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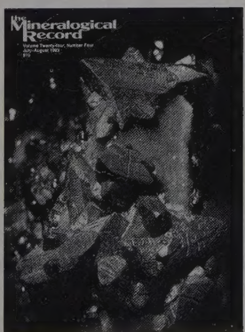
Articles

Columns



COVER: CHALCOPYRITE on TETRAHEDRITE, 15 cm, from the Herodsfoot mine, Liskeard, Cornwall, England. Collection of the Natural History Museum, London; originally sold by the Cornish mineral dealer Richard Talling (1820–1883). Photo by Frank Greenaway. See the article in this issue on the minerals of Cornwall.

notes from the EDITOR

FIELD EQUIPMENT

You're out geologizing in a trackless wilderness or desert area, when at last you discover a fabulous vein of minerals. But in order to properly record the discovery, *and* find your way back to it, you must ask yourself an all-important question: "Where, exactly, am I?"

The accurate answering of this question has posed a problem for field collectors and exploration geologists for centuries. Normally the best way is to have yourself continuously pinpointed on a detailed topographic map during your entire time in the field. Now, however, modern technology can offer an alternative: the portable, hand-held global positioning system (GPS).

Looking a bit like Mr. Spock's tricorder, the GPS *tells* you where you are at the push of a few buttons. The Motorola *Commando SPS* model, for example, will provide you with your first position fix in 24 seconds, accurate to within 100 meters, and will update the fix every second thereafter. It does this using a six-track parallel receiver to simultaneously track six navigation satellites, providing latitude, longitude, altitude, etc. It can store up to 100 waypoints and ten different routes in its memory. The readout is a four-line, 20-character LCD display. The entire device fits in the palm of your hand for single-handed operation, weighs just over a pound, and runs on six AA batteries. The price: around $1,500.

An even smaller model is the *Ensign GPS* model made by Trimble Navigation. It weighs under a pound, tracks up to eight navigation satellites, and gives your position to within 25 meters in about three minutes (updating every few seconds thereafter). Data can be entered and reviewed in English, Spanish, French, German, Italian, Norwegian or Japanese. It will run about five hours on four AA batteries, or twice that long on "power saving mode." The price: about $1,000.

These two remarkable gadgets are available through the mail order catalog of a company called *U.S. Cavalry* ("World's finest military and adventure equipment"). To get a copy, send $3 (in the U.S.) or $5 (international) to 2855 Centennial Avenue, Radcliff, Kentucky 40160-9000, or call 1-800-777-7732.

This is such a fascinating catalog that one can't help browsing through it for other items of possible use to the field collector. Let's see . . . how about the Litton Military Night Vision Goggle for after-dark collecting? ($5,000) Or the Maxa Beam Six Mil CP Searchlight, a hand-held (11.7 pounds) battery-powered light that will put out *six million candlepower* for illuminating those really big stopes underground? ($1,900) There is also a wide range of rappelling and mountain climbing equipment, utility belts, canteens, tents, packs, waterproof matches, knives, helmets, face shields (better than safety glasses for protection while hammering!), and so on. You can even get (for $40) a small portable "Instant Weather Radio" which will automatically supply updated weather forecasts for your area every 4–6 minutes.

Now, if they will only miniaturize to hand-size that ground-penetrating radar (see vol. 20, no. 5, p. 322), for finding hidden pockets in the rock . . . .

CUSTOM SPECIMEN MOUNTING

For many years now, interior decorators have been using large mineral specimens in their decorating work. But the idea of "decorator specimens" does not always carry good connotations in the mind of the serious mineral collector because (a) decorators typically have no specimen sense, and often select badly damaged or extremely common pieces, and (b) many good specimens are too delicate to risk in such open exposure.

This vaguely negative impression is easily dispelled, however. Collectors of cabinet specimens are coming to realize that they can increase their enjoyment of selected (high quality) pieces by giving them a more prominent place in their decor. The more delicate examples can simply be boxed in with clear plexiglas for protection. The critical element is presentation; the specimen which is to accent a decor needs to be mounted in an attractive, professional way so as not to scratch the furniture, and so that it will not appear haphazard.

Bill and Elsie Stone of *The Sunnywood Collection* have been creating some wonderful examples of custom-fitted, highly finished hardwood bases, some with plexiglas boxes over the specimens, and some with ball-bearing roller mounts so that they rotate easily. As a nice option, an engraved brass plate can be affixed, carrying basic label information. Aside from the example shown here, the mountings for the big Alma rhodochrosites pictured in the previous issue (p. 228) are also their work, and their sales room in the Executive Inn during the last Tucson Show was filled to overflowing with elegantly mounted minerals. Write, call or visit (by appointment only): 12068 East Amherst Place, Aurora, Colorado 80014, telephone/fax (303) 368-7497.

Cornwall's Famous Mines

Peter Bancroft
3538 Oak Cliff Dr.
Fallbrook, California 92028

Sam Weller
Lower Boscaswell, Pendeen
West Cornwall, England

For centuries, the copper and tin mines in Cornwall County, England, have proved to be as rich as any in the world. During the last 200 years this mining region has produced an incredible variety of spectacular crystal specimens, many of which today comprise the backbone of numerous private and public mineral collections around the world.

INTRODUCTION

This article will review the earliest days of mining in Cornwall and will include a brief description of Cornwall's regional geology and mineralogy, descriptions of a few of the more important Cornish mines, and notes about the lives and times of its miners. The Botallack mine was selected as the example to feature because of its interesting history, impressive production of minerals and fine crystals, and the fact that it was still operating under an exploration maintenance program that permitted the authors to investigate some of its oldest as well as latest underground workings.

HISTORY OF CORNISH MINING

Cornwall is the southwesternmost county in England, with an area of 1,356 square miles and a population (estimated in 1987) of 453,100. Cornwall is nearly surrounded by water—the Atlantic Ocean to the north and northwest and the English Channel to the south and southwest. Its only land connection is with the county of Devon to the East. Staunch Cornish loyalists will tell you, tongue in cheek, that the Tamar River, which separates the counties of Cornwall and Devon, really separates Cornwall from England. The many megalithic monuments throughout Cornwall, and especially at Lanyon, Mulfra, Chûn and Zennor, as well as finds of a few Early Bronze Age implements, are evidence of extensive settlement, dating back possibly as early as 4,000 B.C.

It is not certain when mining first began in Cornwall, but probably as early as the third millennium B.C. Phoenicians or other explorers discovered and worked alluvial tin deposits along its cliffs and rivers.

The oldest known archeological objects fashioned of tin are a ring and a pilgrim bottle discovered in Egyptian tombs of the 18th Dynasty (1580–1350 B.C.). But tin ores are not found in Egypt, so it is at least possible that tin was being imported from Cornwall in Pharaonic times.

Evidence of an early tin industry in Cornwall was provided by the discovery of tin scoria in excavations at Chûn Castle near St. Just, dating from 300 to 200 B.C. It is known that shipments of tin arrived in Italy about the time that Julius Caesar invaded Britain. A worldwide shortage of tin had existed for at least 2,000 years, and as primitive metallurgists discovered ways to alloy tin with copper to make bronze, new tin workings were opened in many districts throughout Cornwall.

It was soon discovered that all of the mineral wealth in Cornwall was not concentrated only at grass roots and in stream beds. Tin orebodies dipped steeply below the surface, and in some cases extended for miles under the sea. Working underground deposits meant digging in solid rock, a time-consuming, costly and dangerous process.

The first "Stannary Charter" was issued by King John (of *Robin Hood* fame) on October 29, 1201. In addition to granting rights to mine tin ore, some charters also gave other privileges to tinners (miners of tin), such as "exception from all jurisdiction, with but few exceptions." This clause was included to attract miners and also to keep them happy and on the job.

In the 19th century, many mines in the Gwennap, Camborne, Redruth and St. Just areas—notably the Dolcoath, United Mines, Botallack, Levant and numerous others—developed into major copper mines. By 1851, a third of all European copper was mined in Cornwall and Devon, and during the next 50 years Cornwall led the world in

Figure 1. **Geological map of Cornwall and southwest Devon. Courtesy of Newton Abbot.**

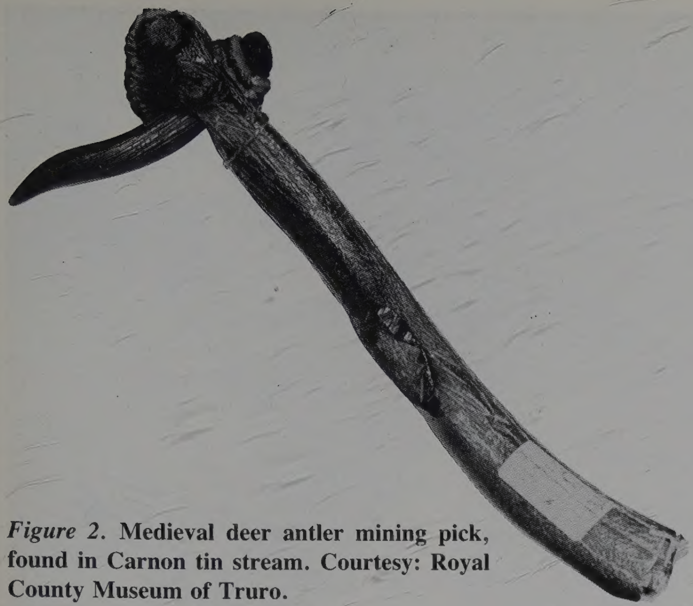


Figure 2. **Medieval deer antler mining pick, found in Carnon tin stream. Courtesy: Royal County Museum of Truro.**

tin production. Mineral wealth was so great that the favorite Cornish toast became, "Here's to fish, tin, and copper."

As Cornish mines pushed deeper, larger pumps and more sophisticated machinery were required. Possibly of equal importance were the skills developed by miners working in dangerous, wet, dimly-lit tunnels and stopes, whose services were in demand in hard-rock mines throughout the world. During the middle of the 19th century, particularly in slack times, hundreds of Cornish miners (known in America as "Cousin Jacks") emigrated to the United States and other countries in search of mining work.

In the late 19th century, increasing costs as mines went deeper, fiscal depressions, dwindling ore deposits, and cheaper foreign competition forced many Cornish mines to shut down. Higher and cheaper foreign tin production in Malaysia and Bolivia was the death knell for Cornish tin mines, most of which were closed by 1932.

Unemployed miners were offered some relief by the discovery of large areas of kaolinized granites, which when refined produced high-quality kaolin known as china clay. This material found a ready market in the ceramic, chemical, textile, and paper industries. Hundreds of tons of refined clay were shipped in 1937 alone. Important new deposits of china clay are being mined today at Dartmoor, Bodmin Moor, and the St. Austell area, known as Hensbarrow Moors.

GEOLOGY

The county of Cornwall, and the western portion of Devonshire which borders Cornwall, form a major metallogenic region that has a distinguished geological history. Devon is, of course, the classic type area for Devonian age rocks. Since the 18th century, Cornwall has been the subject of much of the classic work on metalliferous mineralization. For several hundred years, mines in this peninsular region have produced rich ores of copper, tin, lead, zinc, arsenic, antimony, manganese, tungsten, cobalt, nickel and uranium, as well as significant quantities of fluorite, barite and some gold. During the 19th century, however, except for the years when England was at war, there has been a steady decline in the region's mining activities. Today, only the South Crofty mine is operating, and even this operation is fighting for survival.

Regional Geology

At the close of the Carboniferous Period some 290 million years ago, a long period of sustained sedimentation in the Devonian/Carboniferous sea closed with the Armorican Orogeny. Great thicknesses of sediments were upfolded along an east-west axis to produce the Cornubian mountain range. The enormous tectonic forces created overfolding, faulting and thrusting, plus the general development of slaty cleavages, as well as permitting the intrusions of a major granitic batholith. The batholith is continuous for some 100 miles and was produced over a lengthy period by a series of pulses of chemically similar magma. Today, exposed by erosion, several plutons form a range of granitic hills extending from Dartmoor in the east (the highest) to Haig Fras, the submarine exposure west of the Isles of Scilly. The remnants of the original overlying sediments, now metamorphosed into a series of slates and shales, comprise most of the remaining lowland that encloses the granitic highlands.

Despite two centuries of intensive mining and geological investigations in Cornwall, the precise origins and mineralizing mechanisms that account for the region's enormous mineral wealth are still imperfectly understood. But there is a consensus that the metalliferous elements provided rich and diverse mineralization, at least in part, through magmatic differentiation. Following a long period of magmatic cooling, hot aqueous fluids filled the peripheral network of joints and fissures, thermally and chemically altering country rocks and creating mineral lodes of economic importance.

To complete this oversimplified picture of the region's geology, two other distinctly different areas must be mentioned. First, the rocks forming the Lizard Peninsula complex are the oldest in the region, possibly containing fragments of the lower Palaeozoic ocean floor. At the surface of the complex is an assemblage of gabbros, peridotites, dolerites, amphibolites, gneisses and altered sediments. Extensive serpentinization of the ultrabasic rocks has produced some spectacular coastal scenery, as well as attractive rocks that are utilized by the local craft industry. Substantial copper mineralization, mostly in the form of native copper, was extensively exploited in the 19th century, both at coastal and inland mines.

The other area that should be mentioned is the coastal area northwest of Wadebridge, which exposes a series of volcanic and intrusive igneous rocks that seem to be responsible for mesothermal mineralization. The district, centered in the parish of St. Endellion, was an important source of lead and antimony ores; it includes Wheal Boys, the type locality for bournonite (originally called "endellionite"). In this instance, the source of the mineralization appears to be ancient mafic and ultramafic rocks.

Lodes and Mineralization

Probably governed by the axis of earlier tectonic movements, the lodes in each district generally run in approximately parallel directions. These directions coincide with the major joint systems of the granite that trends northeast-southwest in central Cornwall and that corresponds to the earlier Caledonian orogeny. The lodes are referred to by the miners as "normal" lodes, and typically carry tin, tungsten and copper. Lodes usually dip at angles greater than 70°. Another, later lode system, probably resulting from the Alpine orogeny, is at near right-angles to the normal lode system. These cross-lodes, known locally as "caunter" lodes, are frequently barren or clay-filled but where mineralized they carry a lower-temperature lead-zinc suite. Other primary lode structures, including pipes, floors, stockworks, and vein-swarms, are commonly encountered. Quartz, chlorite and tourmaline are frequently seen as examples of replacement, appearing singly or in concert.

Secondary enrichment and oxidation, especially in the copper lodes in the Redruth/Gwennap area, are responsible for the formation of secondary minerals and large economic deposits of bornite and chalcocite. It can be inferred from the frequent occurrences of supergene enrichment that the region was formerly oxidized and leached above the water table, but that in most areas subsequent erosion has planed off the upper oxidized zones. Nevertheless, an enormous legacy of fine mineral specimens remained. Fortunately for collectors, several hundred vertical feet of the oxidized zone survived intact in the Gwennap district. Numerous 17th, 18th and 19th-century mines in the

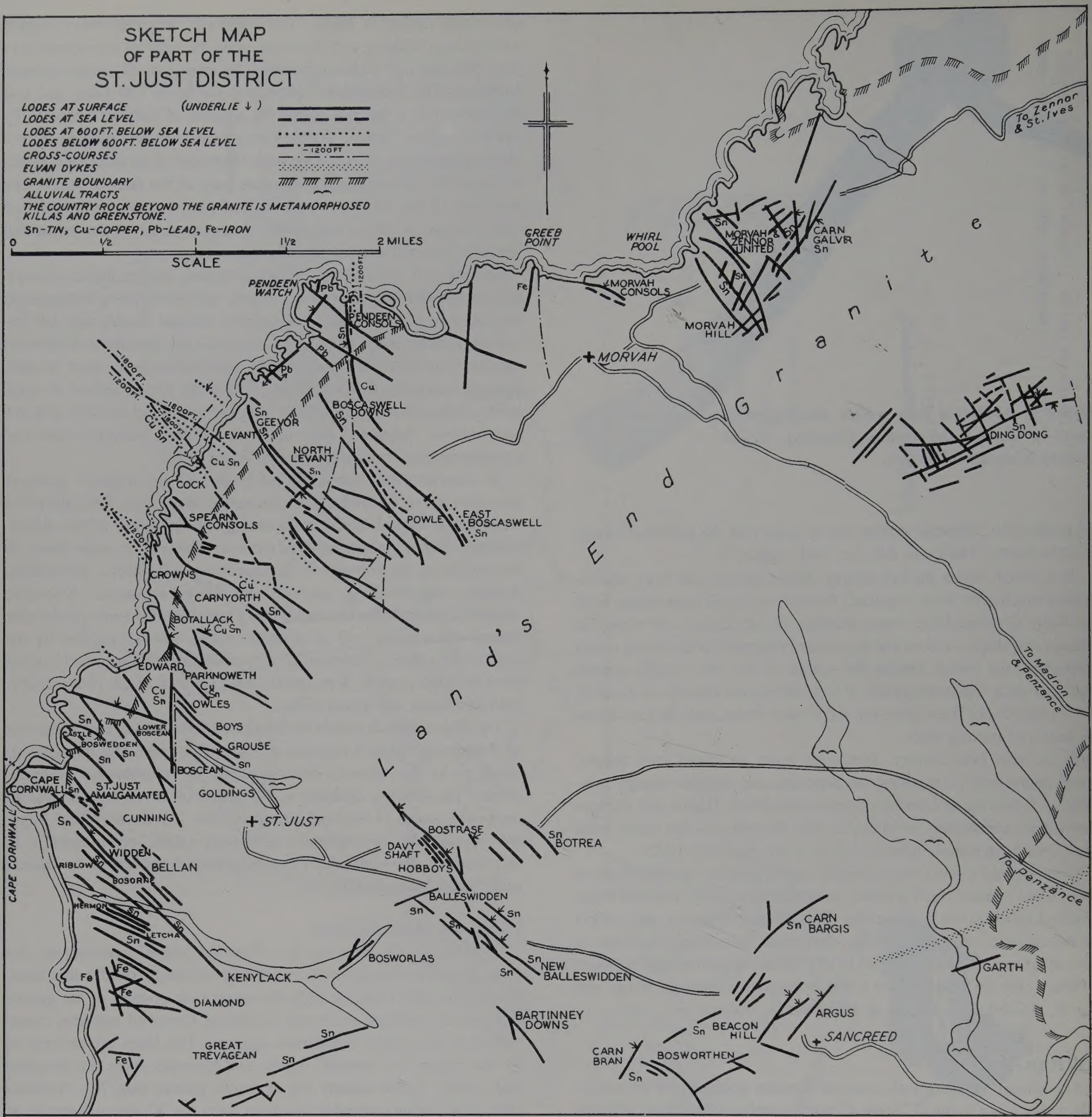


Figure 3. **Mineral lodes in the Land's End area of Cornwall. Courtesy of the Royal Geological Society of Cornwall.**

Gwennap field, including Wheal Gorland of immortal fame, yielded rich harvests of oxidation-zone minerals. The list of species found there as world-class specimens includes azurite, malachite, cuprite, copper, olivenite, clinoclase, liroconite, cornwallite, cornubite, libethenite, pharmacosiderite, and many more.

MINING

Mining Districts

The great majority of Cornwall's mines (J. H. Collins gives details of more than 2,000 past and present mines in Cornwall and West Devon in an incomplete list) were grouped in seven mining districts. These districts were: (1) St. Just in Penwith, (2) St. Ives-Helston (a broad band linking St. Ives to Helston), (3) Camborne Redruth (the central mining district), (4) St. Agnes, (5) the Wadebridge area (including the St. Endellion district and a coastal strip to the east), (6) the St. Austell area (which is also the major china-clay producing area), and (7) the extreme eastern district around Callington that geographically extends across the Tamar River.

Although the majority of the Cornish mines are located within these mining districts, other important major producers occurred in isolation or in small groups outside the listed districts. For example, the celebrated 19th century classic source for bournonite and tetrahedrite is the Herodsfoot mine located southwest of Liskeard.

Figure 4. **Mine Captain Morcom of the Wheal Towan mine showing a copper specimen to financier Thomas Daniel of Truro. Painting of "Gentleman and a miner" by John Opie, 1786. Courtesy: Royal County Museum of Truro.**

Mine Management

Today, much of Cornwall's landscape in the old mining districts is littered with crumbling granite engine-house shells that once sheltered hundreds of beam-engines. Many of the winding, heather-lined, one-lane roads are silent and nearly unused. But during the 19th century, scores of engine-house chimneys emitted clouds of coal-fired gases, and mule-drawn wagons and surface workers moved everywhere. Most mines were independent of one another but seemed to function with considerable efficiency. Each process and each employee was given a typically Cornish name or title.

Mineral rights to a *sett* or *set* (property) were held by mineral-lords (landlords). The property could be a newly discovered and unworked mineral lode, or it might be a working and productive mine. Mineral-lords granted rights to work and develop a mine within a specified set of bounds for a given period of time (usually several years) at specified dues, typically 1/12th of the mine's production, the so-called lord's-dish or lord's share. These mining-right leases often carried minimum numbers of miners to be employed. In the major fields literally every square foot of ground was leased, so cases of accidental or deliberate mining beyond the sett boundary into adjacent territory were frequent and interminable, and expensive litigation often ensued.

Mineral-lords of prosperous mines were always anxious to add to their setts. Less effective neighboring mines were frequently purchased and added to their mine lease area. Thus, flourishing mines grew at the surface as well as underground.

If the successful *pitch* (lease) was on a previously unworked property, a vertical shaft was usually sunk from grass (the surface) to give access later to a series of horizontal levels.

Ground was "won" by hand-drilling and subsequent gunpowder blasting. Until the end of the century, men and boys climbed to and from grass on the ladder roads (vertical ladders), which in the deepest mines could be up to 3,000 feet long! Expensive Welsh coal (Cornwall had none) was reserved for firing the engines to pump water out of the workings, to "wind ore" (hoisting), or drive stamp-mills used in ore-dressing. Each mining site was developed in accordance with its specific needs. On a coastal mine, for example, a pumping machine could be placed below cliff tops, but just above the surf, which shortened the lift and reduced pumping costs.

Some mines achieved immense profits, but most operated in the red, supported by clever advertising that caused otherwise level-headed investors to pour fortunes into large numbers of dubious prospects.

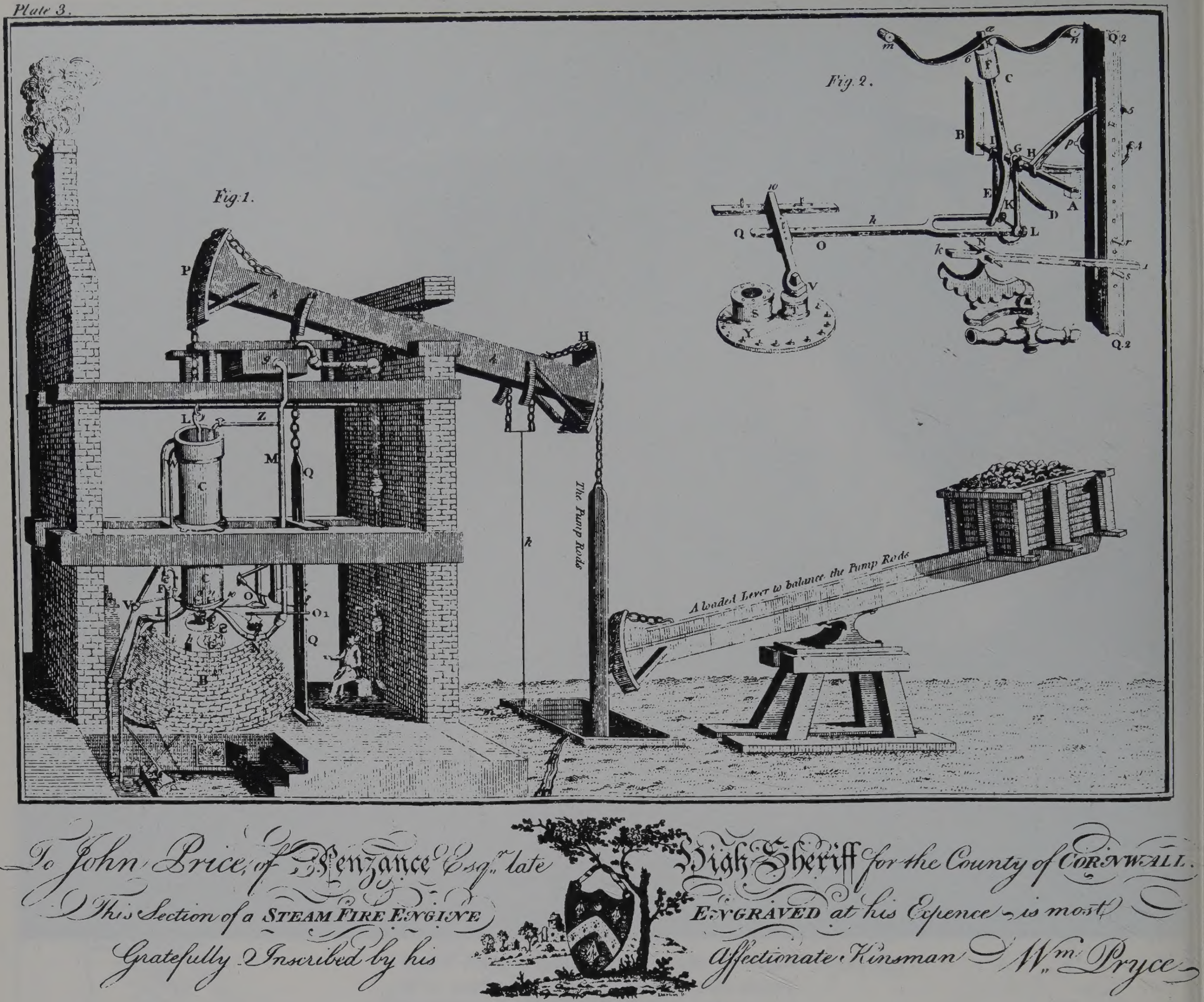


***Figure 5*. Engraving of a mine steam fire engine, published in Pryce's *Mineralogia Cornubiensis* (1778). Cornubia was the ancient name for Cornwall. Courtesy: Royal County Museum of Truro.**

Many mines were small; some were part-time family ventures. The part-time farmer or fisherman who indulged in occasional mining was a familiar figure who varied his calling according to season and weather.

Beginning in the 17th century, surface mines were called *bals,* but by the latter part of the century, the term referred to all mines, both surface and deep. For no known reason, *bal* was changed to the Cornish word *huel,* and later in the mid-1850's to *wheal,* which meant a hole—any hole, including an ear-hole. Today many Cornish mines still bear the title *wheal,* as Wheal Boys, while others have modern names such as West Phoenix mine. Some mines were named *consols* (a short form of "consolidated mines").

The Miners

During the first half of the 19th century, a miner's life was, for the most part, short and cruel. A typical underground shift was eight hours of crawling on hands and knees along narrow galleries and, in a cramped position, hammering through a foot of granite each day by the light of a tallow candle. In the days before the man-engine (reciprocal-moving platforms), a miner could use one-fifth of his energy climbing in and out of the mine. In a deep mine he might have to climb for an hour up vertical ladders that were wet, slimy and often had broken rungs before he could reach grass.

Miners tended to be sickly, with bad lungs and poor hearts. The miner's working life was over before he was 40, and he probably would not live to be 60. Living in damp mud-and-stone huts, many of his children would not reach puberty. A study at St. Just in the years 1840–49 revealed that a quarter of all males buried and half of all females were under the age of five. The average miner received wages of about two pounds a month, forcing everyone in the family to work. At age seven most boys and girls began work at the mines, receiving a few pennies for a 10-hour shift. Some boys were assigned the job of retrieving wooden wedges used to shore up loose rock in abandoned mine tunnels. While girls never worked underground, ado-

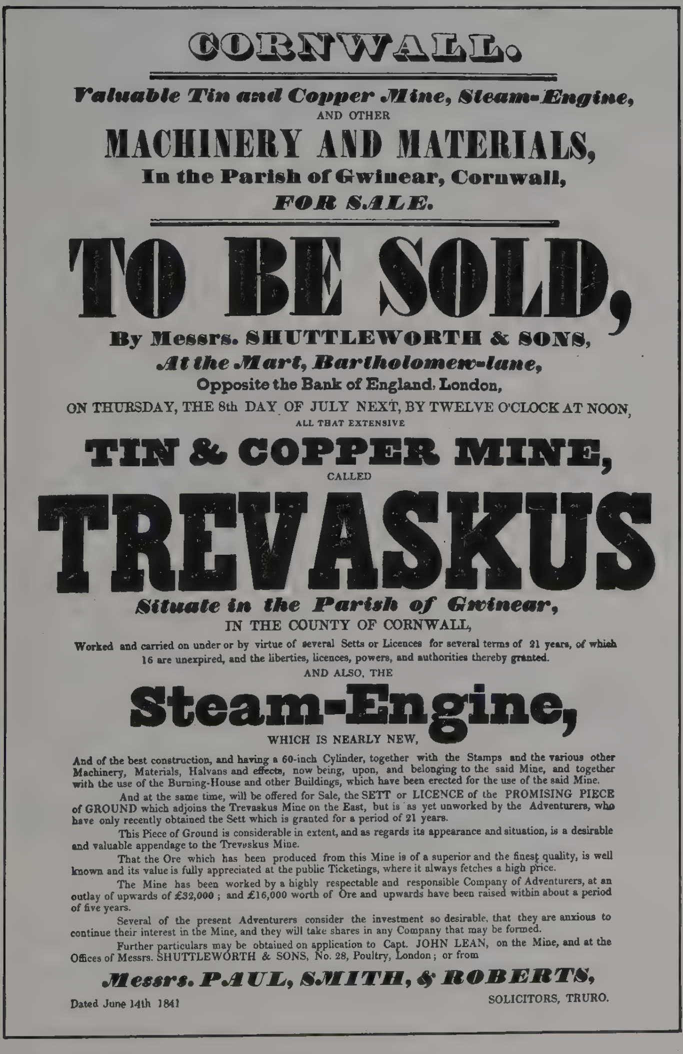
Figure 6. **Winding machine engine house, Levant mine, 1894. Collection of the Royal County Museum of Truro. Photo by Hebert Hughes.**

lescents of 12 or older were hired as bal-maidens to hammer rocks into half-inch pieces. The Consolidated Mines in the parish of Gwennap paid 12 to 14-year-old girls 12 shillings a month.

