ARIZONA-V

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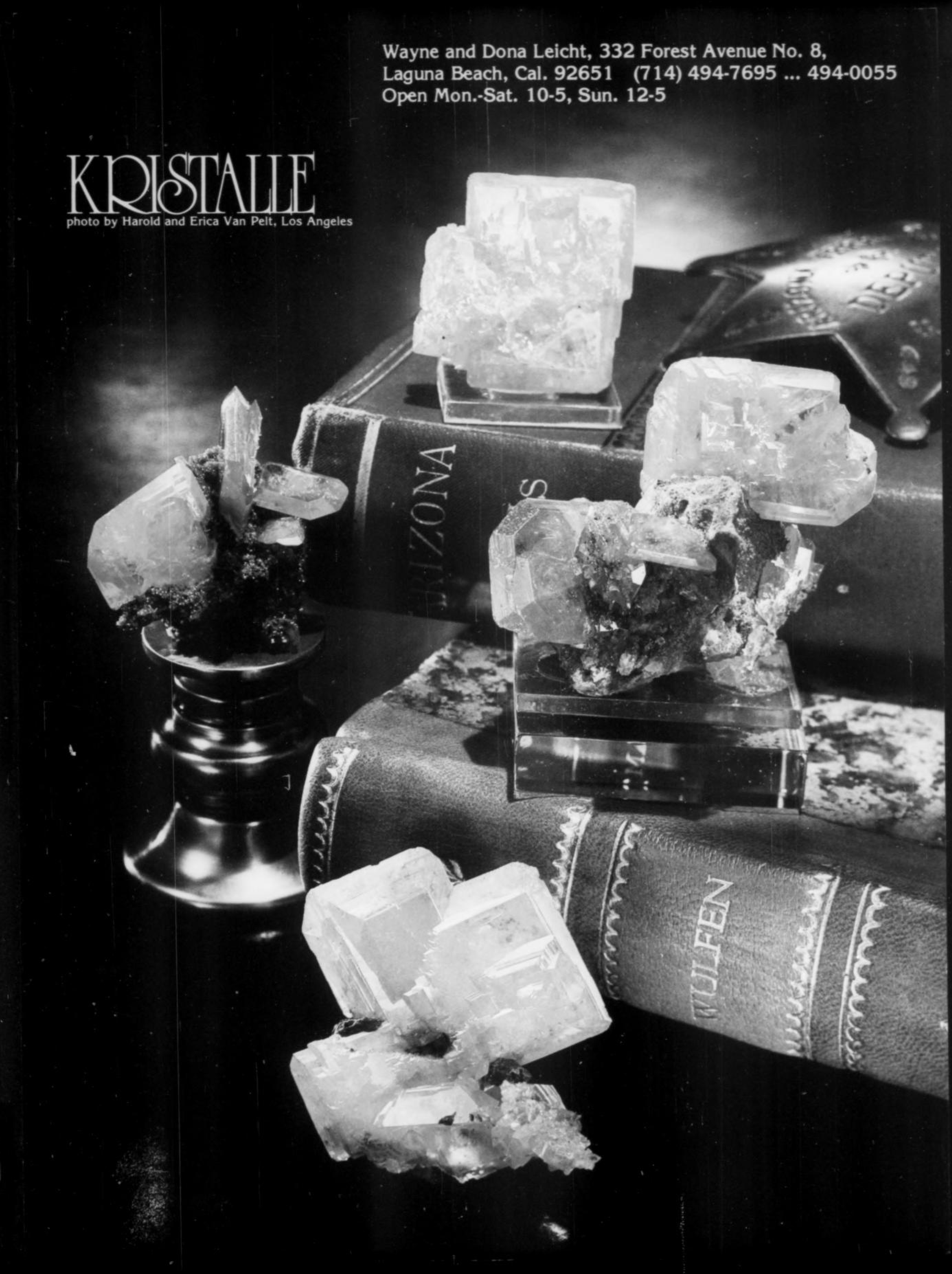
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COVER: COPPER from the Ray mine, Arizona. The specimen is 3 inches wide, and was the winner of the Best Copper Cabinet Specimen and Best Arizona Copper at the 1977 Tucson Show. Evan Jones collection; photo by Wendell Wilson. See the article beginning on page 311 for more on the Ray mine.

notes from the EDITOR

ARIZONA

This issue is the fifth (and last) in our series of special issues on the mines and minerals of Arizona. During the years before *Arizona-I,* about two issues-worth of articles and columns on Arizona were published in the *Mineralogical Record.* Therefore, the total Arizona canon, so to speak, amounts to the equivalent of about seven issues. In that space we have covered or mentioned more than 170 Arizona localities (plus an additional 135 *lost* mines) from which have come approximately 400 different species. Quite a few of those species are represented by attractive, high-quality specimens. In fact, we've published color photos of more than 200 Arizona specimens, including a dozen cover photos.

Whereas it's true that the most popular Arizona minerals are, for the most part, limited to the secondary minerals of lead and copper deposits, the other types of species (pegmatite minerals, uranium minerals, meteorites, etc. etc.) are generally to be found somewhere in Arizona as well. In addition, a great many Arizona localities are still open to collecting and the potential for new discoveries is high. All things considered it seems an inescapable conclusion that, for the mineral collector, Arizona is one of the important places on the map.

But are we finished? Probably not. Although we will not accumulate articles into special issues anymore (one has to draw the line somewhere), there will most likely be more on Arizona mines and minerals providing that people are willing to write the articles for us. A number of interesting and even great localities remain to be covered. Anthony *et al.,* in their *Mineralogy of Arizona,* list over 600 species, including minerals from such famous localities as the Old Dominion mine, the Morenci-Metcalf district, the San Manuel mine, the Inspiration mine, Monument Valley, the United Verde mine at Jerome, the Harquahala mine, the Total Wreck mine, and literally hundreds of others from the well-known to the obscure. Continuously being added to the total are the newly discovered occurrences. It is interesting to note, incidentally, that the potential is much higher for new discoveries but Arizona has so many well-known occurrences that it's difficult for collectors to tear themselves away from these long enough to go exploring.

In any case, there is still much to be written regarding Arizona. As for the past, a comprehensive Arizona index for the Arizona issues and all previous issues of the *Mineralogical Record* is provided here for easy reference to what has already been written.

I want to extend my thanks to all of the authors who graciously contributed well-written and well-researched articles to the Arizona issues; most of these articles required no small amount of time, effort and expense to compile. In addition I would like to thank our special donors, including Randolph Rothschild, for making possible the many color photographs without which the Arizona issues could not have done justice to the subject. *Arizona-V* comes to you in color through the generosity of our anonymous donor from Georgia.

ERRATUM

In the article on Malpais Hill, Arizona (v. 14, p. 109) offretite is misidentified as erionite throughout.

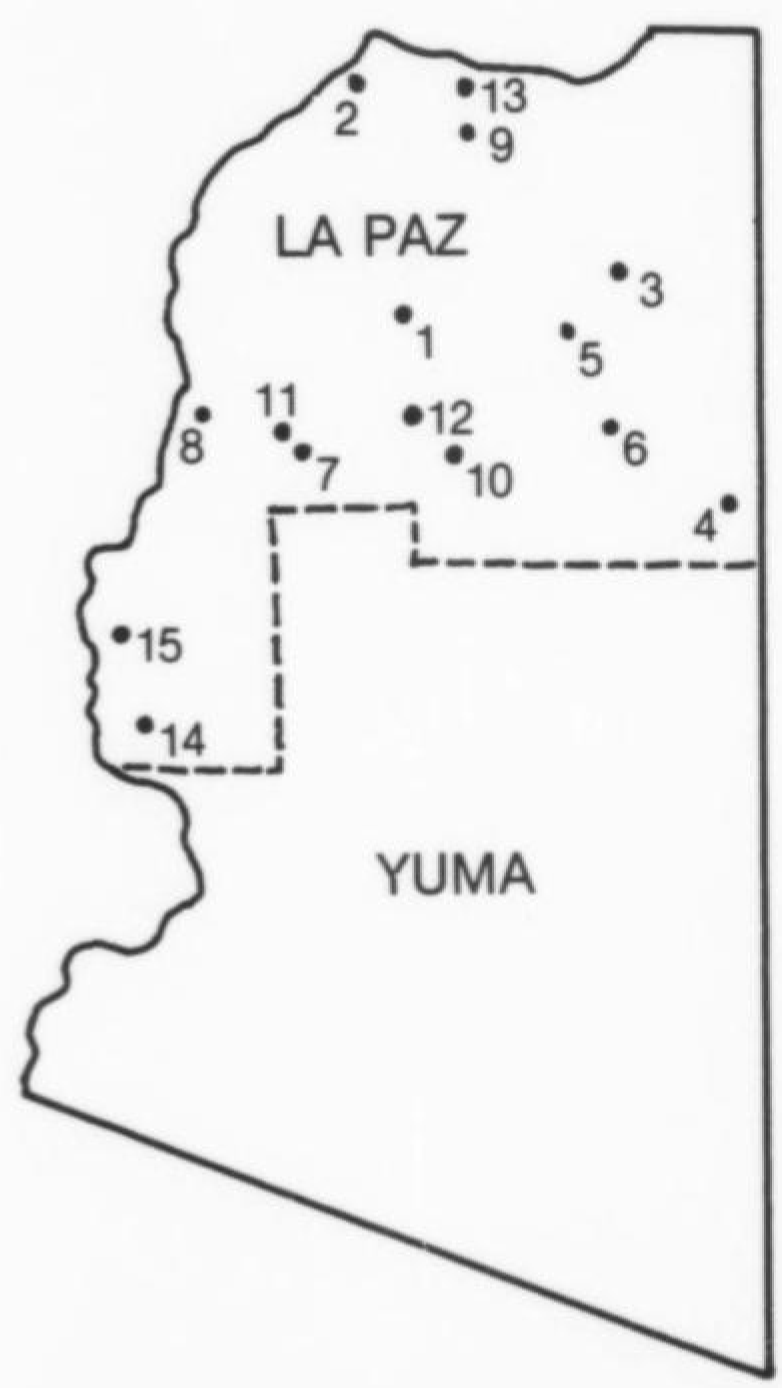
YUMA COUNTY NAME CHANGED

Is nothing sacred? The famous Red Cloud mine is no longer in Yuma County, Arizona. Residents have voted to divide the county in two, the northern half (more or less) being renamed as the new county of La Paz. So now the correct locality name will have to read: "Red Cloud mine, La Paz County, Arizona."

Other mines, mining districts and localities that are now in La Paz County include:

1. Bouse
2. Cienega
3. Cunningham Pass
4. Eagle Tail
5. Ellsworth
6. Harquahala
7. La Cholla
8. La Paz (Weaver)
9. Midway
10. New Water Mountains
11. Oro Fino (Middle Camp) (including Veta Grande claim)
12. Plomosa
13. Santa Maria
14. Silver (Eureka) district (including the Red Cloud, Hamburg, Princess and Melissa mines)
15. Trigo Mountains

The common practice regarding labels in collections is to leave the old locality name unchanged. Newly acquired specimens are given the most up-to-date labeling, but their original labels are retained as well. In any case, all specimens collected in La Paz County from this time forward should be so labeled.



Location map showing mines, districts and localities in newly-created La Paz County.

Lost Mines of Arizona

by **Wendell E. Wilson**
The Mineralogical Record
P.O. Box 35565
Tucson, Arizona 85740

"I was now on the borders of a region in which the wildest romance was strangely mingled with the most startling reality. Each day of our sojourn brought with it some fabulous story of discovery or some tragic narrative of suffering and death."

J. Ross Browne
Fort Yuma, Arizona, 1864

INTRODUCTION

The mountains and plains of Arizona are vast, complex, well mineralized and largely uninhabited even today. No one would dare to suggest that Arizona has given up all its secrets, and that no deposits or mineral occurrences remain to be found. Clearly there must still be orebodies out there waiting to be discovered and developed. If mining companies did not believe this they would not employ exploration geologists. According to legend, more than 130 valuable deposits were found once, and then lost. It is not unreasonable to suggest that some of these legends are true, that a number of deposits presently unknown actually *were* found at one time, and subsequently all knowledge of them was lost.

The literature regarding lost mines in Arizona (and in many other states) is large and relatively unscholarly. It is nearly impossible to verify or refute the various data given—fact and fiction have blended together. This, of course, contributes to the mystery and fascination of lost mines. And even if one chooses to believe that all accounts of lost mines are pure fabrication, they are nonetheless part of the folklore and oral tradition of mining in the Southwest.

People today living in densely populated areas might well find it difficult to understand how something as seemingly obvious as a mine can actually be lost. However, residents of the Southwest who are familiar with its intricate topography and extensive, un-

Did the Jesuit padres of the Tumacacori mission supervise mining in the Santa Ritas? Probably not, but lost mines may be up there anyway.

populated areas understand perfectly. Under certain circumstances it wouldn't be that difficult to lose one even today.

There were additional factors which contributed to the misplacing of valuable deposits: for example, few maps were available in early Arizona. Today we take maps and even roads for granted. But try to imagine traveling for months across many miles of mountains and deserts without a map or a road to guide you, and with little, if any, general agreement on the names of various topographic features and natural landmarks. It would be difficult enough to keep from getting lost and to find your way back to a discovery . . . but try to explain to *someone else* how to get there!

Another important factor in the losing of mine locations was the heavy loss of life among prospectors. Bandits were common, hostile Indians were more common, and running out of water was a serious concern. In addition there was the occasional natural death, made more likely by the absence of doctors and hospitals. With law and order far away, the wise prospector kept his discoveries to himself and rarely filed a claim in Arizona up until the 1870's. So, if he died suddenly, the information on its location died with him.

Lost mines are, of course, mineral deposits and are therefore of some interest to field collectors as well as prospectors and historians. The purposes of this article are: to present some historical background information which will help to put lost mine stories in better perspective; to recount a selection of these stories; and to provide a thorough compilation of Arizona mine names with keys to the literature.

HISTORICAL BACKGROUND

Indian Problems

The Apaches managed to retard prospecting and mining in Arizona until the 1880's. Despite the abundance of cinema and literature concerning the Indian wars, many people do not fully realize how different the Apaches really were from other Arizona Indian tribes. Most Indian tribes fought only when necessary for political reasons, for survival, or to make a point. But to the Apaches fighting was a way of life before the white man arrived. Tough, militant nomads, they were the scourge of the Southwest for centuries, terrorizing other Indians, Mexicans and Anglos with equal efficiency. They made their living almost exclusively by plunder, and were masters of guerrilla tactics and skirmish fighting (Watkins, 1971). Subduing them was a job that had proven utterly beyond the Spanish, and it took the American Army more than 40 years.

No small number of known deposits were abandoned because of the Apaches. The Pima Rebellion of 1751 drove out many miners as well, and records were lost. Relocating some of those mines might be especially difficult because the Apaches are said to have *filled in* many shafts and adits and camouflaged them with rocks and desert vegetation.

Although there were indeed friendlier tribes in Arizona, the Indians in general had no use for gold and silver, other than the occasional trade of a nugget for a blanket or supplies. They were intimately familiar with the land, however, and knew of deposits. J. Ross Browne (1869) wrote that he saw palm-size masses of gold brought in by prospectors who had been assured by Indians that the "heavy yellow stones" littered the ground in certain places. But the Indians could rarely be persuaded to reveal the locations. "Why should we?" Browne quoted them as saying. "You are already taking our country from us fast enough; we will soon have no place of safety left. If we show you where these yellow stones are, you will come here in thousands and drive us away and kill us." True enough. Nevertheless, some deposits actually were found and revealed by Indians; the Vekol mine, for example, yielded several million dollars in silver to the fortunate confidants of local Pima Indians.

The Spanish Period

Hostile and semi-hostile Indians play a large part in lost mine tales from the 1500's to 1890 or so. Other factors are related to whether the stories are set before or after the American annexation of Arizona. A fair amount of mining took place in Arizona during the years of Spanish occupation (from de Niza's expedition in 1539 until Arizona's acquisition by the United States in 1848–1852). Records from this period are almost non-existent, and I have been unable to locate any systematic study of Spanish-period mining in Arizona. Such a lack of hard information makes fertile ground for legend.

Miners of the Spanish period were generally looking only for gold and silver deposits. They worked in relatively small groups, quickly removing and processing easily accessible ore and then making a quick departure before their luck with the Apaches ran out. The Jesuit missionaries of the period established missions and organized the more peaceable tribes around agriculture and cattle raising. The proximity of the padres to the mines worked against them, for it was assumed that they must be involved in mining themselves.

The King of Spain issued three decrees (in 1592, 1621 and 1702) calling upon the Jesuits to cease their mining of gold and silver in New Spain (Egerton, 1974). Finally, in 1767, the king ordered all 678 Jesuit friars rounded up and shipped back to Spain for their disobedience (Polzer, 1968). It is noteworthy that the king's troops found nothing but poverty at the missions. And a few years later the King's Council ordered the destruction of all records pertaining to the imperial debacle, probably because the King had been proven so disastrously wrong in his conclusions.

Nevertheless, this was a rumor that would not die. The populace could draw one of two conclusions: either the Jesuits did no mining and were therefore innocent, *or* they concealed their covert mining operations and buried their accumulations of gold and silver before being expelled, in anticipation of returning. Human nature being what it is, many Mexicans chose to believe the latter.

When Arizona passed to the United States, American prospectors entering the region found (a) abandoned missions surrounded by (b) abandoned mine workings. They too concluded that the padres must have been the controlling force behind the region's mining. This rumor probably constitutes one of the greatest injustices of history; no documentation of Jesuit mining has ever been found. Readers should bear this in mind when reading stories of lost Jesuit mines (however, the mines themselves could in fact exist, even if the friars were not actually involved). A good example is the story of the Lost Treasure of the Padres, supposedly a great mass of gold (between 80 and 2955 mule-loads) which the Jesuit padres of the Tumacacori mission had taken from three great mines: the Purisima Concepcion, the Virgin of Guadalupe, and the Tumacacori. This they hid in the Virgin of Guadalupe mine and blasted it shut before their recall in 1767. Such stories persisted after the Spanish left. One cynic wrote in the *Tombstone Prospector* (September 19, 1909): "About three times a year treasure hunters suddenly discover that they have the key to the situation, and dig up part of the country. This has continued until holes are to be found all over the district."

The American Period

There is practically no mention of the clergy in stories from the American period. Instead the principal individuals come from a wide variety of occupations and nationalities, as was characteristic of the general population at that time. Following the conclusion of the Indian wars in 1886, the influence of Indians in these stories nearly disappears as well.

When the Spanish gave up Arizona in 1848–52, the land was still essentially untamed. Indians had control of a large percentage of the territory, and vast areas were unmapped and unexplored. There were still a great many undiscovered outcrops of rich ore, so obvious that the first white man to enter a valley could not help but notice them even from a distance (as at Bisbee and Ray). Unfortunately, nothing of the sort remains today. It must have been fascinating indeed to be the first members of an advanced culture to see highly mineralized but virtually unmined territory as most of Arizona was in 1850. Spanish mining had been concentrated in the southernmost areas, and then only as minor surface workings or small excavations in search of high grade, easily removable gold and silver. A great deal was left behind, and prospecting from 1850 to 1900 was primitive at best (no topographic maps, aerial photos, geochemical analyses other than assaying, and no systematic exploration by large, well-organized mining company staffs). It is not too surprising that some early discoveries were lost.

SOME HAVE BEEN FOUND

There are always doubters with regard to stories of lost mines. But some of those stories are unquestionably based on fact because some of those mines have actually been found in modern times.

The Lost Breyfogle mine, for example: When Breyfogle dragged himself out of California's Death Valley in 1862 he was carrying a bandanna-wrapped handful of gold specimens. His partners had been killed by Panamint Indians, and he had wandered half-crazed with thirst and sunstroke for uncounted days. During his wandering he found a rich ledge of gold and had enough presence of mind to collect samples before moving on. Despite many searches he was never able to find the gold ledge again. But he had the specimens. George Hearst, father of William Randolph Hearst, obtained a piece of Breyfogle's gold and had prospectors looking for two years without result. Now the surprise: in the early 20th century a strike of gold was made near Breyfogle's search area, across the State line at Johnnie, Nevada. Trace element analysis of Breyfogle's gold samples proves them to be *identical* with Johnnie ore (Hitt, 1982). Somebody found Breyfogle's lost gold ledge after all . . . the story which many had doubted in Breyfogle's time turned out to be perfectly true.

Then there was the Lost Wheelbarrow mine. Two grizzled prospectors were searching the mountains north of Potlatch, Idaho, in 1883. They found a deposit so rich that their crude hand-methods of mining soon yielded nearly 1000 ounces of gold. At this point, greed overcame one partner and he murdered the other. To conceal his crime, he pushed the body into the short adit and blew it shut with dynamite, leaving only a whiskey-barrel wheelbarrow to mark the spot. Years later, after having spent the gold, he returned but never could find the spot which natural weathering and overgrowth had further concealed. So stood the legend, until an Associated Press story dated April 16, 1940 (quoted in Storm, 1946) reported on a discovery made by C. Landis Treischler. He had found a barely discernible trail in the mountains and followed it to a site where he found the weathered remains of a wheelbarrow made from the staves of a whiskey cask. A little digging near a caved tunnel mouth revealed first a human skeleton, then an 1875-model rifle. After mucking out the tunnel for only 22 feet he encountered ore running nearly 100 ounces of gold to the ton. The announcement was made by L. J. Moore, mine manager . . . the story of the Lost Wheelbarrow mine had been true after all.

There are others. In 1950 a Nevada prospector brought some ore samples in from the Jarbidge area – subsequent analysis (Hitt, 1982) proved these to be identical with samples from the Lost Sheepherder mine. The *Mining Record* for March 19, 1942, reports the finding of the Lost Tonto Trail Copper lode in Arizona. Discovery of one of the Lost Peralta mines in Arizona's Superstition Mountains was reported in the *Los Angeles Times* (March 27, 1940) and *Los Angeles Daily News*. It would be interesting to see the results of an exhaustive search of literature and newspapers regarding the various lost mines that have been rediscovered.

PROBLEMS FOR THE SEEKER

The problem of greatest concern in the realm of lost mine literature is the sneaking suspicion that some stories are partially or entirely fictitious. Tale spinners and legendeers can attract rapt attention and even make a profit selling books on lost mines; there is a natural temptation to embroider and fabricate for personal gain. Even mining companies such as the old Arizona Aztec Mining Syndicate are thought to have perpetuated or invented false stories to stimulate potential stockholders.

Another problem is in identification. An abandoned mine is generally devoid of much real evidence regarding the original miners . . . how do we *know* it's really the Lost Goosebump mine?

Then there is the problem of knowing whether or not a particular lost mine has already been rediscovered. It may have been stumbled upon and mined out later by someone who did not realize he'd found the famous Lost Bullfrog mine. Or perhaps he knew, but did not want to report it for "tax purposes."

Finally there is the possibility that the lost mine was mined out *before* it was lost. Hence there will be no prize for the finders.

A SELECTION OF STORIES

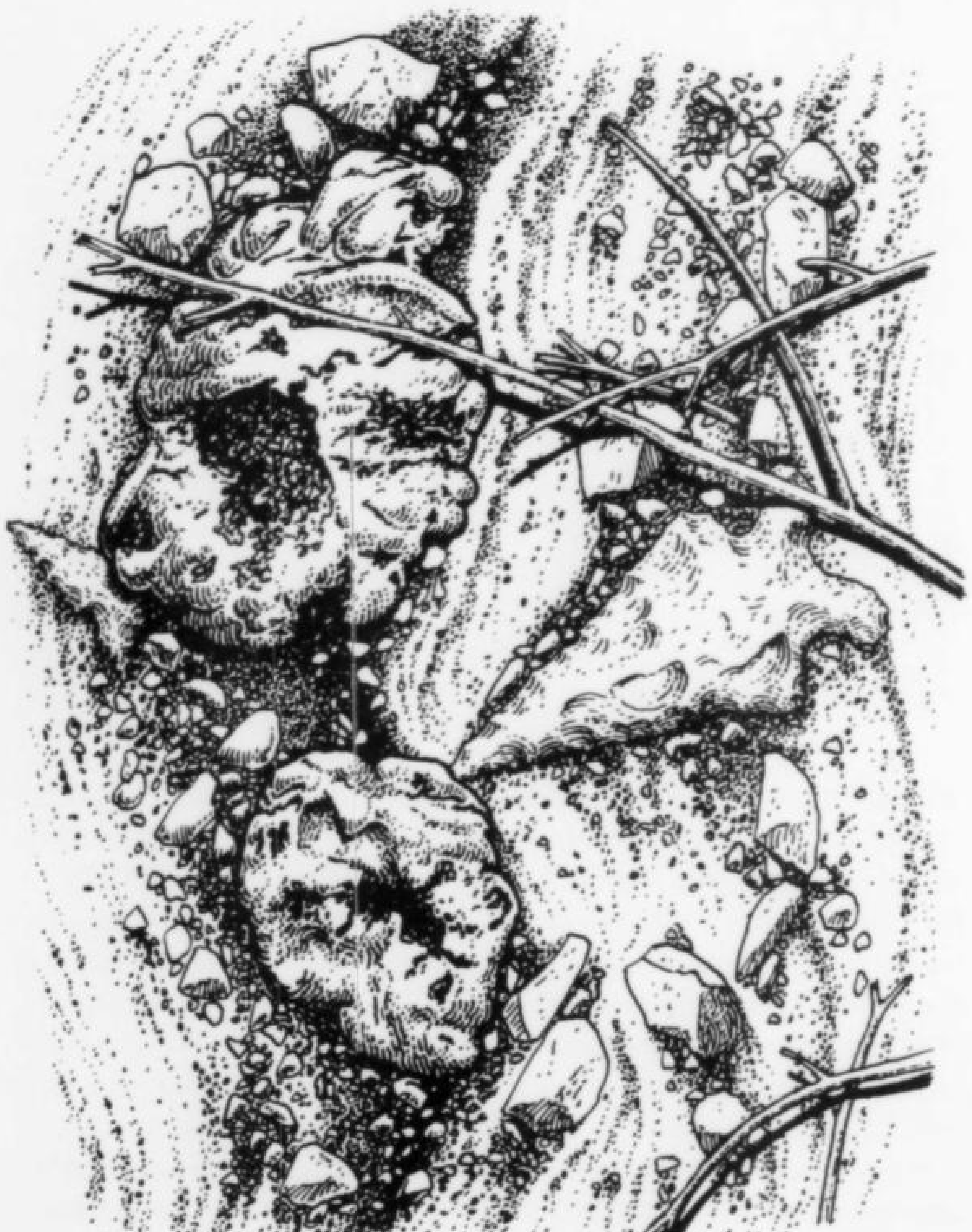
The following accounts of lost mines were all culled from the sizeable literature listed in the bibliography. In some cases there is more than one version of the story relating to a particular mine; these have been more or less composited here. (In fact, there are sometimes significant variances in the same story told by the same author at different times!)

Not included here is a discussion of the most famous one, the Lost Dutchman mine. I have chosen to omit it because it is a long story which is widely known and which has been covered at great length in many books devoted solely to the Lost Dutchman (see Probert, 1977).

Indian Gold and Silver

As mentioned above, Arizona Indian tribes were not altogether unaware of deposits on their land, and occasionally used easily collectible samples for barter. Realizing that the metals had some value to themselves, and an overpowering value to Anglos, they were usually uncooperative in revealing the locations of deposits. Some examples:

Felix Aubrey, a French-Canadian guide, passed through Coyotero Apache country near the Mogollon Rim in 1853. He was met by a group of Indians desiring to trade some gold they had for clothing, food and tobacco. These Indians, he observed, were using gold in place of lead for their bullets, and obviously had a good source somewhere. Browne (1869) also saw solid gold Indian bullets. When pressed about the exact location, they only pointed toward the Rim and made signs to indicate that the nuggets had been collected loose on the surface. Aubrey recorded in his journal that he received $1500 (about 75 ounces or 6 pounds) in gold for some castoff rags of clothing.



Apaches found gold at a number of places . . . but they wouldn't say where. They may even have covered over some deposits to camouflage them.

The Cibecue Apaches also had gold to trade, and their chief, Al-che-sa (who was the mediator at Geronimo's surrender to General Cook in 1886), it is said, always carried plenty of nuggets which he generously traded with local Anglos. In one instance he traded a 25-ounce nugget for $10 worth of supplies, but only laughed when asked about the source. Some feel his source was identical with the Lost Adams Diggings.

A similar story is told about Del Shea ("Red Ant"), chief of the Tonto Apaches in Tonto Basin. His people were also long known to be in possession of trading gold, but in this case it was gold in white quartz which the Indians mined from a small lode. Camp Reno was a military outpost of Fort McDowell which had been established at Reno Pass to block Apache raiding parties. The camp was abandoned in 1870, and soldiers returning to Fort McDowell crossed paths with a couple of recently discharged troopers who said they were heading up to Tonto Basin to find the Apache gold deposit. They were warned of the danger inherent in trespassing on Apache territory, but proceeded anyway and were never seen again. Around 1875 two sheepherders found the bones of several men scattered on a northern slope of Mt. Ord; two of the bodies were in the remnants of military uniforms, and samples of gold in white quartz were found in their packs.

Numerous tales surround Dr. Abraham Thorne, who was captured by Apaches and forced to treat their sick and wounded for several years. During this time he was shown their secret gold placer, but after his release he could never find it again. This deposit is sometimes identified with Geronimo's gold; while held prisoner at Fort Sill, Geronimo attempted to bribe a guard with the location of his gold mine in exchange for freedom. In some versions of the story, Geronimo explains how the deposit was temporarily taken from the Apaches by a group of Spaniards in the 1700's, but was subsequently reclaimed. It was located in Sycamore Canyon and is sometimes referred to as the Sycamore mine. The various locations given for Dr. Thorne's mine and Geronimo's mine are so numerous that there is no point in listing them here.

An Englishman named Reginald Grey married a Yuma Indian woman and learned of an old mine known to her tribe. But, fearing tribal retribution, she would not tell him where it was. Finally reaching a compromise, she agreed to go there by herself periodically, remove gold ore, and bring it back for him. This she did for quite some time, but on one trip she failed to return, and legend says she was killed by her own people. What came to be known as the Lost Squawman mine is supposed to be located near Baker's Tank in Yuma County.

Travelers in Navajo country near Monument Valley noticed that the Navajos wore silver jewelry which they made themselves. Mitchell and Merrick were two former soldiers who had served in northern Arizona with Kit Carson; around 1875 they decided to prospect Monument Valley and the surrounding area until they found the Navajos' source. Apparently they found it because when their bodies were discovered there were packs of rich silver ore nearby. The Navajos claimed innocence . . . they said Paiutes were responsible. Soldiers searched for the mine but never found it. In the 1930's an Indian named Hoskaninni-Begay told Charles Kelly (later superintendent of Capitol Reef National Monument in Utah) that his father and several other Navajo elders had known where the mine was and had made silver jewelry from the ore. But eventually the elders died, one by one, and the secret of its location was lost even to the Navajos.

Somewhere, in a half-fallen cairn of rocks, is Billy Orme's six-shooter. Whoever finds it will also have found his lost silver vein.

The Lost Six-Shooter Mine

Jacob Hamblin knew that his partner Bille Orme was no stranger to drink. So, when he sent Billy off to Ehrenberg for supplies that day in 1889, he made him promise to stay sober until the goods were safely loaded on burros and headed back to their mine at Bullard Peak. Billy kept his promise. When the pack train was ready to leave Ehrenberg, he told the Mexican packers to go ahead without him and he'd catch up later . . . it was time for some serious drinking. From that point on, Billy wasn't entirely clear about what happened. He remembers coming to a wide arroyo one night a day or two out of Ehrenberg, still so drunk he could hardly stay on his horse. Slipping from the saddle, he slept awhile, until his horse woke him near daybreak by pulling on the reins (which Billy had wisely tied around his wrist). Reaching for a rock to throw at the annoying animal, he picked up a black chunk of heavy silver ore. Being a prospector, he recognized it immediately. Staggering to his feet, he erected a cairn of rocks for a claim monument and put his six-gun inside for identification . . . it had his name carved on the handle. Waving good-bye to what he now saw was a sizable ledge of ore, he hoisted another bottle from his saddle bag and set off again. Next he awoke from his stupor near a small ranch where he watered his horse, washed his face and mounted up again. The ranch wife later recalled seeing a man ride in and out looking almost asleep in the saddle. Finally Billy awoke at Culling Well station to find his pockets full of heavy silver ore . . . and his pistol missing. But his mind was fuzzy; where had he been? He vaguely remembered the watering tank and, yes, the silver ledge. Despite several years of searching, he never could find it again. Neither has anyone else.

The Lost Camel's Tinaja

John Gordon, a Scotsman, and Juan Perea, a Mexican, made an unlikely pair of prospectors. And they had not been doing well that summer of '71. Now they found themselves too far out on the furnace-hot Colorado Desert northeast of Yuma, with their food and water exhausted. Juan knew the desert well, though, and suggested they look for a *tinaja,* a natural depression in the rock that might still hold some remnant rainwater. But it was no use, they found nothing and collapsed in the shade of a large boulder to contemplate their fate. Looking out through the rising heat waves, Juan thought he saw something approaching. *Ai Chihuahua!* It was a camel! Stray camels had occasionally been seen on the Arizona desert ever since Lt. Beale's abortive attempt to provide the Army with better-adapted desert transportation. The camel passed by, and it occurred to them that perhaps the camel was in the process of locating a tinaja by smell. Sure enough, after following it a short distance they found one, and all three desert creatures gratefully quenched their thirst. Resting for a few minutes after their long drink, they realized that the ground around the tinaja was littered with gold nuggets. Hastily scooping up all the gold they could carry, they filled their canteens with water and headed happily for Yuma. Subsequently the tinaja dried up and became like the rest of the desert in appearance . . . they never could locate it again.

The Lost Whetstones Mine

Here's one the anthologists missed; it was published as a news item in the *Tombstone Prospector* (September 4, 1904) and reprinted by Winters (1972). It seems that in 1883 a prospector left Army service in Nogales and embarked on a hike to his home in Silver City, New Mexico. Climbing toward a deep pass in the Whetstone Mountains, he encountered increasingly rough terrain and was nearly out of water by the time he reached the crest. Below he saw the San Pedro River and headed down toward it in earnest. There were no trails, and he could not travel through such rough ground in the dark, so he had to reach the river by nightfall. But just over the crest he came into a gulch, the bottom of which was white quartz worn as smooth as glass and ending at a high falls. Running diagonally across the gulch was a seam of gold about 20 inches long. Using his prospector's pick he broke off a sample with difficulty; farther down the gulch he collected two more specimens loose, which consisted of about two-thirds iron oxide and one-third gold. Finally he reached the river in a state of extreme thirst and exhaustion. The next day he pressed on, planning to return in about four months. However, he contracted pneumonia and died within a matter of weeks, telling the story on his deathbed to a friend named Buell. Buell inherited the specimens, and traveled to Benson, Arizona, where he showed the gold around and then made a fruitless search for the deposit.

The Lost Adams Diggings

Adams had been making a modest living driving a freight wagon between Tucson and Los Angeles in the early 1860's. But in August of 1864 he was ambushed by a small party of renegade Indians near the Big Bend in the Gila River. He managed to hang on to a dozen horses, but lost everything else. Riding dejectedly into a nearby village of friendly Pima Indians, fate brought him together with a party of Anglo gold-hunters and an Indianized Mexican named Gotch Ear (because of a deformed ear). Gotch Ear had lived with Apaches and knew of a place to the northeast where much gold could be found. For the price of two horses, a saddle, two $50 gold coins, a red bandanna, a gun and ammunition he promised to take them all there and they could wait to pay him until after they had found the gold. Because the party needed Adams' twelve horses, they offered to make him leader of the expedition and he accepted.

The gold hunters rode out, crossed the Gila and Salt Rivers, then followed the Verde River. Turning eastward again, they crossed the Mazatzal Mountains and passed into the territory of the Apaches. At that time not a single white man lived in the country they were crossing, and not a landmark was known by name. After several days they crossed a canyon of castellated red sandstone and turned into a canyon marked by an abandoned Indian pumpkin patch, then out of the canyon and across a rugged basalt-flow plateau. Descending from the plateau, they picked their way toward a seemingly solid escarpment but, upon reaching it, Gotch Ear led them behind a large rock formation and into a hidden canyon. This, which Gotch Ear said was named Sno-ta-hay Canyon, was almost a perfect Z-shape in layout. After some rough going they entered a small valley containing trees, a stream and a small waterfall about midway. It was an unusual valley in that it was boxed at both ends, the stream passing underground at the terminus. Two hay-stack-shaped mountains overlooked the scene.

The stream was as rich as Gotch Ear had promised, and the men set to work. In a week's time they had constructed a small cabin and accumulated about 5,000 ounces of placer gold in a community cache under a flat hearth stone. At this point a group of Apaches appeared. They were of the Cibecue sub-tribe, a sullen and clannish lot that rarely mingled with other Apaches. They told Adams' group that they could stay where they were and dig, but they were not to enter the upper half of the valley because the Indian encampment was there. An uneasy truce was declared.

One day a member of Adams' group returned and made a present to Adams of a fine 5-ounce nugget, which he said he had dug out of an exposure above the waterfall. Adams chewed him out for endangering the peace with the Indians, but it was too late. Part of the group was ambushed at the canyon entrance and killed, most of the remainder were caught near the cabin and massacred by a force of about 300 Indians. Adams himself and a man named Davidson were in the canyon, between the two groups, and somehow escaped notice; but they watched the cabin being burned and their gold-filled hearth buried under smoldering logs.

For the next 13 days Adams and Davidson picked their way carefully out of Apache territory, trying to remain out of sight, and subsisting as they could. Finally they were rescued by an Army patrol from a military outpost that a few years later became Fort Apache. One more survivor, a man named Brewer, staggered into a New Mexican village after his own lonely trek of 14 days.

Adams found gold in Sno-ta-hay Canyon, and had a 5-ounce nugget to prove it. But, despite years of searching, he never could find that canyon again.

Davidson died shortly thereafter, and Adams spent much of his life organizing various search parties to locate the canyon again. But Adams had a singularly poor sense of direction, and never could find it. The story was widely circulated, Army soldiers were interviewed, newspaper articles written; Adams continued to tell the tale to anyone who would listen, showing for proof the big nugget that caused all the trouble (it was the only gold he managed to salvage, and he eventually sold it in Tucson for $92).

The Lost Adams Diggings have since become almost as famous in the Southwest as the Lost Dutchman mine. People have even searched for it by airplane. J. Frank Dobie devoted almost half of his 1928 classic, *Apache Gold and Yaqui Silver,* to information and interviews he accumulated over many years on the Lost Adams. It's still lost.

The Mine with the Iron Door

Most visitors to the annual Tucson Gem and Mineral Show probably do not realize that they are frolicking in the very shadow of a lost gold mine. It's up in the Santa Catalina Mountains, which dominate the northern skyline of Tucson. Anyone with a good pair of hiking boots and some extra energy can go looking for it.

Indians located the mine in 1698, as the story goes, and operations were supervised by Father Silvestre Velez de Escalante. He was a Jesuit missionary assisting Father Kino at the nearby mission of San Xavier del Bac south of present-day Tucson. The gold ore was so rich that it was hacked out with hatchets.

"Spanish documents" in Tucson indicate that, at the time of the Jesuit expulsion in 1767, many Papago Indians helped in storing smelted gold bars in the mine and sealing it with an iron door. The Jesuits then covered the iron door with rocks and earth, in the hope of returning when their difficulties with the king were cleared up.

But the Jesuits never did return to the Southwest; their place was taken by the Franciscans. Two years after they left, the little mining village near the mine, occupied mostly by Papagos, was attacked by the Apaches and wiped out. The remaining Indians in the area disdained gold, and the exact location of the hidden mine was soon forgotten.

In 1843, Col. Antonio P. Narbona discovered ruins in the Cañada del Oro area while pursuing Apaches. Gold was found in the washes (and can still be panned there in small quantities today). In 1870, men were making "12 to 30 dollars a day each" panning gold.

The most compelling account may be found as a letter published in the February 24, 1880 edition of the *Arizona Daily Star.* The writer was about to join two prospectors returning to the lost mine, which they had rediscovered on a nearly inaccessible mesa in the Catalinas. As evidence, the prospectors had with them about 100 pounds of gold dug from the mine. They related how they had hiked up Cañada del Oro to a box canyon, where they found partially destroyed steps leading up a steep cliff wall. Ascending the wall, they entered a natural cavern where they found the inscription "DOMINUS VOCISCUM," and proceeded out the other end to an isolated mesa. Three days of exploration on the mesa revealed extensive ruins and, finally, a rusting iron door half off its hinges. The letter writer, as he was preparing to leave with them to see the mine, recognized that the story might be only a lie, but said, "I tell you, those gold nuggets give us a good deal of faith." None of the three men were heard from again.

