Minerals of the Bulldog Mountain Mine (or Bulldog Mine)
A Legacy Rich In Silver
Creede Mining District, Mineral County, Colorado, USA
By Ken Kucera

Fabulous mineral specimens from the rich Bulldog Mountain Mine grace private and museum collections the world over. Its mineral wealth is well represented at the Mines Museum of Earth Science. The best-known specimens are native silver in a wide array of habits and mineral associations. Also recovered from the mine was an abundance of fine, well-crystallized baryte, galena, sphalerite, and quartz variety amethyst.

Table of Contents

In January 1985, after producing over 25.3 million ounces of silver and 48.6 million pounds of lead (Homestake, 1992; Huston, 2005), the famous Bulldog Mountain Mine was closed and kept on standby status until 1988, due to low silver prices. With mine production costs at \$7.50 - \$8.00 per ounce of silver, it was not economically viable to operate with silver prices at about \$6.00 per ounce at the time. It was reported 97 of the 114 workers, one-sixth of the population of the Town of Creede, were laid off (US Bureau of Mines Yearbook for 1985). With the closure of the Bulldog Mountain Mine, even though minor surface and underground production of ore would continue in the Creede area for a few more years, almost a century of mining ended in the renowned Creede Mining District.

On August 5, 1992, Homestake Mining Company, owner of the Bulldog Mountain Mine, issued a news release…*"Al Winters, Vice President and General Manager of Homestake Mining Company, announced the company will begin the decommissioning and final reclamation of the Bulldog Mountain Mine."* (Homestake, 1992). The decommissioning and reclamation work was completed in July 1994.

> **An era officially ended with this news release. During the mining period 1969 to 1985, Bulldog Mountain hosted Colorado's largest producer of silver and the fourth largest producer of silver in the United States – the Bulldog Mountain Mine (Mineral Yearbook, 1991). The mine was also home to nearly sixty different ore, gangue, and postmining minerals.**

Introduction

This article provides information on the historically important silver mine in the Creede Mining district, Mineral County, Colorado, known as the Bulldog Mountain Mine. The Bulldog is rich in mining history and mineral lore. The article will summarize aspects of this legendary mine by telling two stories – first, an overview of its rich mining history, the second about the mine's array of fine minerals.

The famous mine sits in the heart of the Creede Mining District and is located about one-half mile northwest of the town of Creede, Mineral County, Colorado. See Figure 11. The last major period of silver production in the prolific Creede Mining District was from the Bulldog Mountain Mine.

In the 1920's, a prospectus was published by a company called the Bulldog Leasing, Mining and Milling Company. The company held property on Bulldog Mountain, near Creede in Mineral County, Colorado. A statement in this prospectus read: "our own Bulldog lode may yet prove to be the great undiscovered mother lode of Creede." Marketing hype or not, it would prove prophetic (Huston 2005).

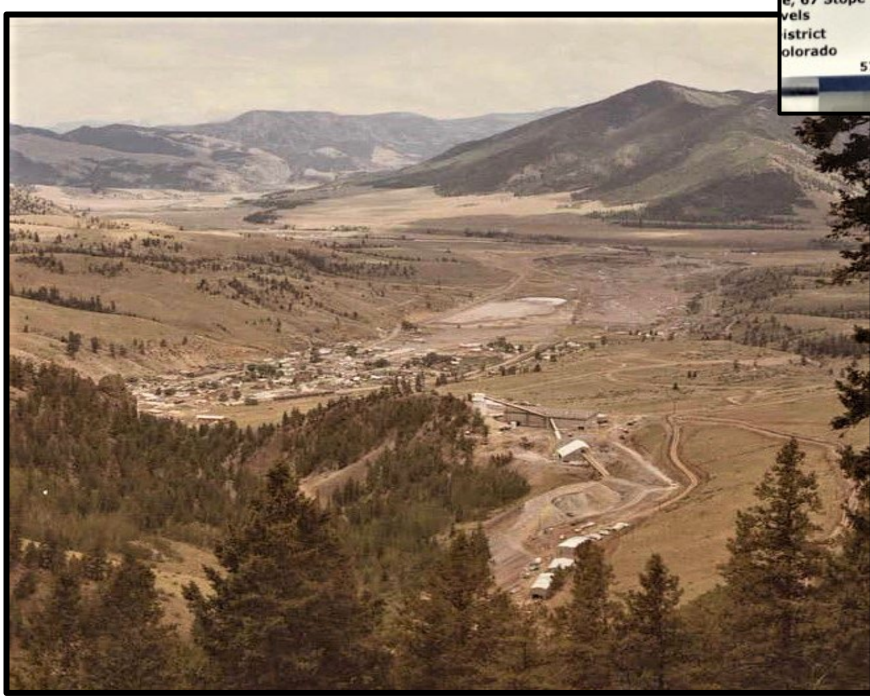


Figure 1 (above): Beautiful, rich vein slice – silver, baryte, and acanthite (after argentite). From the Bulldog Mountain Mine, 67 Stope, 9360 – 9500 Levels, Creede Mining District, Mineral County, Colorado. Hypogene silver, rimmed on both sides by baryte and base-metal/silver sulfides. Ore from this stope was some of the richest in the mine and ran up to several thousand ounces of silver per ton of ore. Specimen dimensions: 12.5 cm x 25 cm x 1.2 cm. Donation from the Daniel Aldrich, Sr. Collection. Mines Museum of Earth Science Collection, catalog #57642.

Figure 2 (left): A 1970 view of the Bulldog Mountain Mine and mill complex. The 9360 Level portal is in the lower center of image, the 300-ton per day capacity mill is shown as the large structure in center foreground, Town of Creede is center left, and the Rio Grande River follows the curved outline of the Creede caldera in the background. Photo credit: Hull, 1970.

Although the Creede area was prospected extensively beginning in the 1890s, Bulldog Mountain and its rich silver ores remained relatively untouched by the early prospectors. The Homestake Mining Company's exploration efforts would find a silver bonanza under the slopes of Bulldog Mountain in 1964. The mine was host to nearly sixty different ore, gangue, and postmining minerals. This bonanza accounted for an array of fine minerals with an astonishing diversity of associations, habits, and textures, not usually seen together in a single mineral deposit (Raines, 1992).

Creede's Bulldog Mountain Mine is famous for its fine specimens of native silver, silver-bearing and base-metal minerals.

Figure 3 (above): Three (3) fine "bird nests" of delicate, tangled wires of silver. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. These silver wire nests grew in vugs and were recovered from the upper oxidized zone of the ore body. Field of view: about 7.0 cm x 5.0 cm. Anonymous collection. Photo credit: Author.

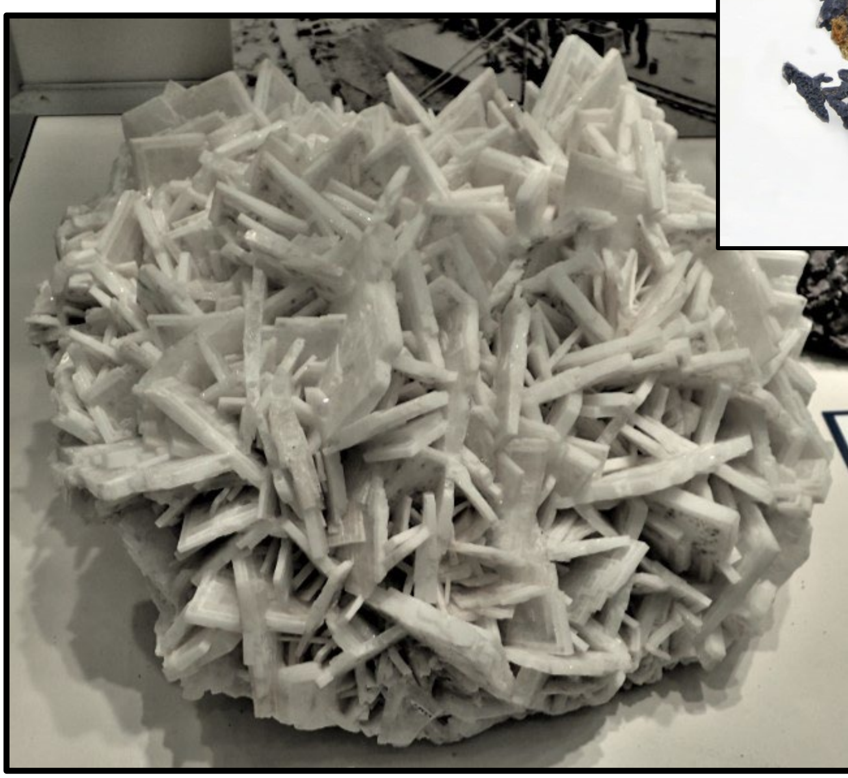


Figure 4 (above): Beautiful branching arborescent growth of silver crystals. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Specimen dimensions: 4.5 cm x 3.8 cm x 2.5 cm. Mines Museum of Earth Science Collection, catalog #56208.

Figure 5 (left)*:* Fine specimen of large, platy baryte crystals. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Specimen dimensions: 32.0 cm x 29.0 cm. Mines Museum of Earth Science Collection, catalog #92.58

Creede minerals, including those found at the Bulldog Mountain Mine, display a wide array of associations, habits, and textures, not usually seen together in a single mineral deposit. (Raines, 1992)

Figure 6 (right): Aesthetic group of silver wires. Specimen dimensions: 2 cm x 1.6 cm x 1 cm. 9360 level, Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Image credit: Archives of John Betts Fine Minerals.

Figure 7 (above): Fine specimen of matte gray galena crystals (including a large spinel twin crystal) with chalcopyrite, quartz, and chlorite. Specimen dimensions: 15 cm x 9.0 cm 6.5 cm. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. CSM Museum of Earth Sciences collection. Image credit: Mines Repository.

Figure 8 (right): Rare euhedral silver crystals. Specimen dimensions: 1.3 cm x 0.5 cm x 0.4 cm. 9360 level, Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Image credit: Archives of John Betts Fine Minerals.

The Town of Creede served as the center of mining activities for Mineral County and the Creede Mining District, as well as the commercial and residential center for the Bulldog's miners. The town sits at the lofty elevation of 8,799 feet in southwest Colorado's San Juan Mountains. In some circles, it's referred to as the "Second Leadville". From 1891 through 1985, the Creede Mining District reportedly produced 85.7 million ounces of silver (Huston 2005) - having a value of about two billion dollars in today's silver prices. The Creede area has hosted floods of miners, merchants, motley assortments of characters drawn to rowdy boomtowns, along with world-renowned silver mines, including its latter day "crown jewel", the Bulldog Mountain Mine.

