Bisbee!

ARIZONA - III

the Mineralogical Record

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ARIZONA
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INDEX MAP

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Volume Twelve, Number Five
September-October 1981

Arizona - III

famous mineral localities:

Bisbee, Arizona

by Richard W. Graeme

a special issue of the Mineralogical Record

Third in a series of four issues devoted to Arizona

COVER: AZURITE on malachite from Bisbee, about 6 inches tall. William Larson specimen; photo by Harold and Erica Van Pelt, Los Angeles.

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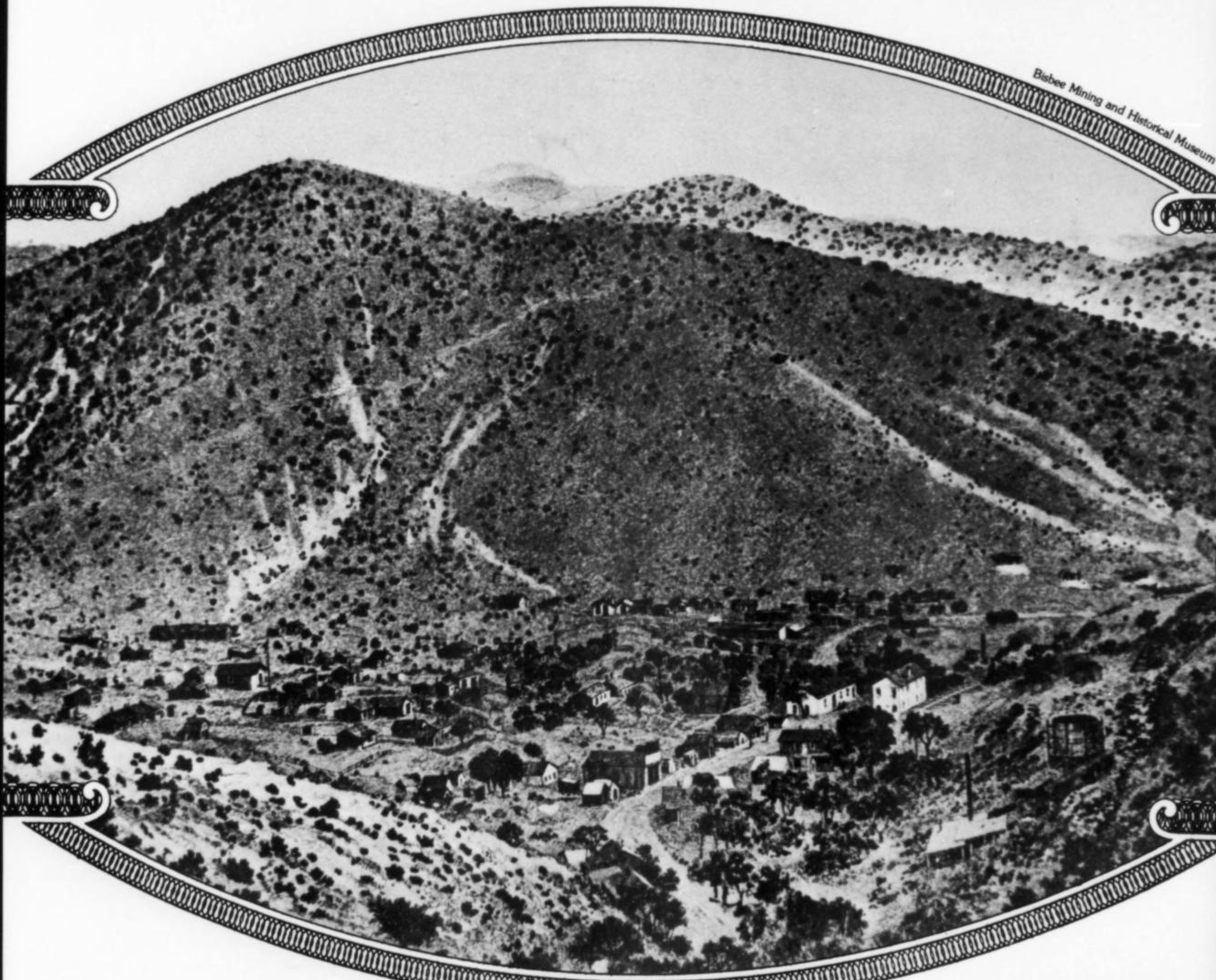

Early Bisbee

famous mineral localities:

Bisbee, Arizona

by **Richard W. Graeme**
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Bisbee, Arizona, ranks among the most famous and prolific of all American mineral localities. Vast numbers of exceptional specimens populate museums and private collections around the world. Though most famous for azurite, malachite and other copper minerals, Bisbee has produced more than 200 different mineral species since the first claim was filed over 100 years ago.

Introduction

Bisbee is located in the Warren mining district of Cochise County, Arizona. Situated in the Mule Mountains at an average elevation of 4950 feet, this picturesque community has grown up along the steep canyon walls. Once a city of 25,000 (Cox, 1938), it is today the home of some 8,000 people.

Typical of the basin and range province, the Mule Mountains rise about 3250 feet above the surrounding broad valley plains, achieving a maximum elevation of 7300 feet. This provides a very temperate environment with the summer temperatures seldom above 95°F while the winter minimums are infrequently below 25°F. Rainfall has an annual mean of 18 inches, most of which falls during July and August in brief but often violent thunderstorms.

The hills, once stripped of their growth, are now sparsely covered with oak and low brush grading into juniper and piñon pine with a few isolated stands of ponderosa pine at the higher elevations. Deer, javelina and game birds are common in the areas surrounding the town.

Active mining began late in 1877 and continued with only minor interruptions until mid-1975. During the last century, hundreds of millions of tons of ore and waste were removed from two open pits and nearly 2000 miles of underground workings. All of this was within a zone approximately 2 by 3 miles, with an overall depth of 4000 feet . . . roughly 4.6 cubic miles.

Copper was by far the most important metal; however, zinc, lead, silver, gold and manganese have all been economically significant. Indeed, Bisbee has produced more zinc, lead, silver and gold than any other district in Arizona.

Gold and silver production was not significant in the district until the early years of this century with the advent of electrolytic refining. Manganese was, for the most part, mined only during the two wars.

Metal production through 1975 is listed below for copper, zinc, lead, silver, gold (Stanley Keith, personal communication) and manganese (Mills, 1956).

Copper	Zinc	Lead
7.7 billion pounds	355 million pounds	324 million pounds
Silver	**Gold**	**Manganese**
100 million ounces	2.7 million ounces	10,989,900 pounds

The amount of copper produced, nearly 8 billion pounds, is difficult to imagine. It would form a cube of solid copper 241 feet on an edge, nearly the length of a football field. Copper is still being produced by leaching of the pit, dumps and underground mines. This should continue for many years.

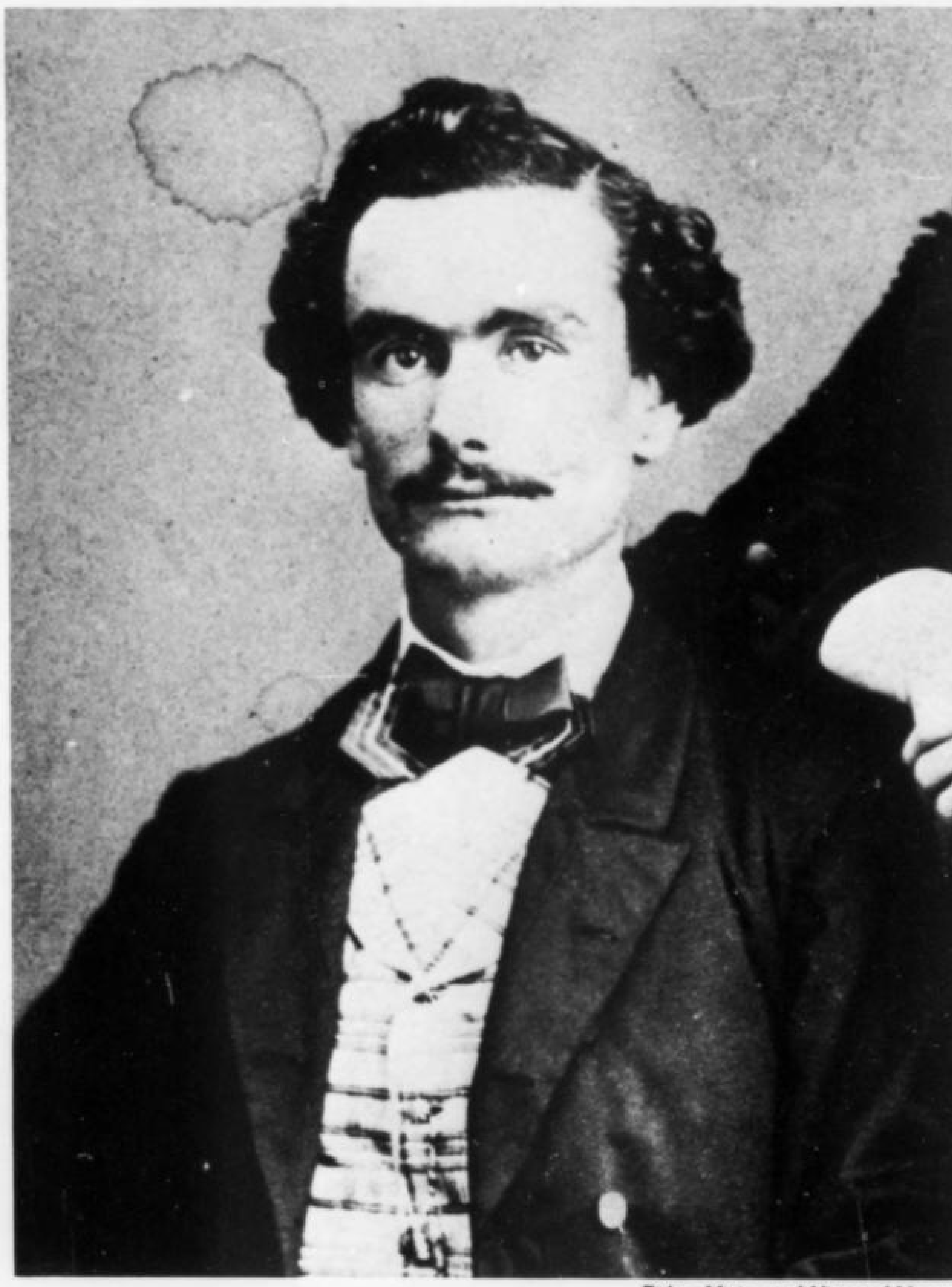
Ownership of all the important mines remains in the hands of Phelps Dodge Corporation. The workings and hills containing them are quite hazardous and therefore closed to all entry.

History

The settling of the many mining districts of the American West is filled with stories of men and women of exceptional courage and foresight; Bisbee is no exception. Perhaps even greater quantities of these rare virtues were required of those who chose the desert Southwest. An unforgiving land, it claimed more lives than all of the Indians and outlaws combined. The Mule Mountains and their main canyon, Mule Gulch, at least, were a bit more hospitable. Here was water and abundant game among the great oaks, willows and tangled wild grape vines lining the stream.

A search for water (and hostile Apaches) brought John Dunn and his party to this canyon. A member of a government scouting party from Camp Bowie, Dunn camped with his group at the first spring they found. The next day, the water being disagreeable, Dunn went further up the canyon until he found a fine spring near what is now known as Castle Rock.

Returning to his group along the rough, south side of Mule Gulch, he found a piece of cerussite float. He traced it to an outcrop at the base of a huge pinnacle of hematite, later known as the Iron Monster (Duncan, 1911). Along with Lieutenant J. A. Rucker and T. D. Bryne, Dunn located the first claim in the district on August 2, 1877, calling it the Rucker claim.



Bisbee Mining and Historical Museum

***Figure 1.* John Dunn, discoverer of the first ore near Bisbee in 1877.**

On the way back to Camp Bowie, Dunn met George Warren, a prospector. Dunn told him of his find and grubstaked him. Warren was supposed to locate as many claims as possible, naming Dunn in each. This agreement was never honored by Warren.

As a young boy, George Warren was wounded and captured by the Apaches when they killed his father. For 18 months, he remained their prisoner. Prospectors, upon seeing a white boy with the Indians, traded 15 pounds of sugar for him. Warren then stayed with the prospectors for some time, learning the "art" himself (Hart, 1926).

Many of the claims located in the district during the next six months had Warren as either the locator or a witness. In spite of his early work, George Warren, for whom the district is named, is better remembered for his folly. Legend has it that he lost his share in the Copper Queen mine in a foot race with a horse and rider over a short course . . . a loss that ultimately was worth more than $20,000,000 (Duncan, 1911). The remainder of his property was taken into "protective custody" by some unscrupulous associates.

Penniless, Warren went to Mexico and sold himself into peonage. Judge G. H. Berry, hearing of this, paid his debt and returned him to Bisbee in 1885. With a small pension from the mining company, George Warren spent the remainder of his life sweeping saloon floors and cleaning cuspidors in exchange for drinks of rotgut whiskey. He died in about 1895, disdained and soon forgotten (Hart, 1926).

The early years in Mule Gulch, as Bisbee was then known, were uncertain ones. The cerussite outcrop found by Dunn was very small and soon gone. A second and much larger prospect had been found in Hendricks Gulch, large enough to warrant building a small smelter, but this venture too ended in failure. Bisbee was struggling to survive.

The copper stain long known to exist on the Copper Queen claim had, to this point, been of little interest. Silver, often found mixed with lead, was the most sought after metal, not copper. Then, with just a little development, the rich ores that became so famous were uncovered.

In the spring of 1880, Edward Riley optioned the Copper Queen claim for $20,000. Having no money himself, he sold half interest in the mine for the same amount to Messieurs Martin and Ballard through the mining firm of Bisbee, Williams, and Company in San Francisco. With this action came the formation of the Copper Queen Mining Company.

Until then, the ore had been carried by 24-mule team wagons to the West Coast, then shipped to Wales for smelting. To eliminate this terrible expense a smelter was soon erected under the direction of Lewis Williams while his brother Ben took charge of the mining. Operations began in earnest and at a profit.

In June of 1881, D. W. James and W. E. Dodge, the principals of Phelps, Dodge, and Company, asked Dr. James Douglas to examine the Atlanta, a claim adjoining the Copper Queen mine. This claim had been offered to the company for $40,000. Douglas was chosen because he had previously been in Mule Gulch to visit the Copper Queen (Douglas, 1909).

Making the requested examination, Douglas emphatically recommended the purchase, but cautioned "that the risks were too great to be taken by a purchaser who was not able and prepared to lose all that he had invested," (Douglas, 1909). The risks were accepted. Thus entered an old established mercantile firm into mining, an entry that was to build one of the greatest copper companies in the world.

Douglas himself was placed in charge of exploration on the Atlanta claim. An anomaly in this rough, primitive camp, he was well educated, cultured, and sensitive to the needs of others. Though often monetarily poor, he was a man of exceptional integrity. When asked about his fee for examining the Atlanta and given the choice of cash or a share of the mine, he reflected, "the cash was greatly needed, but I told them that as I had advised them to take more than an average risk, I would share it with them. And on that sudden impulse and hasty decision depended my whole subsequent career—successful beyond anything I had ever dreamed of," (Langton, 1940).

For over 2 years Douglas searched and explored, sinking prospect holes on small bunches of ore wherever they could be found: two years of vexation and disappointment. Having spent $80,000 in these effects, James and Dodge were thoroughly disheartened—not a single car of ore had been produced.

It was now the spring of 1884, the neighboring Copper Queen orebody had suddenly pinched out and only 90 days of ore remained. All efforts at the Copper Queen to find an extension of the ore failed. Douglas still could not believe that only one orebody was here—surely others were nearby. So it was that James and Dodge, with much misgiving, committed a final $15,000 for a 400-foot shaft on James Douglas's faith. Douglas reflected, "John Prout and I selected the site where the shaft was to be sunk. But long before it reached the 400-foot level, the gloom which hung over both companies had been dissipated, for at 210 feet from the surface the shaft penetrated a very rich orebody, which was almost simultaneously entered by the level being driven east from the foot of the Copper Queen incline. The Atlanta shaft was sunk for 200 feet through ore," (Douglas, 1909).

After some months of negotiations, the terms of amalgamation were arrived at and, in 1885, the Copper Queen Consolidated Mining Company was formed (hereinafter referred to simply as the Copper Queen Company). This precluded, for the time being at least, the bitter litigation over ownership of the apex of the ore that was so common in many of the western mining camps.

Arizona Historical Society

Figure 2. **George Warren, itinerant prospector who filed many of the early claims in the mining district that was later named for him.**

During these years the camp, now called Bisbee after Judge DeWitt Bisbee of San Francisco (an investor in the mines and father-in-law to Ben Williams), had its problems. The threat of Indian attack was still very real. Often were the times when the mine whistle would sound the warning: Apaches had been sighted! Men would grab their rifles while the women and children sought safety in the Copper Queen mine (commonly just called "the Queen") where supplies of food and water were kept for such emergencies.

While the town itself was never attacked, many of the nearby ranches were. In June of 1885, Billy Daniels, a deputy sheriff of Bisbee, and several other men were ambushed at the mouth of Mule Gulch. Daniels was killed but the others escaped (Duncan, 1911).

The often savage acts by the Indians were no match for the heinous crimes the early citizens of Bisbee suffered at the hands of their own. From its first murder in August 1880 until the formation of a citizens vigilance committee for public safety, the "Forty-five-sixty" in March of 1891, nearly two dozen people were shot down. The "Bisbee Massacre" of December 8, 1883, was the most tragic of these crimes:

In hopes of getting the mine payroll, five masked men robbed the Goldwater and Castaneda store, where it was to be deposited upon arrival. While three men went into the store, the others remained outside guarding the street. Johnny Tappiner, a splendid young man, stepped unawares from the Bon Ton Saloon and was shot. Coming out of Joe May's saloon at the same time, a man named Howard was shot. Tom Smith, a deputy, immediately commanded that the shooting stop. He was shot twice and killed. Mrs. Annie Roberts, an expectant mother, was killed when the outlaws fired through the open doors of her restaurant. Running out of the Azurite Saloon, J. A. Nally was shot and so seriously wounded that he died within a few days (Duncan, 1911).

For all their violent actions, very little reward was to be had; the payroll had not yet arrived. Taking all they could find, $600 and a gold watch, they fled to the east. The stage with some $7000 in payroll money arrived less than an hour later.

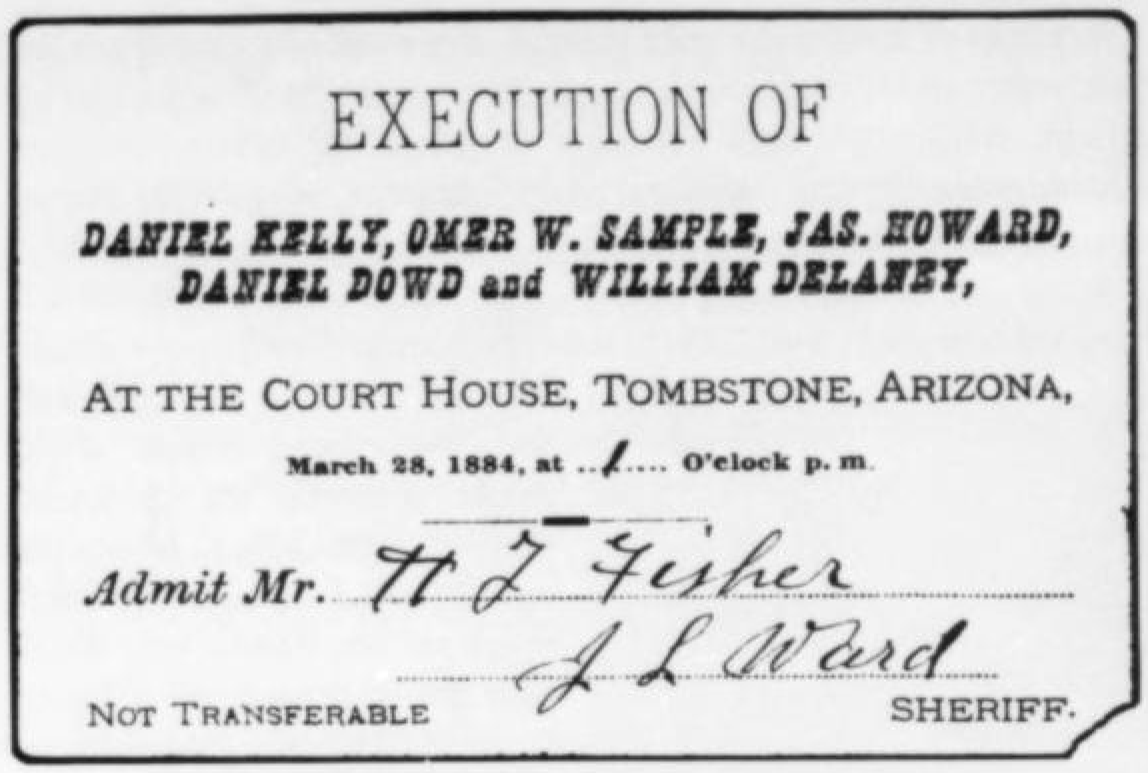
A posse was formed and the trail of the outlaws found. Just outside of Mule Gulch, one John Heath, an early volunteer to the group, tried to persuade Deputy Sheriff Billy Daniels that the bandits had turned north. Daniels, unconvinced, led the posse across the Sulphur Springs Valley to the Chiricahua Mountains, while Heath and another man went north.

The outlaws had returned to a prospector's cabin where just a few weeks earlier they had planned the crime. Dividing the loot, they then separated. Daniels, after a discussion with a prospector, was told the names of these desperados and learned that the man who masterminded the whole affair had not returned with them, his name—John Heath. Daniels sent word to arrest Heath and continued on in pursuit of the others.

The outrage that followed the crime united many people in the effort to capture the remaining five. Within a few weeks, their work was finished and all were confined in the Tombstone jail. One was captured in New Mexico; two near Clifton, Arizona; one in Chihuahua, Mexico; and the last in Sonora, Mexico.

All five of the outlaws were tried together, found guilty of first degree murder, and sentenced to be hung. Heath was tried separately, found guilty of second-degree murder, and sentenced to life imprisonment. This so angered the people of Bisbee that a group went to Tombstone, removed Heath from the custody of the Sheriff, and lynched him from a telegraph pole. To the end, Heath swore his innocence. The general acceptance of this action is shown by the coroner's jury verdict that: "We the undersigned, a jury of inquest, find that John Heath came to his death from emphysema of the lungs—a disease common in high altitudes—which might have been caused by strangulation, self-inflicted or otherwise," (Hankin, undated).

Arizona Historical Society



EXECUTION OF

DANIEL KELLY, OMER W. SAMPLE, JAS. HOWARD, DANIEL DOWD and WILLIAM DELANEY,

AT THE COURT HOUSE, TOMBSTONE, ARIZONA,

March 28, 1884, at ..1.... O'clock p. m.

Admit Mr. W J Fisher

J L Ward

NOT TRANSFERABLE SHERIFF.

Figure 3. **Invitation to a hanging. The men listed on the invitation had been convicted of murder in the "Bisbee Massacre" and sentenced to hang. Their ringleader, however, received a life sentence instead.**

Arizona Historical Society

Figure 4. **Incensed by the lack of a death sentence for John Heath, ringleader of a group the rest of whom were hung for murder, Bisbee townspeople formed a lynch mob and hung him from a telegraph pole. An inquest following his death found that his demise "might have been caused by strangulation, self-inflicted or otherwise."**

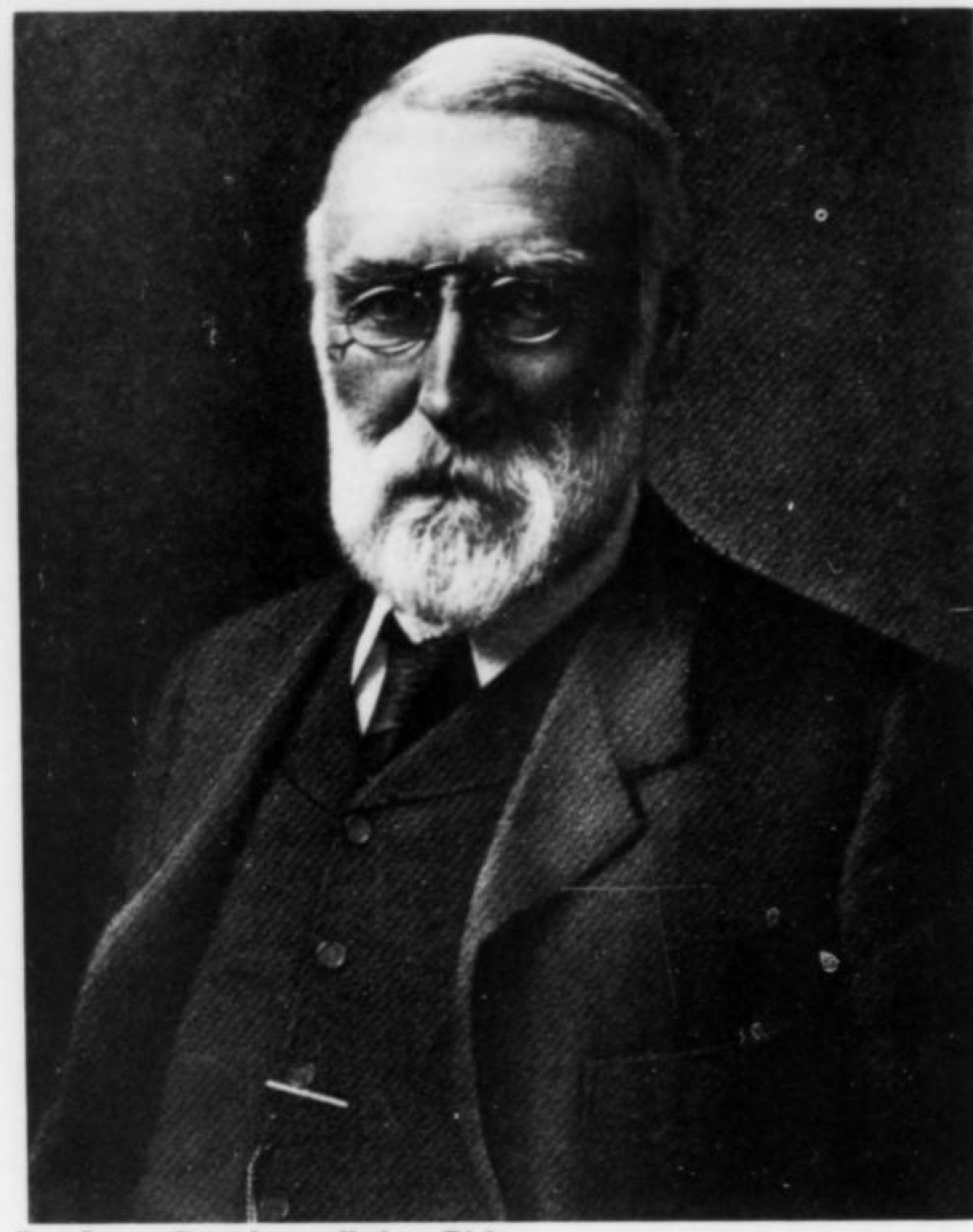


Figure 5. **Dr. James Douglas, called to Bisbee by Phelps, Dodge and Company in 1881 to consult on the possible purchase of the Atlanta claim. Douglas had previously worked at the famous Wheatley mine, Phoenixville, Pennsylvania. In lieu of a fee, Douglas accepted part interest in the Atlanta claim, and subsequently became a major influence in the progress of mining at Bisbee (from Langton, 1940).**

Bisbee Mining and Historical Museum

Figure 6. **Gambling was a favorite pastime in the saloon of Downs, Walsh and Whaley in Bisbee. The man at left is Tony Downs (great-great uncle of the author).**

Arizona Historical Society

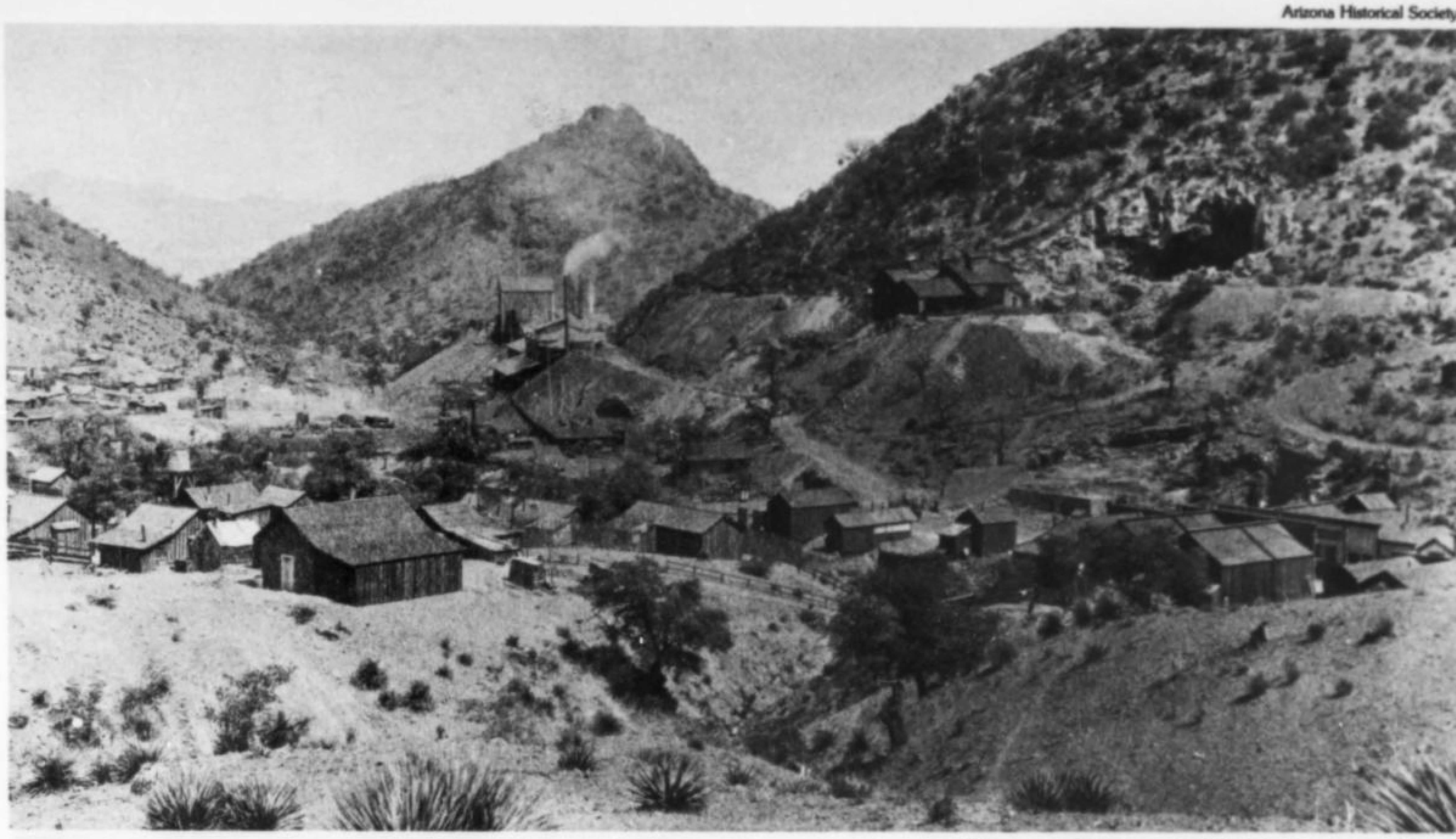


Figure 7. **Bisbee in 1887. The large opening at the right is the open cut of the Copper Queen mine, where Bisbee residents barricaded themselves when Apache Indian raids were threatened.**

Arizona Historical Society

Figure 8. **Brewery Gulch, Bisbee, in 1898. The stack of the Copper Queen smelter lays across the hillside in the distance.**

Another lynching by the citizens of Bisbee had an unusual and lasting effect. Hung for the killing of a defenseless man in the Can Can Restaurant over the affections of a woman, the body of the murderer was still dangling from a tree at the base of Castle Rock when a New York director of Phelps, Dodge, and Company came to see the mine. The director was horrified and convinced that such barbarism could only be the result of unenlightened minds. After returning to New York he sent books and a librarian to Bisbee. Thus Bisbee's library was started, in the hope of encouraging a more cultured, civilized community. Phelps Dodge continued to render this service for 90 years.

By the very early 80's, the ground for a great distance around the Queen had been located (claimed). However, besides the Copper Queen mine, only the Copper Prince had produced any ore to speak of, and even it closed before 1885 because of a depressed metal market.

The price of copper continued to fall and, by 1886, the metal from the Queen was selling for only eight cents a pound, down from 20 cents when the mine first opened. There was little profit in the 500,000 pounds a month the mine produced. At this same time, James and Dodge purchased those interests in the Queen held by Martin and Rielly, thereby achieving control of the mine. Not only did they have the courage to buy, but also to advance the company adequate funds with which to build a new smelter with a capacity of 1,000,000 pounds a month. The hope was that increased production would enable the Copper Queen Company to make a profit. For almost a year the mines were shut down until the new smelter became operational. Only some exploration work and de-watering were carried on at this time.

Even the new, more efficient plant was not the total answer. The need for cheap transportation was even more pressing. Finished copper from the smelter had to be transported out, and 10,000 tons of coke and more than a million board feet of timber for the mines needed to be brought in each month.

Late in 1887, Douglas called upon a Mr. Nickerson, then President of the Atchison, Topeka and Santa Fe Railroad, in hopes of bringing a railroad to Bisbee. Douglas was treated with supreme indifference. Only one course remained: the Copper Queen Company must build its own railroad.

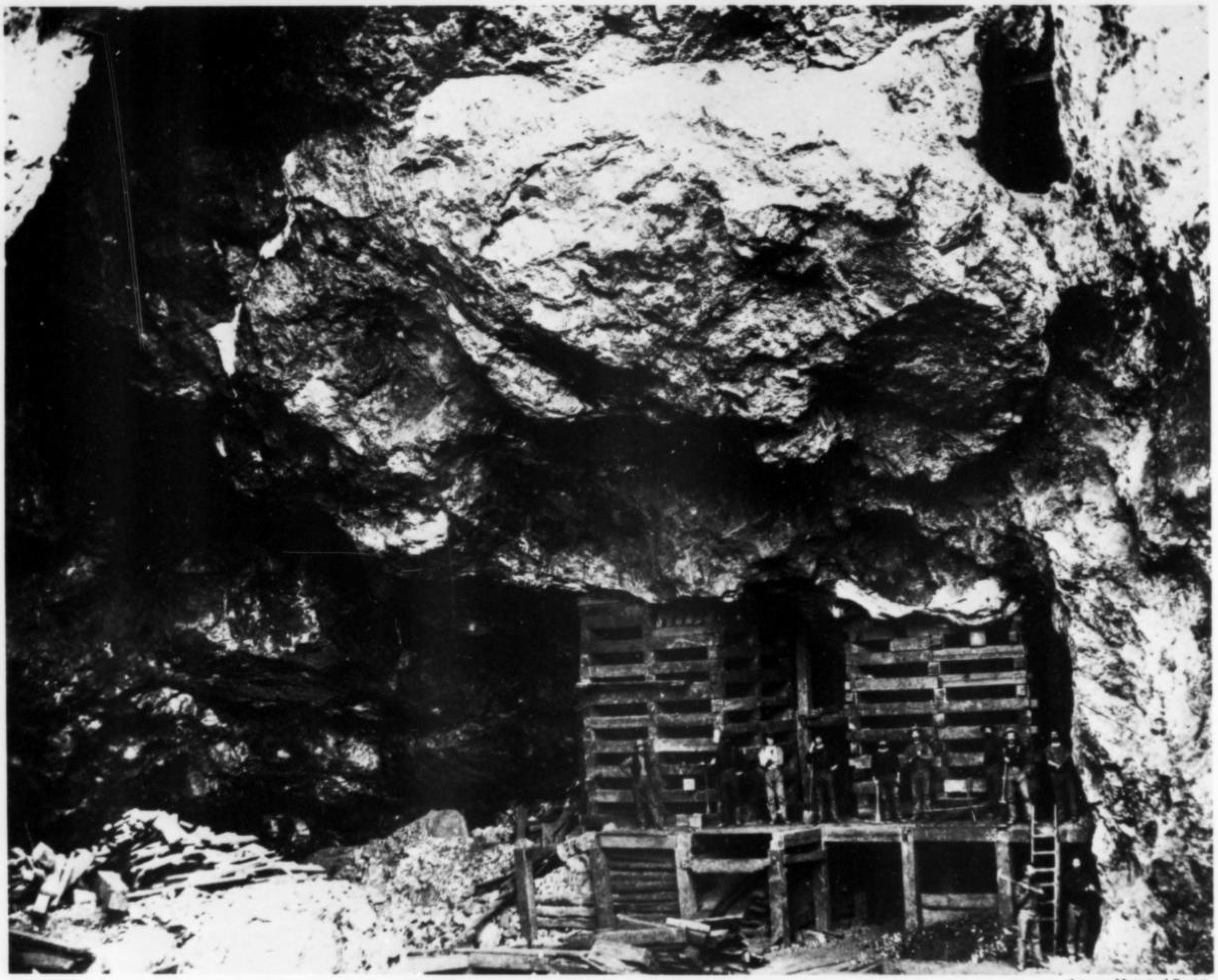


Figure 9. **The Copper Queen mine glory hole in the early 1880's.**

Before the close of 1888, the Arizona and Southeastern Railroad stretched from Fairbanks, Arizona, to the mouth of the Bisbee Canyon, some 40 miles. The cost of freight dropped from $6.00 per ton to about $1.00, a significant savings on the 100 tons handled each day (Douglas, 1909). A futher dispute with the Santa Fe over the remark "that it was not running its railroad for the benefit of the Copper Queen" pushed the A. & S.E. to Benson where it tied into the Southern Pacific Railroad (Myrick, 1975).

A legislated change in 1901 moved control of the road from the Copper Queen mining company to a holding company, the El Paso and Southwestern Railroad. True to its name, the railroad tied into El Paso, then to the Rock Island Line at Tucumcari, New Mexico, and finally to Tucson for a full 772-mile route (Myrick, 1975).

The El Paso and Southwestern Railroad came to a voluntary end in 1924 with a favorable merger with the Southern Pacific Railroad. The shareholders of the E.P. and S.W. received stocks and securities worth more than $60,000,000 (Myrick, 1975).

More than economics and transportation troubled Bisbee. With the growing population crowding into the narrow canyons came sickness and disease, the insidious offspring of poor sanitation. From 1888 to 1890, hundreds died from typhoid fever. Stricken miners lay on canvas cots in Brewery Gulch and along Main Street, their uneasy but brave partners fanning them to reduce their fevers (Cox, 1938).

It was several years before the source of contamination was found. One of the shallow wells was the cause of this disaster. Fortunately, one well in upper Brewery Gulch was found to be free of contamination. So for more than a dozen years the precious fluid was sold house to house, carried on the backs of burros in canvas bags, and priced at 5¢ a gallon. Shortly after the turn of the century, water was pumped to the camp from a fine well field about 9 miles away at Naco, Arizona. The city, to this day, is served by this same system.

The hills, once covered with oak, juniper and manzanita, were stripped to feed the fires of industry and home. With each summer, came heavy rains and floods. Gone was the vegetation that once held the water in check. The sudden torrential flows of water carried everything in its path in the narrow canyon bottoms. Many lives were lost before a subway was built to channel the angry waters.

In 1892, James Douglas and his son Walter went to Europe to investigate the Mankes-Bessemer smelting process. So impressed with the principle was he that immediately upon his return he had one designed for the Copper Queen Company. By 1894, after a number of modifications, Douglas had perfected a method of smelting sulfides that forever changed the way these difficult ores were handled. To a large degree, this method is still basically the one by which most of the world's copper is smelted.

Bisbee Mining and Historical Museum

Figure 10. **Surface fissures formed by subsidence due to the oxidation and later mining of copper deposits below, in the Copper Queen mine.**

After the change in techniques, copper production doubled in two years and by 1899 more than 3,000,000 pounds per month were being produced. Unfortunately though, the crowded conditions at the smelter site next to the Czar shaft precluded any expansion.

A new smelter was a must; the flow of ore from the Copper Queen mines seemed limitless and quite able to support a new facility. The principal owners of the Copper Queen mine had also acquired the mines near Nacozari, some 70 miles south of the Mexican border. Therefore, the logical place for a new smelter was where it would handle the ore from both mines. A site in the lower end of the Sulphur Springs Valley, right on the Mexican border was selected. Here was limitless water and space. A townsite was laid out to support the new facility and it was appropriately named Douglas in honor of the man who had so ably led the Copper Queen Company for 20 years. The new works had a capacity of 10,000,000 pounds per month and cost $2,500,000 to build (Douglas, 1909). Late in 1903 it was blown in, and the old Bisbee facility was completely scrapped.

While Dr. Douglas had always been a proponent of an aggressive acquisition policy in the district, there was one opportunity that was lost, though under peculiar circumstances. The Irish Mag claim, named for a woman of the red-light district in upper Brewery Gulch, lay far to the east of any known ore and was generally considered to be of little value. A group of eight other claims and the Irish Mag were owned by a miner named Daly. Evidently of unsound mind, he had threatened the life of Ben Williams and told Douglas that he had been hired by a group of conspirators to kill him. Shortly afterwards, Daly offered his claims to Douglas for $10,000, a proposal which Douglas was anxious to accept. Williams, however, thought it would look like they had succumbed to blackmail and threatened to resign if the purchase was made; so it was declined.

Soon afterwards, in April of 1890, Daly shot and killed W. W. Lowther, a deputy sheriff who was trying to arrest him for assault. The last seen of Daly was when he fled up the side of Sacramento Hill (Douglas, 1913).

