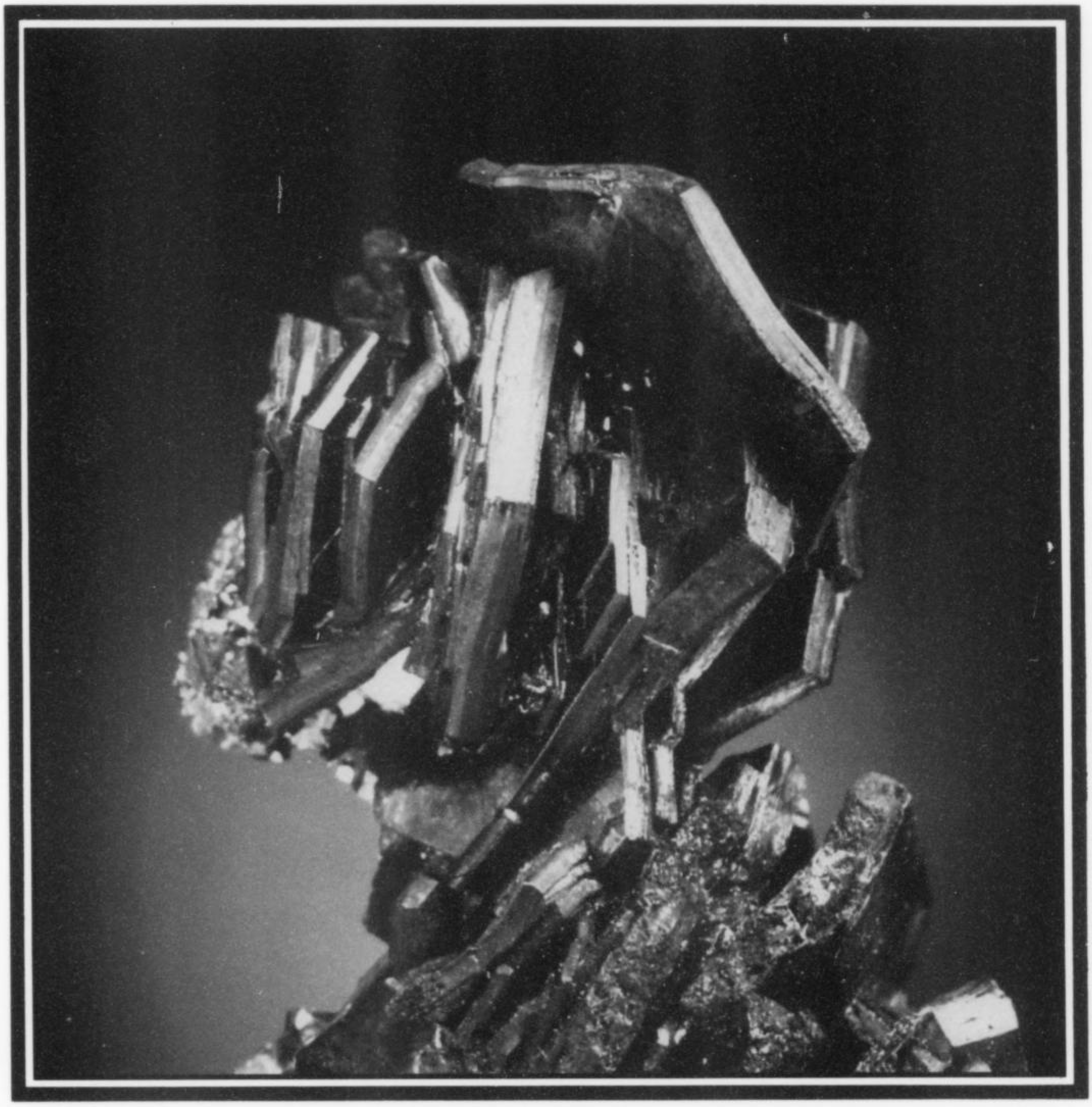
Butte, Montana

Minerals, Mines and History



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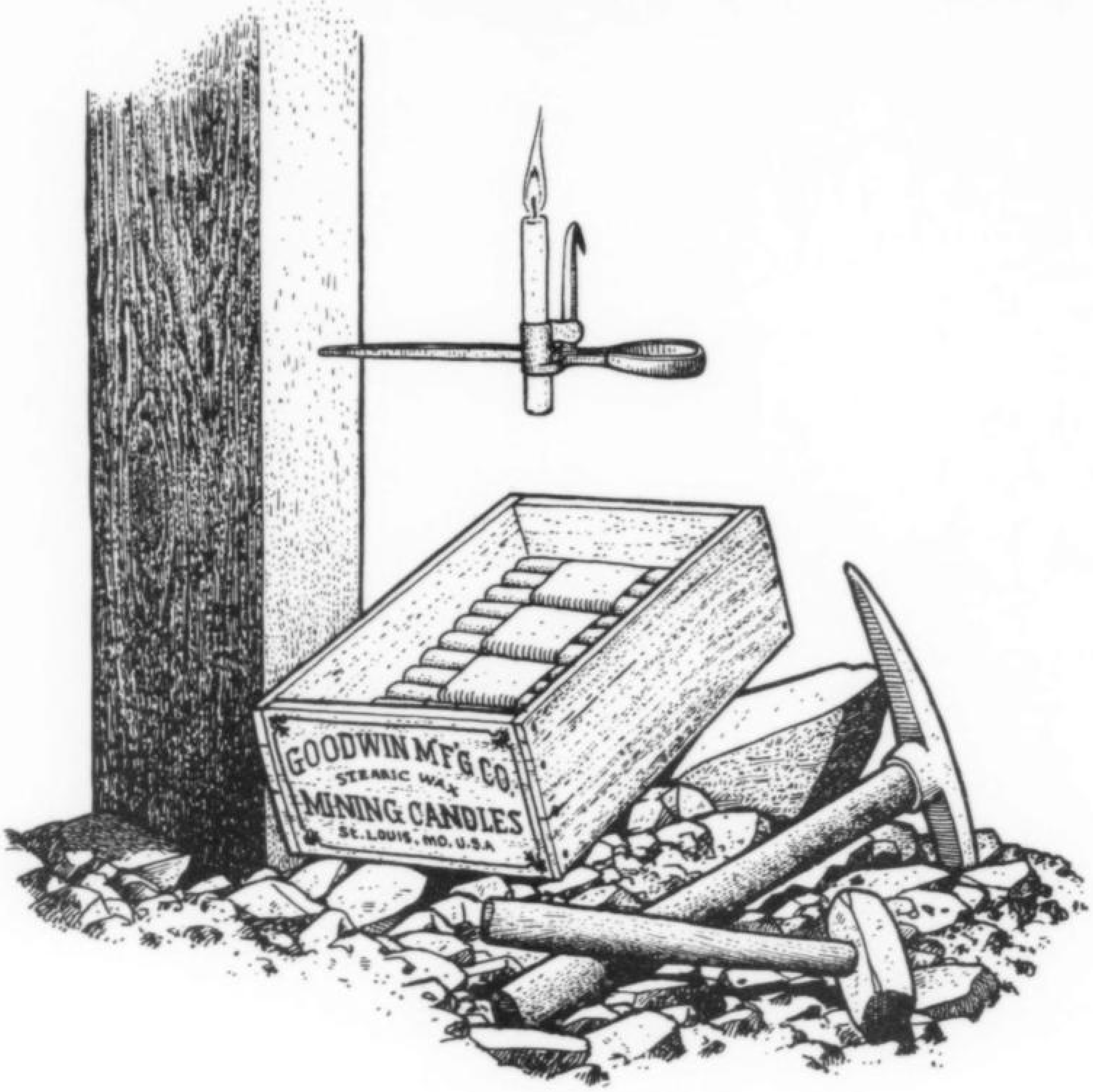

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Front cover: COVELLITE crystal cluster, 3 cm across, From the Leonard mine, Butte, Montana. Frederick H. Pough collection; Jeff Scovil photo.

Frontispiece:
"The Prospecror," (1906) by N. C. Wyeth (1882–1945), oil on canvas, painted to illustrate "The Story of Montana: The Treasure of Butte Hill and Development of the Great Copper Industry" by C. P. Connolly in *McClure's Magazine,* September 1906. Collection of Wells Fargo Bank & Company, Phoenix.

Chapter Illustrations
In pen-and-ink by
Wendell E. Wilson

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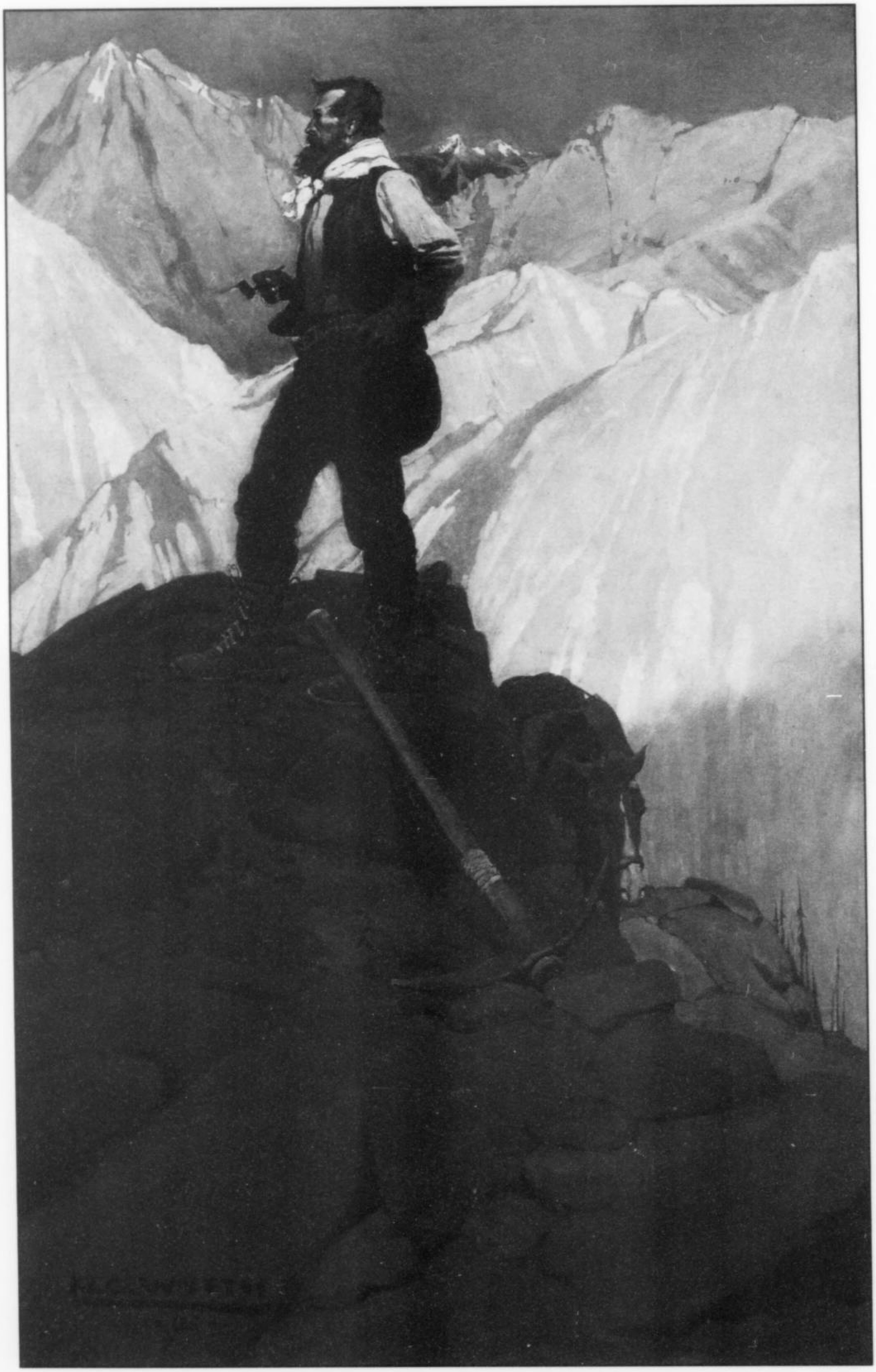

Butte, Montana

Minerals, Mines, and History

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Newark, Delaware 19702

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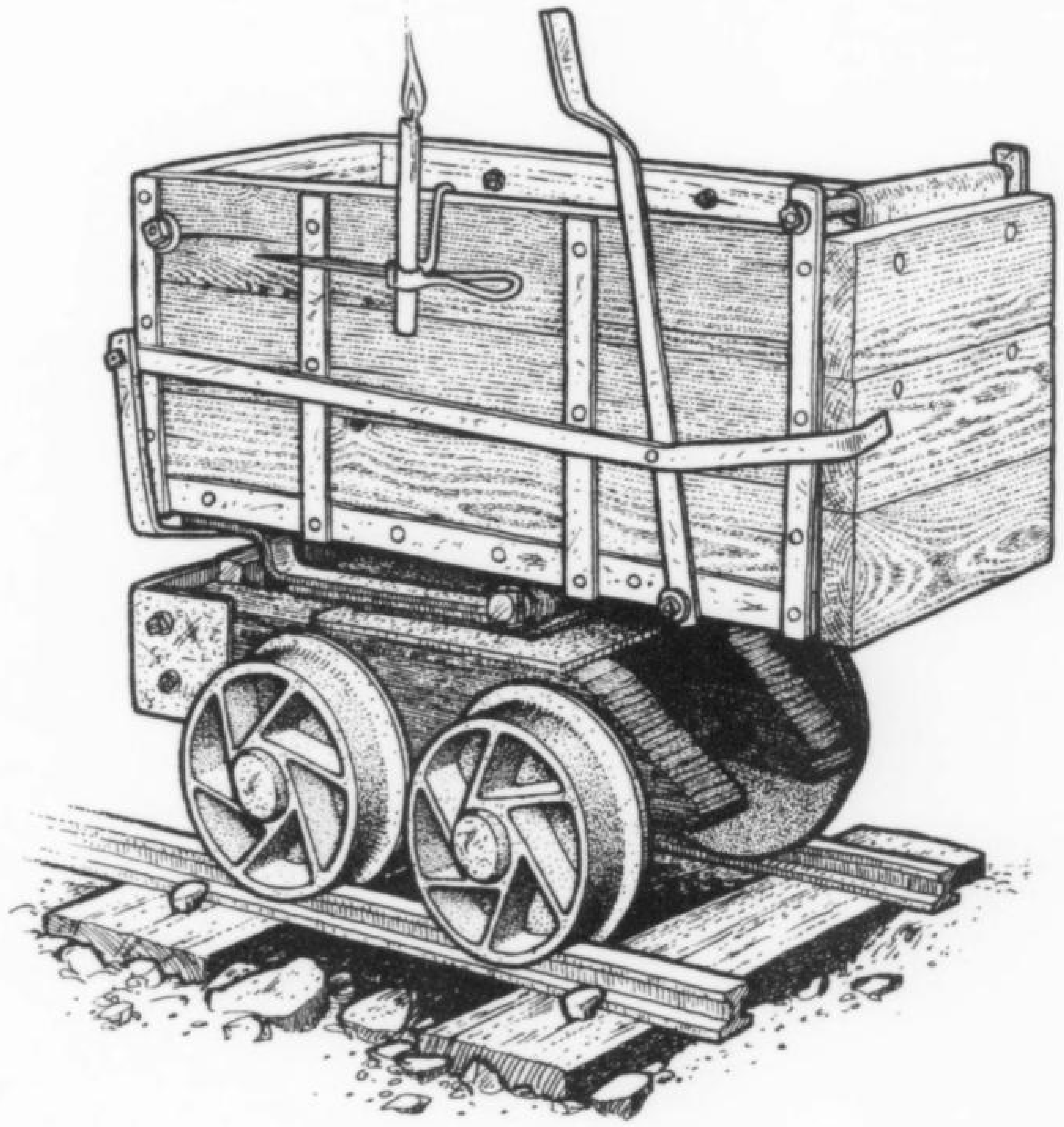
For more than 100 years Butte's dozens of mines have been a source of extraordinary specimens of an equally extraordinary number of minerals. A total of 130 mineral species have been recorded from Butte. Specimens of copper sulfides and sulfosalts like bornite, chalcocite, colusite, covellite, digenite, djurleite, and enargite rank among the finest in the world. The best of Butte pyrite compares with the best anywhere. Handsome specimens of barite, quartz, rhodochrosite, silver, and numerous other species have been found, many of them in extraordinary numbers.

Figure 1. **Steel headframes of the Original (foreground), Kelley #1 (center-background), Steward (left-background) and Kelley #2 (right-background) mines, Butte, ca. 1965. World Museum of Mining photo.**



Introduction

That was the first time I heard the term "vug hole." The ground in the Butte mining camp, especially in the Kelley mine, was just full of vug holes . . . the holes, some football-size, were full of crystals, many as large as a man's fist. As soon as the rest of us found out that the damned place was full of "diamonds," we hammered and chipped at the walls with whatever we could find. Jim had lost us, and even though he yelled menacingly, he couldn't regain control. Finally he just threw up his hands and declared an early lunch.

. . . So wrote a trainee miner, Jerry Dolph, concerning his first trip into an underground stope at Butte, Montana's Kelley mine in the early 1970's (Dolph, 1994).

The wonderful vugs and crystals of Butte, Montana, are, of course, far better known to experienced mineral collectors than they were to new underground miners like Mr. Dolph. Yet for all its outstanding production of specimen minerals, Butte is sadly lacking in a current, or even good, descriptive mineralogy. Although the geologic and engineering literature on Butte is immense, Guilbert and Zeihen (1964) remains the only comprehensive mineralogical study of the district. This work is as valuable today as it was 37 years ago, but it is a study aimed at the practicing geologist, not at the collector of minerals. It includes little descriptive detail, especially as regards crystallized species, unusual associations, or individual mine localities. Similarly, the popular journals are replete with references to individual Butte specimens or producing locations, but nowhere is this information compiled, and too often it is inaccurate.

This paper is designed to fill the void in the literature on one of the most important and productive mineral localities in the world, placing Butte mineralogy in the proper geologic and historical framework of what has been long romanticized as "the richest hill on earth."

Readers whose appetite for Butte minerals is whetted by this article should make a trip to Butte to see the extensive collections at the museum of Montana Tech. For those inclined toward history as well as minerals, the World Museum of Mining is also located in Butte, at the site of the old Orphan Girl mine.

LOCATION AND SETTING

Butte is located in the southwestern quadrant of Montana, at the junction between Interstate Highways 15 and 90. Helena, the State Capital, lies 106 km to the north, and Dillon, Montana, 91 km to the south. Spokane, Washington, the nearest major metropolitan center, is 490 km to the west.

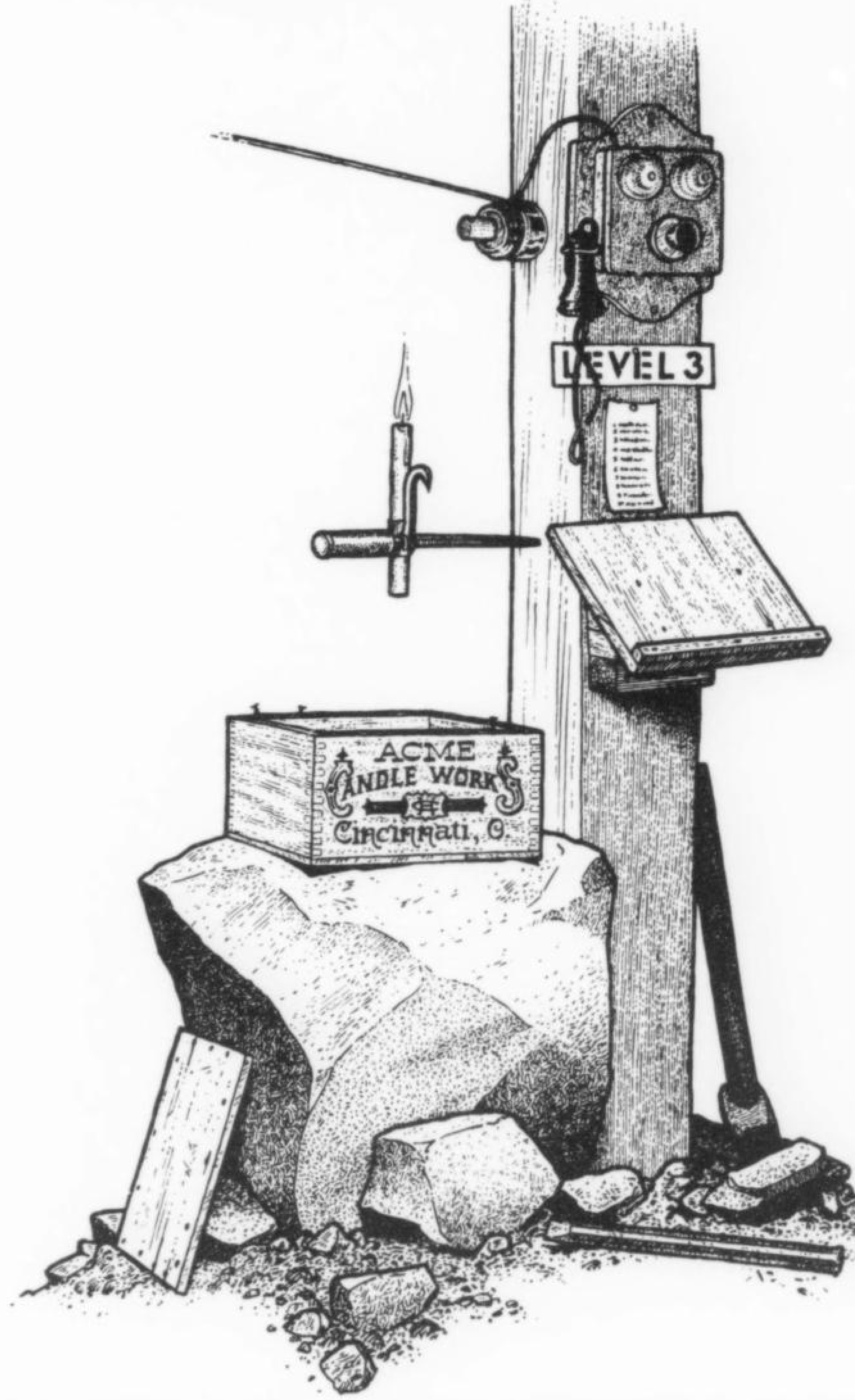
Butte is situated in the Summit Valley, an intermontane valley at an elevation of 1,800 meters (5,400 feet), flanked by the Continental Divide 6 km to the northeast. The area is drained by Silver Bow Creek, which flows west into the Warm Springs Ponds where, together with other tributaries, it forms the headwaters of the Clark River. The Clark Fork, in turn, drains into the Columbia River.

Although the surrounding mountains are heavily timbered, the immediate city area is rather bleak and desolate. Fumes from smelter operations 100 years ago destroyed much of the local natural vegetation. It is still recovering. The climate is mild and pleasant during the summer months. Winters can be long and bitterly cold. Temperatures as low as –49°F have been recorded.

Figure 2. **Miners lighting fuses 900 feet under the Butte Post Office, in the Steward mine, 1897. World Museum of Mining photo.**

Snowfall is moderate compared to that in the adjacent mountains.

Butte, a community of about 30,000, sprawls over the flats below and across the south-facing slope of a large, bare hill called Butte Hill. Not so very long ago, mines like the Emma, Original, and others actually operated within the uptown area. City dwellers went to sleep to the screech of sheave wheels and the roar of broken ore falling into bins. Trains of the Butte, Anaconda, and Pacific Railroad rumbled through town 24 hours a day, delivering ore to the concentrators and smelters at Anaconda and Great Falls. The suburb of Walkerville, northwest of Butte, lies around and near the silver mines of the Rainbow vein system. Some old specimen labels still bear that name. Another suburb called Meaderville, northeast of the city, was largely eradicated by the growth of the Berkeley Pit (Kearney, 1998; Watkins, 2000; Marcus, 2000).



History

The business and exploits of Butte have always centered on mining and, particularly, on the mining of one metal—*copper*. But things did not begin that way. Butte effectively began in 1864 as a gold camp and then a silver camp long before its miners gave serious thought to the red metal.

Separate portions of this history section will describe Butte's early years as a minor gold producer, the middle period as a silver camp of some importance, and finally, beginning in 1882, its years as one of the greatest copper-mining districts in the world. Another section will contain short "biographies" of some of the individual Butte mines, chosen for their special interest to mineral collectors. A final section will briefly describe some of Butte's mills and smelters. These, too, are part of the Butte story. The first large copper smelter in the west was constructed at Butte, as was the first flotation plant in the United States. Innovations in mineral extraction technology originally conceived in the district were considered the state-of-the-art around the world.

The Gold Years

Mining began at Butte in the early summer of 1864, when two men, William Allison and G. O. Humphreys, staked a claim on a small pit in Missoula Gulch which had been noted by Caleb E. Irvine during an Indian trading expedition in 1858. The pit, less than 1.7 meters deep, contained a number of worn elk horns that had evidently been used by aboriginal workers as gads and handspikes. Allison and Humphreys deepened the pit and dug gravel which they washed in Silver Bow Creek to the south. This gravel yielded Butte's first production of placer gold (Weed, 1912; Marcosson, 1957).

By the winter of 1864 the Summit Valley district (Butte's original name) had been organized, with the majority of the placer gold claims staked along Missoula, Buffalo, Town (now Dublin), and Parrot Gulches (Weed, 1912). The gravels from all of the deposits were washed along nearby Silver Bow Creek, the largest stream in an otherwise arid mountain region. By 1867, approximately $1.5 million in gold had been scratched from gravel

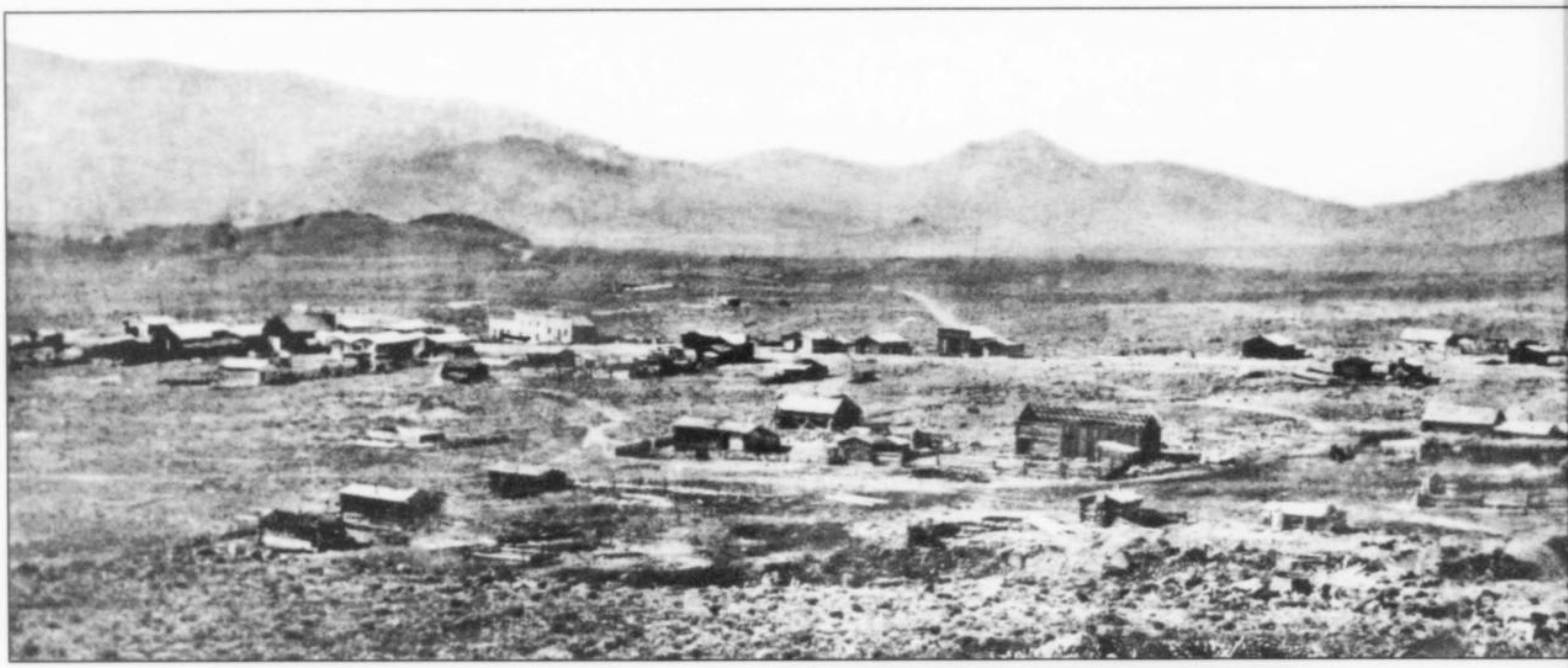


Figure 3. **Butte, Montana, in 1876. World Museum of Mining photo.**

Figure 4. **Marcus Daly.**

trundled down to the Silver Bow by ox teams (Weed, 1912; Kearney, 1998).

This hardscrabble placer camp, having by then taken the name of "Butte" for the prominent conical hill west of the present-day city, remained active through about 1874, by which time gold recovery had substantially waned. Although its days as a placer gold producer had come to an end, the Butte Hill had other treasures waiting to be discovered and exploited.

The Silver Years

The gold washed from the gravels of Missoula Gulch and its neighbors during the 1860's was noted for its ragged texture. This fact led the miners to conclude that the placer gold deposits were located close to their hard-rock source (Blake, 1887b). Prospecting for this primary source led the miners to vein outcrops which swept eastward up onto the hill above (Weed, 1912). The material cropping out was porous and heavily stained by manganese oxides. Where the rock had decomposed sufficiently, precious metals were found at and near the surface of the ground (Blake, 1887b), in an occurrence named the Rainbow vein or lode. The Rainbow was so named (in 1876) by John E. Clayton in recognition of the broadly sweeping curve of the outcrop across the rounded surface of the granitic hill (Blake, 1887b). The bulk of the primary silver produced in the Butte district eventually came from the Rainbow vein system. However, the first true silver strike was not made there.

William L. Farlin had staked a claim covering what would become the district's first silver mine on New Year's Eve, 1874. The claim was called the Asteroid, and it was developed in conjunction with the Dexter Mill over the next several years. In 1879, it was renamed the Travona mine by its new owner, William Clark. Further details of the history of the Travona mine are given in its "biography" below.

By the mid-1870's, most of the important silver-bearing lodes on Butte Hill had been discovered. Because of the complex mineralogy of these ores at depth it wasn't until the successful operation of the Dexter Mill that a satisfactory treatment for Butte silver ores existed (Weed, 1912; Elliot *et al.,* 1992). After exhaustion of the near-surface, free-milling ores, the method utilized was chlorination-roasting. This method consisted of heating the silver ores with salt and blue stone (copper sulfate), followed by amalgamation. This was a modification of the famed "Washoe process" (not to be confused with Butte's Washoe smelter), originally developed to treat the refractory sulfide ores of the Comstock Lode (Lord, 1959).

The most significant silver properties in Butte, alluded to earlier, were some of those located on the Rainbow vein. The value of these properties was first suggested when the Walker Brothers of Salt Lake City received a shipment of rich silver ore from the owners of the Acquisition claim on the Rainbow vein. The Walker Brothers were well known mining investors of the day. The high value of the Acquisition ore led the brothers to dispatch a man by the name of Marcus Daly to the district in 1876, in order to examine the mining prospects for possible purchase. Daly was a practical miner and metallurgist of considerable experience. He had worked on the Comstock, the California Mother Lode, and he had recommended to George Hearst the property that would

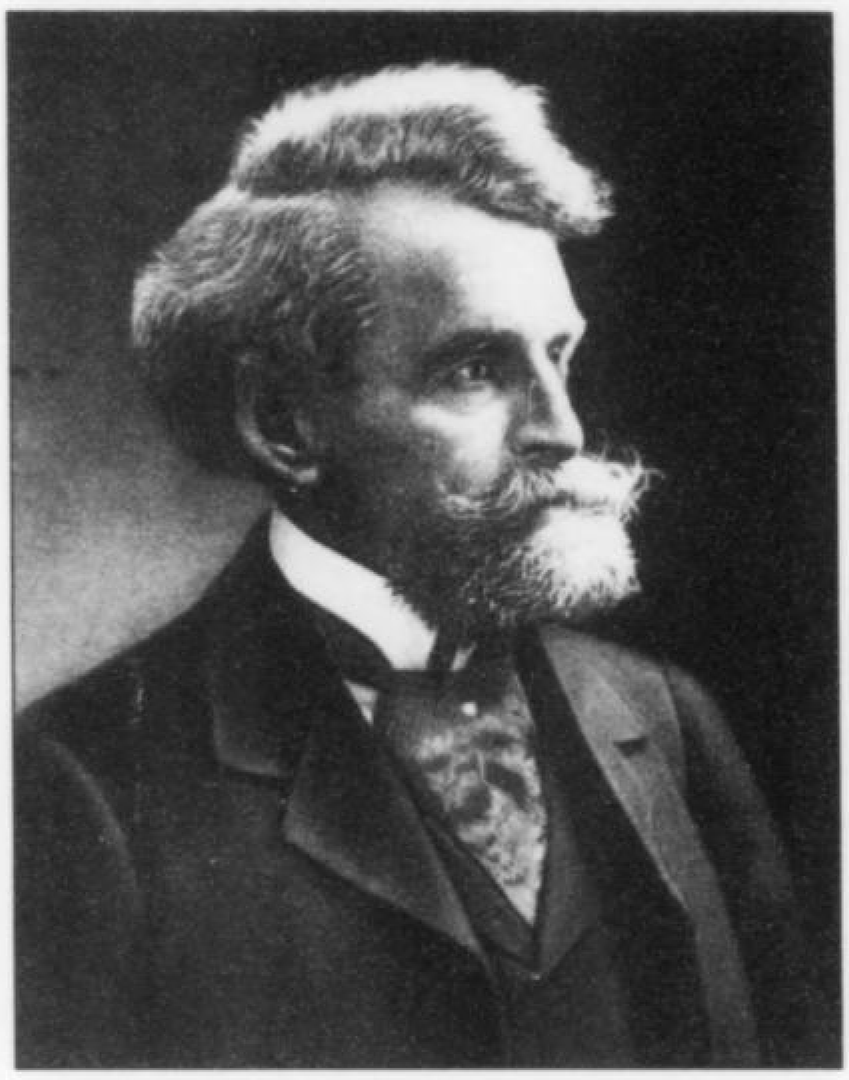


Figure 5. **William A. Clark.**

become the Ontario mine at Park City, Utah. He had previously worked for the Walkers at Ophir, Utah (Shoebotham, 1956).

Daly secured a $5,000 bond on another Rainbow vein property, called the Alice, prompting Robert Walker and John E. Clayton to visit the claims in order to select a location for shaft-sinking. Mining activity at the Alice and other properties on the Rainbow vein would make Butte one of the leading mining districts in Montana Territory for a time. More history of the Alice Mine is given in its "biography" in the following pages.

At the peak of silver mining in 1887 the Butte ores were being processed in five mills, dropping a total of 290 stamps. These mills processed more then 365 metric tons of ore each day (mtpd), the ore yielding an average value of about $25 per ton (Elliot *et al.*, 1992). During the period 1880–1890, Butte mines produced more than 28 million Troy ounces or about 900 metric tons (mt) of silver (Weed, 1912).

The silver panic of 1892–93 wreaked havoc on the silver industry at Butte, as it did throughout the western mining camps. Even before repeal of the Sherman Silver Purchase Act, the Butte mines struggled for survival because of another factor—salt. Because the chlorination-roasting process utilized salt as its chloride source, the high cost of salt had to be reckoned with if the district's ores were to be worked profitably (Blake, 1887a). The salt utilized in processing Butte silver ores originated at Great Salt Lake in Utah, where it was available at $2 to $3 per ton. By the time it had reached Butte by railroad, that price had escalated to about $12 per ton, a factor of four, due solely to the expense of shipping (Blake, 1887a).

Although the production and treatment of silver-bearing ores was the primary industry at Butte well into the 1880's, there were several mines producing small amounts of copper as well. As the silver mines deepened, ores with greater amounts of copper were encountered. While many considered the copper a nuisance which interfered with the efficient extraction of silver and gold, some mines were becoming active in production of the red metal.

The Copper Years

Most of the copper ledges were outcrops devoid of vegetation and at least sparsely colored by copper stain; consequently their presence was noticed early (Weed, 1912). The first body of commercial copper ore to be opened in Butte was that of the Parrot No. 2 mine, located by Joseph Ramsdell in August 1864. However, there was no plant in the west for treatment of the copper ores and only one small plant in the east, located in Baltimore, Maryland. Therefore, the find had no immediate economic value.

The only marginally satisfactory choice available for the prospective copper producers of Butte was to ship their ores to Swansea, the metallurgical capital of Wales in the United Kingdom. No community anywhere could compete with its skilled workmen and the number of smelting works which employed them. However, the shipping of ore across the Atlantic was costly, and the resulting copper plate would reach market only after many months (Marcosson, 1957). Nonetheless, the first shipment of copper ore from Butte to Wales was made in 1866, from William Park's Parrot No. 3 mine.

In response to the cost of transatlantic shipments, several "home-grown" processing facilities were erected at Butte in the early years. For example, in 1868 the Davis Mill and furnace were constructed for smelting the ore from one of the Parrot lodes, which had been developed to a depth of 48 m. However, the inability to flux this ore properly led to its early abandonment (Marcosson, 1957).

In 1872, William A. Clark, a banker from the nearby town of Deer Lodge and later owner of the Travona silver mine described above, visited the district and examined some claims on the large black quartz reefs located just below the big butte overlooking the camp. Although the presence of appreciable values in precious metals had been suspected by others, there were no assays or real proof of value available. Exhibiting an almost uncanny business sense, Clark purchased four properties within the quartz-rich zone anyway: the Original, the Colusa, the Mountain Chief, and the Gambetta claims (Kearney, 1998). These four claims, together with his Travona silver mine mentioned earlier, would launch Clark's career as the first of Butte's Copper Kings.

Clark collected ore samples from his new properties, which he shipped to New York for assay. Learning that the black quartz at the surface did indeed contain a significant amount of silver, he set about educating himself in things mining by enrolling in mining courses at Columbia University in New York City. He returned to Montana in the spring of 1873 and initiated the development of his new properties.

Rather than silver, however, his miners encountered significant copper mineralization almost immediately. At first, copper ore from his claims was hauled 640 km to Corinne, Utah by ox team, and thence by rail to the reduction works in Baltimore and to a newer toll-smelter of the Boston and Colorado Smelting Company at Blackhawk, Colorado. As had transpired earlier, costs incurred during mining, shipping, and processing were prohibitive, rendering unprofitable an ore assaying at $130 per ton in copper and at least $50 per ton in precious metals (Weed, 1912). Faced with such stark economics, Clark arranged for the Boston and Colorado Company to construct a custom smelter at Butte. Thus, in 1879 the first successful copper smelter in Butte was built under the newly formed Colorado and Montana Smelting Company. The new works became known as the Colorado Smelter.

With the establishment of the Colorado Smelter as a successful enterprise, the exploitation of Butte's immense copper resources gained momentum. By 1879, the same year in which the smelter was blown in, almost every vein exposure in the district had been located, and the entire hill was dotted with headframes. By 1885, not less than 25 companies were digging for copper (Sales, 1964). Although only a small percentage of the mines ever turned a profit, and many of them had passed from memory by the turn of the 20th century, it must be recognized that their number was enormous

***Table 1.* Butte mine names.**

Acquisition	Blue Bird	Butte)	Green Copper	Little Gold Hill
Adams	Blue Jay	Daniel Quilp	Green Mountain	Little Ida
Adirondac	Blue Wing	Darling Fraction	Greenleaf	Little Joe
Adventure	Bob Ingersoll	Davis-Daly	Gregory	Little Mina
Agnostic	Bologna	Despatch	Grey Eagle	Little Sarah
Alex Scott	Bonanza	Destroying Angel	Grey Rock East	Little St. Lawrence
Alexander	Boston	Diamond	Grey Rock West	Lizzie (Hayes)
Alice (pit)	Brazil No. 1	Diamond-Bell	Ground Squirrel No. 1	Lloyd
Alisbury	Brazil No. 2	Dixon	Ground Squirrel No. 2	Lone Tree
Alliance	Brilliant	Downey	Ground Squirrel No. 3	Look Out
Allie Brown East	Brittania	Druid	Harrington	Lost Anaconda
Allie Brown West	Buck Placer	Dutton	Hattie Harvey	Louis Barber
Altona	Buffalo	Eagle Bird	Hawkeye	Macawber
Amador	Bullwhacker	East Berkeley (pit)	Henry George	Maggie Bell
Amapore	Bully Boy	East Colusa	Hesperus	Maggie Fraction
Amazon	Bummer	Easter	Hibernia	Magna Charta
Amy Incline	Burke	Edith May	Hibernian	Magnolia
Amy-Silversmith	Burlington	Eighth of May	High Ore	Main Range
Anaconda	Burnett	Elbe	High Top	Mamie
Ancient	Butch Placer	Ella	Highland	Manhattan
Anderson	Butte	Ella Clark	Homestake	Mapleton
Andy Johnson	Caledonia	Ella Ophir	Hope	Marg(ar)et Ann
Anglo Saxon	Cambers	Elm Orlu	Humboldt	Maria
Annie and Ida	Can Can	Elvina	Hyde Park	Marie
Anselmo No. 1	Candlestick	Emma	Ida	Marie Louise
Anselmo No. 2	Carrie	Enterprise	Ida Montana	Mark Anthony
Apex	Carte Blanche	Estella	Iduna	Martha
Ardsley Butte	Centennial	Evaline	Illinois	Mastadon
Argonaut	Champion	Excelsior	Independent	Mat (Adelaide-Mat)
Atlantic	Chattanooga	Exchequer	India Queen	Maximilian No. 1
August Flower	Chicago	Exemption	Iodine	Maximilian No. 2
Aurora	Chief Joseph	Exile of Erin	Iowa	Mayflower
Ausania	Chinook	Fairview	Isele	Michael Davitt
Azor	Clark's Fraction	Fifth of July	J.I.C.	Midnite
Bachelor	Clear Grit	Flag	Jamestown	Mill Site
Badger	Cleopatra	Florida	Jelly Man	Milwaukee
Badger State	Clinton	Four Johns Tunnel	Jersey Blue	Minnie Healy
Baklava	Clipper	Fourth John D.	Jessie	Minnie Irvin
Balm	Colleen Bawn	Fraction	Jessie Wingate	Minnie Jane
Banker	Colorado	Frank Moulton	Josephine	Missing Link
Batchelor	Columbia	Fredonia	Kansas Chief	Missoula
Bazzo	Colusa	Free-for-All	Kanuck	Modoc
Belcher	Colusa-Parrot	Gabriella	Kelley No. 1	Mollie
Belk	Comanche	Gagnon	Kelley No. 2	Molly Murphy
Bell	Confidence	Gambetta	Kennedy	Monahan
Bell-Diamond	Continental (pit)	Gambrinus	Kit Carson	Mono
Belle of Butte	Continental East (pit)	Garfield	Kitty Morris	Montgomery
Belle of Butte East	Continental South (pit)	Garibaldi	Kossuth	Moody & Sankey
Belle of Butte, L.S.	Copper Czar	Gem	La Plata	Moonlight
Bellona	Copper Queen	Geneva	Lackawanna	Moose
Belmont	Corra No. 1	Germania	Late(r) Acquisition	Moose Auraria
Benham	Corra No. 2	Glengarry	Lena K. East	Morning Star
Berkeley (pit)	Creole	Glengarry Silver	Lena K. West	Moscow
Bernard	Crotch	Goddess	Leonard No. 1	Moulton
Bertha	Cuerpo	Gold Hill	Leonard No. 2	Mount Moriah
Betsy Dahl	Cumberland	Gold King	Levena	Mountain Boy
Birdie	Curry	Gold Flint	Lexington	Mountain Central
Black Chief	Cut Hand	Goldsmith	Lillie	Mountain Chief
Black Rock	Czarina (Tsarina) East	Gopher	Liquidator	Mountain Con. No. 1
Black Warrior	Czarina (Tsarina) West	Grabella	Little Annie	Mountain Con. No. 2
Blackbird	Czarromah	Granite Mountain	Little Cinnamon Bear	Mountain Flag
Blackstone	Daly Shaft (Original	Great Republic	Little Darling	Mountain View

Table 1 (continued). **Butte mine names.**

Narrow Gage	Parrot	Rock Island	Snohomish	Tuolumne
National	Parrot No. 5 east	Rocker	Snoozer	Tycoon
Nellie	Pauline	Rockwell	Snowball	Union Co.
Nemo	Pawn Broker	Rooney	Snowdrift	Unita
Neptune	Paymaster	Rose	Snowflake	Unrepresented
Nettie (Hibernia)	Pennsylvania	Rubber Neck	Sooner	Valdemere
Nettie No. 1	Penrose	Ryan	Soudan	Valley East
Nettie No. 2	Philadelphia	Saint Patrick	Speculator East	Valley Queen
Nettie No. 3	Piccolo	Salvadore	Speculator West	Valley West
Neversweat	Pikes Peak East	Samantha	Spread Delight	Venus
Niagra	Pikes Peak West	Sarsfield	Springfield	Vesuvius
Night Hawk	Pilot	Saukie East	St. Clair	Virginius
Nile	Pittsmont	Saukie West	St. Lawrence	Volunteer
Nipper	Plover	Scarfield	St. Lawrence No. 2	Vulcan
None Such	Plutocrat	Schonbar	Stanislas	Wabash No. 1
North Berlin	Pollock	Schweitzer-Monitor	Star of the East	Wabash No. 2
North Star	Poorman	Scotia	Star West	Wake-Up-Jim
Northern Pacific	Poser	Scottish Chief	Stella	Walkerville
Northwestern	Poulin	Self Rising	Stevens	Wapello
Norwich-Plutus	Preferencia	Shark	Stewar(t)d	Washoe/Wyoming
Number Three	Prospector	Silver Bow No. 1	Sulvadore	Wedge
Oden	Quarter Moon	Silver Bow No. 2	Sun Dog	West Colusa
Old Glory	Railroad	Silver Bullion	Sunnyside	West Gagnon
Olive Branch	Rainbow	Silver Chief	Sunrise	West Mapleton
Olsen Fraction	Ramsdell's Parrot	Silver Cleft	Sunset	West Mayflower
Ophir	Rarus	Silver Gate	Sunshine	West Nettie
Original	Raven	Silver King	Surprise	West Stewar(t)d
Oro Butte	Raymond	Silver Lick	Syndicate (pit)	Wild Bill
Orphan Boy	Read	Silver Safe	Tecumseh	Wild Pat
Orphan Girl	Ready Cash	Silver Smith	Tiger Lil	World
Otisco	Reins Copper Co.	Sinbad	Ton-a-Minute	Yankee Boy
Ottowa	Rescue	Single Tax	Tramway	Yellow Jacket
P-80	Rialto	Sioux Chief	Transit	Young & Roundebush
Pacific	Rising Star	Sisters	Travon(i)a	Zadoc
Pacific Slope	Rob Roy	Six O'Clock	Trifle	Zella
Park	Robert Emmet	Smoke House	Tully	Zeus
Parnell	Robert McMinn			

even for a relatively large mining district. Table 1 lists 489 of the mines which existed at Butte, Montana between 1864 and the present day. Sources for the mine names include Brown (1894), Emmons and Tower (1897), Weed (1912), James (1980), Herbort *et al.* (1998), and Kearney (1998).

It is worthwhile for the collector to pause and reflect for a moment here on these mines. Many, if not most, of the names will be unfamiliar to the average mineral collector, yet most of them were real operations, which many years ago produced real ore. Anyone owning specimens with verifiable labels from some of these bygone mines should be very careful with them, indeed. Even mediocre ore specimens are genuine historic treasures.

Between 1880 and 1920, there were up to a dozen smelting operations dedicated to the treatment of the complex copper sulfide ores of Butte Hill. In addition to the aforementioned Colorado Smelter, these included the Colusa Smelter of the Montana Copper Company, the Parrot Silver and Copper Company, the Bell plant, Clark's Colusa, the Butte Reduction Works of the Colusa-Parrot Mining and Smelting Company, the Butte and Boston Consolidated Mining Company, the Montana Ore Purchasing Company, the Great Falls Smelter of the Boston and Montana Consolidated Copper and Silver Mining Company, and last, but scarcely least, the three separate plants at Anaconda of the Anaconda Copper Mining Company (Hofman, 1904). Many of these operations, excluding those owned by the Boston and Montana and Anaconda companies, were custom smelters, toll-smelting the ores from the numerous small mines of the district.

The enormous environmental impact these primitive smelting operations had on Butte and the surrounding area within a very short time bears mentioning here. By the mid-1890's, the Summit Valley had been more or less denuded of vegetation by the noxious sulfur fumes pouring from the various open-stall roasting operations employed by the early smelters. Photographs taken during this period show Butte backed by a dense fog of smoke emanating from the smelters situated south of town along the banks of Silver Bow Creek. C. Owen Smithers, one of Montana's most prestigious professional photographers and a long-time resident of Butte, remarked in the caption of one such photograph taken in the 1890's (James, 1980):

> In the distance can be seen the dense smoke from the smelters. A picture of this kind could not be taken unless a strong wind was blowing. The smoke from the smelters on the outskirts of Butte was so bad that one could not see across the street in the middle of the day.

Although the smelter fumes and their visible impact were perhaps the most immediately noticeable evidence of Butte's burgeoning mining industry, they were not its only unpleasant by-product. Because of the high water-table, dewatering was an essential element of underground mining at Butte. Oxidation of the sulfidic rock exposed by the mining operations resulted in mine waters with very high levels of sulfuric acid. As Silver Bow Creek provided the sole drainage within the valley watershed, it became a *de facto* sewage system for the acid mine waters.

Most of the smelting operations in Butte also involved some sort of wet concentration circuit by which the raw ore was beneficiated to a copper grade at which it could be profitably smelted. Water for concentration purposes was drawn from Silver Bow Creek at points downstream from the mines. Thus, the concentrators had to be able to withstand the highly corrosive nature of the acid water. One approach, utilized by the Colorado Smelter, is described by Goodale (1896):

> [water from Silver Bow Creek is transported to the concentrator] . . . through 2800 feet of 10-inch wooden pipe. The pipe was made by boring out logs and banding them spirally with 1-inch No. 22 iron. It is covered with a mixture of asphalt and sawdust. In explanation of the use of wooden pipe, it should be said that the corrosive mine waters of Butte are discharged into the stream which furnishes the supply for the mill, and iron pipe would not long withstand the action of the acids.

The Silver Bow, forming part of the headwaters of the Clark Fork River, would continue to bear the environmental brunt of mining at Butte for another 80 years. By the late 1980's, the Environmental Protection Agency had designated Butte and the entire Clark Fork Basin as the largest Superfund clean-up site in the nation. The affected portion of the Clark Fork Basin alone is 224 km long. The Berkeley pit, which has received the acidic discharge from the underground mines since pumping operations ceased in 1982, now bears the dubious sobriquet of "the Giant Cup of Poison" (Marcus, 2000).

Daly and the Anaconda

After obtaining the Alice silver mine for the Walker Brothers in 1876, Marcus Daly continued there as mine superintendent, eventually earning a stock interest in the company. In 1880 he sold his interest for $30,000 and began to cast about the district for a promising claim in which to invest both his money and his substantial mining experience. The property he decided upon consisted of a 14-m shaft sunk into a silver-bearing quartz reef located at the center of the district and on top of a hill. It was called the Anaconda (Shoebotham, 1956; Marcosson, 1957). In a very real sense, the Anaconda would be the great grand-daddy of all of the Butte mines. And, while not the first, Marcus Daly would become the greatest of Butte's Copper Kings.

A Civil War veteran named Michael Hickey located the claim on October 19, 1875. The name "Anaconda" was inspired by an editorial written by Horace Greeley of the *New York Tribune* during the Civil War (Marcosson, 1957). Hickey applied for a patent on the claim on February 18, 1878 (Weed, 1912), and by 1880 he had staked out 25 other claims in the area and had begun development work on the Anaconda. A partner, Charles Larabie, owned a half-interest in the claims (Marcosson, 1957).

Under the mining law of the day, in order to hold a patent on a claim, a certain amount of assessment work had to be performed each year, just as a claimant must do on an unpatented claim today. Finding themselves unable to meet these costs, Hickey and Larabie sold a one-third interest in the Anaconda claim to Daly for $14,000, along with an option to purchase the remainder of the property for $70,000 (Shoebotham, 1956; Marcosson, 1957). As part of the deal, Daly stipulated that the initial payment be applied to development work on the claim. By 1881, with the Anaconda showing promising silver potential, Daly began looking for financial backing to enable him to exercise his option and purchase the remainder of the property.

Having failed to convince the Walker Brothers to join him, Daly obtained the backing of a San Francisco mining syndicate consisting of three men: George Hearst, James Haggin, and Lloyd Tevis.

Figure 6. **Early Montana mining stock, 1866. Mineralogical Record Library.**

Figure 7. **Inspecting the working face after a blast, Leonard mine ca. 1879. World Museum of Mining photo.**

These men, under the leadership of Hearst, had opened the world-famous Homestake Gold mine only a few years earlier. With their deep pockets to back him, Daly purchased the option in the name of the Anaconda Silver Mining Company. He received a one-quarter interest in the company as well as the superintendency, and began the first real development of the mine. The same year would see the Anaconda produce about 7,300 mt of oxidized silver ore, grading 930 gm per ton in silver. In order to process this ore, Daly leased the Dexter Mill from William Clark and began planning to erect a larger mill on the Anaconda property (Weed, 1912; Marcosson, 1957; Miller, 1973). Things did not work out that way, however.

In 1882, a new shaft was begun on the property on the recommendation of Hearst. A thin seam of chalcocite was encountered on the 100 foot level (30 m). Later, in a crosscut driven from the 300 foot level (91 m), a nearly solid vein of chalcocite was found. The vein measured 1.7 m in thickness and assayed 55% copper. Immediately realizing the significance of the find, Daly began to quietly purchase claims surrounding the Anaconda, including both the St. Lawrence and the Neversweat, which were located on the same vein system. By 1883 the Anaconda had reached the 600 foot level (183 m), with five working faces, exposing chalcocite veins up to 30 m in thickness (Marcosson, 1957).

Owing again to the dearth of facilities capable of processing Daly's new bonanza, the copper ores of the Anaconda were at first sent via ox-team, rail and ship to Swansea, Wales for metallurgical treatment:

> The copper men at Swansea were amazed at the richness of the shipments from Butte. They wrote back asking if they were receiving an ore or product of some new process in which the copper had been reduced. They had never seen or heard of massive chalcocite ore before. All the chalcocite they, and for that matter the entire world, had seen up to that time was in small specimens in mineralogical collections. (Marcosson, 1957)

Between 1882 and 1884 Daly shipped 34,000 mt of ore to Wales. It averaged an incredible 45% copper. In contrast to abortive attempts earlier, he was able to make a handsome profit on the shipments.

In order to successfully compete with the rich native copper ores produced in the Lake Superior district, and also to meet the rising demand for the metal created by the newborn electrical industry, Daly began planning a facility to treat the ores from his Anaconda mine. As the facility contemplated would be immense in comparison to any regional smelter then in existence, a plentiful supply of water was a prime requirement. Such was not available at Butte. Thus, a site 42 km west of Butte on Warm Springs Creek was selected, and on June 25, 1882 the plat for the new town was completed. The town of Anaconda was officially established in

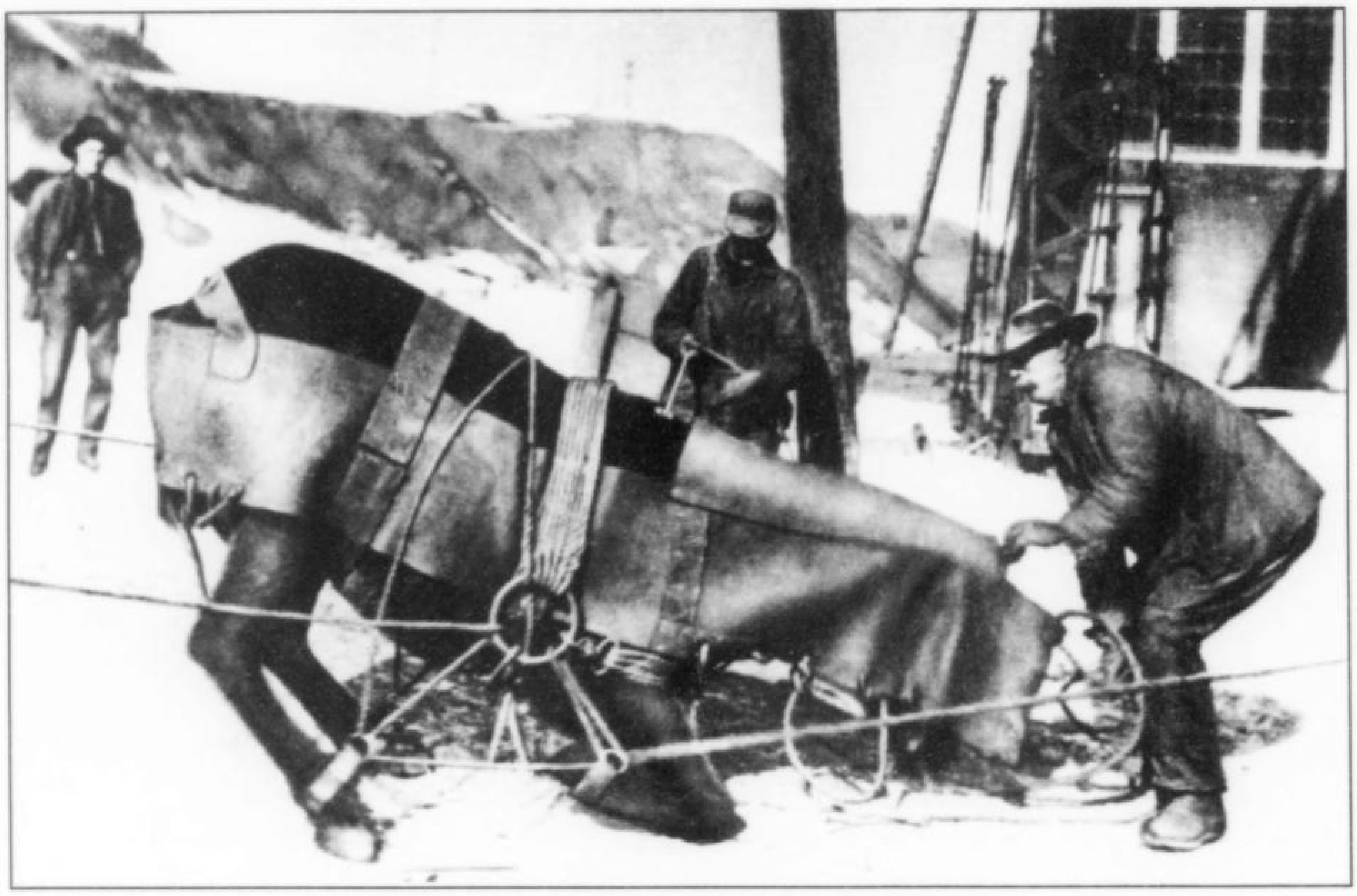


Figure 8. **Trussing up a mule to be lowered down a shaft, Diamond mine, 1908. World Museum of Mining photo.**

1883 (B. Shovers, written communication, 2000). The first postmaster chose the name "Anaconda" after having discarded Daly's perhaps inevitable suggestion of "Copperopolis," probably because a community of that name already existed in Calaveras County, California (Marcosson, 1957).

In October of 1884 Anaconda's first concentrator and smelter was completed. This facility, known as the "Upper Works," was capable of treating 910 mtpd. A brief listing of the machinery employed illustrates the scale of Daly's thinking. The concentrator consisted of 12 Blake crushers, 12 roll mills, 24 trommels, 60 Harz jigs, six hydraulic sizers, 12 settling tanks, and 35 vanners (Goodale, 1896). The concentrate produced by these unit operations was then transferred to the smelter, which consisted of 34 hand-reverberatory roasting furnaces, 25 reverberatory matting furnaces, and two 70-ton water-jacketed blast furnaces. Each unit operation in the concentrator processed about 15 mtpd (Hofman, 1904). This was, of course, in addition to those ores of sufficient grade to be fed directly to the roasting furnaces. After the Upper Works were destroyed by fire in 1889 (an all too common hazard in the early days of pyrometallurgy), they were immediately rebuilt and operated until their ultimate closure in 1901.

An additional facility called the "Lower Works" was blown in by the company in 1888. It too was destroyed by fire the next year and was reconstructed, this time housed in a steel structure. It operated until 1901. Both smelters were replaced by the "Washoe Works" in 1902. The Washoe, known locally as "The Smelter," with its famous, 178 m tall smokestack, continued operation until final closure in 1980. Except for the stack, which is the tallest masonry smokestack in the world and is now on the National Historic Register, the Washoe was dismantled in later years (Kearney, 1998).

The activities of Daly and his syndicate ultimately culminated in the organization of the Anaconda Mining Company on January 19, 1891. The company by this time operated the Anaconda, St. Lawrence, Neversweat, Mountain Con, Diamond, Modoc, High Ore, Moonlight, Green Mountain, Mat, Orphan Girl, and Bell Mines. It ran the concentrators and smelters at Anaconda. It owned large stands of timber to supply the supports to be used underground, and it eventually owned large coal reserves in Carbon, Park, and Cascade Counties of Montana to supply fuel for the smelters. The company constructed the private Butte, Anaconda, and Pacific Railroad to deliver ore from the Butte mines to the reduction facilities. The company was reorganized as the Anaconda Copper Mining Company (ACM) in June of 1895 (Marcosson, 1957).

Amalgamation and the Apex

In 1888, the amount of copper produced in the Anaconda mine exceeded that of Michigan's Calumet and Hecla, and by 1894 copper yields from the mines had almost doubled from their 1889 values to 83,225 mt (Phillips, 1896). At about the same time, copper production costs at Butte were around half of what they were on Michigan's Upper Peninsula (Hyde, 1998).

It was not long before the red river of copper flowing from the veins of Butte Hill attracted the attention of financiers based in New York and London. Consolidation and concentration of industrial interests was the mantra of the business world at the turn of the 20th century. Butte, with its immense resources both proven and probable, became a focus of investor interest. It should be realized that a number of these eastern-based financial people, some with ties to the Rockefeller-Standard Oil group, had been involved in Butte mining early on.

One such man, Henry H. Rogers, the president of ACM and head of the Standard Oil group, was a prime mover in the ultimate consolidation of the Butte mining interests. On a trip to Butte to inspect some mining properties, Rogers had studied a map of the hundreds of mining claims filed on the Hill. These formed a chaotic jumble of intersecting and overlapping properties of potentially competing mining interests. Rogers realized that the district's rich ores could only be efficiently extracted if the properties were consolidated (Marcosson, 1957). Rogers' viewpoint meshed perfectly with the attitude held by Daly, who always had as his ultimate goal the placement of the entire Hill under the umbrella of his beloved Anaconda mine.

Thus Rogers, along with William G. Rockefeller, the secretary and treasurer of the Butte and Boston Company, as well as an officer and director of ACM, and A. C. Burrage, a representative of Boston and Standard Oil capital, organized the Amalgamated Copper Company on April 27, 1899 (Marcosson, 1957; Sales, 1964; Brown, 1973). The purpose of the new organization was to take over Anaconda and to consolidate all other Butte mining interests. The plan had the full support of Marcus Daly, who exchanged his estimated $17,000,000 stake in Anaconda for Amalgamated stock and the position of vice-president of the new concern. James Haggin, the last living member of his San Francisco syndicate, declined to participate.

Amalgamated immediately initiated its plan for consolidation. Through stock swaps and outright purchases they soon acquired the Butte and Boston Company, the Boston and Montana Copper and Silver Mining Company, the Trenton Mining and Development Company, the Washoe Copper Company, the Big Blackfoot Lumber Company, the Diamond Coke and Coal Company, and the Mounted Trading Company (Marcosson, 1957).

Although Amalgamated was successful in bringing many Butte mining operations under its direct influence, the new company was unable to buy out those properties controlled by W. A. Clark or those operated by the Montana Ore Purchasing Company, the latter founded and headed by one F. Augustus Heinze. Clark's reluctance toward consolidation stemmed from a long-time personal, political, and business feud with Marcus Daly. Their feud was born of competition between their companies and later centered upon Clark's repeated attempts to attain the position of U.S. Senator for Montana. Daly had used his own influence to block these attempts, believing that Clark would favor policies inimical to his Anaconda Company. Heinze's opposition to consolidation, on the other hand, was most likely due to his own greedy and conniving personality.

Mining in Butte between 1881 and 1899 had continued on a relatively smooth track, which is surprising given the sheer number of mining concerns operating within an area of about 72 sq km. However, the evolution of the industry toward large consolidated holding companies like Amalgamated, along with a peculiar facet of the 1872 mining law and the potent mix of a few unscrupulous personalities, was to plunge Butte into a decade-long battle for claim ownership. Heinze, the third of Butte's Copper Kings, was one of those unscrupulous personalities and he was at the forefront of the battle.

In 1889, a 20-year-old Frederick Augustus Heinze (nicknamed Fritz), native of Brooklyn, New York and recent mining engineering graduate of Columbia University, came to Butte to seek his fortune. His simple goal at the time was to acquire a mining interest and mine copper ore profitably (Sales, 1964).

Ignorant of the district and its hundreds of claims, Heinze found it necessary to acquire some first-hand underground knowledge in order to choose a property with good profit potential. Accordingly, he went to work for the Boston and Montana Company as an underground surveyor, a job in which he had free access to the company's underground workings and to their geologic and engineering maps (Marcosson, 1957; Sales, 1964). His experience soon focused his attentions on the Rarus, an available but unworked claim which lay in the heart of the rich area being mined by his employers. It was probably also at this time that Heinze's plans and goals began to expand into the unsavory. Thanks to his surveyor's knowledge, knowledge gained while employed by the Boston and Montana Company, Heinze was able to predict the existence of four or five veins underlying the Rarus property. He further surmised that these might prove to be the identical veins from which rich copper ores were being extracted on the deeper levels of the adjacent Pennsylvania and Michael Davitt mines of the Boston and Montana and Butte and Boston Companies respectively (Sales, 1964).

Figure 9. **Frederick Augustus Heinze.**

Heinze was no doubt aware of an unusual aspect of the 1872 mining law, a concept known as the "extralateral right," more commonly referred to as the "apex law." In essence, the apex law gives a claim owner, having within his claim a vein of ore which crops out or "apexes" therein, the right to pursue and mine that vein on its downward course beyond the side line boundaries of the claim and thus beneath the surface of ground owned by another locator. The owner claiming apex may only follow the course of his vein within the projected end lines of his own location. Those end lines must be parallel. Although the law is straightforward, a subtle but important facet of it concerns the definition of "end lines" versus "side lines." The "extralateral right" of a claim owner thus depends to a great extent on how the boundaries of a claim are initially defined, definitions which can be manipulated. Further confusion arose at Butte because the apex concept was based on the relatively simple vein structures of the California gold country and the Comstock Lode. The concept was simply not meant to deal with the Butte veins with their splits and numerous cross-cutting features.

Heinze's sharp intellect seized upon these facts and he quit his surveying job to head back east to organize backing for his business venture. His plan would eventually manifest itself in the formation of the Montana Ore Purchasing Company. The company would own the Rarus mine, as well as various small claims, strategically located adjacent to other properties that were currently producing high-grade ore for their owners (Sales, 1964).

Heinze's grand schemes were frustrated by two important factors. First, the structural geology of the veins traversing Butte Hill was extremely complex, so that tracing individual veins from one property to the next was not always an easy matter. The other factor was a large, 45° westerly dipping cross fault, called the "Rarus" fault, that intersected the Rarus veins between their upper levels within Rarus ground and the valuable orebodies then being mined at deeper levels within neighboring mines (Sales, 1964).

Because the apex law required that a vein to be followed also be continuous, and because the Rarus fault displaced the veins vertically by 125 m, Heinze quickly realized that his visions of grandeur might be scuttled by the quirky structural geology of the Hill.

At this point, it may be fairly said that a reasonable man, realizing the obstacles represented by a 125 m thick block of barren rock, would abandon any plans of establishing an "extralateral right" to his neighbor's orebodies. Fritz Augustus Heinze was not, however, a reasonable man. His exploits in surmounting the seemingly insurmountable have become mythic in mining lore. He recruited well-known and respected geological experts willing to deny the existence of the Rarus fault and to so testify in court. He "acquired" a District Judge in the person of William Clancy to rule in favor of his experts' opinions, and in so ruling, to issue mining injunctions against his neighbors. An injunction was then typically followed by Heinze's establishment of a "shadow company" (not party to the injunctions) that would secretly mine high-grade ore from the adjacent claims to feed his Montana Ore Purchasing Company Smelter (Marcosson, 1957; Sales, 1964; Miller, 1973).

From 1898 until 1906, the year in which Amalgamated finally bought out Heinze's interests for $10,500,000, the mining buccaneer's activities had cost Amalgamated and other target companies approximately $1,000,000 per year to defend themselves from his tactics. He had established at least six "shadow companies" to engage in outright ore theft during the periods, essentially continuous, when both he and the competition were under court-ordered injunction. Heinze's buyout resulted in the abandonment of 110 pending lawsuits in the Butte District Court, involving claims totaling more than $70,000,000 (Marcosson, 1957).

Actual underground battles between miners of the opposing companies occurred during this period (Sales, 1964). Methods of mayhem included the use of choking smoke produced from burning rubber or leather to drive the workers out of the drifts; fire hoses and nozzles connected by pipe with the pump columns in the shafts, thus affording very high pressures; the blowing of powdered lime through 2.5 cm pipe with compressed air, in order to blind any miner foolish enough to remain in range; the use of homemade hand grenades, cut from sticks of dynamite; and in one case, the setting off of an entire case of dynamite lowered by rope down an opposing company's raise. The latter episode resulted in the deaths of two miners.

Flush with the new wealth of the buyout, Heinze returned east to try his luck on Wall Street. There he met a species of pirate even smarter than he was and he quickly got "his clock cleaned." He again came west, as he had arrived the first time—poor. For a time he tried unsuccessfully to ply his apex "trade" in the Coeur d'Alenes. He died of cirrhosis of the liver in Saratoga, New York in 1914. He was only 44 years old (Marcosson, 1957; Sales, 1964).

Even though Heinze's name has become practically synonymous with apex litigation, it should be realized that his were not the first apex suits at Butte, nor were they the last. The case of *King vs. Amy and Silversmith Consolidated Mining Company* (14 S.Ct. 510 (1894)) involving silver claims on the Rainbow vein was tried more than a decade before Heinze began to play his games. *Butte and Superior Copper Company, Ltd. vs. Clark-Montana Realty Company* involving the enormous zinc deposits of the Elm Orlu and Black Rock Mines was decided in 1919 (39, S.Ct. 231 (1919)). This last was a particularly significant suit, because at the time the Black Rock was the most important zinc mine in the world, employing 2,200 men in the mine and adjacent concentrator. Three of Butte's apex suits were finally adjudicated by the United States Supreme Court.

Marcus Daly never lived to see the demise of Heinze and his schemes. In the late 1890's he was diagnosed with diabetes, more than 20 years before insulin was discovered as a means of

Figure 10. **Stock certificate for the Original Butte Mining Company, 1882. Mineralogical Record Library.**

treatment. He spent much of the final years of his life scouring Europe for a cure and returned to the United States in 1900, deathly ill. He passed away at the Hotel Netherland in New York City on November 12, 1900 (in re Daly's Estate, 91 N.Y.S. 858 (1905); Marcosson, 1957). William A. Clark, the last of the Hill's Copper Kings, passed away in 1925. The last of his properties were sold to the Anaconda Company by his estate three years later.

Building of an Empire

The Anaconda Company, under the control of Amalgamated, would eventually emerge from the decade-long apex battles as the premier mining concern on Butte Hill. Even after having vanquished Heinze, Amalgamated found itself under siege on multiple fronts involving a myriad of lawsuits.

Several suits involved disgruntled stockholders of companies which Amalgamated was attempting to purchase. There was also an apex suit by Edward Hickey, the original locator of the St. Lawrence claim, against ACM over the Nipper claim, a property adjacent to the Anaconda (*Hickey vs. Anaconda Copper Mining Co.*, 81 P. 806 (1905)). Another interesting suit was the antitrust case instituted by minority stockholders of the Alice Copper and Silver Mining Company in 1911, which was finally resolved by the United States Supreme Court (*Geddes vs. Anaconda Copper Mining Co.*, 41 S.Ct. 209 (1921)). By far the most important suit of those early days involved neither stock purchases nor apex rights. It was instituted on environmental grounds.

On September 1, 1902 the Washoe Copper Company, the arm of ACM responsible for smelting activities, blew in the gigantic Washoe smelter-concentrator complex at Anaconda, replacing both the Upper and Lower Works. The complex treated about two-thirds of district output, and was responsible for 17 to 20% of the entire U.S. copper production. This production was valued at $45,000,000 per annum, and taxes collected therefrom amounted to about 25% of the taxes collected by the State of Montana (*Bliss vs. Washoe Copper Co.*, 186 F. 789, 796 (1911)).

The pyrometallurgical technologies utilized at this enormous operation were state-of-the-art for their day, but they were far from environmentally friendly by today's standards. Large quantities of sulfur and arsenic oxides were discharged into the atmosphere by the smelter's relatively short 69-meter stack. Thus, on May 4, 1905, Fred J. Bliss, a Deer Lodge County rancher and farmer, along with a number of other area farmers and ranchers, sued to enjoin the maintenance and operation of the Washoe smelter by ACM. They requested $2,300,000 in monetary damages, arguing that the smelter's "smoke zone" caused damage to agricultural lands by poisoning and killing fodder with arsenic, resulting in the death of livestock and the depreciation of land value. The case eventually encompassed over 25,000 pages of testimony, 800 exhibits, and 237 witnesses. Not surprisingly, when all was said and done, the courts effectively ruled that the smelter and the mining operations which fed it were far too valuable at the time to rule in favor of Bliss *et al.* The latter appealed the case all the way to the Circuit Court of Appeals for the Ninth Circuit, one step shy of the Supreme Court, and lost every time (*Bliss vs. Washoe Copper Co.*, 186 F. 789, 811 (1911)).