Location Views of Creede: General Location, Terrain, Historical Mining Context

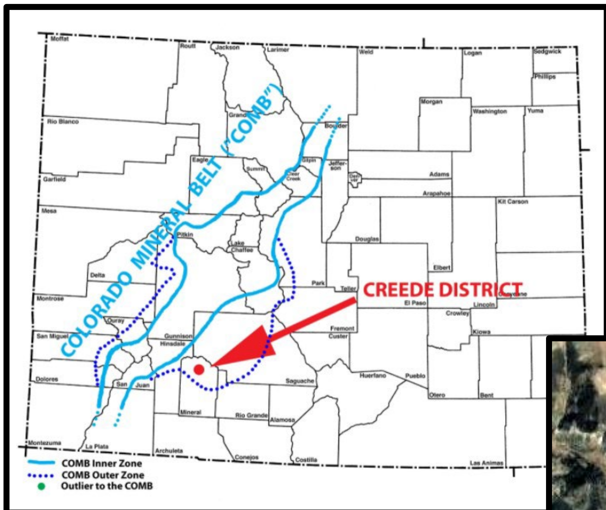


Figure 9 (left): General Location - Map showing the location of the Creede Mining District in the State of Colorado. Credit: Mines Museum of Earth Science Digital Archives.

Figure 10 (below): Terrain – Map showing terrain of area, location of Creede, and location of Bulldog Mountain Mine (red circle). Top of the map is north. Credit: Google maps.

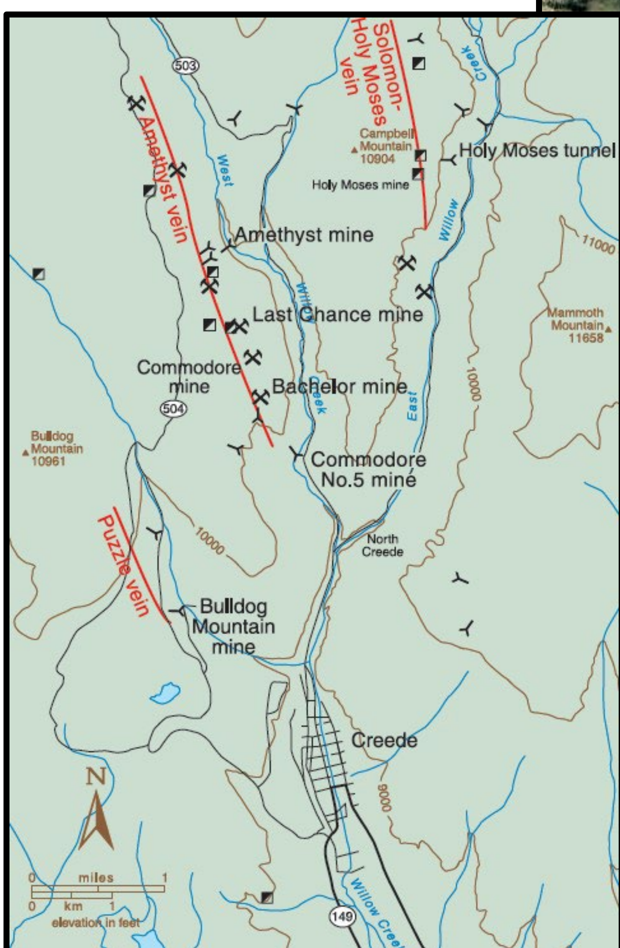


Figure 11 (left): Historical Mining Context - Map of the Creede Mining District showing major mines and three primary silver-bearing veins (Amethyst, Bulldog Mountain/Puzzle, Solomon-Holy Moses). The OH, P and Alpha-Corsair veins are not shown). Cartography credit: modified from William Besse.

The Rich Silver Legacy of the Bulldog Mountain Mine

From 1969 to 1985, the mine produced rich silver and base-metal ores from the Puzzle and West Strand veins, part of the Bulldog Mountain Fault and Vein system**.** See Figures 12 and 15. The Bulldog Mountain Fault system and its high-grade silver ores remained relatively untouched by the thousands of prospectors and miners who explored the Creede area in the 1890's. The area was prospected in the early days through the Bulldog and Puzzle/Nickel Plate tunnels or adits, and in numerous shallow shafts and pits on the mountain's barren cap rock. To the north and south, the Bulldog vein structures pass under large landslide masses, leaving only subtle surface expressions. At the few localities where the Bulldog Mountain veins crop out, they are mineralized only by brecciated chalcedony and manganese oxides, and small baryte veinlets, with no indication of the high-grade ores at depth. At a few outcrops, the "veins" are simply unmineralized faults (Plumlee, 1994; Meeves and Darnell, 1968).

During the period 1969 to 1985, Bulldog Mountain hosted Colorado's largest producer of silver and the fourth largest producer of silver in the United States – the Bulldog Mountain mine (Mineral Yearbook, 1991).

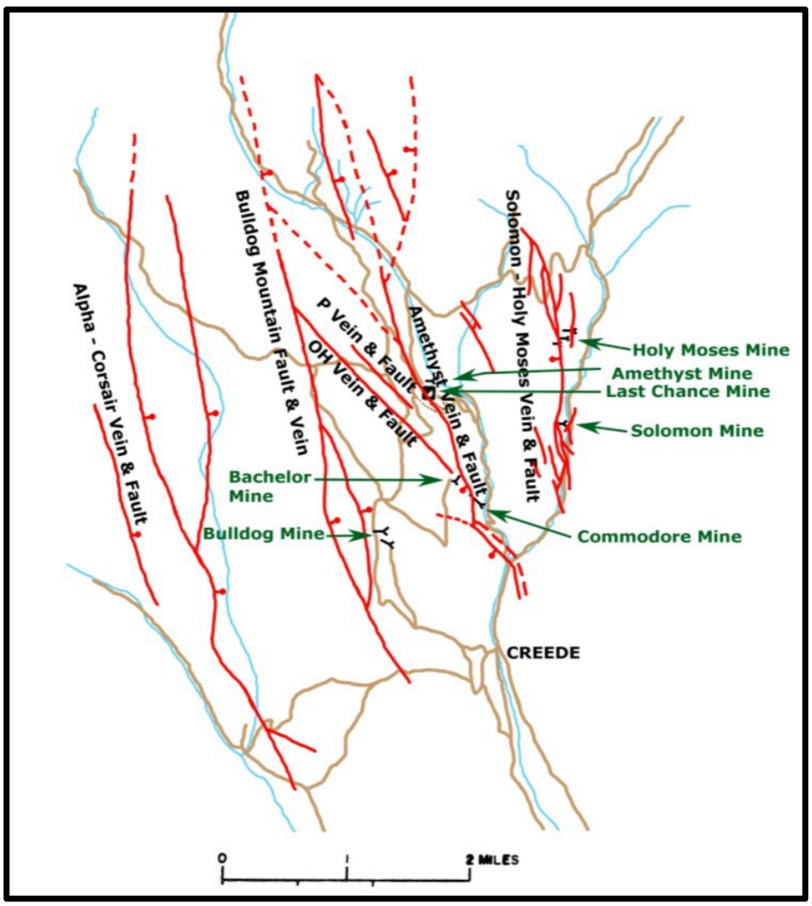


Figure 12 (left): Map showing primary fault and vein systems, including the Bulldog Mountain Fault and Vein system, and major mines, in the Creede Mining District. The Puzzle and West Strand veins, major producers in the Bulldog Mountain Mine, are part of the Bulldog Mountain Fault and Vein system. Credit: Mines Museum of Earth Science digital archives.

The rich silver ores of Bulldog Mountain were not found by the early prospectors....the Bulldog vein structures pass under large landscape masses and are largely concealed.

Small-scale mining operators have deep roots in the Creede area. They have had important roles in the mining district's sociocultural history, generation of employment, and in helping to evaluate and develop mineral resources. From 1894 to 1974, small-scale operators were important players in exploration and development work on Bulldog Mountain, including:

- Dr. A.J. Biles in 1894;
- Bulldog Leasing, Mining, and Milling Company in the 1920's;

- Manning W. “Bill” Cox and Fred Baker, Jr. in the early 1960’s;
- Bulldog Mountain, Inc., 1961 – 1974;
- Humphreys Exploration Company and McCulloch Oil Company of California, 1961 - 1962, and 1968 to 1973, respectively.

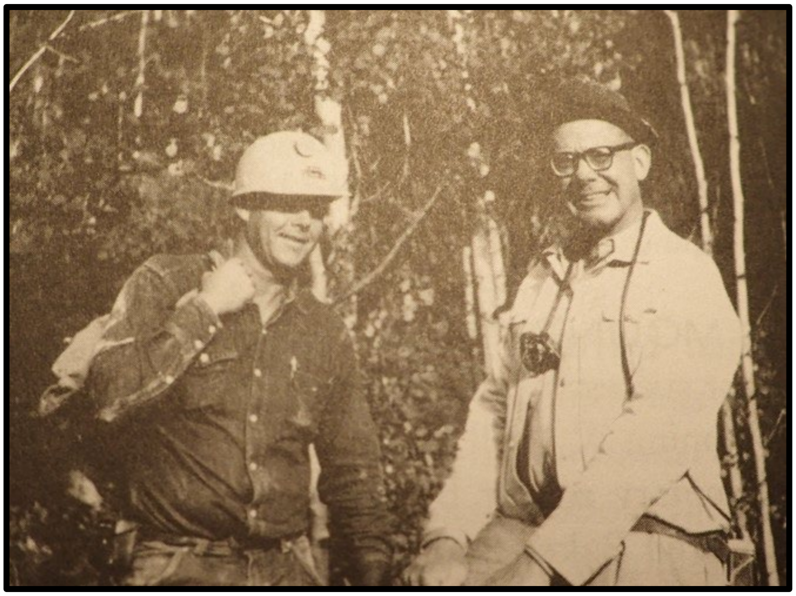


Figure 13 (left): Grainy image of Fred Baker, Jr. (left) and Manning W. “Bill” Cox (right) exploring the “Pogo” claims. Baker and Cox became mining “rock stars” in the Creede district. They were behind much of the latter-day exploration of the Bulldog vein system after mining exploration activities on the vein had been idle for many years. Image credits: John Jackson (photographer) and Richard C. Huston (publisher).

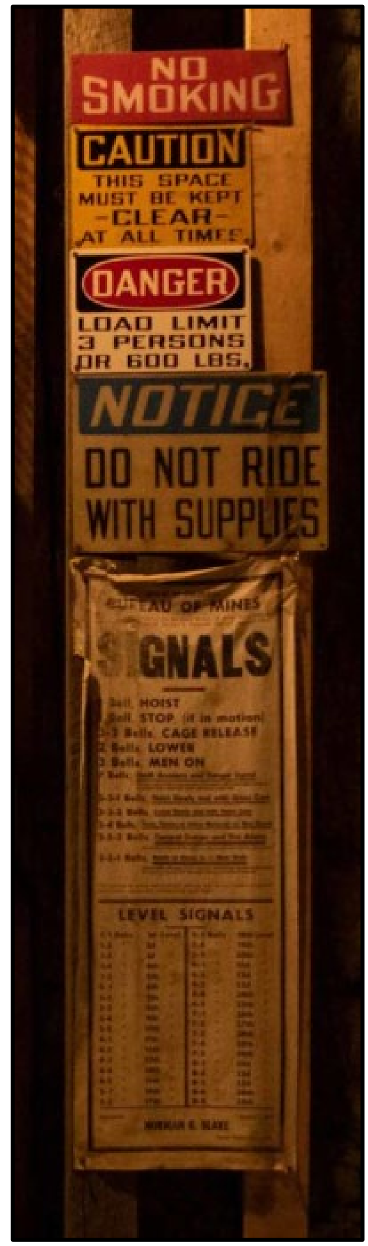


Figure 14 (right): Exhibit signage from the Creede Underground Mining Museum.