As Daly was a fugitive, there was little chance that he would return to claim his property, so a host of claimants suddenly appeared including a "wife" and "son." Daly's common-law Mexican wife, Angela Diaz, had advanced him money to do assessment work; for this reason title was vested by the Supreme Court of the United States to her in 1899. During the long legal battle, she had

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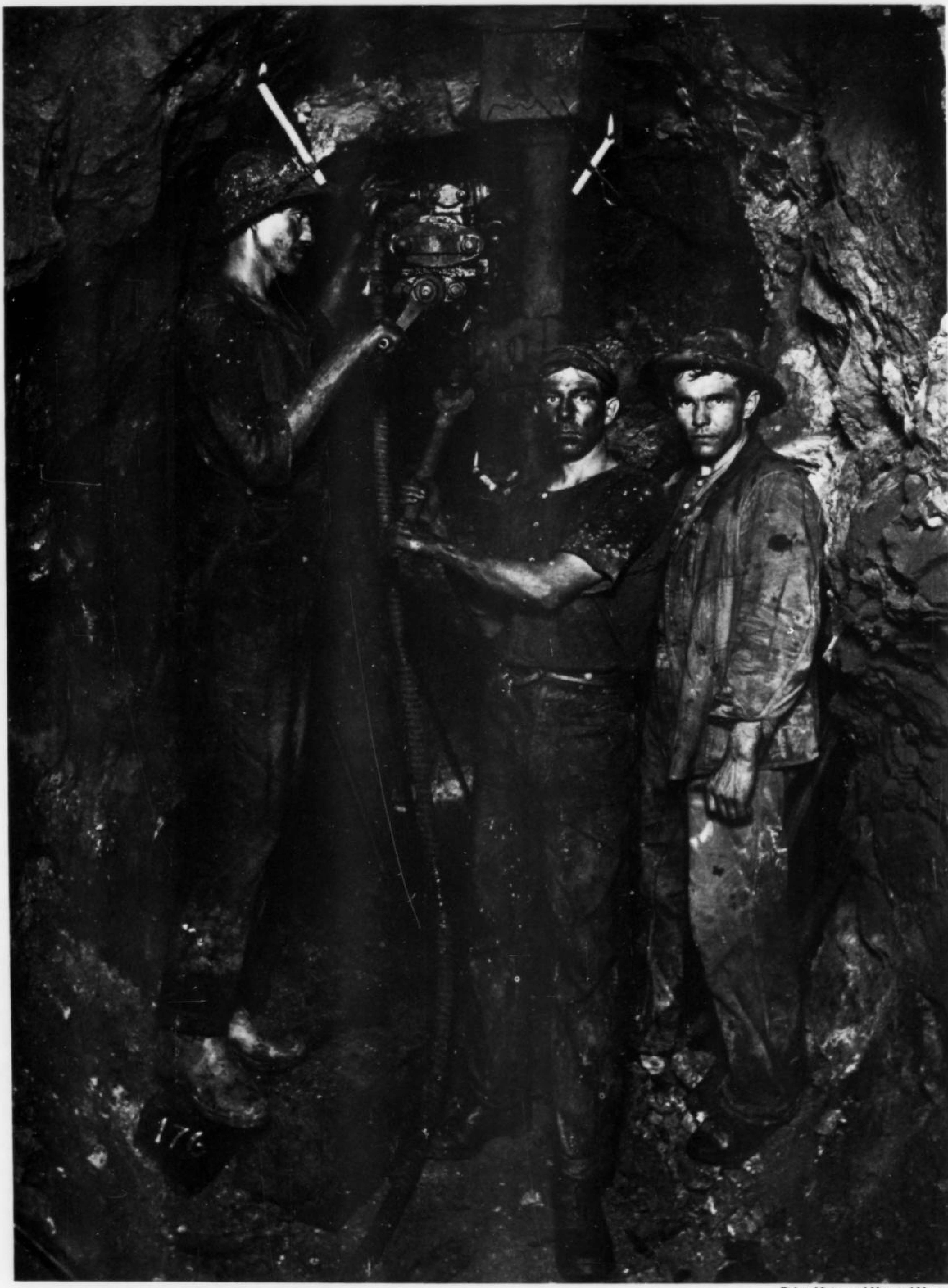
Figure 11. **Ore teams of Jimmy Carr, returning to Bisbee with a load of coke. Early 1880's.**



Bisbee Mining and Historical Museum

Figure 12. **Drilling holes underground around 1905. Note candleholders.**

sold her interest to Martin Costello, a Tombstone saloon keeper, for $1,800 (Cox, 1938). After the favorable decision, Costello sold the property for $500,000 to the Lake Superior and Western Development Company.

Long before the legal battle was over for the "Mag's" ownership, the potential value of Daly's claims became well known. Development on the 800 level of the Spray shaft had found fine orebodies near the Irish Mag sideline. Captain Jim Hoatson came to the district looking for a good property to purchase on behalf of the Lake Superior and Western Development Company. Nothing looked as good to him as the barren, hard limestone knob called "Mag Hill."

In the Calumet, Michigan, area, everyone knew Cap'n Jim and respected his knowledge, so before long he had the money to buy the claim and sink the needed shaft. But for all his knowledge, Hoatson failed to realize just how deep the ores really were, and that it would cost much more to mine the Arizona limestones than it did the rocks in Calumet. On the ragged edge of bankruptcy, Cap'n Jim went back for more money, money to sink just a little deeper, where the ores must surely lie. So it was, on the faith of an uneducated miner, that some of the great names in the steel and iron business invested many thousands more. Their confidence in Jim was rewarded. After finding small bunches of ore on the 850 and 950 levels and building a modest smelter, a fabulous orebody was cut on the 1050 level in 1902 by the Northeast drift (C. & A., 1916). Before the story of the Irish Mag was finished, nearly $10,000,000 in dividends were paid from the 15 acres that made up the claim.

The Calumet and Arizona Mining Company absorbed the Lake Superior and Western Mining Company and set about to develop its vast holdings of favorable ground. It could all have been for naught save for the wisdom and absolute honesty of James Douglas and the partners of Phelps, Dodge and Company.

The law of the apex had been firmly established in the west by the famous Eureka and Richmond ruling. This law, simply put, means that whoever owns the apex of a continuous vein, lode, or formation, has the right to claim ownership of all ores on its dip, even if the vein passes under other claims at depth. There is little doubt that the Copper Queen Company could have claimed for its own all of the ore found by C. & A. and been upheld in court. This would, of course, have been allowed only after bitter litigation at enormous expense. But Douglas said, "We must decide which industry is to prosper here—that of mining or that of lawyers" (Langton, 1940).

So the common boundary law was mutually agreed upon and Bisbee was spared the grief and hatred that so scarred many other districts. Along with the agreement, free access to each other's mines was granted so that the discoveries of one could help the other. Thus began the cooperation between companies and their respective engineers which was heretofore, unknown. Those in the profession today are still reaping the benefits of the shared technical progress that this spirit has brought to the industry. Perhaps this is the greatest contribution Dr. James Douglas made.

Once the future of the Calumet and Arizona Company had been assured by the riches that flowed from its mines, Tom Cole, its president, set out to buy all the ground he possibly could. Douglas, not to be outdone, paid a fortune for property he could have had for a trifle just a few years earlier. In the ensuing scramble, absolutely undeveloped ground went for as much as $40,000 an acre. Stakes were high in this copper game; even after purchase, hundreds of thousands of dollars had to be spent sinking a shaft of up to 2000 feet before the value (or lack of) could be determined.

With no more land to buy, the mining companies set about building the fortunes of their investors. They also spent large amounts building the community and developing safer working places until the camp had no parallel.

To this point, Bisbee had been singularly free of labor troubles, due principally to the efforts of the mining companies to provide a safe work environment, a pleasant community to live in, and wages comparable to what miners elsewhere were receiving. But in early 1917, just 2½ months after America's entry into World War I, a group known as the "Industrial Workers of the World" called a strike in Bisbee without a vote of the miners. Under threat and intimidation, by the third day about 80 percent of the 4,500 men employed underground were staying off the job (Loyalty League of America, 1917). However, members of the mechanical trades never gave any support to the agitators from the I.W.W., and within a few weeks half of the men were back at work underground. But the "Wobblies," as they were called, persisted in their efforts to stop the mines with increased amounts of harrassment. At this same time, most of the other mines in Arizona and Butte, Montana, had also been closed by this group.

With the vital war requirements of the red metal threatened by the effects of the strikes, it was obvious that nothing short of drastic action would end the work stoppage. Convinced that a strike in a time of unprecedented national crisis could only be directed and supported by people of treasonable inclinations, a deportation plan was conceived. Secretly, 2,000 men from every profession in the camp gathered before dawn on July 12, 1917, to begin what they truly saw as their patriotic duty. At the same time, the telephone exchange and Western Union were occupied by interests favorable to the "Loyalty League," as the group called itself. The morning edition of the *Bisbee Daily Reivew* delivered to all homes in the pre-dawn hours, warned that women and children should stay off the street that day.

From house to house, combing every street and alley, the armed and deputized forces of the "Loyalty League of America" swept the whole camp. Every known striker, agitator, or sympathizer was removed and marched to the Warren Ball Park. Here a court questioned each man: "Are you working? Do you want to work? Who can vouch for you?" A great many answered the questions appropriately and were released. However, 1186 men were detained, loaded into cattle cars, and taken to a siding near Columbus, New Mexico. They were left with the warning that, should any return to Bisbee, they would most certainly be killed. The strikers were then abandoned by their guards.

For almost a month, the "Loyalty League" controlled the town until it was completely purged of the anarchistic "Wobblies." There was then and is now little doubt that what was done was for the best: a truly patriotic act. A subsequent investigation ordered by President Woodrow Wilson and conducted by Felix Frankfurter found no federal offense, while the Supreme Court of the United States determined that the participants had acted to enforce "the law of necessity."

During the post-WWI years, Bisbee continued to hold its position as the greatest of copper camps. This was helped by the development of the Sacramento pit. One of the earliest open pits in the world, it produced for most of the 1920's.

The great depression found the two main companies in markedly different positions. The Copper Queen Company, now known as Phelps Dodge Corporation, after mining for some 45 years, had nearly depleted its reserves and had less than one year's-worth of ore left. However, because of its high standard of operating efficiency it was in a very good cash position. On the other hand, the Calumet and Arizona Company had incredible reserves; the Campbell orebody was just being delineated. But because of a too-liberal dividend policy, insufficient funds were available to carry them through this difficult time.

A merger between the two great companies was effected in 1931, with Phelps Dodge Corporation the survivor. Even though copper hit price levels as low as those of the late 1880's, the richness of the

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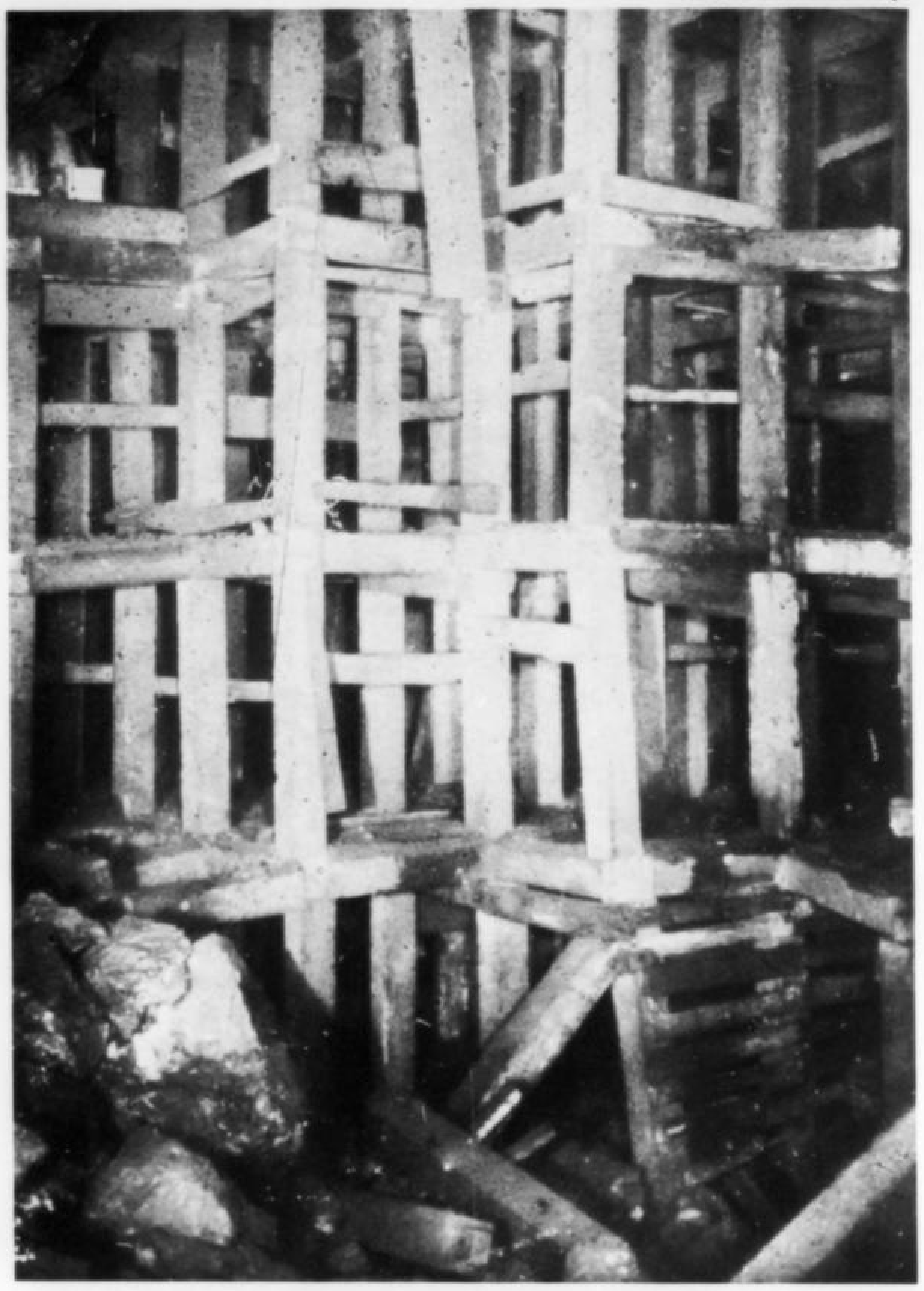


Figure 13. **Square-set timbering in the southwest stope of the Copper Queen mine.**

sulfide bodies in the Junction and Campbell mines kept the camp alive.

By the late 1900's, production was again up to pre-Depression levels. Lessees who had played a significant role in production since 1912 were producing as never before. Several years after the merger, Phelps Dodge leased much of the remaining tonnage in the mines that they themselves had operated for so long. Areas in the Southwest, Czar, Holbrook, and other mines were being exploited by low-overhead lease operations, often at a very handsome profit.

When World War II's need for copper arose, Bisbee was prepared. Though the mines were already operating at near capacity, contracts were entered into with the government on the "Metals Reserve Account" to augment production by mining lower grade ores. Manpower shortages were partially alleviated when several hundred soldiers with mining experience were assigned to work in Bisbee.

With the end of the War, came a sharp drop in copper demand. Lead and zinc ores had often been exploited during the life of the district, but now they became the life's blood of the camp. While important amounts of copper were recovered (some 123,500,000 pounds from 1945 through 1950), it was the rich lead-zinc orebodies in the Junction, Campbell, and the newly-acquired Denn that made the profit. During this time, 1,152,000 tons of mixed ores were mined yielding 105,400,000 pounds of lead and 235,000,000 pounds of zinc (Mills, 1958).

The last significant mining development in the district was the Lavender pit. Stripping started in April of 1951, but it was not until July, 1954, that any ore was shipped to the concentrator. The pit, which was closed in December of 1974, is still a source of copper. Water is continually sprayed into the pit and collected in the nearby Junction shaft for use in a leach operation, a process that will continue to provide copper for many years.

Soon after production from the Lavender pit ended, all operations stopped. The end to this truly great mining camp came in mid-1975 when the underground workings were closed. After nearly a century of providing mankind with one of its most essential elements, Bisbee fell, an early victim to problems never before encountered by the industry. The regulatory zeal that swept the country adding cost after cost, killed her. And too, the flow of cheap copper from half a dozen other countries was also responsible.

But what of Bisbee's future? Hundreds of millions of pounds of copper are still in the ground, as are lesser amounts of lead, zinc, and other metals. Whether they will be mined is doubtful, at least under today's conditions. However, leaching has long been an important aspect of the Bisbee operation. Now this clean, efficient, but painfully slow hydrometallurgical process is still recovering important amounts of copper from the Lavender pit, the dumps, and the underground mines. How long this will continue to be economic is anyone's guess, but perhaps it will last for many years.

Bisbee today remains the quiet picture of a small town, lost in time. Those colorful memories of days gone by hover among the winding streets. Lingering shadows of past mines creep up the steep hillsides, and nature carefully disguises her secrets of what might remain.

With Bisbee's new approach, catering to tourism and retirees, its survival seems assured, but only after near Herculean efforts by many of the residents. The most impressive fruit of their labor and cooperation is the "Queen Mine Tour." Winding through these tunnels and stopes, one quickly becomes part of the exhilarating environment the early miners once experienced. So it seems that Bisbee remains determined to continue activity in the subterranean world of Queen Hill, where more than a century ago the legend began.

Mining Methods

The ores and their host rocks in the Warren mining district were remarkably variable in character. To a large degree, this was a function of supergene action; rocks which had undergone more oxidation were softer. In some areas, notably those near the Czar and Holbrook mines, the rocks were so soft and plastic that they defied all attempts to mine them underground.

For the softest ores that could be mined, a technique developed in England called "top slicing" was used (Hodgson 1914). Starting at the top of the ore, a horizontal slice was mined and heavily timbered. Once all the ore was recovered from this slice, the timber would be blasted, causing the area to cave in. Then a second slice below the tangled mat of timber would be taken, and the new timber blasted again. The resulting timber mat was usually strong enough to support the increasing weight as mining progressed downward. One distinct disadvantage of this method is that the country above is badly broken. So it must first be ascertained that no ore is above such a stope.

The vast majority of mining was done using what is known as the "square set" method. It was continually used from 1881 until the mines closed in 1975. This name was derived from the configuration of the timber. As each 6 x 6 x 8-foot block was mined, a rectilinear set of timber was installed to support the opening. After a predetermined number of sets had been mined, the stope would be gobbed (backfilled with waste rock) for additional support.

Many of the primary sulfide ore bodies were very competent, and could be mined with considerably less timber, perhaps even none. Cut and fill mining was important in the extraction of such ores from 1916 (Wilson, 1916) through mid-1975. Here, the usual approach was to start at the bottom of the ore and remove as much as conditions would allow, then gob the hole and start over on top of the fill.

Shrinkage mining was only of limited value in Bisbee because of the generally irregular shape of the ore bodies. But when used a considerable savings in labor and timber was experienced. With this method, the ore would be broken, but only part of it removed, so that the remaining material would serve as a floor for mining. Once all the ore had been blasted, the stope would be emptied and usually gobbed.

Block-caving is an approach whereby a large block of ground is developed with numerous raises and closely spaced parallel drifts. Then, using large amounts of explosives, the entire block is shattered. The many raises funnel the broken ore down from the block. This technique is successful only under a limited set of circumstances; most important are homogeneity of both the rock and ore grade. The porphyry of Sacramento Hill met these criteria and was mined by this method with limited success.

Mining Equipment

A full cycle in mining consists of drilling, blasting, mucking, timbering, and (in drifts) advancing track and pipelines. The evolution of the equipment used to perform these steps is in itself an interesting story.

Drilling blastholes in the workings was originally done by handsteel. This involved using chisel-bit steel bars of varying lengths, starting with the shortest, and a hammer. A one-man set-up involved using a single jack (4-pound hammer) and drilling a short hole. Most drilling, however, involved two men and a double jack (8-pound hammer), usually drilling a 6-foot hole.

Handsteel drilling was a very popular competition in all of the western mining camps. Intercamp competition soon developed, with granite from Gunnison, Colorado, as the standard medium. On the 4th of July, 1903, the world's record of 38⅜ inches in 12 minutes was set in Bisbee by a two-man team from the Copper Queen Company (Cox, 1938).

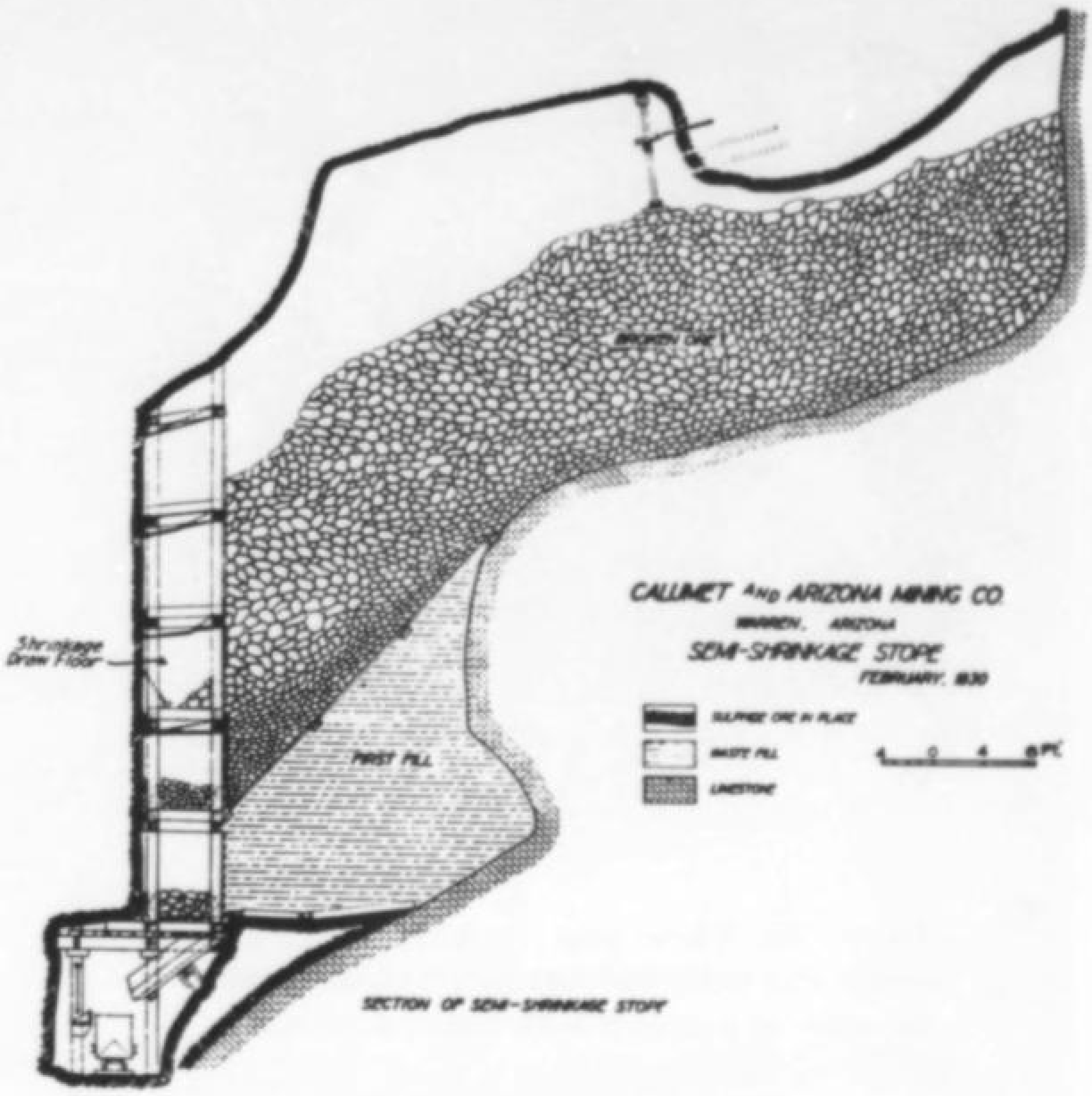


Figure 14. **Construction of a semi-shrinkage stop (Lavender, 1930).**

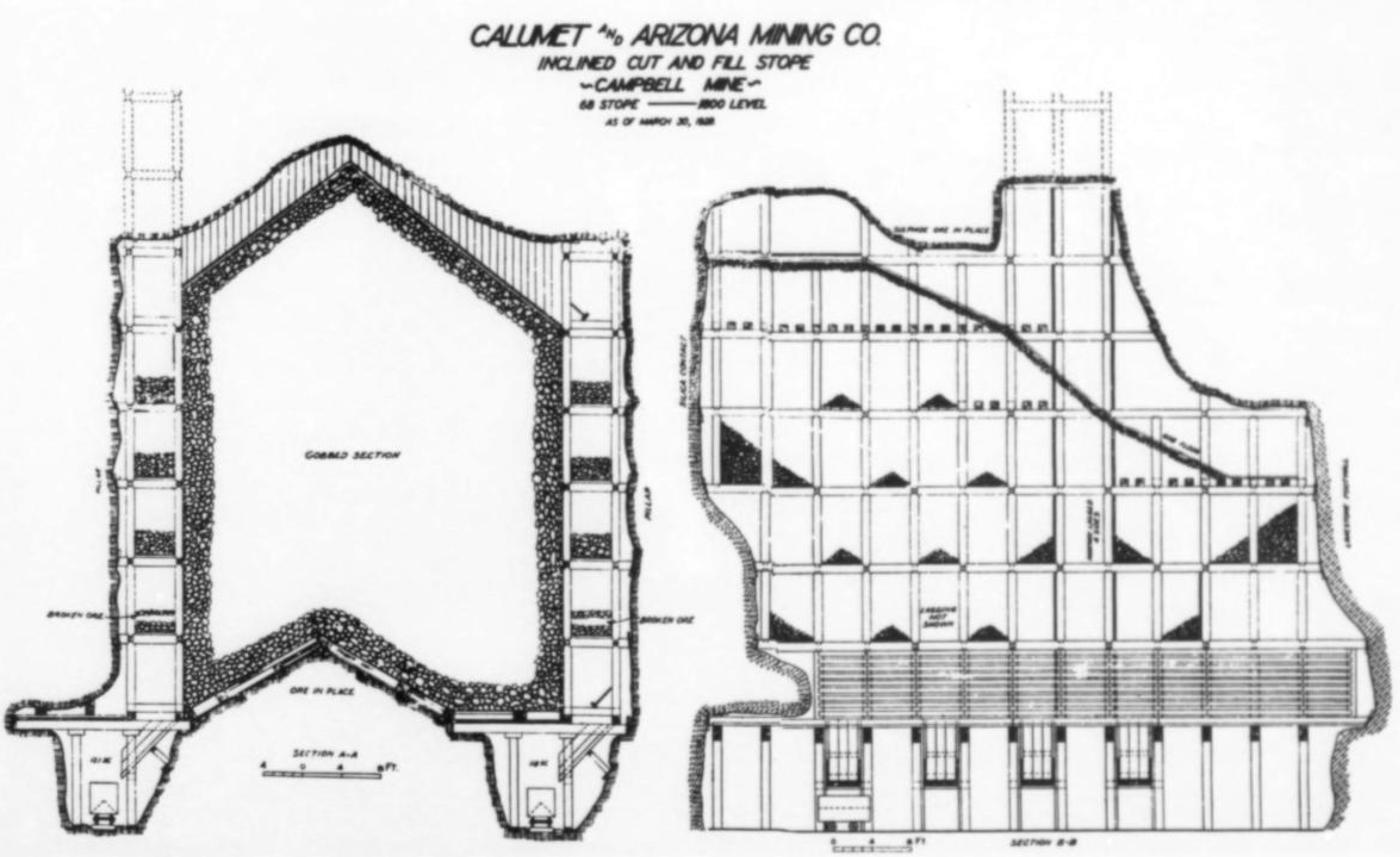


Figure 15. **Timbering scheme used in the Campbell mine. The square sets are tightened with wedges. (Lavender, 1930).**

***Figure 16.* Three men double-jacking. The center man holds and turns the drill steel while the other two strike it with 8-pound hammers.**

The first pneumatic drills were introduced in 1905. While cumbersome by today's standards, they completely replaced handsteel by 1908.

Blasting in the underground changed very little for many years. Dynamite and fire fuses were used until the mid-1960's when a pneumatically loaded ammonium nitrate and fuel oil mixture came into use.

Mucking, or the moving of broken rock, was done totally by hand before 1933. The ore was manually shoveled into half-ton mine cars. In stopes these were trammed (pushed) by hand to a central raise and dumped for transfer to haulage cars on the level below. In small or irregular stopes wheelbarrows were in common use.

These time and labor intensive techniques were replaced by slushers. A slusher is a two-drum (or more) winch arrangement that pulls a bucket-like rake back and forth over the muck pile, carrying small amounts to wherever needed, usually a raise. A few years before closing, several small, rubber-tired, front-end loaders were used in some of the larger stopes.

The transition from hand to mechanical mucking in the tunnels and drifts occurred in 1934 (Mills, 1958). Pneumatic loaders were introduced that traveled on rails and would literally throw the rock into a coupled mine-car.

Prior to 1907, all movement of the mine-cars, both loaded and empty, was by hand; then mules were brought into the mines (Mills, 1958). While a man could only tram a single car, a mule could pull five. Often treated like pets, these animals were well cared for. Each level had a "mule barn" in a dry, well-ventilated area.

Electric trolley haulage was introduced in 1908; however, it was not until 1930 that the mules were totally displaced. From then on trolley and storage battery locomotives (or motors, as they were called) moved all rock and supplies.

Electric lights were put in all of the main haulage drifts in 1907, but personnel lighting was by candle as it had been for 30 years. The holders for these candles were commonly works of art in themselves. Consisting of a spike, a hook, a handle, and a candle-holding loop, they were usually forged from a single piece of steel. The thumb-tab for loosening the grip of the candle-loop came in various designs; birds and animals were common motifs, but the

***Figure 17.* Mules such as this one in the Czar mine, 1908, pulled ore cars at Bisbee for many years.**

Bisbee Mining and Historical Museum

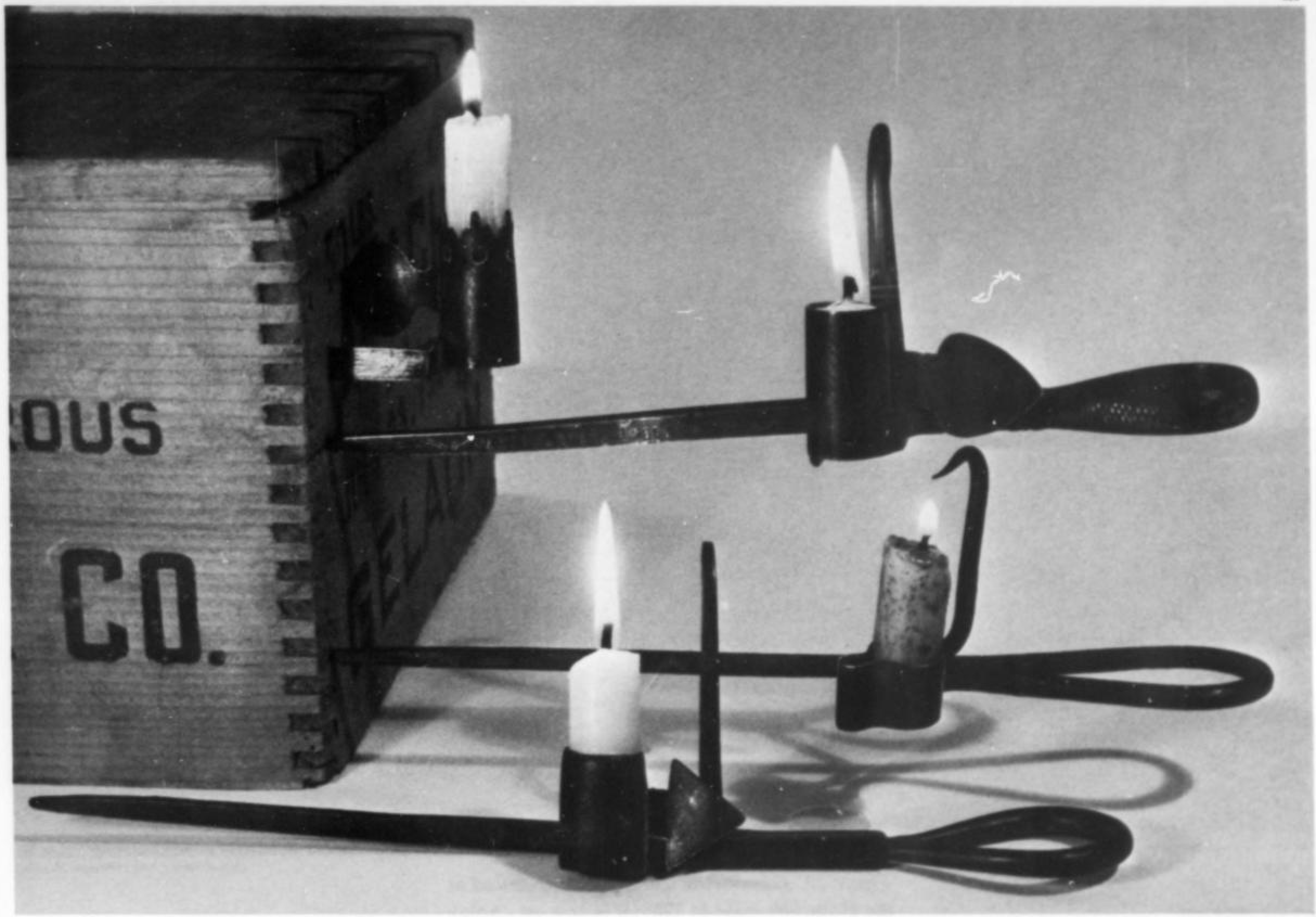


Figure 18. **Miners' candleholders used at Bisbee. The small one was found in the attic of a mining family in Bisbee; old-timers questioned about it confirmed that such small holders were used, either stuck in a notch in the cap or into a timber (Melvin Elkins collection). The Varney-style candleholder (center) was made for the Copper Queen Consolidated Mining Company by a local blacksmith, and bears the initials "C.Q.C.M.CO." (R. Graeme collection). The upper holder is inscribed "L.M. BARBAROS. BISBEE. ARIZ. 1905." and was probably a presentation item to honor a miner (Richard Hauck collection). The holder with the triangular thumb-tab (bottom) is marked "D.E. DAVES," who was a Cornish "cousin jack" miner in Bisbee (Wendell Wilson collection).**

Figure 19. **A mint-condition example of the famous Copper Queen carbide lamp. When the Justrite Manufacturing Company in Chicago received an order for several hundred lamps in 1912, they removed the usual name "Little Giant" from their cast aluminum lamp and replaced it with "Copper Queen" for the Copper Queen Consolidated Mining Company. (Nancy Van Scriver collection.)**

Bisbee Mining and Historical Museum

Figure 20. **This electric trolley was introduced at the Holbrook mine in 1909; it is now on display in front of the Bisbee Mining and Historical Museum.**

most popular was a well-shaped woman's leg, complete with bloomers and shoe.

The use of candles began to fade in 1911 when carbide lamps appeared. Late in 1912, the Copper Queen Company ordered several hundred large, cast aluminum lamps from the Justrite Manufacturing Company, each of which had "Copper Queen" embossed on its side. These make interesting collectors' items today. However, it was not until 1916 that the transition to carbides was complete.

Miners were responsible for purchasing their own lamps and seemed to prefer brass to the cast aluminum type. Two styles of brass lights were in general use: a small cap lamp that would last 2 hours before recharge, and the larger stope lamp that was made to hang from timber on the wall. The latter would usually burn for about 4 hours before refilling was necessary.

Electric cap lamps were first introduced in Bisbee at the Junction and Campbell divisions in 1938 (Mills, 1958). Here again, it took a number of years for one lighting method to replace another. While these lamps were provided by the company, it was not until late in 1944 that all of the miners were using the Edison lamps.

Mines

During the years that Bisbee sent forth its impressive flow of fine minerals, more than 30 separate mines were involved. A great many specimens are improperly labeled as far as actual locality is concerned. Undoubtedly, the majority of those labeled "Copper Queen mine" or "Calumet and Arizona mine" are actually from some lesser known mine.

This problem developed because all of the mines operated by the Copper Queen Consolidated Mining Company, as well as its successor Phelps Dodge and Company and Phelps Dodge Corporation, have continually been referred to as the Copper Queen mines. By the same token, all of those developed by the Calumet and Arizona Mining Company have been called by the name of the controlling company.

In an effort to help collectors who wish to be more specific in their labeling and to know the general time-frame during which specimens were recovered, the following summary of mines is offered. The characteristics shown by various minerals from many of these mines are described further on, in the section on minerals. Together these sections may assist collectors in attributing more specific locality details to their Bisbee specimens, and will provide background for those lucky collectors whose specimens already have detailed but unfamiliar notations on the labels.

Atlanta shaft, Atlanta claim, 400 feet in depth, sinking started in 1884. It was this mine that sent Phelps Dodge on its way to becoming a major force in domestic copper. The Atlanta orebody was cut from just below the 200 level to the 400 level. Because it was in ore and a small shaft, it was abandoned in 1886 and replaced by the more efficient Czar. In 1917, dumps from the Southwest, 5th level, covered the Atlanta shaft.

Baxter tunnel, Baxter claim, started in 1889. Driven by the Copper Queen Company into Queen Hill from the east side to the prospect above the Southwest orebody. Unstable ground and only modest amounts of ore forced abandonment about 1900. Lessees

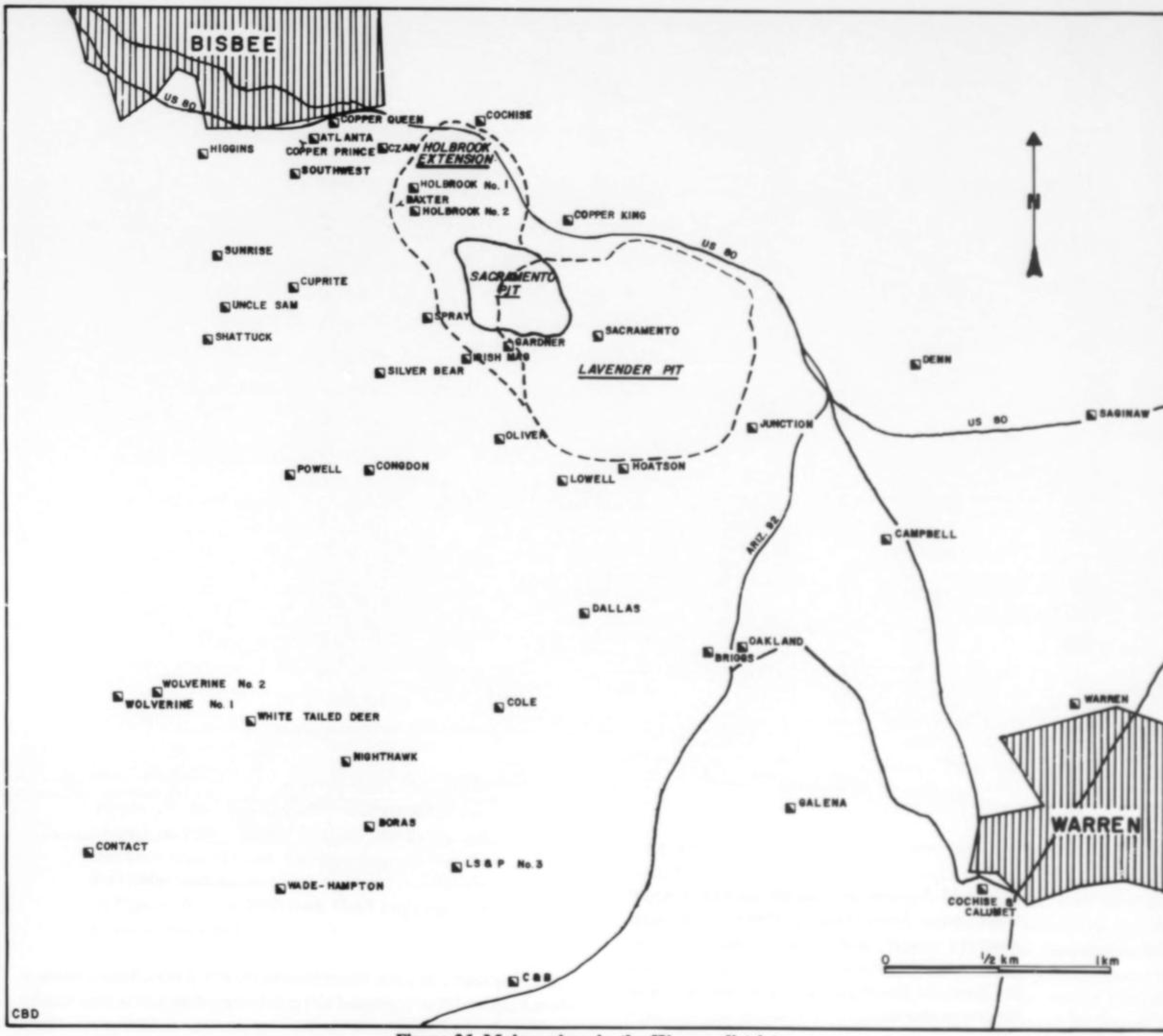


Figure 21. **Major mines in the Warren district.**

removed a small amount of highgrade ore in the mid-1930's.

Boras shaft, Boras claim, 1034 feet in depth, sinking started in 1917. Developed by the Copper Queen Company for lessees, substantial reserves of carbonate ores were opened up on the 400 and 600 levels in 1919. Operations continued until 1926 when it was closed. A small amount of mining was done by lessees from 1938 until 1944, most of this below the 800 level.

In the early 1950's, it was reconditioned for an emergency escape way and ventilation shaft for the Cole shaft. It served in this capacity until the cessation of operations.

Briggs shaft, Hard Cash claim, 1630 feet in depth, sinking started in 1902. Named for Charles Briggs, a banker in Calumet, Michigan, and president of the Lake Superior and Western Development Company, part of the Calumet and Arizona. No ores were shipped from here until 1910 because of water problems. During 1908 and 1909 work was suspended until a drainage drift from the Junction was completed (C and A, 1916). Mostly supergene ores were mined with a few primary sulfides. Operations were suspended in 1922 until 1935 when it was leased. This lasted until mid-1944 when it was permanently closed. The shaft was filled and the dumps leveled in 1949 to make room for a company housing development.

Campbell shaft, Regular claim, 3332 feet in depth, sinking started in 1927. Developed by the Calumet and Arizona Mining Company, it was named for Gordon R. Campbell, an early investor in the company. The original purpose of this shaft was to serve as a ventilation opening in the mining of the ores, east of the Junction shaft. This all changed when in 1929 the magnificent Campbell orebody was discovered; it was the largest mass of ore ever found in the district, containing well over a million tons. Stretching from above the 1600 level to below the 2200 level, this orebody helped make the Campbell the most productive mine in the district. Also, this is the only mine that operated without interruption. The deepest mine in Bisbee, it produced vast amounts of lead and zinc, in addition to copper.

Cole shaft, Triangle and John P. Jr. claims, 1563 feet in depth, sinking started in 1902. The Lake Superior and Pittsburg Development Company, an arm of the Calumet and Arizona Company, sank this shaft. Named in honor of Thomas F. Cole, a heavy investor in the mines of the district. At the time he was manager of the Oliver Mining Company, a subsidiary of United States Steel.