The Bliss suit was historically important in another way. It also made the career of Cornelius Francis Kelley, the attorney for ACM in the case. Kelley had come to Butte with his family as an eight-year-old boy in 1883. His father, Jeremiah, was an old friend of Marcus Daly from their Mineral Hill, Nevada days, and had come to Butte to serve as the superintendent of the Bell mine. Cornelius, after graduating from high school in 1892, went to work for Daly in the Anaconda mine as a surveyor. Two years later, he quit mining life to study law. His mining experience served him well when he later became an Anaconda lawyer during the Heinze apex litigation (Marcosson, 1957). "Con" Kelley eventually became the president of Anaconda, retiring from the company in 1955.

By 1910 the Anaconda Company was in a process of rebirth, after years in the Amalgamated fold. ACM had acquired considerable assets formerly under the control of Amalgamated, as well as several Clark properties. The most significant holdings were those of the former Boston and Montana Company, including the East Colusa, Leonard, Mountain View, and Badger State mines, as well as that company's huge smelter-refinery complex at Great Falls. The Clark properties included the Original and Steward mines and the Butte Reduction Works. Amalgamated was finally dissolved on June 9, 1915, and all of its remaining Butte properties came under the control of a new Anaconda Company. John D. Ryan was the president of the new ACM; Cornelius Kelley was the vice-president (Marcosson, 1957; Miller, 1973).

Large orebodies of zinc and manganese were also being explored and developed at this time (Miller, 1973). The immense zinc deposits of the Elm Orlu and Black Rock mines have already been mentioned. Zinc mining ended at Butte in 1967 when the Elm Orlu-Badger block-caving project was shut down (Miller, 1973). The Emma and Travona manganese deposits are described elsewhere.

Although ACM represented the largest and richest mining company on the Hill throughout its existence, there were other substantial mining concerns operating at Butte until well into the 20th century. Perhaps the most important and famous of these was the North Butte Mining Company, organized in 1904 and finally purchased by Anaconda in 1953 (Kearney, 1998). North Butte owned and operated the Edith May, Gem, Snowball, North Berlin, Tuolumne, Granite Mountain and Speculator mines. Unfortunately, the North Butte Company achieved its considerable fame through tragedy at the latter two operations.

Near midnight on June 8, 1917 an inspection team entered a shaft servicing the interconnected Granite Mountain and Speculator mines to assess the damage to an electrical cable that had fallen loose while being strung by a crew earlier in the day. A section of the paraffin-paper insulation on the cable had become frayed at the 2,400-foot level (732 m), and by a cruel twist of fate, was accidentally ignited by the carbide lamp of one of the inspectors. Within moments the strong draft in the up-cast shaft had turned the entire 3,000 foot length (915 m) of the timbered shaft into a raging inferno. Smoke and gas swept through the workings of the two mines, fouling the air and trapping hundreds of working miners (James, 1980). Although a number of the miners were able to escape through tunnels into adjoining mines, such as the High Ore and Diamond, 167 perished (*Wirta vs. North Butte Mining Company*, 210 P. 332, 333 (1922)). The Granite Mountain-Speculator fire remains to this day the most deadly metal mine disaster in U.S. history (Rugolo, 1995).

The disaster at the Granite Mountain and Speculator mines serves to highlight the immense social, political, and economic troubles that were endemic to Butte during the early part of the last century. Underground mining was, and remains, an extremely hazardous occupation, and the mines which honeycomb Butte Hill were long considered the most dangerous operations of their kind. All told, an estimated 2,100 men lost their lives in Butte's underground mines (Kearney, 1998).

As dangerous working conditions were often coupled with low pay and long hours, organized labor evolved at Butte relatively early. Butte's first miners' union, the Butte Working Men's Union, was founded in 1878, as described in the "biography" for the Lexington mine. By 1887 the Bluebird mine was the only non-union operation in the entire area. The Bluebird was actually 4 km

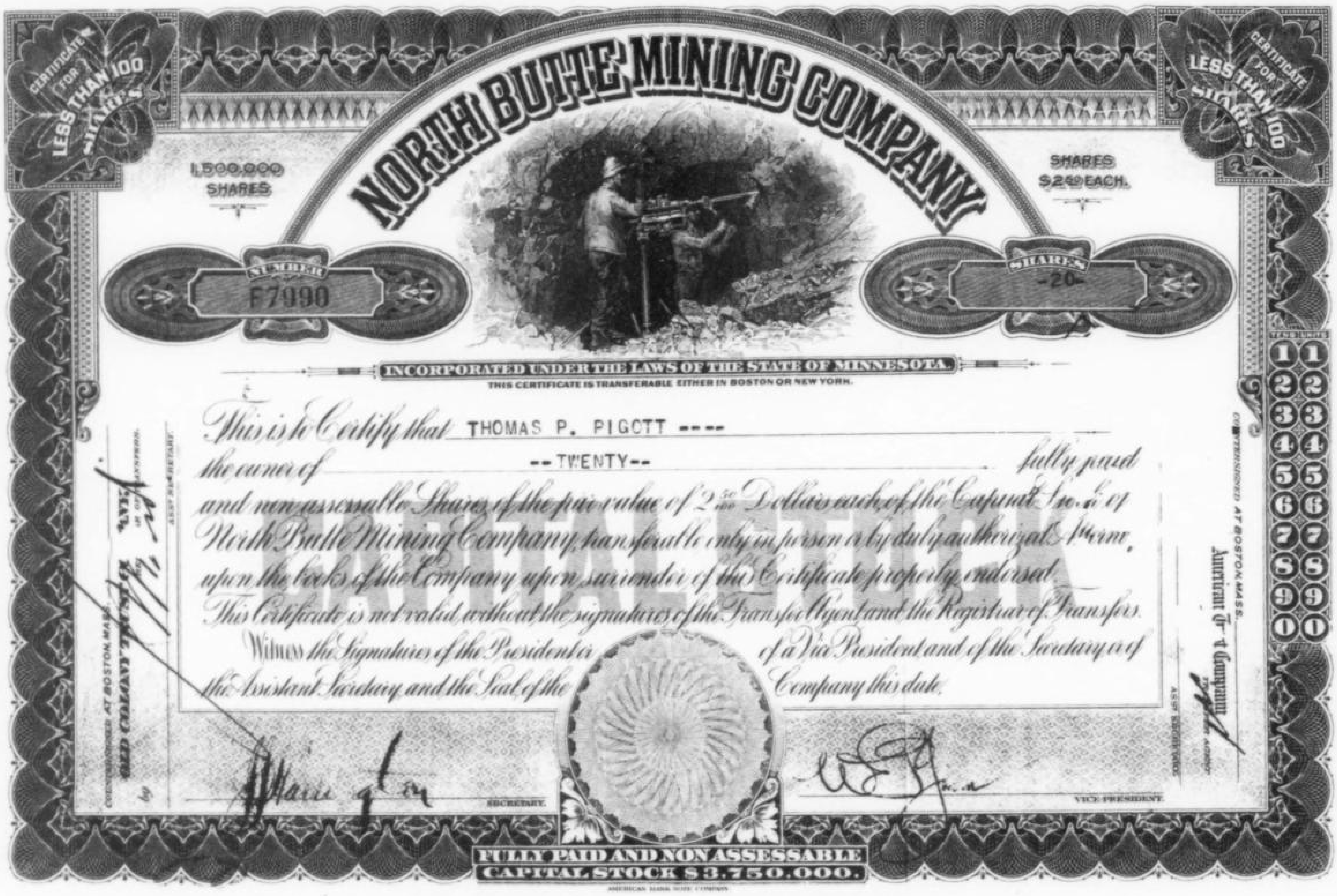


Figure 11. **Stock certificate for the North Butte Mining Company, 1907. Mineralogical Record Library.**

west of the major part of the district. On Miner's Union Day, June 13, 1887, union miners marched on the mine, forced its shutdown, and subsequently marched the Bluebird workers to the Union Hall for induction as members. Excluding only two periods, the Butte mines remained a "closed shop" throughout their long history. The first of these intervals was between October of 1914 and June 8, 1917, the date of the Granite Mountain disaster (Everett, 1998).

Even though organized labor in Butte had held considerable sway before 1914, its effectiveness was seriously diminished by infighting among the various unions and their factions, made worse by ACM efforts to infiltrate and instigate controversy among them. ACM was not a benevolent employer early in the 20th century. The in-fighting came to a head in June 1914 when the Miner's Union Hall was completely destroyed by 10 cases of dynamite stolen from the nearby Steward mine by members of the Butte Mine Worker's Union. The latter was one of the more bellicose factions, whose revolutionary sentiments coincided with those of the anarcho-syndicalist (that is, Marxist-leaning) Industrial Workers of the World (IWW), more commonly known as "the Wobblies" (Kearney, 1998).

In order to control an increasingly ugly situation the governor of Montana mobilized the National Guard on September 1, 1914, and martial law was declared in Butte. Curfews were established and all civil court proceedings were set aside. The critical blow to local unions came on October 11 of that year, when the Anaconda Company announced that all of its operations were now "open shops." The unions were thus effectively marginalized by the company's allowing any able-bodied man, whether he were a union member or not, to work for the largest employer on the Hill. Butte miners continued to labor under these oppressive conditions until the Granite Mountain disaster, nearly three years later (Kearney, 1998).

The shocking death toll resulting from the fire at the Granite Mountain and Speculator mines revitalized union sentiments among Butte working men. By the end of June, 1917, 15,000 miners had gone out in a general strike to demand safer working conditions and a $6.00 per day wage. Their efforts were strengthened by various other Butte trade unions that left work in a show of solidarity. Nevertheless, ACM balked at the demands, while Federal troops arrested union activists and roughed up the strikers.

Hoping to build on the pro-worker sentiments embodied in the strike, an IWW organizer named Frank Little arrived in Butte on July 18, 1917 and began promoting the shut-down of all of the Butte mines. He spoke of the evils of the capitalist owners and their never-ending efforts to keep the working class down. Little soon emerged as a *de facto* voice for the district's underground miners, but his shouts were quickly silenced. Less than two weeks after his arrival in the district, Little was lynched from a railroad trestle south of town. His murderers were never apprehended. Although the general strike continued following his death, it was eventually called off on December 18, 1917 (Kearney, 1998).

The "open shop" returned to Butte during the period 1920–1934. Unions finally became a permanent fixture in the local mining industry after the Taft-Hartley Act strike (B. Shovers, written communication, 2000). Even though the lot of the Butte miner was to gradually improve as the century progressed, tensions between "The Company" and "The Union" would continue until the very end of underground mining. Each contract expiration date would be marked by a strike, some of which were months in duration (Kearney, 1998).

By 1913, Anaconda's continued consolidation of its Butte operations had led to the establishment of a centralized compressed air system to power the hoisting engines at its major mines. Shafts serviced by this system eventually included those of the Gagnon, West Steward, Mountain Con, Diamond, High Ore, Mountain View, West Colusa, Leonard, Tramway, Berkeley, and Pennsylvania mines (Nordberg, 1914). Although the company was understandably reluctant to abandon the considerable capital outlay represented by the compressed air system, the hoisting operations were completely converted to electricity by the early 1930's. Even though ACM had also embraced the new electrical technologies for most ore hauling by that time, horses and mules were still being used for haulage in a few operations. The last underground work animals were retired from the Emma and St. Lawrence mines in 1934 (Kearney, 1998).

At the same time the company had also established the High Ore, Leonard, and Silver Bow copper precipitation plants to extract metal values carried in the waters pumped from the underground mines. The copper was recovered by passing the acidic mine waters over scrap iron in an extensive system of flumes, settlers, and launders. The copper in solution directly replaced the scrap iron. This method is called cementation, and it had been pioneered in the Butte district at the St. Lawrence mine. The Leonard plant alone produced 1,000 mt of relatively pure copper each year by 1914, representing about 60% of the total from the three plants (Febles, 1914). In 1943 ACM concentrated the entire precipitation system at the central pumping station of the High Ore mine, which by 1955 was drawing 6,000 gpm from Butte's underground mines. The next year saw the institution of an underground leaching system as well, whereby pillars and old stope gob were leached with acids introduced from the surface (Miller, 1973).

Labor troubles and depressed copper prices after World War I resulted in shut-downs of numerous operations in Butte. Even when the mines were "in production," it was often only on a part-time basis. Although metal prices recovered somewhat, and mining activity increased during the late 1920's, prices plunged to even lower levels during the Great Depression. During the winter of 1932–33 copper prices had dropped to $0.103 per kg, down from an average of $0.295 per kg only two years earlier (Marcosson, 1957). Butte mining, like most U.S. industry, remained in depression until the dawn of World War II, when the demand for war materiel greatly increased the need for copper, zinc, and manganese. Despite the steep up and down cycles of metal prices, copper production from ACM's Butte mines was approximately 90,900 mt per year from 1895 until 1944 (Miller, 1973).

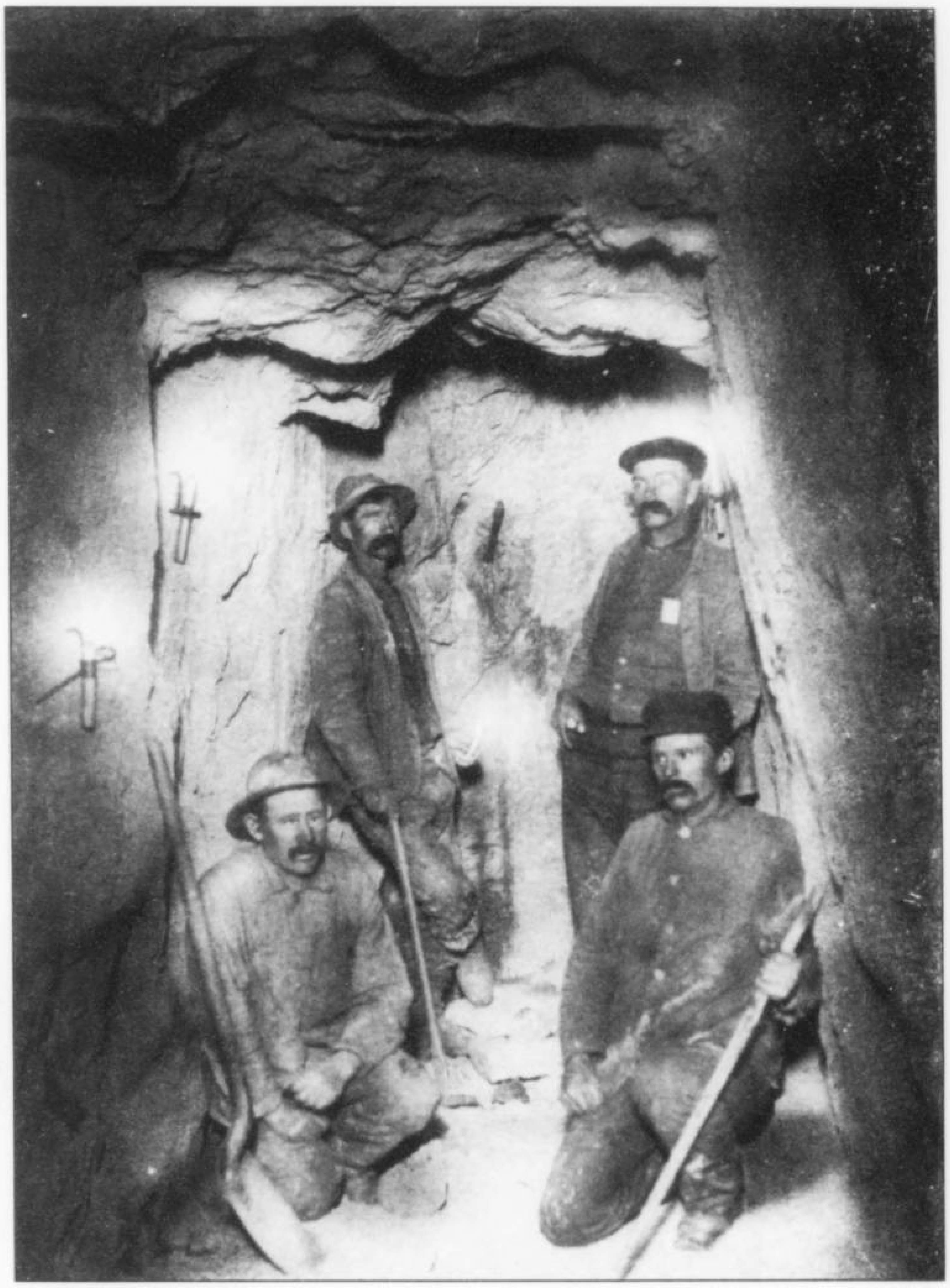


***Figure 12*. Butte miners driving a drift by candle-light ca. 1880. World Museum of Mining photo.**

Figure 13. **A shift of miners ready to go underground at the Leonard mine, 1950's. World Museum of Mining photo.**

In spite of those same cycles in metal values, the period of the 1920's was one of immense expansion for the Anaconda Company. The company branched into end-use fabrication for its copper with acquisition of the American Brass Company and organization of the Anaconda Wire and Cable Company. It acquired other American mining and smelting interests, but undoubtedly ACM's most significant acquisition was one overseas. This was the enormous Chuquicamata copper deposit in Chile, which Anaconda purchased from the Guggenheim interests in 1922. "Chuqui" was the largest copper deposit in the world, and before too long it had made ACM the premier copper producer on earth. Although Chuquicamata was, in any sense of the word, a world away from Butte, it ultimately had an enormous and unfortunate impact on the community.

During World War II, Butte's underground mines produced copper at a record annual rate exceeding 113,000 mt per year. With the cessation of hostilities conditions changed. There was a glut of copper around the world and prices had dropped in consequence. At the same time mining costs had risen precipitously. As a result, copper production from Butte's underground vein mines dropped to only 45,000 mt annually during the immediate post-war years (Miller, 1973). Clearly, something had to be done if mining were to continue to prosper in the Butte district.

The answer was called the "Greater Butte Project" (GBP). Although the project was conceived during the war years, it was announced by Con Kelley, then president of ACM, on September 10, 1947. The announcement was made at the Finlen Hotel in Butte during a dinner given in Kelley's honor. The project would exploit lower-grade underground reserves by the block-caving method, a method of bulk-mining which had been utilized successfully for many years at underground mines in Arizona, Nevada, and elsewhere, but had never been attempted at Butte. The Greater Butte Project would involve the initial investment of some $27,000,000 to sink a new high-hoisting-capacity shaft, called the Kelley in Con Kelley's honor, and to drive accessways into the mineralized area (Popoff, 1956; Marcosson, 1957; Miller, 1973; Kearney, 1998). Shaft sinking commenced in 1948.

Drawing of broken ore began in April of 1952, and by July of 1955, the Kelley had reached its projected capacity of about 13,600 mtpd. Block-caving operations continued at the Kelley until December 1962, when they were suspended in order to avoid creation of slope stability problems for the Berkeley Pit. Over the 11 years of its operation, the Kelley produced 29.5 Mt (million metric tons) of ore at a grade of 0.99% copper. More than 270,000 mt of copper were recovered from the material (Miller, 1973).

Although they were not part of the original GBP concept, the Berkeley pit and later the Continental East pit (East Berkeley pit) together with the Weed Concentrator were outgrowths of the philosophy embodied in the Greater Butte Project. Both reserves and grades of available vein-type underground ore were declining. The mines were growing deeper and mining costs were continuing to spiral upward. If profitable mining were to continue on Butte Hill, ACM would have to move toward bulk-mining of lower and lower grades of ore, and therefore the processing of more material each day. This development led to open pit mining of large tonnages of low grade, near-surface ore.

And Then There Were None

The Berkeley pit was started up in 1955. In 1964, the 38,100 mtpd Weed Concentrator was opened, largely to handle the output from the pit. At the peak of mining the Berkeley pit produced

Figure 14. **Anaconda Company safety poster, ca. 1950. Gene Schlepp collection.**

225,000 mt of rock each day, of which about 20% was mill-grade ore, 40% leach-grade, and the remainder waste. By 1970 the pit was producing 78% of district copper or about 124,000 mt annually (McWilliams, 1959; McClave, 1973; Miller, 1973).

Block-caving operations through the Kelley shaft ended in 1962, but the Kelley was given a new lease on life in 1966. The shaft was deepened to the 4,800 level (1,463 m), and large haulages were driven into the deep workings of the Mountain Con, Steward, and Leonard mines. Underground ore was mined in these three properties and trammed to the Kelley for hoisting through the higher capacity shaft (Miller, 1973).

All was not well at Anaconda, however. Although its Butte operations were producing more copper than ever during this period, ore grades were continuing their decline, mining costs were rising each year, and profits were diminishing. In 1971 the axe fell. The new leftist Allende government in Chile nationalized all mining operations in that country and ACM's Chuquicamata mine was confiscated. In one stroke the company found itself without 75% of its income and 60% of its copper production. The corporation reported a net loss of $375.3 million for that year (Kearney, 1998).

The Chuquicamata nationalization was the beginning of the end. By the end of 1972 ACM had laid off 17% of its workforce and sold important corporate assets, such as its vast Montana timber holdings, in order to raise and conserve cash. Copper prices were going through another of their cyclical downturns, to less than $1.32 per kg; and an attempt to operate the Twin Buttes copper mine in Arizona turned into another money-losing debacle. On February 19, 1975 ACM suspended all underground mining operations at Butte, because they were no longer profitable. More workers were laid off. Later in the year, the organization became the target of a hostile takeover by the Crane Company. Precious cash was siphoned off in order to repel the Crane bid. After failing to enlist Tenneco as a friendly buyer for its mining interests, the Anaconda Company finally sold out to ARCO on March 17, 1976 for $162 million. Marcus Daly's beloved Anaconda Company had come to an end (Kearney, 1998).

ARCO viewed its new purchase as a good investment, largely owing to the tax write-off it could claim because of the loss of Anaconda's Chilean properties. ARCO also made an effort to revitalize its Montana operations, which even included reopening the Kelley mine in September 1979 with a limited work force of 60 miners. The rosy outlook and new activity were short-lived, however. Mining costs in the Berkeley pit were on the rise, while ore grades were continuing to drop. Copper production from the pit had decreased by about 30% between 1973 and 1978. On September 29, 1980 ARCO shut down the Washoe Smelter and the Great Falls Refinery and began shipping copper concentrates from Butte to Japan. Molybdenum concentrates were sent elsewhere. On April 23, 1982 ARCO suspended all operations in the Kelley mine and the Berkeley pit. The final step came on June 30, 1983, when operations at the East Berkeley pit (formerly the Continental East pit) and the Weed Concentrator were terminated. For the first time in nearly 120 years, the great mines of Butte Hill were silent (Herbort *et al.*, 1998; Kearney, 1998).

The final closure of Butte mining operations in 1983 dealt a severe economic blow to the community. Tens of millions of dollars in the form of payroll, services, and taxes instantly vanished. Perhaps more importantly, the town had seemingly lost its very identity. The idea of Butte, Montana without mining was incomprehensible.

After two seemingly endless years of idleness it was announced on December 17, 1985 that ARCO's Butte mining properties had been purchased by the Washington Corporation, a Missoula, Montana-based construction firm. The purchase price was an

Figure 15. **Anaconda Company safety poster, ca. 1950. Gene Schlepp collection.**

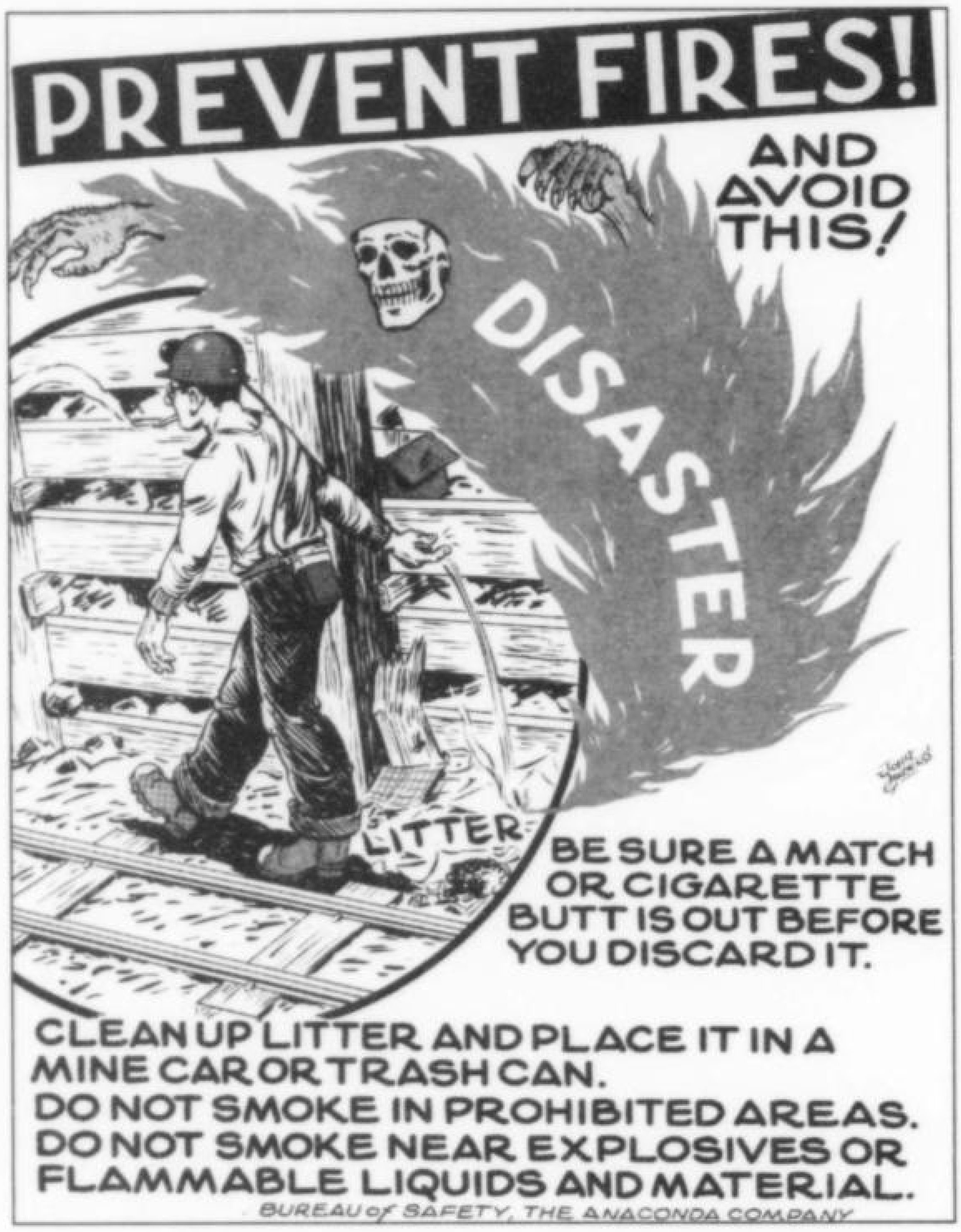


Figure 16. **Anaconda Company safety poster, ca. 1950. Gene Schlepp collection.**

estimated $17 million. Initially, Washington (later renamed Montana Resources) had approached ARCO with a plan to salvage scrap metal from the corpse of the Weed Concentrator. Frank Gardner, a Butte native and president of ARCO's Butte operations, had a different idea. He convinced Washington Corporation's president, Dennis Washington, that a better investment would be to purchase the property and start up mining again. Gardner had approached other mining companies in an effort to sell the Butte properties, but had failed due to concerns about environmental liabilities, as well as the labor instability in Butte. In Dennis Washington he found a more receptive listener (Kearney, 1998).

On July 16, 1986, mining resumed in Butte at the East Berkeley, renamed the Continental Pit. The Weed Concentrator was revived and operated in conjunction with the mine. The operation exploited an extremely low-grade molybdenum-copper deposit, and reserves were sufficient for many years. In 1989, a 49% stake in Montana Resources was sold to ASARCO, effectively giving the operation "in-house" smelting capacity. Copper concentrates were thereafter shipped to ASARCO plants in El Paso, Texas and Hayden, Arizona (Kearney, 1998). Molybdenum concentrates were sold on the open market. ASARCO (and therefore Montana Resources) became a subsidiary of Grupo Mexico in late 1998.

Unfortunately, in the year 2001, the Hill is quiet again. The Continental operation was shut down and placed on stand-by in June 2000 because of skyrocketing electrical costs and deregulation of the Montana power industry. Mining and milling will only resume when a more favorable contract for electricity can be negotiated.

Whether or not the Continental mine resumes operations, Butte, Montana is and always will be a mining town if its citizens have anything to say about it, which they inevitably will. Fearing irreparable loss to its mining history, the community's citizens designated several mines, with their accompanying yards, headframes, and dumps, as historic landmarks. Two of Butte's mines, the Anselmo and the Orphan Girl, are now mining museum centerpieces, while a third, the Belmont, has been converted into a senior citizens' center. The Granite Mountain Memorial sits atop the Butte Hill overlooking the Granite Mountain headframe as an eloquent reminder of the scores of miners who lost their lives there in 1917. Many of Butte's historic uptown buildings have been placed on preservation lists. In 1966 the community at large was designated a National Landmark District (B. Shovers, written communication, 2000). Even if actual mining passes from Butte, the Hill, which spawned an empire and built a State, will forever and rightly be known as "the richest hill on earth."

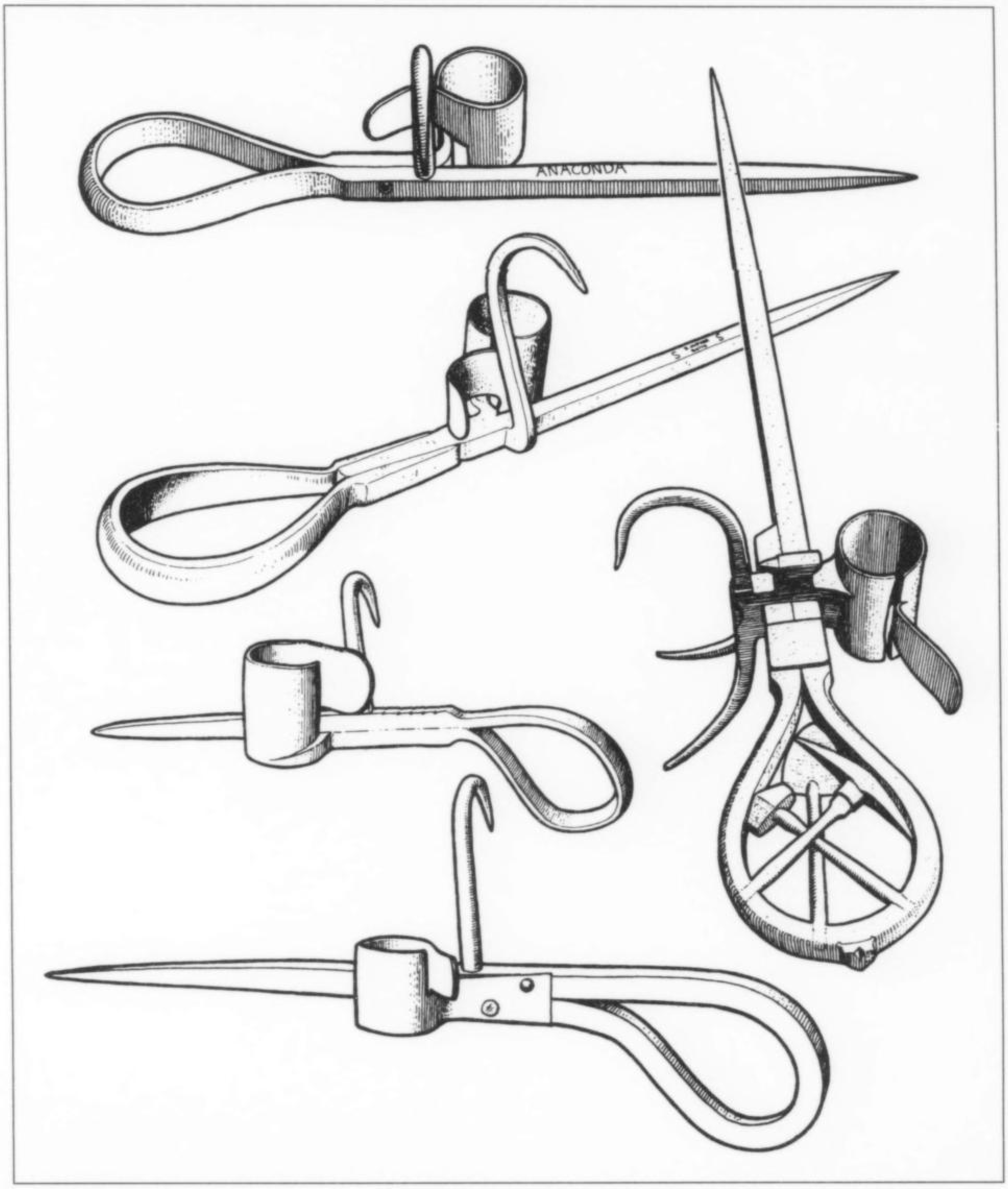
THE MINES

Alice Mine

The Alice mine, the property which gave Marcus Daly his start in Butte mining, was located in the northern suburb of Walkerville. Originally an underground operation dating back to the silver rush of the 1870's, its site was destroyed by more recent operations at the Alice Pit (Elliot *et al.*, 1992; Kearney, 1998). The pit itself has been largely filled in with material from the Alice dump in the last two years (R. Berg, written communication, 2000).

In 1876 when Daly first visited Butte on behalf of the Walker Brothers, the Alice was a raw silver prospect owned by Rollo Butcher. Daly saw potential in the property, and bonded it for his employers. Later, it was purchased for the sum of $25,000 (Shoebotham, 1956). In the meantime Daly, as manager of the property, sank a shaft, constructed a mill, and began producing silver. Through the late 1870's and on into the 1880's, the Alice was the largest and most important silver property on the Rainbow

Figure 17. **Anaconda Company safety poster, ca. 1950. Gene Schlepp collection.**



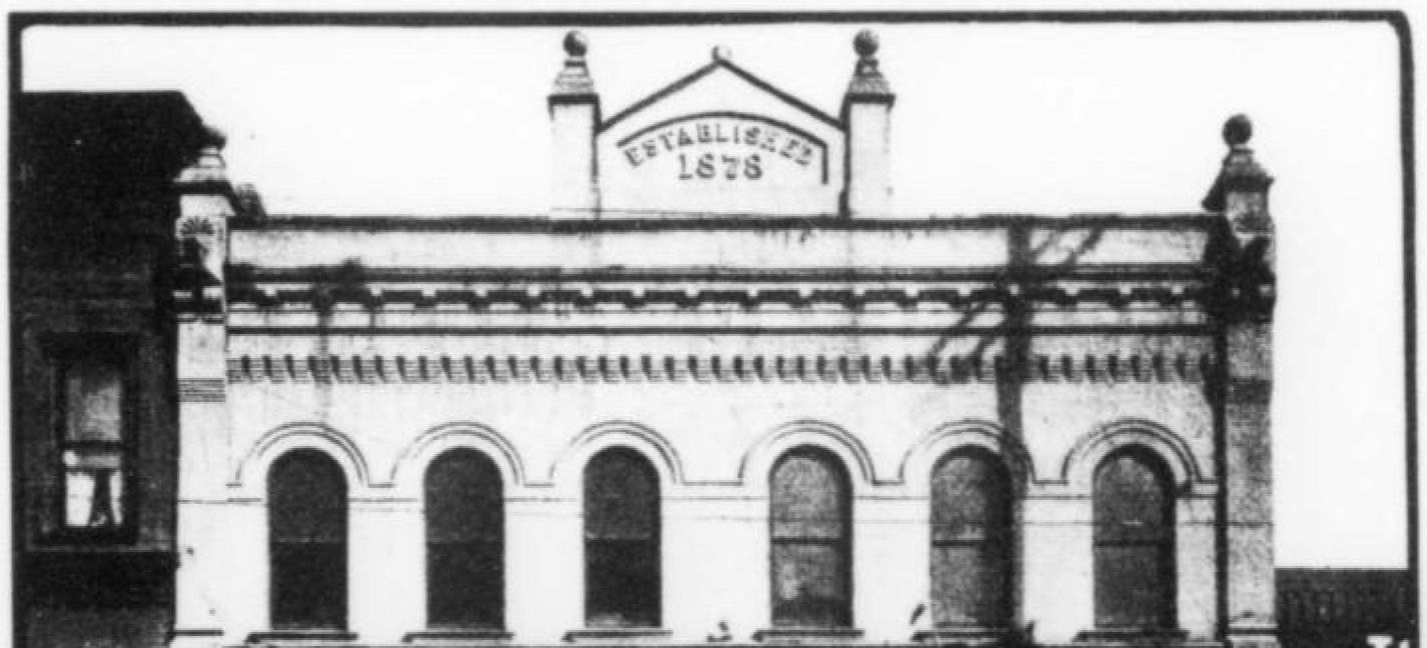


Figure 18. **Miners' candleholders from Butte. *Top:* "Anaconda" brand, 9 inches, sold by the Anaconda Company-owned Montana Hardware Company store. *Upper-middle:* Candleholder made by the blacksmith "S. Mather, Butte" (11.25 inches). *Lower-middle and bottom:* Pistol-grip candleholders (6 inches, 7 inches) sold by the Montana Hardware Company, 1890-1900. *Right:* Fancy custom candleholder (11 inches) with detachable hook/thimble assembly and miniature mining tools, presented to Harry Tembly of the Anaconda Company, Butte, in 1914 (from Wilson and Bobrink, 1984).**

Figure 19. **The store front of the Anaconda Company-owned Montana Hardware Company, established in 1878, where miners purchased their personal tools and equipment.**

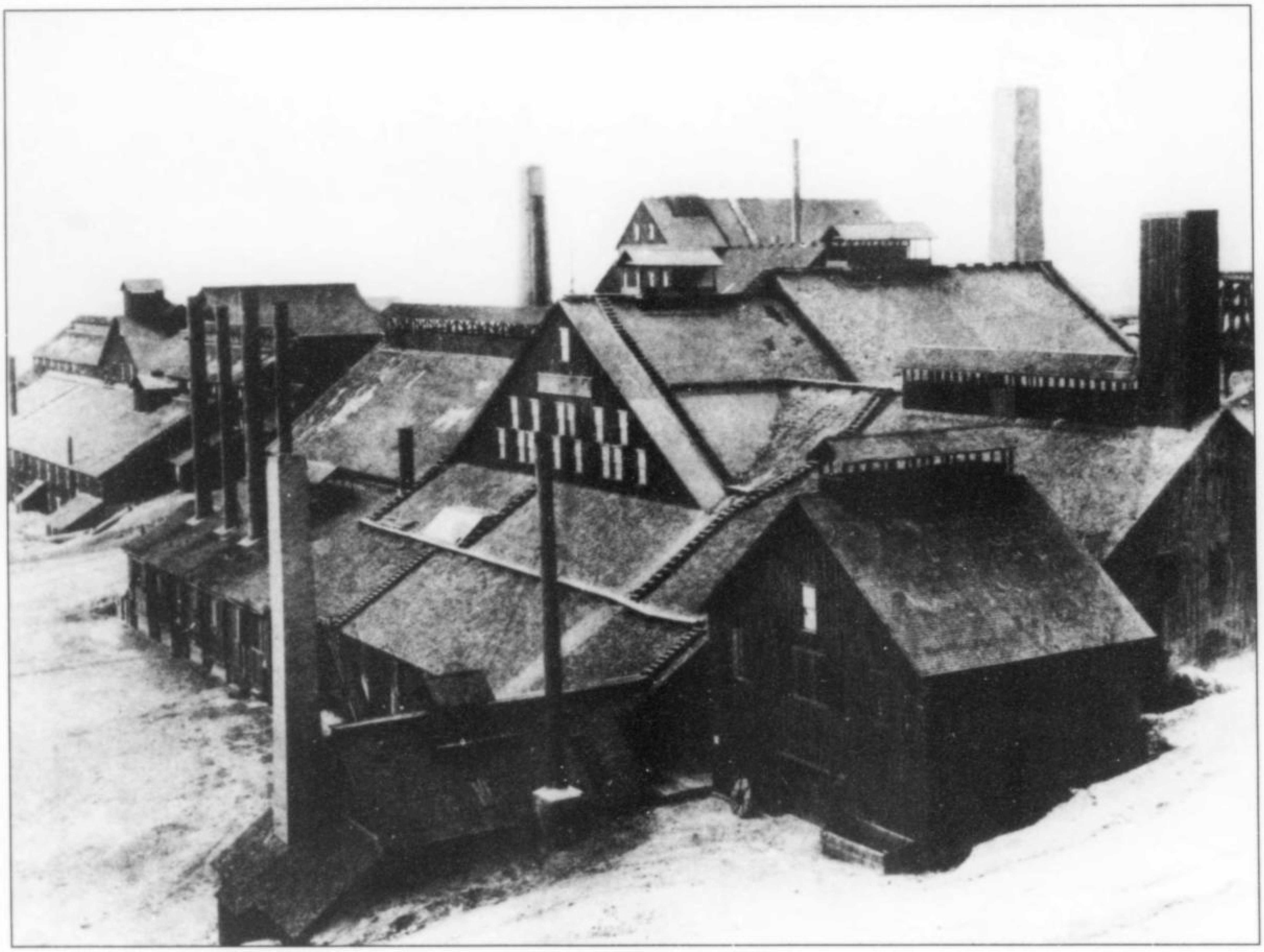


Figure 20. **Surface buildings of the Alice mine, 1880. World Museum of Mining photo.**

vein system (Blake, 1887b). Subsequent to the panic of 1893, it was operated intermittently by leasors. Desultory lease operations continued until about 1940. In 1955 the Anaconda Company began bulk-mining in the Alice pit, soon obliterating all traces of the underground operation. Open pit mining ceased in 1959 (Kearney, 1998).

That year wasn't quite the swan song for operations at the Alice mine. A 1987 revival at the Alice-Lexington Tunnel and the Chief Joseph claim turned out to be more scam than real mining, however. Principals in the New Butte Mining Company, listed on the London stock exchange, were convicted of fraud in 1998 (Kearney, 1998). Nearby mines on the Rainbow vein included the Moulton, the Magna Charta, and the Valdemere. The Alice mine produced fine specimens of native silver, as well as rhodonite, rhodochrosite, and helvite. Native silver also came from the Alice-Lexington tunnel.

Berkeley Pit

The Berkeley pit, named for the old Berkeley underground mine, is one of the most visible remnants of Butte's mining heritage. It is centered over the old Butte suburb of Meaderville which the pit completely obliterated. Other suburbs destroyed by the growth of the Berkeley include East Butte, East Side, McQueen, and Parrot Flat (Elliot *et al.*, 1992; Kearney, 1998).

Although it was not part of the original project concept, the first glimmerings of a Berkeley pit-to-be came with the announcement of Anaconda's "Greater Butte Project" in 1947 (Marcosson, 1957). Subsequent to the initiation of block-cave mining of low-grade reserves on the district's east side, Anaconda geologists discovered that much of the reserve was lower grade than originally thought, but was close enough to the surface to be mined more profitably by open pit methods. The Berkeley pit was born in March of 1955, starting out as a small test pit called the Skyrme on the site of the old West Colusa mine (Kearney, 1998). The test was successful, and by the early 1960's the Berkeley pit was the largest truck-operated open pit mining operation in the United States. It bore this distinction for several years until it was surpassed by the pit at Bingham Canyon, Utah. The Berkeley pit shut down in 1982, after producing 306 Mt of mill-grade ore and 345 Mt of leach-grade ore (Long, 1993).

The Berkeley pit is now largely filled with extremely acid and metal-rich mine water. This water drains into the pit from the underground mines. Metal-rich pit waters produce copper to this day by cementation. Although a considerable resource of copper also remains in place, it is unlikely that it will be mined any time soon. The Berkeley pit produced mineral specimens similar to those from the underground mines, which its growth destroyed. These included the famous Leonard, but specimens from the pit did not match those from underground in either quality or quantity.

East Colusa Mine

The East Colusa mine was only a bit player in the Butte

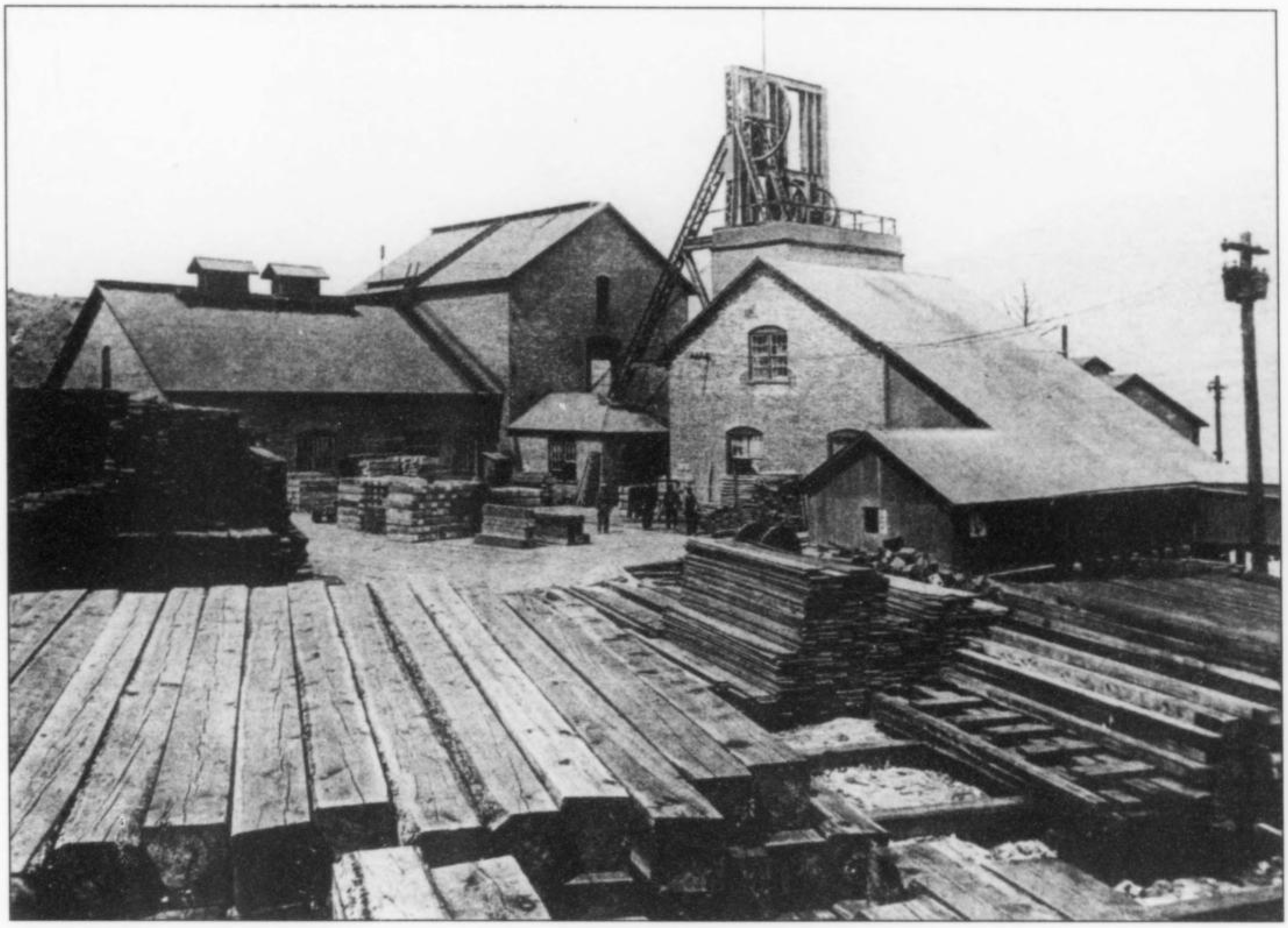


Figure 21. **Headframe and buildings of the Colusa mine ca. 1880. World Museum of Mining photo.**

underground mining scene. It is included in this brief register because it was the major source of the single Butte type-species, the mineral colusite. The East Colusa mine was located north of and adjacent to the Leonard (Elliot *et al.*, 1992). Like the latter, its surface works have completely vanished, swallowed in the growing maw of the Berkeley pit during the 1970's.

The East Colusa was located no later than 1872, when it was purchased as an undeveloped copper prospect along with the Original, Mountain Chief, and Gambetta claims by eventual Copper King, William A. Clark. The property, along with its sister mine, the West Colusa, was purchased by Charles T. Meader on behalf of the Lewisohn brothers in 1878. The Lewisohn company, at that time called the Montana Copper Company, later evolved into the Boston and Montana Company. All of the Boston and Montana interests, including the East Colusa mine, were absorbed by Amalgamated in 1901 (B. Shovers, written communication, 2000).

Although the East Colusa was itself a relatively small operation during its years as an independent entity, the property itself continued to produce until near the very end of Butte underground mining. East Colusa ores were extracted along with those from the Leonard and other properties until 1975. They were trammed to the Kelley shaft for hoisting. In addition to colusite, the East Colusa produced a mineral suite similar to that of the adjacent Leonard mine.

Emma Mine

The Emma mine was closed by a strike in 1959, and its surface plant and headframe were salvaged in the years following. The site is now a park, bounded by Silver Street on the north and Dakota Street on the west.

The Emma, originally the Ancient claim, was located no later then 1894. It was owned by the Butte Copper and Zinc Company. The Emma was originally staked as a silver property, but its production of silver was never important. The mine owed its eventually considerable fame to the production of manganese from rhodochrosite ores. Although modest manganese production began in 1917, it wasn't until the clouds of World War II appeared on the horizon that the property came into its own. In 1940 the Anaconda Company began a joint development of the Emma and Travona mines to produce larger quantities of manganese. By 1944 the two mines were accounting for 98% of the primary manganese production in the United States.

In one of those inexplicable twists of corporate logic the Emma was operated under lease throughout its productive history, while being owned by the Butte Copper and Zinc Company. The Anaconda Company management did not see fit to purchase the property until after it had been permanently shut down (Miller, 1973). The Emma was possibly the most prolific source of specimen rhodochrosite in the world.

Leonard Mine

The Leonard claim was located sometime in the 1870's and was named for Leonard Lewisohn, one of the two financier brothers who were the founding associates of the Boston and Montana Consolidated Copper and Silver Mining Company. The ground on which the Leonard was located was purchased by the Lewisohns from Colonel Charles T. Meader. The Leonard, along with other Boston and Montana properties, was merged into the Anaconda Copper Mining Company in 1910. The mine was located in the former Butte suburb of Meaderville (Elliot *et al.,* 1992). Nothing remains at the site.

The Leonard mine was worked continuously as a distinct entity with its own shaft and headframe until 1962, at which time it was shut down. The mine resumed production through the Kelley shaft in 1966. On September 18, 1973 the headframe was removed to make way for expansion of the Berkeley pit. The Leonard headframe was "dismantled" rather spectacularly with explosives. A sequence of impressive photographs of the demolition was published in Bancroft (1984). The Leonard mine finally shut down permanently in February of 1975.

The Leonard mine was one of the more remarkable producers in the district, not only for the richness of its copper-silver ores, but for its extraordinary horsetail orebodies, which are discussed in the Geology section. Nearby mines, which were also worked in later years through the Leonard-Kelley haulage, included the East Colusa, the Minnie Healy, and the Tramway. The mineralogy of the Leonard mine was the most diverse in the district. Magnificent specimens of enargite, covellite, chalcocite, digenite, pyrite, bornite, and numerous other minerals were found in abundance. During the 1950's many of these specimens were brought to the collector community by miner-dealer Ed McDole.

Figure 22. **Leonard mine headframe, ca. 1890 (Weed, 1912).**

Lexington Mine

The Lexington mine was one of Butte's premier early silver producers. The complex is located on the west side of Main Street at the southern border of Walkerville. Remains at the mine yard include the headframe, hoist house, ore bins, and a steel idler tower (utilized to keep the cables taut between the headframe and hoist), and various foundations (Butte Chamber of Commerce, 1985; Herbort *et al.*, 1998).

The original Lexington claim was staked by two men named Heffner and McCann in 1865. Real development of the property was begun by Andrew J. Davis in the mid-1870's. A local legend has it that Davis acquired his initial interest in the "Lex" in exchange for $20 and a white horse. Davis had full control of the mine by 1876 and began milling ore in the refurbished Hendrix mill in February of 1877. In the next year he tried to cut wages for his unskilled workers, resulting in Butte's first labor strike and the formation of the Butte Working Men's Union. The strike was successful and wages were restored. Ownership of the Lexington passed to a French concern, the *Soçièté Anonyme des Mines de Lexington*, in August, 1881. The French expanded the operation, including the construction of a new 60 stamp mill on the property, and by 1889 the Lexington's 1,400 foot (427 m) shaft was the deepest in Montana.

Like all of the other Butte silver mines, the Lexington was strongly affected by the government repeal of the Sherman Silver Purchase Act. After 1893 it was operated in a small way by leasors. Augustus Heinze leased and operated the mine for a short time in the 1900's. The property was idle during the 1920's, 1930's, and early 1940's. Anaconda reopened the mine in the late 1940's producing zinc from its lower levels. This revival lasted until the mid-1950's.

The Lexington was one of the more prolific sources of specimen minerals in the Butte district. In addition to fine specimens of native silver, rhodochrosite, and sphalerite it has produced chalcopyrite, galena, helvite, rhodonite and other minerals. The Lexington was especially prolific because its shaft and lateral workings penetrated the boundary between two zones (see Geology section), and ores were extracted from both zones.

Mountain Con Mine

The Mountain Con, or simply the Con, was officially known as the Mountain Consolidated mine. It is located near the intersection of Mullin and Minah Streets in the section of Butte called Centerville. The steel headframe as well as the foundation of the mine superintendent's house still exist (Butte Chamber of Commerce, 1985).

Figure 23. **Mountain Con mine, ca. 1900 (Weed, 1912).**

Although the original claim had been staked several years earlier, real development of the Mountain Con began in 1886 under the auspices of Marcus Daly and his San Francisco mining syndicate. Three years later the shaft was 550 feet (168 m) deep; by 1900 it had exceeded a depth of 2,000 feet (610 m) (Herbort *et al.*, 1998). The mine was shut down in February of 1975 after nearly 90 years of more or less continuous operation. It was the very last Butte underground mine to produce ore and it also bore the distinction of being the deepest of them all. The Mountain Con shaft measured 5,380 feet (1,640 m) from the shaft collar to the sump, making it not only the deepest shaft at Butte, but one of the deepest single-lift mine shafts in the United States. Like the Steward, Belmont, and Badger, the Mountain Con was a very hot mine because of its depth. A mechanical ventilation system was installed in the 1930's, when the shaft was already 4,000 feet in depth (1,220 m) (Herbort *et al.*, 1998).

The Mountain Con produced rich copper-silver ore from orebodies in the Syndicate vein. Nearby mines included the East and West Gray Rock, the Poulin, the Buffalo, and the Corra. The Mountain Con produced excellent specimens of bornite, chalcocite, enargite, pyrite, tennantite, and other minerals.

Steward Mine

The Steward mine is located close to the intersection of Woolman and Main Streets, near the Corktown section of Butte (Butte Chamber of Commerce, 1985). The headframe still stands above a shaft, which reached a depth of 3,900 feet (1,189 m). An internal winze reached a depth of 4,600 feet (1,402 m) (D. Johnson, written communication, 2000).

There are various stories of the origins of the Steward mine. The most likely is that told by Shovers *et al.* (1991). The original Steward 10-acre claim was staked on August 9, 1877. One of the claimants was John W. Stewart, for whom the property was named (apparently, the spelling was changed in later years). Two others were the Clark brothers, William A. and Joseph. By 1898 complete control had passed to the Copper King, William A. Clark. In 1902 Clark erected the present steel headframe at a cost of $9,000 (Shovers *et al.*, 1991). He also constructed a brick building to house the steam engines which drove the hoisting machinery. The brick buildings were a hallmark of Clark-owned mines around Butte. The steam engines were later replaced by a compressed air motor, which exists to this day. In 1910 the Steward, along with its neighbor, the Original mine, was sold to the Amalgamated Company for $5.5 million. One story has it that Clark believed the Steward was nearly worked out based on erroneous information provided by his geologists and mining engineers. The Amalgamated engineers proved smarter. Far from being exhausted, the Steward went on to become one of the richest and most productive copper-silver mines on the Hill (Kearney, 1998).

The Steward was one of the last underground mines to operate at Butte. It shut down in February of 1975, in its later years sending its ore over a long haulageway to the Kelley shaft for hoisting. Nearby properties included the Original, the Parrot, the Gagnon, the Clear Grit, and the Late[r] Acquisition. The Steward is known for fine specimens of barite, bornite, tennantite, and other minerals.

Travona Mine

The Travona mine is located at the intersection formed by Crystal Street on the west, Travonia Street on the east, and Interstate Highway 15 on the south. ("Travonia" is a local misspelling of the mine name.) The headframe, which was moved from the old Pennsylvania mine, still stands (Butte Chamber of Commerce, 1985) over a shaft more than 1,500 feet (457 m) deep.

The Travona represents the first silver claim located in the Butte district. It was staked by William L. Farlin on the last day of 1874, based on high silver assays of material from the black ledges adjacent to placer ground he was working at the time. These ledges had already been located but Farlin legally restaked them and named his claim the "Asteroid" in hopes that his new property would "outshine" previous failures (Butte Chamber of Commerce, 1985). One account has Farlin restaking his own lapsed claim (Hyde, 1998). The question of whether the claim was originally his own or someone else's did not deter Mr. Farlin from taking out a $30,000 loan with the bank of William A. Clark in 1875 to develop his mine and the 10-stamp Dexter mill. Four years later, he defaulted on the loan, and ownership of both mine and mill passed to Mr. Clark. It was at this time that the property was renamed the

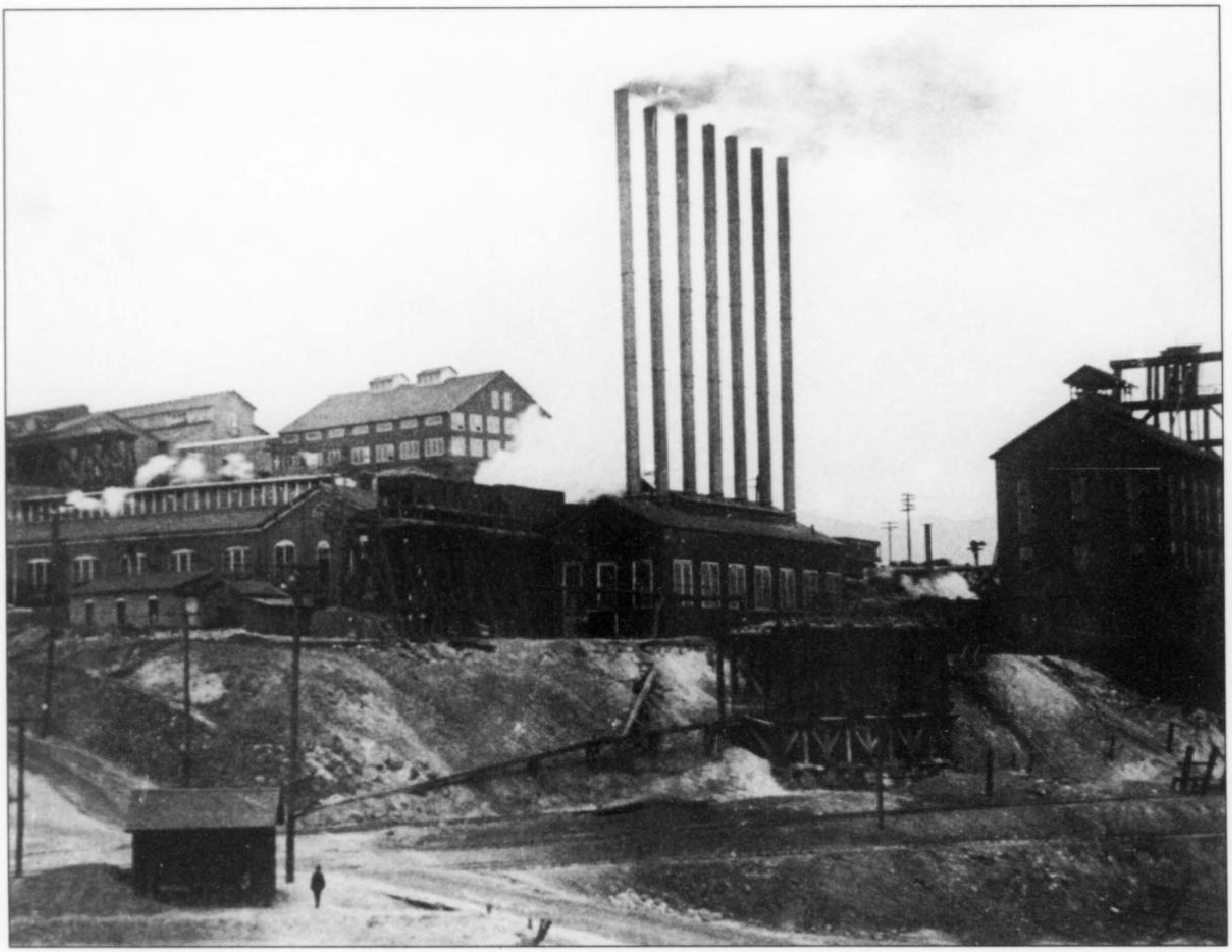


***Figure 24.* Neversweat mine and boilerhouse with its distinctive seven stacks. World Museum of Mining photo.**

Travona mine after a province in the Balkan states. The Travona mine helped to give Mr. Clark his start in Butte mining.

The Travona produced a significant amount of silver, although its yield was very modest in comparison to the quantities of silver derived as a by-product of copper mining. Later the Travona was worked in conjunction with the nearby Emma and produced a fortune in manganese. The mine was shut down in 1954. In addition to more ordinary material, the Travona produced the best rhodochrosite ever found at Butte. Unfortunately, this fine red rhodochrosite was very rare.

MILLS AND SMELTERS

As Butte evolved from a small gold camp to a substantial silver producer, and then to one of the most productive copper mining districts in history, beneficiation and smelting technologies likewise evolved from the simple (panning and sluicing for placer gold) to the complex (grinding, concentration by jigging or flotation, roasting, smelting, and electrolytic refining for copper). Although a small arrastra was constructed in 1866 to work silver-gold ores near the site of the later Finlen Hotel, Butte's first "mill," the Continental, was a small 10-stamp affair which had been hauled over from Stirling, Montana (Weed, 1912). The Continental mill proved to be a financial failure.

The first successful metallurgical works at Butte was the Dexter mill, operated in conjunction with the Travona mine and mentioned in the present paper in that property's "biography." The Dexter consisted of a 10-stamp crushing battery mated to a chlorination-roasting and amalgamation circuit. In 1877, an old 20-stamp dry-crushing mill was brought in from Ophir Canyon, Utah and erected at the Alice mine to begin treatment of that property's rich, free-milling silver ores. Silver was recovered from the crushed ore by direct amalgamation with mercury. Within a year or two, more refractory sulfide ores were being encountered, which gave poor recoveries by this simple method. White-Howell roasters were added and the chlorination-roasting process was adopted at the Alice plant as well. Eventually, all of Butte's silver mills used this chlorination-roasting or modified "Washoe Process" (Weed, 1912).

In the "Washoe Process" the crushed ore in water slurry (pulp) was introduced into an iron pan provided with a stirrer and heated by steam injected through a port at the pan's center. The ore was mixed with appropriate quantities of salt and copper sulfate, heated, and stirred for about three hours. Mercury was added to the pulp at this point, and heating and stirring continued for another period of time. After amalgamation was considered complete, the pulp was sluiced into settling tanks from which the amalgam could then be collected. A silver-gold sponge, as well as most of the mercury, was then recovered by retorting. The mercury was recycled back to the process (Dennis, 1961).

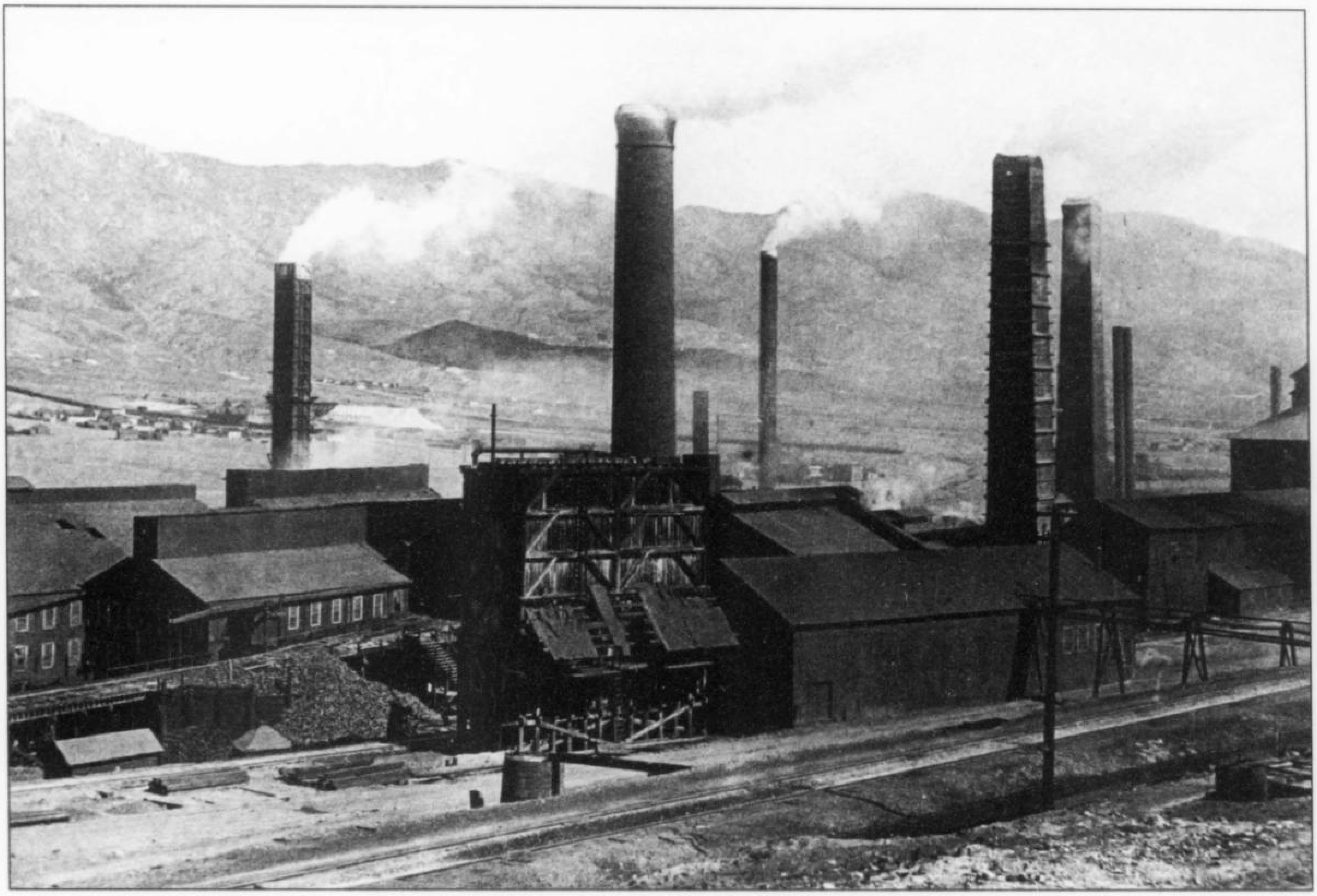


Figure 25. **F. Augustus Heinze's Montana Ore Purchasing Company smelter, Meaderville, Montana, ca. 1900. World Museum of Mining photo.**

Processing of primary silver ores by chlorination-roasting effectively ceased at Butte in 1892 as a result of the repeal of the Sherman Silver Purchase Act. By that time a number of copper smelters were in operation. Smelting of copper sulfide ore and production of commercial grade copper metal had originally been developed at Swansea, Wales. The process involves four basic steps: (1) preliminary roasting for partial elimination of sulfur; (2) smelting in a reverberatory furnace to concentrate the copper into matte and eliminate gangue as slag; (3) conversion (bessemerizing) of the matte to blister copper; and (4) casting the blister into anodes for electrolytic refining (Dennis, 1961). Early smelting operations at Butte concentrated on the first two steps in this process, with the copper matte being shipped elsewhere for refining.

Butte's first successful copper smelter and, indeed, the first large copper smelter in the West, was the Colorado smelter, which began operations in 1879. The reader should note that although the Colorado was predated by the copper smelter at Blackhawk, Colorado, the smelter at Butte was much larger.

The Colorado was located south of the Hill along Silver Bow Creek, just west of the present-day point where South Montana Street crosses the stream. The original wood-fueled smelter produced a copper matte assaying about 60% copper and 21.5 to 24.6 kg per ton of silver (Hofman, 1904). In the fall of 1881, work began on a 45.5 mtpd concentrator adjoining the smelter so that the complex could operate profitably with lower grades of ore. Most of the ore-feed at the Colorado came from the company-owned Gagnon mine but substantial custom-smelting was also done (Goodale, 1896).

Another early smelter bears further description. This was Heinze's Montana Ore Purchasing Company (MOP) smelter. Ground was broken for this operation on October 17, 1892, and the plant was blown in early in 1894 (B. Shovers, written communication, 2000). It became a relatively large complex among the smelters operating at Butte. By 1901 the operation had grown to 70 roasters, 6 reverberatory matting furnaces, 4 blast furnaces, 2 horizontal converters, and 8 upright converters (Hofman, 1904). This was exceptionally large by Butte standards, especially in that the MOP smelter did mostly custom work.

Many, if not all, of Butte's early smelter works utilized open-stalls for the initial roasting of lump-ore. This process involved the stacking of alternating layers of wood and lump-ore within a fire-proof rectangular box, with allowances made for entry of air into the bottom of the stall. Hundreds of these stalls were in operation during the late 19th and early 20th centuries at Butte. In 1891, for example, there were 120 stalls at the Parrot works alone, each stall measuring 2.4 x 1.8 x 1.8 m (Hofman, 1904; Peters, 1911).

By far the largest and most technologically advanced group of smelter and concentration facilities was that erected by Marcus Daly's Anaconda Copper Mining Company near Anaconda, Montana. Some of the operations of the three separate plants have been described in the History section, and only two additional notes need be made here. The Butte district's first electrolytic refining circuit for copper was placed in operation at the Lower Works in 1891. Similarly, the district's first flotation circuit for copper concentration was installed at the Washoe Works in 1914 (Rickard, 1921).