(For a detailed accounting of the historical exploration and development of the Bulldog Mountain Mine, see the 2021 CSM Museum of Earth Science article by Ken Kucera titled…. “The Bulldog Mountain Mine (aka Bulldog Mine), Blocks of Nearly Solid Silver, Creede Mining District, Mineral County, Colorado”.)

“Close, But No Cigar”

Someone other than the Homestake Mining Company almost got to the silver fortune first. In 2001, Robert A. Boppe (retired mine engineer for the Homestake Mining Company’s Bulldog Mountain Mine) wrote that the exploration work done by the Bulldog Leasing, Mining and Milling Company in the 1920’s, came very close to contacting the rich Puzzle vein. Had the company extended its Nickel Plate (Puzzle) tunnel another 200 feet with a little higher elevation along the Bulldog Vein, they would have contacted exceedingly rich silver ore. They would have made the silver discovery on Bulldog Mountain some forty years before the Homestake Mining Company. Boppe also stated some of the Bulldog Mountain Mine’s richest silver ore came from A.J. Biles’s abandoned Kansas City Star claim of 1894, including a stope where massive, highly compacted native silver wire nests were found (Boppe, 2001; Huston, 2005).

The Homestake Mining Company

On September 4, 1963, based on the recommendation from Bill Cox (see Figure 13) and augmented by the preliminary report from Steven and Ratte (1960), most of the properties (55 claims) owned by Bulldog Mountain, Inc., were leased by the Homestake Mining Company making them majority owner. The project was financed by an O. M. E. loan and under a Lease and Option Agreement, Homestake backed the venture by furnishing additional funds plus management (Howell, 1969; Huston, 2005).

The Bulldog Mountain Mine project was directed and managed by the Black Hills Division of Homestake. Numerous Homestake employees from the Lead, South Dakota, gold mining operation, were temporarily transferred to Creede for mine and mill development (Howell, 1969).

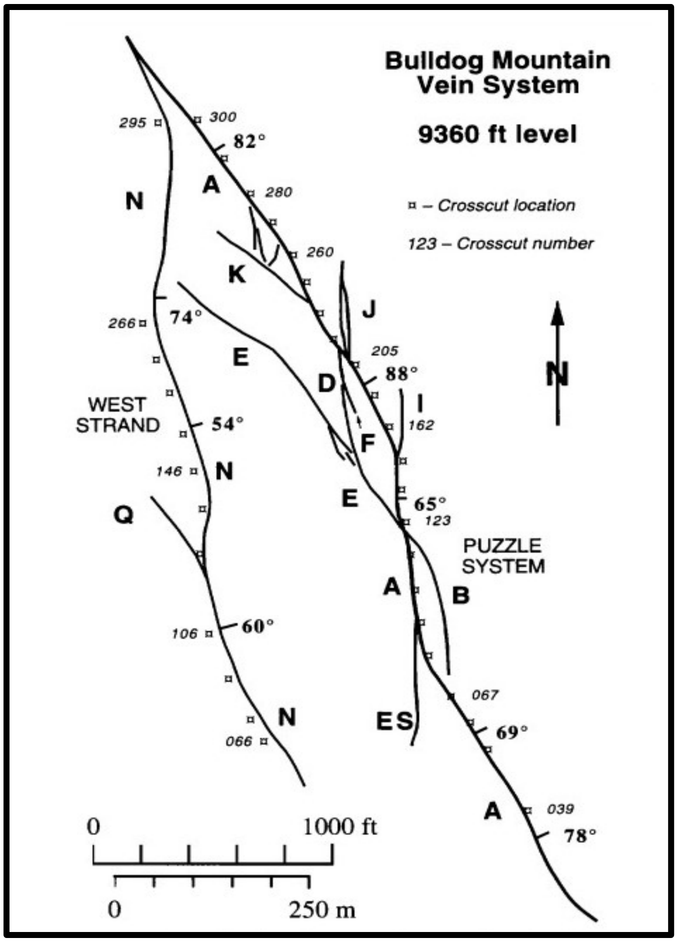


Figure 15 (left): Generalized geologic map of the 9360 ft Level, Bulldog Mountain Mine, showing the attitudes and distributions of major veins within Bulldog Mountain; e.g., Puzzle System (East Strand) and West Strand. Major veins are noted and crosscuts are numbered. (Plumlee and Whitehouse-Veaux, 1994). Reproduced from geologic mine maps compiled by Homestake Mining Company mine geologists.)

The development and start-up of the Bulldog Mountain Mine took six years, from the time the property was leased in 1963 to the first silver and lead production in May 1969. At peak production, the mine employed about 136 employees.

The first Homestake Mining Company's exploration tunnel driven into Bulldog Mountain, the 9700 Level (2956 meters above sea level), was started in June 1964. See Figure 16 on page 9. The 9700 Level was driven along the East Strand of the Puzzle vein for about 7,000 feet. This early exploration and development indicated Homestake had found a rich silver-and-lead bearing vein system similar to the silver-rich upper portion of the Creede district's historic Amethyst vein system (Meeves and Darnell, 1968). The width of ore bodies encountered in this exploration ranged from a stringer of a few inches to a shear zone of some eight feet in width. Mineralization ranged from weak to high-grade. The ore-grade material was oxidized in appearance and contained abundant wire silver, other silver-bearing minerals, and galena (Homestake, 1969). Baryte and quartz were the primary gangue minerals.

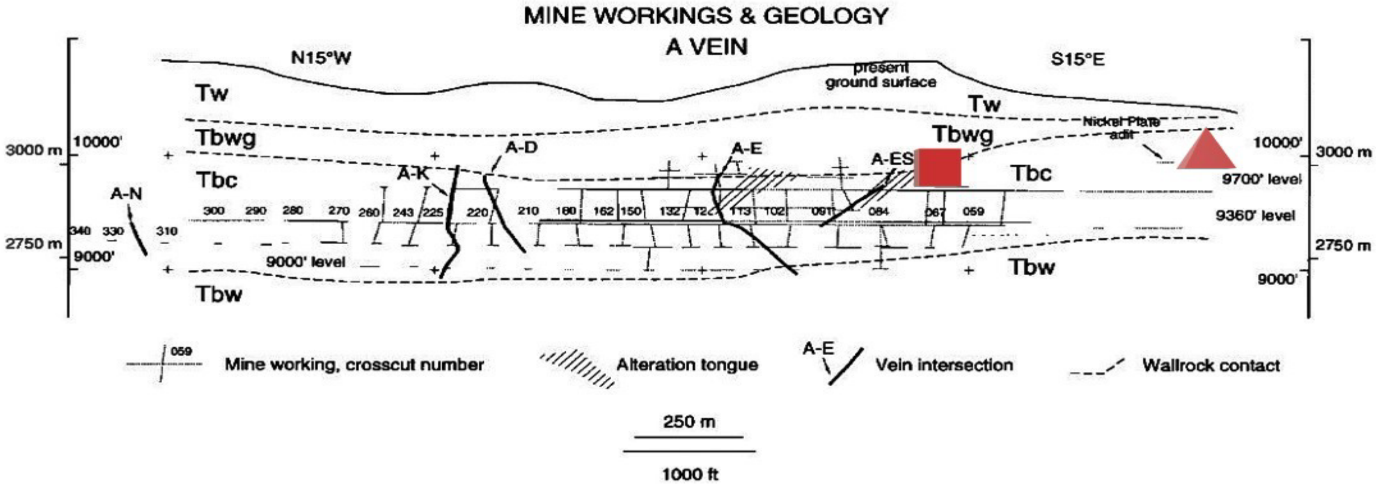
"A" Vein, 9700 Level: Like a "Pirate's Treasure Chest, Only Much Larger!"

Of the veins in the Puzzle system, the "A" vein would be the best developed and most productive (Plumlee, 1994). See Figure 15 above. Driving the 9700 Level exposed very rich silver and lead ore. Robert A. Boppe of the Homestake Mining Company described the encounter…

"While driving tunnel on the 9700-foot level, the miners intercepted some of the most beautiful native silver ever discovered in the Creede mines. There was wire silver that looked like steel wool, massive leaf silver over an inch-wide, and large amounts of ruby silver (pyrargyrite). When the miners went into the mine and saw what the previous shift had blasted into, they could not believe their eyes. It was likened to a pirate's treasure chest, only much larger! This high-grade ore pocket was mined upward a distance of 240 feet from the 9700-foot level."
(Rosemeyer, 2010)

An estimated 24 miles of mine workings would be required for the production of almost 800 tons of silver from the Bulldog Mountain Mine.

Figure 16 (see top of next page): Longitudinal section of the "A" vein in the Puzzle system (East Strand) of the Bulldog Mountain vein system, showing mine workings, vein junctions, lithologic contacts, and location of wall rock alteration caps. Below the red square indicates the location of the famous 67 Stope. The location of the old Nickel Plate Tunnel/adit is indicated by the red triangle. Abbreviation for names of wall rock units: Tw = Wason Park rhyolite: Tbwg = Windy Gulch welding unit of the Bachelor Mountain member of the Carpenter Ridge Tuff; Tbc = Campbell Mountain welding unit of the Bachelor Mountain Member of the Carpenter Ridge Tuff; Tbw = Willow Creek welding unit of the Bachelor Mountain Member of the Carpenter Ridge Tuff. Modified from Plumlee and Whitehouse-Veaux, 1994.



Almost Solid Silver – The Legendary 67 Stope

The 67 stope was a miner's dream! Arguably, the highest-grade silver ore zone in the mine, a nearly vertical zone between the 9,360-ft and 9,700-ft levels on the Puzzle's "A" vein, was along what was called the 67 stope**.** The stope – an open space left behind after the extraction of ore - was composed mainly of native silver, baryte, and sulfides. The ore was extremely high grade, assaying up to several thousand ounces of silver per ton of ore**.** Much of this ore was in the form of compact dendritic silver with baryte, galena, and sphalerite. An amazing sample in the Denver Museum of Nature and Science from the 67 stope weighs nearly 70 pounds and appears to be about two-thirds native silver by volume (Plumlee, 1994).

Figure 17 (above): Very thick, rich vein slice comprised mostly of wire and massive silver, acanthite (after argentite), and baryte. 67 stope, Puzzle Vein, Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Specimen dimensions: 7.0 cm x 5.0 cm x 2.5 cm. Anonymous collection. Photo credit: Author.