Some interesting developments have taken place recently. Around 1950 two men from Davis-Monthan Air Force base in Tucson reported finding parts of an old forge in the Catalinas; it was marked as having been made in Madrid in 1757. Just last year an Associated Press story published in the *Tucson Citizen* (August 14, 1982) reported that Ernest McCallister, mayor of the town of Kearny, claimed to have rediscovered the mine. He petitioned the Arizona Land Department for permission to excavate it (since the Cañada del Oro is now a part of Catalina State Park). The request was referred for comment to the Arizona Parks Department which, by a 3-to-2 vote, recommended *against* granting McCallister's request, even though he offered to give all artifacts to the Arizona Historical Society and to split any gold 50-50 with the state. Board member Priscilla Robinson opined that any digging at a historical site should be undertaken by professionals. Duane Miller felt the digging should be done by state personnel so Arizona could keep *all* the gold. Sam Ramirez said that state officials have neither the funds nor the inclination to go treasure hunting, and that Mc-

According to legend, gold was so thick in the lost Mine with the Iron Door that Jesuits and their Papago conscripts chopped it out of the vein with hatchets.

Callister should therefore be given his chance. The Arizona Land Department agreed with Robinson that excavation should be carried out by professional archeologists and historians; McCallister's application was denied on October 7, 1982. But, of course, the state cannot now excavate the site because McCallister prudently declined to give the *exact* location. Tales of lost mines do not seem to inspire cooperation among people.

The Lost Cinnabar Mine

Here's a story that's never been published anywhere, and it deals with mineral specimens. Back in 1946, George Burnham, a well-known California dealer (*Burminco,* Monrovia), was driving through Arizona and had some spare time to go exploring for minerals. He was driving from Roosevelt Dam toward Payson, and was not far from Payson when he passed a small service station/country store. A few hundred feet past it he turned off on a dirt road. About 100 yards down this road he passed an old mercury mine, a ground-level adit going into the hillside. Proceeding for 3 or 4 more miles, he encountered a cowboy on horseback, and stopped to chat. The cowboy pointed out an old mercury prospect off the road to the right, just about where the road turned to the left. This was in a relatively flat area with isolated hills. Upon examination he saw the prospect to be a vertical cut in a hillside, with white quartz dump material scattered over a 30 to 50 foot area beneath it. The prospect cut had exposed a quartz vein perhaps 8 inches thick, with quartz crystals growing toward the center from both sides. In vuggy areas he found isolated, untwinned cinnabar crystals ¼ to ⅔ inch in size perched on quartz crystals . . . one cinnabar crystal every 2 or 3 feet, and also in the dump material. In 1946 these weren't worth a great deal of money, but today they would be very valuable, especially to Arizona collectors. In any case, he rounded up all the easily collectible specimens, 12 to 15 crystals all together, and returned to his car. Continuing on the dirt road for 4 to 6 more miles, he found himself back on the main road below the service station, having made a wide loop around it. Passing the service station a second time, he continued on to Payson and eventually back home to California, where he sold all of the specimens and gave it no more thought. Many years later he tried to relocate the place, in the company of some Arizona collectors, but never could find the right dirt road . . . perhaps the roads have been changed since 1946. Richard Bideaux, the late Dick Jones, Bob Jones (with the help of a Boy Scout troop to cover more ground) and other experienced Arizona collectors have all searched for the site without success. It has also been searched for by airplane. Burnham himself searched for it again as recently as two years ago. The occurrence remains lost.

Some Others

There are many more stories; here are some of the shorter ones:

A cowboy named Harper was on his way to the doctor in Prescott one afternoon in 1905. Passing through Peach Springs, he stopped to rest in Daniel's Canyon where he accidentally discovered a rich placer deposit. He gathered as much gold as he could carry, then concealed the spot with earth and brush. To help relocate it he mounted a set of deer antlers in a juniper tree overhead, and continued on to the doctor. It turned out that he had a terminal illness. Before dying in the hospital he showed his brother the ore and told him how to find the deposit, but the antlers had apparently fallen off the tree, and his brother had no luck.

Palmer C. Ashley was helping his father work a low-grade deposit in Morgan City Wash between Wittman and Morristown. While his father was in Phoenix one day, young Ashley took a hike up the wash and found an outcrop of white quartz streaked with red and green stains. Taking a sample, he returned and showed it to his father, who recognized it as gold ore. They never were able to relocate the spot amid the many side-canyons. To make matters worse for later searchers, Morgan City Wash has never been marked on any map and, despite the fact that Ashley's find was made in 1934, no local residents remember which wash was called by that name.

In 1949 a couple of prospectors found a 180-ounce gold nugget in Greaterville Canyon. They immediately staked a claim and showed their nugget around in Tucson, then returned to the canyon. Shortly thereafter, a man riding by their camp found the two miners dead, and their gold nugget gone. Though the police could find no signs of violence, it is assumed they were murdered for the nugget (worth perhaps $80,000 today). Their claim has not been relocated either.

John Nummel, never too sharp mentally, managed to lose *two* mines without the help of Indians or anyone else. Nummel had quit his job as a miner at the famous Red Cloud mine in Yuma County, and was hiking to the La Fortuna mine about 40 miles south around the year 1900. While passing through the Chocolate Mountains he came across a ledge of native gold (which he named the Turtle mine, because of fossilized turtles nearby); but he never could retrace his steps. The second mine he found and lost was in 1928 or so when he was employed as a caretaker at the Red Cloud mine (which by then had been closed). Every day he would walk by a different route from his home near Norton's Landing to the mine. On one such hike he found a ledge of silver ore somewhere in the Trigo Mountains but, since he had walked so many routes through the mountains, he was never able to remember exactly where he found it.

The story of the Lost Orphans mine was related in a letter by Thomas Childs, Jr., son of the developer of the famous Ajo mine. His letter is on file at the Arizona Historical Society in Tucson. An epidemic of cholera had struck Caborca, Sonora, Mexico, making orphans of a young Mexican girl and Papago boy. Alone they began a long walk to Gila City, Arizona, where the boy had distant relatives. Along the way they stopped at Tule Tank in the Cabeza Prieta Mountains and, up an arroyo, they came across gold nuggets in a small stream. The girl collected some and kept them for a long time, eventually telling Tom Childs (Sr.) about the find. Childs mounted a careful search, but finally concluded that the deposit had been buried by rubble during the earthquake of 1887.

The Lost Belle McKeever mine is said to be the "richest gold ledge ever discovered in North America." In 1869 the McKeever family was ambushed by Apaches at Big Bend on the Gila River. The son escaped and went to Fort Yuma for help, explaining that his family had been killed and his sister Belle abducted. Troopers were dispatched to trail the Indians, but the Indians separated, so the company of soldiers had to split up as well. Eventually one group of three troopers ran out of water and became lost. At last one of their horses located water by pawing at the ground; nearby they found gold "as big as buckshot" with occasional nuggets as big as blackberries. They dug out 50 pounds of gold in one afternoon, then set about trying to find their way back to civilization. It was a long and grueling walk, the horses and one soldier died, and two soldiers survived. But they never did find the deposit again . . . or poor Belle.

James Hurley was prospecting near Black Mountain in Yuma County when he came across an old wagon half buried in the sand. Nearby was a sand-covered skeleton and in the wagon itself were 15 rotted sacks of rich gold ore. The ore, which yielded about 90 ounces of gold, was of a peculiar color and type which Hurley had never seen before. He showed samples around in Parker and Yuma but none of the other prospectors recognized it. Where had the

(text continued on page 280)

Lost Mines of Arizona

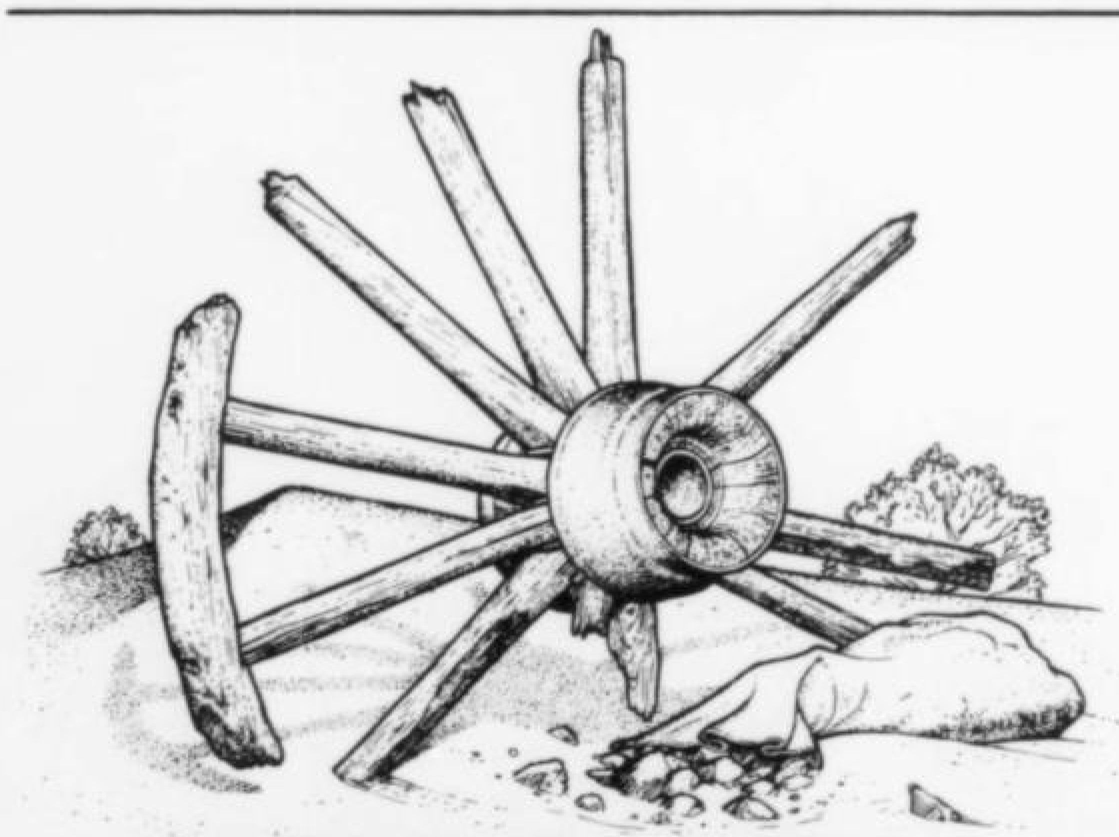
NAME	CONTENT	LOST	LOCATION	COUNTY	REFERENCE
Adams Diggings	Gold placer	1864	Apache reservation	Apache	Granger (1977) p. 54
Al-che-sa mine	Gold	1880's	near Green's Peak	Apache	Penfield (1973) p. 7
Alvarado mine	Gold lode	1880	Middle Well camp	Apache	Granger (1977) p. 139
Antlers mine	Gold	1905	Daniels Canyon near Peach Springs	Mohave	Granger (1977) p. 134
Apache Girl mine	Gold placer	late 1800's	Dos Cabezas Mtns.	Cochise	Granger (1977) p. 88
Apache mine	Gold placer	1862	near Rich Hill	Yavapai	Penfield (1973) p. 83
Ashley mine	Gold lode	1934	Morgan City Wash	Maricopa	Penfield (1973) p. 44
Belle McKeever mine	Gold lode	1869	near Harquahala Mtns.	Yuma	Granger (1977) p. 62
Big Nugget mine	Gold placer	1949	Greaterville Canyon	Pima	Granger (1977) p. 137
Black Burro mine	Gold	1862	Eagle Creek	Graham	Granger (1977) p. 82
Black Maverick mine	Gold	late 1880's	Four Peaks area	Maricopa	Granger (1977) p. 134
Black Mesa mine	Gold placer	1901	W of Rock Springs	Yavapai	Granger (1977) p. 133
Black River mine	Gold	?	White Mtns.	Apache	Probert (1977) p. 12
Blind Man's mine	Gold	?	North of Douglas	Cochise	Probert (1977) p. 13
Blonde Mayo mine	Gold?	1861	Cerro Colorado Mtns.	Pima	Granger (1977) p. 33
Camel's Tinaja mine	Gold placer	1871	Tank Mtns.	Yuma	Granger (1977) p. 71
Cap Linger mine	Tungsten	1918	Hat Mtn., Sauceda Range	Maricopa	Granger (1977) p. 137
Carpenter mine	Silver	1885	Silver Creek near Shumway	Navajo	Penfield (1973) p. 49
Carrizon Creek mine	Gold placer	1848	S of Atascosa Mtns.	Santa Cruz	Granger (1977) p. 50
Castle Dome lost mine	Gold lode	c.1920	between Kofa mine and Ehrenberg	Yuma	Granger (1977) p. 143
Cinnabar mine	Cinnabar crystals	1946	South of Payson	Gila	(G. Burnham, pers. comm., 1983)
Coconino mine	Gold lode	1853	SE of Kingman	Mohave	Granger (1977) p. 42
Cowboy mine	Gold in hematite	1860's	N of Yuma	Yuma	Mitchell (1933) p. 163
(Cowboy mine = Needle Canyon mine?)					
Crater of the Moon mine	Gold	?	Mood Mtn.	Yuma	Probert (1977) p. 21
Cunningham mine	Gold in Malachite	1870	Tyson Valley	Yuma	Keiser (1978) p. 19
Desert Rat's mine	Gold	1870's	Big Bug Mesa	Yavapai	Granger (1977) p. 71
Dodson mine	Gold placer	1872	N of Flagstaff	Coconino	Penfield (1973) p. 25
Dr. Thorne mine	Gold lode	1850–1870's	Superstition Mtns. *or* White Mtns. *or* Verde River *or* Salt River	Maricopa Apache Yavapai Maricopa	Granger (1977) p. 103
(Dr. Thorne mine = Geronimo mine?)					
Dry Washer mine	Gold placer	?	near Twin Buttes	Pima	Penfield (1971) p. 17
Dutchman mine	Gold	1890's	Superstition Mtns.	Maricopa	Granger (1977) p. 107
(Dutchman mine found in 1966?, Gentry (1968))					
Eldon Mtn. mine (of Duncan Teller)	Silver lode	mid-1800's	Eldon Mtn. near Flagstaff	Coconino	Penfield (1973) p. 32
Escalante mine (see Mine with the Iron Door)					
Espejo mine	Copper-Silver	1581	United Verde mine	Yavapai	Granger (1977) p. 19
Estrella mine	Gold	1878	Estrella Mtns.	Maricopa	Penfield (1973) p. 42
Falling Star mine	Gold	?	Mt. Floyd near Seligman	Coconino	Probert (1977) p. 39
Frenchie's mine	Gold	Late 1800's	Estrella Mtns.	Maricopa	Mitchell (1949) p. 26
French Knife mine	Gold lode	1906	near Quartzsite	Yuma	Keiser (1978) p. 26
Frenchman mine	Gold lode	1867	Eagle Tail Mtns.	Yuma	Granger (1977) p. 56
(Frenchman mine found in 1889?, Granger (1977) p. 56)					
(Frenchman mine found in 1895?, Winters (1972) p. 34)					

NAME	CONTENT	LOST	LOCATION	COUNTY	REFERENCE
Frenchman mine	Silver	1858	Estrella Mtns.	Maricopa	Penfield (1973) p. 45
Flying V mine	Gold	early 1900's	near Flying V Ranch Santa Catalina Mtns.	Pima	Granger (1977) p. 139
Gallegos mine	Gold	?	Mohon Peak	Yavapai	Penfield (1971) p. 18
Geronimo mine	Gold lode	1870's	Superstitions	Maricopa	Granger (1977) p. 102
			or Tonto Basin	Gila	
			or E of Prescott	Yavapai	
			or Four Peaks area	Maricopa	
			or Winkelman	Gila	
			or Verde River	Yavapai	
			or near Jerome	Yavapai	
			or Sycamore Canyon	Yavapai	
(Geronimo mine = Dr. Thorne mine?)					
Glory Home mine	Gold	?	near Salome	Yuma	Penfield (1971) p. 19
Golden Bullet mine (of Felix Aubrey)	Gold	1853	Mogollon Rim county	Gila	Granger (1977) p. 51
Gonzales mine (a Peralta mine)	Gold	1874	Superstition Mtns.	Maricopa	Penfield (1962) p. 30
Grijalva mine	Gold	?	Fool's Canyon near Wickenberg	Coconino	Probert (1977) p. 44
Gunsight mine	Gold	?	Chiricahua Mtns.	Cochise	Probert (1977) p. 45
Huachuca mine	Gold lode	early 1900's	W side of Huachuca Mtns.	Cochise	Granger (1977) p. 143
Iretaba mine	Gold	c.1850	Four Peaks area	Maricopa	Granger (1977) p. 50
Jabonero mine	Gold lode	1854	W of Ajo	Pima	Granger (1977) p. 51
Jenkins mine	Gold lode	1937	Superstition Mtns.	Pinal	Penfield (1973) p. 69
Jerome Junction mine	Gold lode	c.1910	Between Prescott and Ash Fork	Yavapai	Granger (1977) p. 137
Jim Carson mine	Gold placer	1875	near Ganado	Apache	Penfield (1973) p. 6
John Carroll mine	Gold placer	c.1900?	Superstition Mtns.	Maricopa	Penfield (1973) p. 40
John Clark mine	Silver	1861	Cerro Colorado Mtns.	Pima	Granger (1977) p. 51
John D. Lee mine	Gold	1871	Grand Canyon	Coconino	Granger (1977) p. 72
John Nummel mine	Silver lode	1928–30	Trigo Mtns.	Yuma	Granger (1977) p. 132
King Tut (Cottonwood) mine	Gold placer		near Pierce Ferry	Mohave	Probert (1977) p. 52
Lafe McKenzie mine	Gold	?	near Naco	Cochise	Penfield (1971) p. 13
Laguna Dam mine	Gold placer	early 1900's	near Laguna Dam	Yuma	Granger (1977) p. 145
Little Colorado mine	Silver (argentite)	1866	mouth of the Little Colorado R.	Navajo	Granger (1977) p. 61
Lone Indian mine	Gold placer	1863	near Laguna pockets?	Yuma	Granger (1977) p. 54
Lord Duppa mine	Silver lode	1870?	Bradshaw Mtns.	Yavapai	Granger (1977) p. 70
Lost Mountain mine	Gold placer	1900's	5 days beyond Oraibi	Navajo	Granger (1977) p. 143
Lost Pick mine	Gold lode	1872	50 m N of Phoenix	Maricopa	Granger (1977) p. 69
Madden mine	Gold lode	1878	Vulture Mtns.	Maricopa	Penfield (1973) p. 44
Mad Squaw mine	Gold	?	Gila Bend Mtns.	Maricopa	Penfield (1971) p. 15
Mangino mine	Gold lode	early 1900's	near Tucson	Pima	Granger (1977) p. 138
Manje mine	Gold lode	1699	Copper Mtns.	Yuma	Penfield (1973) p. 96
Manje mine	Gold	?	near Mobile	Maricopa	Penfield (1971) p. 15
Martinez mine	Gold lode	1910's	near Valenzuela mine	Yuma	Keiser (1978) p. 41
Medicine Man mine	Gold	?	near Ajo	Pima	Penfield (1971) p. 16
Mexican Slave mine	Gold	?	White Tank Mtns.	Maricopa	Penfield (1971) p. 15
Miner mine	Gold placer	1871	Sombrero Butte	Gila	Penfield (1973) p. 36
Mine with the Iron Door	Gold	1780	Santa Catalina Mtns.	Pima	Granger (1977) p. 28
(Mine with the Iron Door found in 1966?, Associated Press, August 14, 1982)					
Mormon Mtn. mine	Silver lode	mid-1800's	Mormon Mtn.	Coconio	Penfield (1973) p. 23
Navajo mine	Silver	1879	Monument Valley	Navajo	Granger (1977) p. 90
Needle Canyon mine	Gold	early 1900's?	Needle Canyon	?	Granger (1977) p. 138
(Needle Canyon mine = Cowboy mine?)					

NAME	CONTENT	LOST	LOCATION	COUNTY	REFERENCE
Nigger Ben mine	Argentite or Gold placer	1870's	Sycamore Springs	Yavapai	Granger (1977) p. 74
Nugget mine	Gold placer	early 1900's	S. of Topock	Yuma	Penfield (1973) p. 94
Old Pete mine	Gold	?	Gila Mtns.	Yuma	Penfield (1971) p. 19
Opata mine	Silver	1776	near Tumacacori Mission	Santa Cruz	Granger (1977) p. 22
Organ Grinder mine	Gold lode	1860's	near Granite Creek	Yavapai	Granger (1977) p. 58
Orphans mine	Gold placer	1870's	near Tule Tank	Yuma	Penfield (1962) p. 38
Pack Rat mine	Gold placer	c.1860	Superstition Mtns.	Maricopa	Granger (1977) p. 126
Padillo mine	Gold	?	near Arivaca	Pima	Penfield (1971) p. 17
Padre mine	Gold-Silver	1751	Table Mtn.	Coconino	Granger (1977) p. 35
Padres mine	Gold?	1700's	Harshaw district	Santa Cruz	Granger (1977) p. 26
Pancho mine	Gold lode	1890's	Little Horn Mtns.	Yuma	Granger (1977) p. 73
Papago mine	Gold lode	1942	Santa Rosa Mtns.	Pima	Granger (1977) p. 136
Pegleg mine (see Frenchman mine, Yuma County)					
Penhatchipit mine (see Frenchman mine, Yuma County)					
Peralta mines	Gold	1840's	Superstition Mtns.	Maricopa	Granger (1977) p. 107
Pima mine	Mercury	1744	Agua Caliente on Gila River	Maricopa	Granger (1977) p. 18
Planchas de Oro mine	Gold	?	near Artillery Peak	Mohave	Probert (1977) p. 69
Puncher Bob mine (see Iretaba mine)					
Purisima Conception mine	Silver-Gold lode	1750	Pajarito Mtns.	Santa Cruz	Granger (1977) p. 20
Rohwers mine	Silver-Antimony	1870	Tyson Valley	Yuma	Keiser (1978) p. 19
Renaldo Pacheco	Vanadinite	1980's	Silver District	Yuma	Shannon (1980) p. 139
San Carlos mine	Silver lode and placer	1872	San Carlos reserv. *or* White Mtn. reserv.	Gila	Granger (1977) p. 64
San Cayetano mine	Silver lode	1772	San Cayetano Mtns.	Santa Cruz	Granger (1977) p. 20
Sanders mine	Gold lode	1879	Superstition Mtns.	Maricopa	Granger (1977) p. 120
Sells mine	Gold	early 1900's	Papago reservation near Sells	Pima	Granger (1977) p. 137
Shepherd Girl mine	Gold placer	early 1900's	near Hackberry	Mohave	Granger (1977) p. 144
Shoemaker mine	Gold placer	late 1800's	Four Peaks area	Maricopa	Penfield (1973) p. 45
Sierra Azul mine	Silver	1680	San Francisco Peaks	Coconino	Granger (1977) p. 18
Silver Antelope mine	Silver lode	c.1890	Lower Queen Creek	Pinal	Granger (1977) p. 82
Silver Stairway mine	Silver	late 1800's	between Gunsight and Quijotoa	Pima	Granger (1977) p. 89
Six-shooter mine (Orme's)	Silver lode	c.1889	Harcuver Mtns.-Ehrenberg	Yuma	Granger (1977) p. 83
Six-shooters mine	Gold lode	1860's	near Cibola or Bouse	Yuma	Penfield (1973) p. 89 *but see* Keiser (1978) p. 30
(Six-shooters mine found? = Copperstone prospect 12 miles north of Quartzsite; R. W. Thomssen, pers. comm.)					
Slashed Tree mine	Gold	early 1900's	Graham Mtns.	Graham	Granger (1977) p. 137
Soldier Brother's mine	Gold lode	1942	Cerbat Mtns.	Mohave	Penfield (1973) p. 49
Soldier mine (see Sanders mine)					
(Soldier mine found in 1904?, Winters (1972) p. 16)					
Squaw Hollow mine	Gold lode	1864	Camp Creek area	Maricopa	Granger (1977) p. 60
Squawman mine	Gold lode	late 1800's	near Baker's Tank	Yuma	Penfield (1973) p. 93
Stoker mine	Gold	?	near Yarnell	Maricopa	Penfield (1971) p. 14
Sycamore mine	Gold	1760's	Sycamore Canyon	Yavapai	Granger (1977) p. 105
Tombstone mine	Silver?	1900's	near Tombstone	Cochise	Granger (1977) p. 143
Tonto Trail mine	Copper lode	?	Four Peaks area	Maricopa	Storm (1946) p. 160
(Tonto Trail mine found in 1942 (Storm, 1946))					
Trigo Mountains mine	Silver lode	c.1885	Trigo Mtns.	Yuma	Granger (1977) p. 81
Trooper mine	Gold placer	1870's	Quitojoa or Baboquivari Mtns.	Pima	Granger (1977) p. 72

NAME	CONTENT	LOST	LOCATION	COUNTY	REFERENCE
Tumacacori mine	Silver	1780	Carreta Canyon, Ataskosa Mtns.	Santa Cruz	Granger (1977) p. 22
Turtle mine	Gold lode	c.1900	Chocolate Mtns.	Yuma	Granger (1977) p. 132
Two Skeletons mine	Gold lode	late 1800's	Mount Ord	Gila	Penfield (1973) p. 36
Two Soldiers mine	Gold lode	c.1880	Superstition Mtns.	Pinal	Penfield (1973) p. 64
Valise mine	Gold lode	1889	Lava Butte	Coconino	Penfield (1973) p. 22
Valverde mine	Gold	1772	Santa Cruz Valley near Guevavi	Santa Cruz	Penfield (1973) p. 72
Velarde mine	Mercury	1716	Northeast Arizona	Navajo	Granger (1977) p. 18
Virgin Guadalupe mine	Silver-Gold	1540	near Tumacacori Mission	Santa Cruz	Granger (1977) p. 21
Wagon mine	Gold lode	late 1800's	Black Mtn. near Parker	Yuma	Penfield (1973) p. 89
Wagoner mine	Gold lode	late 1800's	Superstition Mtns.	Maricopa	Granger (1977) p. 119
Ward mine	Copper-Silver	1875	Red Hills near Florence	Pinal	Winter (1972) p. 17
(Ward mine found in 1917, Winters (1972) p. 17)					
Whetlach mine	Silver lode	1893	Whetlach Canyon, Superstition Mtns.	Pinal	Garman (1975) p. 39
Whetstones mine	Gold lode	1883	Whetstone Mtns.	Cochise	Winter (1972) p. 20
White Horse Hills mine	Gold	?	White Horse Hills	Coconino	Probert (1977) p. 94
Whitlesy mine	Gold lode	1894	Black Mtns. near Oatman	Mohave	Penfield (1973) p. 49
Williamson mine	Silver placer	early 1900's?	Pinal Range	Gila	Granger (1977) p. 138
Woodcutter mine	Gold lode	1898	Gila Mtns.	Yuma	Penfield (1973) p. 98
Yuma's mine	Gold lode	1870	near San Pedro R.	Cochise	Granger (1977) p. 66
Yuma Squaw mine	Gold	c.1880	Yuma-Wickenberg trail	Yuma	Granger (1977) p. 76
(Yuma Squaw mine found in 1890?, Winters (1972) p. 14)					

NOTES: These mines are occasionally known by different names or by no name in particular; a check of the references will give more details. The term "mine" is used loosely here for the sake of consistency, and may refer to deposits which have remained (supposedly) essentially unmined. Some lost mines are discussed in many different books and articles; the references cited on this table are the most recent and comprehensive surveys, from which more references may be obtained. Preference was given first to Granger (1977), the most scholarly study; second is Penfield (1962), which has references, and then Penfield (1973), which has no references. Some mines are listed only in Penfield (1971), in which only the barest information is given. A few are referenced to Probert (1977), which is itself only a bibliography (the best) of further references. Others are referenced individually to articles. It is inevitable that a list such as this will prove to be incomplete, and that some lost mines have inadvertently been listed twice under different names. Considering that the study of lost mines is by nature not an exact science, it is hoped the reader will forgive the resulting omissions and redundancies.



James Hurley found 15 sacks of gold ore in the old wagon. But where had it come from before the driver perished? The peculiar-looking ore matched no known deposit.

wagon been coming from and how far had it traveled? Hurley never could find out, despite several years of search in the surrounding area.

CONCLUSIONS

Some of these stories about lost mines are probably purely fictitious, and some largely true; no one can say for certain which is which. It only stands to reason that there is *some* truth in *some* of the stories; therefore none of them can be dismissed out of hand.

The stories of lost mines make fascinating reading and give a glimpse into times and people long gone, yet the stories live today in an unusual way. All you really need is a car with a full tank, a picnic lunch and a gleam in the eye, and you are ready to go out searching for the real thing. Later you can say to your grandchildren, "Yep, I once searched for the Lost Axehandle mine. Had it almost in sight too, when a (flash flood, avalanche, burro stampede, angry Indian, case of sunstroke . . . choose one) stopped me. Never did go back. But it's up there, I know."

The search for lost mines can reasonably be undertaken as a lark, the benefits of which are exercise, fresh air, beautiful scenery, and a feeling for the history of the land. No greater expectation is justified. If, by some chance, a reader of this should actually find one of these mines, I hope he will consider writing an article for the *Mineralogical Record*.

One final warning though: these stories (especially in their full expansion which I have not given here) have evolved through retelling into a form which can grip the imagination in an uncanny way. Readers should be skeptical of *all* "facts" presented in such stories. Susceptible individuals have long been known to forsake wife, family and job in favor of spending the rest of their lives fruitlessly searching for some lost mine. One book about lost Jesuit mines (by Paul V. Lease, 1965) was published posthumously by his wife, who wrote in the dedication:

". . . To those scores of persons who seem determined to follow in Paul's footsteps, I have only pity and, were not my own peace of mind and personal safety concerned, I would have destroyed this manuscript."

ACKNOWLEDGMENTS

My thanks to Richard Thomssen, Debra Wilson and Robert Jones for reviewing the manuscript. I particularly want to thank George Burnham for his first-hand information on the lost Cinnabar prospect.

AVAILABLE REFERENCES

Probably the best single source for lost mine and treasure publications is **H. Glenn Carson Enterprises, P.O. Drawer 71, Deming, New Mexico 88031.** Their current catalog lists over 400 items, including publications on ghost towns, gold mining, western history, Indian relics, gems and minerals and western collectibles. Bibliographic entries (below) preceded by an asterisk (*) are available through Carson. Many states other than Arizona, particularly those in the Southwest, have legends of lost mines. A large number of related publications are available through Carson.

Another good source is **K. B. Slocum Books, P.O. Box 10998 #620, Austin, Texas 78766,** whose catalog lists over 300 items including maps and metal detectors.

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There are far more books and articles on lost mines than can be mentioned here. Penfield, in his 1971 directory of lost treasures and mines (about 4 percent of which is devoted to Arizona mines), claims to have compiled it from a personal file of 35,000 references . . . now *there's* a bibliography, if only he would publish it. Probert (1977) has the most complete published Arizona bibliography: 97 pages arranged according to mine name. Although there is naturally some duplication in Probert's list (because some books deal with numerous mines and are listed under each one), the depth of his work can be appreciated by noting that he lists 285 references on the Lost Dutchman mine alone! Granger (1977) capsulizes and analyzes many stories in a sound, historical study. The classic works in the field are considered to be those by Dobie and by Mitchell. Especially recommended is the readable and well-illustrated book by Egerton (1974), and the thorough debunking of lost Jesuit mine stories by Polzer (1968) (himself a Jesuit historian).

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famous mineral localities:

the New Cornelia mine Ajo, Arizona

by **William J. Thomas**
P.O. Box 202
Ajo, Arizona 85321

and **Ronald B. Gibbs**
210 La Mina Avenue
Ajo, Arizona 85321

The New Cornelia mine at Ajo, Arizona, is the type locality for ajoite and papagoite. The district has also produced many fine specimens of azurite, cuprite, copper and gem-quality shattuckite.

INTRODUCTION

The New Cornelia mine is the oldest producing open pit porphyry copper mine in Arizona. It has been owned and operated by Phelps Dodge Corporation since 1931. The mine is located adjacent to the town of Ajo in western Pima County, Arizona. The town has a population of about 7,000; approximately 1,400 are employed by Phelps Dodge. Ajo has always been a planned community; Phelps Dodge owns a number of the homes and rents them to its employees. The company also operates the Phelps Dodge Mercantile Store, and the Ajo Improvement Company. Phelps Dodge and its predecessor, the New Cornelia Copper Company, built the plaza and its surrounding buildings, schools, recreation hall and swimming pool.

The locale is typical of the Sonoran Desert in the Basin and Range Province of Arizona, at an elevation of 1,800 feet. The average yearly rainfall is about 9 inches. The summers, extending from mid-May to mid-October, are hot with many days over 100°F. The mild, pleasant winters have only a day or two with freezing temperatures.

Production from the open pit copper mine began in 1917; the leaching plant produced the first electrolytic copper for shipment from Ajo on June 18th of that year. The mine has operated continuously since 1917 except for two forced shutdowns due to adverse world economic conditions – April 20, 1932 to July 2, 1934 and April 17, 1982 to the present. The New Cornelia mine has produced a total of more than 5.9 billion pounds of copper with much lesser amounts of gold, silver and molybdenum. Today the mine is undergoing an expansion that includes increased waste stripping to uncover additional ore which would allow the mine to produce well into the next century.

HISTORY

The earliest history of mining at Ajo is difficult to document. Father Kino, a Jesuit priest and explorer, made extensive journeys into what is now southwestern Arizona from 1691 to 1702, and on these journeys passed through Sonoita, Mexico, several times. Kino made no mention of mining at Ajo in his detailed descriptions of the country he traversed. Thus mining at Ajo in all probability had its beginning after Father Kino's last journey through the area in 1702 (Barr, 1940).

Historians have claimed that Ajo was the first copper district in Arizona worked by Americans of European ancestry. When the first Anglos arrived in the district in 1854, they found abandoned workings, rawhide ore buckets and crude tools as evidence of earlier attempts to mine the small veins of native copper, cuprite and chalcocite occurring in the three green hills that stood where the open pit mine is today. This early work was done by Indians and probably by Mexican miners from Sonora, Mexico, who had prospected as far north as Ajo in quest of silver ore. These Mexican miners worked the veins for a short time and finally abandoned them, probably due to the low precious metal values (Joralemon, 1914; Parsons, 1933; and Gilluly, 1946).

After the war with Mexico and particularly after the Gadsden Purchase in 1853, U.S. government exploring and surveying parties worked the region that is now the southern part of Arizona, and casually mentioned the mineral resources of the Ajo area. It is probable that their reports, and the masses of rich cuprite, native copper and malachite ore carried to California by emigrants, resulted in the organization of the first mining company at Ajo in 1854 – the Arizona Mining and Trading Company. Major Robert Allen, U.S. Army deputy quartermaster-general of the Department

Figure 1. **The New Cornelia mine and the town of Ajo in Pima County, Arizona. Photo by Mickey Prim, Ray Manley Studio.**

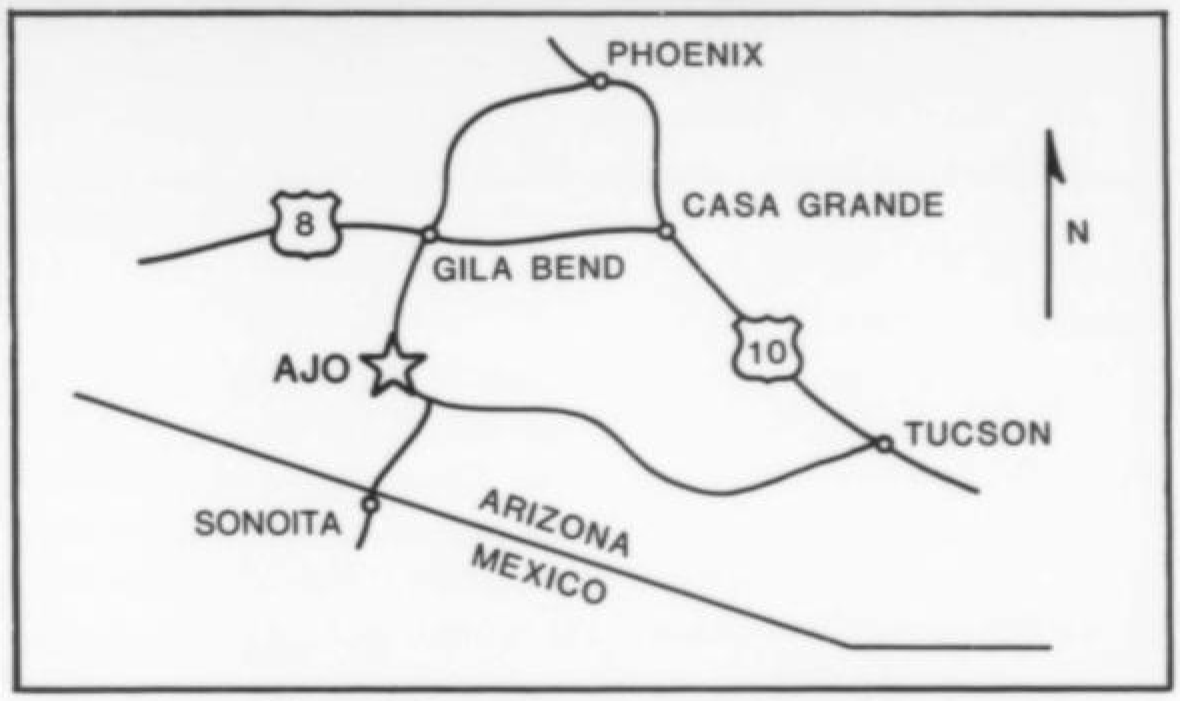


Figure 2. **Location map showing Ajo.**

of the Pacific, was the president of the corporation, and J. Downer Wilson of San Francisco was secretary and treasurer. The names of the men in the first party sent to Ajo were Peter R. Brady, F. Ronstadt, Edward E. Dunbar, G. Kibbers, George Williams, Joe Yancy, Dr. Webster, Charles Hayward, J. R. McElroy, James Porter, Bendel and Cook (Arizona Sentinel 1878; Barr, 1940; and Gilluly, 1946).

After the Gadsden Purchase of 1853, there was brief disagreement over whether the boundary between Mexico and the United States was north or south of the Ajo mines. A battle took place at Ajo where nine miners successfully defended the underground mines against 110 Mexican cavalrymen. In the fall of 1855, it was found that the international boundary lay 40 miles to the south.

Edward E. Dunbar was made superintendent of the main operating underground mine at Ajo. He mined only native copper and cuprite ore which was shipped to Swansea, Wales, where it sold for $400 per ton. This ore and later shipments of sulfide ore to San Francisco failed to support the operations due to high shipping costs. During this same period, the first copper smelter in what is now Arizona was built at Ajo. The smelter was constructed of adobe bricks, and was operated by Peter R. Brady. The facility yielded a total production of less than 100 pounds of copper. After failures like this, the Arizona Mining and Trading Company ceased to exist in 1859 (Arizona Sentinel, 1878; Stevens, 1911; and Gilluly, 1946).

From 1860 to 1890 numerous attempts were made to exploit the high-grade copper vein deposits, but this casual and intermittent work failed due to lack of water and the difficulties of transportation. The St. Louis Copper Company was formed in 1896 by A. W. Hopper and A. J. Shotwell. The company optioned claims from Tom Childs and other claims that covered much of the district. However, the owners of the St. Louis Copper Company found that $45,000 was required to produce concentrates worth $36,000. The company went bankrupt. The Rescue Copper Company was formed to "rescue" the St. Louis Copper Company. On May 1, 1900, John P. Boddie, A. J. Shotwell and others organized the Cornelia Copper Company, named for Boddie's first wife. Then, A. J. Shotwell sold most of his stock in the Rescue Copper Company and in the Cornelia Copper Company, and formed the Shotwell Tri-Mountain Copper Company. The three companies found that the Ajo ore was too lean to be mined profitably. This succession of reorganizations and new stock issues resulted in minimal underground development, and the greatest depth reached in the two or three years of activity was hardly more than 100 feet. Between 1890 and 1907, the companies encountered other problems when they fell victim to several schemes and metallurgical promotions that proved both bizarre and worthless (Joralemon, 1914; and Gilluly, 1946).

The first of these visionary schemes was a smelting process known as the Rendall Ore Reduction process. It was claimed that this strange invention would treat all classes of copper ore – oxides, carbonates, sulfides, chlorides, silicates, and arsenides – with equal facility. It was a process in which a special fluxing gas was to prevent the fusion of metals and gangue rock. Even so, the volatilized ore was to be plunged into a vat containing water to break it up. The ore was then to be crushed in an arrastre. As it turned out, the plant treated all ores with equal difficulty and was a complete failure (Parsons, 1933).

The next and most bizarre scheme was the McGahan Vacuum Smelter, built by Professor Fred L. McGahan (see Fig. 3). The furnace itself was a brick-lined steel cylinder 25 feet high and 6 feet in diameter. Supported on a steel frame were smaller horizontal cylinders to hold the oxygen and hydrogen gases that entered into the reactions. There was a powerful pump to maintain the vacuum. A bewildering array of pipes, gauges, and spigots protruded from all sides of the furnace. McGahan claimed that when the air was pumped out of the furnace and ore was fed in with a little fuel oil and just enough oxygen to burn it, he could regulate the temperature so accurately that all the elements in the ore would be melted, in sequence, one by one. First, the gold would melt and sink to the bottom, where it could be drawn off through the lowest spigot. The next spigot was for silver, the next for copper, then on and on for other elements, and finally, up at the top, spigots for oxygen and hydrogen gas. After the furnace was started, he could burn the hydrogen with the oxygen, and get along without any outside fuel at all. Nothing was lost, and all the elements would come out absolutely pure. The Professor achieved a number of things: he condensed a unique amount of pseudoscientific nonsense into one invention; he exploded a dozen then-prevailing theories in chemistry and physics; and he dissipated the funds invested (Parsons, 1933; and Thomas, 1964).

