:* poor parallel to [001]. *Fracture:* not given. *Density:* could not be measured, 3.22 g/cm^3 (calc.). ***Crystallography:*** Orthorhombic, Pmcn, a 11.91, b 20.42, c 4.714 Å, V Å^3, Z 4, a:b:c = 0.5833:1:0.2309. Morphology: no forms observed. Twinning: none observed. ***X-ray powder diffraction data:*** 5.91 (90), 3.472 (70), 3.246 (100), 2.915 (60), 2.105 (90), 1.687 (60), 1.3451 (60). ***Optical data:*** Biaxial (-), α 1.678, β 1.700, γ 1.701, 2V(meas.) 38.5°, 2V(calc.) 24°, pleochroic: X pale pink to red, Y and Z colorless; X = c, probably with Y = b and Z = a. ***Chemical analytical data:*** Means of 2 sets of electron and ion microprobe data: MgO 7.8, FeO 0.09, Al_2O_3 47.3, B_2O_3 5.1, SiO_2 31.7, TiO_2 4.28, ZrO_2 0.06, P_2O_5 0.07, H_2O 3.5, Total 99.90 wt. %. Empirical formula: $(Al_{5.28}Mg_{1.10}Ti_{0.30}Fe_{0.01})_{\Sigma 6.69}$-$Si_{3.00}O_{18.00}H_{2.21}B_{0.83}$. The ideal formula, $[(Mg_{0.49}Ti_{0.19}Fe_{0.01}\square_{0.31})_{\Sigma 1.00}(Al_{3.80}\square_{0.20})_{\Sigma 4.00}(Al_{1.42}Mg_{0.50}\square_{0.08})_{\Sigma 2.00}][Si(Si_{1.88}$-$P_{0.02}\square_{0.10})_{\Sigma 2.00}O_{15.04}(OH)_{2.96}]B$, is the result of the crystal structure determination, and requires: MgO 7.15, FeO 0.13, Al_2O_3 47.71, B_2O_3 6.24, SiO_2 31.02, TiO_2 2.72, P_2O_5 0.25, H_2O 4.78, Total 100.00 wt. %. ***Relationship to other species:*** The magnesium-dominant analog of dumortierite. ***Name:*** For the relationship to dumortierite. ***Comments:*** IMA No. 92-050. The density calculated from the empirical formula is 3.38 g/cm^3.

FERRARIS, G., IVALDI, G. and CHOPIN, C. (1995) Magnesiodumortierite, a new mineral from very-high-pressure rocks (Western Alps). Part I: Crystal structure. *European Journal of Mineralogy* **7**, 167–174; and CHOPIN, C., FERRARIS, G., IVALDI, G., SCHERTL, H.-P., SCHREYER, W., COMPAGNONI, R., DAVIDSON, C., and DAVIS, A. M. (1995) Magnesiodumortierite, a new mineral from very-high-pressure rocks (Western Alps). II. Crystal chemistry and petrological significance. *European Journal of Mineralogy* **7**, 525–535.

Makovickyite Monoclinic

$Ag_{1.5}Bi_{5.5}S_9$

Locality: Băiţa Bihorului (formerly Rézbánya), Romania. Also found at Felbertal, Austria.

Occurrence: In a dolomite skarn. Associated minerals are: diopside, chondrodite, forsterite, "grossular-andradite," wollastonite, scheelite, molybdenite, bismuthinite, aikinite, sphalerite, chalcopyrite, galena, wittichenite, tetradymite, bismuth, and gold.

General appearance: Compact aggregates of grains up to 2 mm.

Physical properties: *Luster:* metallic. *Diaphaneity:* opaque. *Color:* grey. *Streak:* grey. *Hardness:* VHN_{50-100} 210–221 kg/mm². *Tenacity:* unknown. *Cleavage:* none apparent. *Fracture:* not mentioned. *Density:* could not be measured, 6.70 g/cm³ (calc.). ***Crystallography:*** Monoclinic, C2/m, a 13.37, b 4.05, c 14.71 Å, β 99.5°, V 785 Å³, Z 2, a:b:c = 3.3012:1:3.6321. Morphology: no forms observed. Twinning: none mentioned. ***X-ray powder diffraction data:*** 3.63 (50), 3.485 (50), 2.968 (30), 2.850 (100), 2.272 (40), 2.117 (30), 2.010 (30). ***Optical data:*** In reflected light: light grey, anisotropism quite pronounced in grey tones, bireflectance not noticeable, pleochroism not mentioned. R: (43.2 %) 546nm. ***Chemical analytical data:*** Means of three sets of electron microprobe data: Cu 4.37, Ag 5.37, Pb 3.50, Fe 0.0, Sb 0.09, Bi 68.81, Te 0.69, Se 0.40, S 17.75, Total 100.98 wt.%. Empirical formula: $Ag_{0.77}Cu_{1.07}Pb_{0.26}Bi_{5.12}Sb_{0.01}S_{8.60}Te_{0.08}Se_{0.08}$. ***Relationship to other species:*** A member of the pavonite series. ***Name:*** For Dr. Emil Makovicky, Slovak and Danish mineralogist, University of Copenhagen. ***Comments:*** IMA No. 86-027. Because most of the material consists of intergrowths with other phases, much of the usual information could not be obtained.

ŽÁK, L., FRÝDA, J., MUMME, W. G., and PAAR, W. H. (1994) Makovickyite, $Ag_{1.5}Bi_{5.5}S_9$, from Băiţa Bihorului, Romania: The ⁴P natural mineral member of the pavonite series. *Neues Jahrbuch für Mineralogie, Abhandlung* **168**, 147–169.

Mereiterite Monoclinic

$K_2Fe^{2+}(SO_4)_2{\cdot}4H_2O$

Locality: The D-level of the Hilarion adit, Agios Konstandinos, Lavrion Mining District, Greece.

Occurrence: In a 1 x 2 x 2 m pocket in marble. Associated minerals are: "limonite," smithsonite and gypsum.

General appearance: Heavily etched and rounded subhedral crystals (up to 10 x 8 x 6 mm).

Physical properties: *Luster:* vitreous to greasy. *Diaphaneity:* transparent. *Color:* pale yellow. *Streak:* white. *Luminescence:* non-fluorescent. *Hardness:* 2½–3. *Tenacity:* very brittle. *Cleavage:* none. *Fracture:* conchoidal. *Density:* 2.36 g/cm³ (meas.), 2.35 g/cm³ (calc.). ***Crystallography:*** Monoclinic, C2/m, a 11.841, b 9.553, c 9.942 Å, β 94.90°, V 1120.6 Å³, Z 4, a:b:c = 1.2395:1:1.0407. Morphology: because of the etched nature of the crystals, no forms are listed. Twinning: none observed. ***Optical data:*** Biaxial (+), α 1.497, β 1.501, γ 1.509, 2V(meas.) 73°, 2V(calc.) 71°, dispersion r > v, very weak; nonpleochroic; X = b, Z ^ c probably ≈ 20°. ***Chemical analytical data:*** Means of three sets of electron microprobe data (H_2O by TGA): K_2O 22.70, FeO 17.88, SO_3 40.22, H_2O 18.0, Total 98.80 wt. %. Empirical formula: $K_{1.93}Fe_{1.00}S_{2.01}O_{8.00}{\cdot}4.00H_2O$. ***Relationship to other species:*** The iron analog of leonite, $K_2Mg(SO_4)_2{\cdot}4H_2O$. ***Name:*** For Dr. Kurt Mereiter (1945-), Technical University of Vienna. ***Comments:*** IMA No. 93-045. Some of the data given in this abstract were taken from the original IMA proposal.

GIESTER, G. and RIECK, B. (1995): Mereiterite, $K_2Fe[SO_4]_2{\cdot}4H_2O$, a new leonite-type mineral from the Lavrion Mining District, Greece. *European Journal of Mineralogy* **7**, 559–566.

Morimotoite Cubic

$Ca_3TiFe^{2+}Si_3O_{12}$

Locality: Fuka, Bitchu-Cho, Okayama Prefecture, Japan (Lat. 43°46′ N, Long. 133°26′ E).

Occurrence: In skarns on both sides of a quartz monzonite dike which cuts limestones. The skarns contain: gehlenite, spurrite, garnet, vesuvianite, bicchulite, and other minerals. Minerals associated with morimotoite are: clinopyroxene, feldspar, vesuvianite, "grandite" garnet (intermediate between *gr*ossular and *and*radite), wollastonite, prehnite, perovskite, titanite, fluorapatite, biotite, epidote, hematite, zircon, baddeleyite and calzirtite.

General appearance: Euhedral to subhedral grains up to 15 mm with or without rims of the "grandite" garnet.

Physical properties: *Luster:* adamantine. *Diaphaneity:* opaque. *Color:* black. *Streak:* grey. *Luminescence:* non-fluorescent. *Hardness:* VHN_{50} 1070-1150 kg/mm², Mohs 7½. *Tenacity:* not given, but probably brittle. *Cleavage:* not observed. *Fracture:* subconchoidal. *Density:* 3.75 g/cm³ (meas.), 3.80 g/cm³ (calc.). ***Crystallography:*** Cubic, Ia3d, a 12.162 Å, V 1798.9 Å³, Z 8. Morphology: no forms noted, although it is stated to be euhedral to subhedral. Twinning: none noted. ***X-ray powder diffraction data:*** 3.039 (72), 2.720 (100), 2.483 (51), 2.385 (21), 1.973 (24), 1.687 (26), 1.626 (56). ***Optical data:*** Isotropic, n 1.955. ***Chemical analytical data:*** Means of seven sets of electron microprobe data: MgO 0.87, CaO 31.35, MnO 0.23, FeO 7.78, Al_2O_3 0.97, Fe_2O_3 11.42, SiO_2 26.93, TiO_2 18.51, ZrO_2 1.48, Total 99.54 wt. %. Empirical formula: $(Ca_{2.89}Mg_{0.11})_{\Sigma 3.00}(Ti_{1.20}Fe^{2+}_{0.56}Fe^{3+}_{0.16}Zr_{0.06}Mn_{0.02})_{\Sigma 2.00}(Si_{2.32}Fe^{3+}_{0.58}Al_{0.10})_{\Sigma 3.00}O_{12.00}$. ***Relationship to other species:*** A member of the garnet group. ***Name:*** For Dr. Nobuo Morimoto (1926–), Professor Emeritus of Osaka University. ***Comments:*** IMA No. 92-017. Some of the data given in this abstract were taken from the original IMA proposal. The term "titanian" used in the title of the paper is incorrect. This is a Schaller modifier and is used to indicate the presence of a small amount of titanium; the use here implies a varietal status. In the case of morimotoite, titanium is a major component and the word "titanium" should have been used.