A truly great mine, its first ores were shipped in 1905 and the last in 1975. During this period, it was closed from 1929 until 1934 and again from 1944 through 1947. Operations were resumed at full

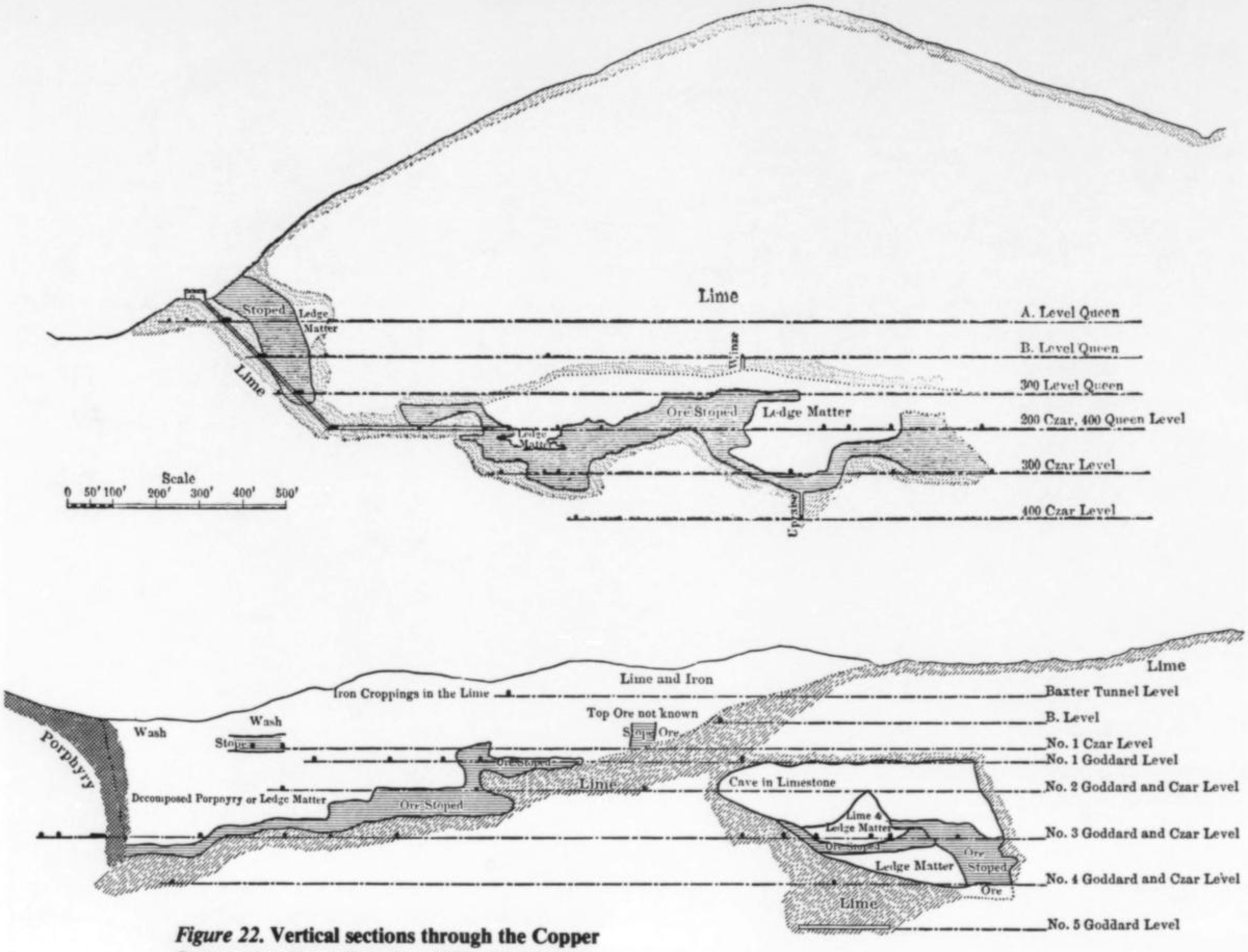


Figure 22. **Vertical sections through the Copper Queen mine (from Douglas, 1899). The famous open cut or glory hole shown in the upper diagram is still in existence, though partially filled in. Note the limestone cavern overlying ore in the lower diagram.**

scale in 1953. Ores from the Oliver, Powell and White-tailed Deer areas were tapped from the Cole.

Copper Prince mine, Copper Prince claim. A contemporary of the Copper Queen mine, mining began there in 1882 and lasted through early 1884. Both a shallow shaft and a tunnel were used to exploit the near-surface ores mined by the Arizona Prince Copper Company. This property was acquired by the Copper Queen Company in 1885 to preclude trespass litigation against the Prince for their mining excusions onto Copper Queen Company ground. The portal to the tunnel is visible today just above the post office, while several stopes have been cut by the highway that bypasses Bisbee.

Copper Queen mine, Copper Queen claim, 400 feet on inclined depth, sinking started 1881. The original work was done through an open cut and two very shallow vertical shafts in 1880 by the Copper Queen Mining Company. These were replaced by the 45-degree inclined shaft, cut some 200 feet to the east of the original discovery site. Mining through the Copper Queen ceased in 1888 when workings from the Czar reached the Atlanta and John Smith orebodies. It was re-opened in 1913 for exploration and a little mining and closed again that same year (Mills, 1958). A fire destroyed the upper 150 feet of the shaft in 1958. Today the Queen Mine Tour affords a good view of the lower portions of the shaft.

Cuprite shaft, Brother Jonathan claim, 911 feet in depth, sinking started about 1905. Designed to replace the older Uncle Sam shaft, the Cuprite shaft was sunk by the Copper Queen Company. Only modest amounts of ore were removed from here, with most of it hauled to the Czar for hoisting. Closed in 1929, it was turned over to lessees in 1934 and was mined sporadically until 1942. From then until mid-1944, low grade ores were exploited for the "metal reserves contract" using furloughed soldiers (Mills, 1956). The shaft was filled in 1968 and covered with dumps from the Lavender pit.

Czar shaft, General claim, 440 feet in depth, sinking started in 1885. This shaft was the first sunk by the Copper Queen Company. During its nearly 60 years of production, this shallow mine yielded more fine mineral specimens than any other in the camp. Little other than carbonate ores were mined from here and its proximity to the Dividend fault zone as well as the stock afforded it a unique geologic environment.

Operated by Phelps Dodge until 1931, it was then leased. In 1942, as at several other shafts, the company resumed operations to support the war effort. The final closing of this very wet, cold mine was in 1944.

In an effort to stop trespassing, a concrete cap was poured over the shaft in 1961. This also stopped the flow of air needed to preserve the shaft timbers from decomposition. As a result, in 1973 the head-frame collapsed and the shaft was filled. The site of this mine is 250 feet east of the main building of the Queen Mine Tour.

Arizona Historical Society

Figure 23. **Sacramento Hill, Bisbee, as it appeared in 1904. Today virtually the entire hill has been removed and the site taken over by the Lavender and Sacramento open pits, as shown in Figure 26. The Holbrook shaft buildings are in the foreground.**

Dallas shaft, Des Moines claim, 2032 feet in depth, sinking started in 1911. Production from 1913 until 1916 was significant, but only modest amounts were mined from 1920 through 1929; it served as the main hoisting shaft for the Gardner and Lowell ores while the Sacramento pit was in operation. The shaft was reconditioned in the late 1940's and re-opened in 1950. The Dallas become an important producer and remained in use until all operations ceased in 1975.

Denn shaft, Robert E. Lee claim, 3157 feet in depth, sinking began in 1907. The Denn and Arizona Copper Company, later part of Shattuck Denn Company, was the developer of this mine. It was named for Maurice Denn who, along with Lem Shattuck and Joseph Muheim, owned the 13 claims developed by this working.

Sunk along the Dividend fault, water was a problem from the start. By 1909 a fine series of oxide ores was found extending from just below the 1000 level to the 1800 level, parallel to the Mexican Canyon fault. Production was continuous until 1920, when large amounts of water were hit by development headings on the 1800 level and the mine was flooded (Bronson and Wilcox, 1930).

Because of depressed metal prices, no attempt was made to dewater the mine until the merger with Shattuck and Arizona in May, 1925 (Mills, 1956). From then, production was continuous to 1944, including large tonnages of zinc-lead silver ores. Phelps Dodge purchased the property in March 1947 and mined some 95,000 tons (Mills, 1956). Later, the shaft was deepened and used to serve the development of the 3100 level.

Gardner shaft, Gardner claim, 1457 feet deep, sinking started in 1890. Purchased by the Copper Queen Company with some reservation in 1890 (Douglas, 1909). Early development work soon dispelled any concerns when it was found that the limestones and the associated halo of ore extended farther to the east than anyone had thought. Also, it was here that the first important primary lead-zinc ores were found. Mining was continuous until the merger with the Calumet and Arizona Company in 1931. Reopened by lessees in 1935, mining continued on a reduced scale until its final closure in 1944. The shaft site was assimilated by an expansion of the Lavender pit in 1968.

Goddard shaft, Goddard claim, 510 feet in depth, sinking started in 1887. Only a modest producer during its short life, it was named for John Goddard of New York who was the owner. The property was acquired in 1888 by the families who controlled Phelps Dodge and was transferred to the Copper Queen Company in 1892. In 1900, when workings from the nearby Holbrook reached the ores developed by the Goddard, it was abandoned. The exact location of this shaft is unknown. Because of the poor ground, the shaft soon caved, and all surface signs were gone by 1909.

Hoatson shaft, Del Norte claim, 1500 feet in depth, sinking started in 1905. Captain Jim Hoatson was a man of unusual faith and mining expertise. It was on these qualities that the early investors in the Irish Mag put their money. To acknowledge that success, the Hoatson was so named. Most of the ores mined here were rich oxides from the great Hoatson orebody that reached from the 1200 level to below the 1400. By 1912, all mined materials were taken to the Junction for hoisting, and the Hoatson became just a service shaft. The mine was closed in 1922.

Higgins mine, Webster claim, shaft 300 feet in depth, collared in 1902, tunnel started 1904. Originally stated by Thomas Higgins, for whom it is named. Early development work was discouraging and the mine was closed in 1906. However, it was leased in 1914 and good ore was found in July of that year (Elsing *et al.,* 1922). Leasing continued until 1916, when mining was taken over by the Higgins Development Company, the owners of the property.

The mine was closed in 1920, when the reserves were nearly depleted, and was sold to Phelps Dodge in 1922 (Mills, 1956). Subsequent work by the new owners developed additional ore, and mining by the company was carried out until 1927. Leases were then given to several individuals who mined it until 1930. The mine again operated under lessees from 1934 to 1944 when it was finally closed. In 1933 the shaft burned; the remaining hole was filled in 1962. The tunnel entrance in Uncle Sam Gulch caved in about 1955 and the Bisbee side was sealed in 1980 to stop trespassing.

Holbrook shafts, old Goddard claim, 525 feet in depth, sinking started in 1889, new Baxter claim, 645 feet in depth, sinking started in 1906. The original shaft was sunk by the Holbrook and Cave Development Company, a group owned by the families that controlled Phelps Dodge. The properties were transferred to the Copper Queen Company in 1892. A producer of principally oxide ores, the Holbrook yielded a great many fine mineral specimens. Before sinking was completed the soft, ever-moving ground caused problems with the shaft alignment. By early 1906 it had become impossible to keep open so it was abandoned and a new shaft was started some 400 feet to the south.

The New Holbrook, as it was called, was a much better and deeper facility providing access to ores below the 500 level. While it, like its predecessor, produced many fine specimens, all of the ores were hoisted at the Sacramento, so an obvious chance for confusion as to source exists. Both shafts were swallowed by the Holbrook extension of the Lavender pit in 1969.

Irish Mag shaft, Irish Mag claim, 1393 feet in depth, sinking started in 1900. The first venture in the district by the Calumet and Arizona Mining Company, this was an incredibly rich though short-lived mine. The main orebody was hit in 1902 on the 1050 level, with some 325 feet of 9-percent copper ore being cut (C and A, 1916). Work was then continuous until 1913, when it was turned over to lessees. In 1917, the mine was closed and the surface facilities removed. The site was covered by dumps from the Lavender pit in 1968.

Junction shaft, Waddel claim, 2727 feet in depth, sinking started in 1903. A Calumet and Arizona property, it was one of the most productive mines in the district. Early in its life, many oxide-zone minerals were mined here, including some very fine specimens. Later only sulfides were produced including substantial amounts of zinc and lead. The Junction was an extremely efficient mine with five concreted compartments and a very fast hoist. For many years it was the central hoisting and pumping facility for the other mines. It still serves as the pumping shaft for most of the district with pump stations on the 2700 and 2200 levels for normal waters and one on the 1800 level for handling acid waters. Active mining and hoisting was stopped in 1958 with the remaining Junction ores being mined through the Campbell. The massive headframe for the operation still stands on the eastern edge of the Lavender pit.

Lavender pit. Harrison Lavender began his career with the Calumet and Arizona Mining Company as a miner in Bisbee. By the time of the merger with Phelps Dodge in 1931, he was the chief engineer. Retained by Phelps Dodge, he eventually became responsible for all of their western operations. He was instrumental in the development of the porphyry ores that resulted in the pit named in his honor following his death.

Initial stripping began in 1950, with the first ores milled in 1954 (Mills, 1956). Continually mined until its closure in 1974, 94,400,000 tons of ore and 281,600,000 tons of leach material and waste were removed for a total of 376,000,000 tons (Phelps Dodge, personal communication, 1975).

The Holbrook extension to the pit was started in 1967 and was so named because it encompassed the area of the Holbrook mines. Many truly fine mineral specimens were found during the mining of this segment of the pit.

Lowell shaft, Galena claim, 1603 feet in depth, sinking started about 1903. The Lowell exploited a group of claims that was purchased by the Copper Queen Company from Senator Clark of Montana in 1903 during the race with Calumet and Arizona for property. No ores were cut in the first 1000 feet and those found later were almost all sulfide. This mine had the questionable distinction of having the first sulfide mine fire in the district. Such fires plagued the Lowell for most of its productive life and a few fires continued to smolder for many years after its closure in 1931. From 1935 to 1940, this mine was operated by lessees. No work was done after 1940 in the Lowell itself; however, some ores were mined from the Dallas. The site was covered by Lavender pit dumps in 1969.

Neptune tunnel, Neptune claim, started in 1881. Actually an adit, not a tunnel, it was the most important producer for the Neptune Mining Company during its short life. The property was sold at a Sheriff's sale in 1886 to interests favorable to the Copper Queen Company and title was transferred to the Queen in 1892. Mining was done only during the years 1881–1882 and again in 1913. The exact location of this mine is uncertain. However, it is believed that it was situated on the western flanks of Sacramento Hill.

Nighthawk shaft, Nighthawk claim, 749 feet in depth, sinking started about 1911. This mine was developed by lessees and from 1923 to 1930 produced significant amounts of mostly oxidized ores. A very modest and unsuccessful operation was undertaken in the mid-1930's. The mine's final closure came in about 1938.

Oakland shaft, Oakland claim, 1380 feet in depth, sinking started in 1916. Developed by the Calumet and Arizona Mining Company to prospect areas east of the Briggs shaft. Even though some ore was found, most was exploited through the larger and more efficient Briggs or hauled to the Junction for hoisting. The Oakland served as a ventilation shaft until 1947 when it was filled to control the exhaust gases from the Campbell fire.

Oliver shaft, Senator claim, 1477 feet in depth, sinking started 1903. An early development of the Calumet and Arizona Mining Company, the mine was named for Henry W. Oliver, a principal investor in the company. Mining was continuous from 1904 to 1922 when it was closed for several years. Re-opened by lessees, the Oliver operated sporadically until 1940. Many types of ore were mined here, using several mining systems (C. and A., 1916). In 1965 the headframe was dismantled and the shaft was filled. Dumps from the Lavender pit covered the mine site in 1969.

Sacramento pit. One of the earliest open pit copper mines, stripping for the Sacramento started in 1917. Mining was done using 3½-cubic-yard steam shovels that ran on standard gauge railroad. Haulage was all on rail with 0–4–0T Porter locomotives pulling 20-cubic-yard cars (Ziesmer and Mieyr, 1923). Ore production started in 1923 and continued through most of 1929 with some 9,000,000 tons delivered to the smelter or mill. Waste and leach materials totaled 23,000,000 tons, for an overall production of 32,800,000 tons (Phelps Dodge, 1938). The resulting pit was just over 700 feet in depth. Mining in the Holbrook extension of the Lavender pit assimilated the Sacramento pit.

Sacramento shaft, Stars and Stripes claim, 1795 feet in depth, sinking started in 1904. Sunk on the eastern flank of Sacramento Hill, the "Sac" was one of the most important mines developed by the Copper Queen Company. For many years, it served as the main

Peter Kresan

Figure 24. **A portion of a stope in the Copper Queen mine, excavated in the 1880's.**

hoisting facility for all of their operations. While it produced mostly sulfide ores, important amounts of oxides were also mined. It operated from 1904 until the merger with the Calumet and Arizona Company in 1931 when operations were suspended. Mining resumed in 1935 and lasted through 1944 with low grade ores being mined for the wartime "metals reserve account" during the last two years (Mills, 1956). The mine was consumed early in the operations of the Lavender pit.

Shattuck shaft, Iron Prince claim, 1139 feet in depth, sinking started in 1904. One of the most productive and profitable operations in the district, it was named for Lem Shattuck, the owner of the group of claims it exploited. This mine was developed by the Shattuck and Arizona Copper Company. Ores from the Shattuck were transported to a railroad loading bin near the Holbrook by a 3300-foot aerial tramway on an 18-degree slope. Principally oxides were produced including large amounts of lead. Operations by the company continued until 1925 when lessees took over. They mined it until 1947 when it was closed. A fire set by children in 1952 destroyed the surface plant and burned out the shaft.

In 1973 Phelps Dodge purchased the property and erected a headframe that had been moved from the Cochise and Calumet shaft. A hoist was installed and the shaft opened up to about the 800 level by the time work was suspended in early 1976.

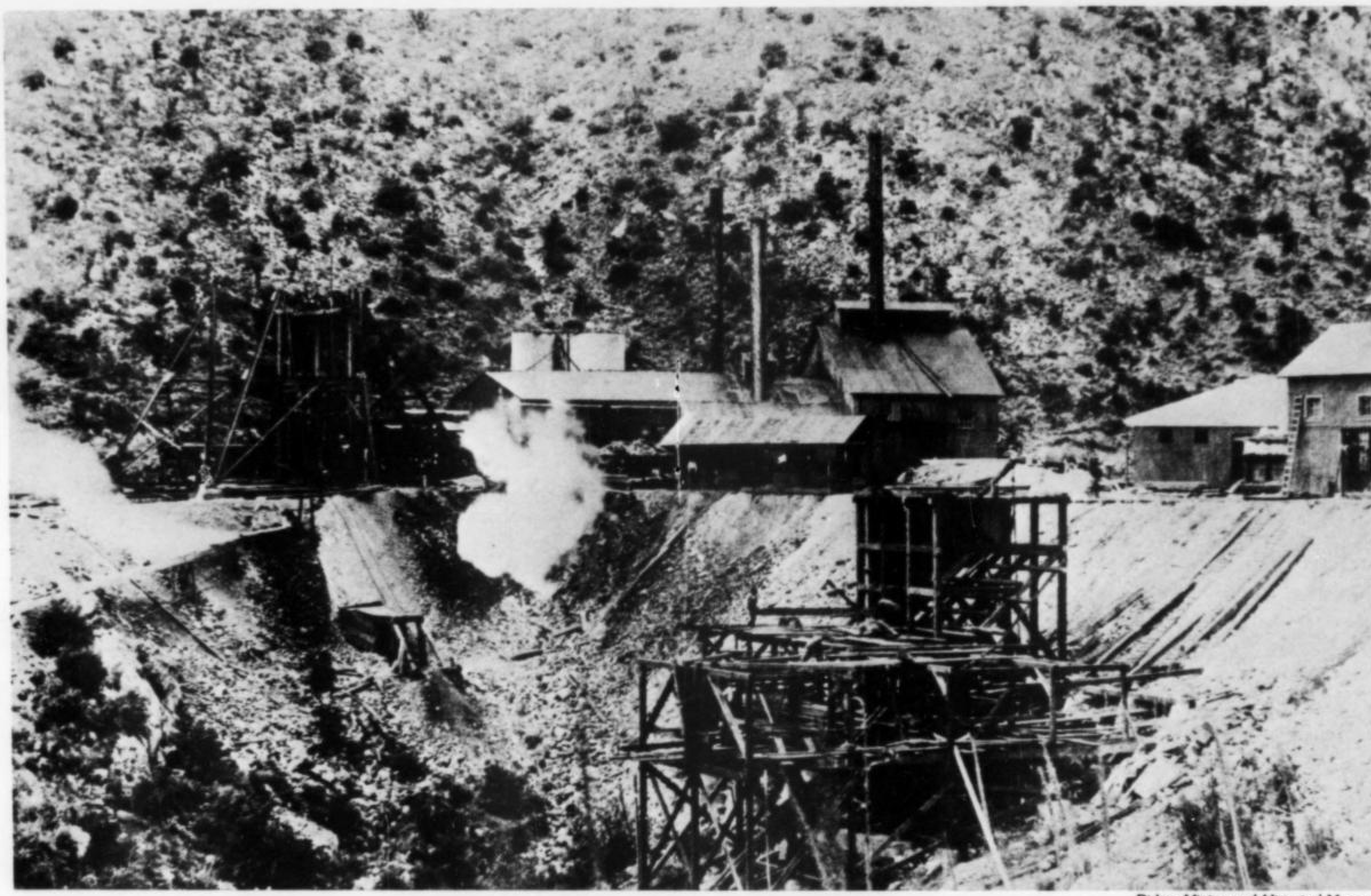
Silver Bear shaft, Silver Bear claim, 1052 feet in depth, sinking started in 1912. Originally intended to prospect the ground south of the Spray, this Copper Queen Company project was only moderately successful. Small amounts of oxide ore were developed and mined from the 400, 600, 700 and 800 levels. Most of this was near the Irish Mag claim. Mining was discontinued in 1922 and the surface facilities removed in 1942. The site was covered by dumps from the Lavender pit in 1968.

Southwest mine, Atlanta claim shaft, 493 feet in depth, sinking started in 1911. The Southwest, a Copper Queen Company property, was used to exploit Queen Hill above the collar of the Czar shaft. Three principal adits and two interior shafts, one a replacement of the other, serviced this expansive mine.

The Southwest mine is unique in the district in having its levels designated according to elevation above sea-level. The bottom level was the Queen tunnel at an elevation of 5300 feet; thus it was called the 3rd level. Correspondingly, the Southwest tunnel at the 5500-foot elevation is the 5th level and so on upwards to the 10th level at 6000 feet. All other mines in the district have levels numbered according to the depth in feet, measured from the collar at the surface downward.

An incredibly rich mine, it exploited the New Southwest orebody which contained nearly a million tons of 10-percent copper ore, all oxides. The ground was unusually competent, and the resulting opening was referred to as "the ballpark."

Mining was continuous in the Southwest until 1931 and was resumed by lessees in 1934 who worked into mid-1944. Important amounts of lead were mined in addition to the copper during all phases of its operation. Today, the Queen Mine Tour uses part of



Bisbee Mining and Historical Museum

Figure 25. **Headframe of the Shattuck shaft on the Iron Prince claim, opened in 1904.**

the 3rd level as its pathway. The newer of the Southwest shafts is visited in the course of the tour.

Spray shaft, Silver Spray claim, 1060 feet in depth, sinking started in about 1889. Development was started by the Holbrook and Cave Mining Company and turned over to the Copper Queen Company in 1892 before any ore had been found. By 1894, the Silver Spray, as it was then known, was a major producer. It was the impressive orebodies developed east of the shaft that inspired Jim Hoatson, on the advice of John Graham, to purchase the Irish Mag and start the C. and A. Company on its way.

Reserves were depleted in the Spray by 1913 and it was leased until 1918 when all of the surface facilities were removed. The shaft was bulkheaded at the collar and covered by dumps from the Sacramento pit. During the early 1930's, a lessee reclaimed the lower part of the shaft from the Holbrook, then raised up through 80 feet of loose dump material, an extraordinary feat. A small wooden headframe served the mine until its final closure in 1940. The site was covered by the Lavender pit dumps in 1968.

Sunrise shaft, Golden Gate claim, 734 feet in depth, raising started in 1919. A unique facility in many ways, the Sunrise was developed by the Copper Queen Company to service the Southwest mine. This shaft was a series of connected raises from the Queen tunnel or 3rd level to its collar at 6000 feet in elevation.

Because the hillside it surfaced on was so steep, no conventional headframe hoist system could be used. So a four-storied structure was erected over the opening with the hoist on the top floor situated over the shaft. The cage was the only one in the district large enough to accommodate a mule. This interesting structure still stands on the south facing slopes of Queen Hill. Its periods of operation are the same as those of the Southwest mine.

Uncle Sam shaft, Uncle Sam claim, 932 feet in depth, sinking started about 1893. Originally developed by the Copper Queen Company to prospect favorable horizons south of the Holbrook. However, nothing of interest was found, principally because of insufficient work, and the mine was abandoned in 1895.

Encouraged by finds in the nearby Shattuck, exploration was resumed by the company in 1905. Ore was found later that same year. Mining continued from that time through early 1923 with the last few years under lessees. The shaft was reconditioned in 1934 and lessees resumed mining off and on until 1942 when the mine was abandoned. Its headframe was removed and sent to Tyrone, New Mexico (Mills, 1958). The shaft was filled with waste from its own dump in 1966.

Wade Hampton shaft, Black Hawk claim, about 400 feet in depth, sinking started in 1913. Sunk on a small showing of lead, silver and gold, only very minor amounts of which were recovered; the mine was abandoned by 1915.

White-Tailed Deer shaft, White-Tailed Deer claim, 602 feet in depth, sinking started in 1911. A Copper Queen Company mine, it was sunk on the strength of encouraging finds in the southern portions of the nearby Cole. By 1913 it was producing a significant amount of ore, principally oxides. Mining by the company continued until late 1920, when it was turned over to lessees who did relatively well. In 1941 Phelps Dodge resumed control of the mine and brought it into production once more to assist in the war effort. The shaft was filled during the summer of 1964.

Wolverine shafts, both on the Broken Promise claim, number 1 was 670 feet in depth and number 2 was 700 feet in depth. Sinking started on number 1 in 1903 and on number 2 about 1912. The sole property of the Wolverine and Arizona Mining Company, it was

Peter Kresan

Figure 26. **The Lavender pit (foreground) and connected Holbrook extension behind it today occupy the site of the former Sacramento Hill (and have assimilated most of the Sacramento pit), as seen in this aerial photo taken from the opposite direction as Figure 23.**

operated only during times of high metal prices. Most of the ores mined were oxides from a southern extension of the Shattuck deposits. A lease on the Higgins tunnel was secured from Phelps Dodge in the late 1920's and the remaining Wolverine reserves were removed through this opening using an interior shaft. Phelps Dodge acquired the property in 1949 for its "nuisance value" (Mills, 1956). The number 2 shaft burned in 1974.

Unsuccessful exploration mines. As in every district a number of mines were developed in the never-ending search for new ore. Many of these were successful while others were not. Sometimes, though, even the latter produced a few fine specimens. For that reason they are listed here:

Bisbee Queen shaft
Bisbee West shaft
Cochise shaft
Cochise and Calumet shaft (developed by Phelps Dodge for water to be used in the Sacramento concentrator)
Congdon shaft
Contact shaft and adit
Copper King shaft
Galena shaft
Glance shaft
Hedberg tunnel
Houghton tunnel
Ivanhoe shaft
Kentucky tunnel
Lake Superior and Boston shaft
Lone Star shaft
Powell shaft
Saginaw shaft
Warren shaft

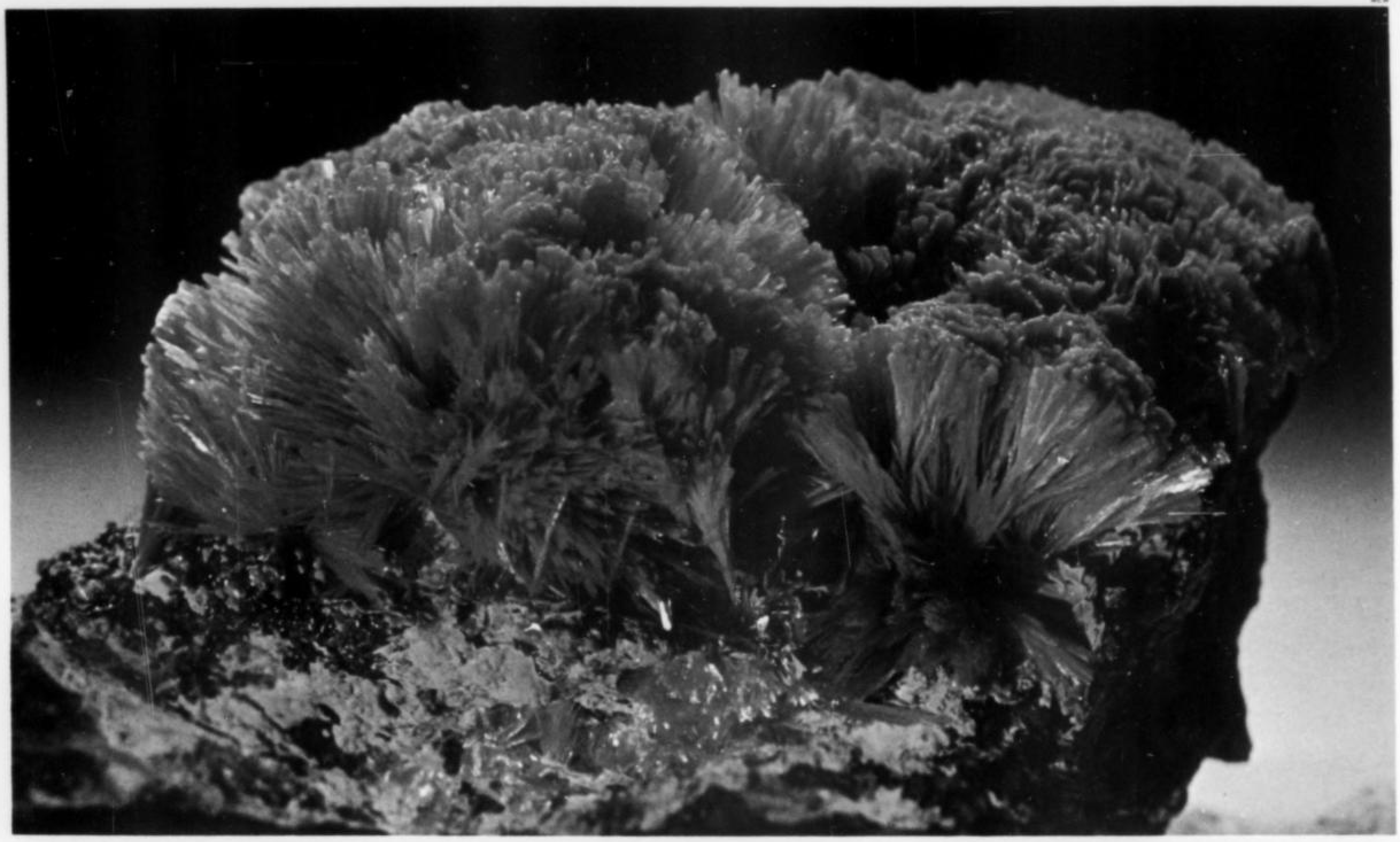


Figure 27. **Aurichalcite, 1⅜ inches across, from the 5th level of the Southwest mine. Lawrence Banks collection.**

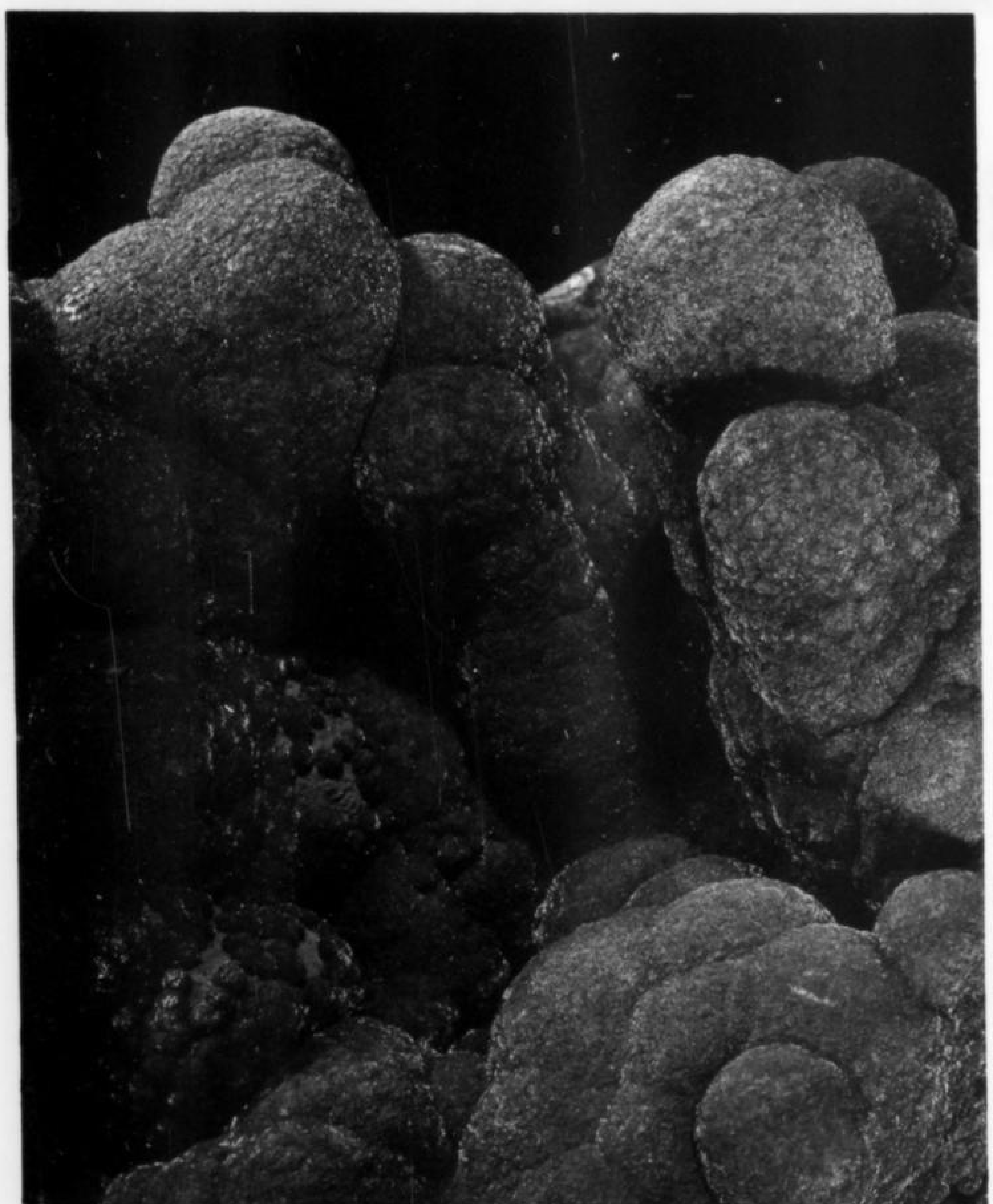


Figure 28. **Azurite, about 4 inches across, from the Junction shaft, 770 level. Sorbonne collection.**

Nelly Bariand

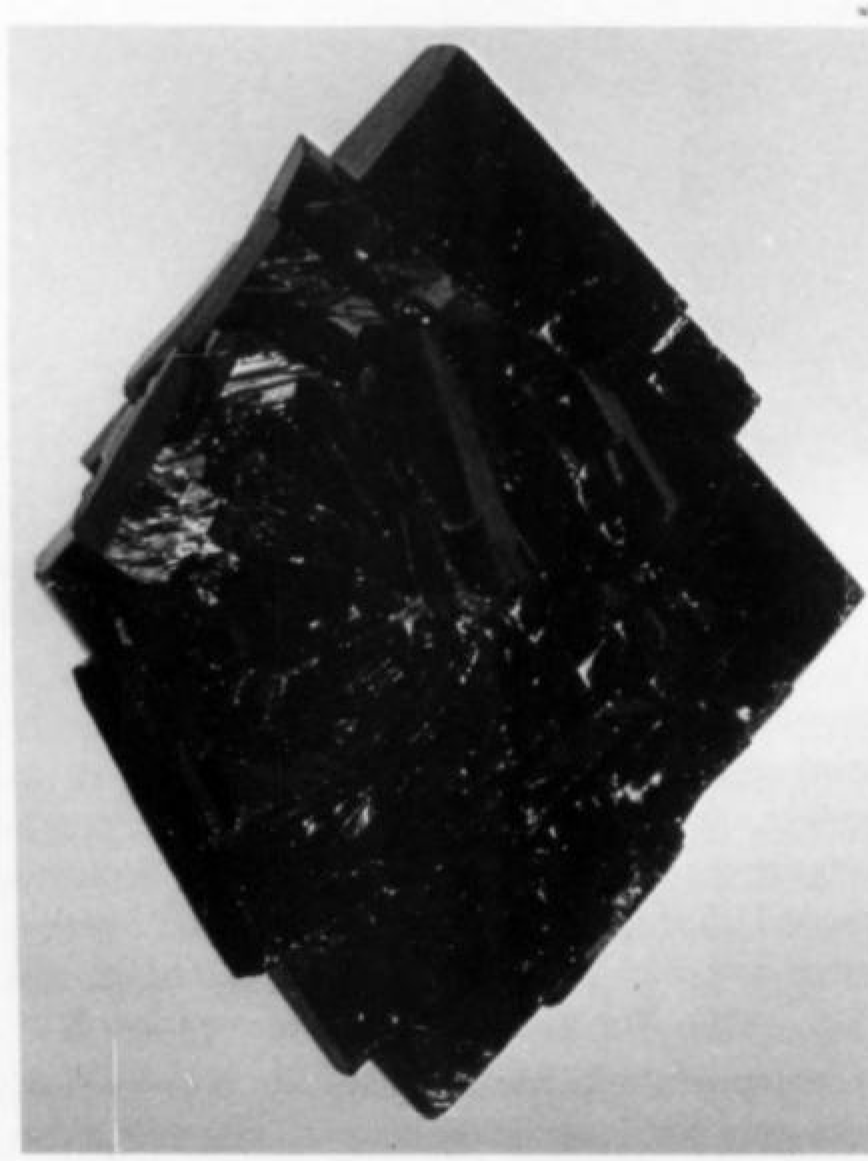


Figure 29. **A very sharp azurite rose 1 inch across, from the Czar shaft. Richard Bideaux collection.**

Figure 30. **Azurite "pinwheel" growth, composed of seven individuals offset from each other by rotation approximately about the *c* axis. Sketch at left shows a top view. About 3 inches across, from the Sacramento shaft. Note that the interior of the crystals is a malachite pseudomorph, overlain by a thin secondary growth of azurite. Graeme collection.**

Figure 31. **Azurite crystals on a matrix 4⅓ inches tall, from the Sacramento shaft. Arizona-Sonora Desert Museum collection.**

Geology

General Geology

The geology of the Warren district has, over the years, received several very fine treatments. For the most part, the interpretations and hypotheses of these workers have stood the test of time. Ransome's classic professional paper (1904) is still the basis for most of the work done in the area. Other important papers that have expanded on Ransome's work include Bonillas, Tenney, and Feuchere, 1916; Trischka, 1938; and Bryant and Metz, 1966. Because of these fine discussions of the district, only an overview will be presented here.

The rocks of the district consist of a basement Precambrian quartz sericite schist overlain by 5500–6500 feet of generally calcareous Paleozoic sediments. These were all intruded during Jurassic times and subsequently mineralized. Erosion then removed an unknown thickness of the sediments and instrusives, bringing the upper mineralized zones in both units near the surface. At this time, supergene enrichment occurred along a relatively level plane.

During lower Cretaceous times, some 5000 feet or so of principally clastic sediments were deposited on this surface. Later, tilting of about 30° to the east and erosion again exposed the western end of the mineralized area to a supergene environment, resulting in what exists today.

Rock Units

Precambrian Rocks

Pinal schist

This Precambrian basement unit is of unknown thickness and has been dated at 1.7 billion years old. Essentially a fine-grained, fissile, quartz-sericite schist, it is probably metamorphosed sediments. Most of the hills north and west of the stock are composed of this unit. While locally mineralized, the Pinal schist has never been known to host ore.

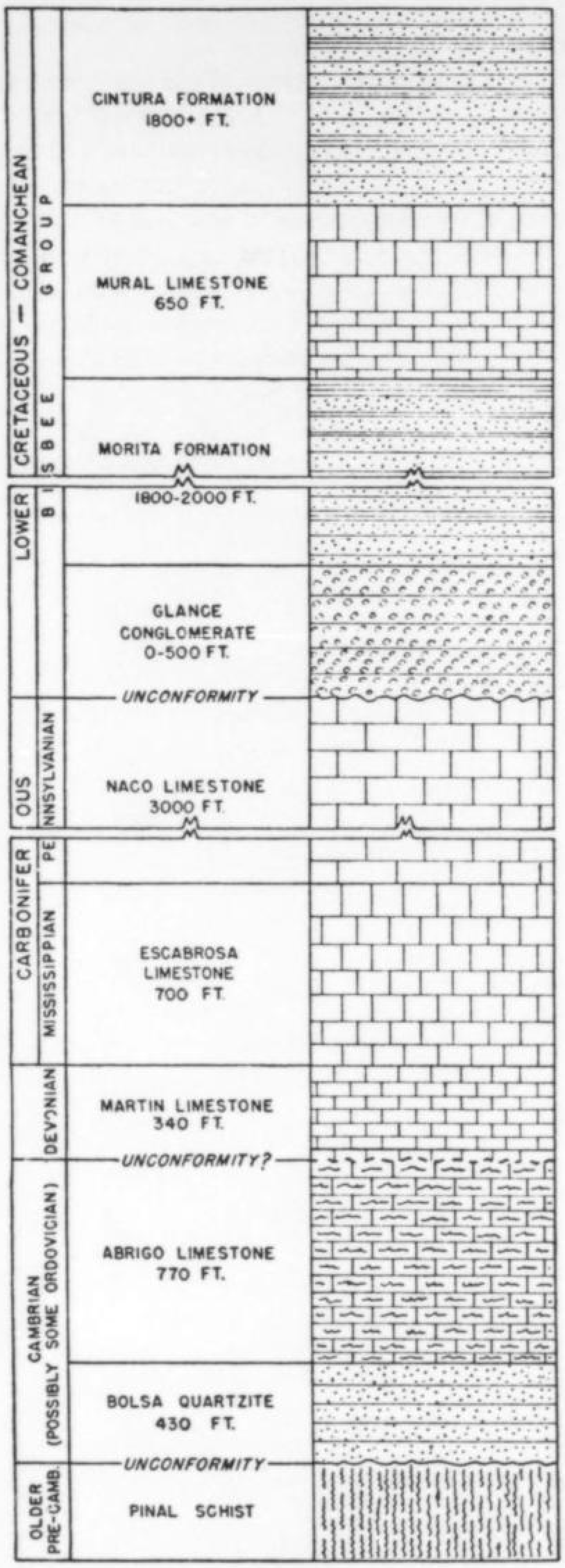


***Figure 32.* Generalized geologic section (from Hogue and Wilson, 1950; after Ransome, 1904).**

Paleozoic Sediments

Bolsa quartzite

Cambrian in age, the oldest member of this unit is a basal conglomerate grading into arkosic grits and finally into crossbedded quartzites. Locally it achieves a thickness of 430 feet. The Bolsa may be pyritic in some areas, but has never been an ore-bearing horizon.

Abrigo limestone

Also Cambrian in age, the Abrigo limestone rests conformably on the Bolsa with a total thickness of 770 feet. It is a thin-bedded, cherty, impure limestone with some calcarous shales and local manganese oxide staining. During the early years of mining, the Abrigo was considered to be of limited potential. Only the top 100 feet or so were explored to any degree. It wasn't until the mid-1950's that its true value as a host for ore was realized. From then until the cessation of mining it was the mainstay of the underground operation.

Parting quartzite

This unit rests atop the Abrigo with no apparent unconformity below or above. Only an average of 8 feet thick, its value lies in its use as a marker bed. Bonillas *et al.* (1916) felt it represented the Silurian, while Ransome (1904) assigned it to the Abrigo.

Martin limestone

While this Devonian unit is only 340 feet thick, it has produced more ore than any of the other limestones. It is a dark gray, dolomitic, compact, fossiliferous unit of moderately thick beds.

Escabrosa limestone

The second most productive horizon in Bisbee, this unit is some 700 feet thick and is of Mississippian age. Generally light in color and thick-bedded, the Escabrosa rests conformably on the Martin and is often a cliff-former. The separation between the overlying Naco and this horizon is indistinct. Based on fossil evidence, the contact is imperceptable in the field.

Naco limestone

Of Pennsylvanian-Permian age, an average of 1500 feet remains. It rests conformably on the Escabrosa and a pre-Cretaceous erosional surface forms its top. This limestone is moderately thick-bedded and quite fossiliferous. Only modest amounts of ore have been discovered in the Naco.

Mesozoic Sediments

Cretaceous sediments, Bisbee group

These units rest on an uneven erosional surface of schist, Paleozoic sediments and granite. They include the Glance, a basal conglomerate; the Morita sandstone; and nearly pure Mural limestone; and the Cintura sandstone-shales for a total thickness of at least 4900 feet. Because these units are post-ore, they are of little relevance and will not be discussed.