A third patent process cost the early stockholders another $20,000 for a complicated hydrofluoric acid leaching plant almost as fantastic as the vacuum smelter. This promoter built a leaching plant that did turn out a few pounds of copper, but at a cost of a dollar a pound (Joralemon, 1914).

In 1907, Utah Copper Company started large tonnage production of a low-grade copper deposit at Bingham Canyon, Utah. Because of the success of this experiment, the desert became alive with geologists and engineers hunting for new "porphyry copper" ore deposits (Barr, 1940).

On September 28, 1909, the New Cornelia Copper Company was incorporated as a reconstruction of the Cornelia Copper Company. Soon thereafter, the Lewisohn interests, advised by J. Park Channing, optioned a majority of the New Cornelia Copper Company stock. Seeley W. Mudd and associates optioned the Rendall property and an English syndicate took an option on Childs' group of claims. The three groups began development about the same time. The English group sank a shaft and found nothing but high pyrite and low copper mineralization. The Mudd group put down four churn-drill holes on the Rendall area. Two holes were in favorable locations and two others were in the barren fanglomerate to the east. Unfortunately, this group still missed the orebody by not drilling deep enough through the rhyolite on the favorable locations. The Channing group drilled five diamond drill holes on the fringes of Copper Mountain. Since this work was in the lower ground surrounding the hard, silicified outcrops of Copper Mountain, Channing also missed the ore deposit. Drilling was discontinued because the amount of ore found was not enough to justify continued exploration. All three groups ignored the three green hills that contained the orebody and allowed their options to lapse (Joralemon, 1914; Gilluly, 1946; and Thomas, 1964).

Successful development of the Ajo district began in the fall of 1911 under the leadership of John C. Greenway, general manager of the Calumet and Arizona Mining Company. After a favorable report was submitted by the company's geologist, Ira B. Joralemon, the company took an option on all the available stock

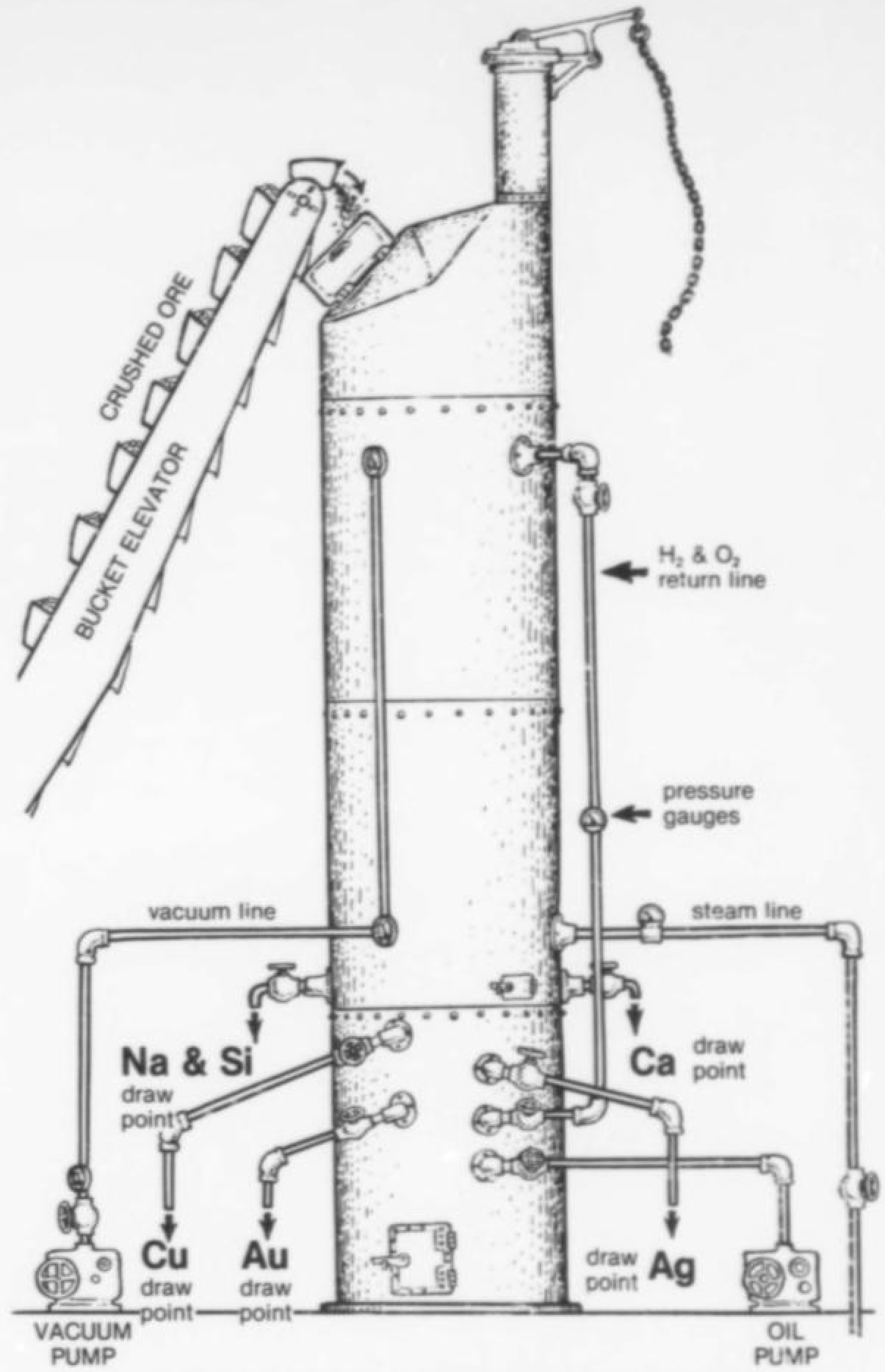


Figure 3. **Idealized drawing of the fraudulent McGahan Vacuum Smelter (from a drawing by T. B. Hinton, General Mine Foreman of the New Cornelia Copper Company, who dismantled it in 1925).**

of the New Cornelia Copper Company and started diamond drilling to delineate what lay beneath the outcrops of Copper Mountain. This work showed that the three green hills were underlain by a large, low-grade copper orebody (Joralemon, 1914; and New Cornelia Copper Company, 1919).

While Calumet and Arizona's drilling program was in progress, options were taken on the property of the Rendall Ore Reduction Company by James Phillips, Jr., Utley Wedge and others, under the name of the Ajo Consolidated Copper Company, and on the Childs group of claims between the New Cornelia and the Rendall properties, by representatives of the United States Smelting, Refining and Mining Company. The latter option was given up following a small churn-drilling program. During the years 1913 to 1917, the Ajo Consolidated Copper Company explored its holdings with drill holes and underground workings. In 1917 the New Cornelia Copper Company took over the holdings of the Ajo Consolidated Copper Company. Afterward, they acquired the Childs group of claims and a large block of ground north of the original holdings, on which the townsite, tailings dumps and plant are now located (New Cornelia Copper Company, 1919; and Barr *et al.*, 1932).

Both the carbonate and the sulfide ores were so unusual in character that it was evident that some departures from the known methods of treatment would be necessary to ensure the success of

Figure 4. **Ajoite crystals on olivenite. The view is about ⅔ inch across. R. Gibbs specimen.**

Figure 5. **Pale blue ajoite needles on dark blue crystals of papagoite. The view is about ½ inch across. R. Gibbs specimen.**

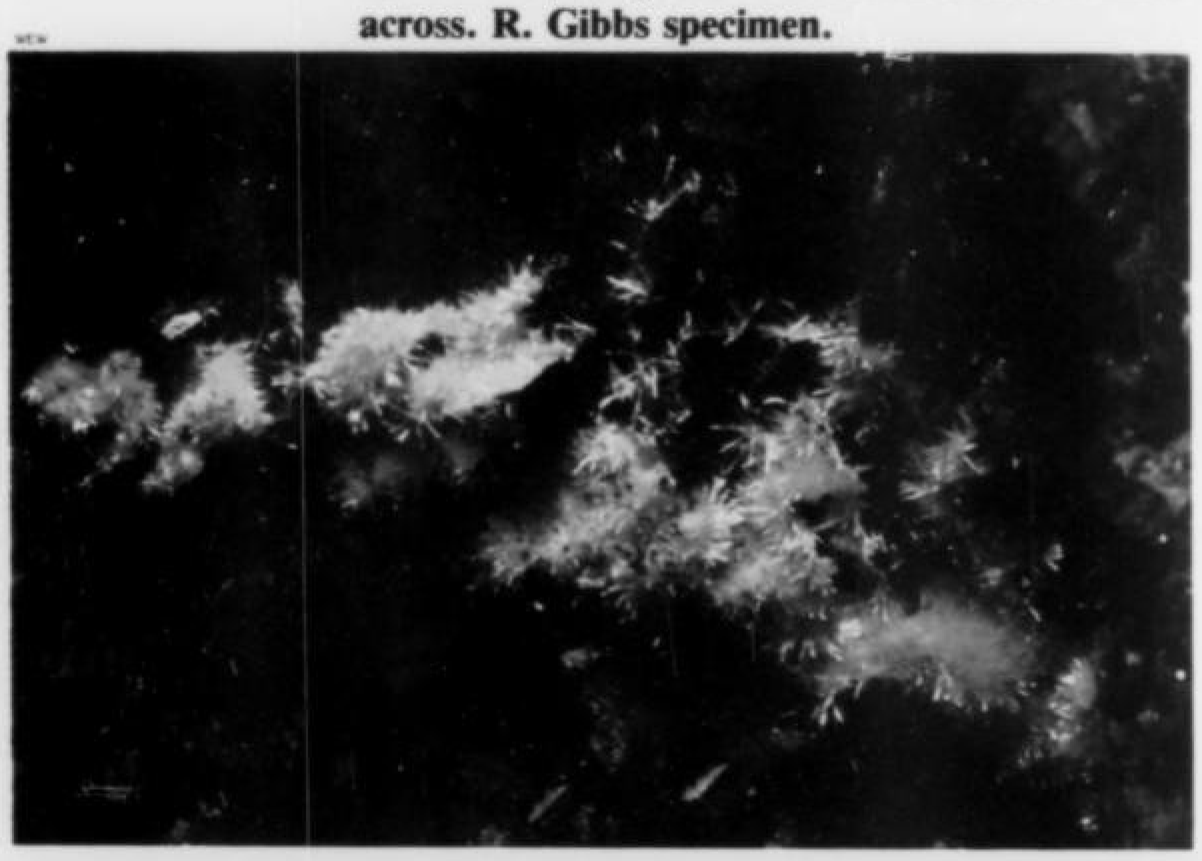
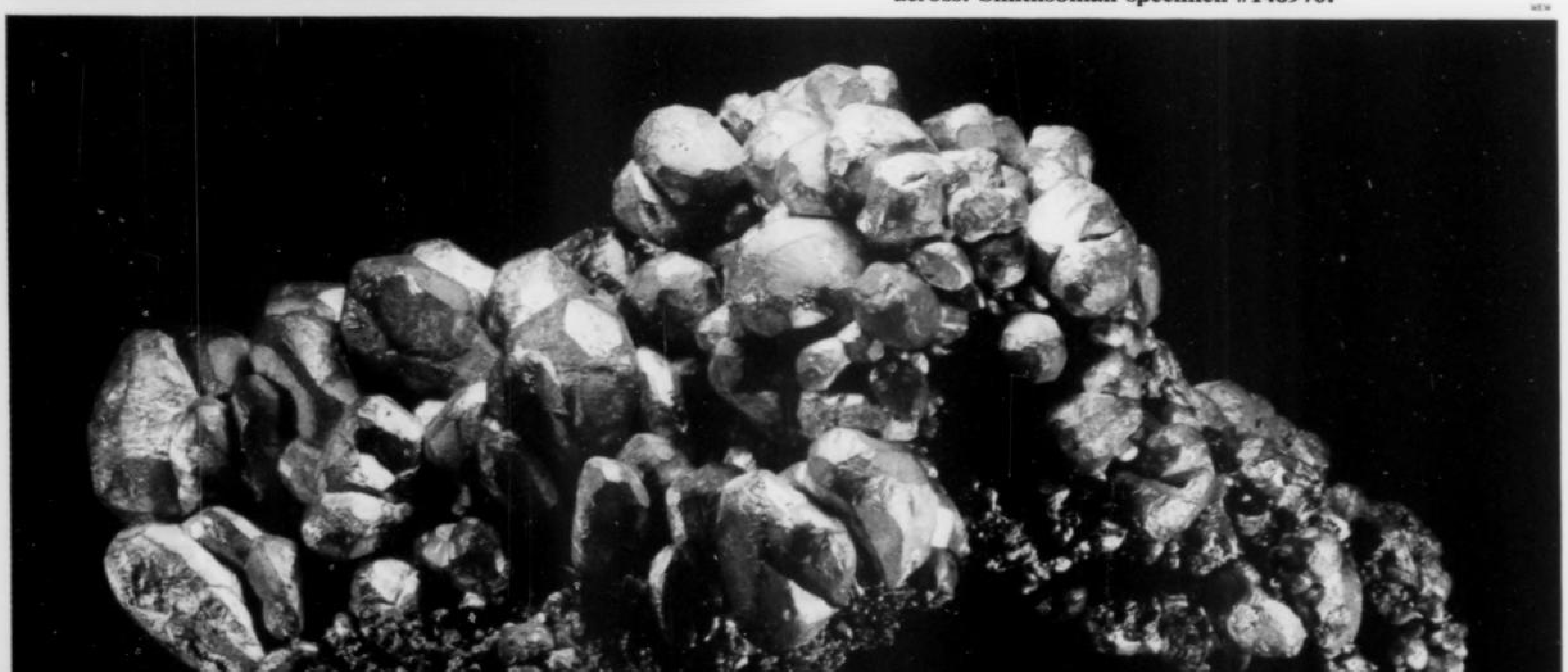


Figure 6. **Azurite crystals partially altered to malachite. The group is 3 inches tall. Smithsonian specimen #125065.**

Figure 7. **Single crystals of copper exceeding 1½ inches in a group measuring 9½ inches across. Smithsonian specimen #146970.**



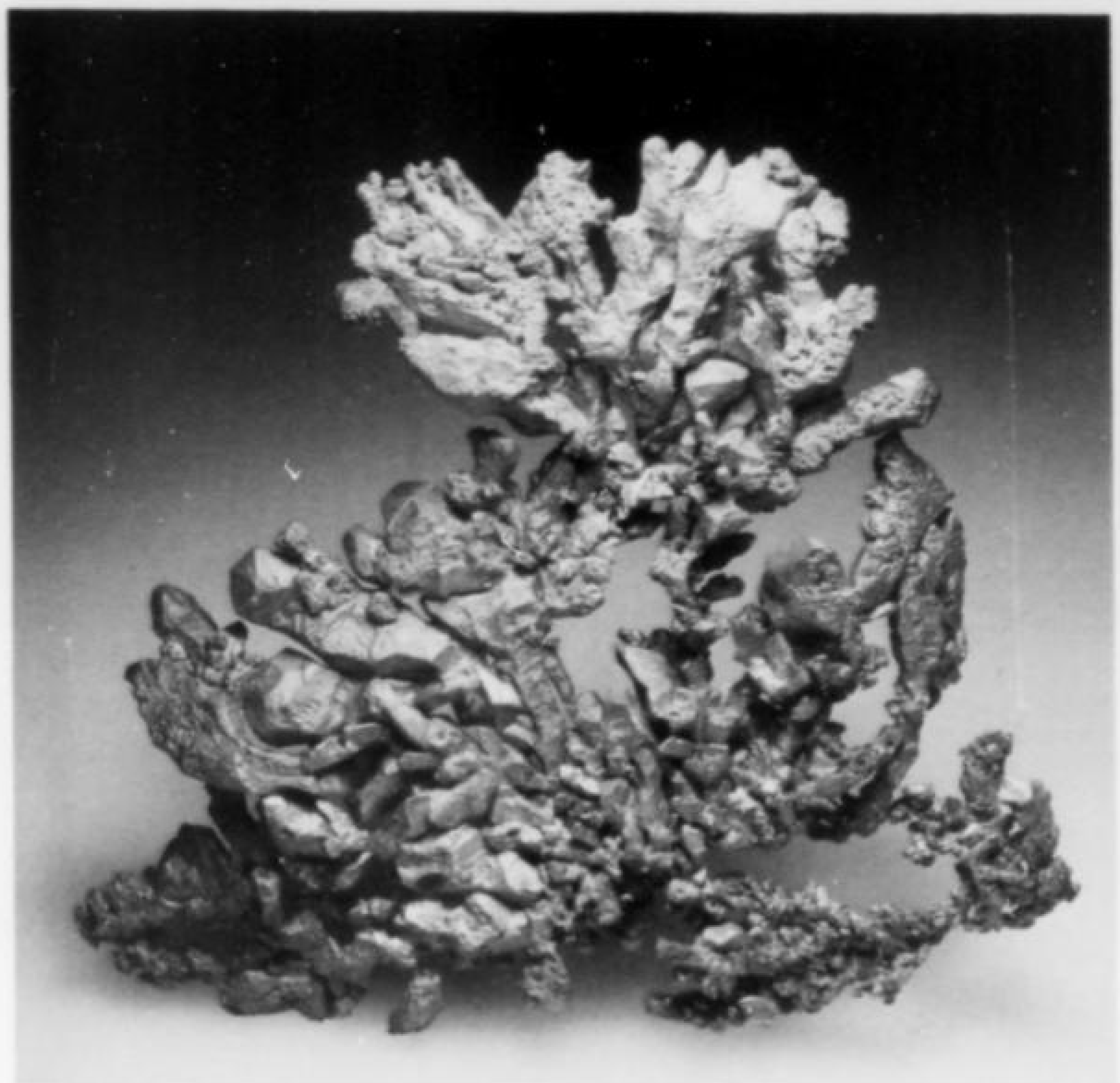


Figure 8. **Arborescent copper crystal group measuring 5⅓ inches across. Francisco Vega specimen.**

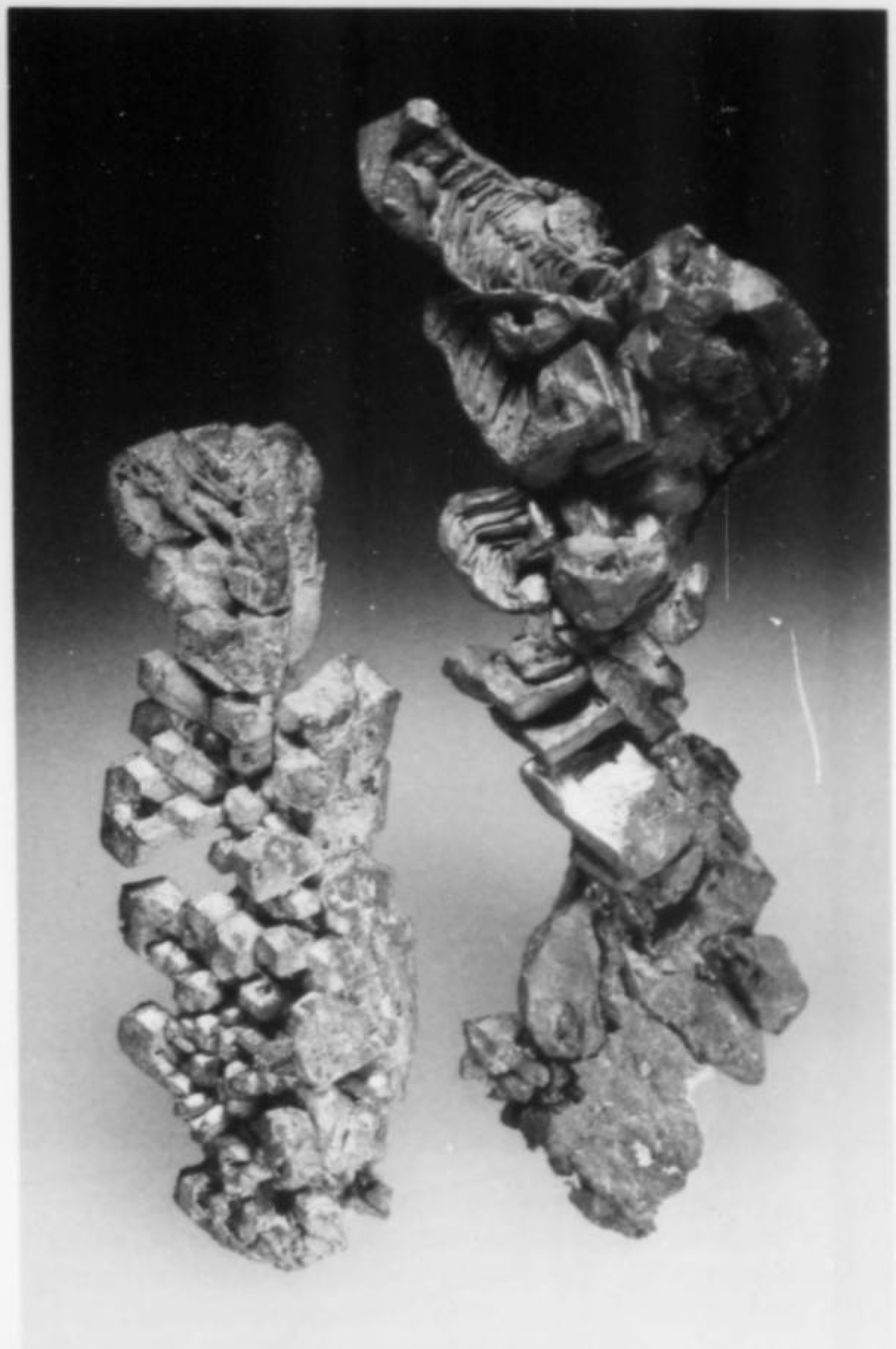
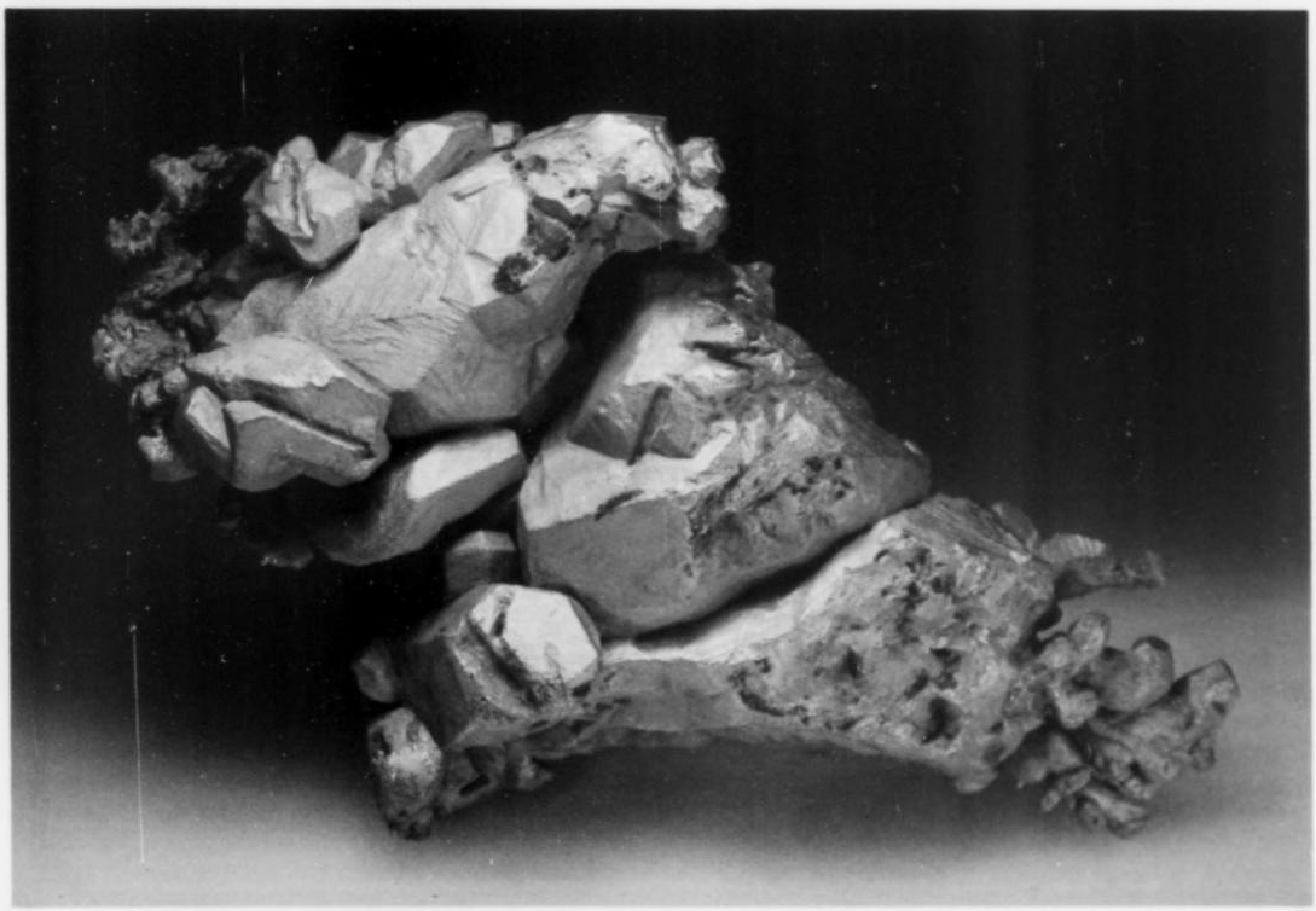


Figure 9. **Copper crystal groups measuring 2 inches and 2¾ inches tall. R. Gibbs specimens.**

Figure 10. **A group of heavy, blocky copper crystals 5½ inches across. R. Gibbs specimen.**



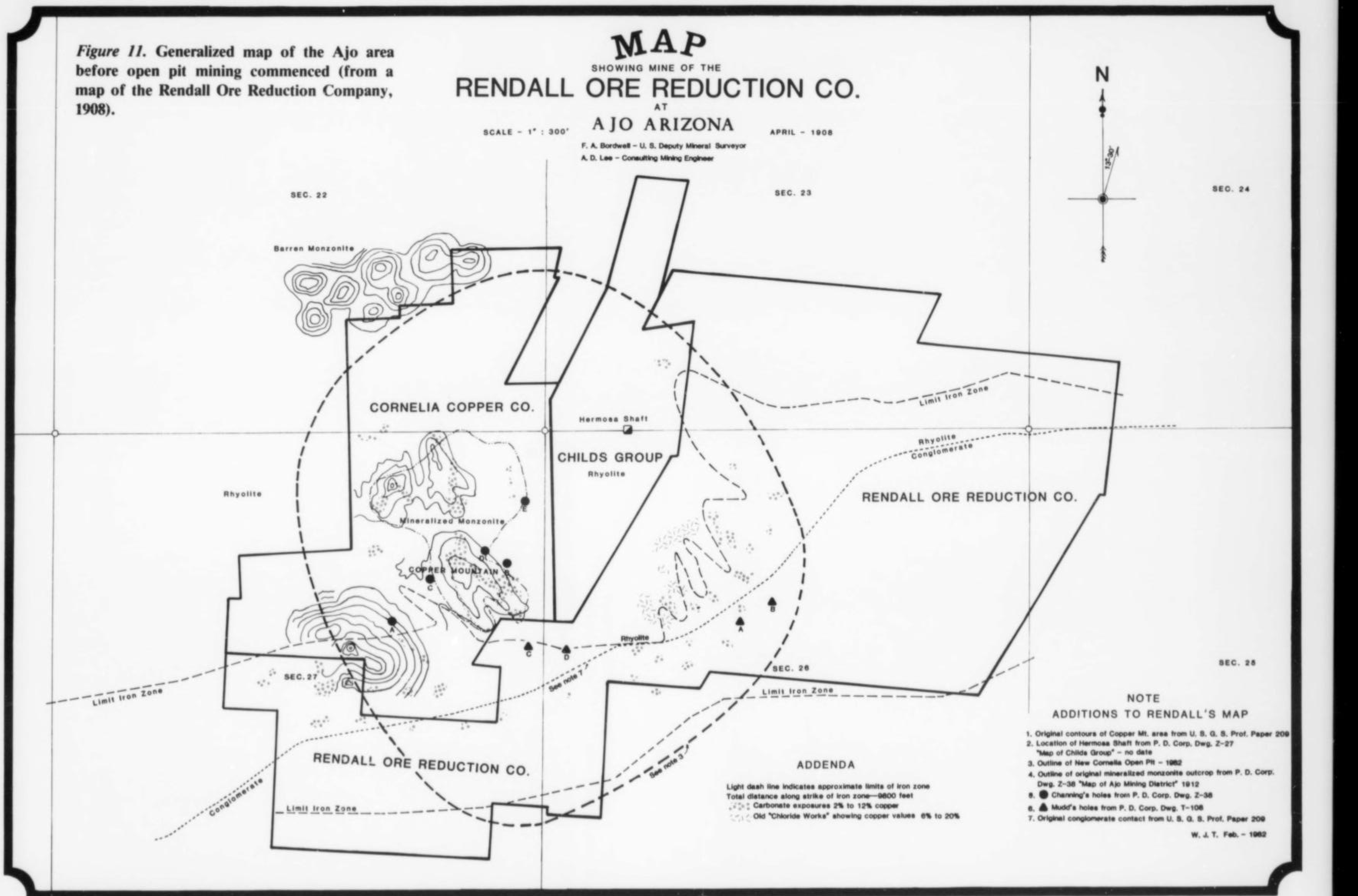


Figure 11. **Generalized map of the Ajo area before open pit mining commenced (from a map of the Rendall Ore Reduction Company, 1908).**

Figure 12. **The three green hills of Ajo are visible in this photo taken during mining of the carbonate ores in 1919.**

Figure 13. **The New Cornelia mine in 1929.**

the enterprise. The New Cornelia Copper Company, under the guidance of Greenway and Dr. Louis D. Ricketts, began the development of a leaching process for the treatment of the carbonate ores in 1912. Experimental leaching work, first conducted with a 1-ton capacity plant, was followed by a 40-ton capacity plant for a period of one year. The larger leach plant was designed to treat 5,000 tons of ore-grade material per day for seven years. This was the estimated period required to treat the available ore (Bell, 1930; Barr *et al.*, 1932).

From 1913 to 1915, before construction work on the leach plant commenced, an adequate water supply for the subsequent operations was developed in the valley 7 miles north of Ajo; the Tucson, Cornelia & Gila Bend Railroad was completed from Gila Bend to Ajo; and a new townsite was constructed (Barr *et al.*, 1932).

The leach plant was completed on May 1, 1917. The first charge of ore was finished on May 17, and by June 1 the bulk of solutions in circulation had become sufficiently concentrated with copper to permit the operation of the electrolytic plant. On June 18, the first car of copper cathodes was shipped east to be melted and cast into finished shapes (New Cornelia Copper Company, 1919).

From the start, the New Cornelia operation was a success. The leach plant continued in operation until July of 1930. During this period, 17 million tons of carbonate ore containing 1.3 percent copper were treated (Bell, 1930).

In 1919, experiments in concentrating the sulfide ores commenced and by 1923 sufficient sulfide ore had been uncovered to warrant building a concentrating plant. The original plant, which had a rated daily capacity of 5,000 tons of ore, was put into operation in January of 1924. By 1929, the concentrator was enlarged and improved to a daily capacity of 15,000 tons. In 1929, the New Cornelia Copper Company was consolidated with the Calumet and Arizona Mining Company and, in 1931, this company merged with Phelps Dodge Corporation (Barr *et al.*, 1932).

Many companies failed at Ajo and it took the foresight of men like Greenway, Joralemon and Ricketts to find the orebody and develop the New Cornelia open pit copper mine. Due to modernization and expansions, the 5,000-ton per day concentrator was increased to 31,000 tons per day; a smelter was placed in operation in 1950; a gas treatment plant consisting of a sulfuric acid plant and a dimethylaniline (DMA) absorption plant was constructed during 1974; and a new molybdenum recovery plant went on line in November, 1980.

Since October 1, 1931, the Ajo property has been operated as the New Cornelia Branch of Phelps Dodge Corporation.

GEOLOGY

Although in many ways unique, the geology of the New Cornelia mine has many things in common with other porphyry copper deposits of the southwestern United States. For a detailed description, the reader is referred to U.S.G.S. Professional Paper 209 by James Gilluly.

Concentrator volcanics of Cretaceous age are intruded by a Laramide-age stock (63 million years old) which is composed of several facies including quartz diorite and the Cornelia quartz monzonite. Unconformably overlying these rocks is the Tertiary Locomotive fanglomerate which contains lenses of andesitic Ajo volcanics. Tertiary andesitic porphyry dikes crosscut all these rocks.

The Concentrator volcanics consist of tuffs, tuff and flow breccias and flows ranging from rhyolitic to andesitic in composition. They are highly fractured and usually show strong phyllic alteration in the mine area. Although poorly mineralized in copper, they host the majority of the molybdenum mineralization.

The intrusive rocks consist of earlier fine to medium-grained quartz diorite and later porphyritic Cornelia quartz monzonite. The quartz monzonite is locally pegmatitic. Both rocks are believed to have come from related magma chambers at depth (Abbott and Rosta, 1974). All the intrusive rocks in the pit have undergone some type of alteration, especially propylitic, phyllic and potassic. There are no exposures of unaltered intrusives in the pit. The intrusives are highly fractured, hosting most of the copper mineralization.

Figure 14. **Polished cabochons of copper in chrysocolla with cuprite. The largest measures over 2½ inches. Gail Richardson specimens.**

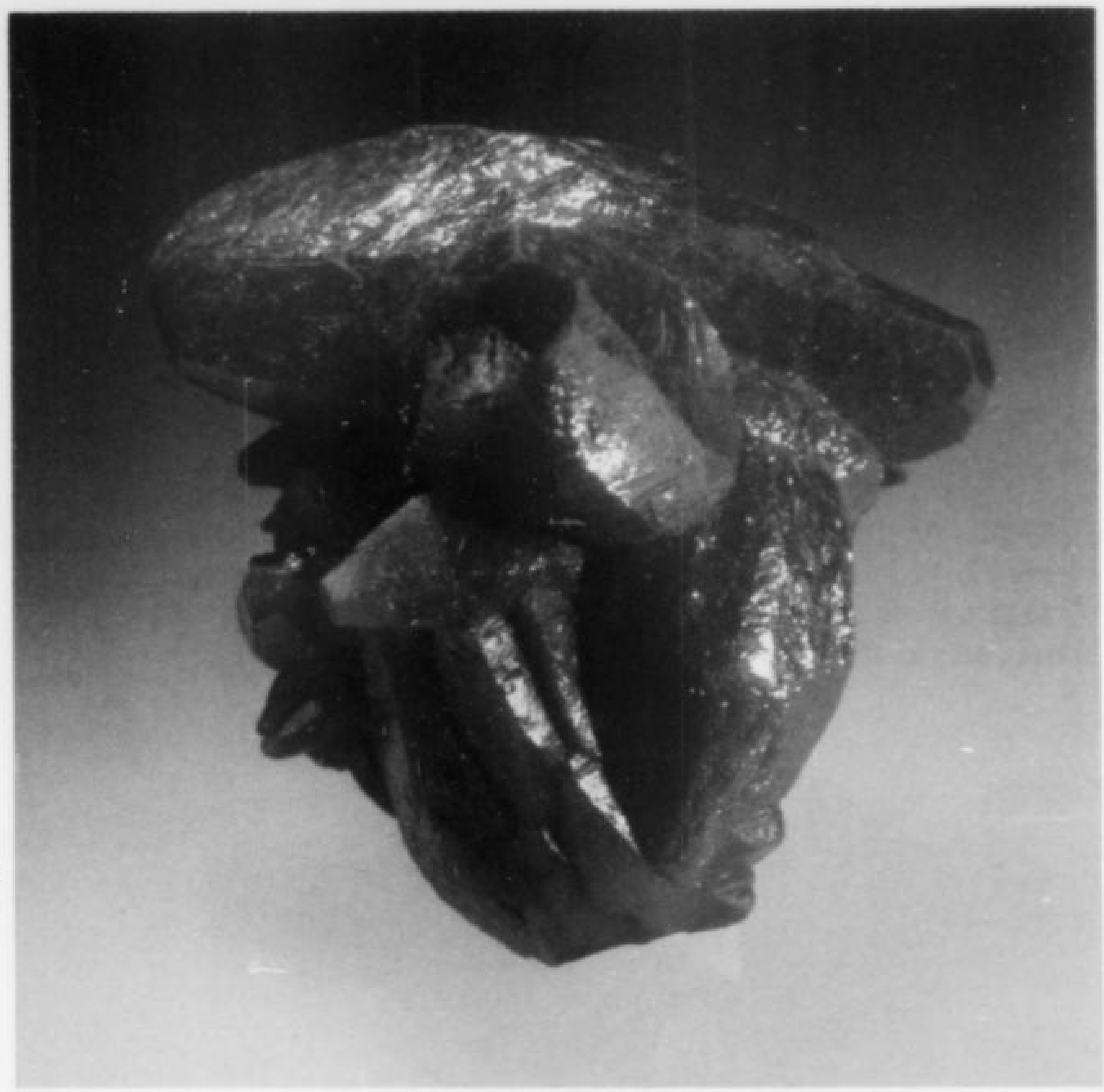
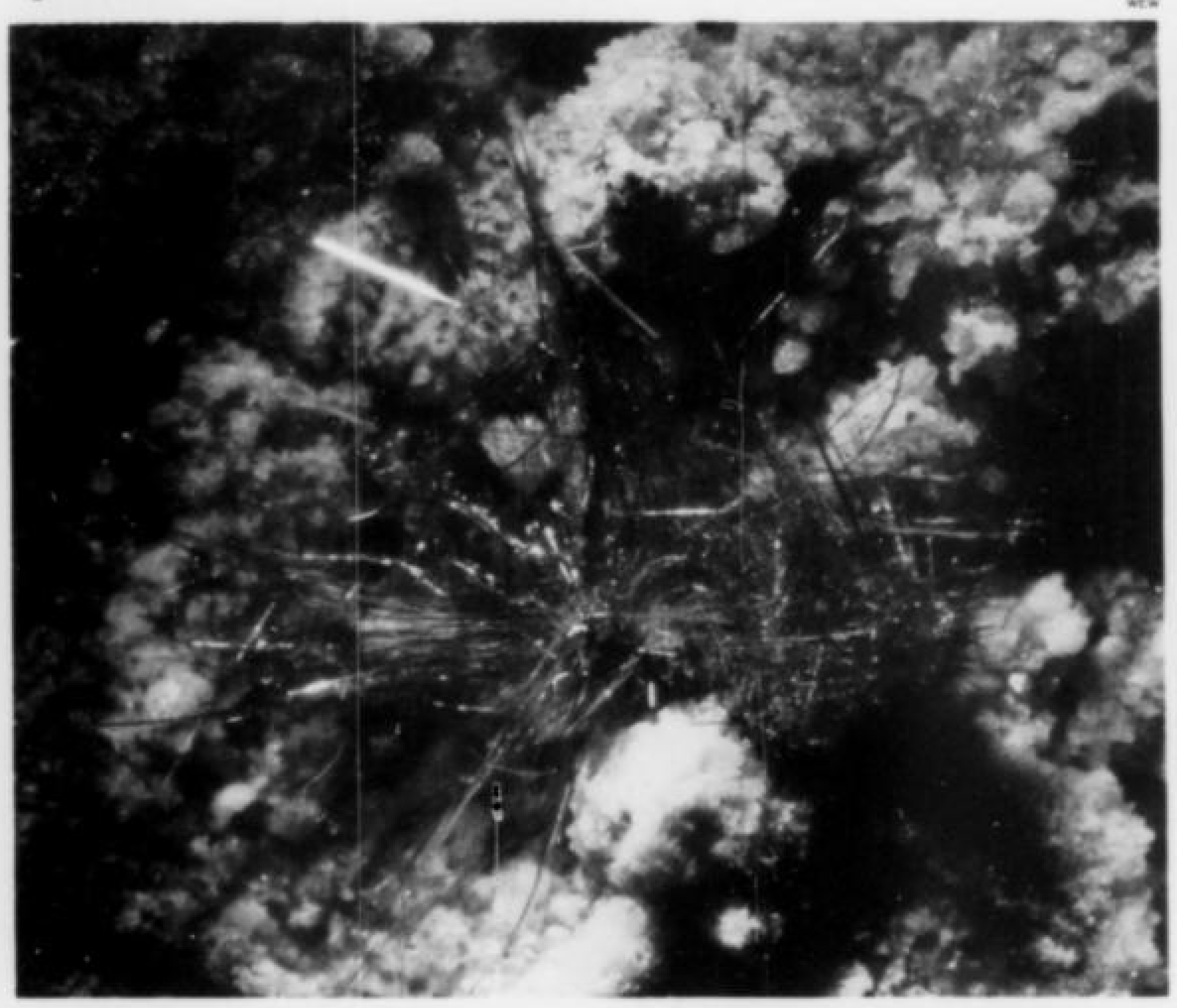


Figure 15. **Calcite crystals colored red by cuprite inclusions. The doubly terminated crystal is ¾ inch long. R. Gibbs specimen.**

Figure 16. **Acicular cuprite (chalcotrichite) spray measuring about ⅕ inch across. R. Gibbs specimen.**



The Locomotive fanglomerate consists of coarse arkose containing pebble to boulder-sized fragments of the older rocks. Most of the cobbles are angular and sometimes contain secondary copper minerals such as chrysocolla and malachite. Minor late-stage mineralization is found in the fanglomerate as small veins of no economic value. Andesitic flows of Ajo volcanics are intercalated within the fanglomerate.