HENMI, C., KUSACHI, I. and HENMI, K. (1995): Morimotoite, $Ca_3TiFe^{2+}Si_3O_{12}$, a new titanian garnet from Fuka, Okayama Prefecture, Japan. *Mineralogical Magazine* **59**, 115–120.

Olkhonskite Monoclinic

$(Cr,V)_2Ti_3O_9$

Locality: On the western shore of Lake Baikal 4.5 km south of the Olkhon Gate strait, Russia.

Occurrence: In quartzite-schists. Associated minerals are: rutile, eskolaite, karelianite, schreyerite, and vuorelainenite.

General appearance: Platy inclusions (1–20 μm x 50–150 μm) in rutile.

Physical properties: *Luster:* metallic. *Diaphaneity:* opaque. *Color:* black. *Streak:* black. *Hardness:* VHN_{65} 1412 kg/mm². *Tenacity:* brittle. *Cleavage:* not observed. *Fracture:* not observed. *Density:* could not be measured, 4.48 g/cm³ (calc.). ***Crystallography:*** Monoclinic, space group unknown, a 7.03, b 5.02, c 18.83 Å, β 119.60°, V 577.8 Å³, Z 4, a:b:c = 1.4004:1:3.7510. Morphology: no forms observed. Twinning: none mentioned. ***X-ray powder diffraction data:*** 2.88 (7), 2.75 (10), 2.43 (7), 2.14 (5), 1.660 (5), 1.426 (7), 1.386 (10). ***Optical data:*** In reflected light: light grey, weak anisotropism, noticeable bireflectance, weakly pleochroic in brownish tints. $R_{max.}$ & $R_{min.}$: (20.1, 18.1 %) 470nm, (19.9, 18.5 %) 546nm, (19.8, 18.4 %) 589nm, (20.0, 18.6 %) 650nm. ***Chemical analytical data:*** Means of twelve sets of electron microprobe data: FeO 0.21, Al_2O_3 0.63, V_2O_3 16.17, Cr_2O_3 21.77, TiO_2 60.83, Total 99.61 wt.%. Empirical formula: $(Cr_{1.12}V_{0.85}Al_{0.05}Fe_{0.01})_{\Sigma 1.03}Ti_{2.98}O_{9.00}$. ***Relationship to other species:*** It is the chromium-dominant analog of schreyerite. ***Name:*** For the locality. ***Comments:*** IMA No. 93-035. Some of the data given in this abstract were taken from the original IMA proposal.

KONEVA, A. A., PISKUNOVA, L. F., USHCHAPOVSKAYA, Z. F., and KONEV, A. A. (1994) Olkhonskoite $(Cr,V)_2Ti_3O_9$—a new mineral from Priol'khonie. *Zapiski Vsesoyuznyi Mineralogicheskoe Obshchestva* **123(4)**, 98–103.

Reederite-(Y) Hexagonal

$Na_{15}Y_2(CO_3)_9(SO_3F)Cl$

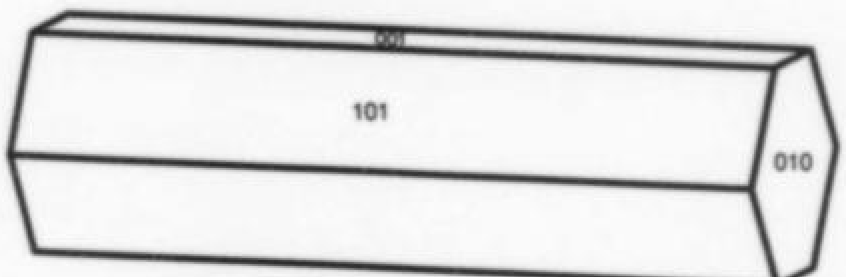
Locality: Poudrette Quarry, Mont Saint-Hilaire. Rouville County, Quebec, Canada.

Occurrence: As inclusions in a trona-filled vug in a sodalite xenolith in syenite. Associated minerals are: trona, shortite, petersenite-(Ce), catapleiite, analcime, and manganotychite.

General appearance: blocky grains (up to 2 mm).

Physical properties: *Luster:* vitreous. *Diaphaneity:* transparent. *Color:* yellow to orange-brown. *Streak:* white. *Luminescence:* non-fluorescent. *Hardness:* 3-3½. *Tenacity:* brittle. *Cleavage:* {001} perfect. *Fracture:* conchoidal. *Density:* 2.91 g/cm³ (meas.), 2.85 g/cm³ (calc.). ***Crystallography:*** Hexagonal, $P\bar{6}$, a 8.773, c 10.746 Å, V 714.1 Å³, Z 1, c:a = 1.2249. Morphology: no forms observed. Twinning: none mentioned. ***X-ray powder diffraction data:*** 6.20 (40), 4.39 (80), 2.774 (80), 2.532 (100), 2.240 (80), 2.067 (30), 1.657 (40). ***Optical data:*** Uniaxial (-), ω 1.548, ε 1.537, nonpleochroic. ***Chemical analytical data:*** Means of ten sets of electron microprobe data: Na_2O 34.04, CaO 0.70, MnO 1.23, FeO 0.42, Al_2O_3 1.31, Y_2O_3 10.24, La_2O_3 1.39, Ce_2O_3 3.54, Pr_2O_3 0.36, Nd_2O_3 1.99, Sm_2O_3 0.52, Gd_2O_3 0.80, Dy_2O_3 1.39, Er_2O_3 1.19, Yb_2O_3 0.37, CO_2 31.91 (calculated from stoichiometry and crystal structure analysis), SO_3 5.07, F 1.86, Cl 2.05, sum 100.38, less O = F + Cl 1.25, Total 99.13 wt. %. Empirical formula: $(Na_{13.63}Al_{0.32}Mn_{0.22}Ca_{0.15}Fe_{0.07})_{\Sigma 14.39}$-$(Y_{1.13}Ce_{0.27}Nd_{0.15}La_{0.11}Dy_{0.09}Er_{0.08}Gd_{0.05}Sm_{0.04}Pr_{0.03}Yb_{0.02})_{\Sigma 1.97}(CO_3)_{9.00}(SO_3F)_{0.79}$-$(Cl_{0.72}F_{0.43})_{\Sigma 1.15}O_{0.69}$. ***Relationship to other species:*** none apparent. ***Name:*** For Dr. Richard J. Reeder, currently co-editor of the *American Mineralogist*. ***Comments:*** IMA No. 94-012. Some of the subscripts in the empirical formula given here are slightly different from those in the paper.

GRICE, J. D., GAULT, R. A., and CHAO, G. Y. (1995) Reederite-(Y), a new sodium rare-earth carbonate mineral with a unique fluorosulfate anion. *American Mineralogist* **80**, 1059–1064.



Rimkorolgite

Rimkorolgite

Orthorhombic

$(Mg,Mn)_5(Ba,Sr,Ca)(PO_4)_4 \cdot 8H_2O$

Locality: Kovdor iron deposit, Kola Peninsula, Russia.

Occurrence: In cavities in dolomitic carbonatites. Associated minerals are: dolomite, collinsite, bobierrite, pyrite, carbonate-fluorapatite and strontiowhitlockite.

General appearance: Pseudohexagonal prismatic crystals (up to 0.07 x 0.03 x 0.02 mm) and as fibrous pseudomorphs after bobierrite.

Physical properties: *Luster:* vitreous to silky. *Diaphaneity:* transparent to translucent. *Color:* yellow-brown to pink. *Streak:* white. *Luminescence:* non-fluorescent. *Hardness:* 3. *Tenacity:* brittle. *Cleavage:* {001} perfect. *Fracture:* uneven. *Density:* 2.67 g/cm³ (meas.), 2.68 g/cm³ (calc.). ***Crystallography:*** Orthorhombic, Pcmm, $Pcm2_1$ or Pc2m a 12.829, b 8.335, c 18.312 Å, V 1958 Å³, Z 4, a:b:c = 1.5392:1:2.1970. Morphology: forms: {001}, {010}, {101}. Twinning: not observed. ***X-ray powder diffraction data:*** 10.51 (100), 3.874 (32), 3.520 (34), 3.081 (78), 3.054 (41), 2.969 (44), 2.839 (34). ***Optical data:*** Biaxial (+), α 1.552, β 1.552, γ 1.558, 2V(meas.) 23°, 2V(calc.) 0°, nonpleochroic; X = c, Y = a, Z = b. ***Chemical analytical data:*** Means of two sets of electron microprobe data: MgO 26.55, CaO 0.1, MnO 1.55, SrO 1.8, BaO 16.95, P_2O_5 36.25, H_2O 17.5, Total 100.70 wt.%. Empirical formula: $(Mg_{5.17}Mn^{2+}_{0.17})_{\Sigma 5.34}(Ba_{0.87}Sr_{0.14}Ca_{0.01})_{\Sigma 1.02}P_{4.01}O_{16.39} \cdot 7.62H_2O$. ***Relationship to other species:*** none apparent. ***Name:*** For *Rimskaya-Korsakova*, *Olga* M. (1914–1987), Russian mineralogist from St. Petersburg University. ***Comments:*** IMA No. 90-032. The calculated density and subscripts in the empirical formula given here are slightly different from those given in the paper. Some of the data given in this abstract were taken from the original IMA proposal.