Intrusive Rocks

Juniper Flat granite

This unit is most prominent to the north and west of the productive zone. The rock is a coarse-grained mass, pink to purplish gray in color, composed principally of two units: a quartz monzonite and a granodiorite. Microcline, or orthoclase and quartz as well as a little biotite and plagioclase are the most common constituents. Usually fresh and free of alteration, it has been dated at 177 million years (Creasery and Kistler, 1962). Economically, only a few small but rich pockets of gold have been found in it. These were in quartz veins associated with fluorite.

Sacramento stock

This intrusive mass is actually composed of two distinct units. They are known as the granite porphyry and the younger granite porphyry. The older unit is a highly altered quartz porphyry. It was intensely silicified and pyritized by early hydrothermal fluids and is almost totally devoid of ore minerals. This, perhaps, was a result of being effectively sealed during early alteration, rendering penetration by later, ore-bearing fluids impossible.

The younger granite is described as a quartz-feldspar porphyry. It has been moderately altered by both hypogene and supergene fluids. This same unit also occurs as numerous dikes in the underground mines and was the ore host for both the Sacramento and Lavender pits. Both intrusions comprising the Sacramento stock are dated at about 180 ± 3 m.y. (Phelps Dodge, personal communication, 1972). However, Lowell and Guilbert (1970) have ascribed an earlier date of 163 m.y. to these units.

Breccias

Breccias are included here because of their wide distribution and their important relationships to the ores. Many types of breccias are recognized in the district. In decreasing order of respective volumes, the terms applied to them are: intrusion, intrusive, silica, igneous, fault, and protoclastic. Of these, only the first three are of major significance and are all pre-ore.

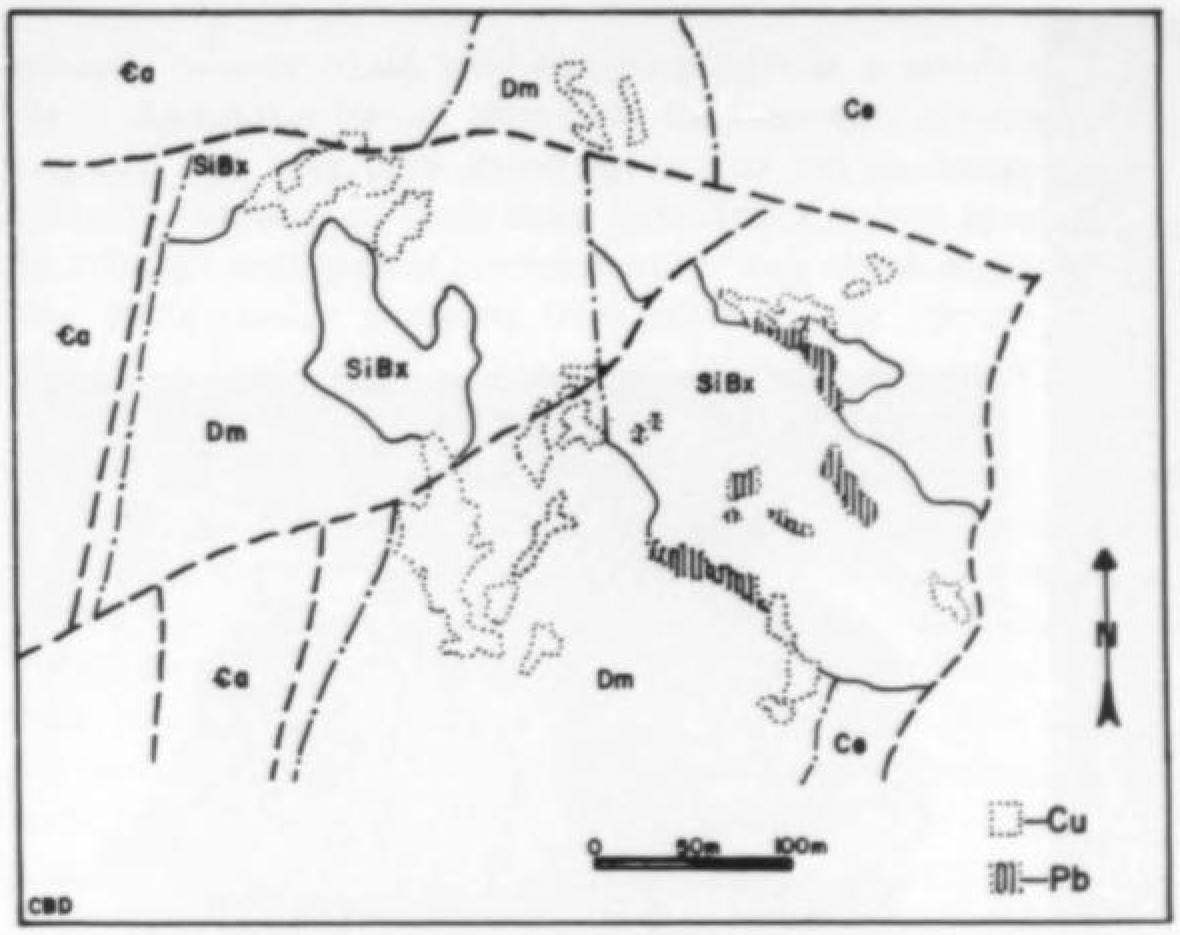


Figure 33. **Silica breccias (SiBx) and their relationship to copper and lead orebodies in the Southwest mine. Note their apparent restriction to the upper Paleozoic units.**

Intrusion breccia

This is the contact breccia of some of the early workers. Most commonly it occurs in the contact zone between the older granite porphyry and the sediments. It appears to have been formed by the active intrusion of the earlier porphyry. It is composed of angular to rounded fragments that represent every pre-Cretaceous unit except the intrusives, showing varying degrees of transport. The breccias usually grade into undisturbed wall rock along the edges. The matrix of this unit consist of a siliceous rock-flour containing small fragments of the brecciated units and commonly significant sulfides. Sufficient sulfides are commonly present as a replacement of the matrix or fragments or both to be of ore grade. This usually occurs in the more siliceous parts of these breccias (Bonillas *et al.*, 1916).

Intrusive breccias

These breccias are found throughout the district ranging in thickness from less than a quarter inch to 500 feet. They are a hetero-

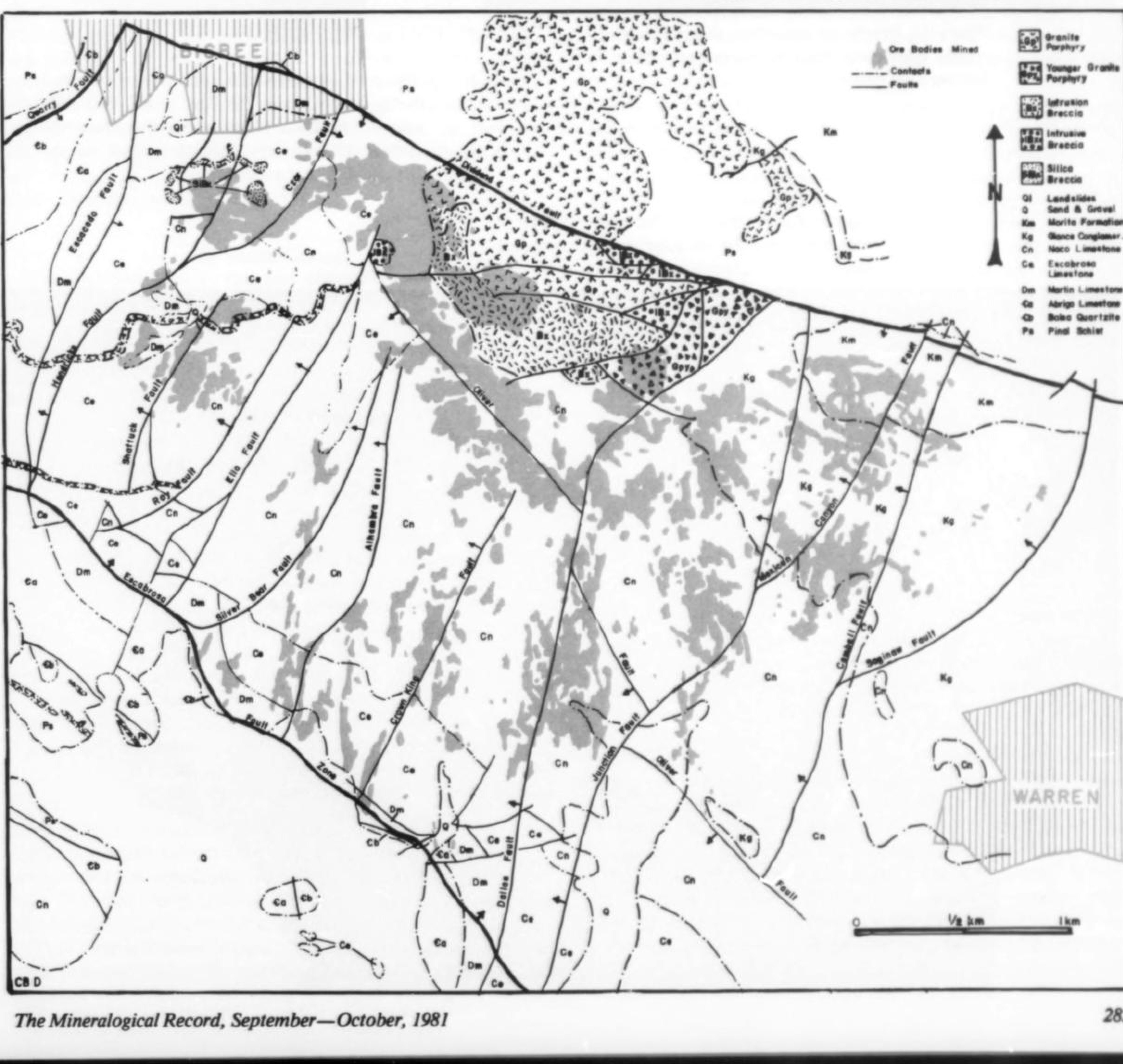
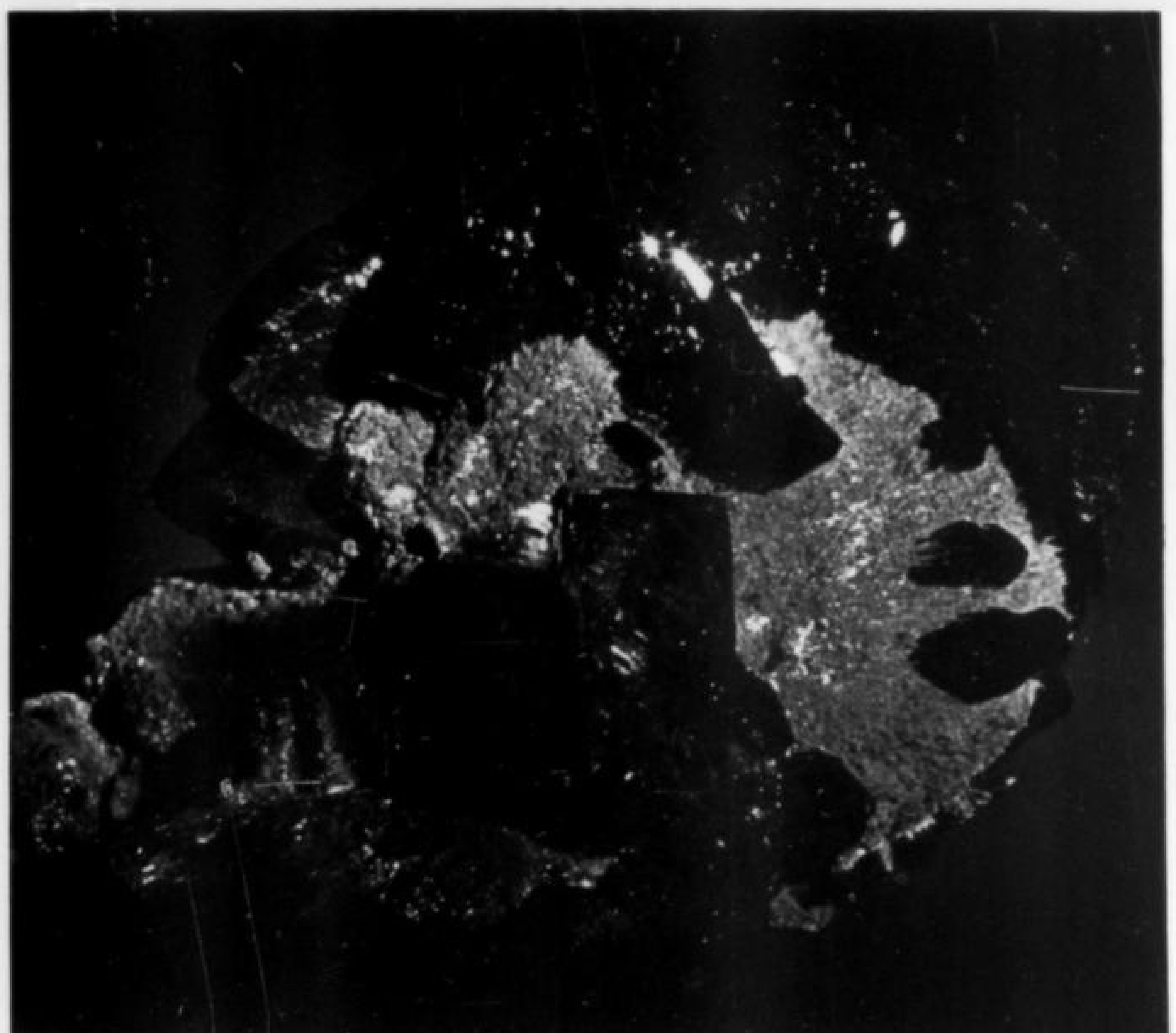


Figure 34. **Generalized surface geology showing a projection of the orebodies mined underground. (After Ransome, 1904; Bonillas *et al.*, 1916; Trischka, 1938; and Bryant and Metz, 1966; supplemented by recent field work.)**



Dane Penland

Figure 35. **Azurite on malachite, about 3 inches across, most likely from the Sacramento shaft. Smithsonian collection.**

Figure 36. **A group of blocky azurite crystals 2 inches across, from the Czar shaft. Originally part of the Kunz-Tiffany collection, later the Arthur Montgomery collection; now in the Richard Bideaux collection.**

Figure 37. **Azurite on malachite, about 2⅜ inches across, from the Czar shaft. Graeme collection.**

geneous mixture of all pre-Cretaceous units in a matrix of rock flour. Amazingly free of alteration, the fragments are angular to rounded and have been found up to 100 feet in diameter, frequently, hundreds of yards from their closest known source. The breccias are usually quite continuous over long distances, and pinch and swell, readily changing from dikes to sills. Bryant (1968) ascribes a fluid intrusion origin and estimates they have a total volume of 800 million cubic feet.

Silica breccias

As the name suggests, these are highly siliceous units. Composed of angular fragments of completely replaced limestone, they have a matrix of cryptocrystalline quartz and specular hematite. Relict fossils representing all of the fossiliferous units can, on rare occasion, be found. Judging from these, movement of the units appears to have occurred downward as well as upward. Indications of lateral movement are found in fragment orientations along their edges. These units are invariably pipe-like and physical connection with porphyry dikes is common (Bonillas *et al.*, 1916). Also, they appear to have been restricted to the Shattuck, Southwest, and the Higgins ore zones. Their importance to ore implacement, because of their permeability, cannot be overstated. Trischka (1932) felt that over 90 percent of the ore mined in the aforementioned areas was in physical contact with the silica breccias. The accompanying illustration shows the typical relationship between these breccias and the associated oxide ores of both copper and lead. The origin and mechanics of these units are still uncertain. Trischka (1928) proposed that they are limestone breccias of fault origin that were later silicified. They closely fit the solution and replacement breccias described by Butler (1913) and Kuhn (1941). As they are restricted to the post-Cambrian Paleozoic sediments, the silica may well represent a remobilization of their abundant cherts (Keith Coke, personal communication, 1973).

Structural Geology

The Dividend fault is the most important fault zone in the district. It is an ancient structure that has experienced numerous periods of activity. A normal fault, it trends northwest with a southwesterly dip of from 60° to vertical. Displacement ranges from 4900 feet at its eastern most exposure, to in excess of 2000 feet near its western end. Underground, this zone is from 39 feet to more than 240 feet thick. It divides the Mule Mountains along their major axes from the mouth of Mule Gulch to the beginning of Tombstone Canyon, where it terminates against the Quarry fault.

The Quarry fault is the westernmost and one of a series of north-northeast trending fault zones that are more or less perpendicular to, and south of, the Dividend fault. Among these faults are: the Quarry, Escacado, Shattuck, Czar, Silver Bear, Mexican Canyon, and Campbell. Most terminate at the Dividend zone. Generally these faults dip steeply to the west. Some 2½ miles to the south and sub-parallel to the Dividend zone is the Escabrosa fault zone. It is here that most of the north-northeast faults end. A few sinuous structures with a generally northwest trend complete this summary of the important breaks in the productive zone. The end result of all this faulting is a series of blocks bounded by major fault structures.

Geologic History

Little can be reconstructed of the Precambrian other than to say that, after metamorphism was complete, the schist was intruded by several basic dikes and then peneplained. Onto this level surface were deposited nearly 1200 feet of Cambrian sediments as it subsided, rapidly at first, then at a much slower rate.

Then there is a hiatus, leaving no record from the late Cambrian until Devonian times. The record resumed as the Devonian seas deepened and dolomitic sediments developed. During the Mississippian period and deposition of the Escabrosa limestone, the seas were much more shallow, as indicated by numerous reef formations. Deposition of limestone lasted through Pennsylvanian into Permian times when uplift occurred. The Paleozoic sediments had by then reached a total thickness perhaps greater than 6500 feet and were undergoing erosion. At some point during late Triassic or early Jurassic times, while still relatively flat lying, the sediments underwent extensive faulting, and activity along the Dividend fault zone occurred.

How quickly intrusion followed is unknown, but about 180 million years ago a quartz porphyry followed the Dividend fault through the schist into the overlying sediments. Extensive peripheral breccias were formed along the contact with the wall rocks.

Subsequently there came intense silicification of both the intrusion and the sediments. The Paleozoic rocks were locally silicified as much as 2½ miles from the locus of intrusion. This was closely followed by heavy pyritization in the porphyry, schist, and silicified sediments. Large replacement bodies of pyrite were scattered throughout the limestones.

Following the same path along the Dividend fault and close in time came a second intrusion. It forced its way through the schist, earlier porphyry, and the now-silicified sediments. Numerous dikes intruded the limestones, commonly for great distances. Soon thereafter, intrusive breccia dikes and sills also invaded the sediments, while an irregular pipe-like mass of breccia 500 feet in diameter pushed its way into the stock. The silica breccias probably also formed during this time.

As a result of the intrusive and breccia complex nearly a mile across in their midst, the adjacent sediments became irregularly metamorphosed for a short distance. Replacement by garnet, diopside, wollastonite and vesuvianite near the porphyry shortly gives way to tremolite, actinolite, and edenite indicating only minor effects of high temperatures. This assemblage in turn soon grades into recrystallized limestones followed by unaltered rock. In all, a contact metamorphic halo of little more than 1500 feet developed around the stock.

Metamorphic effects in the limestones are also noted along many, but not all, of the porphyry dikes. Generally, quartz is the most abundant mineral, followed by epidote and garnet. No truly definitive pattern is obvious in these instances because of the overlapping nature of the aureoles, and also the irregular and erratic development.

Paragenesis

When the mineralizing fluids were introduced is still being debated. Bain (1952) suggests 104 million years ago, Bryant (1968) 130 m.y., while others (Anthony *et al.*, 1977) feel the mineralization is quite close in age to the porphyry or 180 m.y.

Following the oft-used channels in the limestones, the fluids formed hundreds of widely-scattered replacement bodies without evident connection. The size of the replacement orebodies was quite variable, ranging from several thousand tons to a few exceptional masses of more than a million tons. Bryant and Metz (1966) report that possibly two-thirds of the ores mined came from masses of 25,000 tons or less.

Ground preparation was the key to their deposition. Aside from structures, silicification was the most important of the controlling features. The immense aureole of ore around Sacramento Hill in the contact zone illustrated this. Here, replacement by ore is apparently restricted to the more siliceous areas. In the limestones away from the contact influence, large barren zones are found with every feature of ore areas except silicification. Yet, seldom are silicified masses of any size found that are not mineralized.

Other features found in areas hosting ore include intersecting structures, breccias and/or porphyry, and alteration minerals such as epidote and garnet. Massive pyrite, and recrystallization of the country rock are also common.

In spite of all of these clues, prospecting for new orebodies has always been exceedingly difficult. While, as stated, many of these features are present in ore zones, the breccias, porphyry, and structural characteristics are much larger and far more widespread than the ore. Therefore, their presence simply indicates a favorable area with no guarantee of economic mineralization. Alteration is much the same. Finding it only indicates that mineralizing fluids could have been there, not that they have been or, if so, that any ores were deposited. So elusive are the orebodies that just inches away from them there is little if anything to betray their presence. Because of this a continual prospecting program was essential. At no time in the near-century of mining has there ever been more than just a few years of ore in sight.

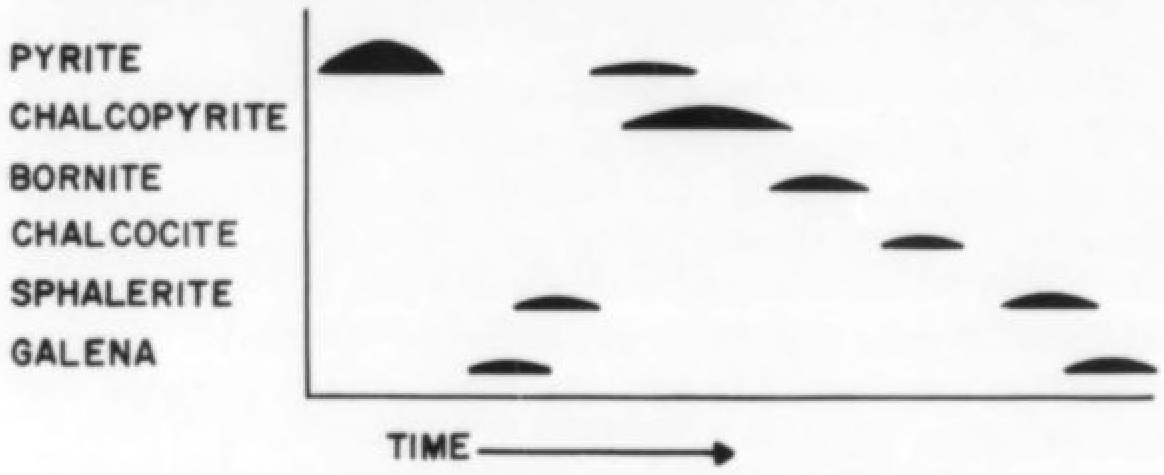


Figure 38. **Hypogene (primary) paragenetic sequence.**

Hypogene Paragenesis

Lead and zinc mineralization seem to have occurred during several separate periods. Additionally, it is often highly localized. Consequently the overall hypogene (primary) paragenesis may be confusing, with the apparent sequence dependent upon the area being studied. Bain (1952) suggests that the sequence was: pyrite→galena→sphalerite→chalcopyrite→bornite. Schwartz and Park (1932) found it to be: pyrite→chalcopyrite→bornite→chalcocite→sphalerite→galena, while Tenney (1913) indicated pyrite→sphalerite→galena→chalcopyrite→bornite to be the sequence. No doubt each of these workers is correct in the context of the specimens examined. Perhaps, then, a combination of all of these more closely represents the actual sequence.

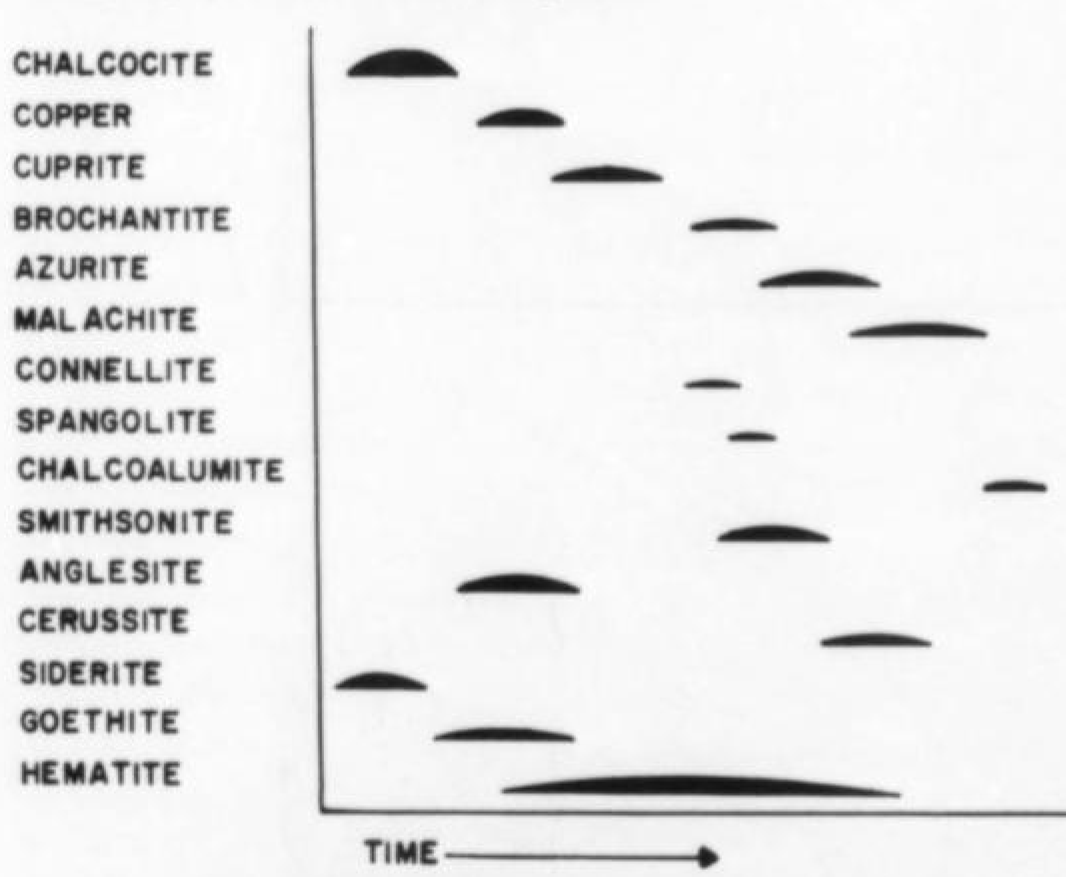


Figure 39. **Generalized supergene (secondary) paragenetic sequence.**

Supergene Paragenesis

At some point in pre-Cretaceous times activity along the Dividend fault was renewed. The north or footwall side was uplifted an unknown amount and all the sediments were removed. There is no reason to suspect that they had not been mineralized to the same extent as those that remain. What may have happened to that copper has long been debated. Some suggest that perhaps the unusually rich supergene deposits along the Dividend may well be relics of these ores (Bonillas *et al.,* 1916).

Also during this period, enough of the overlying units were removed from the hangingwall or south side to subject these sulfides to supergene (secondary) enrichment. A deep canyon was cut along the Dividend fault line from the stock to the east, giving even further access to fluids which caused enrichment. By Cretaceous times, an enriched zone more or less parallel to the surface had formed. Boulders of gossan and stream-worked secondary minerals in the lower Glance conglomerate confirm this enrichment period. The deposition of more than 3900 feet of sediments in the shallow Cretaceous seas effectively sealed the ores from further attack. Later uplift, almost doming, around the old Juniper Flat intrusion tilted the beds about 30° to the east. Erosion again uncovered some mineralized areas. This time, only the western part was exposed.

An interesting aspect of many of Bisbee's supergene minerals is that their source within the district is easily determined. So distinctive are they, that not only the mine but the ore zone and frequently even the stope can be recognized. No two areas were subjected to the same set of conditions so specimens from each area are somewhat different. The principal differences are morphology, associated species, color and hue, and paragenetic sequence.

Because of their significance to the mineralogy of the district, a discussion of some of the supergene characteristics is instructive. A marked difference is apparent between those areas that underwent more than one period of supergene activity and the sections that did not. If a north-south line were drawn in the vicinity of the Spray shaft it would come very close to separating the two areas.

Supergene assemblages vary in the relative proportions of minerals they contain. For example, to the west malachite is by far the most abundant secondary product, followed by azurite, cuprite, copper and chalcocite. Here, chalcocite is very much in the minority when compared with any of the other minerals. In the eastern sector, exclusive of the porphyry ores, chalcocite is the most common, then cuprite, copper, azurite and malachite. This, of course, is a function of the degree of supergene activity.

A comparison of the morphologies of azurite in the two areas reveals that western specimens are most frequently massive, reniform and stalactic. While large crystals are unusual, pseudomorphs of malachite after azurite up to 1½ inches were not uncommon. To the east, very few reniform or massive groups were found. Here, almost all azurites were well crystallized, commonly exceeding 2 inches. Well-formed pseudomorphs of malachite after large azurite crystals abound in this area.

A few stalactites of azurite in the Sacramento shaft and malachite in the Campbell shaft, when found, had a non-vertical orientation indicating formation prior to tilting. Conversely, in the western area stalactites, horizontal fluid level lines and precipitated minerals inevitably show a post-tilting growth orientation.

The depth to which the supergene fluids penetrated was, of course, a function of permeability. Along major structures secondary minerals were found at unusual depths. In the Campbell shaft, wulfenite has been found in the 2566-foot level along the Campbell fault. This is some 1170 feet below the pre-Cretaceous surface. No primary ores were cut in the Denn shaft, along the Dividend fault, above the 2000-foot level, or 975 feet below the old surface (Bronson and Wilcox, 1930). To the west, the Hoatson orebody was oxidized for over 1365 feet below the present surface along the Junction fault.

In the areas affected by post-Cretaceous supergene action, nearly total oxidation took place at depth. In the Shattuck, for example, no sulfides, primary or secondary, were found above the 800-foot level.

Supergene gangue minerals

Enormous volumes of acids were generated by alteration of pyrite during supergene activity. One of the several features attributable to this is the huge amount of clays, principally halloysite and kaolinite. Derived, for the most part, from the porphyry and metamorphic feldspar minerals, tens of thousands of tons were formed. So pervasive are the clays that along the west and south sides of the stock, erosion developed low-lying areas, indicating the lack of resistance to weathering.

Quite plastic in nature, these clays were both a boon and bain to the miners. Almost always heavily iron-stained, they would frequently contain enough disseminated copper minerals to constitute an ore. While easily removed, keeping the workings open often proved impossible. Ground opened one day would be completely closed the next, crushing the largest of timbers. The Holbrook shaft was lost in 1906 to these clays.

A common product of early supergene activity was siderite. Commonly found in large masses with boxwork structure, it frequently occurred under or adjacent to chalcocite orebodies. Carbon dioxide filled the voids in the boxwork. Further exposure to supergene fluids altered the siderite to limonite (Trischka, *et al.*, 1929).

Oxidation Caves

Perhaps the most interesting, yet least known, oxidation feature is the caves accompanying many of the secondary orebodies. A significant reduction in volume accompanied the total oxidation of the primary sulfides. This, coupled with lesser amounts of limestone removed by the acids generated during this process, has left voids above the oxides.

The host limestones compensated for the removed support in several ways. If the beds were thin or broken, they would slump and fill the opening with rubble that usually became cemented with calcite. Numerous crystal-filled pockets would in some areas develop between the broken limestone boulders. These effects can often be identified as much as 1000 feet above and have served as guides to ore (Wisser, 1927). When slumping occurred less than 300 feet from the surface, a roughly conical depression formed. Such features dot the hills in the Czar, Southwest, and Shattuck areas.

In the thicker bedded, more competent horizons where most of the district's ores occurred the effects were somewhat different. Instead of complete collapse the beds would spall off leaving a stable, often somewhat domed ceiling. Many hundreds of such caves were found in the district. Typically of very large size, they would have a floor of limestone boulders immediately overlying an oxide orebody. The accompanying illustration from Douglas (1899) shows these features (Fig. 22).

The largest of these caves was in the Shattuck mine. Crescent-shaped, it curved around a silica breccia, attaining a maximum height of 275 feet, a width of 340 feet, and a total length of 600 feet. It contained many large boulders. One end of the cave was over copper ore, while the other was over cerussite. So closely associated with the ores were the caves that Wendt (1887) was of the opinion that the copper carbonates in the Queen and Atlanta areas had been deposited as such in pre-existing openings.

Associated with both the complete filling by rubble and the doming structures were sag caves. Formed as the beds sagged over the openings or rubble, they are usually small. Seldom more than 6 feet high, they may be as much as 100 feet in length and width. Because they invariably occur peripheral to the other openings, only very rarely do they contain any minerals other than calcite and aragonite.

As a source of fine minerals, Bisbee's caves were exceptional. Ransome describes some of them in his 1904 paper: "The walls of these caverns were covered with velvety moss-green malachite and sparkled with the blue crystals of azurite, while from the roofs hung translucent stalactitic draperies of calcite, delicately banded and tinted with the salts of copper."

An equally fascinating account of a small cave hit in the Southwest orebody before 1900: "A room, not too big, perhaps 50 feet in curved length and 20 feet high and 15 or so feet wide. The walls were all manner of irregular lumps of black azurite dotted with

Arizona Historical Society

Figure 40. **Calcite cave growths, probably in the Southwest mine.**

malachite. From the back (ceiling) hung limonite stalactites with azurite crystals here and there on them. The floor was mostly a thin crust of blue on malachite" (M. J. Cunningham, personal communication, 1952).

In 1907 a cave-like opening 20 feet in diameter, with drusy stalactitic cuprite, was hit above the 1050-foot level of the Irish Mag shaft. The Junction shaft has a series of caves up to 65 feet across between the 2200 and 2566 levels. These are filled with iridescent stalactitic and botryoidal siderite.

The most common cave minerals are calcite, aragonite and gypsum. The carbonates are commonly tinted by copper and iron. It is in these caves that their loveliest forms are attained. Occasionally, a cave would fill with calcium carbonate-rich water after stalactites and other growths had developed. The result would be single-crystal stalactites of up to 20 inches and oriented crystal overgrowths on many of the formations. At the water line, sunburst-like crystal groups of up to 3 feet across would develop around the tips of the stalactites.

Other minerals found in Bisbee's caves include cerussite, conichalcite, descloizite, goethite, hematite, mimetite and smithsonite.

Minerals

Herein lies the enduring fame of Bisbee. There are at least a dozen copper deposits worldwide whose metal production has or will exceed that of the Warren mining district. But no mine or district other than Tsumeb can claim such an abundance of remarkably fine specimens. In spite of the simplicity of the mineralizing fluids and the relatively modest effects of hydrothermal alteration, an impressive assemblage of minerals developed. A total of 214 species have been confirmed. In addition, 17 more are either reported but unconfirmed or are represented by specimens whose identity or origin is in question. Of the confirmed species, paramelaconite, shattuckite, bisbeeite, chalcoalumite, graemite and almost certainly spangolite were originally described from Bisbee.

In a general way, all of the minerals found can be categorized by origin. These categories are: rock forming, alteration, hypogene, supergene, and post-mining. Obviously there is some room for overlap between the classes. But it seems most beneficial to list such minerals only in the group that most typically represents their mode of occurrence.

Table 1. Rock-forming minerals at Bisbee.

albite	calcite	labradorite	orthoclase
allanite	celadonite	microcline	rutile
andesine	dolomite	muscovite	sanidine
apatite	enstatite	oligoclase	titanite
augite	hornblende	olivine	tourmaline
biotite			zircon

Table 2. Alteration minerals at Bisbee.

(This group includes both hydrothermal and metamorphic products.)

actinolite	chrysotile	halloysite	rhodochrosite
allophane	clinochlore	illite	scapolite
alunite	clinochrysotile	kaolinite	scheelite
anatase	clinozoisite	laumontite	sepiolite
andradite	diaspore	magnesite	stevensite
anhydrite	dickite	magnetite	talc
antigorite	diopside	natrolite	thomsonite
barite	édenite	prehnite	tremolite
bixbyite	epidote	pumpellyite	vesuvianite
brucite	fluorite	pyrophyllite	wollastonite
chamosite	forsterite	pyrrhotite	zoisite
chromite	grossular	quartz	

Table 3. Hypogene (primary) minerals at Bisbee.

aikinite	cosalite	greenockite	sphalerite
alabandite	digenite	marcasite	stannoidite
altaite	djurleite	molybdenite	stromeyerite
bornite	enargite	polybasite	tennantite
canfieldite	famatinite	powellite	tetrahedrite
chalcopyrite	galena	pyrite	uraninite
cinnabar	gold	rickardite	wittichenite

Table 4. Supergene (secondary) minerals at Bisbee.

anglesite	chrysocolla	hisingerite	pyrolusite
antlerite	claringbullite	hydrohetaerolite	pyromorphite
aragonite	conichalcite	hydrozincite	rosasite
atacamite	connellite	ilsemannite	sengierite
aurichalcite	copper	jarosite	shattuckite
azurite	covellite	langite	siderite
bayleyite	cuprite	leadhillite	silver
beudantite	cyanotrichite	lepidocrocite	smithsonite
bindheimite	delafossite	linarite	spangolite
bisbeeite	descloizite	malachite	stibiconite
boehmite	devilline	manganite	stolzite
braunite	dioptase	mimetite	sulfur
brochantite	embolite	minium	szomolnokite
bromargyrite	fornacite	mottramite	teineite
carbonate-cyanotrichite	gibbsite	murdochite	tenorite
	goethite	osarizawaite	tilasite
cerussite	graemite	paramelaconite	turquoise
cesarolite	graphite	paratacamite	tyuyamunite
chalcoalumite	groutite	pharmacosiderite	vanadinite
chalcocite	gypsum	plancheite	variscite
chalcophanite	hausmannite	plattnerite	willemite
chalcophyllite	hematite	plumbojarosite	wulfenite
chalcosiderite	hemimorphite	pseudomalachite	
chlorargyrite	hetaerolite	"psilomelane"	

There is little doubt that most of the minerals classified as post-mining in their formation have also formed in some places prior to mining. However, because of their known readiness to form as post-mining minerals their earlier, supergene formations have probably gone unrecognized as such.

Table 5. Post-mining minerals at Bisbee.

anthonyite	epsomite	kornelite	rhomboclase
basaluminite	fibroferrite	lime	roemerite
bianchite	goslarite	melanterite	rozenite
botryogen	halotrichite	matavoltine	siderotil
chalcanthite	hexahydrite	pickingerite	voltaite
copiapite	hydrobasaluminite	ransomite	
coquimbite			

Catalog of Occurrences

The following catalog of Bisbee mineral occurrences is based principally on field observations made by the author over the last 25 years, coupled with a study of thousands of specimens in collections both great and small. Nearly all of the species identifications resulting from this work have been confirmed by X-ray analysis, and such confirmation is indicated by an asterisk (*) following the locality of the analyzed specimen under each species heading. This information has, of course, been augmented by the extensive literature as cited and as listed in the bibliography. Perhaps the most important and perishable data preserved through this study are the accounts of occurrences, environments and associations which have been so freely given by those miners and professionals who personally collected many of Bisbee's finest specimens.

Peter Kresan

Figure 41. **Natural limestone cavern in the Southwest mine, 7th level, opened in 1914. This cave, in Devonian Martin limestone, formed as a result of oxidation and shrinkage of a sulfide orebody below.**

Unfortunately there are numerous gaps in the information available, particularly for those mines operated by the Calumet and Arizona Company from 1907 until they were acquired by Phelps Dodge in 1931. Additionally, very few data have been preserved regarding occurrences in the mines developed by the Wolverine and Arizona Company. Also, numerous minor and some major finds in the other mines have either gone unrecorded or have been forgotten.

This catalog, then, should not be considered a final work, but rather a beginning in the development of a more complete understanding of Bisbee's mineralogy. In the countless surviving specimens there lies a wealth of unrecorded information, both in terms of unrecognized species and locations. It is hoped that such information will eventually come to light.

Actinolite $Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$**

A common mineral in the district, but especially in the contact metamorphosed sediments peripheral to the Sacramento stock. In these it is found as black to green fibrous masses with diopside, tremolite and epidote.

Aikinite $PbCuBiS_3$

Reported from the district (Anthony *et al.*, 1977).

Alabandite MnS

This mineral has been identified in only two mines. Its intimate association with, and rough similarity to, sphalerite in the Junction occurrence indicate that it may well have been much more com-

**Formulas are taken from Fleischer (1980).

mon. Hewett and Rowe (1930) further speculate that alabandite may well have been the source of the many manganese oxide ore bodies exploited in the area.

Higgins mine—tunnel level, 3 crosscut, as minute grains disseminated in dolomitic rocks (Hewett and Rowe, 1930).
100 level, as massive material in a manganiferous dolomite with rhodochrosite (Hewett and Rowe, 1930).

*Junction shaft—2300 level,** as massive brown-green material with rhodochrosite in massive iron-rich sphalerite.

Albite $NaAlSi_3O_8$

Found as a minor constituent of the Sacramento stock (Notman, 1913), and in the Juniper Flat granite (Bonillas *et al.*, 1916).

Allanite $(Ce,Ca,Y)_2(Al,Fe)_3(SiO_4)_3(OH)$

Reported from the district (Anthony *et al.*, 1977).

Allophane (amorphous hydrous aluminum silicate)

In the Sacramento stock, found as a hydrothermal alteration mineral (Schwartz, 1947).

Altaite PbTe

Campbell shaft—2200 level, as small (to 1/10 inch) blebs intergrown with canfieldite interstitial to granular pyrite (Sidney Williams, personal communication, 1981).

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

An extremely common mineral, occurring as a hydrothermal product in both the stock and sediments, and usually found adjacent to sulfide bodies. Only a few occurrences are noteworthy:

Cole shaft—1200 level, as large, irregular, light green masses.

*Denn shaft—3100 level,** deep green masses encasing euhedral pyrite.

*Lavender pit,** as large, irregular boulders with halloysite.

Lowell shaft—1300 level, as attractive white to green banded specimens with kaolinite and halloysite (Tenney, 1913).

Anatase TiO_2

A common alteration product of titanite in partially altered (sericite-chlorite) Juniper Flat granites (Sidney Williams, personal communication, 1981).

Andesine $(NaAlSiO_3O_8)/(CaAl_2Si_2O_8)$, 70-50 percent/30-50 percent

As small, but abundant phenocrysts with labradorite and hornblende in several surface dikes near the Shattuck, Wade Hampton, and Wolverine mines (Bonillas *et al.*, 1916).

Andradite $Ca_3Fe_2^{+3}(SiO_4)_3$

A hydrothermal alteration product with only two verified occurrences; however, it is certain to be more common.

Lowell shaft—800 level, 806 drift, as brown, fine-grained crystals with quartz (Tenney, 1913).
1000 level, found in the mule barn as green-brown crystals with sphalerite, pyrite, tremolite and quartz (Tenney, 1913).

Anglesite $PbSO_4$

An important ore of lead that is widely-distributed in the district.

Campbell shaft—1800 level, as large, black to gray crystals with cerussite. Also, as spearhead-shaped crystals with leadhillite (Anthony *et al.*, 1977).

Gardner shaft, black to gray bands surrounding galena.

Shattuck shaft—200 level, occurring as grains and large masses, mixed with cerussite sands.

Anhydrite $CaSO_4$

Junction shaft—1800 level, several small, light brown veins in a porphyry dike with pyrite.