> **The statement in the old 1920's prospectus from Bulldog Leasing, Mining and Milling Company saying "our own Bulldog lode may yet prove to be the great undiscovered mother lode of Creede" turned out to be true.**

The Bulldog Mountain Mine was eventually developed along four major mining levels. These levels were labeled according to their elevation in feet above sea level: 9000 Level (2,744 meters), 9200 Level (2,805 meters), 9360 Level (2,854 meters), and 9700 Level (2,957 meters). See Figure 16 at top of this page. The productive workings extended vertically from slightly below 9,000 ft to near 10,000 ft in elevation - about 1,000 feet in all (300 meters). An estimated 24 miles of mine workings were required for production of ore (e.g., tunnels, adits, drifts, shafts, raises, and winzes) (Boppe, 2001). From 1969 to 1985, the mine produced the bulk of the rich silver-lead ore from the Puzzle (East Strand) and West Strand veins.

A “High Graders” Paradise

In the 1970’s, the Bulldog Mountain Mine became well known as a source for fine mineral specimens and being a “high graders” paradise. Hundreds, if not thousands of native silver specimens, ranging from micro-sized to cabinet sized, were brought out in miners’ lunch pails and ended up in the commercial pipeline going to eager collectors and mineral dealers all over the world. Mineralogically, the Bulldog Mountain Mine is primarily remembered for hundreds of superb wire silver and nearly solid massive silver specimens. Arguably, the most outstanding occurrence of silver and the best preserved in collections, includes nests of silver wires in vugs of beautiful pale to dark lavender amethyst crystals. See Figure 18. High-grading was not limited to silver. Spectacular crystalline specimens of base-metal sulfides, particularly galena, also made it to the private mineral markets.

Figure 18 (left): A prime target of “high grading”. Nests of aesthetic wire silver and acanthite (after argentite) in a matrix of lavender, euhedral amethyst crystals. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Wire silver group to about 1.7 cm. Vertical FOV 4.0 cm. Anonymous collection. Photo credit: Author.

In a story told by Ken Wyley, a former miner in the Bulldog Mountain Mine and current resident of Creede, he describes miners finding and “high grading” a large mass of silver that was blasted loose from the 9360 level, 67 stope, of the Puzzle vein**:** (Rosemeyer, 2010).

“When the day-shift miners entered their working place at the start of shift, they barred down the back of the stope and then wet down the muck pile to spot chunks of native silver to be liberated. To their surprise they found a large chunk of the vein, about the size of a small washtub, partially buried in the muck pile. On closer inspection they noticed that the chunk was about 75% native silver that gleamed in their mine lights. One miner set up to start drilling a round at the far end of the stope while the other miner attacked the huge chunk of silver ore with a miner’s axe to knock off the barite and quartz. When he finally removed most of the waste, he tried to cut up the mass with the axe but could only make shallow cuts in the silver. At lunchtime both miners attacked the mass with the axe, acting as a wide chisel, and a double jack and proceeded to cut the chunk up into manageable pieces. It took them a week to ferret all the pieces out of the mine and to their homes.“

These rich silver-bearing and base-metal ores of the Bulldog Mountain Mine were deposited as geologic movement within the Creede Mining District caused fractures and zones of fractures in the surrounding country rocks. Hydrothermal solutions rich in silver, lead, zinc, and silica ascended toward the surface in distinct stages where their contents were deposited in the fractures. These epithermal veins contained banded agate, beautiful amethystine quartz, rich native silver, and a variety of silver, lead, and zinc sulfides and sulfosalts. This set the stage for the geologic and mineralogical development of one of the richest silver districts in the United States – the Creede Mining District.

"Quick Read" - Geology and Mineralogy of the Creede Mining District

The geology and mineralogy of the Creede Mining District and San Juan Mountain areas have been described in detail in numerous excellent sources. Interested readers are referred to the Appendix on page 41 of this article for more detailed information and references about this geology and mineralogy.

Mineralogy and Paragenesis of the Bulldog Mountain Mine

The Six Stages of Mineralization

Plumlee and Whitehouse-Veaux (1994) identified a complex interaction of six stages of mineralization along the Bulldog Mountain fault and vein system that were the basis for silver and base-metal production at the Bulldog Mountain Mine. These included five stages of hypogene mineralization and a sixth stage of leaching sulfides and sulfosalts. Each stage has a characteristic set of minerals deposited or leached and characteristic spatial distributions within the vein system. The transitions over time between the six successive mineralization stages are gradational and are generally characterized by intergrowths or inter-banding between mineral assemblages characteristic of adjacent stages.

Plumlee and Whitehouse-Veaux constructed a paragenesis diagram for selected minerals found in the Bulldog Mountain system. The diagram below shows minerals in the approximate sequence of their formation or deposition, with minerals deposited earliest shown toward the top of the diagram and later deposited minerals tending toward the bottom. The stages of mineralization, "A" through "F", are indicated at the bottom of the diagram.

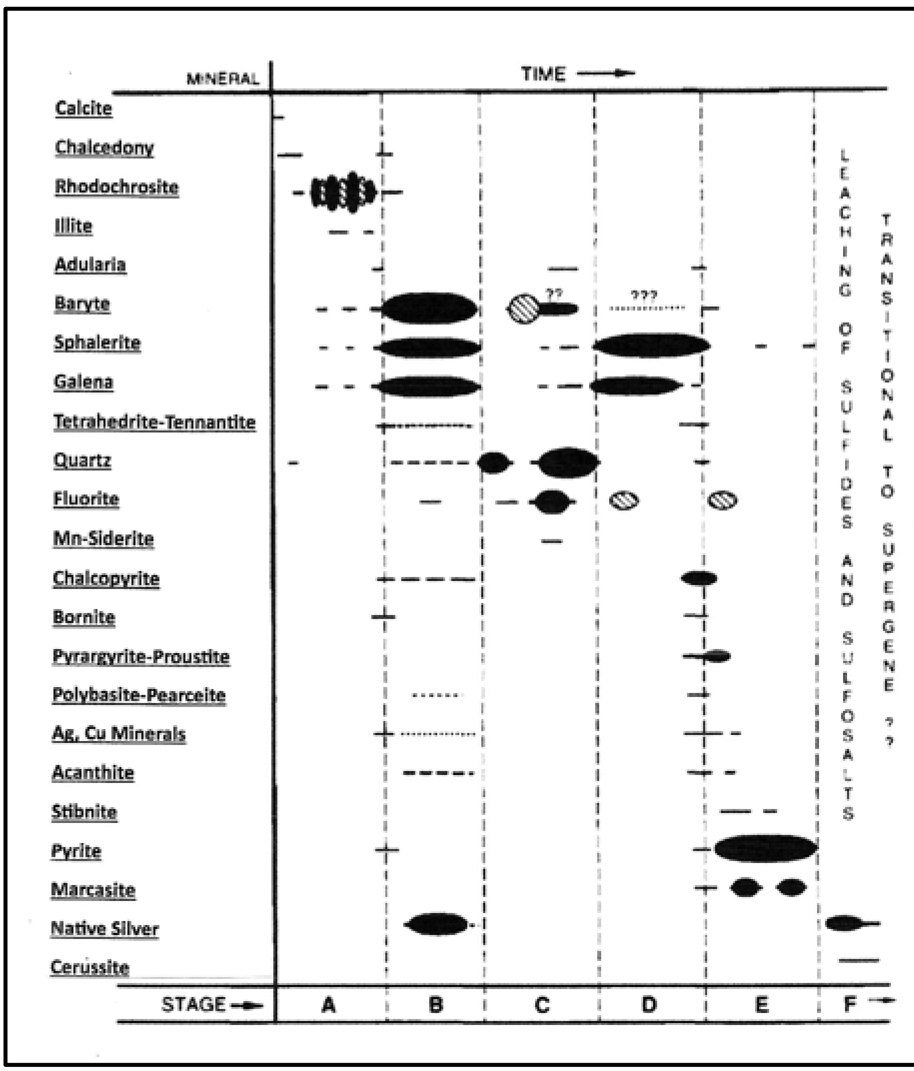
Figure 19 (below): Mineral Paragenesis for the Bulldog Mountain Vein System, By Stages of Mineralization (A – F) Modified After Plumlee and Whitehouse-Veaux (1994)

Diagram Key:

Mineral deposition is shown in horizonal trending black ovals and lines, mineral leaching is shown by shapes with slanted or "hatched" lines. The thickness of the symbol for a given mineral is proportional to its abundance. The dashed vertical lines show approximate temporal boundaries for the major stages, although the transitions between most stages were largely gradational. Abbreviations in figure:

Ag, Cu Minerals = various silver-copper sulfides and sulfosalts, including mckinstryite, jalpaite, chalcocite, and miargyrite

These complex mineral assemblages were produced by many geological processes. Plumlee and Whitehouse-Veaux (1994) state…"Large-scale changes in vein mineralogy over time produced discrete mineralization stages. Short-term mineralogical fluctuations produced complex inter-banding of mineralogically distinct generations. Fluid chemistry evolution within the vein system produced large-scale lateral zoning patterns within



certain stages. Hypogene leaching substantially modified the distributions of some minerals. Finally, structural activity, mineral deposition, and mineral leaching modified fluid flow pathways repeatedly during mineralization, and so added to the complex mineral distribution patterns within the Bulldog Mountain vein system."

Plumlee described the Bulldog system as a strongly zoned deposit, both vertically and horizontally. The mineralization stages "A" through "F" produced these zones. Their dominant mineral assemblages are discussed below from oldest to youngest. The stage's percent of total vein system mineralization is shown in parentheses.

- "Stage A" (25%) was dominated by the deposition of rhodochrosite along the lower levels of the Bulldog mine's ore zone. Chalcedony and amethyst were deposited in minor amounts early in the stage. Few other minerals were deposited during this stage. Wetlaufer (1977) documented the presence of minor disseminated galena and sphalerite, local adularia, calcite and baryte, and isolated small masses of green illite found in stage A rhodochrosite.

Figure 20 (above): Slice showing reddish-brown rhodochrosite with layers or inter-bands of baryte and gray sulfides. Horizontal FOV 8.0 cm. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Anonymous collection. Photo credit: Author.

The transition from stage A to stage B was gradational and typically represented by inter-banded or intergrown rhodochrosite between layers of either baryte or fine-grained sulfides (sphalerite, galena, pyrite, bornite).

- "Stage B" (35%) in the northern parts of the Bulldog ore zone is characterized by large quantities of fine-grained sphalerite and galena, with smaller amounts of tetrahedrite, baryte, and +/- chlorite, quartz, rhodochrosite, and hematite. To the south, stage B ores become progressively richer in baryte and massive native silver, with alternating generations of baryte and fine-grained sphalerite and galena. Native silver +/- acanthite (paramorph after argentite) assemblages are primary hypogene minerals and are locally abundant in the southern stage B sulfide ores, with chalcopyrite and other Cu and Ag sulfides and sulfosalts present in minor amounts. Silver values in the northern parts of the Bulldog ore zone appear to be primarily in silver bearing tetrahedrite crystals forming along bands of sphalerite (Raines, 1992).

Figure 21 (right): Rich vein slice showing Stage B native silver, acanthite (paramorph after argentite), other sulfides, and baryte. From 67 Stope, Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. CSM catalog #57643. Specimen size: 10 cm x 8.0 cm. CSM Museum of Earth Science collection. Catalog #57643. Donation from Carl Kroll collection.