BRITVIN, S. N., PAKHOMOVSKY, Ya. A., BOGDANOVA, A. N., KHOMYAKOV, A. P., and KRASHOVA, N. I. (1995) Rimkorolgite $(Mg,Mn)_5(Ba,Sr,Ca)(PO_4)_4 \cdot 8H_2O$—the new mineral from Kovdor Iron Deposit, Kola Peninsula. *Zapiski Vsesoyuznyi Mineralogicheskoe Obshchestva* **124(1)**, 90–95.

Sabelliite

Hexagonal (trigonal)

$(Cu,Zn)_2Zn[(As,Sb)O_4](OH)_3$

Locality: The abandoned Is Murvonis Mine, Domusnovas, Iglesias district, Sardinia, Italy. A mineral with similar morphological and chemical characteristics has been found on mine dumps near Schwaz, Austria.

Occurrence: In a quartzitic outcrop as rare, minute crystals often overgrown on foliated aggregates of theisite. Other minerals found in the deposit are: fluorite, galena, sphalerite, chalcopyrite, tetrahedrite-tennantite, aurichalcite, malachite, azurite, brochantite, rosasite and hemimorphite.

General appearance: Intergrown aggregates of tabular, cylindrical (coin-like) crystals with diameters rarely exceeding 400 µm; also as isolated crystals up to 200 µm in diameter and 15 µm thick.

Physical properties: *Luster:* adamantine. *Diaphaneity:* transparent. *Color:* emerald-green. *Streak:* light-green. *Luminescence:* non-fluorescent. *Hardness:* VHN_{15} 386 kg/mm², Mohs about 4½. *Tenacity:* brittle. *Cleavage:* none. *Fracture:* not mentioned. *Density:* could not be measured, 4.65 g/cm³ (calc.). ***Crystallography:*** Hexagonal (trigonal), $P\bar{3}$, a 8.201, c 7.315 Å, V 426.07 Å³, Z 3, c:a = 0.8920. Morphology: only {001} observed. Twinning: none observed. ***X-ray powder diffraction data:*** 4.11 (55), 3.66 (52), 2.522 (100), 2.166 (88), 1.805 (92), 1.550 (100), 1.513 (85), 1.427 (54), 1.320 (55). ***Optical data:*** Uniaxial (-), ω 1.802, ε 1.797, nonpleochroic. ***Chemical analytical data:*** Means of twenty sets of electron microprobe data: CuO 43.56, ZnO 19.48, SiO_2 0.71, As_2O_5 23.07, Sb_2O_5 6.59, H_2O 6.05, Total 99.46 wt.%. Empirical formula: $Cu_{2.19}Zn_{0.96}(As_{0.80}Sb_{0.16}$-$Si_{0.05})_{\Sigma 1.01}O_{4.31}(OH)_{2.69}$. ***Relationship to other species:*** It has structural similarities with spangolite, theisite, namuwite and schulenbergite. ***Name:*** For Dr. Cesare Sabelli (1934–) of the Consiglio Nazionale delle Ricerche, Firenze, Italy. ***Comments:*** IMA No. 94-013. Very minor amounts of the data given in this abstract were taken from the original IMA proposal. The authors give $(Cu,Zn)_2Zn[(As,Sb)O_4](OH)_3$ as the ideal formula, which implies that there is less than two Cu and more than one Zn whereas the empirical formula shows more than two Cu and slightly less than one Zn. I thought that the formula might be expressed better as $Cu_2(Zn,Cu)[(As,Sb)O_4](OH)_3$ and asked the authors to comment on this. They replied (Olmi, personal communication) that they preferred their ideal formula because "it shows that the Zn atoms (not the Cu ones) are coordinated both octahedrally and tetrahedrally."

OLMI, F., SANTUCCI, A., and TROSTI-FERRONI, R. (1995) Sabelliite, a new copper-zinc arsenate-antimonate mineral from Sardinia, Italy. *European Journal of Mineralogy* **7**, 1325–1330 and OLMI, F., SABELLI, C., and TROSTI-FERRONI, R. (1995) The crystal structure of sabelliite. *European Journal of Mineralogy* **7**, 1331–1337.

Shannonite

Orthorhombic

Pb_2OCO_3

Locality: Grand Reef mine, Graham County, Arizona, U.S.A.

Occurrence: In silicified breccia. Associated minerals are: cerussite, fluorite, plumbojarosite, hematite, Mn-oxides, muscovite-$2M_1$, quartz, litharge, massicot, hydrocerussite, minium and unnamed $PbCO_3 \cdot 2PbO$.

General appearance: As mm-sized porcellanous crusts (individual crystallites are platy and anhedral and range from 10 to 400 nm).

Physical properties: *Luster:* waxy. *Diaphaneity:* opaque. *Color:* white. *Streak:* white. *Luminescence:* non-fluorescent. *Hardness:* VHN_{100} 97 kg/mm², Mohs 3-3½. *Tenacity:* brittle. *Cleavage:* none apparent. *Fracture:* uneven. *Density:* could not be measured, 7.31 g/cm³ (calc.). ***Crystallography:*** Orthorhombic, $P2_122_1$ or $P2_12_12_1$, a 9.294, b 9.000, c 5.133 Å, V 429.3 Å³, Z 4, a:b:c = 1.0327:1:0.5703. Morphology: no forms observed. Twinning: none observed. ***X-ray powder diffraction data:*** 6.49 (30), 4.14 (30), 4.02 (40), 3.215 (100), 3.181 (90), 2.931 (30), 2.858 (40), 2.564 (35). ***Optical data:*** Complete data could not be determined because of the fine-grained nature. The value of n calculated from reflectance measurements is 2.09; orientation unknown. ***Chemical analytical data:*** Means of eight sets of electron microprobe data (with CO_2 by CHN analyzer): PbO 89.90, CO_2 9.70, Total 99.60 wt. %. Empirical formula: $Pb_{1.91}C_{1.05}O_{4.00}$. ***Relationship to other species:*** The synthetic equivalent is well-known as one of a series of intermediate products of the controlled thermal decomposition of lead carbonate to lead oxide at elevated temperatures. ***Name:*** For David M. Shannon (1942–), a mineral dealer who helped collect the first samples of the mineral. ***Comments:*** IMA No. 93-053.

ROBERTS, A. C., STIRLING, J. A. R., CARPENTER, G. J. C., CRIDDLE, A. J., JONES, G. C., BIRKETT, T. C. & BIRCH, W. D. (1995): Shannonite, Pb_2OCO_3, a new mineral from the Grand Reef mine, Graham County, Arizona, U.S.A. *Mineralogical Magazine* **59**, 305–310.

Strakhovite

Orthorhombic

$NaBa_3(Mn^{2+},Mn^{3+})_4Si_6O_{19}(OH)_3$

Locality: The Ir-Nimi manganese deposit, Taikan Ridge, Far East, Russia.

***Occurrence*:** At the contact between braunite ore and alkali basalt. Associated minerals are: braunite, taikanite, namansilite, pectolite, and a manganese-bearing amphibole.

General appearance: Equant to slightly elongate grains (up to 0.07 mm).

Physical properties: *Luster:* vitreous to greasy, but see comments. *Diaphaneity:* translucent. *Color:* black with a greenish tint. *Streak:* green. *Luminescence:* nonfluorescent. *Hardness:* VHN_{100} 683–764 kg/mm², Mohs 5–6. *Tenacity:* brittle. *Cleavage:* {110} imperfect. *Fracture:* conchoidal. *Density:* 3.86 g/cm³ (meas.), 3.82 g/cm³ (calc.). ***Crystallography:*** Orthorhombic, Pnma, a 23.42, b 12.266, c 7.181 Å, V 2062.88 Å³, Z 4, a:b:c = 1.9093:1:0.5854. Morphology: no forms observed. Twinning: not mentioned. ***X-ray powder diffraction data:*** 4.580 (5), 3.303 (9), 2.999 (10), 2.715 (5), 2.655 (10), 2.156 (4), 1.648 (5). ***Optical data:*** Biaxial (+), α 1.767, β 1.793, γ 1.871, 2V(meas.) 60–65°, 2V(calc.) 62°, dispersion $r > v$, strong; pleochroism strong, X = light green, Y = green, Z = dark olive green to brown; X = c, Y = b, Z = a. ***Chemical analytical data:*** Means of four sets of electron microprobe data: Na_2O 2.85, CaO 0.03, MnO 14.16, BaO 39.20, Al_2O_3 0.23, Mn_2O_3 11.65, Fe_2O_3 0.03, SiO_2 30.03, H_2O 2.40, Total 100.58 wt.%. Empirical formula: $Na_{1.09}(Ba_{3.02}Ca_{0.01})_{\Sigma 3.03}(Mn^{2+}_{2.36}Mn^{3+}_{1.74})_{\Sigma 4.10}(Si_{5.90}Al_{0.05})_{\Sigma 5.95}O_{18.86}(OH)_{3.14}$. ***Relationship to other species:*** none apparent. ***Name:*** For N. M. Strakhov (1900–1978), for his contributions to the study of sedimentary ore deposits and phosphorites. ***Comments:*** IMA No. 93-005. Some of the data given in this abstract were taken from the original IMA proposal. The subscripts of the empirical formula given here are slightly different from those given in the paper. The indices of refraction indicate that the luster should be adamantine, not vitreous to greasy as given.

KALININ, V. V., PUSHCHAROVSKY, D. Yu., YAMNOVA, N. A., DIKOV, Yu. P., and BORISOVSKY, S. E. (1994) Strakhovite $NaBa_3(Mn^{2+},Mn^{3+})_4Si_6O_{19}(OH)_3$—a new Na-bearing silicate of Ba and Mn. *Zapiski Vsesoyuznyi Mineralogicheskoe Obshchestva* **123(4)**, 94–97.