Although copper reigned as king at Butte until recent times, zinc production started to become important after the turn of the 20th

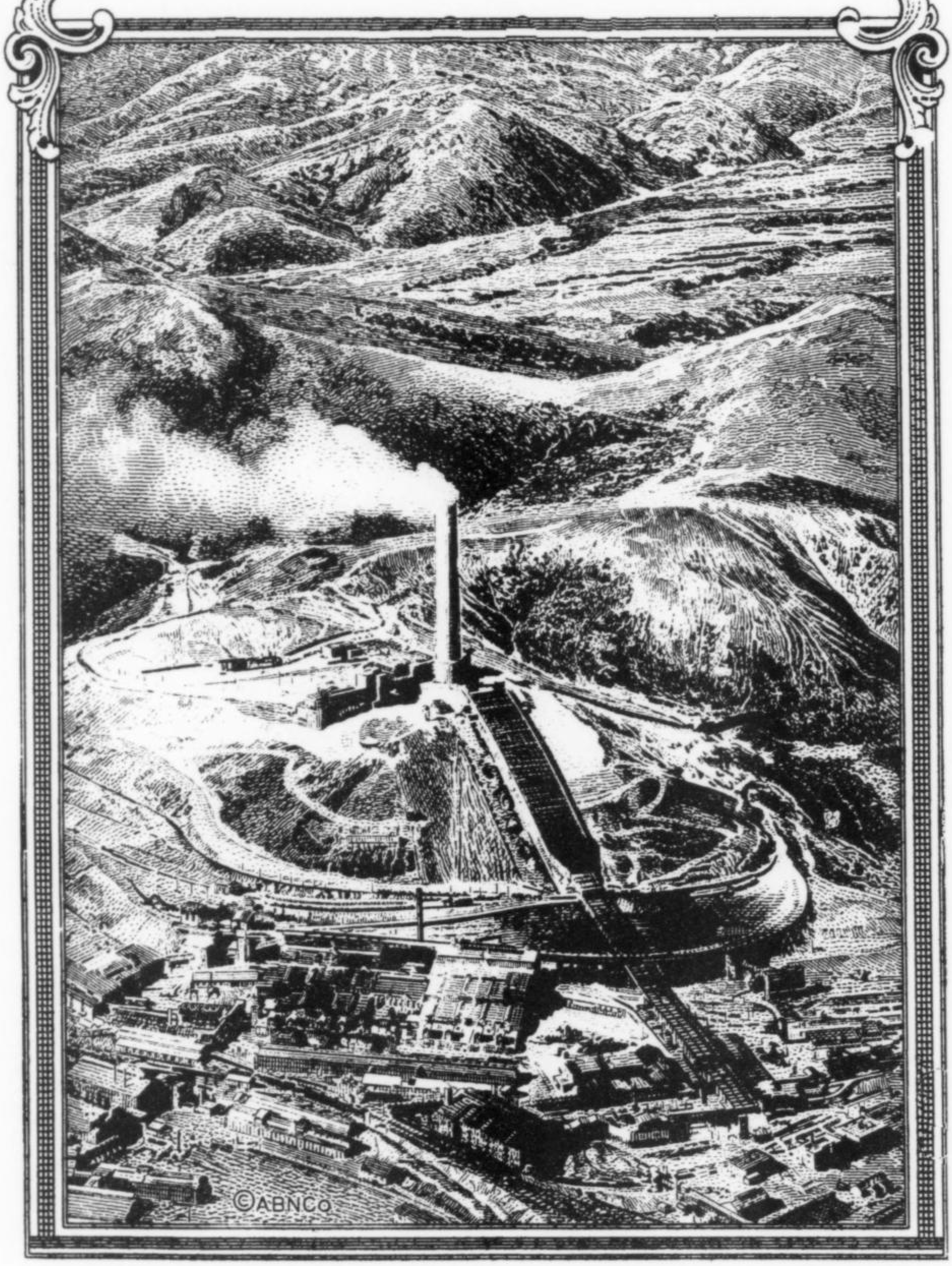
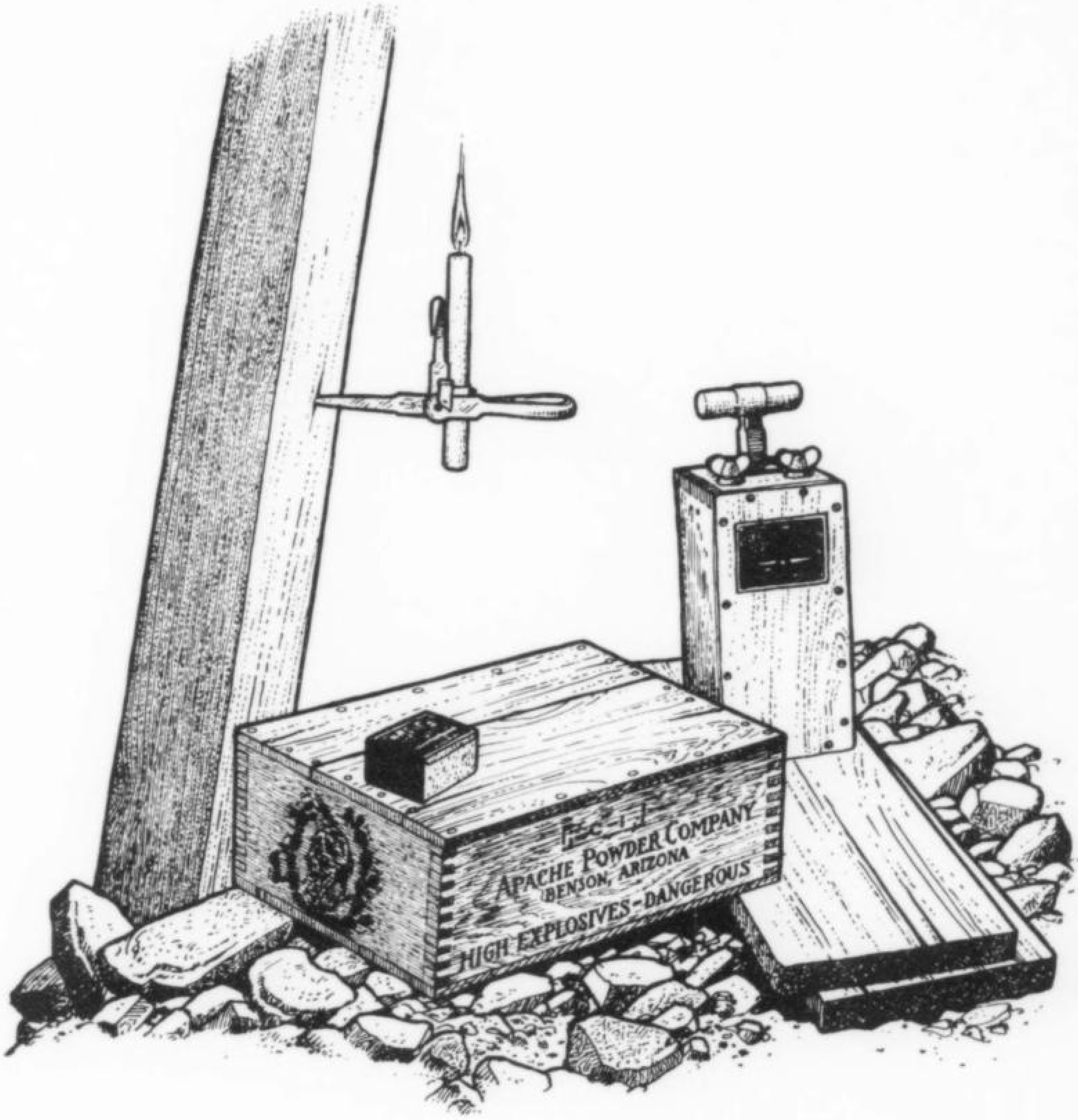


Figure 26. **Hilltop smelter of the Anaconda Company as depicted on their 1967 stock certificate in an engraving (based on an aerial photo) by the American Banknote Company. Mineralogical Record Library.**

century. In August 1911, the first zinc flotation circuit was brought on line at the concentrator of the Black Rock mine. This was the first flotation plant of any kind anywhere in the United States. The process, developed by J. M. Hyde, was the subject of a patent-infringement lawsuit instituted by Minerals Separation Ltd., a British firm which had done the pioneering work on flotation concentration of sulfide ores. The suit, ultimately adjudicated by the United States Supreme Court, was decided in favor of the Butte and Superior Company (Rickard, 1921). The Clark Company's Timber Butte concentrator also employed flotation to concentrate zinc ores from the Elm Orlu mine (Simons, 1916). The world's first and largest electrolytic zinc recovery plant was installed at the Great Falls smelter and refinery in 1916. This process had been home-developed by Anaconda metallurgists F. Laist, F. F. Frick, and J. O. Elton, all headquartered at the Washoe Works.

Like most of its mines, Butte's early metallurgical plants are largely gone. As earlier mentioned, the masonry stack is the sole remnant of the Washoe Works, closed as recently as 1980. The ore bins still stand at the site of Clark's concentrator on Timber Butte, south of town. Black slag piles remain near the site of Clark's Butte Reduction Works along Silver Bow Creek (B. Shovers, written communication, 2000) and at Anaconda, but as environmental remediation proceeds, even these may disappear.



Geology

General Geology

The geology of the Butte district is extremely complex and has been reviewed by many workers, beginning essentially with the opening of the underground mines. Only a very general description can be given here.

The mineralized region around Butte, Montana, measures about 12 km east-west by 6 km north-south. The district is located along the western flank of a large composite igneous body called the Boulder Batholith (Knopf, 1957; 1964), emplaced 76–78 m.y. ago (Tilling *et al.,* 1968; Martin and Dilles, 2000). It consists of at least 15 separate intrusions, the largest of which is called the Butte Quartz Monzonite. Abundant aplitic and pegmatitic rocks are associated with the quartz monzonite. The Butte Quartz Monzonite is host to the district's many ore deposits.

Ore deposits of the Butte district form a very large, classically zoned, porphyry copper system (Sales, 1954; Lowell and Guilbert, 1970). Based on a production and resource compilation prepared by Anaconda Company geologists in 1980 and now stored at the International Archive of Economic Geology, American Heritage Center, University of Wyoming, Long (1993) estimated that the original Butte porphyry system contained 7.5 MMt (billions of metric tons) of mineralized rock at an average grade of about 0.4% Cu, of which no more than 800 Mt had by then been mined. Other statistics given by the same author indicate that the total copper inventory at Butte is significantly greater than those of the gigantic porphyry copper deposits at Bingham Canyon, Utah and Morenci, Arizona. For some metals, notably zinc, silver, and manganese, it is many times larger.

Butte ore deposits consist of (1) continuous high-grade veins, (2) large areas of closely spaced branching veins and veinlets called horsetail zones, and (3) porphyry-style disseminated mineralization (Weed, 1912; Sales, 1914; Meyer *et al.,* 1968). Porphyry-style mineralization consists of typical low-grade, high-tonnage chalcopyrite and molybdenite mineralization in narrow quartz-dominated veinlets. The vein and horsetail deposits are lower tonnage and much higher grade, and the veins are considerably wider. Vein and horsetail mineralogy is also much more complex. Veins and horsetail zones are collectively called Main Stage mineralization, whereas most of the disseminated mineralization is pre-Main Stage.

The north-trending Continental Fault is a major structural feature of the district. It is primarily a dip-slip fracture (the eastern side upthrown) with at least 500 m and perhaps as much as 1,200 m of vertical displacement. The Continental Fault divides the ore deposits of the district into two geographic regions. West of the fault, ore deposits consist of the big veins, horsetail zones, and considerable disseminated mineralization. East of the fault, disseminated mineralization with only very minor Main Stage veining is present (Ratcliff, 1973).

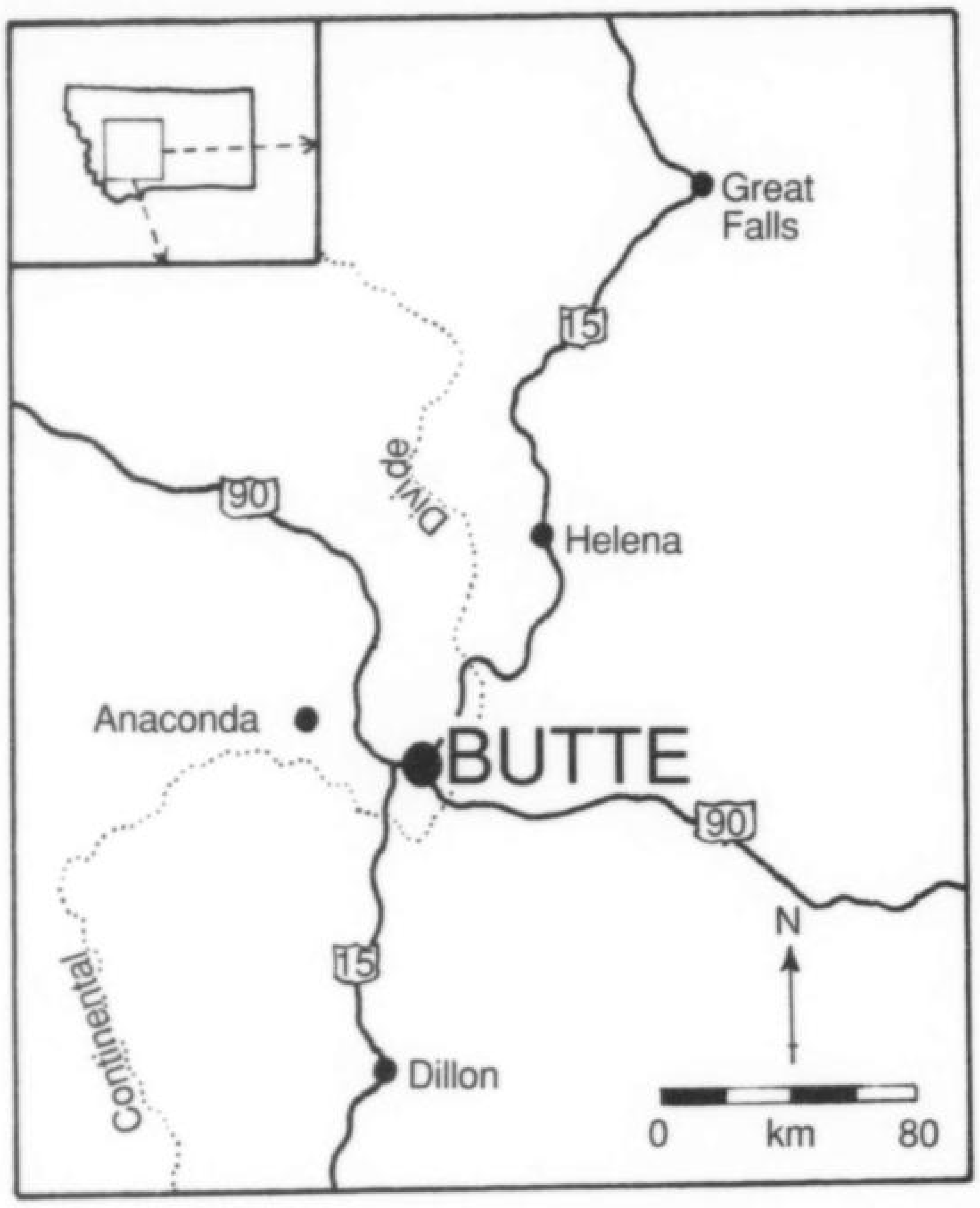


Figure 27. **Location map.**

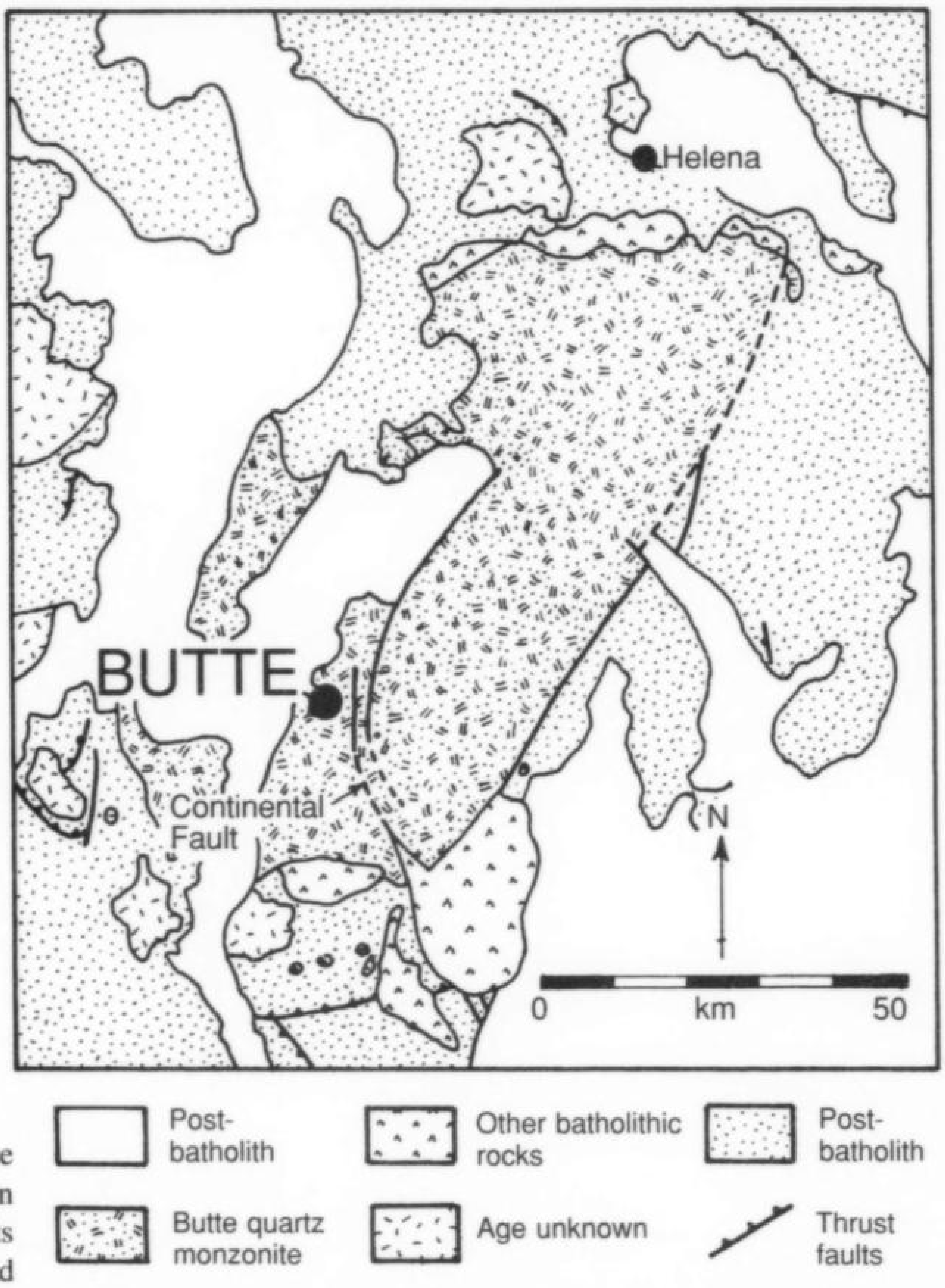


Figure 28. **Simplified geologic map of the Butte area (adapted from Meyer *et al.*, 1968).**

Pre-Main Stage Mineralization

Pre-Main Stage mineralization constitutes an important resource of metals at Butte, but it is not an important source of specimen material. Nevertheless, a brief discussion of pre-Main Stage events is necessary to an understanding of the complex mineralization and alteration patterns of the district.

The earliest pre-Main Stage mineralization is found in the EDM and PGS veinlets. The former consist of quartz-chalcopyrite veins with alteration envelopes containing secondary biotite, K-feldspar, and sericite. The name EDM signifies Early Dark Micaceous. The PGS veinlets are zonally exterior to the EDM series and consist of quartz-magnetite-chalcopyrite veins with alteration envelopes containing pale green sericite, hence the name PGS. Together the EDM and PGS veinlets contain most of the pre-Main Stage copper at Butte. Cutting both the EDM and PGS veinlets, but deeper in the system, is a zone of barren quartz and quartz-molybdenite veinlets with thin alteration envelopes of K-feldspar. The two veinlet types are considered to be contemporaneous. The quartz-molybdenite veinlets contain all of the economic molybdenum mineralization at Butte. The latest pre-Main Stage mineralization consists of quartz-pyrite veinlets with gray sericite alteration envelopes. These are called GS veinlets and contain no valuable minerals (Brimhall, 1973; Rusk *et al.*, 2000a).

West of the Continental Fault, pre-Main Stage mineralization occurs largely at depth. EDM, PGS, and quartz-molybdenite veinlets occur in two broad domes—the Anaconda Dome, centered north of the Belmont shaft, and the Pittsmont Dome, centered east of the Pittsmont shaft (Rusk *et al.*, 2000b). The top of the zone of dense quartz-molybdenite veining lies at about the 2,800 level (853 m) of the Belmont shaft in the Anaconda Dome (Meyer *et al.*, 1968). The two domes are separated by a zone of pervasive quartz-sericite-pyrite alteration which extends to a depth of at least 2 km.

East of the Continental Fault, pre-Main Stage mineralization is exposed at the surface. This may represent an upthrown extension of the deeper mineralization to the west. Alternatively, it may represent a separate mineralized system (Ratcliff, 1973; Czehura and Zeihen, 2000). Until recent months pre-Main Stage molybdenum and copper had been produced from the Continental pit.

Fragments of pre-Main Stage EDM and quartz-molybdenite veinlet material have both been found in the Modoc breccia near the Leonard mine. The Modoc quartz porphyry and breccia have been dated at about 75–76 m.y. by U-Pb methods on zircon (Martin and Dilles, 2000). This date is little different from dates on the Boulder Batholith and suggests that at least some of the pre-Main Stage mineralization is directly related to the intrusion of the Butte Quartz Monzonite.

Main Stage Mineralization

Main Stage mineralization was formerly mined in Butte's great underground mines. The veins and horsetail zones generally lie above, but also crosscut the pre-Main Stage mineralization. The vein deposits have been the source of nearly all of the specimen minerals which have so delighted mineral collectors (L. Zeihen, written communication, 2000).

Information in the following discussion of structure, age and origin is derived from Weed (1912), Sales (1914, 1949), Meyer *et al.* (1968), Gustafson (1973), and Proffett (1973).

Several sets of fractures host the Main Stage mineralization in the Butte district. Among these the most important are the Anaconda veins, the Blue Fault veins, and the horsetail zones. Relatively minor mineralization also occurs at depth in the Steward veins and in the Hanging Wall Steward veins, but these will not be discussed here. Although they offset veins and add to the structural complexity of the district, fracture sets which host little or no

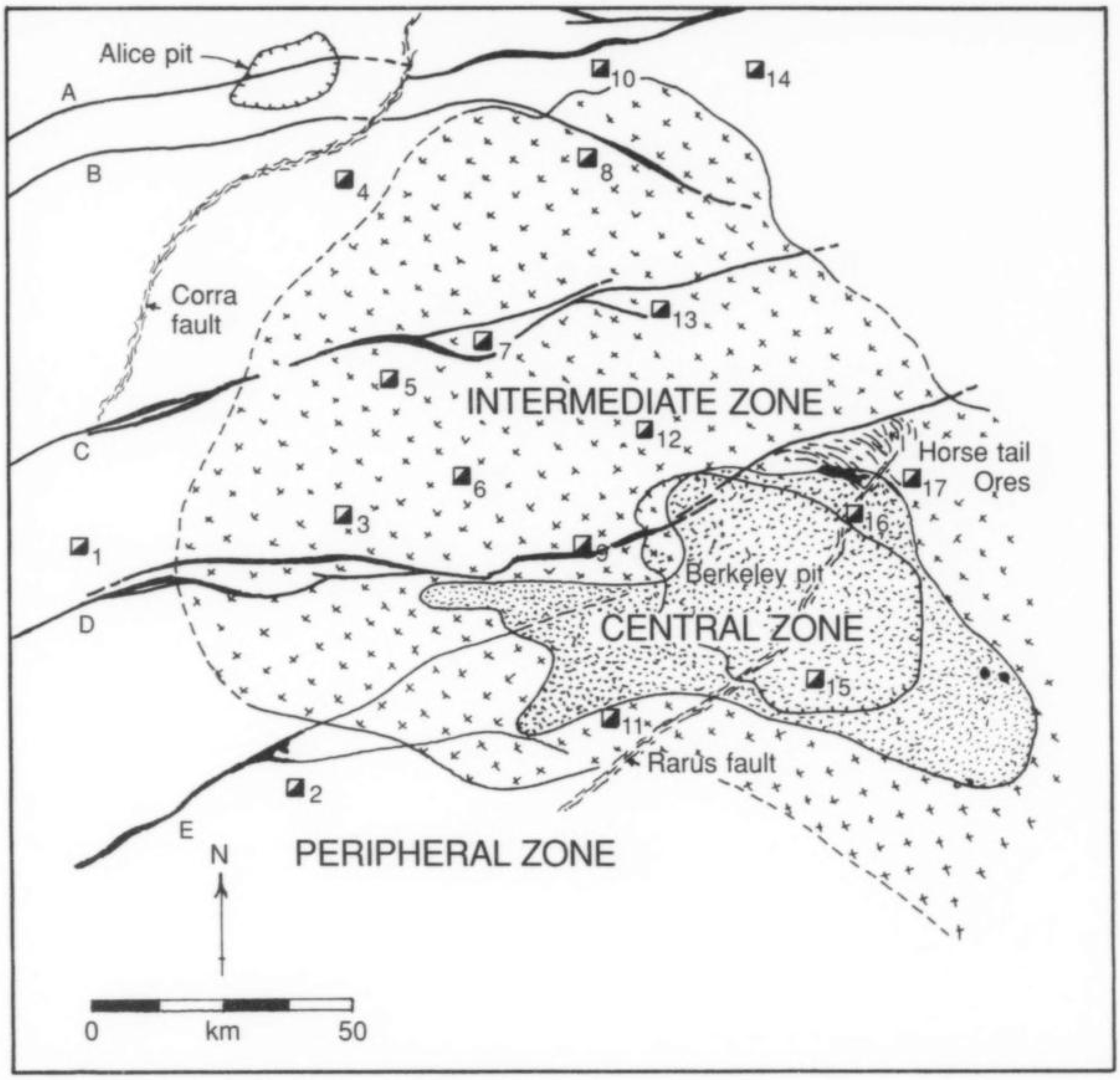


Figure 29. **Major Anaconda-age veins and important mine shafts shown relative to the Butte zonation pattern.** ***A:*** **Rainbow vein,** ***B:*** **State vein,** ***C:*** **Syndicate vein,** ***D:*** **Anaconda vein,** ***E:*** **Emma-Travona vein.** ***1:*** **Anselmo mine,** ***2:*** **Emma mine,** ***3:*** **Steward mine,** ***4:*** **Lexington mine,** ***5:*** **Mountain Con mine,** ***6:*** **Kelley mine,** ***7:*** **Green Mountain mine,** ***8:*** **Badger mine,** ***9:*** **Anaconda mine,** ***10:*** **Elm Orlu mine,** ***11:*** **Belmont mine,** ***12:*** **High Ore mine,** ***13:*** **Speculator mine,** ***14:*** **Black Rock mine,** ***15:*** **Silver Bow mine,** ***16:*** **Tramway mine, and** ***17:*** **Leonard mine (adapted from Guilbert and Zeihen, 1964).**

mineralization (such as some of the Middle Faults, the Rarus and Corra Faults) will also not be considered.

The Anaconda veins represent the first fracture set among the big veins to open and receive mineralization. They trend approximately N70E to E-W, and generally dip steeply to the south. The major veins range up to 3.5 km in length and extend at least 1.6 km down dip. Their maximum thickness is about 45 m but an average value is probably 6 to 9 m.

There are five major Anaconda veins, about 15 minor veins, and innumerable splits which have produced ore. The major veins are depicted together with zonation and some of the major mine shafts on the map of Figure 29 at the Mountain Con 1,500 level datum (457 m). It should be recognized that each of these major veins is a vein system. Local segments and splits often bear the names of individual mines or even numbers. There is a large area on the eastern side of the district in which Anaconda veins are essentially absent. This area, lying west of the Leonard #2 shaft and northwest of the Berkeley pit, is bounded on the north by the State vein.

The Anaconda veins have been by far the most important ore sources among the Main Stage deposits. Weed (1912) describes essentially solid masses of chalcocite in the Anaconda vein proper, which were 8 m thick and up to 70 m in both length and height. These were not uncommon in the early days and constituted the great copper bonanzas for which Butte became world-famous.

After the E-W set the next fractures to open were the Blue Fault or Blue veins. The Blue Fault veins trend N30-60W and dip mostly to the south, steeply on the northern side of the district and more gently to the south. The Blue Fault veins are best developed in the aforementioned area in which Anaconda structures are absent. The Blue Fault veins are much less persistent than the Anaconda veins, both horizontally and vertically, and are also narrower. Although they tend to become more productive at depth, as at the Steward mine (Proffett, 1973), the Blue Fault veins have been significantly less productive of ore.

Although the Blue Fault veins are generally later than the Anaconda veins, it is clear that some of the latter were still open and receiving mineralization at the time the Blue Faults were formed. In many instances the Blue Fault veins clearly offset fractures of Anaconda age as much as 60 m, but in others Blue Fault mineralization turns into and merges with Anaconda structures. In still other cases Blue Fault gouge merges into Anaconda gouge, suggesting that movement along the Blue Fault was transmitted into the Anaconda fracture, and the latter was reopened. Some of the structural relationships among the crosscutting veins and fractures are illustrated by the map of Figure 30. Note the left-lateral offset of the Anaconda-age Steward vein by the Blue Fault-age 3461 vein.

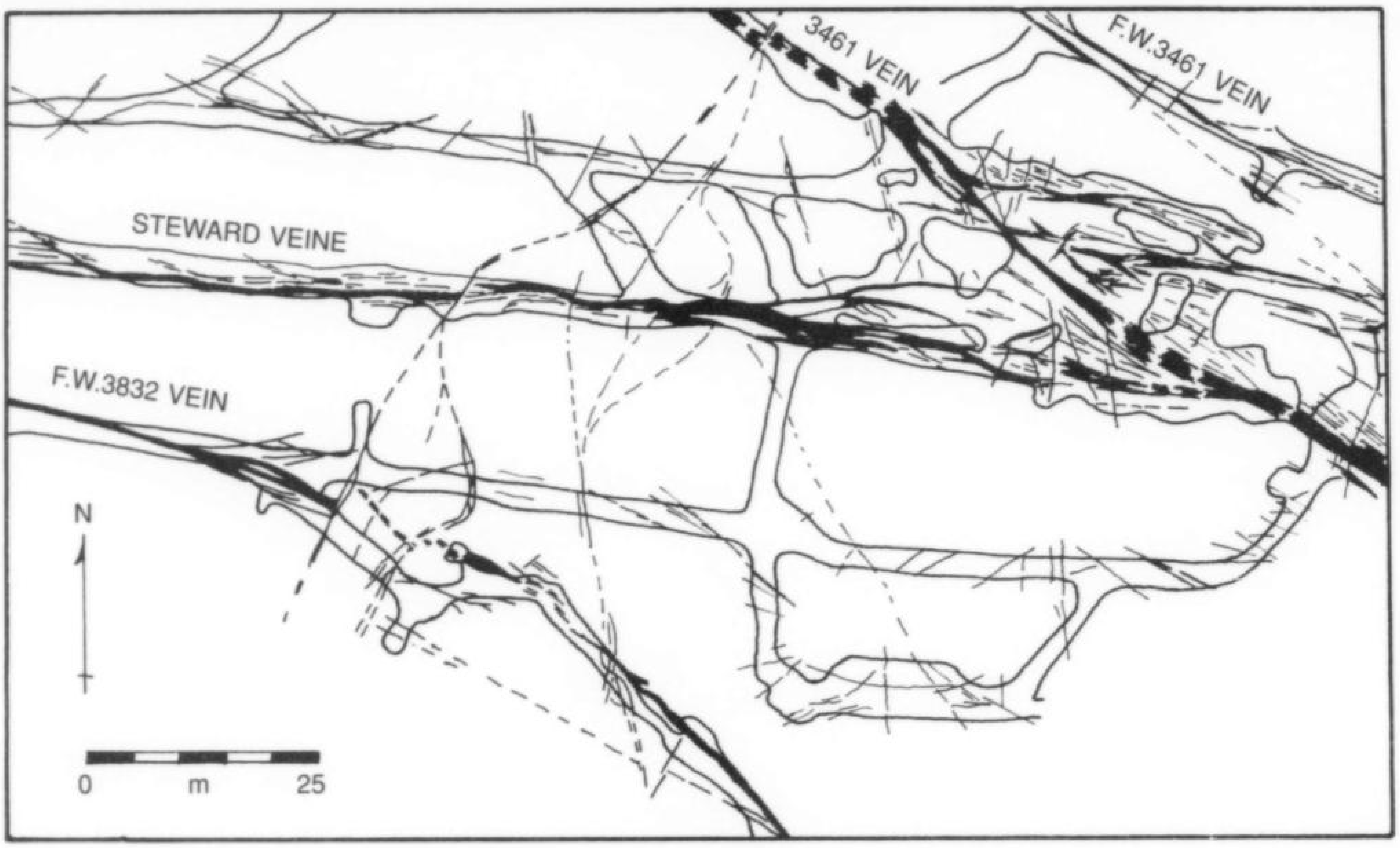


Figure 30. **Steward mine vein structures on the 3,800-foot level (adapted from Proffett, 1973).**

The horsetail zones are developed in a northeasterly trending belt on the eastern flank of the veined area. They turn off of some of the Anaconda structures in a generally NW-SE to N-S direction. The term "horsetail zone" was first employed by Sales (1914). The present more current description is derived largely from Gustafson (1973).

The horsetail zones are similar to stockworks in that they consist of closely spaced, mineral-filled fractures; but they are different in that the fractures do not form a crosscutting network. Rather, the fractures are subparallel and, in fact, comprise a series of *en echelon* bifurcations off of some of the large Anaconda veins. As the vein maps show, the horsetail analogy is apt. The mineralized fissures within the horsetail zones ranged from less than 1 cm to about 0.7 m in thickness. Disseminated copper minerals also occurred abundantly in their wall rocks and, generally, the entire mass of veinlets and wall rocks was mined as ore.

The largest and most productive of the horsetail zones, actually consisting of three essentially contiguous zones (designated the East Colusa, the North Bennett, and the Minnie Healy from north to south) was that developed in the Leonard-Colusa-Tramway mining area. This area is shown in the center of the detail map of Figure 31. The heavier lines represent segments of the Anaconda vein-proper.

The Leonard-Colusa-Tramway mining area encompassed the famous Leonard, East Colusa, Tramway, and Minnie Healy mines. The mined area measured about 300 by 600 m in plan. The top of the East Colusa zone lay at the Leonard 1,200 level (366 m). The Minnie Healy zone was mined to the Leonard 3,800 level (1,189 m). This area of horsetail mineralization was bounded on the north by the Middle Fault and on the south by the No. 16 fault-vein.

Main Stage veins and the horsetail orebodies are closely tied to a system of E-W trending quartz porphyry dikes. Some of these are also shown on Figure 31 in the stippled pattern. These dikes, which are lithologically identical to the Modoc quartz porphyry, have been age-dated at 69–72 m.y. by U-Pb methods on zircon. These are preliminary dates only (Martin and Dilles, 2000) but, together with data on the Butte Quartz Monzonite and pre-Main Stage mineralization, they suggest that district igneous activity and mineralization were either diachronous or long in duration.

Brimhall (1978, 1979, 1980) proposed that the metals contained in the Main Stage vein and horsetail deposits were derived by hydrothermal reworking of the older porphyry-style mineralization. The E-W system of quartz porphyry dikes may have provided the heat source.

Zonation

The mineral and metal zonation of the Butte district was first described in the classic work of Sales (1914). The only major modification to the pattern reported by Sales nearly 90 years ago has been recognition of a Deep Level Chalcopyrite Zone (Guilbert and Zeihen, 1964) of little mineralogical interest.

The Butte district was developed to a depth of 2,000 to 2,300 feet (600 to 700 m) at the time of Sales (1914), who divided these upper levels of the district into Central, Intermediate, and Peripheral Zones. These are more or less symmetrical about the Anaconda Dome but are offset slightly to the north and west.

Zonation is depicted in plan view in Figure 29. Zoning in the third dimension is shown in Figure 32. The zone boundaries are not vertical and, in fact, form concentric, shallow shells over the Anaconda Dome. The boundary between the Peripheral and Intermediate Zones is inclined into the section. The area marked "Gap" represents a change in plane of the section, due to the change in orientation of the State vein.

Veins in the Central Zone contain copper minerals with only traces of zinc. In the Intermediate Zone copper is still the most important metal, but significant zinc has also been produced, particularly at the outer fringes of the zone. Silver, zinc, lead, and manganese together with some gold are found in the Peripheral Zone. Copper is important only in minor, scattered orebodies. Silver and gold also occur in small quantities in the Central and Intermediate Zones, but manganese is largely absent from the inner zones. Because the zone boundaries are inclined at shallow angles from the vertical, some of the deeper mines located near zone boundaries have produced different metals from top to bottom of the mine. The Lexington mine shown on the cross-section of Figure 32, for instance, has produced silver from the upper levels in the Peripheral Zone, but copper and especially zinc have been

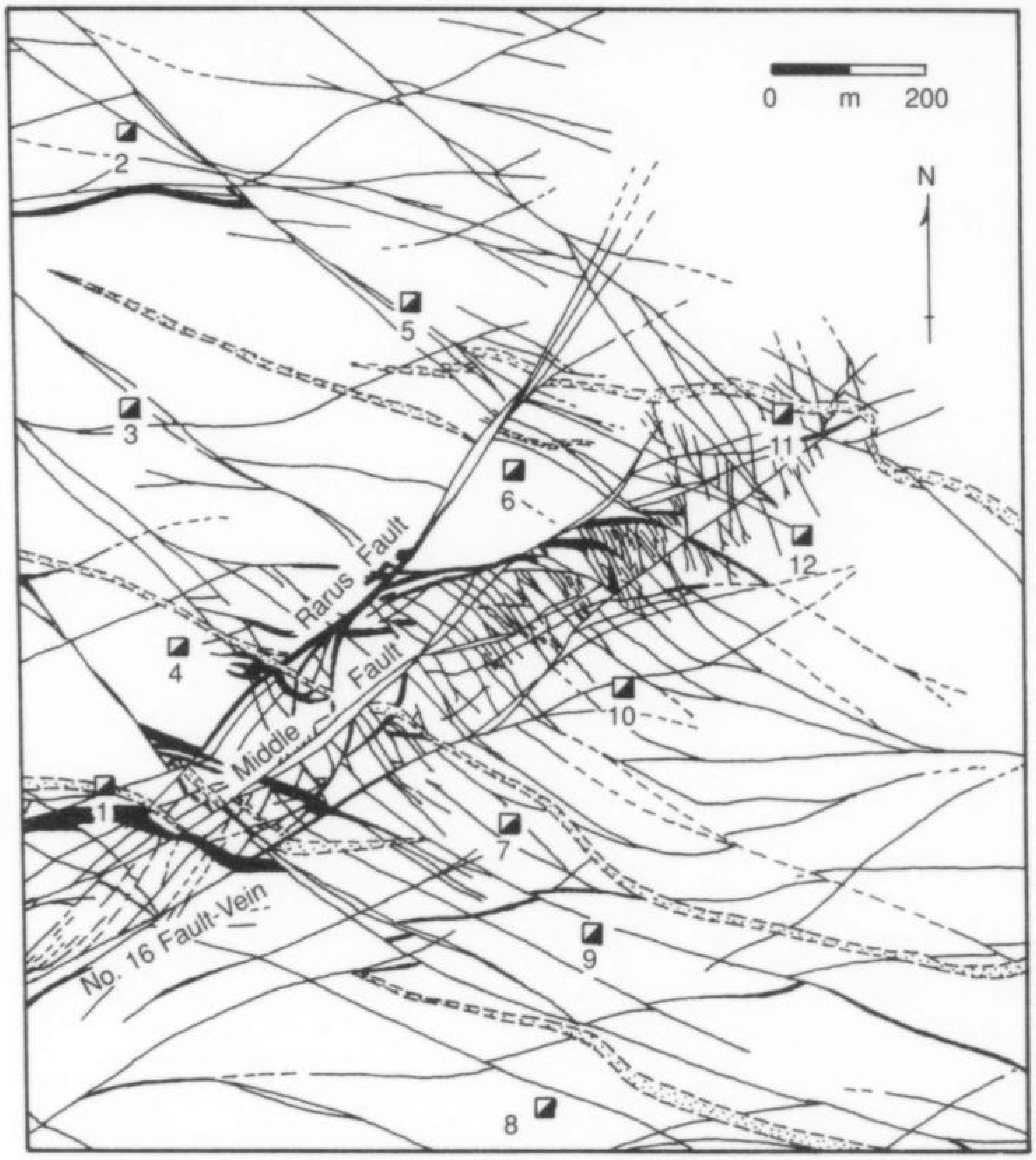


Figure 31. **Vein structures in and near the "horsetail zones" (center); stippled areas are quartz porphyry dikes. Mine shafts: *1:* St. Lawrence mine, *2:* Speculator mine, *3:* High Ore mine, *4:* Mountain View mine, *5:* Modoc mine, *6:* West Colusa mine, *7:* Rarus mine, *8:* Silver Bow mine, *9:* Berkeley mine, *10:* Tramway mine, *11:* East Colusa mine, *12:* Leonard #2 mine (adapted from Gustafson, 1973).**

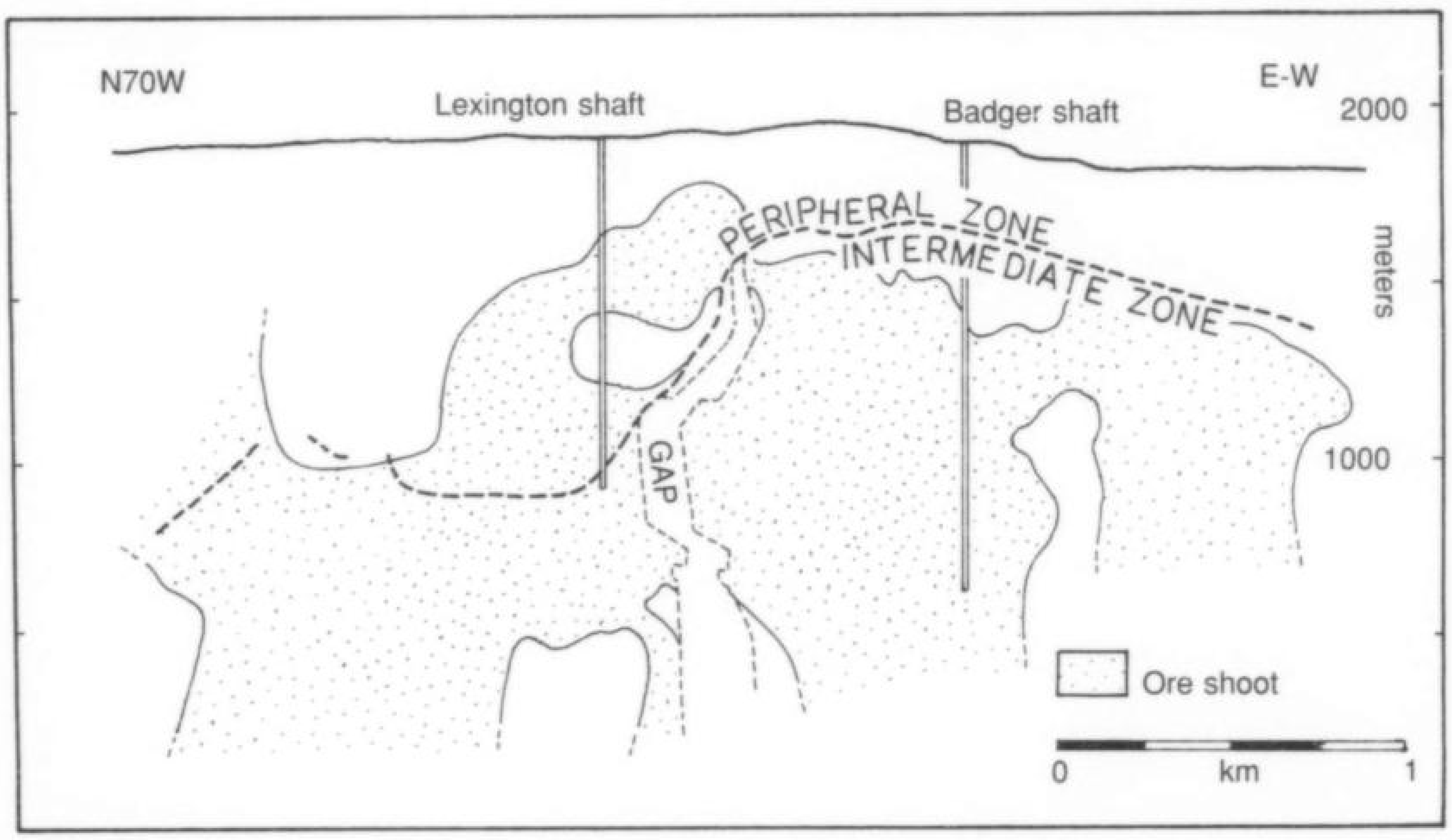


Figure 32. **State vein, longitudinal section looking north (adapted from Meyer *et al.*, 1968).**

important products from the lower levels in the Intermediate Zone.

The district is also zoned with respect to mineralogy. The great chalcocite-enargite orebodies which have produced so many fine mineral specimens occurred in the Leonard-Colusa-Tramway mining area, as well as in the Anaconda mine. These are all located within the Central Zone. The Berkeley pit also lay largely within this innermost zone. Although they are found in smaller amounts elsewhere, this same area hosted the rare species colusite and betekhtinite, together with most of the high-sulfur copper minerals, covellite, digenite, and djurleite. Bornite and tennantite are relatively unimportant in this innermost zone (Meyer *et al.*, 1968).

Chalcocite-enargite ores persist outward into the Intermediate Zone. Bornite gradually becomes more abundant at the expense of chalcocite, especially to the northwest at the Badger mine, and tennantite begins to substitute in significant quantity for enargite. It should be noted that enargite contains more sulfur than tennantite, and it is most abundant in association with the high-sulfur copper sulfides of the Central Zone (Meyer *et al.*, 1968).

Further westward, in the Original, Steward, and Mountain Con mines, bornite-chalcocite ores are abundant and tennantite is by far the most abundant Cu-As mineral. At depth the bornite-chalcocite assemblages give way to chalcopyrite with small stringers of bornite and sphalerite flanking the Main Stage veins. This represents the Deep Level Chalcopyrite Zone, which was first recognized by Guilbert and Zeihen (1964). The area of abundant chalcopyrite in the big veins describes a shallow dome whose apex

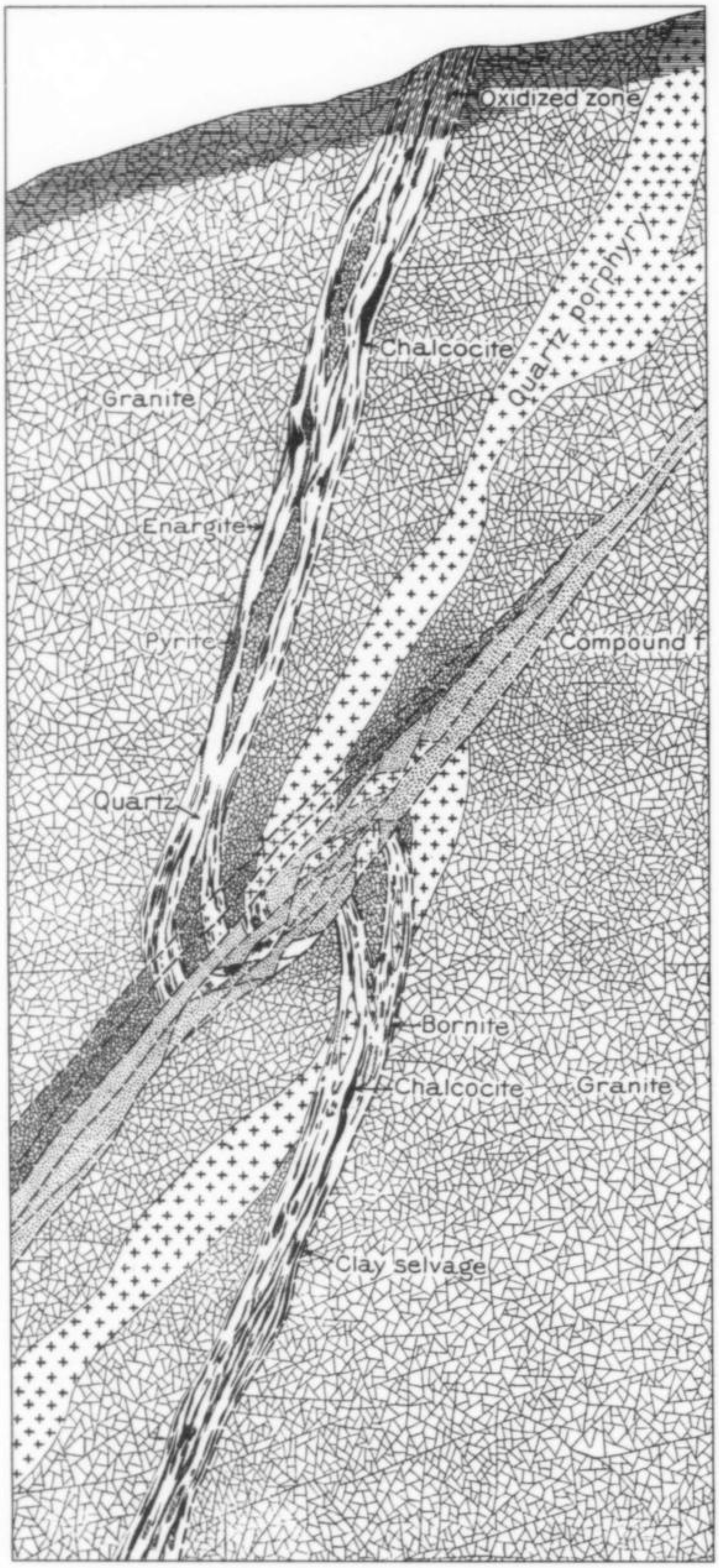


Figure 33. **Idealized cross-section through the Anaconda vein (Weed, 1912).**

lies near the Mountain Con shaft at about the 3,400 level (1,037 m). This Deep Level Chalcopyrite Zone should be distinguished from the pre-Main Stage mineralization of the Anaconda Dome. The latter represents earlier porphyry-style mineralization, whereas the former consists of filling of chalcopyrite in Main Stage veins.

Mineralization of the Peripheral Zone is found largely on the north and south flanks of the district. To the west any mineralization is covered by younger volcanic rocks, while to the east the outer zone appears to be narrow and poorly developed (Figures 28 and 29). A little zinc-manganese mineralization has been found northeast of the Leonard-Colusa mining area in closely spaced veinlets, and a small amount occurs in the Continental area on the east side of the Continental Fault (Ratcliff, 1973). These are very minor occurrences.

On the north side of the district the major mines are located along the large, arcuate vein system called the Rainbow. The Rainbow vein mines, together with the Lexington, whose shaft collar is located near the State vein system, have been large producers of silver. In the unoxidized ores silver mineralogy includes stephanite, acanthite, and other minerals. In the oxidized zone native silver and some chlorargyrite were found, and many fine specimens of the former were collected a century ago. The major manganese phase is rhodonite, with lesser amounts of rhodochrosite. There has been relatively little commercial production of manganese.

To the south and southwest, silver and manganese have been produced from the Emma-Travona vein system. Mines of this area have produced less silver than those of the Rainbow vein, but most of the manganese in the district has come from the giant rhodochrosite orebodies of the Emma mine, which ranged up to 30 m in thickness. It is interesting to note that rhodonite was entirely absent from the Emma orebodies (L. Zeihen, oral communication, 2000), although it was found in the southwestern deposits. Further to the west and southwest at the Travona and especially the Orphan Girl mines, rhodochrosite is present, but so too is fairly abundant Mn-bearing siderite (Pardee, 1918).

In all of the zones sphalerite is the only primary zinc mineral, although sphalerite pseudomorphs after wurtzite are also present. Pyrite is ubiquitous, although it is less abundant in the Peripheral Zone than in the inner zones. Pyrite is also disseminated in the wall rocks adjacent to the Main Stage veins.

Alteration envelopes associated with Main Stage veins overprint alteration accompanying pre-Main Stage mineralization. The thick-

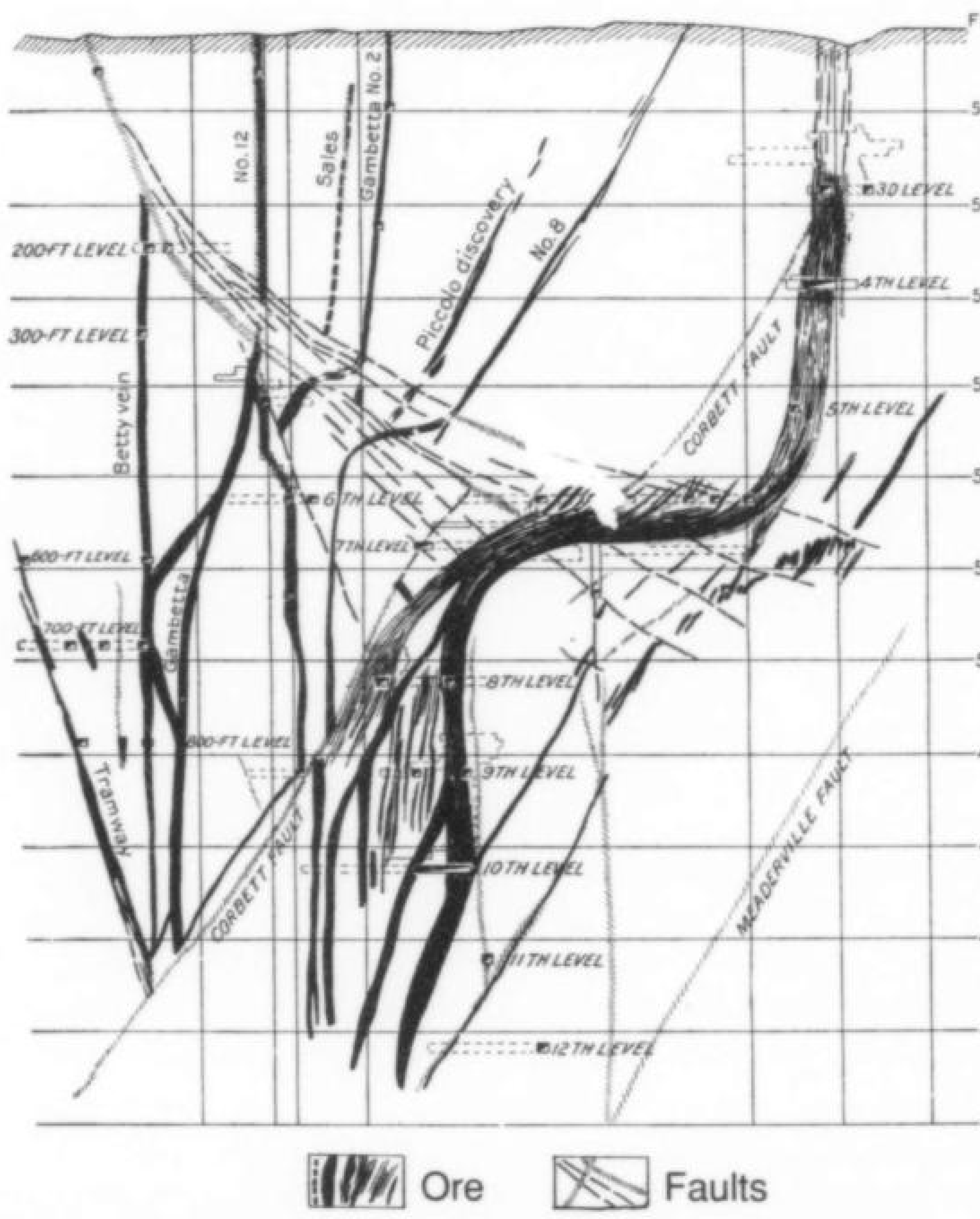


Figure 34. **Leonard mine and adjacent workings, north-south cross-section (Weed, 1912).**

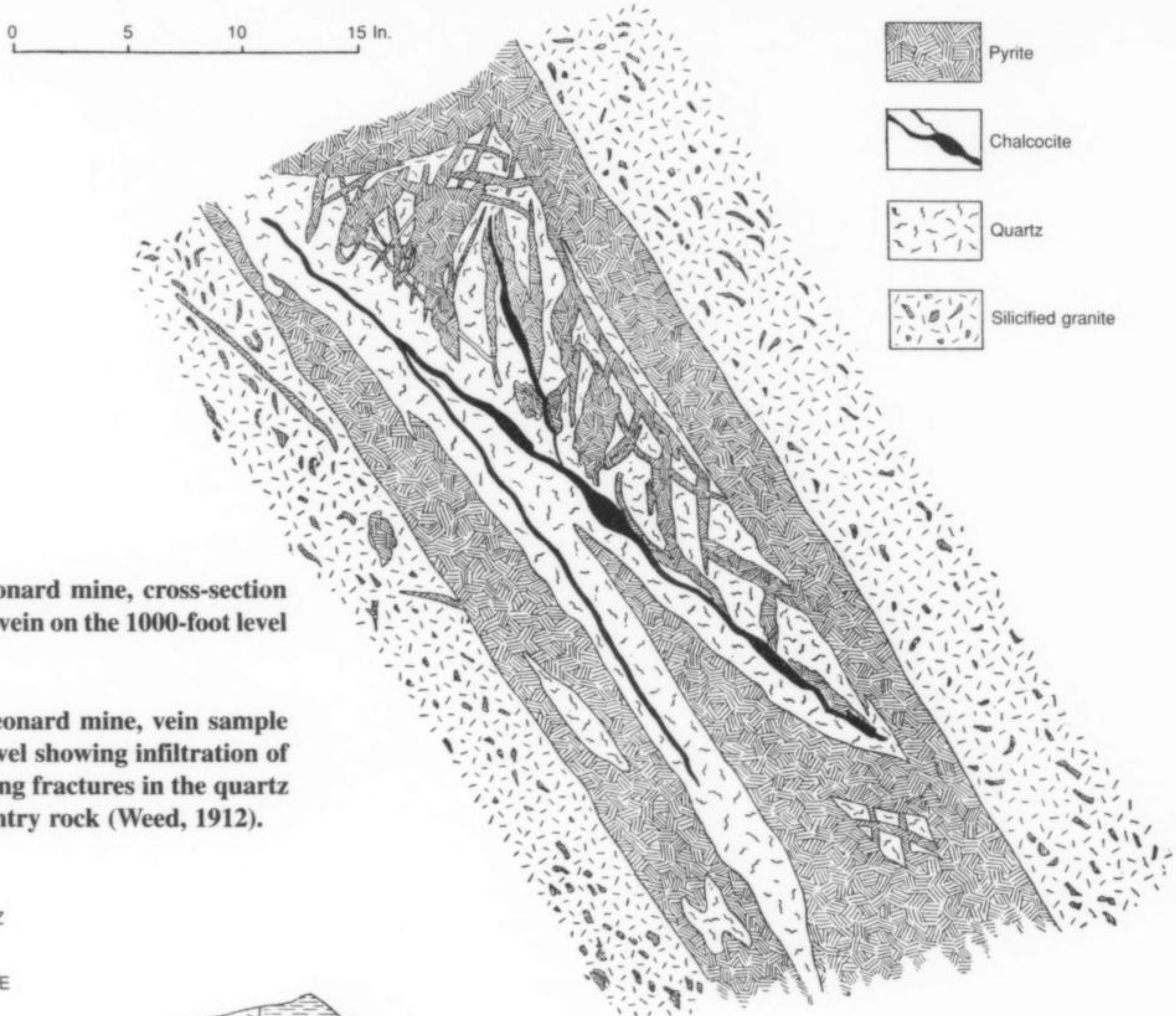
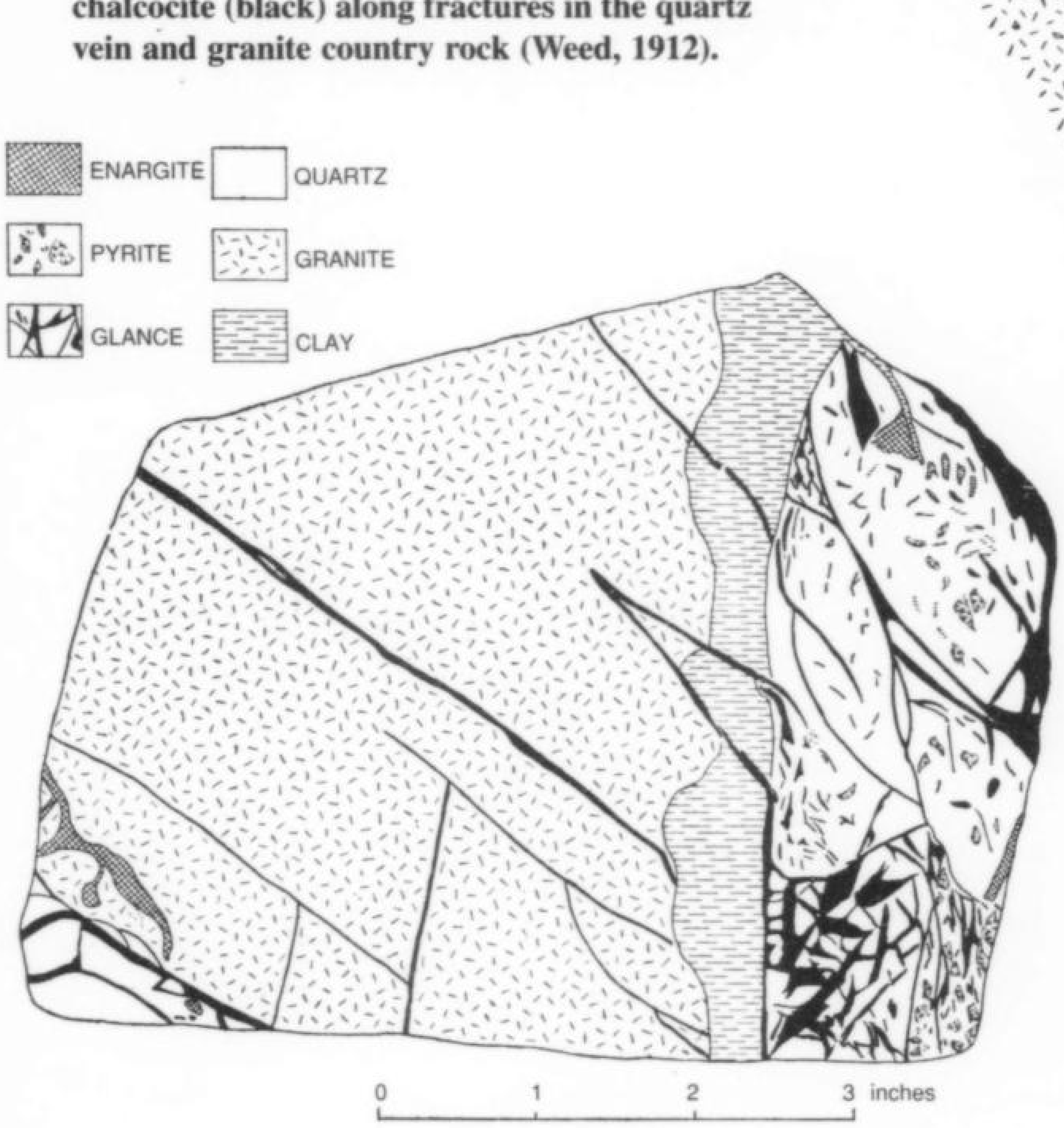


Figure 35. (right) **Leonard mine, cross-section of a pyrite-chalcocite vein on the 1000-foot level (Weed, 1912).**

Figure 36. (below) **Leonard mine, vein sample from the 1000-foot level showing infiltration of chalcocite (black) along fractures in the quartz vein and granite country rock (Weed, 1912).**



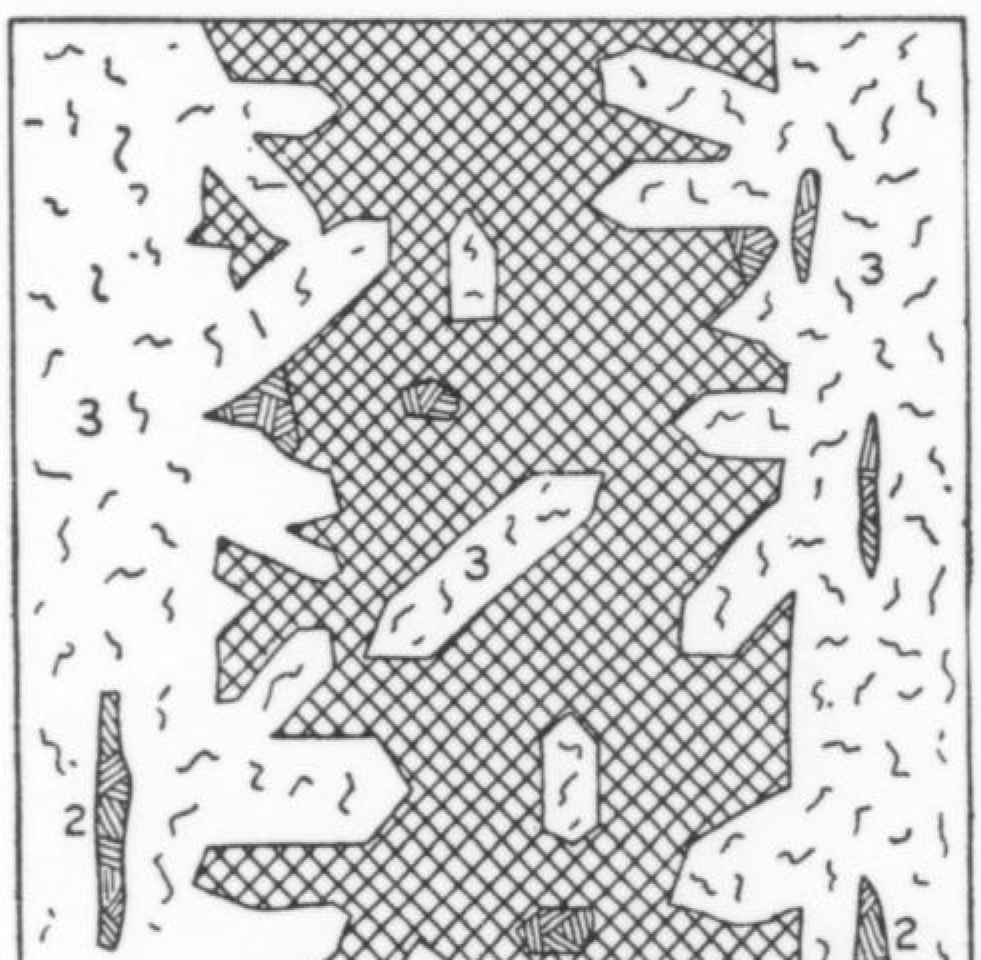


Figure 37. **Leonard mine, vein sample from the 1000-foot level showing chalcocite filling in a vein lined with quartz crystals and (2) pyrite (Weed, 1912).**

ness and mineral content of the envelopes vary from zone to zone. Within the Central Zone, Main Stage veins are enclosed by broad envelopes of pervasive sericitization with silicification immediately adjacent to the veins. Advanced argillic alteration assemblages also occur adjacent to veins of the Leonard mine area and the Berkeley pit. In the Intermediate Zone, alteration envelopes are much more narrow, with sericitization adjacent to the Main Stage veins and argillic and propylitic assemblages on the fringes of the altered areas. Patterns within the Peripheral Zone are similar to those of the Intermediate Zone, but the alteration envelopes are even more narrow (Meyer *et al.,* 1968).

Supergene Mineralization

The process of supergene enrichment, involving deposition of secondary chalcocite and lesser quantities of other copper minerals at and near the water table, has operated throughout the Butte district. It has been economically important only at the Berkeley pit and to a lesser extent at the Continental pit.

At the Berkeley pit, supergene enrichment affected Main Stage veins and horsetail ores as well as their wall rocks. The enrichment formed a blanket deposit lying near the water table. The upper surface of the deposit conformed more or less to present surface topography, but "prongs" extended downward along the vein fractures and intersections. Depending on timing of movements on the Continental Fault, the enrichment may have taken place in the late Pliocene or Pleistocene (McWilliams, 1959; McClave, 1973).

Oxidation

Mineral collectors who are especially enamored of the colorful oxidation species occurring in the mineral deposits of the American Southwest may perhaps be disappointed in Butte, Montana. Few of the oxidized base metal minerals are abundant, nor do many specimens compare to those from other localities. The descriptions below come from Blake (1887b), Weed (1912), Sales (1914), Pardee (1918), and McClave (1973).

Although oxidation locally extends to depths exceeding 300 m along fractures, the oxidation zones at Butte are generally shallow and very poorly developed. Oxidation usually does not continue below a depth of about 90 m, and it is often incomplete. Relict sulfide and sulfosalt minerals present together with their oxidation products in the same hand specimen are more the rule than the exception.

A wide area east of the Continental Fault was stained by oxidized copper minerals. Ores rich in cuprite and chrysocolla were mined in this area for a few months around 1900 at the Bertha, Bullwhacker, and Maggie Fraction mines, but the tonnage was very limited. Mining did not proceed below a depth of 30 m, and the development of fairly high-grade oxidized ore was restricted to narrow veins. Until recent months this area had been the site of the Continental pit operation, which depended on the extraction of low-grade sulfide ores. Essentially no oxidation minerals have been present in the modern ore feed, and the oxidized zone was found to be relatively small. The oxidized zone above the supergene enrichment blanket at the Berkeley pit was even less extensive.

The outcrops of the veins in the Peripheral Zone were marked by malachite and azurite staining, as well as extensive manganese oxide mineralization derived from the oxidation of rhodonite and rhodochrosite. The outcrops of the copper-rich veins in the Intermediate and Central Zones were far less impressive, with little development of gossans or other secondary minerals. One exception was the Parrot ledge (a segment of the Anaconda vein), which was brightly copper-stained. There was also a small but relatively important oxidation zone at the Silver Bow mine, and chlorargyrite was unusually abundant in the ores for a time. The principal reason for the poor development of oxidized zones at Butte is the very high water table.

Table 2. **Butte metal production.**

Copper (Cu)	9.80	Mt
Zinc (Zn)	2.29	Mt
Manganese (Mn)	1.68	Mt
Lead (Pb)	0.40	Mt
Molybdenum (Mo)	0.04	Mt
Silver (Ag)	22.40	kt
Gold (Au)	0.09	kt

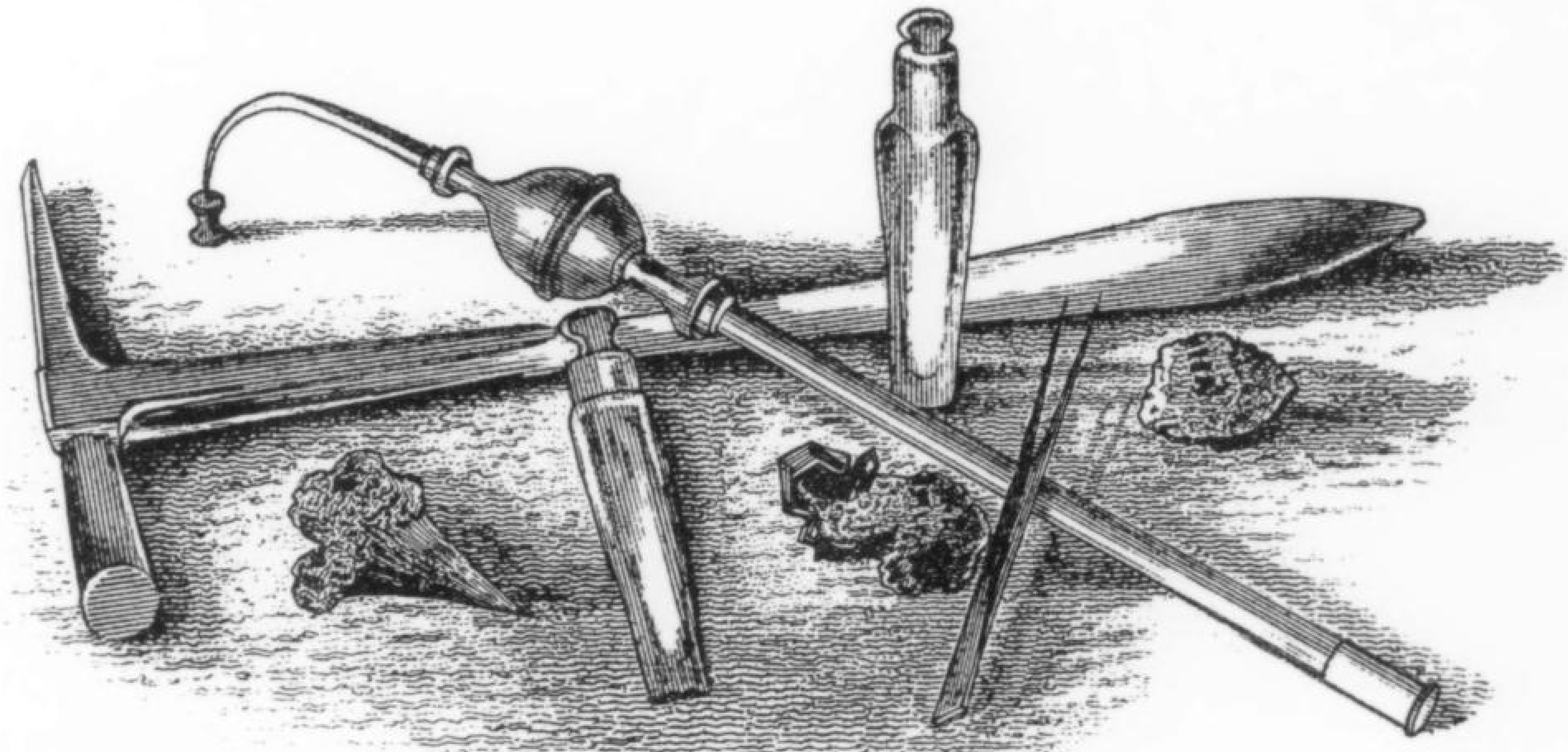
Mt = millions of metric tons; kt = thousands of metric tons

Metal Production

The metal production of the Butte district is staggering (Table 2). These statistics are derived from Meyer *et al.* (1968), Miller (1973), and especially from Long (1993) and Long *et al.* (2000). They are complete through 1998, but additions of molybdenum, copper and silver from the present Continental pit and leach operations do not materially alter them. They do not include lesser, but significant, quantities of cadmium, bismuth, selenium, tellurium, all classes of arsenic compounds, and sulfuric acid.

It is difficult to assign a dollar value to Butte's production of minerals. Metal prices have varied by a factor of ten or more, over more than 130 years of mining. Even so, most of Butte's large production has taken place during periods of relatively low metal prices. Zinc-lead production began in 1905 and ended in 1967. Although small quantities of rhodochrosite ore were shipped to Eastern steel producers beginning in 1917, the greatest production of manganese began about 1940 and ceased in 1959 when the Emma mine was closed. That it has not been reopened, although significant resources remain, is a statement about the price of manganese. Copper production has been continuous since 1879. It has only been since the late 1950's that the price has remained consistently above $0.66 per kg or $0.30 per pound (Marcosson, 1957; Gilmour *et al.*, 1993; Hyde, 1998). A good estimate for the value of Butte's total metal production would probably be somewhere between $8 and $10 billion. Estimates ranging as high as $22 billion (Marcus, 2000) are excessive in terms of historic metal prices.

Production figures tell only a portion of the Butte story. For copper, silver and zinc the produced metals constitute half or less of the total known to have originally been present (Long *et al.*, 2000). For copper only about 30% of the known resource has been produced to date, and there is also about 14% of the original copper remaining in the Main Stage veins (Long, 1993). Who knows how many fine mineral specimens old Butte could still produce?



Mineralogy

Weed (1912) listed 37 mineral species from Butte, Montana. Concerning the mineralogy of the district in general, he stated, "The minerals in the Butte ores are neither rare nor of great variety."

In a pair of popular articles Harter (1928) and Smith (1941) recorded 44 and 79 minerals from Butte respectively. Although a number of these have been later deleted from the list, these represent an increasingly significant departure from the statement by Weed. In their far more comprehensive study, based on exhaustive chemical analyses, optical, and X-ray diffraction work in the Anaconda Company laboratories, Guilbert and Zeihen (1964) listed 134 species from the district; allowing for changes in nomenclature, this list includes 129 currently valid species. The present work adds one new mineral, pyromorphite, to the catalog of Butte minerals, bringing the total to 130.