Anthonyite $Cu(OH,Cl)_2 \cdot 3H_2O$

*Cole shaft—1300 level,** in a raise some 40 feet above the track, in an area between the Lowell and Dallas shafts. Occurs as a violet crust of corroded crystals to 1/5 inch on crumbly, cupriferous pyrite. This occurrence was on the edge of a sulfide stope that had burned many years before and was being re-opened. The mine walls were washed before much material could be collected.

Antigorite $(Mg,Fe)_3Si_2O_5(OH)_4$

Found near the numerous porphyry dikes and not uncommon in the Sacramento contact zone.

Cole shaft—1400 level, as a white-green, flaky material with pyrite.

Holbrook shaft—500 level, 555 drift, banded pink and green layers of platy antigorite with calcite, pyrite and hematite (Tenney, 1913).

Lowell shaft—1300 level, 13-9 stope, green radiating plates and needles with pyrite and chalcocite (Tenney, 1913).

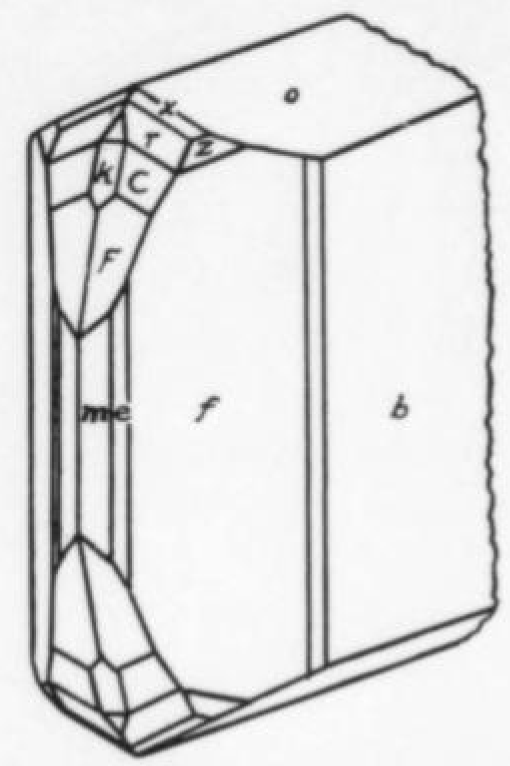


Figure 42. **Antlerite from Bisbee (Palache, 1939).**

Antlerite $Cu_3(SO_4)(OH)_4$

First described from Bisbee by Palache (1939a).

*Cole shaft—700 level, 99 stope,** translucent, deep-green acicular crystals of up to 4/5 inch with large cuprite crystals in a siliceous goethite.

*Lavender pit,** small, radiating groups with carbonate-cyanotrichite and copper.

Shattuck shaft, equant crystals on fine-grained brochantite.

Apatite $Ca_5(PO_4)_3(F,OH,Cl)$ (probably fluorapatite)

A very common constituent of the stock and numerous dikes, usually found as microcrystals with quartz, some feldspar, biotite and sericite.

Aragonite $CaCO_3$

One of the more spectacular minerals from the district, aragonite has been found in all of the major oxide zones. Occurring principally in the numerous caves associated with the larger oxidized ore bodies, it has several common forms. Stalactitic masses of incredible size are not unusual. Most attractive, however, are the other habits such as flos ferri, coralloidal, acicular and bladed. Commonly colored by compounds of copper and iron, these large groups are perhaps the finest known outside of Styria, Austria. Because of the wide-spread occurrence of this mineral, only a few important locations will be noted.

Cole shaft—800 level, as green acicular crystals on white calcite.

Czar shaft—200 level, white with red-brown flos ferri groups of a yard or more; colorless blades of 0.4 by 2½ inches, in large groups on iron-stained massive aragonite.

Shattuck shaft—300 level, oriented blades of 0.4 inch on helicitic calcite.

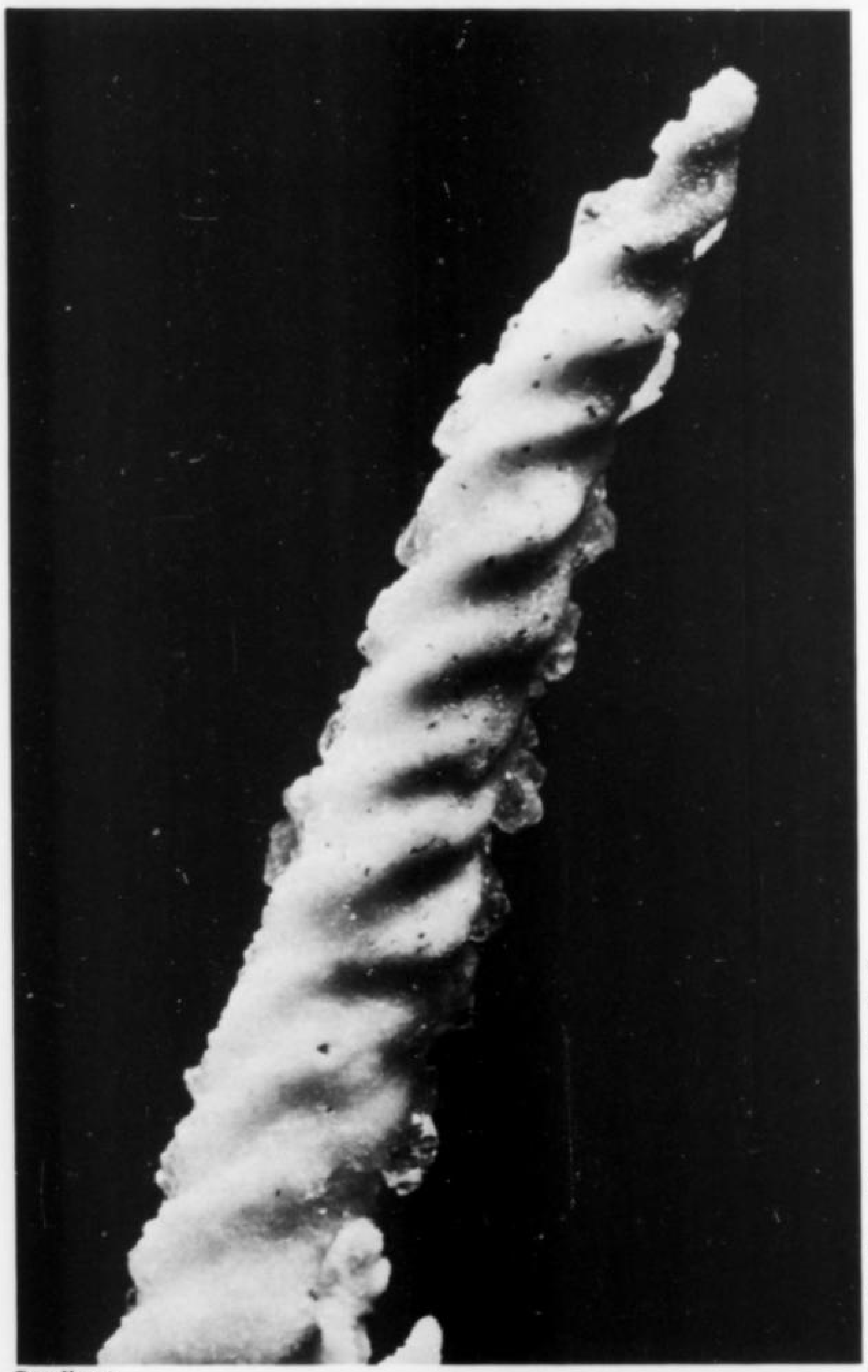
Southwest mine—4th and 7th levels, as colorless blades of up to 2½ inches in groups or oriented on botryoidal calcite. *6th level,* a unique area with helical intergrowths much like machine screws, with both right and left-handed twists on the same specimen. Some

Peter Kresan

Figure 43. **White aragonite crystal group 5 inches across, with minor brown dolomite, from the 7th level of the Southwest mine. Graeme collection.**

Peter Kresan

Figure 44. **Spiral aragonite cave formations, 7½ inches tall, from the 6th level of the Southwest mine. The cavern was discovered in the 1920's, and recently nine unusual specimens of spiral aragonite were collected there. The spiral growths occurred randomly mixed with other more common habits, and generally projected downward from the ceiling and horizontally from the walls. Both left and right-handed spirals are known, averaging 4 inches in length, to a maximum of 8 inches. Associated with minor rosasite and in some cases stained brown by iron oxides. Cause of the habit is unknown. Graeme collection.**



Peter Kresan

Figure 45. **A single spiral growth of white aragonite from a limestone cavern on the 6th level of the Southwest mine. Flecks of blue-green rosasite are associated; the aragonite growth is 3 inches tall. Graeme collection.**

of these were in excess of 8 inches in length and speckled with rosasite.

Atacamite $Cu_2Cl(OH)_3$

Cole shaft—700 level, 110 stope,* as fibrous tufts up to 0.1 inch with cuprite and hematite.

Czar shaft, blocky, 0.2 inch crystals with malachite on chrysocolla.

Shattuck shaft—400 level, very small crystals on siliceous hematite.

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

As a fine-grained constituent of a Precambrian diabase dike in the Pinal schist with olivine and hornblende (Bonillas *et al.*, 1916).

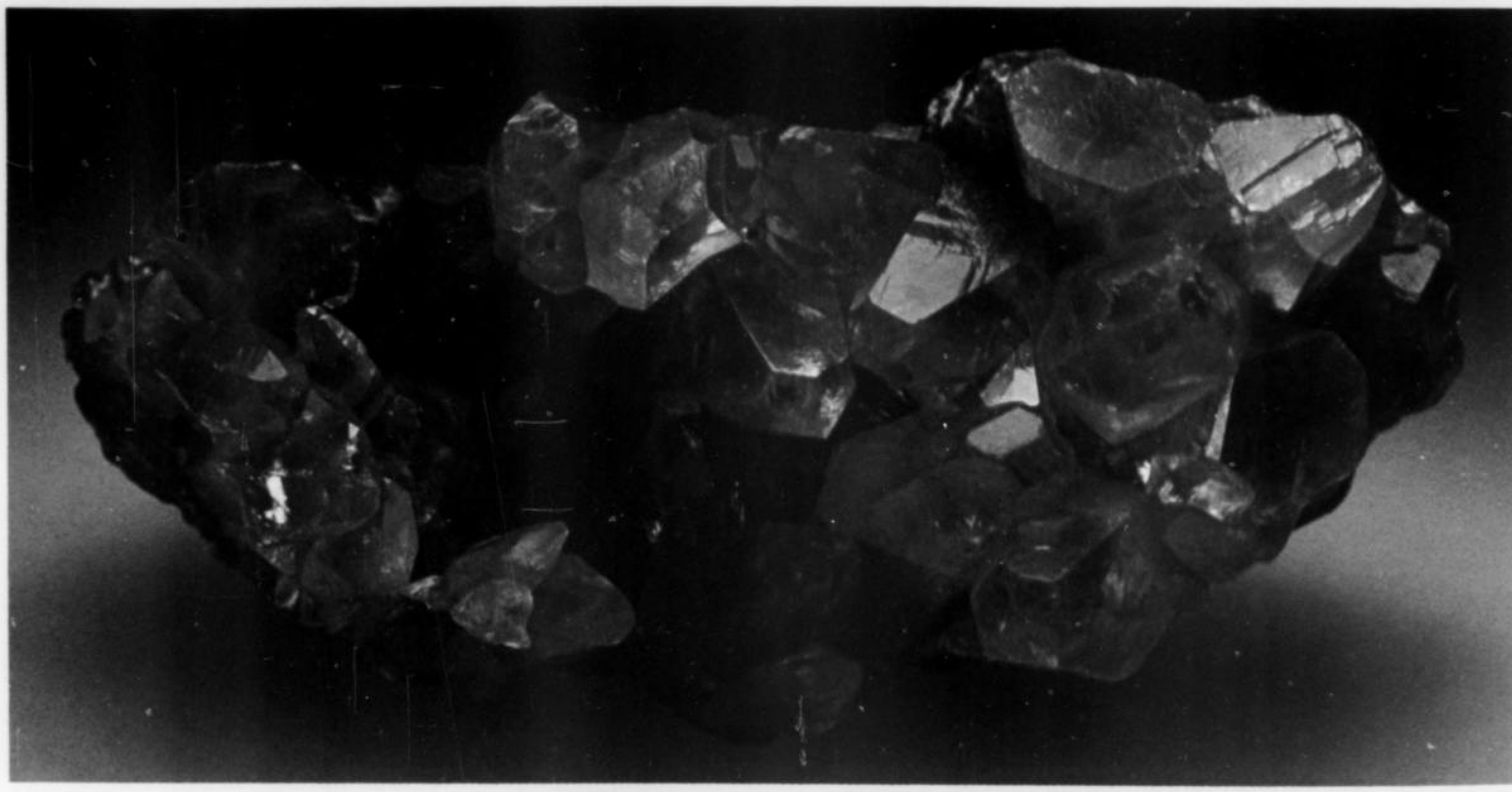


Figure 46. **Calcite with malachite inclusions, probably from the Southwest mine. Arizona-Sonora Desert Museum collection.**

Figure 47. **Calcite with malachite, 4 inches across, from the Southwest mine. Arizona-Sonora Desert Museum.**

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

Common as large, fine specimens. The most significant locations are:

Cole shaft—1200 level, 26J stope, as radiating, banded, reniform masses to 2½ inches thick with hemimorphite.

Copper Queen mine, in beautiful tubes lining cavities (Kunz, 1885).

Shattuck shaft, fibrous crystals up to 2 inches with dioptase.

Southwest mine—5th level, as acicular crystals in growths over a yard across with lace-like calcite that it frequently colors.

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

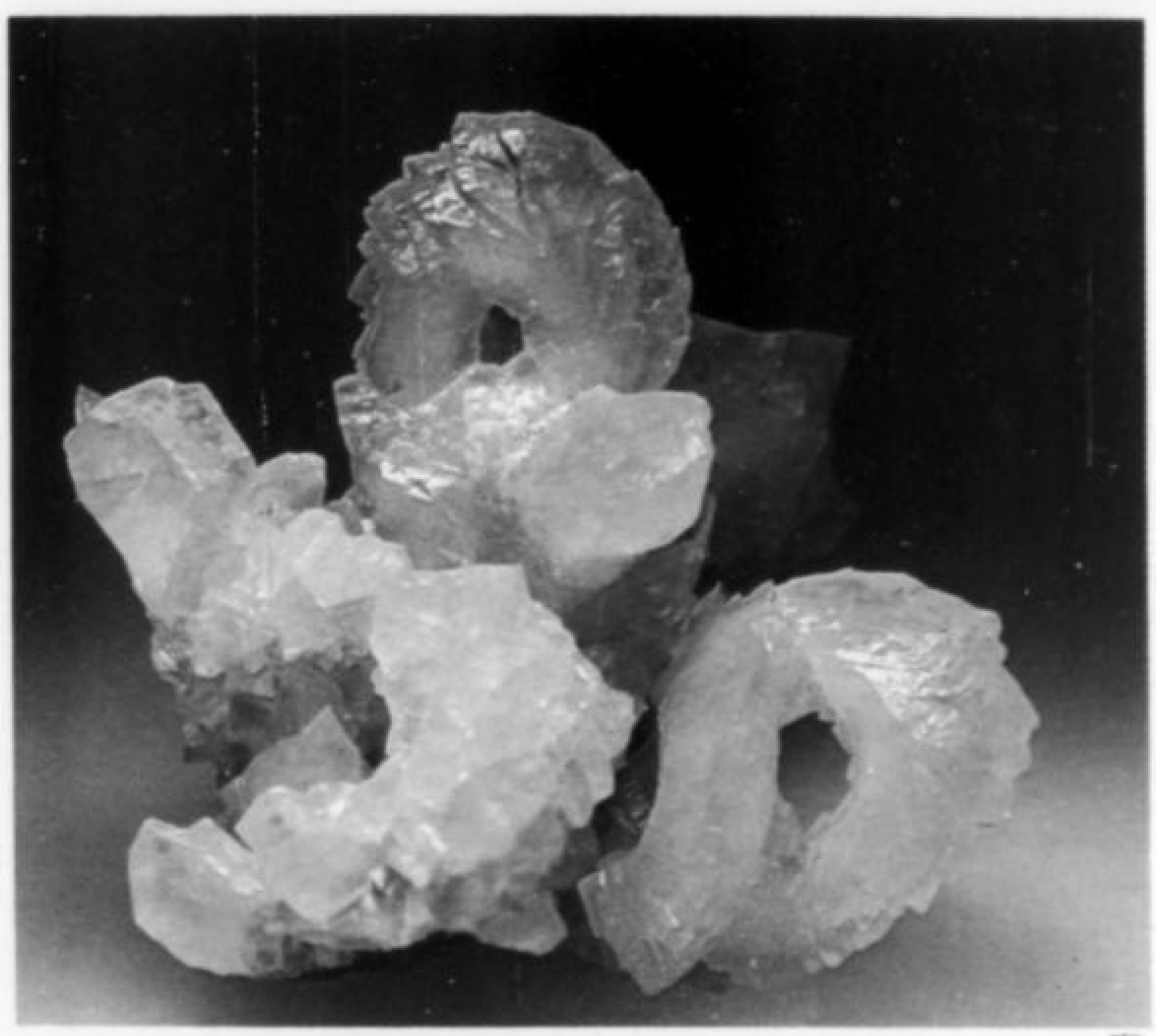
No other mineral is more closely associated with the mines in Bisbee than azurite. From its beginning, this district has almost continuously produced fine specimens. At no time during the almost 100 years of mining was there a span of more than just a few years when azurite was not being mined. The array of forms, range of hues, and the wide variety of associations, combined to produce Bisbee's most breathtaking masterpieces. Among the most common forms are: reniform masses, ranging from a very pale blue to near black; drusy or velvet; pisolitic sprinklings on malachite boxwork; spherical aggregates of crystals showing no point of attachment (rosettes); stalactites of up to 4 inches; tabular crystals to 3.1 inches; and bladed crystals to 4¾ inches.

A point of interest: the author has never seen a large (over 3 inches) crystal that is not actually a parallel, secondary growth on a pseudomorph of malachite after azurite. While a great many of the crystals appear to be single-generation azurite incompletely altered to malachite, a close examination of the interface between the azurite and malachite will show that the azurite is simply an incomplete overgrowth on a previous generation of azurite crystal that had been completely altered to malachite.

The list of associated minerals runs the gamut of secondary species, but the more common ones are malachite, hematite,

Figure 48. **Calcite crystals, some with limonite inclusions, 4⅓ inches across, from the 2700 level of the Campbell shaft. Arizona-Sonora Desert Museum collection.**

Figure 49. **Coiled calcite crystal aggregates from the 7th level of the Southwest mine, 2½ inches across. Arizona-Sonora Desert Museum collection.**



"limonite," "psilomelane," smithsonite, cerussite, cuprite, copper, chalcocite, calcite, quartz and chrysocolla.

Because every producing mine in the Warren district yielded good quality azurite, only the more prolific and classic locations are noted below.

Atlanta shaft—300 and 400 level. The great Atlanta orebody gave up deep blue, reniform masses commonly with equal amounts of malachite. These masses frequently weigh up to 220 pounds.

Campbell shaft—1600 to 2000 levels, found in the oxidized portions of the Campbell orebody along the Campbell fault. The area produced thousands of sharp singles and groups with individual crystals to 4 inches. Almost black, they always have the appearance of heavy alteration and are on, or have included, angular, siliceous fragments. Associated minerals include fine cerussite, smithsonite and hematite.

Cole shaft—800 level, as small rosettes to 2 inches.
1000 level, bladed groups with malachite and minor cuprite.
1200 level—141-F stope, as numerous, deep blue groups with later malachite and occasionally yellow, ⅛ to ⅕-inch smithsonite crystals.

Copper Queen mine, a prolific producer until its closure in 1888.
400 level, from the great Southwest orebody came masses of tabular crystals, intergrown to form small, open spheres dusted with tiny octahedra of malachite-coated cuprite. It occurs also as large plate-like groups of tabular crystals of up to 2 inches. They usually had a preferred orientation on limonitic matrix. Additionally, many botryoidal specimens with malachite were obtained.

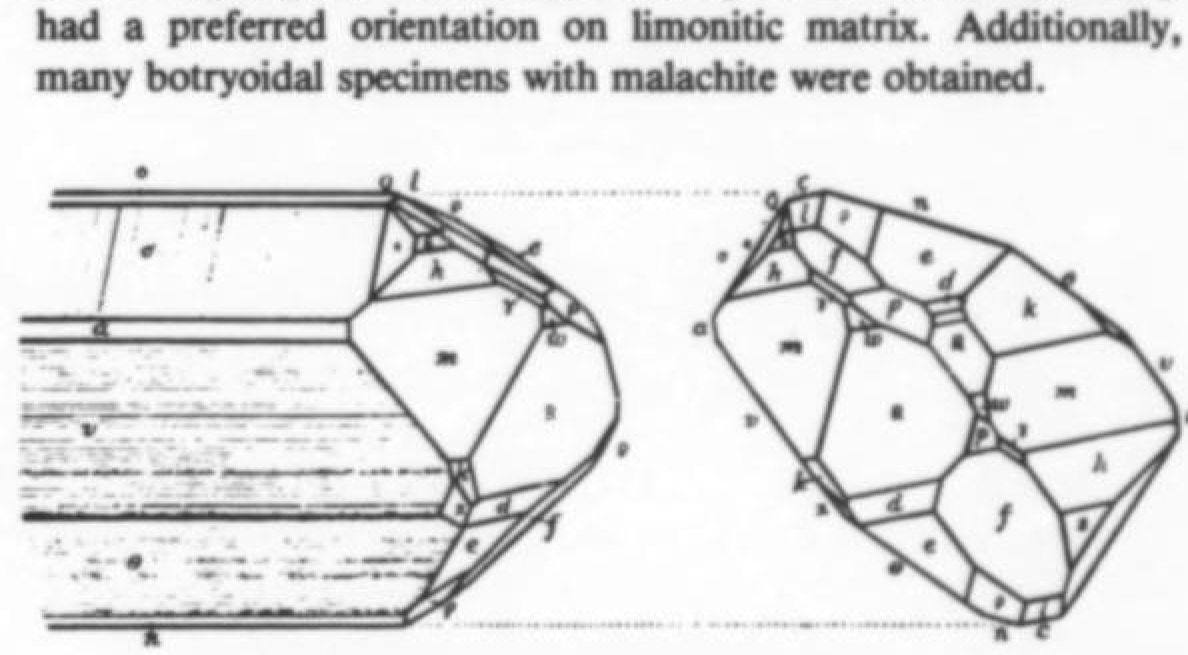


Figure 50. **Azurite collected from the "deep workings" of [one of] the Copper Queen mines in 1909. The specimen consisted of 2-inch azurite crystals on malachite pseudomorphs after azurite to 2¾ inches (Palache, 1927).**

Czar shaft, the most prolific and important locality in the district. It also exploited the Southwest orebody and produced groups similar to those of the Copper Queen mine.
100 level, in the Dividend zone, yielded numerous, small (8 inches) pockets of drusy crystals.
200-400 level, in a heavy, plastic, hematitic clay, many dark blue glassy rosettes of up to 6 inches. Often, a dozen of these were in a single shovelful of muck.
300 level, as huge masses of many tons with malachite and psilomelane. The pockets within these masses frequently contained stalactites and well-defined solution level lines commonly indicated by malachite deposition, a change in azurite hue and/or habit.

Figure 51. **A slab of azurite crystals, no matrix, probably from the 200 level of the Czar shaft. About 4½ inches tall. Formerly Don Olson collection, now in the Arizona-Sonora Desert Museum collection.**

Holbrook shaft; because of its proximity to the Czar, many similar samples were produced.
300 level, as thin, bright-blue, reniform specimens typically with malachite (zincian).
400-500 levels, as pisolitic deposits with some siliceous inclusions on boxwork malachite. Also found as faithful replacements of fossils in the Martin limestone.
500-600 level, 2 to 2½-inch crystals on a siliceous goethite.

Irish Mag shaft*—1050 level,* numerous groups of sharp, brilliant, 4/5-inch crystals.

Junction shaft*—770 and 900 levels,* bright blue partial overgrowth of reniform malachite in masses of up to 110 pounds. These striking specimens were on psilomelane which, when removed, revealed some unusual forms of exceptional beauty.

Lavender pit, large groups of pisolitic azurite on boxwork malachite and numerous reniform masses. Also, as 2/5 to 4/5-inch rosettes on yellow smithsonite and fine 4/5-inch crystals with malachite and cuprite in siliceous goethite boulders.

Sacramento shaft; the largest and finest crystals from the district came from this mine in a series of small, unconnected orebodies, from just above the 1200 level to areas below the 1400 level. While the groups were seldom large, and the crystals were usually poorly secured to the matrix, many specimens were recovered. These crystals were either tabular or bluntly terminated blades to 6 inches, always with the appearance of altering to malachite. The most common matrix was a very compact and somewhat siliceous limonite or hematite.

Shattuck shaft, highly crystalline reniform masses with later malachite.

Barite $BaSO_4$

Occurred as a vein and gangue mineral in the many near-surface manganese deposits.

Higgins mine*—tunnel level,* rough white to brown, bladed crystals of up to 4 inches. Also as a wide (3 feet) vein on the surface.

Lavender pit,* 1/5-inch, amber blades with azurite and malachite.

Basaluminite $Al_4(SO_4)(OH)_{10}\cdot5H_2O$

Lavender pit,* radiating spheroids with copper and hydrobasaluminite.

Southwest mine*—7th level,** white earthy dehydration product of hydrobasaluminite, with which it is associated in a heavy fault zone.

Bayleyite $Mg_2(UO_2)(CO_3)_3\cdot18H_2O$

Cole shaft*—800 level,** bright, yellow crust on compacted fault gouge near the Cole interior shaft.

Beudantite $PbFe_3^{+3}(AsO_4)(SO_4)(OH)_6$

Southwest mine*—6th level,** very small pseudocubic crystals and massive material, apple-green in color. Found associated with calcite in a calcite-cemented jarosite-silica breccia.

Bianchite $(Zn,Fe)SO_4\cdot6H_2O$

Noted only as a post-mining mineral.

Campbell shaft*—2000 level,** white crust on broken iron-rich sphalerite and chalcocite.

Junction shaft*—1600 level,** small, colorless stalactites.

Bindheimite $Pb_2Sb_2O_6(O,OH)$

Campbell shaft*—1800 level,** white, wart-like crust on malachite and chalcocite.

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

Widely distributed as a major constituent of most of the intrusive rocks and as an alteration mineral in the younger porphyry.

Bisbeeite $CuSiO_3\cdot H_2O$

A species of questionable validity. The Shattuck mine is the type locality (Schaller, 1915).

Shattuck shaft*—200 level, 174 prospect,* blue-white, acicular pseudomorphs of shattuckite with malachite and quartz.

Bixbyite $(Mn^{+3},Fe^{+3})_2O_3$

Shattuck shaft*—500 level,* as nearly pure, course grained masses (Sidney Williams, personal communication, 1981).

Boehmite $AlO(OH)$

A minor constituent of the pervasive alumina clays, it occurs with gibbsite and hematite.

Bornite Cu_5FeS_4

A very important ore mineral, usually massive and found associated with chalcocite, chalcopyrite, pyrite, and galena. Only several outstanding occurrences are noted.

Campbell shaft*—1600-2000 levels,* as incredible masses in the Campbell orebody. Often consisting of several thousand tons, they also contained chalcopyrite, chalcocite and pyrite.
2500 level, granular masses of poorly-formed crytals to 1/5 inch.

Cole shaft*—1400 level,39A stope,* superb crystals of almost 4/5 inch in groups. A few specimens were attractively associated with gold.

Junction shaft*—2500 level,* in masses of several hundred tons or greater; coarsely textured and highly colorful, half-inch-sized inclusions of chalcopyrite occur in these masses.

Botryogen $MgFe^{+3}(SO_4)_2(OH)\cdot7H_2O$

Campbell shaft*—2200 level,** a post-mining orange crust with copiapite.

Braunite $3Mn_2O_3\cdot MnSiO_3$

A common mineral in the many scattered manganese deposits.

Higgins mine, 300 feet above the tunnel level in an open cut with manganite, barite, quartz and conichalcite.

White-tailed Deer mine, large (1 inch) rough crystals in irregular replacement pods in limestone; a surface exposure (Anthony *et al.*, 1977).

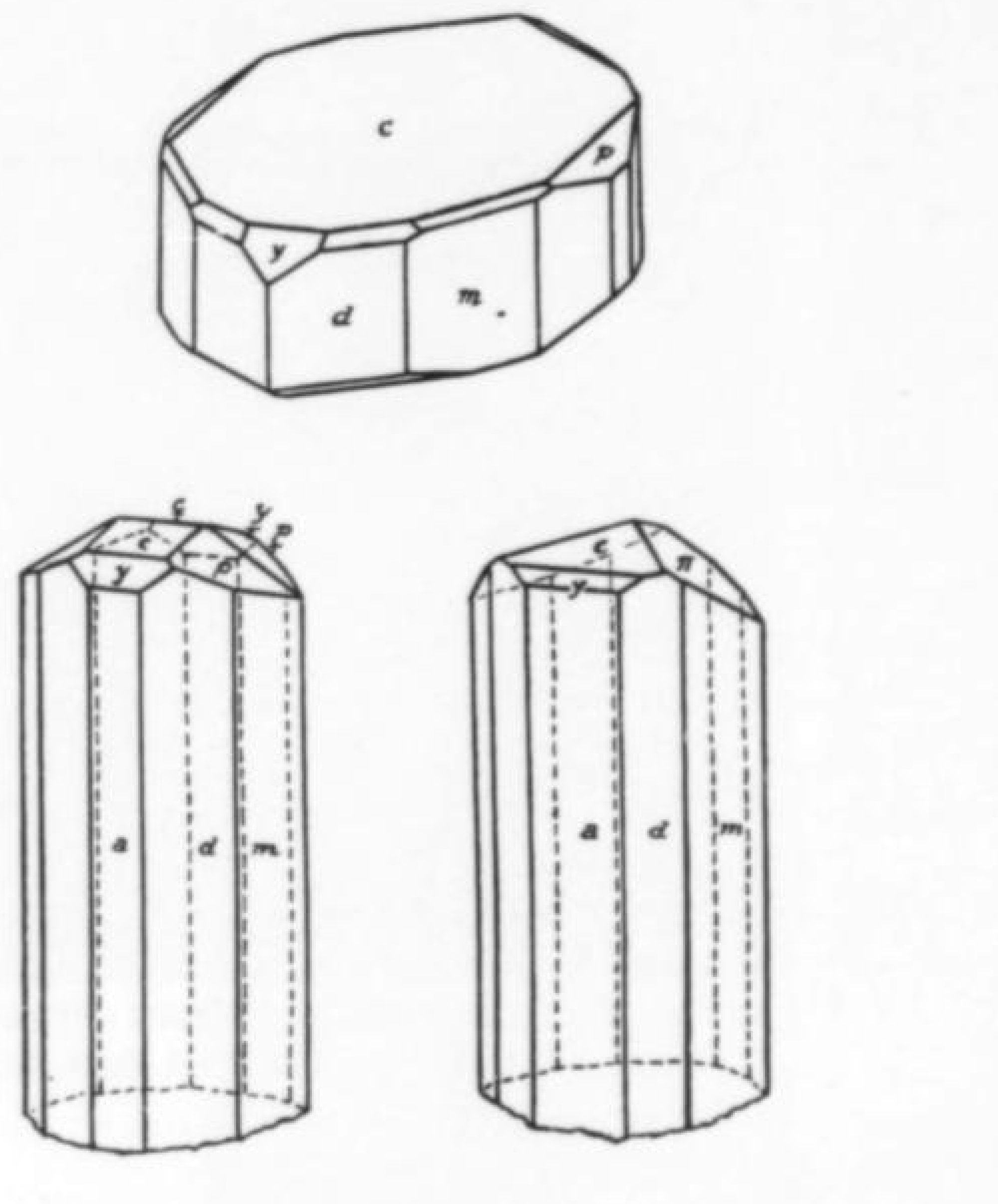


Figure 52. **Brochantite crystals from the Shattuck mine (Palache, 1939).**

Brochantite $Cu_4(So_4)(OH)_6$

Bisbee has produced what may well be the finest brochantite known. It was so common in several of the mines that it was an important ore. While it has been found in every mine in the district, it is seldom recognized because of its marked similarity to malachite. The most significant occurrences are listed below:

Czar shaft, very large, spongy masses of tiny crystals. The overall color of these pieces is a medium green, much lighter than the color normally associated with the mineral.

*Holbrook shaft,** fine groups of small (1/5 inch), prismatic crystals with cuprite and malachite. Also as acicular groups filling voids in goethite with azurite.

Irish Mag shaft, groups of prismatic crystals to 2/5 inch on hematite with minor malachite.

Lavender pit, acicular crystals and small prisms, filling pockets in a siliceous hematite with azurite, malachite, and cuprite.

Shattuck shaft; Bisbee's finest examples of this mineral came from this mine (Palache, 1939b).

300 level, superb groups of crystals of 3 by 1/4 by 1/4 inches in jackstraw intergrowths. These came from large masses of this mineral found adjacent to, or within, silica breccias. Consequently, the specimens are frequently united with specular hematite and siliceous breccia fragments.

Southwest mine—4th level, as spherical aggregates of prismatic crystals typically with specular hematite.

Uncle Sam shaft—"N" level, large amounts of a brochantite sand in a silica breccia.

Bromargyrite AgBr

*Cole shaft—700 level, 99 stope,** sharp lemon-yellow crystals of 1/10 inch on brilliant cuprite.

*Shattuck shaft—200 level,** partial replacements of silver.

Brucite $Mg(OH)_2$

Czar shaft—300 level, 293 drift, pale green, very small tabular crystals with chalcedonic quartz, kaolinite, limonite and copper (Tenney, 1913).

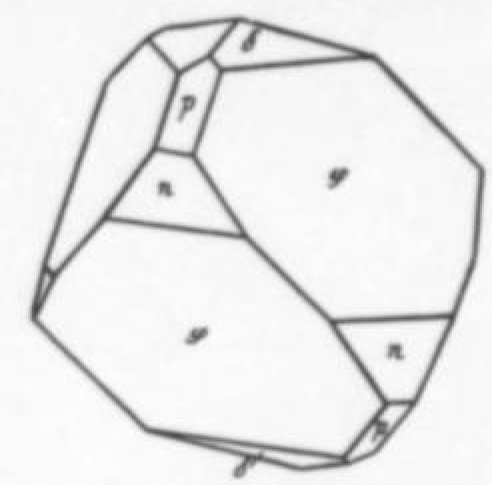


Figure 53. **Calcite crystal from Bisbee (Guild, 1911).**

Calcite $CaCO_3$

An extremely abundant mineral throughout the district. It is common as a hydrothermal mineral in veins cutting all rock types. However, the fine calcites for which Bisbee is noted are principally of secondary origin. Crystals are found as growths and linings in the several thousand caverns, water courses, and pockets discovered during mining. They exhibit a seemingly never-ending series of forms, habits and associations. The range of colors is incredibly varied with more than a dozen other species as inclusions known to impart their color to the calcite. Occasionally, several species will combine to give a multicolored crystal. Only the more significant locations are listed.

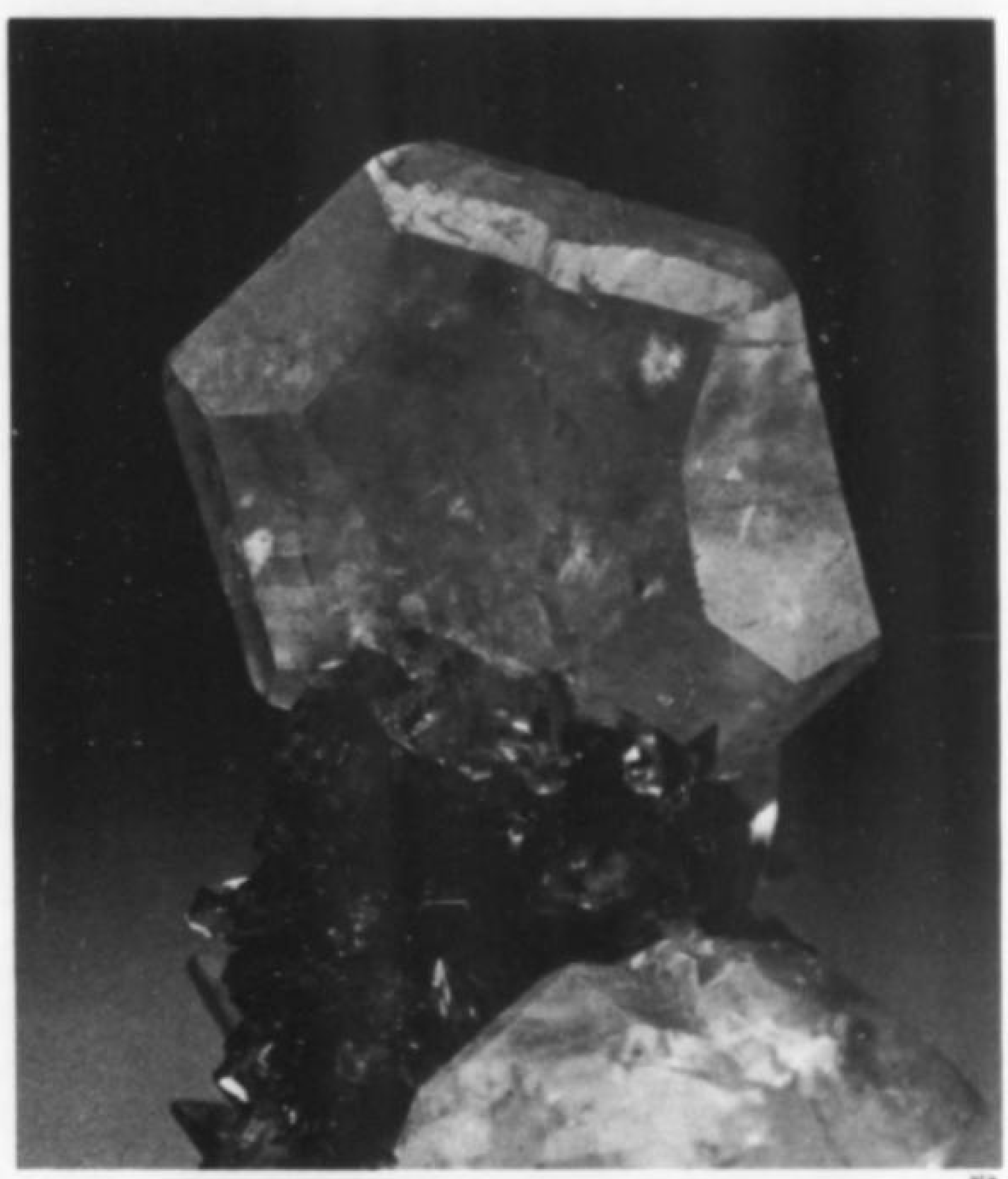


Figure 54. **A colorless, 1-inch calcite crystal on matrix from the Cole shaft, 1200 level. Melvin Elkins collection.**

Campbell shaft—1600-1900 levels, in the oxidized portions of the Campbell orebody.

1800 level, between the Dallas and Junction mines, as white, translucent, tabular blades of 2 to 4 inches on yellow-stained quartz.