Takedaite

Hexagonal (trigonal)

$Ca_3B_2O_6$

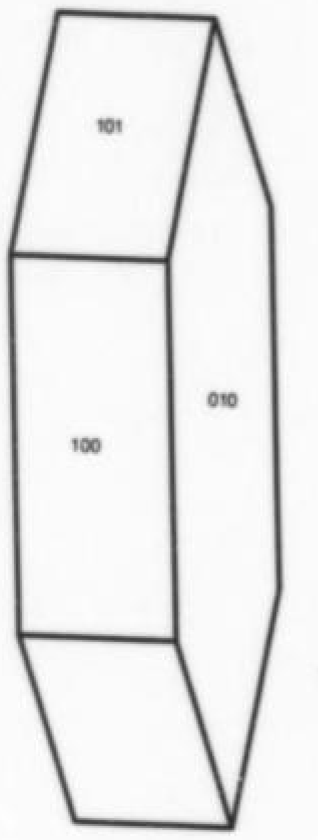
Locality: Fuka, Bitchu-Cho, Okayama Prefecture, Japan (Lat. 43°46′ N, Long. 133°26′ E).

***Occurrence*:** In a vein (about 10 cm thick which expanded to 2 m thick and almost 3 m long in one part) developed along the boundary between crystalline limestone and gehlenite-spurrite skarn. Takedaite occurs in the expanded part of the vein. Associated minerals are: frolovite, calcite and an unidentified mineral. Nifontovite, olshanskyite, sibirskite and pentahydroborite occur at the circumference of the expanded area.

General appearance: Aggregates of granular crystals up to 0.8 mm long and 0.3 mm wide.

Physical properties: *Luster:* vitreous. *Diaphaneity:* transparent. *Color:* white or pale grey. *Streak:* white. *Luminescence:* non fluorescent. *Hardness:* VHN_{25} 478 kg/mm², Mohs 4½. *Tenacity:* brittle. *Cleavage:* none observed. *Fracture:* uneven. *Density:* 3.10 g/cm³ (meas.), 3.11 g/cm³ (calc.). ***Crystallography:*** Hexagonal (trigonal), $R\bar{3}c$, a 8.638, c 11.850 Å, V 765.7 Å³, Z 6, c:a = 1.3718. Morphology: no forms observed. Twinning: none mentioned. ***X-ray powder diffraction data:*** 2.915 (100), 2.756 (61), 2.493 (44), 2.160 (19), 2.044 (21), 1.976 (18), 1.895 (75). ***Optical data:*** Uniaxial (-), ω 1.726, ε 1.630. ***Chemical analytical data:*** Wet chemical analysis gave the following data: CaO 71.13, B_2O_3 28.41, ignition loss 0.14, Total 99.68 wt. %. Empirical formula: $Ca_{3.05}B_{1.96}O_{6.00}$. ***Relationship to other species:*** The natural analogue of synthetic $Ca_3B_2O_6$. ***Name:*** For Prof. Hiroshi Takeda (1934–), of the Mineralogical Institute, University of Tokyo. ***Comments:*** IMA No. 93-049. Some of the data given in this abstract were taken from the original IMA proposal.

KUSACHI, I., HENMI, C., and KOBAYASHI, S. (1995): Takedaite, a new mineral from Fuka, Okayama Prefecture, Japan. *Mineralogical Magazine* **59**, 549–552.



Varennesite

Varennesite

Orthorhombic

$Na_8Mn_2Si_{10}O_{25}(OH,Cl)_2 \cdot 12H_2O$

Locality: Demix-Varennes quarry, which lies between the villages of Varennes and Saint-Amable, in Verchères County, Quebéc, Canada, approximately 20 km east of Montreal.

***Occurrence*:** As a primary, late-stage mineral in a sill. Associated minerals are: eudialyte, aegirine, natrolite, serandite, mangan-neptunite, microcline, albite and zakharovite.

General appearance: Tabular crystals (up to 4 mm long).

Physical properties: *Luster:* vitreous. *Diaphaneity:* translucent to transparent. *Color:* pale brownish yellow to orange. *Streak:* white. *Luminescence:* non-fluorescent. *Hardness:* approximately 4. *Tenacity:* brittle. *Cleavage:* {010} good. *Fracture:* conchoidal. *Density:* 2.31 g/cm³ (meas.), 2.34 g/cm³ (calc.). ***Crystallography:*** Orthorhombic, Cmcm, a 13.447, b 15.022, c 17.601 Å, V 3555 Å³, Z 4, a:b:c = 0.8952:1:1.1717. Morphology: forms, {100}, {010}, {101}, rarely {001}. Twinning: none mentioned. ***X-ray powder diffraction data:*** 10.049 (100), 8.823 (50), 5.025 (20), 4.138 (10), 3.806 (20), 3.659 (10), 3.148 (10), 2.718 (50), 2.405 (10), 2.171(10). ***Optical data:*** Biaxial (+), α 1.532, β 1.540, γ 1.550, 2V(meas.) 89°, 2V(calc.) 84°, dispersion weak $r > v$; pleochroism from yellow-green (Z) to very pale yellow (X); X = c, Y = a, Z = b. ***Chemical analytical data:*** Means of three sets of electron microprobe data: Na_2O 19.25, K_2O 0.21, MgO 0.03, CaO 0.11, MnO 6.50, FeO 3.25, SrO 0.15, Al_2O_3 0.48, SiO_2 48.26, TiO_2 2.56, SO_3 1.02, H_2O 18.47, Cl 2.20, sum 102.49, less O = Cl 0.50, Total 101.99 wt. %. Empirical formula: $(Na_{7.64}K_{0.05}Ca_{0.02}Sr_{0.02})_{\Sigma 7.73}(Mn_{1.13}Fe_{0.56}Ti_{0.39}Mg_{0.01})_{\Sigma 2.09}(Si_{9.88}Al_{0.12})_{\Sigma 10.00}$-$[(OH)_{1.24}Cl_{0.76}]_{\Sigma 2.00}(SO_4)_{0.16} \cdot 12.00H_2O$. ***Relationship to other species:*** none. ***Name:*** For the locality. ***Comments:*** IMA No. 94-017. The name is pronounced VARENAIT (i.e., the "es" is silent). The calculated density and the empirical formula given here differ slightly from those given in the paper. The crystal drawing given in the paper is not in the standard orientation so it has been redrawn here.

GRICE, J. D. and GAULT, R. A. (1995) Varennesite, a new species of hydrated Na-Mn silicate with a unique monophyllosilicate structure. *Canadian Mineralogist* **33**, 1073–1081.

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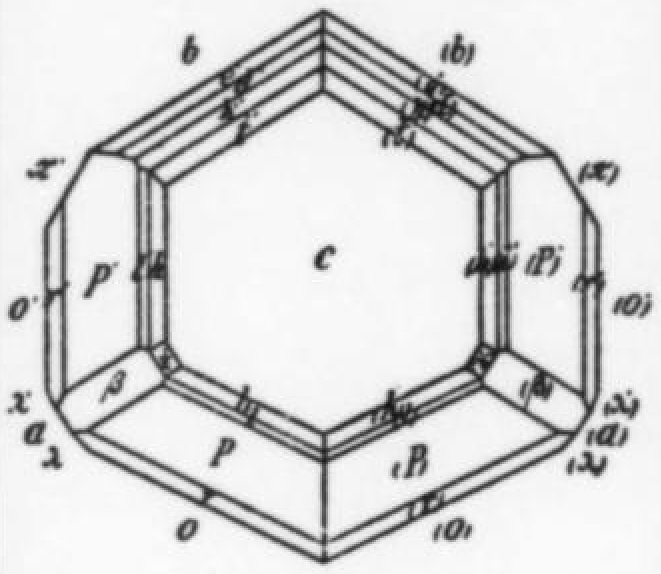

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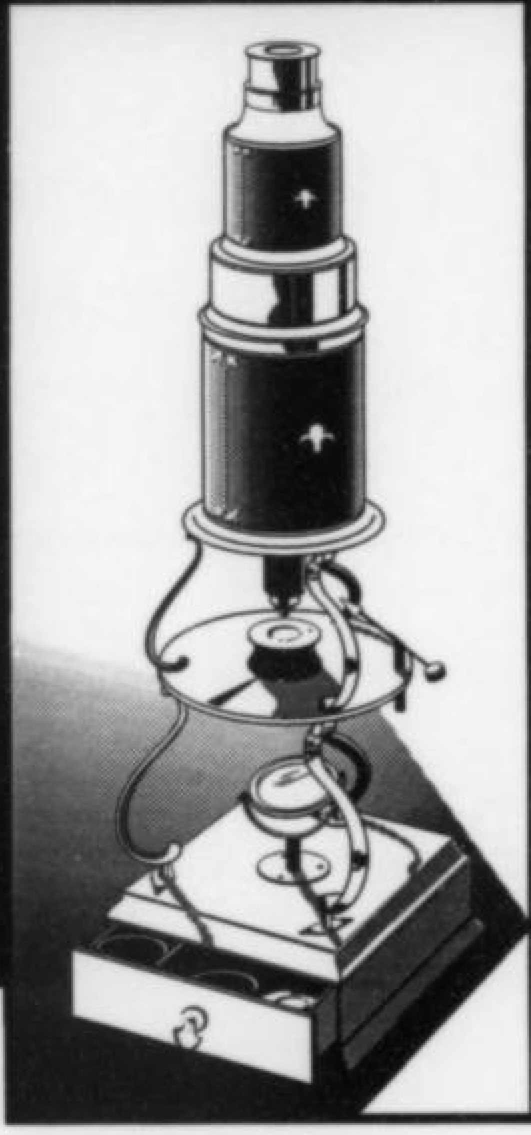