Minerals shown in bold print on Tables 3 and 4 are described here individually. Minor ore minerals, which are present only as a few specks in polished sections, are not described individually, nor are many rock-forming minerals and alteration species. The mineralogy section is followed by some collecting stories from Butte's underground mining days.

Table 3. **Hypogene vein minerals.**

Acanthite	**Dolomite**	**Proustite**
Aikinite	**Enargite**	**Pyrargyrite**
Alabandite	Ferberite	**Pyrite**
Alunite	**Fluorite**	**Quartz**
Andorite	**Galena**	**Rhodochrosite**
Anhydrite	**Gold**	**Rhodonite**
Ankerite	**Greenockite**	Rutile
Apatite	**Gypsum**	Scheelite
Arsenopyrite	**Helvite**	Seligmannite
Barite	Hematite	**Siderite**
Betekhtinite	Heulandite	**Silver**
Bornite	Hinsdalite	Sphalerite
Calcite	Huebnerite	Stephanite
Chabazite	**Luzonite**	Stilbite
Chalcocite	Magnetite	Stromeyerite
Chalcopyrite	**Marcasite**	**Tennantite**
Colusite	**Molybdenite**	**Tetrahedrite**
Covellite	Orthoclase	Uraninite
Digenite	**Pearceite**	Wavellite
Djurleite	**Polybasite**	Wittichenite

List modified from Guilbert and Zeihen (1964) and Meyer *et al.* (1968).

Table 4. **Supergene minerals.**

Allophane	**Chrysocolla**	Nontronite
Alunite	**Copper**	Pseudomalachite
Anglesite	**Cornwallite**	**Pyrolusite**
Arsenolite	Covellite	**Pyromorphite**
Autunite	**Cuprite**	Quartz
Azurite	**Cryptomelane**	Ramsdellite
Beraunite	**Ferrimolybdite**	Romanechite
Boehmite	Goethite	Rutile
Brochantite	**Gold**	Sepiolite
Calcite	**Gypsum**	**Silver**
Cerussite	Halloysite	**Smithsonite**
Chalcanthite	Hematite	**Tenorite**
Chalcocite	Jarosite	**Turquoise**
Chalcosiderite	Kaolinite	Wavellite
Chlorargyrite	**Libethenite**	**Wulfenite**
Chlorite	**Malachite**	

List modified from Guilbert and Zeihen (1964) and Meyer *et al.* (1968).

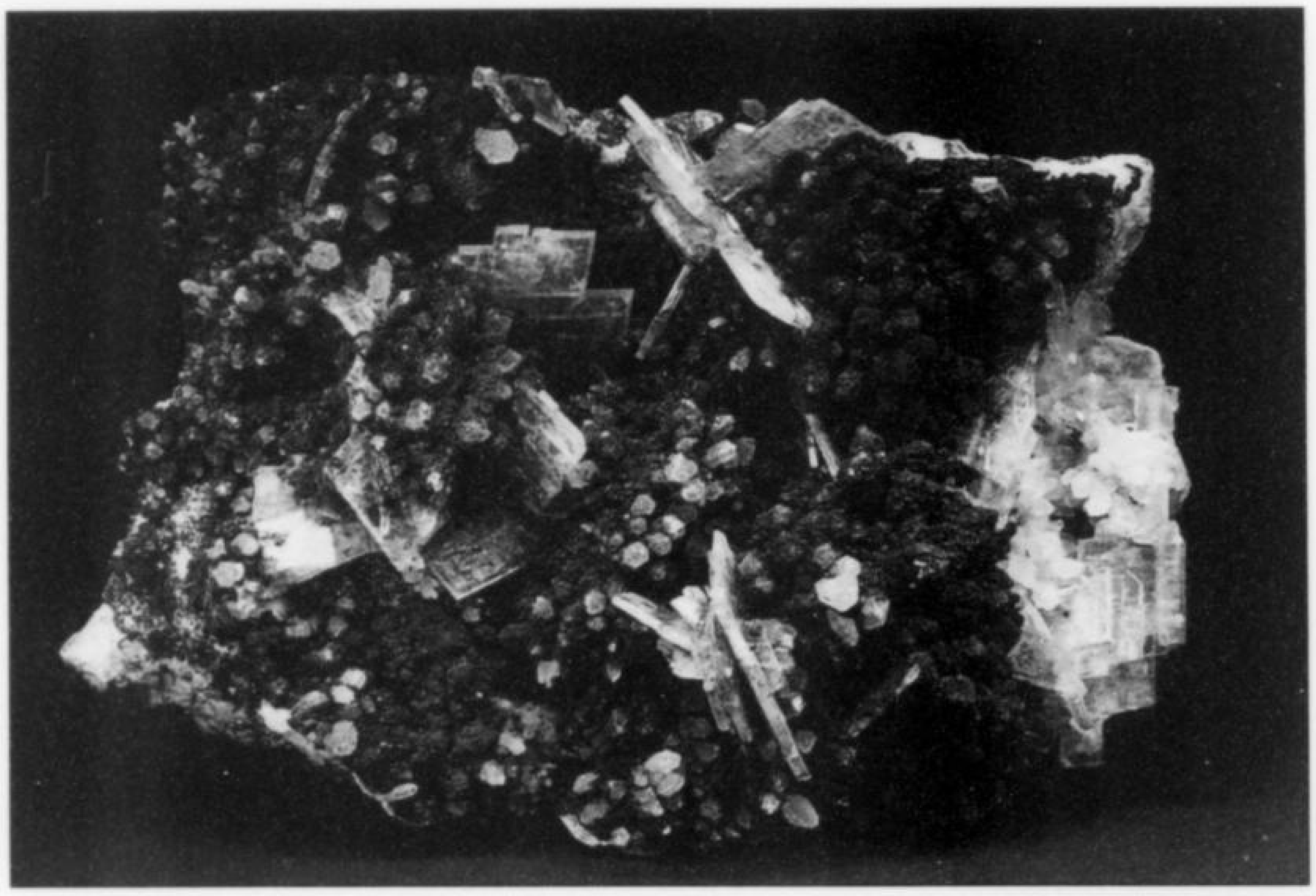
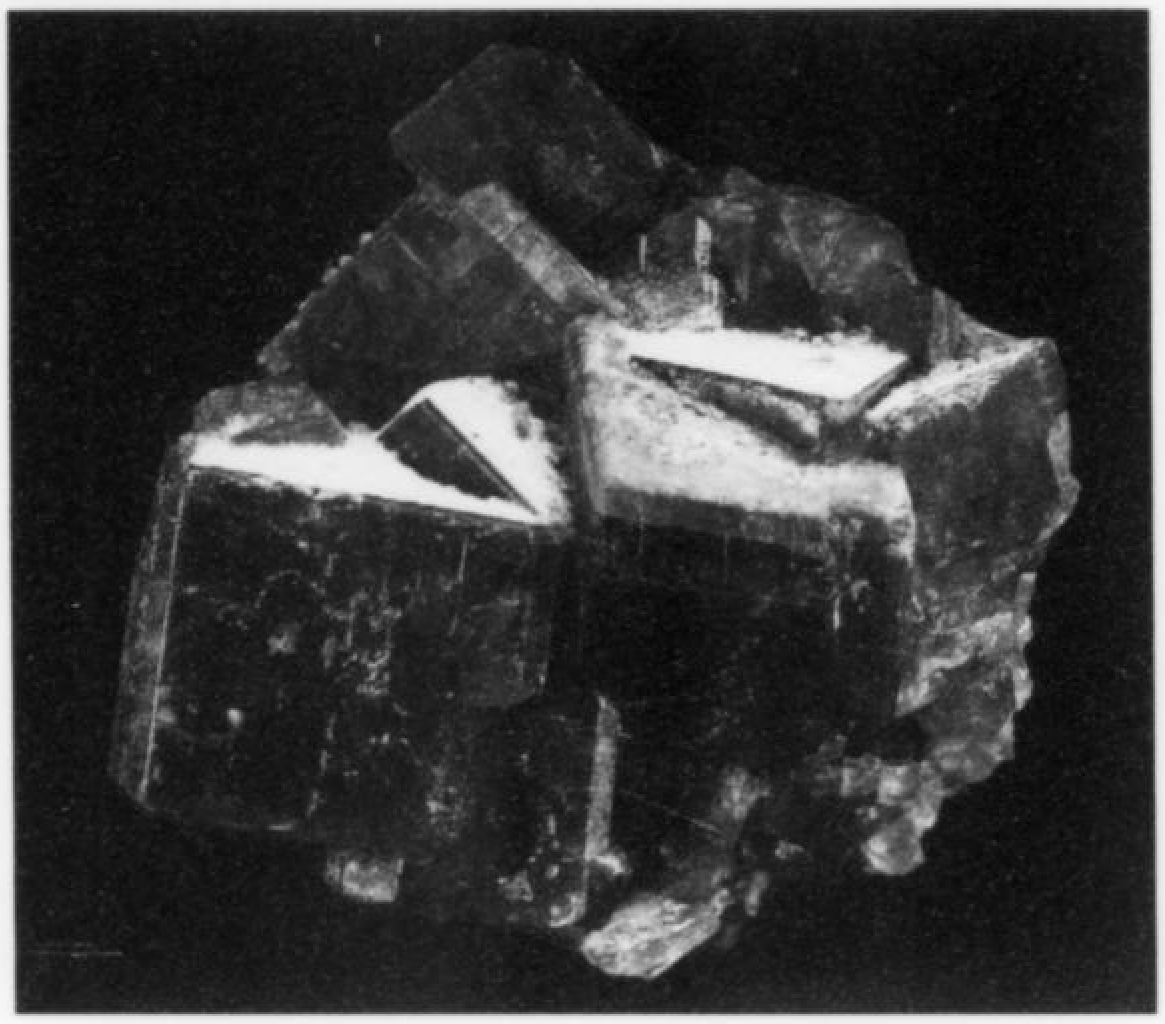


Figure 38. **Barite crystals with tennantite on quartz monzonite, 15 cm, from Butte. R. Jenkins collection; G. Grenier photo.**

Figure 39. **Barite crystal cluster, 7.5 cm, from the Mountain Con mine. George Loud collection; G. Grenier photo.**



Where appropriate, the following mineral descriptions are credited to their literature sources. Many Butte species listed are undescribed in the literature; consequently a number of the descriptions here are based on specimens which the authors have personally examined. Collections are referenced as follows: CL (Chet Lemanski), DH (Don Halterman), DPh (Don Phillips), FP (Fred Parker), GL (George Loud), JL (junior author), PC (Peter Chin), RJ (senior author), and SM (Steve Misiur).

Acanthite Ag_2S

Acanthite was recognized by the earliest workers at Butte. Blake (1887b) reported the species as small specks and larger anhedral masses disseminated in quartz at the silver mines along the Rainbow vein, especially at the Alice mine. It also occurred as thin films on fractures in pyrite. Smith (1941) reported large masses and trapezohedral crystals to 1.4 cm in maximum dimension, again from the silver mines in the northern part of the district. These mines are in the Peripheral Zone. Guilbert and Zeihen (1964) also noted the rare occurrence of acanthite in some of the ores of the Intermediate Zone.

Alabandite MnS

Alabandite was first reported from the Butte district by Hewett and Pardee (1933). It was originally found in some mill concentrates. Meyer *et al.* (1968) recorded the mineral in place as thin black films on rhodochrosite cleavages at the Emma mine. The species was apparently a product of thermal metamorphism of rhodochrosite adjacent to a post-mineral rhyolite dike. The alabandite was developed at distances up to 12 m from the dike.

Anglesite $PbSO_4$

Anglesite was first reported from Butte by Guilbert and Zeihen (1964). It was reported to be of rare occurrence in the oxidation zones in both pyrite-rich and pyrite-poor environments. A specimen from the upper levels of the Berkeley pit (RJ) contains anglesite replacing galena. The anglesite forms boxwork replacements of galena in small cavities. It is colorless and transparent to black in color and has apparently grown along former galena cleavages or grain boundaries. The cavities measure no more than 3 mm across.

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

An unspecified member of the apatite group is widespread as a trace constituent of the igneous rocks of the Butte district (Guilbert and Zeihen, 1964). More interestingly, the mineral also occurs in some of the Main Stage vein deposits. It is found as aggregates of dull, gray-green, hexagonal prisms, individuals of which measure about 0.25 mm in length. These partially encrust slender quartz crystals at the Steward mine and the Berkeley pit (RJ). Gemmy pink and blue apatite also occurred at the Leonard and East Colusa mines (D. Johnson, written communication, 2000). Crystallized apatite has been observed encrusting enargite crystals as well (R. Berg, oral communication, 2000).

Arsenopyrite FeAsS

Arsenopyrite was very sparse in the Intermediate Zone at Butte, but it occurred in considerable quantities in some veins well to the north of the mining district (L. Zeihen, oral communication, 2000).

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

Azurite is an uncommon mineral at Butte, because of the poor development of oxidized zones. It was noted by a number of workers, however, including Blake (1887b), Weed (1912), McClave (1973), Ratcliff (1973), and Melchiorre *et al.* (2000). In none of these reports was the mineral described as crystallized.

Crystals of azurite do occur at Butte, in the Continental pit area as tiny prisms and microbotryoidal masses, which line vugs in quartz-chalcopyrite rock. The material was probably collected from a vein because the chalcopyrite is massive. The crystals are royal blue, very lustrous, and measure about 0.5 mm across. Associated minerals include malachite, libethenite and an unidentified iron oxide species.

Barite $BaSO_4$

Barite was a widespread but relatively uncommon gangue mineral in the Butte veins. Pearce (1887) first noted its occurrence between the 200 and 300 levels (61 and 91 m) of the Gagnon mine with hübnerite and other minerals. Brown (1894) recognized its presence in what he called "the Copper Area," but no mine names were given or any occurrences described. Weed (1912) mentioned pale cream-yellow crystals of barite in vugs in chalcocite and "crackled" calcite in the Steward mine at the intersection of the Clear Grit and Steward veins. Weed (1912) also reported pale brown, tabular crystals of barite with hübnerite and "bronze tetrahedrite" (now recognized as colusite) in the deep levels of the Leonard mine, between 1,000 and 2,000 feet (305 and 610 m). Sales (1914) reported similar pale brown crystals from the Parrot mine. Smith (1941) described 1-cm pale yellow tablets on rhodochrosite from the Emma mine.

The color of barite crystals produced at the Steward mine in recent years is commonly a golden-brown, resembling the barite from the Black Cloud mine at Leadville, Colorado (RJ). Similar material has been found at the Mountain Con mine. The latter specimens consist of intergrowths of plates, the individuals of which measure 3 x 3 x 1 cm. Another Steward mine specimen exhibits 2.5-cm, white and translucent barite plates intergrown with and partly coated by tennantite. A specimen (RJ) from the 2,000 level (610 m) of the East Colusa mine displays similar white barite tablets, measuring about 1.5 cm, encrusted by enargite. Enargite is generally one of the earliest-formed copper minerals, while tennantite is one of the latest.

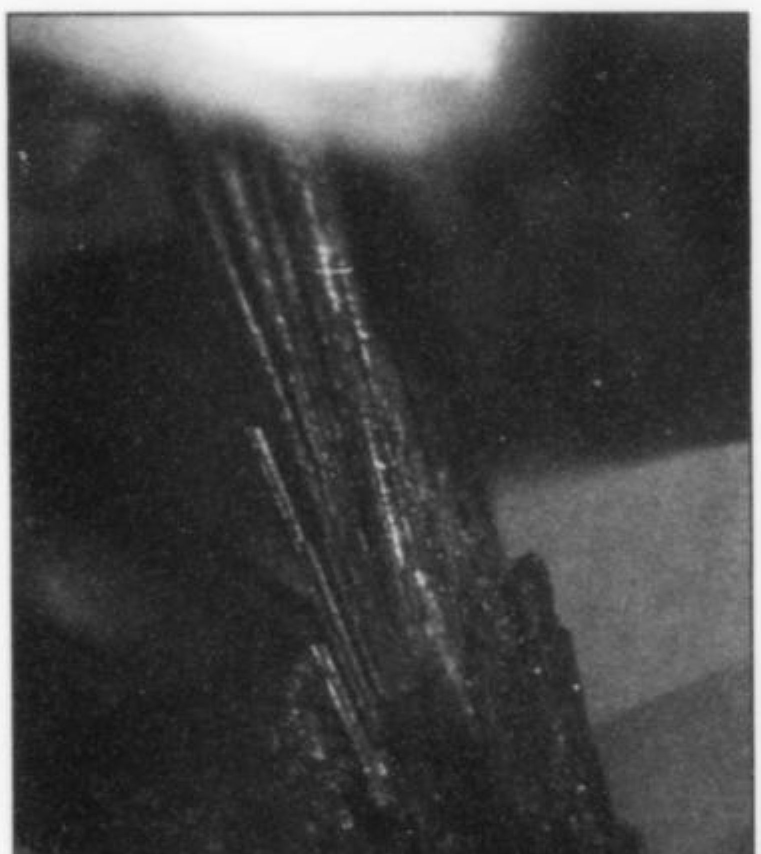


***Figure 40.* Betekhtinite needles, 4 mm, from the Steward mine. Peter Chin collection; G. Grenier photo.**

Betekhtinite $Cu_{10}(Fe,Pb)S_6$

Betekhtinite was originally reported from Butte as a queried species by Guilbert and Zeihen (1964). It was found as sparse grains in polished surfaces in the ores of the Central, Intermediate, and Deep Level Chalcopyrite Zones. Later, a single vug was encountered in which the species occurs as crystals. The identification was confirmed on this well-crystallized material by X-ray diffraction (L. Zeihen, oral communication, 2000). Other cavities containing betekhtinite were later found.

Crystallized betekhtinite from Butte has never been described in the literature. Specimens from the Leonard and the deep levels of the Steward mine consist of plates of small, transparent to white quartz crystals, over which the betekhtinite is distributed as mats of black to blue-black, acicular crystals. The crystals average about 2 mm in length, ranging up to 5 mm, and are deeply striated parallel to the *c*-axis. A few exhibit a brassy tarnish, and some are overgrown by a second generation of quartz. In most specimens the betekhtinite is relatively sparse. In another specimen from the Steward mine the betekhtinite occurs as a single 1-cm needle entirely enclosed within a doubly terminated calcite crystal (JL). In a specimen from the Anselmo mine betekhtinite is present as a few 0.5-mm acicular crystals standing upright on a covellite plate (DH).

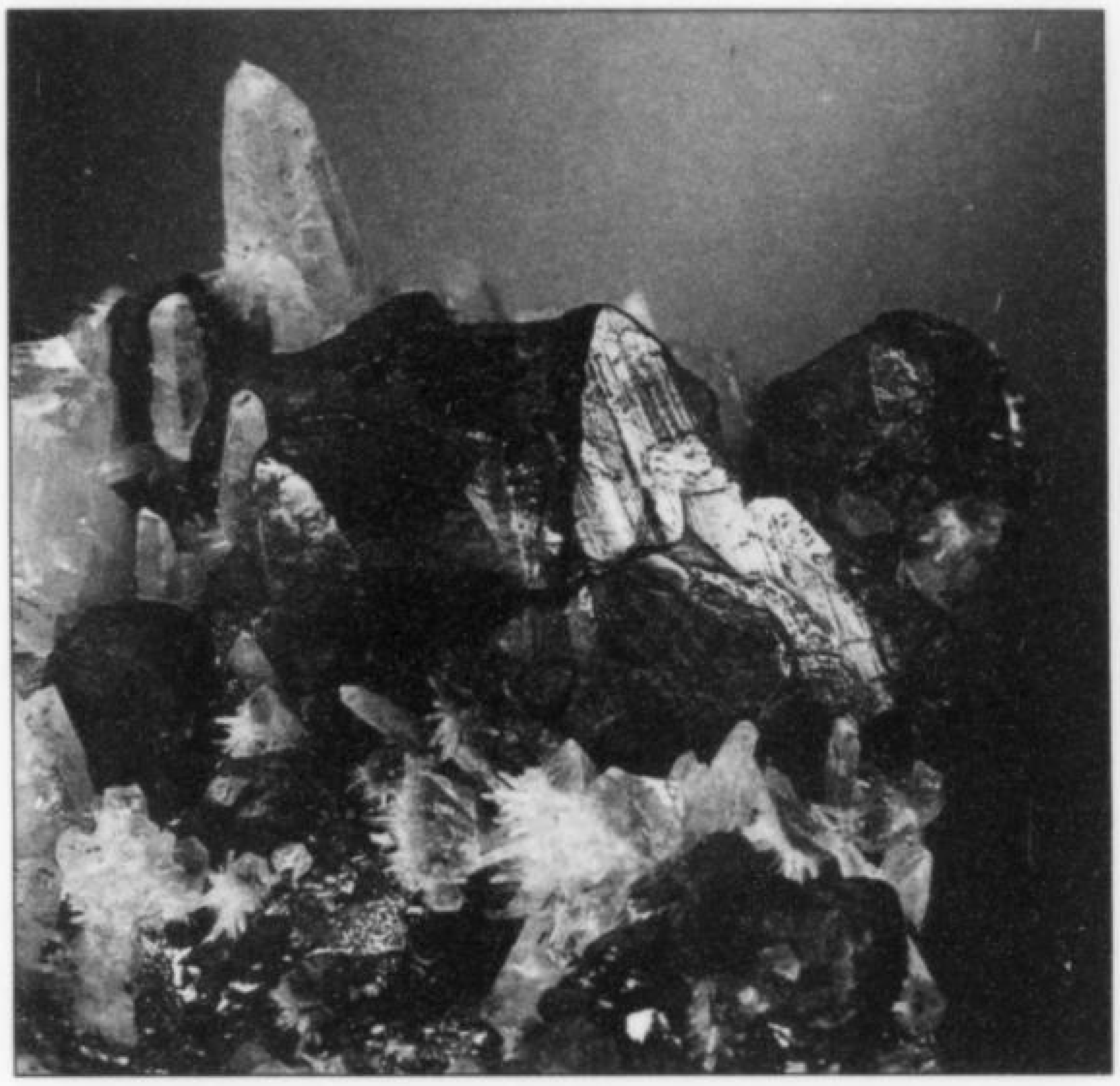


***Figure 41.* Bornite crystals to 3.5 cm with quartz, from Butte. Seaman Mineral Museum collection; G. Robinson photo.**

Bornite Cu_5FeS_4

The bornite crystals of Cornwall are probably superior to those found at Butte. So too are some examples from Bristol, Connecticut. Recent examples from the former Soviet Union are also sharp and very large. Nonetheless, bornite crystals from Butte are very, very good, and they were relatively common at one time.

Bornite was a significant source of copper at Butte, though far less important than either chalcocite or enargite. Sales (1914) stated that, even on the scale of an individual hand specimen, some bornite was nearly always present in the ore. It occurred in all three zones and was especially abundant in the Intermediate Zone.

Bornite crystals from Butte are generally complex dodecahedra or cubes modified by dodecahedral faces. They range up to 3 cm in maximum dimension, but 3 to 6 mm is more common. The crystals are generally purplish brown to bluish black in color, but some

Figure 42. **Bornite crystals to 1 cm with pyrite, from Butte. Roebling collection, Smithsonian Institution; Wendell Wilson photo.**

Figure 43. **Rounded bornite crystals with quartz on matrix, 13 cm, from the Steward mine. R. Jenkins collection; G. Grenier photo.**

exhibit the "peacock" tarnish. Rounded edges and terminations are very common; indeed, most crystals look as if they have been partially melted. Some relatively sharp crystals exhibit stepped growth faces, the steps defining equilateral triangles (RJ). Frueh (1950) and Morimoto and Kullerud (1961) studied the disorder and polymorphism in Butte bornite crystals respectively. The bornite crystals are often associated with pyrite crystals, implanted on a bed of quartz prisms. They are also found on surfaces of massive ore and, more rarely, have been observed associated with rhodochrosite (Smith, 1941).

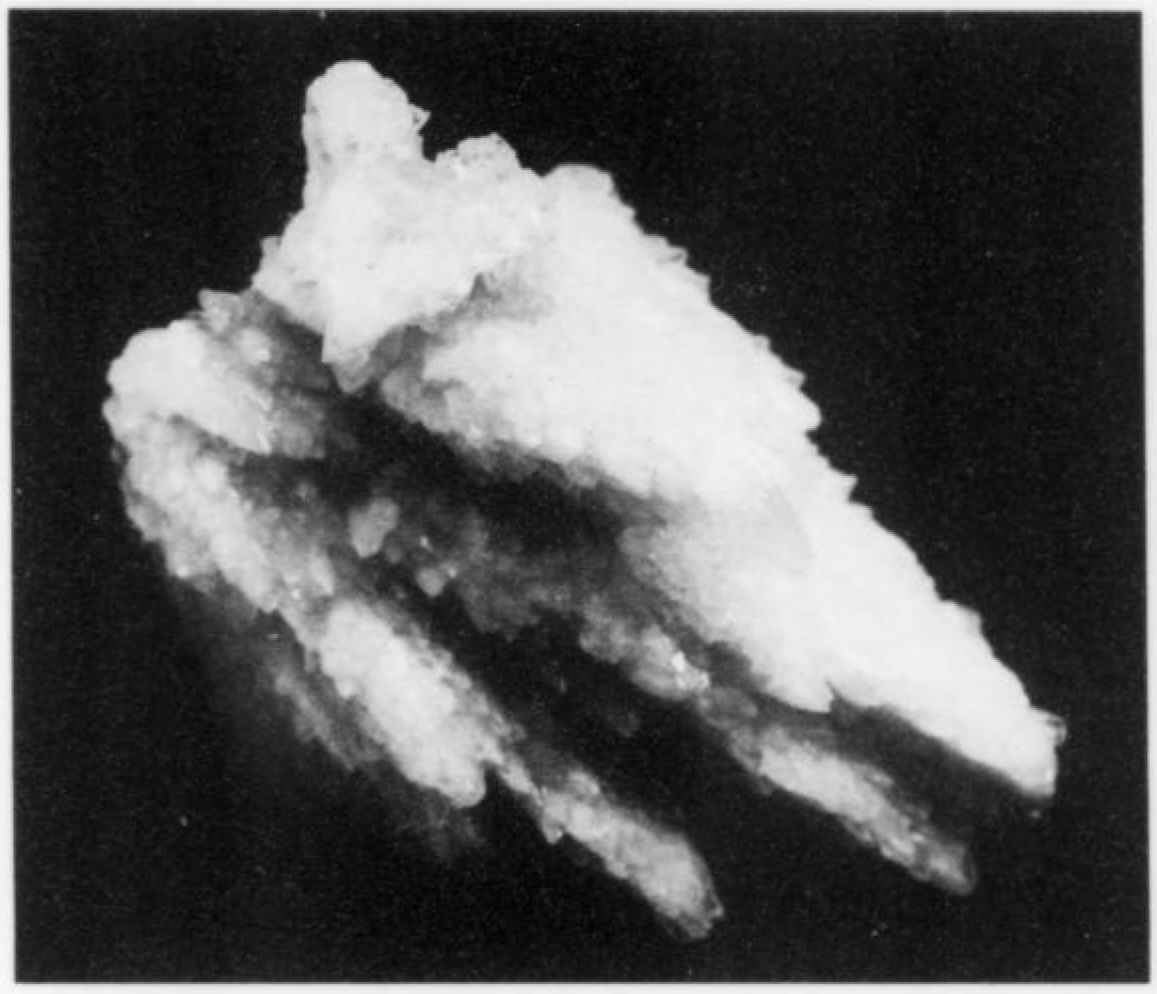
Weed (1912) reported crystals of bornite on chalcocite from the Leonard mine. He also mentions crystals from the 1,300 level (396 m) of the Parrot mine and at the Mountain Con mine. Smith (1941) described a specimen of 5 mm, cuboctahedral crystals on lean ore from the Anselmo mine. Other fine specimens have come from the Badger and Steward mines. One unusual occurrence of bornite is at the Goldsmith mine in the Peripheral Zone, where it is associated with rhodochrosite (RJ).

Calcite $CaCO_3$

Except for the rhodochrosite of the Peripheral Zone, carbonate minerals were by and large not abundant at Butte. There are, however, a few reports of calcite in the Main Stage vein deposits. Brown (1894) reported crystals having the diameter of a pencil, projecting into vugs in quartz at the Acquisition claim on what he termed "the Middle Silver Belt." The Acquisition claim was near the more modern Steward and Anselmo mines. The same author also reported calcite crystals from his "Southern Silver Belt," which would encompass the historic Travona, Emma, and other mines. Weed (1912) described small vugs in the Little Mina mine in which pyrite crystals were encrusted with drusy quartz. Flat-lying "dogtooth" calcite crystals were perched on the quartz, and

Figure 44. **Calcite crystals with malachite, 5 cm, from the Mountain Con mine. Chet Lemanski collection; G. Grenier photo.**

Figure 45. **Manganoan calcite crystals, 5 cm, from the Alice mine. J. Lorengo collection; G. Grenier photo.**



all three minerals were partly coated with chalcopyrite and galena. The same author also reported calcite crystals from the Steward mine. Similar material has been found at the Mountain Con mine. Pink mammillary manganocalcite has been found at the Lexington mine (RJ). Scalenohedral crystals of pale pink manganocalcite with "stair-step" edges and faces formed by overgrowths of smaller crystals were also found at the Alice pit. The larger crystals reach 3 cm in length. Butte calcite fluoresces a dull pinkish red in both shortwave and longwave ultraviolet radiation. The response is relatively weak and is only slightly less intense in longwave radiation (C. Lemanski, oral communication, 2001).

Cerussite $PbCO_3$

Blake (1887b) reported slender, silky crystals of cerussite in some of the high-grade, near-surface silver ores of the Alice mine. Cerussite was also reported by McClave (1973) in the oxidized zone at the Berkeley pit, associated with smithsonite, rhodochrosite, and secondary copper species.

Chalcanthite $CuSO_4 \cdot 5H_2O$

As it is at so many localities, chalcanthite is a post-mining product at Butte. Weed (1912) describes efflorescences and stalactites of considerable size in a number of the old underground workings, especially at the Silver Bow mine.

Chalcocite Cu_2S

That most eminent of Butte geologists, Reno H. Sales, wrote in 1914 that, "Chalcocite crystals are of frequent occurrence but they have no commercial significance." Several generations of mineral collectors have been grateful for the truth in the first half of this statement, but those with limited budgets would take exception to the second part. Indeed, as with a number of species, it is debatable whether Butte has produced the world's best chalcocite crystals, but they are certainly among the finest. It is not surprising that choice specimens are pricey.

Chalcocite was the most abundant copper mineral of the Main Stage vein deposits, and it was (and still is) an important source of copper in the near-surface, enriched mineralization. It was found at essentially all of the mines of the Central and Intermediate Zones, and occurred at a few deposits in the Peripheral Zone as well. During Butte's underground mining era it probably accounted for 60% of district copper production (Sales, 1914). Fine crystal specimens of chalcocite have come from the Badger, Belmont, Leonard, Mountain Con, and Steward mines.

Chalcocite crystals from Butte consist of (1) typical orthorhombic prisms, invariably deeply striated on the prism faces, and (2) thick pseudo-hexagonal plates. The plates, which are actually twins, or in some instances, pseudomorphs after covellite crystals, are more common. The crystals are medium to dark gray, often with a bluish or purplish iridescence; they have a metallic luster, ranging from dull to brilliant. They may be very sharp or their edges may be ragged. The crystals may occur isolated on matrix or they may be found in groups of various sizes and shapes. Individual chalcocite plates measure up to 5 cm across (Smith, 1941). However, some of the most precious specimens are in the thumbnail and small miniature size range with crystals around a centimeter. The smaller prisms are also generally the more perfect.

Chalcocite was found associated with nearly all of the other copper minerals, as well as with quartz and pyrite (Weed, 1912; Sales, 1914). It is probably most commonly associated with enargite, bornite, and covellite. Pseudomorphs of chalcocite after covellite were found at the Leonard mine. Thompson (1916) mentions similar chalcocite replacements of covellite on the 2,400 level (732 m) of the South Bell vein, High Ore mine. Chalcocite also occurs replaced by chalcopyrite at the Leonard mine (Weed, 1912). Partial pseudomorphs of bornite after chalcocite crystals were found on the 2,800 level (854 m) of the Badger mine (Smith, 1941). Pseudomorphs of chalcocite after 2 mm hübnerite crystals have been found at the Leonard mine (RJ).

"Chalcoborn," a textural term originated by Charles Meyer, is an interesting intergrowth that has been found at the Leonard, Stew-

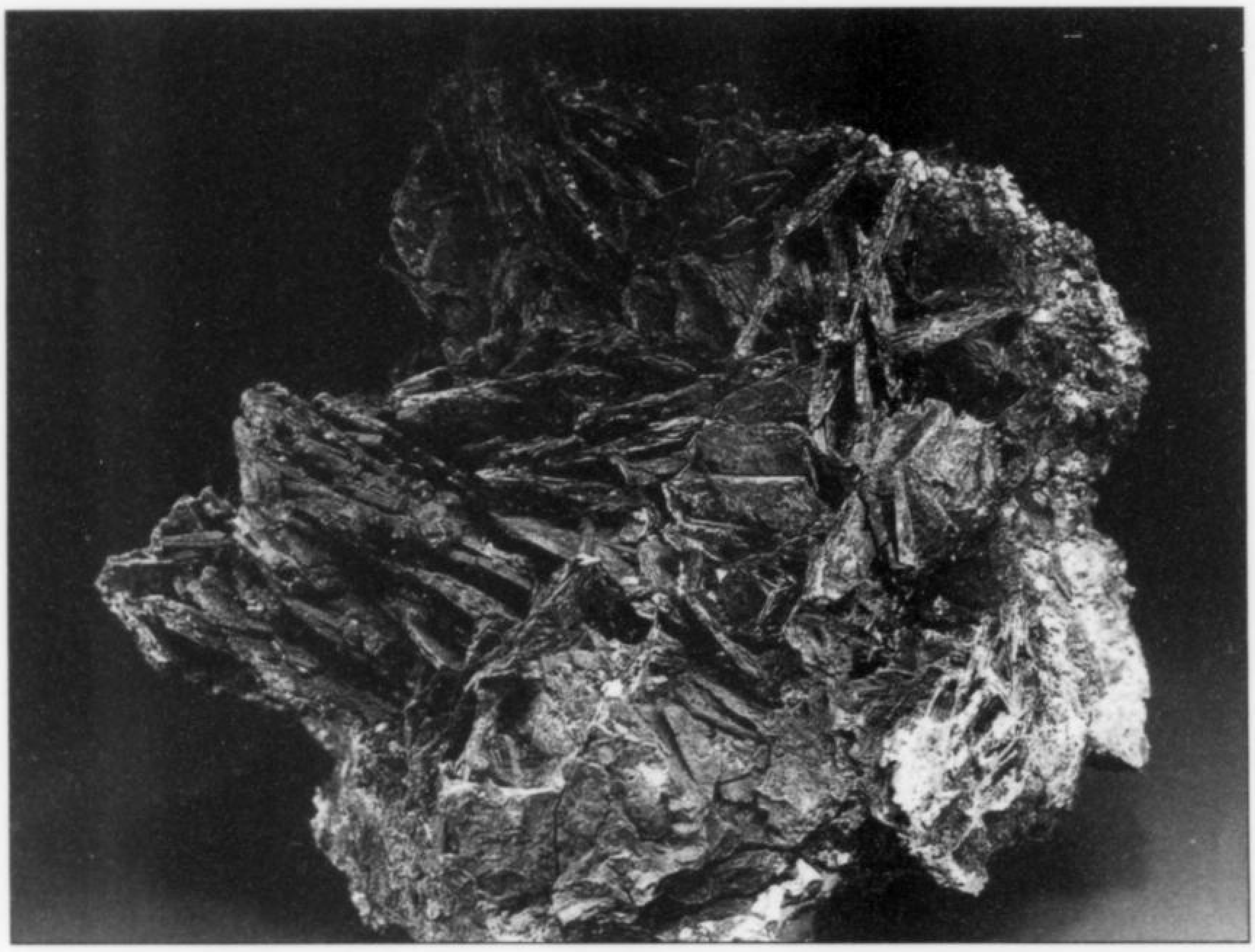
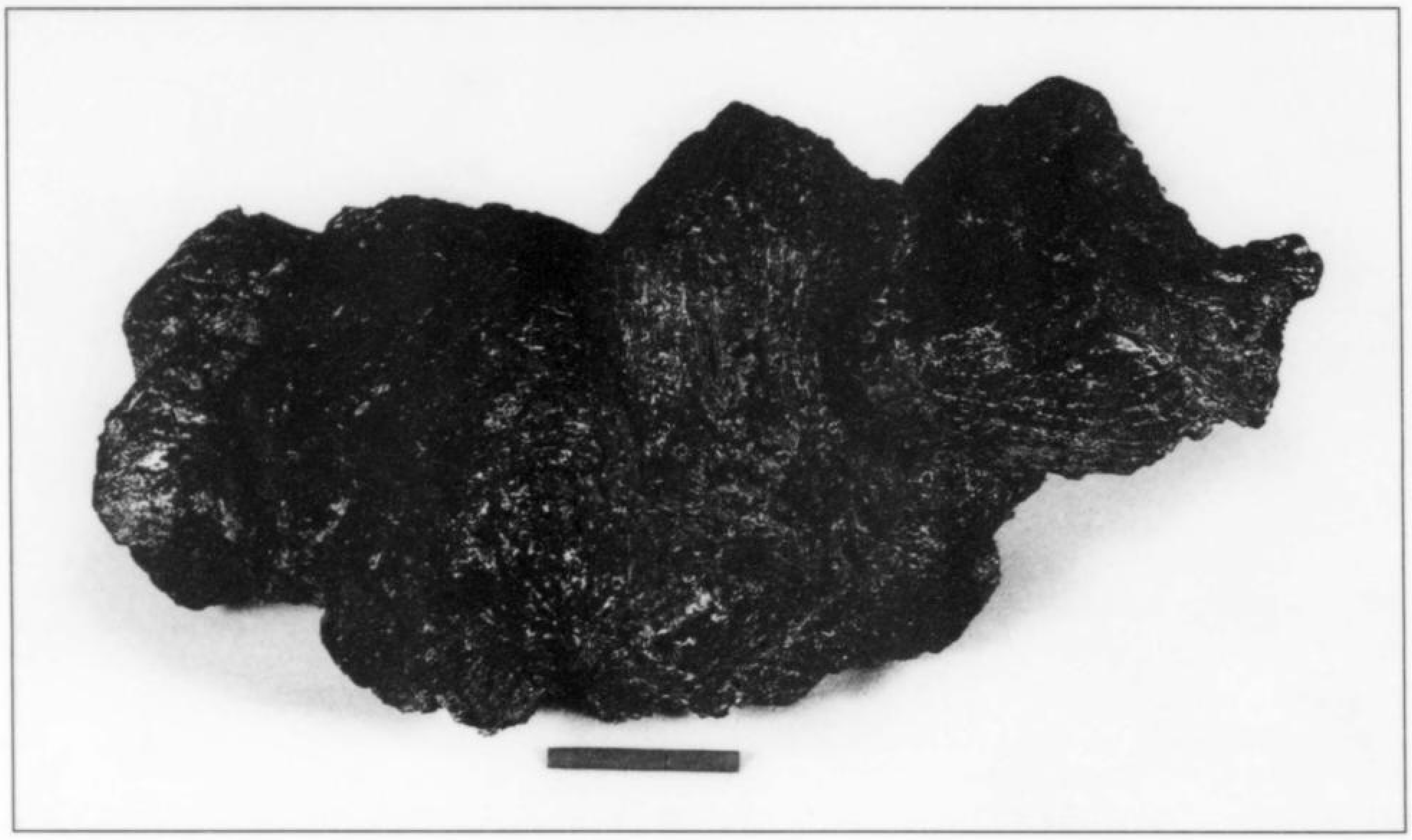


Figure 46. **Chalcocite pseudomorphs after platy covellite crystals, 10 cm, from the Leonard mine. George Loud collection; G. Grenier photo.**

Figure 47. **Chalcocite pseudomorphs after thick covellite crystals, 17 cm, from the 1500-foot level of the East Colusa mine. Harvard collection; Rock Currier photo.**



ard, and other mines. The material consists of dense, blue-black to purple-black aggregates of crystals having the outward form of bornite, but actually consisting of chalcocite containing minute inclusions of bornite. This is regarded as a primary texture, not a pseudomorph (L. Zeihen, oral communication, 2000).

Chalcopyrite $CuFeS_2$

Unlike at most of the world's great copper deposits, chalcopyrite was not an important ore mineral at Butte. The species is abundant in the Deep Level Chalcopyrite Zone and in much of the disseminated mineralization, but for the most part, this material has remained unmined. In the upper levels of the Main Stage deposits chalcopyrite is a late and very minor mineral.

Brown (1894) reported crystals of chalcopyrite in what he termed "the Copper Area," but no mine names were given, nor were the occurrences described. Weed (1912) described chalcopyrite replacing chalcocite along fractures at the Leonard mine. Sales (1914) reported small, imperfect crystals of chalcopyrite at the Altona and Amazon mines, in the area of the present Continental pit operation. Smith (1941) stated that chalcopyrite is often associated with bornite, and that it sometimes occurs crystallized on smoky or clear quartz crystals. He further reported that chalcopyrite and tetrahedrite are the only primary copper minerals present in the silver ores of the Peripheral Zone. Meyer *et al.* (1968) also reported chalcopyrite in the Peripheral Zone as drusy crystals with tennantite on rhodochrosite. Sphenoidal crystals of chalcopyrite measuring 0.25 to 0.5 mm across were found on the 800 level (244 m) of the Lexington mine (RJ), associated with siderite rhombohedra. One interesting specimen of sphenoidal chalcopyrite comes from the Steward mine (JL); it exhibits tiny chalcopyrite crystals in 5 mm clusters, directionally overgrown by drusy quartz.

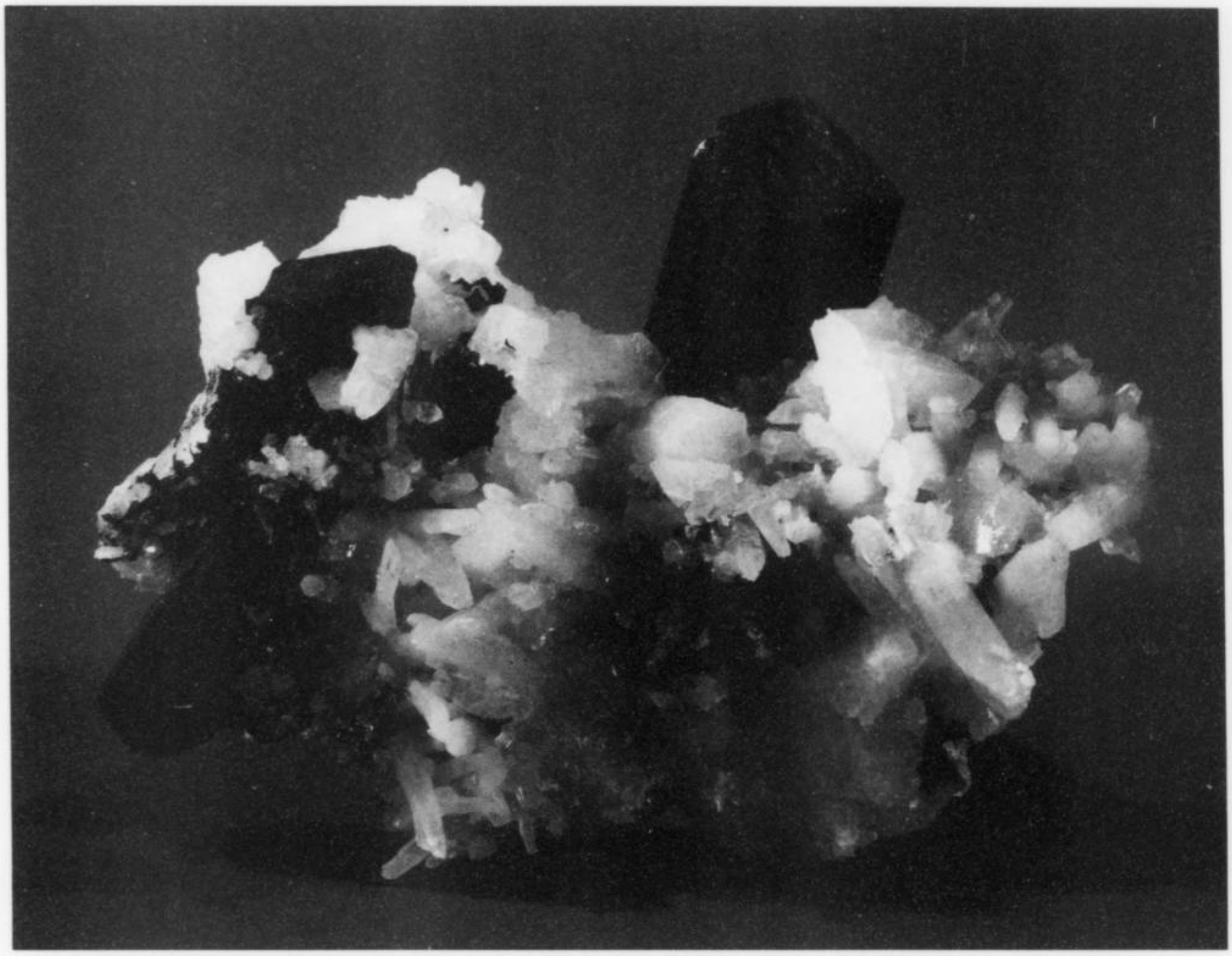


Figure 48. Chalcocite crystals on quartz, 6.5 cm, from the Leonard mine. Formerly a Richard Kosnar specimen, then David Eidahl collection; Harold and Erica Van Pelt photo.

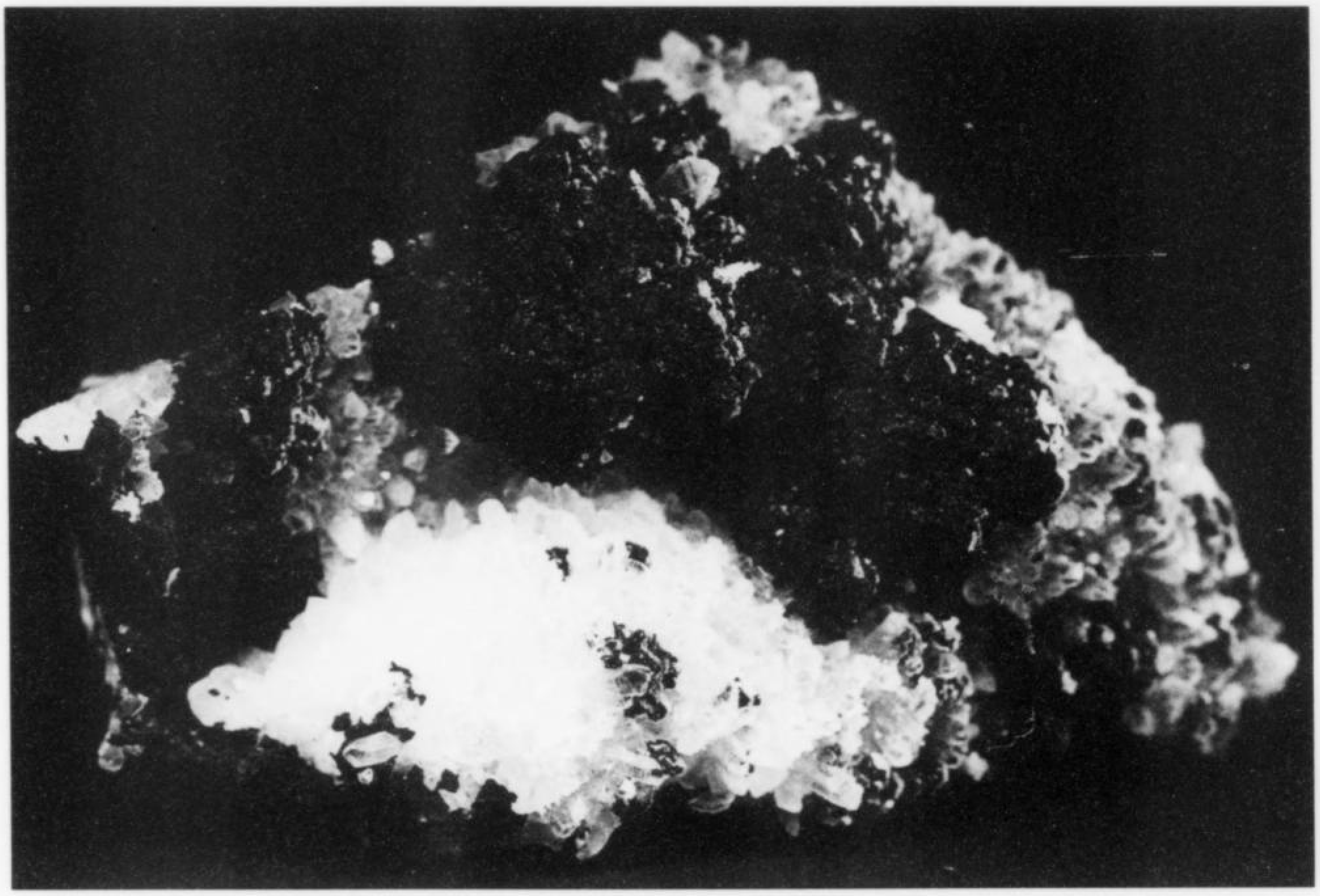


Figure 49. Tarnished chalcopyrite on quartz, 8 cm, from Butte. Fred Parker collection; G. Grenier photo.

Because of the quartz overgrowth, the chalcopyrite clusters are visible in one direction only. Botryoidal chalcopyrite, with and without acicular siderite, was found at the Mountain Con and other mines. The individual botryoids range up to 2 cm across. Pseudomorphs of chalcopyrite after enargite have been found at the Leonard mine.

Chlorargyrite AgCl

Chlorargyrite was reported by Weed (1912) as thin films staining other minerals at the Moody & Sankey, Iowa, and Kossuth claims on the extreme western side of the district. The same author also reported the species in the unusually well-developed oxidized zone of the Silver Bow mine. Chlorargyrite was apparently much less abundant than native silver in the Butte oxidized zones.

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

Mammillary, green-blue chrysocolla occurred with cuprite, native copper and other minerals in the East Ridge area (Weed, 1912). East Ridge is the site of the present day Continental pit operation.

Colusite $Cu_{26}V_2(As,Sn,Sb)_6S_{32}$

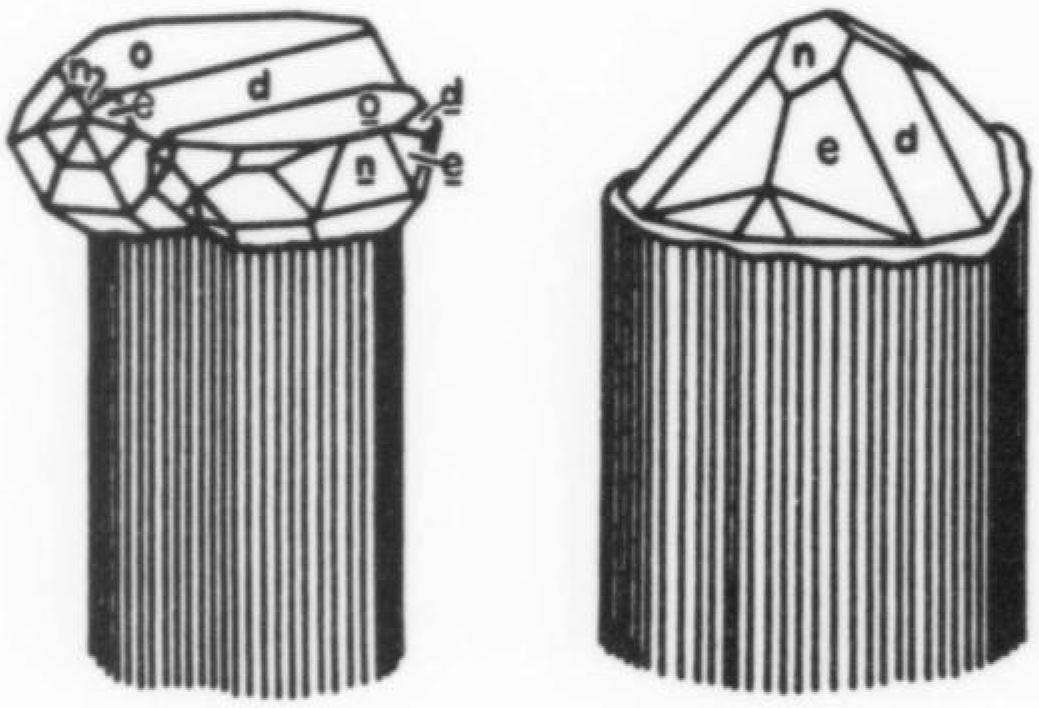


Figure 50. **Colusite crystals perched on enargite crystals from the Leonard mine (*o* = {111}, *e* = {012}, *n* = {112}, *d* = {011}) (Bideaux, 1960).**

Figure 51. **Colusite crystals with pyrite crystals to 1.3 cm, from the East Colusa mine. Bill and Brigitta Wray collection; Jeff Scovil photo.**

Butte is the type locality for only the mineral colusite. Although the species is now known from several other localities, colusite crystals from Butte remain the world's finest. The name, in reference to the West and East Colusa mines, was originally given by Anaconda Chief Geologist Reno H. Sales to an unknown metallic species which consistently showed tin on analysis. Professor Louis Graton (1880–1970) at Harvard had recognized the material to be tin-containing as early as 1917 but never completed his investigation (Berman and Gonyer, 1939). The mineral was finally described by Landon and Mogilnor (1933) as a new member of the sphalerite group, and the name colusite was at that time formalized. Zachariasen (1933) published the initial crystallographic studies of the new species. Nelson (1939) reported on the paragenesis and underground occurrence of the mineral, also providing new chemical analyses based on bulk samples. Berman and Gonyer (1939) restudied the mineral's crystallography, in the process redefining both the chemical formula and the unit cell dimensions, and determined that it was a member of the tetrahedrite group. There remains some doubt as to the identity of the material originally studied by Landon and Mogilnor (1933), although Berman and Gonyer (1939) retained the name colusite.

The original colusite came from the 1,200 level (366 m) of the Leonard mine. It was also found at the Mountain View, West Colusa, and Tramway mines (Landon and Mogilnor, 1933). The mineral was especially abundant between the 2,800 and 3,000 levels (854 and 915 m) of the Tramway mine. This occurrence provided the bulk samples for the analyses reported by Nelson (1939). The "bronze tetrahedrite" reported from the Leonard mine area by Weed (1912) and Sales (1914) is probably colusite. In more recent years the mineral was found in even greater abundance in the deep horsetail ores of the East Colusa mine; most colusite specimens in modern collections came from this property.

Colusite from Butte occurs as crystalline masses and veinlets, and more significantly as aggregates of isometric, hextetrahedral crystals. Twinned crystals are also common (Nelson, 1939). Crystals of colusite are silver-white, tending toward bronze. Massive, crystalline material is a very distinctive pale bronze color, by which it is readily recognized. Bideaux (1960) reports colusite crystals on enargite, which measured 6 mm in maximum dimension. Nelson (1939) showed photographs of broken colusite crystals 8 to 10 mm across. Individual colusite crystals are more commonly 1 to 2 mm across.

As reported by Nelson (1939), the occurrence of colusite was largely restricted to the Anaconda-age veins and especially the horsetail structures of the Central Zone. The mineral was usually associated with enargite, in close proximity to areas of glassy quartz and pyrite. Colusite may be veined by enargite and both minerals in turn may be veined by tennantite. Chalcocite and

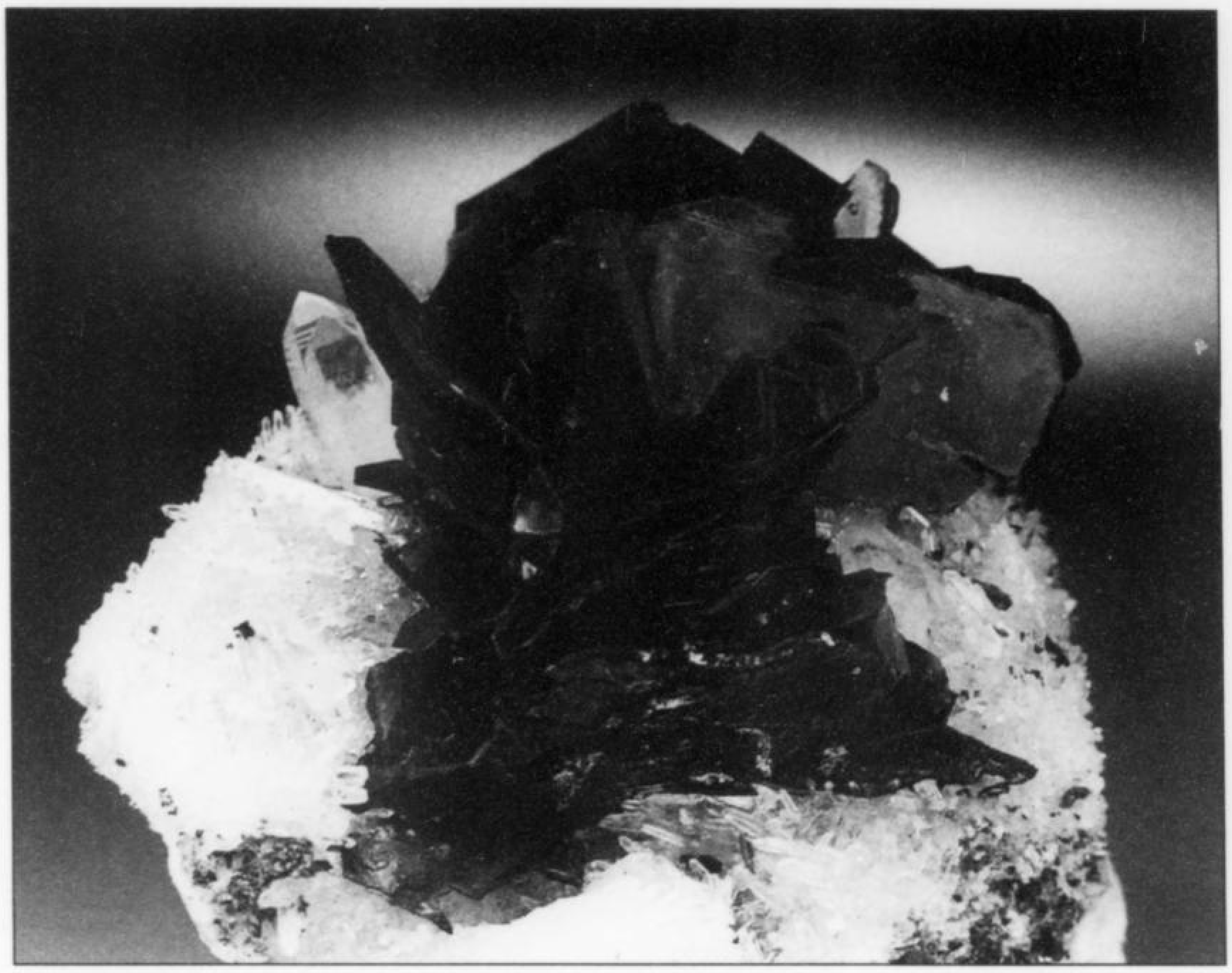


Figure 52. **Covellite crystals on quartz, 4.1 cm, from the East Colusa mine. Betty Llewellyn collection; Jeff Scovil photo.**

bornite are exclusively later, although chalcocite is also a frequent associate of colusite. In contrast, colusite from the East Colusa mine, the source of the specimens in most modern collections, is somewhat different in its associations. It occurs in glassy white quartz, but the only sulfide commonly associated is pyrite. The other copper minerals are largely absent. One unusual specimen from the East Colusa mine exhibits colusite associated with abundant molybdenite (JL).

A little colusite was also found as tiny inclusions in the ores of the Mountain Con and other mines of the Intermediate Zone, close to the Central Zone boundary. Guilbert and Zeihen (1964) determined trace amounts of colusite in the Deep Level Chalcopyrite Zone. Because the zone boundaries are overlapping and somewhat ill-defined, these reports of the mineral are not unusual. One interesting occurrence of the species was described by Bideaux (1960) on an enargite specimen owned by Butte mineral dealer Ed McDole; the colusite occurred as epitaxial overgrowths of complex crystals and twins on the terminal faces of enargite prisms from the Leonard mine.

Copper Cu

Native copper is a rare mineral at Butte. It was first reported by Emmons and Tower (1897), who noted dendritic crystals of native copper on joint surfaces in relatively fresh quartz monzonite. No locality was specified. It was also recognized by Ratcliff (1973) in the Continental pit area, where it formerly occurred in small amounts in the walls of the small pits at the Butte-Duluth, Bullwhacker, and Sarsfield mines, together with chrysocolla, cuprite, azurite, malachite, and tenorite. All of these mines predated the present Continental pit. The copper occurred as cores of cuprite nodules, the latter coated in turn by chrysocolla or azurite and malachite. Native copper also occurred in deep red to maroon, felted mixtures with cuprite on the northeast and south sides of the Berkeley pit. These mixtures occupied the leached sites of preexisting silicates. Although it does not represent an occurrence of native copper, *sensu stricto*, Weed (1912) mentions metallic copper replacing nails on the floors of drifts and even impregnating mine timbers in old worked-out levels of the Silver Bow mine.

Cornwallite $Cu_5(AsO_4)_2(OH)_4 \cdot H_2O$

Cornwallite was reported without description by Guilbert and Zeihen (1964). One specimen we have seen exhibits cornwallite as a deep, grass-green, microbotryoidal crust on a fracture surface in nodular malachite and azurite (RJ) from the Continental pit area. Isolated cornwallite botryoids have also been found with malachite on enargite at the Leonard mine (RJ).

Covellite CuS

Covellite crystals from Summitville, Colorado may be the best and largest in the world. However, for sheer quantity of high-quality specimen material, no locality on earth can rival Butte. Butte covellite groups grace collections, public and private, throughout the world, and because of its rich color and luster, even the massive mineral is attractive.

Covellite was recognized as a significant ore mineral at Butte very early and has been mentioned by numerous workers in the camp's voluminous literature. The best description of its occurrence at Butte is that of Thompson (1916), who described two major occurrences: (1) in the Anaconda-age veins and horsetail zones of the Leonard mining area, and (2) in the Blue Fault-age, Edith May and Gray Rock veins of the Speculator and East Gray Rock mines respectively. The individual mines comprising the Leonard mining area have been named in the Geology section. Minor occurrences of covellite mentioned by Thompson (1916) include those in the Mountain View, Tramway, Diamond, High Ore, Bell, and Buffalo mines. In addition, Weed (1912) noted the

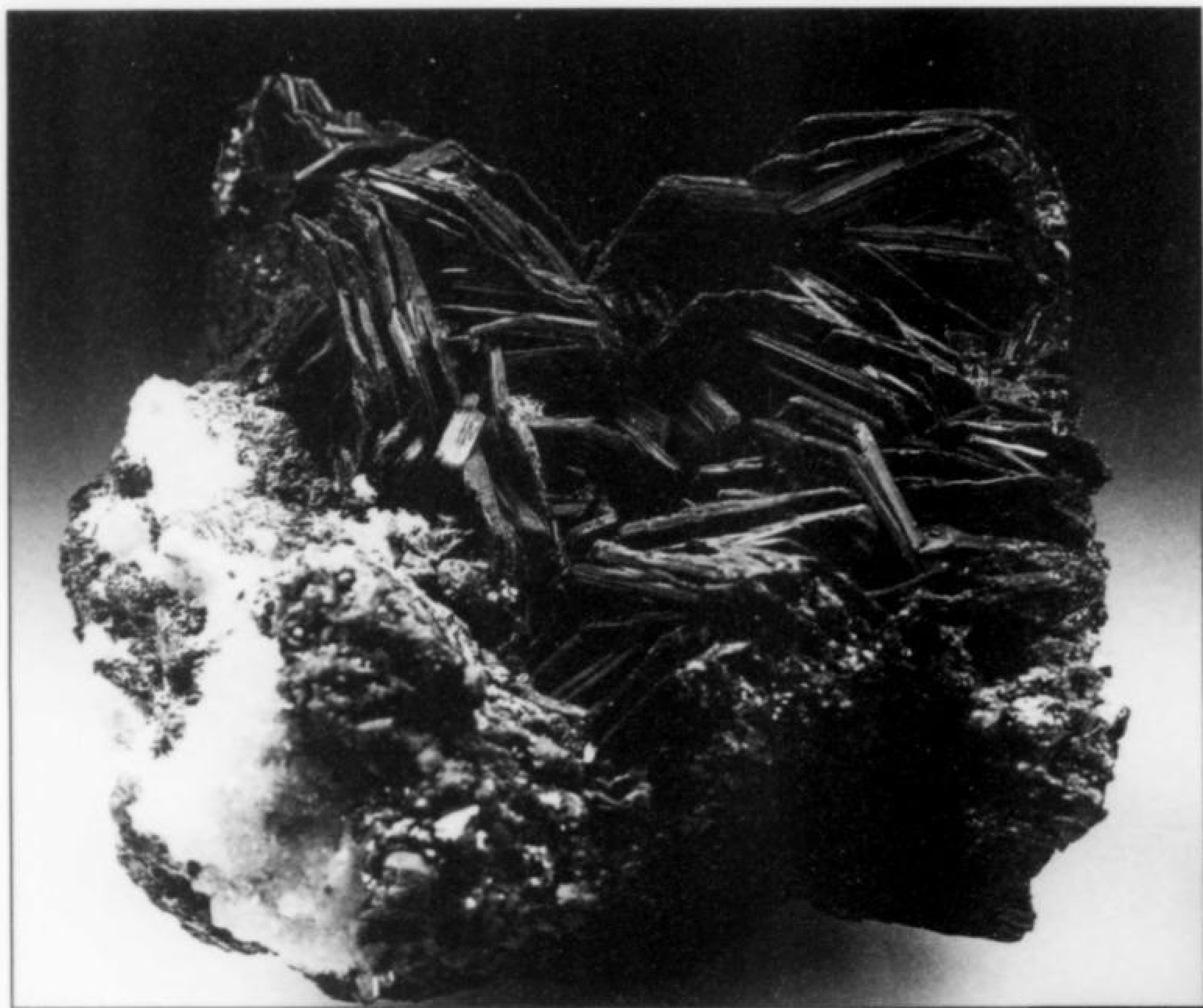
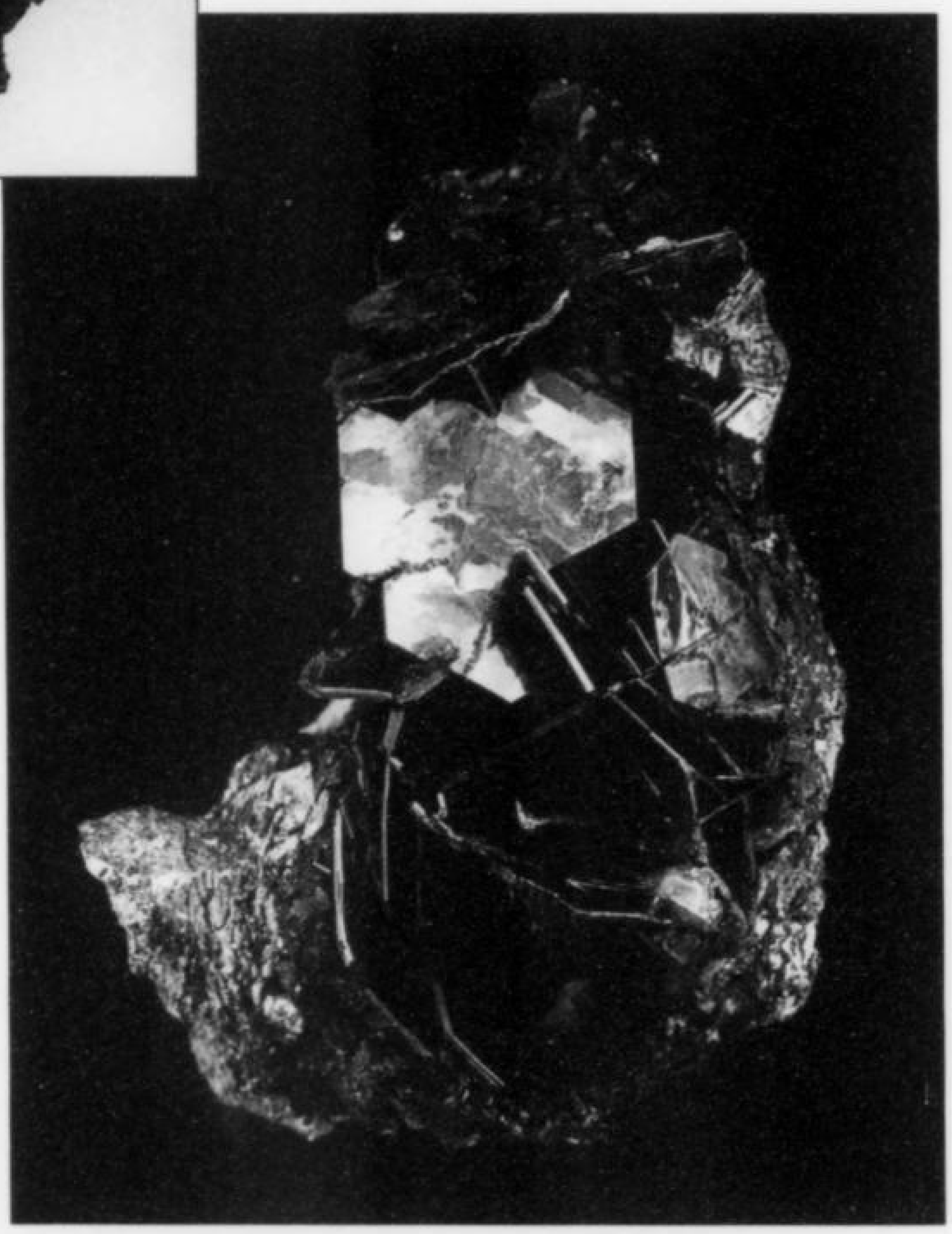


Figure 53. Covellite crystal cluster, 7 cm, from Butte. Forrest Cureton collection; Wendell Wilson photo.

Figure 54. Covellite crystal cluster, 5.7 cm, from Butte. Gene Meieran collection; Jeff Scovil photo.



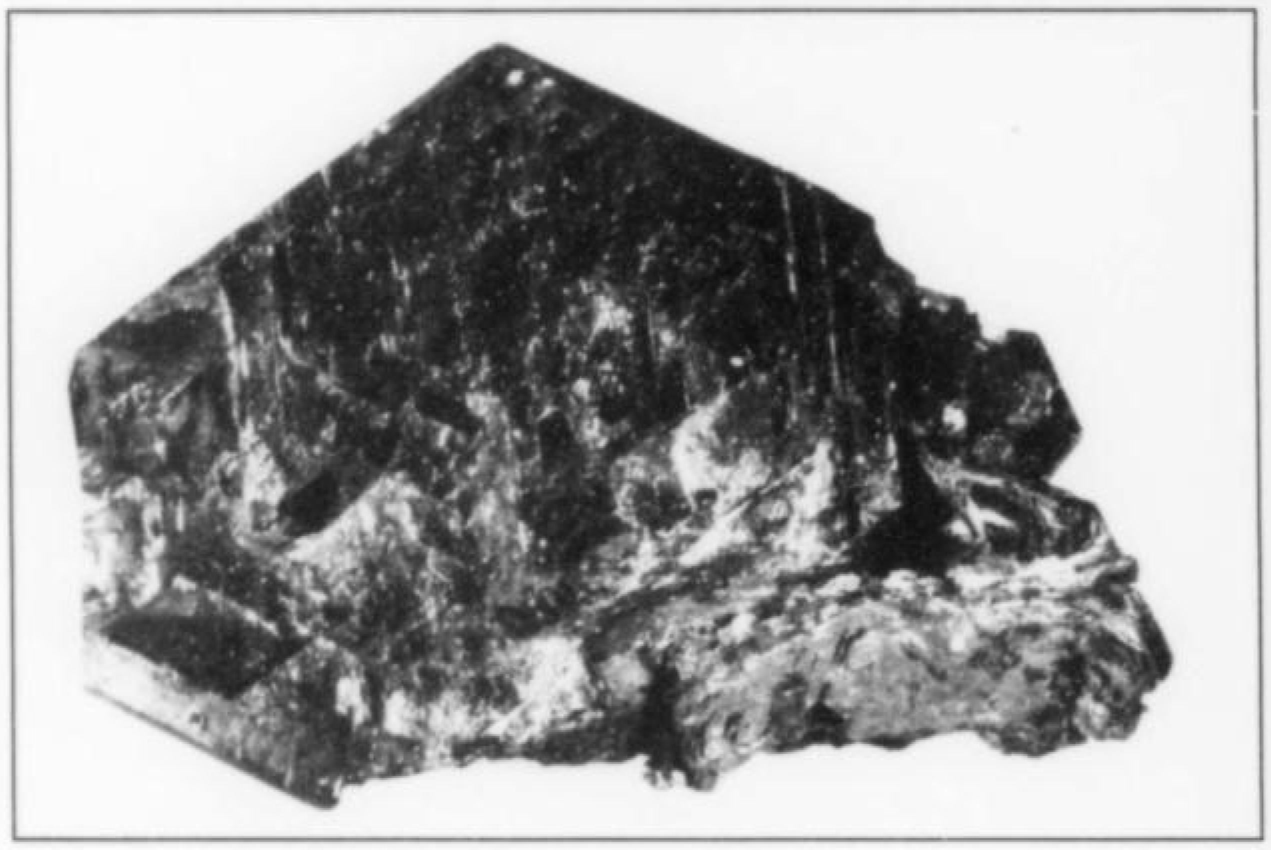


Figure 55. Covellite crystal, 5.8 cm, from the Leonard mine. George Holloway collection; Rock Currier photo.

Figure 56. Covellite crystal group, 7.7 cm, from the Leonard mine. Frederick Pough collection; Jeff Scovil photo.