The andesite porphyry dikes range in age from pre- to post-fanglomerate. They range in color from bluish gray to black and are fine grained; however, some contain plagioclase phenocrysts. One dike in particular has distinctive, large phenocrysts and is known as the Hospital porphyry. It is a conspicuous feature on the east side of the pit.

The entire porphyry copper deposit is within a fault block which rotated during Basin and Range movement on the Little Ajo Mountain fault. Because of this rotation, the original flat-lying fanglomerate now dips steeply to the south.

In the pit itself, there are several important faults. One set which

Figure 17. **Malachite pseudomorphs after blocky azurite crystals on velvet malachite, 2¾ inches tall. W. Thomas specimen.**

Figure 18. **Acicular malachite on matrix, 1 inch tall. W. Thomas specimen.**

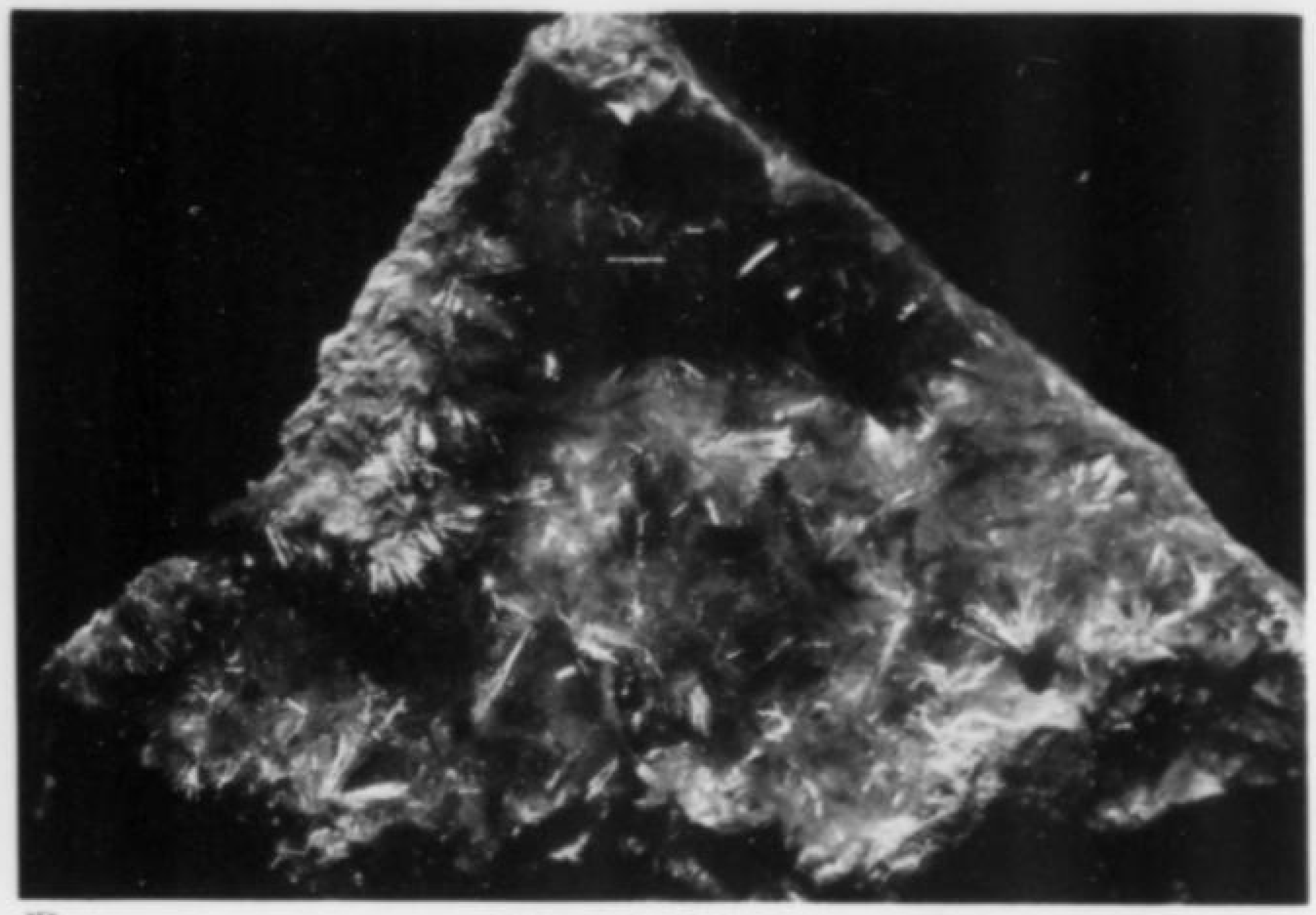
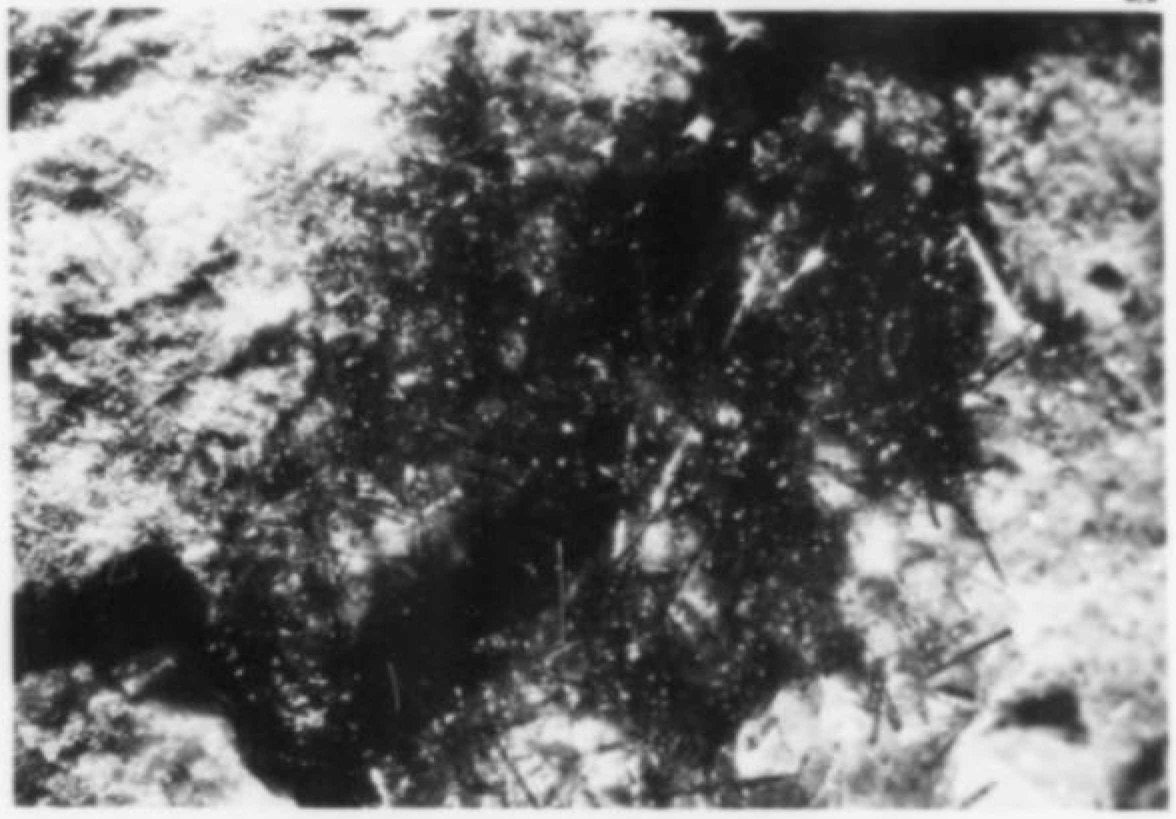


Figure 19. **Olivenite crystals on pale blue ajoite, ⅔ inch across. W. Thomas specimen.**

Figure 20. **Olivenite crystals on matrix. The view is about ¼ inch across. W. Thomas specimen.**



strikes northeast and exhibits a shallow dip to the southeast divides the orebody into imbricate slices which make copper values somewhat erratic in the southern part of the mine. These faults were probably formed as gravity slides when the orebody was being rotated. Another set, which is more recently formed, shows normal offset and strikes north-northeast to northwest and dips steeply to the east. These fault sets sometimes cause slope stability problems and include the Arkansas Mountain fault, the Charlie fault and the Easy fault. The Arkansas Mountain fault also brings relatively unaltered rocks on the northwest into contact with the altered, mineralized rock in the mine.

Several stages of vein formation occur in the deposit. The earliest consists of quartz veins with some copper and molybdenum sulfides. Next, potassic veins containing quartz and/or anhydrite with potassium feldspar, chalcopyrite, bornite and minor pyrite formed in the core of the deposit. These veins make up the bulk of the commercial mineralization. The third set of veins to form was the phyllic veins composed of quartz, sericite, pyrite and minor chalcopyrite.

Eventual exposure by erosion produced zones of secondary enrichment and oxidation. The zone of secondary enrichment at Ajo is very narrow and accounts for only a small portion of the orebody. Bornite, chalcocite and chalcopyrite form rich veins with quartz in this zone. These high-grade veins are almost entirely hypogene in origin but have been enriched somewhat by supergene chalcocite, bornite and minor chalcopyrite (Gilluly, 1946).

Pre-fanglomerate oxidation produced a nearly barren zone which locally contains azurite, malachite, cuprite, native copper and rarely ajoite, shattuckite and papagoite. Abundant finely disseminated hematite colors this zone red. Immediately below is the zone of supergene enrichment dominated by veins and veinlets of chalcocite. Most of the copper in these zones has migrated downward.

The recent oxidation period differs from the first by a lack of downward migration of copper (Gilluly, 1946). Sulfides were transformed in place to malachite, azurite and chrysocolla. Some minor chalcocite also was formed. Malachite was much more dominant than in the early oxide zone and formed the bulk of the early ore which was processed by leaching.

The orebody as we see it today is believed to have been formed by a quartz monzonite intrusion and the resultant brecciation, fracturing, and hydrothermal fluid flow associated with that intrusion. Abundant copper sulfide veins were formed containing the primary ore minerals. Erosion then cut into the core of the deposit, forming an oxidized zone above a shallow water table and a thin supergene enrichment zone at the water table. The fanglomerate was deposited on this erosion surface. Rotation of the fault block south of the Little Ajo Mountain fault occurred during Basin and Range tectonism. During the same event, the orebody was tipped onto its side and cut by faults into imbricate slices. During this rotation, the Arkansas Mountain fault placed less altered rocks to the northwest in juxtaposition with the altered rocks in the pit. Finally, erosion formed the landscape to its present topography, with a second oxidized zone capping the primary sulfide orebody.

MINERALOGY

Ajo is best known for its suite of copper silicate minerals (especially ajoite, papagoite and shattuckite) and is the type locality for ajoite and papagoite. These and shattuckite occur with other minerals in the old oxide zone preserved by faulting beneath the new oxide zone. Shattuckite is of interest to lapidaries for excellent

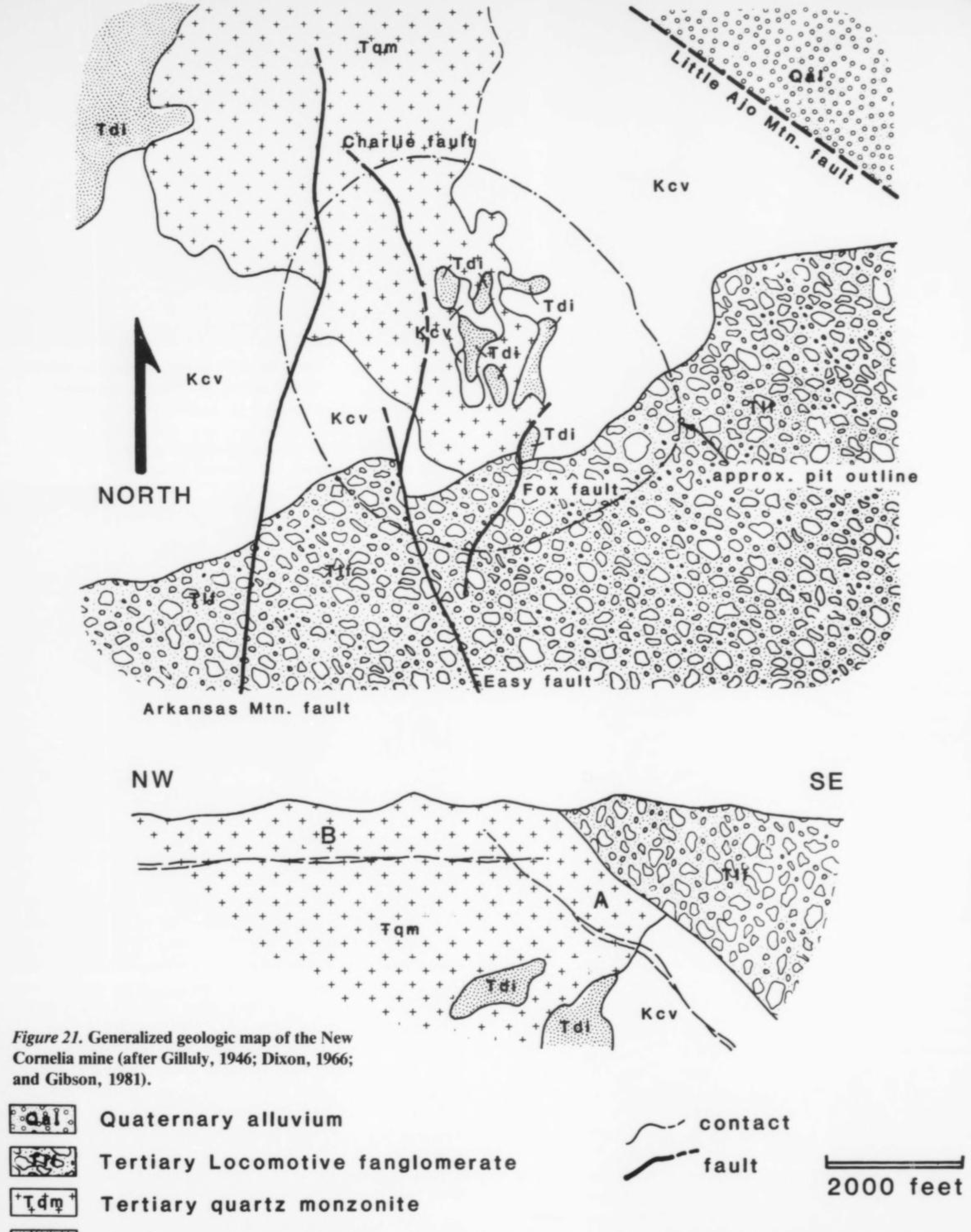


Figure 21. **Generalized geologic map of the New Cornelia mine (after Gilluly, 1946; Dixon, 1966; and Gibson, 1981).**

cabochons and carvings because it is often found in massive, crystalline veins up to 6 inches wide.

A pocket of exceptional quality azurite and malachite was found in the mid-1970's. Many large and lustrous azurite crystals and masses of radiating crystalline malachite were recovered on the west side of the mine in the old oxide zone. Very beautiful malachite pseudomorphs after azurite, some with an oriented secondary overgrowth of azurite, were recovered from the same area.

Ajo has also produced some exceptional copper specimens, from large, euhedral crystals an inch across to delicate, arborescent, fern-like groups. These were also found in the old oxide zone.

As mentioned above, the orebody was subjected to two periods of oxidation. The first, or older, was the most significant. It produced the copper silicate-arsenate suite, the spectacular azurite and malachite specimens, native copper and many other copper oxides. This zone was preserved by burial under the Locomotive fanglomerate and faulted to its present southerly dip. The second, or younger, oxide zone was richer in copper than the first and was dominated by malachite, chrysocolla and azurite. The second oxide zone produced the material that was processed in the acid leach plant constructed in 1917. Very little of this zone remains. Specimens from this zone are scarce, leading one to believe that the zone was not productive of mineral specimens.

Figure 22 presents the paragenesis of mineral formation in the New Cornelia orebody. The silicate suite is based on hand specimen observation. Shattuckite was the first to form, but its parent mineral is unknown. Perhaps it was high-grade chalcopyrite and chalcocite veins, such as those found below the old oxide zone.

CATALOG OF MINERALS

This catalog of Ajo minerals is derived from the literature as cited and listed in the bibliography, and from personal observations by the authors. William J. Thomas, now retired, was employed at Ajo for 38 years as an engineer, and his mineral collecting and field observations span that period. Ronald Gibbs has worked at the New Cornelia Branch for four years as a geologist and currently as an engineer.

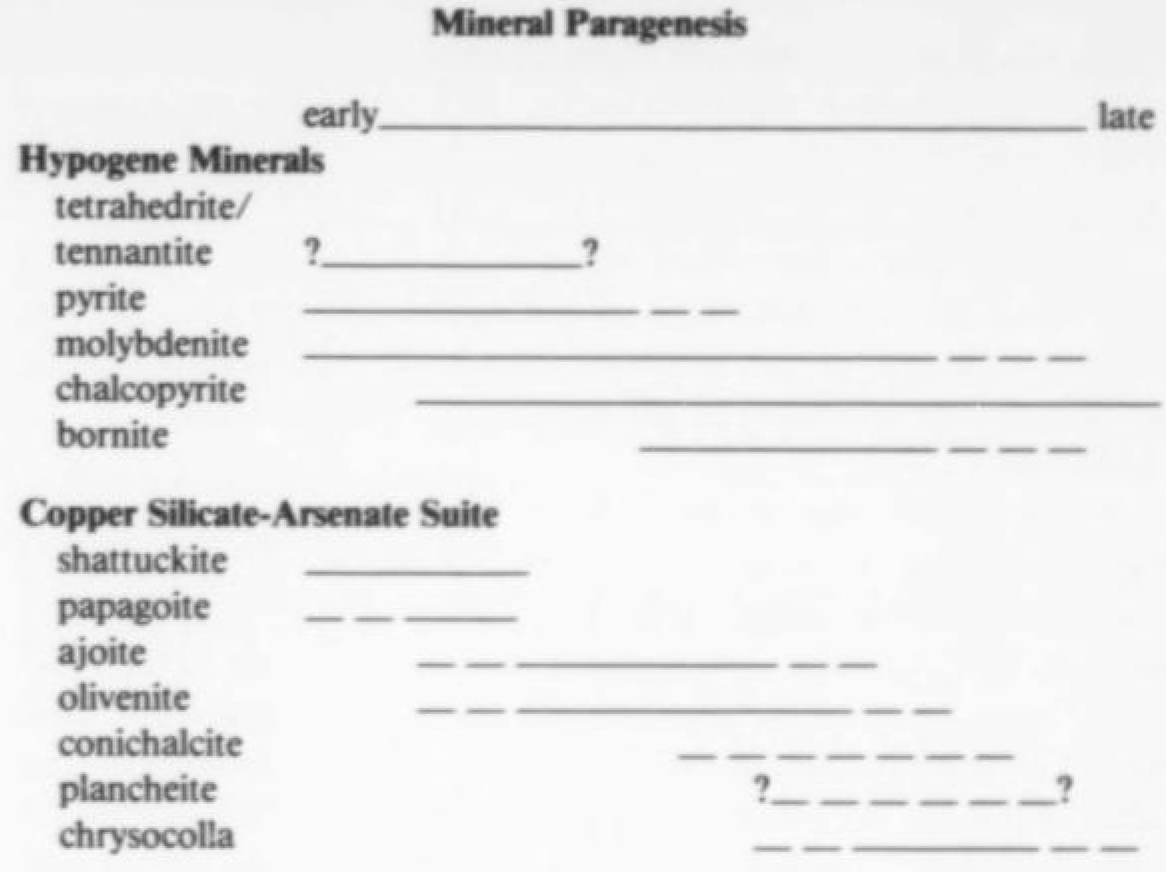


Figure 22. **Mineral Paragenesis at the New Cornelia mine.**

Ajoite $(K,Na)Cu_7AlSi_9O_{24}(OH)_6 \cdot 3H_2O$

Ajo is the type locality for this mineral. The original samples were collected by Harry Berman in 1941. This new mineral was later investigated by Schaller and Vlisidis who published their results in 1958. It occurs as massive fracture-coatings and vein-fillings and occasionally as well-formed, elongated, bladed or acicular crystals in vugs associated with shattuckite, quartz, sericite, pyrite, conichalcite, kaolinite, barite, olivenite and pyrolusite. Shattuckite veins are nearly always surrounded by much wider zones of abundant ajoite. It is generally seen as a replacement of shattuckite but has also been noted as having been replaced by shattuckite (Schaller *et al.*, 1958).

Allanite $(Ce,Ca,Y)_2(Al,Fe^{+3})_3(SiO_4)_3(OH)$

Noted as an accessory mineral in the quartz monzonite (Williams, 1966) and intergrown with epidote (Khin, pers. comm., 1981).

Rock-forming Minerals

anatase	forsterite	plagioclase
allanite	hornblende	rutile
augite	microcline	titanite
biotite	monazite	topaz
brookite	orthoclase	zircon
fluorapatite		

Hypogene and Alteration Minerals

actinolite	enargite	phlogopite
anhydrite	epidote	pyrite
bornite	galena	quartz
chalcopyrite	gold	silver
chamosite	ilmenite	sphalerite
clinochlore	magnetite	tennantite
clinozoisite *	molybdenite	tetrahedrite
diaspore	muscovite	tourmaline

Secondary Minerals

ajoite	connellite	neotocite
allophane	copper	nontronite
alunite	covellite	olivenite
ankerite	cuprite	opal
aragonite	dolomite	palygorskite
atacamite	epsomite	papagoite
aurichalcite	ferrierite	plancheite
azurite	goethite	planerite *
barite	gypsum	pseudomalachite
beidellite	halite	psilomelane *
bieberite	hematite	pyrolusite
bisbeeite *	heulandite	shattuckite
brochantite	jarosite	siderite
calcite	kaolinite	stibiconite *
chabazite	laumontite	stilbite
chalcanthite	malachite	sulfur
chalcocite	melanterite	tenorite
chrysocolla	mottramite	turquoise
conichalcite		

* Unconfirmed or of questionable nomenclature; see description.

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

One drill-core specimen of Concentrator volcanics from an unknown location in the pit contained actinolite. It occurs as glassy, transparent, bright green crystals in $^1/_{16}$-inch radiating sprays.

Allophane (amorphous hydrous aluminum silicate)

Found rarely as a thin blue-gray coating on botryoidal hematite in both oxide zones.

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

Locally abundant in the uppermost portions of the mine, especially in the eastside volcanics. Occurs as dense, porcelaneous, pale greenish yellow veins to 3 inches thick associated with jarosite and iron oxides (Gilluly, 1946).

Anatase TiO_2

Minor amounts have been observed in the altered rock which contained the type specimens of papagoite (Hutton and Vlisidis, 1960). It is one of the minerals associated with alpine veining formed during alteration of the orebody (Williams, 1966).

Anhydrite $CaSO_4$

Found in the core of the orebody as a constituent of primary hypogene veins. It occurs as lavender, brown or white, sugary to coarsely crystalline masses associated with quartz, chalcopyrite and bornite. It is observed only at depth. In the upper part of the mine it has been replaced by gypsum. No euhedral crystals have been seen, but veins up to 6 inches thick of almost pure anhydrite have been observed. Some molds of thick, tabular crystals to 1 inch wide, that may have been anhydrite, have been observed in leached chalcopyrite veins.

Ankerite $Ca(Fe^{+2},Mg,Mn)(CO_3)_2$

Found as massive veins and in cavities as druses of small euhedral crystals with curved faces. It weathers to a buff color, is commonly coated with calcite and is sometimes associated with barite. Gilluly (1946) reported it as a late hydrothermal mineral.

Aragonite $CaCO_3$

Rarely seen as small, radiating, acicular crystals associated with malachite in areas of recent water seepage.

Atacamite $Cu_2Cl(OH)_3$

First noticed in 1946 on Arkansas Mountain by Dr. L. E. Reber, Jr., a Phelps Dodge geologist. It is rarely seen as dark green parallel intergrowths of small crystals associated with malachite and chrysocolla in the upper-most levels of the pit.

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

Micro-phenocrysts of augite are found in the groundmass of the Hospital porphyry (Gilluly, 1946).

Aurichalcite $(Zn,Cu)_5(CO_3)_2(OH)_6$

Reported as a sparse associate with papagoite (Anthony *et al.*, 1977). One specimen of fine, acicular tufts of sky-blue aurichalcite associated with calcite and pyrolusite was collected from the east side of the mine by W. Thomas.

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

Azurite was found mainly in the most recent oxide zone as thin veins and coatings with malachite and chrysocolla. In the 1970's a spectacular pocket was found in the upper west side. It contained large crystals, many exceeding 1 inch in length, associated with malachite and barite (Wilson, 1976). Curiously, some crystals are lustrous while others are dull. Occasionally, fine pseudomorphs of malachite after azurite were found with the azurite. Some of these pseudomorphs have an oriented secondary overgrowth of azurite.

Barite $BaSO_4$

Generally found in the upper levels of the mine in the Concentrator volcanics associated with specular hematite and quartz. It is also found with malachite, azurite, jarosite, ankerite and goethite as small, clear prisms or white, thin, tabular plates.

Beidellite $(Na,Ca_2)_{0.33}Al_2(Si,Al)_4O_{10}(OH)_2 \cdot nH_2O$

Common as replacements of plagioclase on the borders of the mineralized area. Also found in fault gouge and as coatings in the zone of oxidation (Gilluly, 1946).

Bieberite $CoSO_4 \cdot 7H_2O$

A pink efflorescence in a drainage ditch was identified as bieberite but no cobalt source-mineral has been found (Gilluly, 1946).

Biotite $K(Mg,Fe^{+2})_3(Al,Fe^{+3})Si_3O_{10}(OH,F)_2$

A primary constituent of the volcanic and igneous rocks of the mine. Large crystals occurred in the pegmatites but are generally replaced by chlorite (Gilluly, 1946).

Figure 23. **Azurite crystal group about 2 inches tall. W. Thomas specimen.**

Bisbeeite $CuSiO_3 \cdot H_2O$

The only reference to this mineral states that it occurs in veins in the mine (Anthony *et al.*, 1977). We have not been able to verify the bisbeeite occurrence at Ajo.

Bornite Cu_5FeS_4

The second most prominent ore mineral in the mine, after chalcopyrite. Chiefly of hypogene origin, minor amounts are present as an alteration of chalcopyrite. Found as grains, stringers and veins sometimes exceeding 6 inches thick.

Brochantite $Cu_4(SO_4)(OH)_6$

Rarely seen as a druse on calcite associated with gypsum in areas with recent water seepage. It has also been found rarely as fine, acicular crystals from the upper westside oxide zone.

Brookite TiO_2

Veinlets in the porphyry stock contain minor brookite (Williams, pers. comm., 1981). It was also tentatively identified by Gilluly (1946) as a replacement of titanite.

Calcite $CaCO_3$

An extremely common and widespread mineral. Common as films and fracture fillings, especially in fault zones, but also frequently found as euhedral crystals. Most crystals are less than ⅛ inch but some have exceeded 2 inches in size. Crystal forms are very diverse and can be extremely complex but the scalenohedron is the dominant form. Occasionally other minerals are included within the calcite, such as malachite, goethite and cuprite (variety chalcotrichite). Some extraordinary crystals of bright red calcite colored by included chalcotrichite, and associated with native copper have been recovered.

Chabazite $CaAl_2Si_4O_{12} \cdot 6H_2O$

An uncommon mineral found in vesicles and open fractures in gray andesite dikes associated with calcite and gypsum.

Chalcanthite $CuSO_4 \cdot 5H_2O$

Frequently observed near springs and seeps in the mine, associated with other sulfates as a bright blue botryoidal crust.

Chalcocite Cu_2S

A supergene mineral more dominant in the early oxide zone.

Found as massive veins up to 3 inches in width and as sooty coatings on pyrite. Associated with chalcopyrite, bornite and quartz.

Chalcopyrite $CuFeS_2$

This is the dominant ore mineral of the deposit. It is found in veins from hairline cracks to several inches thick associated with quartz, bornite, molybdenite, anhydrite and pyrite. Euhedral crystals are extremely rare and usually distorted. Nearly all is hypogene but some is present in minor amounts as a supergene enrichment (Gilluly, 1946).

Chamosite $(Fe^{+2},Mg,Fe^{+3})_5Al(Si_3Al)O_{10}(OH,O)_8$

This member of the chlorite group occurs in the mineralized area where it fills fractures and, to some extent, replaces the wall rocks (Gilluly, 1946).

Chrysocolla $(Cu,Al)_2H_2Si_2O_5(OH)_4 \cdot nH_2O$

A common mineral in the oxide zones. It was most common in the younger oxide zone where it was one of the most important minerals for the early leaching operation (Gilluly, 1946). It is found as massive vein fillings and encrustations and rarely as pseudomorphs after malachite. It occurs as an alteration product of malachite, azurite, plancheite and pseudomalachite. On rare occasions, excellent masses of blue chrysocolla with native copper and cuprite have been recovered which are highly prized for cabochons.

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

This chlorite occurs as pseudomorphic replacements of biotite and hornblende in the igneous and volcanic rocks (Gilluly, 1946).

The variety *pennine* has been found in veins as dark green scaly masses with euhedral quartz and calcite.

The *aphrosiderite* variety of clinochlore was found by Gilluly as broad "leafy" rosettes in the pegmatitic masses. This variety is no longer accepted (Fleischer, 1980).

Clinozoisite $Ca_2Al_3(SiO_4)_3(OH)$

The presence of this mineral has not been confirmed but was tentatively identified as altered from plagioclase in the volcanic and igneous rocks (Gilluly, 1946).

Conichalcite $CaCu(AsO_4)(OH)$

Found sparingly in the old oxide zone associated with olivenite, ajoite and shattuckite. It is usually found as massive vein fillings or fracture coatings. Crystals are usually minute and equant.

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

Has been reported in vugs in cuprite (Anthony *et al.*, 1977).

Copper Cu

Native copper was found during the earliest days of mining at Ajo and, with cuprite, formed the ore shipped to Swansea, Wales, in 1855. It has been found at the erosion surface upon which the Locomotive fanglomerate was deposited (Gilluly, 1946), and is associated with chalcocite, hematite, cuprite, tenorite, chrysocolla, malachite, calcite and shattuckite. At various times considerable amounts of native copper have been mined. Several pieces weighing over 200 pounds, and numerous other pieces of at least 100 pounds, were sent to various museums. Many of the smaller specimens are well crystallized and range from fine wire to crystals over 1 inch across. Much of the material is irregularly distorted as filiform and arborescent habits.

Covellite CuS

Found sparingly as minute blebs in chalcocite veins on the south side of the orebody and as a thin sheen on chalcopyrite in many places (Gilluly, 1946).

Cuprite Cu_2O

Found in both oxide zones but most commonly in the older zone (Gilluly, 1946) as massive veins and blebs with malachite, chrysocolla, tenorite, hematite and native copper. More rarely it has been seen with and replacing shattuckite. It rarely occurs as cubic and octahedral crystals as large as ½ inch. The acicular variety *chalcotrichite* is frequently seen, sometimes enclosed by calcite. At one time chalcotrichite was so common that miners made baseballs of it.

Diaspore AlO(OH)

This mineral is found in the contact metamorphism zone on the east side of the pit (Williams, 1966).

Dolomite $CaMg(CO_3)_2$

A little dolomite is found in the ores as a lining in drusy cavities (Gilluly, 1946). Infrequently, it is seen as microcrystals with shattuckite.

Enargite Cu_3AsS_4

Minor amounts of enargite have been recognized in the copper ores (Williams, 1966).

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

The iron-rich variety *pistacite* occurs in small amounts as an alteration product of the dark minerals and plagioclase of the Cornelia quartz monzonite and Concentrator volcanics. It is intimately associated with specular hematite, chalcopyrite and quartz in small veins (Gilluly, 1946). Allanite is sometimes intergrown with epidote as noted by Khin (pers. comm., 1981).

Epsomite $MgSO_4 \cdot 7H_2O$

Epsomite was identified from material taken from a desiccated crust along a rainwater pool (Gilluly, 1946). This mineral is not common but occurs as translucent, white, delicately fibrous crusts from the mineral waters along drainage ditches.

Ferrierite $(Na,K)_2MgAl_3Si_{15}O_{36}(OH) \cdot 9H_2O$

This zeolite is found in the Hospital porphyry dike. It occurs as small radiating groups of thin tabular or acicular crystals which are white or slightly yellow-stained. It is associated with calcite and heulandite, and was identified by William S. Wise, of the Department of Geological Sciences, University of California at Santa Barbara (pers. comm.).

Fluorapatite $Ca_5(PO_4)_3F$

A minor accessory mineral in the igneous rocks (Gilluly, 1946). Recently, larger euhedral crystals to ½ inch were observed in open fractures in quartz monzonite with chlorite and quartz on the 940 level. Although healed, the crystals are badly fractured.

Forsterite Mg_2SiO_4

Forsterite is a minor constituent of the Cornelia quartz monzonite and its porphyritic and diorite facies (Gilluly, 1946).

Galena PbS

Galena is rarely seen as a massive vein filling. A few minute, euhedral, cubic crystals were collected from the volcanics on the east side of the pit above the 1300 level.

Goethite FeO(OH)

Goethite was identified positively in only a few specimens. In these it occurred as a constituent of a yellow-brown to deep brown limonitic crust on the rusty outcrops of the oxidized part of the orebody (Gilluly, 1946). Minute crystals of goethite as ocher-yellow, golden brown and blackish brown fibrous balls have been found on and in calcite crystals which are sprinkled with pyrite and quartz crystals.

Gold Au

Finely disseminated gold is closely associated with the copper sulfides, but cannot be seen (Gilluly, 1946). Gold is of economic importance since it is recovered during electrolytic refining. Native gold was found in the gravels of the Cornelia arroyo during the early development of the mine, and more recently in a brecciated quartz chalcopyrite vein.

Gypsum $CaSO_4 \cdot 2H_2O$

Small amounts of gypsum occur in the weathered zone associated with jarosite (Gilluly, 1946). Crystals are commonly flattened, prismatic or acicular. Gypsum is commonly found as thin vein and fracture fillings below the oxide zone. It is probably derived from the hydration of anhydrite. Occasionally gypsum has been found in large, transparent masses up to 2 feet across, enclosing bright, irregular specks of bornite and chalcopyrite.

Halite NaCl

A little halite, associated with epsomite, was found as encrustations formed along ditches carrying water. It seems likely that this halite is of meteoric origin and is concentrated by evaporation of rain water. It probably has no genetic connection with the ore deposition (Gilluly, 1946).

Hematite Fe_2O_3

Hematite is common and widespread in the oxide zones. It occurs as brilliant crystals with quartz in joints and cracks, as earthy masses and coatings, massive veins and as the colorfully iridescent variety *turgite*.

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

Abundant small, clear euhedral heulandite crystals have been found with calcite and ferrierite in the Hospital porphyry. It has also been found with pink orthoclase, clear rounded calcite crystals and sprays of stilbite in leached chalcopyrite veins in the north end of the pit.

Hornblende $(Ca,Na)_{2-3}(Mg,Fe^{+2},Fe^{+3},Al)_5(Al,Si)_8O_{22}(OH)_2$

Hornblende is a primary mineral of the Cornelia quartz monzonite and the Concentrator volcanics. In the mineralized parts of the Cornelia quartz monzonite it has been completely altered to chlorite (Gilluly, 1946).

Ilmenite $Fe^{+2}TiO_3$

Ilmenite at Ajo appears to have been formed in two ways. A little of it is associated with magnetite as a primary accessory constituent of the Cornelia quartz monzonite, but much of it seems to have been formed by the alteration of titanite during ore deposition (Gilluly, 1946).

Jarosite $KFe_3^{+3}(SO_4)_2(OH)_6$

Jarosite is usually found as yellow-brown earthy masses and coatings in the weathered zone, and has been observed encrusting earthy hematite on weathered outcrops (Gilluly, 1946). Occasionally, small gemmy euhedral crystals are found scattered on white Concentrator volcanics.

Kaolinite $Al_2Si_2O_5(OH)_4$

Kaolinite is found predominantly on the east side of the pit as a weathering alteration product of orthoclase feldspar and muscovite. It has been noted as a white web-like filling in cracks with ajoite and it has been found in a few cracks on Arkansas Mountain as a mixture with malachite.

Laumontite $CaAl_2Si_4O_{12}\cdot 4H_2O$

Laumontite has been found rarely as vesicle fillings consisting of elongate pink crystals intergrown with calcite in the andesite dikes.

Magnetite $Fe^{+2}Fe_2^{+3}O_4$

Magnetite is a primary accessory constituent of the Cornelia quartz monzonite and occurs as microscopic, discrete, euhedral octahedrons. It is also found associated with pegmatite veins as veinlets of magnetite which are commonly very thin but locally are as much as 4 inches thick (Gilluly, 1946).

Malachite $Cu_2(CO_3)(OH)_2$

Malachite was the most common weathering product of the copper minerals. It was also the dominant ore mineral processed in the leach plant. It was present chiefly as veinlets and coatings on fractures and was commonly found coated in part by azurite, tenorite or chrysocolla (Gilluly, 1946). The most beautiful specimen material is the malachite pseudomorphs after azurite which were mined from a single fissure on the west side of the mine in the early 1970's. A large number of very esthetic groupings of azurite crystals and malachite pseudomorphs were removed from this vein. Occasionally very attractive acicular malachite specimens are found on the east side of the pit.

Melanterite $Fe^{+2}SO_4\cdot 7H_2O$

Melanterite occurs as yellowish and green concretionary crusts on exposed surfaces of seeps and drainage channels.

Microcline $KAlSi_3O_8$

Microcline formed coarse crystals in the pegmatitic masses in the central part of the New Cornelia orebody. Crystals of microcline were commonly anhedral, but cleavage faces several inches across were rather common. In places, vugs more or less filled with chalcopyrite and bornite contained microcline crystals 3 or 4 inches across, with well-developed domes and clinopinacoids (Gilluly, 1946).

Molybdenite MoS_2

This mineral is widely distributed in the orebody and is commonly present as smears on slickensides (Gilluly, 1946). In small vugs bright, hexagonal, euhedral crystals and fine rosettes of molybdenite are seen occasionally on euhedral quartz crystals.

Monazite $(Ce,La,Nd,Th)PO_4$

Monazite has been noted as an accessory mineral in the quartz monzonite (Williams, 1966).

Mottramite $PbCu(VO_4)(OH)$

Mottramite occurs in trace amounts as a yellowish green crust on weathered outcrops of Hospital porphyry (Gilluly, 1946).

Muscovite $KAl_2Si_3O_{10}(OH)_2$

In outlying areas and in the pegmatitic core, muscovite occurs as "books" of broadleaved, coarse crystals. The variety *sericite* is much more abundant and is found around the core of the orebody.

Neotocite $(Mn,Fe^{+2})SiO_3\cdot H_2O$

This black mineral forms beautiful dendrites on white volcanics. On the west side of the pit, the volcanics are brittle and highly fractured and many fractures are coated with dendrites.

Nontronite $Na_{0.33}Fe_2^{+3}(Si,Al)_4O_{10}\cdot nH_2O$

A brownish crust on malachite on the north slope of Arkansas Mountain, and a yellowish crust on the east side of the pit was identified as nontronite (Gilluly, 1946). It has also been noted in the south end of the pit as yellowish to pistachio-green crusts filling minor cracks. It is opaque, brittle and lustrous to earthy in appearance.

Olivenite $Cu_2AsO_4(OH)$

Olivenite is commonly found with ajoite and shattuckite in the older oxide zone. It frequently forms euhedral acicular crystals seldom over 1/16 inch in size and ranges in color from light olive-green to almost black.

Opal $SiO_2\cdot nH_2O$

Opal is infrequently seen associated with chrysocolla in the oxidized portion of the mine (Gilluly, 1946). The variety *hyalite* is sometimes seen as clear, transparent globules coating chrysocolla and malachite in the uppermost part of the mine.

Orthoclase $KAlSi_3O_8$

The most conspicuous and one of the most abundant gangue minerals at Ajo is orthoclase. It occurs both as phenocrysts in the Cornelia quartz monzonite and as minute crystals in the groundmass of the monzonite (Gilluly, 1946).

Palygorskite $(Mg,Al)_2Si_4O_{10}(OH)\cdot 4H_2O$

Occurs as thin flexible sheets or "mountain leather," and as spongy masses with calcite crystals along shear planes.