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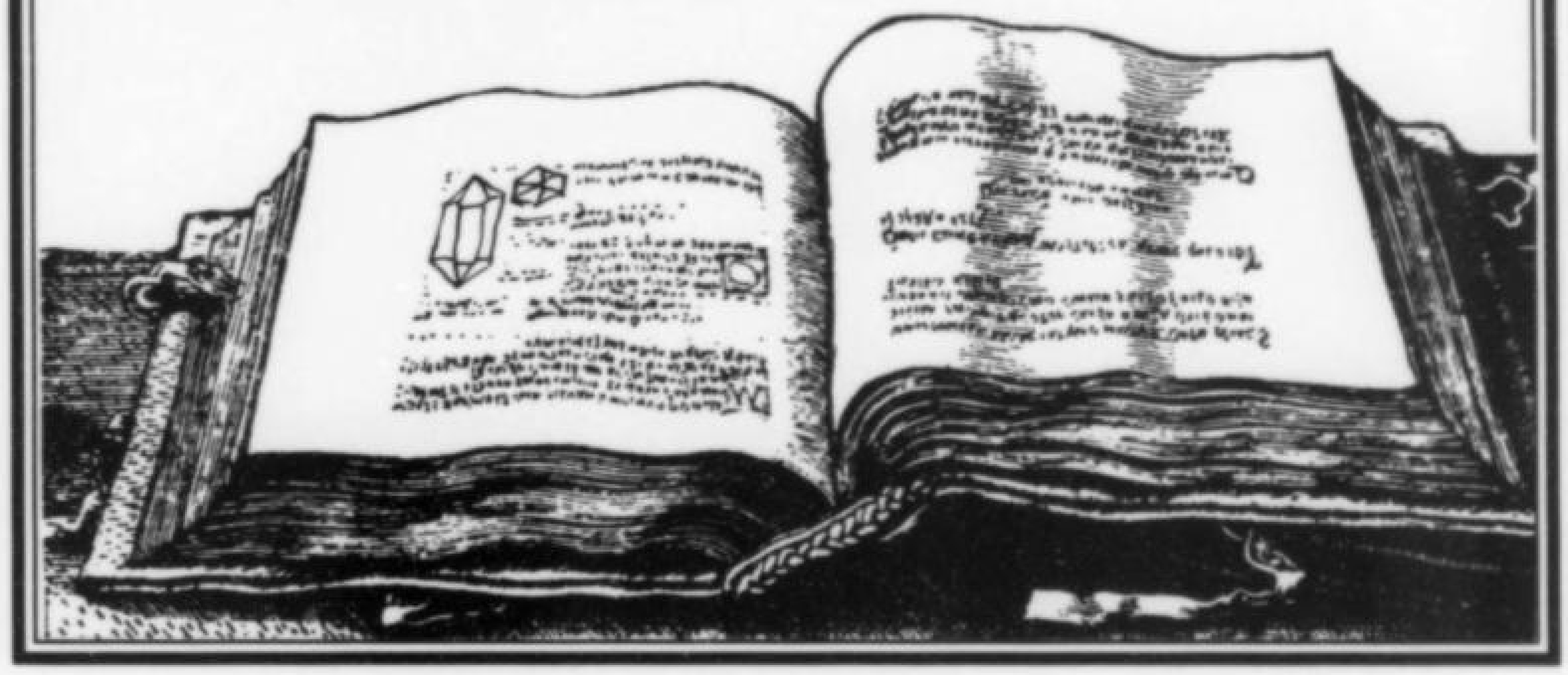

Minerals of New Mexico

by Stuart A. Northrup, third edition, revised (and abridged) by Florence A. LaBruzza. Published (1996) by the University of New Mexico Press, Albuquerque, NM 87131-1591; hardcover, 8 x 10 inches, 356 p., 8 maps, $75; ISBN 0-8263-1662-X.

New Mexico was among the first states (in 1944) to have a substantial state mineralogy published, and justifiably so. The region is rich in mineral occurrences, and is a paradise for the micromounter and field collector. Stuart Northrup's second edition of 1959 has now been brought up to date through the efforts of Florence LaBruzza (a zoologist and avid micromounter), incorporating 35 years of new research and field discoveries.

The species descriptions have been expanded to include the discoveries made since the late 1950's, and the bibliography has been enlarged accordingly, from about 1,400 entries to 1,800. A new appendix listing all known species from each district is a welcome addition. Maps showing counties and districts have been retained in revised form. As for other new material, a brief biography of Northrup is an excellent addition (as would have been some notes on LaBruzza). The historical review of New Mexico mineralogy and mining is reproduced essentially verbatim from the 1959 edition, with only a few inches of new text to cover the decades since then.

LaBruzza has made substantial deletions for the sake of brevity, reducing the book from 665 pages down to 356 pages (on a 30% larger page size). Cuts include special discussions of meteorites, hydrocarbons, some archeology, the history of mineral discoveries in the state, notes on unpublished records used, economic aspects of the state's mineral industry, and annotated lists of analyzed minerals, museum specimens, fluorescent species, radioactive minerals, and the minerals found in collectible high-quality specimens(!).

Also deleted is basic mineralogical data for each species. Although such facts as hardness, density, cleavage and habit can certainly be found in other general mineralogy texts, they would have been handy for the collector using the book as a guide to identification; the remaining descriptive data are rather fragmentary or non-existent. The most unfortunate deletion, however, is the chemical formula for each species; only an imprecise verbal rendering of the composition is given. LaBruzza would have been better advised to delete instead the abundant usage of obsolete mineral names and pointless varietal terms, in accord with modern professional scholarship and I.M.A. recommendations. Many varietal and obsolete names are even given their own subheadings, which are virtually indistinguishable in typeface and size from the main species headings. Another worthwhile deletion would have been Northrup's unusual (and pointless) cross-indexing of junior authors in the bibliography.

Like the 1959 edition, this book contains not a single specimen or locality illustration of any kind, save for one unidentified crystal drawing on the cover. Although fairly standard in the 1950's, the lack of illustrations is now a major shortcoming which is difficult to understand in a modern topographical mineralogy, especially one priced as high or higher than the recently published and abundantly illustrated mineralogies of Maine and Arizona.

The principal function of a revision of this sort is to incorporate new data and associated references; this has been accomplished, and the book can be recommended on that basis, although the previous edition should still be retained for those portions not included in the new edition. It is, however, behind the times in other ways which may be disappointing to the modern mineralogist and advanced collector, especially in view of the price.

W.E.W.

Rocks from Space: Meteorites and Meteorite Hunters

by O. Richard Norton, Illustrations by Dorothy S. Norton, published (1994) by Mountain Press Publishing Company, Missoula, Montana; softcover, 15 x 23 cm, 449 pages, ISBN 0-87842-302-8, price $18 (inside cover), $20 (outside cover).

This book, written by a former director of the Grace Flandrau Planetarium and Science Center at the University of Arizona and the Fleischmann Planetarium at the University of Nevada at Reno, appears to have a tough time deciding whether to be an honest-to-goodness scientific text or a popular history of meteorite collecting. It oscillates between the two concepts in rather uneven fashion. The preface does contain a *caveat* that it was intended to be: ". . . a book with little or no scientific prerequisites attached." But a ternary composition diagram for the olivine group is not without some prerequisite—particularly when the diagram is wrong!

In spite of that, I found the book to be a worthwhile effort. Mr. Norton has done a great deal of drudge work in pulling together material from many sources and has turned that material into readable, and often entertaining, text. Mrs. Norton, likewise, has produced illustrations which enhance the usefulness of the book, while eight plates of color photographs add a little pizzazz overall.

The book is divided into four parts, followed by an epilog, five appendices, a glossary, a list of references, and two indices—general, and a list of meteorites.

Part I—Falls, Finds, and Craters, describes meteoroids, meteorites, meteor showers and meteorite craters around the world, historical events involving meteorites, how meteors are tracked, and so on. It occupies 124 pages, and is the longest portion of the book. Here is where the reader discovers interplanetary dust, what presumably happened in the great Siberian Tunguska event of 1908, what meteorites do when they land on earth, and a host of other interesting tidbits of information. It is a sort of natural history of meteorites.

Part II—What is a Meteorite?, concentrates on how to recognize a meteorite, and describes the various classifications (chondrite, achondrite, iron, stony-iron) in readily assimilable terms. It is the most scientific portion of the book, and certainly contributed a lot to my understanding of the subject. My only quibble, as I said, is with the composition diagram for the olivine group on page 178, in which the neat little bracket indicating a composition of 15–30% fayalite is at the wrong side of the triangle. In its present position it indicates 15–30% forsterite, not fayalite. Similarly, the percentage scale should either be doubled to run in both directions, or be dispensed with entirely. The error is one every student of phase equilibria has made at one time or another, but simply for that reason it should have been recognized and corrected earlier.

Part III—Meteorite Hunters, is essentially the history of how some of the great meteorites were discovered and recovered. It names and gives brief biographies of some of the individuals in the field of meteorite collecting, and describes the machinations, lawsuits and risks involved in finding, protecting and laying claim to ownership. Some of the stories found here are interesting as miniature examples of many human efforts—conception, development, fruition, and eventual lapse into senescence and decay. There are lessons to be learned here that have wider application than meteorite collection.

Part IV—Origins, discusses asteroids, comets, and theories of meteorite sources and development. It touches on the Oort Cloud, and ventures into the more recent theories of the influence of large meteorite impacts on the development of life on Earth. Smallest of the parts, at a mere 44 pages, it is, nonetheless, a good summary of current thinking.

The appendices, which touch upon etching meteorites, lists of commercial dealers and lists of laboratories, are likely to be of more interest to the hobbyist than the theoretician.

All in all, the book is a good compendium and a pleasant read. I enjoyed it, though a couple of things left nagging doubts in my mind. On page 87, for instance, the author describes the fall of the meteorite which struck a car in Peekskill, New York, in 1992. He says: "She reached down and touched the meteorite and noted it was still warm and smelled of sulfur." That's very interesting. It is interesting because meteorites, before their fall, have been orbiting in space for untold millions of years. They have cold-soaked temperatures not far from absolute zero (-273° C). During their fall, a layer of the outer surface heats up and sloughs off, but there is normally not enough time for the heat to penetrate to the interior. People who find and pick up recently fallen meteorites are usually surprised to find how *cold* they are. The book doesn't mention that. I wonder why?