By the late 1850's, high-grade copper was pinching out in Cornish mines, while at the same time vast copper deposits were being discovered on Lake Superior and in Chile. Adventurers thought tin production would see them through, but the discovery of extremely rich tin deposits in Bolivia and Malaysia brought Cornish mining to its knees. As hundreds of mines in western Cornwall shut down, miners had but two options—stay in misery and unemployment, or emigrate to countries rich in minerals and in need of trained miners. L. L. Price of the Royal Statistical Society stated that by 1888, "one-third of all miners had left Cornwall for good."

The majority of miners were full-time professionals within whose ranks a two-tiered hierarchy existed. The largest group was the tributers, a corps of elite, self-employed miners whose reward was a fraction of the ore they extracted. They paid mine management for the powder (explosives), dips (tallow candles) and other materials they used. These fiercely proud individuals would climb to grass each night carrying heavy drill-steels to be sharpened by the tool-smith at the miners' expense.

Miners were also required to make monthly contributions to the mine surgeon and to the welfare fund. Some mines had a death club that paid a miner's widow one shilling from every man working in the mine. The accident club, financed by miners, paid five shillings a week until the injured miner was determined fit, or for life if he



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Situate in the Parish of Gwinear,

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AND ALSO, THE

Steam-Engine,

WHICH IS NEARLY NEW,

And of the best construction, and having a 60-inch Cylinder, together with the Stamps and the various other Machinery, Materials, Halvans and effects, now being, upon, and belonging to the said Mine, and together with the use of the Burning-House and other Buildings, which have been erected for the use of the said Mine.

And at the same time, will be offered for Sale, the SETT or LICENCE of the PROMISING PIECE of GROUND which adjoins the Trevaskus Mine on the East, but is as yet unworked by the Adventurers, who have only recently obtained the Sett which is granted for a period of 21 years.

This Piece of Ground is considerable in extent, and as regards its appearance and situation, is a desirable and valuable appendage to the Trevaskus Mine.

That the Ore which has been produced from this Mine is of a superior and the finest quality, is well known and its value is fully appreciated at the public Ticketings, where it always fetches a high price.

The Mine has been worked by a highly respectable and responsible Company of Adventurers, at an outlay of upwards of £32,000; and £16,000 worth of Ore and upwards have been raised within about a period of five years.

Several of the present Adventurers consider the investment so desirable, that they are anxious to continue their interest in the Mine, and they will take shares in any Company that may be formed.

Further particulars may be obtained on application to Capt. JOHN LEAN, on the Mine, and at the Offices of Messrs. SHUTTLEWORTH & SONS, No. 28, Poultry, London; or from

Messrs. PAUL, SMITH, & ROBERTS,

SOLICITORS, TRURO.

Dated June 14th 1841

Figure 7. **Broadsheet of the pending sale of the Trevaskus tin and copper mine and its steam engine, June 14, 1841. Courtesy: Royal County Museum of Truro.**

Figure 8. **Cathedral Room in the South Condurrow mine, 460 fathoms (2,760-foot level), 1890's. Collection of the Royal County Museum of Truro. Photo by J. C. Burrow.**

was blinded. Should the mineral lode lean-out (become unprofitable), the miners could well end the month in debt.

The second group of mine workers were the tut-workers, who were paid weekly as laborers. These men ranged from underground laborers to specialists at sinking shafts, raising winzes and timbering. As contract workers, they were certain of payment for their efforts, quite in contrast to tributers, who depended upon good fortune for income.

Other important mine employees included the aforementioned bal-maidens or spalling girls. These young women worked at the surface, usually on ore-dressing floors, breaking down rocks to smaller sizes acceptable to mills and smelters. Some bal-maidens cobbed ore by breaking off richer pieces from the gangue waste. These "comely" young girls wore large, floppy white bonnets that were tied at the throat with a bow, black long-sleeved blouses, and white skirts to the ankle. Depending upon the assignment, the girls used short-handled hammers, shovels, or wheelbarrows. Mines hired as many as 100 girls from lists of eager applicants. Bal-maidens were said to be healthy, reliable and hard-working.

Health of Miners

The health of Cornish miners, working in what was called the "sunless hell," became so bad that a number of doctors made studies to determine the exact causes of their poor health. Eventually remedies were effected that greatly improved life in the mines. About 1885, Dr. A. E. Permewan issued a report to the Cornwall County Council, that included the following observation:

> Doctors had claimed that 600 out of every 1,000 Cornish miners died of consumption; the Cornish miner was exposed to certain evils which shortened his life; one special illness was "miner's complaint" which combines bronchitis, emphysema, and loss of elasticity of the lung, fostering tubercular disease which ends quickly in death; before the man-engine and gig [small man-elevator] were invented our Cornish miners were constantly out of breath from climbing; many miners walked in wet clothes from the shaft to the changing house in the teeth of the keen ocean air; it was frequently too expensive to pump fresh air into the ends of long tunnels. Some air was so bad that candles repeatedly went out; miners ate poor-quality food, heavy hoggans [vegetable and fish or meat and potato pies] that could fall ten fathoms without breaking.

Dr. Permewan concluded his report:

> Working conditions today have greatly improved; most mines now have clothes-changing houses called "drys" which are connected to the shaft so that wet miners no longer walk in the wind.

Figure 9. **Worker loading a wheelbarrow with arsenic crystals at Tolvadden, Cornwall, 1890. Note cotton swabs in worker's nose for protection against deadly dust. Collection of the Royal County Museum of Truro.**

Figure 10. **Cornish bal-maidens (women who crushed ore by hand with bucking hammers), 1890's. Collection of the Royal County Museum of Truro.**

Before the introduction of dynamite, many miners were seriously injured or killed by premature explosions. One culprit was the prohibited practice of tamping black powder into drill holes by using the reverse end of a drill-steel instead of the prescribed copper tamping bars. Miners made fuses by filling straws or goose quills with black powder. (Where formerly miners suffered fractured skulls and many were blinded, now the more stable dynamite either kills or does no hurt, and injuries to eye and head have been greatly reduced.) Sick clubs to which the miners contributed were established in every mine. Dr. Permewan considered it a point in favor of the miners in that "as a class they are temperate, and cases of drunkenness are rare."

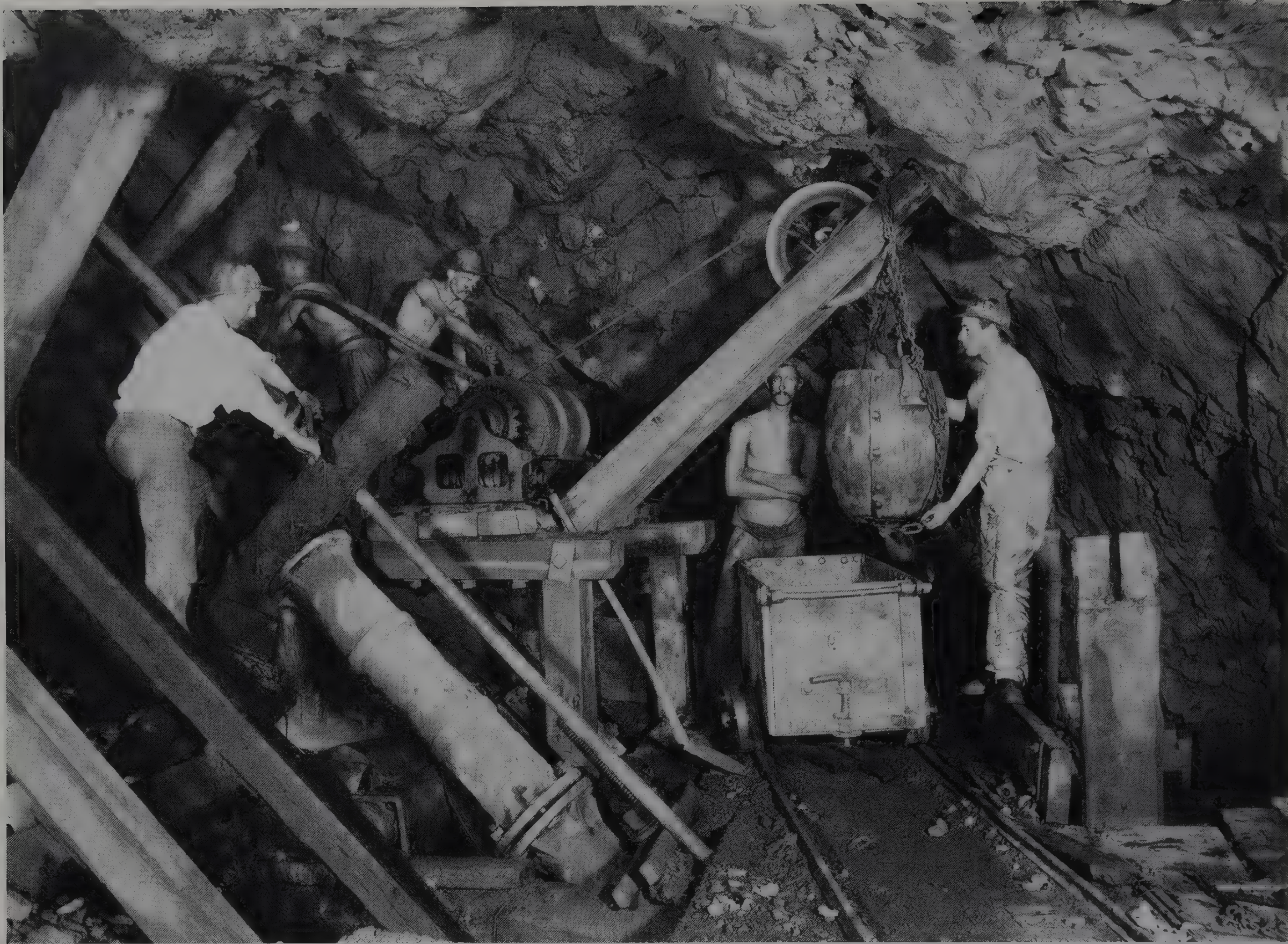


Figure 11. **Miners deep in the Cook's Kitchen mine, Camborne, ca. 1910's. Collection of the Royal County Museum of Truro.**

Poisonous Arsenic

As early as the 1810s, Cornish mines began producing ores rich in arsenic. An arsenic works was established at Falmouth in midsummer 1812 by Dr. Richard Edwards, a physician and chemist. By 1844, four arsenic works were active in the Carnon Valley. The largest works had seven large chimneys and two very high stacks to help carry away the extremely poisonous and voluminous white smoke and the accompanying stench, said to be like garlic. A celebrated legal case was tried in 1851 (verdict unknown) because of the deaths of cattle and other animals from eating poisoned herbage downwind from the stacks.

In 1874 the Botallack Arsenic Works was built, consisting of a half-dozen circular kilns, each 3 feet in diameter. The ovens were connected to 72 arched chambers with many orifices in their connecting walls, giving the deadly fumes a distance of 374 yards in which to deposit white arsenous oxide crystals. After the crystals had cooled, workers, "protected" by wads of cotton stuffed into their nostrils, dismantled sealed doors and entered the chambers. Using shovels to knock the arsenous oxide crystals from walls and ceiling, they shoveled the white powder into wooden wheelbarrows. It is said that arsenic workers lived no more than two years after employment.

The destructive Mexican boll weevil invaded the United States in 1892, laying waste to large cotton-farming areas in the southern and southwestern states. Arsenous oxide powder from Cornwall was widely used as an insecticide in combating the weevil. No arsenic flues are operating in Cornwall today.

Mine Accidents

During the 19th century, serious mine accidents occurred with distressing frequency. Those involving only injuries or a few fatalities are largely unreported in the literature. The following incidents are some of the more unusual or spectacular:

On April 10, 1863, a serious accident occurred in the Botallack mine's Boscawen's shaft. At that time, gig rails descended to the 190-fathom (1,140-foot) level in the shaft inclined at 32°. With eight men and a boy aboard, the hauling chain broke, sending the gig to the bottom of the shaft and killing all aboard. A contemporary broadsheet of the time wrote:

Each one was injur'd fearfully.
Bruis'd, broken, smash'd and dead;
A sickening spectacle! For some
had lost part of the head.

On January 5, 1872, a newly greased tram-wagon at the Botallack mine was set in motion by violent winds above the cliffs, causing the wagon to run away down a near-vertical ore-haulage incline, smashing into a small shed and seriously injuring three bal-maidens. Post-accident regulations must have been effective, for no additional accidents to trams were reported.

A "disastrous calamity" took place on February 29, 1875, at the Unity Safety Fuse Works at St. Day, Cornwall. In an explosion, five

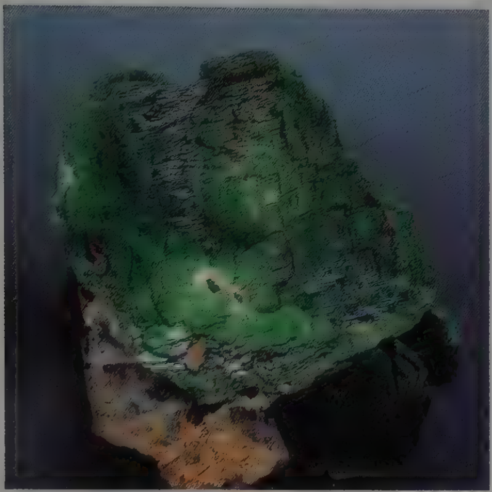


Figure 13. **Metatorbernite on altered granite, 10 cm, from the Old Gunnislake mine, Calstock. Collection of the Natural History Museum, London (Russell collection). Photo by Frank Greenaway.**

Figure 12. **Bournonite with quartz, 6.7 cm, from the Herodsfoot mine, Liskeard. Collection of the Natural History Museum, London (Ludlam collection). Photo by Frank Greenaway.**

Figure 14. **Connellite needles up to 8 mm, from the United mines, St. Day, Gwennap. Collection of the Natural History Museum, London. Photo by Frank Greenaway.**

Figure 15. **Cassiterite on topaz, 5.5 cm, from Trevaunance, St. Agnes. Collection of the Royal County Museum of Truro (Philip Rashleigh collection). Photo by Frank Greenaway.**

people were killed and a number injured. The following verse was written by Thomas Morris as a memorial to the dead:

Again we've heard of saddening news,
And five have lost their breath;
At the factory of the safety fuse,
They met with sudden death.

Last Saturday it did take place,
The powder it did explode;
But the fire made them a grave,
What horror and what woe.

The furious blast of death did come,
To haste their souls away;
Their mortal frames lie in the tomb,
Sleeping till the last day.

In 1888 the Old Wheal Drea mine filled with water to the collar and was abandoned. Richard Boyns, surveyor for the neighboring Wheal Owles mine and also purser of Botallack, attempted to keep newly developed workings at Owles a safe distance from Drea, now the "house of water." His mine plans showed that 16 fathoms (96 feet) of solid rock protected his mine from Drea's nearest approach.


Pentireglaze Mine
WADEBRIDGE
Wh. Mexico
East Wh. Rose
Wh. Rose
Wh. Hope
Cligga Mine
Polberro
Blue Hills
Wh. Kitty
Chiverton Mines
ST. AGNES
4.
Wh. Coates
3.
REDRUTH
TRURO
Wh. Busy
Unity Wood
Wh Gorland
Wh. Jane
Ting Tang
St. Day Untd. Mines
St. Day Consols Mine
East Pool
Tincroft
Pednandrea
S. Crofty
Wh. Sparnon
CAMBORNE
Wh. Uny
Dolcoath
Wh. Basset
Wh. Grenville
Tresavean
Wh. Pendarves
ST. IVES
Wh. Trenwith
Providence Mines
St. Ives Consols
Wh. Alfred
Wh. Herland
Wh. Carpenter
Basset and Grylls
1.
Ding Dong
2.
Binner Downs
Crenver and Abraham
Wh. Lovell
Geevor
Levant
Botallack
Wh. Owles/Wh. Edward
Penberthy Croft
Wh. Metal
Wh. Vor
Great Work
Balswidden
ST. JUST
HELSTON
Gt. Wh. Fortune
FALMOUTH
Wherry Mine
ST. MICHAEL'S MOUNT
Trewavas Head Mine
Wh. Penrose
Wh. Rose
LIZARD COMPLEX
LANDS END
LIZARD POINT

Figure 16.

THE KEY MINES OF CORNWALL AND WEST DEVON

LEGEND

1. ST. JUST
2. ST. IVES-HELSTON
3. CAMBORNE-REDRUTH
4. ST. AGNES DISTRICT
5. WADEBRIDGE-ST. ENDELLION
6. ST. AUSTELL AREA
7. EAST CORWALL/WEST DEVON (TAMAR)

+ Levant — MINE LOCATION

GRANITE PLUTON OUTCROP

SCALE IN MILES (Approximate only)

0 5 10

NICK TALBOTT 1991

Figure 17. Fluorite on quartz, with chalcopyrite, 13 cm, from the West Caradon mine, St. Cleer, Liskeard. Collection of the Natural History Museum, London. Photo by Frank Greenaway.

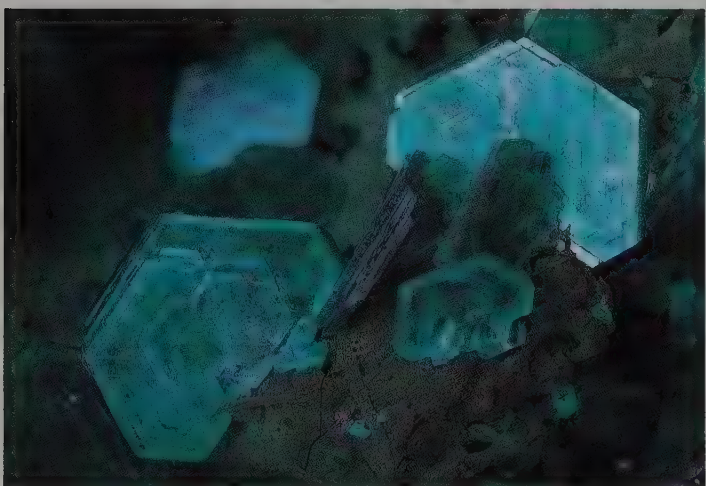


Figure 18. Chalcophyllite, in hexagonal plates up to 5 mm, from Wheal Unity, St. Day, Gwennap. Collection of the Natural History Museum, London (Talling specimen). Photo by Frank Greenaway.

Figure 19. Chalcocite on calcite, 7.1 cm, from the Levant mine, St. Just. Collection of the Natural History Museum, London (Semmons collection). Photo by Frank Greenaway.

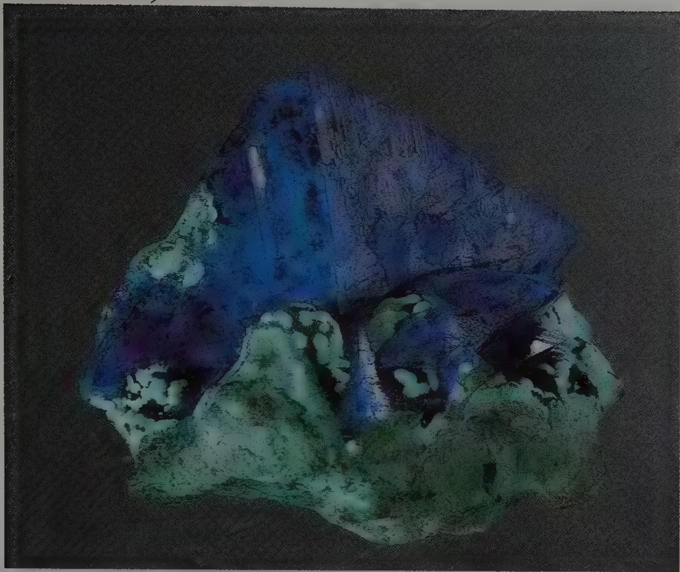


Figure 20. **Liroconite on strashimirite, 2.1 cm (largest known crystal of species), from Wheal Gorland, Gwennap. Collection of the Royal County Museum of Truro. Photo by P. Bancroft.**

Figure 21. **Ludlamite on quartz; the largest crystal is 1.2 cm, from Wheal Jane, Kea. Collection of Paul Lowe. Photo by Arnold Fisher.**

Figure 22. **Cuprite on goethite, in crystals up to 1 cm, from the Phoenix mine, Linkinhorne. Collection of the Natural History Museum, London. Photo by Frank Greenaway.**

Figure 23. **Calcite on galena, 13 cm, from Wheal Wrey, Liskeard. Collection of the Natural History Museum, London (Talling specimen). Photo by Frank Greenaway.**

But on January 19, 1893, at 8:45 a charge was fired on the Owles's 65-fathom level, which accidentally holed into the water-filled Drea. Instantly a vast body of water burst into Owles, where 40 men were at work, and then cascaded down shafts to lower levels. The Owles was completely flooded to the collar in 30 minutes. Survivors reported a thunderous noise and hurricane of wind that blew out candles. In darkness and terror men raced for their lives, some attempting the ladder-roads to the surface 390 feet above. Twenty miners died in the flood and their bodies have never been recovered. The Wheal Owles remains their grave. In the trial that followed, it was shown that Boyns, a self-educated surveyor, had, over the years, failed to make allowance for magnetic variation. The continuing error had kept miners off course until they holed into the "house of water" with disastrous results. Boyns, by now a very sick man, was found guilty and fined 15 pounds sterling (about $500 in today's money).

The Levant mine had a man-engine that was a German invention, akin to a pump rod (see vol. 17, page 8, for an illustrated example). Miners using a man-engine ascended and descended by stepping onto and off platforms of a reciprocating engine rod. In 1919, the fitting at the top of the rod broke and 31 men were killed when they plunged to the bottom.

Figure 24. **Sketch of Botallack mine as it probably looked in the 1860's. By Nick Talbott, geological draftsman for South Crofty mine.**

The Botallack Mine

Cornwall has many great mines, and Botallack was one of the most famous. Botallack was selected as the example to feature in this article because of its history, ore production, machinery, and exceptional crystals and because the mine was, until recently, still open, permitting us to investigate some of its underground workings.

LOCATION

The Botallack mine is located north-northwest of the town of St. Just, on the western tip of the Cornish peninsula. The mine is situated near the prominence called Botallack Head, which projects into the ocean about a mile north of the town of St. Just. The immediate district includes the Levant mine (to the north), the Geevor mine (to the northeast), the Carnyorth mine (to the east), Wheal Owles (to the south) and the St. Just United mine (to the southwest). Specific sites along the coast include Jowl Zawn, Wheal Cock Zawn, The Crowns, De Narrow Zawn, and Zawn a Bal.

HISTORY

Probably the first mining at the Botallack cliffs was during medieval times, but the oldest surviving record is a letter dated January 1754. It was written by John Maddern of St. Just to William Usticke at Castle Yard in London, to say: "Botallack adit goes on pretty well."

During Botallack's early years, especially when the world market was depressed, mine management used every possible scheme to sell tin. One of the more interesting occurred in 1843, when Stephen Harvey James and Richard Davey instructed Dixon & Company of Sheffield to make a dinner service of pure tin (the exact words were "as full of tin as possible consistent with hardness"). The intention was to induce mine agents and others to follow the example and so to stimulate the demand for tin. A Botallack Plate service cost less than 50 pounds sterling. One service that had been in almost constant use for thirty-four years showed no scratches, antimony having been used as a hardener. Stephen James claimed the tin dinner sets were "clean and sweet, and serviceable in every respect; and that they were undoubtedly a good investment if only for the saving of crockery."

During the 18th and 19th centuries, rich Botallack lodes produced enormous quantities of tin, copper and arsenic. Collins noted that, by 1865, miners were working 220 fathoms (1,320 feet) below adit. The Botallack became one of the most colorful mining scenes in the British Isles. Its pumping engine perched atop Crowns Rock. On the side of

Figure 25. **The Botallack mine area (from Barton, 1963).**

the cliff, another engine operated the whim-winder that ferried men and ore in an iron gig up and down the Boscawen's incline shaft. The shaft's entrance was but 30 feet above tide level and was frequently flooded by the sea during winter storms.

A fascinating description of the Botallack mine was published in 1855 by J. N. Leifchild in his *Cornwall, Its Mines and Minerals*. The following excerpts are presented exactly as they were written.

> Botallack mine is really one of the greatest sights in Cornwall in connection with bold scenery and magnificent marine views. It is a copper mine; but tin and iron are found there. It is established at the western extremity of the great copper and tin lodes, running eastward through Cornwall as far as the Dartmoor Hills. If you know veins by sight, you may trace them running along the rocks into the sea.
>
> When first established, the capital expended must have been very large, since the natural difficulties greatly increased the ordinary expense of erecting mining machinery and mining gear. The separate parts of an enormous steam engine were lowered 200 feet down the almost perpendicular cliff.
>
> To gain entrance to the sub-oceanic excavations in this extraordinary mine is no slight matter. You have to pick your way down to a small counting-house, erected on a cliff half-way between the summit and the ocean. Having obtained permission and guidance, you attire yourself in woolen mining dress, and putting on a large felt hat, and tying three or four candles to your buttonhole, while you will have to carry another lighted in the hand, you enter the trapdoor entrance to the mine. Over the dark vacuity beneath, you see the loaded kibble [bucket] rushing past its descending companion. As you descent, you depend upon candles alone, which throw but a faint and mocking light into the gloomy abyss below. Down the ladders. Another ladder? Yes, another and another! At the bottom you are in one of an apparently endless series of galleries terminated by dismal trap-holes, which lead to nothing but headlong destruction.
>
> Your progress in a mine is never equal or familiar, but is ingeniously compounded by walking, stooping, crawling, crouching, descending, climbing, creeping, and grumbling.
>
> Pray, have no fear of those unknown abysses, but thinly covered over with planks, which you must cross now and then in these levels. True the planks are shaky and slippery and slight, but the quicker you get over them the better. And now you see miners with short pickaxes labouring at the ore.
>
> Your guide informs you that, "Proud moment, you are now four hundred and eighty feet under the ocean—why, boats and vessels are sailing over our heads—a situation never to be enjoyed in any other mine."
>
> Let us look at our metallic ceiling—lift up the candles that are going at a galloping consumption. What makes the rock so damp and dripping here? Pray, guide, how many feet, do you think, of thickness of rock we have between us here and the sea? "Why, gentlemen, I should say about three or four feet where that wooden plug preserves the development of a positive hole upward to the ocean." But listen—yes! It comes, the heavy roll of the large boulders, the ceaseless grinding of the pebbles, the fierce thundering of the billows, placed a tempest in its most appalling form too vividly before us ever to be forgotten. We retreated affright. The miners seem to have perfect confidence that the rocky shield, thin as it is in some parts, will defend them against the incursion of the Atlantic.
>
> At the counting-house, gallons of water are awaiting us, and tallow, mud, ooze, and iron-rust all give way to the application of soap. Off go our miner's caps, and woolen jackets, and wide inexpressibles, and away we go, fanned by the refreshing breeze of that ocean, the echo of whose sound we have fearfully heard under its depths.