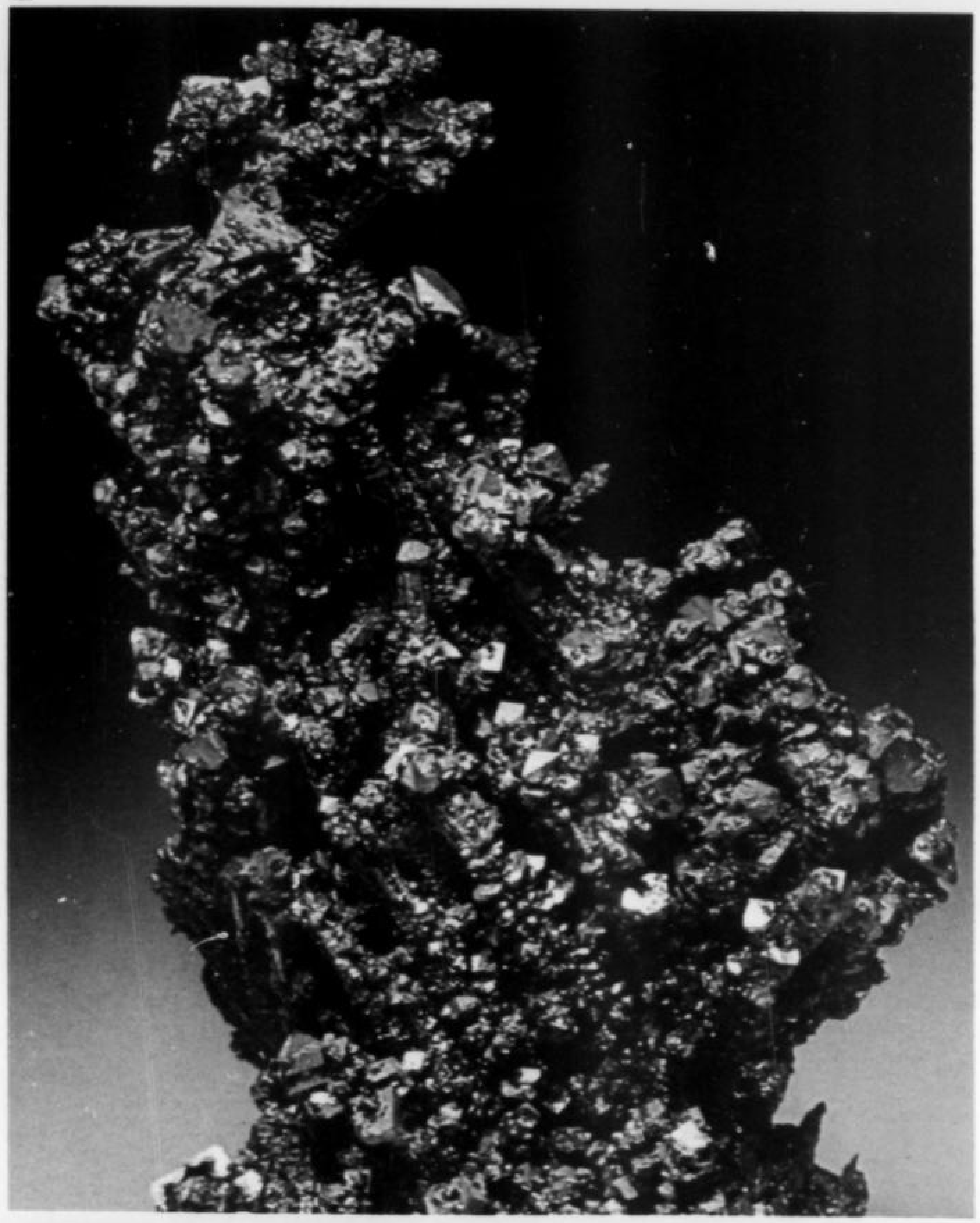


Figure 55. **Copper with cuprite, about 2 inches tall, probably from the Irish Mag mine. Richard Bideaux collection.**

Figure 56. **Copper pseudomorphs after cuprite to about ⅕ inch, from the Cole shaft. Richard Bideaux collection.**

Figure 57. **Cuprite with copper, about 3½ inches across, from the Dallas mine, 1400 level, 10-D stope. Graeme collection.**

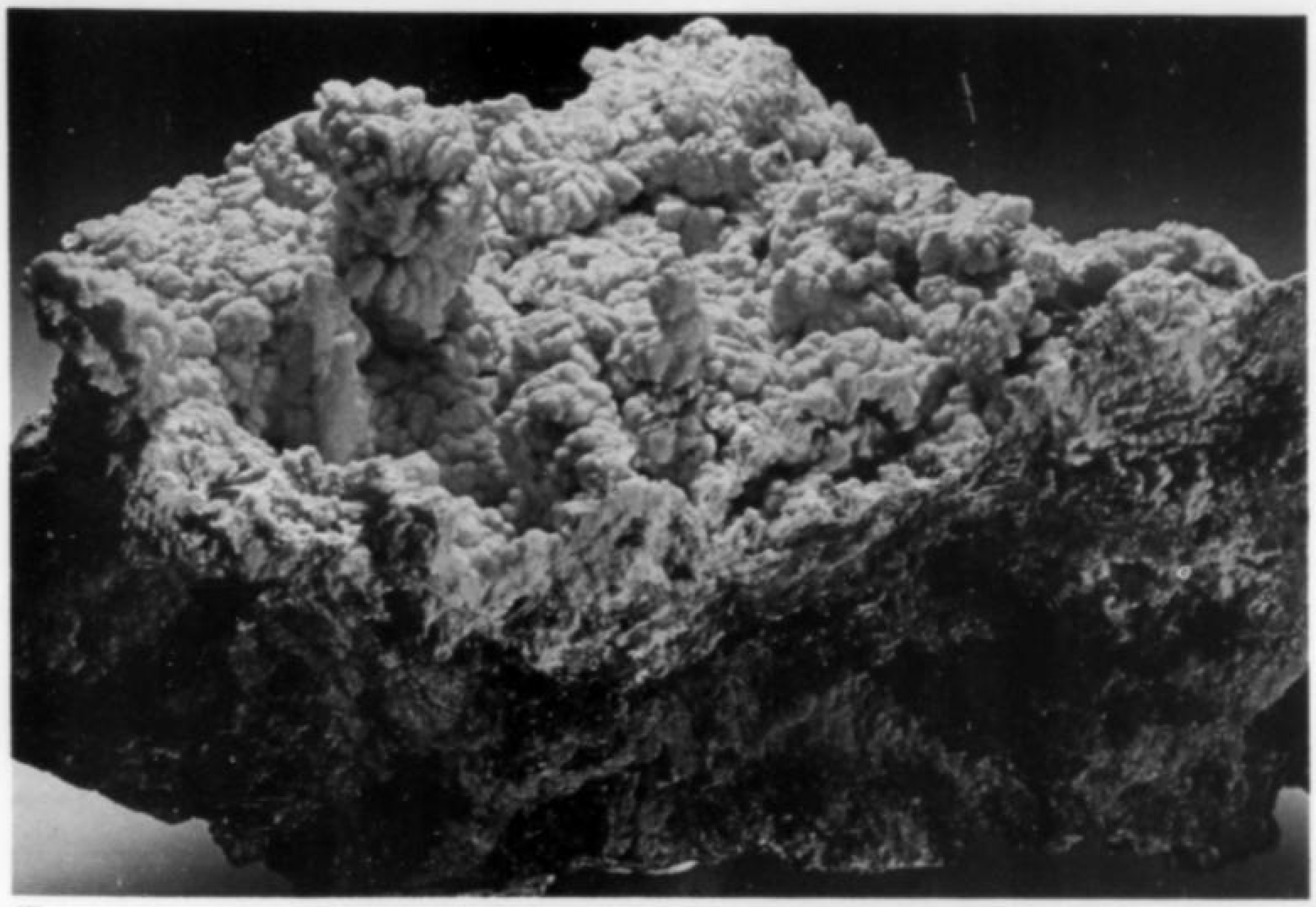
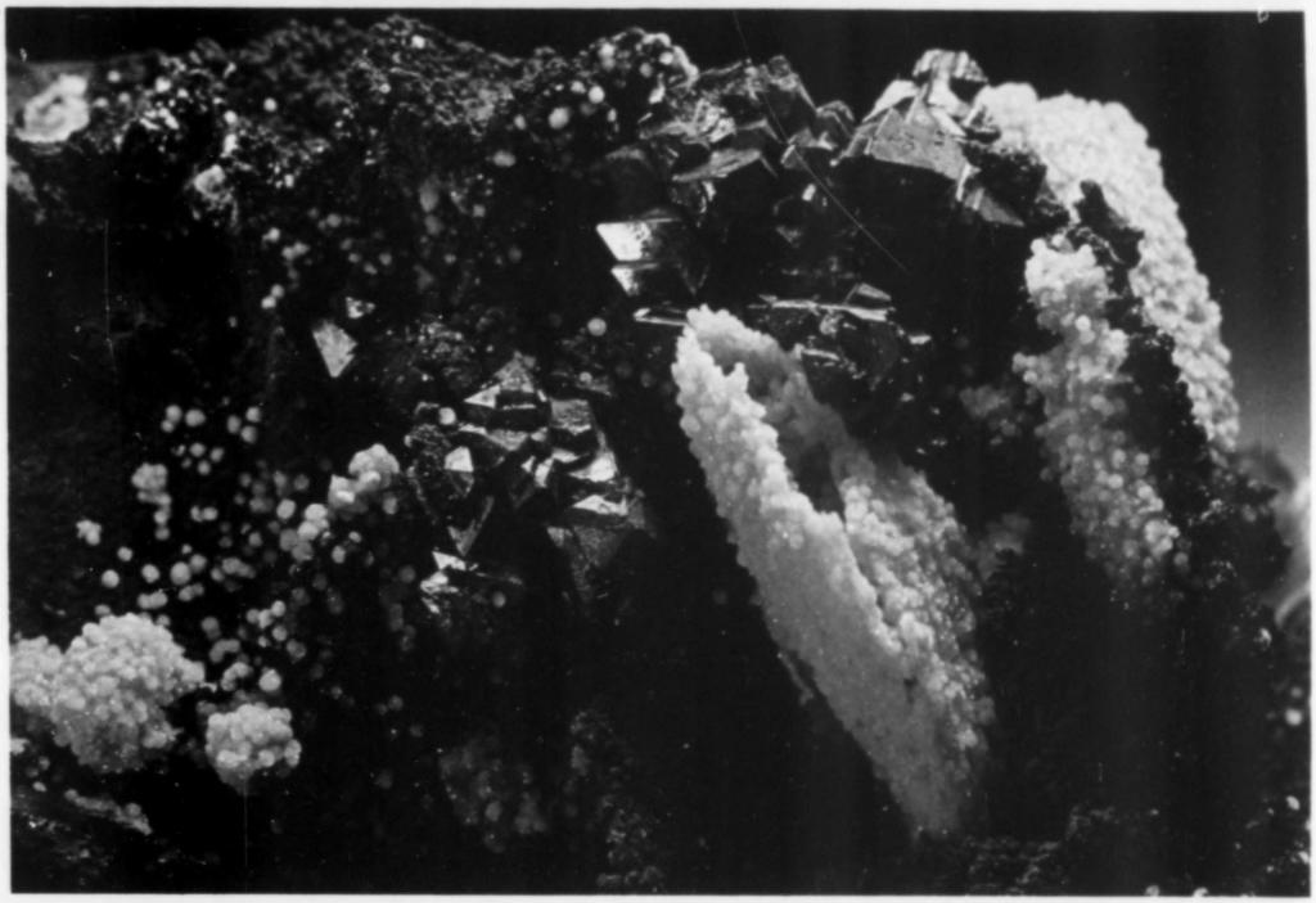


Figure 58. **Chalcoalumite on azurite and malachite, 3¾ inches across, from the Lavender pit. Graeme collection.**

Figure 59. **Chalcoalumite pseudomorphs after azurite crystals to ⅔ inch, with octahedral cuprite crystals, from the Lavender pit. Richard Bideaux collection.**



2200 level, near the Warren shaft, as amber-colored, 2¾ to 4-inch modified scalenohedrans lining a 65 by 33 by 3-foot watercourse.
2500 level, colorless, complex 1¼ to 2¾-inch crystals scattered across masses of ⅔-inch rhombs. A spectacular (11 by 26 by 5 feet) pocket was found containing pseudohexagonal tabular crystals, randomly oriented in unusual abstract forms and lightly coated with goethite.
2700 level, large complex crystals coated with goethite, lining a number of voids in the Denn sideline area.

Cole shaft; this mine has yielded a wide variety of forms and associations.
500 level, 1⅜-inch scalenohedrons in limestone near the Powell shaft.
800 level, groups of small, tabular blades with malachite. Also, as green-tinted stalactites.
1000 level, small, equant crystals over cuprite with azurite.
1200-1400 level, an unusually wide array of forms with malachite and copper from the 26-J, 26-K and 26-L stopes.

Copper Queen mine; the original Copper Queen orebody had an unusually large amount of calcite. A myriad of small, cave-like openings were encountered which contained calcite formations tinted with malachite. Also, colorless blades over malachite were common as were scalenohedrons with inclusions of fibrous malachite.

Czar shaft—200 level, with inclusions and overgrowths of copper, the encased copper being bright; inclusions of chalcotrichite-coated copper formed brilliant red groups to 10 inches.
300 level, as complex, colorless to amber crystals to 4 inches. Large (10-foot) copper and iron-tinted stalactites as well as pure white botryoidal masses.

Dallas shaft—1400 level, small crystals filled with bright copper.

Denn shaft—1700 level, elongated water-clear groups on copper.

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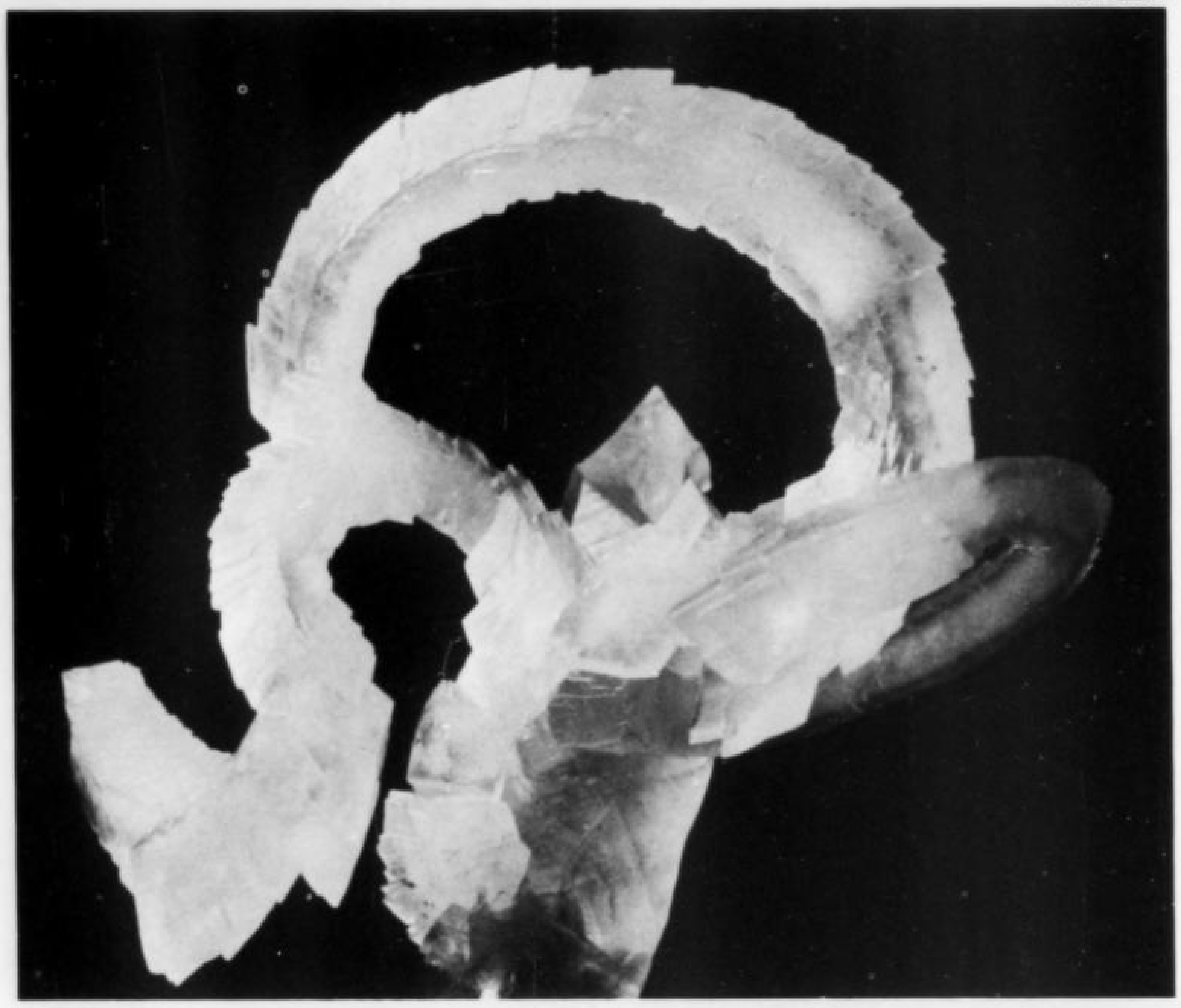

Figure 60. **Calcite crystals in curved, oriented aggregates, 2⅛ inches tall, from the 7th level of the Southwest mine. These coiled or curved composites occurred in cavities in a silica breccia over a zone extending from 20 feet above the 7th level to 15 feet above the 8th level. Typically the pockets would contain all normal rhombohedral crystals, except for one or two of these curved composites. The pockets were commonly up to 1 foot in diameter, but three pockets measured 6 feet across. The composites reach 20 inches in length and ¾ inch across. Cause of the habit is unknown. Graeme collection.**

Shattuck shaft—200 level, superb helictic groups of 10 inches or more. As stalactites of up to 10 feet with smaller ones, many colored by iron and copper. Also as small but lovely crystals with inclusions of both malachite and shattuckite.

300 level, gray lustrous groups with inclusions of cerussite sand.

Southwest mine; this extensive mine was the largest source of fine calcite. This is mainly because of the number of the large caves encountered.

10th level, complex groups overgrowing rosasite and hemimorphite.

7th level, multicolored formations in the many caves. Translucent green blades were colored with conichalcite. In the new Southwest orebody, botryoidal groups with individual spheres up to 2½ inches were found. Also as highly contorted growths of stcked rhombohedrons to 4 inches. Some of these form rings, others form spirals which change from right-handed to left-handed in the same stack. Additionally exceptionally large crystals (10 inches) were found in pockets lined with small scalenohedrons.

Canfieldite Ag_8SnS_6

Campbell shaft—2200 level, occurs with stannoidite and altaite interstitial to granular pyrite (Sidney Williams, personal communication, 1981).

Carbonate-Cyanotrichite $Cu_4Al_2(CO_3,SO_4)(OH)_{12}\cdot 2H_2O$

*Cole shaft—1200 level, 141F stope,** ⅖-inch fibers on goethite.

*Lavender pit,** small, radiating aggregates with copper and antlerite.

Celadonite $K(Mg,Fe^{+2})(Fe^{+3},Al)Si_4O_{10}(OH)_2$

Reported from the district (Anthony *et al.*, 1977).

Cerussite $PbCO_3$

Common in the area and important as an ore mineral; however, good specimens are unusual.

Atlanta shaft, cerussite sand in Hendricks Gulch on this claim.

Campbell shaft—1800 level, colorless to white sixling twins, often with anglesite, as groups or singles.

1900 level, small (⅕ inch) crystals with copper; also as ⅖-inch crystals with azurite and malachite.

Figure 61. **Cerussite crystal group 4 inches across, darkened with manganese oxides, probably from the Shattuck mine. Richard Bideaux collection.**

Cole shaft—1200 level, several fine V-twins 2 inches on each leg, colored a light red-brown.

Shattuck shaft—200 level, several hundred tons of cerussite sand with a few unattached, black sixling twins and boulders of anglesite with galena cores.

Cesarolite $PbH_2Mn_3O_8$

Reported from the district in the upper Paleozoic limestone (Hewett and Fleischer, 1960).

Chalcanthite $CuSO_4 \cdot 5H_2O$

Widely-distributed as a post-mining mineral; undoubtably, though, it has also occurred as a legitimate supergene product, but because of its common post-mining occurrences it remains unrecognized as such.

Campbell shaft, stalactites and crust in the abandoned workings on all levels.

2400 level, a stalagmite of several yards in diameter and almost 3 feet high was found in an old stope.

Cole shaft—800 level, compact fibrous growths 4 inches thick, in old stope fill.

Junction shaft—1500 level, stalactitic growths completely closing 42 crosscut.

1800 level, tabular crystals of up to 1⅜ inches in an old crosscut.

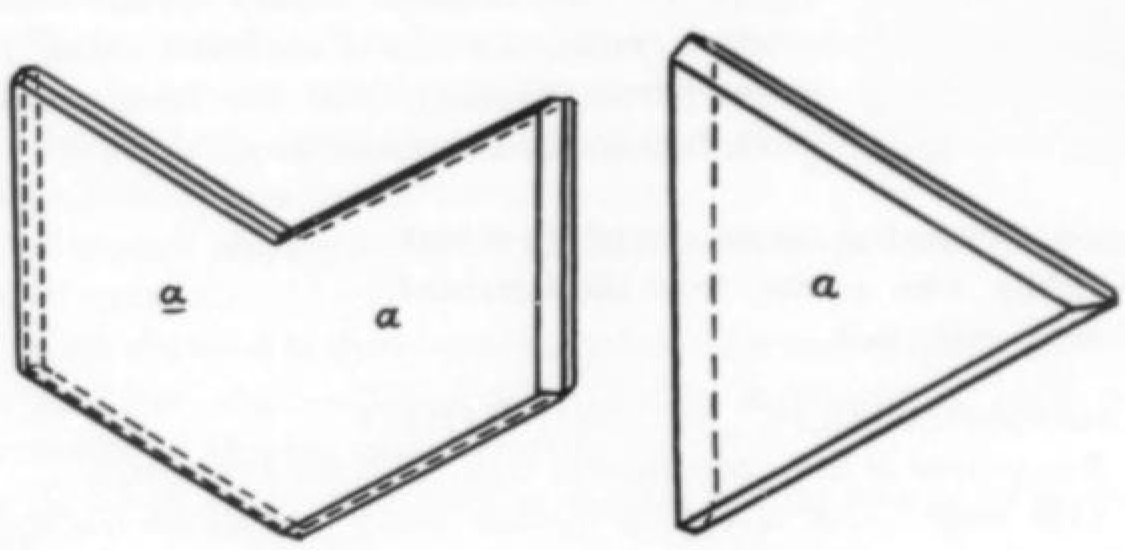

Figure 62. **Chalcoalumite from the Sacramento pit (after Williams and Khin, 1971). Left: twin on (13$\bar{6}$) and (010); right: twin on (100).**

Chalcoalumite $CuAl_4(SO_4)(OH)_{12} \cdot 3H_2O$

Bisbee is the type locality for this species and has produced the finest specimens known (Williams and Khin, 1971; Larsen and Vassar, 1925).

Copper Queen mine, large botryoidal crusts on limonite or as layers on malachite.

Czar shaft, found as crusts on malachite and azurite; probably formed at their expense.

*Holbrook shaft—300 level,** possibly the source for the type material. Found as crusts on malachite, as pseudomorphs after azurite and malachite, and as small stalactites in boxwork malachite.

*Lavender pit,** crusts on reniform azurite, often altered to gibbsite; as fine aggregates of very small crystals in siliceous goethite with cuprite; and in pockets with malachite (Williams and Khin, 1971).

Chalcocite Cu_2S

A widely distributed and important ore mineral, both in hypogene and supergene occurrences; the latter were much more important economically. Many underground orebodies were profitable to mine because of this mineral; the Sacramento pit as well as the later Lavender pit were dependent upon it. Chalcocite may well have been the most significant ore mineral in Bisbee. Because of its wide distribution and usually nondescript occurrence, only a few localities are mentioned here.

Campbell shaft—1600-1800 levels, several scattered locations with silver, malachite and chlorargyrite.

Figure 63. **Chalcocite crystals to 1/16 inch, from the 2566 level of the Campbell shaft. Melvin Elkins collection.**

2100 level, ⅛ to ⅜ inch, steel-gray prisms (Carl Trischka, personal communication, 1960).

2500 level, ¼-inch pseudohexagonal twins on massive bornite.

Cole shaft—800 level, massive with pockets of chlorargyrite.

1000 level, a pocket of crystals to 1¼ inches. Only two specimens were saved, as a curiosity, by the miners who did not recognize the significance of their find.

Junction shaft—1500 level, as massive material with malachite and silver.

Lavender pit, as the principal ore, coating pyrite and, occasionally, completely replacing crystals of up to ⅜ inch.

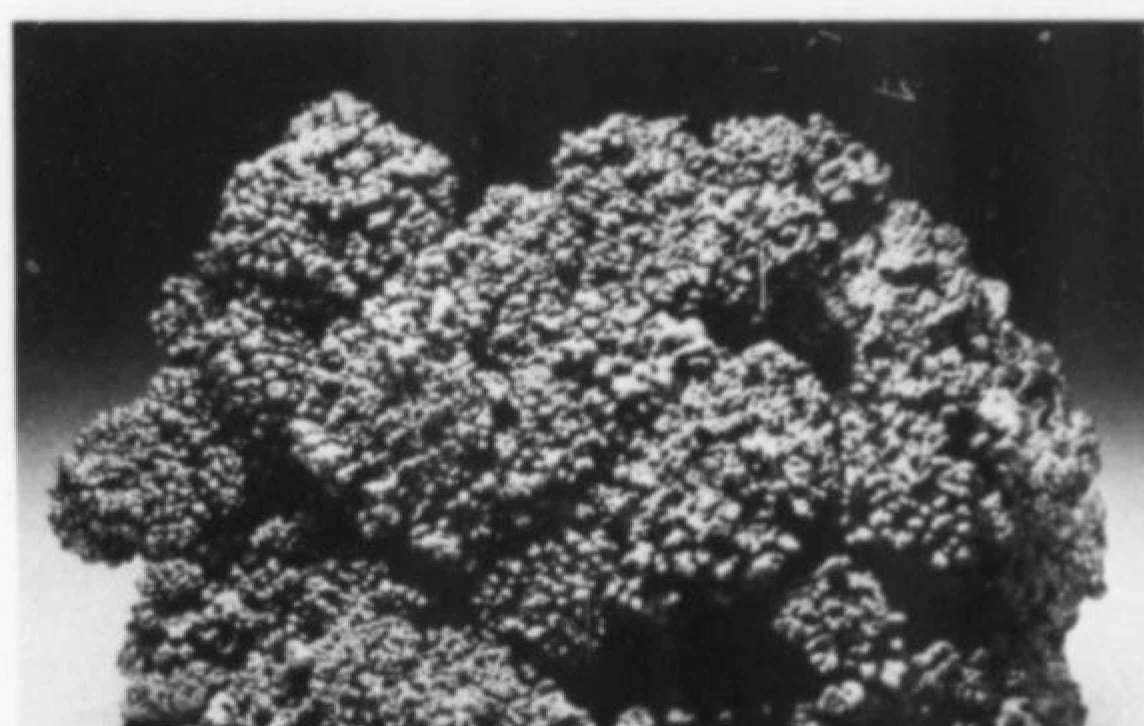

Figure 64. **Black chalcophanite 3½ inches across from the 14 crosscut, 1400 level, Cole shaft. Lawrence Banks collection.**

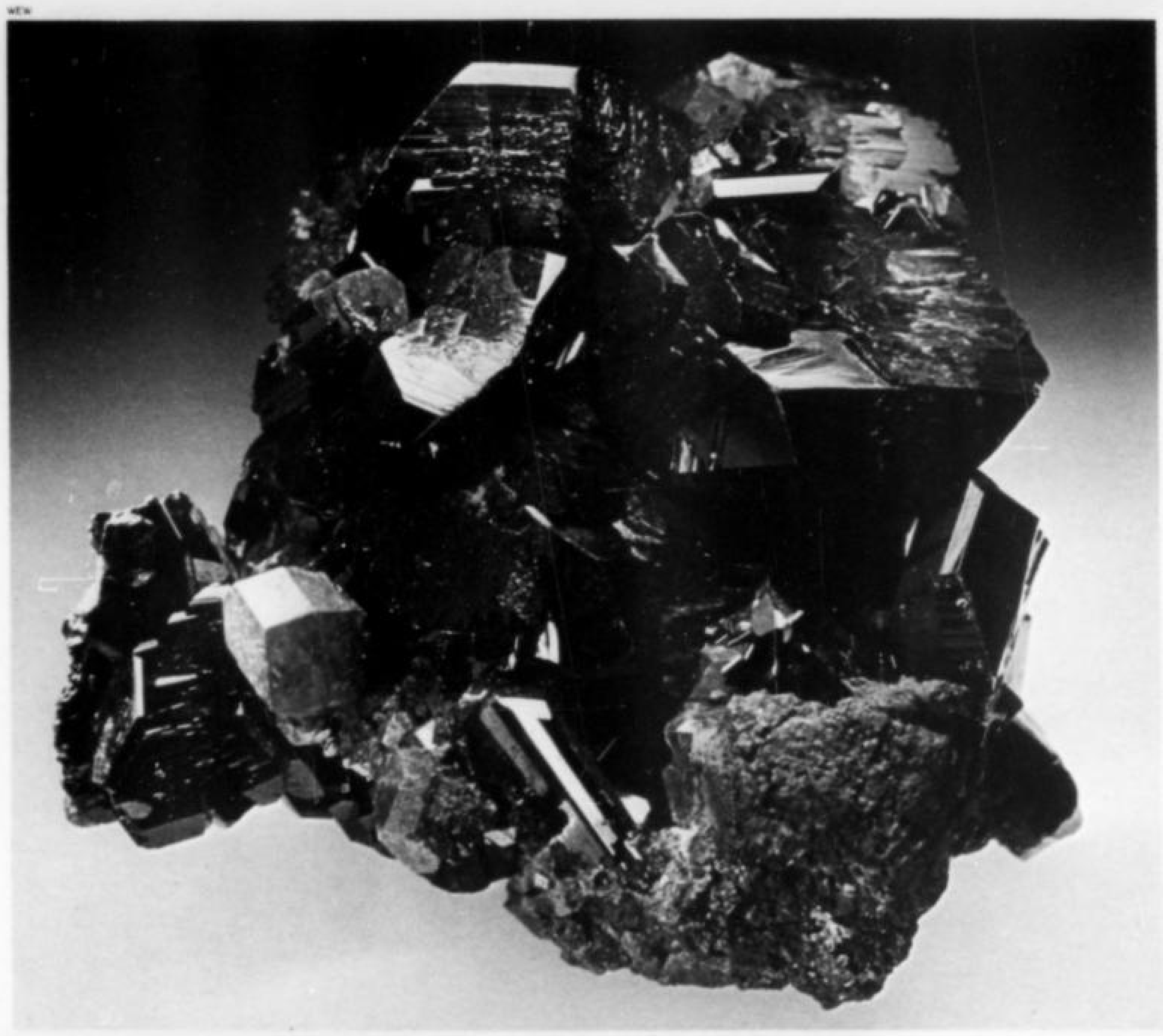

Figure 65. **Dodecahedral cuprite crystal with azurite crystals, the whole specimen about 2 inches across, possibly from the Sacramento shaft. Richard Bideaux collection.**

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Figure 66. **Octahedral cuprite crystals to ⅜ inch on malachite, with azurite, from the Lavender pit. Graeme collection.**

Chalcophanite $(Zn,Fe^{+2},Mn^{+2})Mn_3^{+4}O_7 \cdot 3H_2O$

Recognized in three occurrences only, all in the Cole shaft.

*Cole shaft—1300 level,** as 1/10-inch, sharp crystals on leached Martin limestone, 50 feet above the level. Also in 26-K stope as inclusions in hemimorphite and a coating on copper.

*1400 level, 7 crosscut,** with goethite as drusy, reniform and stalactitic groups in a small cave.

Chalcophyllite $Cu_{18}Al_2(AsO_4)_3(SO_4)_3(OH)_{27} \cdot 33H_2O$

Widely-distributed, but always in very small amounts (Palache and Merwin, 1909).

Figure 67. **Figure 71. Cuprite crystals to ⅛ inch from the Dallas mine, 1400 level, 10-D stope. Graeme collection.**

*Cole shaft—700 level, 110 stope,** sharp, blue-green hexagonal blades on several 2 to 2¾-inch specimens with cuprite and connellite.

1200 level, 202 stope, as numerous, scattered, bladed crystals with spangolite, connellite, cuprite and malachite.

Czar shaft—100 level, a thin crust of small crystals with connellite on cuprite and limonite.

Irish Mag shaft—1050 level, the most prolific source in the district. From an orebody of nearly pure cuprite, copper and limonite came specimens as scattered ⅛ to ⅓-inch blades with cuprite and connellite.

Chalcopyrite $CuFeS_2$

The most common hypogene ore mineral. Found as near-pure masses of many thousands of tons, associated with pyrite, bornite, chalcocite and quartz. In spite of its abundance, good crystals are exceedingly rare.

Campbell shaft—2966 level, 55 stope, iridescent sphenoidal crystals of ⅗ inch on small colorless quartz.

Chalcosiderite $CuFe_6^{+3}(PO_4)_4(OH)_8 \cdot 4H_2O$

Cole shaft—1200 level, in small amounts of green bladed crystals with quartz.

Shattuck shaft, reported from this mine (Anthony *et al.*, 1977).

Chlorargyrite AgCl

Widely-distributed throughout the district, and probably the source of most of the silver in the supergene ores.

Briggs shaft—1300 level, as microcrystals along fractures in a malachite, chalcocite and hematite ore.

*Campbell shaft—1600-1800 level,** common in small amounts with malachite.

Cole shaft—800 level, with malachite on massive chalcocite.

Junction shaft—1500 level, colorless cubes to ⅛ inch on malachite with silver and chalcocite.

Shattuck shaft, as cement in a silica breccia (Anthony *et al.*, 1977).

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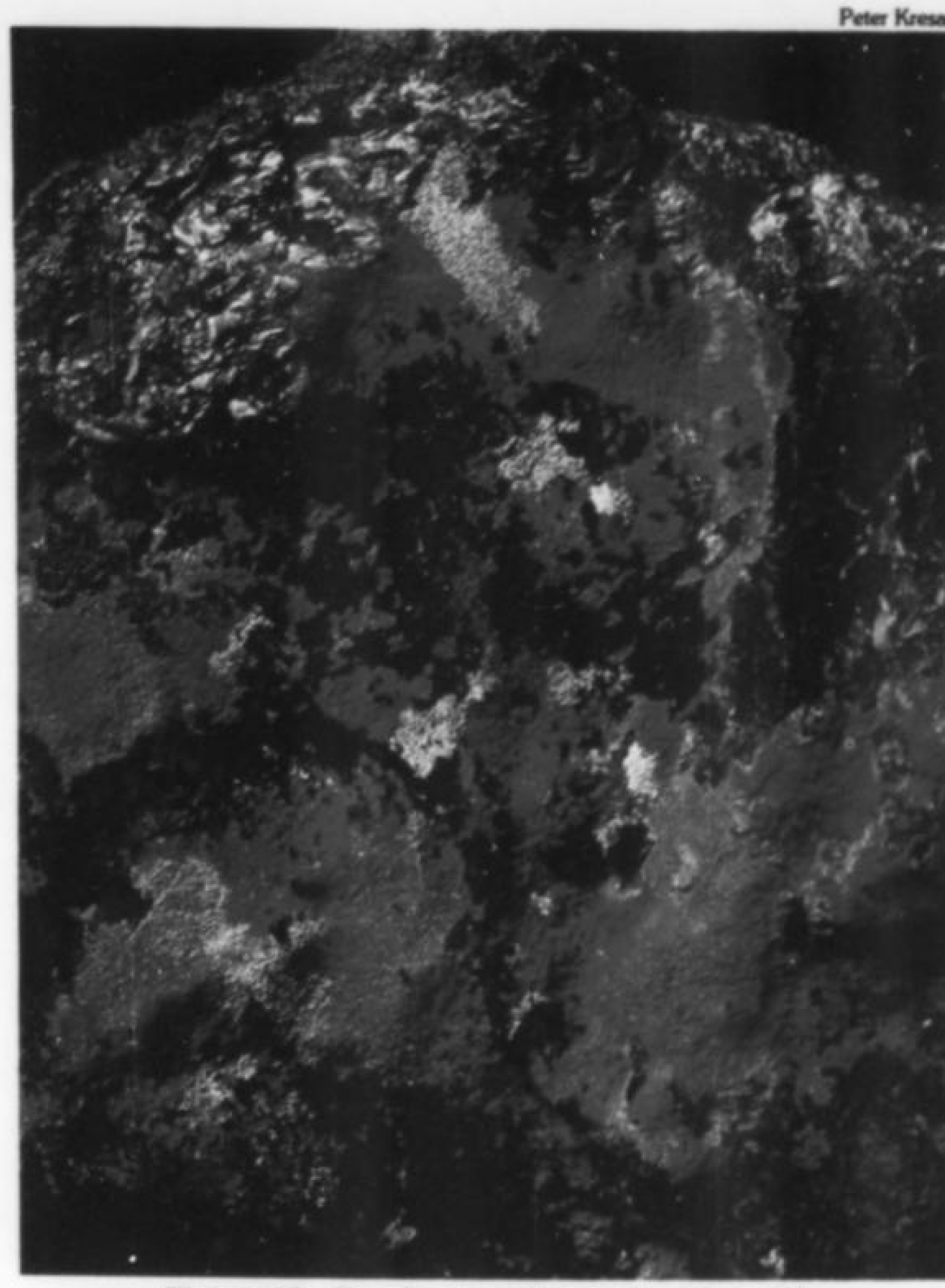
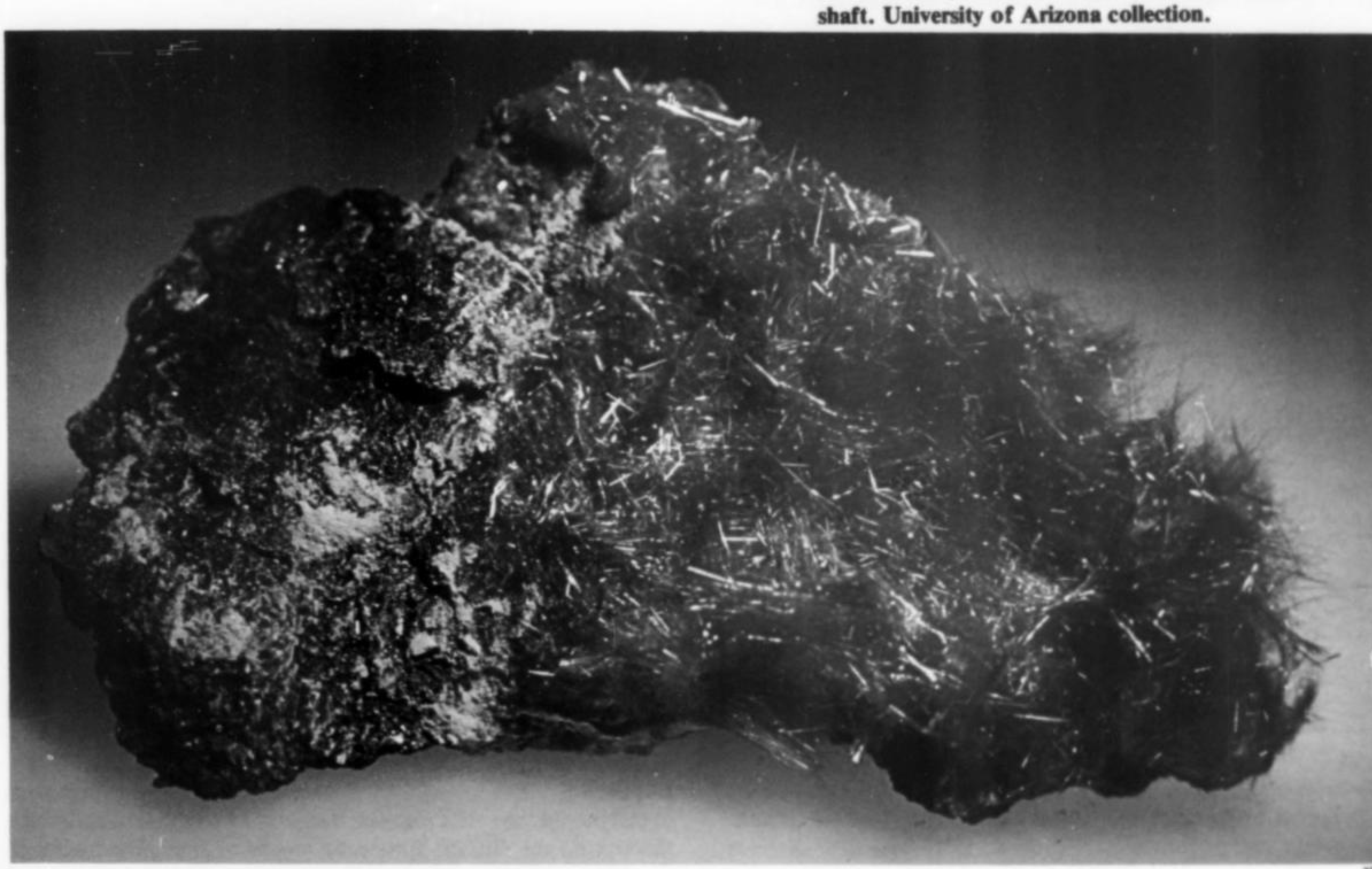


***Figure 68.* Cuprite pseudomorphs after delafossite, about 4½ inches across, from the Czar shaft. Graeme collection.**

***Figure 69.* Cuprite, variety chalcotrichite, 3¼ inches across, from the 1000 level of the Cole shaft. University of Arizona collection.**



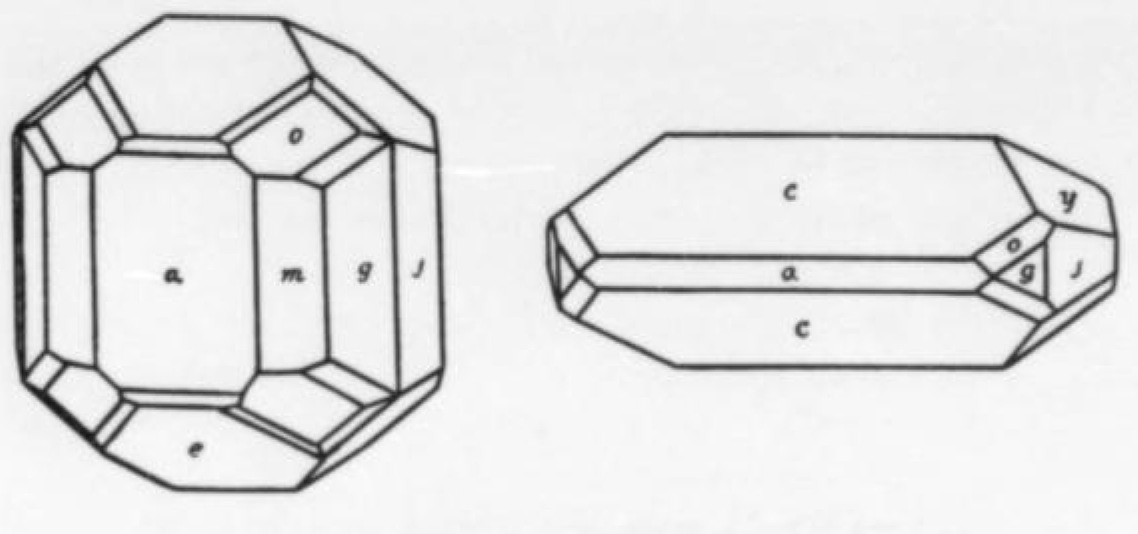


Figure 70. **Conichalcite (originally described as "higginsite") from the Higgins mine (Palache, 1920).**

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

Reported from the district, as *delessite* (magnesian chamosite) by Anthony *et al.* (1977).

Chromite $Fe^{+2}Cr_2O_4$

Reported from the district (Anthony *et al.*, 1977).

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

Ubiquitous in the oxidized ores, though seldom found as attractive specimens. It is known to occur with all of the principal oxide minerals. Apparently it is one of the last secondary minerals to form. Pseudomorphs of chrysocolla after malachite and azurite are common, azurite probably having been replaced by malachite first. Chrysocolla has been observed forming as a post-mining mineral of gelatinous character.

Cole shaft—1300 level, near the shaft, as a post-mining mineral.

Copper Queen mine, common in the ores and as remarkably pseudomorphs after azurite (1⅜ inches).

Czar shaft—300 level, as attractive specimens with tenorite and cuprite and as pseudomorphs after fibrous malachite.

Shattuck shaft, possibly more common here than at any other mine.
200 level, with shattuckite and as pseudomorphs after malachite.

Chrysotile $Mg_3Si_2O_5(OH)_4$

Probably somewhat common as the asbestiform serpentine found throughout the contact zone. However, only one location has been confirmed:

Gardner shaft—700 level, 748 drift, as 1⅝-inch fibers along a 33-foot zone flanked by tremolite and diopside (Tenney, 1913).

Cinnabar HgS

A slight dusting with pyrite on schist in a prospect on the southwest side of upper Tombstone Canyon.

Claringbullite $Cu_4Cl(OH)_7 \cdot \frac{1}{2}H_2O$

From a single specimen; as one or two small crystals in a pocket in massive cuprite (Sidney Williams, personal communication, 1981).

Clinochlore $(MgFe^{+2})_5Al(Si_3Al)O_{10}(OH)_8$

Common throughout the district as an alteration mineral with serpentine. Found with sericite north of the Dividend fault and also as matrix for a breccia in Brewery Gulch ("penninite," Anthony *et al.*, 1977). As a replacement of quartz in the contact zone around Sacramento Hill ("penninite," Bonillas *et al.*, 1916).

Cole and Dallas shafts, as coarse crystals formed during retrograde metamorphism of garnet-epidote tactites; commonly found in the deeper levels (Anthony *et al.*, 1977).

Chlinochrysotile $Mg_3Si_2O_5(OH)_4$

Lavender pit—Holbrook extension, as scaly micaceous intergrowths with stevensite (Anthony *et al.*, 1977).

Clinozoisite $Ca_2Al_3(SiO_4)_3(OH)$

Reported as pseudomorphs after biotite with chlorite, sericite, sphene, quartz and muscovite (Schwartz, 1958).

Conichalcite $CaCu(AsO_4)(OH)$

Found in almost all of the many scattered surface manganese deposits associated with braunite, psilomelane and calcite.

Higgins mine—300 feet above the tunnel level, in an open cut on the Twilight claim. As exceptional dark yellow-green prismatic crystals up to ⅜ inch. As a yellow-green fracture filling in massive braunite. At one time (Palache and Shannon, 1920) conichalcite from the Higgins mine was described as a new species named "higginsite" but was later recognized as conichalcite.

*Shattuck shaft—200 level,** bright, transparent ⅛ inch crystals with chrysocolla.

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

An uncommon, but surprisingly widely distributed mineral inevitably associated with cuprite. Bisbee has produced the finest connellite known in remarkably attractive specimens.

Cole shaft, several locations have produced fine specimens in this mine, the most important on the 1200 level.
700 level, 99 stope, and 110 stope, as radiating groups in massive cuprite with spangolite and minor chalcophyllite.
1000 level, free-standing acicular crystals to ⅛ inch in vugs in massive cuprite.
1200 level—202 stope, as several near-pure masses of radiating connellite of up to 2½ inches in diameter, and in masses of cuprite with pockets of acicular crystals with spangolite and chalcophyllite.