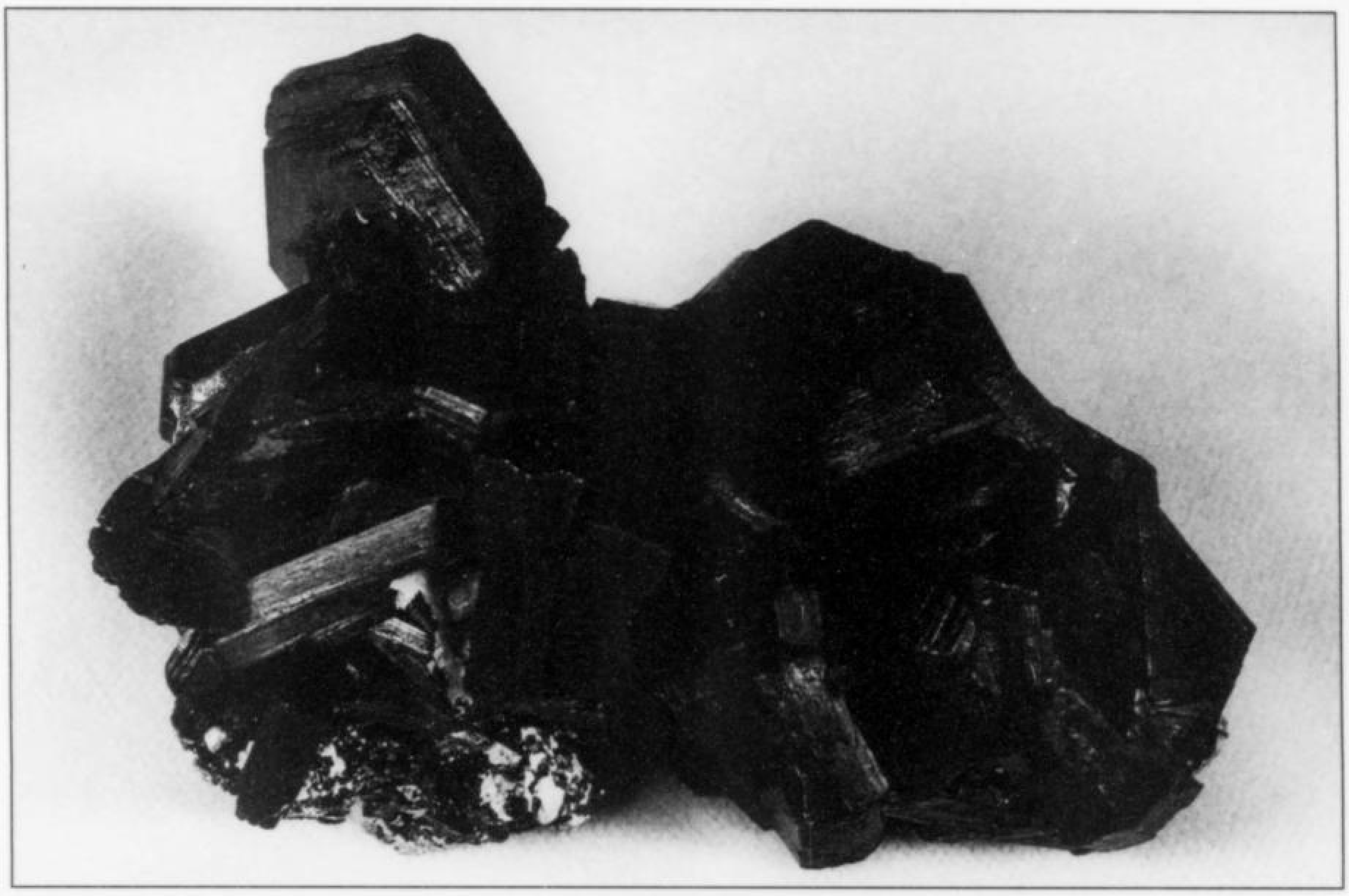


Figure 57. Covellite crystal cluster, 7 cm, from the 1900-foot level of the Leonard mine. Canadian Museum of Nature, Key collection; Rock Currier photo.

Figure 59. Covellite crystal cluster, 6.6 cm, from the 1900-foot level of the Leonard mine. Canadian Museum of Nature, Key collection; Rock Currier photo.

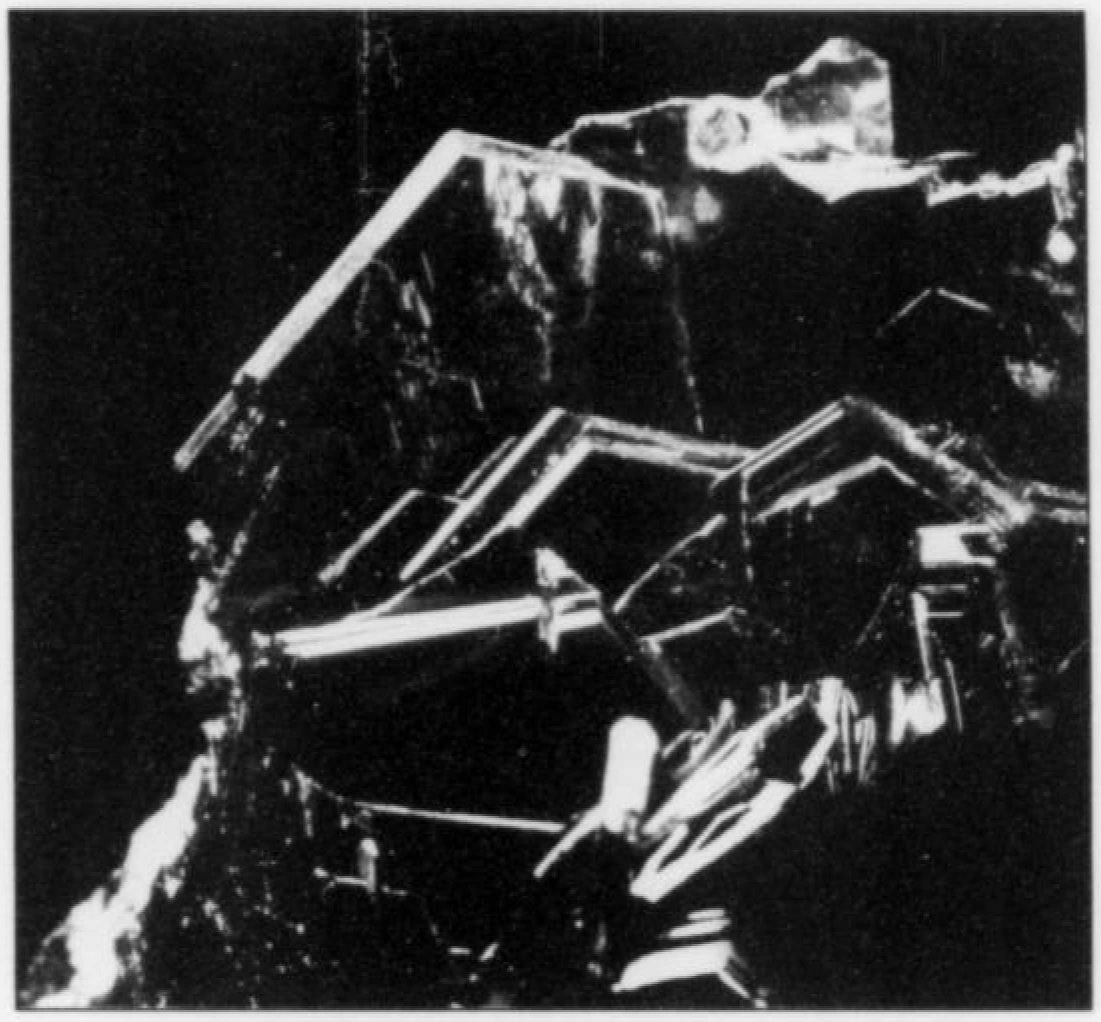


Figure 58. Covellite crystal cluster, 3 cm, from the East Colusa mine. Canfield collection, Smithsonian Institution; Wendell Wilson photo.

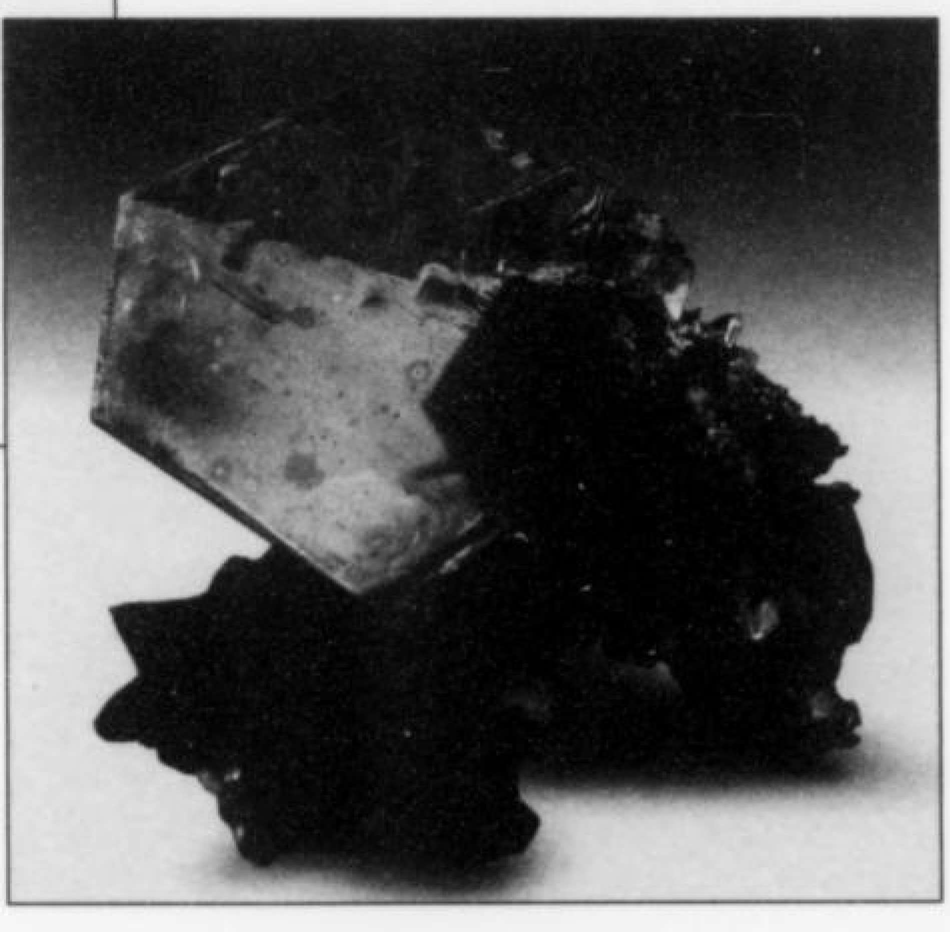


Figure 60. Covellite thumbnail crystal, 1 cm, from Butte. Jim Vacek collection; Jeff Scovil photo.

presence of covellite in some of the ores of the Mountain Con mine. A few specimens of covellite, and covellite with betekhtinite, have also been found at the Anselmo mine (DH). Covellite was also found in local abundance in the Berkeley pit in more recent years (McClave, 1973). It generally occurred where sphalerite was present. An amorphous substance, similar in composition to digenite, was associated. Small amounts also occur in the secondary enrichment blanket of the Continental pit area (Ratcliff, 1973).

Whereas both Emmons and Tower (1897) and Weed (1912) reported that Butte covellite always occurred in massive form, crystals were noted by Sales (1914) and Thompson (1916). Covellite crystals from Butte are thin hexagonal plates up to 7.5 cm across, occurring as isolated single crystals, as fan-shaped or jackstraw groups, as books of plates similar to micas, and as groups of books. The crystals have a metallic luster and a deep, indigo-blue color which tarnishes to purple. The color also ranges to various shades of gray when the crystals are coated or partially replaced by chalcocite, digenite, or bornite. The crystals and books are often studded with minute crystals of pyrite along their prism edges. Pyrite crystals may also be found in between the covellite plates.

Covellite crystals and groups occur on druses of quartz crystals or on massive, mixed sulfide minerals in the Leonard mine area. The sulfides include pyrite, enargite, chalcocite, digenite, and bornite. Much material extracted during the 1970's came from the 3859 and 3885–3886 stopes of the Leonard mine (D. Johnson, written communication, 2000). Thompson (1916) noted that covellite tended to occur where enargite was present, also that it generally formed bunches in the veins of this area. These masses ranged up to 1 meter in maximum size. Covellite often replaced enargite, and that author described specimens in which covellite plates cut across crystals of enargite. Covellite may also be in part replaced by chalcopyrite (Meyer *et al.,* 1968), and pseudomorphs of chalcocite, digenite, or bornite after covellite have been found (GL, RJ). In turn covellite has been found as pseudomorphs after enargite. Covellite was also found coating centimetric sphalerite crystals at the Leonard mine (JL). The species was present to the lowest limit of workings in the Leonard mining area. Meyer *et al.* (1968) reported covellite interleaved with kaolinite and dickite, on the Leonard 3,800 level (1159 m).

Cryptomelane $K(Mn^{+4},Mn^{+2})_8O_{16}$

Black, mammillary "psilomelane" was reported by both Weed (1912) and Pardee (1918) from vein outcrops on the north and southwestern sides of the district, where it formed as a product of the oxidation of rhodochrosite and especially rhodonite. This material is largely the mineral species cryptomelane. Guilbert and Zeihen (1964) reported that cryptomelane was common in pyrite-poor environments. A little of this material was mined as manganese ore before development of the great rhodochrosite orebodies (Pardee, 1918).

Cuprite Cu_2O

Cuprite was first recognized at Butte by Emmons and Tower (1897), in association with native copper and tenorite, which they reported as "melaconite." Weed (1912) added more information. Cuprite was found in at least small amounts in vein outcrops throughout the district. It was apparently most abundant in the East Ridge area, the site of the present Continental pit. It was found there with copper, chrysocolla, tenorite, and other minerals. The cuprite occurred, in part, as red-brown nodules with native copper cores. Another interesting occurrence of cuprite was in the Berkeley pit, where it occurred in felted mixtures with native copper, occupying sites of pre-existing silicates in the oxidized capping (McClave, 1973). In none of these occurrences is the cuprite crystallized.

***Figure 61.* Digenite crystals, 6 cm, from the Leonard mine, one of the finest known specimens of the species. Smithsonian collection; Chip Clark photo.**

Digenite Cu_9S_5

Digenite is a relatively abundant mineral at Butte, where it is frequently intergrown with covellite in massive form. Much more rarely, it occurs crystallized. The world's largest and best digenite crystals have unquestionably come from Butte.

Butte digenite is dark blue to black. Crystals consist of elongate cubes, frequently with rounded edges and terminations. In many samples the crystals occur in parallel growths that form rounded pyramidal shapes. Miller (1971) describes an example, shown to him by the late Ed McDole, which exhibited a single 1.2 x 2.5 cm digenite prism perched on white quartz crystals. He regarded this as the finest digenite specimen ever produced at Butte up to that time. What is probably an even better digenite specimen from the collections of the U.S. National Museum is shown here. Another exceptional specimen in the Chin collection (PC) is about 4 cm long. Because digenite is a high-sulfur copper mineral, it was most abundant in the Leonard mine area and presumably in overlying parts of the Berkeley pit. McClave (1973) reports an amorphous substance with the composition of digenite from the Berkeley pit. Other specimens examined for the present study have come from the Belmont mine (RJ) and the Anselmo mine (DH).

Digenite from Butte has been studied by a number of workers. Buerger (1941, 1942) reported on the so-called "blue chalcocite,"

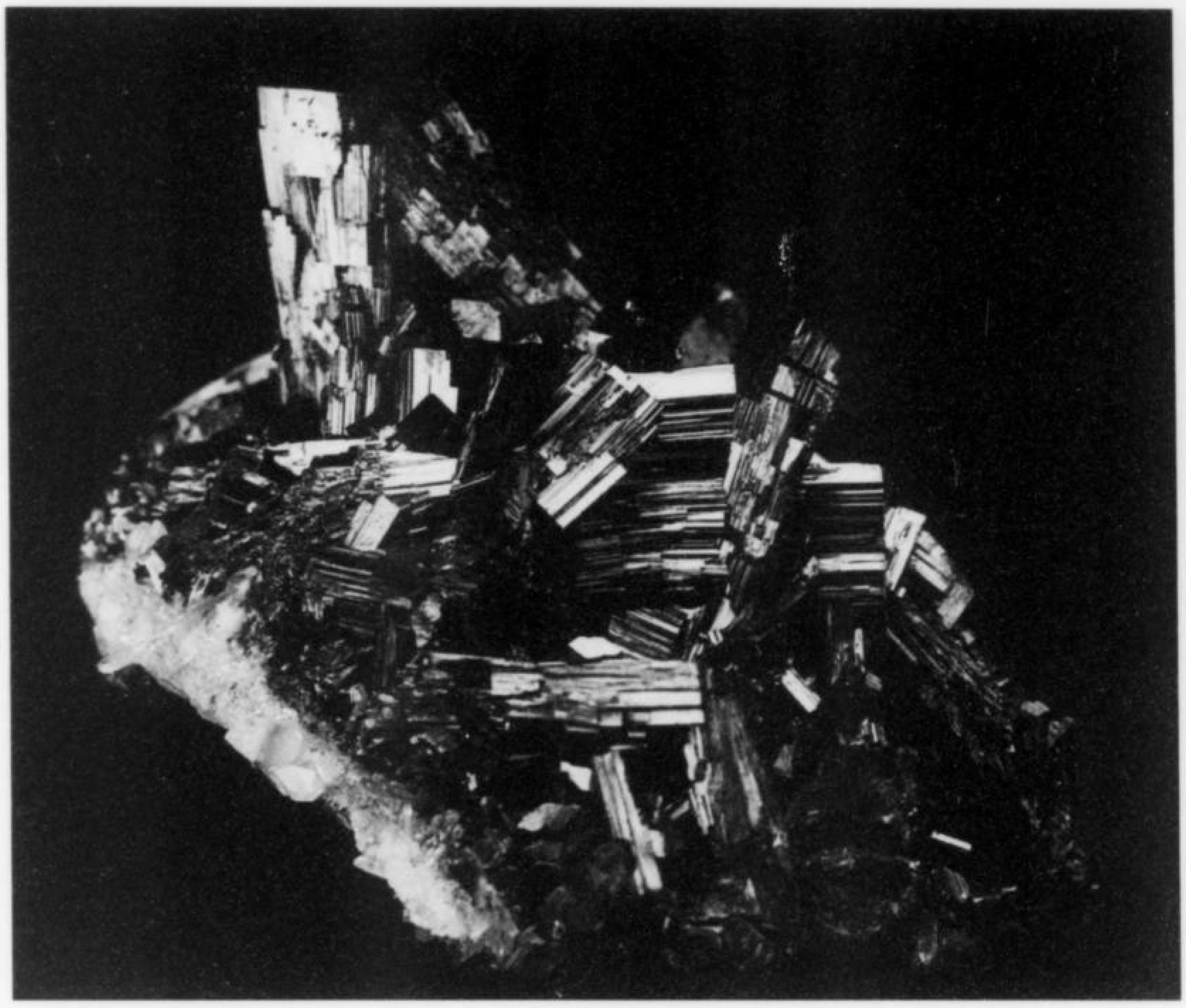


Figure 62. **Enargite crystals on quartz, 11.5 cm, from Butte. Canfield collection, Smithsonian Institution; Chip Clark photo.**

the name by which digenite was known before the species was formally described. He reported X-ray studies, largely using synthetic material. Morimoto and Gyobu (1971) refined the mineral's composition and reported on its stability.

Djurleite $Cu_{31}S_{16}$

Morimoto (1962) and Roseboom (1962) described the copper sulfide mineral, djurleite. Among other localities, they reported the new species from Butte, Montana. Roseboom (1962) suggested that it should be a common mineral at Butte.

If djurleite is common at Butte, it is seldom recognized. The mineral is blackish or bluish lead-gray, dull to brightly metallic, and it is identical in appearance to chalcocite. Djurleite may be distinguished from chalcocite only by X-ray diffraction (L. Zeihen, written communication, 2000). Djurleite crystals from Butte are short prisms or thick pseudohexagonal tablets similar to twinned chalcocite. This twinning on {110} is very common. The edges of the crystals are often ragged. Twinned crystals on one specimen from the Leonard mine range from 6 mm to 1 cm across (RJ). They are brittle and break very easily. Some exhibit a faintly brownish tarnish. Meyer *et al.* (1968) suggested that most of the djurleite at Butte should occur in the Leonard area because of its close chemical relationship to the other copper sulfides that were so abundant there.

Dolomite $CaMg(CO_3)_2$

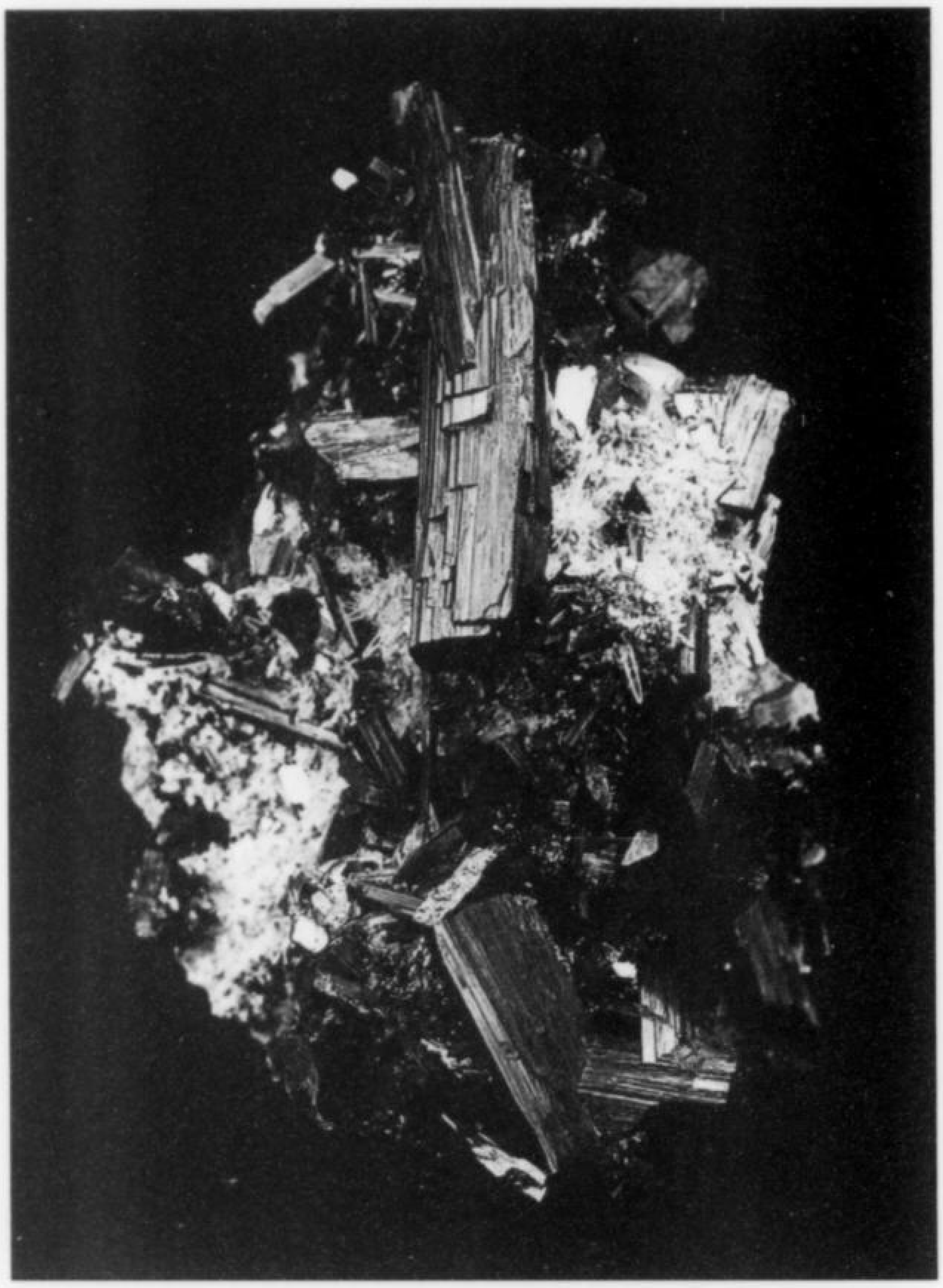
Dolomite is reported without description by both Smith (1941) and Guilbert and Zeihen (1964). One specimen from the Alice mine on the Rainbow vein consists of typical, saddle-shaped rhombohedra overgrown on larger crystals of rhodochrosite (RJ). The dolomite crystals are medium brown and measure about 0.5 mm across. The rhodochrosite rhombohedra measure up to 1 cm in maximum dimension. A little pale beige dolomite in saddle-rhombs averaging about 1 mm across coats other minerals in vugs at the Leonard mine (CL). Similar material on sphalerite and iridescent pyrite has also been found at the Lexington mine (RJ).

Enargite Cu_3AsS_4

To collectors, enargite is one of the most familiar minerals from Butte. It is arguable whether Butte has produced the world's best enargite, but this is largely a matter of taste. Butte is certainly one of the most important enargite localities on earth, and high-quality specimens from Butte are present in most mineral collections.

The mineral was found in nearly every mine of the Central and Intermediate Zones, and during Butte's underground mining era it probably accounted for 25 to 40% of district copper production (Sales, 1914). Fine crystal specimens were found at the Badger, Belmont, East Colusa, Gagnon, Mountain Con, Original, Steward, and other underground mines, as well as the Berkeley pit, but the mineral is best known from the Leonard mine. Superb specimens of enargite were collected at the Leonard right up until the mine's closure in 1975.

Crystals of enargite from Butte were known to both Weed (1912) and Sales (1914). The latter author reported "beautifully formed" crystals ranging up to 2.5 cm in length, while the former described crystals with bright, mirror-like terminations and dull prismatic faces owing to coatings of mossy chalcocite. Smith (1941) reported larger crystals up to 4 cm long, but no specific mine localities were listed. Enargite occurs as single striated crystals and as parallel, divergent, jackstraw, or radiating groups. Vugs in massive enargite, with enargite crystals stretching from wall to wall, are very common. The mineral is most often associated with quartz, pyrite, covellite, and chalcocite, but may be associated with any of the other copper minerals as well, together with barite and fluorite. Thompson (1916) noted its frequent association with covellite in



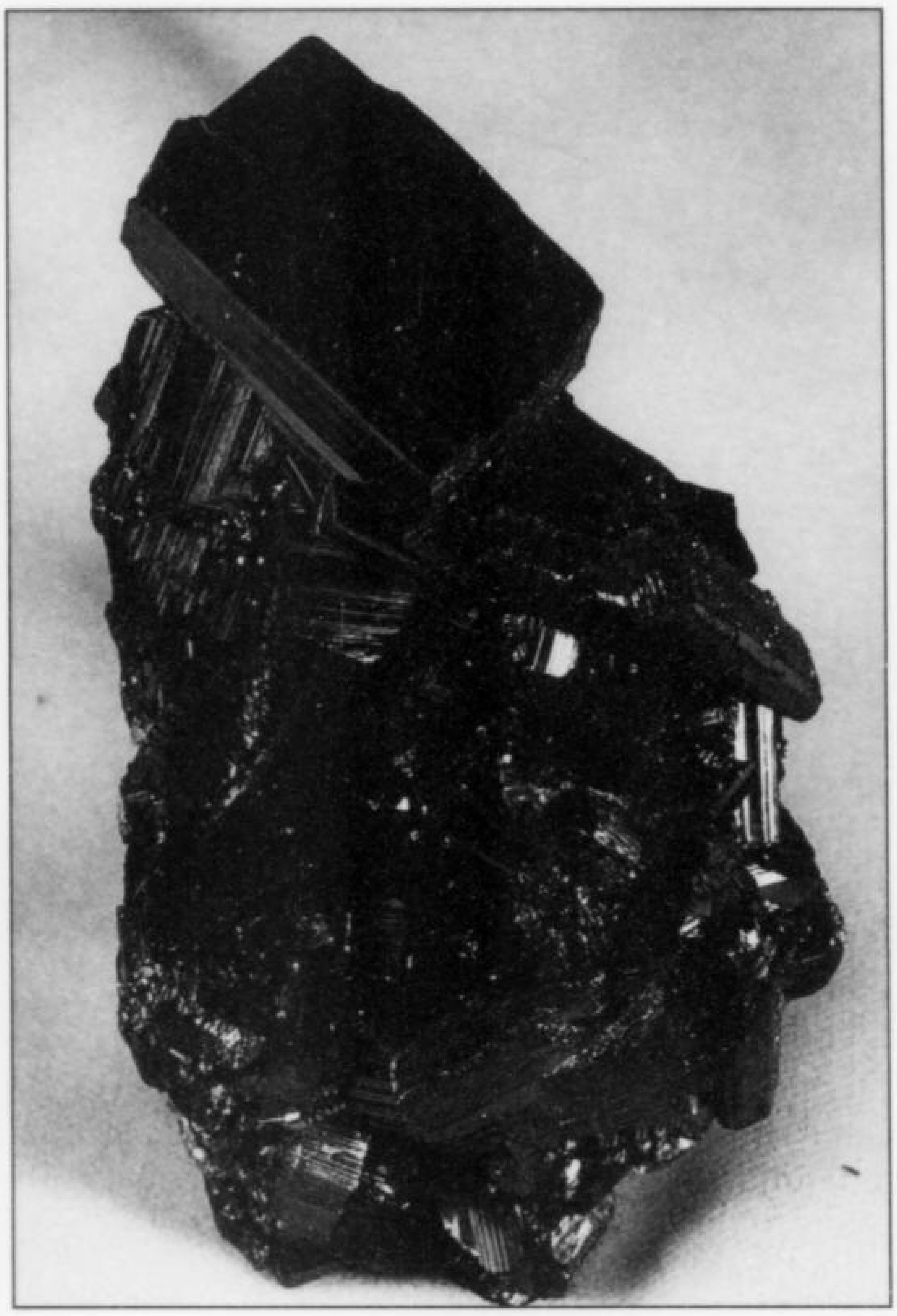


Figure 63. **Enargite crystal cluster, 8.9 cm, from Butte. Formerly David Wilber collection; Rock Currier photo.**

Figure 64. **Enargite crystals with quartz and pyrite, 10 cm, from Butte. Smithsonian collection.**

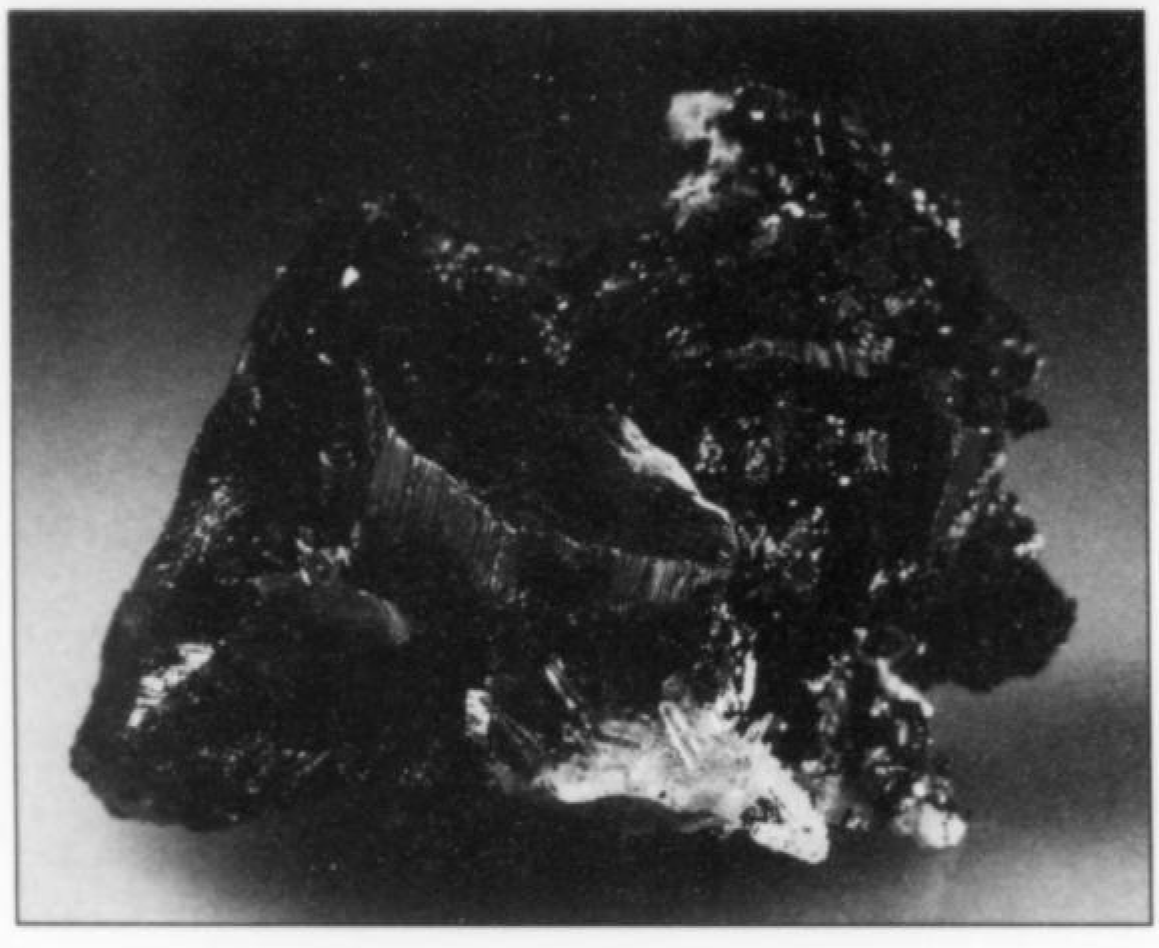


Figure 65. **Enargite crystal, 2.2 cm, with quartz, from the Leonard mine. Forrest Cureton collection; Wendell Wilson photo.**

the Anaconda-age veins of the Leonard mine area.

Sales (1914) also reported pseudomorphs of enargite after hübnerite from the High Ore vein of the Mountain View mine. Smith (1941) described chalcopyrite pseudomorphs after enargite (CL, RJ), as well as tennantite casts after enargite (FP). One specimen from the Leonard mine exhibits pyrite casts after enargite with enargite (RJ); the enargite casts are about 7 mm in length, the individual pyrite crystals 0.3 mm across.

Ferrimolybdite $Fe_2(MoO_4)_3 \cdot 8H_2O$

A specimen from the Roosevelt Drive area south of Butte exhibits ferrimolybdite as bunches of canary yellow prisms in cavities in deeply altered and iron oxide-stained quartz monzonite (JL). The crystals average about 0.5 mm in length. The same specimen contains molybdenite as irregular 5–6 mm plates without crystal outline. Neither Guilbert and Zeihen (1964) nor Meyer *et al.* (1968) reported ferrimolybdite from Butte, but the Roosevelt Drive area is outside the mining district proper.

Fluorite CaF_2

Fluorite is a widespread, but rather uncommon constituent of the Butte veins. Massive material, generally violet, has been found in small amounts in many mines. Brown (1894) reported small crystals from the Estella claim, but neither the size nor the color of these crystals was mentioned. The Estella claim was situated along the Syndicate vein, west of the Mountain Con mine. Smith (1941) described fluorite crystals from both the Elm Orlu and Badger mines. In the Elm Orlu occurrence the fluorite was found in vugs, associated with rhodochrosite. At the Badger mine it was found as both octahedra and cubes modified by octahedral faces. The octahedral crystals are exclusively pale green in color, the cubes pale violet.

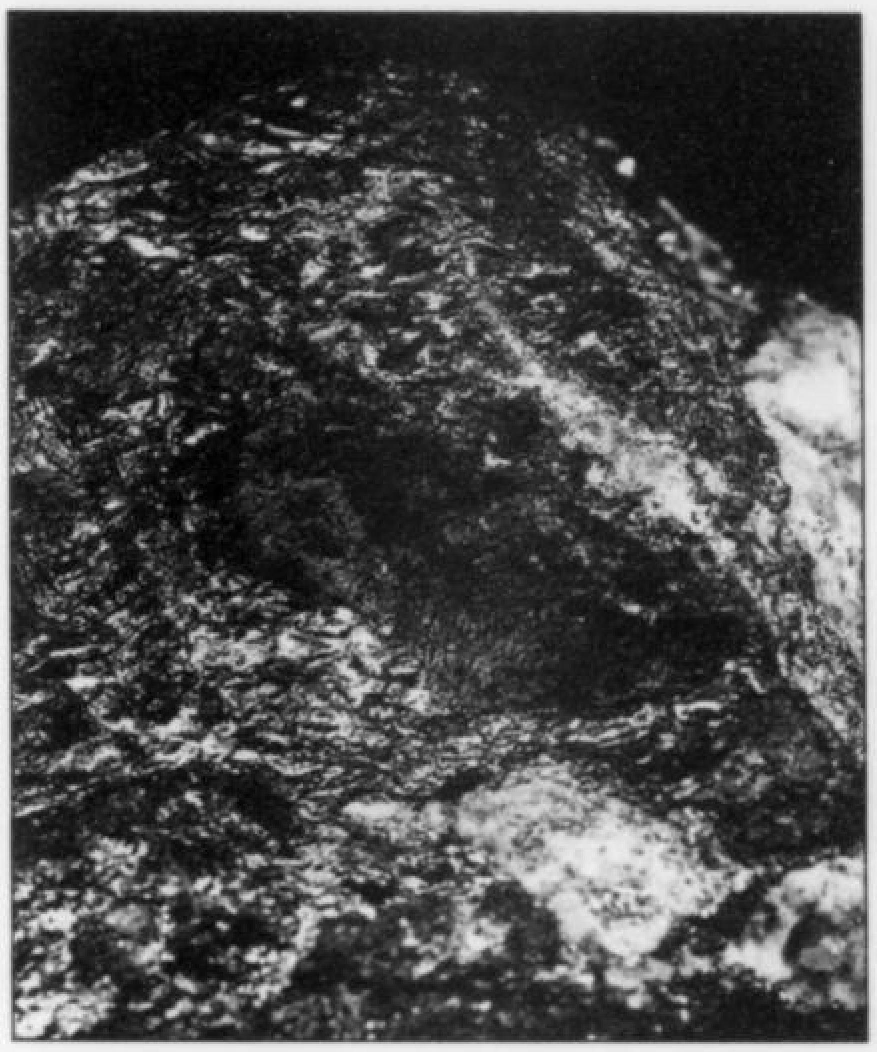


Figure 66. **Bismuth-pink luzonite coating a fracture in covellite and pyrite, 7.5 cm, R. Jenkins collection; G. Grenier photo.**

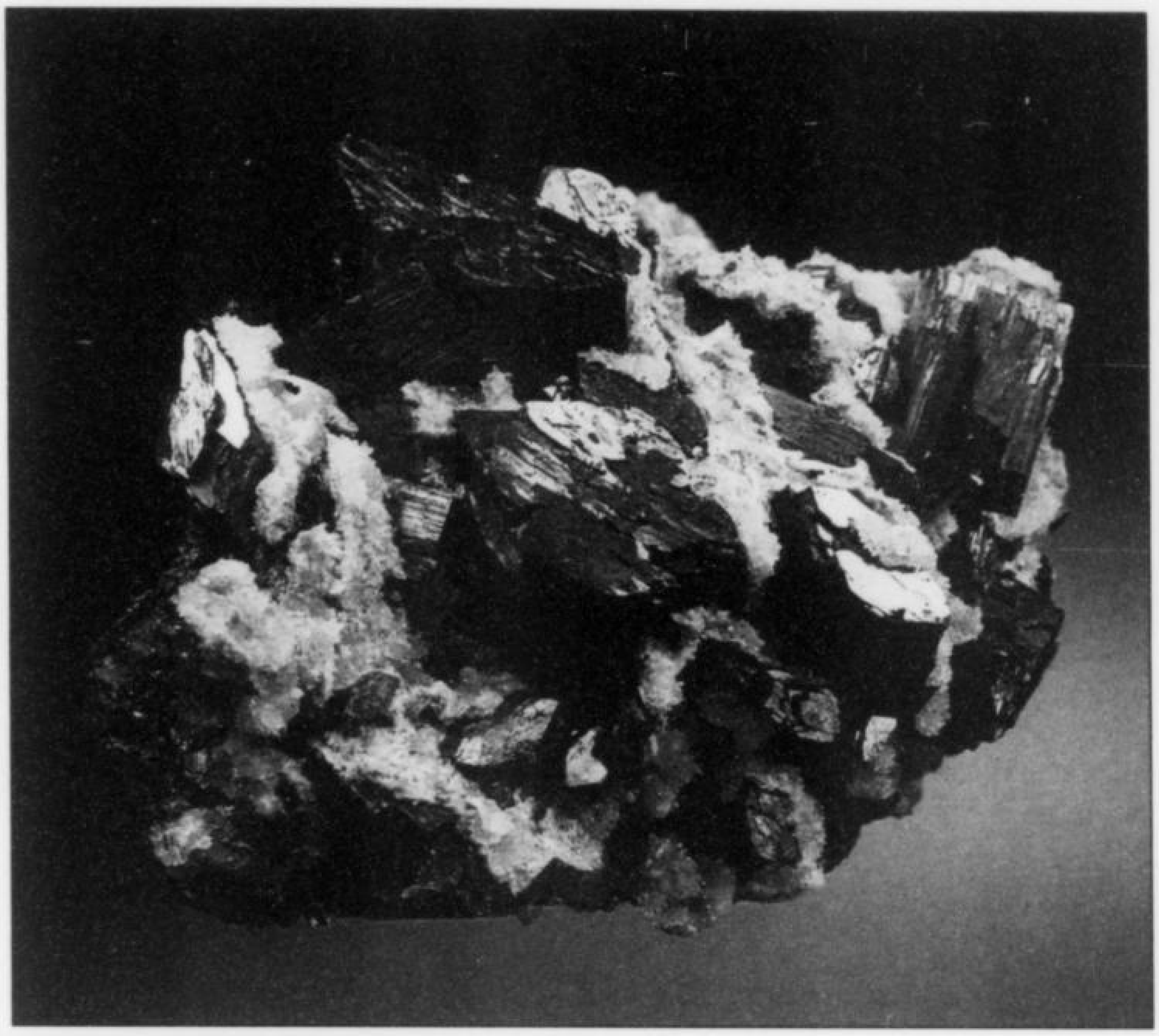


Figure 67. **Enargite crystals with quartz, 6.5 cm, from the Leonard mine. Seaman Mineral Museum collection; G. Robinson photo.**

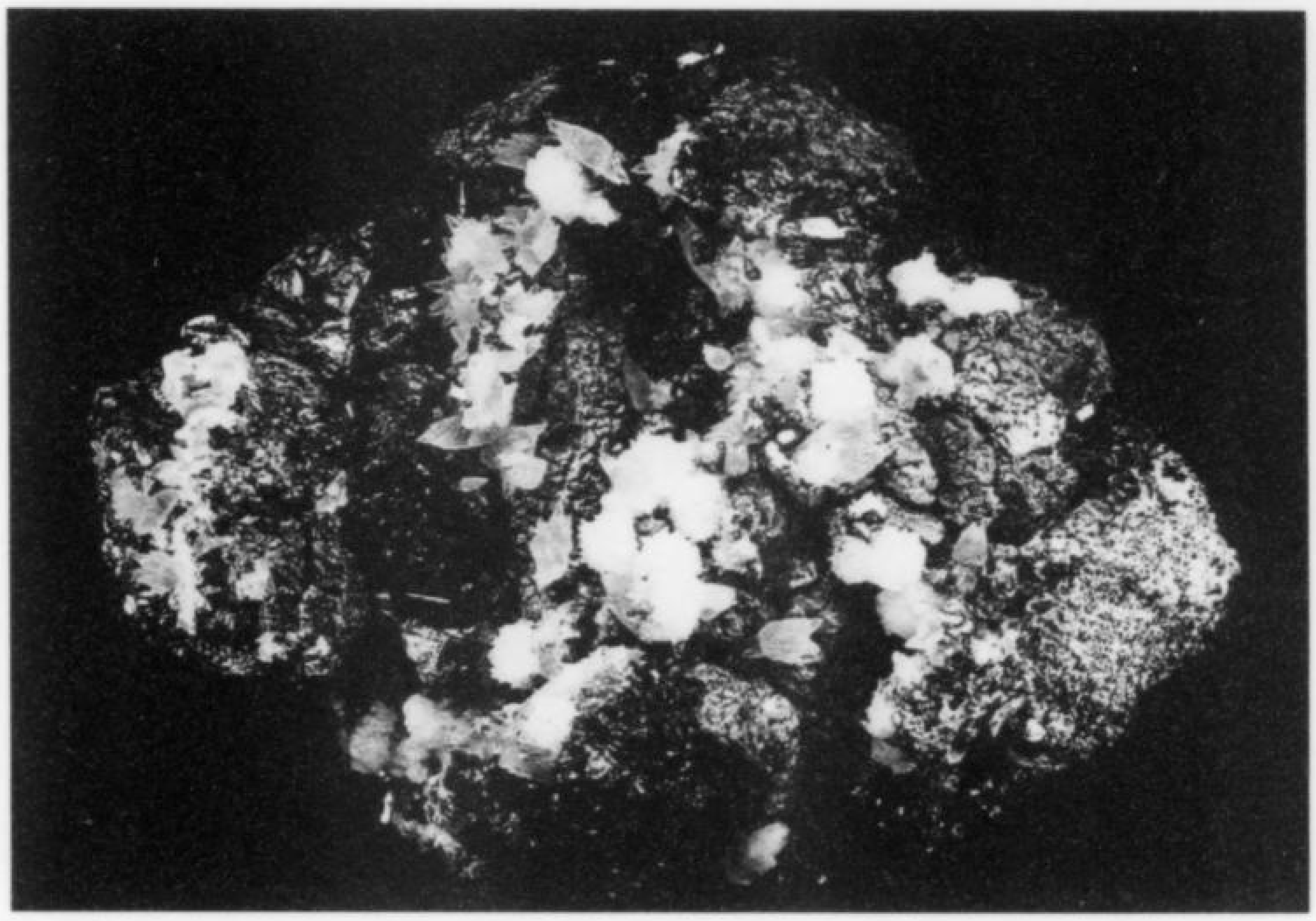


Figure 68. **Calcite crystals on corroded galena and sphalerite, 9 cm, from the Steward mine. Fred Parker collection, G. Grenier photo.**

Galena PbS

Galena occurred in at least small amounts at most of the Butte mines, but was abundant at only a few localities. The mineral is prominent as disseminations in the rhodonite of veins in the Peripheral Zone, associated with sphalerite and small amounts of pyrite. Significant orebodies of galena were mined at the Emma and Orphan Girl mines (Smith, 1941), and the mineral was relatively abundant in the Old Glory, Lexington, and Gray Rock veins, north of the Mountain Con mine (Sales, 1914). A specimen from the East Gray Rock mine exhibits coarsely crystalline galena with a somewhat sheared texture, being replaced by covellite (RJ). Small crystals occurred with chalcopyrite crystals atop "dogtooth" calcite in vugs at the Little Mina mine (Weed, 1912). Galena, in 1-mm to 1.5 cm cuboctahedra associated with black sphalerite crystals, came from the Syndicate pit at the western terminus of the Syndicate vein (JL, RJ). Similar material was found on the 800 level (244 m) of the Lexington mine (RJ). The galena is associated with crystallized black sphalerite, tiny quartz prisms, and a few siderite rhombohedra. One exceptional specimen from the Steward mine exhibits 2.5 cm etched galena cubes together with sphalerite and scattered druses of tiny white calcite scalenohedra.

Gold Au

Gold was the metal which caused the first modest rush to Butte in 1864. This was placer gold, which had weathered out of some of the vein outcrops, especially from the silver-rich veins of the Peripheral Zone. To judge by the relatively low value ascribed to Butte's placer gold, it is probably more properly classified as electrum, although there is no definitive record of its silver content.

Native gold was also reported in the oxidized zones of the silver-rich veins themselves, together with cryptomelane, ramsdellite, romanechite, native silver, and small amounts of chlorargyrite (Meyer *et al.,* 1968). Weed (1912) describes a single specimen of native gold from the 1,000 level (305 m) of the Leonard mine. It occurred as flakes and scales on a fracture surface in chalcocite. Gold is present in small quantities in all of Butte's copper ores, and the lion's share of district production has been a byproduct of copper mining. The mineralogic residence of this gold has never been reported in the literature.

Greenockite CdS

A little canary-yellow greenockite was found as coatings on sphalerite in the Emma-Travona vein system. The mineral was confirmed by X-ray diffraction; it is not hawleyite (L. Zeihen, oral communication, 2000).

Gypsum $CaSO_4 \cdot 2H_2O$

Gypsum is a very rare mineral at Butte. Brown (1894) reported crystals up to 3.5 cm in fractures in quartz monzonite in the oxidized zone at the Black Rock mine. Bard and Gidel (1914) mentioned long, delicate crystals found in vugs on the deeper levels of unnamed mines. White and partially transparent gypsum blades averaging about 1 cm, but ranging up to 5 cm long, have been found on quartz, pyrite, enargite and chalcocite at the Leonard mine.

Helvite $Mn_4Be_3(SiO_4)_3S$

Helvite is very rare at Butte. It was first reported by Hewett (1937) as a single specimen from the west drift on the 200 level (61 m) of the Lexington mine. It occurs as lemon-yellow, anhedral grains up to 2 mm across, as well as 1-mm-thick veinlets, both imbedded in or traversing rhodonite and rhodochrosite. The specimen also contains quartz and sulfide minerals. Apparently based on information obtained from M. H. Gidel, then Chief Mineralogist for the Anaconda Company, Smith (1941) reported helvite from the Alice, Goldsmith, and Moulton mines as well. Dunn (1977) also reported the species from the "East Moulton" property, but there is no listing of such a mine in any tabulation of historic Butte mines (see Table 1); it is likely that this reference concerns workings on the eastern side of the Moulton claim.

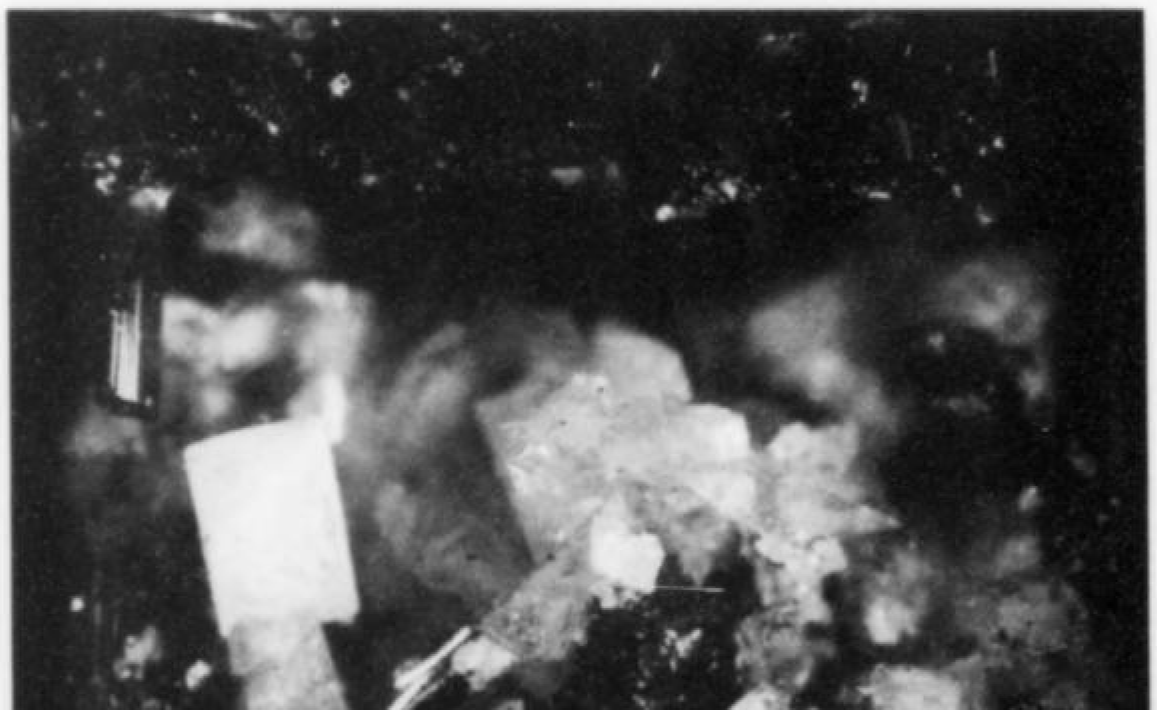


Figure 69. **Hinsdalite in pseudocubic crystals to 1 mm, from the Leonard mine. Jerry Lorengo collection; G. Grenier photo.**

Hinsdalite $(Pb,Sr)Al_3(PO_4)(SO_4)(OH)_6$

Hinsdalite is a very rare mineral at Butte. Guilbert and Zeihen (1964) recognized it in trace quantities only in the Central Zone. Roberts *et al.* (1974) describe excellent microcrystals implanted on enargite and covellite. Hinsdalite crystals on two specimens consist of tablets or rounded pseudo-cubes, averaging about 1 mm in maximum dimension and implanted on enargite and covellite. The hinsdalite is white to a yellowish or greenish cream color, with a slightly pearly luster; both specimens come from the Leonard mine. Some years ago a local Butte collector obtained a number of Butte hinsdalite specimens in which tablets up to 2 mm were deposited on slender, 1.2-cm quartz crystals (L. Zeihen, oral communication, 2000); the specific mine locality is unknown.

Hübnerite $MnWO_4$

Hübnerite was first reported from Butte by Pearce (1887), associated with pyrite, sparse enargite, and wurtzite (see Sphalerite) between the 200 and 300 levels (61 and 91 m) of the Gagnon mine. Weed (1912) and Sales (1914) mentioned its occurrence in the Anaconda, Leonard, West Colusa, Shannon, Jessie, Steward and Mountain View mines as well. Pardee (1918) also reports hübnerite from the Tramway mine. Pseudomorphs of enargite after hübnerite crystals were found in the High Ore vein of the Mountain View. Lovering (1933) also reported the mineral from some of the silver-gold deposits of the Peripheral Zone where it was apparently a commercial source of tungsten for a brief time. In none of these reports was the size of the hübnerite crystals listed. One specimen examined for the present study (JL) consists of a flat plate of moderately altered quartz monzonite, over which hübnerite is distributed as 4-mm to 1-cm blades lying on their prism edges. The blades are partly to wholly pseudomorphed to dull gray-black enargite. Where unaltered they are translucent with red-brown internal reflections. The pseudomorphs are interesting, in that the striations of the original hübnerite are preserved as lines of tiny "bubbles." The mine locality for this specimen is unknown.

Libethenite $Cu_2(PO_4)(OH)$

Crystalline, olive-green libethenite occurs with malachite and radiating azurite in a specimen from the Continental East pit (RJ). L. Zeihen (oral communication, 2000) states that the species was confirmed by X-ray diffraction in samples from this area.

Luzonite Cu_3AsS_4

Gaines (1957) first reported the sparse occurrence at Butte of the rare mineral luzonite. It was also determined in the exhaustive studies of Guilbert and Zeihen (1964), in trace amounts only in the ores of the Central Zone. The latter authors also considered its occurrence to be possible in the Intermediate Zone. In neither report, however, was the luzonite described. The following description is therefore derived from two specimens which were personally examined by the senior author (RJ), both from the Leonard mine.

Luzonite from Butte is a copper red color, grading toward grayish pink with a metallic luster. The color is distinguishable from that of fresh bornite because it lacks the overtones of lavender. Luzonite tarnishes gray, but retains a pinkish hue. It occurs as massive fracture coatings and sparse crystals in rich covellite-digenite ore. On one specimen enargite is also present, but it is not in contact with the luzonite. Luzonite crystals are roughly rectangular in shape, with rounded edges and terminations. The largest crystals measure 3 mm in length.

The only mineral for which luzonite may be easily mistaken is famatinite. This species was also reported at one time from Butte (Bard and Gidel, 1914; Gaines, 1957), but was not recorded in the exhaustive studies of Guilbert and Zeihen (1964); it is no longer considered a valid Butte species.

Malachite $Cu_2(CO_3)(OH)_2$

A number of workers (Blake, 1887b; Weed, 1912; Guilbert and Zeihen, 1964; McClave, 1973; Ratcliff, 1973) have reported malachite from various parts of the Butte district. In nearly all of these reports the mineral is described as stains with azurite and other minerals, which have little mineralogical significance. The single report of crystallized malachite in the literature is that of Weed (1912), noting it from the Moody & Sankey, Iowa, and Kossuth mines on the extreme western side of the district. The species occurs as needles filling vugs in porous manganese oxides.

Marcasite FeS_2

Weed (1912) reported that marcasite was very abundant at Butte. Bard and Gidel (1914) reported that the species was uncommon, and that its distribution did not seem to be restricted by depth. They record a specimen of marcasite on pyrite-bornite-chalcocite ore from the 1,800 level (549 m) of the Badger mine. This view of the rarity of marcasite is shared by Guilbert and Zeihen (1964), who record the very sparse occurrence of the species only in the Peripheral Zone; they consider the mineral to be absent from the other zones. Groups of thin, tabular marcasite crystals occurred on the 800 level (244 m) of the Lexington mine (RJ). The crystals measure about 5 mm in maximum dimension and exhibit a brownish brassy color and luster.

Molybdenite MoS_2

Molybdenite was first recorded at Butte by Emmons and Tower (1897). They found it as plates on fracture surfaces in altered quartz monzonite and as thin, greasy films in relatively fresh quartz monzonite at the Gagnon and Neversweat mines. Weed (1912) also reported the mineral from the Gagnon mine, as veinlets flanking the big veins, and in a number of veinlet occurrences in the East Ridge area. This is the site of the present Continental pit operation, in which molybdenite is a major ore mineral (Ratcliff, 1973). The species has also been found in some of the pegmatites and is important in the Anaconda and Pittsmont Domes, which underlie the Main Stage veins (Guilbert and Zeihen, 1964; Meyer *et al.*, 1968). In most of these occurrences the molybdenite is found as small, hexagonal flakes or scales, but it occasionally occurs as larger, well-formed crystals. Specimens exhibiting 1.5 to 2.5-cm hexagonal crystals have been found imbedded in quartz at the Emma mine and encrusting iron-stained pegmatite in the Roosevelt Drive area south of the mining district proper (RJ).

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

Smith (1941) reported polybasite with pearceite, rhodochrosite, rhodonite, and other silver minerals at the Star West mine. The species has also been found with pyrargyrite and acanthite at the Anselmo mine (DPh).

Proustite Ag_3AsS_3

Smith (1941) reported proustite together with pyrargyrite, acanthite, and tetrahedrite, as disseminated specks in the primary silver ores. No crystals are described, and no mine names are given.

Pyrargyrite Ag_3SbS_3

Pyrargyrite was found as small crystals lining fractures in altered granite at the Springfield mine (Weed, 1912). The Springfield mine was located on a minor east-west vein, lying west and north of the Rainbow vein.

Pyrite FeS_2

Pyrite crystals from Leadville and Climax, Colorado, from Spruce Ridge, Washington, and especially those found more recently in several of the polymetallic deposits of Peru, are larger,

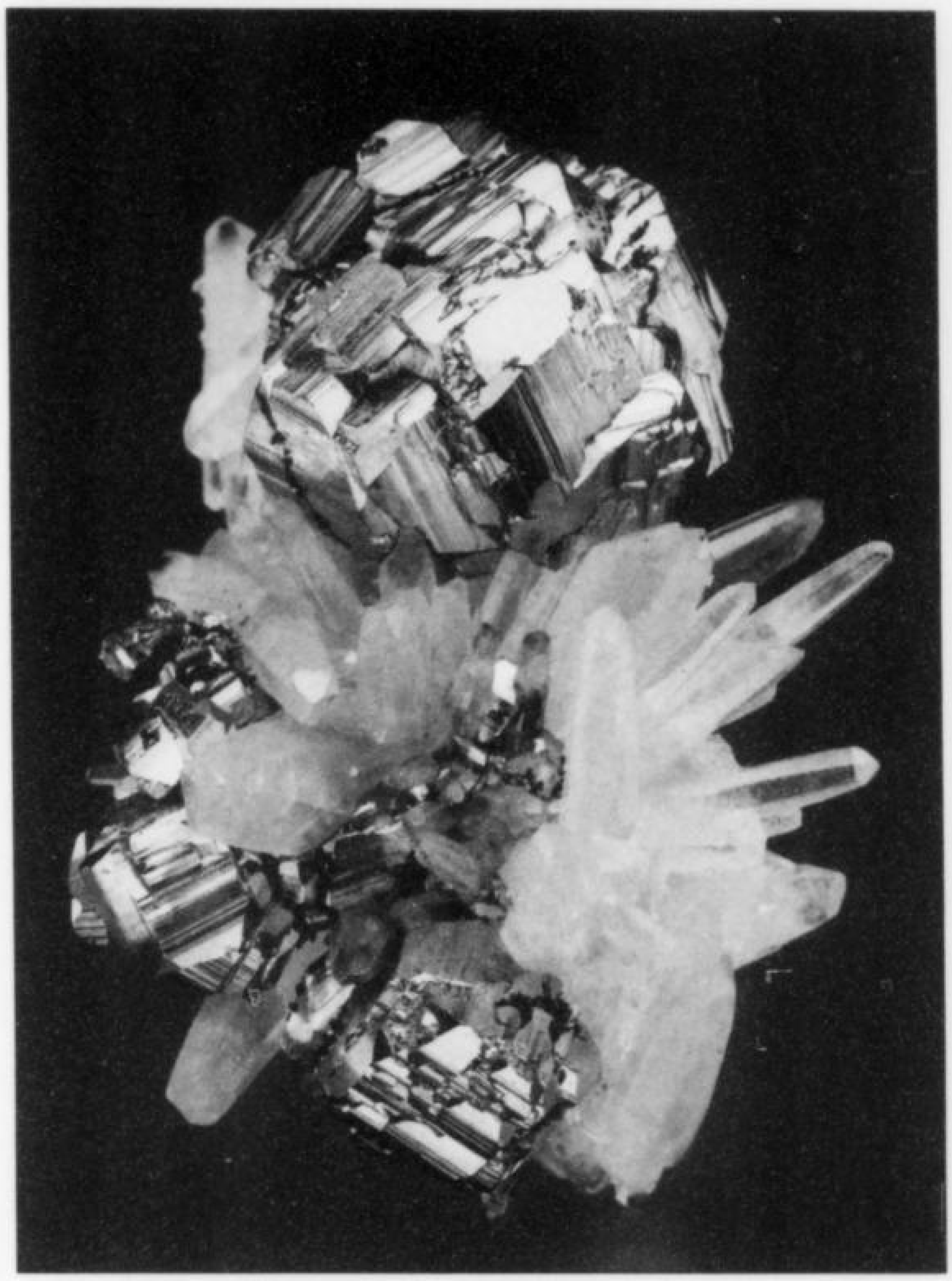


Figure 70. **Pyrite with quartz, 4.7 cm, from the Leonard mine. Canadian Museum of Nature collection; Jeff Scovil photo.**

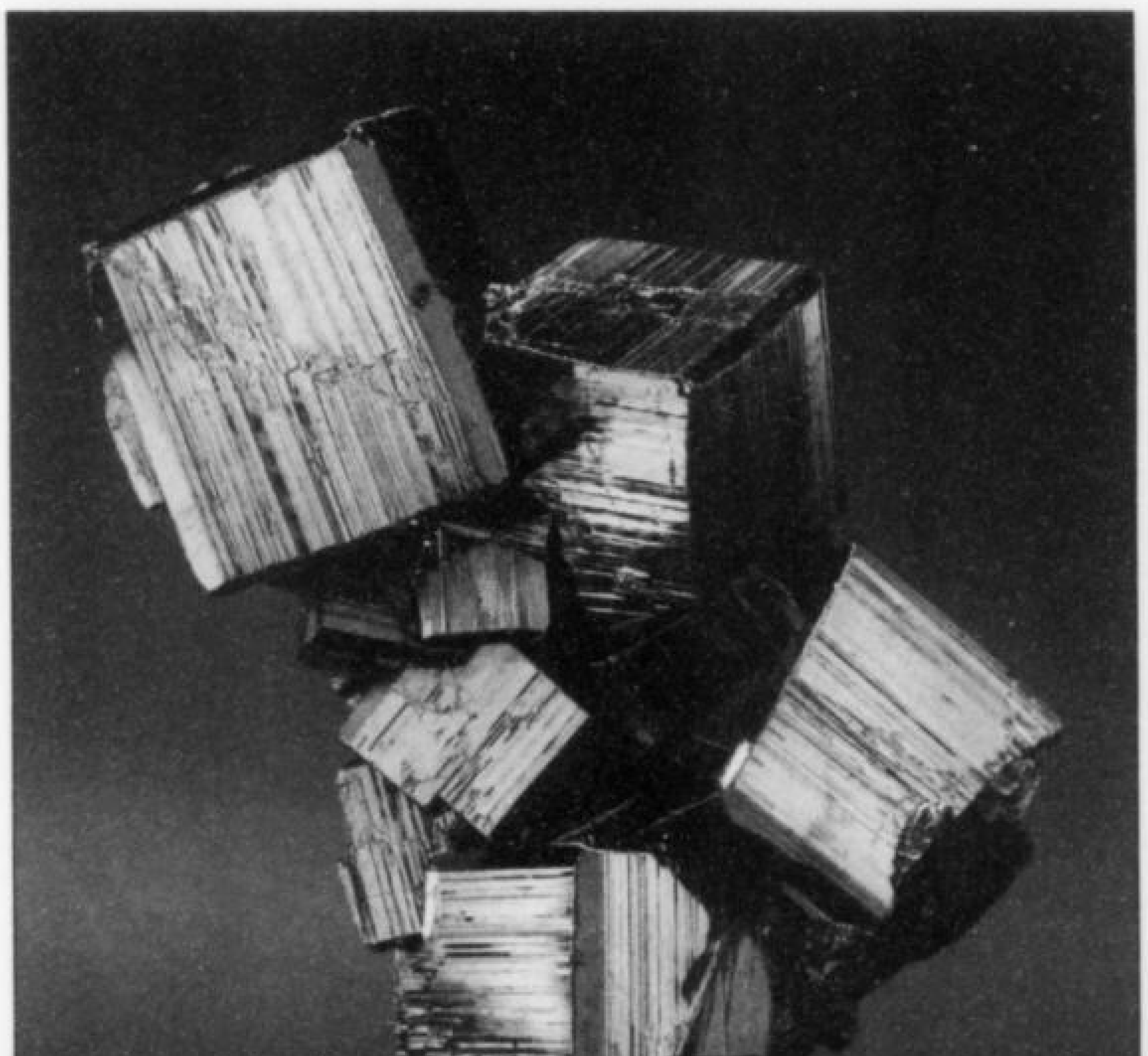


Figure 71. **Pyrite crystal cluster, 9 cm, from the Leonard mine. Peter Bancroft collection; Harold and Erica Van Pelt photo.**

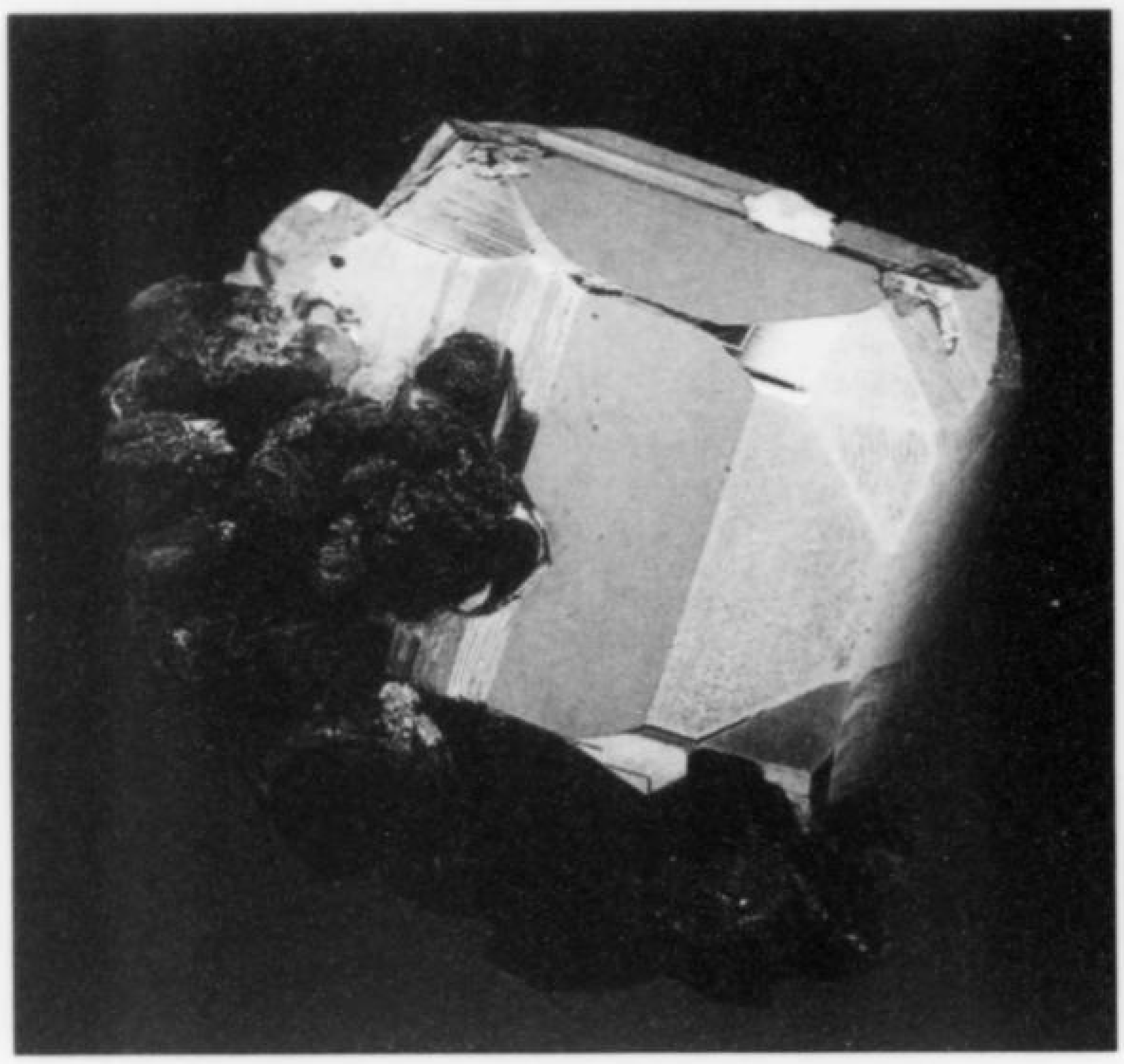


Figure 72. **Pyrite crystal with wurtzite, 4.3 cm, from the Leonard mine. Francis Benjamin collection; Jeff Scovil photo.**

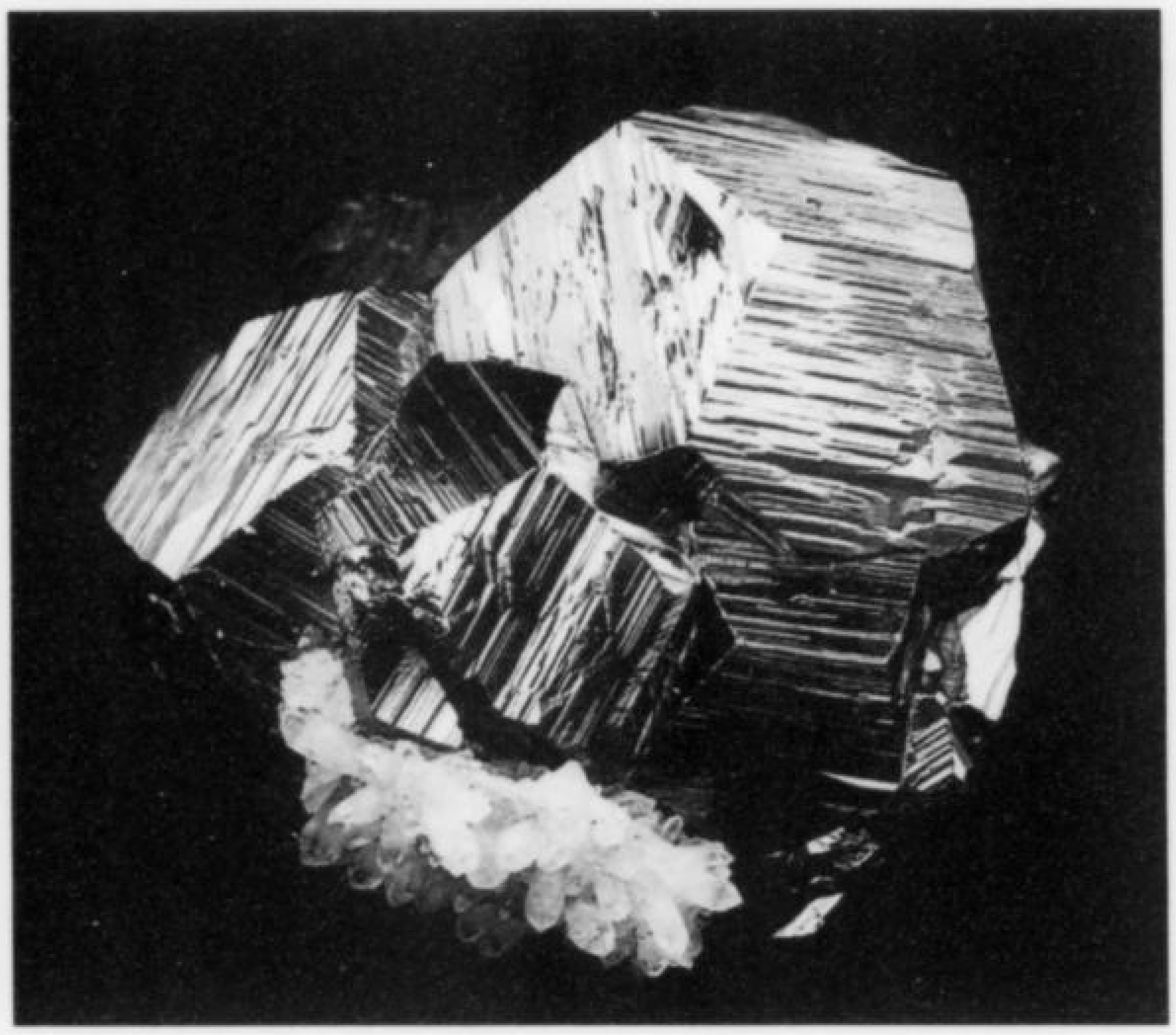


Figure 73. **Pyrite crystal cluster, 4.5 cm, from Butte. Smithsonian collection and photo.**

but for beauty of the individual specimen and diversity of mineral associations, Butte pyrite is competitive with that from any other locality.