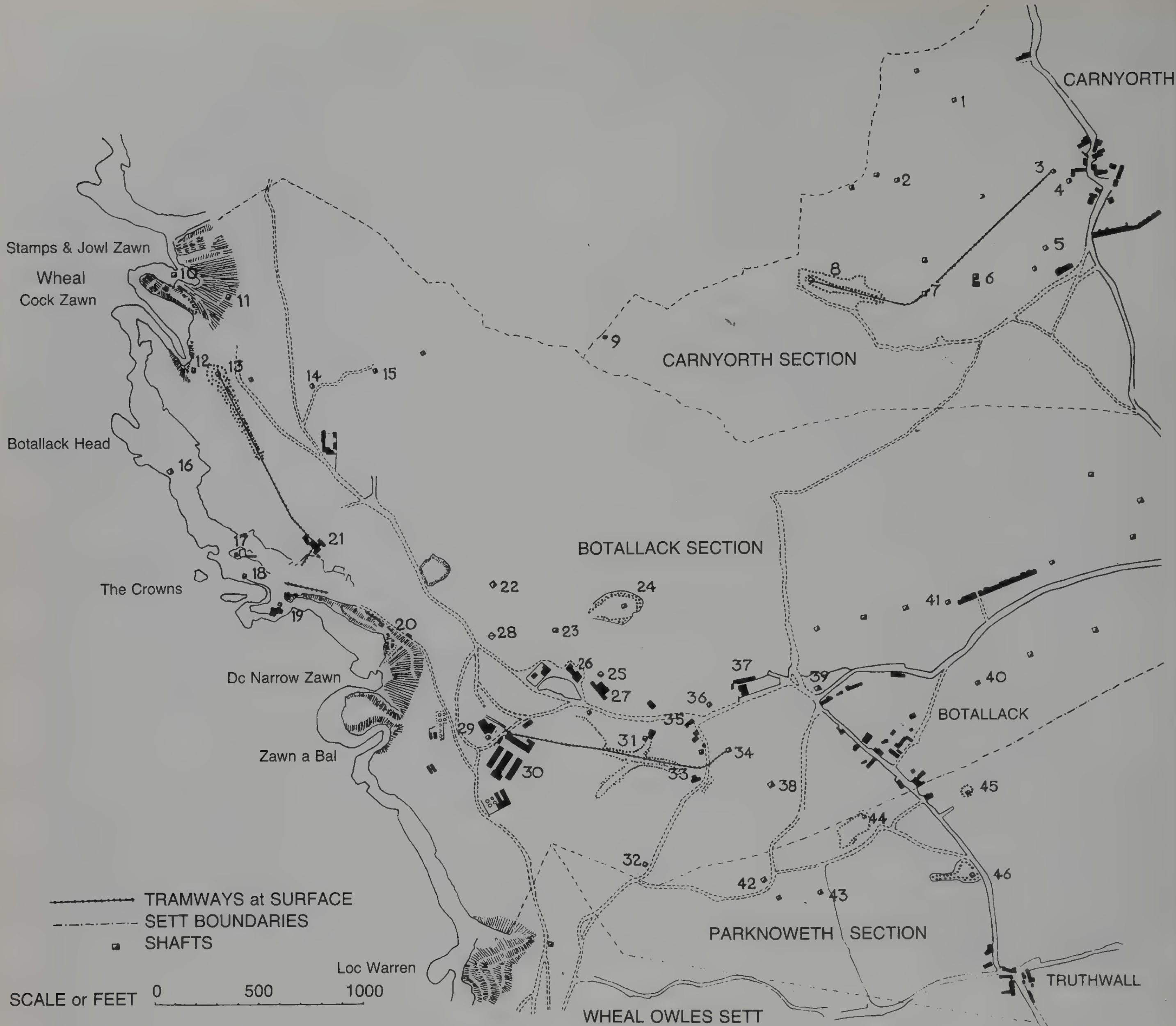
Until the middle of the 19th century, the Botallack mine was relatively isolated from the rest of the world. The trip from London by stage took 12 days. Then, in 1859, Brunel's Great Western Railway was built into Cornwall, and London was just one day away by train. Botallack rapidly became one of Cornwall's greatest attractions, and over the following years, thousands of tourists took the "joy ride" in the mine's gig down the shaft and then trammed in mine cars through tunnels out under the sea.

Of great local interest was the visit of the Prince and Princess of Wales (later to be King Edward VII and Queen Alexandra) to Botallack in 1865. When the royal party alighted at the bottom of the shaft to begin its tour, Mine Captain John Boyns remembered to his dismay that he had forgotten his gloves. He knew it would be unthinkable to offer his bare hand to the royal lady in time of need. When that time arrived, he wrapped his hand in a piece of newspaper and hastily offered her assistance. Thinking he was presenting her something to read, she attempted to scan the paper. Captain Boyns was forced to explain his difficulty, upon which the Princess burst into laughter, threw away the paper, and took the ungloved hand of her loyal but embarrassed subject.

Records of Botallack production during its long periods of operation are very incomplete. Frequently, ore tonnages and records of employment that supposedly referred to Botallack, were, in fact, composite figures that included other nearby mines under the same ownership or management.

J. H. Collin's statement of Botallack production seems to be accurate. From 1836–1895, mined ore brought the following sums: tin, £829,664; copper, £220,701; and arsenic, £6,481.

Mining continued at Botallack with varying degrees of success until June 1895, when the combined effects of mine flooding from the influx of seawater and low world metal prices caused its closure. As a sign of poor times, the adventurers had received no dividends in the last 22 years. During the next decade, unemployed miners handpicked the dumps and upper levels of the mine, earning an estimated £30,000.



CARNYORTH SECTION: 1. *Great Works Shaft* 2. *North Shaft* 3. *Rodd's Shaft* 4. *Stock Shaft* 5. *Guide Shaft* 6. *Engine Shaft* 7. *Lobby Shaft* 8. *Pearce's Shaft* 9. *Nineveh Shaft*
WHEAL COCK SECTION: 10. *Providence Shaft* 11. *Tolven Shaft* 12. *Wheal Cock Shaft* 13. *New Shaft (Skip Shaft)* 14. *Chicken Shaft* 15. *Wheal Hen Shaft*
BOTALLACK SECTION: 16. *Hard Shaft* 17. *Wheal Button* 18. *Boscawen Diagonal Shaft* 19. *Crowns Engine Shaft* 20. *Wheal Hazard Shaft* 21. *Crowns Whim* 22. *Cliffields Shaft* 23. *Flat Rod Shaft* 24. *Park Bunny Shaft* 25. *Old Engine Shaft* 26. *Account House* 27. *Whim and Saw Mill* 28. *Site of Allen Shaft* 29. *Narrow Shaft and Stamps* 30. *Dressing Floors* 31. *Botallack Engine Shaft* 32. *Chycornish Shaft* 33. *New Whim* 34. *Davy Shaft* 35. *Stores* 36. *Wheal Loor Shaft* 37. *Botallack House* 38. *Parknoweth Shaft* 39. *Ludgvan Shaft* 40. *Durloe Shaft (obliterated by new road)* 41. *Shaft believed to be on Wheal Chase Lode*
PARKNOWETH SECTION: 42. *Parknoweth Engine Shaft* 43. *Flat Rod Shaft* 44. *Buzza Shaft* 45. *Higher Buzza Shaft (obliterated by new road)* 46. *Lane Shaft (filled in by road widening)*

***Figure 26*. Surface plan of the Botallack mine (Noall, 1972).**

In 1908 a new, modern mining company was formed to exploit greatly increased metal prices and the remaining metalliferous riches in the sett. The new company, The Cornish Consolidated Tin Mines, Ltd., under the directorship of Francis Allen, was floated with a capital of £150,000. It was not a success, and ceased trading in March 1914, just prior to World War I. Most of the new venturer's capital was dissipated in the mis-sited and costly Allen's shaft.

In recent years, Geevor Tin Mines, Ltd. acquired a mining lease on the Botallack mine. Work was commenced on clearing and refurbishing the Allen's shaft and sampling the mine's ore. The intention was to raise an inclined shaft from the bottom of Botallack to the surface near the operating Geevor ore-dressing mill. Geevor Tin Mines, Ltd., also acquired rights to the old Levant mine complex located between Geevor and Botallack. More than 500 miners worked the three mines vigorously, and good production, plus a high tin price, brought the company record profits. But in 1985 the world tin crash dropped tin prices by nearly half overnight, ending any possibility that Geevor had much of a future. The only good news was that, at least for mineral collectors, some excellent mineral specimens were salvaged before the mines closed.

OUR VISIT

Underground at Geevor

We spent a day in the Geevor mine, accompanying mine Captain Alan Brewer on his daily rounds. Knowing of our desire to visit old

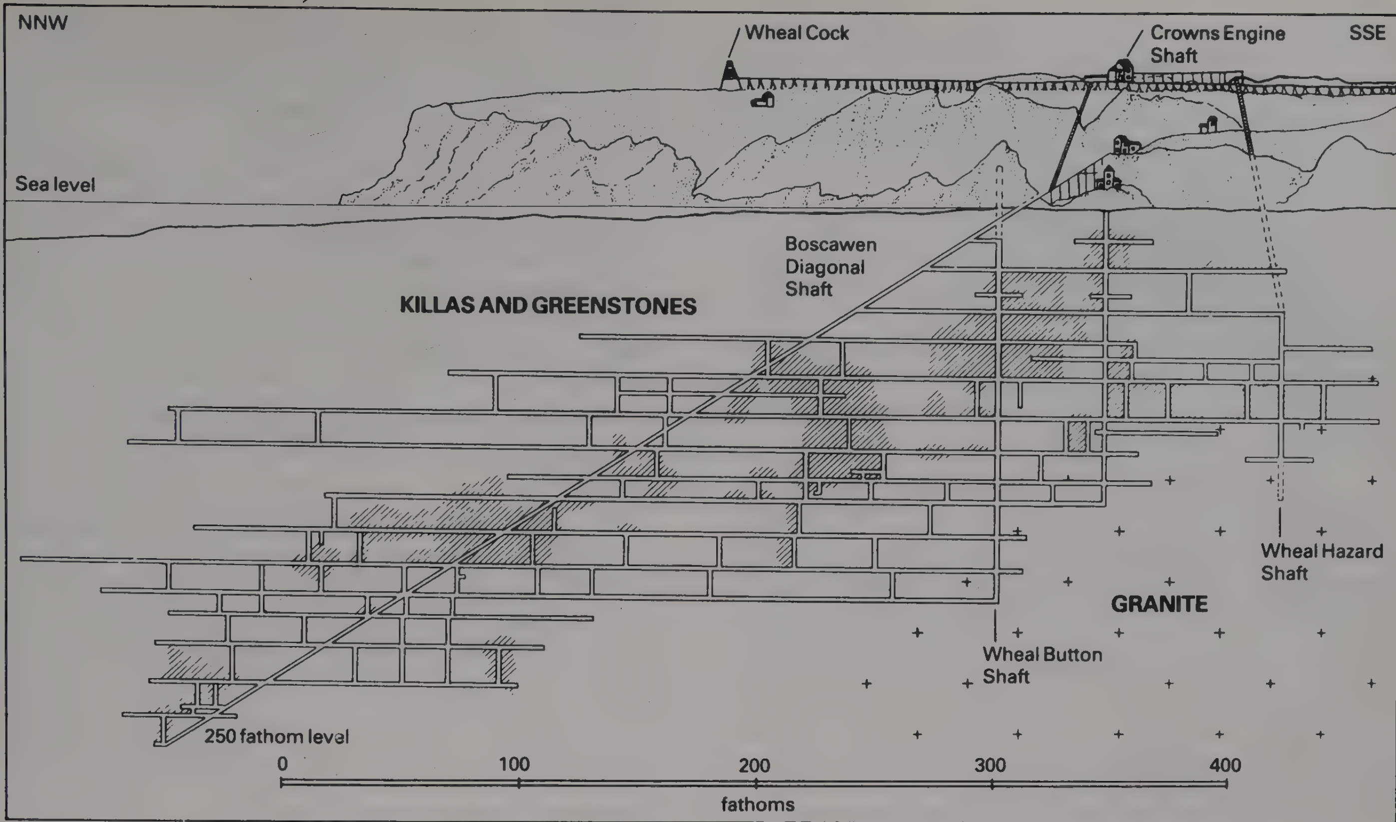


Figure 27. **Section through the workings of the Crowns Lode, Botallack mine; orebodies are shown cross-hatched (from Embrey and Symes, 1987).**

underground workings, Brewer modified his routine so we could explore some of the more remote sections of the mine.

Captain Brewer knew the Geevor mine like a book, having spent more than 30 years in and about the premises. He had survived many close calls, but nearly lost his life in 1970. With shift boss Garfield Geach, Brewer had entered a crosscut on the 19th level (1,300 feet down) to detonate a hung (misfired) round left from the previous shift. He successfully shot the round, and the blast breached into the flooded Boscaswell mine nearby, releasing a nearly disastrous torrent of water into Geevor. The two men were swept three-quarters of a mile down the tunnel by waist-deep water to the old Wethered shaft, where they were able to grab onto ladders and climb to safety. No lives were lost, as the two men were the only ones underground at the time.

For six hours we followed our fast-moving guide through a labyrinth of shafts, tunnels and stopes. We climbed over piles of blasted debris and scrambled down slippery galleries, steadying ourselves on improvised wooden platforms while hanging a tentative boot over a jet-black abyss to gain a foothold on an iron chain or slimy rope ladder. Occasionally we entered small stopes where men were operating pneumatic drills that produced noise levels well above the threshold of pain. Some miners worked more than a mile from the nearest shaft station, carrying their drill-steel, blasting materials and mining equipment with them and then manhandling it up into the working stopes.

After walking through more than 2 miles of mine tunnels, back we came to a great black steel door weighing many tons, which once effectively sealed off Geevor while Levant was being dewatered. The rusty door was seldom used, so we had to locate a drill-steel to pry it open before we could advance into Levant country. We were now 1,400 feet below the surface and out under the bed of the Atlantic Ocean. On the way back, we came to the old Levant shaft. Leaning out into the shaft and looking upward, we could see the faint glimmer of the sky 1,400 feet above. Brewer soberly reminded us that until the 1880's, Levant miners climbed to and from grass each day on ladders in this shaft.

Back in Geevor, we entered the "old men's" section, which was last worked in the mid-1860's. There the ladders were so bad we began using our safety ropes. In many areas it was necessary to move through small, twisting passageways on hands and knees. All surfaces were coated with wet, reddish Geevor slime. At one place progress could only be made over a huge rock by climbing hand over hand up a thick 60-foot rope bolted to the ceiling above. At the top, a tunnel exited into a huge chamber, perhaps 80 feet high and at least 50 feet wide, with part of its floor filled with a black pool of water of unknown depth.

While waiting for the cage to return us to the surface, we discussed places in Geevor that had produced fine crystals. The Coronation lode around levels 9 to 18 is interlaced with limestone lenses in which were found large numbers of fine calcite specimens, some in association with ferruginous quartz. In various levels, especially level 17, many interesting calcite crystals were discovered associated with pyrite or marcasite in a wide range of crystal habits and colors. The North Pig lode recently contributed a number of attractive, steely lustered, elongated hexagonal twin crystals of chalcocite. In 1979, the Grenville lode produced some superb hexagonal chalcocite plates with beveled edges. More recently, the North Pig lode yielded chalcocite specimens associated with bornite and tennantite, some of them also coated with black, powdery uraninite.

The Botallack Surface Works

The old horse-drawn tramway, which connected the cliff-top mines of Wheal Edward, Wheal Drea, Wheal Owles, Wheal Hazzard, Botallack, Parknoweth mine, Wheal Cock and others, also passed the charming granite Botallack manor farmhouse. Though the tram no longer operates, the manor house with its door lintel dated 1642 still stands, along with other old buildings, some in sad need of repair.

At Botallack mine, Allen's shaft is topped by a modern steel headframe that stands ill at ease among the mining relics of yesteryear. Nearby, open and still explorable, is a multi-layered labyrinth of medieval-age tunnels known locally as "tin floors." Walking toward the cliff on a narrow trail, we passed over an unroofed concrete floor, the remains of the ore treatment buildings, and under the central arch flue that carried poisonous arsenic waste gasses to the 100-foot-high terminal stack perched high on the cliff's edge. To the west beyond the stack are a series of old granite engine-houses of the Owles, Edward, and Drea mines. Beyond is the solitary stack of Cape Cornwall United Mines, and another a few miles farther west is the Longships Lighthouse resting precariously on a pile of phonolite (green volcanic rock). Thirty miles farther west are the Isles of Scilly, and another 3,000 miles farther is the Statue of Liberty.

The path dips steeply downward past great, jagged wreaths of hornfels and metabasite showing interesting effects of metasomatism and metamorphic alteration. We finally reached the old whim steam-engine house that, until 1885, alternately wound either the man-gig or an ore tram to and from the famous diagonal (inclined) Boscawen's shaft. Around the cliff we came to the Crowns, the site of a mid-19th-century pumping engine.

In the same area there are numerous lenses and veins containing streaks of pure copper. Inside the Wheal Hazzard adit, crystalline paratacamite and good quality heulandite specimens are found in treacherous ground. Seen along the cliff face are well-developed exposures of prehnite, axinite, and various altered silicates, as well as pillow lavas, volcanic bombs, invertebrate fossil debris and amygdules of calcite and zeolite material—a strange assemblage! Just above Crowns, 19th-century miners earned "beer money" risking their necks to hammer out splendid gemmy almandine garnets.

Underground at South Crofty

The last of our underground mine visits in Cornwall was at South Crofty. This mine is not open to tourists, so we felt privileged by the invitation to "go down South Crofty." Our guide was Nick Talbot, a personable mine surveyor, local mining historian, advanced mineral collector, and unusually talented artist.

The South Crofty, located between Camborne and Redruth about 25 miles northeast of Botallack, was formerly known as the Huel Longclose and Huel Dudnance copper lodes. It later became the New Cook's Kitchen mine and in 1894, was acquired by South Crofty.

Today, the bottom operations in South Crofty are at 510 fathoms (3,060 feet) and are as deep as Dolcoath—"deepest and queen of Cornish mines." During its 300 years of operation, South Crofty developed an underground maze of tunnel with a total length of more than 100 miles.

After donning work clothes, gum boots, hard hats, electric lamps, catalytic breathing units and safety lines, as well as picks and collecting bags, we boarded the Robinson's shaft cage. We shared our cramped space with a maintenance crew, feeling much like tightly packed sardines as we dropped into blackness. For the next few minutes our cage jerked and rattled as we were subjected to repeated blasts of cold air and a steady shower of water spraying through our overhead safety screen.

Our cage stopped at the 2,280-foot level in an uncomfortably hot and humid atmosphere. We immediately removed our work coats and, following Nick Talbot, walked out into an area of the mine known as the Roskear lode. Our tunnel led us to a well-lighted station that also was the top of a long, steep incline. On slippery steps we walked down to the 2,520 level, which is actually in the old Dolcoath sett.

About 300 feet from the bottom station, we came to the end of a tunnel where miners were drilling in the face. High temperatures, dripping water, and a constant din from rock drills produced working conditions that seemed nearly unbearable. Miners were stripped down to red-stained undershirts, "Y-front" pants, ear protectors, hard hats and gum boots. Everything was covered with a red hematitic slime, creating an eerie scene in the semi-darkness. We were told that the long-hole drilling technique being used required large amounts of powder (dynamite), which when detonated rattled cups and saucers alarmingly in the homes of Tuckingmill and Camborne half a mile above. In the ceiling of a side tunnel we discovered clusters of sparkling cassiterite crystals, which we barred down with drill-steel. It wasn't long before our eyes were filled with red sweat.

Next, Talbot led us up and down through levels that in years past had produced notable specimens of copper, bismuthinite, cassiterite, cuprite and chalcocite. It was especially interesting to crawl into some of the more ancient parts of the mine in ground belonging to past mines with names immortal to mining history, such as Dolcoath and Cooks Kitchen.

Six hours later we were hoisted to the surface. Within minutes we entered the change room and took a hot shower, that in the parlance of local miners, magically "transformed red Indians into white men." We were now ready to relax with a cup of hot, sweet tea.

MINERALS

The Botallack sett, together with its closely associated mines, such as Wheal Cock, Wheal Owles and Wheal Edward, plus the cliff exposures, have produced a large range of mineral species, many of them found as high-quality specimens. The suite includes rare species as well as others that are interesting for their unusual crystallizations.

Botallack is the type locality for stokesite and botallackite, as well as the unique or first British location for several rare species. Numerous native metals or their compounds are reported, including arsenic, beryllium, bismuth, cobalt, copper, iron, lead, manganese, silver, tin, tungsten, uranium and zinc.

Any listing of mineral species found in certain mines is bound to be incomplete. In the case of minerals from Botallack, several species reported in various journals now seem unlikely to have occurred there at all, and have been omitted. The following list comprises only extant Botallack material or species reported by accepted authorities.

Actinolite $Ca_2(Mg,Fe^{2+})_5Si_8O_{22}(OH)_2$

Numerous cliff and surface exposures, usually occurring as dark-green bladed to fibrous crystal aggregates. It is a common metamorphic mineral in this classic contact zone.

Almandine $Fe^{2+}_3Al_2(SiO_4)_3$

Fine, deep red, translucent trapezohedral almandine crystals occurring in a metamorphosed greenstone matrix have been collected from the mines and adjacent cliff exposures (Alderman, 1935).

Analcime $NaAlSi_2O_6{\cdot}H_2O$

Analcime was reported in the 19th century from cliff exposures (Collins, 1892); but Russell (1910) considered it unlikely.

Aragonite $CaCO_3$

Aragonite was a fairly common local species, found in a very wide range of habits. It occurred as white, gray, red or bluish green globular concretions, and also in acicular or fibrous habits and fine hexagonal prisms, typically doubly terminated.

Arsenopyrite FeAsS

Arsenopyrite was found abundantly as an ore species (Greg and Lettsom, 1858), but few fine specimens seem to have survived in collections. The finest example, to our knowledge, consists of sharp, silvery, repeated twins (about 1.5 cm in size) intergrown with dark brown cassiterite on slate-hornfels matrix. This was a mid-19th century specimen from the John Jago Trelawney collection.

Atacamite $Cu_2Cl(OH)_3$

Atacamite specimens commonly exhibit a misleading range of both colors and habits. Well-crystallized examples were commonly found, especially in the submarine sections of all of the district's coastal mines. Exceptionally fine and well-crystallized specimens were noted at Botallack, Wheal Hazzard and Wheal Cock.

Augite $(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al)_2O_6$

Augite occurs as small, dark greenish black crystals in the cliffs, and also in the Wheal Cock (and formerly the Parknoweth mine) dump materials.

Axinite $Ca_2Fe^{2+}Al_2BSi_4O_{15}(OH)$

Large, choice, clove-brown, near-gemmy crystals of axinite that compare favorably to the classic Bourg D'Oisans material, occur in the cliffs at Stamps and Jowl Zawn. It is also reported from the Botallack mine and the Wheal Cock section (Greg and Lettsom, 1858). The material is notable for the range of crystallographic forms exhibited. Goldschmidt (1913) figures 16 Botallack axinites.

Bismuth Bi

Bismuth, in silvery metallic masses and sometimes small, crude rhombohedral crystals, usually occurs in a limonitic jasper (Greg and Lettsom, 1858; Wolloxall, 1989).

Bismuthinite Bi_2S_3

Tarnished dull-gray, lath-like crystals and acicular sprays of bismuthinite, very inferior to the classic Fowey Consoils specimens or the recent bright South Crofty material, were found at Botallack and Wheal Cock. Specimens are preserved in the County Museum, Truro.

Bornite Cu_5FeS_4

Numerous good specimens of bornite, some exceptional, are often associated with chalcocite, though, surprisingly, not tennantite, which was abundant at the Levant mine. Old specimens are labeled "erubescite."

Botallackite $Cu_2Cl(OH)_3$

Botallackite, which is trimorphous with atacamite and paratacamite (Hawthorne, 1985), was first described by Professor A. H. Church in 1865. The specimens were supplied by the Cornish dealer Richard Talling. Jealous of his source, Talling gave the location as Botallack mine, but in fact it was Wheal Cock, which later became part of the Botallack sett (Kingsbury, 1954). Botallackite forms thin crusts of pale green microcrystals.

Brochantite $Cu_4(SO_4)(OH)_6$

Brochantite is rare at Botallack, not having been reported in the earlier literature. However, a specimen is recorded in the catalog of the Natural History Museum, London.

Brushite $CaHPO_4 \cdot 2H_2O$

Small, white, monoclinic crystals of brushite are found associated with siderite at Wheal Cock (Wolloxall, 1989).

Calcite $CaCO_3$

In general, calcite is a surprisingly uncommon species in Cornwall (Collins, 1892), no doubt due to the area's paucity of fossil carbonate debris to supply the carbonate radical building blocks. The mines of the St. Just district, together with the nearby Levant mine at Trewellard, were celebrated for the beauty and diversity of their crystalline calcites. A noteable form, often in pale pink, rose or orange tones, locally called "roses," was abundant. Frequently calcite was found at Botallack in association with crystalline chalcocite, chalcopyrite, pyrite or marcasite.

Cassiterite SnO_2

Cassiterite occurs abundantly in many habits and associations, in all parts of the Botallack sett. It is typically brown to black, in crystals up to 5 mm (Russell, 1920). In general, the crystalline cassiterites from the St. Just mining region are inferior in both size and quality to the St. Agnes district.

Chalcanthite $CuSO_4 \cdot 5H_2O$

This brightly colored secondary copper species occurs abundantly in the altered sections of all the area's mines. Old specimens are labeled as "cyanosite." Since part of the copper can be replaced by cobalt, iron, manganese and zinc, visual identification is unreliable. Random P.D.X. examination of numerous locally collected specimens suggests a complete series, at least between chalcanthite and melanterite (the iron analog). Recently collected, well-crystallized examples from old underground workings in Botallack, Wheal Edward, Wheal Hazzard, Wheal Cock and the nearby Levant mine demonstrate how quickly these species can form in a post-mining environment.

Chalcocite Cu_2S

Numerous splendid specimens of chalcocite (usually labeled "copper glance") were obtained from several of the lodes in the Botallack sett. A wide variety of habits, including prisms, unusual pseudohexagonal lenticular crystals and rarer twined forms, have been observed.

Chalcopyrite $CuFeS_2$

Chalcopyrite is an abundant ore mineral, but surprisingly infrequently encountered in old specimens from this area. This may be due to the early period of the mine sett's primary copper production and also, perhaps, because collectors of the period preferred the very high-quality crystalline examples, in association with quartz from the Gwennap and St. Agnes areas. Most surviving Botallack specimens are of the "blister copper" type.

Chlorite $(Mg,Fe^{2+})_5Al(Si_3Al)O_{10}(OH)_8$ (?)

Often a gangue mineral locally, the most interesting specimens of chlorite are those where it is an inclusion in quartz crystals (Russell, 1910).

Cobaltite CoAsS

Sparse, massive, submetallic inclusions of cobaltite occurred in the skarn assemblage below the Crown's engine house (Kingsbury, 1954).

Connellite $Cu_{19}Cl_4(SO_4)(OH)_{32} \cdot 3H_2O$

The 19th-century specimens of connellite were acicular to botryoidal, bright blue to turquoise-blue and were misidentified as "tallingite" (Church, 1965b). Three years ago, during the Geevor Mines reprospection of Botallack, one of us (SW) collected choice, rich crystalline examples consisting of thick silky crusts of dark blue crystals overgrowing well-crystallized botallackite.

Copper Cu

Copper occurred abundantly in all parts of the Botallack sett. It is especially well known as mossy, arborescent and sheet-like masses (Wolloxall, 1989). It has also been found rarely as pseudomorphs resulting from the reduction of cuprite.

Cuprite Cu_2O

Many good cuprite specimens were obtained, especially in the mine's earlier (shallower) period as a copper mine. Fine examples from the Rashleigh and other early collections were exhibited in the Royal Institute of Cornwall's collection at the County Museum, Truro.

Danalite $Fe^{2+}_4Be_3(SiO_4)_3S$

This rare beryllium silicate occurs sparsely in the cliffs of Chy Cornish Cove at Botallack, as resinous, reddish brown masses. It is almost indistinguishable from the associate skarns, and was found by accident by the geologist John Hart, who generously communicated his discovery to one of us (SW). Wolloxall (1989) reports masses in the cliffs at Wheal Cock Zawn.

Devilline $CaCu_4(SO_4)_2(OH)_6 \cdot 3H_2O$

Devilline is known from a recent rare find, though probably previously overlooked, in association with other, more frequently occurring species in local mines. A specimen is recorded in the catalog of the Natural History Museum, London.

Figure 28. **Malachite-coated copper wires, 15 cm, from the Botallack mine, St. Just. Collection of the Natural History Museum, London. Photo by Frank Greenaway.**

Digenite Cu_9S_5

As with devilline, digenite is a recent rare discovery at Botallack, but again, probably previously missed. A specimen is recorded in the catalog of the Natural History Museum, London.

Djurleite $Cu_{31}S_{16}$

Djurleite was previously thought to be an uncommon associate with chalcocite in Botallack and Wheal Cock specimens. However, a substantial find of excellent supposed chalcocites during the Geevor reprospection proved on investigation to be djurleite and/or djurleite pseudomorphs after chalcocite.

Dolomite $CaMg(CO_3)_2$

Dolomite is an uncommon local species, but old specimens are known, often labeled as "pearl spar." The best, in association with specular hematite, are very reminiscent of the North British material.

Epidote $Ca_2(Al,Fe^{3+})_3(SiO_4)_3(OH)$

Well-crystallized specimens of epidote as thin, light green, radiating groups of crystals on dark hornblende rock in the Crowns rock are reported by J. H. Collins (1892). In fact, there are several local surface and cliff exposures, but they tend to be massive. Even today, crystalline epidote is found exposed intermingled with garnet on Crowns.

Erythrite $Co_3(AsO_4)_2 \cdot 8H_2O$

Erythrite is rare at Botallack. Recently one of us (SW) collected a sample of massive cobaltite with powdery dustings from the Crowns. It is mentioned by Greg and Lettsom (1858).

Fluorapatite $Ca_5(PO_4)_3F$

Fluorapatite has been found as small, prismatic, semi-transparent crystals in colors ranging from white through creamy to yellowish green (Collins, 1892). The specimen in the Royal Institute of Cornwall's collection is embedded in chloritic gangue and is from the Wheal Cock section.

Fluorite CaF_2

Fluorite was found relatively infrequently in all the local mines, but not as a common gangue species.

Goethite α–$Fe^{3+}O(OH)$

Goethite is an abundant and frequently well-crystallized species in all of the mines in this area. Botallack, and in particular the Parknoweth section, yielded particularly fine, lustrous, jet-black, botryoidal groups. Another local delight is the splendid, small radiating golden sprays of acicular goethite crystals extending from water-clear quartz found in cavities in the limonitic jasper. Also frequently encountered in matrix cavities are goethite pseudomorphs after sharp, well-crystallized siderite "bow-tie" twins.