Quintin Wight

A Collector's Guide to Rock, Mineral, & Fossil Localities of Utah

by James R. Wilson. Published (1995) as Miscellaneous Publication 95-4 of the Utah Geological Survey, 2363 South Foothill Drive, Salt Lake City, UT 84109-1497; tel: (801) 467-0401. Softcover, 8.5 x 11 inches, 148 p. + 16 p. color plates, ISBN 1-55791-336-8, price: $8.95 (glued binding), or $9.95 (spiral binding), plus $3 shipping.

This book is a welcome addition to the literature on Utah minerals, aimed at the amateur who wants to collect specimens in the field. It begins with brief introductory reviews of basic information needed for at least a superficial understanding of basic mineralogy, petrology and paleontology. The average collector would do well to review this material periodically; it is written succinctly and clearly. There is a brief review of the literature, a references list of 68 citations, and some notes on collection-building.

The main part of the book, however, is Chapter 6, "A Guide to [177] Collecting Sites" for about 100 species of minerals plus a selection of fossils and rock types. The arrangement is by county, with brief data on minerals, geology, history, collecting, access, land status, references and where to find maps. (The minerals themselves are not usually described.) The directions for reaching each locality are particularly precise and should be easy to follow, despite the general absence of maps.

In the middle of Chapter 6 is a 16-page color section with over 80 mineral specimen photos and a few scenic views . . . remarkable in a book priced under $10! The photographs, mostly by John R. Shupe, are all well done, showing specimens of good to excellent quality.

At the end is a glossary of common geological terms and an index.

Wilson's guidebook does not supplant K. C. Bullock's 1981 *Minerals and Mineral Localities of Utah*, a simple geographical listing of over 570 species from a far greater number of localities, supported by a much larger bibliography. Nor is it a substitute for B. S. Butler's massive (672-page) 1920 Professional Paper on *The Ore Deposits of Utah*, which every Utah mineral collector should own. Neither of these earlier works is very useful as a practical field guide, however; Wilson's guidebook fills a need for an up-to-date, collector-oriented, user-friendly reference for the Utah field collector. And the amazingly low price makes it a real bargain affordable by anyone.

W.E.W.

Eine Sammlung Erzäht

["The Story of a Collection"] by Otto Fitz. Published (1993) by the Institut für Bodenforschung und Baugeologie, Abteilung Baugeologie, Universität für Bodenkultur, Gregor Mendel-Strasse 33, A-1180 Vienna, Austria; softcover, 80 p., 169 illustrations (11 in color), price: 200 öS (Austrian Schillings).

This interesting book (in German) presents an overview of the history of the 200-year-old rock and mineral collection in the Department of Economic Geology at the University for Bodenkultur in Vienna. Documentation is provided through early museum records and especially via fascinating old specimen labels that have been preserved. The core of the collection originated in part with Crown Prince Rudolf von Habsburg-Lothringen (1858–1889) and his instructor, Ferdinand von Hochstetter.

W.E.W.

Val Vigezzo: i minerali delle albititi

by V. Mattioli, R. Appiani, V. Cini, P. Gentile, D. Preite and P. Vignola. Published (1995) by Edizione Linea Due, Marnate (VA); softcover, 14.5 x 21 cm, 87 p., illustrated in color, price: DM 24.00

The Val Vigezzo (Vigezzo Valley) lies across the Italian province of Novara and the Swiss Canton of Ticino. This new book on the mineralogy of the valley includes a well-illustrated list of minerals with brief descriptions and compositions, modes of occurrence, crystal sizes and notes on identification. Introductory material describes the geology of the area, which is characterized by albite mineralization. Useful maps in color are provided and there is a comprehensive bibliography.

M. O'Donoghue

Letters

MARTIN EHRMANN

I was very much interested to read the biography of Martin Ehrmann (vol. 25, p. 347–370) by Bill and Carol Smith. In 1941 a note about Martin's distribution of part of the Calvert Collection appeared in *Rocks and Minerals*. It stated that . . .

> Dr. A. B. Cummins, Director of Research for the Johns Manville Co., had purchased from Martin Ehrmann, of New York City, several thousand pounds of the remaining unclassified Calvert Collection. After making a few selections of his own, Dr. Cummins offered the entire remaining lot to the members of the Plainfield [New Jersey] Mineralogical Society. He had the specimens cleaned and displayed on long benches in his large barn and spacious garden where selections could be made.

I later purchased the Cummins collection from his estate (1977), and still have 11 Ehrmann specimens, three of which are marked as having come from the Calvert Collection.

Another brief article in *Rocks & Minerals* (August 1943, p. 240–241) discusses Martin's acquisition of the Calvert Collection, apparently quoting from a letter written by Martin to John C. Pohl, Jr. Quoting from the letter:

> We arrived in a northwest suburb of London [summer of 1938] where the collection was housed in a three-story brick store-house. When we entered the building . . . I saw hundreds of cases and cabinets crammed to their utmost capacity with specimens representing almost every branch of science. Many of the specimens had been flung pell-mell upon the floor and even piled to the ceiling in amazing disorder. All were [heavily] covered with . . . London's dust and grime, for the building had not been opened for many years.
>
> I picked up a specimen at random that appeared to be crystallized but [was] heavily coated with dust. I asked for a water tap to wash it but was told there was none in the building. A cobbler's shop was next door, and there I went to wash the specimen. The beauty of the washed specimen so amazed me that, on the strength of this one specimen alone, I then and there decided to buy the collection.

In a footnote the editor states that "Some of the finest specimens from the Calvert Collection now repose in the collection of [the author] Mr. John C. Pohl, Jr. of Easton, Pennsylvania."

Anthony Thurston
Boylston, Massachusetts

Your article about Martin Ehrmann prompted me to write you about some chronology.

In 1930 I was a student at the University of Pennsylvania (class of '32), and took a course in mineralogy under Dr. Oldach. Since I was the only student in the class, I got first-class instruction. I had been collecting minerals since the 1920's, mostly in Pennsylvania Dutch country, French Creek, the Wheatley mines, and many other places in Pennsylvania and New Jersey. Dr. Oldach got me interested in micromounting—the University has fine microminerals from the collections of Rev. Rakestraw and C. S. Bement. I became hooked, and from that time on microminerals were my specialty.

I think I first learned of Martin Ehrmann

Martin L. Ehrmann

through his ads in *Rocks & Minerals*. When I saw his ad for the Calvert Collection ca. 1939, I decided to visit him. His quarters in Rockefeller Center were high up. On entering the office I found myself in a small finished room with a case or two of some fine crystallized minerals. I asked about micromounts, and Mr. Ehrmann invited me to look over the [Calvert] collection for possibilities. A door from his office opened into a large, unfinished, barn-like storage room with lots of beautiful cabinets higgledy-piggledy everywhere. I spent hours opening drawers of dusty, scattered material, and garnered quite a few specimens, which he identified mostly as English. I remember chalcopyrites, cassiterites, and a beautiful Pennsylvania red wulfenite on green pyromorphite.

Around 1946 I sold my collection (almost 1,000 specimens) to Neal Yedlin for $250. This got Mr. Yedlin started in micromounting. Unfortunately he remounted all of my specimens, so their provenance was lost.

Robert L. Jacoby
Summerville, South Carolina

Congratulations on the Ehrmann article . . . a remarkable job of historical research and communication of the values so important to our hobby and vocation.

In the summer of 1939 my family took me from our Atlanta home to New York for the World's Fair. My interest in minerals had begun earlier, and I knew enough to search out dealers in New York. Fortunately, I found Martin Ehrmann's Rockefeller Center office and display rooms. Despite the attraction of the Fair, I spent most of my time with Martin. I recall drawer after drawer of eye-popping specimens from the Calvert Collection and other sources. There were dioptases (African and Russian), sulfurs, Cornwall minerals, barites, and on and on. Martin gave me free run to look at his inventory. He supplied explanations of why one specimen was better than another, and anecdotes about locations and collectors. At the end of my stay in New York, my family bought some specimens for me, but Martin insisted on giving me many more. These formed the core of my collection for many years thereafter, and most are still in my possession.

Beyond the minerals and the personal relationship with Martin, I came to the impression that he was a man of integrity with great expertise and taste. His values and concerns with people (especially a 14-year-old budding collector, namely me) gave our hobby uncommon distinction. Martin was a prince.

After that summer, I never saw him again but was dimly aware of his activities during World War II and beyond. Regardless, his influence on my collecting and specimen preference was profound.

Edward E. David, Jr.
Bedminster, New Jersey

I received the September–October issue of the *Mineralogical Record* and read the article on Martin Ehrmann's life first. I am very impressed; congratulations on your excellent work.

The story of the large, gemmy kunzite crystals (page 357) reminds me that Martin shipped a large box containing at least ten beautiful kunzite crystals to my address in Heidelberg before beginning his trading tour in Europe.

The large tanzanite (page 364) which he had cut into a 122.7-carat gem sat on the writing desk in my laboratory for about 5 minutes. Then he took it to fly to Washington, D.C.

Werner Lieber
Heidelberg, Germany

I enormously enjoyed your splendid biography and appreciation of Martin Ehrmann.

It may be of interest that Martin's sales of large facet-grade specimens to museums, especially the Smithsonian, often resulted in my cutting the pieces. He would sometimes get me to agree ahead of time that I would cut them, and then would tell the museum, "If you buy this rough, Sinkankas will cut it." For cutting the large stones I was paid in non-gem mineral specimens, classics from famous localities (such as azurite altering to malachite from Tsumeb). I was happy with the deal, and received quite a few fine specimens in this way.

John Sinkankas
San Diego, California

The Martin Ehrmann article is absolutely marvellous. You really caught the essence of Martin's personality and character.

The linarite crystal shown in Figure 3 is actually 4 mm long (not 1 mm) and is from Caldbeck Fells, Cumbria, England (not Cornwall). It went with the rest of our collection to the National Museum of Canada when we came to Ottawa, but had not yet been adequately labeled and accession at the time Quintin Wight photographed it. (It has since been assigned CMN #81519.)