Papagoite $CaCuAlSi_2O_6(OH)_3$

The Ajo occurrence of this rare mineral is the type locality. Papagoite occurs as somewhat flattened, slightly elongated, cerulean-blue crystals, and is associated with aurichalcite, shattuckite, ajoite, barite and iron oxides. It was found originally in narrow veinlets and as veneers on slip surfaces in altered granodiorite porphyry at the 1750 level, in an area that has now been entirely removed (Hutton and Vlisidis, 1960). A recent find of papagoite was made in sheared oxidized granitic porphyry. Virtually every crystal had been broken and later healed.

Phlogopite $KMg_3Si_3AlO_{10}(F,OH)_2$

Ferrous phlogopite occurs in the volcanics on the west side of the pit (Williams, 1966).

Plagioclase $(Na,Ca)Al(Al,Si)Si_2O_8$ – general formula

Plagioclase in a wide range of compositions occurs in the Ajo district; anorthite, andesine and oligoclase are of igneous origin, and albite is a hydrothermal derivative of them (Gilluly, 1946).

Plancheite $Cu_8Si_8O_{22}(OH) \cdot H_2O$

Recently, massive plancheite was found in the first oxide zone, altering to chrysocolla, and associated with ajoite and malachite.

Planerite $(Cu,Ca)Al_6(PO_4)_4(OH)_8 \cdot 5H_2O$

This mineral was doubtfully identified as a weathering crust from Camelback Mountain and several other localities in the quadrangle (Gilluly, 1946). Fleischer (1980) calls it a variety intermediate in composition between coeruleolactite and turquoise.

Pseudomalachite $Cu_5(PO_4)_2(OH)_4 \cdot H_2O$

A few specimens taken from the northeast rim of the pit contain pseudomalachite which is altering to pale blue chrysocolla (Williams, pers. comm., 1981).

Psilomelane Manganese oxides

Some botryoidal coatings and crusts in the weathered zone along the Hospital porphyry have been referred to as psilomelane by others in the past. We have not verified it.

Pyrite FeS_2

Pyrite is a widespread but not an abundant mineral at Ajo. It occurs in veinlets and as discrete grains in the silicates, quartz and magnetite of the orebody. It is cut by chalcopyrite, bornite, hematite, sericite and chalcocite. Commonly the grains appear shattered and partly replaced by these minerals. Infrequently pyrite is euhedral, in crystals as large as 1½ inches in diameter, bounded by pyritohedron and cube faces (Gilluly, 1946).

Pyrolusite MnO_2

Pyrolusite has been identified in association with ajoite and olivenite as a thin, black film (William, pers. comm., 1981).

Quartz SiO_2

Quartz is one of the most abundant minerals in the mine. It is an essential constituent of the Cornelia quartz monzonite, and it occurs as fillings of innumerable fractures and as replacement masses (Gilluly, 1946). Vugs and open fractures in the core of the orebody and in the pegmatitic areas commonly were lined with euhedral quartz crystals to 6 inches in size. These are usually coated with small calcite and sericite crystals. Occasionally small euhedral quartz crystals occur perched on calcite crystals as clear singles, some of which are sceptered.

Rutile TiO_2

Rutile occurs as stumpy, euhedral to somewhat rounded prisms as a microscopic constituent of the Cornelia quartz monzonite. It also occurs as minute needles of sagenite in the chloritized biotite (Gilluly, 1946; and Hutton *et al.*, 1960).

Shattuckite $Cu_5(SiO_3)_4(OH)_2$

At various times mining has encountered large quantities of this attractive mineral. It ranges in color from light blue to almost blue-black. It is found in veins up to several inches wide that are commonly made up of interlocking rosettes of radiating crystals. Occasionally voids are found containing dark blue acicular tuffs. It is associated with quartz, calcite, conichalcite, olivenite, ajoite, chrysocolla and plancheite. Bisbee was the type locality for shattuckite, but Ajo has the distinction of providing the material to Vlisidis and Schaller (1967) for determination of the presently accepted formula for the mineral.

Siderite $Fe^{+2}CO_3$

Only one specimen has been verified. It contains small, light brown, translucent, botryoidal siderite.

Silver Ag

Silver is present in the sulfide ores and is recovered at the refinery. No silver-bearing mineral has been recognized during the microscopic examination of the ores and nothing is known of the mineral species in which silver is present. However, a few flakes of native silver were observed associated with copper, cuprite and tenorite in the old oxide zone.

Sphalerite $(Zn,Fe)S$

Sphalerite is uncommon at Ajo. It was seen in small quantities in relations which suggest it was formed by replacement of pre-existing pyrite. In one specimen it is cut by veinlets that contain chalcopyrite and bornite (Gilluly, 1946). During 1940, a vein of pyrite and sphalerite 2 to 3 inches wide occurred on the 1620 level in the northeast corner of the pit. Since that time only small micro-crystals of sphalerite have been infrequently observed on the east side.

Stibiconite $Sb^{+3}Sb_2^{+5}O_6(OH)$

Stibiconite was doubtfully identified by Gilluly (1946).

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

This mineral was found on the 1300 level on the north end of the mine. Small, light yellow, bladed crystals of stilbite were found associated with pink orthoclase, clear complex crystals of calcite and abundant clear crystals of heulandite in a leached chalcopyrite vein.

Sulfur S

Sulfur is seen as deformed, irregular crusts along water courses in high pyrite areas and as earthy material with gypsum in highly altered leached rhyolite.

Tennantite $(Cu,Fe)_{12}As_4S_{13}$

Tennantite is locally abundant in one small area in the southwest part of the mine. It is nearly pure, i.e. there is almost no antimony. The amounts of iron, silver and zinc are also unusually low (Williams, pers. comm., 1981). It is associated with minor amounts of bornite, chalcopyrite and rare covellite.

Tenorite CuO

Massive, compact tenorite occurs in the south end of the mine with cuprite, chrysocolla and native copper. Rarely it is pseudomorphous after cuprite (variety chalcotrichite).

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

Tetrahedrite is scarce, having been recognized in only two of several hundred ore specimens examined (Gilluly, 1946).

Titanite $CaTiSiO_5$

This mineral is a primary constituent of all the igneous rocks of the mining district. It occurs as euhedral crystals in the Cornelia quartz monzonite, where it is commonly 1/32 inch in length and locally exceeds ⅛ inch (Gilluly, 1946).

Topaz $Al_2SiO_4(F,OH)_2$

Topaz has been found on the east side of the pit, especially in the Concentrator volcanics with alpine veining (Williams, 1966).

Tourmaline $NaFe_3^{+2}Al_6(BO_3)_3Si_6O_{18}(OH)_4$

Rocks on the east side of the pit, especially the Concentrator volcanics, contain minor amounts of tourmaline (Williams, 1966).

Turquoise $CuAl_6(PO_4)_4(OH)_8 \cdot 5H_2O$

The only turquoise found was soft, altered, light blue material which occurred as 1/16 to ⅛-inch veins in the Concentrator volcanics on the northeast rim of the mine.

Zircon $ZrSiO_4$

Zircon occurs as small, stout crystals in the New Cornelia quartz monzonite (Gilluly, 1946; Hutton and Vlisidis, 1960; Williams, 1966).

ACKNOWLEDGMENTS

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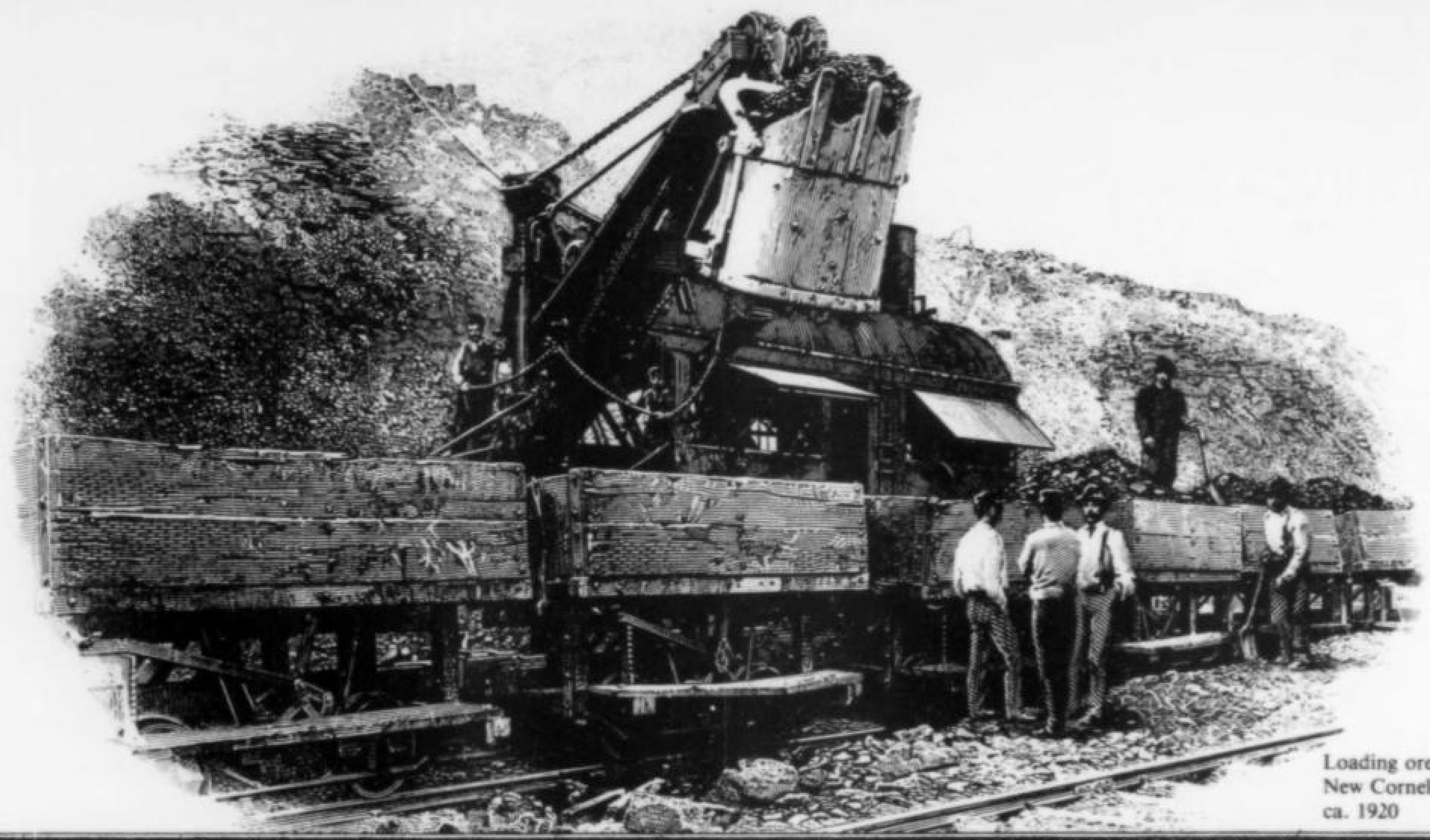

Loading ore at the New Cornelia mine, ca. 1920

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the Glove mine

by **Wendell E. Wilson**
P.O. Box 35565
Tucson, Arizona 85740

and **Richard Bideaux**
252 W. Ina Road
Tucson, Arizona 85704

From 1955 to 1959 the Glove mine, in the Santa Rita Mountains, produced thousands of fine wulfenite specimens. A variety of attractive colors and distinctive habits qualify this wulfenite as among Arizona's best.

LOCATION

The Glove mine is located in the western foothills of the Santa Rita Mountains, in Santa Cruz County, Arizona, about 40 miles south of Tucson. It is situated in the north-central part of the Tyndall mining district just north of Cottonwood Canyon, in Sec. 30, R.14E, T.20S, *Mt. Wrightson, Arizona,* 15-minute quadrangle. Access is easy by way of the Arivaca exit on Interstate Highway 89/19, north of Tubac, and from there by a dirt road into the mountains.

HISTORY

The first claims in the Glove area were filed by Edward T. Sheehy and associates in 1907. During the early years a total of 16 claims were filed, though only two eventually proved to be of economic value. Prospecting and development work were carried out from 1907 to 1911, and between 1911 and 1917 production was more or less continuous. The ore, a mixture of argentiferous galena, smithsonite and sandy-textured cerussite, was hand-sorted and hauled by mule team to the train station at Chaves, Arizona. Only about $15,000 worth of ore was shipped during this period because, amazingly, they failed to discover the main ore pipe (Olson, 1961).

The years from 1918 to 1950 were largely unproductive, and only two cars of ore were shipped to the smelter. In 1951, Edward Sheehy and his associates sold the property to Sunrise Mining Company, and the mine became active once again in 1952. The adit level was extended and the main ore pipe was discovered. During the eight years that followed, more than a million dollars in ore were shipped to the smelter, and the ore pipes were worked downward into the beginning of the sulfide zone below the 300 level. It was also during this period that most of the fine wulfenite was collected (Olson, 1961).

Since 1960, mining has been intermittent, and mostly in the sulfide zone. During the 1970's development work was done by Colorado Fuel and Iron (1972) and another million dollars in ore was shipped by Sunrise Mining Company (1974–1976) and McFarland and Hullinger (1976–1977) (Arizona Department of Mineral Resource file data). Colorado Fuel and Iron drilled about 20 holes looking for other "bonanza"-grade orebodies, but without success. Later, St. Joe Minerals drilled several very long holes on the premise that there might be a copper or molybdenum porphyry deposit at depth, but without success. Since that time, major company interest seems to have lapsed.

MINE WORKINGS

The adit entrance and main incline provide access to the mine and its various levels down to the 460 level. The main ore pipe is represented now by a long, plunging, tubular stope of variable width and irregular shape, which is intersected by drifts on the various levels (Arizona Department of Mineral Resources file data, maps compiled by C. F. & I. Steel Corp., 1969). The major wulfenite pockets occurred within this pipe and in limestone caverns adjacent to it on the south side, above the 300 level.

GEOLOGY

Anthony (1951) reported on the geology of the Montosa-Cottonwood Canyons area and made note of colorless, transparent wulfenite crystals in a fault zone in the west adit of the Glove mine.

Harry J. Olson was mine geologist at the Glove mine from 1957 to 1959 and wrote the only detailed geologic description (1961, 1966); his work is summarized here.

The Glove deposits are situated in a synclinal block of Paleozoic sediments that was breached by Laramide (?) intrusions of quartz

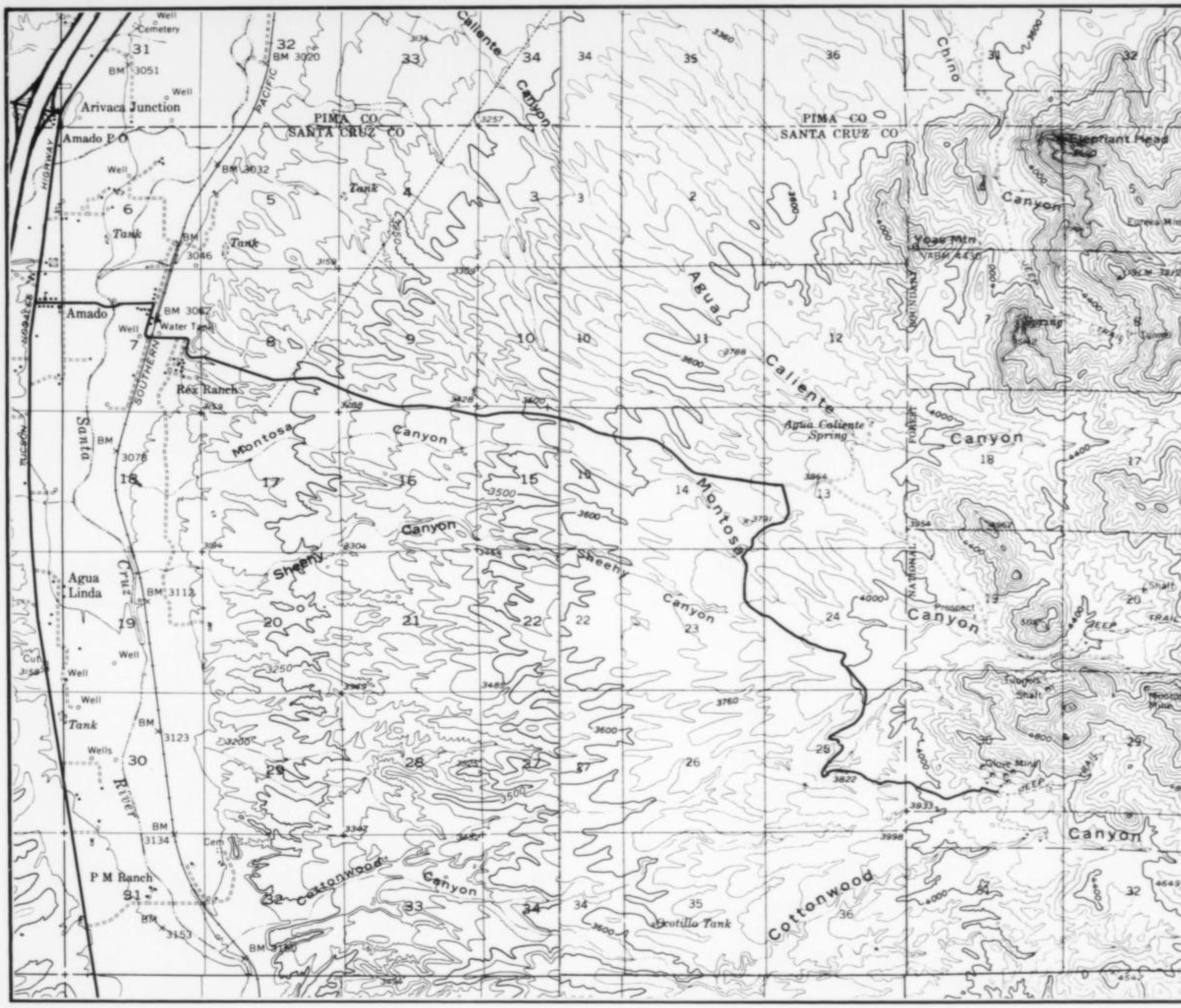


Figure 1. **Location map.**

monzonites and by a latite porphyry sill. The sedimentary rocks are limestones, siltstones and shales of the Pennsylvanian-Permian Naco group, dipping approximately 60° northwest.

Mineralization is primarily in the limestone, near contacts with quartz monzonite and latite porphyry. Massive lead-zinc-silver sulfide ore was deposited as a series of irregular, coalescing, limestone replacement pipes plunging approximately eastward at variable angles. These pipes were emplaced along permeable zones in the limestone created by faults and fault intersections.

Weathering of the sulfides left voids and released sulfuric acid which dissolved additional limestone, forming a complicated system of caverns. Although most of the caverns with secondary minerals were sites of primary mineralization (before the caverns formed), a number of pipes and solution channels appear to be post-mineralization caverns leached in barren limestone. Many of these caverns subsequently became filled or partially filled with secondary minerals and collapse breccia.

The orebodies were oxidized down to approximately the 360 level, and in the lower portion (300 to 360 levels) were enriched in silver and zinc. Oxidized ore consisted mainly of cerussite, anglesite and wulfenite with abundant gypsum, iron and manganese oxides, and sulfide remnants. Wulfenite decreased and smithsonite encrustations of "dry bone ore" increased in the lower 60 feet of the oxidized zone. The oxidized zone is entirely above the water table and is dry.

Wulfenite was common as fine crystals throughout the oxidized zone and as spectacular cavern linings above the 300 level. In one stope between the 180 and 210 levels, wulfenite was the principal lead ore.

In the sulfide zone, below the 360 level, the ore consisted of approximately equal amounts of galena and sphalerite plus smaller amounts of pyrite, chalcopyrite and supergene covellite.

MINERALS

One of us was fortunate enough to have collected at the Glove mine during its most specimen-productive period (1955–1959), and reported on these activities in a newsletter (Bideaux, 1959).

The first visit was made in January 1955, when the new development work was just beginning in earnest. A few fragile yellow crystal groups of wulfenite on limonite were found in the older upper workings at this time. As the new shaft, now a transfer raise and airway inside the mine, was encountering only sparse cerussite, it was assumed that the last had been heard of the Glove mine as a wulfenite locality. Thus it was quite a surprise in October of 1955 to receive an invitation to see a large pocket of crystals which had been found on deepening the shaft. This invitation was offered by Carl Richardson, a consultant in Tucson, through Jack Splane, the mine's chief engineer. Mr. Splane stated that the pocket had been

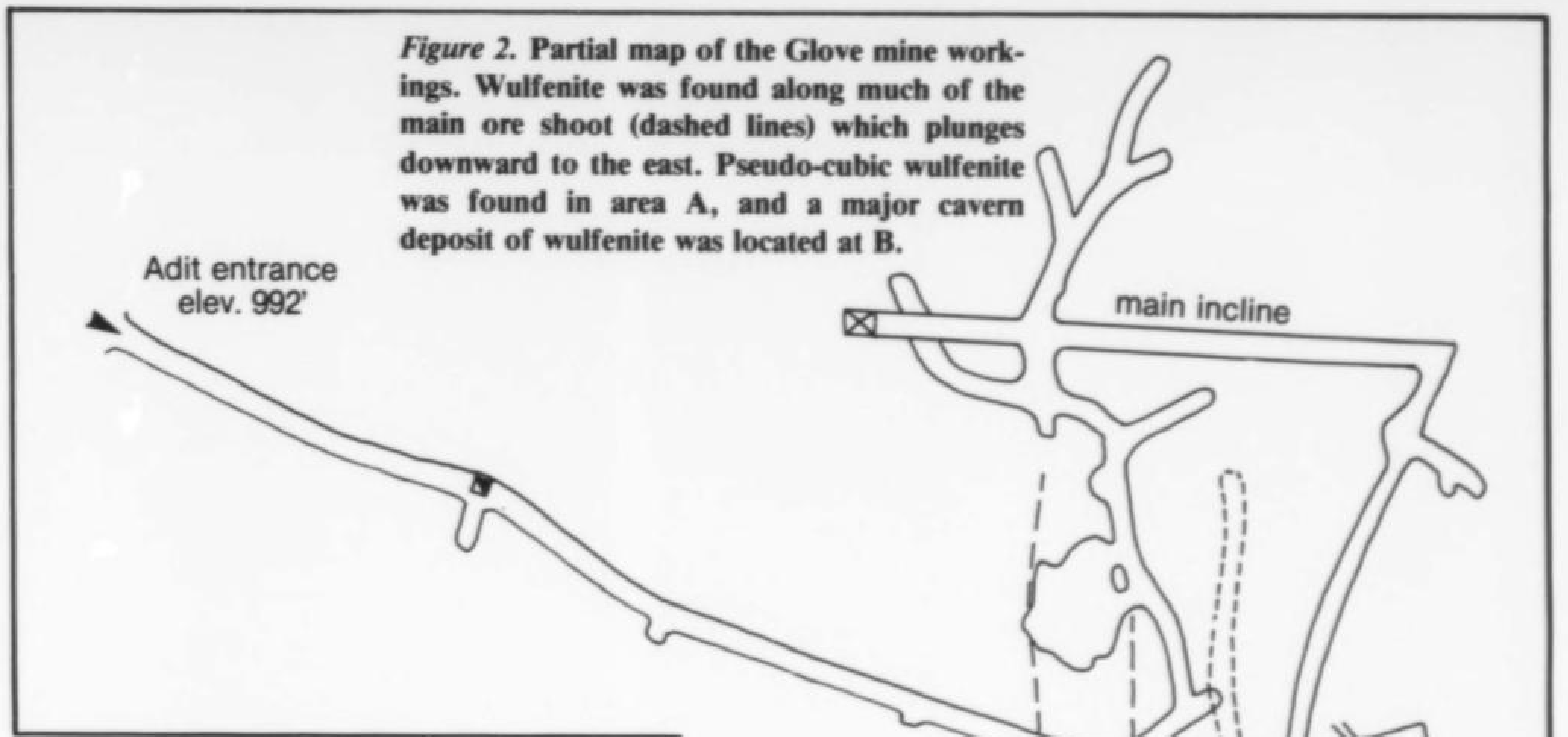
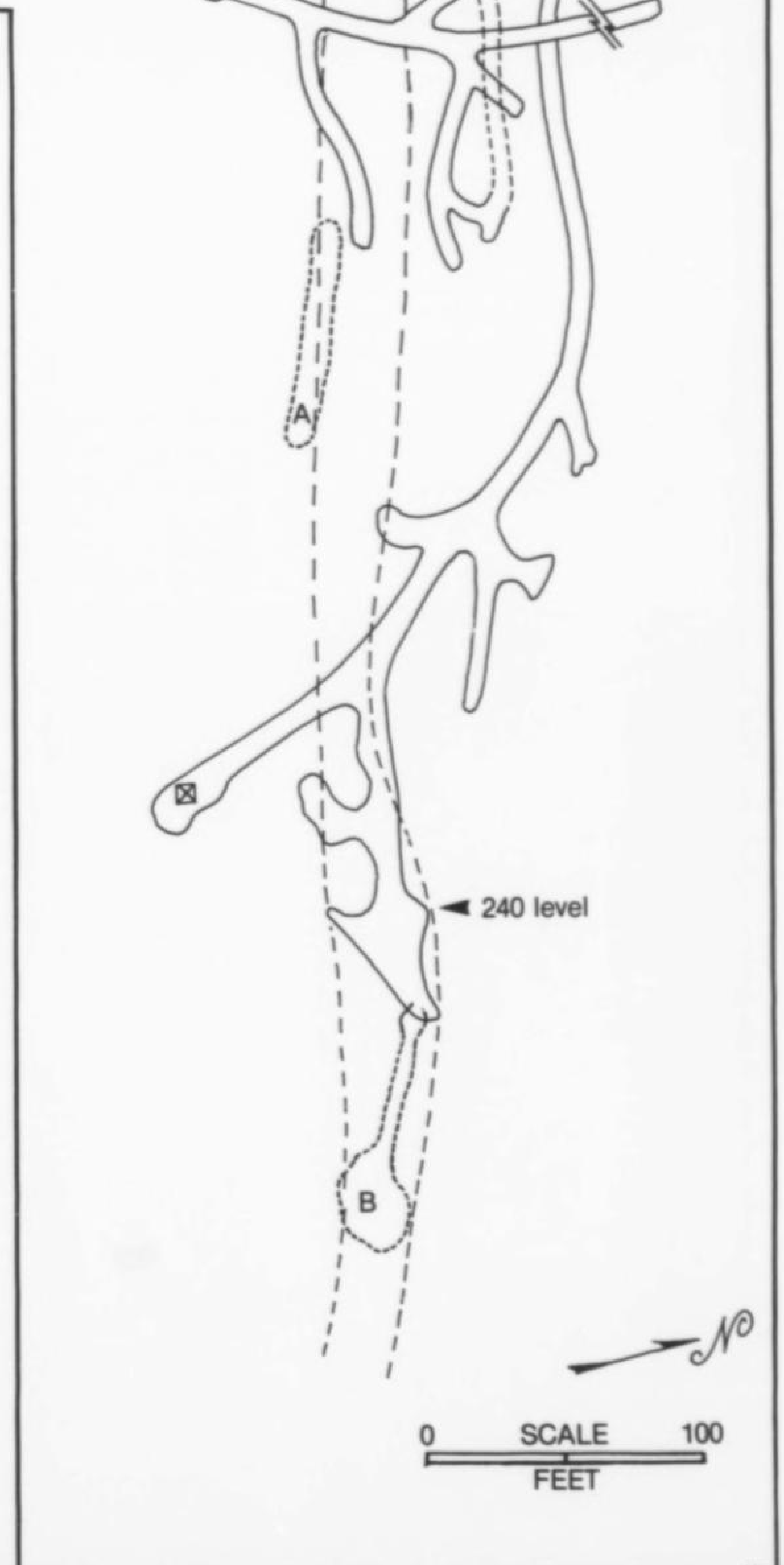



Figure 2. **Partial map of the Glove mine workings. Wulfenite was found along much of the main ore shoot (dashed lines) which plunges downward to the east. Pseudo-cubic wulfenite was found in area A, and a major cavern deposit of wulfenite was located at B.**

found about 100 feet below the adit level and that the crystals were quite large but so fragile that it might prove impossible to collect any. As Mr. Splane had also been an engineer at Tiger, it was apparent that something rather unusual must have been uncovered, as he would not be easily impressed by wulfenite.

This first pocket was typical of many found during the life of the mine. The inclined shaft had narrowly missed it; a miner had noticed a rubble-choked watercourse and had cleared it out, thus making the pocket accessible. Two other channelways were seen which led from the pocket into the surrounding rock and necked impassably after a few feet. Other pockets were later uncovered by following these. The central cavity was about 6 by 10 feet wide and 4 feet high. The deposition of wulfenite crystals had reached its maximum thickness in the main pocket; the walls were covered with a wulfenite crystal aggregate up to 14 inches thick in many places. Near and in the channelways out of the pocket were large isolated single crystals and groups attached to the walls. The color of the crystals on the walls and top of the pocket ranged from brown to lemon-yellow, while the isolated crystals were a light brown. On the floor of the pocket was a thin layer of mud-covered crystals which were nearly black in color; on the mud layer a thick druse of tiny brilliant black needles of plattnerite had been deposited. Throughout the entire pocket the crystals were separated from wallrock by a thin layer of hard manganese oxide.

Enough collecting had previously been done in the pocket that the floor was thickly littered with broken wulfenite plates, a foot thick in places, which proved somewhat precarious and heartrending to crunch about on. The management was convinced that there was ore around the pocket (there wasn't) and had miners drilling about the mouth of the pocket preparatory to blasting it at the end of the shift. Due to this deadline, collecting had to be rather hurried; there was not time to get back into the limestone and remove large groups on matrix as was done in later pockets, after the market value of the wulfenite crystals had been recognized.

Where the wulfenite crystals were isolated, singles and groups over 2 inches in an edge could be snapped off the walls, some with a little manganese oxide attached to act as a base. In the main pocket, a good specimen-sized area would be selected, and the crystals about it stripped away down to the wallrock. The specimens could then be removed by chipping away at their bases until they fell away from the rock. Most of the groups taken in this way are about 6 inches thick, although they could have easily been much thicker. One hazard of such collecting comes from the wulfenite crystals themselves; they are thin tabular, with sharp corners and beveled edges. Severe cuts resulted unless much care was taken. Also, there was no ventilation in the pocket.

Figure 3. **Wulfenite, about 2¾ inches across, collected by Al Haag. Bideaux collection.**

Figure 4. **Wulfenite crystal 3 inches across, collected in the 1970's. Bideaux collection.**

Since the discovery of this first pocket at least 25 others were found as mining progressed. The contents of these, which ranged from about watermelon-size to 35 feet long, were variously removed by mine employees, mineral dealers and private collectors. At least 350 powder boxes of specimens of good quality were removed from the mine, in addition to many lower-quality specimens.

Albert Haag, a mineral dealer in Tucson, purchased one pocket from which he removed a number of large, superbly crystallized specimens. These can be seen at the U.S. National Museum in Washington, D.C., the American Museum of Natural History in New York City, and Harvard University in Cambridge, Massachusetts. The largest crystals are part of a specimen in the National Museum; two crystals on this rather small specimen measure about 4⅓ inches (10.9 cm) from edge to edge.

Harry J. Olson had perhaps more experience at the Glove mine than any other individual. In a recent letter (1983) he described some of his recollections:

"Reportedly the early wulfenite discoveries at the Glove mine occurred in the proximity of the main ore zone from the adit level to

Figure 5. **Wulfenite group 5 inches across. Bideaux collection.**

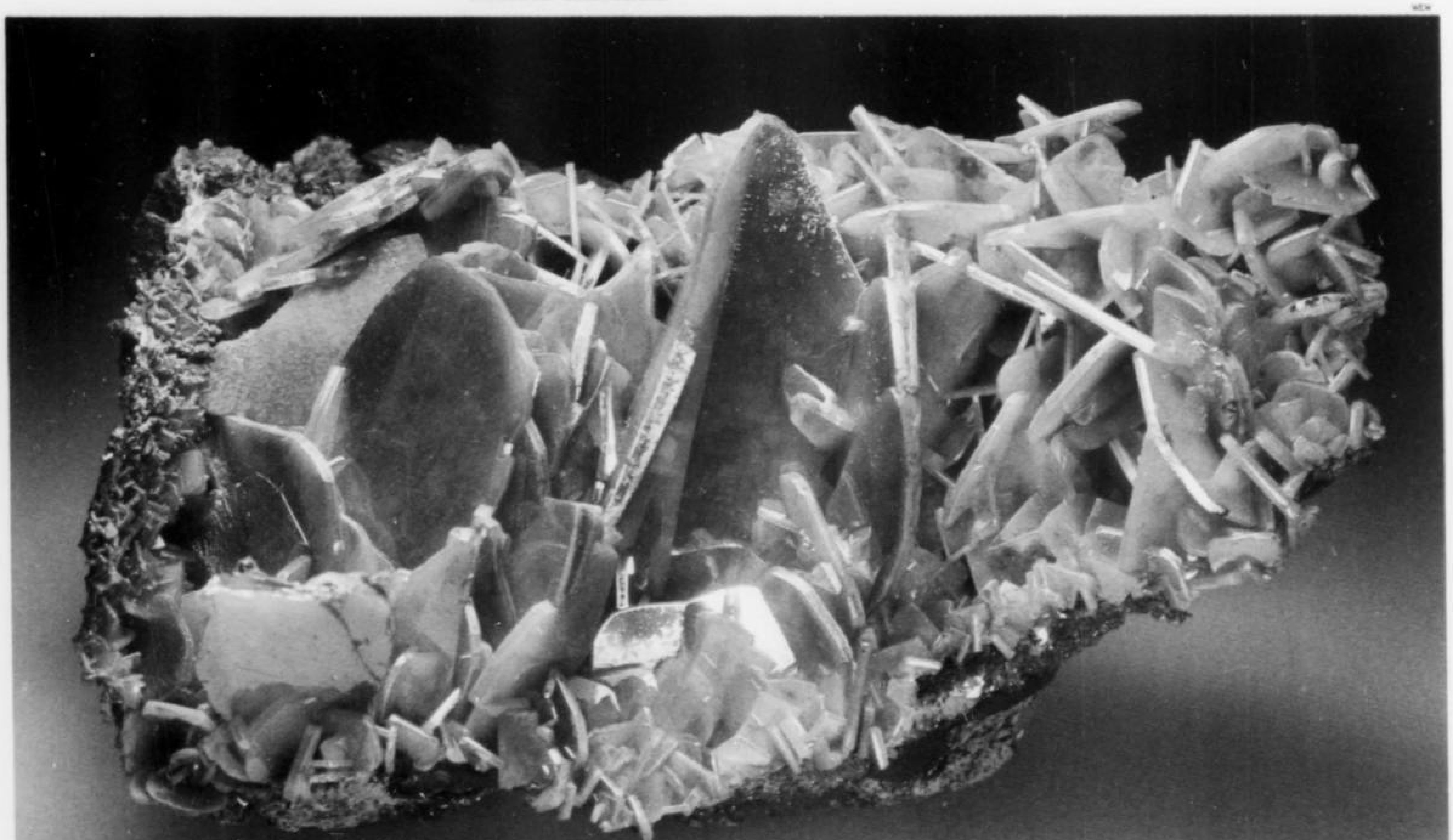


Figure 6. **Wulfenite crystals to ½ inch. Bideaux collection.**

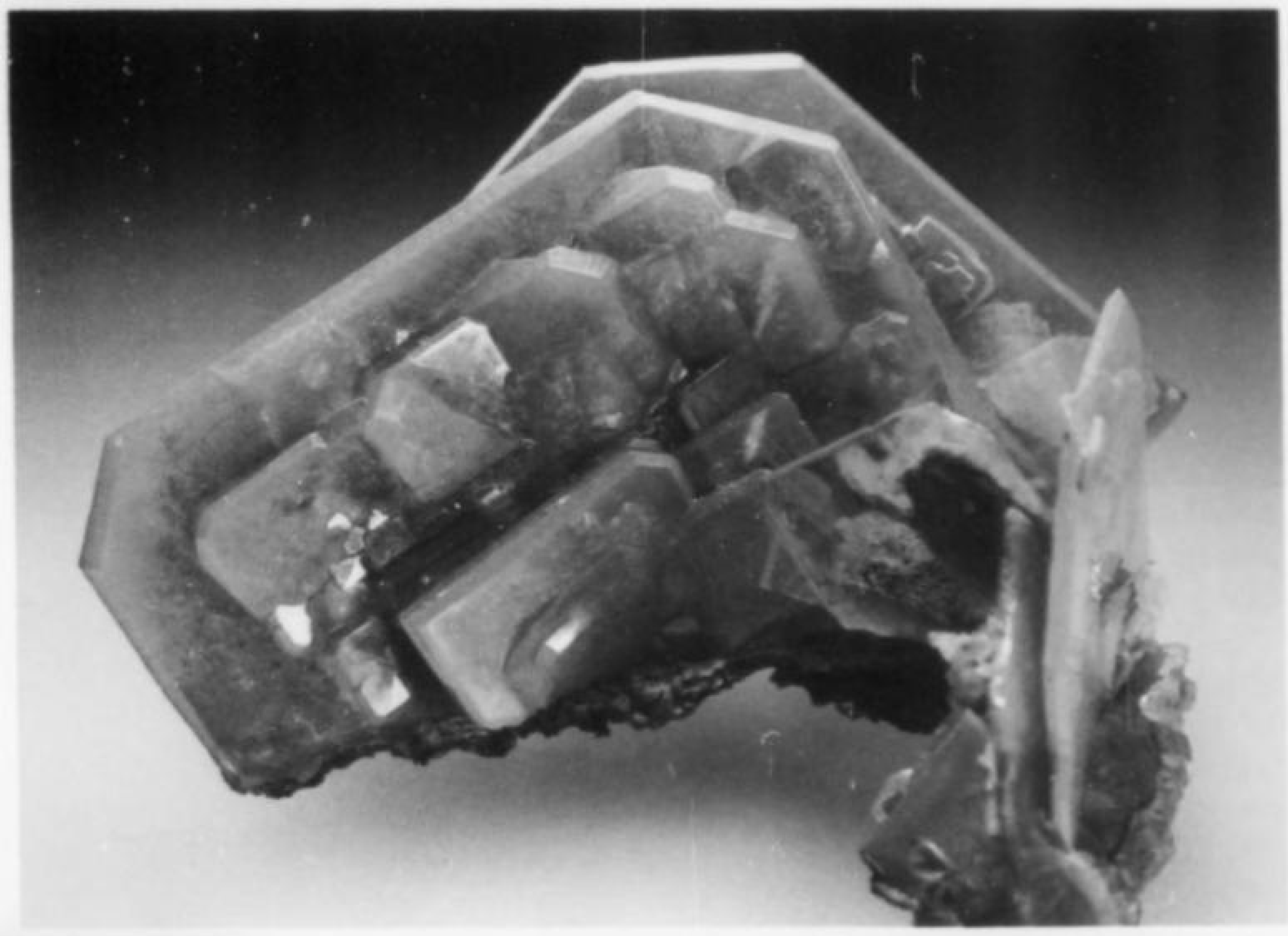
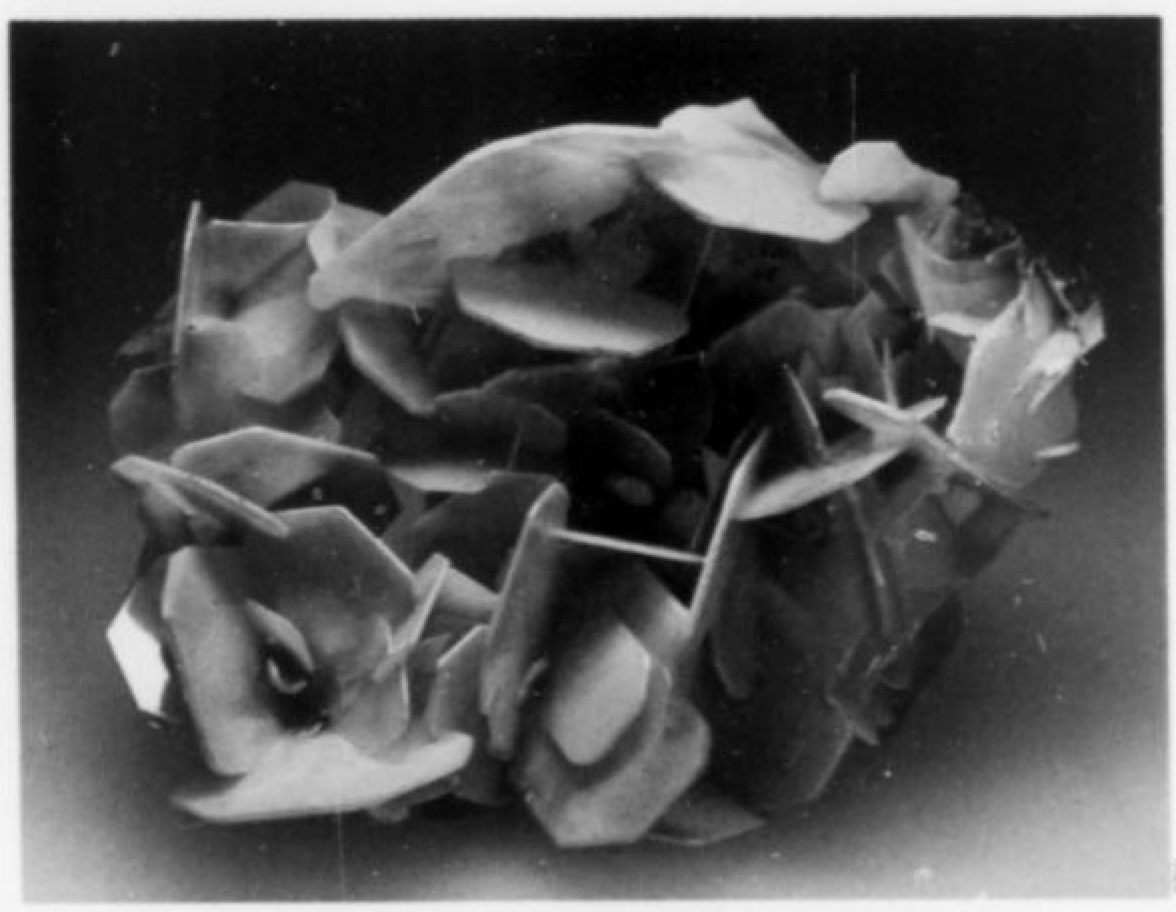


Figure 7. **Wulfenite group 2½ inches across. Bideaux collection.**

Figure 8. **Wulfenite group 2⅞ inches across. Bideaux collection.**



the 180–210 levels. I saw several small pockets in the upper workings off the adit level. These occurrences were usually in thin open caverns probably related to relict watercourses. The wulfenite specimens here were mainly thin crystal plates ranging from colorless to pale straw yellow in color. However, by the time that I saw these occurrences, most of the crystals had been essentially 'mined out' and what I saw were probably 'left overs' and not representative of the thicker, darker yellow to orange colored crystals which I later saw in mineral collections.