Hematite α–Fe_2O_3

Hematite occurs at Botallack in the botryoidal ("kidney ore") habit as well as specular hematite (Greg and Lettsom, 1858). Fine specimens also exist of the "nail head" habit, in association with crystalline aragonite.

Herderite $CaBe(PO_4)F$

Herderite has been found just recently at Botallack, as rare, small specimens. One is in the collection of the Natural History Museum, London.

Heulandite $(Na,Ca)_{2\text{-}3}Al_3(AlSi)_2Si_{13}O_{36} \cdot 12H_2O$

Heulandite commonly occurs in the rocks at cliff base, and is especially abundant in the Wheal Hazzard section, where it forms small, translucent, pearly surfaces and clear to lemon-yellow colored crystals richly coating altered hornfels matrix.

Langite $Cu_4(SO_4)(OH)_6 \cdot 2H_2O$

Langite has, until recently, been a reported but not confirmed Botallack species. Numerous good specimens were found during the Geevor reprospection in association with connellite, often overgrowing botallackite.

Malachite $Cu_2(CO_3)(OH)_2$

Malachite seems to have been mainly present during Botallack's earliest pre-19th century working period as a copper mine. A nice botryoidal crystalline specimen labeled "green carbonate of copper" exists in the Royal Cornwall Geological Society's collections.

Magnetite $Fe^{2+}Fe^{3+}_2O_4$

Well-crystallized specimens of magnetite consist of small, octahedral crystals in hornfels. These are usually labeled "oxidulated iron" in 19th century collections. Less well-crystallized material occurring as veins and bands is fairly commonplace in the cliffs about Botallack and in the Crowns Rock, often in association with garnet, epidote and axinite (Robson, 1949).

Manganite MnO(OH)

Manganite was reported by J. H. Collins (1892) as occurring at Botallack in brilliant crystals. Only dump-collected examples from Botallack, Parknoweth and Wheal Cock have been seen by us.

Natron $Na_2CO_3 \cdot 10H_2O$

There is a specimen of Botallack natron listed in the catalog of the Natural History Museum, London.

Orthoclase $KAlSi_3O_8$

Well-formed orthoclase phenocrysts are abundant in the dump material from the 1908–1914 Allen shaft. Occasional well-formed crystals in association with schorl and quartz may be found in vugs occurring in the pegmatitic phases of this material. The varietal form *adularia* occurs as small, sharp, lustrous crystals in the hornfels below Wheal Owles (Russell, 1910).

Paratacamite $Cu_2(OH)_3Cl$

Good specimens of paratacamite were frequently found in crystals up to 1.5 cm, especially in the mine's submarine copper lodes. In the past, atacamite and paratacamite were commonly confused due to their variability of color (Kingsbury, 1954). Excellent material, though not of comparable quality to the former Burra, Australia, or Atacama, Chile, specimens, was recently recovered from the Wheal Hazzard section during the reinvestigation of the Geevor mine.

Pharmacosiderite $KFe^{3+}_4(AsO_4)_3(OH)_4 \cdot 6–7H_2O$

Pharmacosiderite occurred as infrequent apple-green to yellow cubes usually in association with arsenopyrite.

Phenakite Be_2SiO_4

Phenakite, a very rare Cornish species, was first mistakenly reported by Sowerby (1811) as "Argilla Electra" (white tourmaline). It occurs rarely as opaque white, small extended prismatic crystals associated with scheelite, cassiterite, chlorite and orthoclase below Wheal Cock. It has also been collected from the cliff section below Wheal Cock, and from the cliff section below Wheal Owles, where it occurs as brilliant, long prismatic crystals from 8 to 10 mm in size formed on quartz in association with adularia in cavities in veins of hornfels/slates (Russell, 1920).

Pitticite amorphous hydrous ferric arsenate-sulfate

A specimen of Botallack pitticite is recorded in the catalog of the Natural History Museum, London.

Prehnite $Ca_2Al_2Si_3O_{10}(OH)_2$

Translucent, pale green crystalline crusts of prehnite occur on hornfels in association with stilbite. It has been found in a cliff vein between Botallack and Wheal Cock and at the cliff base near Wheal Button (Greg and Lettsom, 1858).

Pyrrhotite $Fe_{1-x}S$

Pyrrhotite was reported by Collins (1871) without giving further data.

Quartz SiO_2

Quartz in numerous habits is plentiful in all of the mines of the Botallack sett (Collins, 1892). A fine-textured, quartz-rich jasper, frequently of lapidary quality, and ranging in color from yellow through chocolate-brown to black seems to be a gangue in this area. Splendid quartz crystals line numerous vugs. Frequently these crystals have imbedded goethite pseudomorphs (after siderite), specular hematite and, more rarely, surface schorl and/or chloritic inclusions. Veins and pockets occur with yellow or pale amethystine to violet-colored quartz in ferruginous-jasper. Opal of the non-gem "wood opal" variety has been reported.

Rhodochrosite $MnCO_3$

Rhodochrosite is known from a recent surface find, but manganoan calcites (usually in association with iron/manganese jaspers) were commonplace, suggesting the presence of a continuous series between the formerly abundant red-colored manganoan calcite and rhodochrosite. The older specimens are labeled "diallogite" or "carbonate of manganese."

Schorl $NaFe^{2+}_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$

Schorl is a common accessory mineral in the local granites. Pleasant specimens of schorl encapsulated in water-clear quartz, often extending from the host prism, may still be collected from the Botallack dumps.

Scheelite $CaWO_4$

Scheelite was formerly regarded as a rare species at Botallack, although collector Arthur Russell (1920) found excellent crystals to 1.5 cm embedded in chloritic matrix at the Stamps and Jowl Zawn. In recent years one of us (SW) and the late Richard Barstow collected numerous crystalline and massive specimens from the Wheal Cock dumps at night with the aid of a portable ultraviolet lamp. Scheelite has also been collected most recently from the cliffs about Wheal Button.

Siderite $Fe^{2+}CO_3$

Siderite is a common mineral at Botallack, Wheal Owles and Parknoweth. Old specimens are usually labeled as "chalybite" or "spathose" iron ore. It occurs in many habits including botryoidal, simple rhombohedrons (often with curved faces), and in complex aggregations of offset crystals. The color ranges from pale lemon-yellow to bright brownish red.

Silver Ag

Silver from Botallack is recorded in the catalog of the Natural History Museum, London. We are not aware of the present-day location of a definite Botallack specimen, or indeed of galena, which is also recorded.

Skutterudite $CoAs_2$

Skutterudite was reported as a rare species by Collins (1871) but he may have confused it with cobaltite.

Sphalerite (Zn,Fe)S

Few extant specimens of Botallack sphalerite are known. The specimen in the Royal Cornwall Geological Society's collection is very dark, possibly the ferroan variety.

Stannite Cu_2FeSnS_4

Stannite is found only infrequently now on the dumps, but was

Table 1. **Important British collectors and dealers in Cornish minerals (listed chronologically).**

1. Dr. Johann Joachim Becher (1635–1682)
2. Sir Hans Sloane (1660–1753), collector
3. Dr. John Woodward (1665–1728), collector, author
4. Rev. William Borlase (1695–1772), collector, author
5. Robert Hoblyn (1710–1756), collector
6. Dr. William Hunter (1717–1793), collector
7. William Pryce (1725–1790), collector, author
8. Philip Rashleigh (1729–1811), collector, author
9. John Stackhouse (1741–1819), collector
10. Rt. Hon. Charles F. Greville (1749–1809), collector
11. Count Jacques de Bournon (1751–1825), collector, author
12. Sir John St. Aubyn (1758–1839), collector
13. John Hawkins (1761–1841), collector
14. Charles Hatchett (1765–1847), collector
15. John [IV] Williams (1777–1849) and descendants, collectors
16. Edward Pendarves (1778–1853), collector
17. Sir Humphrey Davy (1778–1829), collector
18. Sir John Heuland (1778–1856), dealer
19. Joseph Carne (1782–1858), collector
20. George Croker Fox (1784–1880), collector
21. Robert Were Fox (1789–1874), collector
22. Alfred Fox (1794–1874), collector
23. John Lavin (1796–1856)
24. Robert Hunt (1807–1887)
25. John Garby (1812–1864)
26. Baroness Burdett-Coutts (1814–1906), collector
27. Thomas Light Richards (1816–1887), part-time dealer
28. Richard Talling (1820–1883), dealer, collector
29. Clement le Neve Foster (1841–1904)
30. William Semmonds (1841–1915)
31. Sir Arthur Russell (1878–1964), collector
32. Arthur Kingsbury (1906–1968), collector
33. Richard Barstow (1947–1982), dealer

reported as an uncommon ore species in the 19th century (Collins's papers; Russell and Vincent, 1952).

Stilbite $NaCa_2Al_5Si_{13}O_{36}\cdot 14H_2O$

Stilbite is mentioned in the early literature on the district (Carne, 1822), but we have thus far failed to rediscover the presumed lost location. It is probably rare, but, in view of the existence of other zeolite species, it has a reasonable probability of occurrence.

Stokesite $CaSnSi_3O_9\cdot 2H_2O$

Botallack is the type locality for stokesite, specifically Wheal Cock Zawn of Rose common cliffs. Stokesite was first described by Hutchinson (1899) while researching the Joseph Carne (1782–1856) collection at Cambridge. The original single specimen is a crystal occurring on axinite and was cataloged as "selenite on axinite." In 1975 another specimen was found at Wheal Cock Zawn (Couper and Barstow, 1977).

Torbernite $Cu(UO_2)_2(PO_4)_2\cdot 8\text{–}12H_2O$

Few known specimens of Botallack torbernite survive, although it was common at nearby Wheal Edward, and uraninite was, at one period, mined in Botallack (Collins, 1892).

Tremolite $Ca_2(MgFe^{2+})_5Si_8O_{22}(OH)_2$

Tremolite was reported by Collins (1871).

Vivianite $Fe^{2+}_3(PO_4)_2\cdot 8H_2O$

Vivianite was reported by Collins (1871).

Wolframite $(Fe,Mn)WO_4$

Wolframite at Botallack is not abundant or well-crystallized, but occurred massive and, infrequently crystalline, in association with crystalline cassiterite in all parts of the sett.

Table 2. **English museums having significant Cornish collections.**

1. Natural History Museum, London
2. Royal County Museum of Truro
3. Camborn School of Mines
4. Penzance Geological Museum
5. Plymouth City Museum
6. University Museum, Oxford
7. Sedgewick Museum, Cambridge

Woodwardite $Cu_4Al_2(SO_4)(OH0_{12}\cdot 2\text{–}4H_2O$

A specimen of Botallack woodwardite is recorded in the catalog of the Natural History Museum, London.

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SELECTED BIBLIOGRAPHY

ALDERMAN, A. R. (1935) Almandine from Botallack, Cornwall. *Mineralogical Magazine,* **24**, 42–48.

ANONYMOUS (1854) The mines and miners of Cornwall. Offprint from *Chamber's Repository* (n.d., ?1854), 1–32.

ANONYMOUS (1864) *Report of the commissioners appointed to inquire into the condition of all mines in Great Britain.* HMSO, London.

ANONYMOUS (1974) *Mining in Cornwall Today.* Cornish Chamber of Mines, Truro.

BANCROFT, P. (1984) *Gem and Crystal Treasures.* Western Enterprises, Fallbrook, California, and Mineralogical Record, Tucson, Arizona, 377–380.

BARTON, D. B. (1963) *A Guide to the Mines of West Cornwall.* Barton, Truro.

BIDEAUX, R. (1973) "The Collector," *Mineralogical Record,* **4**, 79–80.

BORLASE, W. C. (1874) *Historical sketch of the tin trade in Cornwall, from the earliest period to the present day.* William Brendon & Son, Plymouth.

CARNE, J. (1822) On the Mineral Productions and the Geology of the Parish of St. Just. *Transactions of the Royal Geological Society of Cornwall,* **2**, 290–358.

CHURCH, A. H. (1865a) Notes on a Cornish mineral of the atacamite group. *Journal of the Chemical Society,* London, **18** (new series vol. 3), 212–214.

CHURCH, A. H. (1865b) On some hydrated cupric oxychlorides from Cornwall. *Journal of the Chemical Society of London,* **18**, 77–83.

COLLINS, J. H. (1871/1892) *A Handbook to the Mineralogy of Cornwall and Devon*. London and Glasgow.

COLLINS, J. H. (1907) "Notes on notable mines." London & West Country Chamber of Mines. Records 1904–1907, **2**: 192–201, 220–228.

COUPER, A. G., and BARSTOW, R. W. (1977) Rediscovery of stokesite crystals in Cornwall, England. *Mineralogical Record,* **8**, 294–297.

DAVISON, E. H. (1926/1930) *Handbook of Cornish Geology*. 1st ed. Penzance 1926 (2nd ed. Truro 1930).

EDMONDS, E. A., McKEOWN, M. C., and WILLIAMS, M. (1975) *British Regional Geology of South-West England*.

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

FOOTE, A. (1892) *The Naturalist's Leisure Hour and Monthly Bulletin*. February.

GOLDSCHMIDT, V. (1913) *Atlas der Krystallformen*. Carl Winters Universitätsbuchhandlung, Heidelberg.

GREG, R. P., and LETTSOM, W. G. (1858) *Manual of the Mineralogy of Great Britain and Ireland*. van Voorst, London.

HALL, T. C. F. (1914) The Geological History of Cornish Lodes. *Trans. Cornish Inst. Min. Mech. Metall. Eng.*, Vol. 2.

HAWTHORNE, R. C. (1985) Refinement of the crystal structure of botallackite. *Mineralogical Magazine,* **49**, 81–83.

HENDRIKS, E. M. (1923) The physiography of Southwest Cornwall. *Geological Magazine,* London.

HENWOOD, W. J. (1843) The Metalliferous Deposits of Cornwall and Devon: with Appendices, on Subterranean Temperature: the Electricity of Rocks and Veins: [etc.]. *Transactions of the Royal Geological Society of Cornwall,* **5**, 1–512.

HOSKING, K. F. G. (1951) Primary ore deposition in Cornwall. *Transactions of the Royal Geological Society of Cornwall,* **18**, 309–356.

HUTCHINSON, A. (1899) On stokesite, a new mineral from Cornwall. *Philosophical Magazine,* **48** (5th series), 480–481.

JENKIN, A. K. H. (1927/1948) *The Cornish Miner,* 2nd. ed. Allen & Unwin, London.

KINGSBURY, A. W. G. (1954) New occurrences of rare copper and other minerals [in Devon and Cornwall]. *Transactions of the Royal Geological Society of Cornwall,* **18**, (part 4 for 1952), 386–406.

KINGSBURY, A. W. G. (1964) Some minerals of special interest in South-West England.

LEIFCHILD, J. R. (1855) *Cornwall: its Mines and Miners*. Longman *et al.*, London.

LEWIS, W. S. (1923) *West of England Tin Mining,* Exeter.

MANTELL, C. L. (1949) *Tin: its mining, production, technology, and applications*.

NOALL, C. (1972) *Botallack*. Barton, Truro.

NOALL, C. (1973) *The St. Just Mining District*. Barton, Truro.

ORDISH, H. G. (1967/1968) *Cornish Engine-Houses, a Pictorial Survey,* and *Cornish Engine-Houses, a Second Pictorial Survey*. Barton, Truro.

PENHALLURICK, R. D. (1986) *Tin in Antiquity, its mining and trade throughout the ancient world with particular reference to Cornwall*. Institute of Metals, London.

ROBSON, J. (1949) Cornish Mineral Index. *Transactions of the Royal Geological Society of Cornwall,* **17**, 455–475.

RUSSELL, A. (1910) Notes on the occurrence of zeolites in Cornwall and Devon. *Mineralogical Magazine,* **15**, 377–384.

RUSSELL, A. (1920) On the occurrence of phenakite and scheelite at Wheal Cock, St. Just, Cornwall. *Mineralogical Magazine,* **19**, 19–22.

RUSSELL, A., and VINCENT, E. A. (1952) On the occurrence of varlamoffite (partially hydrated stannic oxide) in Cornwall. *Mineralogical Magazine,* **29**, 817–826.

SOWERBY, J. (1811) *British Mineralogy*. London.

TEW, D. H. (1981) Man Engines in Cornwall. *Journal of the Trevithick Society,* no. 8, 47–53.

THORNE, M. G., and EDWARDS, R. P. (1985) Recent Advances in Concepts of Ore Genesis in southwest England. *Transactions of the Royal Geological Society of Cornwall,* **21**, 113–152.

TODD, A. (1967) *The Cornish Miner in America*. D. Bradford Barton, Ltd., Truro, England.

TROUNSON, J. H. (1980) *Mining in Cornwall* 1850–1960. 2 vols.

TROUNSON, J. H. (1982) "Cornish stacks and engine houses." *Journal of the Trevithick Society,* no. 9, 73–84.

VAN MARCKE DE LUMMEN, G., and VERKAEREN, J. (1985) *Mineralogical observations and genetic considerations relating to skarn formation at Botallack, Cornwall, England*. 535–547.

WOLLOXALL, T. (1989) Famous mineral localities: Botallack. *UK Journal of Mines and Minerals,* no. 6, 4–11.

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The Rush Creek District, Marion County, Arkansas

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The miners of Rush Creek discovered smithsonite crystallized in an amazing variety of forms. According to one local journalist, "not a week passes that does not bring in [a smithsonite sample] different in color, texture, or weight from anything that has been found" (Shiras, 1916).

INTRODUCTION

The mountains surrounding Arkansas' Rush Creek mining district are rich in zinc and history. At the center of the district lie the ruins of Rush, a mining town that grew, prospered, and eventually perished with fluctuations in the price of zinc. Those who lived and worked there always believed that the local mines were destined to become as famous and prove as rich as the great deposits of Joplin, Missouri. Actually, the town found itself isolated within the Ozark Mountains, constantly fighting obscurity. The main product of the Rush Creek mines was zinc carbonate (smithsonite), which was removed in rather pure and colorful masses up to several tons in weight. During the boom years it was common to see smithsonite specimens lining shop windows, decoratively arranged on porches, and perched on tree stumps in miners' front yards.

Rush is located along the southern edge of the Ozark Plateau in north-central Arkansas. The White and Buffalo Rivers and their tributaries have slowly incised the plateau, carving a dendritic pattern of hollows into the land. River valleys are narrow and sinuous, with outer banks of meander bends often bounded by bluish gray limestone and sandstone bluffs up to 75 meters in height. Although relief is less than 250 meters, the hillsides are steep, bluffs numerous, and floodplains small to absent, giving the area a rugged appearance. Valleys and ridges are covered by a thick forest consisting largely of white oak, hickory, walnut, pine and cedar.

Although zinc and lead mineralization is widespread across the Arkansas Ozarks, mining activity was especially concentrated along the Buffalo River in southern Marion County, where the mineral-bearing Everton Formation has been exposed by erosion. As delineated by McKnight (1935), the Rush Creek district includes 15 producing mines and numerous prospects lying within the lower Rush and Clabber Creek Valleys and along the Buffalo near its confluence with these streams. Zinc was mined intermittently between 1886 and 1962, with activity reaching a peak during World War I. Over this time an estimated 47,000 tons of concentrates were shipped from the area (Stroud *et al.*, 1969), accounting for about 40% of the total zinc output of northern Arkansas. Although such production figures didn't often raise an eyebrow outside of Arkansas, the Rush Creek district was widely known as a producer of very pure oxidized zinc ores, especially zinc carbonate. It has been estimated that 80% of the district's output was smithsonite (Brichta, 1949).

During the 1960's and 1970's many of the mines were under private ownership and collecting was tolerated. However, most of the Rush Creek district has since been included within the boundaries of the Buffalo National River. Both entry into the mines and mineral collecting are now prohibited. Between 1985 and 1987 fences were installed at the remaining mines as a safety precaution.

HISTORY

The early settlers of the Arkansas Ozarks overlooked zinc for quite some time. Aside from the fact that zinc had few practical uses in pioneer life, its ores carried low market values and were difficult to smelt. A small-scale smelting operation had been attempted at Calamine, Sharp County, in 1857 and again in 1871, but with little commercial success. Lead, on the other hand, was of great utility for the manufacture of ammunition. Galena had been identified in Marion County as early as 1818 (Schoolcraft, 1819), was locally mined and smelted before and during the Civil War, and was even used as a form

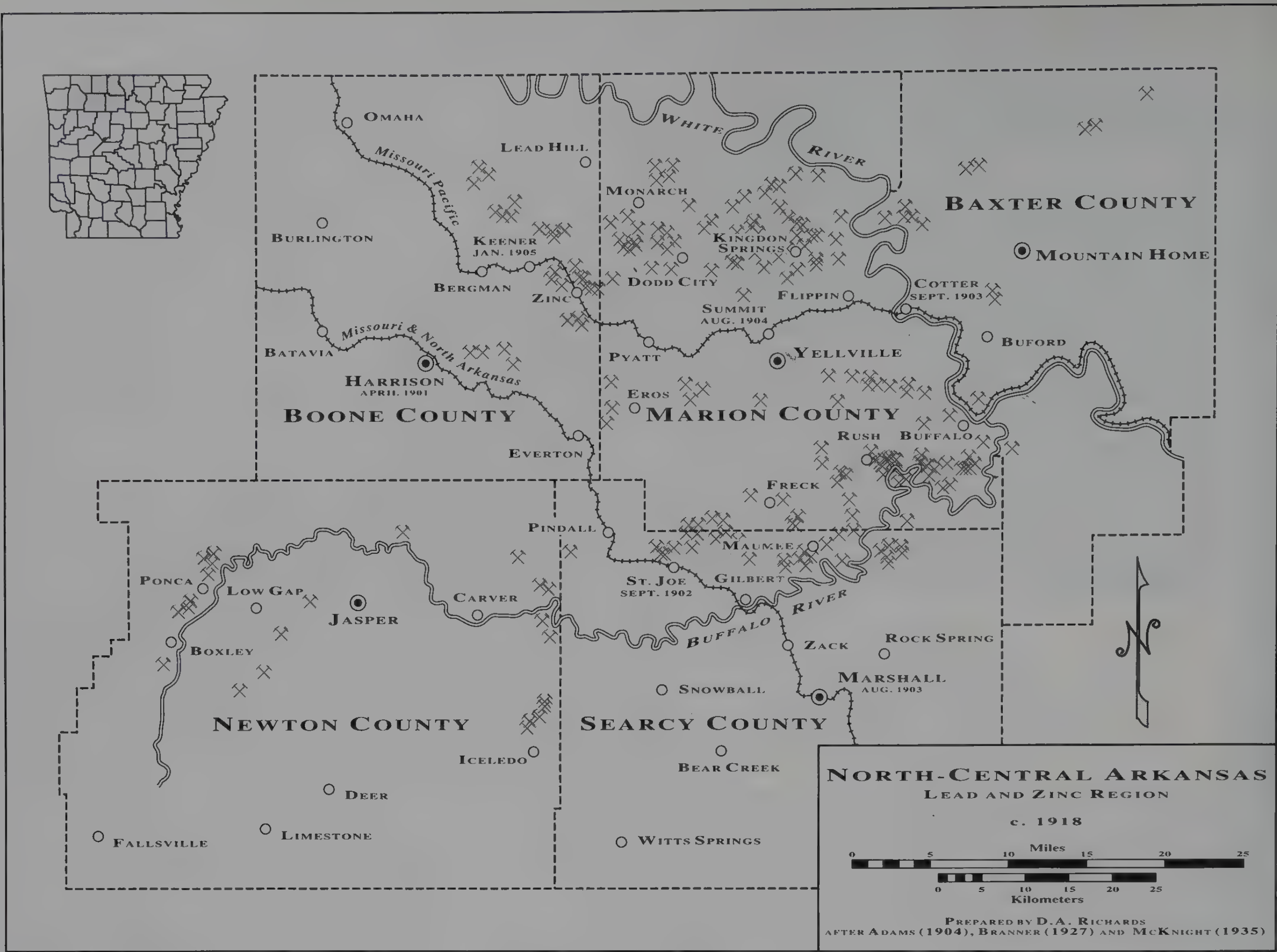

***Figure 1.* Mines and transportation facilities of the north-central Arkansas zinc and lead region. Rush is located in the southeastern corner of Marion County. Dates denote the arrival of regular railroad service.**

of currency in some areas.

Likewise, the prospectors who began to work their way across northern Arkansas in the 1870's and 1880's were largely indifferent to base metal ores. They had been lured by colorful legends describing lost Spanish and French mines of silver and gold (which persist to the present day). Because the zinc and lead ores of the region have an extremely low precious metal content, most prospectors eventually moved on in disappointment, while others resorted to fraudulent schemes to make a living.

Prospectors first became interested in Rush Creek in the late 1870's, perhaps enticed by rumors of a lost Spanish silver mine in the vicinity (Hand, 1940). At this time, Rush was inhabited by a handful of pioneers farming small plots of bottomland and operating a grist mill. Several specimens of a glittering ore, known to the local residents as "flickers," had been found around the Allen Setzer homestead. By one account, Setzer's daughters came across the first "flickers" while searching for their cows (*St. Louis Daily Globe-Democrat,* 2 September 1895). Setzer and several neighbors, including Andy George, Jim McCabe and Tom Alexander, teamed up with veteran prospector John Wolfer to work Setzer's claim, dubbed the Morning Star. The ore was identified as zinc carbonate, but an assay incorrectly reported a sample to contain substantial amounts of silver. Based on this information, the group organized the Rush Creek Mining Company in 1886, and contracted with two men from Joplin to build a small smelter on the site, which was completed in late December. A few days later a test charge was loaded in and the claimholders gathered around to watch the molten silver flow into the sand molds. According to local folklore:

> Old John Wolfer . . . was going around with his little bucket to catch the silver. The fumes riz up in the air and made the beautifullest rainbow you ever seed, but there wasn't a drap of silver come out. (*St. Louis Daily Globe-Democrat,* 2 September 1895)

Wolfer recognized the brilliant display of multicolored fumes as zinc oxide vapor and cursed accordingly: "zinc, by thunder!"

Not everyone looked upon zinc as an undesirable by-product. As the silver smelter was being constructed, two fledgling zinc mining firms were organizing within the district. By 1886 the Buffalo Zinc and Copper Company had sunk a shaft for the White Eagle mine at the mouth of Rush Creek. Sphalerite was encountered at a level 12 meters below the Buffalo River, several tons of ore were piled up, and the small company town of Exeter was constructed. Organizers of the American Mining and Investment Company prospected the Clabber Creek Valley, opening the Philadelphia and Leader mines around 1887 and establishing a rival town, Rentschler.

Meanwhile, Wolfer and the other claimholders of the Morning Star

Figure 2. **Morning Star silver smelter in 1988 following stabilization by the National Park Service.**

each sold their shares for several hundred dollars apiece. It was not long afterwards that the prospect came to the attention of a railroad survey party that had established a camp along Rush Creek. The engineer in charge, Captain George W. Chase, was very intrigued with the Morning Star and its colorful ore, and seeing more of an opportunity to make a fortune in zinc mining than in civil engineering, he sent in his resignation and purchased an interest (Kansas City, Ft. Scott & Memphis Railroad, 1899). Along with several associates, Chase organized the Morning Star Mining Company in 1891, and quickly developed the failed silver prospect into a promising zinc mine. A large opencut revealed rich replacement deposits of smithsonite. Huge boulders of nearly pure zinc carbonate several tons in weight were removed intact.

From the onset of mining it was evident that the lack of transportation facilities would be the principal factor limiting development of the region. The Rush camp was over 70 km from the nearest railroad, and the rugged terrain inhibited further railroad construction. Overland freighting was slow and difficult owing to the lack of passable roads. Even during the boom years, after three decades of mining and road improvements, a stage ride into Rush was an experience not soon forgotten:

> To get to Rush I crossed Rush Creek 43 times and when not in the creek was on the worst road ever, the ground being cut hub-deep and frozen. A storm on the ocean was not a circumstance to a ride in the stage. I walked three of the 12 miles and would have been pleased to have walked more, but the darned creek kept getting in the way. (Anonymous, 1916).

Ore was loaded into canvas sacks and hauled by team 13 km over the mountains to Buffalo City on the White River, then transferred to barge or steamboat and shipped 110 km downstream to Batesville. At this point it would be loaded into railroad cars bound for smelters in Missouri or Wisconsin, or sent on to New Orleans for shipment to Belgium. The Arkansas Mining and Investment Company was the first to experiment with the use of barges on the Buffalo River, but this could only be attempted when the river was above normal stage and always carried with it the element of risk. Due to swift currents and treacherous rapids, some ore barges never made it to Batesville.