Together with quartz, pyrite is one of the most abundant minerals in the Butte ore deposits. It was known to the earliest workers there (Blake, 1887b; Emmons, 1887, Brown, 1894; Emmons and Tower, 1897; Weed, 1912; Sales, 1914). Pyrite is an early mineral in the Butte veins and frequently occurs as large, crystalline masses, intergrown with quartz and partially replaced by the various copper-bearing species. It also occurs as crystals completely enclosed in the copper ore minerals. It is far more interesting as crystals projecting into vugs. Fortunately for collectors, these were extraordinarily abundant right up until the end of Butte underground mining

Pyrite crystals from the Main Stage vein deposits are generally pyritohedral or, more rarely, octahedral. Octahedra modified by cubic faces are found, and diploidal modifications are also known. Interestingly, simple cubic pyrite crystals are essentially absent from the big veins. Some crude cubes of pyrite occur in the altered wall rocks adjacent to the veins, but they are scarce in this setting as well.

The pyrite crystals range up to 10 cm in maximum dimension and occur very commonly in the 1 to 3-cm size range. They may be perfectly crystallized at any size. The crystals are brassy yellow in color, with a bright metallic luster. Associated minerals may include all of the copper-bearing species, sphalerite, galena, quartz, barite, the carbonate minerals, and others. Octahedral pyrite crystals nestled in beds of white to clear quartz crystals, or pyritohedra sitting among bright enargite prisms from Butte make breathtaking specimens.

Crystals of pyrite occurred at nearly every Butte mine, and were so reported by the early workers listed above. Smith (1941) reported finely crystallized pyrite from the Belmont mine. Other Butte mines which produced exceptional pyrite include the East Colusa, the Leonard, the Mountain Con, the Original, and the Steward. A few good pyrite specimens were also found in the Main Stage veins exposed in the Berkeley pit.

Pyrolusite MnO_2

Fibrous, submetallic black pyrolusite was reported from the Butte district by both Weed (1912) and Pardee (1918). It was especially abundant in vein outcrops on the north side of the district, particularly in the Rainbow vein and northward, where it was a product of the oxidation of rhodochrosite and rhodonite. Pyrolusite from the Zadoc claim in north Butte consists of silky black fibers, averaging about 1 cm in length, coating cavities in white quartz (RJ). The mineral occurs as more blocky crystals averaging about 4 mm in length at the Marg(ar)et Ann mine, also in north Butte (JL).

Pyromorphite $Pb_5(PO_4)_3Cl$

"Stains of oxides and phosphates of lead" were reported from the Alice mine by Blake (1887b), but pyromorphite was not recognized in the studies of Guilbert and Zeihen (1964). The mineral is therefore here reinstated from Butte. A single specimen came to the senior author (RJ) in a small lot of samples collected from the Berkeley pit prior to 1962. Because it was collected so early in the life of the mine, it obviously came from the pit's upper benches. The identification was confirmed by both X-ray powder diffraction and electron probe micro-analysis.

Butte pyromorphite consists of brown, hexagonal, barrel-shaped crystals with a typical waxy luster. The crystals average about 2 mm in length and are deposited on vug surfaces in cavernous quartz. Pyromorphite is abundant on the single specimen. Both the quartz and some of the pyromorphite are coated with mossy chalcocite.

Quartz SiO_2

Quartz and pyrite are the two most abundant constituents of the Main Stage vein deposits (Weed, 1912; Sales, 1914). Quartz is also abundant in the vein wall rocks and in the pegmatites of the Butte and Whitehall areas, occurring commonly in megascopic crystals.

The best description of Butte quartz is that of Smith (1941). Quartz crystals from the Central and Intermediate Zones are milky to water-clear. They may have a faint amethystine or smoky tint, and range up to 5 cm in length. Generally, they are very slender, and may be studded with crystals of pyrite, enargite, chalcocite, bornite, and other minerals. A second generation of quartz may

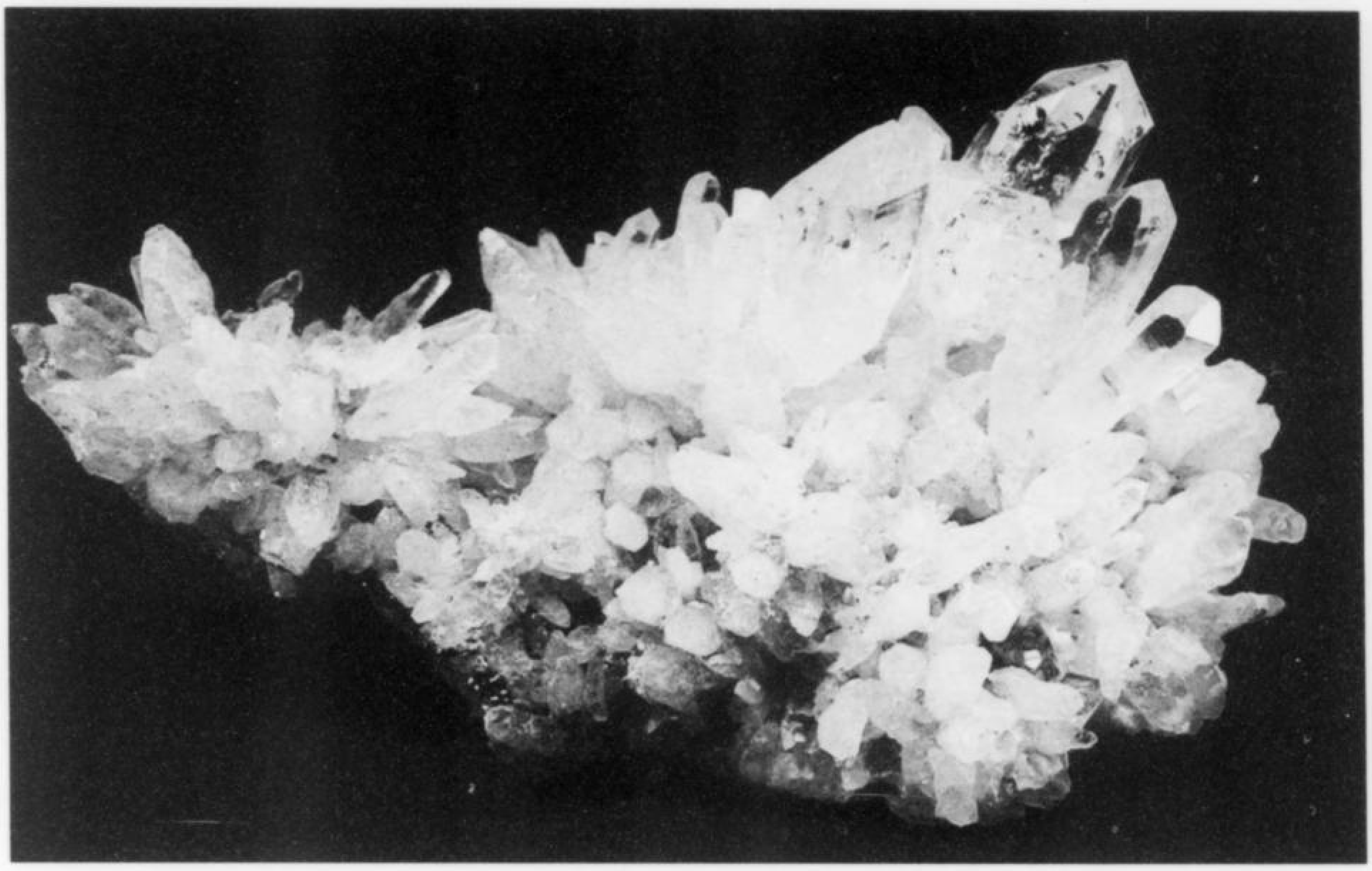


Figure 74. **Quartz crystal cluster, 7.5 cm, from Butte. R. Jenkins collection; G. Grenier photo.**

form druses atop the sulfides as well. "Scepter" crystals with a faint smoky tone are also known; the specimens are probably from the Central Zone, but the mine is unknown. Other specimens from the Central Zone consist of long, slender crystals diverging essentially from a single point (CL). These are very attractive. In the Peripheral Zone quartz crystals are generally milky to gray in color. These gray crystals have been found at the mines on both the Rainbow and Emma-Travona veins. Small milky quartz crystals are very common, overlying rhodochrosite crystals in samples from the Emma and Travona mines (Pardee, 1918). A specimen from the 800 level (244 m) of the Lexington mine exhibits pink rhodochrosite phantoms enclosed within a 5 cm quartz crystal (RJ). A bornite specimen from the Steward mine in the collection of the U.S. National Museum exhibits quartz pseudomorphs to 2 cm after barite tablets on the face opposite the bornite.

Rhodochrosite $MnCO_3$

Butte has probably produced more specimen-grade rhodochrosite than any other locality in the world, but only a small part of it has ranked in quality with the best from Colorado, Peru, or South Africa. Nevertheless, Butte rhodochrosite is interesting for its diversity of colors and associations and for the large number of individual mines which produced good specimens.

Miller (1971) described the better specimen material from several Butte mines. The Emma mine in uptown Butte produced rhodochrosite specimens by the hundreds. These consist of flat plates and groups of various sizes and shapes. Individual rhombohedral crystals reached 7.5 cm on an edge. Isolated rhombs on drusy quartz were also found. The color is an opaque, milky pink to rose and the rhodochrosite is commonly coated with minute quartz crystals or studded with tiny pyrite cubes or chalcopyrite and tennantite crystals. When the sulfides are partially or wholly oxidized, the rhodochrosite becomes pitted and discolored. In a very few specimens from the Emma mine the rhodochrosite is transparent and gemmy (L. Zeihen, oral communication, 2000). In one interesting specimen from the Emma mine the rhodochrosite forms stacks of centimetric rhombohedra coated by a second generation of tiny rhodochrosite crystals. The second generation of crystals lends the specimen an unusual pearly luster.

The Elm Orlu mine, northwest of Butte along the Rainbow vein, produced a few groups of lavender rhodochrosite, while the Travona mine, southwest of the Emma, produced several groups of red rhodochrosite comparable in color and brightness to material from Colorado. Pardee (1918) also reported beige rhodochrosite from the Travona mine. Other specimens of Travona mine rhodochrosite are similar to material from the Emma, but tend to contain more quartz.

Other rhodochrosite localities at Butte include apparently all of the other mines along the Rainbow vein (Blake, 1887b). However, present knowledge of the vein's mineralogy suggests that this author mistook considerable rhodonite for rhodochrosite. The upper portions of the Black Rock vein, a split in the Rainbow system, were composed exclusively of quartz and rhodochrosite (Sales, 1914). Brown (1894) reported the species from the Anselmo mine, as well as the Hope and Volunteer claims. Weed (1912) stated that it was relatively abundant at the Lexington mine where it was associated with rhodonite. Specimens from the 800 level (244 m) of the Lexington mine consist of brown and bright pink translucent rhombohedra, averaging about 8 mm on an edge (RJ), associated with quartz, sphalerite, and pyrite. A small amount of brilliant rose-red rhodochrosite also occurred at the Lexington mine. Weed (1912) noted the occurrence of rhodochrosite at several of the silver properties in Missoula Gulch and in the Blue Fault-age veins of the Gagnon mine. In this latter occurrence, the mineral was associated with bornite and other Cu minerals. Rhodochrosite cemented sulfide breccias on the deep levels of the Belmont mine (Meyer *et al.,* 1968), and poorly crystallized material was found in the Mountain Con mine (L. Zeihen, oral communication, 2000). Ratcliff (1973) described minor vein-hosted rhodochrosite in the present Continental pit area. Very small amounts were also found with smithsonite, cerussite, and other minerals in the poorly developed oxidized zone above the chalcocite enrichment of the Berkeley pit (McClave, 1973). In a sample from the pit examined by one of the authors (RJ) the rhodochrosite is pale pink and finely granular.

Some readers will recall a number of mineral dealers marketing rhodochrosite labeled "Leonard mine" in the mid to late 1980's. The material is unquestionably rhodochrosite, occurring as cavernous groups of bright to rather dull pink rhombohedra averaging about 6 mm on an edge, but the provenance is doubtful. The

Figure 75. **Rhodochrosite crystal cluster, 7.5 cm, from the Lexington mine. George Loud collection; G. Grenier photo.**

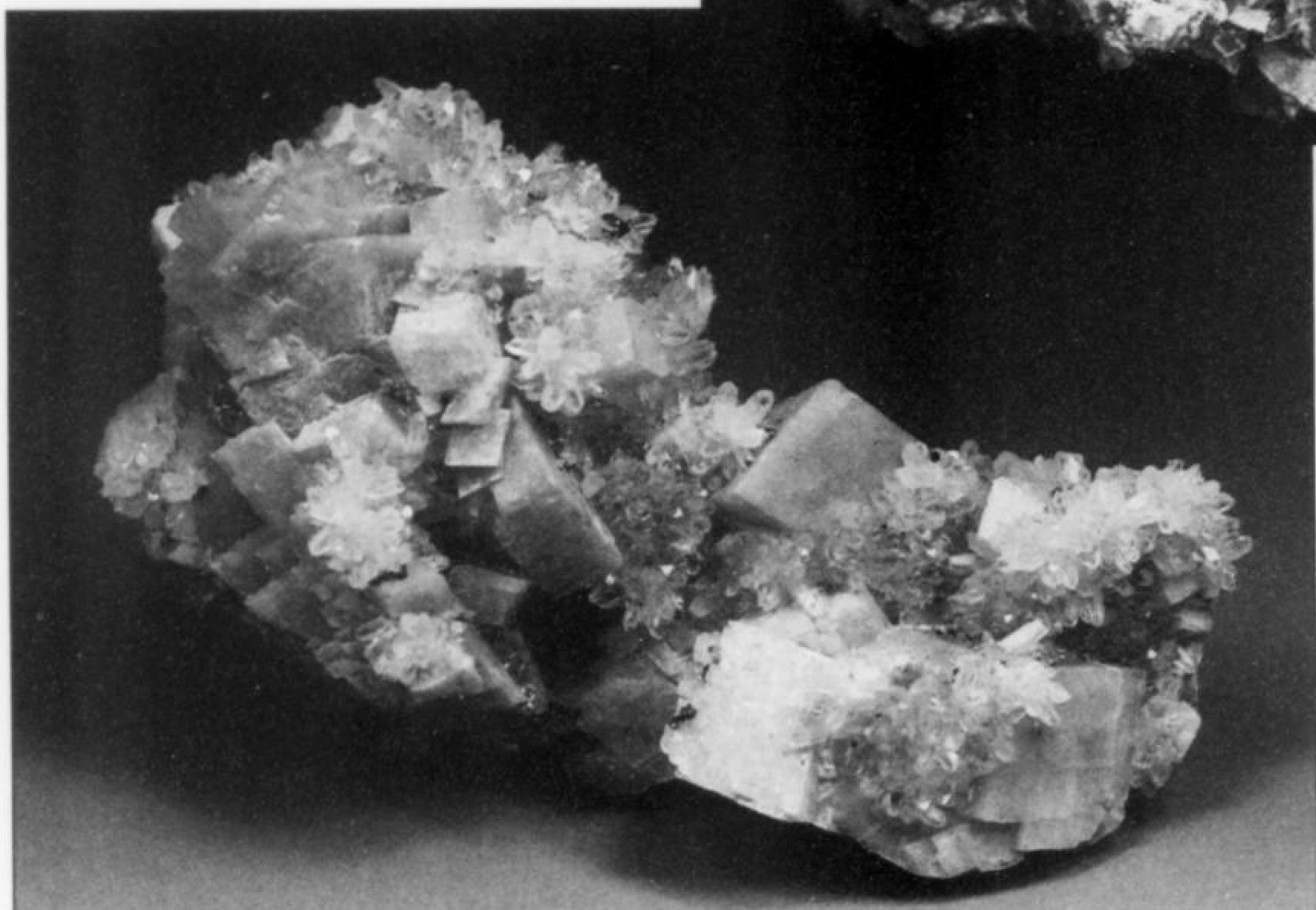


Figure 76. **Rhodochrosite crystals with quartz, 5 cm, from the Travona mine. R. Jenkins collection; G. Grenier photo.**

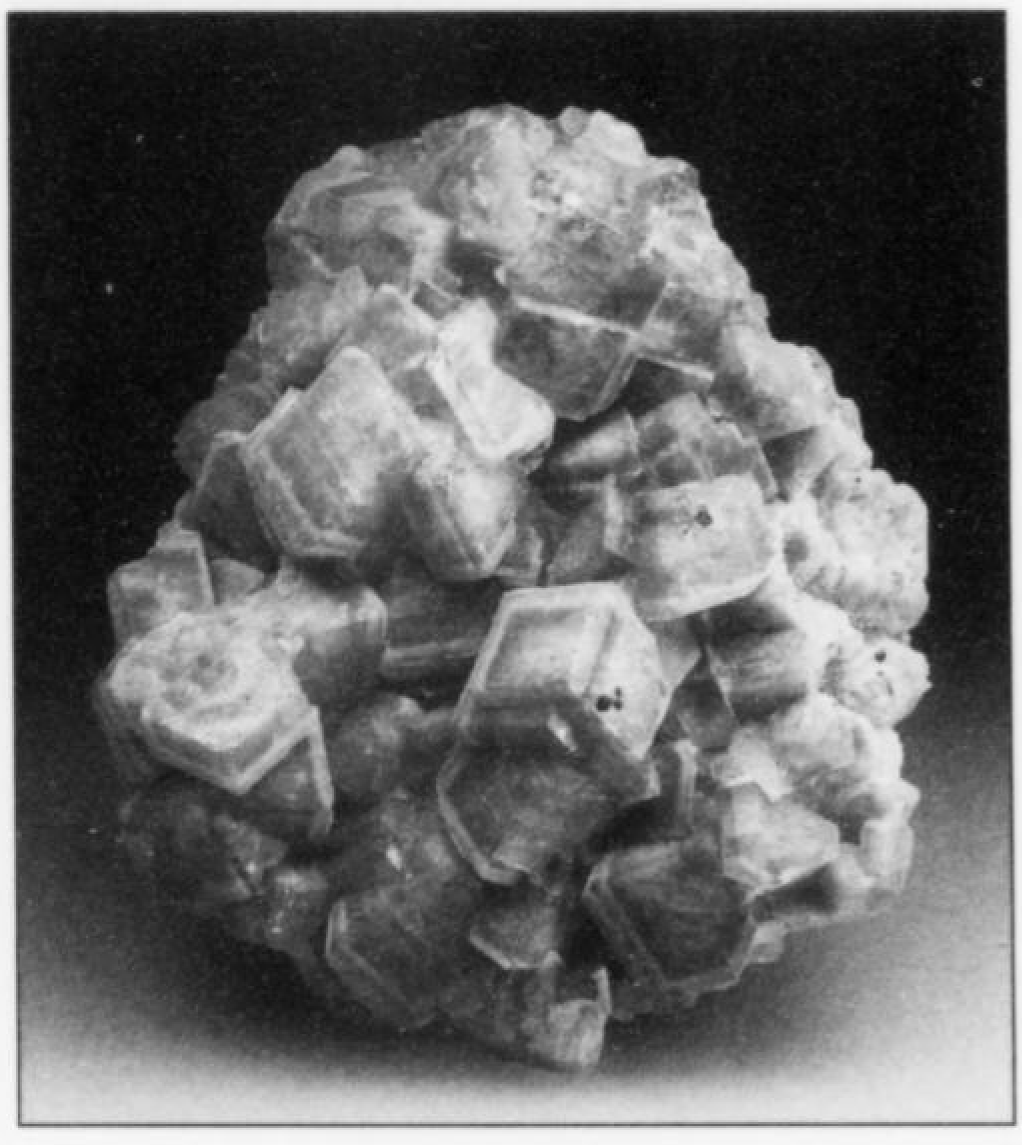


Figure 77. **Rhodochrosite crystal cluster, 7 cm, from Butte. Frederick Pough collection; Jeff Scovil photo.**

Leonard mine was in the heart of the Central Zone, as a result of which rhodochrosite should not have occurred there in any significant quantity. L. Zeihen (oral communication, 2000) regards the location as very doubtful. Specimens the authors have seen do resemble some rhodochrosite from the Emma and Travona mines, however.

Rhodonite $(Mn,Fe,Mg,Ca)SiO_3$

Rhodonite was first mentioned in the Butte literature by Emmons (1887). The mineral was abundant at all of the mines along the Rainbow vein including the Alice, Amy-Silversmith, Goldsmith, Magna Charta, Moulton, and Valdemere mines. Weed (1912) noted rhodonite from the Lexington mine on the State vein system, where it was common together with rhodochrosite. The same author reported rhodonite from the Late(r) Acquisition, Nettie, and Philadelphia claims on the southwestern side of the district. He also noted rhodonite in the Original, Gem, and Clear Grit veins, on the southern fringe of the Intermediate Zone. Bard and Gidel (1914) observed that in deposits containing both species, the relative abundance of rhodonite and rhodochrosite did not change with increasing depth.

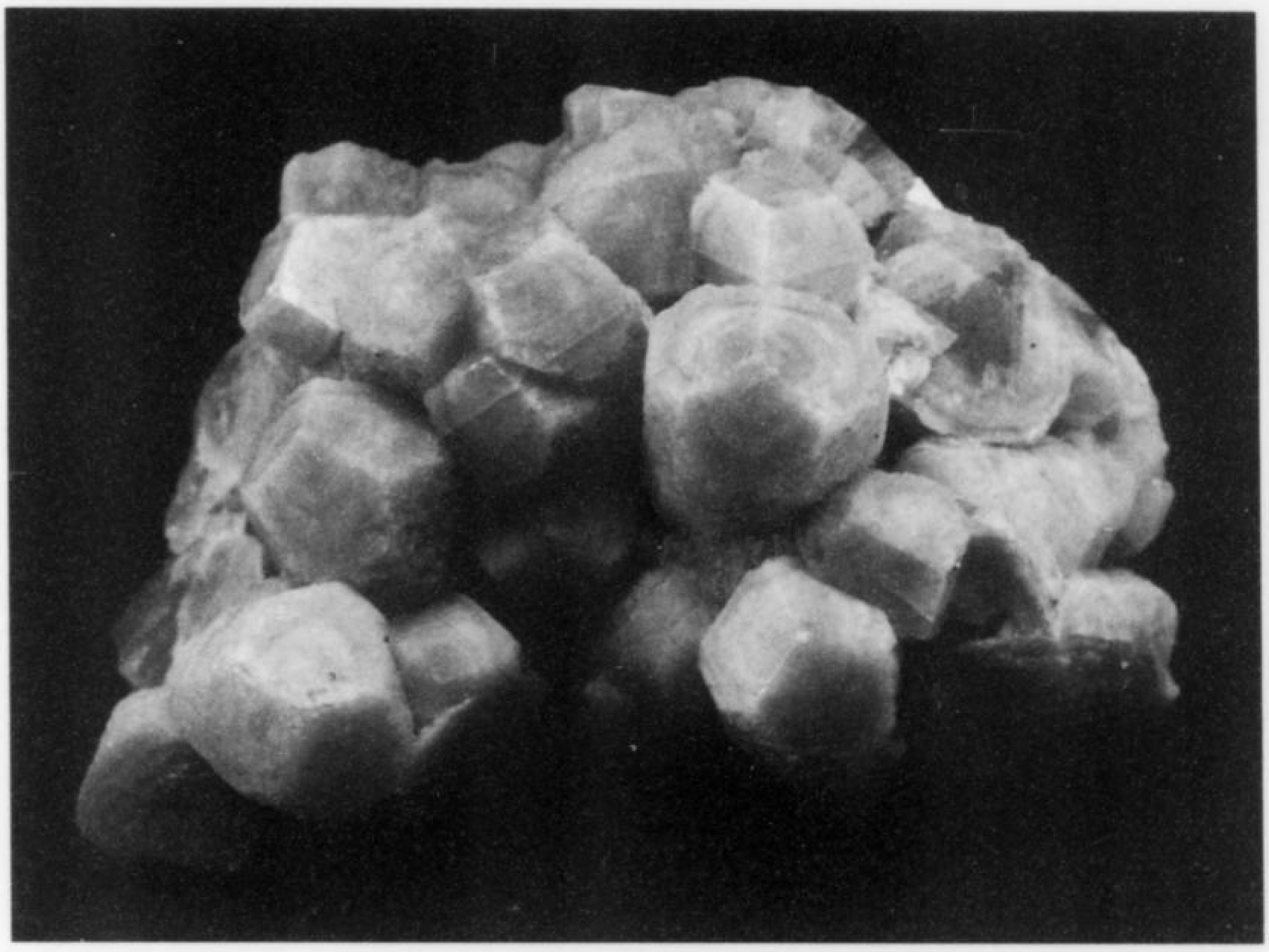


Figure 78. **Rhodochrosite crystal cluster, 4 cm, from the Emma mine. R. Jenkins collection; G. Grenier photo.**

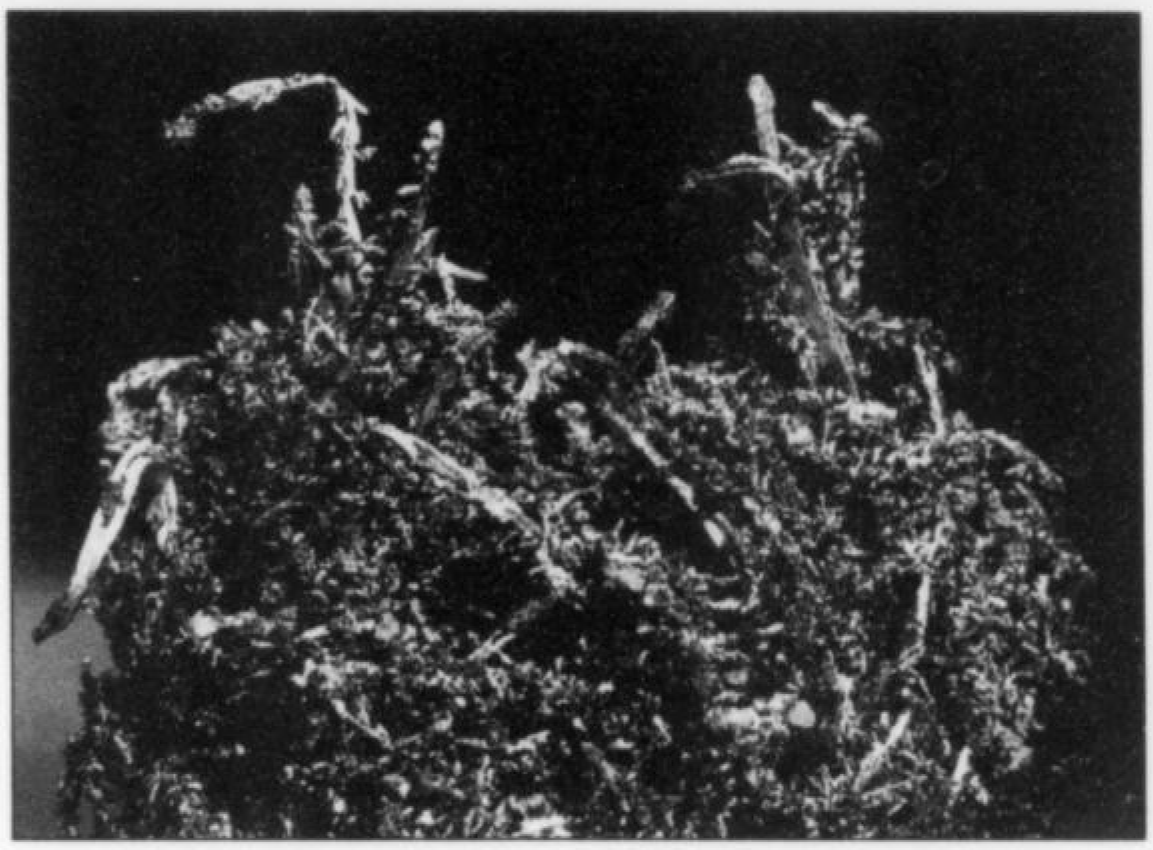


Figure 79. **Wire silver mass, 4.8 cm, from Butte. Forrest Cureton collection; Wendell Wilson photo.**

The most complete description of Butte rhodonite is that of Pardee (1918). The mineral was never found crystallized, but rather occurred as compact, fine-grained masses, frequently intergrown with quartz. The color varies from pale pink to bright rose, and the rhodonite takes a good polish. Polished material tends to appear more intensely colored. Some rhodonite from the Alice mine dumps was apparently worked as an ornamental stone in the early days, and slabs of this material occasionally appear in dealers' lapidary stocks even to this day. In addition to quartz and rhodochrosite, other species associated with rhodonite include galena, helvite, sphalerite, and very small amounts of pyrite. Most of these occur as small masses or crystals imbedded in the rhodonite. Rhodochrosite and quartz are occasionally found as discrete crystals on rhodonite in vugs.

Siderite $FeCO_3$

Pardee (1918) first recognized siderite (an Mn-rich variety) at Butte on the dump of the Burlington mine on the southwestern side of the district. The species was also reported by Smith (1941) from some unnamed veins north of Big Butte and Walkerville. Guilbert and Zeihen (1964) recorded the mineral in minor to trace amounts in both the Intermediate and Peripheral Zones. In none of these references are crystals mentioned, or are the occurrences described.

Crystals of siderite from Butte may be the typical golden-brown rhombohedra, or scalenohedra so acute that the crystals are virtually acicular in habit. Rhombic crystals averaging about 1 mm across have been found coating rhodochrosite on the 800 level (244 m) of the Lexington mine (RJ) and also encrusting quartz crystals at the Orphan Girl mine (RJ). One extraordinary example from the latter locality is a flat plate of 2 cm stalactites composed of minute brown rhombohedra, overgrown on larger rhodochrosite crystals. Acicular siderite has been found associated with botryoidal chalcopyrite at the Mountain Con mine (JL, RJ), and as mats on quartz-chalcopyrite rock at the Steward mine (JL, RJ). The siderite needles range from 2 to 4 mm in length and are a dull brown color.

Silver Ag

At one time late in the last century, silver was relatively plentiful at Butte, but now native silver specimens from the district are rare and precious. Blake (1887b) described specimens (apparently) from the Alice mine on the Rainbow vein, which must be breathtaking. These consist of mats of entangled wires completely covering fracture surfaces. The individual wires are "several inches long." He also reported flakes, scales, and impregnations along the vein median line filling the open space between quartz crystals. Similar material occurred at the other silver mines on the Rainbow vein. Emmons and Tower (1897) reported native silver as coatings on fractures in chalcocite in the "copper area." Weed (1912) recognized tiny wires in 2 to 6 mm vugs in bornite and chalcocite on the upper levels of the Parrot mine. Silver also occurred as coatings and mossy aggregates elsewhere in the Parrot. The same author reported native silver as mossy aggregates on fracture surfaces with chalcopyrite, pyrite, galena, and sphalerite at the Kit Carson claim on the extreme western side of the district.

Very thin wires of native silver perched on stubby quartz crystals were found at the Leonard mine. Tiny scales on slickenside surfaces were found on the 800 level (244 m) of the Lexington mine (JL). Wire silver was also found in the Alice-Lexington

Figure 80. **Smithsonite on barite crystals, 6 cm, from Butte. George Loud collection; G. Grenier photo.**

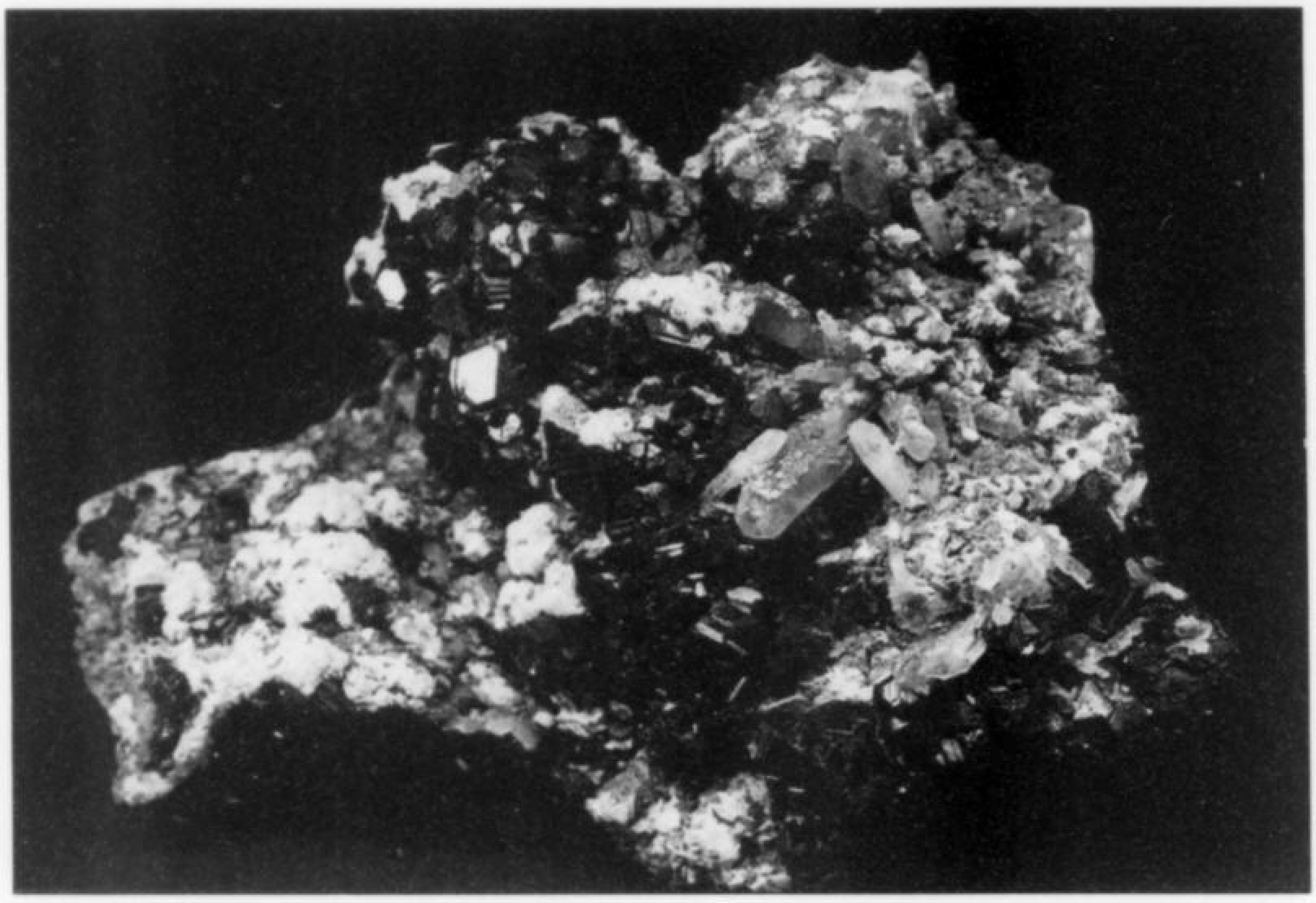


Figure 81. **Sphalerite with quartz, 9 cm, from the Lexington mine. R. Jenkins collection; G. Grenier photo.**

Tunnel (RJ). Smith (1941) reports pseudomorphs of native silver after pyrite and galena; no localities are specified, but presumably they are from mines in the Peripheral Zone.

Smithsonite $ZnCO_3$

Smithsonite is not a common mineral at Butte, despite the abundance of sphalerite. McClave (1973) reports smithsonite with cerussite, rhodochrosite, and other minerals in the weakly oxidized zone at the Berkeley pit. A small quantity of typical, green-blue, botryoidal smithsonite has also been found at the Leonard mine (DPh). Orange-yellow botryoidal smithsonite has also been found on blocky white barite crystals from an unknown mine.

Sphalerite ZnS

Sphalerite is an important ore mineral at Butte, large amounts of which were mined at the Anselmo, Badger, Black Rock, Elm Orlu, Emma, Orphan Boy, and Orphan Girl mines. Sphalerite also occurred in at least trace amounts in most of the mines of the copper-producing area.

Despite the abundance of sphalerite in the Butte ores, crystals of the mineral are not common. Emmons and Tower (1897) report sphalerite from the Bellona mine at the west end of the Syndicate vein and from the upper levels of the Gagnon mine, but they state, "It is always crystalline, but rarely with crystal outline." Weed (1912) mentions vuggy sphalerite-quartz ore from the Snowball claim, but no crystals are described. Similar material also occurred at the Mountain Con mine.

Sphalerite crystals from Butte consist of honey brown to black dodecahedra ranging from 0.5 to 1 cm across. Examples have been examined from the Black Rock mine (RJ), from the Syndicate pit (JL, RJ), from the 800 level (244 m) of the Lexington mine, and from the Steward mine (FP). Crystal specimens from the Syndicate pit, the Steward mine, and especially the Lexington mine are very attractive. Sphalerite from the Syndicate pit and from the Steward mine is associated with crystallized galena.

"Wurtzite" was first reported from the 200 and 300 levels (61 and 91 m) of the Gagnon mine by Pearce (1887), as brown to black masses and as rare, small, hemihedral hexagonal pyramids associated with quartz and barite. "Wurtzite" was also reported from the 1,600 level (488 m) of the Gagnon, as well as the West Colusa and Leonard mines by Weed (1912). One rich specimen from the

Leonard mine consists of brown-black masses and microstalactites coating a fracture surface in quartz-enargite ore. The area coated by "wurtzite" measures about 10 x 10 cm. Guilbert and Zeihen (1964), however, have shown that all Butte "wurtzite" is actually sphalerite. Such specimens are thus properly labeled sphalerite pseudomorphs after wurtzite.

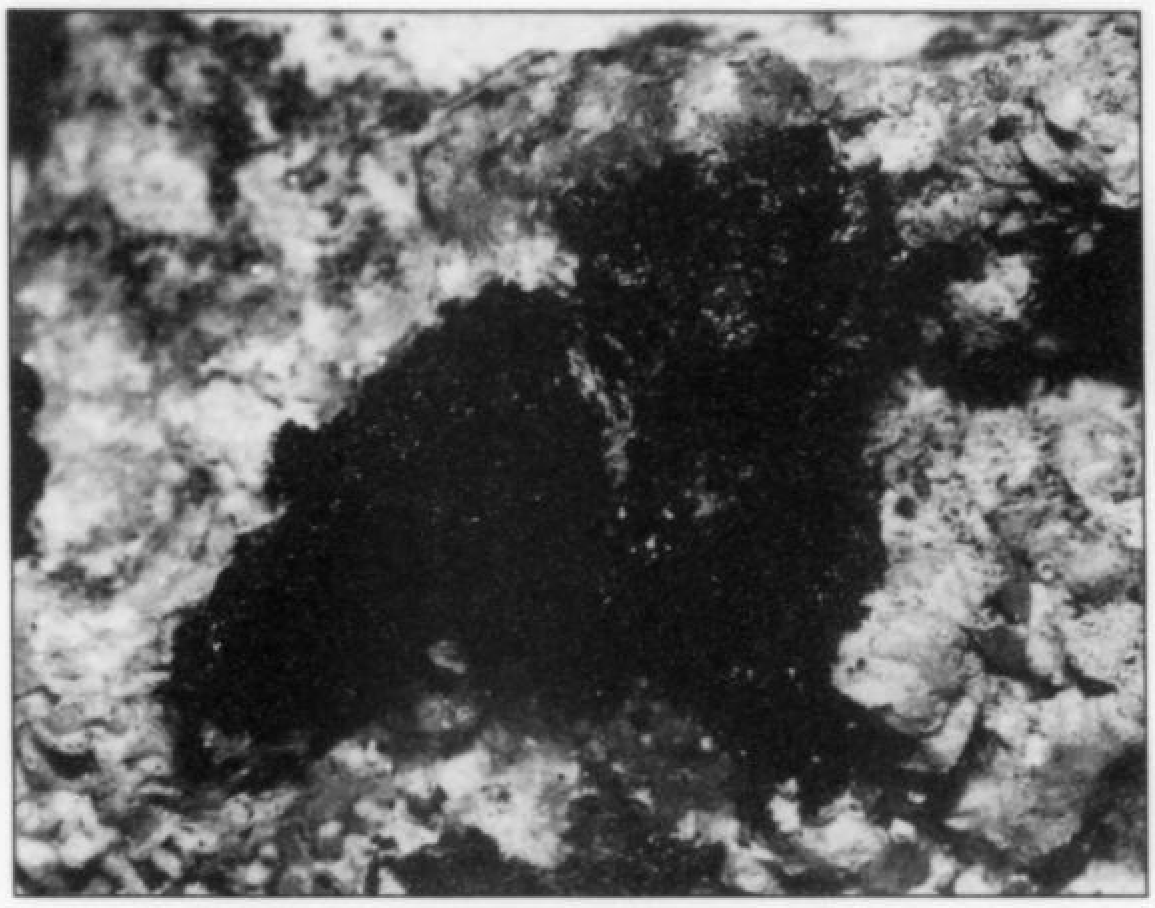


***Figure 82.* Stephanite in crude crystals, 1.5 cm, on quartz and rhodochrosite, from the Goldsmith mine. R. Jenkins collection; G. Grenier photo.**

Stephanite Ag_5SbS_4

Stephanite was apparently one of the more abundant silver minerals at Butte in the early days. Brown (1894) reported its occurrence (without description) in the mines of what he called "the Northern Silver Belt." This is the Rainbow vein of the Peripheral Zone. Smith (1941) described large masses *and* crystals from the Goldsmith and Amy-Silversmith mines of this area. He describes one specimen weighing about 3 kg, of which about 75% is stephanite. A second specimen from the Goldsmith mine exhibits a tabular crystal of stephanite measuring 3.5 x 3.5 cm. Stephanite crystals from the Goldsmith are implanted on quartz or pale pink, chalky rhodochrosite and are associated with pyrite and chalcopyrite.

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

Although tennantite at Butte was known to Weed (1912), that author reported no crystals of the mineral. Drusy, glistening tetrahedra of the species were, however, described by Sales (1914) from the Badger, Gem, and Speculator mines. These were locally abundant, coating fractures and the walls of vugs. Smith (1941) described similar material from the Anselmo, Diamond, High Ore, Mountain Con, and Steward mines. In neither of these reports is the size of the crystals given. Specimens examined by the authors exhibit tetrahedra averaging about 1 mm in maximum dimension. In addition to the fracture coatings, tennantite crystals also form aggregates of considerable size. Smith (1941) also reported hollow casts of tennantite after enargite, but no mine name was given. Meyer *et al.* (1968) mentioned drusy tennantite and chalcopyrite crystals, both perched on rhombohedra of rhodochrosite in some of the ores of the Peripheral Zone. Again no mine names were given. Another variety of tennantite found at the Leonard mine consists of dense nodular aggregates of minute, dull black tetrahedra, sometimes studded with tiny quartz crystals. These resemble sycamore seed pods (CL).

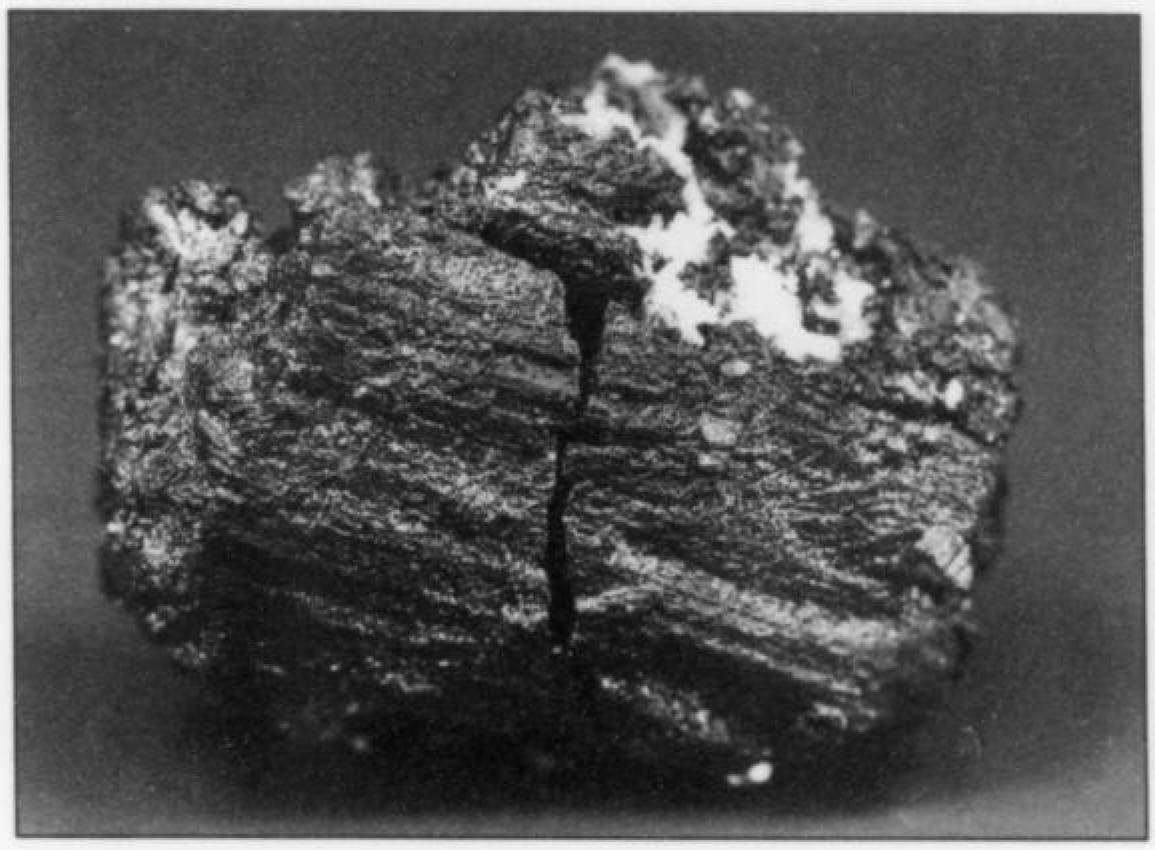


***Figure 83.* Tennantite pseudomorph after enargite, 3 cm, from Butte. Fred Parker collection; G. Grenier photo.**

Tenorite CuO

Tenorite was reported from Butte by Emmons and Tower (1897) and Weed (1912). The latter noted the mineral without description in the East Ridge area. He also mentioned earthy black copper oxide at several unspecified localities in the area of the Main Stage veins. A number of specimens collected by Anaconda geologist Gerry Gray in the Continental mine area in 1957 contain tenorite. The mineral consists of compact-granular to fibrous black masses associated with cuprite, native copper, chrysocolla, and other minerals. The site of the Continental mine is the East Ridge area of Weed (1912).

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

Tetrahedrite is not abundant at Butte. Emmons and Tower (1897), Weed (1912), and Sales (1914) all reported the mineral from the locality. The latter two authors described bronze and more typical gray, metallic, massive varieties. However, the former is probably colusite (Landon and Mogilnor, 1933), while the more typical of the latter material is nearly always tennantite (Guilbert and Zeihen, 1964). L. Zeihen (oral communication, 2000) recalls identifying tetrahedrite only in the ores of the Marg(ar)et Ann mine, well to the north of the Rainbow vein. Brown (1894), however, mentioned tetrahedrite from the Valdemere and other mines at the eastern end of the Rainbow vein where it carried a part of the silver values.

Turquoise $CuAl_6(PO_4)_4(OH)_8 \cdot 4H_2O$

A little very scarce, very pale blue turquoise was found on the upper benches on the west side of the Berkeley pit (Guilbert and Zeihen, 1964; L. Zeihen, oral communication, 2000).

Wulfenite $PbMoO_4$

Weed (1912) reported wulfenite in unusually deep oxidized zones on the 1,200 level (366 m) of the Anaconda mine and on the 1,400 level (427 m) of the Pennsylvania mine. Wulfenite was found in small seams, but the occurrences were not further described. One Butte wulfenite specimen exhibits 1-mm dark brown tablets lying flat on a fracture surface in chalcocite-enargite ore (RJ), associated with a little malachite. The mine location is unknown.

Erroneous Reports

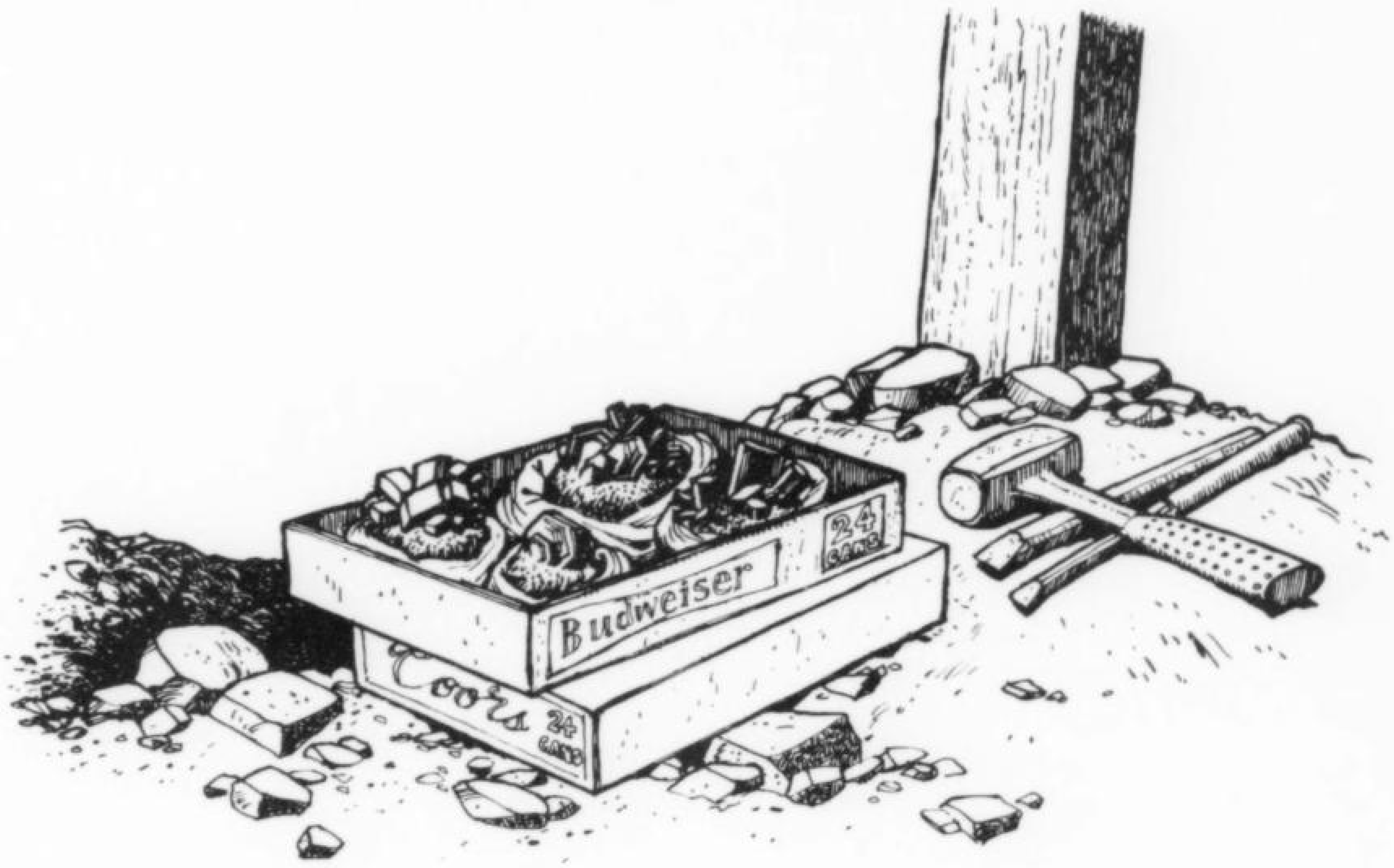
We have already pointed out two inconsistencies in the labeling of Butte minerals in the mineral descriptions; here, we would like to make note of some others. As with any large mining district with an extensive mineral list, many mineral species have been attributed to Butte which do not in fact occur there. Some of these misattributions have resulted from mistaken identifications, some simply from changes in nomenclature. Examples of these are numerous in the early Butte literature. Harter (1928), for instance, reported **franklinite** and **zincite** from Butte. With today's knowledge of the geology, both of Butte and of Franklin-Sterling Hill, this is foolishness. But in another time, it was perhaps believable. Still other misattributions consist of locality errors. These have resulted from collector error and perhaps even from willful misrepresentation.

An example of one or the other of these latter two sources of error is the **ludwigite** supposedly from the Leonard mine, which was marketed by a number of mineral dealers in the 1980's. The material was available in such large quantities that it was undoubtedly wholesaled by the person who had collected it. This mineral is certainly ludwigite but its Butte provenance is extremely unlikely. Ludwigite is a relatively rare mineral which occurs in a few boron-bearing skarn deposits. There are no carbonate rocks in the near vicinity of the Butte mining district and hence, no development of skarns. Ludwigite does, however, occur at Phillipsburg and near Helena, Montana.

Although a little faintly **amethystine** or **smoky quartz** has been found in the Main Stage vein deposits of the mining district, much larger quantities of better quality material have been mined from pegmatite bodies in the southern part of the Boulder Batholith. One occasionally encounters specimens of these in dealers' stocks labeled "Butte." However, localities for the better-quality quartz specimens are outside of the mining district proper, and many are on the eastern side of the Continental Divide closer to Whitehall, Montana. Similarly, **schorl** specimens from the Homestake Pass-Delmoe Lake area are sometimes labeled "Butte" but these, too, are outside the mining district.

The senior author (RJ) encountered several other examples of mislabeling in the past year, all with specimens coming from the same old collection. One example was a specimen of **magnesiochromite** and **zaratite**, which was labeled "Butte." If it is from Montana at all, it is from the Stillwater Complex near Livingston. A second specimen was a pretty example of **rhodochrosite**, labeled "Lexington mine, Butte." The rhodochrosite bears no resemblance to any examples of the mineral which we have seen from Butte, but it bears a striking similarity to some rhodochrosite from the Sunnyside mine, Colorado. A third specimen is a sample of **mottramite**, together with an X-ray pattern identifying the mineral as such. While the chemical composition of mottramite certainly does not preclude its existence in the oxidized ores at Butte, especially in the Peripheral Zone, the matrix does not resemble anything which we have ever observed from Butte.

Figure 84. **Collectible copper desk accessories manufactured in Butte, 1920's to 1950's. Herb Obodda collection; Jeff Scovil photo.**



Collecting at Butte

The following collecting anecdotes were provided by Duane Johnson of Butte. Mr. Johnson was hired by Frank Monninger, ACM-president, Montana Mining Division, in August, 1974 as Geologist-Mineralogist and official company Specimen Collector. In that the underground operations were shut down only six months later, some of his activities were prematurely curtailed. Even so, his memories are interesting:

My main emphasis was the Leonard mine, because I had to make the Anaconda Company money, and I felt my best chances for hitting "the Mother Lode" was in good crystallized specimens of covellite, chalcocite, enargite, colusite, digenite, djurleite, pyrite, quartz, or combinations of these minerals.

My day in the Leonard mine would start by driving to the Kelley mine, changing into my work duds in the dry (change room and shower), grabbing my mine lamp from the lamp room, move my name and i.d. tag from *out* to *in* on the peg board, and walk over to the sheets (station platform) to wait for the cage. The cage was three-tiered, and the lowest tier was loaded first with about fifteen miners squeezed in very tight. Loading all three tiers probably took about fifteen minutes; and if it was cold outside, and it was usually about 10°F in the winter mornings or colder, the wind chill at the collar of the shaft could be as much as –50°F. The trick was to wait for the last tier to load; but size and seniority ruled, so I usually rode on the lowest tier. My old Navy "P" coat and long johns helped somewhat.

The five compartment, concrete-lined Kelley shaft serviced a large area underground, including the Leonard mine and the East Colusa shaft. We were lowered to the 2000 level of the Kelley, where we caught a "man-train," which traveled about 1.2 miles over to the Leonard shaft. The train tracks went under the bottom of the Berkeley pit, which was about 1,600 feet deep at that time. The surface Leonard headframe was gone, as the Berkeley pit had consumed most of that area.

The underground Leonard air hoist was very temperamental, hard to run, and the hoisting engineers had to be careful. They were exceedingly talented, however, and you put your trust in them to get you down and get you back up in one piece. Towards the latter days of underground mining at Butte, a cog was missing from the sheave wheel on the Leonard hoist, so you were going down the shaft in a jerky motion. Also, the Leonard shaft was starting to flop at about the 2200 level, so the cage was lowered to that level, slowed almost to a stop, eased through the bad ground, and then resumed speed to the 3500, 3600, or 3800-foot levels to drop off the miners.

The Leonard cage was smaller, so seven miners were packed in tightly; and down we would go to the working areas. My first stop was usually the 3800 level, and I would walk over to the 3885–3886 stope (3800 level, 85–86 stope) to look for massive covellite and digenite. This was a new stope and was close to the famous 3859 stope, where most of the covellite was mined in the early 1970's. It was mined out, when I arrived on the scene; but just to look at the size of the hole left after mining was amazing. Your mine light, when shined up from the bottom of the stope, would not reach the top. It was rumored that 3859 covellite kept the underground operations going for two years.

After bagging up a few sacks of ore at 3885–86 and carrying it to the station, I would hike over to the East Colusa shaft and ring the engineer for a ride up to the 3600. Usually in the mornings, the East Colusa shaft was used to lower timbers, powder, ice, and other mining equipment and supplies. The main Leonard shafts were pulling ore, so you couldn't use them except for noon hour and quitting time. If the East Colusa skip was busy, I would have to crawl up the ladders to the 3600 level, which was a chore, as I carried two canvas tool bags containing cardboard boxes, toilet paper for wrapping, and miscellaneous screw drivers, pry bars, chisels, and hammers for digging out specimens.

The 3600 level had an astounding array of mineralogical treasures. I would spend hours in and around 3650, up ten ladders from the floor of the 3600. Good specimens of barite, enargite, octahedral pyrite, pyrite pyritohedrons, and good iridescent pyrite along with quartz crystals were collected. The ore in 3650 had a tarnished appearance, as if it had been scorched or burned.

After 3650 I would hike down and over to the 3620 for the possibility of finding small, gemmy, pink to light blue apatite crystals. Apatite was rare in the Leonard mine, and in fact, it was not common anywhere in Butte.

Then over to the East Colusa shaft, ring for the cage, and ride up to the 3500 level. The first stop was to check out 3536 for enargite crystals. I found a large vug of enargite, barite, pyrite, and quartz crystals in dazzling arrays of colors, sizes, and shapes. The light from the mine lamp would reflect off the myriad of crystal faces, and you would just sit there and admire the beauty. Out comes the rolls of toilet paper and small boxes, then carefully pick out and wrap the treasures. One time, I spent from 9:00 A.M. to about 10:00 P.M. in 3536 digging and wrapping specimens. I had to collect all I could, as other hands would be grabbing and high-grading specimens, after I had left the area. Other areas on 3500 had good octahedral pyrite, barite, quartz, and some apatite.

A new stope on the 3800, the 3864, was being mined towards my last days working underground. Climbing up two sets of ladders after getting drenched with hot, blue copper water, which can cause open sores on your skin, was a drift about two hundred feet long, completely encased in a perpetual fog. There was a fan bag hanging down near the entrance of the stope, blowing out somewhat cool air. The shift boss told me there were some good crystals in some "bug holes," so I had better check it out. It was so hot (rock and water temperature at 142°F) and foggy; I would crawl and creep along the walls of the stope, feeling for crystals or pockets with crystals in them. In about three to five minutes, I would turn around and creep back out to the fan bag. This was the only area in the stope where there was no fog, and it was somewhat cooler. Drink water, wrap specimens, and head back to Dante's Inferno one more time. There was a ledge or shelf in that stope, on the right side, that had behind it, a clay-filled (dickite) pocket full of beautiful barite crystals, both singles and multiples, some on enargite and quartz, along with pyrite and doubly terminated quartz crystals. Octahedral pyrites were abundant and of fairly good size. As I remember, I don't think I ever found the back of that damn stope. 3864 was later abandoned, because of the terrible working conditions.

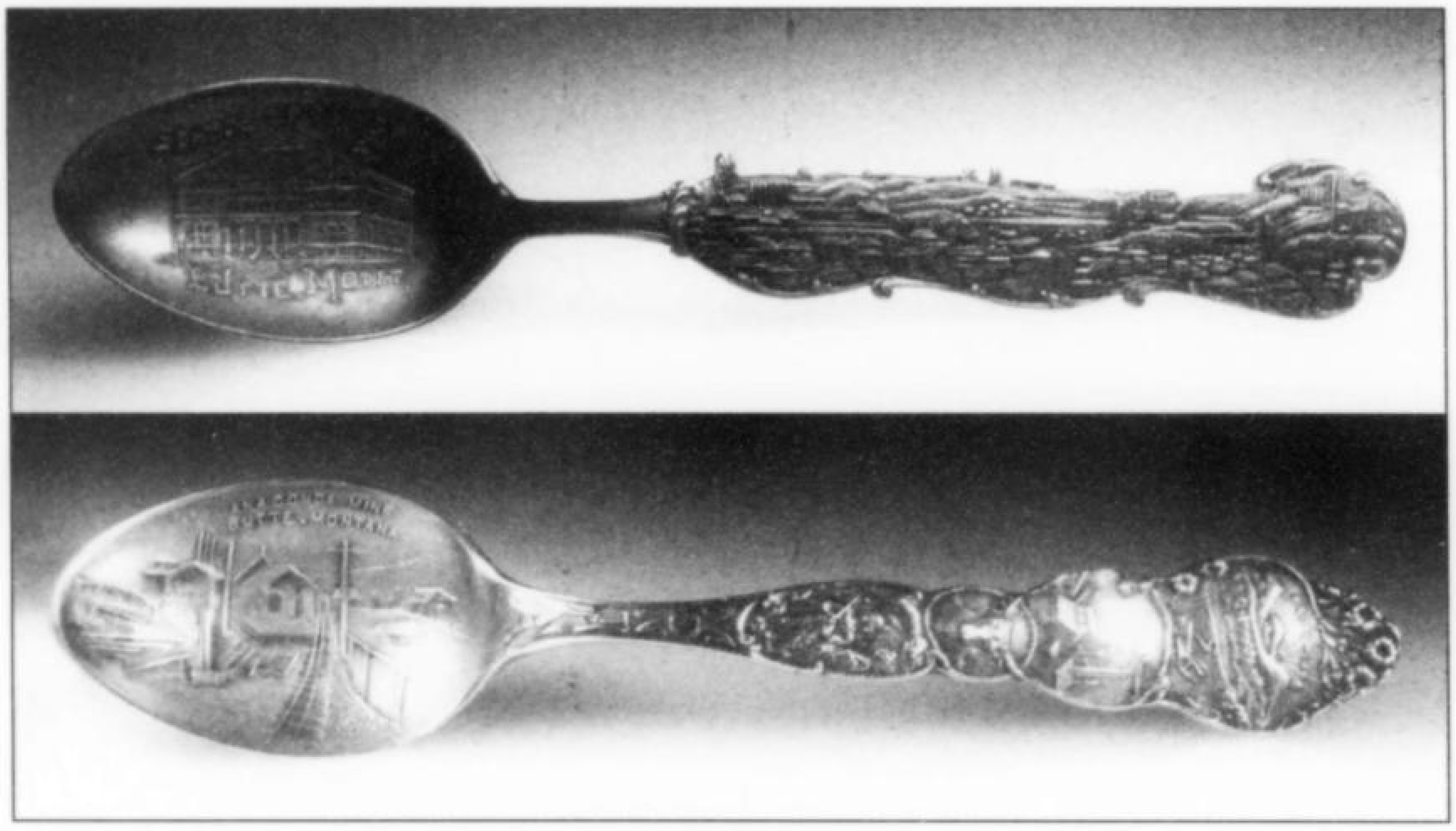


Figure 85. **Collector spoons made in Butte. *Top:* Silver spoon picturing the Anaconda mine in the bowl, on the back of which is written "Supreme Temple, Daughters of the Nile, June 1924, Butte, Montana." *Bottom:* Copper spoon picturing the Butte School of Mines in the bowl, and the headframe-filled skyline of Butte on the handle. Bruce Wadleigh collection; Wendell Wilson photos.**

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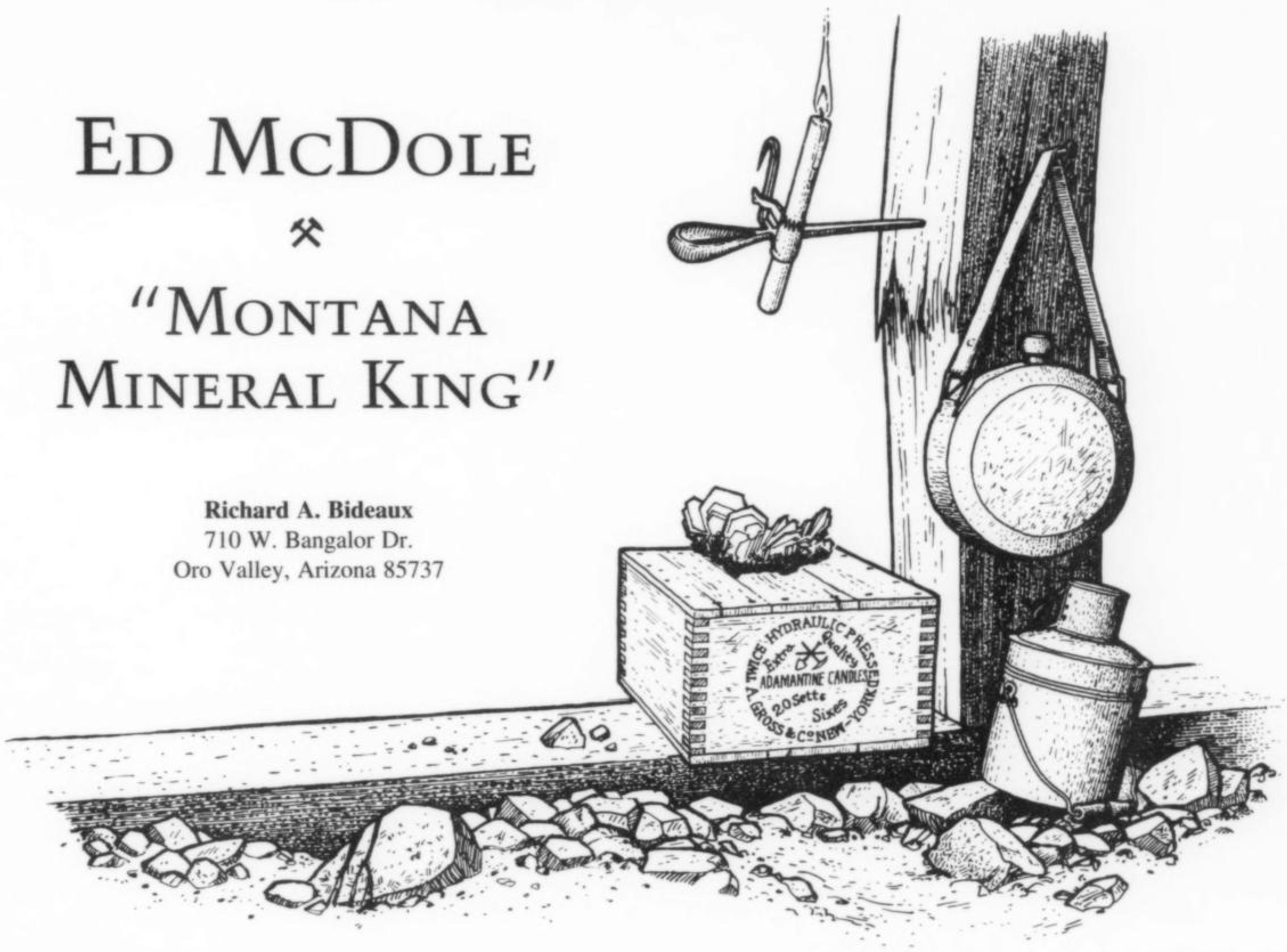

In the 1950's and 60's the name Ed McDole became synonymous with superb (if not always colorful) minerals from the mining camps of the American West. He collected many of them himself and bought others from miners, doing business out of his hotel room in Butte, Montana, or the trunk of his trademark Lincoln. Collectors and curators who knew him still fondly remember his eccentric personality, his fabulous specimens, his tall tales, and the excitement inspired by his infectious love of minerals. As his tombstone states, he was truly "a legend in his own time."

Ed McDole was not a traditional type of man, and writing a traditional biography of him would be virtually impossible for a variety of reasons. Perhaps he can best be described through the memories of some people who knew him. Hal Miller of Boulder, Colorado wrote:

> In the fall of 1955 Butte was an exciting city. The price of copper was high and miners were arriving daily from every mining camp in the west. Butte was known then as the capital of the "tramp miner." Many of the good crystal-producing mines were in production. The East Colusa and the Leonard, near Meaderville, were producing fantastic crystal groups of enargite, pyrite, covellite, digenite, and colusite. The Emma mine, in "down-town" Butte, was producing rhodochrosite specimens by the hundreds.
>
> One overcast November day I received word from Ed McDole that he had something special to show me. I knew this had to be good or Ed would not have taken the trouble to call. Arriving in Butte shortly after shift change I hurried up the street, past the Emma mine, to the Old Lincoln Hotel

where Ed resided. The whirring and clanging of the sheave wheels at the tops of the numerous gallows frames added to the excitement. At that time many operating shafts were in down-town Butte. Making my way up the dimly lighted staircase I arrived at Ed's room to be greeted by "Hello, Miller, you old bounder, how are you? If you can guess what I have here I'll buy your supper." Ed reached for a cigar box on top of a pile stacked near the door and cautiously opened it to reveal three specimens about 3 by 3 inches covered with euhedral crystals, somewhat less than 1/4 inch long, of a mineral which I did not recognize. I lost my chance for a free supper, but it was worth it. A pocket of digenite crystals had just been opened up and these were among the first to come out. Digenite crystals had never been common at Butte, as a matter of fact even the massive ore is rare. Years later, however, Ed visited me in Colorado and revealed the best of all the Butte digenites—a single crystal about 1 by 1/2 inch perched on a quartz matrix. I doubt that its equal exists anywhere in the world.

That same evening Ed showed me a few fine rhodochrosite crystals of a type not common in Butte. These were deep red transparent ?-inch rhombohedra with milky quartz rosettes. They could be confused with Colorado specimens, but at that time rhodochrosites were not coming out of Colorado. [Quoted from: Harold W. Miller (1971) Rhodochrosite crystal localities in the west. *Mineralogical Record*, **2**, 105–110.]

Hal Miller recently added:

I recall Ed in a rented room at the Lincoln Hotel in Butte, lying on his bed, reading a text on mineralogy or chemistry; there was a basin in the room, where he would wash minerals. Ed bought specimens by the powder-box-full from miners, who were working then on seven shifts. Ed worked two shifts himself, one under his own name and another under an assumed name. He was a contract miner, paid by the tonnage of ore he delivered. And, like many miners, he naturally took time to collect specimens when the opportunity presented itself.

Who was this Ed McDole, tramp miner and mineral collector *extraordinaire?*

The first I knew of Ed McDole was when he showed up unannounced in front of our family home in Tucson, Arizona, driving a big black Lincoln. He had minerals to show my father, George Bideaux, and me, which we looked at standing by his car in front of the house. The specimens he showed us which made the biggest impression on me were two from the Blackbird mine, Lemhi Co., Idaho.

One was a large piece with a rounded matrix covered with green ludlamite crystals on which were a number of long, upstanding, purplish-green tapering vivianite crystals, beautiful to see, but much too large for our collection. Then he showed us a smaller piece, a hand-sized loose spray of large vivianite crystals, which would have fit our collection perfectly.

He apparently had heard we had Glove wulfenites (dating this meeting into the latter 1950's). I showed him some of our pieces available and I thought we were just about to make a deal, which I certainly was anxious to do. He walked around his car, I thought to show us something else from the other side; instead, he got in, and simply drove off, leaving father and me staring after him. To this day I don't know what happened there—later I heard second-hand "We were too hard to deal with" although no trade values had even been mentioned.

From Mike Evick (Calgary, Canada):

I first met Ed McDole while on a field trip in southeastern British Colombia. My companion and I phoned the chief geologist at the Bluebell mine, located at Riondel, British Colombia, and asked for permission to visit the property with the view to collect specimens on behalf of the Vancouver City Museum.

At that time, Frank Shannon was the chief geologist and, as I represented a museum, we were certainly welcome to visit the property. Shannon suggested the quicker the better, as he was entertaining an interesting collector at the mine who would be gone by the next day. We left almost immediately, and an hour and a half later, via ferry, we were at the mine site.

That day in Shannon's office was my first contact with Ed McDole. His field car at that time was a fire-engine-red Lincoln Premier, which he took on roads more suitable for a jeep. Lincolns became his trademark, and from the Premier he graduated to black Continentals.