There is a sequel to Martin's trip to Mexico with Foshag Sr. and Jr. in 1940. The "huge Buick" was brand new when he took it down there. It got pretty badly beaten up in driving over burro trails and worse. Soon after his return, Martin drove us down to Philadelphia to attend a monthly dinner and meeting of the Philadelphia Mineralogical Society. He parked it on a lot opposite the Academy of Natural Sciences where the meeting was held. When we came out after the meeting, the car was gone. We had to go to the police station to report this, then take the train back to New York. For quite a while, there was no report on the car. Martin had hoped it would never be found, and that he would get a sizable insurance settlement. Unfortunately, it was found two months later in a Philadelphia suburb, with several bullet holes in it.

Louis and Pauline Moyd
Ottawa, Ontario

In the early 1960's Martin Ehrmann visited my house to see my collection (I am now 86). He was enthusiastic, because two years previously I had acquired a collection of Transylvanian minerals including gold, silver and tellurides. I traded him a specimen of hessite for a kunzite crystal, and later obtained a Brazilian green beryl which he had traded to the University of Bonn.

Gerhard Schweisfurth
Niederschelden, Germany

Regarding Martin Ehrmann's birthplace, *Rawa Russka* (now *Rava Russkaya*): prior to World War I, this town was in the Austro-Hungarian Empire (not Russia), specifically in the province of Galicia. Martin's brother, Max, served before the war as a conscript in the Austrian Army. [Ed. Note: My grandmother was also from Galicia, and her family considered themselves to be Austrian.]

Leo Bodenstein
Miami Beach, Florida

The article by Bill and Carol Smith on Martin Ehrmann was first rate. Some small items may be of interest:

The correct spelling (p. 364) of Martin's tanzanite source, "Ali Juyawati," is *Ally Juyawatu*. We were associates at one time; his name was frequently misspelled, even on government documents. The other person referred to in that paragraph is E. F. W. "Ted" Wolff, though I cannot confirm that Ted and Martin knew each other.

John Saul
Paris, France

REGIONAL MINERALOGIES

I agree fully with Art Smith's opinion ["Regional Mineralogies," in the *Mineral Books* issue, vol. 26, no. 4, p. 112–134] that locality books are an immense help in ascertaining where a specimen—especially an older one—came from. I have concentrated on such books, particularly for Central European localities, and have a wonderful collection of old atlases dating back to 1904, before all the Central European name changes.

A particularly good reference is the rare book by Gustav Leonhard, *Handwörterbuch der topographischen Mineralogie* (Heidelberg, 1843). It consists of 596 pages in small print, listing every mineral known at the time in alphabetical order, and all of the known localities for each species.

Another extremely useful work is Carl Hintze's *Handbuch der Mineralogie* (Leipzig, 1904–). It gives information on the minerals, à la the Dana System, but after each species it lists several pages of localities, by provinces, and so detailed as to include varieties and colors at each locality worldwide.

Yet another very useful "secret weapon" for answering perplexing locality questions is the June 1928 issue of *Mineralogical Magazine* (still available as a reprint). This issue contains a 39-page article by Prague mineralogist František Slavík and BM(NH) mineralogist and curator Leonard Spencer entitled "Place names of mineral localities in Central Europe." It covers what was then Czechoslovakia, Austria, Hungary, Yugoslavia, Italy, Romania and Poland, listing both the old and new names (and important minerals) for a multitude of localities.

There is little available on Transylvanian mines (in the major languages, at least), but Adolf Helke's *Die jungvulkanischen Gold-Silber-Erzlaggerstätten des Karpathenbogens* (Berlin, 1938) is very useful. It contains a lot of geology plus descriptions of the mines and the minerals found there.

Some geographical corrections to Mr. Smith's fine article: Although the Black Forest is mineralogically important enough to have its own sub-heading, it is really just an area within Baden-Würtemberg. Also, Schmitz's 1982 book on the famous mineral localities of Niedersachsen should be classified under Niedersachsen and not Saxony, an entirely different region.

Keep up the good work! You're still no. 1 in my book.

Kay Robertson
Los Angeles, California

CHINESE MINERALS

Have just returned from Changsha, Hunan Province, China. I was very impressed with the amount of construction going on and the number of people who were or wanted to be mineral specimen and fossil dealers. I am sure that Changsha will become for Chinese minerals and fossils what El Paso was to Mexican minerals.

I was also impressed with how adept the Chinese have become in manufacturing, repairing and "doctoring" minerals specimens. They have gotten so good at manufacturing cinnabar specimens that unless it is absolutely obvious that they are genuine you must assume that they are fake. There are no loose single crystals of cinnabar available to buy because all the good crystals are manufactured into matrix specimens which command a higher price and all the not so good crystals are broken into little thin rectangular cleavage sections that can bring up to $1500 a Kg in the traditional Chinese medicine market.

They are also experimenting with irradiating specimens. They have a one-day turn around on turning clear quartz into smoky quartz and they are also irradiating fluorite. I have no clear idea yet which colors of fluorite are irradiated and which are natural. I also have no clear idea of whether the irradiated colors are stable.

Rock H. Currier
Baldwin Park, California

DEER HILL AMETHYST

There is a new location at Deer Hill, Maine, where gem-quality amethyst has been found since the spring of 1995. I visited the location a couple of times in June and was able to obtain some excellent amethyst. Some wonderful finds were made by hard-working men last summer. The men were getting up about 4:00 a.m., arriving at the location at dawn and working until dark. Some had bread bags full of specimens, and I have seen a fist-size crystal of deep rich purple color, known locally as "grape." Gems over 100 carats in size have been cut from this amethyst.

Most of the material that has been found is white quartz; occasionally good crystals are found. Zoning is standard in most pieces; some have clear overgrowths and smoky quartz overgrowths. The deep royal-purple amethyst sometimes exhibits red and/or blue flashes. A few of the pieces exhibit a variation of color depending upon the direction viewed.

Most of the amethyst found is of pale color, and even this material is difficult to find. I would describe collecting at Deer Hill as "digging a grave through hard pan for one small measley piece of amethyst if I am lucky." Two trips to the old location last year netted me nothing worth writing about.

The area where the new discovery was made has been heavily worked and dug out into a pit over 8 feet deep and several yards long at least. We aren't bragging about what we got, but some of the other collectors could with what they have found. There are still many gems to be found in Maine at locations which cost no fee.

Deer Hill has been known as a location for quartz and amethyst for over 50 years. The amethyst that has been found at the new site last year is as good as or better than any that has been found in Maine.

Deer Hill is located in the White Forest National Forest, Stow Township. No "mining" is allowed. All work is done with hand tools. Best of all, there is no fee for collecting, and no limits. The quartz-amethyst locality is in an absolutely magnificent beech forest; with little undergrowth, this forest is easy to walk through. Chipmunks abound and they love to share your lunch or other snacks. The old location is "easily" reached by hiking up to Deer Hill Spring, then turning left and hiking on up toward the top of the mountain. Before you get to the top you will come to a small valley with a number of the huge beech trees toppled over from digging. The trail from the spring to the location is steep, and the new location is not as easily found as the old. It is at about the same elevation around the base of the summit to the east. Unfortunately there are no trails leading to this new location. Everybody has been taking different paths, leaving no trails that can be easily seen.

Further information about this location and others may be obtained from us (Nicholas and Marsha Rochester, 403 Main St., Oxford, ME 04270). Recently we have reprinted *Maine Pegmatite Mines and Prospects*, with the permission of the Maine State Geological Survey. It is available by mail from the above address at $6.00 per copy.

Nick Rochester
Oxford, Maine

Ed. Note: See the fine Deer Hill amethyst, found in 1967, pictured on p. 175 of vol. 14.

ANNUAL INDEX

Sorry to see that your annual index no longer lists categories for "Articles," "Departments," "Authors," "Localities" and "Minerals."

Hugh McCulloch
Bay Head, New Jersey

The new format for our annual indexes is exactly that used in the first section of the 25-year index, and at the same level of detail. Within a single alphabetical file you can look up any author and also any article or column title for which you can remember at least one key word. Key words would include any mineral name or locality name that forms a part of a title, or the general title of a column, e.g. "Book Reviews." Were we to also publish an annual "General Index" at the same level of detail as is present in the General Index section of the 25-year index, the space requirement would be too large, approximate five times the space needed for the Author-Title Key Word

Index alone. We'll save that for the 10-year index that will cover 1995–2004. Ed.

CALL FOR PAPERS— 18th FM-TGMS-MSA Mineralogical Symposium

The 18th Mineralogical Symposium sponsored jointly by Friends of Mineralogy, The Tucson Gem and Mineral Society, and the Mineralogical Society of America will be held in conjunction with the 43rd Tucson Gem and Mineral Show, Saturday, February 15, 1997. The topic of the symposium will be **copper and copper minerals**—the theme "mineral" for the show. Papers on the descriptive mineralogy, paragenesis, classic and new localities, etc. are invited. An audience of knowledgeable amateurs as well as professional mineralogists and geologists is expected.

If you wish to present a paper, please write or call Dr. Karen Weinrich, Chairperson (*GeoExpositions*, P.O. Box 5054, Golden, CO 80401; 303-278-1218) with your topic, a few sentences describing the paper, and your address and phone number. Presentations will be 15 or 20 minutes in length followed by a brief period for questions. Upon acceptance of topics all authors will be required to submit a 200–300 word abstract by September 15, 1996 (**firm date**). Those abstracts deemed to be scientifically sound and substantive by the editor of the *Mineralogical Record* will be published in the January/February issue, which will be available for sale at the 43rd Tucson Gem and Mineral Show.