Figure 22 (right): Stage B vein slice of interlayered native silver, acanthite (paramorph after argentite), and baryte, showing epithermal banding. From 67 Stope, Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Specimen dimensions: 10.5 cm x 9.5 cm x 1.5 cm. CSM Museum of Earth Science Collection. Catalog #57644.

Figure 23 (left): Aesthetically challenged, but remarkably large specimen of stage B massive silver with white baryte and miscellaneous sulfides. Weighing in at 53 pounds! Specimen dimensions: 30 cm x 27 cm. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. CSM Museum of Earth Science collection. Catalog # 58052. Donation from the Carl Kroll collection.

Figure 24 (right): Stage B dark gray, sharp acanthite (paramorph after argentite) crystals to about 8 mm on a quartz and baryte matrix. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Anonymous collection. Photo credit: Author.

The number and volume of sulfide and baryte generations increases greatly in the southern parts of the Bulldog vein system. Multiple generations of baryte with few or no intergrown sulfides are commonly separated by fine-grained layers of galena and/or sphalerite. The total number of baryte and sulfide generations is not known, but Plumlee and Whitehouse-Veaux (1994) identified at least 13 distinct generations in one well-crustified sample. The most abundant sulfides present in stage B are sphalerite and galena.

Stage B is the most spatially extensive and mineralogically complex of all the stages. The total volume of stage B minerals increases from north to south in the Bulldog Mountain vein system. In the north, stage B fills veins that are less than 30 cm wide, while in the south portion of the system, stage B minerals fill veins as much as 3 meters wide.

- “Stage C” (15%) mineralization was dominated by deposition of major inter-banded amethyst and milky quartz, sometimes with aesthetic, well-formed amethyst crystals, along with moderate amounts of green fluorite, and minor amounts of adularia, galena, sphalerite, and manganiferous siderite. In addition, major leaching of stage B baryte occurred.

Figure 25 (above): Stage C lavender colored quartz variety amethyst on bladed white baryte matrix. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Specimen size: 18.5 cm x 7.5 cm x 10 cm. Anonymous collection. Photo credit: Phil Persson.

Figure 26 (left): Stage C light purple quartz variety amethyst with green fluorite along with corroded black acanthite (after argentite) and minor wire silver. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Vertical FOV about 8 cm. Anonymous collection. Photo credit: Phil Persson.

- “Stage D” (8%) was comprised of coarse-grained sulfide minerals with abundant euhedral crystals, relative to stage B sulfides. Large amounts of sphalerite and galena were deposited in the upper and northern portions of the Bulldog ore zone during stage D. Plumlee states a baryte and silver-rich facies of stage D may be present in the southern parts of the vein system. Late in stage D, complex assemblages of minerals were deposited in modest amounts throughout the vein system containing chalcopyrite, tetrahedrite, polybasite, bornite, pyrargyrite, and a variety of other sulfides and sulfosalts. See Figure 29.

Figure 27 (above): Stage D cubo-octahedral galena Xls to about 1 cm with small yellow-brown Mn-siderite Xls on drusy quartz matrix. Horizontal FOV 4.5 cm. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Anonymous collection. Photo credit: Author.

Figure 28 (right): Stage D sharp, gemmy crystals of orange-brown Sphalerite on a matrix of massive pyrite and galena with drusy red quartz. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Specimen dimensions: 12.8 cm x 10.7 cm x 4.8 cm. Anonymous collection. Photo credit: Jasun McAvoy & mineralman.com

- Stage D-E transition (2%). A complex assemblage of Cu-, Ag-, As- and Sb-rich sulfides and sulfosalts marks the transition from stage D sphalerite, galena and sulfosalt assemblages to stage E botryoidal and radial pyrite and marcasite. This transition is marked by rapid fluctuations in mineralogy and/or mineral composition.

Figure 29 (right): Transition from stage D to E, deep red to gray pyrargyrite and other sulfides and sulfosalts, with bronze-colored radial pyrite and lessor marcasite. Dimensions: 8.5 cm x 8 cm x 6.5 cm. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Anonymous collection. Photo credit: Phil Persson.

- “Stage E” (10%) represents the final sulfide stage and is characterized by large amounts of botryoidal and radial pyrite and lesser marcasite, with modest sphalerite, tetrahedrite, stibnite, baryte, pyrargyrite-proustite, acanthite (after argentite), and minor famatinite and xanthoconite-pyrostilpnite.

Figure 30 (above): Stage E bronzy-colored botryoidal pyrite with lesser marcasite. Horizontal FOV 12 cm. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Anonymous collection. Photo credit: Author.

- “Stage F” (5%) was the final stage of mineralization along the Bulldog vein system and is characterized by the widespread formation of native silver and coincident leaching of earlier galena and silver-bearing sulfides and sulfosalts. Wire silver, ranging in size from less than 1 mm to over several centimeters in length is the dominant silver morphology.

  Cerussite (lead carbonate) was also a product of stage F leaching. Cerussite replaces galena along the upper parts of the Bulldog ore zone.

Figure 31 (right): Stage F attractive wire silver nest on leached acanthite (after argentite) and baryte matrix. Horizontal FOV 4.0 cm. Bulldog Mountain Mine, Creede Mining District, Mineral county, Colorado. Anonymous collection. Photo credit: Author.

Figure 32 (left): The sculptural quality of this large wire silver specimen is outstanding. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Specimen dimensions: 4.7 cm x 3.0 cm x 1.2 cm. Anonymous collection. Photo credit: Mineral Auctions.com

Figure 33 (below): Stage F dense mats of wire silver resembling "steel wool" on acanthite (paramorph after argentite) and baryte crystals substrate. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. FOV about 10 cm. Anonymous collection. Photo credit: Author.

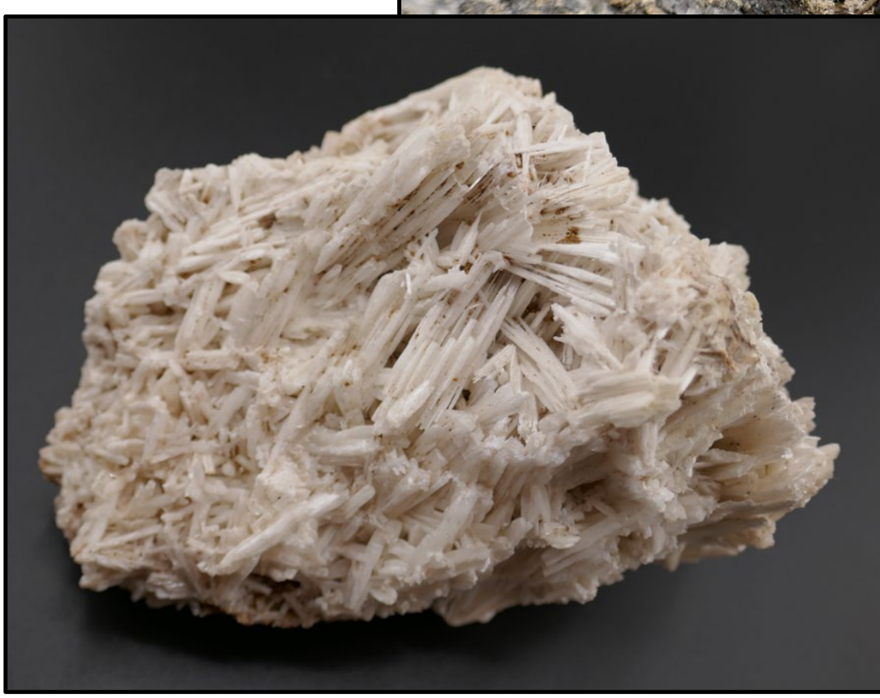


Figure 34 (left): Cerussite variety "jackstraw" with crystals to about 2 cm. Horizontal FOV 12.0 cm. Bulldog Mountain Mine (?), Creede Mining District, Mineral County, Colorado. Anonymous collection. Photo credit: Author.

Minerals Overview

The Bulldog Mountain Mine was an exceptional producer of silver and base-metals. The mine would produce over 25 million ounces of silver from the rich native silver deposits, as well as from silver-bearing minerals such as acanthite, pyrargyrite, and argentiferous galena. The Bulldog would also produce 48.6 million pounds of lead (Homestake, 1992; Huston, 2005).

Native Silver

Native silver is by far the most abundant silver mineral in the Bulldog Mountain vein system and accounts for the bulk of the economic value of the ore. The mine is well known for its spectacular specimens of silver.

Silver specimens noted by Smith (1974), Raines (1988), Raines (1992), and Smith (2008), were found in a remarkable number of habits and associations. These included single wires, dense groups of wires resembling “steel wool” and “bird nests”, “ropes” formed of composite subparallel wires, leaves and thin sparkling “spangles”, blebs/grains, euhedral crystals many with spinel twinning, delicate arborescent growths, and solid masses of thick vein material.

The Bulldog Mountain Mine hosted nearly sixty different ore, gangue, and postmining minerals.

Silver-Bearing Minerals

The silver values of the ores were enhanced by complex assemblages of silver-bearing minerals. These minerals include: primary acanthite and acanthite paramorphs after argentite, polybasite, and pyrargyrite. Acanthite, the most abundant silver-bearing mineral at the Bulldog, occurred as cubic or blocky crystals (Raines, 1988) and as shiny, black, needlelike microcrystals partially encrusting masses and wires of native silver. Polybasite occurred with other sulfides in the silver-rich banded ore. Pyrargyrite occurred as aesthetic dark ruby-red masses and microcrystals associated with other sulfides and sulfosalts. Other uncommon silver-bearing minerals include: jalpaite, mckinstryite, miargyrite, pearceite, pyrostilpnite, and xanthoconite.

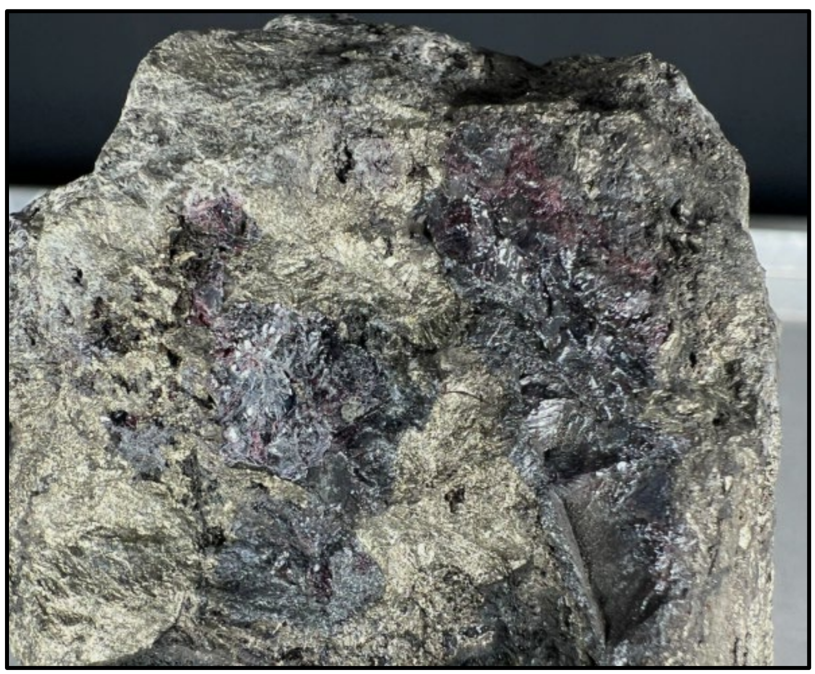


Figure 35 (right): This is a classic mineral assemblage from the mine. Rich specimen of silver-bearing, deep red "ruby silver" pyrargyrite, in massive bronze-colored pyrite with lesser marcasite. Specimen Dimensions: 7.0 cm x 5.5 cm x 3.5 cm. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Anonymous collection. Photo credit: Phil Persson.