I must have made a good impression on Ed during our short encounter at the Bluebell mine, as he took a number of specimen boxes out of the Lincoln and I was treated to some of the finest minerals I had ever seen. As he worked his way through these he removed a specimen with eight lustrous indigo-blue cubes on a hard matrix. He handed the specimen to me and waited for my comments. Although this was my first exposure to a matrix specimen of that species, I blurted out "This is a boleite!" Ed broke out in a grin and said that I was "in a select group of a few people that were able to identify the mineral first time around."

At first contact I didn't pay much attention to his dress, which consisted of black shoes, black shiny pants and a silk shirt unbuttoned halfway down on his large stomach. Not once did I see Ed in any other dress than this, which was his preference and he stayed with it until he passed away in 1970. Another McDole trademark was that he usually could be seen smoking or sucking on a big cigar.

Ed always traveled with a car-trunk-full of custom-made redwood boxes that were variously compartmentalized and cotton-filled. These housed his finest specimens, which he showed and occasionally would sell or trade. Ed insisted on being paid in cash and was known for carrying $100 bills. Although that isn't unusual now, in the 1950's it certainly was an attention-getter.

Over the ten years or so I knew him, Ed and I would get together in various U.S. or Canadian towns and swap yarns and minerals for a few days and then go our separate ways until our next rendezvous. These get-togethers were always set up with a phone call from Ed, which usually he would open with his standard greeting "Hello, you old bounder," and suggest I meet him halfway, usually in the city or town of his choice.

Ed was fairly free with information on where he self-collected and, as a matter of interest, I've listed a number of these: at the Crown Point mine, Lake Chelan, Washington (large molybdenite crystals in quartz); the Blackbird mine, Cobalt, Lemhi Co., Idaho (vivianite-ludlamite); the Beaver mine, Beaver Mountain, British Columbia (linarite); the Rock Candy mine, Kennedy Creek, British Columbia (fluorite-barite in large crystals and specimens); Majuba Hill, Pershing Co., Nevada (clinoclase-olivenite); [near Lost Trail Pass] Lemhi Co., Idaho (ferrimolybdite). In Arizona, at the Rowley mine, near Theba, Maricopa Co. (wulfenite-mimetite); the Apache mine, Gila Co. (vanadinite); the Red Cloud mine, La Paz Co. (wulfenite).

***Figure 1.* Ed McDole (center) with cigar, talking to Sid Williams (left) and an unidentified person at the 1968 Tucson Show. McDole was adamant about not being photographed; this is the only known picture of him, taken at considerable risk by Dick Thomssen.**

Dick Thomssen of Carson City, Nevada adds to this list places he personally collected with Ed: in the Pine Grove Hills, Lyon Co., Nevada (lace calcite); and in Utah, at Spor Mountain and Topaz Mountain, Thomas Range. Gene Schlepp (Western Minerals, Tucson, Arizona) supplied me several invoices verifying Ed's sale of specimens from some of these localities.

Mike Evick continues:

> One of his most interesting field collecting experiences described to me was his first trip to the Grandview mine, deep in the Grand Canyon, Arizona, which was very successful as he came out with some fine brochantites and cyanotrichites. (This locality had been forgotten since the 1920's, until Ed rediscovered its specimen potential.) Ed said he learned an important lesson coming out of the Canyon. This was to cache water at various points on the way down and not carry your whole supply to the bottom and lug it all the way up along with the rocks.
>
> Ed had a great love for black and gray minerals. I didn't realize that he couldn't distinguish colors but relied on his excellent knowledge of crystallography to identify species as best he could.

Dick Thomssen recalls:

> Ed once bought, from west of Salt Lake, near Tooele, Utah, a batch of twinned cinnabar crystals, measuring up to 3/4 inch, which he couldn't have identified by color, but only through his knowledge of their crystallography.

John Patrick of El Sobrante, California recalls:

> Once he came to the house and insisted that I come out and look at his new "black" Lincoln. I told him that the color was burgundy. He demanded to know what in hell burgundy was. When I told him that was a brownish-purple, he let loose quite a string of profanity. It seems he had seen what he thought was a black Lincoln in a car dealer's window in Reno, Nevada and told the salesman he wanted to buy the "black" Lincoln for cash. The salesman, no fool he, caught on immediately that Ed was color blind and Ed drove away with his new "black" Lincoln. He did get rid of that car about a year later and showed up with a truly black one.
>
> Another time Ed showed me a specimen of yellow wulfenite, into which a Red Cloud mine crystal had been glued. I bought the specimen without pointing out the disparity to him. Later I removed the 3/4-inch bright red floater and it was added to my wife's thumbnail collection.

Once through Bideaux Minerals I had supplied to Ed an erythrite from Schneeberg, Germany. Somewhat surprisingly Ed turned back up and said some people in California had told him the crystals were not as red as they should be. I assured him that they were about as red as that mineral could be (this was long before the marvelous Bou Azzer, Morocco specimens) which statement he accepted.

But, curious, I asked him why he couldn't tell for himself? He then admitted to me he was red color blind. I probed more deeply, asking "How he did see such specimens?" He replied "As shades of gray." To this day I consider it remarkable that he could be so interested in specimen mineralogy without being able to see this very important and beautiful color. I would suppose he was green color blind as well; my ophthalmologist assures me the condition is entirely genetic, and the only color to be distinguished is blue, with all other colors seen as gray.

One day Ed showed up at the Bideaux household with a batch of remarkable Arizona scheelites. He had stopped to see George Burnham (Burminco, Monrovia, California) and had seen there a nice scheelite crystal George had just acquired. Getting the source's name and address, Ed immediately drove to Bisbee where he was able to acquire the balance of the lot. The Cohen tungsten mine in the Dos Cabezas Mountains, Cochise Co., opened during World War II, had been on standby for some time. The watchman did some work on his own in the vein, and uncovered what must have been a remarkable pocket of quartz crystals studded with large scheelites. These he had rudely cleaved off the matrix; he offered the entire lot to Loris Woolery in Bisbee, who was building his fine collection at that time. Loris bought the lot, and it was he who had later sold the one crystal to Burminco.

As persuasive as Ed was, it isn't surprising that all but a couple of crystals that Loris wanted to keep (and did—they are now on display at the Arizona Department of Mineral Resources in Phoenix) ended up in Ed's hands. And fortunately for us, Ed's next stop was at our home in Tucson. As I was an impoverished college student, I picked out only two, a fist-sized crystal for our own collection, and another of about equal size for trade. Then I talked my father into buying the best one Ed had for sale, a handsome yellowish-brown crystal weighing half an ounce short of twelve pounds. Ed was certainly reasonable in his prices. Our keeper cost $6, and the smaller crystal for trade cost $5; it later went to Dr. Fred Pough in exchange for an original 1785 copy of Wulfen's book on wulfenite (worth today perhaps $7,500). The large crystal, costing $50, was advantageously traded to the Smithsonian, where it was on public display for many years and probably still resides, as perhaps the largest scheelite crystal so far found in the U.S.

Ed had interactions with other Arizona collectors and dealers also. Al and Bernie Haag (Tucson, Arizona) once told me that they had sold Ed a very fine and expensive legrandite specimen, but it was too big for the compartment in one of his boxes. He asked them for a claw hammer and screwdriver, and, while they watched through the screen door, hearts in their mouths, he sat on their back concrete steps and successfully made the trim.

Gene Schlepp recalls that one year Ed had a room in the old Desert Inn at the time of the Tucson show. Ed had mined some extraordinary hübnerite crystals from the Adams mine, San Juan Co., Colorado. These needed to be cleaned of quartz using hydrofluoric acid, which Ed set out to do. Sometime later Al McGuinness pointed out to Ed that not only was the iron drain being attacked, but also the porcelain lining of the bathtub.

Ed in later years worked out of Ely, Nevada, where he kept the bulk of his specimen material, and finally in the Silverton-Ouray, Colorado area.

Mike Evick provided me with a copy of *The Silverton Standand and The Miner* for June 5, 1970 describing the circumstances of Ed's death and subsequent services. In that article he is referred to as Emorry Edward McDole (his relatives confirm that his real first name was Emory) and also as Edward Stephen McDole. Ed was born July 24, 1912, at Goodman, Wisconsin, and he passed away on the evening of May 21, 1970 in his hotel room in Silverton, Colorado; he was 58 years old. He lies buried outside Silverton. Friends later paid for and erected a fine headstone.

His presumably excellent "personal collection," however, was nowhere to be found after his death. It was variously supposed to be in a bank vault in Butte, Montana or Ely, Nevada. Toward the end of his life Ed would drive to Durango, Colorado and rent a Jeep, which he would drive back into the mountains on collecting trips. Hal Miller knew many of Ed's favorite specimens, but he never saw them again after Ed died; it is Hal's opinion that Ed had these stashed in a forgotten mine tunnel, perhaps along with cigar boxes full of the hundred dollar bills which he was known to carry.

At the Tucson Gem and Mineral Show in February of 1971, several collectors contributed to an Ed McDole memorial showcase, showing some of the finest specimens that had passed through Ed's hands during his long career. In 1972 Ed's friends John Patrick and Al McGuinness established the Ed McDole Memorial Trophy at the annual Tucson Show. They were also the judges, using as their sole criterion what Ed would have called the "best rocks in the show." Part of this tradition evolved from an evening in 1966 when John Patrick and his wife Masako had invited Ed for dinner, serving big thick steaks. Although Ed was not much of a drinker because of his diabetes, he did have a taste from a bottle of *Lion Heart* rum. It was later from the remains of this bottle that the winner of each year's McDole Trophy had to take a public drink on the "Old Bounder." McGuinness would then top off the bottle with more rum, to assure that "there will always be some of Ed's original rum in that bottle." This important trophy, widely considered to be the highest honor that a mineral collection could receive, continued to be awarded each year until the death of Al McGuinness in 1990, after which time it was retired. Following is a list of the recipients of the McDole Trophy.

1972	Ed Swoboda
1973	David Wilber
1974	Keith Proctor
1975	F. John Barlow
1976	Steve Smale
1977	Julius Zweibel
1978	F. John Barlow
1979	Keith Proctor
1980	David Eidahl
1981	Philip Scalisi
1982	James Bleess
1983	Kent England
1984	William Moller
1985	James Minette
1986	Keith Proctor
1987	Thomas McKee
1988	James Bleess
1989	Alexander Schauss
1990	Steve Neely

ACKNOWLEDGMENTS

My thanks especially to Mike Evick and Hal Miller, also John Patrick, Gene Schlepp and Dick Thomssen. Wendell Wilson suggested this tribute, and early did extensive digging for facts and people that might be useful sources.

Figure 2. **Ed McDole's tombstone, erected by his friends.**

ABSTRACTS of the 23rd Annual TUCSON MINERALOGICAL SYMPOSIUM

MINERALS OF AFRICA

Map: Africa 1851

Introduction

Susan Eriksson & **Robert B. Cook**, Chairmen

The 23rd Annual Tucson Mineralogical Symposium sponsored by the Mineralogical Society of America, Friends of Mineralogy, and the Tucson Gem and Mineral Society will be held on Saturday, February 16, 2002 at the Tucson Convention Center. Admission is free and everyone is welcome. "Minerals of Africa" is the theme of this year's Tucson Show and also the subject of the 2002 symposium.

Africa is an enormous continent, containing 54 countries scattered over an area of 30 million square kilometers. This giant land mass boasts an incredible array of terranes and geologic settings. Its mineral deposits reflect this geologic diversity and include such world-class occurrences as the great diamond pipes of South Africa and neighboring countries; the fossil placers of the Wittwatersrand Basin, the Phalaborwa Complex, the Kalahari manganese field, and the Bushveld Complex, all in South Africa; Tsumeb and Rossing, Namibia; Broken Hill, Zambia; the great copper, cobalt, and uranium occurrences of the Democratic Republic of the Congo and adjacent Zambia, among others. Most, if not all, of these have gone through sporadic episodes of wonderful mineral specimen productivity, and, if these were not enough, there is an even longer list of mineral deposits and districts of lesser economic and geologic importance that in themselves have been world-class specimen producers. This second list would include the Alto Ligonha pegmatites, Mozambique; the many gem and related deposits, and celestine and quartz occurrences of Madagascar; Bou-Azzer and Toussit, Morocco; the Mount Malosa area, Malawi; Kombat, Guchab, and nearby deposits of the Otavi Mountains, the Onganja mine, and the gem deposits of the Usakos or Erongo Mountain district, Namibia; aquamarine-bearing and topaz-bearing pegmatites in Plateau State, Nigeria; the gem zoisite ("tanzanite") and tsavorite garnet occurrences, Tanzania; the olivine occurrence on St. Johns Island, Egypt; and the classic senarmontite and associated species locality in Algeria, to name only a few.

Despite Africa's phenomenal mineral wealth, the available literature other than that of relatively recent vintage dealing with the technical aspects of well-developed or new economic deposits is sparse. This is in part the result of Africa's diverse history of indigenous peoples and their incredibly large suite of local languages, the effects of European colonialism, and the general inaccessibility of large parts of the continent. Nevertheless, modern works focused on descriptive mineralogy, including specimen and gem production, are beginning to emerge (for example the works of Cairncross and Dixon, 1995, and Cairncross *et al.*, 1997, related to South Africa) and successfully augment the older, regional works such as Lacroix's (1922, 1923) masterpiece on Madagascar and Buttgenbach's (1947) treatise on the mineralogy of the Belgian Congo. An important component of this emerging literature base is represented by site-specific papers published in such journals as the *Mineralogical Record* and *Lapis.*

The papers presented in this year's symposium reflect Africa's great mineral specimen heritage and are authored by persons with first-hand knowledge of many of the deposits listed above. These include professional geologists, professors, mining engineers, and mineral specimen miners and dealers. Many of the photographs have been taken recently and transferred from Africa digitally via the internet for use specifically in this symposium, further enhancing the truly international and up-to-date flavor that has become the hallmark of this event.

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The Messina Copper Mines, South Africa

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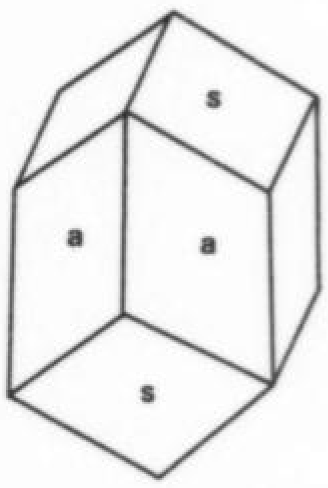
In 1985, the Messina copper mines drew attention from mineral collectors worldwide when many quartz crystals with beautiful turquoise-blue inclusions of ajoite were discovered. Before this time, the locality was famous for quartz included with papagoite and shattuckite, although these were never plentiful.

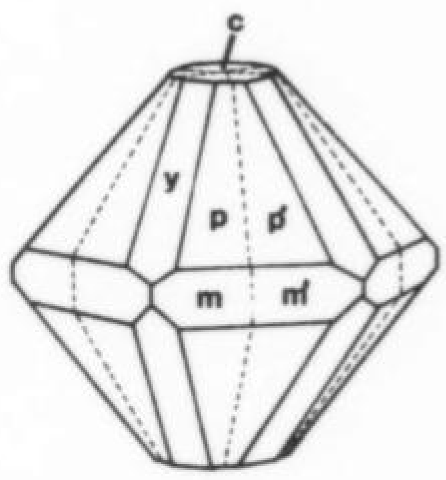
The mining district is located close to the northern border between South Africa and Zimbabwe. Several economic copper orebodies were hosted within gneisses of the Archaean Limpopo Belt, a high-grade metamorphic terrain that represents a collisional zone between the Zimbabwe and Kaapvaal cratons. The location of the orebodies is fault-controlled, and they are interpreted as hydrothermal replacement ores, with copper mineralization concentrated in breccia pipes.

Five mines exploited the copper ore: Artonvilla, Harper, Spence, Western Campbell and Messina (No. 5 Shaft), the latter being the main locality for specimens. All of these mines are now closed.

European exploitation of the deposits began in 1906 and the last mine closed in 1996. However, every "modern" mine was located on ancient, African workings and archeological artifacts such as stone hammers, soapstone carvings and iron tools have been recovered from these sites. The only metal won from the ore was copper, in the form of chalcopyrite, bornite and chalcocite.

Good specimens of barite, calcite, chalcocite (rare), chalcopyrite, copper, epidote, hematite, piemontite and quartz have been collected from these mines. However, the quartz is most famous. Nineteen mineral species are known as inclusions in Messina-mine quartz, three or more often occurring within single quartz crystals. Plates of crystals several square meters in diameter and weighing several hundred kilograms have been collected, as well as exquisite thumbnail specimens.





Mineral Highlights from Southern Africa: A Tour of the Desmond Sacco Collection

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The mineral collection of Desmond Sacco has been assembled over the past 40 years. The strength of the collection lies in its concentration of southern African specimens—particularly from Namibia, South Africa, Mozambique, Zaire, Zimbabwe and Zambia—as well as northern African specimens from Morocco. The collection consists of just over 3,000 specimens and all are on display in dust-proof glass cases. The specimens are miniature to cabinet-sized and larger, and the emphasis is on aesthetics and perfection, rather than rarities and non-crystalline specimens. Even so, extremely rare species such as germanium-rich beudantite, schneiderhöhnite, stottite and scorodite, can be seen in the collection as well-crystallized, aesthetic specimens.

Namibia is the most strongly represented country in the collection, and the Tsumeb mine dominates all other featured localities, with approximately two-thirds of the specimens in the collection having come from this one mine. The strength of the collection, as a whole, is that individual species, such as azurite, smithsonite, wulfenite, mimetite and many others, are represented by dozens of specimens that have been produced by the various localities over a long time. As such, there is a chronological continuum of specimens seldom seen in private collections.

The Kalahari manganese field in South Africa is also a focal point. The N'Chwaning I mine rhodochrosites, some of which were personally collected by Desmond Sacco, are amongst the finest known. Other noteworthy specimens include tourmalines from Namibia, Zimbabwe and Alto Lighonha, Mozambique; cuprite and carrollite from Zaire; quartz and prehnite from the Brandberg in Namibia; baddeleyite from Palabora, South Africa; topaz from Klein Spitzkoppe and aquamarine and schorl from Namibia.

The Occurrence of Dioptase in African Mineral Deposits

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Dioptase began to appear from central Africa in about 1890, a century after its description from specimens found at Altyn-Tyube in the Khirgisen Steppe, Karaganda district, Kazakhstan. Since then, thousands of dioptase specimens from at least 15 African localities, all of which are copper or complex base-metal deposits containing significant copper, have found their way into museum, university, and private collections. Within individual deposits, specific dioptase occurrences are mineralogically simple regardless of the overall complexity of the deposit as a whole. Lists of commonly associated species are usually quite short and include chrysocolla, azurite, plancheite, chalcocite, malachite (and other carbonates) and quartz.

Fine dioptase specimens are attributed to a number of localities in the Republic of the Congo. These include 'Mbumba and other occurrences on Pimbi "Hill" near Sanda in the Mindouli region, about 100 km west of Brazzaville. Specimens containing somewhat elongated to tabular crystals to 1.5 x 5 cm have been found there, some of which are associated with attractive, velvety plancheite. The isolated though well-known Reneville occurrence, located approximately 100 km northwest of Brazzaville, historically has yielded literally tons of dioptase specimens carrying "French Congo" labels. Associated minerals are azurite, quartz, plancheite, cerussite and mottramite. Good dioptase specimens have also been reported from copper prospects at M'Foati.

In recent years, good dioptase specimens have been found at the Mashamba West mine, Katanga, and at an old locality known as Tantara in the Democratic Republic of the Congo. Mashamba West dioptase is commonly seen in small scattered crystals to 3 mm on cobaltoan calcite. The older literature mentions the occurrence of dioptase at the Kambove, Shinkolobwe, Tshiniama, Molongoie, and Tendu mines (Buttgenbach, 1947).

Superb dioptase specimens have been found at three Namibian occurrences: Tsumeb, Omaue and Guchab (Jahn, 2001). It has also been reported as a rare accessory mineral at the Kombat mine. Tsumeb has produced thousands of dioptase specimens containing sharply formed, translucent to transparent crystals to 5 cm, typically on white calcite or dolomite and occasionally associated with cerussite and duftite. Fine dioptase specimens in stout, translucent crystals to 2 cm in vuggy massive dioptase and as individuals on white calcite and quartz were recovered in the early 20th century from the Rodgerberg mine near Guchab station, about 15 km east of the Kombat mine (Henglein, 1921). A significant number of attractive specimens containing transparent, somewhat elongated dioptase crystals to about 1 cm on pale blue chrysocolla or plancheite have been produced from the Omaue deposit at Kaokoveld since about 1985. Recorded Omaue dioptase production between 1985 and 1996 is given as 3,510 kg (nearly 4 tons!)by Piper (1998).

Good dioptase specimens containing crystals to 3 cm have been attributed to Mavoyo, Angola. Specimens were occasionally available while this mine was active in the late 1970's and 1980's.

Relatively minor dioptase occurrences have been reported in both Zimbabwe and South Africa. These include prospects in the Lomagundi district, the Inez mine in the Hartley district, and the Midway mine, Fort Victoria, Zimbabwe. Crystals to 1 cm long have been found near Christiana, North-West Province, and small crystals on gossan occur in the base metal deposits in the Aggeneys district, Cape province, South Africa.

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The Reopening of the Tsumeb Mine, Namibia by Tsumeb Specimen Mining Ltd.

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In 1996, the famous Tsumeb mine was closed and allowed to flood, ending almost a century as one of the world's great sources of mineral specimens. During its productive history the mine was the source of 247 different mineral species, became the type locality for 52 of these (40 of which are still only known from this single source), and became famous for approximately 65 mineral species which occur there in well-crystallized specimens of a quality unequaled by examples from anywhere else in the world (Gebhard, 1999).

In 2001 the Tsumeb mine was reopened by Tsumeb Specimen Mining, Ltd. for the specific purpose of producing specimens. Months of preparatory work included installing a high-capacity submersible pump, pumping the mine down to the 8th level, clearing the upper levels of mill tailings and related debris, reinstalling air, water and electrical lines, purchasing and installing a compressor, and thoroughly reviewing the previous operator's records.

Preliminary work indicated that specimen potential existed near the east and west ends of the orebody between the 5th and 8th levels; consequently the 5th level became the target of initial mining. Two crews are working separate headings, each driving drifts from the periphery of the deposit into zones where parts of the orebody were recorded as having been left intact as pillars or barriers. A fifth miner runs a scoop tram that is used to load and haul broken rock after each daily blast. Mining is overseen by Vitek Urbansky, a Cornish miner, and Kieviet Rust, a former Tsumeb shift boss.

Significant quantities of azurite and lesser amounts of malachite have been encountered. Most azurite is nodular, occurring in clay seams. Some is well crystallized as radial groups to 8 cm in diameter consisting of flat, somewhat etched, locally malachite-replaced crystals. Sparse cavities in adjacent dolomitic limestone have yielded sharp, sword-shaped azurite crystals as individuals and in small groups, a large percentage of which have been replaced completely by malachite. Only a very few azurite crystals comparable in quality to some of the best produced in the last years of metal mining have been encountered. Azurite is graded on site, specimen material being shipped to London for cleaning and sale; nodular non-specimen material is stored on site for sale to the lapidary and carving trades.

Two areas have produced a relatively small quantity of twinned cerussite crystals. The first is an oxidized zone in brecciated dolomite where well-developed, transparent, tan to gray cyclic twins up to 2 cm across occur with rosasite on broken rock fragments. The second is in a zone of altered dolomite which yielded approximately 40 very nice, reticulated groups to about 5 x 5 cm. Other parts of the 5th level have produced several hundred specimens of botryoidal azurite and malachite, pale blue aragonite, large rounded groups of greenish gray, velvety mottramite, and massive chalcocite containing attractive open cavities lined with acicular malachite.

The future of the venture is uncertain. After weeks of effort to reach them, parts of the orebody thought to have remained intact have proven to have been already mined out. Other areas, although certainly containing good material, have not produced the extraordinary specimens required to make the operation profitable. Still, history has shown that the potential is there, and persistence coupled with some degree of good luck should result in a somewhat erratic though continuous stream of Tsumeb specimens to the market place.

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The Minerals of the Erongo Mountains, Erongo District, Central Namibia

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Central Namibia's Erongo Mountains are largely composed of Karoo Formation equivalent granites with ages of emplacement estimated at around 500 million years. There are substantial skarn deposits cropping out in the western flanks of the range. The Erongo pegmatites occur as swarms trending roughly east-west. The relationship of these pegmatites to the region's dominant Uis tin-tantalite pegmatite swarms is unknown at this time.

The Erongo pegmatites, while essentially untouched, were thoroughly prospected during the German Colonial period but largely ignored because tin or tungsten ore reserves were insufficient to justify mining. Since the early 1900's, small pockets of various mineral species have been periodically encountered, and specimens from these minor discoveries have found their way into various European collections. There are numerous Erongo beryls (var. aquamarine) contained in German collections, and the British Museum has an impressive Namibian andradite-grossularite (var. demantoid) labeled *"Tubussis 1936."*

Since the Republic of Namibia gained its independence from The Republic of South Africa in 1991, artisans among the indigenous population have gained access to the country's mineral resources. These resources are vested in the state and managed under the Minerals Act of 1991 which guarantees access to bonifide prospectors. In mid-1999, impressive specimens of schorl associated with microcline produced by these indigenous miners emerged on the local market. In the years since, there has been a minor flood of spectacular specimens in a variety of species including: quartz, fluorite, various micas, beryl (var. aquamarine and goshenite), schorl exhibiting various morphologies, apatite, jeremejevite, topaz, and siderite. In some instances, these species have established new global size and quality standards. With these recent discoveries, Namibia's Erongo Mountains have become an important source for often-extraordinary examples of generally common pegmatite minerals.

Graphite with growth spirals from Arises River Marbles, Wlotzkas Baken, western Namibia

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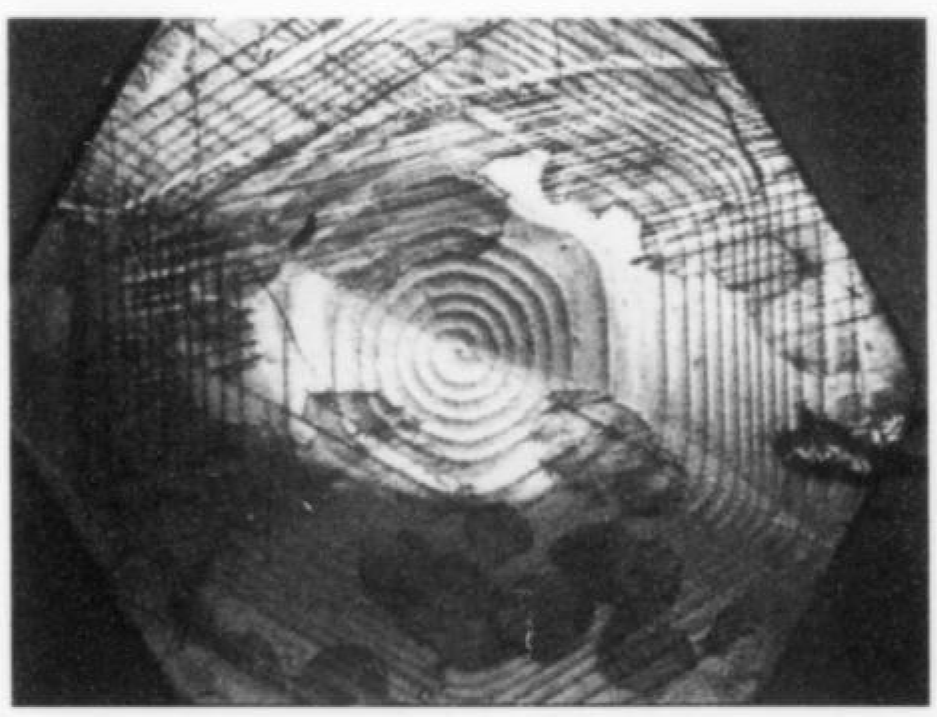
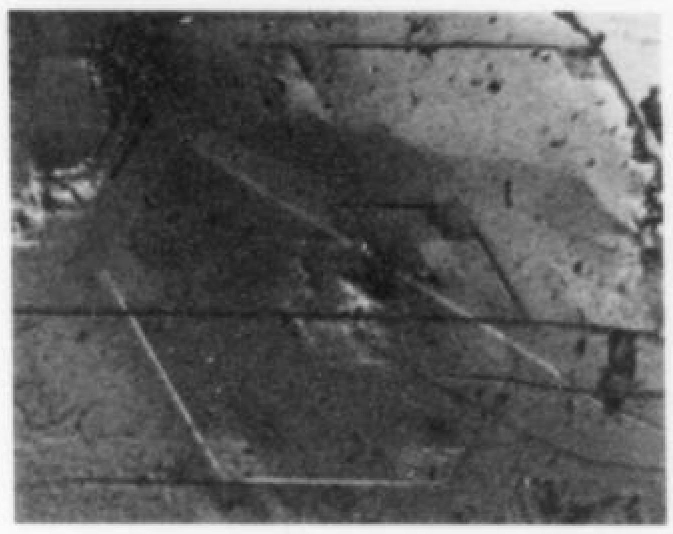
Miami University
Oxford, Ohio

John A. Jaszczak
Department of Physics and the A. E. Seaman Mineral Museum
Michigan Technological University
Houghton, MI

Graphite may not be the first mineral to come to mind when thinking about significant specimens from Africa; however, Neoproterozoic marbles of the Swakop Group, near Wlotzkas Baken, western Namibia have produced exceptional sharp, euhedral graphite crystals up to 2 cm in size. Of particular interest and beauty in these graphites is the array of well preserved microtopographic features on their {001} faces. A unique aspect of the observed surface microtopography is the presence of growth spirals and hillocks on three different length scales. The largest spirals are rounded to polygonized and can be seen without magnification (Fig. 1). The second order features are hexagonal growth hillocks that are spatially correlated with the steps of the macrospiral (Fig. 2). The morphology suggests the formation of these polygonized hillocks by some mechanism other than simple spiral growth. The third length scale features are spirals found on terraces forming the vicinal faces of the second-order hillocks. These spirals have steps that are 6.7 Å high (unit cell length along





[001]). The double-layer steps also show some regions with partial step separation into 3.3 Å-high monolayer steps. The observed microtopographic features give us insight into the conditions and mechanisms by which these graphites formed during carbonate metamorphism. Crystal growth was from a fluid phase at relatively low temperature and low carbon supersaturation. Furthermore, graphite growth was dominated by the spiral growth mechanism, unrestricted by the surrounding calcite.

Yellow Orthoclase (Sanidine) from South Betroka, Madagascar

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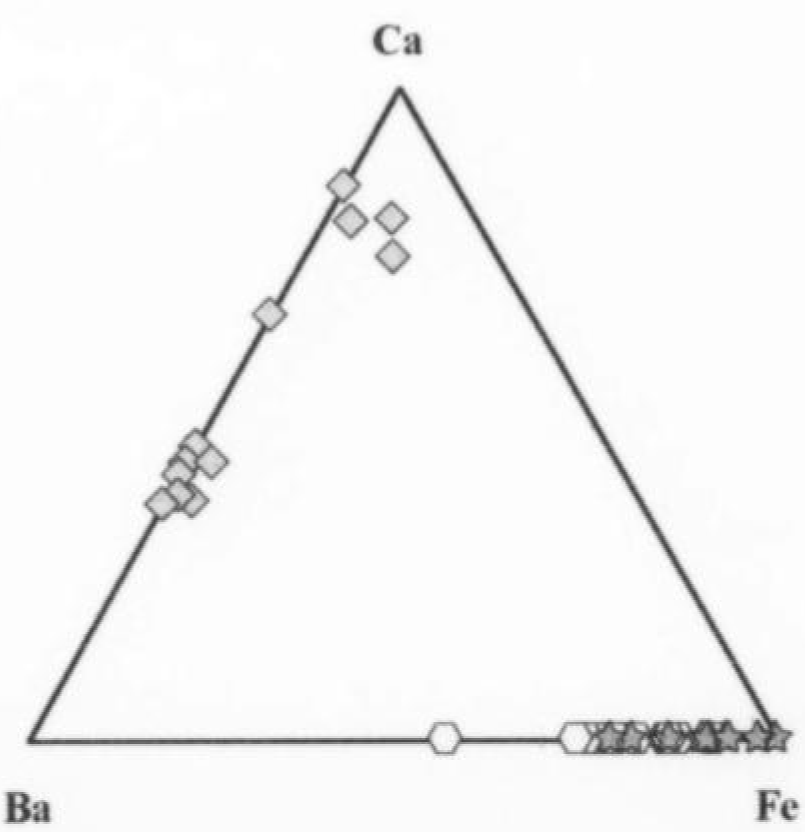
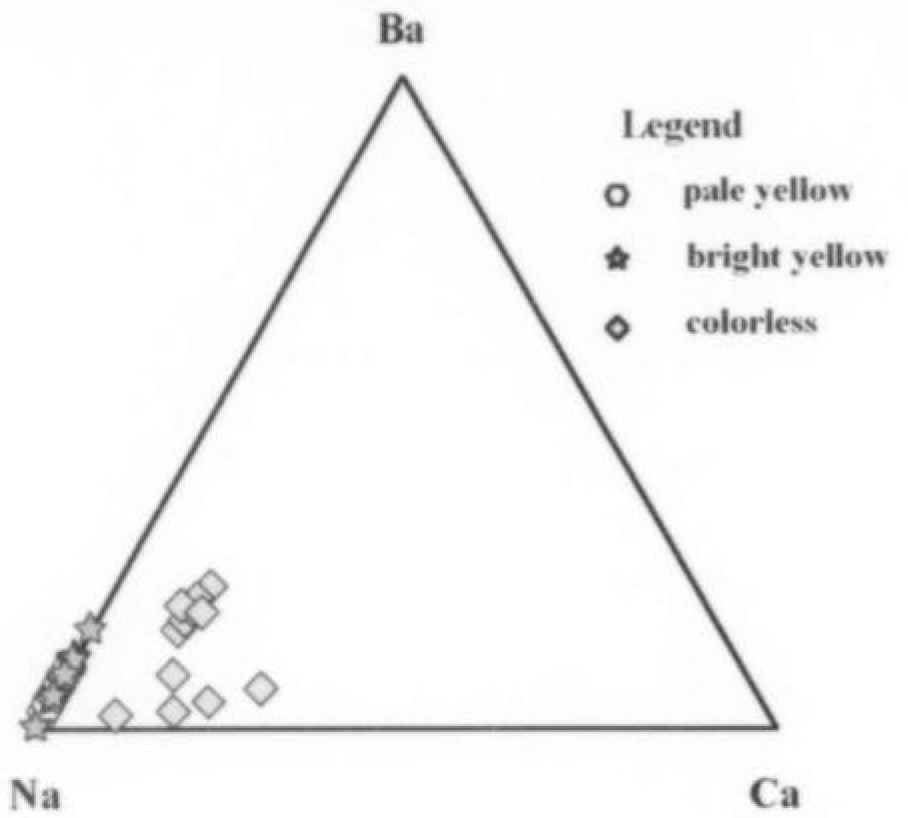
Lacroix (1922) first reported transparent yellow orthoclase from near the village of Itrongay between the small towns of Betroka and Benenitra in his *Minéralogie de Madagascar.* He described the feldspar as coming from a pegmatite containing associated zircon and diopside. Pezzotta (1999) reported that feldspar locations occur within a belt extending for about 40 km, with feldspar found mainly in marble lenses cut by pegmatites. The marble is cut by a network of coarse-grained veins of granular, colorless to yellow feldspar, locally associated with spinel, diopside, apatite and zircon. Well-formed crystals of gemmy yellow feldspar occur in cavities within the veins of coarse-grained orthoclase, especially where the pegmatites break up into thin veins and stringers in the marble. The crystals are world-renowned as premier examples of ferrian orthoclase.





In the summer of 2001 we visited the famous deposit at South Betroka. Bright yellow to colorless feldspar crystals were collected from the site and (along with others) were analyzed to determine their structural state and chemical composition. X-ray diffraction analyses show that all samples are, in fact, high to low **sanidine** rather than orthoclase.

Electron microprobe analyses show that the yellow crystals are enriched in Fe and that the colorless ones contain little or no Fe. The Fe content of yellow samples reaches up to 1.18 weight percent Fe_2O_3. Representative analyses of yellow crystals yield the following formula: $(K_{0.963}Na_{0.028}Ba_{0.003})_{0.994}(Al_{0.968}Fe_{0.031})_{0.999}Si_{3.001}O_8$, whereas colorless crystals give this formula: $(K_{0.942}Na_{0.039}Ba_{0.010}$-$Ca_{0.007})_{1.000}Al_{0.996}Si_{2.998}O_8$. Two ternary diagrams show the range of minor-element composition relative to three color categories (bright yellow, pale yellow, and colorless). The higher Fe-bearing, yellow crystals contain the lowest content of Ca and less Ba than the colorless crystals.

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Londonite, a New Mineral: the Cs-dominant Analog of Rhodizite from Madagascar

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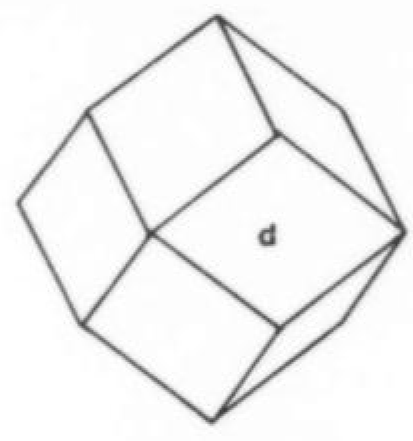
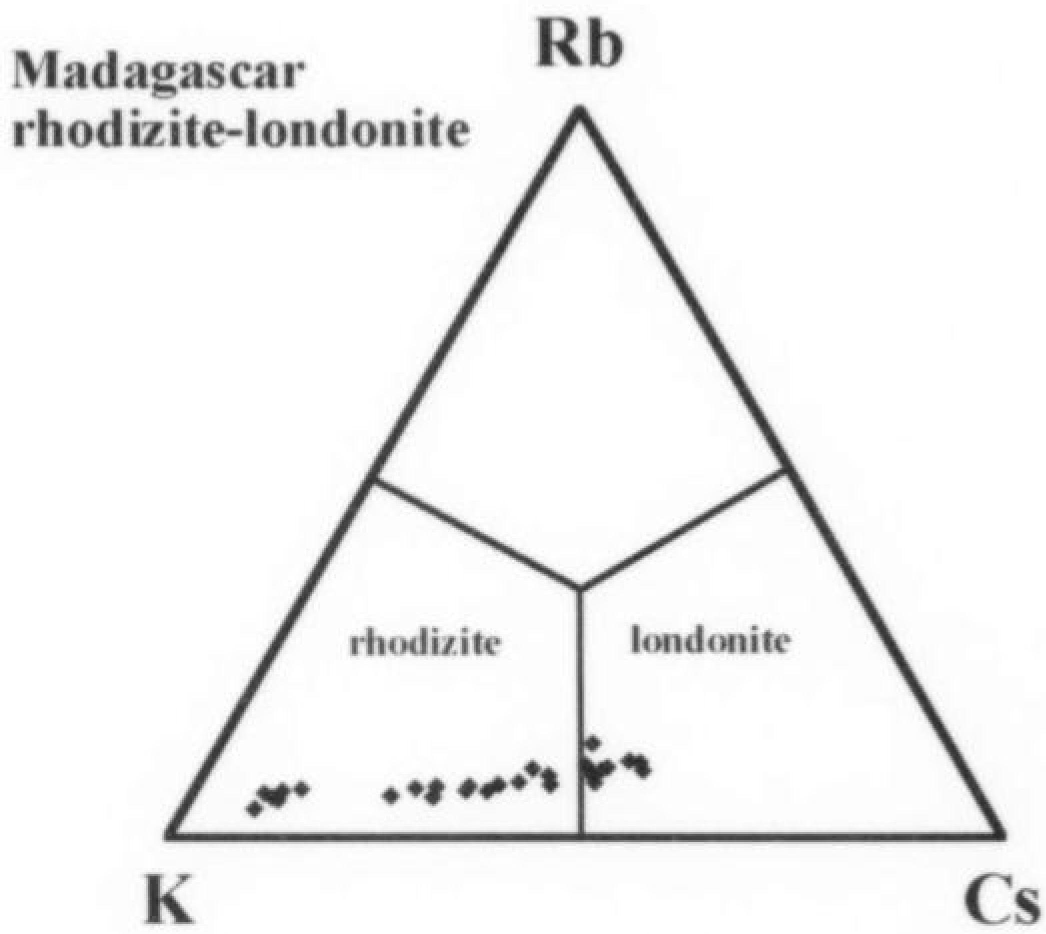
Londonite, $(Cs,K,Rb)Al_4Be_4(B,Be)_{12}O_{28}$, is the Cs-dominant analog of rhodizite. It occurs with rhodizite in the Antandrokomby pegmatite dike in the Manandona valley, Antsirabé region, and at Ampanivana and Antsongombato in the Betafo region south of Mahaiza, Madagascar. Londonite occurs in the inner zones and in miarolitic cavities of highly evolved pegmatites rich in red tourmaline. Associated minerals include microcline, quartz, albite, tourmaline (elbaite-liddicoatite-schorl series), Cs-rich beryl, spodumene, danburite, Mn-rich fluorapatite, hambergite, microlite, manganocolumbite, manganotantalite, behierite, and hafnian zircon, among others.



Londonite

Londonite occurs as equidimensional crystals a few millimeters across, and exceptionally in crystals over 7 cm in maximum dimension. The dominant morphology is dodecahedral and rare deltoid dodecahedral modified by tristetrahedral, tetrahedral and very rare cube faces. Crystals are colorless to white to yellow with a white streak. Luster is vitreous and the crystals are translucent to transparent. Mohs hardness is 8. It has no cleavage or parting, and is brittle with a conchoidal fracture.



Microprobe analyses reveal a wide range of K and Cs content and overall low Rb abundance. The empirical formula based on 28 atoms of oxygen and calculated from an average of five analyses from Antandrokomby is: $(Cs_{0.48}K_{0.38}Rb_{0.09}Na_{0.03}Ca_{0.02}Mn_{0.01})_{\Sigma 1.01}(Al_{3.98}$-$Li_{0.02}Fe_{0.01})_{\Sigma 4.01}Be_4[(B_{10.99}Si_{0.01})_{\Sigma 11.00}Be_1]_{\Sigma 12.00}O_{28}$ with B and Be by stoichiometry. The color of crystals is not diagnostic; without quantitative chemical analyses, it is nearly impossible to unambiguously distinguish londonite from rhodizite. Even a single crystal may have domains of both londonite-dominant and rhodizite-dominant composition.

The mineral is named after Dr. David London (b. 1953), professor of Geology and Geophysics, University of Oklahoma, in recognition of his experimental studies of evolved granitic melts and his contributions to our understanding of the origin of granitic pegmatites.

continued on overleaf

The Friends of Mineralogy, Inc.

Visit the national Friends of Mineralogy website at www.indiana.edu/~minerals/fm.html

Who We Are:

Vol 1, No 1, Mineralogical Record, Spring 1970

The *Friends of Mineralogy* was founded in Tucson, Arizona, on February 13, 1970. Its objectives were to promote better mineral appreciation, education and preservation. The chief aims and activities of *FM* include:

* Compiling and publishing information on mineral localities, and important mineral collections.
* Encouraging improved educational use of mineral specimens, collections, and localities.
* Support a semi-professional journal of high excellence and interest designed to appeal to mineral amateurs and professionals, through which *FM* activities may be circulated.
* Operating informally in behalf of minerals, mineral collecting, and descriptive mineralogy, with voluntary support by members.

The Mineralogical Record has agreed to an affiliation with the Friends of Mineralogy whereby it will publish its written material and news of its activities. The *Friends of Mineralogy* will support the *Mineralogical Record,* since the aims of both are similarly educational and directed toward better coordination of the interest and efforts of amateurs and professionals.

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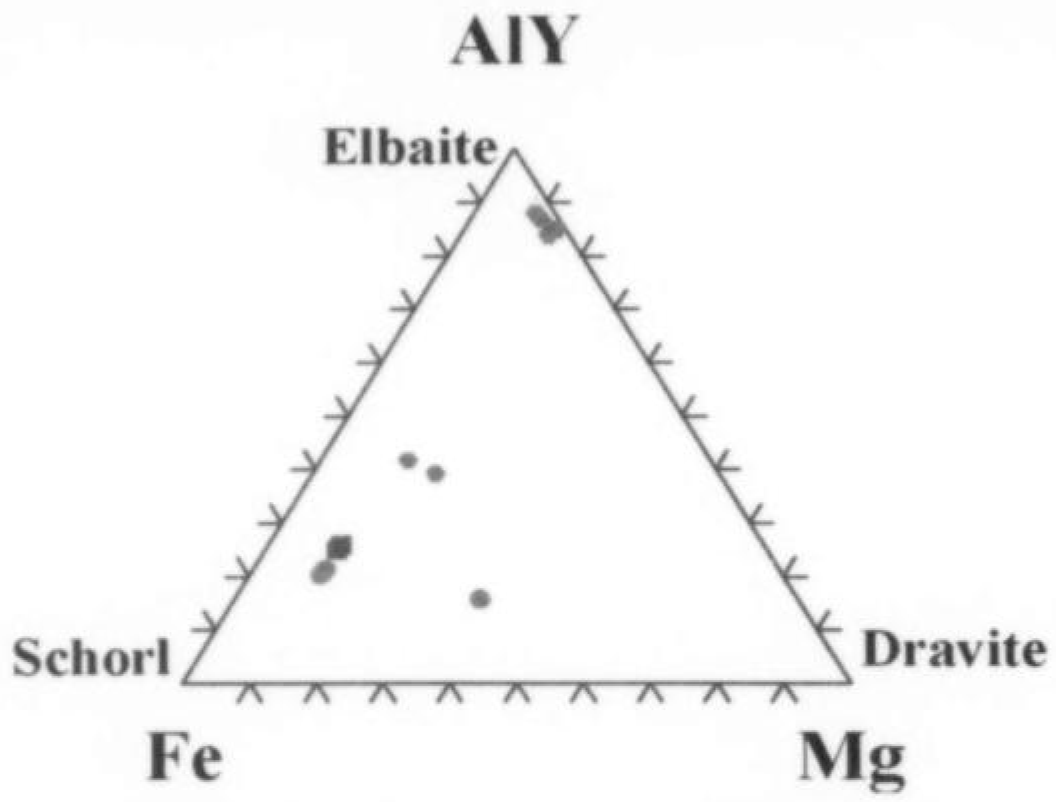

Figure 1. **Y-site Fe-Al-Mg composition of Antandrokomby tourmaline.**

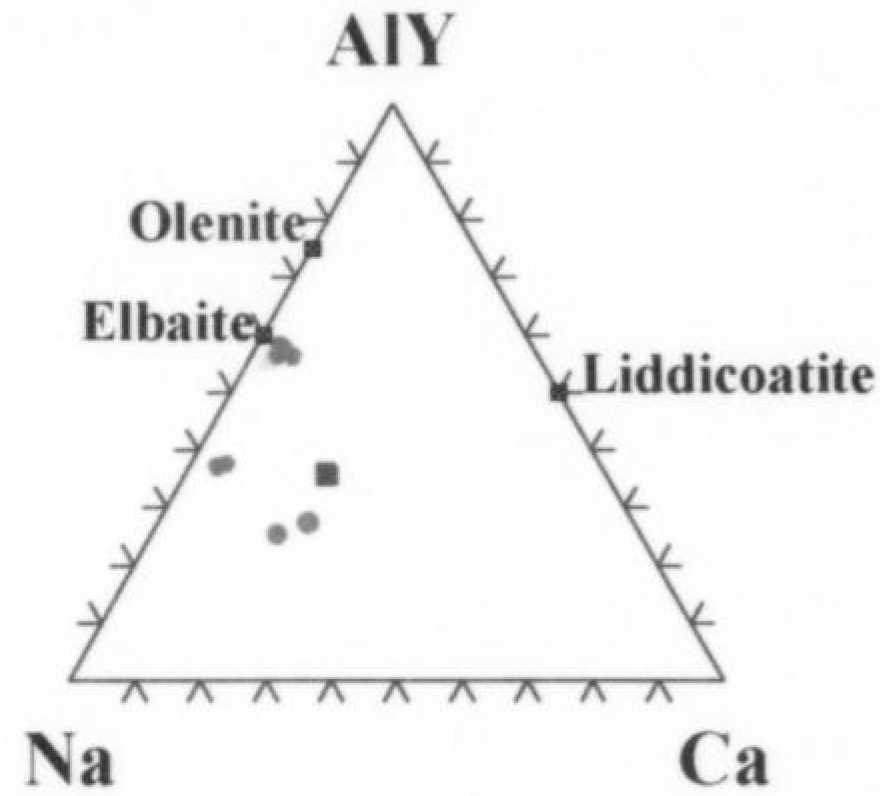

Figure 2. **Na-AlY-Ca composition of Antandrokomby tourmaline.**

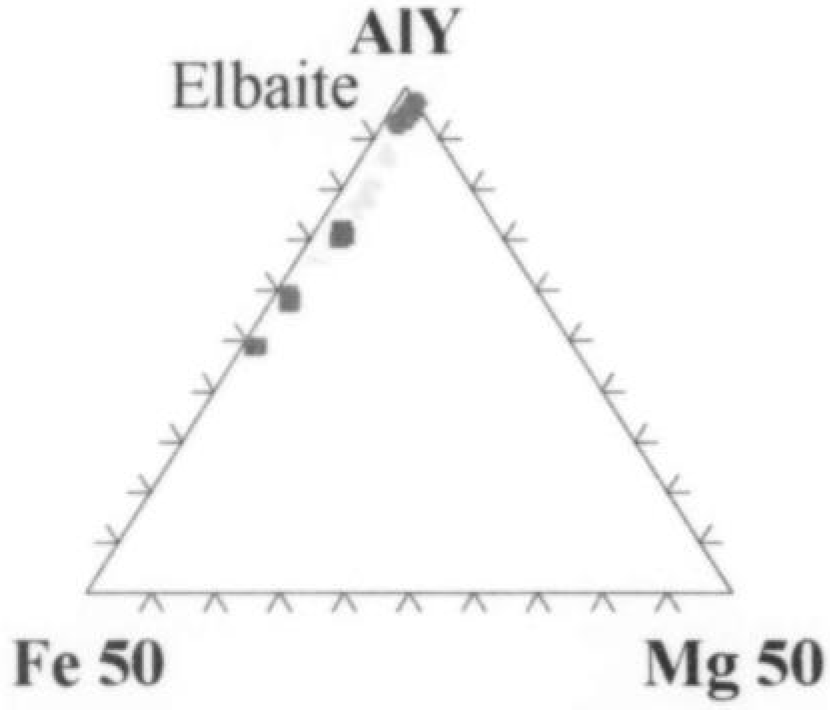

Figure 3. **Y-site Fe-Al-Mg composition of Fianarantsoa and Anjanabonoina tourmaline.**

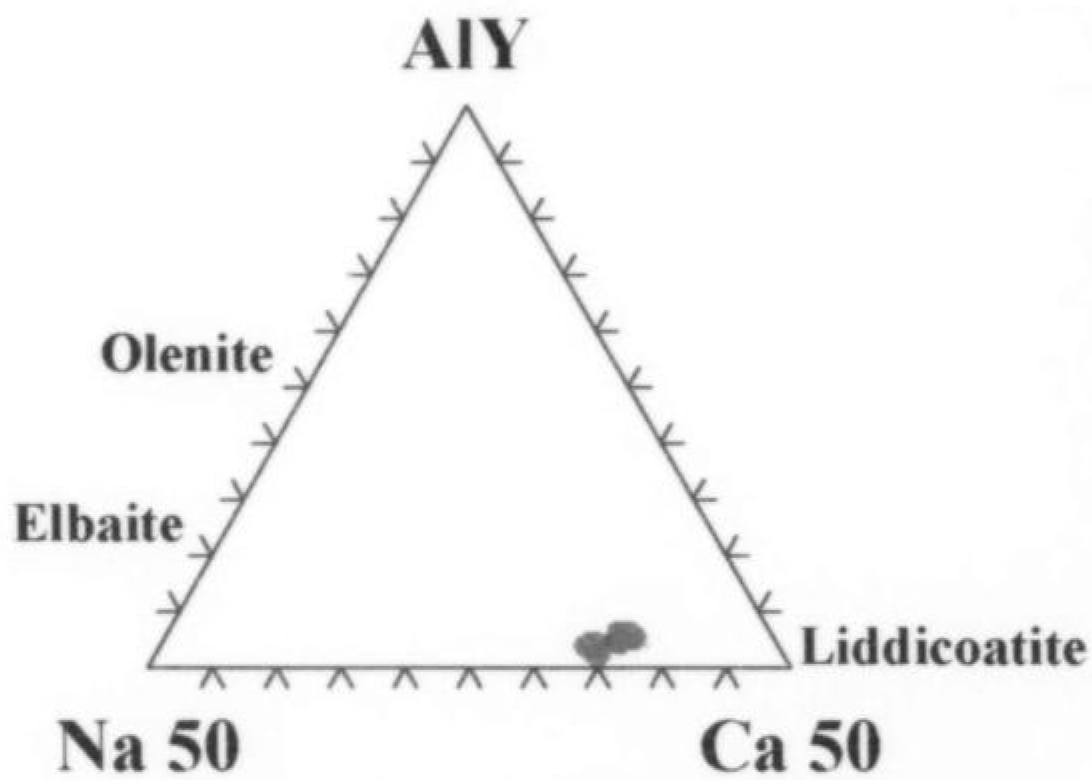

Figure 4. **Na-AlY-Ca composition of Fianarantsoa and Anjanabonoina tourmaline.**

Tourmaline from the Antandrokomby, Anjanabonoina and Fianarantsoa Pegmatites, Madagascar

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Antandrokomby Pegmatite

The Antandrokomby pegmatite is a thin, steeply dipping dike located near the village of Ambatolampy, about 35 km south of Antsirabé, Madagascar. It has produced gem tourmaline as well as rhodizite and beryl since 1900. Tourmaline occurs throughout the pegmatite. Earliest-formed tourmaline in the footwall occurs as a comb structure of prismatic crystals up to 30 cm in length, with pronounced dark olive-brown cores and thin, deep red rims. Within miarolitic cavities, later gem-quality reddish purple tourmaline occurs as stubby crystals up to 4 cm in size. Vibrant pink, fibrous crystals encrust the pocket crystals and represent the final stages of tourmaline crystallization.

Electron microprobe analyses reveal that the tourmalines are not liddicoatite, but principally schorl to elbaite in composition. Early Fe-rich cores contain appreciable Y-site Mg and Ca (Fig. 1 and 2), suggesting that the tourmaline chemistry reflects the fact that the pegmatitic melt was contaminated by the dolomitic country rock. Early-formed tourmalines are Mn-rich and Fe-rich. X-site vacancies range from 0.0 in the early Fe-rich schorl to 0.28 in the later red tourmaline. TiO_2 concentrations decrease from about 2.0 weight percent in the cores to less than 0.2 weight percent in the rims.

Fianarantsoa and Anjanabonoina Pegmatites

Large polychrome tourmaline crystals over 10 cm long with deep red cores and green rims have long been produced from the Fianarantsoa region in Madagascar.

The Anjanabonoina area has been productive since the beginning of this century. Most tourmaline is produced from placer deposits derived from large tourmaline-bearing pegmatites. The tourmalines may exceed 20 cm in maximum dimension and are spectacularly color-zoned, displaying 3-rayed stars of deep-red color, and alternating pink, green, yellow and nearly colorless bands.

Electron microprobe analyses of zoned crystals from both localities reveal that the tourmalines are liddicoatite, with about 0.7 apfu Ca in the X-site and very low Mg (Fig. 3 and 4). FeO ranges from about 2.6 weight percent in the green zones, to less than 0.06 weight percent in the red zones. TiO_2 concentrations are significantly lower than that of Antandrokomby tourmaline. MnO shows a pronounced oscillation from the green to the pink zones, approaching 1 weight percent in the pink zones and less than 0.01 weight percent in the green zones.

What's New in Minerals

Denver Show 2001

by Thomas Moore

[September 10–17]

Wendell Wilson and I had been booked to fly the United Airlines shuttle to Denver on the afternoon of Tuesday, September 11, 2001. As it turned out, the morning of that day will always bear resonances unrelated to the Denver mineral show. I hope that readers will understand if this report comes out sounding less chipper than usual; a muted tone also characterized the atmosphere of the show, as specimen-shoppers were understandably unable fully to enjoy minerals in the usual way. Every TV screen in every hotel room showed, in endless replay, the horrifying destruction of the World Trade Center in New York.

With the nation's airlines still grounded on Thursday, we finally embarked somberly on the 13-hour drive to Denver from Tucson. The personal irony is that I had been looking forward to the easy one-hour-plus flight, instead of the seven-hour flight from eastern Connecticut (with at least one plane change) that I'd always taken to Denver before. On those previous flights, as the plane passed south of Manhattan, I would always make it a point to look out the window and down at the glistening, crystal-like shapes of the World Trade Center's twin towers, spectacular far below in the dawn, even while the rest of the city lay submerged in haze. Now, instead, we took in the desert vistas and the majestic Rocky Mountain scenery, from southern Arizona up through New Mexico and Colorado: beauty that no mere terrorist can ever hope to deface.

Mindful of the disasters in New York and Washington, the Show itself did its part to join in supportive solidarity. The Board and the Trustees of the Denver Mineral Council and the committee in charge of the Denver Gem and Mineral Show voted unanimously to donate the net proceeds from admissions in 2001 to a victims' relief fund for the families of those who died. Yes, it was a "muted" show; many regular show-goers chose to stay home or couldn't make it because of canceled flights, and some dealers lost money because of reduced customer traffic. But, in spite of everything, the Show did go on, and with lots of interesting minerals too. So, minerals being our business, let's get down to it.

Lanny Ream (P.O. Box 2043, Coeur d'Alene, ID 83816) has continued the good work he was beginning just before this year's Tucson Show, extracting large numbers of very large and fine **heulandite** specimens from the prospect he calls the "Rat's Nest claim," near Challis, Custer County, Idaho. About 100 top specimens have appeared so far, and Lanny had most of them in his room in the Holiday Inn. On a pale gray, altered andesite, the heulandite forms as typically fan-shaped crystal aggregates to 4 or 5 cm across their tops, and these occur on thick cavity-lining beds of pure white hair-like **mordenite** crystals. The luster of the heulandite is very bright, and the color is a gorgeous pale peach-pink. Some miniatures consist of two or three intergrown heulandite fans without matrix, but the really dramatic ones are the matrix pieces, which reach up to a foot across. Other specimens show mordenite alone, with the blankets of filiform crystals rising up in places to form white "puffball" mounds to 5 cm across. Glistening, freestanding mordenite crystals comprise the puffballs—but no petting! These are not the flexible Indian okenite puffballs that they resemble.

In the same wild region of central Idaho, at a place called Antelope Flats, Lanny has dug some very large specimens of a new and unique phenomenon: **milky quartz pseudomorphs after apophyllite.** Individual pseudomorphed crystals can reach 4 x 7 cm, while still displaying their forms sharply enough to recall instantly the Indian apophyllite crystals of the same habit: thick tetragonal prisms with large pyramid faces and no pinacoids. The quartz is grayish white, forming thick casts with bumpy surfaces covering a thin (fluorescent) calcite layer, under which lies a boxwork of quartz where the big apophyllite crystals used to be. These specimens are not beautiful, but crystal clusters can reach 45 cm across. All came, Lanny says, from a single huge cavity in a surface exposure.

The long-famous Elmwood lead-zinc mines near Carthage, Smith County, Tennessee have for decades turned out stunningly beautiful specimens of **calcite**, **fluorite** and **sphalerite** in prodigious abundance. At the Main Show, fully a third of all the specimens in the large booth of Bryan Lees' *Collector's Edge Minerals* were Elmwood pieces from a recently acquired accumulation built over 20 years during the mine's heyday. The specimens are of such uniformly high quality that they obviously must have been carefully cherry-picked from vast numbers of specimens by someone with close access to the mine and its output. Specimen sizes range from thumbnails to "museum" behemoths. As this material is generally familiar, it need not be over-described here—but picture lustrous, gemmy, perfectly formed pale yellow to deep orange calcite crystals to 15 cm; pale to deep purple fluorite cubes (some of the darker ones having scalloped surfaces) in all sizes; brilliant reddish brown sphalerite crystal-hodgepodges on plates of cherty matrix; 10-cm spheres of pale yellow **barite** crystals; oh yes, and a few fine **galena** specimens too. This was surely the best Elmwood assemblage gathered in one place in a long time, and prices were reasonable, especially considering the sheer-beauty factor. Several other dealers around the show had Elmwood spreads just about matching that of *Collector's Edge* for quality, if not in numbers of specimens. If you want a good Elmwood something-or-other, or even a suite, now's the time.

A remarkable 100 or so old-time, gemmy green **"hiddenite" spodumene** crystals from the classic locality on the Warren Farm, Alexander County, North Carolina were on view in the Holiday Inn room of Terry and Jean Ledford of *Mountain Gems & Minerals* (P.O. Box 239, Little Switzerland, NC 28749). These loose single crystals were collected who-knows-how-long ago, reportedly from

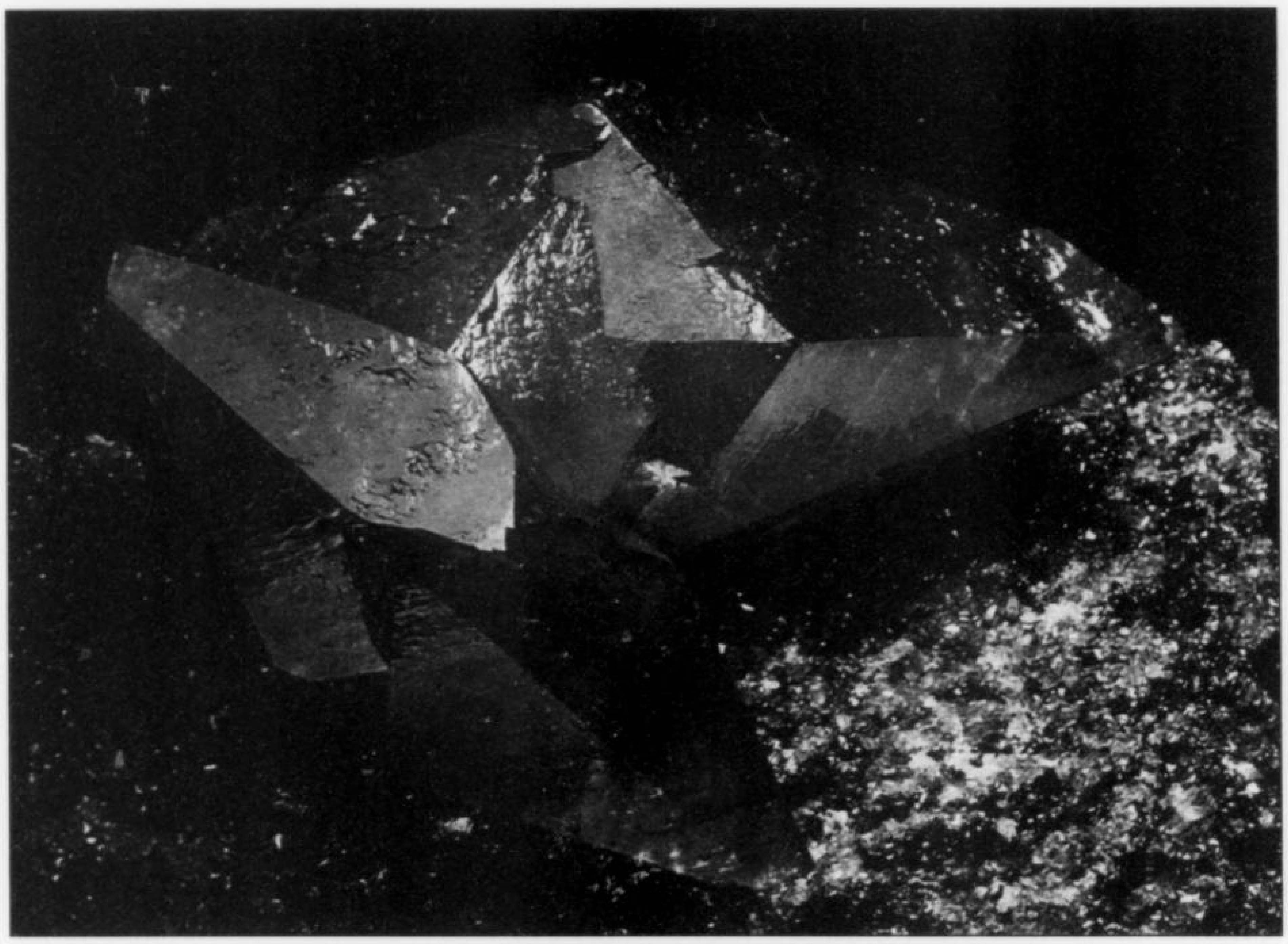


Figure 1. **Calcite crystals to 26 cm from the Cumberland shaft, Elmwood mine, Smith County, Tennessee. Steve Neely collection; Jeff Scovil photo.**

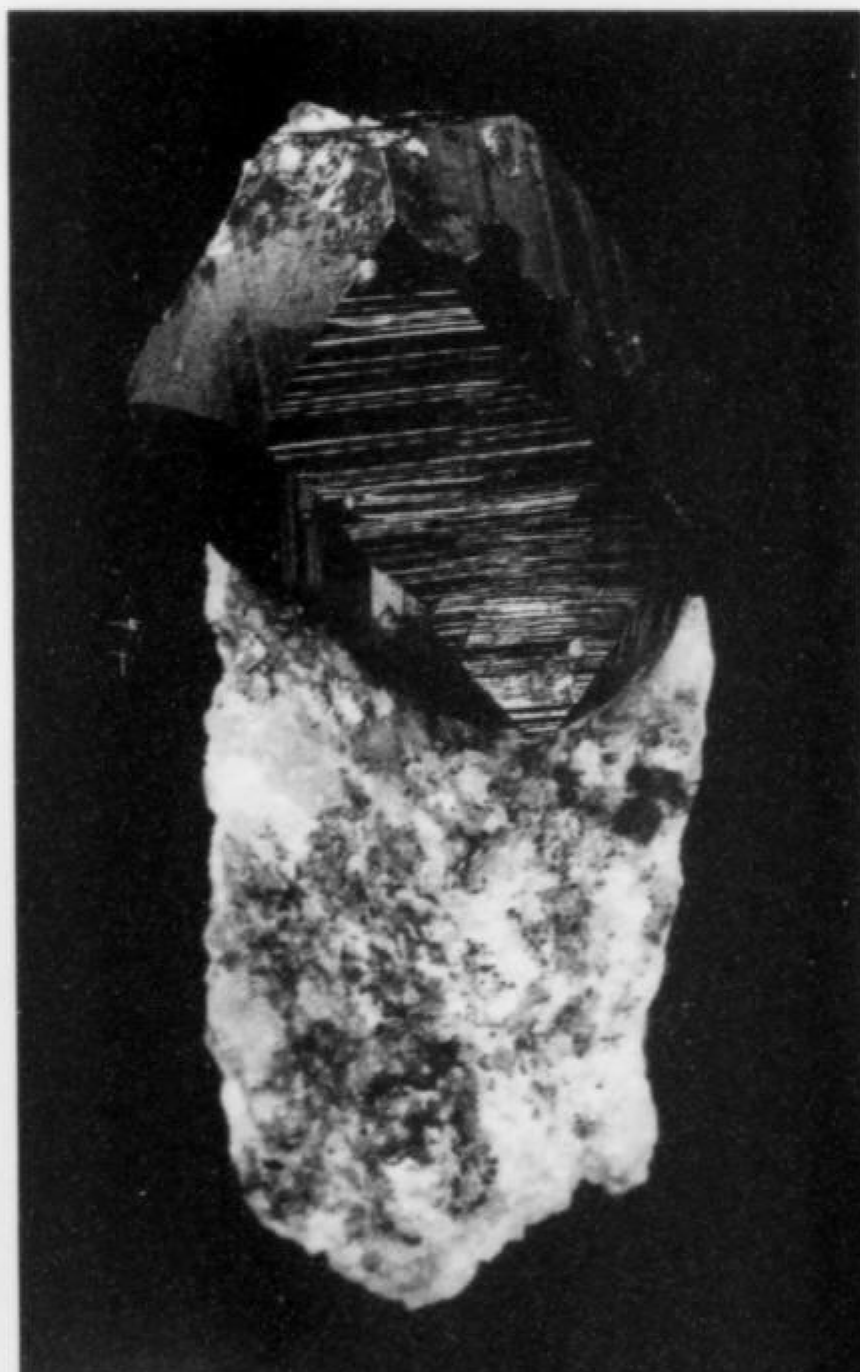


Figure 2. **Uraninite crystal on matrix, 5 cm, from Nuristan, Afghanistan. Herb Obodda specimen; Jeff Scovil photo.**

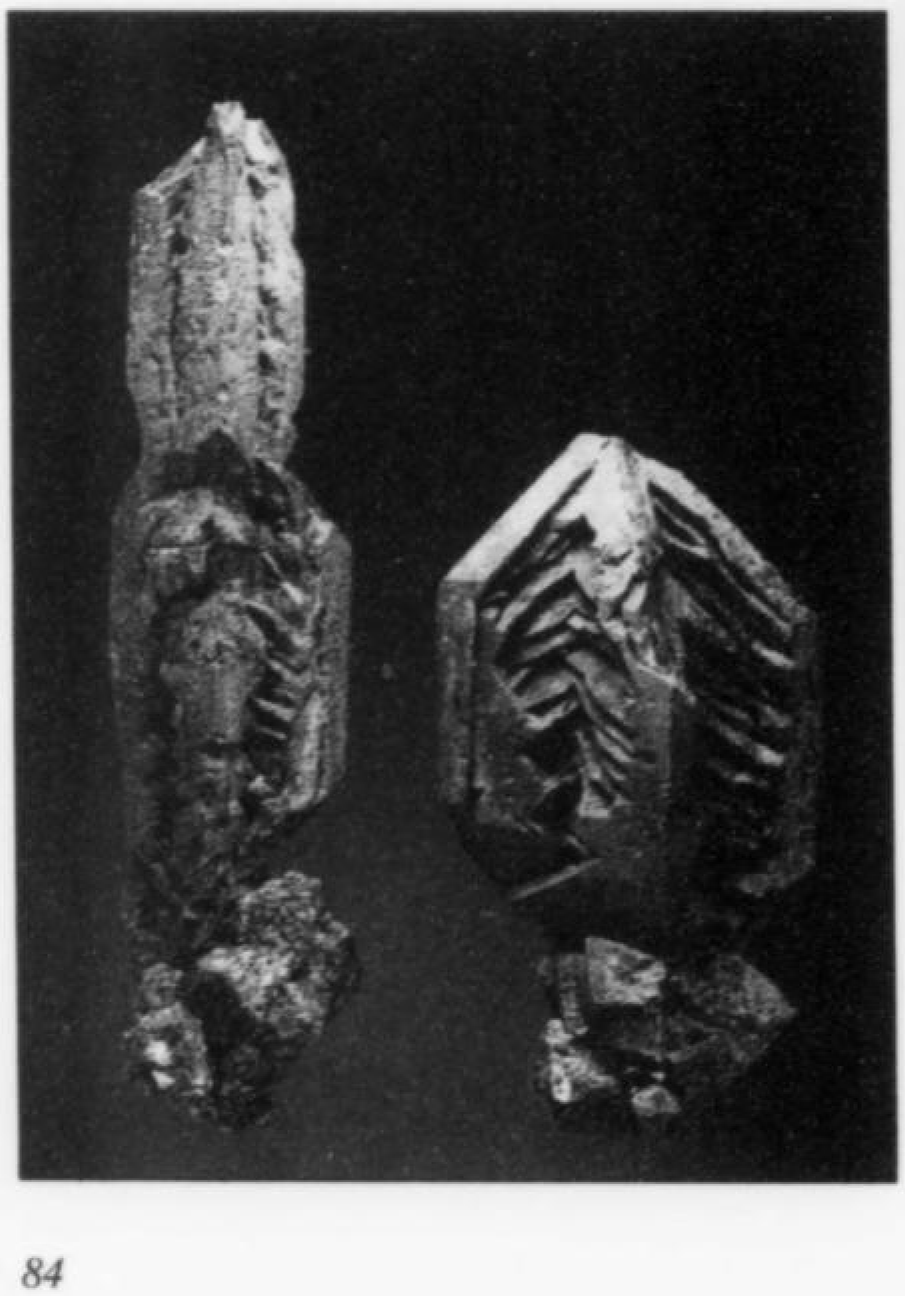


Figure 3. **Hematite (?) crystals to 11.4 cm, from Patagonia, Argentina. Attard's Minerals specimen; Jeff Scovil photo.**

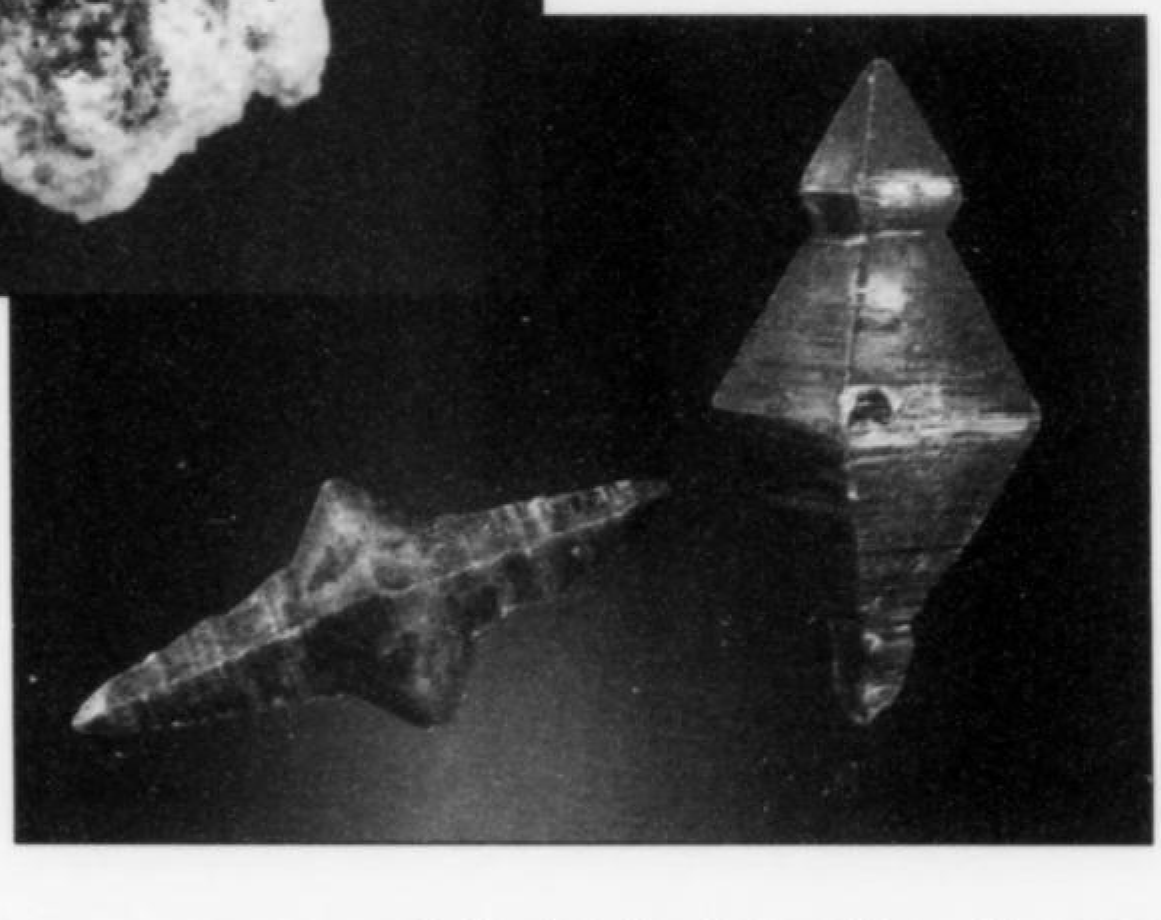


Figure 4. **Anatase crystals to 1.9 cm, from Jaboticatubas, Minas Gerais, Brazil. Hawthorneden specimen; Jeff Scovil photo.**

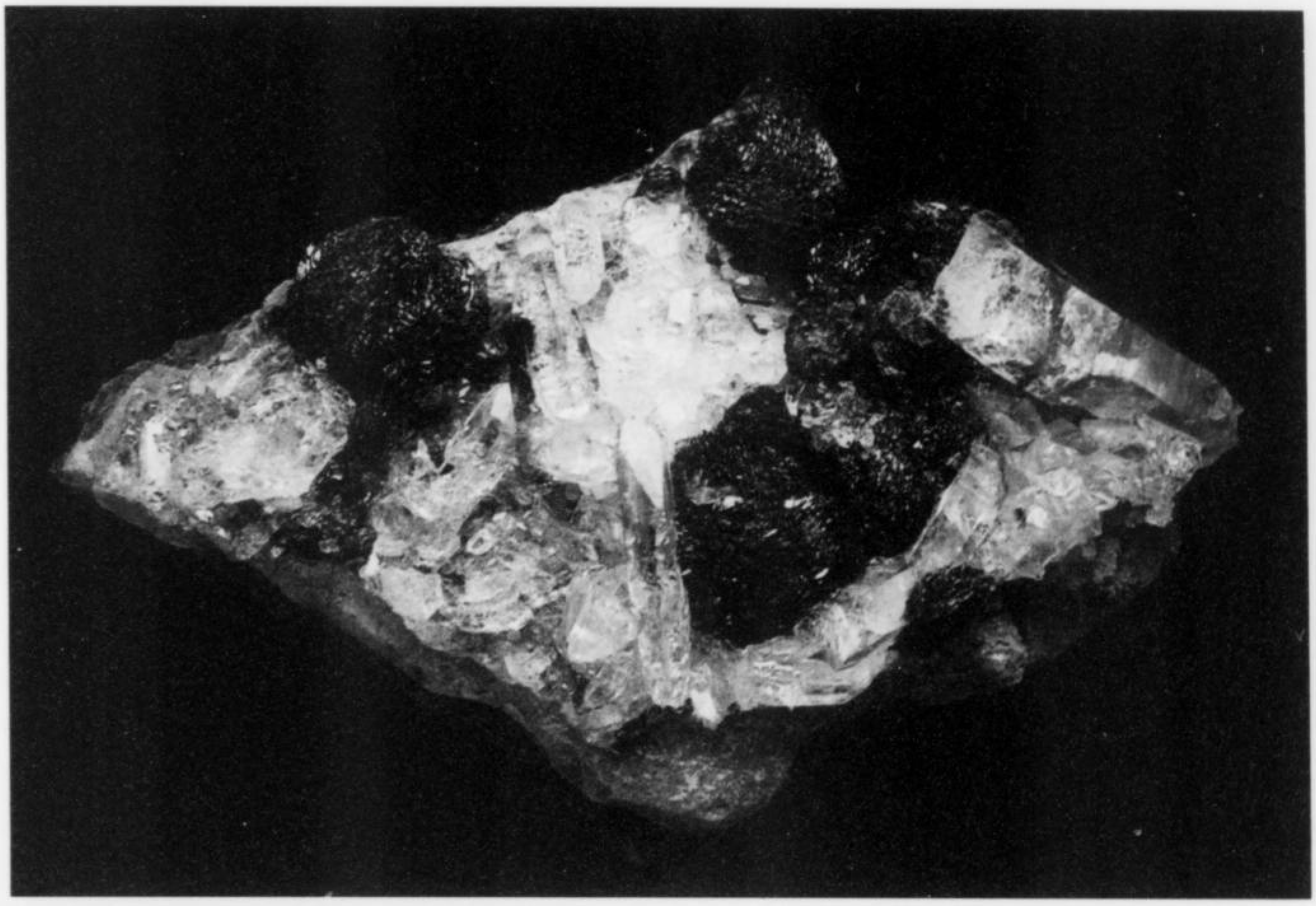


Figure 5. Pumpellyite crystal aggregates on matrix, 7.3 cm, from Sichuan, China. Jürgen Tron collection; Jeff Scovil photo.