"The first large scale occurrence of wulfenite that I observed was dike-like in shape and extended from the 180 to the 210 level slightly below and along the south side of the main ore zone (location A, Fig. 2). The wulfenite in this occurrence was golden orange in color and pseudo-cubic in habit – the only such occurrence in the mine of which I am aware. Altogether about 100 tons of wulfenite were shipped to the smelter from this stope. The two railroad cars that were filled with this ore glistened as if filled with gold, and represented the most beautiful ore that I have ever seen.

"The picture (Fig. 11) was taken in the cavern that extended from the back of the east end of the main ore zone on the 240 level to about or slightly above the 300 level (location B, Fig. 2). The cavern did open on the ore zone on the 240 level but was not intersected on the 300 level. The upper part of the wulfenite cavern was a small passage which opened into a room about 6 to 8 feet in diameter which was high enough to pass through by bending. The opening was covered with gypsum crystals and less abundant calcite, coated with a thick layer of wad. At the east side of the opening, the passage narrowed and continued downward at about a 25°–30° incline for 50 to 60 feet, where it opened into a domed cavern about 10 feet wide and 20 feet long and slanting downward at about the same angle. The sides and most of the back were covered by gypsum, calcite and wad as in the cavern above, but contained veins and minor encrustations of wulfenite crystal aggregates. The floor of the cavern was filled with roof collapse features which were loosely to tightly cemented and covered with gypsum, calcite, limonite, wad and small aggregates of wulfenite.

"While collecting some wulfenite crystals beneath one of the boulders on the floor, I undermined the mass sufficiently so that it began 'working' which alarmed me sufficiently so that I moved out from the undercut just in time to see the boulder break free and begin to roll down the slope toward me. I backstepped until stopped by the end of the cavern and, by good fortune, was able to use my outstretched arm to divert the boulder from pinning me to the wall.

"The back of the dome was a solid encrustation of golden colored wulfenite crystals which brought forth such a cry of surprise and delight from me when I first saw it that A. M. 'Fred' Durazo, the mine superintendent, came charging down the passageway im-

mediately afterwards thinking that I had had some misfortune or accident.

"Later, after the discovery had been reported to G. W. 'Jerry' Irvin, the mine manager, I was assigned to collect the wulfenite specimens with a miner named Tamayo (whose last name I cannot recall). Together we spent about a month collecting the wulfenite specimens by carefully prying the crystal aggregates off the back and packing them in paper in powder boxes that had been cut in two. The passageway up from the wulfenite cavern was so narrow that only one person could crawl through at a time. The boxes with the wulfenite specimens were passed up in groups of six, one at a time, to a wide spot on the passage where they were placed. Then Tamayo and I moved upwards to repeat the process again at another wide spot until all the boxes were in the small room which opened upon the 240 level.

"Very few of the specimens were lost due to breakage, and I imagine that most of the specimens which were mined are now scattered throughout the world in museums and mineral collections. The large aggregate in the mineral museum at the geology department at the University of Arizona has an extensive 'bruised' area in the center which resulted from the specimen falling on my hard hat as it was being pried off the back.

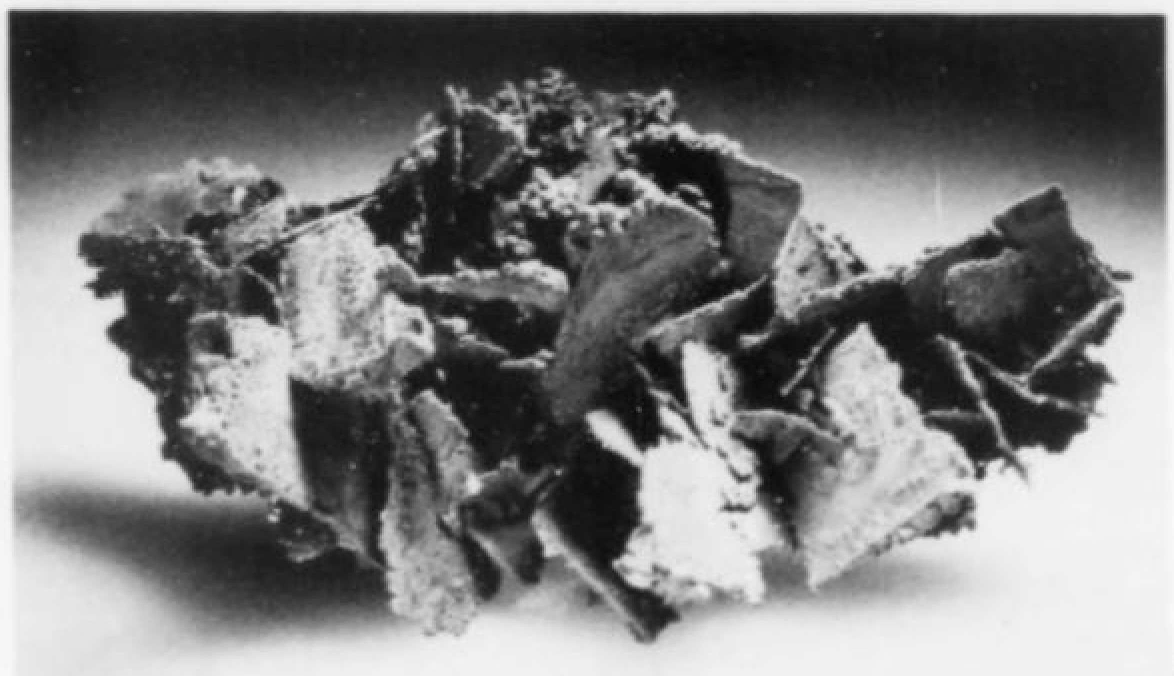
"The most memorable specimen that I collected was one at the very top of the dome, and about the size of my head. It was formed of golden orange, perfectly shaped platy crystals about 1 to 1½

***Figure 9.* Adit entrance recently bulldozed shut by the Forest Service.**

***Figure 10.* The Glove mine area (1982); adit entrance is marked "A."**

Figure 11. **Wulfenite lining cavern walls in the major occurrence found at location B, Figure 2. Harry J. Olson photo, 1958.**

Figure 12. **A group of manganese oxide pseudomorphs after wulfenite, 3¾ inches across. Bideaux collection.**



inches on a side. There were crowned by a single crystal in the middle of the aggregate about 4 inches on a side which stood vertically above the rest of the crystals."

The last specimens from this operation were brought out in August of 1958, when a cave-in in the stope closed the entrance. The pocket was later barely undercut by another stope; backfilling in this stope had progressed by late 1959 to the point where a few bruised crystal groups again reached the market.

Crystals from this last pocket are a uniform bright orange with rounded outlines, and reach a maximum size of 3 inches. The size of the specimens taken was limited only by the constricted access through which they had to be removed. The largest specimens, about 1 by 2 by 2 feet, are on display in the mineral museums of the University of Arizona at Tucson and the New Mexico School of Mines at Socorro, New Mexico.

Glove mine wulfenite occurrences are unusual in that the crystals from each of the different pockets have a different, easily recognizable character. Most othei deposits provide only one principal type of wulfenite crystals. The habit of the crystals from the Glove mine varies from thin tabular through pseudocubic to acute pyramidal; colors ranged from black and brown through yellow and orange to colorless. Occasionally crystals with zoned coloration were found, some having brown centers and yellow margins.

Some pockets exhibited more than one episode of wulfenite deposition. One small pocket contained crystals of a dark brown color, nearly cubic in habit, which were completely encrusted by greenish descloizite in a layer up to about 1/10 inch thick. Later, thin tabular yellow crystals of wulfenite, usually slightly larger along the edges, grew over the descloizite layer on each side, with all crystals having parallel edges and bases. These have been called "descloizite sandwiches." Some of these groups are an inch on an edge.

In another pocket, microcrystals of wulfenite of a prismatic habit were found implanted on manganese oxide. A thin coating of litharge dusts both the crystals and the matrix. Transparent, highly-modified wulfenite crystals had then grown in parallel position on the bases of the original crystals, presenting the appearance of either dumb-bells or toad stools, depending on the orientation of the first crystals.

Several vanadium-bearing minerals have been noted in the mine in small amounts. In addition to the above mentioned green descloizite, one pocket of wulfenite was associated with small purplish balls of descloizite. Where only a little descloizite was present on the specimen, the balls were implanted in the crystal plates, but in some areas the wulfenite was completely replaced by descloizite. Yet another pocket produced tabular wulfenite crystals which had an incrustation of descloizite only on the prism faces; in some places the wulfenite crystals had been leached out, so that only the brownish descloizite remained. Where the wulfenite had been attached by an edge, only a thin bridge of descloizite remained. Minor amounts of small brown to yellow mimetite and vanadinite crystals have also been seen.

Some rather large masses of bluish hemimorphite were found in the upper workings, while smithsonite was rather common on some of the lower levels. Although mostly "dry bone," some of the smithsonite occurred as small, botryoidal, white to blue-green masses in cavities in the rock, and only rarely covered any appreciable area. A few small, single crystals of smithsonite with multiple rhombohedron terminations have also been found.

Copper minerals occurred very sparingly in the mine. Chrysocolla stains and a few needles of malachite replacing cerussite were all that were seen. Silver values in the ores reached substantial amounts, particularly in the lower workings, but no

Figure 13. **Yellow-orange wulfenite crystals *in situ,* exceeding an inch on an edge, thickly lining a cavern (location B, Fig. 2). Harry J. Olson photo, 1958.**

silver mineral was ever definitely identified.

Thomssen (1957, 1959) described the occurrence of minute plattnerite needles on wulfenite with descloizite and mimetite.

Until recently the Glove mine was on caretaker status and a lessee did locate some relatively small but significant wulfenite pockets. The major pocket of these later discoveries (early 1970's) produced some fine, bright yellow wulfenite crystals which are again distinctive from any other finds. In some cases manganese oxides have entirely replaced the wulfenite crystals to form interesting pseudomorphs.

Despite the fact that the mine remains in private ownership, the U.S. Forest Service very recently bulldozed the dump over the adit entrance and closed the other openings to the mine.

CONCLUSIONS

If the Glove mine is reopened, and development work is carried on, perhaps this mine will again produce excellent wulfenite specimens. In any case, it will be long remembered for what it has already supplied.

ACKNOWLEDGMENTS

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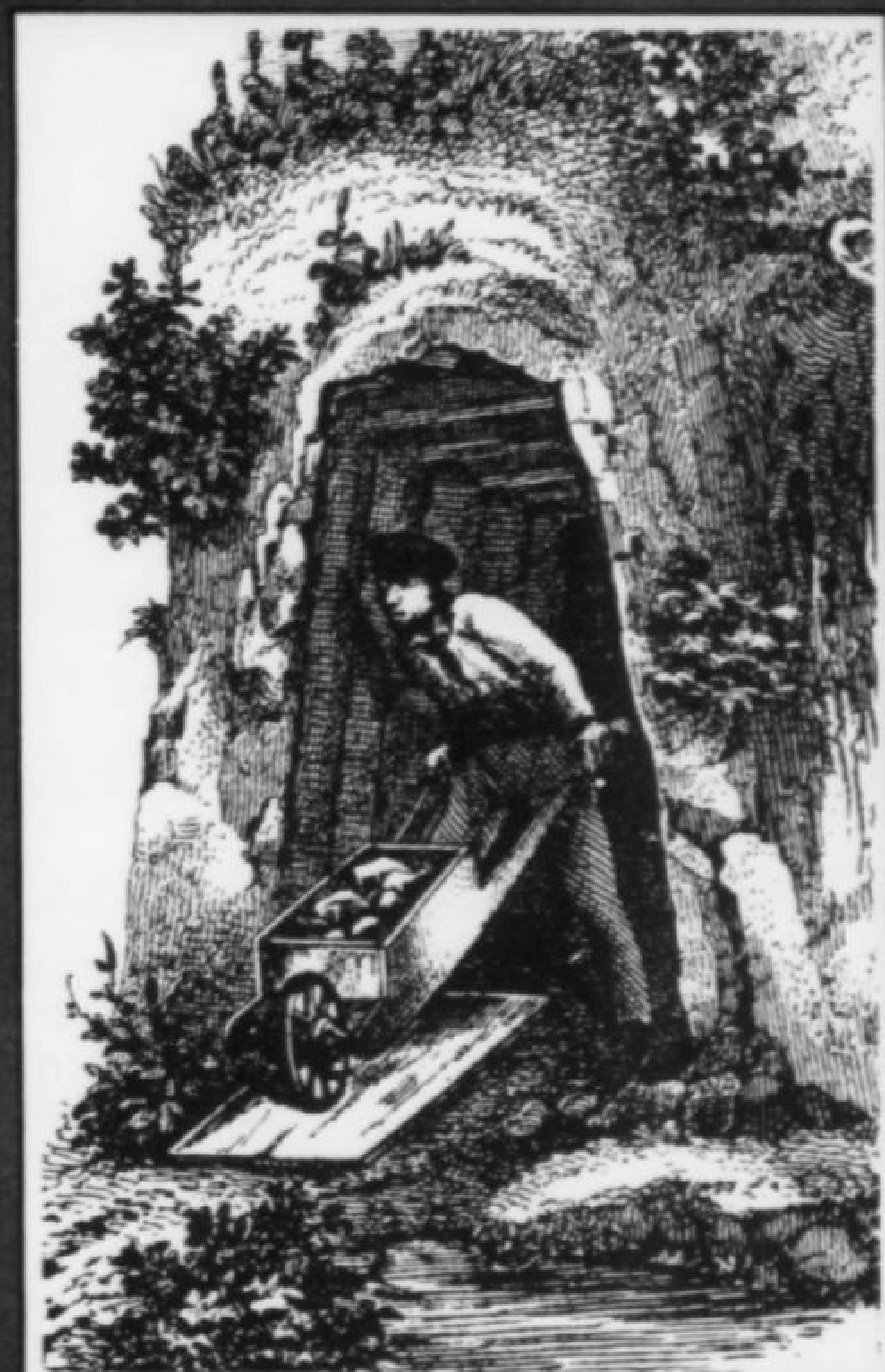

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famous mineral localities:

the Ray Mine

by **Robert W. Jones**
3520 N. Rose Circle Dr.
Scottsdale, Arizona 85251

and **Wendell E. Wilson**
4631 Paseo Tubutama
Tucson, Arizona 85715

Since mining first began in the Ray area more than 100 years ago, over two billion dollars in ore and thousands of fine mineral specimens have been removed. Superb examples of native copper, cuprite and chrysocolla are still being discovered and preserved.

LOCATION

The Ray copper deposit is located in Pinal County, Arizona, about 75 miles east-southeast of Phoenix and 70 miles north of Tucson. The area is known as the Mineral Creek mining district, and is situated in the valley of Mineral Creek between the Tortilla and Dripping Spring Mountains.

HISTORY

Showings of copper attracted the attention of local Indians, who early mined small amounts of chrysocolla using large diabase hammers (Metz and Rose, 1966). Written records kept by Army soldiers date back as far as 1846, when Lieutenant William H. Emory wrote in his log: "From the many indications of gold and copper ore at this place, I have named it Mineral Creek." Unfortunately, marauding Apaches made the area too dangerous for mining until the 1870's, when many claims were first filed. One of these early claims was located by a man named Bullinger; he named it after his sister, Ray. Mining began in 1880 with the construction of a five-stamp mill by the Mineral Creek Mining Company.

In 1883 the Ray Copper Company was formed through a $5,000,000 stock issue. The company had acquired 17 claims in the area and had a 30-ton copper smelting furnace nearby, designed to handle ore consisting primarily of native copper. A concentrating mill with a capacity of 75 tons a day was also constructed, but little real mining was carried out. Workings consisted primarily of a 300-foot adit, a 100-foot shaft and a 50-foot crosscut.

In 1899 the Ray, Taylor and Innes groups of claims were purchased by the Globe Mines Exploration Company Ltd. of London for £260,000 (about $1,250,000). The understanding at that time was that the ore contained between 4 and 5 percent copper, sufficient for a profitable operation.

The British operators promptly moved in and, it is said, they made an interesting sight in their safari shorts and cricket outfits, riding their polo ponies and dressing formally for dinner each night. They brought with them steam tractors which pulled wagon trains of building supplies from the nearest railhead at Red Rock, 43 miles away. The town of Kelvin was founded, a 250-ton mill erected along with shops, an office and various staff buildings, and a 7-mile narrow-gauge railway laid from the mill to the mines. The Ray mine was deepened to 344 feet and ore was blocked out on three levels. A new smelter was built in 1900, but it was destroyed by fire before getting into operation. By the end of 1900 the company had processed about 16,000 tons of ore which, unfortunately, proved to contain only 2 percent copper instead of the expected 4 to 5 percent. The operation was a failure and the mine was abandoned.

James D. Hague was called in as a consultant, and he confirmed that the ore grade was about 2 percent: too low to be profitable. But he made a prophetic statement in his report (quoted in Ransome, 1919): "The mine (has) . . . possibilities of large value, sooner or later, by improvement in methods of treatment, which may make a 2 percent ore profitable."

The property lay idle for several years, but in 1905 a railway connection between Kelvin and Phoenix was established, and by the following year the Calumet Copper Company was shipping 40 tons of high grade ore a day from its mines near Mineral Creek. The Kelvin Reduction Company began experimenting with a leaching operation at the Ray mine. In 1907 the Ray Consolidated Copper Company was formed by Daniel C. Jackling and most of the property formerly held by the British company was acquired. Jackling had made a considerable success of mining operations at Bingham, Utah, with similar low-grade copper ore.

It was becoming obvious that the low-grade ores of the area were

Figure 1. **A view down Mineral Creek, taken around 1912. The small town in the foreground is Sonora, Ray Hill is to the left. (U.S.G.S. file)**

going to require large-scale operations (at a considerable cost) if they were going to become profitable. Over a five-year period, Jackling raised about $17,000,000 to build a mining complex of sufficient scale. During this time the Arizona Hercules Copper Mining Company (capitalized at $10,000,000) and the Kelvin-Calumet Mining Company (capitalized at $6,000,000) also moved into the Ray area.

By the end of 1909 the Ray Consolidated Copper Company had spent $300,000 on prospecting alone, and had delineated ore reserves of about 50,000,000 tons. Two main shafts and 30 *miles* of crosscuts had cost the company $10,000,000. Claims owned by the Gila Copper Company and the Ray Central Copper Mining Company were acquired. And all of this was done before the first actual ore was shipped in 1911. Waterworks were constructed at Ray and Hayden, and a large concentrating mill and power plant were built at Hayden. The Hayden smelter was completed in 1912 by the American Smelting and Refining Company (today's ASARCO). With its first shipment of low-grade ore, Ray became the first of Arizona's large porphyry copper deposits to get into operation.

Ray was the site of a number of mining innovations that later spread to other districts. Louis S. Cates developed the block-caving method here, whereby the orebody is undercut with a number of funnel-shaped excavations leading directly into ore cars on a haulage level. The orebody is then shattered with explosives; the broken ore settles downward under the influence of gravity and is fed into the ore cars. This method yielded a significant savings in mining costs.

In the years following World War I, the Ray mine produced about 65 million pounds of copper per year. A number of corporate takeovers and mergers ensued, culminating in acquisition by Kennecott Copper Corporation in 1933. Following the depression, copper production rose from 40 to 100 million pounds per year in 1942.

During the 1940's tremendous strides were made in the development of earth-moving equipment. Diesel trucks carrying over 50 tons of ore per load replaced the awkward ore trains, and mobile shovels could bite out up to 11 tons of ore at once. Bulldozers and road graders replaced teams of hand-laborers. Finally, in 1955, Kennecott abandoned underground mining altogether in favor of a system of huge open pits. The switch, along with improvements in the mill, cost Kennecott $40,000,000.

From 1911 through 1979, the Ray area yielded over 5 *billion* pounds of copper, 55,000 ounces of gold, 8 million ounces of silver, 12 million pounds of lead, 6½ million pounds of molybdenum and a quarter million pounds of zinc (Arizona Bureau of Mines file data). The gross value of all production has been estimated at more than two billion dollars.

Today the town of Ray is gone; it was dismantled in 1963 for expansion of the pit. The mine itself was closed in 1982 and is now on a "care and maintenance basis" awaiting an improvement in copper prices.

GEOLOGY

General

The mountains surrounding Ray are typical of the generally northwest-trending basin-and-range structure. Major fault systems run parallel to the length of the ranges. Southeast of Ray the ranges are separated by the valleys of Mineral Creek and the Gila River; to the north they join into a rugged plateau. The Tortilla Mountains west of Ray are generally composed of Precambrian schist and granite. The Dripping Spring Mountains to the east are younger Precambrian and Paleozoic sedimentary rocks dipping gently to the

Figure 2. **A view of the Ray pits looking northward up Mineral Creek. Background-left: West pit. Center: Pearl Handle pit and Pearl Handle extension. Extreme right and off view: Silicate orebody. Foreground center: Kennecott mine buildings. Horizon left-center: Teapot Mountain. Center-bottom to middle-right: trace of Mineral Creek. Photo: Ray Manley Studio.**

south. Both ranges contain Precambrian and Late Cretaceous-Early Tertiary intrusions and are overlain by later volcanic rocks and sediments (Metz and Rose, 1966).

Detailed geology at Ray is complex, but it is sufficient here to categorize the ore deposit as of the disseminated porphyry-copper type well known in the American Southwest. Such deposits form through the influence of an intrusive calcalkaline porphyritic rock of intermediate composition (the Granite Mountain quartz monzonite porphyry at Ray). Structural faulting and fracturing of the intrusion and neighboring country rocks allowed intimate penetration of hydrothermal fluids which presumably resulted from the solidification of the intrusion itself. These solutions attacked the various rock types in a corrosive manner, causing profound alteration. During and after this alteration, pyrite, copper sulfides and other sulfur-bearing minerals were introduced as disseminated flecks within veinlets, and as replacements of earlier minerals. Normally the copper sulfide dissemination is so sparse that it may entirely escape notice in a casual inspection of the rock; however, local concentrations do tend to develop as a result of weathering and the action of groundwater. The main copper orebody at Ray consists of a flat-lying blanket of secondary copper sulfide ore a few feet to several hundred feet thick developed in the Pinal schist (Metz and Rose, 1966; Ransome, 1919; Anthony *et al.,* 1977) and associated with some primary ore. As of 1982 the U.S. Bureau of Mines estimated that the Ray area has ore reserves of 660 million tons containing 0.79 percent copper; that equals contained copper of well over 10 billion pounds.

Mineralization

Structurally the Ray ores are among the most complex of all porphyry copper deposits. Structural controls on ore emplacement include the Porphyry Break and several major faults that intersect it, the Emperor fault which controlled secondary sulfide enrichment, and the Pioneer fault which clearly affected deposition of crystallized minerals (Metz and Rose, 1966).

Another feature related to mineralization was reported by miners who were present during the stripping of overburden preparatory to open pit mining in the early 1950's. A caliche-clay zone was observed running 2 to 3 feet thick between the overburden and the orebody (C. McCroskey, personal communication). This "cap" was exceptionally rich in native copper, much of it heavily encrusted with cuprite crystals or matted chalcotrichite masses. The cuprite crystals were so thick on some specimens that copper was visible only on broken edges. In contrast, Ransome (1919) reported a capping containing considerable chrysocolla and malachite. This suggests two different cappings; the narrow zone described by the miners may have been located between Ransome's capping and the orebody. Or perhaps the two cappings are actually the same zone observed at different sites. Ransome did not have the benefit of large open pit exposures.

An exceptional specimen of cuprite on copper from this caliche-

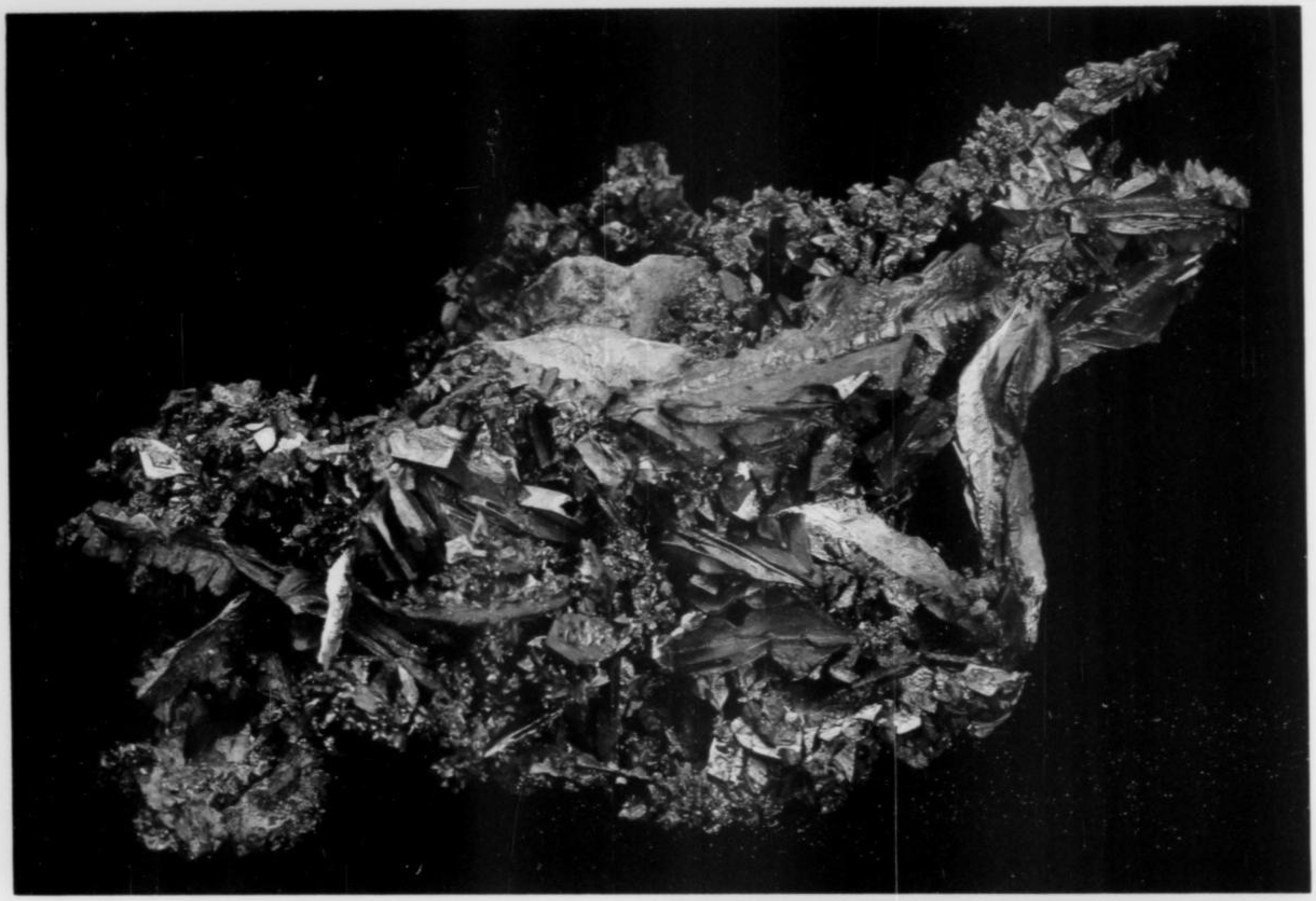


Figure 3. **Large group of copper crystals; winner of the trophy for best Arizona copper (cabinet class) at the 1977 Tucson Show. Evan Jones collection; photo by R. Jones.**

Figure 4. **Malachite coated copper crystal group 5 inches across, from Ray. Arizona-Sonora Desert Museum specimen; photo by W. Panczner.**

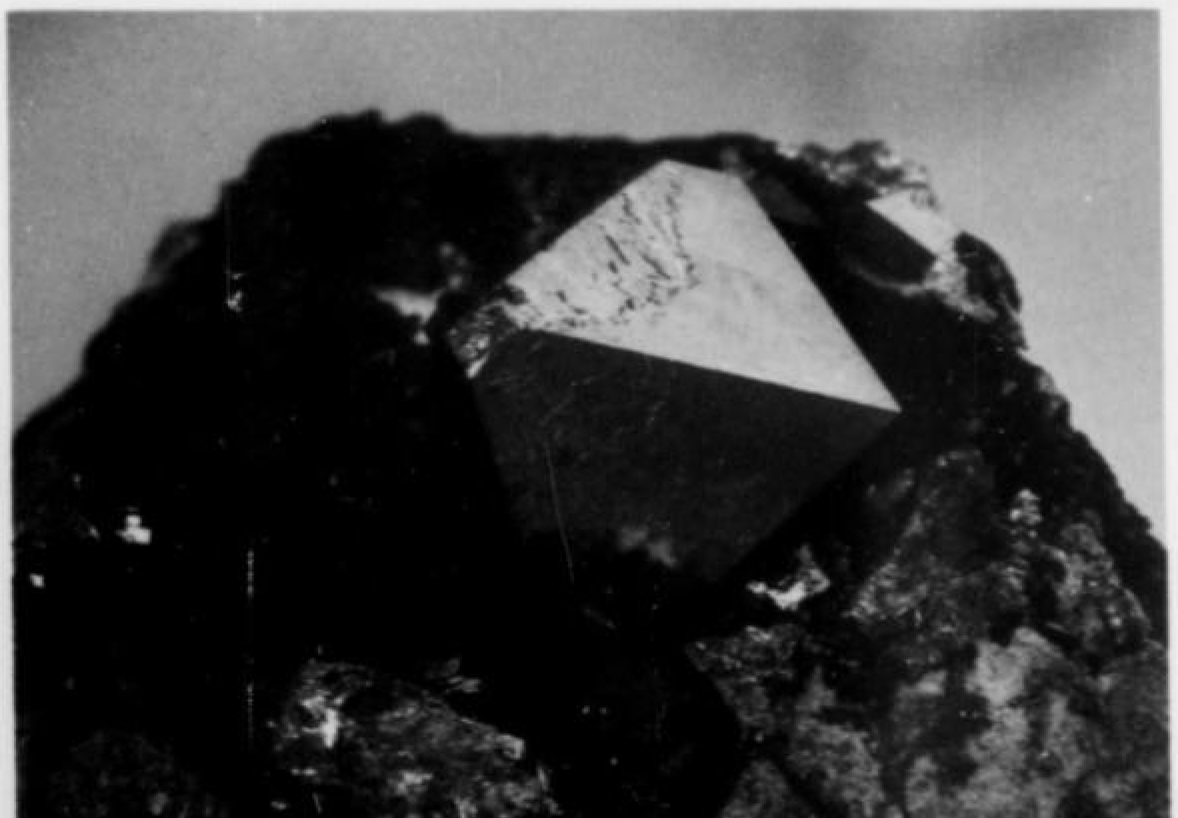


Figure 5. **Large, half-inch cuprite octahedron from Ray. Evan Jones collection; photo by R. Jones.**

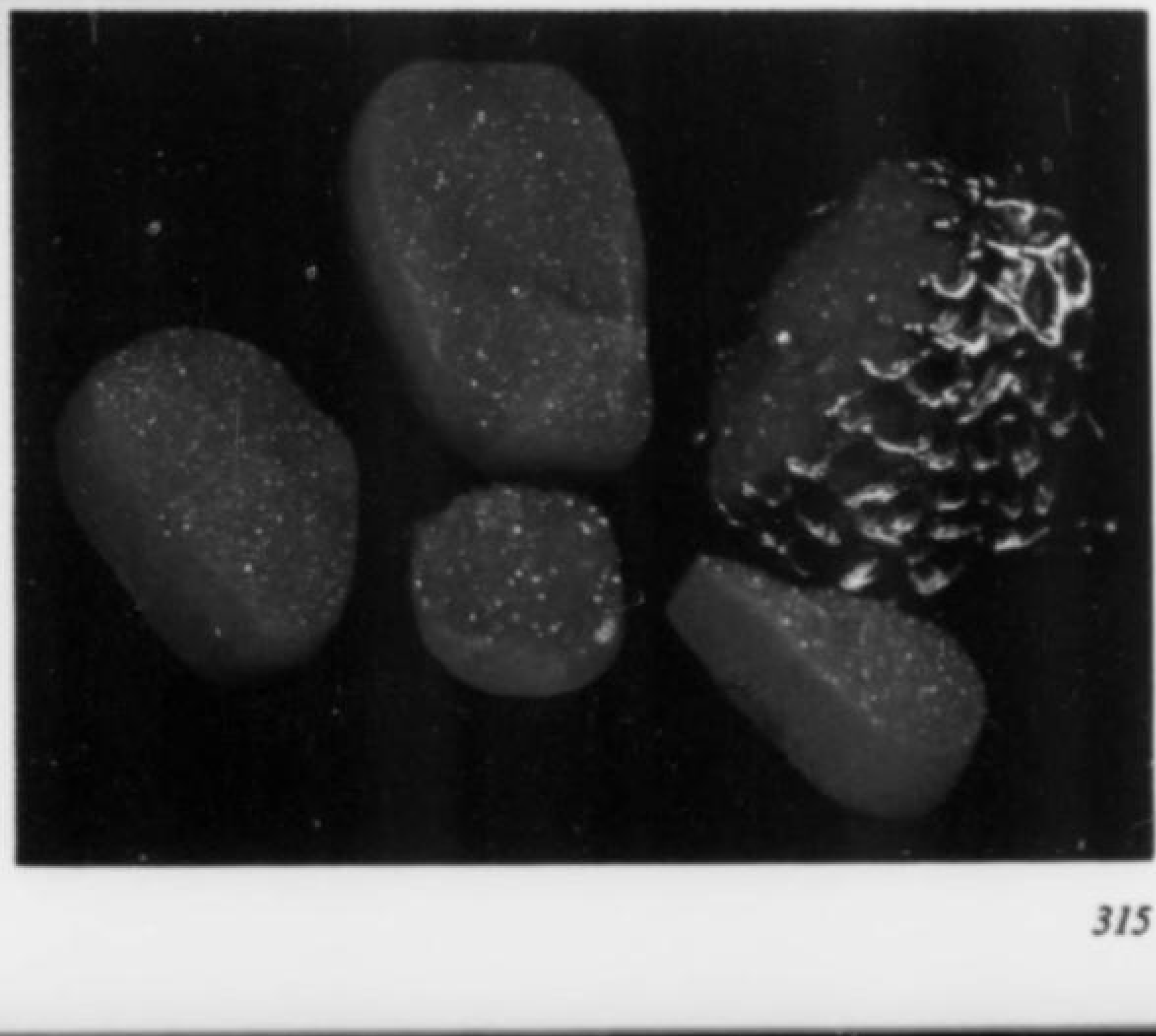
clay zone may be seen in the Fred and Nadine Jones collection in Globe. It is a 2-foot-long undulating piece of native copper coated with bright red cubes of cuprite; the crystals are generally a quarter inch in size, lustrous and undamaged. This particular piece was collected from the clay zone during the removal of overburden.

Particularly important to the mineralogy of the deposit is the relationship of the Emperor fault to Mineral Creek: the Creek follows the fault. As a result, water percolated downward with relative ease through the gravels and fault gouge, resulting in some intense secondary mineralization. It has been suggested that the flow of the creek, particularly during times of local flooding, may set up the type of electrical field which would encourage the deposition of copper and associated minerals (J. Witner, pers. comm.). It is along this fault/creek area that a number of exceptional mineral concentrations are found. Regarding the relationship between

Figure 6. **Cuprite crystals on matrix about 6 inches across, from the Ray pit. Curley Talbot specimen; photo by R. Jones.**

Figure 7. **Chrysocolla pseudomorph group about 4 inches across. Arizona-Sonora Desert Museum specimen; photo by R. Jones.**

Figure 8. **Gem-grade chrysocolla (called "gem silica" because it is primarily chrysocolla-colored chalcedony) with a thin capping layer of drusy quartz crystals. The ring is by Melba Mediz; photo by R. Jones.**



ground water and mineralization, Ransome (1919) discusses the waters of Mineral Creek and the waters found at depth in the mine during underground operations. Metz and Rose (1966) also comment on the Emperor fault's importance to mineralization calling it, ". . . the most obvious control of secondary sulfide enrichment. . . . This low angle fault with its thick gouge zone apparently caused a perched water table during the enrichment cycle and is responsible for the high grade supergene ore directly beneath it." Mine geologists and contract collectors attest to this area as being exceptionally productive of specimens.

Another unique feature of the Ray deposit is the separate Silicate orebody which is rich in chrysocolla and other copper silicates. It is located just east of the Pearl Handle pit, in diabase. The origin of the silicate orebody has not been established but, "There is evidence

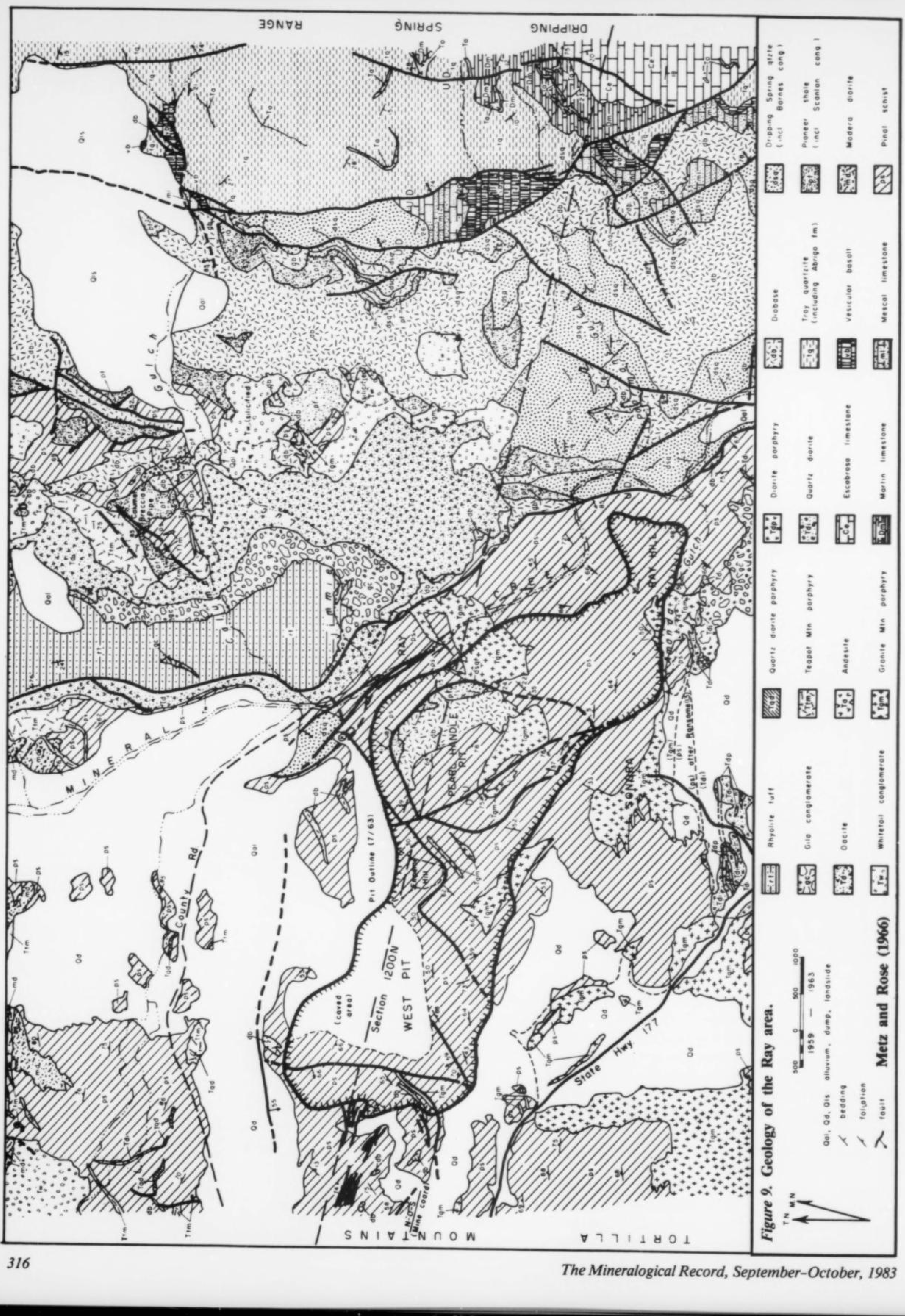


Figure 9. **Geology of the Ray area.**

that hot spring activity may have contributed to the precipitation of copper from ground water" (Metz *et al.*, 1968).