Karen Wenrich
Golden, Colorado

FLUORSPAR DISTRICT CORES

Anyone associated with a university or museum geology department may request a *free* collection of mineralized drill cores from the undersigned. They are from the core library dump of Allied Chemical Company which operated numerous mines in the Illinois-Kentucky fluorspar district (the most famous being the Minerva No. 1 mine). Cores are 1.5 inches and about 0.75 inch in diameter, and are from 1 to 4 inches in length. Associated minerals in various combinations include: barite, calcite, chalcopyrite, fluorite, galena, quartz and sphalerite. Matrix, when present, includes limestone or sandstone. Some cores show banding, brecciation and vein fractures associated with Mississippi-Valley-Type deposits. Some 2-inch diameter cores of igneous rock with little or no mineralization from a Colorado fluorspar district are also available. Collections run 8 to 14 pounds shipping weight. Please remit postage (which is from $4.00 to $8.00) for surface mail in the U.S. Specific requests are welcome. All inquiries must be on department stationery.

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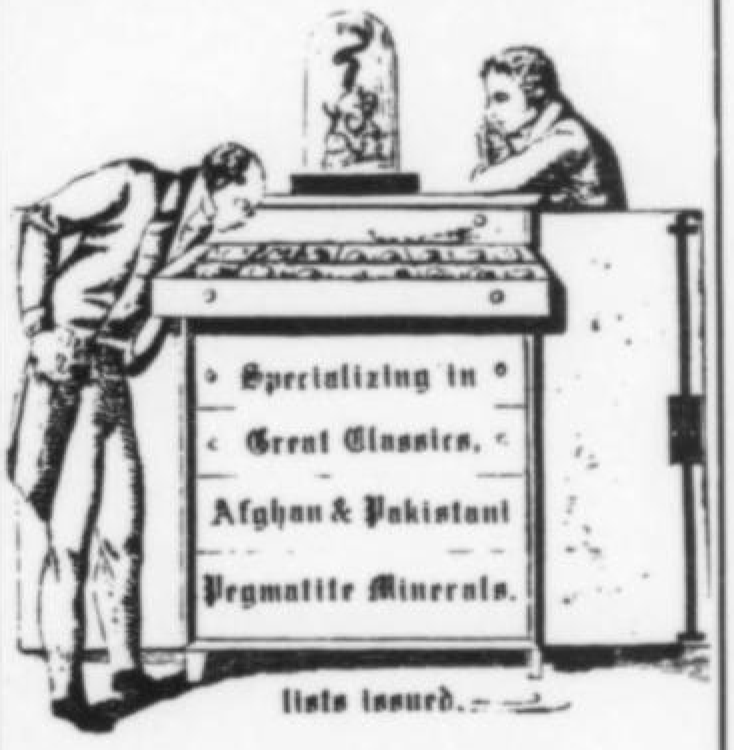

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Specialty: Worldwide minerals & gems

Musée de géologie de l'Universite Laval

Curator: André Lévesque
Tel: (418) 656-2193
E-mail: alevesqu@ggl.ulaval.ca
Fax: (418) 656-7339
Geology Dept., 4th floor
Adrien-Pouliot Building
Québec, Que., Canada G1K 7P4
Hours: 8:30–5 M–F
Specialties: Quebec and worldwide minerals and fossils; Miguasha fishes

Museum of Geology

Director: Philip R. Bjork
Tel: (605) 394-2467
South Dakota School of Mines & Technology
501 E. St. Joseph Street
Rapid City, SD 57701-3995
Hours: 8–5 M–F, 9–4 Sat., 1–4 Sun.
Specialty: Black Hills minerals, esp. pegmatites

Penn State Earth & Mineral Sciences Museum

Curator: Andrew Sicree
Tel: (814) 865-6427
Steidle Building
University Park
State College, PA 16802
Hours: 9–5 M–F & by Appt.
(closed holidays)
Specialties: Mineral properties exhibits; "velvet" malachite; old Penna. minerals, mining art

Arizona-Sonora Desert Museum

Curator: David W. Thayer
Mineralogist: Anna M. Domitrovic
Tel: (520) 883-1380
Fax: (520) 883-2500
2021 N. Kinney Road
Tucson, AZ 85743-8918
Hours: 8:30-5 Daily (Sept.-Feb.)
7:30-6 Daily (Mar.-Aug.)
Specialty: Arizona minerals

M. Y. Williams Geological Museum

Curator: Joe Nagel
Tel: 604) 822-5586
University of British Columbia
6339 Stores Road
Vancouver, B.C., Canada V6T 1Z4
Hours: 8:30–4:30 M–F
1:30–4:30 W (Collector Shop)
Specialty: B.C., Pacific NW, Canada; Exhibit Quality

Marshall Mint & Museum

Curator: Hugh Roy Marshall
Tel: (702) 847-0777
Fax: (702) 847-9543
P.O. Box 447 (96 N. C St.)
Virginia City, NV 89440
Hours: 9–5 seven days
Specialties: Nevada precious metals specimens

Private Museums

Hampel Mineralogical Museum

Curator: Lance T. Hampel
Tel: (414) 255-4540
P.O. Box 39
Germantown, WI 53022
Hours: by Appt.
Specialty: Midwest minerals

Europe

Setesdal Mineral Park

Curator: Ole Fritjof Frigstad
Arnar Hansson
Tel: (011) 47-37-93-13-10
Fax: (011) 47-38-19-90-10
N-4670 **Hornnes, Norway**
Open May–October
Specialties: Minerals and mining equipment from Evje and Iveland; Norwegian minerals

Mineralogical Museum School of Mines, Paris

Curator: Lydie Touret
Tel: (31) 140-51-9143
Fax: (31) 146-34-2596
E-mail: touret@musee.ensmp.fr
60, Boulevard St. Michel
F-75272 **Paris,** Cedex 06, France
Hours: 2-6 Tue.–Fri.,
10-12, 2–5 Sat.
Specialties: Worldwide minerals, Early "type" specimens, one of the best worldwide systematic collections

Giazotto Mineralogical Museum

Curator: Adalberto Giazotto
Tel: 39-50-501587
Lungarno Gambacorti 39
Pisa, Italy
Hours: by Appointment
Specialty: Italian and Worldwide minerals

Museu Mollfulleda of Mineralogy

Director: Joaquim Mollfulleda Borrell
Tel: 34-3-792-2626 or 3571
Fax: 34-3-795-7031 or 7306
c/. de l'Església, 37-39
08350 Arenys de Mar,
(Barcelona) Spain
Hours: Tue-Sun 11–1:30,
Sat. also 6–8 pm
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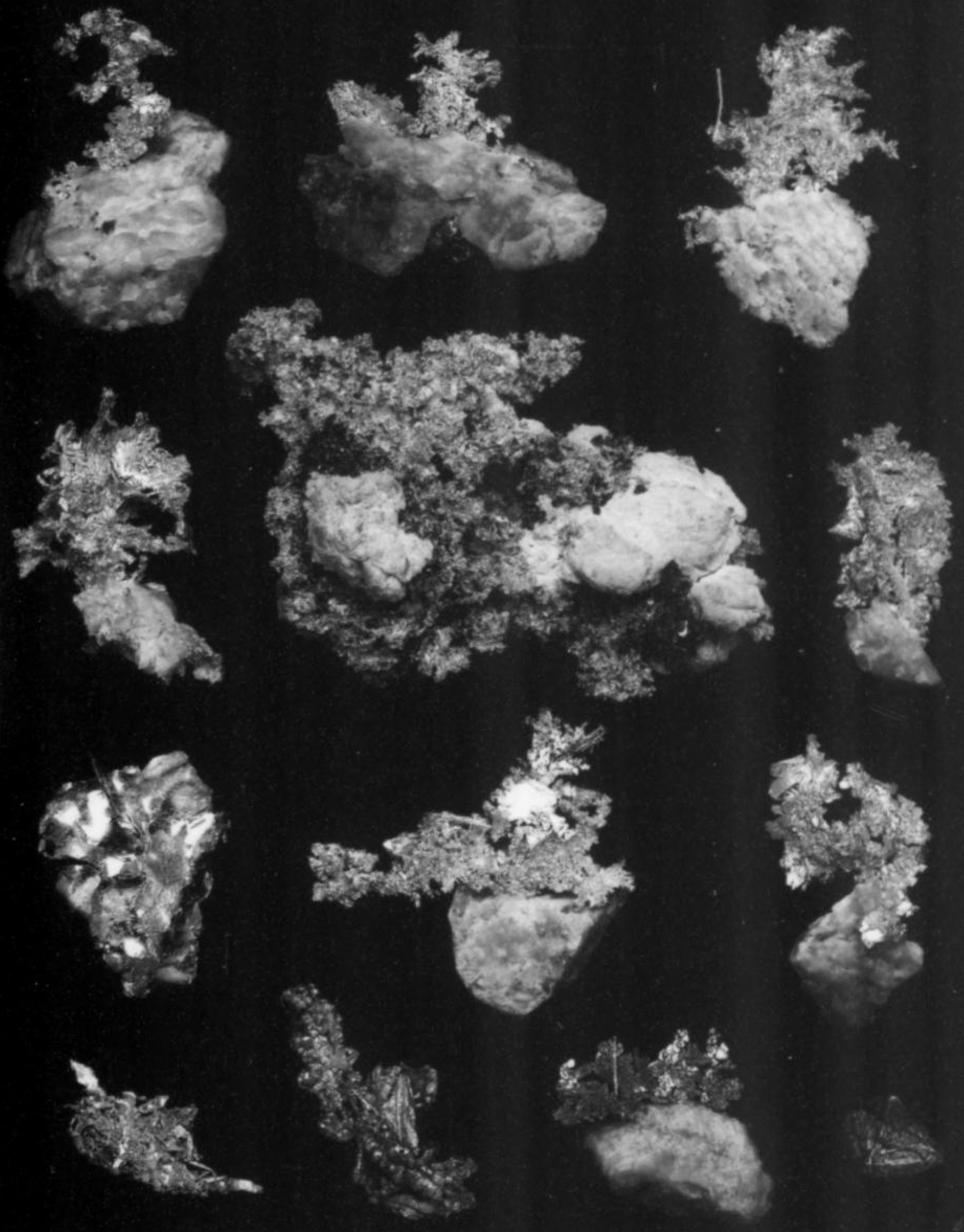

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