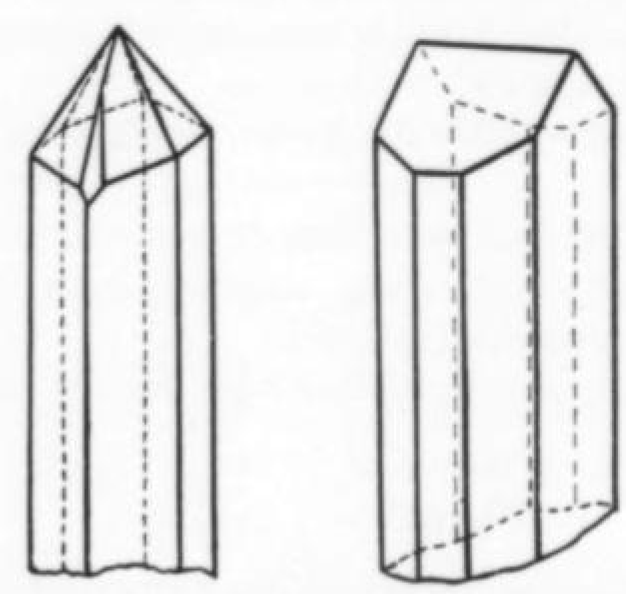


Figure 71. **Connellite from Bisbee; left: from the Copper Queen mine (originally described as "footeite" by Koenig, 1891); right: from the Lowell shaft (originally described as "ceruleofibrite" by Holden, 1922).**

Copper Queen mine, as unusually large acicular crystals with paramelaconite. Free-standing, radiating crystals to ⅗ inch on malachite-coated cuprite.

Czar shaft, with aurichalcite (Roberts *et al.*, 1974). In large nodules of cuprite and tenorite with spangolite.

Irish Mag shaft—1050 level, (Ransom, 1904).

Lowell shaft, as blue, fibrous crystals originally described as a new mineral, "ceruleofibrite," but subsequently recognized as connellite (Holden, 1922; Holden, 1924).

Southwest mine—5th level, as impressive aggregates of radial crystals in nodules of cuprite with tenorite and chrysocolla.

Copiapite $Fe^{+3}Fe_4^{+3}(SO_4)_6(OH)_2 \cdot 20H_2O$

Observed only as a post-mining mineral.

*Campbell shaft—2100 level,** bright yellow crystals on pyritic limestone walls of a crosscut.

Czar shaft—400 level, near the Gardner, as a yellow crust with coquimbite.

Junction shaft—1500 level, as a heavy crust with roemerite.

Copper Cu

Copper, as the native element, was found in important quantities throughout the district, apparently always of supergene origin. It

Figure 72. **Copper crystal, about 4½ inches long, from the 2200 level, Campbell shaft. Graeme collection.**

has long been recognized as an ore mineral, commonly disseminated in hematitic clays with cuprite. Almost always it is the oxide-zone mineral in closest proximity to sulfides. It is most often found below the carbonate and oxide ores as discussed by Douglas (Douglas, 1899).

Campbell shaft, as crystals coated with silver (Schwartz, 1934).
1900 level, 105 stope, as arborescent groups with numerous crinoid buttons.
2100-2200 level, as large orebodies of massive copper in hematite. Some 14,000 tons of the element were mined in these two stopes. Found as skeletal crystals of up to 4 inches and as groups of smaller skeletal crystals. Also found as highly crystalline masses with ⅗-inch crystals.
2966 level, as post-mining, crystallized specimens with cuprite and gypsum. Formed in copper-rich solutions, not as a replacement of scrap iron.

Cole shaft—600 level, as small, unusually bright, well-crystallized specimens.
1000 level, with cuprite and delafossite as cubic pseudomorphs of copper after cuprite.
1200-1300 levels, with malachite and calcite, some of which are the most attractive specimens ever recovered. Here crystals of up to 6⅗ inches were found in the 26k stope.

Copper Queen mine, common as arborescent groups.

Czar shaft—300 level, in the Southwest orebody as large, well crystallized masses (Douglas, 1899). An unusual occurrence of large crystals, some coated with silver, was noted by Petereit (1907).

Dallas shaft—1400 level, 10 stopes, in masses that exceeded 220 pounds; as small crystals in calcite.

Denn shaft—1700 level, common in groups of large, sharp crystals.

Hoatson shaft—1400 level, as spongy, malachite-coated specimens near the bottom of the Hoatson orebody.

Irish Mag shaft, as pseudomorphs after cuprite with cubes modified by octahedral and dodecahedral faces in cavities in limonite (Emmons, 1917).
1250 level, as fine crystalline groups with cuprite.

Lavender pit, found as large blackened masses, often with malachite and cuprite. Also fist-sized irregular masses with a radiating structure. Formed as a post-mining occurrence, filling cracks in and covering old mine timbers near the bottom of the pit.

Coquimbite $Fe_2(SO_4)_3 \cdot 9H_2O$

Campbell shaft—1800 level, originally yellow-green but colorless following dehydration, in needle-like crystals with roemerite.

Cole shaft—700 level,* yellow-green crust with voltaite.
*800 level,** green crust of an inch or two thick, covering large areas of massive pyrite with halotrichite.

Czar shaft—400 level, as exquisite lavender crystals on copiapite.

Cosalite $Pb_2Bi_2S_5$

Campbell shaft, as exsolutions in galena with aikinite, chalcopyrite, pyrite, and sphalerite (Fabien Cesbron, personal communication, 1981).

Covellite CuS

A widely occurring important ore mineral most often of supergene origin. Although common, attractive specimens are exceedingly rare.

Junction shaft—2000 level, a hypogene occurrence with one small pocket of ⅕-inch bladed crystals with pyrite.

Lavender pit—Holbrook extension, in the hanging wall of the Dividend fault. Large amounts of massive, deep blue-black covellite were mined with silver along many of the fractures.

Cuprite Cu_2O

Cuprite is one of the most common secondary minerals in the district. It was possibly the most economically important non-sulfide mineral. Bisbee's cuprites are among the finest in the world, and the acicular variety *chalcotrichite* is unequalled anywhere. Only those areas that produced outstanding specimens will be covered here.

Cole shaft—1000 level; Bisbee's finest chalcotrichite. Specimens of up to 26 inches across with free-standing, hair-like crystals of 1¼ inches on limonite were recovered in quantity. Also found were mats of coarse, intergrown, elongated cubes. Pseudomorphs of cuprite after delafossite on goethite were abundant. An unusual occurrence of elongated cubes with delafossite in quartz-lined fossils was found in the Naco limestone.

Czar shaft—300 level, as ⅕-inch cubes covering and seemingly oriented on sharp crystals of copper.
400 level, crystal-lined pockets in small, irregular pods (8 inches) of cuprite. These crystals were typically ¼ inch or larger and brilliant, frequently associated with connellite.

Dallas shaft—1400 level, 10 stopes, as ⅛ to ⅕-inch brilliant cubes on wire-like copper with numerous siliceous fragments.

Denn shaft, fine groups of simple cubes to ⅗ inch in massive hematite with copper.

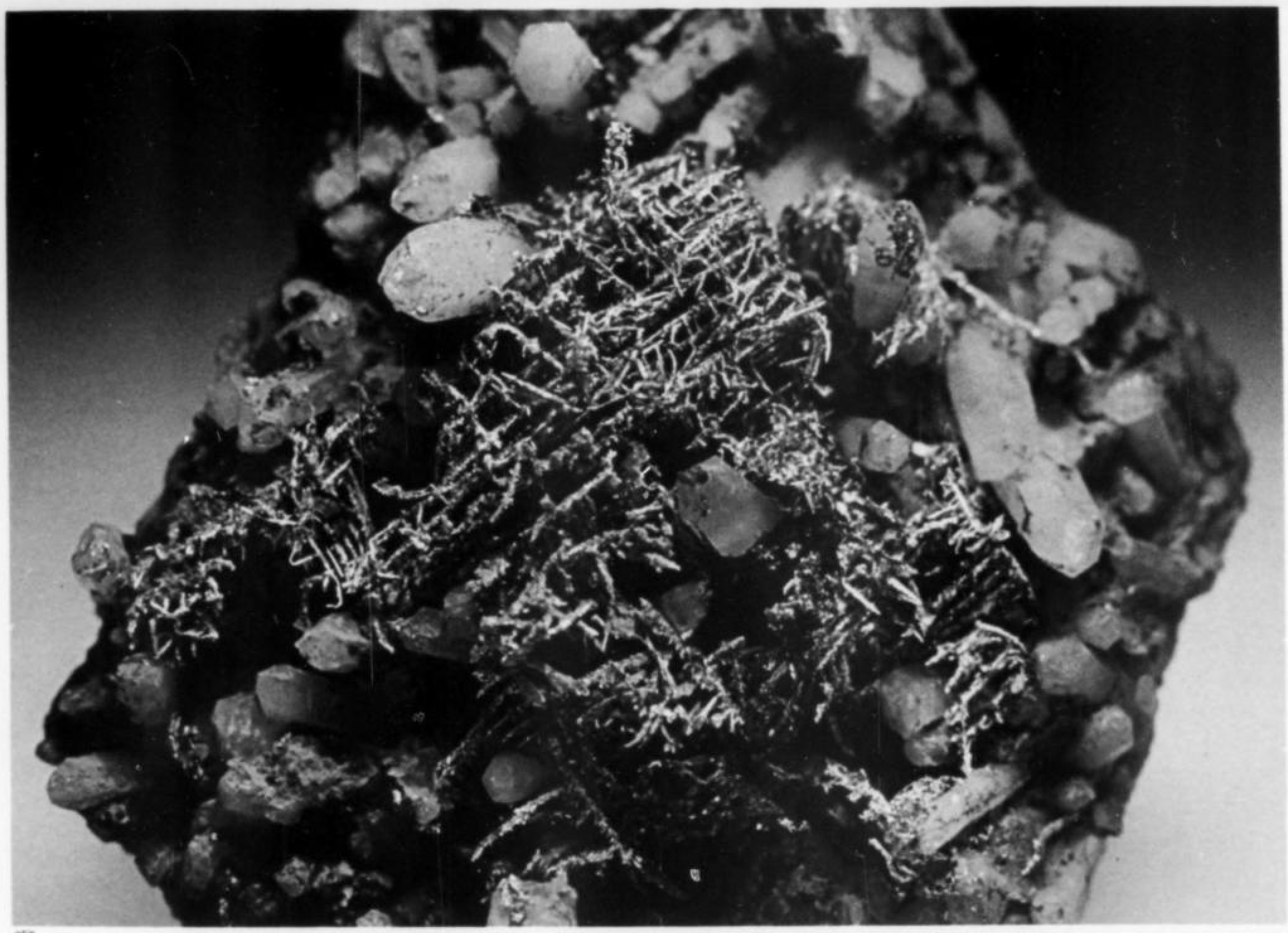


Figure 73. **Gold crystals on quartz matrix about 2 inches tall, from Shattuck mine. Arizona Bank collection, Bisbee.**

Holbrook shaft, nice specimens of chalcotrichite with calcite. Fine cubic crystals on hematite and pockets of crystals in massive cuprite and copper were found.

Irish Mag shaft, this is the district's locality for the finest cuprites. Fine, modified cubes to ⅜ inch on goethite and 1¼-inch simple cubes in massive cuprite-hematite ores. Occurred as large arborescent masses of copper completely covered with drusy cuprite. Often found as large crystals filling voids in spongy copper.

Lavender pit—Holbrook extension, as boulders of 10 tons or more of massive cuprite and copper. These large masses contained many pockets of small (¼ inch) crystals as cubes, elongated cubes or dodecahedrons. Some of these pockets reached 8 inches in size. Also as brilliant, sharp octahedrons to ⅗ inch in a siliceous goethite with azurite, malachite and chalcoalumite.

Southwest mine—5th level, as irregular pods of massive cuprite within tenorite, chrysocolla and kaolinite. Voids in these masses commonly contained fine crystals ⅕ to ¼ inch in size.

Cyanotrichite $Cu_4Al_2(SO_4)(OH)_{12} \cdot 2H_2O$

Lavender pit,* as bright blue, acicular growths covering malachite and azurite, sprinkled with later azurite crystals.

Delafossite $CuFeO_2$

Common in small amounts.

Cole shaft—1100 level,* as superb specimens of brown-black, tabular, hexagonal plates to ⅗ inch with small cuprite crystals.

Hoatson shaft—1400 level, with kaolinite, copper, cuprite and hematite (Rogers, 1913).

Descloizite $PbZn(VO_4)(OH)$

Dallas shaft, reported from here in small amounts (Bonillas *et al.*, 1916).

Higgins mine—tunnel level,* as tabular, red-brown blades in a breccia.

Shattuck shaft, noted in considerable amounts (Bonillas *et al.*, 1916).

300 level, as brown drusy crusts from a cave. As stalactites of a few inches in length (Anthony *et al.*, 1977).

Sacramento shaft, in minor amounts (Bonillas *et al.*, 1916).

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

Reported from the district (Anthony *et al.*, 1977).

Diaspore $AlO(OH)$

As a microscopic constituent of sericitized quartz monzonite (Anthony *et al.*, 1977).

Dickite $Al_2Si_2O_5(OH)_4$

Lavender pit, as a dense, white, earthy material cementing massive pyrite (Anthony *et al.*, 1977). Also as a white to gray

Peter Kresan

Figure 74. **Green graemite pseudomorph after a prismatic teineite crystal ¾ inch long, with red cuprite, from the 1200 level of the Cole shaft. Graeme collection.**

material encasing euhedral octahedrons of pyrite (5/8 inch).

Digenite Cu_9S_5

Reported from the district with djurleite (Roseboom, 1966).

Diopside $CaMgSi_2O_6$

An extremely common alteration mineral in the contact zone around Sacramento Hill. Associated with epidote, garnet, magnetite and tremolite.

Dioptase $CuSiO_2(OH)_2$

Known from one location only:

Shattuck shaft, as small crystals on massive aurichalcite with a matrix of specular hematite and breccia fragments.

Djurleite $Cu_{31}S_{16}$

Associated with digenite (Roseboom, 1966).

Dolomite $CaMg(CO_3)_2$

Occurs district-wide as dolomitic beds in the Martin limestone.

*Campbell shaft—2833 level, 9 crosscut,** as pockets of tiny crystals in very pure, massive dolomite.

*Southwest mine—7th level,** as white to tan overgrowths on the tips of large aragonite crystals.

Edenite $NaCa_2(Mg,Fe)_5Si_7AlO_{22}(OH)_2$

Lowell shaft—800 level, 820 drift, as fibrous white to gray material with tremolite and kaolinite (Tenney, 1913).

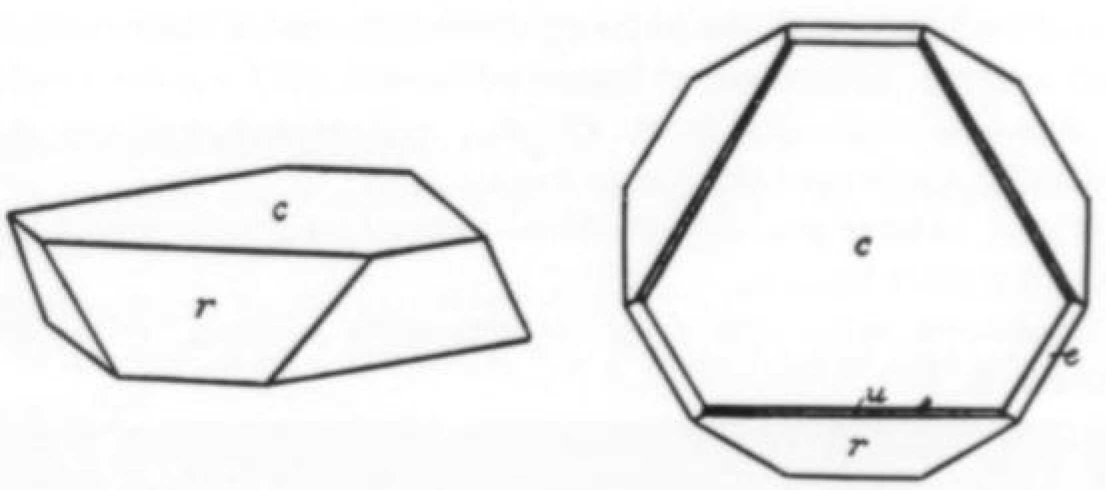


Figure 75. **Delafossite crystals from the 14th level, Hoatson shaft, found with kaolinite, copper, cuprite and hematite (Rogers, 1913).**

Embolite $Ag(Cl,Br)$

Campbell shaft, as yellowish modified cubes on malachite (Roberts *et al.,* 1974).

Enargite Cu_3AsS_4

Campbell shaft—1700 level, as small, rounded spots in chalcocite with tetrahedrite, tennantite and minor famatinite in chalcocite veins cutting bornite (Schwartz and Park, 1932).

Enstatite $Mg_2Si_2O_6$

A rock-forming mineral in the district (Anthony *et al.,* 1977).

Epidote $Ca_2(Al,Fe)_3(SiO_4)_3(OH)$

Pervasive in the contact zone around Sacramento Hill and in dikes in the limestones. Commonly medium green-yellow to black; crystals small and unusual. Associated with garnet, quartz and tremolite.

Epsomite $MgSO_4 \cdot 7H_2O$

*Campbell shaft—2700 level, 47 crosscut,** as colorless prismatic crystals of up to 2 inches on cuprian melanterite. Also associated with hexahydrite and siderotil.

Famatinite Cu_3SbS_4

Campbell shaft, minor inclusions in chalcocite with tetrahedrite, tennantite and enargite (Schwartz and Park, 1932).

Fibroferrite $Fe^{+3}(SO_4)(OH) \cdot 5H_2O$

Known only as a post-mining mineral.

Shattuck shaft—700 level, as pulverulent crust on mine walls (Sidney Williams, personal communication, 1980).

Fluorite CaF_2

Widely distributed in the district. Occurs most commonly as an accessory mineral in the Juniper Flats granite.

Campbell shaft—2966 level, as small green cubes at the contact between the Abrigo limestone and Bolsa quartzite.

3233 level, 42 crosscut, as 3/8-inch, lime-green cubes on milky quartz.

Fornacite $(Pb,Cu)_3[(Cr,As)O_4]_2(OH)$

*Shattuck shaft—200 level,** as very small yellow-green crystals with mimetite, hematite, chrysocolla, quartz and shattuckite.

Forsterite Mg_2SiO_4

Of contact metamorphic origin in the Martin limestone around Sacramento Hill.

Spray shaft—500 level, 27-3 stope, as green, euhedral, small crystals with zoisite, tremolite, pyrite and minor epidote (Tenney, 1913).

Galena PbS

An abundant and economically important mineral. Usually massive; crystals are small, rough and dull when found. Associated with pyrite, sphalerite and, to a lesser extent, chalcopyrite.

Campbell shaft—2300-2700 levels, as large orebodies with sphalerite near the Denn shaft.

Junction shaft—2000-2100 levels, with sphalerite.

Shattuck shaft—200 level, as anglesite-coated boulders in cerussite sand.

Gibbsite $Al(OH)_3$

Observed as an alteration product of chalcoalumite (Palache *et al.,* 1944),

*Lavender pit—Holbrook extension,** as pale blue crusts on azurite, a probable replacement of chalcoalumite.

Goethite $FeO(OH)$

One of the most common gangue minerals in the oxidized ores, being the principal constituent of "limonite." While abundant, good specimens of goethite are unusual. Only these locations that have produced such pieces are noted.

Cole shaft—1400 level, botryoidal masses with 3/8-inch pseudomorphs of goethite after pyrite.

Junction shaft—2700 level, as many lustrous, botryoidal and stalactitic specimens of large size on a porous siliceous limestone.

Shattuck shaft—600 level, as bright, botryoidal masses with calcite.

Gold Au

Disseminated throughout the ores, but seldom found in visible amounts. Gold has been of significant economic importance since the turn of the century when electrolytic refining came into wide use. Some placer gold was recovered on the eastern fringes of the district, but that associated with the copper ores was of the greatest importance from an economic standpoint.

Cole shaft—1400 level, 39A stope; small spots of gold on massive bornite and a few specimens of gold on bornite crystals have been found.

Shattuck shaft—300 level; small specimens of crystalline wire gold were found on heavily iron-stained quartz.

400 level, large amounts in a silica breccia.

Uncle Sam shaft—"M" level, as very small flakes with a lightly iron-stained quartz sand in the bottom of a small cave adjacent to a silica breccia.

Goslarite $ZnSO_4 \cdot 7H_2O$

*Campbell shaft—1700 level,** as a crust on timber in an abandoned stope.

*1800-1900 level,** as stalactitic growths composed of numerous crystals with an overall length of 20 inches.

Junction shaft—1600 level, as antler-like stalactitic groups of rough ⅖-inch crystals.

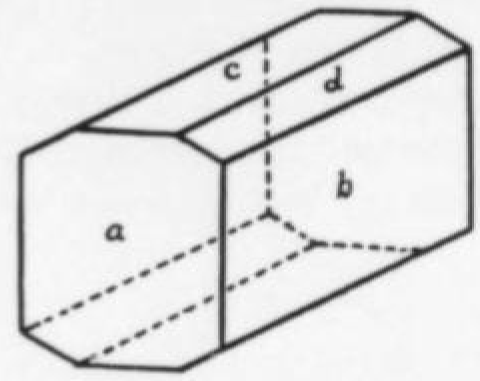


Figure 76. **Graemite crystal, from the 1200 level of the Cole shaft (Williams and Matter, 1975).**

Graemite $CuTeO_3 \cdot H_2O$

Bisbee is the type locality for this species. Only a single specimen is known from here (Williams and Matter, 1975).

*Cole shaft—1200 level, probably 202 stope,** blue-green blades found on and replacing teineite and as pseudomorphs after teineite with malachite and cuprite. (Ed. note: this species was named in honor of the author, who found the only known specimen.)

Graphite C

An unusual supergene occurrence:

*Dallas shaft—1400 level,** found as a metallic-lustered veneer on hematite with copper along a fault.

Greenockite CdS

Found in very small amounts with most of the sphalerite in the district as a yellow powdery coating or, rarely, as microcrystals. Much, if not all, of the greenockite reported from Bisbee is probably hawleyite, though this has never been confirmed.

Grossular $Ca_3Al_2(SiO_4)_3$

An abundant alteration mineral, most notably around Sacramento Hill. Found as granular masses of ⅕ inch, yellow-green crystals with diopside, quartz, idocrase and tremolite.

Groutite MnO(OH)

*Campbell shaft—1800 level,** found with pyrolusite in a solution-enlarged fault.

2000 level, as small, black-brown crystals on soft manganese oxide with calcite.

Gypsum $CaSO_4 \cdot 2H_2O$

Common as both an accessory mineral in some of the supergene ores and as a post-mining growth.

Campbell shaft—1300 level, large areas (16 feet) of 2-inch radiating crystals of post-mining origin.

2200 level, Denn sideline area, fine specimens of colorless, 1⅝-inch crystals on post-mining copper.

Dallas shaft, as 1¼-inch, colorless crystals on malachite.

Junction shaft—1400 level, as composite crystal stalactites up to 6 inches.

2000 level, light-brown crystals to 3 inches, of post-mining origin.

Southwest mine—4th level, as ram's-horn growths to 12 inches and as large, porous blocks; also as copper-stained, prismatic crystals to 8 inches.

6th level, ram's-horn growths to 3 feet in length and flower-like growths, often iron-stained, in a small cave. Also as colorless, thin, bladed crystals.

Halloysite $Al_2Si_2O_5(OH)_4$

A common mineral in the contact zone around Sacramento Hill. Noted from both hydrothermal alteration and supergene origins.

Holbrook shaft, a translucent material with flakes of silver as inclusions and minor malachite.

*Lavender pit,** as large pieces, often copper or iron-stained. Also as greenish gray crusts and pods ("metahalloysite") resembling impure chrysocolla (Anthony *et al.,* 1977).

Halotrichite $Fe^{+2}Al_2(SO_4)_4 \cdot 22H_2O$

Widespread as a post-mining mineral.

*Campbell shaft—1800 level,** ram's-horn growths of 3 inches in diameter and 18 inches in length on massive pyrite.

1900 level, hair-like growths covering large areas; as attractive multi-ram's-horn growths.

Junction shaft, as attractive, multi-ram's-horn groups to almost 3 feet across.

Hausmannite Mn_3O_4

White-tailed Deer mine, on the surface replacing limestone, in association with braunite (Anthony *et al.,* 1977).

Hematite Fe_2O_3

A ubiquitous gangue mineral of both hypogene and supergene origin. The specular variety has been found in every mine in the district as an alteration product, particularly in the Abrigo limestone. Specularite is pervasive in the silica breccias of the Southwest/Shattuck areas, commonly being the principal constituent of the matrix. Supergene hematite is, of course, very widespread and common. The most obvious occurrences are the gossens that cover the Sacramento stock. In the secondary orebodies it is the most common gangue mineral and commonly contains enough disseminated copper and/or cuprite to constitute ore.

Only areas that are of special interest are noted:

Cole shaft—1400 level; specularite replaced 4-inch beds in the Abrigo limestone with ⅘-inch foliated crystals.

Lavender pit, as a vein of compact "needle ore" 12 inches thick, and as large, handsome, iridescent specimens.

Shattuck shaft—200 level, 45 raise, as compact reniform and stalactitic specimens with minor malachite.

400 level, as large amounts of unconsolidated specularite sand adjacent to a silica breccia.

Southwest mine—6th level, as unusually brilliant, iridescent specimens.

Figure 77. **A group of colorless hemimorphite crystals 2¾ inches tall, from the Cole shaft, 1200 level, 26-J stope, Melvin Elkins collection.**

Hemimorphite $Zn_4Si_2O_7(OH)_2 \cdot H_2O$

Cole shaft—1300 level, as fine, large crystals to 4 inches with chalcophanite, rosasite and copper on hematite.

*Southwest mine—10th level,** with rosasite and calcite.
5th level, as small crystals with rosasite.

Hetaerolite $ZnMn_2O_4$

Probably much more common than the few confirmed locations would indicate:

*Campbell shaft—1900 level,** as very fine botryoidal to stalactitic groups.

Junction shaft, as numerous, small, reniform specimens.

*Cole shaft—1300 level,** in large drusy overgrowths of goethite.

Hexahydrite $MgSO_4 \cdot 6H_2O$

*Campbell shaft—2700 level, 47 crosscut,** a dehydration product of epsomite, with siderotil.

Hisingerite $Fe_2^{+3}Si_2O_5(OH)_4 \cdot 2H_2O$

Reported from the district (Anthony *et al.*, 1977).

Hornblende group $(Ca,Na_2)_{2-3}(Mg,Fe^{+2},Fe^{+3},Al)_5(Al,Si)_8O_{22}(OH)_2$

A minor constituent of several andesite dikes; exact species undetermined.

Galena shaft—1300 level, as phenocrysts to ⅖ inch.

Hydrobasaluminite $Al_4(SO_4)(OH)_{10} \cdot 36H_2O$

Lavender pit—Holbrook extension, white flakes with basaluminite (Anthony *et al.*, 1977).

*Southwest mine—7th level,** white to colorless ⅘ to 1¼-inch blades along a fault in a sulfide stope.

Hydrohetaerolite $Zn_2Mn_4O_8 \cdot H_2O$

*Campbell shaft—1900 level, 105 stope,** in limestone with hetaerolite and calcite.

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

*Campbell shaft—1600 level,** as a white crust or film on zincian malachite.

Illite $(K,H_3O)(Al,Mg,Fe)_2(Si,Al)_4O_{10}[(OH)_2,H_2O]$

In altered granite with sericite, kaolinite, allophane and alunite (Anthony *et al.*, 1977).

Ilsemannite $Mo_3O_8 \cdot nH_2O$

Blue stains on intensely silicified, brecciated limestone with fluorite and scheelite (Anthony *et al.*, 1977).

*Lavender pit,** blue crust on porphyry in a dike from near the concentrator.

Jerosite $KFe_3(SO_4)_2(OH)_6$

Possibly the most abundant secondary mineral in the district. It has been recognized in vast quantities in all of the producing mines. Only the most significant occurrences are noted:

Hoatson shaft—1200 level, 0.04 to 0.08-inch crystals on malachite.

Lavender pit, 0.08-inch crystals on heavily oxidized porphyry.

Shattuck shaft, as hexagonal scales on massive hematite (Palache *et al.*, 1944).

Southwest mine—5th, 6th, and 7th levels, very large earthy masses of several thousand tons, probably relics of massive pyrite bodies.

Kaolinite $Al_2Si_2O_5(OH)_4$

Large plastic masses, some nearly pure, more commonly iron-stained. Most common in the Czar and Holbrook mines. Also as an alteration product of feldspar in the Sacramento stock (Anthony *et al.*, 1977).

Kornelite $Fe_2^{+3}(SO_4)_3 \cdot 7H_2O$

Reported as a post-mining crust on massive pyrite in some of the old mine workings (Merwin and Posnjak, 1937).

Campbell shaft, as pale pink fibers with copiapite and voltaite (Fabien Cesbron, personal communication, 1981).

Labradorite $(NaAlSi_3O_8)/(CaAl_2Si_2O_8)$, 50-30 percent/50-70 percent

Phenocrysts with andesine and hornblende in several surface dikes near the Shattuck, Wade Hampton, and Wolverine mines (Bonillas *et al.*, 1916).

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

As a thin, sky-blue crust of small tabular crystals on fractures in or near chalcopyrite. Occurs with greenish films of brochantite. An uncommon mineral but widely distributed in the deep workings of the district (Anthony *et al.*, 1977).

Laumontite $CaAl_2Si_4O_{12} \cdot 4H_2O$

Reported from the district as a product of hydrothermal alteration (Anthony *et al.*, 1977).

Leadhillite $Pb_4(SO_4)(CO_3)_2(OH)_2$

Campbell shaft—1800 level, with malachite and silver on chalcocite (Anthony *et al.*, 1977). Also as small, white to gray, tabular crystals on quartz fragments.

Cole shaft, reported from here (Anthony *et al.*, 1977).

Lepidocrocite $FeO(OH)$

Reported from the district, with goethite (Anthony *et al.*, 1977).

Lime CaO

Campbell shaft—1300 level, in calcined limestone walls in the main vent for the Campbell fire.

Linarite $PbCu(SO_4)(OH)_2$

*Cole shaft—700 level, 110 stope,** as ⅕-inch spots in hematite with malachite. Easily confused with azurite.

Magnesite $MgCO_3$

In small amounts as an alteration product in the Martin limestone near the Sacramento stock.

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

As masses with hematite, garnet and epidote in the contact metamorphic zone (Tenney, 1913).

Campbell shaft—2500 level, as an accessory mineral in a porphyritic dike.

Malachite $Cu_2(CO_3)(OH)_2$

Bisbee has produced some of the finest specimens of malachite in the world. The wide variety of forms and associations, particularly with the closely related carbonate, azurite, have enhanced the appeal of this already attractive mineral.

As a source of ore, malachite contributed heavily to the economic success of the early mines and continued to provide copper up to the last day of operation. When mined as an ore this species was seldom exploited as large masses or highly attractive specimens, but rather as myriads of thin veinlets and acicular tufts disseminated in massive hematite. Malachite has been found as exceptionally faithful pseudomorphs after azurite, brochantite, calcite, copper, cuprite and delafossite. Shattuckite, chrysocolla, chalcoalumite and limonite are known to have replaced malachite.

Because of the number of important localities for malachite and the many fine pseudomorphs it has formed, the two habits will be treated separately.

Non-pseudomorphic Malachite

Atlanta shaft—300-400 levels, as the principal ore mineral in the Atlanta orebody. Found as specimens, of medium green partial overgrowths on dark drusy azurite and as fibrous crystals with calcite.

Campbell shaft—1600 level, thin but attractive plate-like specimens of reniform and stalactitic malachite.
2000 level, as large, irregular pods of radiating zincian malachite in limestone adjacent to an oxidized orebody.

Cole shaft—600 level, large specimens of loose, fibrous, zincian material.
1200 level, as unusually attractive, compact, lustrous, erratic forms encased in soft, spongy, highly zincian material from the *26J stope.*

1400 level—26L stope, lustrous crystals to ¼ inch on white calcite. Only five specimens were recovered.

Copper Queen mine, the original Copper Queen orebody was a surface outcrop of massive malachite that was unique to the district with respect to its size and purity. For the first 100 feet of depth, this 65-foot-diameter irregular mass, was nearly all malachite. Diluted as it was with calcite and the wall rock taken with it during mining, it averaged 24 percent copper (pure malachite is 62 percent copper). This malachite was massive with a radiating structure and had a silky luster. Individual pieces were often found to be over 6 inches thick.

400 level, as a light green material on azurite.

Czar shaft; this mine was undoubtedly the producer of Bisbee's finest malachites.

200 level, pockets lined with botryoidal and stalactitic growths.

300 level, lustrous, radiating specimens in soft manganiferous clays that ring like fine crsytal when struck. Also as reniform masses of a yard or more and up to 6 inches thick with velvet-like surfaces, and as stalactites.

400 level, as botryoidal pieces 20 to 30 inches across.

Holbrook shaft—200 level, as a light green zincian material on pale azurite.

300 level, as numerous, velvety pocket linings scattered throughout the hematitic clays.

400 level, hugh blocks of a ton or more in a decomposed breccia. Here the malachite was up to 2 feet thick in banded, reniform masses.

Junction shaft—770 level, recovered as pieces of a yard across and 4 inches thick, partially covered with light blue azurite.

1600 level, radiating aggregates of brilliant crystals on massive chalcocite.

Lavender pit—Holbrook extension; in November of 1969 a wedge-shaped mass of compact, banded malachite of 39 by 3 feet and 8 to 24 inches thick was encountered. Including intermixed manganese oxides, an estimated six tons of material were recovered. Early in 1970, boulders of box-work malachite with azurite were found. One of these weighed 1500 pounds.

Shattuck shaft—500 level, as thin shells in manganese oxides with velvet interiors.

700 level, as 2¾-inch thick reniform masses.

Southwest mine—5th and 6th levels, in pockets in hematite with acicular crystals of up to ⅜ inch, with calcite.

4th level, as stalactites to 4 inches and botryoidal groups with acicular overgrowths from a small cave in the manganiferous Martin limestone.

Uncle Sam shaft—"N" level, as thin plates of coarsely crystalline intergrowths with small, colorless cerussite crystals.

Malachite Pseudomorphs

Campbell shaft; this mine produced the greatest number and the best quality pseudomorphs of malachite after azurite.

1300 level, near the Briggs shaft; the last round in a short raise opened up a 6-foot by 3-foot by 10-inch pocket dipping about 30° to the east. This void was filled with very sharp blades to 6 inches on an irregular surface of hard, yellow-white limonite. Many hundreds of specimens were recovered from this area. The best of these are 10 inches across and have more than 60, 3 to 4-inch crystals oriented in pinwheel fashion.

1600 level, Campbell orebody, as numerous intergrown wafer-like crystals, some of which are up to 4 inches on an edge.

1800 level, as somewhat rough, prismatic groups with 2¾-inch crystals found to be common. Commonly these include siliceous fragments.

1900 level, as spectacular, highly lustrous, equant, composite crystals of up to 2¾ inches on bright unaltered azurite. Also as rough blades of up to 4 by 7 inches.

Cole shaft—1200 level, as large (2 feet) pseudomorphs after copper, with calcite.

Copper Queen mine, as sharp blades of malachite after azurite to 2 inches, commonly altered to chrysocolla.

Czar shaft—300 level, as numerous small pseudomorphs of malachite after cuprite on azurite.

400 level, as sharp blades of malachite pseudomorphs after azurite to 1⅜ inches on a dark, siliceous goethite.

Sacramento shaft—1200-1400 level, as both bladed and tabular pseudomorphs of malachite after azurite, typically of large size. Many show a partial parallel overgrowth of azurite. In some cases this overgrowth has been altered to malachite as well.

Shattuck shaft—300-400 level, as remarkable pseudomorphs of malachite after brochantite; found as intergrown groups of crystals with individuals to ¼ by 2¾ inches.

Southwest shaft—4th level, as an interesting replacement of calcite scalenohedrons.

Manganite $MnO(OH)$

Possibly common in the massive manganese orebodies scattered throughout the district; however, only one confirmed occurrence is known:

Lowell shaft, in a veinlet cut by the shaft near the 1000 level, with pyrolusite, as distinct needle-like crystals (Tenney, 1913).

Marcasite FeS_2

Cole shaft, as concretions in unmineralized Abrigo limestone.

Melanterite $FeSO_4 \cdot 7H_2O$

Common in many of the old mine workings.

Campbell shaft—2700 level, 42 crosscut,* as remarkable cuprian melanterite crystals, pseudo-octahedral in form, of up to ⅝ inch, with epsomite.

Cole shaft—900 level,* as almost colorless, acicular growths.

Czar shaft—400 level, as thick, greenish crusts on pyritic limestone.

Metavoltine $K_2Na_6Fe^{+2}Fe_6^{+3}(SO_4)_{12}O_2 \cdot 18H_2O$

As a post-mining mineral, abundant in the one known locality:

Campbell shaft—2100 level,* greenish yellow, hexagonal plates on pyritic limestone. Associated with copiapite, coquimbite, voltaite and roemerite.

Microcline $KAlSi_3O_8$

Reported from the district (Anthony *et al.,* 1977).

Mimetite $Pb_5(AsO_4)_3Cl$

Campbell shaft—1800 level, with wulfenite, copper and malachite on hematite.

Cole shaft—600 level, reported from here (Anthony *et al.,* 1977).

Shattuck shaft—200 level,* in minor amounts with shattuckite and malachite.

Southwest mine—7th level,* as up to ⅛-inch crystals with plattnerite and calcite in a large cave.

Minium Pb_3O_4

Southwest mine—6th level,* as earthy, red-orange material with jarosite and plumbojarosite.

Molybdenite MoS_2

Campbell shaft—3100 level, a film on quartz and schist in the 15 crosscut.

Lavender pit, somewhat massive with bornite.

Mottramite $PbCu(VO_4)(OH)$

Higgins mine, as crystals ("psittacinite" of Taber and Schaller, 1930).

Shattuck shaft—400 level, as drusy, botryoidal specimens.

Murdochite $PbCu_6(O,Cl,Br)_8$

Higgins mine,* as black, drusy crusts on siliceous fragments in a breccia with hematite and plattnerite.

Peter Kresan

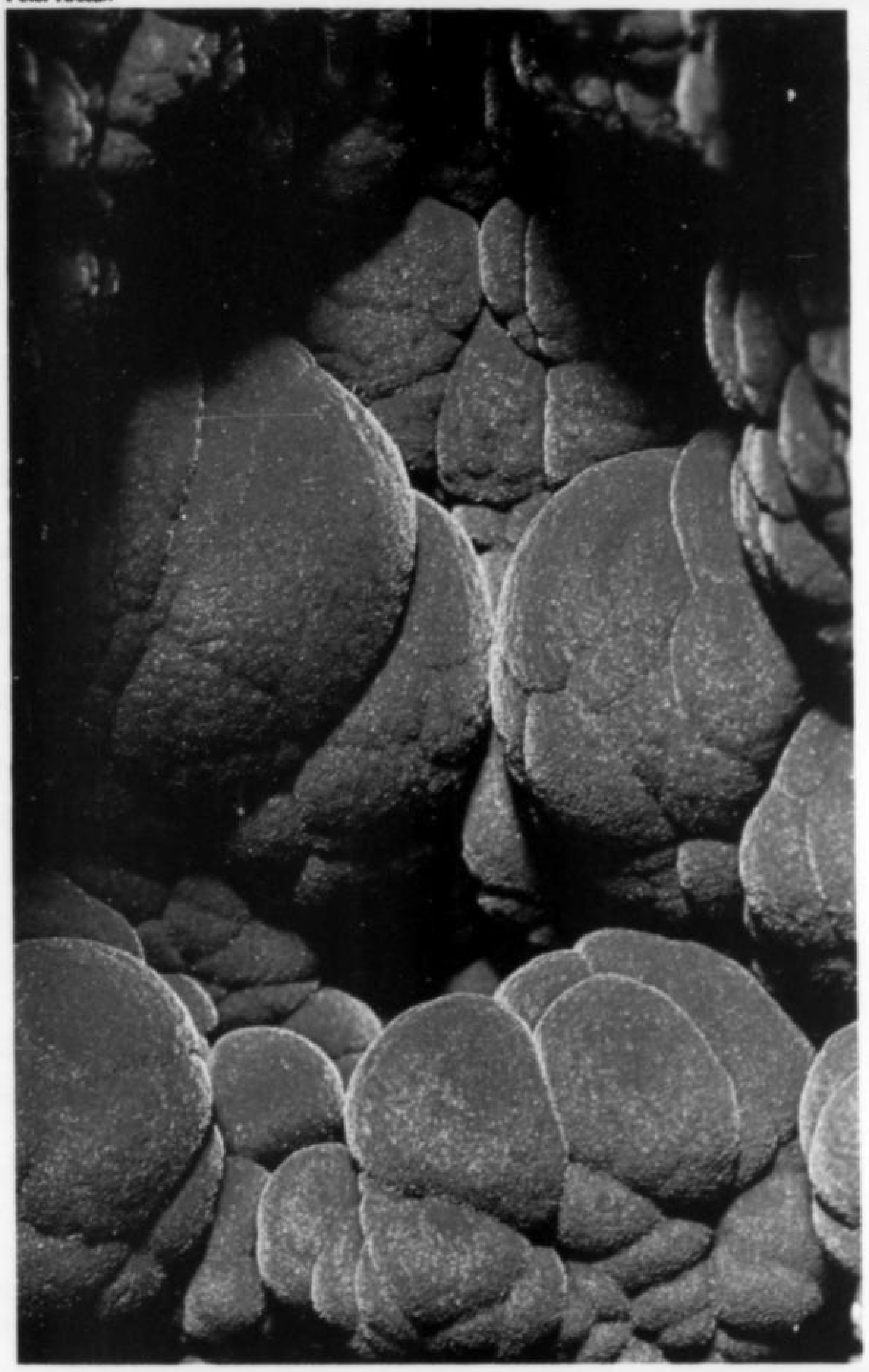


Figure 78. **Botryoidal velvet malachite 3 inches across, from the Shattuck shaft. Graeme collection.**

Muscovite $KAl_2(Si_3Al)O_{10}(OH)_2$

As some of the "sericite" in the Sacramento stock (Schwartz, 1947).

Natrolite $Na_2Al_2Si_3O_{10} \cdot 2H_2O$

Lowell shaft—1300 level, as white, fibrous, needle-like crystals, being replaced by quartz; also with calcite. The occurrence is in an andesite dike (Tenney, 1913).

Oligoclase $(NaAlSi_3O_8)/(CaAl_2Si_2O_8)$. 90-70 percent/10-30 percent

Lowell shaft—1300 level, 1314, in a pegmatitic dike as large (⅘-inch) crystals with euhedral quartz and biotite (Tenney, 1913)

Olivine $(Mg,Fe)_2SiO_4$

As a constituent of several Precambrian dikes in the Pinal schist, with hornblende and augite (Bonillas *et al.*, 1916); composition (fayalite or forsterite) not indicated.

Orthoclase $KAlSi_3O_8$

A common rock-forming mineral, notably, in the Juniper Flats granite.