The Silicate orebody is described as follows: "At the inception of development work on the Silicate orebody the mineralogy was thought to be quite simple. . . . As time passed and research progressed, the mineralogy became less and less simple" (Metz *et al.*, 1968). Though intended to describe the Silicate orebody only, that statement might well be applied to the entire deposit. Ransome (1919), for example, reports that in his day native copper did not form an important constituent of the ore. When the pits were opened, however, so much native copper was found it was necessary to stockpile it because the extraction processes in use were not designed to handle it. The company finally installed a roller crusher in the pit and ran the copper stockpile through to flatten it out for direct shipment to the smelter. The men operating that crusher report the work was not without hazard because the large (to 1 inch) cuprite crystals would explode when they hit the rollers and scatter crystal fragments in all directions! (R. Dalton, pers. comm.).

COLLECTING

Ray has produced a limited variety of superbly crystallized minerals. Chrysocolla pseudomorphs were described by Thompson (1980). Cuprite occurs as large and excellent crystals and as masses of bright red, acicular "chalcotrichite." Native copper in arborescent masses is commonly found coated with cubic crystals of cuprite, and these specimens are perhaps the most widely recognized as characteristic of Ray. Fine, gem-grade chrysocolla (actually chrysocolla-stained cryptocrystalline quartz) veined with green malachite and black tenorite is among the most beautiful gem materials found in Arizona. Calcite crystals have been found colored red and yellow by inclusions of cuprite and iron oxides.

Noteworthy collector species are limited largely to those mentioned above; but the large quantity and high quality of such specimens have made Ray a popular Arizona locality for several decades. Though mineralization at Ray is widespread and largely disseminated in character, certain features of the orebody have created areas which are exceptionally productive of fine specimens.

Kennecott Copper Corporation, recognizing the mineralogical significance of the various crystallized species for collection and research, has for a number of years contracted with professional collectors to salvage mineral specimens. Originally Southwestern Mineral Associates held the contract; today it is held by John Mediz of Copper City Rock Shop in Globe. The enlightened attitude of Kennecott management in this regard is to be highly commended. Through their cooperation, thousands of fine specimens have been saved from the crusher and now grace many public and private collections.

It should be noted that Ray is an operating mine and access by collectors other than the contractors is generally prohibited. Nevertheless, arrangements to tour the mine can sometimes be obtained by writing to the mine office at Ray.

Figure 10. **Company geologists checking mineralization in the Ray open pit while contract collector John Mediz (foreground) works in copper and cuprite seam. Photo by R. Jones, 1980.**

MINERALS

Those species occurring at Ray in specimens having some significance to collectors are discussed below. All others are listed on Table 1.

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

Azurite is not common and has not been found in significant crystals at Ray. Ransome (1919) reported azurite as thin seams coating pebbles in the Copper Canyon area. Phillips *et al.* (1971) report azurite as a constituent of a Holocene-age log found at Ray and replaced by a number of copper minerals. It has also been reported along the Pioneer fault under the Barcelona section of the mine. Recently azurite has been found sparingly along the Emperor fault as druses and small spherules to ¼ inch. Examples of this type may be seen in the representative mineral collection in the mine company office. Rarely azurite is also reported as very thin seams interlayered with malachite and chrysocolla along the Emperor fault.

Brochantite $Cu_4(SO_4)(OH)_6$

Coatings of a green sulfate often found directly on native copper (J. Witner, pers. comm.) are assumed to be brochantite but could be antlerite. In the Fred and Nadine Jones collection in Globe there is a 10-inch specimen of massive to microcrystalline brochantite reported as being from Ray. If true, it was collected very early in the open pit work.

Calcite $CaCO_3$

Massive calcite is found in seams within the orebody. Crystals have been noted on the side of the Pioneer fault opposite from where native copper is usually found (J. Mediz, pers. comm.). Small, white, discoidal plates to ⅕ inch were noted in an early specimen from the McCroskey collection. In the Witner collection pale pink rhombohedrons to ⅙ inch were noted in association with cuprite and native silver in a goethite nodule. It is also one of the constituents of certain feldspar pseudomorphs. Occasionally scalenohedral crystals to ¼ inch are found in small plates. These are often green due to included malachite. Without the malachite this same type of crystal is typically transparent or white.

The most significant find of calcite from Ray occurred in late 1975 when a seam was encountered on the 2100 level of the Silicate orebody, just east of the Pearl Handle pit. Miners reported seeing a myriad of colorful red and yellow "flashes" of crystals in the lights of the electric shovel during one night of operations (D. Fountain, pers. comm.). On later investigation these proved to be scalenohedral calcite crystals to 2½ inches, as single floaters or in small clusters attached to matrix. The color was due to bright red inclusions of chalcotrichite, the yellow possibly due to included jarosite or other iron minerals. Unfortunately, most of the calcite crystals were trucked away to the mill; but a few were salvaged once it was realized what they were. The better examples of these can be seen in several private collections including those of Mr. and Mrs. William McCarty (El Toro, California), Mr. and Mrs. Reg Barnes (Mesa, Arizona), and Mr. and Mrs. Les Presmyk (Mesa, Arizona). The Barnes specimen took the trophy for Best Arizona Calcite at the Tucson Gem and Mineral Show in 1981.

Chrysocolla $(Cu,Al)_2H_2Si_2O_5(OH)_4{\cdot}nH_2O$

Chrysocolla constitutes an abundant and major ore of the Silicate orebody along with other copper silicates. It is also common in the other orebodies coating seams and as thick crusts along cracks and joints. It is believed to have formed from the general oxidation of the ores and is not the result of alteration of ore veins in place (Metz *et al.*, 1968). Ransome reports that the black chrysocolla noted early during mining contains some manganese oxide as the coloring agent.

A careful examination of Ray chrysocolla by Schwartz (1934) indicated that it is ". . . composed mainly of spherulitic aggregates of highly birefringent chrysocolla with colloform structure in plain light. . . . Under crossed nicols it appears very complex in veinlets of a later generation cutting the earlier chrysocolla and some apparently amorphous layers in the spherulites."

For the lapidary, chrysocolla occurs in thick seams intimately mixed with thin layers of malachite, rarely azurite, and black tenorite. The layering can follow almost any combination of sequences (J. Mediz, pers. comm.), suggesting that deposition of the minerals involved was virtually simultaneous. This material takes a very high polish and provides an almost riotous mixing of the beautiful blue-green of chrysocolla with the various shades of green malachite and contrasting black tenorite. Significant quantities of this material in veins several inches wide and running through one or more 40-foot benches have been found in the recent past (W. Thompson, pers. comm.).

Even more remarkable than the gem grade chrysocolla from Ray are the colorful pseudomorphs of chrysocolla after azurite (?). This find was first reported by Wilson (1977) and then described more fully by Thompson (1980). Wayne Thompson, president of Southwestern Mineral Associates, was responsible for recovery of these remarkable pseudomorphs.

The pseudomorphs ranged in color from a dirty tan when found in a wet crumbly condition close to the quartzite and in the lower part of the occurrence (J. Witner, pers. comm.) to a beautiful, deep sky-blue in the upper portions of the occurrence. Found in the Silicate orebody on the 2300 level, the better crystals came from the Whitetail conglomerate about 20 to 30 feet from contact with the quartzite. Crystals seldom exceed 1 to 1½ inches in length. Being very brittle and badly jarred by blasting of the ore, most of the crystals had been broken from the matrix but were faithfully replaced after extraction. Some matrix specimens were recovered with 30 or more crystals. Several hundred specimens were found in all. An excellent example of this material may be seen in the company collection housed in the main offices in the pit area; it has also been pictured in color in the *Mineralogical Record* (Thompson, 1980).

Exactly what mineral has been replaced by the chrysocolla in this instance isn't known. Witner suggests there may be as many as three or four different original minerals. Azurite has been strongly suggested as a possibility. This may well be but it should be noted azurite crystals of any size, let alone of sizes approaching 3 inches, have never been found here. Some favor gypsum as the major, if not the only mineral being replaced. Gypsum crystals of excellent form have been found; and replacement of them is not an uncommon occurrence. The grouping of the crystals, the visual form of the crystals, and the flat, almost feathery termination habit noted on some smaller crystals resemble gypsum. Aragonite has also been suggested as a possible candidate. Aragonite is not, however, a reported mineral from Ray. It should be noted that most of the crystals found do not have sharp boundaries along the prism faces, making crystal measurements of interfacial angles quite difficult and unreliable in many cases.

"Medmontite," a mixture of chrysocolla and mica, has been reported from the silicate orebody (Stephens and Metz, 1967).

Copper Cu

Though Ransome (1919) reports copper as being less than abundant at the deposit it has proven to be nearly ubiquitous. It is found as grains throughout the silicate orebody. Drilling has revealed its presence to at least 800 feet (D. Fountain, pers. comm.). Its relative abundance along both the Pioneer and Emperor faults, as well as the eye-witness accounts of its abundant occurrence in a clay-caliche zone capping the orebody, have been noted above. Clarke (1952) reported that the "largest and best specimens (of copper and cuprite) have been obtained in the schist just west of the diabase."

Copper is found in large, arborescent masses and sheets, some of which exceed 3 feet in length. Crystals tend to be very small, seldom over a quarter inch, though faces to a half inch are seen. Unaltered copper is not common in the deposit; most of it is found with a light to heavy coating of cuprite. Both may have been derived from the sulfides, though Schwartz (1934) reports such as being the case only for the copper. It is generally believed that the cuprite is more likely to have formed from previously crystallized copper. Copper is also found coated with a green patina, probably brochantite. It has been reported with silver in half-breed nuggets. One such nugget in the Fred and Nadine Jones collection is mostly copper with little, if any, silver showing. Witner (pers. comm.) reports that native copper found in the south end of the Pearl Handle pit tends to be associated with chalcocite while at the north end of the same pit it is associated with cuprite.

For the collector the most spectacular copper specimens from Ray, and from almost anywhere in fact, are the large bladed and twinned crystals first reported by Wilson (1974). The discovery was made in late 1973 (Panczner, 1975) during mining at Ray. Just how many crystals and specimens came out cannot be determined, though Panczner (1975) reports examining several thousand. Continued digging after the initial find suggests that crystals occurred along a zone above and on the Emperor fault (J. Witner, pers. comm.) running from the 1860 to the 1780 levels. Minor remnants occurred at the 1740 level but were unremarkable.

There are several interesting features associated with these copper crystals. The blades are frequently flat with a tapered form, often coming to a distinct point. Many show distinct spinel twinning making them very desirable as specimens. On some crystals small cubes to ⅕ inch are oriented along the flat crystal boundaries. On still other specimens, twisted crystals have been noted by Panczner (1975) and others. Some crystals are twisted through a complete 360°, and are imbedded or intergrown in such a way as to preclude falsification.

The largest of these bladed and twinned crystals reaches nearly 6 inches and is nearly an inch across the flat. Major specimens can be found in several collections including those of Mr. and Mrs. Bryant Harris (Fallbrook, California), Evan Jones (Scottsdale, Arizona), Wayne Thompson (Phoenix, Arizona) and the Arizona-Sonora Desert Museum (Tucson, Arizona). The Museum specimen is particularly important in that the original green patina, assumed to be malachite (cuprite has also been reported on many of these crystals when found), has not been removed. Unfortunately, virtually all the crystals were cleaned before sale so examples of coated crystals are very scarce. Continued recent mining in the same general area has not unearthed any additional twinned crystals (J. Mediz, pers. comm.).

Cuprite Cu_2O

Though never listed as a major ore of the deposit, cuprite is nonetheless ubiquitous in association with copper and by itself. Already mentioned is its frequency of occurrence as a coating on copper throughout the deposit, particularly along the Pioneer fault, Emperor fault and in the overlying clay atop the orebody. It also occurs as descrete crystals in fractures within the orebody. The mineral collection at Arizona State University once had two blocks of rock upon which were attached fine cubes of cuprite approximately 1 inch across (the specimens were stolen).

Of late some very fine cuprite crystals have been found which deserve detailed description. These occurred along the Emperor fault toward the north end of the Pearl Handle pit, and were found early in 1981 by John Mediz (pers. comm.). One of us (RWJ) obtained a specimen upon which rests a nearly complete, sharp and bright deep red octahedron of cuprite showing slight cube modifications. It is ¾ inch from point to point. Another similar crystal, slightly skeletal and incomplete but even larger, is in the John Witner collection.

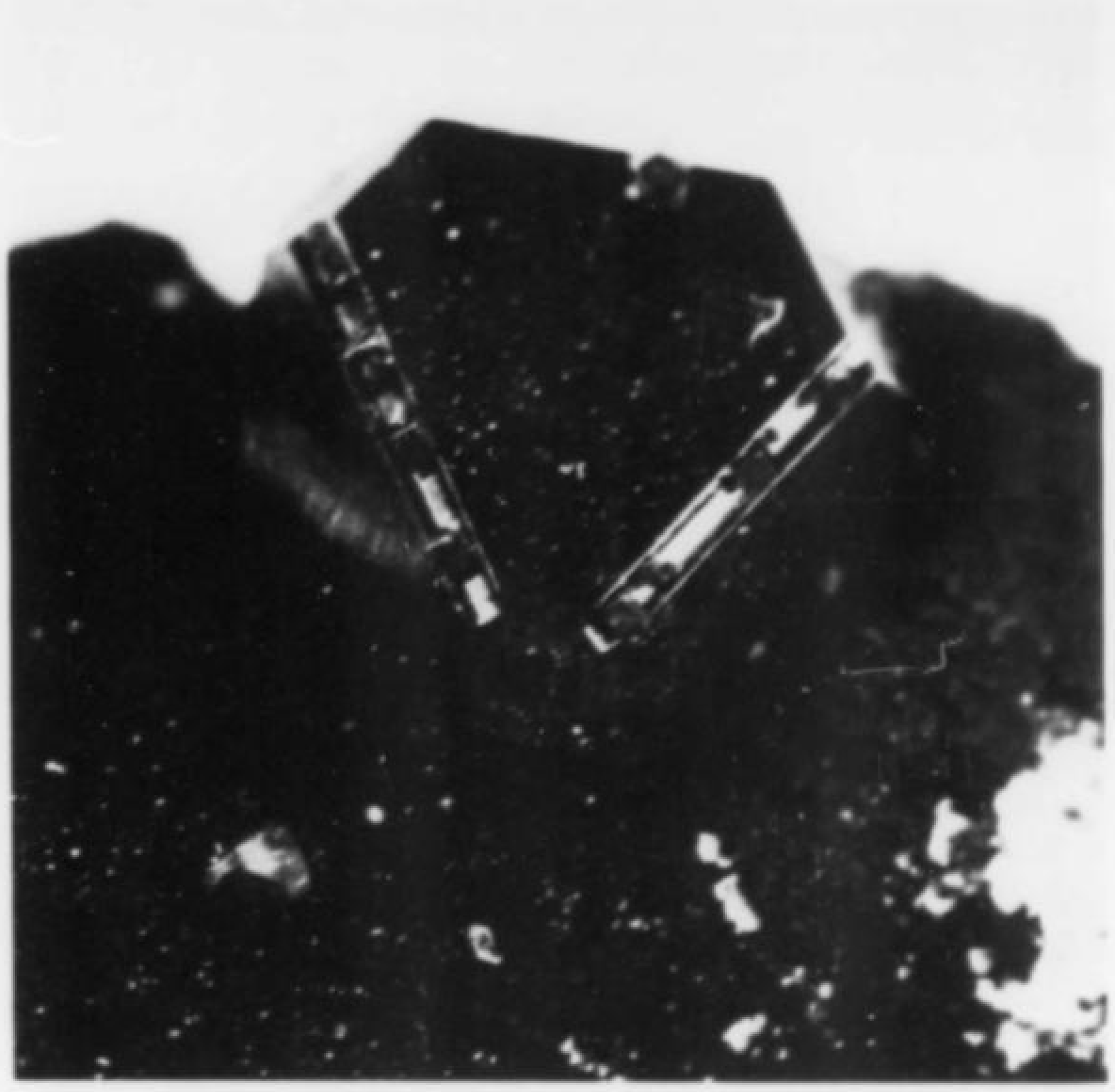


Figure 11. **An unusually modified cuprite crystal measuring about ⅕ inch, from the Ray open pit. The crystal is dominantly octahedral but shows cube faces along hoppered dodecahedron faces. Arizona State University collection; photo by R. Jones.**

These crystals were collected from a brecciated fault zone, and range in size from micros to ⅗ inch on an edge. The dominant form is the octahedron but cube and dodecahedron modifications are common. The matrix consists of a black velvety material, possibly manganese oxides or tenorite coating breccia fragments. Associated with these octahedral crystals are a later growth of very sharp, bright red cubes of cuprite to about ¼ inch. These are usually clustered around the base of the larger crystals but in rare cases are epitaxially oriented along dodecahedron faces modifying the octahedrons. These oriented cubes are beautifully spaced, with almost mathematically regularity. No other copper mineral was found with the cuprite but small needles of transparent gypsum to ¼ inch may be seen on a few specimens.

Along with the cuprite comes its acicular or fibrous variety, chalcotrichite, which is very common in certain areas of the pits. It can be found directly on copper, on cuprite, enclosed in calcite (which see), and by itself in brilliant red felted masses and hand-size bird's nest clusters in openings in the ore (D. Fountain, pers. comm.). Needles can reach an inch in length and are hair-like. They are commonly oriented at 90° to each other in three-dimensional latticeworks which make spectacular micromounts. Witner (pers. comm.) reports seeing chalcotrichite in felted masses of perfect cubic form to ⅙ inch on an edge, suggesting the possibility of replacement. Wayne Thompson (pers. comm.) also reports seeing these to $^1/_{16}$ inch.

Witner has a mass of black material which is clearly of organic origin, replaced possibly by iron or manganese minerals. The material has a definite twig-like form. Scattered randomly on these "twigs" are minute red cuprite cubes.

Dioptase $CuSiO_2(OH)_2$

Dioptase has been found along the Emperor fault by Thompson (pers. comm.) in brilliant green, simple prisms to ½ inch forming druses. In the McCroskey collection is a single specimen which has brilliant, emerald-green rhombs to ⅛ inch; the crystals are transparent with a high luster and are closely packed in a 1-inch vug. Dioptase has also been collected as crystals scattered on quartz linings covering chrysocolla and tenorite seams in the Silicate orebody.

Feldspars

Large twinned phenocrysts of feldspar have been collected for years in the Ray area, principally from a region just north of the pits along the Kelvin-Superior road (Flagg, 1958). These have always been popular with local collectors. Sharp crystals to 1 inch are common and examples nearly 2 inches long and nearly an inch wide were once fairly common. These are loosely held in matrix; complete crystals are easily removed.

Gypsum $CaSO_4 \cdot 2H_2O$

Attractive gypsum sprays on native copper have recently been found in significant numbers. The crystals are up to 2 inches long, in diverging sprays 3 or more inches across. They are water-clear and colorless unless stained. Occasionally they are also found in flattened sprays 1 or more inches long in thin seams in the ore. Finally, they can be encountered as randomly occurring needles to ⅖ inch in length with cuprite, copper and other minerals. (See also the discussion under chrysocolla regarding pseudomorphs.)

Halotrichite $FeAl_2(SO_4)_4 \cdot 22H_2O$

Two-foot-long white fibers of halotrichite were found by John Witner (pers. comm.) adjoining the stream gravels of Mineral Creek along the Emperor fault.

Libethenite $Cu_2(PO_4)(OH)$

Libethenite, a rare copper phosphate, is found occasionally in seams as microcrystals showing distinct and sharp orthorhombic form. The color is bright deep green. Thompson (pers. comm.) also reports finding it in the Silicate orebody.

Malachite $Cu_2(CO_3)(OH)_2$

Malachite is not as important at Ray as it is in some other Arizona deposits. It does occur sparingly as velvet crusts of acicular crystals in the Silicate orebody. It occurs as coatings, usually on cuprite, less commonly on copper. It has also been found as thin crusts in layers with azurite and black chrysocolla (tenorite?) on cobbles in the Copper Creek area (Ransome, 1919). Schwartz (1934) reports that malachite commonly forms as coatings directly from cuprite. Specimens of cuprite measuring to ⅕ inch have been found with a malachite coating.

Malachite has also been reported as a thin layer formed on the noted chrysocolla pseudomorph crystals (which see). If true, this would support the theory these pseudomorphs are after azurite (John Witner, pers. comm.).

A small number of very fine to crude groups of malachite pseudomorphs after azurite (?) crystals were found by Thompson and others (pers. comm.) along the Emperor fault south of where the chrysocolla pseudomorphs were found. An excellent example may be seen in the mine office collection; the crystals are nearly 2 inches in a spray about 3 inches across.

In the Silicate orebody malachite also occurs as bright, radiating tufts of needles to a half inch or so, sitting isolated on drusy quartz in chrysocolla pockets. For the lapidary it is found intimately associated with chrysocolla, sometimes as the dominant mineral, and with tenorite.

Quartz SiO_2

Quartz is found abundantly as crystal points usually ⅛ inch high forming drusy coatings lining chrysocolla vugs. It occurs as the variety chalcedony and, when impregnated with chrysocolla ("gem silica"), can be cut into very colorful semi-precious gems. The rich blue material is most highly prized and very rare here. It may also enclose some malachite and have a green color.

When found lining chrysocolla vugs it is the final mineral of a sequence including chrysocolla, malachite and tenorite. The exception to this is the occasional radiating tuft of malachite, sometimes to a half inch, found on the quartz. Thompson (pers. comm.) also reports that scattered micro dioptase crystals are rarely found on quartz lining. Schwartz (1947) reports quartz as forming veinlets which cut the porphyry. It has also been reported as one of the minerals replacing feldspar in some pseudomorphs.

Silver Ag

Silver is occasionally encountered at Ray and does constitute a source of revenue from the ore. Generally it is found as small platy masses seldom over a half inch in size, in chalcocite, particularly in the area of the West pit. It has been reported in half-breeds but the only one examined for this study was almost lacking in silver. Ransome (1919) reports it in the #3 mine with cuprite and chrysocolla.

Of interest to collectors are those rare instances when native silver wires are found, usually on cuprite. The wires are hair-like, to a half inch long, usually curving slightly. They may also be associated with calcite and native copper. It is difficult to say how much of this material occurs because it is not easy to see, is usually tarnished and thinly scattered in the openings of the cuprite-coated arborescent copper. It is more easily recognized when occurring as platy masses to a half inch on cuprite-coated copper. Material of this type has recently been collected along the Mineral Creek-Emperor fault area (J. Mediz, pers. comm.).

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

A few small, emerald-green plates of torbernite to ⅛ inch were found intimately associated with red chalcotrichite by Thompson (pers. comm.). Witner (pers. comm.) also reports it as occurring rarely as scattered flakes of the same size along joints in the matrix.

***Table 1.* Minerals known to occur at Ray.**

Species	*Description*	*References*
Allanite	Grains in igneous rocks	Cornwall (1982)
Alunite	Nodules to 6 inches	Ransome (1919)
Andalusite	Grains in schist and protore	Ransome (1919)
Apatite	Euhedral grains in igneous rocks	Cornwall (1982)
Azurite	(see text)	
Barite	Rare pink rosettes to ¼ inch	J. Witner (pers. comm.)
Biotite	Common in many rock types	Schwartz (1947) (1958) Ransome (1919) Banks (1982) Cornwall (1982)
Bornite	Minor grains in porphyry	Cornwall (1982)
Brochantite	(see text)	
Calcite	(see text)	

Chalcocite	Massive veins 8 inches to 2 feet wide with silver. Also as disseminations, coatings and replacements	C. McCrosky (pers. comm.) D. Fountain (pers. comm.) Schwartz (1947)
Chalcopyrite	Common as disseminated grains	Ransome (1919) Cornwall (1982)
Chlorite	Found in various rock types	Ransome (1919) Schwartz (1947) (1952)
Chrysocolla	(see text)	
Copper	(see text)	
Covellite	Rare and unconfirmed	Ransome (1919)
Cuprite	(see text)	
Delafossite	Rare, with chalcotrichite	Anthony *et al.* (1977)
Descloizite	One specimen known	Anthony *et al.* (1977)
Dioptase	(see text)	
Epidote	Grains in igneous rocks	
Feldspars	Orthoclase, oligoclase, andesine, labradorite and bytownite reported in igneous rocks, commonly altered (see text)	Ransome (1919) Schwartz (1952) Cornwall (1982) Flagg (1958)
Galena	In rocks surrounding orebodies	D. Fountain (pers. comm.)
Garnet	Discrete grains of almandine noted in granodiorite	Cornwall (1982)
Goethite	Common, powdery and as replacements	Phillips *et al.* (1971)
Gold	Not visible but recovered in processing	Metz and Rose (1966)
Gypsum	(see text)	
Halloysite	An important ore it contains 3.2 percent copper	Stephens and Metz (1967) Schwartz (1952)
Halotrichite	(see text)	
Heulandite	No description	Schwartz (1934)
Hornblende	Green, poor crystals in rocks	Ransome (1919) Schwartz (1947) Cornwall (1982)
Hydromicas	As pseudomorphs after feldspars	Schwartz (1952)
Ilmenite	Finely disseminated in schists and dike rocks	Ransome (1919) Cornwall (1982)
Jarosite	Found as a replacement log; may be widespread	Phillips (1971) J. Witner (pers. comm.)
Kaolinite	Common alteration product	
Libethenite	(see text)	
Magnetite	Minor igneous accessory mineral in most formations	Cornwall (1982)
Malachite	(see text)	
Molybdenite	As plates and veins to 1 inch, widely distributed	Ransome (1919)
Monazite	Minor igneous accessory	Cornwall (1982)
Montmorillonite	White to blue-green and copper-bearing (to 17 percent)	Stephens and Metz (1967)
Muscovite	In igneous rocks	Ransome (1919)
Neotocite	Massive, some copper-bearing	Metz *et al.* (1968)
Nontronite	Green clay	Anthony *et al.* (1977)
Pyrite	Common and widespread but no good crystals	Ransome (1919)
Pyroxene	Accessory in dike rocks	Cornwall (1982)
Quartz	(see text)	
Rutile	Microcrystals in igneous rocks	Ransome (1919)
Silver	(see text)	
Sphalerite	Occurs outside of orebody	D. Fountain (pers. comm.)
Talc	Yellowish material with molybdenite	E. Jones (X-ray ident., pers. comm.)
Tenorite	Black, massive, in seams	Ransome (1919)
Titanite	Widespread as grains in rock	Cornwall (1982)
Torbernite	(see text)	
Tourmaline	Accessory in schists	Ransome (1919)
Zircon	Widespread accessory	Ransome (1919) Cornwall (1982)

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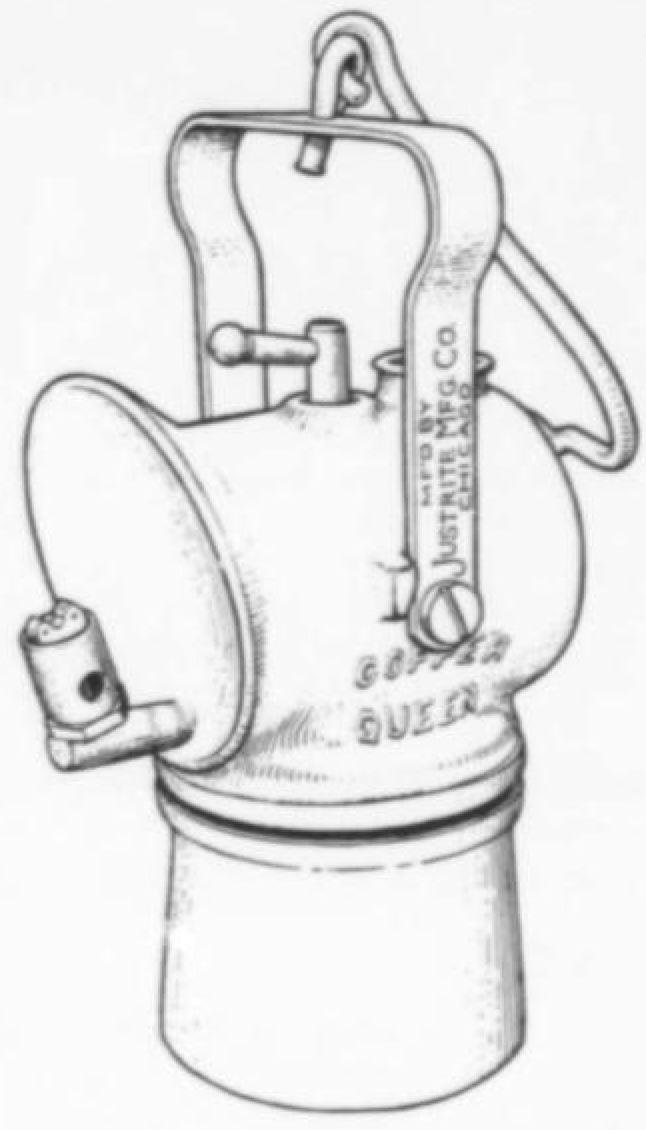

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Scottsdale, Arizona 85253

As one might expect, Arizona's abundance of prolific specimen localities has led to an abundance of private collectors specializing in minerals of the state. A quick listing might reveal 20 or 30 fine private collections specializing in whole or in part in Arizona minerals. One of the best of these is the collection of Les and Paula Presmyk in Mesa, Arizona.

Les is Assistant General Mine Foreman at the Magma mine in Superior, Arizona. He began collecting more than 20 years ago, and has been specializing in Arizona minerals for about 12 years. He also does a little dealing on the side, like many collectors, and has passed along a large number of excellent Arizona pieces . . . his small painted number on specimens ("LP" followed by a catalog number, on a gray rectangle) identifies many fine examples as having passed through his hands at one time or another.

Being actively involved in mining at the Magma mine, Les is particularly fond of Magma minerals. Over the years he has acquired dozens of fine pieces, primarily barite and calcite. Although it is generally assumed that golden barite of the type which made the mine famous years ago is no longer found there, an important strike was made in 1981. The new discovery occurred on the 3600 level, in an area where no barite of any significance had been found before. The discovery yielded several hundred specimens (which have all found their way to appreciative collectors by now). According to Les, there is potential for the recovery of more specimens if mining resumes in that area.

Other highlights of the collection include a number of fine Arizona silvers. Few collectors are aware that Arizona has produced any silver specimens at all, much less the large and attractive crystalline groups in the Presmyk collection. One example (shown here in Figure 6) appeared in the Silver Anniversary publication of the Tucson Gem and Mineral Society. It was incorrectly identified as having come from Tombstone, but is actually from the Stonewall Jackson mine at McMillan, north of Globe. The collection contains other fine silvers from the Toughnut mine at Tombstone and the Silver King mine north of Superior.

The malachite pseudomorph shown here in Figure 7 is an old specimen (1947) from the Live Oak *mine* at Inspiration, Arizona, north of Miami. The underground workings have since been consumed by the enormous Live Oak *pit*. So the Live Oak mine is truly an extinct locality.

Among the most notable specimens in the collection is the vanadinite from the Old Yuma mine shown here in Figure 1. The piece was acquired from the old Lazard Cahn collection, and was probably collected shortly before 1940. This makes it one of the oldest specimens known from that famous mine, and definitely one of the finest vanadinites from there. The habit is distinctive, and rather unlike most other Old Yuma vanadinite.

Other exceptional pieces include a remarkable copper specimen from Bisbee (Fig. 3) acquired from an old Bisbee collection but resembling in habit the copper from the Ray mine (as on the cover of this issue). And of course no Arizona collection would be complete without a selection of spectacular wulfenites from various localities, some of them self-collected.

Examples pictured on the following two pages were selected in part to illustrate some localities not previously mentioned in the Arizona Issues of *the Mineralogical Record* (e.g., Figs. 6-8); perhaps these localities will be the subject of future articles some day. Private collections in Arizona, like the Presmyk collection, contain a wealth of such specimens.

Anyone interested in viewing more of this collection should make arrangements with Les, as the specimens are generally kept in a safe deposit box.

Figure 1. Vanadinite from the Old Yuma mine The largest crystal measures ¾ inch. Collected before 1940.

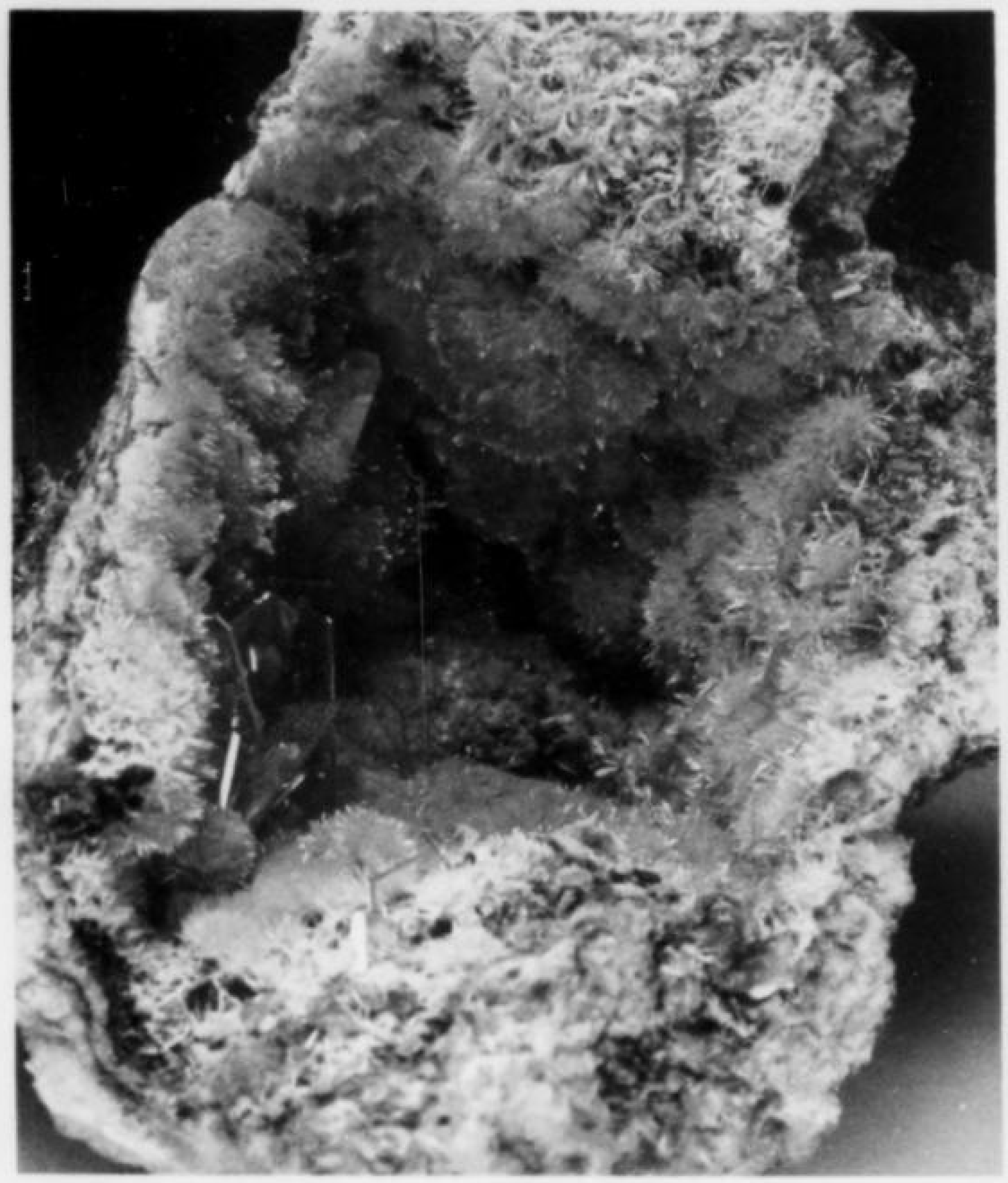
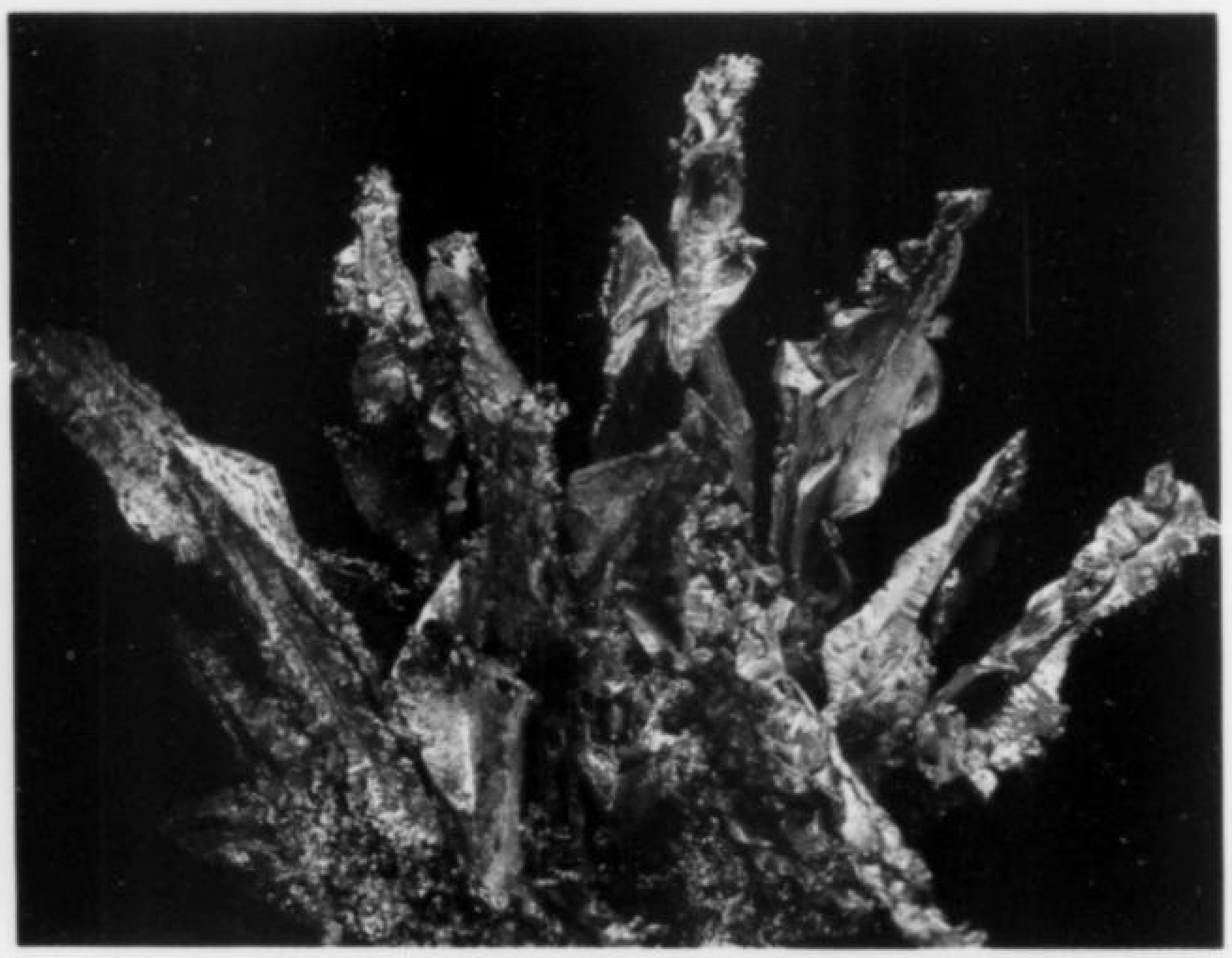


Figure 2. A 3-inch pocket in barite lined with yellow to red-orange mimetite and a few red-orange wulfenite crystals, from the Rowley mine. Self-collected in 1970.

Figure 3. An exceptional spray of copper crystals 4¾ inches across, from Bisbee.