Base-Metal Minerals: Galena and Sphalerite

As mining continued to greater depths, the predominant mineral assemblage extracted changed to base-metal sulfides, and the silver values declined significantly. Argentiferous galena became an important ore of silver. Open vugs within the Bulldog Mountain vein system gave sulfide minerals a chance to grow into free space, resulting in spectacular crystallized groups of galena. This period of extracting lower-grade silver-bearing base-metal ores was also a boon to mineral collectors, as many fine galena crystals were recovered along with associated gangue minerals. Miners soon found out that mineral dealers and collectors would pay handsomely for good specimens of crystallized base metal sulfides.

Galena was the primary ore of lead. Some of these galena ores were classified as argentiferous. During stage B of mineralization, galena was deposited, then partially replaced by argentite. The argentite was subsequently partially replaced by native silver. The remaining argentite was then paramorphed by acanthite (Raines, 1992).

The zinc sulfide sphalerite, along with galena, is one of the most common base-metal sulfide minerals. It is commonly seen in fine-grained, brown bands and crusts intergrown with galena. These bands and crusts often form a base for sulfides and sulfosalts deposited later in mineralization.

Secondary Minerals

A suite of colorful secondary minerals formed from supergene alteration in the oxidized portions of orebodies in the Bulldog Mountain Mine. The minerals include cerussite, native copper, cuprite variety chalcotrichite, ktenasite, mimetite, pyromorphite, and rosasite. A few of these are rare, occur in micro-crystals, and are seldom seen in collections. Of interest to the cabinet-sized specimen collector are the groups of cerussite crystals forming “jackstraw” groups from the Bulldog (Raines, 2023). Individual crystals of cerussite can reach a few centimeters in length.

Gangue Minerals

Gangue minerals in the Bulldog vein deposit included: baryte, calcite, chamosite, fluorite, gypsum, hematite, kaolinite, marcasite, orthoclase variety adularia, pyrite, quartz, rhodochrosite, and Mn-siderite. Most of the gangue minerals are not of specimen quality, exceptions being baryte and quartz.

Figure 36 (left): Classic and most abundant gangue mineral at the mine. Large plate of sharp white bladed baryte crystals with some black acanthite (after argentite) and minor wire silver. Specimen dimensions: 22.0 cm x 10.5 cm x 6.5 cm. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Anonymous collection. Photo credit: Phil Persson.

Baryte, intergrown with galena and sphalerite, is the most abundant gangue mineral in the Puzzle vein (Eckel, 1997). A large number of fine crystallized baryte specimens were collected and sold by miners who worked in the Bulldog Mountain mine. Many of these beautiful specimens were in combination with amethystine quartz and silver wires. A few miners decided to go a bit further by skillfully adding beautifully curved wires of native silver to specimens. There are some fakes out there. Buyer beware!

Quartz is an abundant gangue mineral in the Puzzle vein and occurred in several varieties; e.g., clear, white, amethystine, and chalcedony.

Post-Mining Minerals

The common postmining minerals are goslarite and melanterite.

For additional information about mineralogy of the Bulldog Mountain Mine, readers are referred to the following references: Arthur Smith (1974, 2008), Holmes and Kennedy (1983), Foley et al (1993), Hull (1970), Raines (1988, 1992), Eckel (1997), Meeves and Darnell (1968), Rosemeyer (2010), Wetlaufer (1977), and Plumlee and Whitehouse-Veaux (1994).

Description of Mineral Species

Acanthite Ag_2S (silver sulfide)

Acanthite is an important ore of silver. Both primary acanthite and acanthite paramorphs after argentite are present in the Bulldog Mountain vein system (Hull, 1970; Eckel, 1997; Kosnar, 1979a; Arthur Smith, 2008). Acanthite is recognized as paramorphic after argentite because it is not stable after formation.

Acanthite has been observed in numerous forms or habits. Crystals, to about 1 cm can display sharp, cubic habits. They have also been noted as highly modified or irregular crystals that, when intergrown, form small masses. Crystals have been observed on baryte and quartz and are found associated with native silver, pyrite, pyrargyrite, and polybasite. Acanthite was particularly common as dusty black coatings on white baryte or quartz. It was closely associated with wire silver that often appears to have grown from silver sulfide. Electron microprobe analysis revealed the presence of acanthite in wires of native silver (Hull, 1970). Skeletal crystals of acanthite were common and are of two types: most were incompletely formed crystals, while others appeared to have been etched or partly reabsorbed. See Figure 24. Thin, shiny black acicular crystals to 2 mm were common. Delicate arborescent groups of these acicular crystals, similar to those from the Commodore mine, were larger and more common at the Bulldog Mountain Mine. Arborescent crystals are the last acanthite to form and may partially coat wire silver or larger cubic acanthite crystals, giving them a hairy appearance. See Figures 37 and 39. Most of these arborescent groups are small, less than 1 mm, but rarely patches of crystals may reach 5 mm across (Arthur Smith, 2008). Acanthite appears to replace galena in specimens with a high content of silver.

Figure 37 (left): Free-standing dendritic to acicular group of acanthite crystals to about 1.5 mm. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Photo credit: Rocks & Minerals article "Collecting Microminerals in the Creede Mining District", Volume 83, September/October 2008, by Arthur E. Smith.

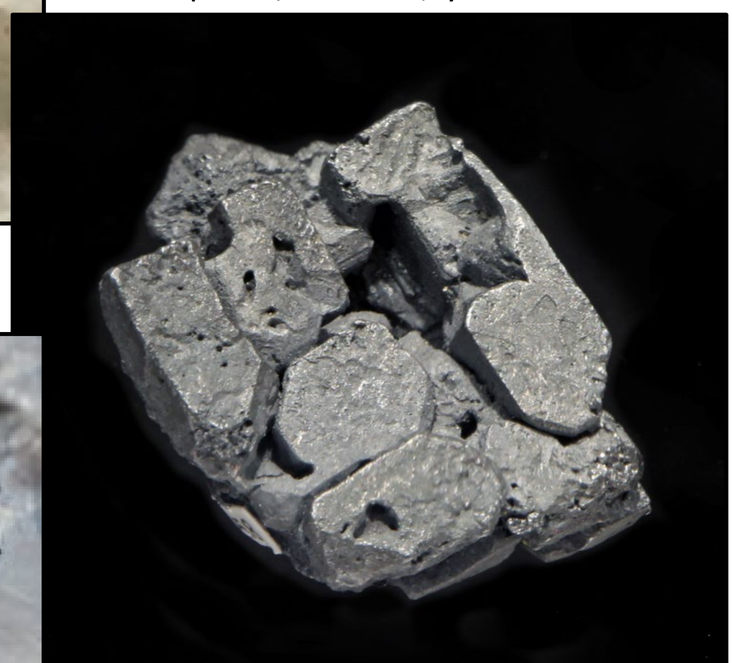


Figure 38 (above): Acanthite crystals after argentite. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Dimensions unknown. CSM Museum of Earth Science collection on loan from Dave Bunk. Photo credit: Ron Wolfe.

Figure 39 (left): Acanthite (black coating and short acicular Xls) partially encrusting a 1.7-mm tall silver wire. Puzzle vein, Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Tom Rosemeyer specimen. Dan Behnke photo in Rocks & Minerals article "Creede – The Last Wild West Silver Mining Camp in Colorado", Volume 85, September/October 2010.

Stage B acanthite is locally abundant in the central and southern Bulldog vein system.

Stage E was dominated by the deposition of botryoidal pyrite and lesser marcasite, with minor amounts of acanthite, and other sulfides and sulfosalts.

Adularia $KAlSi_3O_8$ See Orthoclase.

Alunite $KAl_3(SO_4)_2(OH)_6$ (hydroxylated aluminum potassium sulfate)

Occurs as a pale greenish yellow mineral with a waxy luster. It was noted only on the 9700 level and only at localities where the vein is oxidized (Hull, 1970; Eckel, 1997).

Anglesite $PbSO_4$ (?) (lead sulfate)

Argentite Ag_2S (silver sulfide) – paramorphed by acanthite.

Baryte $BaSO_4$ (barium sulfate)

Some of the finest specimens of baryte from Colorado are from the Bulldog Mountain Mine. Baryte was the most abundant vein mineral and was dominant throughout the Bulldog vein system except locally where pyrite or quartz are more abundant. Massive and crystalline baryte were commonly intergrown with galena and sphalerite forming alternating layers with the sulfides.

Spectacular white tabular crystals of baryte occurred in the Bulldog Mountain Mine. They are generally crystals having flattened, tabular habits. Impressive intergrown crystals to 15 cm in diameter covering matrix are known. The Bulldog 9360 Level produced amethystine quartz and sphalerite that retained molds of earlier baryte crystals (Eckel, 1997, Hull, 1970). Grains, masses, and wires of silver were often associated with baryte. Baryte was often dusted with sooty-black acanthite microcrystals and with crystalline masses and euhedral crystals of other sulfides.

Figure 40 (right): An outstanding group of large, lustrous white tabular baryte crystals. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Horizontal FOV 12 cm. Specimen size 25 cm x 18 cm x 9 cm. Anonymous collection. Photo credit: Phil Persson.

Figure 41 (above): Aesthetic plate of white baryte with tabular to discoidal habits. Crystals to a maximum of about 1.5 cm. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Horizontal FOV 15 cm. Overall specimen size 23 cm x 16.5 cm x 3.5 cm. Anonymous collection. Photo credit: Phil Persson.

In stage B, the number and volume of baryte generations increases greatly in the southern parts of the Bulldog vein system, as opposed to northern parts of the system.

In stage C mineralization, widespread leaching of baryte from earlier stages occurred in the upper portions of the Bulldog vein system. In hand samples from different locations, molds from stage B baryte are present in stage C white quartz, amethystine quartz, and sphalerite, where tabular baryte crystals have been leached and removed by hypogene fluids.

Stage E mineralization was dominated by the deposition of botryoidal pyrite and lesser marcasite, with minor amounts of baryte, sulfides, and sulfosalts.

Bornite Cu_5FeS_4 (copper, iron sulfide)

Bornite is an uncommon mineral at the Bulldog Mountain Mine. Bornite was observed as iridescent masses in quartz with small stibnite crystals. It also occurred with galena and acanthite (Arthur Smith, 2008).