In 1893 Capt. Chase organized an effort to send an exhibit of Rush Creek ores to the Chicago World's Fair. Serving as the centerpiece was a 5700-kg boulder of smithsonite from the Morning Star which measured 2 meters in greatest dimension and carried only 10% gangue. It had been blasted off an immovable mass of zinc carbonate estimated at over 100,000 kg. With much difficulty, the specimen was rolled on skids at the mine, pulled by twelve teams of oxen to the riverbank, poled down the Buffalo on a barge, and eventually transferred to its own railroad car for a sidetrip to the state capital. Politicians in Little

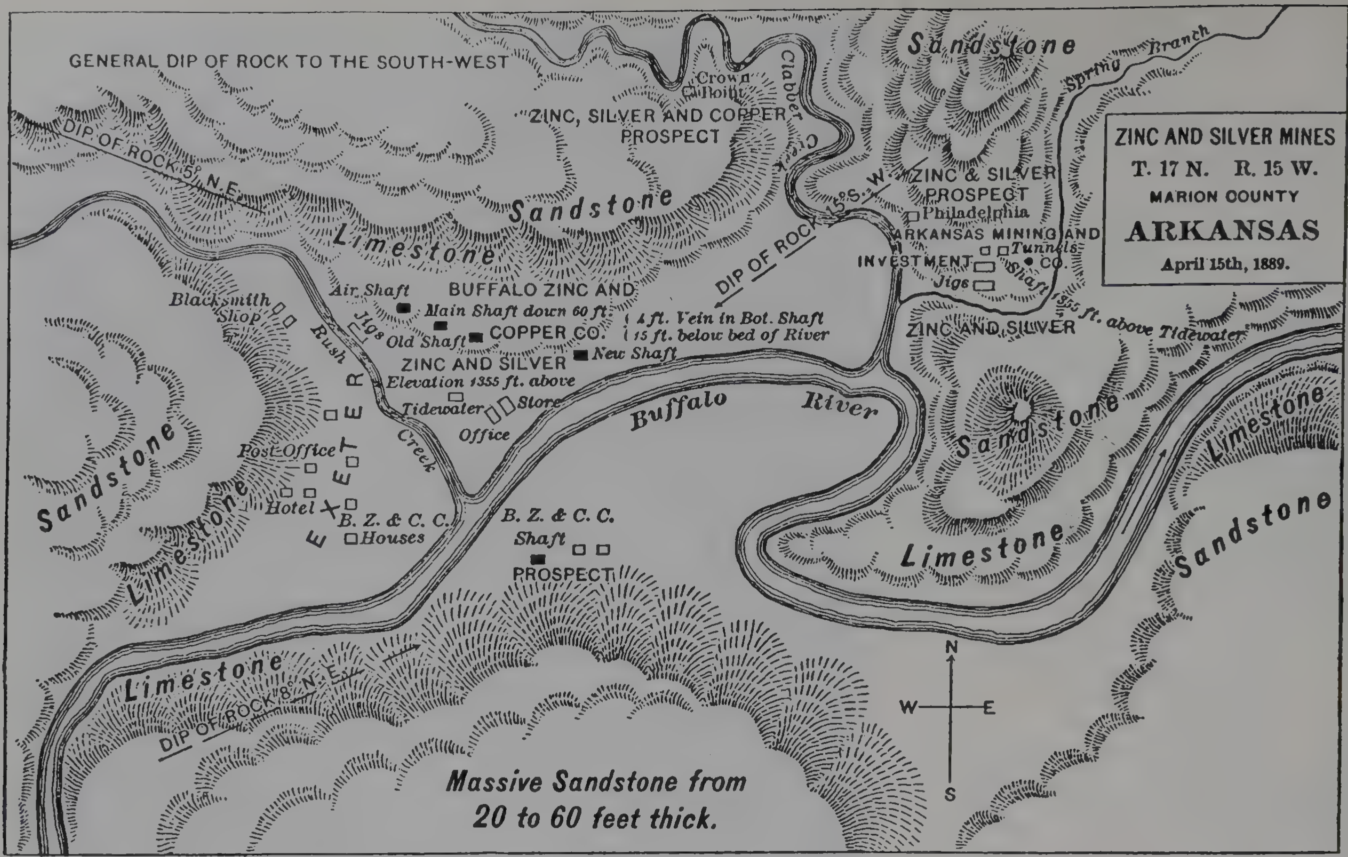

Figure 3. An 1889 map of the lower Rush Creek district showing locations of zinc, copper and silver prospects (Anonymous, 1889). Although zinc is the only metal found in anything approaching economic quantities, rumors of silver and gold discoveries on Clabber Creek persisted until at least 1902.

Rock, eager to tout the riches of their state, proclaimed it to be the largest piece of pure zinc ore the world had yet seen. The Morning Star boulder received much attention at the World's Fair, and was awarded the gold medal premium for carbonate of zinc. However, Capt. Chase was upset that several sphalerite specimens intended for the exhibit had been stolen from the railcar enroute to the exposition. According to Chase, the judges felt that the Rush Creek sphalerite was of superior quality, but it did not receive an award due to the small quantity present (*Mountain Echo,* 29 September 1893).

The World's Fair exhibit was successful in providing much needed publicity for the fledgling mining region. The smithsonite nugget made such an impression that the Morning Star gained widespread recognition, becoming the first mine mentioned in any conversation about northern Arkansas, and the property to which all others in the region were compared. Optimism ran high. From southeastern Kansas and northeastern Oklahoma came frequent reports of the discovery of rich lead and zinc orebodies, as the famous mining region around Joplin, Missouri, gradually expanded westward. Northern Arkansas was seen by many as the southern extension of this huge Ozark zinc and lead field, and expectations were that it would prove every bit as rich as Joplin.

Within a few years, all lands not previously occupied by homesteaders were staked and claimed. However, few claimholders were interested in producing ore; most intended to hold the land until a railroad built into the region and then sell out at a substantial profit. Assessment work requirements were often fulfilled by building roads or company townsites, while actual mining was carried out only "for the purpose of raising the hopes and expectations of the investors" (Stacey, 1905). Many prospects were deliberately blocked out to display the largest face of ore, with care taken to place the highest grade material on top of the ore pile. At this point work would be suspended, the operators being hesitant to go farther into the mountain out of fear the orebody would pinch out. Even the Morning Star was no exception to this type of activity. As a result, a stalemate developed between mining and railroad interests; mine owners delayed developing their properties pending the arrival of a railroad, while the railroads waited for increased mining activity and clear evidence of large reserves. As of 1898, very little ore had been shipped, and this only to test transportation methods and market conditions.

The situation changed abruptly in early 1899 when zinc concentrate and spelter prices took a sharp upward turn. For a period of several months every conveyance in the region was filled to capacity (Branner, 1900) and Rush, being one of the more established mining camps, soon found itself inundated by a steady stream of miners and speculative investors. J. H. Hand resigned his position as a schoolteacher to prospect for zinc. He described the migration into northern Arkansas:

> They showed up suddenly and unexpectedly, ready to buy anything that showed a shine. Needless to say they found ready sellers. Due to overlapping of some local mining district boundaries, conflicting claims to the same prospect arose innocently, while willful outright claim jumping became practiced to an extent that led to near mob violence and much litigation. (Hand, 1940)

Figure 4. **A 5700-kg smithsonite boulder from the Morning Star mine which received a gold medal at the 1893 Chicago World's Fair (Kansas City, Ft. Scott & Memphis Railroad, 1899).**

Development was aided by a sudden influx of capital from East Coast and Joplin sources. This initiated an era of mill building, with the Morning Star Mining Company completing the first mill in the district in 1898. For the first time several mines, including the Morning Star, Red Cloud, Beulah and Silver Hollow, began to ship ore on a fairly regular basis.

After two years of sustained mining activity, several plans were announced to build railroads across the Arkansas Ozarks. In February 1901 the new owners of the Morning Star chartered their own company to build a 160-km line connecting Rush to Newport, the head of navigation on the White River. The Morning Star Railroad was a highly ambitious plan for such a small mine, although some felt it was no more than a bluff. Only a few weeks later construction began on the White River branch of the Missouri Pacific Railroad, and by the following year the St. Louis & North Arkansas (later to be the Missouri & North Arkansas) was at work on a route running roughly parallel. Faced with direct competition from two larger corporations, the Morning Star Railroad never made it past the initial survey stage. The two remaining railroads were completed by 1905, the Missouri Pacific passing 16 km north of the Rush camp and the St. Louis & North Arkansas passing 19 km to the south. This still left the Rush Creek producers with a costly wagon haul over poor roads. All attempts to lure a spur into the district were unsuccessful.

Following a period of near inactivity between 1907 and 1914, the mines were quickly reopened and mills rebuilt when spelter prices tripled at the onset of World War I. As laborers poured in from the surrounding region, Rush expanded from a village of less than a hundred inhabitants to a disorganized town of 2,000 to 3,000, outstripping Yellville as the largest community in Marion County. Much of the population lived in tents or makeshift shacks. There was much commotion in the spring of 1915 when work began on the Yellville, Rush & Mineral Belt Railway, a narrow-gauge line which was to connect Rush to the Missouri Pacific at Summit Junction. Work proceeded on schedule, and within a year the route had been graded down the Clabber Creek Valley (Fair, 1969).

John Conness Shepherd arrived in Rush in 1914 and quickly became one of the town's most important citizens. Aided by experience in the Mexican mining industry and an ample supply of capital, Shepherd was instrumental in increasing the productivity of Rush Creek by unifying several mines under one operation and applying an innovative approach to mineral processing. By 1916 the J. C. Shepherd Mining Company held leases to the McIntosh, Red Cloud, Philadelphia, Monte Cristo and Leader properties. The McIntosh concentrator was rebuilt as a gravity mill using concentrating tables instead of jigs, which proved much more efficient than the standard milling practices of the region. The Philadelphia mill was upgraded and used as a central milling facility in the Clabber Creek Valley, receiving ore from the Leader via a short ground tram, from the Philadelphia via a chute on the hillside lined with rail, and from the Monte Cristo via a 400-meter aerial tramway which carried ore 60 meters above Clabber Creek. In a region where most companies operated only one or two mines, the J. C. Shepherd Mining Company quickly became the largest producer in northern Arkansas.

During the three-year period between 1915 and 1917 the Rush Creek mines yielded about 70% of their total production. However, the boom was not to last. By 1917 the demand for zinc was falling, and operators were unable to find a market for their ore. As the mines began closing a mass exodus of laborers and shopkeepers ensued which reduced the town to its pre-war size. The railroad was left unfinished, and by 1920 all mines were closed.

Mining activity since 1920 has been very limited. The Morning Star Mining Company reopened the Morning Star, Ben Carney and Capps mines in 1925. When these mines closed again in 1931 the unemployed miners took to ore-gouging to support their families through the Great Depression. Small-scale commercial mining resumed during World War II on the Edith, Leader and Silver Hollow properties. In 1959 a second Rush Creek Mining Company removed ore from the White Eagle, Monte Cristo, Philadelphia and Lonnie Boy mines, but the operation proved unprofitable and was abandoned in 1962.

By the mid-1960's Rush was referred to locally as Rush Ghost Town. Whereas visitors during World War I found a valley filled with the constant roar of concentrating mills and intermittent bursts of dynamite, today the Rush Creek Valley is quite peaceful, attesting to nature's ability to recuperate from the destructive effects of man. The hillsides are again covered by dense vegetation which hides the mine

Figure 5. **Facilities of the Morning Star mine (Adams, 1904). An elevated railway carried ore to the mill (center). The silver smelter, which was briefly put back into service to produce cement for construction of the mill in 1898, is visible in the lower right.**

portals and tailings piles for much of the year. All that remains of the townsite is a row of dilapidated houses and an abandoned facade-front general store. Ironically, it is the old Morning Star smelter that has proven to be the town's most resilient structure. The silver smelter will probably remain standing long after the zinc boomtown has decayed away.

PROSPECTING, MINING, and MILLING

Prospects were opened simply by digging on surface outcrops of smithsonite or sphalerite. It was not difficult to find showings of zinc in ledges, streambeds, or "at the grassroots." The early prospectors were quick to note that the Morning Star and several other mines on Rush Mountain were located at about the same stratigraphic level, ranging between 11 and 14 meters below a distinctive sandstone unit of 1 meter thickness (McKnight, 1935). This Key (or Ledge) sandstone served as an important guide to exploration and could be easily identified by its "resemblance to coarse brown sugar and decomposed appearance" (Wittich, 1916). Due to the surficial nature of the orebodies and the extent of prospecting activity following the 1899 rush into the area, all of the major deposits were discovered prior to 1900.

Diamond and churn drills were used only sparingly in exploration, but were successful in locating unoxidized ore horizons at depth on several properties. However, the economics of the region did not favor the excavation of deep shafts or inclines to mine sphalerite below the water table. Of the major properties, only the White Eagle, Beulah and Silver Hollow were known as sulfide mines, and none of these reached more than 20 meters below the surface.

Prospects were opened with little more than picks, hammers, hand drills and dynamite. It was not until World War I that compressed air drills began to see use. A prospect would be worked as a cut or shallow pit as long as topography permitted, and then continued as an adit following the ore-bearing horizon into the mountainside. Narrow ore runs were mined as adits with crosscuts as necessary. Blanket veins or multiple-fracture zones, such as the McIntosh, Capps and Red Cloud deposits, were worked with the room-and-pillar method. Where two ore horizons were separated by an interval of barren rock, the mine would be worked with underhand bench stoping (e.g. upper level of Monte Cristo) or, if the interval was greater than 8 meters, as separate adits connected by a winze (e.g. Silver Hollow and McIntosh).

Due to the nature of the zinc deposits, a large amount of capital was not required to start up a mine. Most were located well above the water table and could be mined as adits, thus avoiding the cost of machinery for ore hoisting and continuous water pumping. In the richer replacement deposits smithsonite could be removed as a free ore and marketed without crushing or cleaning. In addition, timbering of adits was rarely deemed a necessary expense due to the hardness of the country rock and the presence at many mines of a highly resistant sandstone caprock.

Because the orebodies were small, numerous and relatively inexpensive to work, the valley came to be populated by dozens of small operations rather than dominated by a few giant corporations. Someone interested in mining had only to find a landowner that would stake him a lease and put up an acceptable grubstake (Shiras, 1916). Two-

Figure 6. **Main Street, Rush, Arkansas (*Engineering and Mining Journal,* 19 August 1916).**

Figure 7. **Morning Star concentrator in 1918 after extensive wartime modifications (*Engineering and Mining Journal,* 16 February 1918).**

man and three-man operations survived by mining free ore from near-surface replacement pockets—the ore was simply hand-cobbed and shipped as a pure product. If the accumulation of bucking (hand-processed) ore from such an operation grew to a size that warranted the purchase of concentrating equipment, a small crusher and hand jigs would be brought in, but any rock which ran less than 12% zinc was necessarily thrown onto the dumpsite.

The first generation of concentrating mills (those erected between 1898 and 1903) followed closely the mineral dressing technology employed in Joplin. These "flatland" mills did not take full advantage of the Ozark topography as an energy source, nor were they ideal for the mixed carbonate/sulfide ores of northern Arkansas. Ore was separated by a series of steam jigs, but much of it ended up in the tailings which often assayed over 8% zinc. All steam engines were fueled by wood, as timber was plentiful and close at hand.

During World War I more attention was paid to mill design and recovery. The most radical change in processing technology was the introduction of concentrating tables, again following the lead of Joplin. It was found that if the ore was ground much finer, separation on a concentrating table could lead to a marked improvement in recovery, such that at some mills the jigs were completely dispensed with (Shiras, 1918). In the early years tabling had been ignored because it was commonly thought that smithsonite did not have a high enough specific gravity to be properly differentiated. The J. C. Shepherd Company's McIntosh concentrator served as a model mill during this period. It was the first true gravity mill in the district, built into the side of Rush Mountain so that elevators were only necessary to return middlings to the rolls (Wittich, 1916). Many concentrating plants were forced to convert from steam to oil engines during the war, as the immediate hillsides had been stripped bare of timber and there was a severe shortage of manpower to cut timber and oxen teams to haul the wood. At one point the Morning Star employed as many people cutting timber

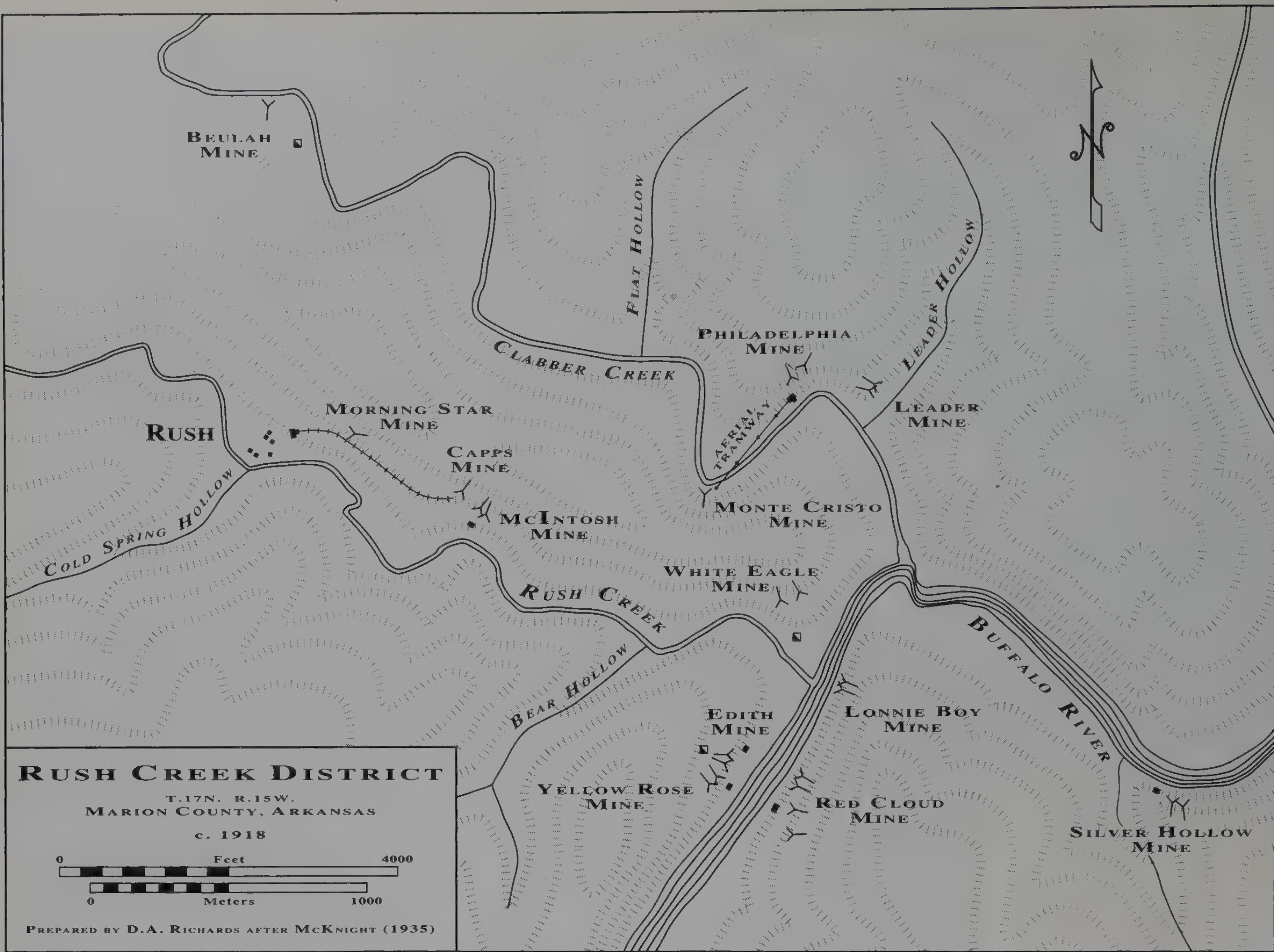

Figure 8. **Mines of the Rush Creek district.**

to feed the steam plant as there were mining ore.

In 1959 the Rush Creek Mining Company brought in a mill from the Tri-State district and reassembled it near the site of the White Eagle mine. This mill operated for three years and was the only one to employ flotation methods to separate the ores.

The north Arkansas smithsonite concentrates were nearly free of iron and lead impurities and produced a high-quality spelter. During the war much of the output was marketed to the St. Louis chemical industry, where it was converted to zinc oxide and used in the manufacture of rubber and paint pigments. "Mixed ores" containing intergrown smithsonite and sphalerite presented a difficult problem for several mines, because the two components could not easily be separated by the jigging or tabling technology of the day. Smelters imposed penalties for carloads which ran over 1% sulfur, so that mixed ores had to be sold at prices significantly less than that of pure carbonate concentrates (McKnight, 1935).

NOTES on INDIVIDUAL MINES

The Rush and Clabber Creek Valleys abound with prospect holes and abandoned adits, although the names of many have been lost with time. The major producing properties are described below. Several prospects in the headwater regions of the Rush and Clabber Creeks were included in McKnight (1935) within the Rush Creek district, but will not be discussed here.

Ben Carney

The Ben Carney adits lie between the Morning Star and Capps mines on the southwest side of Rush Mountain. The property was worked as part of the Morning Star after 1894.

Capps

The Capps mine was opened in August 1915 by the Morning Star Mining Company and operated until the spring of 1928. This property adjoins the McIntosh, the two mines being interconnected by underground tunnels. McKnight noted the occurrence of smithsonite crystallized in visible rhombohedrons—the only known occurrence in the district.

Leader

The Leader mine consists of two short adits in Leader Hollow that were originally opened by the Arkansas Mining and Investment Company. Smithsonite was the principle ore. In 1894 W. A. Chapman reported the discovery of a new mineral from the Leader and named it "brannerite" in honor of former Arkansas State Geologist John Casper Branner. However, Branner had the mineral reanalyzed and found it to be indistinguishable from smithsonite.

Lonnie Boy

The Lonnie Boy is located on the Buffalo River directly across from the mouth of Rush Creek. Two tunnels, the longer one 75 meters, follow brecciated fractures just above the normal water level. Most of the ore from this mine marketed during World War I consisted of free smithsonite. The adits have been under water several times, and are now mostly filled with sand.

Mattie May

An 80-meter adit on the Mattie May property follows a small brecciated monoclinal fold. This mine was largely a smithsonite producer, from which it was reported that 150 to 180-kg masses were pulled out intact. Dolomite, calcite and gypsum are among the gangue minerals.

McIntosh

The McIntosh was discovered around 1888 by William McIntosh and veteran prospector Carter Guthrie. Smithsonite and sphalerite were produced from several interconnecting tunnels and stoped rooms following fractures adjacent to the Rush Creek fault.

was covered by an unsightly layer of calcium carbonate which was easily removed in hydrochloric acid. Scalenohedral calcite crystals to 15 cm were also present. Although quickly gutted of prime specimens, the "cave" was continuously enlarged by collectors, breaking through to new chambers. It has since been fenced and posted by the government.

Morning Star

The Morning Star was first prospected around 1886, and the property was operated intermittently until 1927. Ore was localized on several large fractures paralleling the Rush Creek fault, all evidence of which has since been removed by mining. The mine was worked as a series of opencuts following these fractures into the hillside, and was commonly referred to as a great "zinc quarry." Smithsonite was the principle ore, including much in botryoidal and stalactitic form. The Morning Star is renowned for the production of "turkey fat," a variety of smithsonite having a bright canary-yellow color due to the presence of cadmium sulfide. Very little mineralization was left in the area.

Figure 9. **Upper portal of the Monte Cristo mine (photograph by the author).**

Monte Cristo

The Monte Cristo property was prospected as early as 1899, but was not a steady producer until World War I. There are adits at two levels, the main (upper) level being worked as a bench. Due to the varied mineralogy and easy access, this mine was a favorite among collectors in the 1960's and 1970's. The principle ore is a gray to brown smithsonite, although turkey fat is also present. A distinctive red smithsonite variety known as "sealing wax" has been found only at the Monte Cristo (McKnight, 1935). In addition, the upper level has yielded fine scalenohedral calcite crystals and attractive thumbnail-size specimens of aragonite, hemimorphite and gypsum.

Near the entrance to the main Monte Cristo adit a large solution-collapse breccia pipe has been exposed and partially mined out. This breccia is unique in that it is composed of boulder-sized limestone clasts covered by sheets of terminated quartz crystals 0.5 to 1.5 cm in diameter. There is little or no material filling the voids, so that enough room exists to crawl among the clasts. In the 1960's mineral collectors opened a new section of the breccia (known as the "cave") and removed large sheets of quartz crystals on limestone and hemispherical quartz "snowballs" with sphalerite cores. Much of the quartz

Philadelphia

The Philadelphia and several nearby mines, including the Yellow Jacket and Last Chance, were originally worked by the Arkansas Mining and Investment Company as early as 1887. The main adit follows a brecciated monoclinal flexure for 350 meters into the mountain, the width of the brecciated zone varying from 3 to 6 meters. This mine was noted for its cadmian smithsonite, and McKnight (1935) reported the occurrence of large gray smithsonite stalactites with turkey fat smithsonite cores near the portal.

Red Cloud

The Red Cloud workings consist of a labyrinth of stoped-out rooms and drifts which tend to follow a northwest-southeast structural trend. The perimeter walls were almost completely stripped of smithsonite and sphalerite before the operation was abandoned, but collectors have managed to obtain samples by robbing the pillars. Pink-spar dolomite and dogtooth calcite are plentiful, although much dolomite has been stained by iron oxides. Chalcopyrite and its alteration product, malachite, are often associated with the dolomite.

Silver Hollow

The Silver Hollow mine is located along a sharp bend in the Buffalo River about 2 km downstream from the confluence with Rush Creek. It lies in a highly vulnerable position, close to water level along the steep outside bank. Ore was discovered on two levels separated stratigraphically by 15 meters. Both levels produced mainly sphalerite, although the quality of the sphalerite ore at this location was degraded by the presence of excessive pyrite. Workings at the lower level are quite extensive; an adit extends into the mountain for some 300 meters but is now partially flooded and filled with sand. The upper level opens into a large mined-out breccia chamber about 16 meters in height from which were removed large boulders of sphalerite up to one ton in weight that required no milling. Rust-colored calcite is a common gangue mineral in the upper level, and has been found in dogtooth crystals up to 20 cm.

The Silver Hollow mine was quite active between 1903 and 1907 and again during World War I. It formerly supported the small company town of Keystone, which was located directly across from the mine on the north bank of the river, and of which no evidence remains. As there was little space on the steep hillside to store large quantities of ore, a concentrating mill was built as soon as the property was developed in 1903. The crushed limestone from the milling operation was simply dumped on the riverbank where it would be swept downstream by floodwaters every few years. After the mill was abandoned at the end of the war the mill building and equipment suffered a similar fate.

White Eagle

The original White Eagle shaft of the Buffalo Zinc and Copper Company reached 12 meters below the nearby Buffalo River. One drift reportedly ran directly under the river and eventually collapsed, flooding the workings. Several additional shafts were sunk on this property, and during the First World War ore was removed from three adits at the base of Rush Mountain, several hundred feet away. The White Eagle was one of the few efforts directed at working sphalerite below the water table, and for most of its history was operated by men from Joplin, Missouri, who were more familiar with this type of mining. Branner (1900) stated that the finest crystals of dogtooth calcite in the region came from the White Eagle. However, the productive adits have caved and all shafts have been filled in.

Yellow Rose and Edith

These two mines exploit the same deposit, located along fractures and shatter breccias which McKnight (1935) interpreted to be at the southern termination of the Rush Creek fault. A legal dispute over the exact position of a section corner resulted in the deposit being worked as two properties. The Edith was worked as a 15-meter shaft, formerly with two drifts running to the surface, while the Yellow Rose was worked as a small opencut. The primary ore mineral was a gray botryoidal smithsonite.

GEOLOGY

The geology of northern Arkansas was first investigated in 1857 and 1858 by state geologist David Dale Owen (1858). Although there was no active zinc mining at this time, Owen did collect samples of zinc ores from the lead prospects in northern Marion County. After mining commenced, field surveys were conducted by the Arkansas Geological Survey (Branner, 1900) and the United States Geological Survey (Bain, 1901; Adams, 1904). Both the Branner and the Adams reports include descriptions of the early Rush Creek workings. The definitive study of the region, albeit over a half-century old, was compiled between 1927 and 1930 by Edwin T. McKnight of the USGS (McKnight, 1935).