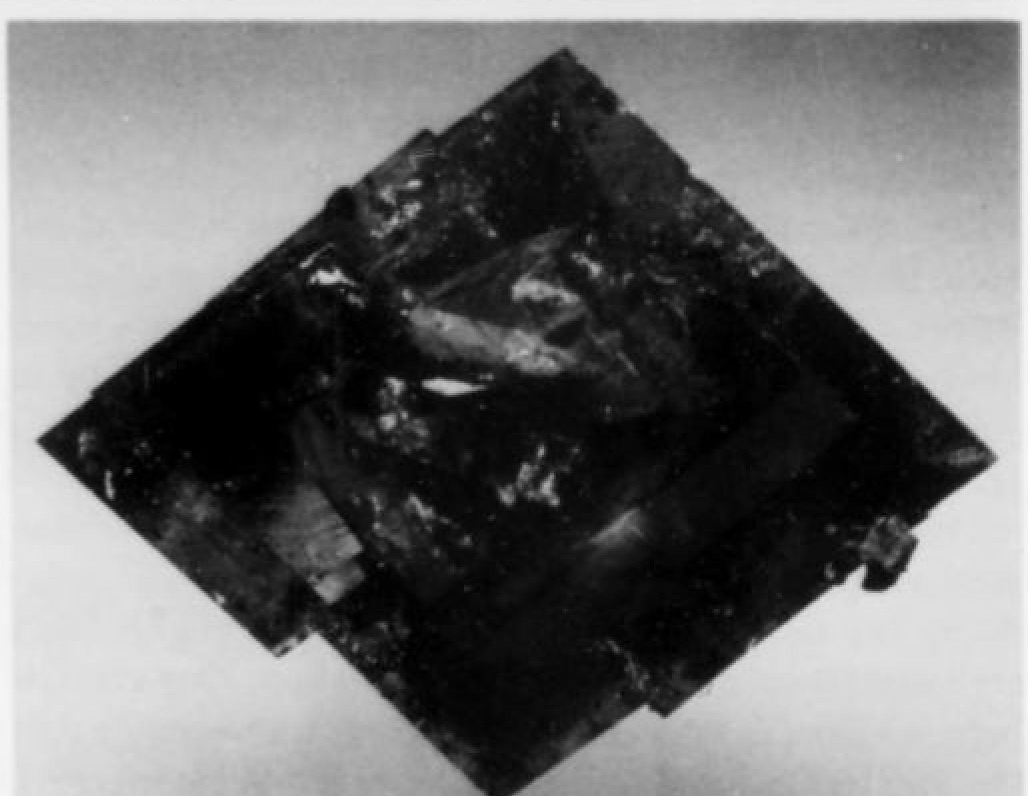


Figure 4. Golden barite crystal 1$^{5}/_{16}$ inches across, from the 3600 level of the Magma mine, collected in 1981.

Figure 5. **Cerussite crystals to 1 inch on matrix, from Bisbee.**

Figure 6. **Silver, with a pink patina, from the Stonewall Jackson mine, McMillan, Arizona. This specimen won the prize for best Arizona silver at the 1979 Tucson Show. It stands 3¾ inches tall.**

Figure 7. (above) **A large (1⅛ inch) malachite pseudomorph after azurite, coated with drusy quartz, from the underground workings of the Live Oak mine, Inspiration. Collected in 1947.**

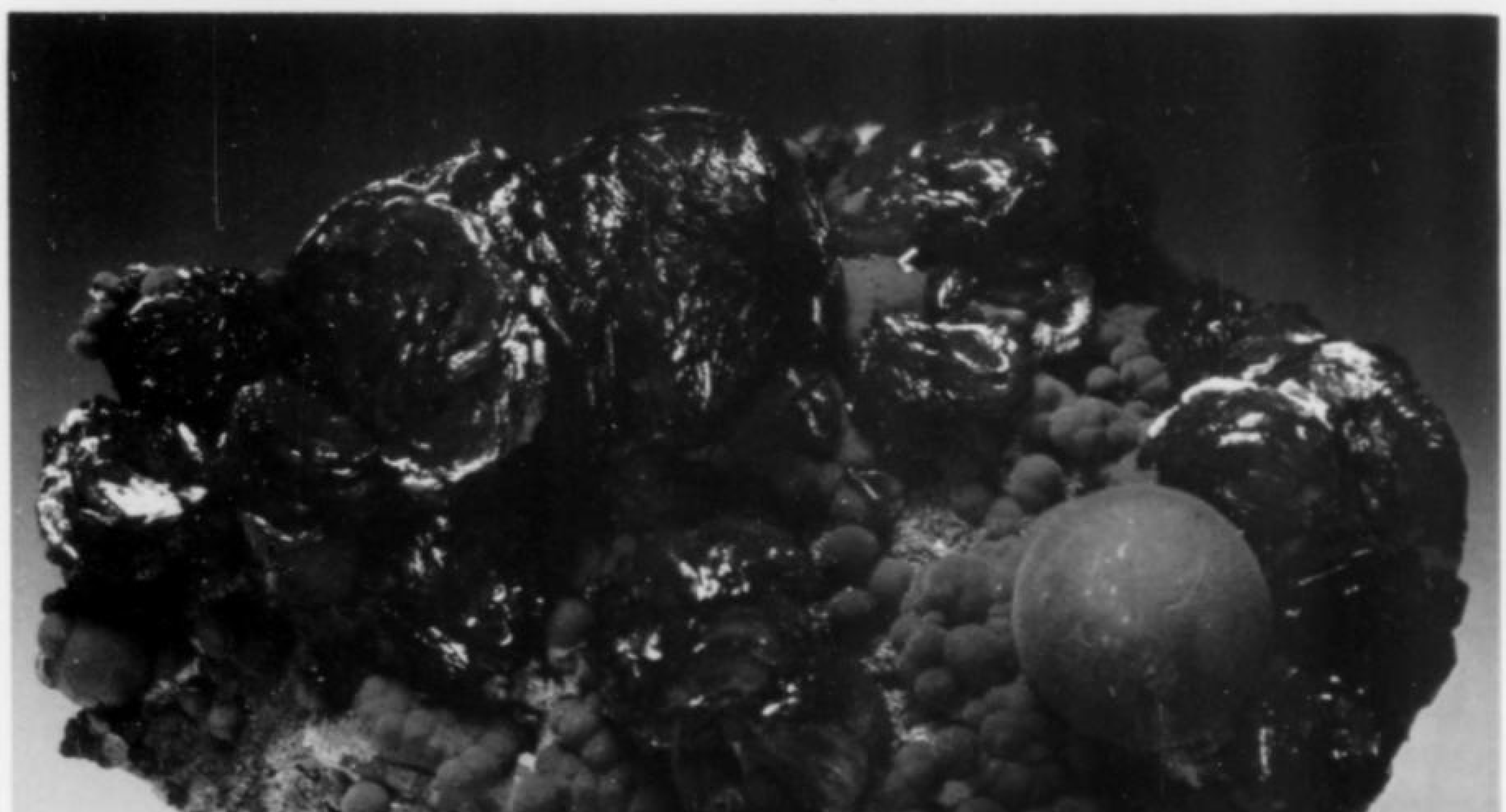


Figure 8. **Azurite showing "electric blue" internal reflections, with malachite, from the Morenci mine. The specimen, collected in 1981, is 2⅜ inches across.**

Richard L. Jones 1933-1982

by **Richard A. Bideaux**
252 W. Ina Road
Tucson, Arizona 85704

In the early 1950's, before this era of mineral shows, fellow collectors were fewer and not so easily located. Mineral collecting is more fun, however, if you have a friend with whom to share it and such a friend is a necessity for field collecting, especially underground.

At that time there were a few mineral dealers in Tucson – one day, at a dealer's shop long since vanished, I met and made such a friend; we remained friends for many years until his death, after a long battle with leukemia, on March 20, 1982.

Dick Jones and I were out nearly every weekend, all over southern Arizona. When I entered the Army in 1960, he moved from Tucson to Casa Grande, Arizona. We perhaps made an incongruous pair. I will always remember the description given (repeated to us third or fourth hand) of the persons who had sold some specimens from a locality we were trying to keep quiet: "a short, fat white man and a tall, dark Mexican." But our abilities were complementary and two are more effective than one – there were no localities we visited which we didn't at least penetrate, and one of us was always the right size and shape to work the pockets.

During this time our major successes were the large discoveries of wulfenite at the Glove mine (where we worked for months) and later the Defiance mine, where we were collecting on our own behalf, and also selling for the mine owners. At the Rowley mine we found wulfenite and mimetite in open pockets untouched.

We were not always successful; in fact we reckoned that only one time out of ten did we bring back enough to pay for the trip. Perhaps our worst fiasco was a 1964 search for the "lost cinnabar prospect" – three days spent grinding back and forth over central Arizona roads, trailing a compressor, looking for the "turn-off." That one is still lost, but I believe to this day that it does exist. (See the article in this issue on lost mines, by Wilson, for more details on the lost cinnabar prospect.)

Dick gradually moved more into the commercial end of the mineral business, finally giving up his typewriter repair business. Few can say that they have discovered and developed commercially collectable localities, previously unknown to collectors, but this was Dick's specialty. A record of his finds shows me that he ranked with that other great American field collector, Edwin Over. Thoroughness in preparation and background research, while tedious, were among Dick's secrets. He became remarkably familiar with the literature, reading masters' theses and other publications while building a fine library of his own. Clues gained in this fashion, combined with persistence, paid off in the rediscovery of other "lost" localities and "new" discoveries. His astute field observations would do credit to the most successful exploration geologist. He was a good contributor to *Mineralogy of Arizona,* wherein he revealed the location of many of his discoveries.

Kent England

Dick Jones, Tucson Show, 1979.

In the collecting arena of Arizona, Nevada, Colorado and New Mexico there are between half-a-million and a million mining claims. Many of these were located as early as the 1860's and have been abandoned for decades. The early miners cared nothing for crystals – so, although it's like looking for a "needle in a haystack," it is still possible today to stumble into a prospect containing untouched crystallized minerals, or even to find crystals in outcrops. The metallic minerals have generally been removed from the surface, but the gangue minerals – quartz, fluorite, barite, epidote – all provided valuable discoveries for Dick.

In New Mexico he discovered several fine fluorite localities in Catron County, which he worked for years during the summers; these have never been located by anyone else. He also prospected for and discovered a "breccia pipe" containing remarkable smoky quartz crystals twinned on the Japan law, the location of which he likewise successfully kept secret.

Once I accompanied Dick to another arduously made new find. It started with his noticing a jar of colorless topaz crystals left by a hunter in a gasoline station in Globe. He tracked these nearly to their source, alluvial boulders of rhyolite in a miniature Thomas Range occurrence with pseudobrookite, spessartine and bixbyite. On another occasion, by noticing and back-tracking stream float he

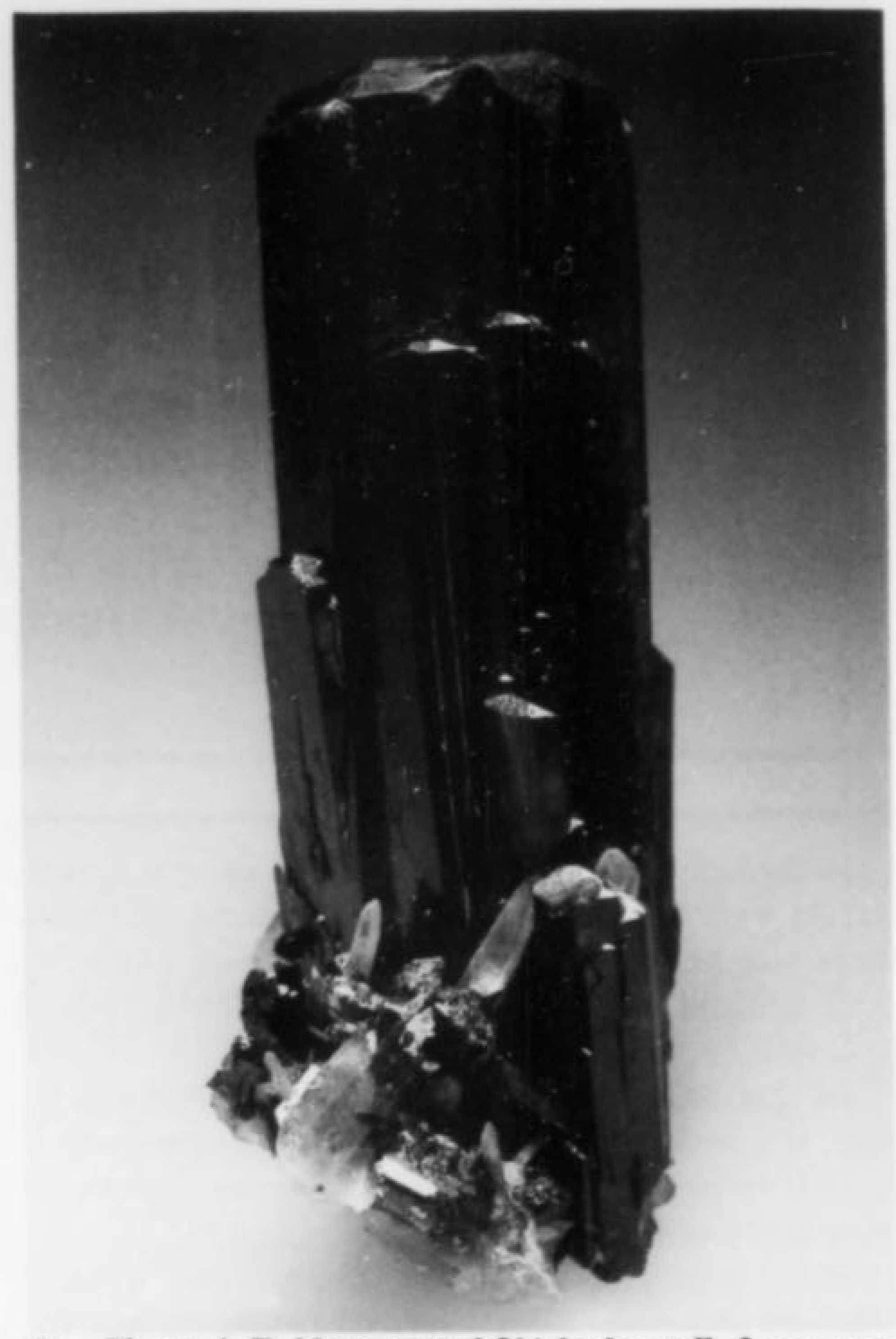


Figure 1. **Epidote crystal 3½ inches tall, from near Hawthorne, Mineral County, Nevada. Collected in 1981.**

Figure 2. **A magnificent Japan-law twin of smoky quartz from the El Tigre claim, El Capitan Mountains, Lincoln County, New Mexico. Collected in 1976.**

Figure 3. **The finest of thousands of specimens of purple octahedral fluorite collected in Catron County, New Mexico. The group is 3¾ inches across; collected in 1969.**

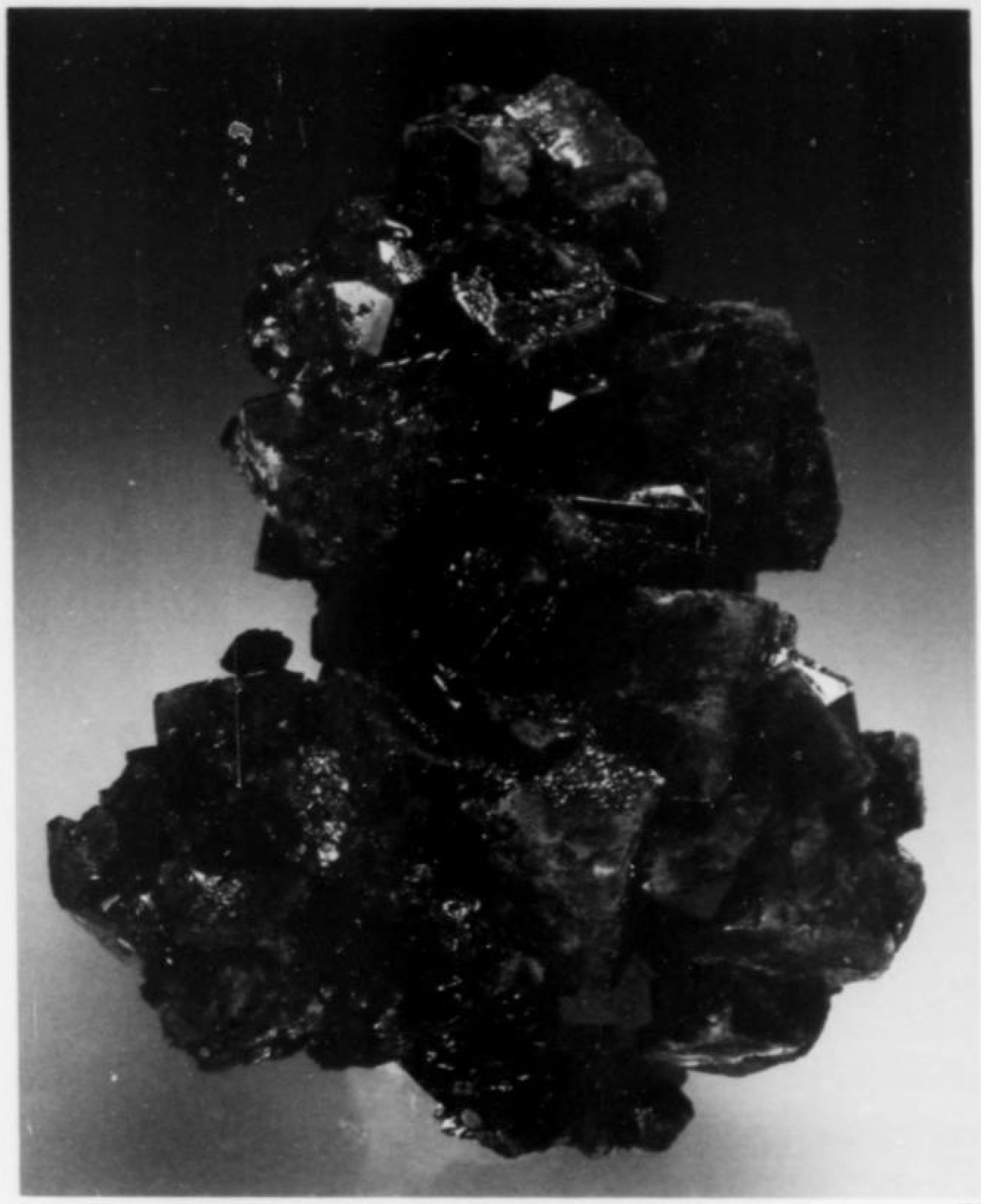


Figure 4. **Azurite and malachite from the New Cornelia mine, Ajo, Arizona; collected in 1962.**

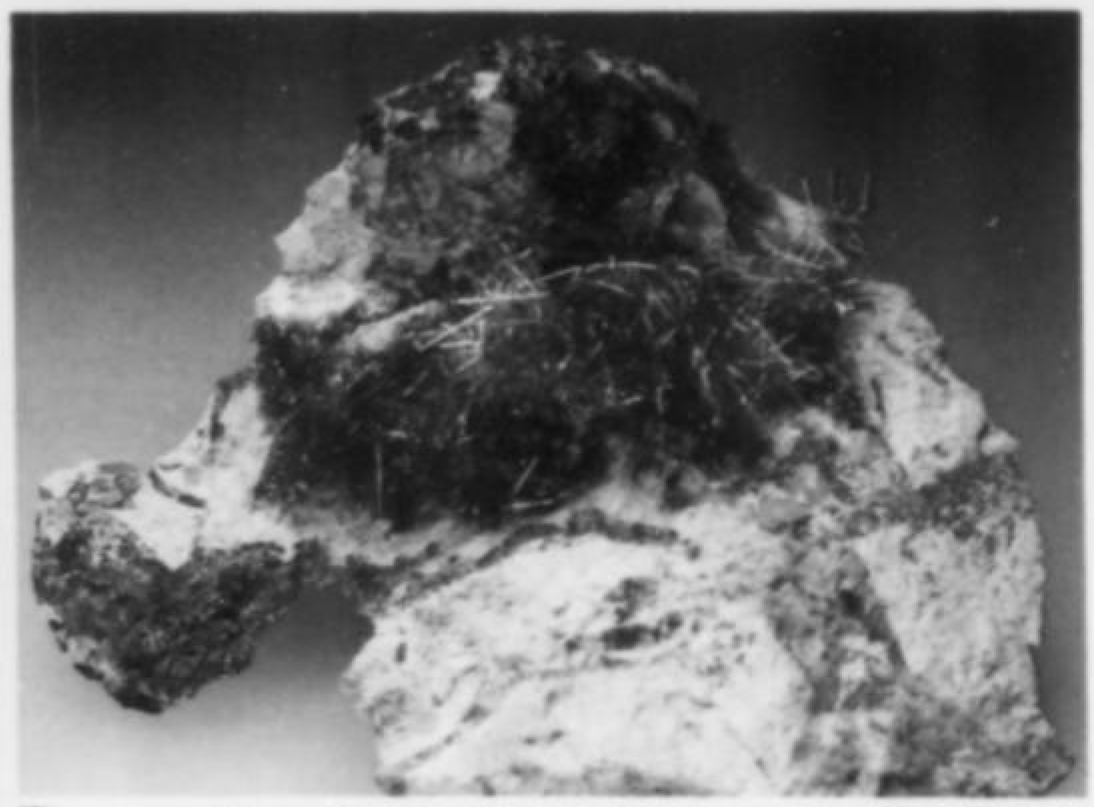


Figure 5. **Cuprite needles from the Grand Reef mine, Arizona. Only two small pockets of cuprite have been found there, this being the best example. The cuprite area measures about 1¼ inches across. Collected in 1970.**

Figure 6. **A superb crystal of Red Cloud mine wulfenite measuring 1¾ inches, on matrix. Collected in 1974.**

All specimens shown here were collected in the field by Dick Jones, and are now part of the Tom McKee collection.

discovered a small occurrence of large vanadinite crystals in place near Patagonia. The same story was repeated at the Grand Reef mine: a single fragment of linarite in debris on a new road eventually led to exceptional matrix specimens. Dick made new discoveries of cerussite at the Flux mine after a lapse of 50 years, and he found azurite and brochantite in the Waterman Mountains.

There were disappointments of course. Many trips were made to the Hilltop mine, looking for wulfenites without success, and the 1915 Renaldo Pacheco vanadinite locality near the Red Cloud mine was never located for sure. In 1980–81 he was hot on the trail of beautiful yellow prisms of the "endlichite" variety of vanadinite, near Hillsboro, New Mexico. While he certainly had the right "hole in the ground," with a few crystals to prove it, the big pocket never materialized.

On occasion, Dick went further afield. Several trips were made to Prince of Wales Island to try to rediscover the Over-Montgomery collecting areas of the 1930's, with some success and considerable discomfort and danger. Another time visits were made to Boleo, from which I remember Dick's discussion of clues provided by stratification of the Cumenge shaft dump. He was in early on the collecting of wulfenite and mimetite at the San Francisco mine, in Sonora, chasing down several pockets from their indications on tunnel walls.

One of Dick's and my favorite localities was the Old Yuma mine, the closest fine mineral locality to Tucson. After patiently researching the legal status of the ground, Dick saw and took his opportunity to lay claim to it in 1979. Shortly after the 1982 Tucson show, when Dick had been told he must re-enter the hospital for further treatment, he decided to sell the Old Yuma to Southwestern Mineral Associates, Inc., of which I am a part. As we walked the ground and Dick explained his usual close observations, we both knew it would be one of his last good days. I can only hope that Dick is into other pockets of fine minerals wherever he may be.

Ramsdellite
from the Mistake mine

by **William H. Wilkinson**
4435 East Brott
Tucson, Arizona 85712

Robert W. Allgood
and **Genne M. Allgood**
3439 East Bermuda, Apt. C
Tucson, Arizona 85716

and **Carlos Williams**
124 Spruce Street
Kingman, Arizona 86401

INTRODUCTION

Since 1981, when specimens were introduced by Fred Haynes, ramsdellite (misidentified by us as hollandite) in fine crystals from the Mistake mine has been available on the mineral market (Wilson, 1981). The Mistake mine is a small prospect located in Sec. 12, T.8N., R.5W., about 10 km north of Wickenburg in Yavapai County, Arizona. It is shown on the Sam Powell Peak quadrangle.

GEOLOGY

At the locality a small manganese deposit occurs in a brecciated zone in a Cretaceous andesite flow. The andesite overlies Precambrian Yavapai Series rocks and caps a ridge which is tilted to the northwest. The breccia zone is a vertical feature which cuts through the andesite. The zone is dissected by the Hassayampa River. The breccia may have been formed by faulting. Breccia fragments are rounded and cobble to boulder size (6 to 26 cm). Interstices between fragments have been partially or wholly filled with manganese oxides. Vugs between fragments are commonly found to contain crusts of ramsdellite crystals.

RAMSDELLITE

The original identification made by one of us (WHW) was based on the presence of barium as indicated in a spectrographic qualitative analysis (hollandite = $Ba(Mn^{+4}Mn^{+2})_8O_{16}$). Subsequent chemical analyses have yielded only 0.5 to 0.8 weight percent Ba, which is insufficient for hollandite (14 percent Ba). The analyses indicate relatively pure MnO_2 (Table 1).

Twelve specimens were analyzed by X-ray diffraction performed on a Phillips APD 3600 X-ray diffractometer equipped with a computerized search system for comparison with JCPDS powder data.

Figure 1. **View of the Mistake mine portal looking east across the Hassayampa River.**

Figure 2. **Ramsdellite from the Mistake mine. The crystals are about 8 mm across. University of Arizona collection.**

Figure 3. **Ramsdellite altering to pyrolusite. The specimen is 6 cm across. Carlos Williams collection.**

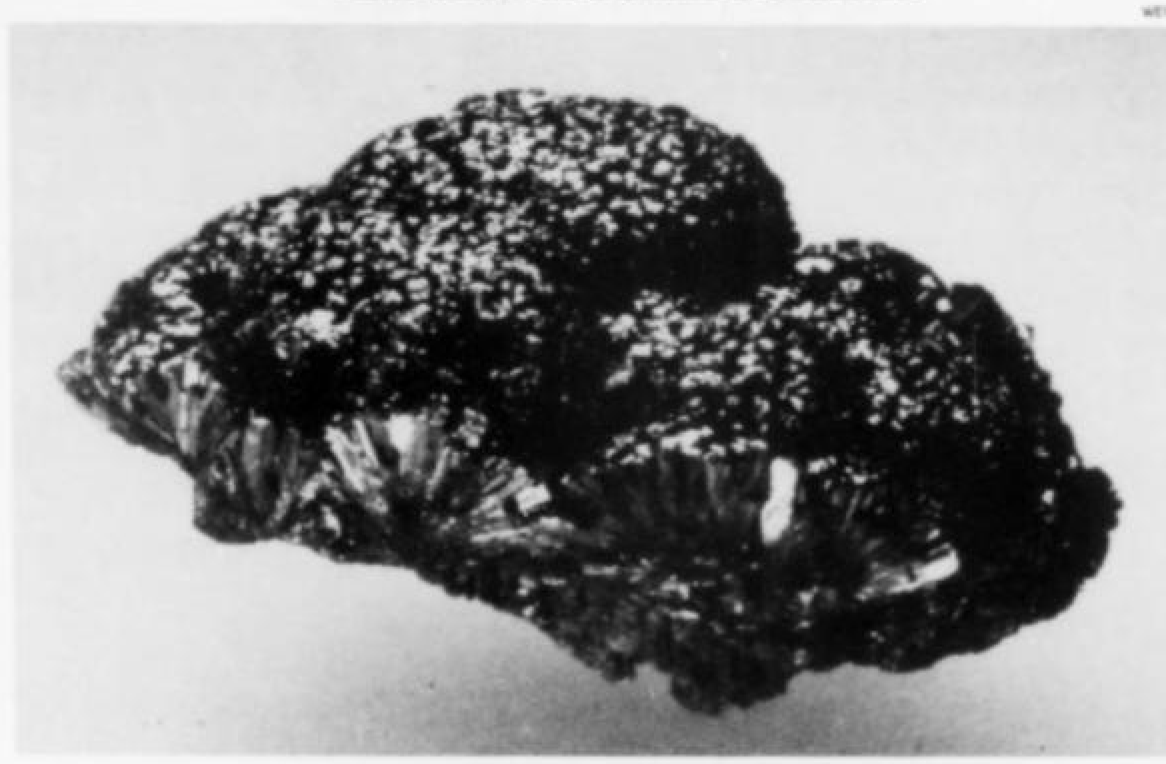


Figure 4. **Botryoidal habit of pyrolusite and ramsdellite. The specimen is 2.3 cm across. University of Arizona collection.**

If more than one phase is present, the computer will identify both and calculate the percentages of each phase present. Results were confirmed by manual comparison. Most of the samples proved to be a mixture of ramsdellite and pyrolusite, one specimen proved to be ramsdellite alone, and traces of romanechite were indicated for two samples. No indication of hollandite was found. Ramsdellite and pyrolusite are dimorphs of MnO_2.

The proportion of ramsdellite and pyrolusite varies systematically. The freshest and most lustrous crystals are primarily ramsdellite. As the crystals become duller in luster and develop a dull black coating, the proportion of pyrolusite increases. Dull, botryoidal material is primarily pyrolusite with a minor amount of ramsdellite.

The crystals are short, stubby prisms with sharply defined faces. Prism faces are lustrous and distinctly striated parallel to the *c* axis. Terminations are step-like and slightly domed, with a duller luster and brownish cast. Despite the indistinct terminations, the crystals can be identified as orthorhombic. Perfect cleavages parallel the prism faces; separation along these in the more altered crystals results in a sheaf of acicular fragments. Poorer quality crystals have a dull to velvety black coating. Crystal size ranges up to 1 cm, and crystal clusters to 20 cm have been recovered intact. Also present is a botryoidal habit, primarily pyrolusite consisting of radiating acicular crystals in crusts to 3 mm thick; these may be lustrous or may have the dull black coating.

DISCUSSION

Ramsdellite, which is the orthorhombic dimorph, appears to

Table 1. **Partial chemical analyses (plasma arc spectrography) of ramsdellite and pyrolusite from the Mistake mine, Yavapai County, Arizona (by R. W. Allgood). Values in weight percent.**

SAMPLE NO.	Mn	Ba	Cu	Pb	Zn	Fe
1	59.0	0.798	0.121	0.109	0.042	0.119
2	61.2	0.675	0.352	0.155	0.062	0.124
3	57.9	0.529	0.109	0.115	0.035	0.088
4	62.2	0.562	0.141	0.153	0.044	0.081
AVERAGE	60.1	0.641	0.181	0.133	0.046	0.103

have been the original mineral to crystallize, and has been altered in varying degrees to pyrolusite (the tetragonal dimorph). This is in keeping with the observation by Fleischer *et al.* (1962) that ramsdellite inverts irreversibly to pyrolusite at a temperature near 310° C. They state that ". . . very likely this inversion would occur at temperatures below 300° C if sufficient time were allowed."

ACKNOWLEDGMENTS

Our thanks to Wendell Wilson for the specimen photographs.

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Black Dioptase from Tiger, Arizona

by **John Sampson White** and **Joseph A. Nelen**
Department of Mineral Sciences
Smithsonian Institution
Washington, D.C. 20560

The U.S. National Museum of Natural History, Smithsonian Institution, was recently given, for identification, a wulfenite and fluorite specimen from Tiger, Arizona. The specimen contained several small cavities lined with black prismatic crystals less than 0.5 mm in length. The specimen was submitted by Brad Van Scriver of Garden Grove, California.

The result of X-raying the black mineral proved more puzzling than informative; the resulting pattern is that of the usually green mineral dioptase [$CuSiO_2(OH)_2$], but why is this sample black? A polished thin section was prepared for microprobe analysis, revealing pitch-black and uniformly opaque crystals. A preliminary qualitative analysis utilizing an electron microprobe, equipped with a non-dispersive detector, indicated major copper and silicon and traces of aluminum. To eliminate the possibility that the black color was caused by some form of finely dispersed carbon, one of the crystals was analyzed with a Leco 589-600 low-carbon analyzer. The results were negative at a detection limit of less than 0.2 percent.

Returning to the microprobe, the unknown was analyzed, along with two dioptase crystals from the Smithsonian collection (NMNH #R18586 from Guchab, Namibia, and NMNH #R3549 from the People's Rupublic of Congo). The standards used were fayalite for SiO_2 (Rockport, Massachusetts, NMNH #85276), cuprite for CuO (Bisbee, Arizona NMNH #48780) and hornblende for Al_2O_3 (Kakanui, New Zealand, NMNH #143965). Analyses were obtained with the electron beam (1) focused down to about 1 micron and (2) defocused to a larger radius of about 50 microns. Table 1 shows the results of these analyses. Table 2 contains analytical data for the three samples but, for the purpose of this table, the purer of the two green dioptase crystals (R3549) was used as the standard in refining the results for the other two samples, (R18586) and the unknown. All of the probe data have been corrected for background and further refined using a modified version of a MAGIC IV correction program. For comparison, the ideal composition of dioptase is also included in each table.

When the data in parts (1) and (2) of Table 1 are examined, it can be seen that the narrow-beam results (1) for the two known dioptase crystals are very similar to those obtained in the analysis of the unknown. The wide-beam results, (2), while basically the same for the two green dioptase crystals, are quite different from those produced by the unknown. These data invite several significant observations. First, fayalite and cuprite are poor standards to use in analyses of dioptase. Second, in spite of the inadequacy of the figures representing the total amounts of SiO_2 and CuO in Table 1, due to the use of fayalite and cuprite as standards, the Si/Cu ratios (atomic percent) of both green dioptases and the unknown are essentially the same. Finally, Table 1 shows that the narrow beam must have boiled off H_2O from the dioptase samples, while the analysis of the unknown was unaffected by the beam size. This conclusion is further supported by the production of little black dots on the surface of the green dioptase analyzed with the narrow beam, and the absence of such dots on the specimens analyzed with the wide beam.

Table 2, in which all figures are corrected against the dioptase standard, shows that both the SiO_2 and the CuO values for the unknown are increased, just as one would expect if the H_2O had been driven off from these crystals through heating.

As a final test of the effect of heating dioptase until water is lost, a sample of green dioptase (R18586) was heated in a test tube until it turned black. Condensed water was observed in the test tube. When X-rayed the heat-treated black dioptase produced a pattern identical to that of the unknown and nearly identical to that of unheated green dioptase. Some very minor and subtle variations in both the intensities and positions of a few minor lines in the patterns were observed. Weak lines in the positions of the two strongest lines of tenorite (CuO) are most certainly present.

***Table 1.* Analyses of Unknown and Dioptase using fayalite, cuprite and hornblende as standards.**

(1.) 1-micron beam	SiO_2	CuO	Al_2O_3	Si/Cu(At.%)
Ideal	38.1	50.5		
Unknown	44.0	48.2	0.5	1.21
R18586	42.3	47.1	0.1	1.19
R3549	43.3	49.3	0.1	1.16
(2.) 50-micron beam	**SiO_2**	**CuO**	**Al_2O_3**	**Si/Cu(At.%)**
Ideal	38.1	50.5		
Unknown	43.9	47.9	0.4	1.21
R18586	38.8	41.9	0.1	1.22
R3549	38.6	42.6	0.1	1.20

***Table 2.* Analyses of Unknown and Dioptase using Dioptase #R3549 as the standard. 50 micron beam**

	SiO_2	CuO	Al_2O_3	Si/Cu(At.%)
Ideal	38.1	50.5		
Unknown	42.5	55.5	0.5	1.02
R18586	37.7	49.0	0.1	1.02
R3549	37.8	50.6	0.1	0.99

The authors believe, therefore, that the black crystals of the unknown became black through heating (low red heat, about 700°C) of normal dioptase. Whether accidental (mine fire?) or intentional, we do not know. In the process water was driven off from the sample. Diffuse X-ray diffraction lines in the positions of the two strongest lines for tenorite (CuO) are present, suggesting that some tenorite was formed during heating and accounts for the black color. Associated minerals (wulfenite, mimetite, fluorite) are similar to those present on Tiger specimens in the Smithsonian collection; however, the wulfenite is paler in color, the mimetite is opaque instead of transparent, and the fluorite is chalky and opaque rather than transparent. These differences are additional evidence that the black dioptase specimen has undergone heating.

Arizona Index
to the Mineralogical Record, 1970-1983

INTRODUCTION

This cumulative index on subjects relating to Arizona covers the complete run of the *Mineralogical Record*, from vol. 1, no. 1 in 1970 through the present issue. For easy reference, pages in the various Arizona issues are preceded by the appropriate Roman numeral for that issue. These are:

Arizona-I May-June 1980 (vol. **11**, no. 3)
Arizona-II July-August 1980 (vol. **11**, no. 4)
Arizona-III (All-Bisbee issue) September-October 1981 (vol. **12**, no. 5)
Arizona-IV March-April 1983 (vol. **14**, no. 2)
Arizona-V September-October 1983 (vol. **14**, no. 5)

References to other issues are preceded by the volume number in bold-face type.

Mineral species references followed by a question mark (?) are in some doubt as to identification and/or locality. Mineral species page references given in parentheses indicate that the species is mentioned only on a table, and that looking it up will yield no additional information except possibly a literature reference.

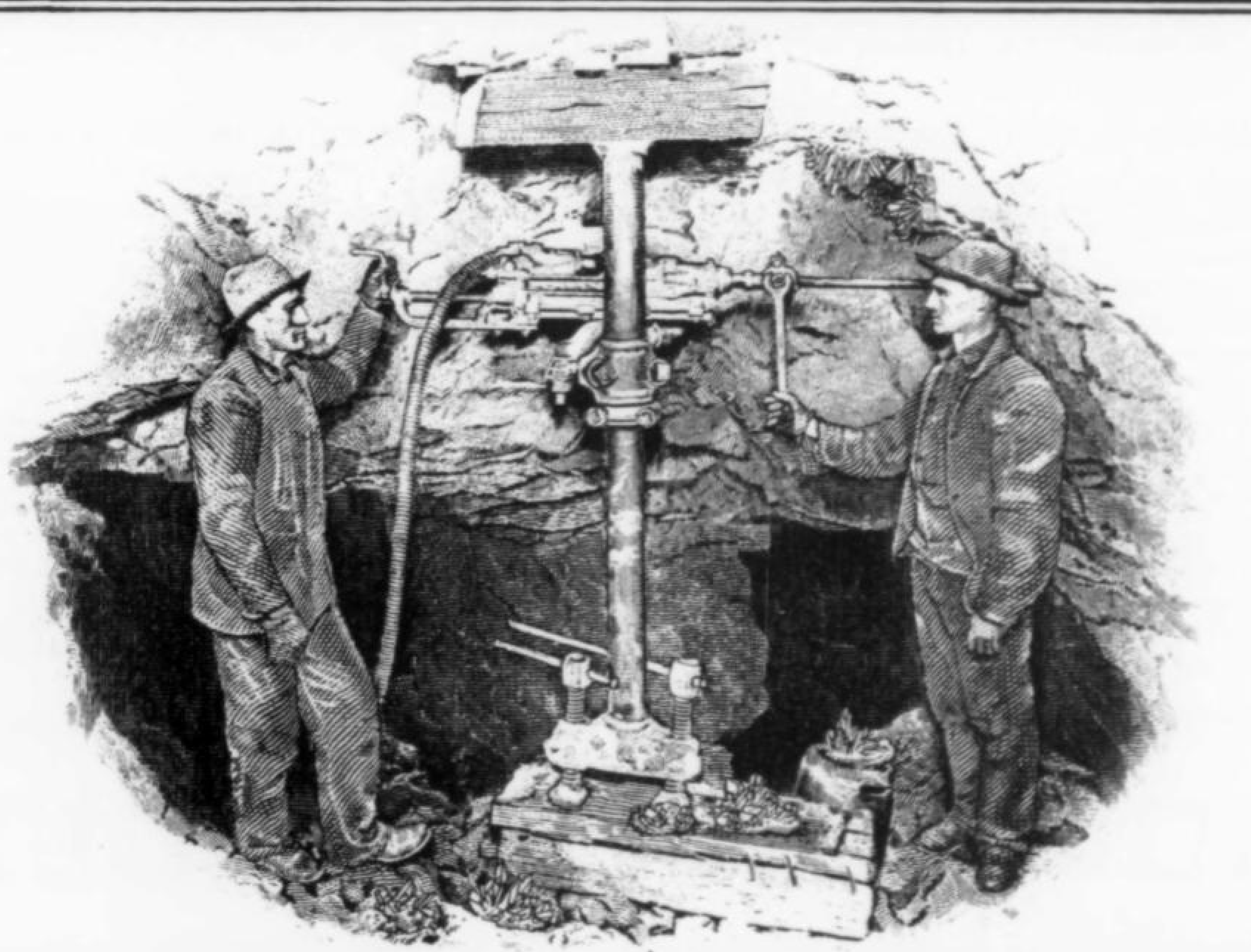
This index is not exhaustive; not every mention of a particular mine or species is listed. For example, only the most important discussions of species such as Red Cloud wulfenite are indexed, even though that species from that mine may be casually mentioned in many other places where little real information is given. Similarly, although the Copper Queen mine may be mentioned many times under various mineral species discussions, it is indexed only for the section describing the mine itself. Some species are indexed to a district (e.g., Bisbee, Courtland-Gleeson, Tombstone) and looking up that reference may yield further information on different occurrences within that district. However, an attempt *has* been made to be comprehensive with respect to indexing each locality mentioned at least once, and each mineral species from a given locality at least once. Note that the index is divided into four sections: Articles, Authors, Localities and Minerals. W.E.W.

Articles

Authors

Localities

Minerals



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