A stage B bornite-pyrite-chalcopyrite assemblage was found at two localities in the lower Bulldog vein system, where massive pyrite was intergrown with fine-grained black silica and replaced by massive chalcopyrite. Chalcopyrite was then replaced and veined by bornite and microscopic intergrowths of digenite, tetrahedrite, galena, and silver-copper sulfides

(Plumlee and Whitehouse-Veaux, 1994). Electron microprobe analysis was used to confirm the presence of bornite grains in wires of native silver (Hull, 1970).

Microscopic bornite, as well as tetrahedrite, miargyrite, famatinite, and various Ag-Pb sulfosalts form the bulk of the transitional D-E stage mineral assemblage.

Bromargyrite (?) AgBr (silver bromide) J. Attard analysis of M.M. Judy specimen reportedly was from Bulldog (MINDAT).

Calcite $CaCO_3$ (calcium carbonate)

Calcite, the earliest hydrothermal mineral in the Bulldog vein system, was deposited during stage A in wall-rock vugs distant from the main veins of the system. It is not an abundant mineral in the ore deposits, occurring only in small crystals (Raines, 1988; Plumlee and Whitehouse-Veaux, 1994).

Cerussite $PbCO_3$ (lead carbonate)

Cerussite is the most abundant secondary lead mineral noted from the Puzzle vein. It generally occurs as small, white or colorless prismatic crystals growing in vugs in galena and as a coating on fractures (Eckel, 1997). In polished sections, cerussite can be seen replacing galena (Hull, 1970; Plumlee and Whitehouse-Veaux, 1994). The Bulldog Mountain Mine has produced excellent intergrowths of white crystals of cerussite to at least 2.5 cm on quartz matrix (Kosnar and Miller, 1976). Groups of "jackstraw" crystals have been found in the oxidized portions of the Bulldog fault system and some of these crystals have twinned growths (Raines, 1988).

Figure 42 (right): This is an aesthetic miniature-sized cerussite specimen composed of a white "jackstraw" clusters of translucent, spear-points. The crystals have an adamantine luster and a partial darker oxide coating. Dimensions unknown. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. CSM Museum of Earth Science collection on loan from Dave Bunk. Photo credit: Ron Wolfe.

Chalcanthite $CuSO_4 \cdot 5H_2O$ (hydrous copper sulfate)

Most of the chalcanthite is probably post-mine in age. The mineral forms clusters of moderate blue fibrous crystals on the mine walls, and as stalactites and stalagmites. Depending upon ventilation conditions in the mine, mixtures of bluish copper sulfate in varying stages of dehydration are formed and it is probable that other copper sulfate minerals in addition to chalcanthite are present (Hull, 1970). According to Hull, one sample gave an X-ray diffraction pattern suggesting a mixture of chalcanthite and antlerite $Cu_3(SO_4)(OH)_4$.

Chalcocite Cu_2S (copper(I) sulfide)

Chalcocite is an uncommon mineral at the Bulldog Mountain Mine. In polished sections, it is seen as a bluish grey mineral apparently replacing galena, native silver, and sphalerite (Hull, 1970).

Stage B chalcocite is present in minor amounts in the Bulldog's central and southern vein systems (Plumlee and Whitehouse-Veaux, 1994).

Chalcopyrite $CuFeS_2$ (copper, iron sulfide)

Chalcopyrite occurs throughout the Bulldog vein system and is generally closely associated in space with tetrahedrite. Chalcopyrite and tetrahedrite form layered sequences of botryoidal shapes. Chalcopyrite occurs as sphenoidal crystals, small masses, and irregular grains. See Figure 43 below. Much of the chalcopyrite is covered by pyrite and is difficult to identify. Blebs of chalcopyrite and tetrahedrite are a common alteration product within early-stage sphalerite in the Bulldog Mountain vein system (Eckel, 1997; Plumlee and Whitehouse-Veaux, 1994).

Chalcopyrite is commonly present in stage B mineralization in the central and southern Bulldog vein systems. A stage B chalcopyrite-pyrite-bornite assemblage was reported at two localities in the lower Bulldog vein system, where massive pyrite was intergrown with fine-grained black silica and replaced by massive chalcopyrite. The chalcopyrite was in turn replaced and veined by bornite and microscopic intergrowths of digenite, tetrahedrite, galena, and silver-copper sulfides (Plumlee and Whitehouse-Veaux, 1994).

Megascopic chalcopyrite and pyrargyrite, along with microscopic tetrahedrite, bornite, miargyrite, famatinite, and various Ag-Pb sulfosalts form the bulk of the transitional stage D-E mineral assemblage.

Figure 43 (left): Chalcopyrite crystal 3 mm across with quartz crystal. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Photo credit: Rocks & Minerals "Collecting Microminerals in the Creede Mining District", Volume 83, September/October 2008, by Arthur E. Smith.

Chamosite variety Thuringite $(Fe^{2+})_5Al(Si,Al)_4O_{10}(OH,O)_8$ (chlorite group; hydrous iron, aluminum silicate)

Thin white coatings on many of the arborescent copper crystal groups are thought to be chamosite (Plumlee and Whitehouse-Veaux, 1994).

Chlorite group

Chlorite group mineral(s) was reported as thin, pale gray coatings on some minerals (Plumlee and Whitehouse-Veaux, 1994). See Chamosite variety thuringite.

Copper Cu (native element)

The Puzzle vein of the Bulldog Mountain Mine contains three textual types of native copper: small grains, curved wires, and delicate arborescent clusters of copper crystals with limonitic jasper, cuprite, and with spangles and arborescent crystals of native silver (Hull, 1970). The arborescent clusters are up to about 2 cm and show crystals with a flattened, elongated habit, while others appear to be spinel-law twins. See Figure 44 below. Grains of copper have been seen only in the upper part of the vein in intensely oxidized localities, while curved wires of copper have been found associated with cuprite, variety chalcotrichite (Eckel, 1997).

The oxidized zone produced hundreds of fine microcrystal groups of native copper recovered from a clay seam by miner and Creede resident, Al Birdsley (Arthur Smith, 2008). Birdsley reportedly stored them in a half-gallon jug at his home in Creede (Rosemeyer, 2010).

Figure 44 (above): Fine copper crystal group 1.7 cm long showing spinel twinning. The specimen was recovered from a clay seam in the oxidized zone of the Puzzle vein, Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Many microcrystalline copper groups, such as this one, were collected by Creede resident and miner, Al Birdsey in 1972. Tom Rosemeyer specimen. Dan Behnke photo in Rocks & Minerals article "Creede – The Last Wild West Silver Mining Camp in Colorado", Volume 85, September/October 2010.

Covellite CuS (copper sulfide)

Covellite is minor in abundance. It has been noted in polished sections where it occurs as irregular grains at mutual boundaries of sphalerite and galena grains, where the covellite appears to replace either the sphalerite or galena or both (Hull, 1970).

Cuprite Cu_2O variety chalcotrichite (copper oxide)

Cuprite, variety chalcotrichite, was found in intensely oxidized portions of the Puzzle vein with native copper. It occurs as delicate nests of red fibrous crystals (Raines, 1988; Eckel, 1997).

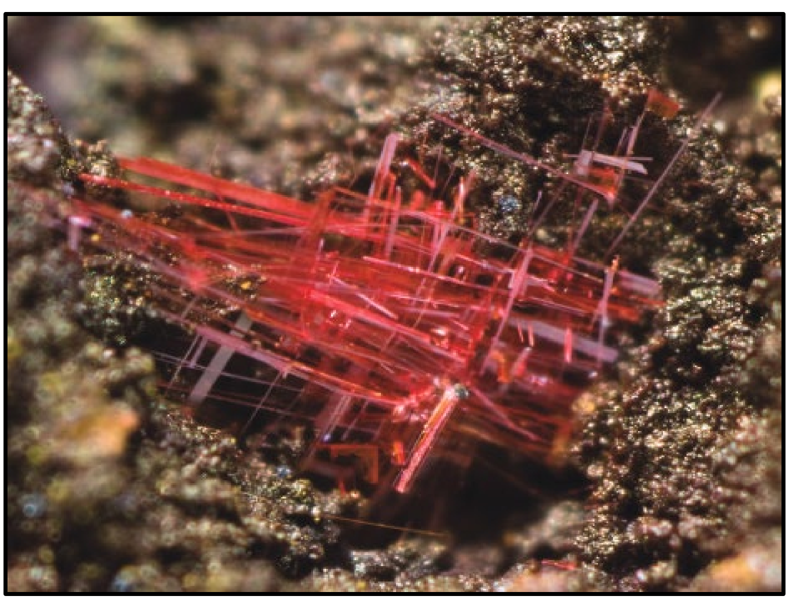


Figure 45 (left): Cuprite, variety chalcotrichite, occurs as beautiful micro-sized reticulated capillary masses on gossan in the oxidized zone of the Puzzle vein. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. The specimen is 3.6 mm across and was collected by Al Birdsey in 1974. Tom Rosemeyer specimen. Dan Behnke photo in Rocks & Minerals article "Creede – The Last Wild West Silver Mining Camp in Colorado", Volume 85, September/October 2010.

Digenite Cu_9S_5 (copper sulfide)

Digenite occurred as veinlets with tetrahedrite, galena, and other sulfides (Plumlee and Whitehouse-Veaux, 1994).

Dolomite $CaMg(CO_3)_2$ (calcium, magnesium carbonate)

Hull (1970) states that dolomite was found as narrow veinlets of an orange-pink color cutting across a layered barite vein.

Famatinite Cu_3SbS_4 (copper, antimony sulfide)

Famatinite, jalpaite, mckinstryite, and miargyrite are among the minerals present in a complex assemblage of Cu-, Ag-, As-, and Sb-rich sulfides and sulfosalts found in the transition between stages D to E of mineralization in the Bulldog Mountain vein system (Plumlee and Whitehouse-Veaux, 1994).

Stage E mineralization was dominated by the deposition of botryoidal pyrite and lesser marcasite, with minor famatinite and other sulfides and sulfosalts.

Fluorite CaF_2 (calcium fluoride)

Fluorite was not abundant at the Bulldog Mountain Mine. It has been reported as pale yellow-green to green, cubic crystals and irregular masses, with colorless and purple varieties being less common. Cubic molds formed by the removal of fluorite have been observed (Plumlee and White house-Veaux 1994; Eckel, 1997; Foley et al 1993).

Fluorite is locally present in stage B ores as light yellow-green to green, sub- to euhedral cubes and masses between barite, sphalerite, and other sulfide generations.

Local leaching of stage C fluorite during stage D is indicated by the occurrence of cubic fluorite molds in some stage D sphalerite.

Galena PbS (lead sulfide)

Galena is the most abundant mineral of economic importance in the Puzzle vein and it is found throughout the horizontal extent of the vein system. Sulfides in the Bulldog vein system were dominated by fine-grained and in some areas, course-grained galena and sphalerite. There is repeated layering of finely and coarsely crystalline varieties of galena, sphalerite, and quartz, suggesting a rhythmic change in the depositional environment and/or in the ore-forming fluid during galena deposition (Eckel, 1997; Plumlee and Whitehouse-Veaux, 1994).