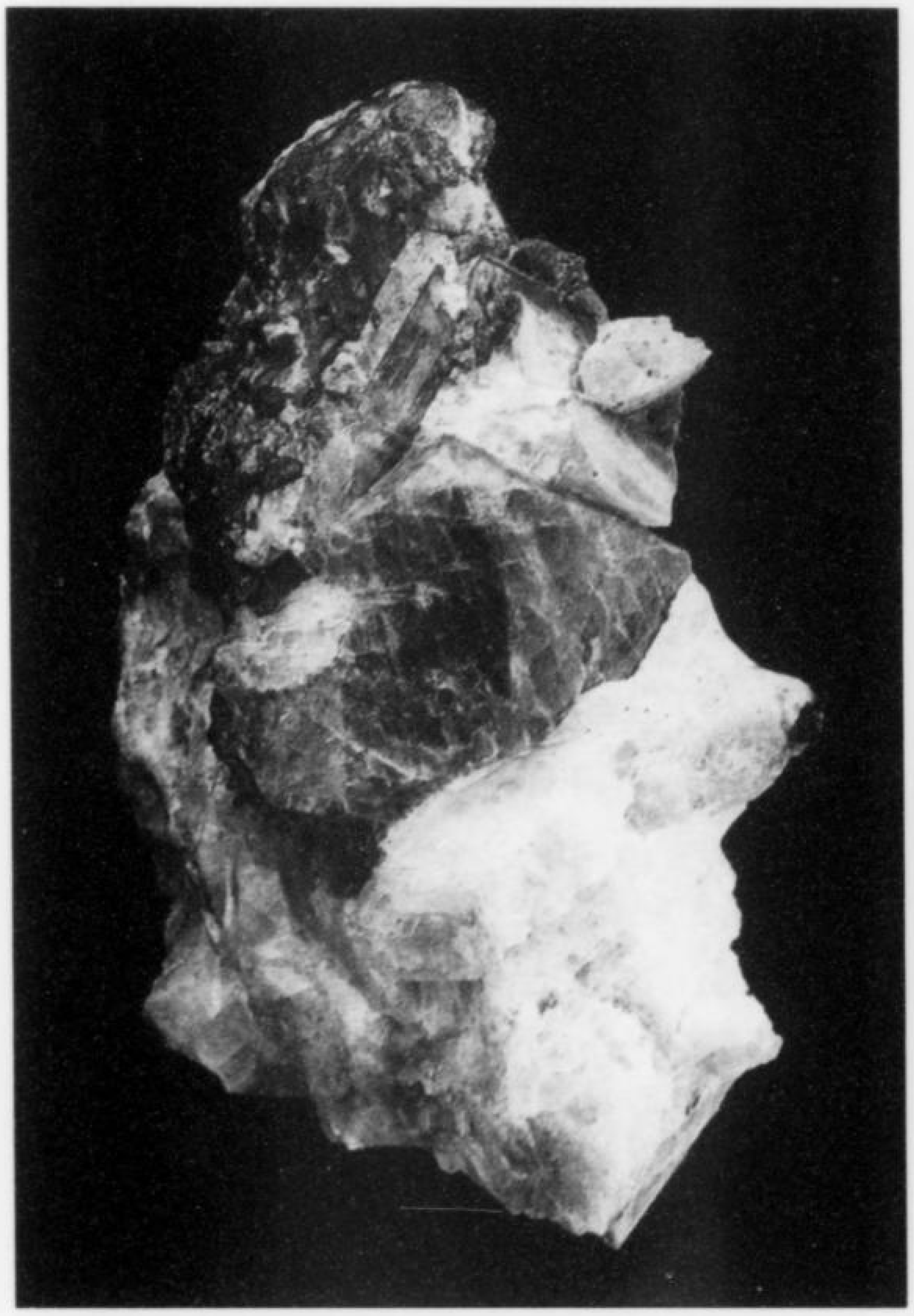
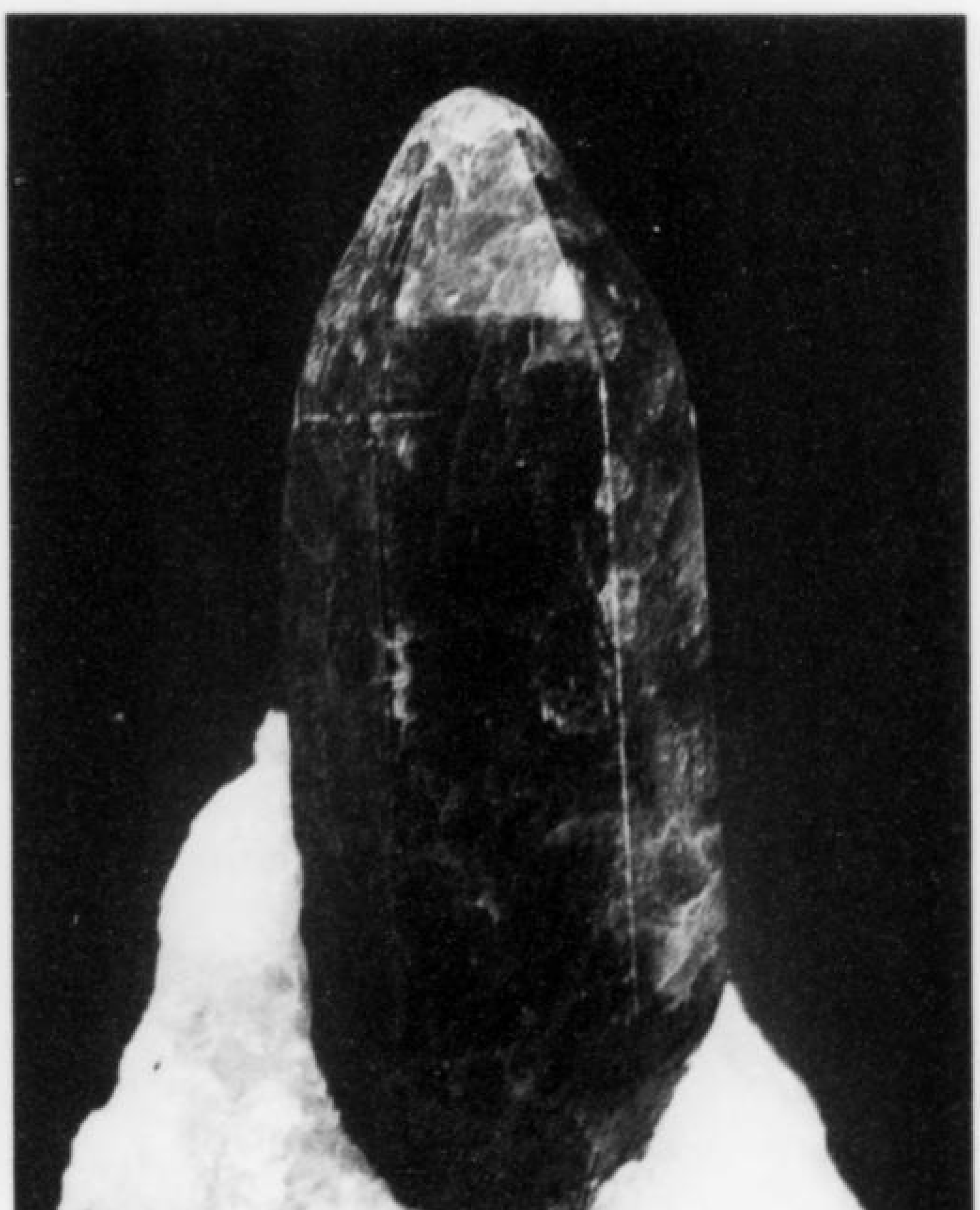


Figure 7. Purple sodalite (the sulfur-rich variety known as "hackmanite") crystal in winchite, 9.2 cm, from the Kokscha Valley, Badakhshan, Afghanistan. Herb Obodda specimen; Jeff Scovil photo.

Figure 6. Afghanite crystal, 2.2 cm, from Sar-e-Sang, Badakhshan, Afghanistan. Herb Obodda specimen; Jeff Scovil photo.



a single pocket, and had been unavailable until the Ledfords acquired the lot. The color is a rich medium green, and gemminess is total (unless you subtract points for the inevitable small etching channels). The crystals are sharp, with slightly scalloped, sloping terminal faces, some of these with the odd little curl on top that we've seen in pictures (such as the one in Bancroft's *Gem and Crystal Treasures*, in the Hiddenite, North Carolina chapter). All of the hiddenite crystals are thin, and have lengths ranging from 2 to 5 cm, and prices ranging from $400 for a small thumbnail to $5000 for the single 5 cm-long specimen. I hardly need to add that these are major classics, close to impossible (until now) to find on the market. A reminder is sometimes necessary that, although gemological varieties like hiddenite are not as well-defined as actual species, true hiddenite (like emerald) must draw some of its color from chromium. Much green spodumene from Brazil has incorrectly been labeled "hiddenite" though lacking the chromium chromophor.

At the *Tyson's Minerals* stand at the Main Show, Rod Tyson was proudly showing a world's-best-for-species item collected this past summer at the Big Fish/Rapid Creek area in the far northern Yukon (relevant Special Issue: *Yukon Phosphates*, vol. 23, no. 4). The species is **whitlockite**, best known heretofore in microcrystals from the Palermo #1 mine, New Hampshire, and other old phosphate pegmatite occurrences. No micromounts, these new ones, but rather lustrous gray-white to palest green, translucent tabular crystals from 5 mm to 2 cm, growing individually and as tight clusters on dark blue matrix of massive rare phosphates (gormanite, kulanite, arrojadite, etc.). A superlative thumbnail with a 2.2-cm whitlockite crystal standing up edgewise on matrix was priced at $500, but other thumbnails, still impressive, ran down to $50. And for $900 there is one 5 x 6-cm piece of matrix covered with jumbled white whitlockite crystals all around 1 cm.

A nice Mexican entry in the what's-new derby is some brand-new, beautiful "optical" **calcite** from near Rodeo, Durango, Mexico. Matthias Jurgeit of Lampertheim, Germany has been digging the specimens from an unnamed prospect, as have also some local farmers, so that the excavation is now about 4 meters wide and 7 meters deep. The calcite vein is hosted by a rhyolitic tuff, and it contains vugs up to 60 cm wide. Since this past January, between 250 and 300 specimens have been produced, of which about 30 are butterfly twins; the rest are very attractive sprays of steep scalenohedral crystals, and rounded clusters of flattened rhombohedrons. Specimen sizes range from 4 cm up to around 15 cm. The luster is silky, and the crystals are almost colorless to faintly gray, and completely transparent. Matthias Jurgeit partners up with Ed Huskinson in a dealership called *Luadra Minerals* (4804 Steinke Dr., Kingman, AZ 86401), whither you may apply for specimens (since more will almost surely come out, and the Mexican prospectors, Ed says, are learning the skills necessary for damage-free collecting).

In the same room at the Holiday Inn, Matthias Jurgeit was showing some nice specimens from Cerro del Mercado, Durango, Mexico, the source of gemmy yellow **fluorapatite** crystals. Since 1828 the hematite-infused breccia of Cerro del Mercado has been mined for iron; for decades during the 20th century the apatite crystals were plentiful on the specimen market, becoming much less plentiful after the mine closed in 1975. But commercial mining began in another part of the orebody in 1993, and now the pretty crystals are trickling out again. In the Luadra room in Denver, about a dozen loose gemmy crystals to 3 cm and a couple of flats of miniature-sized matrix specimens with apatite crystals to 2 cm were available. The hexagonal-prismatic crystals seem almost never to be doubly terminated, but sharp pyramidal single terminations are common enough, and the crystals are often transparent enough so that one sees the rough reddish matrix straight through all that rich orange-yellow. A few of the single crystals have waxy looking bits of grayish white hyalite opal adhering to their sides.

Andy Seibel (P.O. Box 2091, Tehachapi, CA 93581) has acquired about 20 very nice specimens of the **boleite** that Ed Swoboda mined in the 1970's from the renowned Amelia mine at Boleo, Baja California, Mexico. All specimens consist of brownish/reddish/greenish, amorphous-looking stabilized matrix in which are embedded the sharp, deep blue boleite cubes, all around 1.5 cm on edge. Specimen sizes range from 4 x 4 to 6 x 8 cm. I saw no stepped edge-ridges that might betray possible overgrowths of pseudoboleite on any of the blue cubes: they are bright, sharp, and clean crystals, and, of course, utterly distinctive for this classic occurrence.

A shipment of very fine **Japan-twinned quartz** from Peru only got in to Denver on Saturday, and spies alerted me in time so that I could see the specimens and get the scoop from their owner, Giovanni Russo of *Mineral Center* (Gran Mercado Inca, Av. La marina 884, Tiendas 13-14 Pueblo libre, Lima, Peru). Last January, about 150 of these quartz specimens, in sizes from small miniatures up to cabinet pieces, were found in a vein in the polymetallic ore deposits of the Mina Flor del Peru #2, near Pampa Blanca, Castrovirreyna province. A few shows ago I reported on a similar hoard of Japan-twinned quartz whose locality was then given simply as "Pampa Blanca"; it turns out that this is the name only of the nearby town, and the mine from which the earlier lot came is the Flor del Peru #1, #2 or #3, all three mines being within a few miles of the town. The quartz crystals are mostly frosty (a very few are glassy), but the twinning form is sharp, with varying re-entrant angles, and the twins reach an amazing 12 cm across. Most of the large clusters, to 25 x 25 cm, consist of conventionally prismatic quartz crystals with just one or two Japan-law twins sitting prominently in their midst, but there are also a few clusters of *all* Japan-law twins, including one fascinating 15 x 22-cm group of maybe 100 twins, from 1 to 4 cm, all flaring irregularly from matrix, like butterflies on a log preparing for takeoff. There is little or no matrix on the majority of the pieces, and no hint of any associated species.

A pocket found very recently in the Viboras vein of the Machacamarca mine near Cotavi, Potosi, Bolivia has given up a number of unusual **bournonite** crystals measuring individually from 3 x 3 cm to a giant 6 x 6 cm! The crystals are tabular, apparently twinned "cogwheel" plates with a dull to metallic luster and/or an earthy black coating on the big plate faces and a complexity of small, much more lustrous, steel-gray faces around the edges—big metallic gray "ears," unlike any bournonite crystals generally familiar to collectors. Cement-gray shards of rock and subhedral brown rhombohedra of siderite cling here and there to the surfaces. Rob Lavinsky of *The Arkenstone* had about 20 miniature to small cabinet-sized specimens; *Excalibur Minerals* had about ten more, and there were isolated examples in other hotel rooms.

Brad and Star Van Scriver of *Heliodor* were offering—besides the show's best hoard of almost surrealistically fine new Moroccan **vanadinite**—about 15 thumbnails and small miniatures of a very appealing blue **fluorapatite** just found in a pegmatite prospect somewhere in the state of Paraiba, Brazil. Sharp, very lustrous, deep blue to mottled blue-white, translucent to gemmy fluorapatite crystals reach 1.5 cm; they are fat hexagonal prisms with pyramid and pinacoid faces, and they rest on velvety beds of fine-grained muscovite with a few incomplete gray-green elbaite crystals lurking inside the mica. Specimens with one or two bright blue apatite "barrels" lightly attached to the silvery gray matrix score an aesthetic Ten.

The sharp loose prisms of **xenotime** from Bahia, Brazil have been known for some time, but three huge crystals shown in the hotel ballroom by Doug Wallace may well be the world's best xenotime specimens (Marty Zinn bought the very best one early on in the show). Doug, of *Mineral Search, Inc.* (11882 Greenville Ave., Suite 123, Dallas, TX 75243) gave the locality name as "Ibiajara"—fairly close, by Brazilian locality-name standards, to what has been given in the past. The xenotime crystals are a deep yellowish brown, slightly rough-surfaced tetragonal prisms ending smartly either in four equal pyramid faces or in two, for a wedge-shaped termination; the Big Three are 4, 5 and 5 cm high. Flashing yellow-brown highlights play just under the bright glassy surface. Doug got the three giants, and eight thumbnail crystals too, from the Jerry Manning (Texas) collection. Xenotime is a phosphate of yttrium and the rare-earth metals, and analyses of these specimens show a very high 8% dysprosium content.

Also from Brazil, Luis Menezes (R. Esmeralda, 534, Belo Horizonte—30410-080—Brazil) had his usual bunch of small surprises. For one, he had much *better* thumbnails than previously of **beryllonite** from the Telirio mine, Linopolis, Minas Gerais (already familiar as the source of the fine, sharp **brazilianite** crystals of late). The beryllonite comes as sharp cyclic twins, milky white to translucent to transparent and colorless, reaching 1 cm, in about ten thumbnail clusters without matrix (average price $125). And there is one astonishing, lustrous, transparent-colorless fishtail twin of beryllonite measuring 6 x 7 cm (unfortunately broken along the twinning plane, but soon to be repaired).

From another mysterious small hole near Linopolis came, last June, about 20 matrix specimens and 100 loose groups of medium-green **gormanite** in spheres of radiating acicular crystals, on sharp blades of "cleavelandite" albite. The spheres reach 3 cm across, and are earthy green in surface appearance. The best specimen Luis had is a 6 x 6-cm albite matrix with two intergrown 3.5-cm gormanite balls.

Luis' third noteworthy offering consisted of several flats of loose thumbnail and small miniature-sized crystals of **andalusite** from the Jenipapo mine, Itinga, Minas Gerais. Not pretty, but quite good for the species, the andalusite crystals are an opaque to translucent pinkish brown; the wedge-terminated prisms get up to 4 x 4 x 5 cm, with traces of the massive quartz in which they are found embedded. The quartz, in turn, forms veins in a schist surrounding a pegmatite. Luis has hopes for more specimens in the future as exploration continues.

A geologist friend of Dave Bunk has brought up a substantial consignment of specimens of very fine **inyoite** with **meyerhofferite** from an evaporite deposit at Nacimiento Sijes, Satta province, Argentina. About 50 surprisingly attractive miniature and cabinet-sized specimens were to be found in Dave's room in the Holiday Inn. The inyoite forms colorless, transparent rhombohedrons to 8 cm, partly tinted pale brown by included clay. Some of the inyoite in the clusters of crystals is still entirely "clean," i.e. not yet dehydrated or altered, while in other specimens the inyoite crystals show partial fillings of needle crystals of white meyerhofferite. Specimens range from miniatures for as little as $10 to big 22-cm clusters for $1000.

Also from Argentina (an "undisclosed" locality some 400 km southwest of Buenos Aires) have come two of the oddest **magnetite** (?) specimens anyone has ever seen, both in the keeping of John Attard (www.attminerals.com). One specimen, measuring 3 x 3 x 6 cm, is a prism of four equal sides, the sides bordered by solid black pillars, but deeply cavernous on the faces, with parallel-growth chevrons pointing upwards; at the top, four ridges slope up from the corners like flying buttresses to form a "roof." The other specimen, measuring 1.5 x 1.5 x 11 cm, is a long tower of the same stacked-chevron development up the shaft, and a small wedge termination. Surfaces on both specimens are sandpaper-rough, and the overall color is black, with some red staining. John was told that the species is either hematite or hematite pseudomorphous after magnetite ("martite"), although somehow they look more like magnetite, especially as there are simple black magnetite octahedrons around one end of each specimen.

Europe pretty much struck out this time in the what's-new batters' box, but this seems a good place to salute Wayne and Dona Leicht of *Kristalle* for their usual juicy selections (as also at Springfield and Tucson each year) of old European classics. Chief among these at the Main Show in Denver were six outstanding old Kongsberg, Norway **wire silver** specimens, from a couple of loose 3 x 4-cm nests of bright, thin wires to a majestic 17-cm piece with silver wires of varying thicknesses "nesting" all over a cluster of white rhombohedral calcite crystals to 2 cm.

Brilliant black plates of **hematite** with epitaxial rutile from Cavradischlucht, Graubünden, Switzerland are hardly "new" either, but Marshall Kovall of *Silver Scepter Minerals* (P.O. Box 3025, Kirkland, WA 98083) had about 15 terrific miniatures of the material, dug recently by some heroic Strahler. The hematite plates are up to 3.5 cm wide, and they sit up singly, edgewise, or else form subparallel, offset clusters ("iron roses") on gneiss matrix, with albite crystals to 1 cm. There is very little damage on any of these specimens, and they're bargains at $75–$350.

At Gilbert Gauthier's stand at the Main Show I talked with Dr. Georg Gebhard (D-51545 Waldbröl-Grossenseifen, Germany) about the currently very hot localities for **aquamarine, tourmaline-group species**, and jeremejevite in the Erongo Mountains, Namibia. Especially interesting among the specimens being offered by Gebhard were the combinations of gemmy aquamarine crystals with deep bluish black **foitite**, a high-iron member of the tourmaline group. Foitite crystals from Erongo are highly lustrous, with rich blue internal reflections sometimes discernible in backlit portions of thin crystals; most of the foitite crystals are thin-prismatic to acicular, occurring in parallel bundles and jackstraw clusters, and a few thicker crystals show etching down to a ridge of trigonal (Mercedes-Benz) shape on one end. There may be one or two rarer tourmaline-group species present, and whether or not the beautiful, thick, lustrous black "schorl" crystals from this locality are also foitite is a matter of some debate. The crystals come in all sizes up to about 10 cm, and the ones with aquamarine, or on matrix with little green fluorite cubes, are very striking. Rocko and Mandy Rosenblatt of *Rocko Minerals* (Box 3A, Route 3, Margaret—ville, NY 12455) were meanwhile offering, in the Holiday Inn, their best-yet specimens of Erongo schorl, in flashing black clusters of near-perfect 8-cm crystals.

Ongoing digging in the Erongo wastes has recently also turned up a pocket of **jeremejevite** crystals from 1.5 to 4 cm long, all specimens being thin, loose singles. They vary from almost colorless to a pale greenish blue to a most desirable (but unterminated) deep blue; from the last type some nice faceted gems have already been cut. Gebhard had five loose gemmy jeremejevite crystals, and the Leichts had five more.

Meanwhile, old Namibia specialists Christian and Petra Gornick of *Fine Minerals Worldwide* (Reutergartenweg 20, D-31319 Sehnde (Höver), Germany) came through at the Main Show with some really beautiful **hematoid quartz** specimens from the "Oranje River," a vast collecting area straddling the border between Namibia and South Africa (though the better specimens are found on the Namibian side). I have noted these before, but there were no thumbnail-sized specimens before, let alone specimens as nice as

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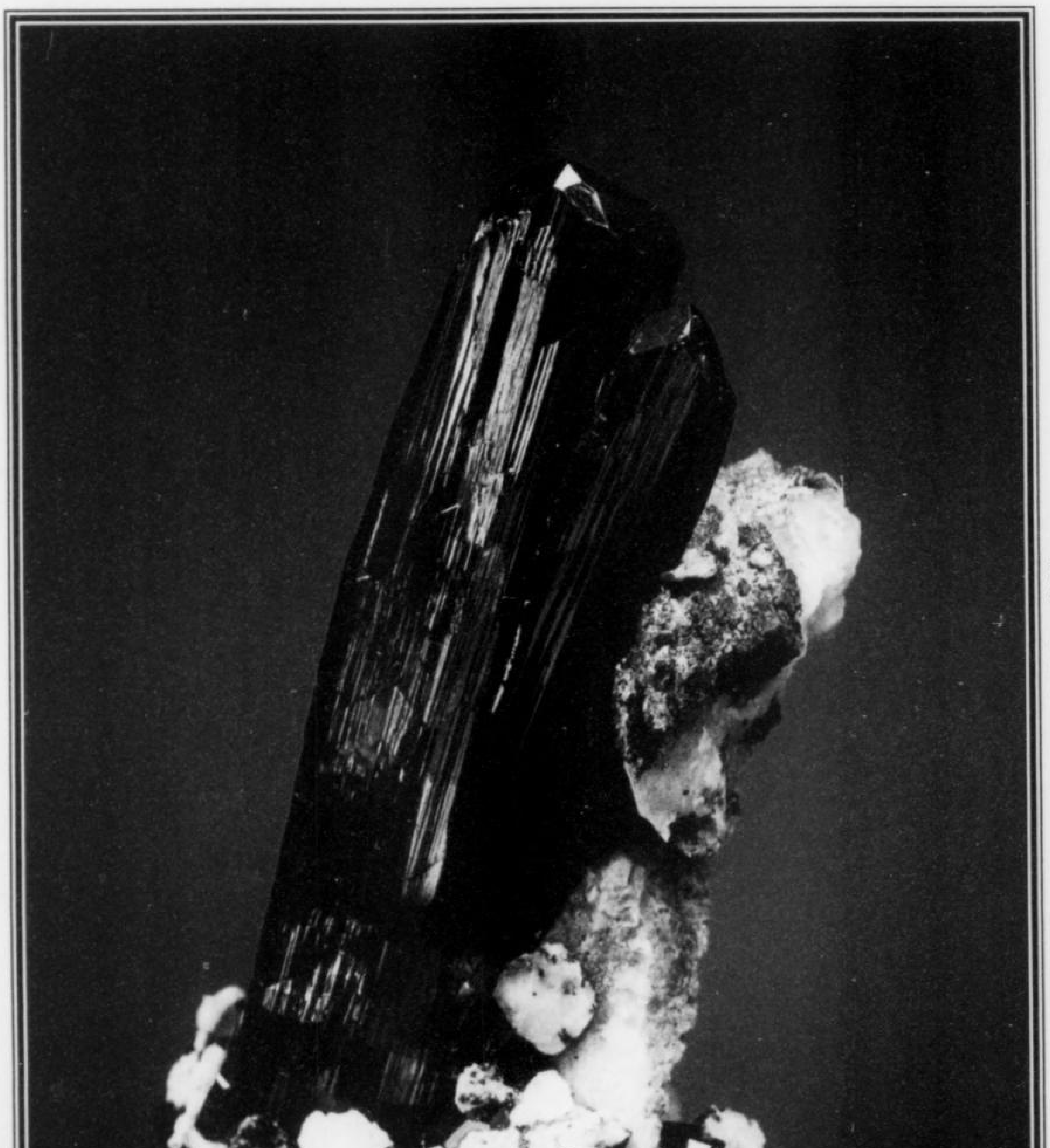
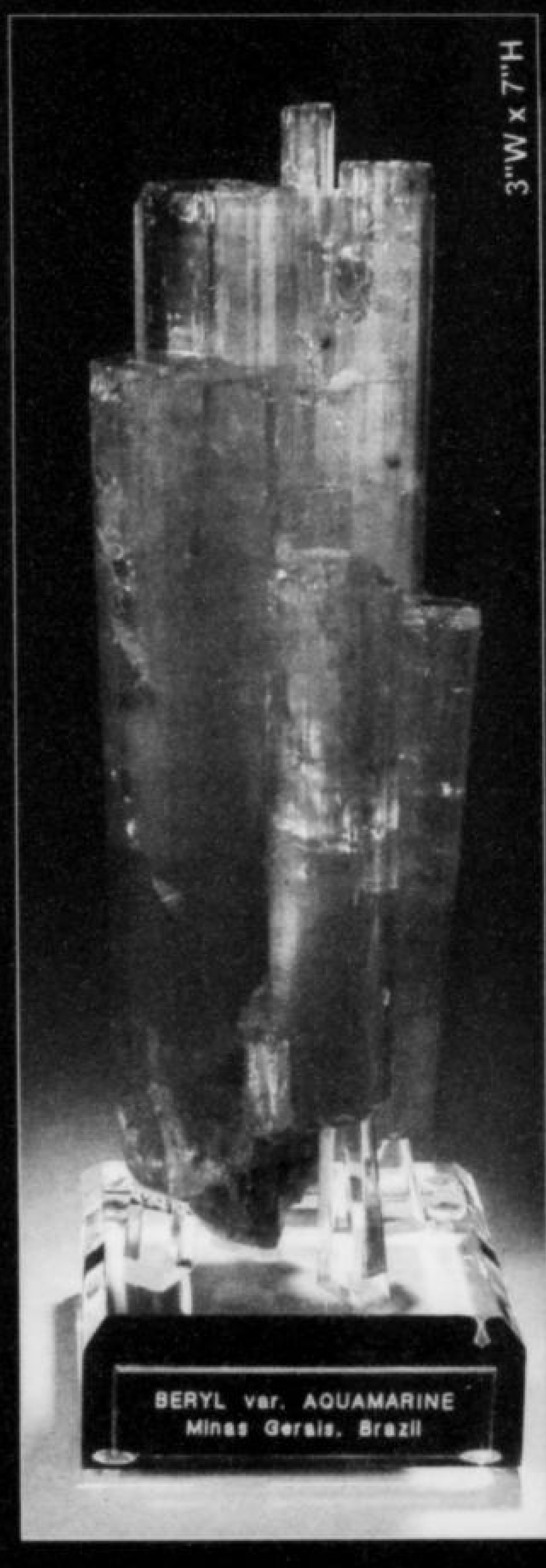

William Severance Collection; Jeff Scovil Photo

Azurite investing Quartz, 7.6 cm

Tsumeb mine,
Tsumeb, Namibia
Ex Mrs. Richard L. Smith III collection, 1972

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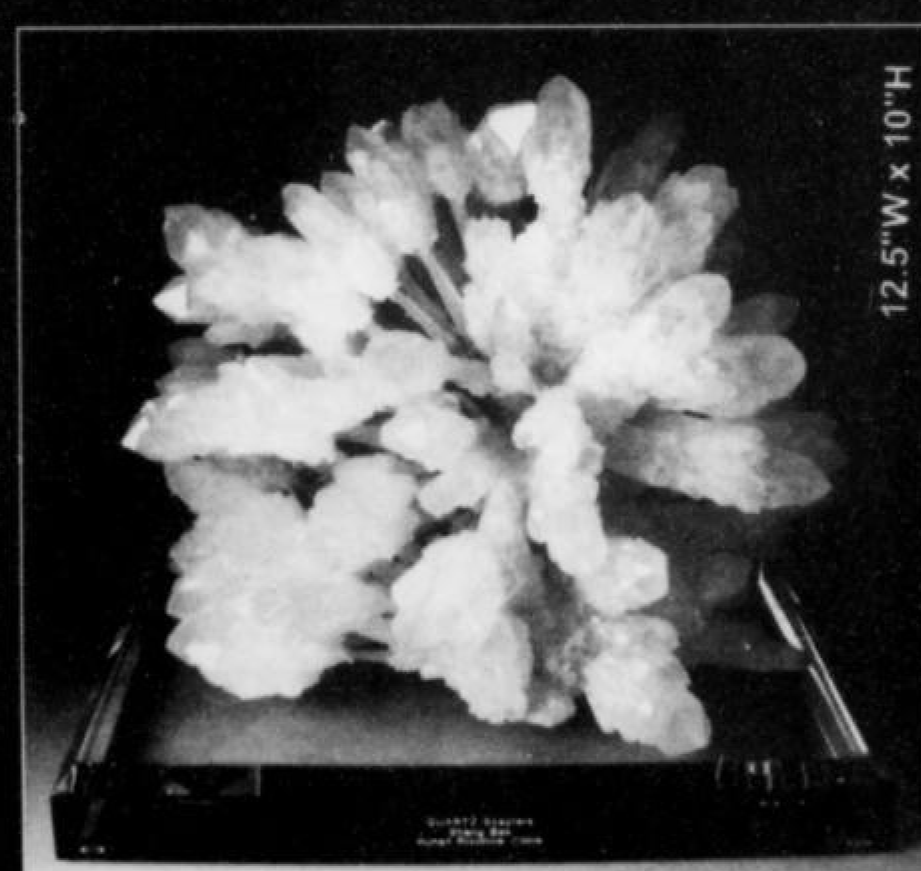
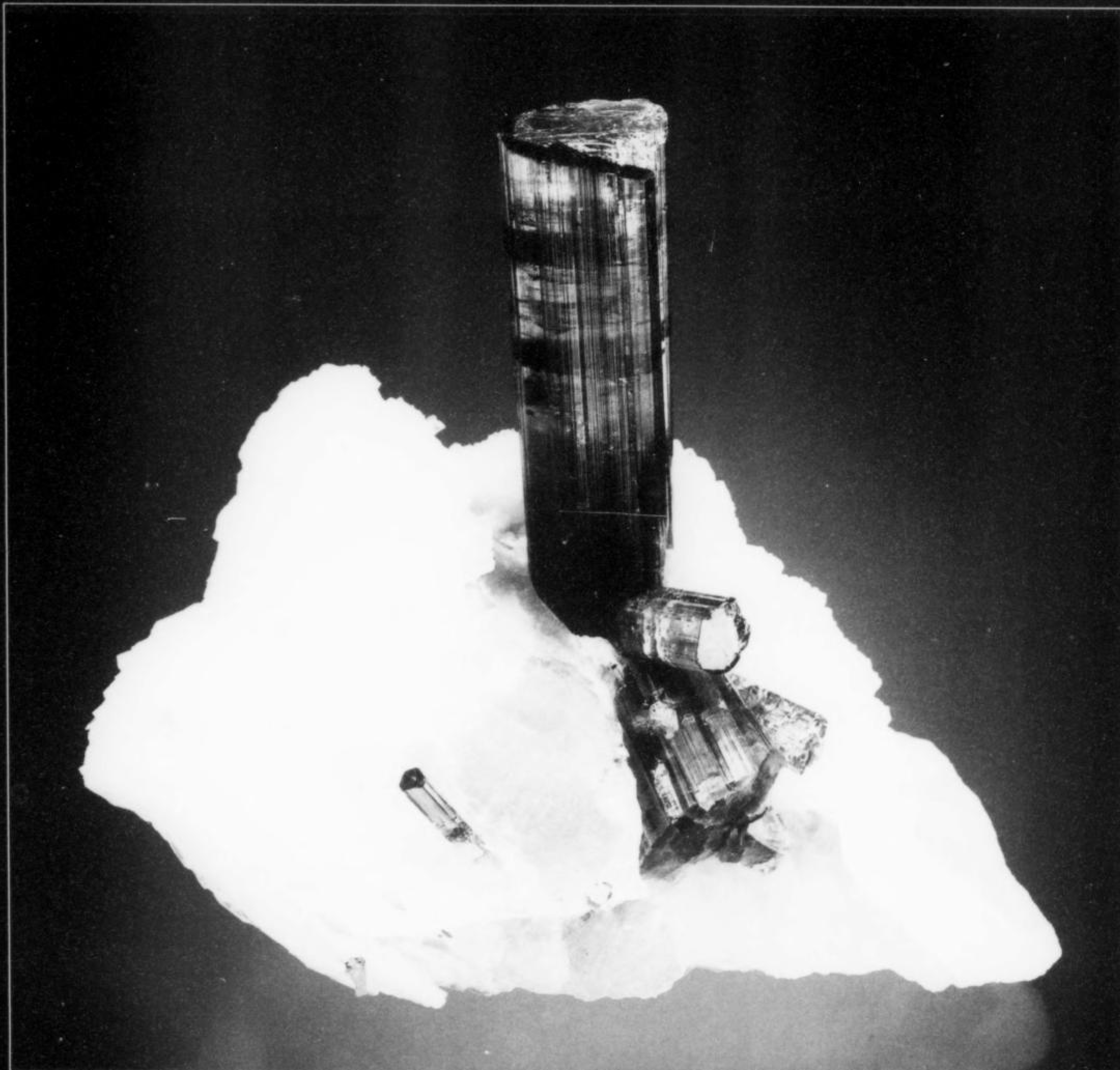




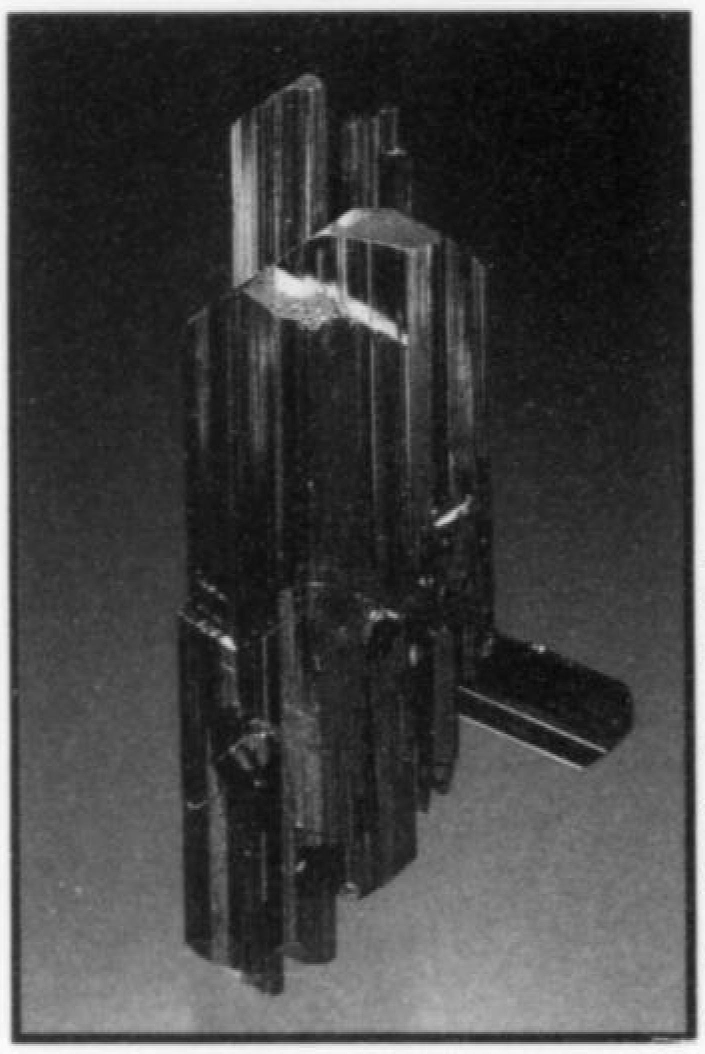
JEFF SCOVIL

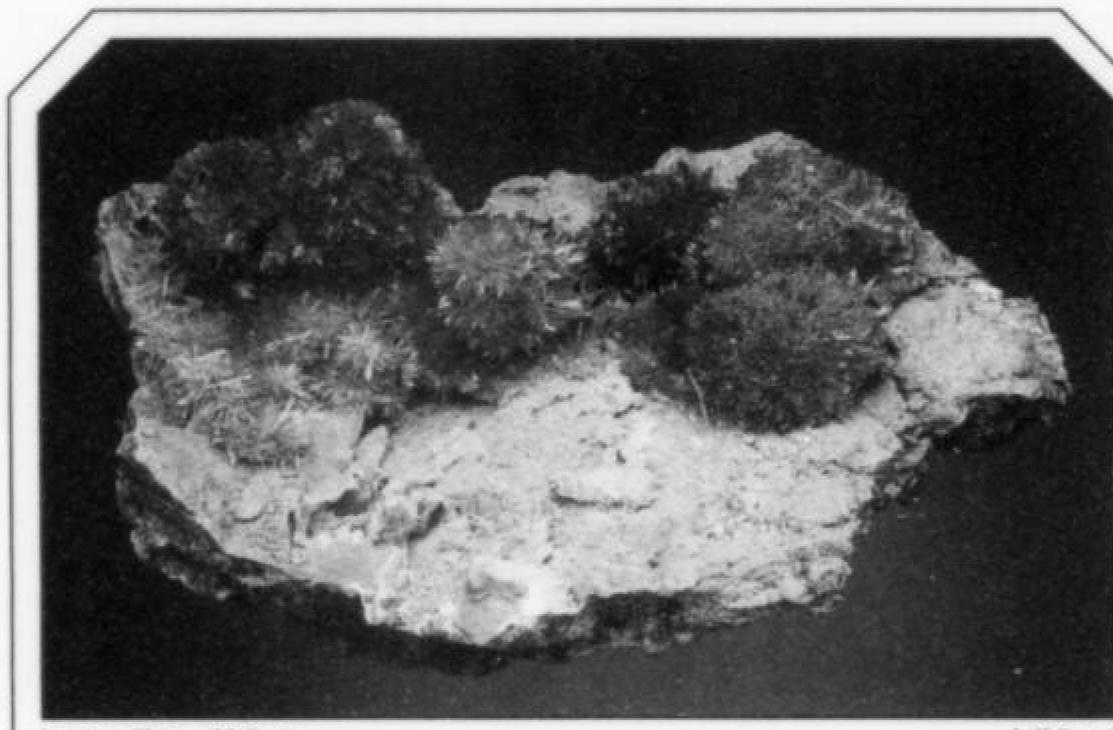
Elbaite, 12.4 cm wide, from the Pederneira mine, Minas Gerais, Brazil

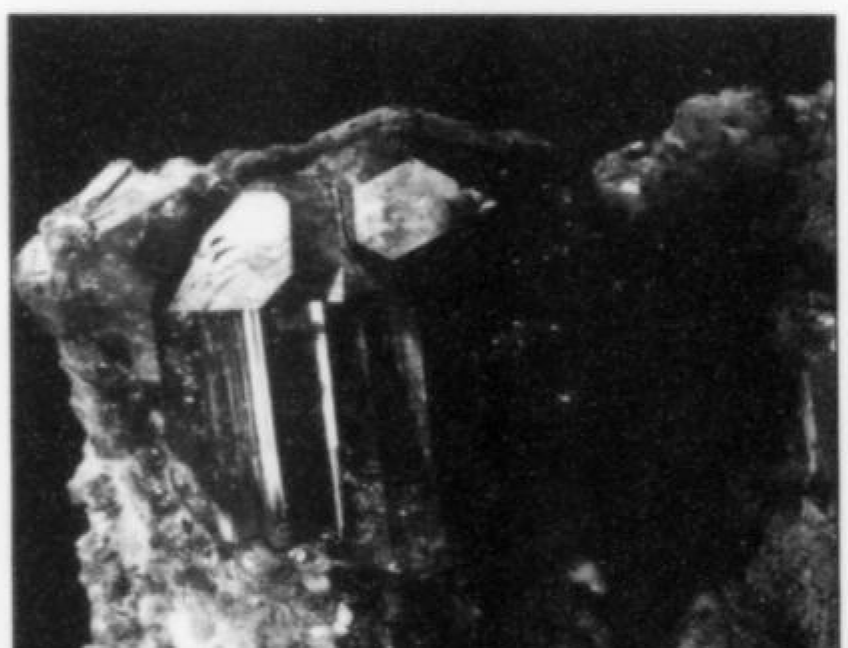
Calcite on Fluorite, Elmwood, Tenn., 5 inches. From Tom Palmer, Feb. 1981, Photo used in our 1993 calendar and *Ming Pao* (Hong Kong newspaper), Nov. 17, 2000

Clara and Steve Smale
COLLECTORS

PHOTO BY STEVE SMALE







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the Gornicks' fat, doubly terminated 2-cm prisms with bright brick-red zones sharply bounded by colorless zones. The miniature-sized quartz specimens show prisms zoned in many colors from yellow to pink to brick-red to amethyst, from inclusions of hematite, lepidocrocite, and an unknown species. A big dig for further specimens is now on, but the best thumbnails here were already good deals at around $20.

You might recall that at the end of his recent Ste.-Marie-aux-Mines show report, Bill Larson described his meeting with a French dealer who was selling off some fine old classics, mostly from Madagascar, from the collection of Jean Jacques Francis Béhier (1903–1963), who once worked as a mineralogist for the Geological Survey of Madagascar. Well, apparently the dealer didn't sell everything off in France, for here he was in a Holiday Inn room, making his maiden visit to the Denver Show with a still-considerable lot of material from the Béhier collection. He is Alain Martaud of *Mineraux de Collection* (33 Rue Compans, 75019 Paris, France), and he was having a fine time showing off his good stuff to appreciative inquirers. Included were Madagascar rare-earth classics like sharp **betafite** crystals to 4 cm; well-composed earthy brown sprays of 2-cm **euxenite** crystals; swarms of loose 1 and 2-cm cubes of lustrous black **thorianite**; and **allanite** crystal groups from Madagascar and from Alto Ligonha, Mozambique. In addition there were Scandinavian classics like loose, sharp 2-cm pyritohedrons of **cobaltite** and sharp, lustrous pseudo-octahedrons of **glaucodot** from Sweden; well crystallized **leucophanite**, **columbite** and **thortveitite** from Norway; and richly brownish red, euhedral crystals of **eudialyte** to 2 cm in complex ultra-alkaline matrix, *not* from the Kola Peninsula, Russia, but from 19th-century localities in Greenland. European classics from the same collection included Cumbria, England **fluorite** and **calcite**; fine "toenail" crystals of **azurite** from Chessy, France; "**heliodor" beryl** from the island of Elba, Italy; and much else. There was also a Tsumeb array, with fine small specimens of **mimetite, smithsonite** and **hydrocerussite after cerussite**. Educational classics, a friendly reception, and generally very reasonable prices, all made this (for me, at least) perhaps the most enjoyable hotel room visit at the Denver Show this year.

Yet another educational-room experience, and another dealership new to the U.S. show scene, was Igor Mikhailov's *"Axinite-PM" Ltd.* (22 A Rogova str., Moscow, Russia 123479). Although there were indeed many fine Russian minerals here, especially from Dal'negorsk, the really new, unfamiliar items were from the ex-Soviet republics of Kazakhstan and Uzbekistan. The copper mines of Dzhezkazgan, Kazakhstan were well represented by many excellent specimens of **chalcocite, betekhtinite** and **djurleite**, from thumbnail to 5-cm sizes, in lustrous metallic black crystal groups, the djurleite distinguishable from the chalcocite by its prismatic crystals, splintery aspect, and blue-purple iridescence. Also there were, predictably, some very fine Dzhezkazgan **bornite** crystals on drusy quartz matrix. Much rarer from Dzhezkazgan are the floater single crystals and groups of **cuprite** that show reports have noted before: Mikhailov had dozens of these, with fairly lustrous and sharp (though slightly corroded) deep red cuprite octahedrons in 1.5 or 2-cm singles and in groups to 3 cm.

But this reporter had never heard of an open-pit copper mine called the Itauz mine, which lies, Mikhailov says, about 40 km from Dzhezkazgan, and which supplies some very fine specimens of **cuprite** and **native copper**. Of the copper there were 200 or so thumbnails and miniatures in the room: fuzzy arborescent groups and sharp stacks of spinel-twinned crystals individually to 1 cm. The luster is not bright, but the price is still right—around $40 for an excellent thumbnail. Also from the Itauz mine comes a very dark cuprite, in lustrous, blackish red, distorted octahedrons to 5 mm composing loose groups and scattered over platy masses of subhedral copper crystals. Next, from the Karzemkkul deposit, Kustany Oblast, northern Kazakhstan, the dealership had about 30 miniatures of massive black **magnetite** solidly covered on open-seam surfaces by brilliant black, sharp magnetite octahedrons to 1 cm, further bedecked with grayish green, isolated, sharp books of **clinochlore** to 1.5 cm. These specimens were mined two years ago. From Sortuz, Kazakhstan, came three 4-cm matrix pieces of greenish (pyromorphite-infused) iron gossan with open seams lined by vividly red-orange, equant **wulfenite** crystals to 5 mm. But the truly weird **wulfenite** specimens are those from Sedjak, Uzbekistan: bright red-orange loose crystals to 2 cm, so thick along the *c*-axis as to appear almost equant. This room in general taught you what "exotica" can mean—familiar species in unfamiliar manifestations from deepest Central Asia, is what it can mean.

Concerning the minerals of the Deccan basalt flows of India, I should mention that longtime Indian dealer K.C. Pandey (of *Superb Minerals India Pvt. Ltd.*) is now publicizing the new museum of Indian minerals he has just opened in Nasik; the museum is called "Gargoti," and doubtless contains specimens just as beautiful as those which filled his room, as usual, in the Holiday Inn. I should also mention that two of the most spectacular of the display cases at the Main Show were filled with Indian specimens, many of them supplied by Pandey, from the collection of Steve and Clara Smale. But what I will *really* mention is that Berthold Ottens of *Ottens Mineralien* (Klingenbrunn-Bahnhof 24, D-94518 Spiegelau, Germany) brought to the Main Show a few small specimens of two little-known rarities from the Deccan region: **pentagonite** and **julgoldite**. Pentagonite is a dimorph of cavansite, has the same incandescent blue color, and occurs in the Wagholi quarry, Poona (and in smaller quarries in the vicinity), in association with the familiar cavansite. The difference is that pentagonite crystals are acicular, reach 1 cm long, and occur in needly sprays very unlike the balls or parallel-growth sheaves of cavansite. A few specimens have just recently been found which are better than the (mostly micro-sized) pentagonite specimens known previously; the brilliant blue sprays rest on pocket linings of white to colorless-transparent heulandite crystals, with a little stilbite. These sprays range from 1.5 to 2.5 cm across. Ottens had ten matrix specimens from 4 to 10 cm. Julgoldite, on the other hand, is a complex silicate belonging to the pumpellyite group. It is dull black, and occurs as microcrystals coating white mordenite needles; these specimens make you think that a white zeolite has been attacked by a mold, i.e. they are not pretty. But the few thumbnail specimens which Ottens had, found two years ago in Jalgaon, are probably the best specimens possible, at least in India, of this very rare species.

Web shoppers and earlier show-report readers may already know of the tremendous specimens of the rare-earth silicate **chevkinite-(Ce)** lately uncovered in the Nanga Parbat area of Pakistan. I saw fewer of these in Denver than I had expected to, but three crystal groups held by Andreas Weerth might attain the size record: the brownish black chevkinite crystals are heavy blades to 6 cm across, most of them dull-lustered but a few very glossy. Also Andreas had what may be the world's biggest crystal of the hexagonal cancrinite-group species **afghanite**: a tapered medium-blue, fairly sharp prism 4.5 cm long, embedded in white marble, from the lazurite locality in the Kokcha Valley, Badakhshan, Afghanistan. Herb Obodda, Dudley Blauwet and a few other dealers had fairly good supplies of the pretty pink "hackmanite" (the widely used name for this variety of **sodalite**) from the Kokcha Valley. The embedded "hackmanite" crystals, though edge-rounded, are still fairly sharp at their best, and reach 5 cm across. They exhibit an interesting color change, from pale lilac/magenta in artificial light to a deep purple/magenta in sunlight. This is not a passive, alexandrite-like color change but a genuine photo-sensitive darkening which takes about 10 seconds once a specimen is brought out into direct sunlight. And the phenomenon is reversible, the specimens turning pale again after being left in the dark for a few hours. They are also intensely fluorescent, glowing orange in longwave ultraviolet light and pale blue in shortwave, and phosphorescing for an incredibly long time after the light is turned off. Further, Herb Obodda's hackmanite crystals are embedded, not in the white marble we'd expect, but in yellowish brownish white groundmasses of an amphibole called **winchite**, with large, tabular glassy crystals of the winchite surrounding the hackmanite crystals. Peculiar stuff indeed.

China has produced beautiful specimens of at least three as-yet undetermined **copper species** occurring in big, heavy blocks of dense red hematite ore (it *looks* like hematite, though cuprite would make more sense). These are so new that Debbie Meng's two specimens are all that there were in Denver (Debbie has more, but they're still back in China). Given that these are green secondary copper minerals in ore matrix, it is surprising that they come from the same locality that has lately been producing the radically different-looking specimens of pink inesite, colorless apophyllite, and brown hubeite: the Daye mine in Hubei province. Debbie's larger piece is a 10 x 15-cm matrix with a deep cavity opened up on much of its surface. In the cavity, aurichalcite-like tufts of lustrous bluish green needle-crystals (brochantite?) vie for attention with sprays and sprinklings of a thin-prismatic, lustrous, blackish electric-green mineral (atacamite?), in crystals to perhaps 2 mm. The specimens remind me of the brochantite/cyanotrichite combinations from the old Grandview copper mine in the Grand Canyon (although these carried no atacamite). Under it all, as a seam lining, is a velvety black manganese or copper oxide. At any rate, these are dramatically beautiful specimens; if commercial quantities become available the specimens should become instant Chinese "classics."

Finally, shaft #3 of the Wuling antimony mine, Qingjiang, Wuling County, Jiangxi Province, China, has very lately yielded what are certainly some of the world's finest **stibnite** specimens. *Collector's Edge Minerals* acquired the lot, and I was able to see some of the top pieces during a visit, in July, to the *Collector's Edge* shop in Golden, Colorado; at the Denver Show, many of these specimens and hundreds of others were available from *Collector's Edge* in their booth at the Main Show and in their room at the Holiday Inn.

The stibnite crystals are a very clean metallic gray-black, lightly striated, and with a uniformly brilliant luster along the prism faces (most termination faces are matte-gray), and there is remarkably little damage on any of them. Most of the specimens are single loose crystals, but there are also dozens of crystal clusters in subparallel growth and irregular jumbles; many preserve small matrix base plates and/or have side-adhering shards of gray chert sparkling with microcrystals of quartz (there are no other associated species). The sheer size of the stibnite crystals is amazing. The biggest I saw in Golden is 40 cm long (and only about 1.5 cm wide and thick—with no repaired breaks!). Several other crystals attain lengths of around 35 cm, and one slightly flattened 1 x 2.5 x 35-cm floater is actually doubly terminated. A highly aesthetic 37-cm specimen has two thin, bright prisms, 23 and 26 cm, rising from a 4-cm piece of matrix held to the side by girderworks of smaller crystals, and then a terminated 8-cm prism continuing due south from there. All crystal terminations are very simple: pairs of flat, faces forming simple low-angle wedges, only a few having one or two additional terminal faces beveling the chisel. These simple terminations are markedly different from the complex and highly lustrous terminations typical of old Japanese specimens and of stibnite crystals brought out during the last few years from the Xikuangshan antimony mine near Lengshuijiang, Hunan, China.

Two large stibnite pockets were encountered in the Wuling mine late in 2000. In late November the first pocket was hit in shaft #2, but blast damage and faulty recovery techniques destroyed most of the contents. In early December a second large pocket was hit in shaft #3, and this time the miners were counseled and coached in damage-avoidance by several Chinese mineral dealers who had had experience in collecting out crystal pockets at the Xikuangshan antimony mine; consequently the shaft #3 pocket at the Wuling mine yielded several hundred fine specimens, of which 25 or so are world-class. Although the mine has been in operation for about 20 years, all stibnite crystals found before the discovery of these two pockets were processed as antimony ore—credit Civilization, therefore, with having taken one small step forward. Prices for these exceptional pieces at Denver were pretty civilized too: an abundance of fine large cabinet specimens of stibnite were available for $300 to $500. Four-figure prices were asked for some really large and spectacular clusters in the glass cases, but excellent smaller specimens, with stibnite crystals to 8 cm long, could be had for under $100.

Space constraints forbid a detailed review of all the displays at the Main Show. It was heartening to see, however, that all of the cases were filled, some by local collectors coming to the last-minute rescue when some of the out-of-state collectors and museum curators who had planned to bring exhibits got caught in the nationwide grounding of all airlines. Crowds at the Main Show were thin by the standards of previous years, but some dealers still did reasonably well, and those buyers who did come were treated to some very beautiful sights.

About ten showcases of minerals were supplied by various private collectors, clubs and institutions, addressing the theme of the "minerals of the Pikes Peak batholith"; fine, often enormous specimens of that Colorado trademark, smoky quartz with green microcline ("amazonite"), were all over the hall. But top honors in the Colorado minerals department must go to the big case full of miscellaneous Colorado specimens self-collected between 1972 and 2001 by Dan and Dianne Kile. This case proved the Kiles to be Colorado field collectors without peer (at least without *living* peer . . . the late Clarence Coil being another famous name in Colorado field collecting), and no slouches, either, at presenting specimens aesthetically for display. In a way almost moving, the case summarized a field-collecting career of the highest skill and devotion.

I've already mentioned the two breathtaking cases of Indian minerals put in by Steve and Clara Smale. Memorable also was a fine case on St. Andreasberg, Germany, with an ancient, amazing pyrargyrite specimen over a foot across, put in by Herb Obodda. The Smithsonian's case of new acquisitions showed examples of familiar occurrences available at recent shows, in specimens of the highest caliber. (The Smithsonian's Paul Pohwat made it into town with their exhibit just under the wire—his comrades, scheduled on a slightly later flight, got stranded in Washington.)

But it was Irv Brown's case of 22 extremely fine cabinet specimens that was the standout for show-stopping minerals. Following Irv's personal philosophy, there were no labels here to detract from the aesthetic impact. His exhibit was aimed squarely at the cognoscenti, as if to say, "If you don't already know what these are, you don't know enough to fully appreciate them anyway." Picking highlights here is a futile exercise, since all specimens were world-class, but personally I favored the Siberian sperrylite; the Kongsberg silver; the Idaho pyromorphite; the Cosquez mine, Colombia specimen with a 2 x 3-cm deepest green emerald crystal on a bed of sharp gray calcite rhombs; and the stunning Tsumeb cuprian adamite (from the one best pocket), an insanely bright green 4 x 7-cm cluster topped by a perfect 4 x 4-cm fan of thick crystals.

So it was a good Denver Show after all, despite everything. Even if the world should be harrowed by war and uncertainty in the coming months, let's promise ourselves to prevail over the forces that would keep us from enjoying what we love in life. **See you in Tucson!**

[**ERRATUM:** The **chevkinite-(Ce)** specimen illustrated in the previous issue (p. 489, Fig. 3) was actually from Jordi Fabre, not Mountain Minerals International.]

Franklin Show 2001

by **Joe Polityka**

[September 29–30]

After the events of September 11, 2001 at the World Trade Center in lower Manhattan (where my wife and I both work) I realized that after family and friends, health, country and the Almighty, one's hobby can provide comfort in times of stress and need. With that in mind I packed up my family and headed to the Franklin, New Jersey Show. Unfortunately, the day started off cold, damp and dreary; however, by noon the sun was out and blue sky could be seen in all directions.

Lots of folks obviously felt the way I did; attendance was good and about 50 or so tailgaters were set up on the athletic field adjacent to the indoor show. Of course, many old friends were there and, despite the somber mood, minerals were traded, bought and sold with the same vigor as at previous shows. The 25 dealers set up inside the building had plenty to look at; as in previous years there were many one-of-a-kind specimens with something to please every collector.

One surprise tailgater was Terry Szenics (4 Manchester Drive, North Massapequa, New York 11758). Terry told me he was back in the US and in the mineral business. Terry had several items in the "What's New" department, including specimens of the new species **lemanskiite** (a copper arsenate) from Guanaco, Chile. The specimens consist of generous sky blue, pearly masses in a rock matrix, mostly in miniature to small cabinet sizes. His second new item is **penfieldite** (a lead oxychloride) from Sierra Gorda, Chile. The transparent to white, bipyramidal crystals reach about 5 mm in size and are associated with blue **boleite** microcrystals. These were popular items at the show but Terry assures me he still has a good supply of both minerals available.

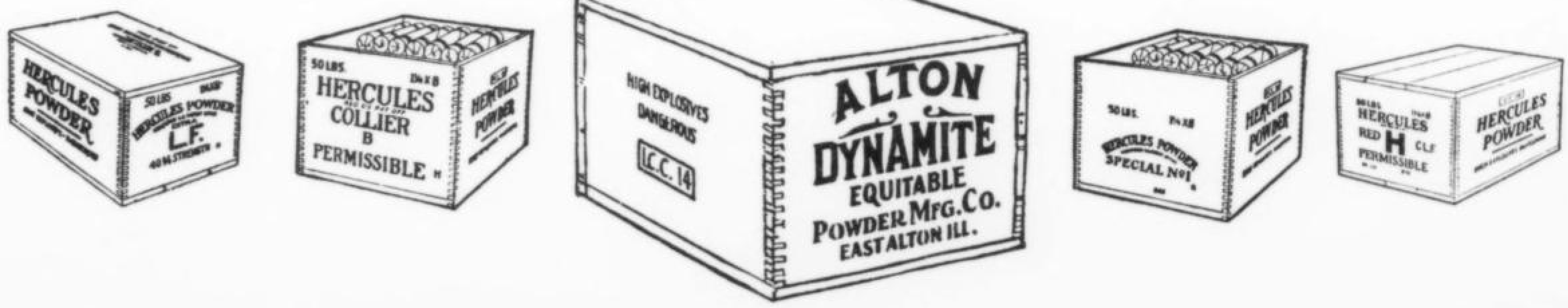
Carter Rich had his usual well-rounded inventory of specimens. Carter also was disbursing several flats of classic botryoidal **mimetite** from the old San Pedro Corralitos locality, Chihuahua, Mexico. The specimens, from the original find of the 1960's, were stashed away in the Fred Croad collection until Carter recently liberated them. They are all miniatures and small cabinet-size pieces having that pleasing lemon-yellow color we are all familiar with.

Rocko Rosenblatt of *Rocko's Minerals* (Box 3A, Route 3, Margaretville, NY 12455) had **vanadinite** crystals to 2 cm from Mibladen, Morocco. Most specimens are in miniature to small cabinet sizes and are from the recent find. Some specimens are the familiar aggregates of crystals while others consist of crystals on a white, bladed barite matrix. Prices were very reasonable.

Rocko also had transparent jackstraw **quartz** groups, in all sizes, from Jinkouhe, Sichuan Province, China. The crystals reach about 5 cm, most of them also doubly terminated, and are reminiscent of the old Jeffrey quarry, Arkansas groups. Some crystals have inclusions of what appears to be graphite.

In the evening I attended a club-sponsored dinner-lecture. The speaker was Lance E. Kearns, Professor of Geology at James Madison University in Virginia. Lance spoke about the mineralogy of the Franklin marble, a rock formation close to the hearts of the collector of Franklin, New Jersey minerals.

Be sure to set aside a day to visit this show next year. And, don't forget, bring your duplicate minerals so you can set up at the outdoor show.



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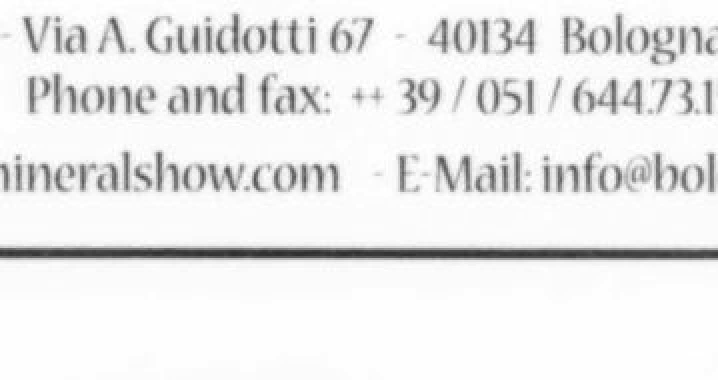

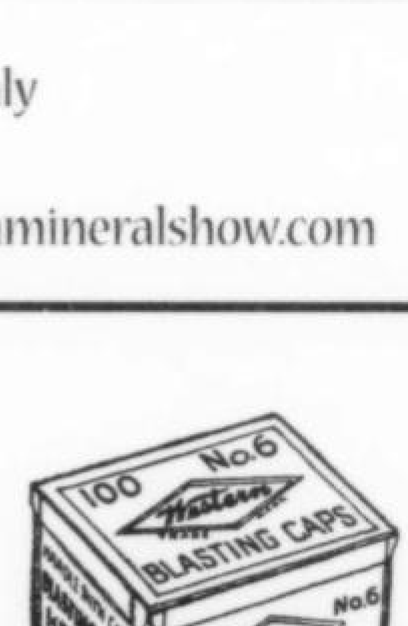

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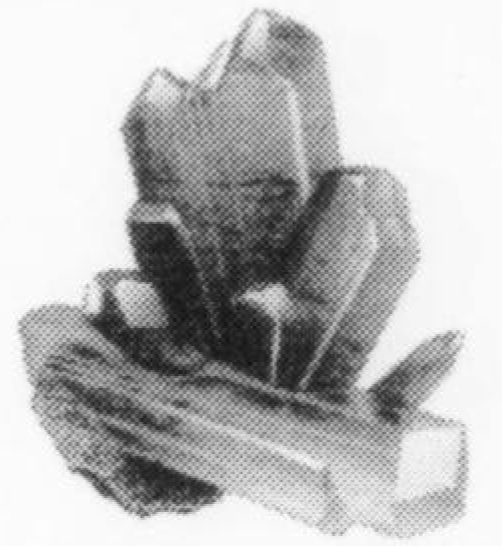

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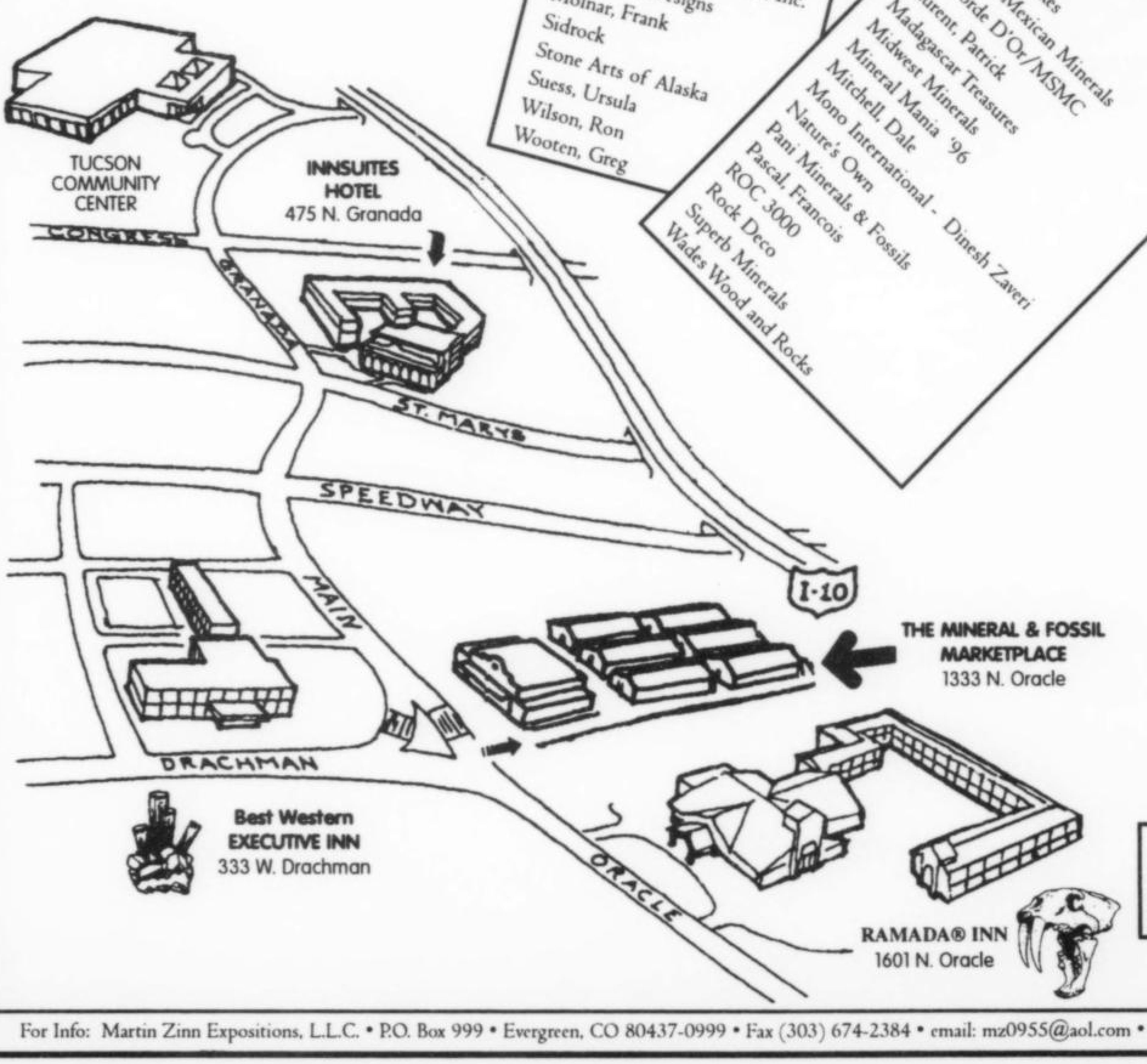

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