The Rush Creek ores occur as stratabound deposits in a carbonate host rock. Sphalerite, the primary ore mineral, was epigenetically emplaced within the carbonates by heated fluids of non-magmatic origin. These basic characteristics are common to numerous other orebodies of the American Mid-continent region which are collectively referred to as Mississippi Valley–type deposits. Various geological

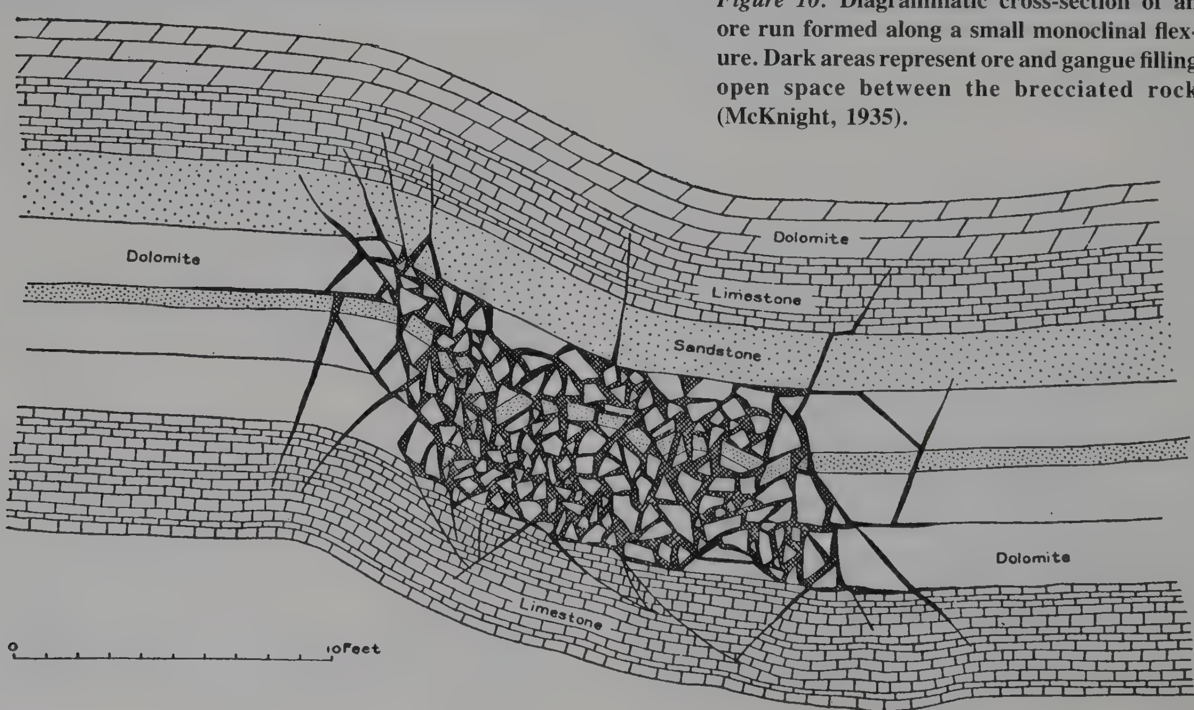

Figure 10. **Diagrammatic cross-section of an ore run formed along a small monoclinal flexure. Dark areas represent ore and gangue filling open space between the brecciated rock (McKnight, 1935).**

and geochemical lines of evidence suggest that the north Arkansas ores are genetically related to those of the Tri-State district, Viburnum Trend, Old Lead Belt, and other Mississippi Valley—type deposits of the Ozark Plateau (Leach and Rowan, 1986). Mineralization is believed to have been a product of a regional-scale hydrothermal system active during the final stages of the late Paleozoic Ouachita Orogeny (Bethke and Marshak, 1990). Lead and zinc were leached from sediments of the Arkoma Basin and transported by geothermally heated brines to the basin perimeter. As the mineral-bearing brines were driven into the Ozark Plateau, zinc and lead precipitated as sulfides where the necessary physical and/or chemical traps existed.

The Arkansas Ozarks are composed of nearly flat-lying sedimentary rocks, ranging in age from Cambrian to Pennsylvanian, which thin northward and gradually pinch out over the Ozark dome. Disseminated mineralization can be found over a large interval of the stratigraphic column, but commercial lead and zinc production has been limited to the Lower Ordovician Everton and Mississippian Boone Formations. In the Rush Creek district all mining has taken place within the Everton, a 120-meter sequence of shallow-marine sandy limestones and dolomites. Many of the mines were opened on the same stratigraphic level, which ranges from 11 to 14 meters below the Key Sandstone unit and 45 to 70 meters below an unconformity with the St. Peter Sandstone. The rock at this level is a fine-grained to medium-grained dolomite. Within the district the ore-bearing interval varies in thickness from less than a meter up to 6 meters.

Most of the productive orebodies are irregularly shaped runs, lenses and blanket veins that tend to parallel bedding. Often these ore runs are concentrated around zones of slight structural deformation which has brecciated the rock over the narrow interval, providing a channel of high permeability for mineral-bearing fluids. Such breccias have been referred to by various authors as shatter breccias or tectonic breccias. At the center of the district, shatter breccias are associated with the Rush Creek, Monte Cristo and Silver Hollow faults. Although the faults themselves are seldom mineralized, deposits may occur to either side along parallel fissures and flexures. The individual orebodies are rather small. The Red Cloud is the largest mine in aerial extent, at which tunnels totaling 750 meters in length have been excavated within a 120 by 180-meter area.

In several of the Rush Creek mines solution collapse breccias occur in close association with tectonic breccias; the two have been shown to be physically and mineralogically continuous at the Monte Cristo (Long *et al.*, 1986). However, many of the solution collapse breccias have a rock matrix that was lithified prior to mineralization, leaving little open space for dolomite and sphalerite. As a result, solution collapse breccias were not as important as ore receptors in this district.

Wall-rock alteration consisted of the silicification of limestone in the outer margins of breccia chambers and immediately surrounding the ore channels, and was accompanied by the precipitation of drusy quartz on open surfaces. Sphalerite then crystallized as open-space filling in shatter breccias and cross-cutting veins, and also as a replacement of country rock. The deposition of "pink-spar" dolomite was nearly contemporaneous with that of sphalerite; dolomite crystals occur both intergrown with and on top of sphalerite. Similarly, chalcopyrite can be found growing on top of sphalerite and pink-spar dolomite or embedded within either mineral. Coarsely crystalline quartz precipitated as a late-stage gangue and was followed by calcite in the form of euhedral crystals and large cleavage masses.

Most of the exploited deposits have undergone extensive oxidation, during which zinc was leached from sphalerite and reprecipitated as smithsonite and, less commonly, as hemimorphite, hydrozincite and aurichalcite. The oxidation products occupy vugs and pockets remaining after primary mineralization, fill voids created upon dissolution of sphalerite, and replace limestone and dolomite. Additional zinc was retained as "tallow clay" or "buck fat," a white to reddish brown clay that may fill pockets and veins, carrying up to 22% zinc (McKnight, 1935).

MINERALOGY

Mississippi Valley–type deposits are noted for their simple mineralogy. The Rush Creek mineralogy has been further simplified by the absence of lead ore minerals and the gangue minerals barite and fluorite, all of which are common constituents of other Mississippi Valley–type deposits. Galena and cerussite occur in economic quantities less than 20 km away, but have not been encountered within the Rush Creek district.

***Figure 11.* Prismatic aragonite crystals to 6 mm, on smithsonite (collected by Gay Richards).**

Aragonite $CaCO_3$

Aragonite has been found in the upper level of the Monte Cristo mine as radiating sprays of clear columnar crystals on smithsonite.

Aurichalcite $(Zn,Cu^{2+})_5(CO_3)_2(OH)_6$

Aurichalcite is occasionally present in association with sphalerite and chalcopyrite. It has been reported from the Ben Carney, Beulah and Red Cloud mines.

Calcite $CaCO_3$

Calcite is common as both a primary and secondary constituent of the Rush Creek ores. Primary calcite includes large cleavable vein-filling and vug-filling masses and singly or doubly terminated scalenohedral crystals modified by small rhombohedral faces. Dogtooth points to 20 cm have been recovered from the Silver Hollow mine, and McKnight (1935) reported crystals to 30 cm from the Philadelphia mine. Primary calcite is typically transparent with a pleasant amber to rust coloration. Pockets containing large calcite points are often filled by a reddish clay.

Secondary calcite usually occurs in the form of flattened (disk-shaped) rhombohedrons of a milky white color. These grow together to form spheres, rosettes and botryoidal to stalactitic aggregates that have been compared to hailstones. McKnight (1935) reported seeing "hailstone calcite" on an ore pile at the Monte Cristo mine, where it had evidently been mistaken for smithsonite by the miners. Secondary calcite crystallized later than smithsonite, and is often found perched on smithsonite.

Chalcopyrite $CuFeS_2$

Although chalcopyrite is found throughout the district, it is nowhere abundant. It occurs as small tetrahedra, up to 3 mm on edge, perched on sphalerite or dolomite. Sharp, brass-yellow crystals have been found, but more often the crystals are tarnished or in the process of oxidizing to malachite and/or limonite.

Figure 12. **Radial arrangement of wheat-sheaf crystals of smithsonite; 5 mm in diameter.**

Figure 13. **Rounded trigonal aggregates of "turkey fat" smithsonite on drusy quartz; 2.5 cm.**

Figure 14. **"Turkey fat" smithsonite coating dolomite; 11 cm. All specimens collected by the author at the Monte Cristo mine and photographed by the author unless otherwise noted.**

Figure 15. **Calcite scalenohedron with quartz and dolomite; the crystal is 7 cm long (collected by Ed and Gay Richards).**

Figure 16. **Single saddle of smithsonite pseudomorphous after dolomite, perched on sphalerite; the saddle is 1.3 cm in height.**

Figure 17. Rice-grain crystals of "turkey fat" smithsonite (to 6 mm) on drusy quartz; 6 cm.

Figure 18. Brown smithsonite hemispheres on drusy quartz; 2.8 cm.

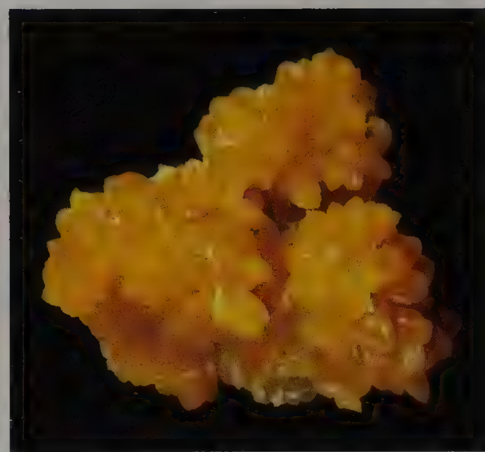

Figure 19. "Turkey fat" smithsonite in rice-grain crystals; 1.8 cm.

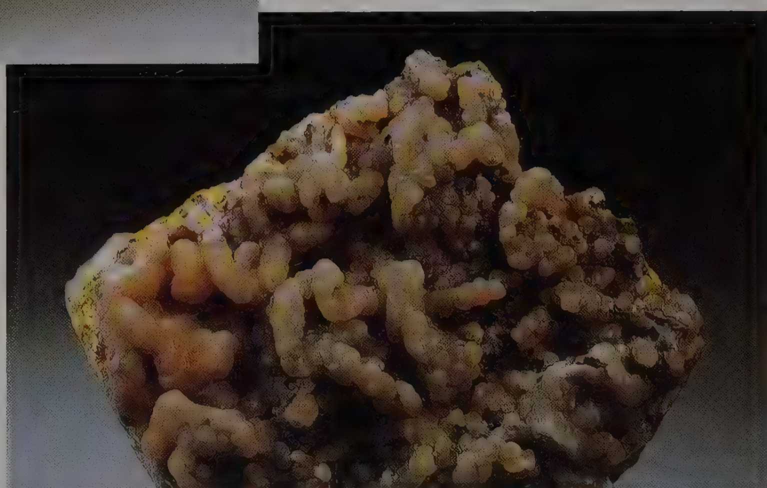

Figure 20. Veneer of eggshell smithsonite on botryoidal brown smithsonite; 10 cm (collected by Ed and Gay Richards).

Dolomite $CaMg(CO_3)_2$

Dolomite is ubiquitous in the Rush Creek district and occurs in close association with sphalerite, a fact that was utilized by early prospectors. The most common habit is saddle-shaped aggregates of curved rhombohedrons. Much dolomite has been stained by iron-bearing solutions, or even replaced in part by limonite, leaving a brown pseudomorph.

Greenockite CdS

Greenockite is present as a minor constituent of turkey fat smithsonite and possibly as a bright yellow powder in open vugs. Individual crystals are unknown.

Gypsum $CaSO_4 \cdot 2H_2O$

Gypsum occurs as clear to white tabular crystals on smithsonite. It has been identified from the Monte Cristo, Red Cloud and Mattie May mines.

Hemimorphite $Zn_4Si_2O_7(OH)_2 \cdot H_2O$

Hemimorphite is present as thin tabular crystals, ranging from colorless to pale brown. Crystals are usually quite small, occurring as a druse on sphalerite or smithsonite. Hemimorphite is often found in association with tallow clay. Although not abundant within the Rush Creek district, other mines in northern Arkansas reportedly marketed hemimorphite as an ore.

Hydrozincite $Zn_5(CO_3)_2(OH)_6$

Hydrozincite is not a common oxidation product, but is believed to be present in some workings as a chalky white powder (Branner, 1900). There has been much debate as to the appearance and abundance of hydrozincite in the Rush Creek mines. Elderhorst (in Owen, 1858) introduced the name "marionite" to a variety of hydrozincite which he incorrectly suspected to be a new mineral. McKnight (1935) pointed out that "flour carbonate," a dull white veneer of smithsonite which forms a late coating on other varieties of smithsonite, may have been mistaken for hydrozincite in earlier surveys. Hydrozincite may be distinguished by its fluorescence.

Marcasite FeS_2

Both Potter (1971) and Long *et al.* (1986) mention the presence of minute subhedral inclusions of marcasite within sphalerite. However, marcasite has not been noted in crystals of any significance.

Malachite $Cu_2(CO_3)(OH)_2$

Malachite is common at the Red Cloud mine as 2 to 4-mm anhedral to subhedral crystals on dolomite, derived by the *in situ* alteration of chalcopyrite. Elsewhere, at the McIntosh mine and others, it is often associated with black smithsonite.

Pyrite FeS_2

Pyrite is of widespread occurrence throughout the district, but is only occasionally found as euhedral crystals. Cubic crystals modified by octahedral, trapezohedral and pyritohedral forms are found in the upper level of the Silver Hollow mine, but are limited to microscopic size (McKnight, 1935).

Quartz SiO_2

Quartz is a common gangue mineral associated with each deposit in the district. A post-ore phase was deposited as sheets of terminated crystals lacking prism faces. Terminal faces range in diameter from microscopic up to 5 cm at the McIntosh mine.

Smithsonite $ZnCO_3$

The habits, textures and colors of smithsonite vary from mine to mine and from pocket to pocket, such that the locality of some specimens can be inferred based on their distinctive appearance. This diversity was apparently a source of much confusion to the Ozark frontiersman, who was largely inexperienced in matters of mining and often had difficulty distinguishing ore from gangue. Many local residents never did add smithsonite or sphalerite to their vocabulary, preferring instead to refer to both as "min'ral." The most abundant varieties of smithsonite were given additional nicknames such as *turkey fat, sealing wax, eggshell* and *honeycomb*—terms almost as colorful as the ores themselves.

Although pure zinc carbonate is white, smithsonite commonly exhibits allochromatic coloration due to the presence of transition metals and their compounds. Shades of gray and brown are the most abundant, although white, black and yellow are all common. Occasional pockets tend toward orange, red or reddish purple. The most sought-after specimens have been stained bright canary to lemon yellow by the presence of greenockite inclusions (Schaller and Fairchild, 1938). In the vernacular of the day, yellow smithsonite was known as "turkey fat" and a pocket of yellow smithsonite was said to have been "turkeyfied." More attractive specimens of turkey fat were spared from the mill crusher and sold for ornamental purposes at $5 per pound. The luster ranges from dull to vitreous. McKnight (1935) compared the bloom on a fresh botryoidal surface to "that on a grape before it has been destroyed by handling."

Zinc which has been transported in solution and precipitated as a carbonate is most commonly deposited as a crustiform or colliform coating on sphalerite, pink-spar dolomite or limestone. These incrustations may have botryoidal, reniform or mammillary free surfaces, and can reach 2 cm in thickness. Thicker incrustations often display concentric banding of contrasting colors when viewed along a broken edge. As oxidation proceeds, sphalerite underlying the smithsonite may completely dissolve away, leaving the incrustation supported by a fragile boxwork of black smithsonite platelets (honeycomb carbonate) that have formed along grain boundaries. Where large sphalerite crystals have dissolved, the smithsonite remains as a mold which may be botryoidal on both inside and outside surfaces. Stalactitic smithsonite is less common, although several workers reported encountering pockets of large stalactites during the early days of mining. Delicate stalactites of only 2 to 3 mm in diameter can reach several centimeters in length. These tend to break under their own weight and can accumulate in small piles which become incorporated into smithsonite at the base of the pocket.

Figure 21. **Botryoidal gray smithsonite; 5 cm.**

Individual crystals include both scalenohedral and rhombohedral forms and often exhibit curved faces. Scalenohedral varieties include rounded dogtooth points which grade into more elongate rice-grain crystals, and bow-tie or wheat-sheaf aggregates composed of tightly packed scalenohedrons. These may reach 8 mm in length. Simple rhombohedrons are known only from the Capps mine (McKnight, 1935). Many of these forms display a characteristic three-fold symmetry in cross-section. Globular smithsonite occurs as hemispheres and nearly perfect spheres up to 1.5 cm in diameter, and also as teardrop shapes. Both crystals and globular forms are more likely to be found on a matrix of fine-grained to medium-grained quartz; on this surface the mineral has tended to nucleate and grow as isolated crystals rather than as massive incrustations. In some cases these crystals may grow together to form a thin shell on the quartz.

Interesting pseudomorphs are created when zinc replaces calcium and magnesium in carbonate rocks and minerals. It is common to find brilliantly colored smithsonite that has replaced and preserved the form of saddle-shaped dolomite crystals. A complete continuum exists from smithsonite covering dolomite to total pseudomorphic replacement. Where zinc has replaced calcium in the wall rock, the resulting ore ("rock bone") closely resembles the original limestone in texture and color, and is identifiable only by its density. McKnight (1935) also noted an occurrence of smithsonite pseudomorphous after scalenohedral calcite at the Monte Cristo mine.

Of course, not all zinc carbonate is vitreous in luster and aesthetically pleasing to the eye. Most of the ore marketed was massive, cellular, earthy or granular.

Sphalerite ZnS

Sphalerite occurs in association with dolomite and quartz as fine disseminated grains and as coarse-grained, vug-filling masses with cleavage faces up to 4 cm in diameter. Where crystals have developed they are often highly modified. Color ranges from a translucent rosin-yellow ("rosin jack") to an opaque black ("black jack") with increasing iron content. Brownish red ("ruby jack"), yellow and dark green sphalerite are also known. Owing to the extent of oxidation within the accessible mines, specimens exhibiting resinous, euhedral crystal faces are not abundant.

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BIBLIOGRAPHY

ADAMS, G. I. (1904) Zinc and lead deposits of northern Arkansas. *United States Geological Survey Professional Paper* **24**, 118 p.

ANONYMOUS (1889) Zinc mining in Arkansas. *Engineering and Mining Journal,* **47**, 431.

ANONYMOUS (1916) The Rush zinc district. *Engineering and Mining Journal,* **101**, 485.

BAIN, H. F. (1901) Preliminary report on the lead and zinc deposits of the Ozark Region. *Twenty-second Annual Report of the Department of the Interior.*

BETHKE, C. M., and MARSHAK, S. (1990) Brine migrations across North America—The tectonics of groundwater. *Annual Review of Earth and Planetary Science,* **18**, 287–315.

BRANNER, G. C. (1927) *Outlines of Arkansas' Mineral Resources.* Bureau of Mines, Manufactures, and Agriculture and the Arkansas State Geological Survey, Little Rock, 352 p.

BRANNER, J. C. (1900) *Annual Report of the Geological Survey of Arkansas for 1892: The zinc and lead region of Northern Arkansas,* **5**, 375 p.

BRANNER, J. C. (1901) The zinc and lead deposits of North Arkansas. *Transactions of the American Institute of Mining Engineers,* **31**, 572–603.

BRICHTA, L. C. (1949) Investigation of Rush Creek Zinc district, Marion County, Arkansas. *United States Bureau of Mines Report of Investigation* **4488**, 15 p.

BRITTAIN, D. (1906) Mining conditions in Arkansas. *The Lead and Zinc News,* **10**, 5–7.

CHANCE, H. M. (1890) The Rush Creek, Arkansas Zinc district. *Transactions of the American Institute of Mining Engineers,* **18**, 505–508.

CHAPMAN, W. A. (1894) *Natural Resources of Boone and Marion Counties, Arkansas.* Brown Printing Company, Little Rock, Arkansas. Second printing, 110 p.

FAIR, J. R. (1969) *The North Arkansas Line: The Story of the Missouri and North Arkansas Railroads.* Howell-North Books, San Diego, 304 p.

HAND, J. H. (1940) *Arkansas Mines Review.* Arkansas Mine Owners League, 42–45.

JUST, E. (1943) An Arkansas travelogue II—The manganese and zinc deposits of northern Arkansas. *Engineering and Mining Journal,* **144** (1), 46–49.

KANSAS CITY, FT. SCOTT & MEMPHIS RAILROAD (1899) *Wealth in Northern Arkansas.* 13 p.

LEACH, D. L., and ROWAN, E. L. (1986) Genetic link between Ouachita foldbelt tectonism and the Mississippi Valley–type lead-zinc deposits of the Ozarks. *Geology,* **14**, 931–935.

LONG, K. R., KELLY, W. C., OHLE, E. L., and LOHMANN, K. C. (1986) Ground preparation and zinc mineralization in bedded and breccia ores of the Monte Cristo mine, North Arkansas. *Economic Geology,* **81**, 809–830.

McKNIGHT, E. T. (1935) Zinc and lead deposits of Northern Arkansas. *United States Geological Survey Bulletin* **853**, 311 p.

OWEN, D. D. (1858) *First Report of a Geological Reconnaissance of the Northern Counties of Arkansas, made during the years 1857 and 1858.* Johnson & Yerkes, state printers, Little Rock, 256 p.

POTTER, R. W. (1971) Geochemical, geothermetric, and petrographic investigation of the Rush Creek mining district, Arkansas. University of Arkansas M.S. Thesis.

ROGERS, S. (1985) *Rush Historic Structures Report.* Unpublished National Park Service Report.

RUHL, O. (1911) Past and present of zinc mining in Arkansas. *Mining and Engineering World,* **35**, 373–376.

SCHALLER, W. T., and FAIRCHILD, J. G. (1938) Cadmium in smithsonite from New Mexico. *American Mineralogist,* **23**, 894–897.

SCHMITZ, E. J. (1898) Notes of a reconnaissance from Springfield, Missouri into Arkansas. *Transactions of the American Institute of Mining Engineers,* **28**, 264–270.

SCHOOLCRAFT, H. R. (1819) *A View of the Lead Mines of Missouri.* Charles Wiley & Co., New York. 299 p.

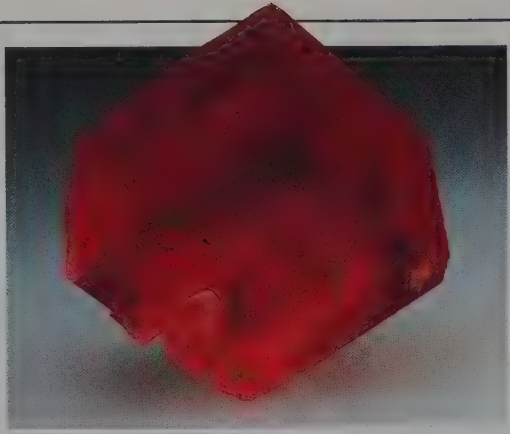
SHIRAS, T. (1916) Great activity in the North Arkansas zinc fields. *Mining and Engineering World,* **45**, 179–181.

SHIRAS, T. (1918) The North Arkansas zinc and lead field. *Engineering and Mining Journal,* **105**, 313–315.

STACEY, A. G. (1905) Arkansas. *The Mining World,* **22**, 72–73.

STROUD, R. B., ARNDT, R. H., FULKERSON, I. B., and DIAMOND, W. G. (1969) Mineral resources and industries of Arkansas. *United States Bureau of Mines Bulletin* **645**, 418 p.

WITTICH, L. L. (1916) Exploitation of Arkansas zinc. *Engineering and Mining Journal,* **102**, 295–297.



Kongsberg Silver, 12.1 cm

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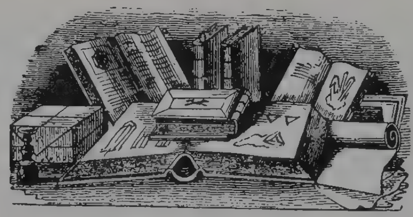

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CLINOMIMETITE

The History and Substantiation of the Natural Monoclinic Dimorph of Mimetite

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ABSTRACT

Clinomimetite, space group $P2_1/b$ (pseudo $P6_3/m$), $a=10.189(3)$, $b=20.372(8)$, $c=7.46(1)$ Å, $\gamma=119.88(3)°$, $V=1342(2)$ Å$_3$, $Z=4$, is a monoclinic dimorph of mimetite, $Pb_5(AsO_4)_3Cl$, which has long been known to exist in nature. It occurs as barrel-shaped or short-prismatic euhedral crystals at Johanngeorgenstadt, Erzgebirge, Sachsen, Germany. Clinomimetite has a pale greenish yellow color, density of 7.36(1) g/cm^3, and hardness (Mohs) of 4. Optically it is biaxial negative, $2V=8(\pm3)°$. The five strongest diffraction lines are: [$d_I(hkl)$] $3.048_{10}(221)$, $3.008_7(122)$, $2.947_7(300)$, $2.106_6(242)$, and $1.903_5(402)$ Å. Clinomimetite is extremely similar to mimetite, but its biaxial optics and superstructure diffractions on over-exposed precession photographs are the definitive criteria for distinguishing the two species. The locality and the Ca content may be indicative of species, but morphology and color are not reliable distinguishing criteria.

INTRODUCTION and HISTORY

Although mimetite is very popular with collectors as a display mineral, prized for its intense colors, high luster and various crystalline forms, "mimetite" specimens may actually represent two distinct mineral species, mimetite and clinomimetite. Mimetite, $Pb_5(AsO_4)_3Cl$, was first recognized as a transparent green-yellow lead-arsenate mineral by Wallerius (1747); it is probably the most common secondary lead arsenate mineral to be found in the oxidized zone of base metal orebodies. By analogy with other apatite-group minerals with space group $P6_3/m$, mimetite was presumed to be hexagonal by Hendricks *et al.* (1932). More than thirty years later, a monoclinic superstructure with space group $P2_1/b(b\cong2a, \gamma\cong120°)$ was reported for both synthetic and natural samples of "mimetite" by Keppler (1968, 1969), Brenner *et al.* (1970), and Förtsch and Freiburg (1970). Using both furnace-equipped X-ray precession cameras and optical microscopes with heating stages, these investigators found that the phase transition between the monoclinic and hexagonal dimorphs is rapid and reversible at temperatures ranging from 98 to 120° C in different samples. By analogy with the Cl disordering in chlorapatite (Mackie *et al.*, 1972), all of these researchers arbitrarily attributed the low-temperature phase transition of mimetite to the order-disorder transition of Cl atoms in the [00z] anion columns, that is, the difference between the hexagonal and monoclinic dimorphs is due to the ordering of Cl in the half-occupied (0,0,z) position which causes the symmetry reduction from hexagonal to monoclinic. Nevertheless, Förtsch and Freiburg (1970) and Brenner *et al.* (1970) also indicated some uncertainty about their conclusion regarding the cause of the phase transition and suggested that superstructure diffractions may result from polycrystalline twinning because different superstructure diffraction patterns were observed in their quenched "mimetite" samples. Their uncertainty arose also from the structure model of vanadinite (isostructural with mimetite) proposed by Hendricks *et al.* (1932) and later refined by Trotter and Barnes (1958) using visual estimates of intensities from films. The vanadinite structure accommodates Cl atoms in the fully occupied (0,0,0) position, in which disordering is impossible, rather than in the half-occupied (0,0,z) site in hexagonal chlorapatite (Hughes *et al.*, 1989). Resolution of the uncertainty has not been easy, as experimental difficulties of X-ray diffraction studies are more than trivial for mimetite in which the scattering is so dominated by a single, highly absorbing element (Pb). A further delay in the resolution of this problem might have been caused by the incorrect structure model of hexagonal mimetite of Sokolova *et al.* (1982), who refined the Cl at the (0,0,z) site, analogous to the Cl in hexagonal chlorapatite structure. Thus, this twenty-plus-year-old question remained unanswered until the recent study of Dai *et al.* (1991) who refined the three-dimensional atomic arrangements of both hexagonal and monoclinic dimorphs of "mimetite" with great precision and established the mineralogical status of this monoclinic phase.

My entry into the topic came through a study of the crystal structures and crystal chemistry of minerals in the vanadinite-pyromorphite-mimetite ternary system (Dai, 1990). As a part of this work, ten mimetite samples from various localities were examined at room temperature by optical microscope and long-exposure precession photographs taken along *a*, *b*, and [110] directions. Recently, four additional samples were examined, and all of the results are summarized in Table 1; hexagonal mimetite seems more common than the monoclinic phase in nature. In the course of the examinations, at least five crystals from each specimen were examined—specimens from the same locality possess the same symmetry. This observation suggests that the locality may be an indicative (though not definitive) criterion for the two species. The crystal structure of the monoclinic dimorph from Johanngeorgenstadt, Germany, was refined using single-crystal X-ray intensity data by Dai *et al.* (1991). The structure data indicate that the hexagonal-monoclinic phase transition is caused by the relocation of the $6s^2$ lone-pair electrons of $Pb(1)^{2+}$ from the three-fold axis in the hexagonal space group, rather than by order-disorder transition of

Cl in the [00z] columns. The refined hexagonal structure accommodates Cl at the fully occupied (0,0,0) position. In the hexagonal mimetite, the $6s^2$ lone-pair electrons of $Pb(1)^{2+}$ are restrained along the three-fold axis by the symmetry, whereas, in the monoclinic structure the lone-pair electrons move away from the pseudo-three-fold axis into a direction nearly perpendicular to the axis. The new phase was named clinomimetite reflecting its monoclinic structure (Dai *et al.*, 1991; Dai, 1990). The mineral and name have been approved by the Commission on New Minerals and Mineral Names of the International Mineralogical Association. The type specimen is preserved at Smithsonian Institution (NMNH B13647); the mineralogical description of this new mineral species follows.