Osarizawaite $PbCuAl_2(SO_4)_2(OH)_6$

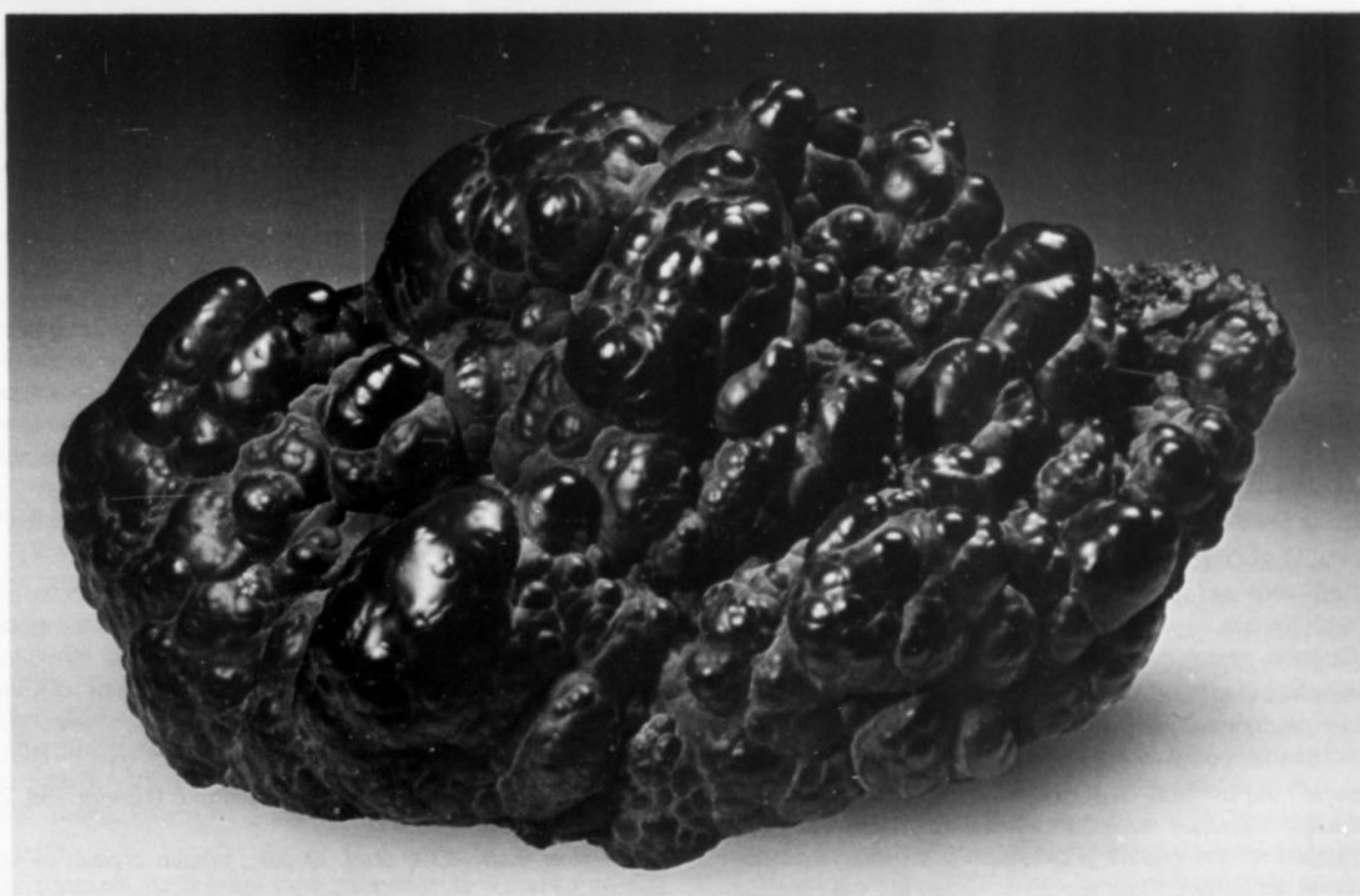
*Copper Prince mine,** known only from dump specimens (put on the surface in 1882). Associated with malachite and hematite.

Paramelaconite $Cu_2^{+1}Cu_2^{+2}O_3$

Bisbee is the type locality for this exceedingly rare mineral. While the district has produced the finest known specimens of paramelaconite, the mineral has not again been encountered since the original find:

Copper Queen mine, as very large crystals on goethite with connellite, cuprite, copper, malachite and tenorite (Koenig, 1891).

Figure 79. **Hard botryoidal (or possibly stalactitic) malachite 5 inches across from the Czar shaft. Arizona-Sonora Desert Museum collection.**



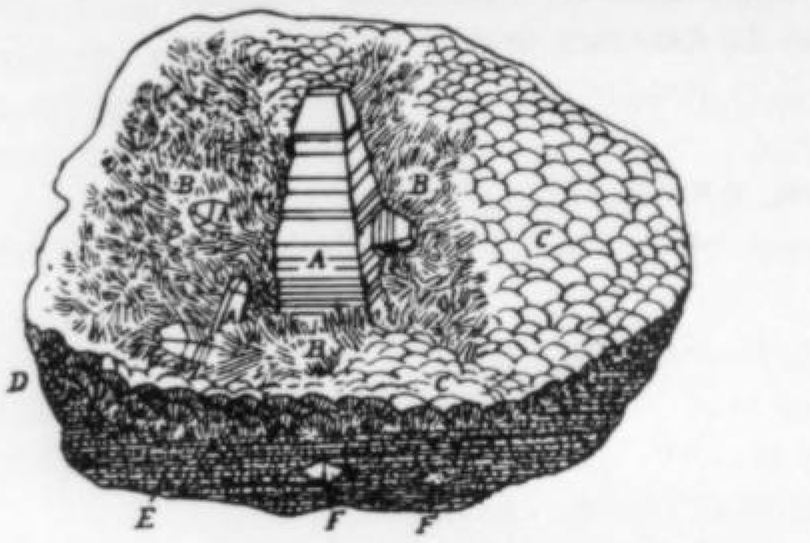


Figure 80. **A large paramelaconite crystal (A) of purplish black color and metallic adamantine luster, on deep blue acicular connellite (B), with limonite (C, D) and copper (F) on cuprite/limonite matrix (E) from the Copper Queen mine (Koenig, 1891).**

Paratacamite $Cu_2(OH)_3Cl$

*Cole shaft—700 level,** with cuprite, hematite and malachite as 1/10-inch crystals.

*Holbrook shaft,** with cuprite, malachite and azurite in a dump specimen containing numerous 1/5-inch crystals.

Pharmacosiderite $KFe_4(AsO_4)_3(OH)_4 \cdot 6\text{–}7H_2O$

*Lavender pit,** as minute octahedrons on psilomelane in leached quartz-feldspar porphyry.

Pickeringite $MgAl_2(SO_4)_4 \cdot 22H_2O$

Shattuck shaft—500 level, as long, clear prisms with rounded, corroded surfaces. This is a post-mining occurrence (Sidney Williams, personal communication, 1981).

Plancheite $Cu_8Si_8O_{22}(OH)_4 \cdot H_2O$

Shattuck shaft—400 level, as botryoidal crust on quartz and hematite (Sidney Williams, personal communication, 1981).

Plattnerite PbO_2

*Southwest mine—7th level,** 1/10-inch crystals on altered Martin limestone with mimetite and calcite. This occurrence is in a large cavern.

Plumbojarosite $PbFe_6^{+3}(SO_4)_4(OH)_{12}$

Undoubtedly more common than the few confirmed occurrences would suggest:

Atlanta shaft, as samples from the dump.

*Southwest mine—6th level,** in an oxidized lead-zinc stope that daylights in Hendricks Gulch. With hematite, cerussite and malachite near the Sunrise shaft.

Polybasite $(Ag,Cu)_{16}Sb_2S_{11}$

Identified as a few grains in massive galena from an unspecified mine (Bonillas *et al.*, 1916).

Powellite $CaMoO_4$

Bisbee Queen shaft, from this exploration shaft on the east edge of the district (Anthony *et al.*, 1977).

Prehnite $Ca_2Al_2Si_3O_{10}(OH)_2$

Cole shaft—800 and 1000 levels, occurs as small but well formed crystals with quartz, epidote and grossular in meta-limestones (Fabien Cesbron, personal communication, 1981).

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

*Lavender pit,** as a crystalline crust on massive malachite with azurite and quartz.

"Psilomelane" $BaMn^{+2}Mn_8^{+4}O_{16}(OH)_4$

An extremely abundant secondary mineral associated with most of the supergene species, and the principle ore in the many manganese deposits in the district. Exact species uncertain but wet chemical analyses revealed Ba and Mn.

Pumpellyite $Ca_2MgAl_2(SiO_4)(Si_2O_7)(OH)_2 \cdot H_2O$

Reported from the district (Anthony *et al.*, 1977).

Pyrite FeS_2

Uniquitous in the district as masses of incredible size. Mining operations have exposed bodies of tens of thousands of tons. Bryant estimated that several hundred million tons were deposited (Bryant, 1968).

Pyrite has been of major importance to the district as the host for supergene chalcocite which formed the ore for the Sacramento and Lavender pits. In spite of the vast amounts of this mineral available, very few specimens of any quality have been found.

Campbell shaft—2100 level, large plate-like specimens of bright, complex, 2/5-inch crystals.

Cole shaft—1200 level, many hundreds of single euhedral pyritohedrons to 3 inches in chloritic zones in the Abrigo limestone.
1400 level, as groups of large pyritohedrons (4¾ inches) in sericite on the edge of a massive pyrite body.

Czar shaft—400 level, as faithful replacements of fossils in unmineralized Martin limestone.

Pyrolusite MnO_2

Common in the many widely scattered surface manganese deposits. Usually associated with psilomelane, barite and braunite.

Pyromorphite $Pb_5(PO_4)_3Cl$

Reported from the district (Anthony *et al.*, 1977).

Pyrophyllite $Al_2Si_4O_{10}(OH)_2$

With barite, common in the Sacramento stock (Anthony *et al.*, 1977).

Pyrrhotite $Fe_{1-x}S$

An uncommon mineral in the district, restricted to the contact zone and around the Sacramento stock.

Gardner shaft—900 level, 909 drift, as massive material with magnetite, hematite, pyrite, sphalerite and chalcopyrite (Tenney, 1913).

Sacramento shaft—1400 level, with magnetite and hematite in tremolite (Tenney, 1913).

Quartz SiO_2

One of the most common and significant alteration minerals. Found as an important constituent in all of the intrusives. Ubiquitous in the altered sediments around the contact zone, as hydrothermal veins and as fossilized wood in the Cretaceous sediments, and as chert nodules in the Paleozoic sediments. Tremendous amounts of quartz are tied up in the silica breccias in Queen Hill.

Campbell shaft—3100 level, 15 crosscut, as milky crystals to 3 inches with light green fluorite.

Cole shaft—1100 level, in large groups of pale amethystine crystals to 1/5 inch each.

Junction shaft—2700 level, in an unusual large pocket of fine amethyst crystals to 1/3 inch, ranging from near colorless to almost black as a function of their location in the void. Those near the bottom are darker and larger.

Ransomite $CuFe_2^{+3}(SO_4)_4 \cdot 6H_2O$

A post-mining mineral.

*Campbell shaft—1800 level,** as a blue crust of acicular crystals commonly covering large areas of cupriferous pyrite; associated with roemerite.

Cole shaft—700 level, as radiating acicular groups to 3/5 inch on pyrite.

Rhodochrosite $MnCO_3$

Higgins mine—100 level, with alabandite (Hewett and Rowe, 1930).

Junction shaft—2300 level, as pale, tabular crystals in vugs in alabandite.

Rhomboclase $HFe^{+3}(SO_4)_2 \cdot 4H_2O$

Common as a yellow-white crust in a great many workings.

Czar shaft—400 level, as small, white, bladed crystals.

Rickardite Cu_7Te_5

Junction shaft, as small purple fragments in a sulfide pulp (Crawford, 1930).

Roemerite $Fe^{+2}Fe_2^{+3}(SO_4)_4 \cdot 14H_2O$

One of the most common post-mining minerals in the district.

Campbell shaft—1800 level, as a thick crust on the floors and walls of several abandoned workings.

*Junction shaft—1500 level,** as spongy crusts of up to 16 inches thick on the floor of the 44 crosscut.

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

Cole shaft—1200 level, 26J stope; this locality has produced some of the world's finest rosasite. As pieces of reniform and stalactitic material in excess of 12 inches, some totally free of matrix. Typically associated with colorless calcite and jarosite.

Copper Queen mine—"A" level, as numerous ⅕-inch spheres of deep blue-green material on hematite.

Southwest mine—5th level, inclusions in calcite.
*10th level,** with hemimorphite and calcite.

Rozenite $Fe^{+2}SO_4 \cdot 4H_2O$

Known only as a post-mining mineral.

*Campbell shaft—2700 level,** as a thin white crust on pyritic limestone in the 42 crosscut. Associated with hexahydrite.

Rutile TiO_2

As an accessory mineral in the Juniper Flat granite and in the Sacramento stock (Schwartz, 1947).

Sanidine $(K,Na)AlSi_3O_8$

Reported from the district (Anthony *et al.,* 1977).

Scapolite group $(Na,Ca,K)_4Al_3(Al,Si)_3Si_6O_{24}(Cl,SO_4,CO_3)$

Holbrook shaft—500 level, near the Spray shaft, identified in a thin section of metamorphosed Abrigo limestone with tremolite and wollastonite (Tenney, 1913); exact composition and species (marialite or meionite) not given.

Scheelite $CaWO_4$

Near Warren, on silicified limestone with fluorite and ilsemannite (Anthony *et al.,* 1977).

Sengierite $Cu_2(UO_2)_2(VO_4)_2 \cdot 6H_2O$

Cole shaft—800-1300 level, found in what is known as the "Gash Country," as large, bright yellow spots on massive chalcocite, with malachite and chlorargyrite (Hutton, 1957).

Sepiolite $Mg_4Si_6O_{15}(OH)_2 \cdot 6H_2O$

Cole shaft—1000 level, with talc and antigorite in epizonally altered dolomitic limestones (Fabien Cesbron, personal communication, 1981).

*Southwest mine—6th level,** as small spongy pieces and numerous compact nodules in a small cave. Commonly overgrown with reniform dolomite, this sepiolite is most probably residual material from the dissolution of moderately altered limestone.
7th level, as many tons of light, popcorn-like pieces in an occurrence similar to that on the 6th level, but here associated with aragonite and a chalk-like dolomite. The two occurrences of sepiolite in this mine are separated from each other by about 3000 feet.

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

Bisbee is the type locality for this attractive mineral (Schaller, 1915).

*Shattuck shaft—200 level, 174 prospect,** as light blue radiating masses that are pseudomorphs after malachite. Found as large, compact masses with acicular tufts in the voids; associated with malachite, quartz, bisbeeite (?) and calcite.

Siderite $FeCO_3$

A very common, early-stage supergene mineral. Trischka *et al.* (1929) has discussed its relationship to ore and its use as a prospecting guide. In spite of its abundance, good specimens are limited to the Junction occurrence.

Czar shaft—400 level, as iridescent drusy boxwork, in part altering to smithsonite.

Gardner shaft—800 level, as pseudomorphs after pyrite in limestone.

Hoatson shaft—1400 level, as ⅕-inch transparent rhombs on massive boxwork.

*Junction shaft—2200-2566 levels,** a most remarkable occurrence of this mineral. In an area from just above the 2200 level to near the 2566 level, a series of interconnected voids and small caves were found filled with irridescent stalactites and botryoidal masses of siderite. Specimens of incredible size and beauty were recovered from here. This area contains an estimated 30,000 tons of siderite. Associated with quartz, and commonly encasing fresh, euhedral pyrite, this occurrence was derived from a large body of pyrite.

Siderotil $Fe^{+2}SO_4 \cdot 5H_2O$

*Campbell shaft—2700 level, 42 crosscut,** a cuprian variety replacing melanterite, associated with hexahydrite.

*Junction shaft—1600 level,** as crystal-terminated stalactites to 1⅝ inches.

Silver Ag

Widely distributed but seldom abundant; always of supergene origin.

Campbell shaft—1600-1800 levels, common in the secondary ores of the Campbell orebody with malachite and chlorargyrite on chalcocite.

Cole shaft—800 level, on chalcocite with malachite and chlorargyrite.

Czar shaft—300 level, as large, thin pieces interlaid with fault gouge in the Dividend zone.

Holbrook shaft, as ⅖-inch flakes in massive, translucent halloysite with minor malachite.

Junction shaft—1500 level, on chalcocite with malachite and chlorargyrite.

Lavender pit—Holbrook extension, with massive covellite in the hanging wall of the Dividend fault.

Smithsonite $ZnCO_3$

Common in the oxidized ores as boxwork (Trischka, 1929). Most Bisbee smithsonite is yellow, ranging in hue from a pale to a vivid, lustrous, lemon-yellow. The color is a result of included cadmium.

Campbell shaft—1900 level, as rough, ⅛-inch, yellow crystals on zincian malachite with azurite.

Cole shaft—1200 level, 141F stope, as vivid ⅛ to ⅕-inch crystals on azurite.

*Copper Queen mine—"A" level,** as blue-white reniform specimens with cerussite (pseudomorphs after calcite) and rosasite.

Czar shaft, as boxwork with siderite.

Holbrook shaft—300-400 levels, boxwork with azurite and malachite.

Lavender pit—Holbrook extension, large boulder-like masses of boxwork, some with reniform surfaces and associated with ⅕-inch crystals of azurite or rosettes to ⅗ inch.

Spangolite $Cu_6Al(SO_4)(OH)_{12}Cl \cdot 3H_2O$

Bisbee is the most probable type locality for this handsome mineral (Palache and Merwin, 1909). In any event, the district has produced the finest known specimens of this rare species. While the mineral is widely distributed, it is nowhere abundant.

Czar shaft, as crystals of remarkable size (⅗ by ⅘ inch) in vugs of massive cuprite with minor amounts of connellite.

Holbrook shaft—300 level, as ⅕ by ⅗-inch hexagonal crystals lining vugs in crystalline cuprite with an unidentified black mineral.

Irish Mag shaft—1050 level, as ⅛-inch crystals on brilliant

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Figure 81. **Acicular malachite from the Lavender pit. Graeme collection.**

Figure 82. **Malachite sprays to 1½ inches from the Czar shaft. Graeme collection.**

Figure 83. **Non-pseudomorphous malachite crystal group 1⅜ inches across, on calcite from the Cole shaft, 1400 level, 26-L stope. Melvin Elkins collection.**

Figure 84. Malachite pseudomorphs after azurite, 6¼ inches across, from the 1900 level of the Campbell shaft. Arizona-Sonora Desert Museum collection.

Figure 85. Malachite pseudomorph after azurite, 1¾ inches tall, from the 1900 level of the Campbell shaft, 105-C stope. Graeme collection.

Figure 86. Malachite pseudomorph after azurite, 1½ inches tall, from the 1300 level, Campbell shaft. Richard Bideaux collection.

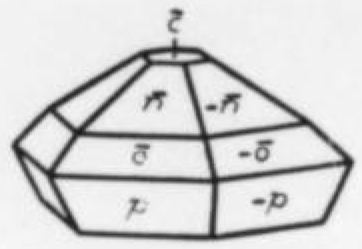

Figure 87. **Spangolite crystal from Bisbee (Frondel, 1949).**

cuprite. Also as ¼-inch crystals with malachite on cuprite and hematite.

Sphalerite (Zn,Fe)S

A very common mineral in most of the district's mines. Important amounts were mined from the Campbell, Denn and Junction shafts. Always massive and iron-rich, it commonly appears to have been one of the earliest ore minerals to form.

Campbell shaft, as large orebodies on the *2566, 2700 and 2833 levels;* commonly triboluminescent.

Junction shaft—2200, 2300, and 2566 levels, as orebodies with galena.

Stannoidite $Cu_8(Fe,Zn)_3Sn_2S_{12}$

Campbell shaft—2200 level, very fine grained, interstitial to pyrite (Sidney Williams, personal communication, 1981).

Stevensite $Mg_3Si_4O_{10}(OH)_2$

Lavender pit—Holbrook extension, from the oxidized ores; intimately intergrown with clinochrysotile (Anthony *et al.*, 1977).

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

Cole shaft—1000 level, found with chalcocite (Anthony *et al.*, 1977).

Stolzite $PbWO_4$

Campbell shaft—1800 level, as very small, yellow-gray to tan crystals on chalcocite with silver, malachite and chlorargyrite (Arizona-Sonora Desert Museum collection).

Stromeyerite AgCuS

Campbell shaft, as blades in chalcocite with tetrahedrite and tennantite (Schwartz and Park, 1932).

Cole shaft—800 level, as irregular intergrowths with chalcocite.

Junction shaft, with chalcocite (Schwartz and Park, 1932).

1500 level near the Hoatson shaft, with chalcocite, malachite and silver.

Sulfur S

Frequently found but never in large amounts.

Campbell shaft—1300 level, as brilliant, translucent crystals to ⅕ inch on calcined limestone crosscut walls in the main vent for gasses from the Campbell fire.

Junction shaft—1500 level, reported from here (Anthony *et al.*, 1977).

Lavender pit, dull, earthy material in leached porphyry.

Wolverine shaft—600 level, as sandy material with hematite, above an oxidized orebody (Tenney, 1913).

Szomolnokite $Fe^{+2}SO_4 \cdot H_2O$

Lavender pit, as brown, warty crusts enclosing pyrite grains (Anthony *et al.*, 1977).

Talc $Mg_3Si_4O_{10}(OH)_2$

Boras shaft—900 level, common in epizonally altered dolomite (Fabien Cesbron, personal communication, 1981).

Spray shaft, formed as a result of contact metamorphism (Tenney, 1913).

Teineite $CuTeO_3 \cdot 2H_2O$

Cole shaft—1200 level,* as bright blue crystals to ⅜ inch, altering to graemite with cuprite and malachite.

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

Campbell shaft—1700 level, as rounded grains in chalcocite with tetrahedrite, enargite and minor famatinite, all of this in bornite (Schwartz and Park, 1932).

Denn shaft—3100 level,* as a massive argentiferous occurrence with quartz.

Tenorite CuO

Abundant in all of the district's mines as an important ore mineral. It occurs in its most pure form as rinds on cuprite nodules. Commonly found disseminated in hematitic and manganiferous masses.

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

A widely distributed mineral as minor inclusions in some of the primary copper sulfides.

Campbell shaft—1700 level, as rounded spots with tennantite, enargite and minor famatinite in chalcocite (Schwartz and Park, 1932).

*2700 level,** near the Junction shaft with massive bornite and minor pyrite. In this occurrence it is argentiferous.

Cole shaft, reported from here (Anthony *et al.*, 1977).

Oliver shaft—1350 level, as rounded inclusions in bornite (Tenney, 1913).

Thomsonite $NaCa_2Al_5Si_5O_{20} \cdot 6H_2O$

Reported from the district (Anthony *et al.*, 1977).

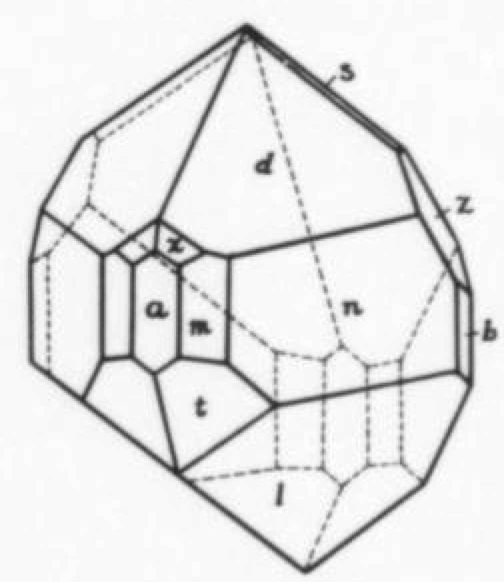

Figure 88. **Tilasite crystal from the White-Tail Deer mine (Williams, 1970).**

Tilasite $CaMg(AsO_4)F$

In an outcrop near the White-Tailed Deer mine. Found as complex crystals up to ¼ inch with braunite, conichalcite, and calcite (Williams, 1970).

Titanite $CaTiSiO_5$

A common accessory mineral in the Juniper Flat granite; sometimes as well formed crystals in vugs with chlorite and quartz (Anthony *et al.*, 1977).

Tourmaline group $(Na,Ca)(Mg,Fe^{+2},F^{+3},Al,Li)_3Al_6(BO_3)_3(Si_6O_{18})(OH,F)_4$

As a nest of small, prismatic crystals in muscovite northwest of Bisbee (Anthony *et al.*, 1977); exact species not indicated.

Tremolite $Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$

One of the most common minerals in the contact metamorphic zone around Sacramento Hill. Also found throughout the district adjacent to the many dikes. Typically, it occurs as white to green fibrous laths associated with quartz, epidote, magnetite and any of the garnets.

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

Perhaps the source of the world's finest turquoise, Bisbee has produced this mineral commercially only relatively recently; the first turquoise was found in 1953.

Cole shaft—1200 level, as minute stringers in massive pyrite.

Lavender pit; this mine was the source of all of the district's finest material. Found in the Glance conglomerate on the east side of the pit, it was commonly in large pieces associated with quartz.

Tyuyamunite $Ca(UO_2)_2(VO_4)_2 \cdot 5\text{–}8H_2O$

Campbell shaft, reported from this mine (Anthony *et al.*, 1977).

*Cole shaft,** as large yellow patches on massive chalcocite.

Uraninite UO_2

Campbell and Denn shafts, as microscopic inclusions, usually euhedral, in some of the primary sulfide ores. Associated with pyrite, galena and quartz (Bain, 1952).

Czar shaft—400 level, as a light dusting of 0.02-inch cubes on fine-grained massive pyrite.

Vanadinite $Pb_5(VO_4)_3Cl$

*Shattuck shaft;** known only from specimens found on the dump. Found as the variety *endlichite* in thin crystals to ⅘ inch filling voids in a calcite-cemented jarosite breccia.

Variscite $AlPO_4 \cdot 2H_2O$

Cole shaft—1200 level; occurred as compact masses of up to 33 pounds in colors, ranging from a pale green to a deep green. Associated with minor pyrite.

Vesuvianite $Ca_{10}Mg_2Al_4(SiO_4)_5(Si_2O_7)_2(OH)_4$

A common contact metamorphic mineral in the zone around Sacramento Hill (Bonillas *et al.*, 1916).

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

A common post-mining mineral in many of the old workings.

*Campbell shaft—2100 level,** as exceptionally large, ⅕ to ⅖-inch, deep green to black octahedrons on massive pyrite with copiapite.

Cole shaft—700 level, as spongy aggregates of small crystals in groups up to 4¾ inches across.

Willemite Zn_2SiO_4

Campbell shaft—1500 level, as a fluorescent variety (Anthony *et al.*, 1977).

Wittichenite Cu_3BiS_3

As a primary mineral in some of the mines, observed as exsolution blebs in bornite (Anthony *et al.*, 1977).

Wollastonite $CaSiO_3$

A widespread but not abundant product of contact metamorphism. Found typically as white to greenish fibers with epidote, tremolite, magnetite and grossular.

Wulfenite $PbMoO_4$

Campbell shaft—1800 level, 59 stope, as ⅕-inch, zoned, straw-colored to colorless crystals with calcite and minor anglesite. Also from east of the Campbell fault as attractive, yellow-orange, ⅗-inch crystals with copper, malachite and mimetite on hematite.

2566 level, as bright orange, ⅘-inch crystals on hematite in an oxidized fault zone.

Holbrook shaft, as ⅛-inch yellow-brown crystals on azurite and malachite.

Zircon $ZrSiO_4$

As small crystals in Pinal schist with tourmaline in granite, northwest of Bisbee (Anthony *et al.*, 1977).

Zoisite $Ca_2Al_3(SiO_4)_3(OH)$

An uncommon contact metamorphic mineral in the district (Schwartz, 1956).

Spray shaft—500 level, 27-3 stope, as fibrous gray groups with tremolite, talc, forsterite and pyrite (Tenney, 1913).

Uncle Sam shaft—"M" level, near the shaft with epidote, quartz, pyrite and chalcopyrite (Tenney, 1913).

Reported but Unconfirmed

The following minerals have been reported from the district, but lack confirmation regarding species or locality.

Acanthite, Ag_2S (Esker Mayberry, personal communication, 1962).

Algondonite, Cu_6As (Kuhlmeyer collection).

Aluminite, $Al_2(SO_4)(OH)_4 \cdot 7H_2O$.

Beaverite, $Pb(Cu,Fe,Al)_3(SO_4)_2(OH)_6$ (Graeme collection).

Bournonite, $PbCuSbS_3$ (Kuhlmeyer collection).

Cornwallite, $Cu_5(AsO_4)_2(OH)_4 \cdot H_2O$ (Mayberry collection).

Domeykite, Cu_3As (Kuhlmeyer collection).

Ferrimolybdite, $Fe_2(MoO_4)_3 \cdot 8H_2O$ (Trischka collection).

Franklinite, $(Zn,Mn^{+2},Fe^{+2})(Fe^{+3},Mn^{+3})_2O_4$ (Kuhlmeyer, oral communication).

Litharge, PbO (O. D. Brown collection).

Manganosite, MnO (Kuhlmeyer, oral communication).

Matlockite, PbFCl (French collection).

Molybdite, MoO_3 (Trischka, personal communication).

Nickeline, NiAs (Schwartz and Park, 1932).

Pyrope, $Mg_3Al_2(SiO_4)_3$ (Tenney, 1913).

Spinel, $MgAl_2O_4$ (Bonillas *et al.*, 1916).

Sternbergite, $AgFe_2S_3$ (Tenney, 1913).

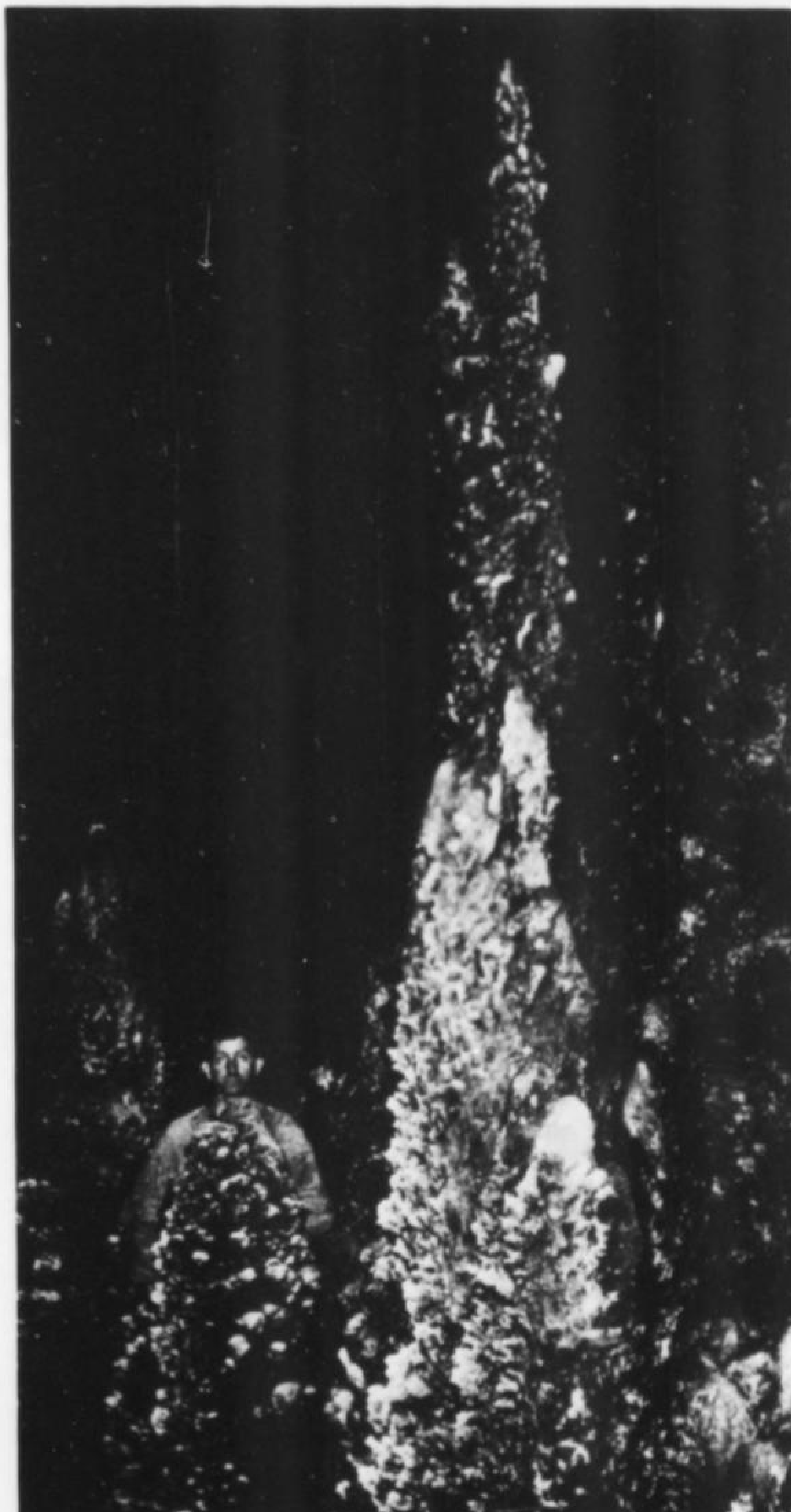

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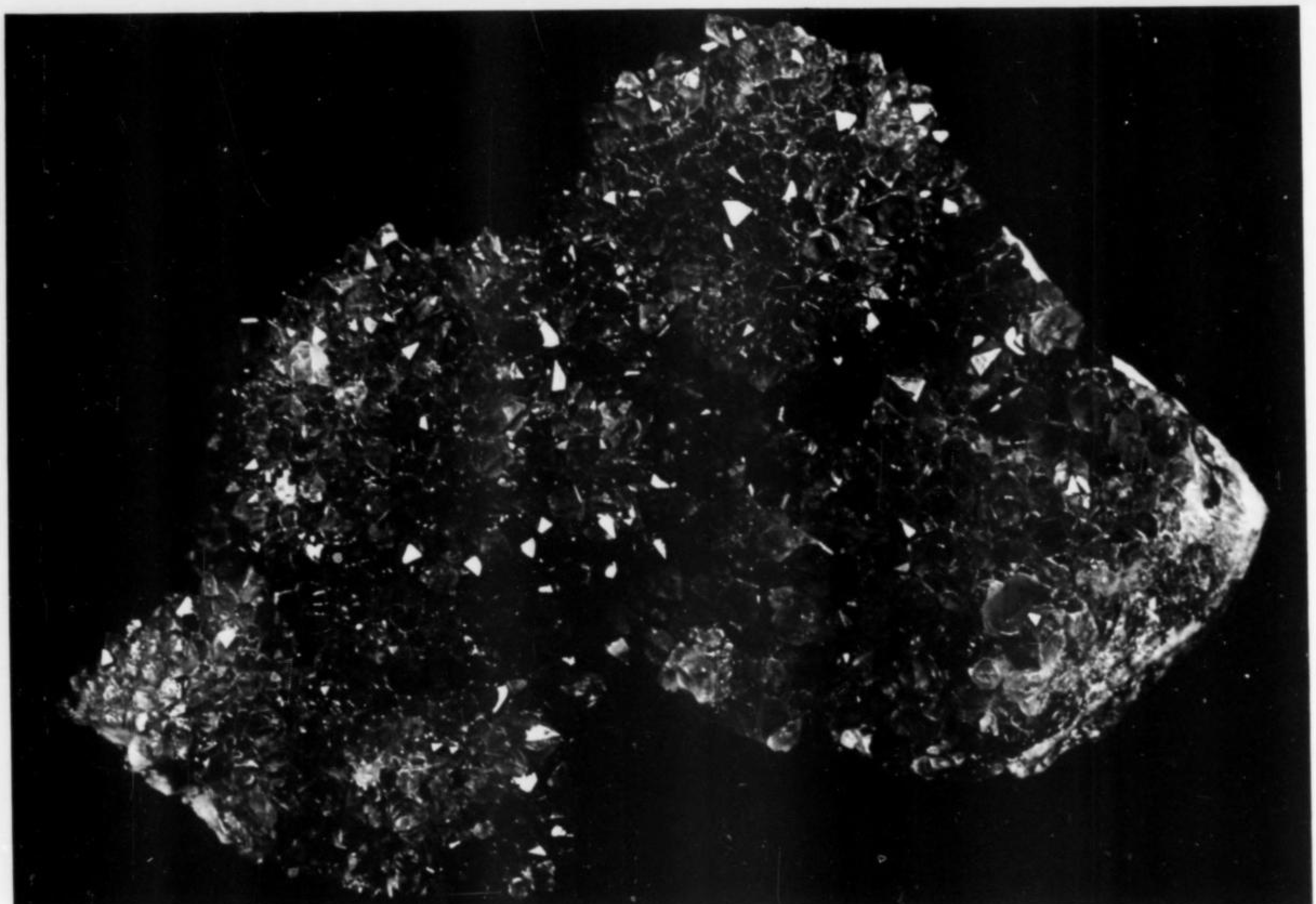
***Figure 89.* Stalagmites, Bisbee.**



William Panczner

Figure 90. **Amethystine quartz group 5½ inches across from the 2700 level, Junction shaft. Arizona-Sonora Desert Museum collection.**

Figure 91. **Polished turquoise 1½ inches across from the Lavender pit. Melvin Elkins collection.**

Acknowledgments

No work of this nature, regardless of scope, is possible without uncommon amounts of assistance from others. It is with pleasure and deep appreciation that I acknowledge the immense and often protracted help so unselfishly given. I say thank you to:

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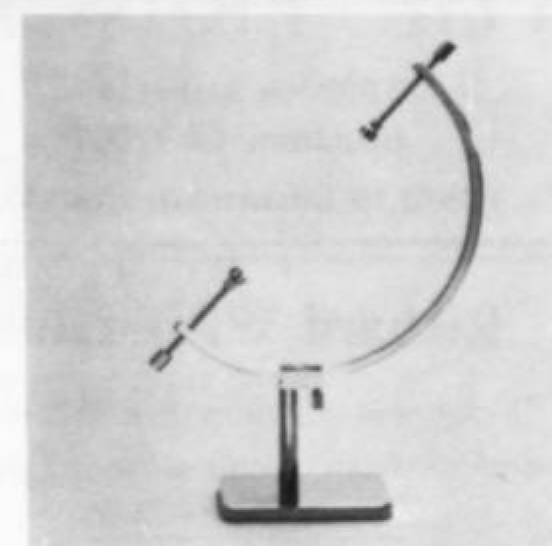

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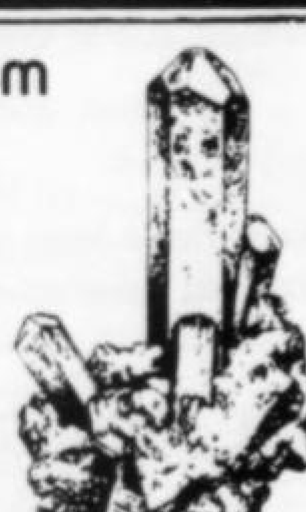

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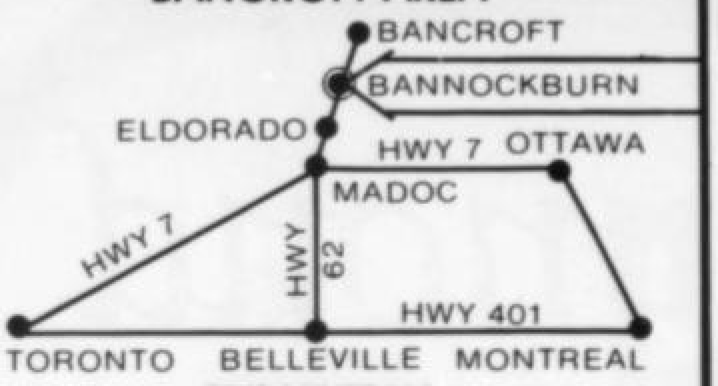

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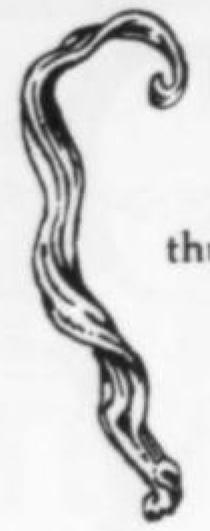

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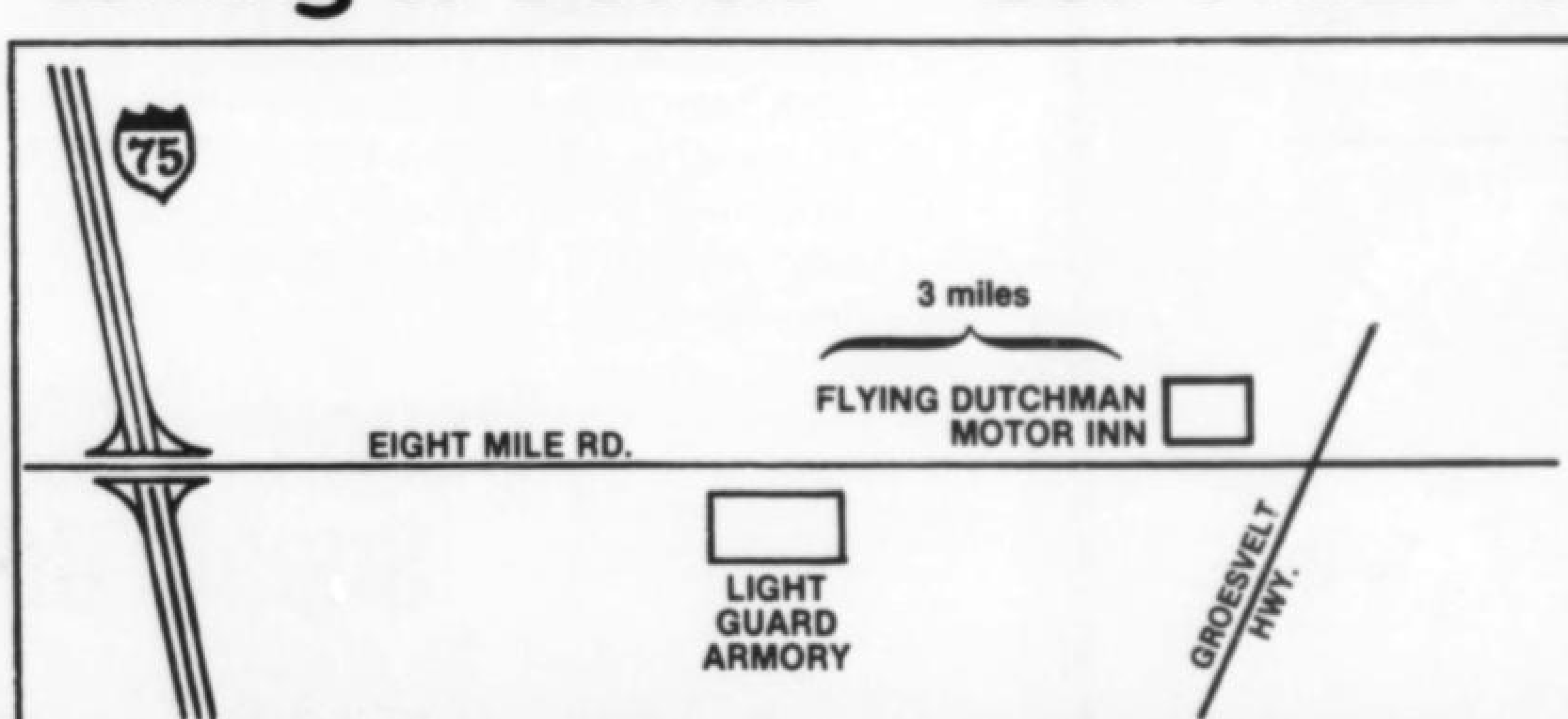

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