OCCURRENCE

The type specimen of clinomimetite, NMNH B13647, was collected from Johanngeorgenstadt, Erzgebirge, Sachsen, Germany, a noteworthy locality for mimetite (Palache *et al.*, 1951). A historical overview of this classic locality was given by Quellmalz (1990). In addition to the type locality, monoclinic mimetite has been reported from Eureka, Utah, USA (Keppler, 1968); Horhausen, Westfalen, Germany (Keppler, 1968); and the Black forest region, Germany (Förtsch and Freiburg, 1970).

Clinomimetite from Johanngeorgenstadt occurs as barrel-shaped or short-prismatic euhedral crystals elongated parallel to the *c*-axis. Three clinomimetite specimens (NMNH B13647; AMNH 15037; AMNH 15039) from the type locality exhibit two distinct mineral associations: (1) greenish yellow, short-prismatic clinomimetite crystals (Fig. 1) coexist with black romanechite and red hematite coating a weathering surface of quartzite matrix, and (2) pale greenish yellow, barrel-shaped clinomimetite crystals (Fig. 2) embedded in a marly matrix on quartzite. The mineral assemblage and bulk texture of the samples strongly suggest that the clinomimetite is a secondary mineral crystallized in the oxidation zone of base-metal deposits.

This study confirms that white, transparent and spindle-shaped "mimetite" from Eureka, Utah (AMNH 15041) is clinomimetite (Fig. 3). Two mimetite samples (Table 1) from Mount Bonnie, Australia, exhibit different habits but both have hexagonal symmetry; one specimen (Table 1, No. 9) displays prismatic and colorless crystals, and a museum sample (Table 1, No. 14) has thick tabular/short prismatic and greenish yellow crystals. Apparently, morphology and color are not reliable criteria for distinguishing mimetite and clinomimetite.

PROPERTIES, CHEMISTRY, and CRYSTALLOGRAPHY

Clinomimetite from the type specimen (NMNH B13647) is pale greenish yellow and has a hardness of 4 (Mohs) and a density of 7.36(1) g/cm³ measured with a micro-pycnometer in H_2O at 20° C and 7.37 g/cm³ calculated based on the measured formula. Optically, clinomimetite is biaxial negative with $2V = 8(\pm 3)°$ and all three indices of refraction higher than 2.0. Because of the extremely similar internal atomic arrangements and essentially identical chemical composition of mimetite and clinomimetite, the indices of refraction of the two species must be closely comparable; $\eta_\alpha \sim \epsilon_{mimetite}$ (2.129) and $\eta_\beta \cong \eta_\gamma \sim \omega_{mimetite}$ (2.144; Mason and Berry, 1968). Using the measured $2V = 8°$ and assuming $\eta_\alpha = 2.129$ ($\epsilon_{mimetite}$), and $\eta_\gamma = 2.144$ ($\omega_{mimetite}$), the η_β can be calculated using the equation (Wright, 1951):

$$\cos^2(V_z) = \eta_\alpha^2(\eta_\gamma^2 - \eta_\beta^2)/[\eta_\beta^2(\eta_\gamma^2 - \eta_\alpha^2)].$$

The calculated η_β is 2.1439, which differs from η_γ by at most 0.0001. Thus, it is practically impossible to measure the difference between the η_β and η_γ using immersion oils. Consequently, the crystallographic orientation of the indicatrix axes is tentative: $X = c$, and $Y \Lambda b$ or $Z \Lambda b = 29.88°$.

Clinomimetite was chemically analyzed on the JEOL electron microprobe at the University of Colorado using an operating voltage of 15 KV and a sample current of 10 nA. Except for those reported here, no other elements were detected with an energy dispersive analyzer and none with atomic number 9 or greater were significantly above the detection limit in wavelength-dispersive quantization. The standards used are NaCl (Cl), Garnet P130 (Mn), InAs (As), galena (Pb), barite (S), kyanite (Si), fluorapatite (P, Ca). Data were corrected for ZAF effects using Magiv V. Ten analyses yielded the following composition of clinomimetite (weight %): PbO = 74.61 (73.47–76.28), CaO = 0.00 (0.00–0.01), SiO_2 = 0.14 (0.13–0.15), As_2O_5 = 22.05 (21.98–22.18), Cl = 2.58 (2.56–2.61), SO_3 = 0.15 (0.12–0.20), P_2O_5 = 0.33 (0.27–0.39), Total = 99.86, and the empirical formula: $Pb_{9.99}[As_{5.74}Si_{0.07}S_{0.06}P_{0.14}]_{6.01}Cl_{2.18}O_{23.91}$ on the basis of total 50 negative charges per formula. Using the same analytical conditions and standards, Dai (1990) analyzed at least six crystals from each of four hexagonal and one monoclinic samples; all mimetite crystals contained 0.4 to 1.4 weight % of Ca, but Ca contents in all clinomimetite crystals were undetectable. Thus, Ca content can be used as an indicative criterion to distinguish the two species.

The reader is referred to Dai *et al.* (1991) and Dai (1990) for detailed crystal structure and crystal chemistry data for clinomimetite. The systematic absences on the over-exposed precession photographs of clinomimetite are consistent with space group $P2_1/b$. The unit-cell parameters [$a = 10.189(3)$, $b = 20.372(8)$, $c = 7.46(1)$ Å, $\gamma = 119.88(3)°$], refined from diffraction angles of 25 reflections automatically centered on a CAD4 diffractometer equipped with graphite-monochromated Mo$K\alpha$ radiation, are closely comparable to those of mimetite [space group $P6_3/m$, $a = 10.211(2)$, $c = 7.419(4)$ Å, $\gamma = 120°$; Dai *et al.*, 1991]. The first setting of the monoclinic cell is used to facilitate the structural comparison between clinomimetite and mimetite. Powder X-ray diffraction data (Table 2) were obtained using a 114.6-mm Gandolfi camera with Cu$K\alpha$ (Ni-filtered) radiation. The

***Table 1.* "Mimetite" samples examined.**

Location	*Symmetry*	*Source*	*Habit*
1. Tsumeb mine, Namibia	Hexagonal	Limper Museum, Miami University	Spindle-shaped or prismatic
2. Tsumeb mine, 8 level, Namibia	Hexagonal	NMNH R18603	Prismatic
3. Gweunag, Cornwall, England	Hexagonal	NMNH 103833	Prismatic
4. Mapimi, Durango, Mexico	Hexagonal	David Crawford	Prismatic or spindle-shaped
5. Durango, Mexico	Hexagonal	David Crawford	Wheat-sheaf polycrystalline
6. San Pedro Corallitas, Chihuahua, Mexico	Hexagonal	Limper Museum, Miami University	Ball-like polycrystalline
7. Los Lamentos, Chihuahua, Mexico	Hexagonal	Limper Museum, Miami University	Spindle-shaped or prismatic
8. Los Lamentos, Chihuahua, Mexico	Hexagonal	David Crawford	Spindle-shaped
9. Mount Bonnie, Australia	Hexagonal	David Crawford	Prismatic
10. Johanngeorgenstadt, Germany	Monoclinic	NMNH B13647	Short-prismatic
11. Johanngeorgenstadt, Germany	Monoclinic	AMNH 15037	Short-prismatic
12. Johanngeorgenstadt, Germany	Monoclinic	AMNH 15039	Barrel-shaped
13. Eureka, Utah	Monoclinic	AMNH 15041	Spindle-shaped
14. Mount Bonnie, Australia	Hexagonal	AMNH 48684	Thick-tabular/short-prismatic

Figure 1. (right and below) **Short-prismatic clinomimetite crystals to 9 mm from Johanngeorgenstadt, Germany. The American Museum of Natural History collection (AMNH 15037). Photo by Jacklyn Beckett.**

Figure 3. **Spindle-shaped clinomimetite crystals to 8 mm long from Eureka, Utah. The American Museum of Natural History collection (AMNH 15041). Photo by Jacklyn Beckett.**

Figure 2. **Barrel-shaped clinomimetite crystals to 6 mm from Johanngeorgenstadt, Germany. The American Museum of Natural History collection (AMNH 15039). Photo by Jacklyn Beckett.**

indexing of the powder diffractions is comformable with the single-crystal diffraction data collected on the same crystal. The reflections with $k = $ odd are too weak to be visible on the Gandolfi film, although there are 265 $k = $ odd reflections with $I > 3\sigma_I$ in the single-crystal diffractometer data set used for the structure refinement, which violate the $P6_3/m$ symmetry (Dai *et al.*, 1991). Thus it may require a Rietveld refinement of accurate diffractometer data to identify clinomimetite with powder methods.

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

I(%)	$d_{meas.}$(Å)	$d_{calc.}$(Å)	*hkl**
20	4.418	4.417, 4.416	(200), (040)
20	4.210	4.212	(121)
30	3.433	3.436, 3.436, 3.435	(102), (022), ($\bar{1}$22)
50	3.342	3.337, 3.336, 3.340, 3.341	($\bar{3}$20), ($\bar{1}$60), (140), (220)
100	3.048	3.049, 3.049, 3.046, 3.045	(221), (141), ($\bar{3}$21), ($\bar{1}$61)
70	3.008	3.011, 3.010, 3.009	(122), ($\bar{2}$22), ($\bar{1}$42)
70	2.947	2.945, 2.944	(300), (060)
60	2.106	2.106, 2.104, 2.103	(242), ($\bar{4}$42), ($\bar{2}$82)
20	2.051	2.047, 2.047, 2.048, 2.048	($\bar{4}$22), ($\bar{1}$82), (162), (322)
40	1.995	1.995, 1.995, 1.994, 1.994	(223), (143), ($\bar{3}$23), ($\bar{1}$63)
50	1.961	1.957, 1.957	(341), (2$\bar{6}$1)
40	1.928	1.928, 1.928	(420), (180)
50	1.903	1.900, 1.900	(402), (082)
10	1.717	1.718, 1.718, 1.718, 1.716	(204), (044), ($\bar{2}$44), ($\bar{5}$,10,1)
10	1.663	1.670, 1.670, 1.668, 1.668	(440), (280), ($\bar{2}$,12,0), ($\bar{6}$40)
20	1.629	1.628, 1.628, 1.628, 1.628	(224), (144), ($\bar{1}$64), ($\bar{3}$24)
20	1.596	1.597, 1.596, 1.594	(502), (0,10,2), ($\bar{5}$,10,2)
40	1.575	1.576, 1.575, 1.575	(304), (064), ($\bar{3}$64)
40	1.554	1.552, 1.551, 1.552, 1.552	($\bar{6}$21), ($\bar{1}$,12,1), (1,10,1), (521)
10	1.375	1.370, 1.369, 1.373, 1.373	(602), (0,12,2), (344), (264)
10	1.341	1.341, 1.340, 1.340, 1.340	(424), (184), ($\bar{1}$,10,4), ($\bar{5}$24)
10	1.328	1.323, 1.323, 1.326, 1.326	(542), (2,10,2), (621), (1,12,1)

* The unit cell is defined by the monoclinic first setting; *c* is unique.

REMARKS

Clinomimetite is extremely similar to mimetite in terms of physical and optical properties because of their similar internal atomic arrangements and compositions. Based on the studies of Dai (1990), mimetite appears more common than clinomimetite in nature; this may be because the hexagonal structure of mimetite can be stabilized by either minor deficiency of $PbCl_2$ or Ca^{2+} substitution for Pb^{2+} at the Pb(1) site (Dai *et al.*, 1991). Although it is impossible to distinguish the minerals in hand-specimen or by Gandolfi X-ray film techniques, there are some criteria useful for distinguishing the two species. The locality is a preliminary indication of species; Table 1 shows that samples from the same locality appear to consistently exhibit the same symmetry. Chemically, minor amounts of Ca substitutions for Pb tend to correlate with hexagonal symmetry. However, the definitive criteria for distinguishing mimetite and clinomimetite are the biaxial optics and superstructure diffractions on over-exposed precession photographs exhibited by clinomimetite.

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REFERENCES

BRENNER, P., ENGEL, G., and WONDRATSCHEK, H. (1970) Blei-Apatite mit Uberstruktur. *Zeitschrift für Kristallographie*, **131**, 206–212.

DAI, Y. (1990) X-ray crystallographic studies on: (1) Crystal structure and crystal chemistry of lead-bearing apatites in the vanadinite-pyromorphite-mimetite ternary system and (2) A preliminary study on the thermal-induced Al-Si disorder in the crystal structure of sillimanite. Ph.D. dissertation at Miami University, Oxford, Ohio.

DAI, Y., HUGHES, J. M., and MOORE, P. B. (1991) The crystal structures of mimetite and clinomimetite, $Pb_5(AsO_4)_3Cl$. *Canadian Mineralogist*, **29**, 369–376.

FÖRTSCH, E., and FREIBURG, I. B. (1970) Untersuchungen an Mineralien der Pyromorphit-Gruppe. *Neues Jahrbuch für Mineralogie Abhandlungen*, **113**, 219–250.

HENDRICKS, S. B., JEFFERSON, M. E., and MOSLEY, V. M. (1932) The crystal structure of natural and synthetic apatite-like substances. *Zeitschrift für Kristallographie*, **81**, 352–369.

HUGHES, J. M., CAMERON, M., and CROWLEY, K. D. (1989) Structural variations in natural F, OH, and Cl apatites. *American Mineralogist*, **74**, 870–876.

KEPPLER, U. (1968) Monokliner Mimetesit, $Pb_5(AsO_4)_3Cl$. *Neues Jahrbuch für Mineralogie Monatshefte*, 359–362.

KEPPLER, U. (1969) Zum Modifikationswechsel Chlor-haltiger Apatite. *Neues Jahrbuch für Mineralogie Monatshefte*, 64–67.

MACKIE, P. E., ELLIOT, J. C., and YOUNG, R. A. (1972) Monoclinic structure of synthetic $Ca_5(PO_4)_3Cl$, chlorapatite. *Acta Crystallographica*, **B28**, 1840–1848.

MASON, B., and BERRY, L. G. (1968) *Elements of Mineralogy*. W. H. Freeman and Company, San Francisco.

PALACHE, C., BERMAN, H., and FRONDEL, C. (1951) *The System of Mineralogy*. Volume II, John Wiley and Sons, Inc., New York.

QUELLMALZ, W. (1990) A brief look at the Saxon Erzgebirge. *Mineralogical Record*, **21**, 565–570.

SOKOLOVA, E. V., EGOROV-TISMENKO, YU. K., and YAKHONTOVA, L. K. (1982) Crystal structure of rare arsenates—duftite and mimetite. *Vestnik Moskovskogo Universiteta, Seriya 4, Geologiya*, 50–56 (in Russian).

TROTTER, J., and BARNES, W. H. (1958) The structure of vanadinite. *Canadian Mineralogist*, **6**, 161–173.

WALLERIUS, J. G. (1747) *Mineralogia, eller Mineralriket*. Stockholm, 515 p.

WRIGHT, F. E. (1951) Computation of the optic axial angle from the three principal refractive indices. *American Mineralogist*, **36**, 543–556.

Microminerals

Bill Henderson and **Marcelle Weber**

Solid Inclusions

Years ago, the European gentry were generalists. They could speak intelligently on a great variety of topics, as the world's body of knowledge was a minute fraction of what it is today. Many maintained "cabinets" in which they displayed curios and natural objects. Next to a bird's nest might be a fossil; beside that a stuffed animal and a specimen of quartz from the Alps. Over the years, as knowledge accumulated, more people felt it necessary to specialize in a single area and collect only one type of object. We, of course, collect minerals. Of late, though, even greater specialization has become the vogue. Those warped individuals to whom this column is dedicated collect primarily microminerals. Others collect pegmatite phosphates, minerals of New England, twinned crystals, or even specimens from a single locality.

One attractive specialty is collecting solid and/or liquid inclusions in minerals. This column is devoted to photos of microcrystals included within larger crystals; in most cases, both the host and guest crystals can be seen in the photos.

The first two specimens shown (Figs. 1 and 2) are of goethite in quartz from a roadcut on Route I-95 in East Haven, Connecticut. The roadcut is just east of the point where the highway passes over the south end of Lake Saltonstall. The cut passes through one of three Triassic lava flows which trend north-south along the Triassic Basin in Connecticut. Goethite occurs there as attractive sprays of brown to gold-colored needles in colorless, smoky or amethystine quartz.

Approximately 1.3 miles north of the above locality and just off Laurel Street is the Cinque quarry. It is located in the same Triassic flow. Besides blue and green quartz micro-crystals, it is possible to find remarkably good amethyst crystals in attractive druses, and goethite again as inclusions in colorless to amethystine quartz. Figure 3 shows quartz phantoms delineated by iron oxides.

Completely different is the fluorite with a dark purple phantom from Mantena, Minas Gerais, Brazil, shown in Figure 4. Besides the phantom, there are included a number of minute pyrite crystals. Of course, as inclusions go, these are not the greatest, but the specimen is so beautiful that we could not resist showing it. This specimen and others like it were obtained from Carlos Barbosa, a well-known Brazilian dealer.

Native copper is frequently seen as inclusions in other minerals. In Figure 5 it appears within natrolite crystals in a specimen from the Mass mine, Mass, Ontonagon County, Michigan.

Transparent gypsum is a very satisfying host for inclusions because its transparency and single perfect cleavage make photographing or viewing of inclusions relatively easy. An example is the dendritic copper in gypsum shown in Figure 6. The specimen is from the Mission mine, Pima County, Arizona.

We think of realgar as a mineral crystallizing in equant or reasonably equidimensional crystals. In Figure 7 is shown realgar as acicular crystals included in colemanite. This illustrates a fairly common phenomenon among included crystals; they are frequently acicular, even though their normal free-growing habit is equant. The specimen is from Boron, Kern County, California.

Several minerals are found as ring-shaped inclusions. The boulangerite ring within a calcite crystal shown in Figure 13 is an example. Such rings are also found at the same locality (Rogers mine, Madoc, Ontario) enclosed in fluorite. Not shown are similar rings of rutile within topaz from Tetapati, San Luis Potosi, Mexico. The inclusion examples shown thus far are of low-temperature minerals within a low-temperature host. The rutile inclusions in topaz were formed at a much higher temperature.

Many sulfide minerals occur frequently as inclusions. One such is millerite, shown as inclusions of typically acicular crystals in calcite (Fig. 14). The specimen is from Coralville, Johnson County, Iowa. Another such sulfide mineral is marcasite, also included within calcite, shown in Figure 15. This is from Pint's quarry, Raymond, Black Hawk County, Iowa. Both of these specimens were photographed using a polarizing filter, without which the strong double refraction of calcite would have produced the usual confusing double image. Pyrite is a third sulfide commonly found as inclusions. In Figure 8 is shown a complex pyrite crystal in quartz, from Spruce claim, Goldmeyer Hot Springs, King County, Washington. That it is an inclusion


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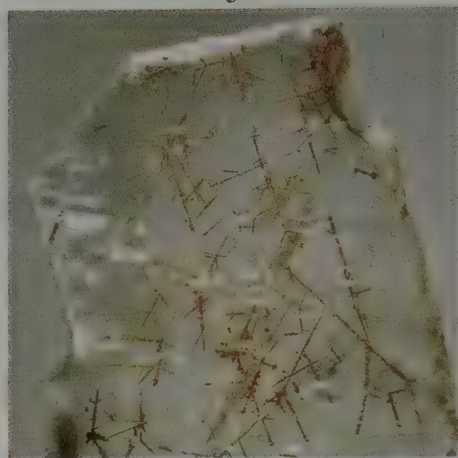
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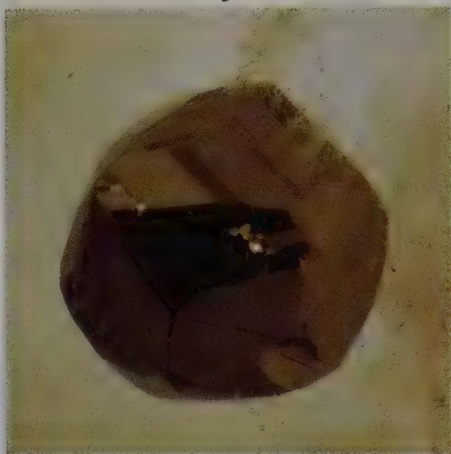
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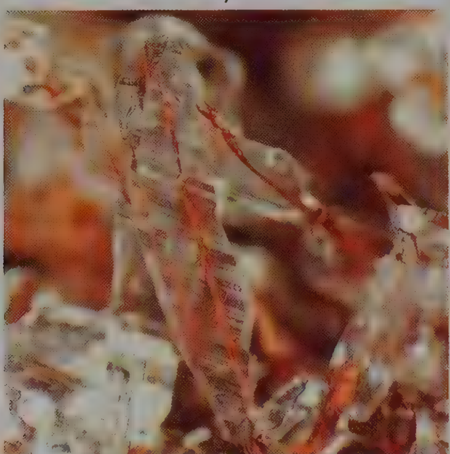
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Figure 1. **Radiating brown goethite in quartz; field of view 2 mm. From roadcut on Rt 95, East Haven, New Haven County, Connecticut. Marcelle Weber specimen and photo.**

Figure 2. **Golden brown needles of goethite in quartz from the same locality as in Figure 1. Width of quartz crystal 4.5 mm. Bill Henderson specimen and photo.**

Figure 3. **Quartz crystals with yellow-brown inclusions of goethite delineating phantoms; from the Cinque quarry, East Haven, New Haven County, Connecticut. Size of crystal group 3 mm. Marcelle Weber specimen and photo.**

Figure 4. **A fluorite phantom with pyrite inclusions from Mantena, Minas Gerais, Brazil. Size of crystal 1.5 mm. Bill Henderson specimen and photo.**

Figure 5. **Native copper inclusions in natrolite, from the Mass C shaft, Mass mine, Mass, Ontonagon County, Michigan. Field of view 1.5 mm. Marcelle Weber specimen and photo.**

Figure 6. **Dendritic copper inclusions in cleavage fragment of gypsum; field of view 7 mm. From the Mission mine, Pima County, Arizona. Bill Henderson specimen and photo.**

Figure 7. **Colemanite with inclusions of acicular realgar, from Boron, Kern County, California. Field of view 2.2 mm. Bill Henderson specimen and photo.**

Figure 8. **Pyrite inclusions and veil of liquid inclusions in quartz from the Spruce claim, Goldmeyer Hot Springs, King County, Washington. Size of pyrite crystal 1.2 mm. Bill Henderson specimen, photo by Omer Dean.**

Figure 9. **Bright red inclusion of hematite in quartz from the Gobabor Mountains, Namibia. Height of quartz crystal, 1.6 cm. Bill Henderson specimen and photo.**

Figure 10. **Metahewettite inclusions in gypsum; size of largest crystal 2.8 mm. From the Hummer mine, Montrose county, Colorado. Bill Henderson specimen and photo.**

Figure 11. **Griceite on and included in villiaumite from the Poudrette quarry, Mont Saint-Hilaire, Quebec, Canada. Field of view 1 cm. Marcelle Weber specimens and photo.**

Figure 12. **Red inclusions of pseudobrookite in pale yellow roedderite crystal, from Bellerberg, Eifel District, Germany. Size of crystal 0.9 mm. Bill Henderson specimen and photo.**

Figure 13. **Boulangerite ring in a 2.5-mm calcite crystal from the Rogers mine, Madoc, Ontario, Canada. Marcelle Weber specimen and photo.**

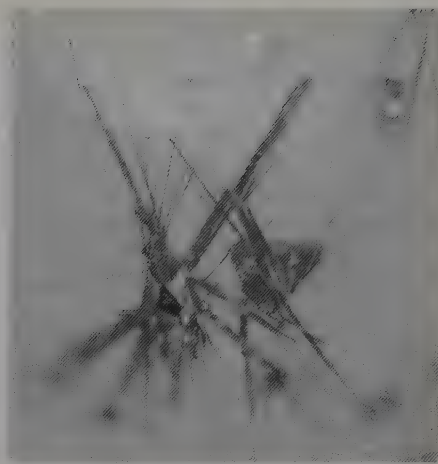

Figure 14. **Millerite needles in calcite; size of crystal group 3 mm. From Coralville, Johnson County, Iowa. Marcelle Weber specimen and photo.**

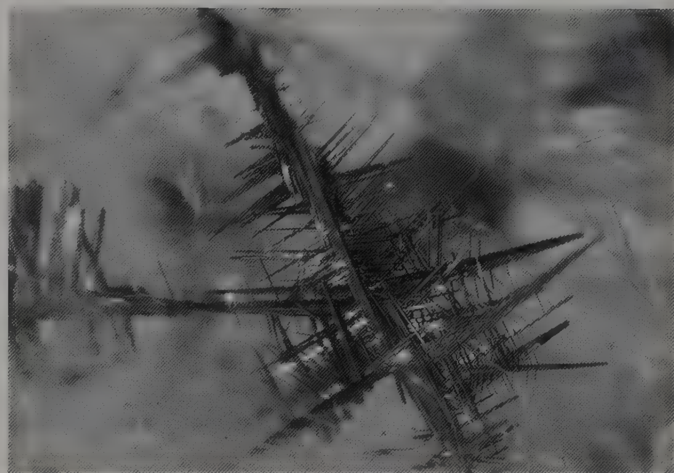

Figure 15. **Dendritic needles of marcasite in calcite, from Pints quarry, Raymond, Black Hawk County, Iowa. The field of view is 2.3 mm. Bill Henderson specimen, photo by Dan Behnke.**

and not a free-growing crystal is shown by the veils of *liquid* inclusions within the quartz, one of which partially covers the pyrite in the lower left corner of the photograph.

Liquid inclusions, by the way, can make fascinating microscopic specimens themselves. Picture, for instance, a single fluid inclusion within quartz, the fluid inclusion in turn containing liquid, a large vapor bubble which disappears on heating, and solid inclusions of halite, hematite and potassium-iron-chloride minerals, all as free floating, euhedral crystals! Liquid inclusions can be used to determine the approximate temperature and pressure at which mineral deposits formed, and to investigate the composition of the fluids from which the minerals were deposited. They are so important to economic geologists and others that there is even a *Journal of Liquid Inclusion Research*.

Perhaps the most colorful inclusion shown here is the one in Figure 9, of hematite in quartz. The hematite inclusion is so thin that the true blood-red color of the mineral is revealed. The specimen is from a new locality in the Gobabor Mountains, Namibia.

We turn finally to some more exotic species. After all, it is not just common minerals which can occur as inclusions. In Figure 10 are shown brick-red crystals of metahewettite, a rare calcium vanadate mineral, enclosed in gypsum. It appears that the metahewettite crystals acted as nuclei, encouraging the growth of gypsum crystals around themselves. The specimen is from the Hummer mine, Paradox Valley, Montrose County, Colorado.

A doubly rare combination is the white griceite in and on red villiaumite from the Poudrette quarry, Mont Saint-Hilaire, Quebec, shown in Figure 11. The specimen is nice in another way—griceite has the formula LiF, while that of villiaumite is NaF; both these cubic fluorides are present in the one specimen. Mont Saint-Hilaire is the type and only locality for griceite.

Figure 12 shows a specimen which is one of our favorites for its beauty and for the rarity of the host mineral. It is composed of red, radiating crystals of pseudobrookite within roedderite, and is from Bellerberg, Eifel District, Germany. Roedderite is found at this locality in silicate xenoliths. It and eifelite, also found in the same area, are members of the osumilite group.

There must be literally thousands of different mineral combinations of inclusion and host, and many are available in attractive micromineral specimens. Obviously, most, including such popular combinations as rutile in quartz, are not shown here. A collection of the little beasties would clearly be very interesting, as well as scientifically valuable. Certainly, we take delight in adding to those which we already have.

Finally, one of us (WAH) would like to make a plea for help. Very rarely, certain acicular minerals such as the acicular variety of cuprite, some pyrite, and millerite, while remaining straight, form twisted (not bent) crystals like a perfectly uniform screw. Crystals which do this are always extremely thin, and there may be only one or two such crystals among hundreds without a twist. I am very interested in such crystals of any mineral for use in a future publication. Would readers of this column please tell me of such crystals they may have? I would like to borrow, exchange for, or purchase them for photographing.

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Museum notes

Smithsonian gets $3 Million for New Mineral Hall

Mrs. James Stewart Hooker has donated $3 million toward the renovation of the Hall of Geology, Gems and Minerals at the Smithsonian's National Museum of Natural History. This is the largest cash gift in the museum's history.

To commemorate her generosity, the museum will name the 20,000-square-foot exhibit hall the **Mrs. James Stewart Hooker Hall of Geology, Gems and Minerals.**

A total of $5.25 million has been raised toward the $10 million renovation, including $1 million from the Harry Winston Research Foundation and $1.2 million from American Mining Congress member companies.

"It gives me great pleasure to help further the educational goals of the National Museum of Natural History by supporting this monumental renovation," Mrs. Hooker said. "I am delighted the museum is continuing its active interest in our Earth and in the discovery of its many treasures."

In 1977, Mrs. Hooker donated the exquisite 75-carat Hooker Emerald to the museum. The gemstone is cut in an elegant beveled square measuring 27 mm (1.06 inches) on each edge. The gem, set in a brooch, surrounded by 109 round diamonds and 20 baguettes was designed by Tiffany & Company.

The Mrs. James Stewart Hooker Hall of Geology, Gems and Minerals will incorporate the most up-to-date earth science information and will highlight dynamic earth processes including crystal and ore formation, volcano and earthquake origins, the theory of plate tectonics and the formation of the solar system.

Exhibit areas will include a number of special displays. The introductory "Harry Winston Gallery" will highlight the Hope Diamond—the most popular icon of the Smithsonian. "Mineral and Crystal Treasures" will emphasize the importance of minerals in our everyday lives. A walk-through two-story mine exhibit will feature actual crystal pockets and ore veins embedded in rocklike walls. The "rock processes" section will feature large touchable specimens and computer interactives demonstrating how rocks recycle, melt and freeze, bend and break and cook under pressure. The innovative "plate tectonics" section will incorporate a "shake theater"in which visitors will have the opportunity to experience the simulated tremors of an earthquake. The "planetary origins" area will explore the evolution of the solar system.

"Mrs. Hooker's philanthropic gift symbolizes yet another invaluable public/private partnership with the museum—one that will allow us to explore and present the beauty, complexity and magnitude of earth sciences," Museum Director Frank Talbot said.

The current gem, mineral and earth science halls will close in June 1994, and the renovated complex will re-open in early 1996.

S. R. Perren Gem and Gold Room

Nearly 1,000 gems and 70 gold specimens light up the Royal Ontario Museum (ROM) in Toronto this summer when the S. R. Perren Gem and Gold Room opens to the public Saturday, July 3, 1993. In an intimate setting, this permanent gallery houses the finest pieces in the ROM's renowned gem and gold collections.

The gems are arranged according to their mineralogical and gemmological groups with special attention to colors and varieties. A few gem crystals show what gems look like in their natural state before they are cut and polished. Lit by state-of-the-art and energy-efficient fibre optics, each gemstone interacts directly with the light to bring out its individual characteristics. Colorless and frosted acrylic platforms are used in the displays so as not to detract from the color and dazzle of the gemstones. Detailed information about the gems is provided in a series of booklets outside the cases, leaving the interiors relatively free of labels.

Most of the gold specimens are housed in a single wrap-around case. The central area is devoted to spectacular specimens of Ontario gold. Large gold nuggets, probably from the California gold rush days, and six gold medals awarded to well-known Canadians for achievements in geology are included in the display. The exhibit is enhanced by the neighboring interim exhibit **Magnificent Minerals: Building the ROM Collections,** which features over 200 outstanding mineral specimens from all over the world.

The Gem and Gold Room also caters to children: eight displays are positioned close to the floor so that youngsters can easily see into them. Highlights include a deep amethyst geode from Brazil and a large "fake diamond" cut from cubic zirconia.

Just outside the exhibit room, two interactive, multimedia videos provide more information about the properties of gems. By manipulating "buttons" on the screen visitors can view gems from different angles, alter the shape of a variety of gems, discover why diamonds sparkle and how accurate cutting can enhance the brilliance of a gem.

The S. R. Perren Gem and Gold Room is named after Dick Perren (1907–1986), an internationally known gem dealer who was a mentor to many young jewelers and gemologists. The generosity of the Perren family and their friends helped to make this gallery a reality. It is the first phase and the centerpiece of the new Earth Sciences Gallery which will display the Museum's collections of minerals, rocks and meteorites. The Museum is currently seeking funding to develop the Earth Sciences Gallery.

The S. R. Perren Gem and Gold Room is included with Museum admission which, as of Saturday, May 22, 1993, is $7 for adults, $4 for seniors and students; $3.50 for children, and $15 for family groups. For 24-hour information in English and French call (416) 586-5551.

The Mineralogical Museum of Wrocław University

We would like to supplement the excellent issue on mineralogical museums in Eastern Europe (vol. 19, no. 1, 1988) with information on the largest mineral collection in Poland, housed at the Mineralogical Museum of the Wrocław (Vrotslav) University. The Museum was founded in 1812 but it received a real impetus three years later with the purchase of the Mender collection from Freiberg, reportedly second only in excellence to the famous collection of Abraham G. Werner. Of special value was a set of proustite crystals from Saxony. Unfortunately, those and other superb specimens were lost in the course of history. A beautiful, 1.5-cm transparent crystal of scheelite from the Mt. Sniezka (Sudety Mts.), still on display, is a reminder of the high quality of that collection. Many eminent mineralogists worked as curators of the Museum, among them Professor Carl Hintze (carlhintzeite) author of the monumental *Handbuch der Mineralogie*. During World War II the most precious part of the collection was stored outside Wrocław for safekeeping. That was fortunate because the city, declared by Nazis a Fortress, was destroyed, including the building of the Mineralogical Museum. After the war, a major part of the mineral collection returned to Wrocław due to the efforts and enthusiasm of Professor Kazimierz Maślankiewicz, gemologist, promoter of mineralogy, and for many years a curator of the Museum.

Today, the collection numbers 35,000 registered specimens organized into four sections: (1.) systematic collection (15,000 specimens from all over the world); (2.) meteorites (153 specimens—largest collection in Poland); (3.) minerals of Poland; (4.) gemstones. The Museum preserves a few holotypes and cotypes, including stilpnomelane, sarcopside, tarnowitzite, and jaskolskite. Among curiosities there are small but well-developed crystals of vivianite in the hollow of the bone of a fifteenth-century miner who died in an accident in a galena mine in Bytom. A special attraction is a recently excavated 1-ton block of serpentinite with several centimeter-long radial crystals of aragonite from Naslawice.

The Museum specializes in minerals from Lower Silesia—an old mining region once famous for superb quality chrysoprase and nephrite (a large boulder of nephrite from Jordansmuhle, now Jordanów, is on display at the Natural History Museum in New York). The southern part of Lower Silesia still attracts mineral collectors hunting for pegmatitic minerals, agates, transparent barite crystals and other minerals. For them a visit to the Wrocław Museum is a must before or after field trips. The Museum treasures a collection of minerals from old, abandoned Silesian mines like Złoty Stok (Reichenstein)—once the world's largest producer of loellingite and arsenopyrite.

Because of the limited space, only a small part of the collection is on display. Meteorites, for instance, are shown by request only. Besides the permanent exhibits (mineral systematics, gemstones, minerals of Lower Silesia) there are also temporary exhibits: currently minerals of the Kola Peninsula.

A visitor to the Museum is greeted by a friendly staff fluent in English and German. True mineral lovers may count on a cup of tea or coffee and a chat on mineral wonders. The visit to the Museum may be combined with a visit to the neighboring Geological Museum that hosts a large collection of fossils and rocks.

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Uniwersytetu Wrocławskiego
Cybulskiego 30
50-205 Wrocław, Poland
and
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Miekzarskiego 60
41-200 Sosnowiec, Poland

Uzbek Science Education Center (Geological Museum)

The Republic of Uzbekistan in central Asia (until recently part of the Soviet Union) is at the crossroads between East and West. Both Alexander the Great and Ghengis Khan made their headquarters in Uzbekistan during their military campaigns along the ancient Silk Route. Uzbekistan is known for its cotton, bountiful agricultural products, and a wealth of mineral resources. Some of the largest copper, molybdenum and gold mines of the former Soviet Union are located in Uzbekistan. Other metals produced are silver, tin, tungsten, tellurium, selenium and cadmium, as well as evaporite minerals, gemstones and decorative building stones.

All geological activities in Uzbekistan, including mineral exploration, come under the direction of the Institute of Geology and Geo-

physics, headed by Director Ibrahim Kh. Khamrabaev. Dr. Khamrabaev is also a Lenin Prize winner (1966), in recognition of his role in the discovery of major gold deposits in western Uzbekistan. For the results obtained from his genetic modeling, in 1990 he was awarded the Republican Premium Prize for the discovery of extensive tungsten deposits. The mineral *khamrabaevite* is named in his honor (see *American Mineralogist*, **70**, 1329).

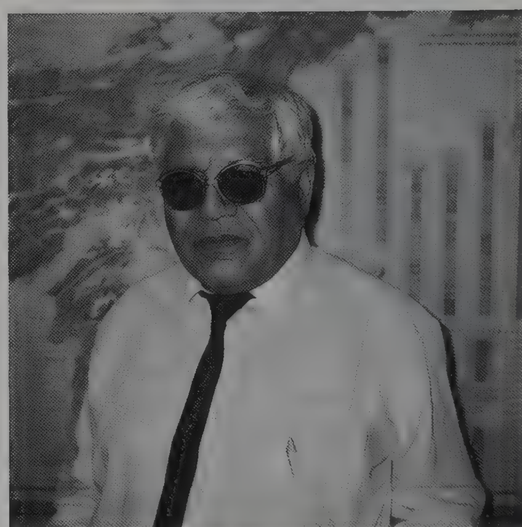

Figure 1. **Dr. I. Kh. Khamrabaev in his office by a geologic map of Uzbekistan.**

The Science Education Center (Geological Museum) in Tashkent is part of the Institute of Geology and Geophysics. Funding for the museum is also provided by the Uzbek Academy of Sciences. The Director of the museum is Rustam G. Yusupov. As implied by its name, the museum's major function is education. There, classes are given to high school students, and university researchers attend the center to upgrade their degrees through post-graduate research.

The center's museum is in a new facility that was dedicated in 1990. Unlike American museums that specialize in displaying individual world-class crystal groups, the Geological Museum in Tashkent emphasizes economic geology and historical geology. In the main display hall, mineral exhibits are grouped by mining district, metallogenic type, and commodity. There are also extensive displays of industrial minerals, mineral products, and a wide array of building stones.

Only 15% of the collection of 60,000 specimens is on display. The remainder are housed in a section of the building reserved for instruction and research. In the Academic Hall all geological materials that

Figure 2. **Science and Education Center (Geological Museum) Tashkent, Uzbekistan.**

are used for research leading to a publication are deposited. It is where minerals first described from Uzbekistan can be seen. These include native chromium, khamrabaevite, kuramite, chatkalite, nekrasovite, mohite, kyzylkumite, vyacheslavite and others.

The two separate galleries in the museum feature paleontology and the life of dinosaurs. The Fauna and Flora Hall contains the Uzbek historical paleontological study collections from the Proterozoic to Recent in age.

The Science Education Center (Geological Museum) is located at 1 Prospect Furkat, Tashkent, 700027. It is open to the public from 9 am to 4 pm, Monday through Friday. For those wishing to call the Director Rustan G. Yusupov (who speaks French), the phone number is: (3712) 45-08-66.

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Division of Geology and Earth Resources
Washington State Department of Natural Resources
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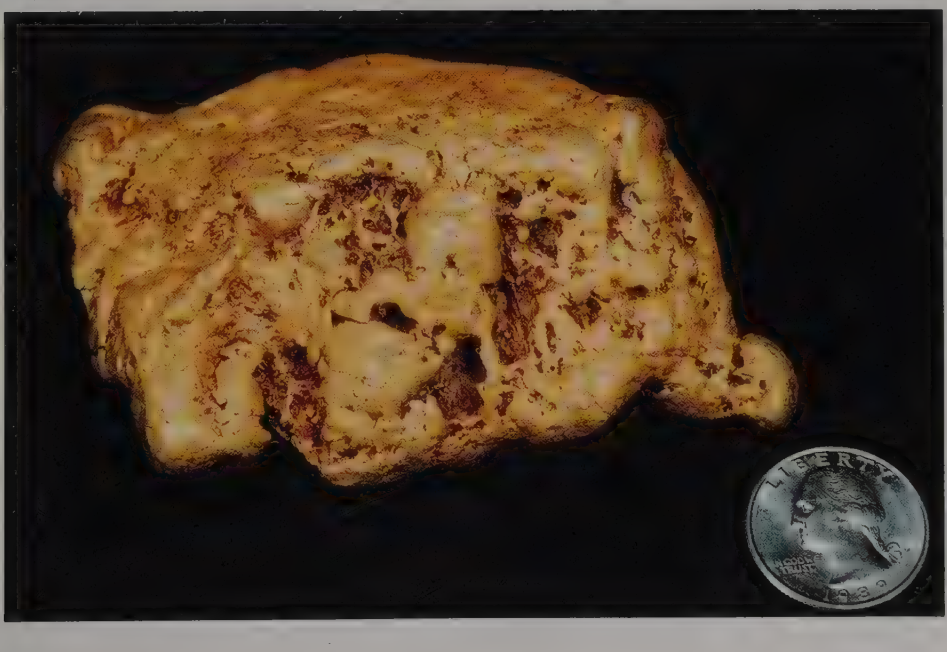
Lacey, Washington 98503

Stolen Nugget Recovered

On December 11, 1992, a 27.4-ounce gold nugget was stolen from the Mineral Museum at Montana Tech, in Butte, Montana. The 11.4-cm nugget, known as the *Highland Centennial Nugget,* was discovered in 1989 (Montana's centennial year) in the Stratton family placer mine on Cooley Gulch in the Fish Creek area of the Highlands near Butte. The Stratton family had mined the deposits since Fred Stratton's initial claim in 1892.

Two larger Montana nuggets were once known: a 15-pounder was found at Deadwood Gulch near Marysville in 1865, and a 7-pounder was found at Nelson Gulch near Helena a few decades later. Both have since disappeared. The 2-pound Highland Centennial Nugget, worth about $8,700 in bullion value but perhaps as much as $40,000 to a collector (according to Montana Tech President Lindsay Norman), is thus the largest surviving gold nugget from Montana and is a significant piece of Montana mining history.

Figure 3. **The Highland Centennial nugget.**



According to the *Montana Standard* (January 7, 1993), thieves attacked the museum vault over lunch hour, extracting some 60 screws to remove the metal bars supporting a thick Plexiglas window. Passing up a number of valuable gemstones, they took the big nugget and ran.

The break in the case came on the evening of January 1, when Highway Patrol Officer Bob Toombs arrested a man for driving under the influence on Iron Street near Interstate 15. The suspect attempted to trade information for his release, claiming to have held the nugget in his hand just prior to his arrest. This double-cross of his friends backfired, and he was locked up in the Butte jail, where he was questioned by detective Tom Green of the Butte Sheriff's Department. Acting on the information obtained by Green, and from other local tips, Anaconda-Deer Lodge police raided an Anaconda home and recovered the nugget.

The nugget will remain as evidence in the safe at the Anaconda jail until the legal proceedings have been concluded. Montana Tech President Norman says that security will be improved at the museum before the nugget is again placed on display.

Carleton College gets Kennedy Collection

Carleton College in Northfield, Minnesota has been given the extensive species collection of Fred C. Kennedy of Rochester, Minnesota. The collection consists of 3,593 specimens representing about 3,500 species, 96% of all the known mineral species.

Kennedy spent more than 50 years building the collection, which contains more species than either the Harvard or the Smithsonian collections. Despite its comprehensive nature, the Kennedy collection occupies a surprisingly small amount of space: four metal cabinets, each about the size of a double-drawer file cabinet. The largest specimens are no more than an inch or two in size, and many are microscopic. Shelby Boardman, Carlton professor of geology noted that, "to the naked eye, most specimens look like nothing; but others are quite spectacular."

To help organize the collection, Kennedy has also provided Carleton with a computerized data base listing species, locality, replacement cost and other information. Although he has given over the bulk of the collection to the college, Kennedy plans to continue acquiring new species, and will periodically turn over these additions to Carleton.

Because of the generally small size of the specimens, the collection will probably not be widely used for teaching purposes in Carleton geology courses. However, students will have access to the collection for study, and Boardman hopes to open the collection to outside researchers.

"We have to decide on the ground rules," said Boardman, "but one of the things I would like to do is let mineralogists and crystallographers examine the collection and perhaps, under special circumstances, be allowed to 'check out' some of the materials. There may be a substantial number of people who are interested in having access to a resource such as this."

Carleton College is located at One North College Street, Northfield, Minnesota 55057.

Letters

MORE ON EARLY COLLECTIONS

Our mineralogical memorabilia include a few antique collections contained in a trunk or box, and one of them (Fig. 1) is very similar to that owned by the Department of Geology of the Rand Afrikaans University, Johannesburg, and described by Dr. Bruce Cairncross in his letter to the *Mineralogical Record* (v. 23, p. 445).

Our collection is housed in a fine wooden box measuring 16.5 x 26 x 39 cm, slightly larger than the metal trunk described by Dr. Cairncross. It contains three trays, two of them holding 20 specimens each in 7 x 5 x 1.5-cm cardboard boxes, and one holding 30 specimens in 6 x 4 x 1-cm boxes. There are 70 specimens all together, some of them minerals and some of them rocks.

The label on the lid (Fig. 4) is similar, but not identical, to that described by Dr. Cairncross: the reference to the 1884 exhibition award is there, but the name of the company is "Thomas D. Russell" rather than "Russell & Shaw," and also the street address and a few other details are different.

A label with each specimen (Fig. 5) shows the firm's name and address. All labels are in the same handwriting, which is different from that in the Rand Afrikaans University collection.

Some of the labels bear notes written in French by a different hand. Since we purchased this collection in Germany, one can see it has traveled somewhat across Europe, while its companion traveled all the way to South Africa!

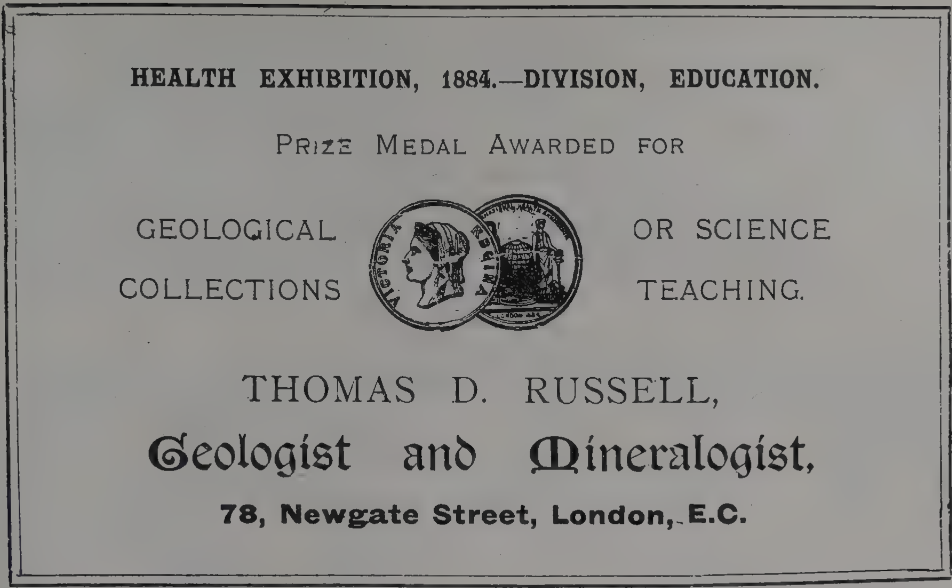
Another collection in our possession (Fig. 6) is housed in a wooden box measuring 37 x 29 x 12 cm; it contains four cardboard trays with 64 specimens each in 4 x 3-cm partitions (256 specimens in total). The specimens have no labels; a number on each of them relates the specimen to a list glued to the inside of the lid. The list is handwritten in English and gives the name of each mineral. Locality information is scarce or absent.

A third collection (Fig. 2), also in a wooden box, 36 x 28 x 11 cm, includes 100 mineral specimens (50 in the bottom of the box and 50 in a wooden tray). A companion collection consists of 25 isolated crystals, mounted on wooden pegs glued to the bottom of a 24 x 20 x 7-cm box (Fig. 3).

Figure 1. **Thomas D. Russell mineral and rock collection.**

Figure 2. **Austrian collection of 200 minerals (label printed in Graz).**

Figure 3. **Austrian collection of 25 single crystals.**


HEALTH EXHIBITION, 1884.—DIVISION, EDUCATION.

PRIZE MEDAL AWARDED FOR

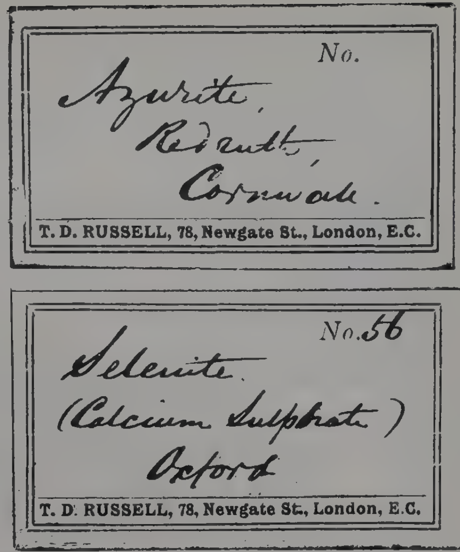
GEOLOGICAL COLLECTIONS OR SCIENCE TEACHING.

THOMAS D. RUSSELL,

Geologist and Mineralogist,

78, Newgate Street, London, E.C.

Figure 4. **Label from inside the lid of the box in Figure 1.**


No.

Azurite, Redruth, Cornwall.

T. D. RUSSELL, 78, Newgate St., London, E.C.

No. 56

Selenite (Calcium Sulphate) Oxford

T. D. RUSSELL, 78, Newgate St., London, E.C.

Figure 5. **Specimen labels from Russell Collection.**

Figure 6. **Victorian mineral collection. Can anybody shed any light on this and the other collections?**

The specimens in both of these collections are numbered but, unfortunately, no mineral or locality list has survived along with them. An amusing color lithograph inside the lids reads in English, German and French: "Collection of Minerals—Trade Mark." The name and address of the printer (Lith. Th.Schneider's Weu Preshun, Gratz) indicates that these sets were assembled in Austria.

All of the specimens in the four collections described above are relatively unspectacular, but they allow a fascinating glance at 19th century mineralogy, old localities, and old mineral and variety names. We feel that they deserve preservation, as an interesting historical footnote to our mineral collecting heritage.

We too would appreciate any further information which readers may have on the Russell Company and on the other such collections.

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DAMAGED ISSUES

As a charter subscriber to your excellent magazine, I look forward to each new issue for its content and the always outstanding photography. It is regretful, however, that on several occasions your publication is received in deplorable condition. Not only is your magazine treasured as an information source, it is also held in high esteem for its resale value, especially considering that each issue forms part of a valuable complete set. I don't know who is to blame for such damage, but I feel you should be made aware of what is happening, and take whatever steps may be necessary to correct it.

David S. Mudry
Amherst, Virginia

Today I received the *Minerals of Greenland* issue, which unfortunately arrived damaged. Within the last year or so, all issues that I have received have suffered damage of some sort—usually bent and creased corners, or cuts and scratches on the magazine surface. I consider each issue of the *Mineralogical Record* almost as valuable as each specimen in my collection. Can I have the *Record* mailed to me in a more protective wrapper? Would having it mailed first class (at additional cost) protect it better? Please let me know what options are available.

John King
Bowling Green, Ohio

Each time an issue is mailed out we shortly thereafter receive around ten or twelve requests for replacement of damaged copies. That's not bad on a mailing of over 6,000 copies, and certainly not enough to justify the thousands of dollars it would cost to mail all copies in a cardboard envelope.

Most damaged issues are the victims of postal system sorting machinery, or the individual mail carriers. A few are sometimes damaged by the machine at our printer's plant which bags each issue for mailing. If you have repeated problems with damage, it is most certainly due to your local post office.

Of course, different people have varying ideas of what constitutes significant damage. We cannot guarantee delivery of all regular subscription copies in super-mint condition; that is beyond our control, and beyond what anyone should reasonably expect in the delivery of a periodical.

Nevertheless, we have a great deal of sympathy for subscribers who love and collect the Mineralogical Record *so enthusiastically. Some people have suggested we should offer a custom-packaged subscription at twice the regular rate, using a heavy cardboard package for maximum protection. Better yet, you could wait until the end of the year and order a second (mint) set of the previous six issues at the cover price, to be shipped in a cardboard box. Or you could hand-select six mint copies when you visit our booth at the Tucson or Denver Shows, and hand-carry them home. What would be best and least expensive for the really meticulous collector would be to order a* ***two-year*** *subscription every year, with instructions to the Circulation Manager to mail out one subscription as usual, and then send to you a boxed mint set of the previous six issues every December. Then you'd have a working copy of each issue arriving when published, and a pristine collector set of each volume arriving at year-end. (Many people already do maintain a double subscription for a working set and a saving set.) So this is what we will offer. Call it the* ***Perfectionist's Special****: a double subscription for one year, the second set shipped mint at year end. The regular price of a two-year subscription will apply, giving significant savings over the cover price on the second set.*

The Editor

MICROMOUNT BOOK

While the help of many people is acknowledged in my book *The Complete Book of Micromounting,* nowhere does it mention the contributions made by Dr. Wendell E. Wilson as editor. I would like to correct that omission. Dr. Wilson spent many hours of labor in editing and laying out the volume, and its finished appearance says a great deal for his patience, perseverance and expertise. I owe him a debt of thanks for his help and for his dedication to quality in the final production.

Quintin Wight
Ottawa, Ontario

I'm ecstatic that Neal Yedlin's book on micromounting has been completed. Please hurry my copy to me. Enclosed is my personal check in the amount of $65.00.

I had written to you several years ago inquiring as to the status of Neal's unfinished book and you were kind enough to explain the circumstances. Mr. Desautels was still with us at the time, but it was unknown if the book would ever be completed. I am sure that the combined efforts of three outstanding micromounters will provide a lasting resource for the mineral collecting community. Please extend my thanks to Quintin Wight for his efforts and I look forward to receiving his book. Somewhere, Neal must be smiling.

Lloyd Kleist
Alta Loma, CA

KIPUSHITE

I received a letter recently from Dr. Pete J. Dunn of the Department of Mineral Sciences at the Smithsonian Institution, who nicely explained to me that I had incorrectly stated in my Black Pine mine article (vol. 23, p. 477) that kipushite equals veszelyite. Dr. Dunn points out that kipushite is a valid, established mineral species and is isostructural with philipsburgite, not with veszelyite, as I had written.

Dave Waisman
Republic, Washington

MINERAL COLLECTORS' COMPUTER FORUM

We mineral collectors on CompuServe would like others to join us and discover a new kind of communication and its power. Learn faster, cheaper, and easier many things you most want to know about earth sciences and hobbies, and most any other subject as well. Arrange specimen trades and sales with economical speed and ease. Enjoy chatting with fellow collectors around the globe.

On CompuServe, we have recently started meeting in the Geology section of the SCIENCE forum. We range from novice collectors to professional scientists. Among us are a wide variety of interests, including minerals, fossils, gems and geology. We are from all over the nation, and looking for more members, especially among CompuServe's rapidly growing overseas membership.

This is a truly unique communications medium. It is as fast as faxing, can be cheaper than ordinary mail, and if you want, it is "on display" like a *classified ad in an instantaneous worldwide newspaper*. Programs, documents, databases, and spreadsheets can be transmitted in ready-for-computer-use form. Messages can be directed to a person, not a place, so travelers can receive it anywhere they have the use of a computer with modem and a phone line. This medium is uniquely ideal for trading, buying, and selling specimens as well as exchanging information. In the short time since we became active, we have arranged numerous cross-country trades, given and received directions for collecting sites, helped each other identify minerals, made available free mineral/locality identification databases with instructions, and answered newcomer questions from "does heat turn topaz blue?" to "how can I help teach my new geology class without much money?"

Computers are growing cheaper and easier to use all the time. Have you priced them lately? CompuServe is also rapidly growing in ease of use, range of services, and membership, especially overseas membership. If you have not tried it within a year, you have not tried it. Computers have other uses for many purposes, including more uses for the rockhound in identifying specimens, locating them, and organizing a collection. Join our group and learn these and other uses for your computer as well! CompuServe has unique uses in many other areas as well. If you have a problem, you can at the press of a button join a worldwide club of people who know about the subject and ask the entire membership your question in a single step, often getting several answers within hours.

A computer forum is a sort of electronic meeting area, including electronic equivalents of (1) bulletin boards where conversations can take place with (optionally) anyone in the world able to look on and join in, (2) libraries of "reference book" files and programs available for anyone to get a computer-ready copy over the phone, and (3) conference rooms where groups of people can "meet" for real-time conversations, like a conference call (but cheaper).

When our mineral collectors' forum grows up, you might see a member in Australia informing a mineralogist in the U.S. about a new mineral find, and someone else in Germany joining in unexpectedly to ask about trading for specimens from the new find. If you will be traveling, post a message asking what mineral-collecting opportunities are available where you are going and see if some locals answer.

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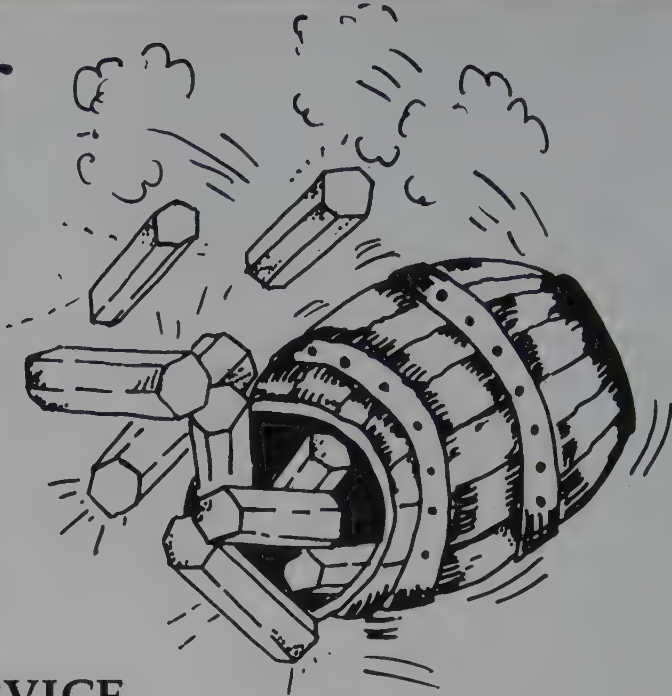

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