Spectacular cubic galena crystals to an impressive 10 cm occurred in open pockets in the Bulldog system. Many of the cubic crystals exhibit skeletal development and twinning, while others show several generations of growth and resorption (Raines, 1988).

Figure 46 (right): Galena crystals showing skeletal octahedral habit to 7 mm with smaller galena crystals on pale amethystine quartz. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Anonymous collection. Photo credit: Author.

Stage B galena commonly grew contemporaneously with fibrous sphalerite. In the far south reaches of the vein system, the sphalerite generations become more massive, with a muddy “schalenblende” texture. Galena is typically present as finer-grained inter-bands within or replacements of muddy sphalerite bands. In places, a powdery, black sooty variety of galena coats vugs in the vein system (Hull, 1970).

The bulk of stage D mineralization was dominated by relatively coarse-grained to euhedral (generally 0.5 cm to 4 cm) galena and sphalerite crystals generally occurring on top of stage C quartz. The galena crystals are commonly found in spectacular skeletal and twinned forms, smooth faced, or partly intergrown with each other (Raines, 1988). Many microscopic crystals have thin coatings of pyrite, chlorite, and clay minerals that make them difficult to distinguish from cubic acanthite after argentite. (However, many of the galena cubes are more modified than acanthite and are a dull pale gray in contrast to the acanthite and sulfosalts that are generally black.) Unusual geometric patterns on the galena growth surfaces have been noted. In some localities, etch pits are readily visible on crystal surfaces. Galena crystals in the upper levels of the Bulldog vein system are typically smaller (generally around 1 cm) than those in the middle vein levels (Arthur Smith, 2008; Plumlee and Whitehouse-Veaux, 1994).

Goethite α-$Fe^{3+}O(OH)$ (iron oxyhydroxide)

Iron oxide is present throughout the Bulldog mine although generally minor in amount. The color of the iron oxide ranges from dark yellow-orange to dark yellowish-brown. Hull (1970) analyzed several samples by X-ray diffraction, revealing a high percentage of quartz in nearly every sample. Nearly pure goethite was found in only a single sample. Most of the iron oxide analyzed can best be called a limonitic jasper (Hull, 1970).

Goslarite $ZnSO_4 \cdot 7H_2O$ (hydrous zinc sulfate)

The mineral goslarite is usually considered as post mining efflorescence. It forms nests of white, dense hair-like capillary material on walls and floors of the Bulldog workings.

Gypsum $CaSO_4 \cdot 2H_2O$ (hydrous calcium sulfate)

Gypsum probably formed as a post-mining product from the oxidation of pyrite (Arthur Smith, 2008). It occurred as small colorless, elongated crystals in small cavities (Meeves and Darnell, 1968). Gypsum was also observed as flat, monoclinic crystals less than 2 mm in size.

Halloysite $Al_2(Si_2O_5)(OH)_4$ (member of Kaolinite subgroup)

Typically found as earthy to somewhat waxy looking extremely fine-grained clayey masses, usually white to tan in color. So called “spangle” silver, very thin sheets and ribbons of silver, occurred on quartz associated with halloysite and “limonite” in oxidized zones of ore (Rosemeyer, 2010).

Hematite Fe_2O_3 (iron oxide)

Hematite is the most abundant iron oxide in the vein systems north of Creede. In the Bulldog Mountain mine, it occurred as a reddish-brown coating on fractures where it was closely associated spatially with pyrite, sphalerite and galena (Plumlee and Whitehouse-Veaux, 1994, Hull, 1970; Eckel, 1997).

Illite $K_{0.65}Al_{2.0}[Al_{0.65}Si_{3.35}O_{10}](OH)_2$ (phyllosilicate, or layered alumino-silicate)

Wetlaufer (1977) documented the presence of illite, a clay mineral occurring as minor isolated green masses or pods in stage A rhodochrosite. The relation of the illite to other clay minerals and vein minerals is uncertain.

Jalpaite Ag_3CuS_2 (silver, copper sulfide)

Jalpaite is present in a complex assemblage of Cu, Ag, As, and Sb-rich sulfides and sulfosalts found in the transition between stages D and E of mineralization (Plumlee and Whitehouse-Veaux, 1994; Eckel, 1997).

Jarosite (?) $KFe^{3+}{}_3(SO_4)_2(OH)_6$ (potassium, iron sulfate hydroxide)

Jarosite resembles “limonite” so closely that it’s difficult to recognize. It is likely more abundant in Colorado mining districts than indicated by its recorded occurrences (Eckel, 1997).

Jarosite was assumed to be a secondary yellow mineral that occurred as small spheres and hemispheres to 0.6 mm in diameter appearing to be composed of minute platy crystals. Jarosite also formed yellow coatings on other minerals, particularly pyrite and other sulfides (Arthur Smith, 2008).

Kaolinite $Al_2(Si_2O_5)(OH)_4$ (hydrous aluminum silicate)

Kaolinite, or a related mineral, occurred in oxidized ores where it was associated with cerussite. Kaolinite occurred as a minor constituent of clay samples which contained abundant amounts of illite, montmorillonite, or nontronite (Plumlee and Whitehouse-Veaux, 1994; Hull, 1970).

Lepidocrocite $\gamma\text{–}Fe^{3+}O(OH)$ (iron hydroxide)

Lepidocrocite was identified by XRD analysis from the Puzzle vein (Hull, 1970).

"Limonite" – Though not a specific mineral name, it is a general term for mixtures of fine-grained, poorly crystalline or amorphous, hydrated iron oxides. MINDAT defines "limonite" as: "Currently used as a field-term for unidentified massive hydroxides and oxides of iron, with no visible crystals, and a yellow-brown streak. 'Limonite' is most commonly the mineral species goethite, but can also consist of varying proportions of lepidocrocite, hematite, and/or maghemite, along with impurities of other minerals." There is an occurrence in the Bulldog Mountain Mine referred to as "limonitic material" (Rosemeyer, 2010).

Marcasite FeS_2 (iron sulfide)

Marcasite commonly forms botryoidal crustified layers with pyrite next to wall rock in fracture zones. Stage E mineralization was dominated by the deposition of botryoidal pyrite and lesser marcasite (Plumlee and Whitehouse-Veaux, 1994). A lot of marcasite may very well have been deposited as marcasite, but then was later altered to pyrite (Raines, 1988). The botryoidal iron sulfide is very unstable as a general rule and alters readily to melanterite.

An interesting note is the association of botryoidal iron sulfide (marcasite and pyrite) with pyrargyrite - this "ruby silver" mineral is almost never found without marcasite/pyrite from ores from the Bulldog Mountain mine (Raines, 1988).

McKinstryite $Ag_{5-x}Cu_{3+x}S_4$ (silver, copper sulfide)

Mckinstryite, famatinite, jalpaite, and miargyrite, are among the minerals present in a complex assemblage of Cu-, Ag-, As-, and Sb-rich sulfides and sulfosalts found in the transition between stages D to E of mineralization in the Bulldog Mountain vein system (Plumlee and Whitehouse-Veaux, 1994; Eckel, 1997). With wire silver, the mckinstryite can fill cavities and microfractures that cut sulfide-rich zones.

Melanterite $Fe^{2+}(H_2O)_6SO_4 \cdot H_2O$ (hydrated iron sulfate)

Melanterite is most often found in mines as a post-mining formation on mine walls and mineral specimens. It is especially prevalent on marcasite and pyrite, as a whitish-gray colored powdery material. (Specimens that show formation of melanterite should be isolated from other specimens to prevent a chain reaction that could spread the melanterite.)

Miargyrite $AgSbS_2$ (silver, antimony sulfide)

Present in a complex assemblage of Cu-, Ag-, As-, and Sb-rich sulfides and sulfosalts found in the transition between stages D to E of mineralization in the Bulldog Mountain vein system (Plumlee and Whitehouse-Veaux, 1994).

Mimetite $Pb_5(AsO_4)_3Cl$ (lead arsenate chloride)

White to colorless, acicular mimetite crystals to 2 mm long were noted from the Puzzle vein in the Bulldog Mountain Mine, sometimes associated with pyromorphite crystals in oxidized areas (Eckel, 1997; Arthur Smith, 2008). The presence of mimetite is of special interest because it is one of the few chlorine bearing minerals (pyromorphite being the other) noted in the Bulldog Mountain vein system.

Figure 47 (right): 2.1 mm colorless crystal of mimetite from the oxidized zone of the Puzzle vein, Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Tom Rosemeyer specimen. Dan Behnke photo in Rocks & Minerals article "Creede – The Last Wild West Silver Mining Camp in Colorado", Volume 85, September/October 2010.

Montmorillonite $(Na,Ca)_{0.33}(Al,Mg)_2(Si_4O_{10})(OH)_2 \cdot nH_2O$ (phyllosilicate group of minerals)

The clay mineral montmorillonite occurred as a veinlet four inches wide that filled a fracture zone in the Bulldog Mine. The montmorillonite was veined by nontronite (Hull, 1970).

Nontronite $Na_{0.3}Fe_2((Si,Al)_4O_{10})(OH)_2 \cdot nH_2O$ (phyllosilicate group of minerals)

In the Puzzle vein, the yellow-green, waxy clay mineral nontronite occurred in a ¼ inch veinlet in a larger montmorillonite veinlet. (Hull, 1970, XRD; Papke, Nevada Bureau of Mines, 1970). The nontronite also filled vugs in the center of a baryte vein.

Orthoclase $KAlSi_3O_8$ - variety adularia (potassium, aluminum silicate)

Clusters of microscopic (0.5 mm) rhombohedral adularia crystals are intergrown with stage C quartz in the upper levels of the Bulldog ore zone (Wetlaufer, 1977; Plumlee and Whitehouse-Veaux 1994).

Pearceite (?) $[Ag_6As_2S_7][Ag_9CuS_4]$ and **Polybasite** $[Ag_6Sb_2S_7][Ag_9CuS_4]$ (silver, copper, arsenic sulfosalt and silver, copper, antimony sulfosalt, respectively)

Pearceite crystals up to 1 mm reportedly occurred in small vugs at the Bulldog Mountain Mine associated with acanthite, silver, baryte, and common sulfides. Identified by XRD (C.F. Lewis, written communication, 1980; Eckel, 1997).

Polybasite crystals up to 1 or 2 mm were found with pyrargyrite, silver, amethyst, acanthite after argentite, calcite, and pyrite. Polybasite also occurs in the mine as small, pseudohexagonal crystals associated with acanthite, silver, and common sulfides in white baryte ore (A.E. Smith, Jr., written communication, 1982; C.F. Lewis, written communication, 1983; Eckel, 1997). Most specimens of polybasite are massive and seen in the banded ore (Raines, 1988).

Thin, crude, hexagonal prismatic crystals of pearceite-polvbasite were reported to be fairly common. Rarely, compact aggregates of the crystals form what appear to be prismatic crystals that have a hexagonal outline. Some of the flat faces of the crystals are smooth, but most are grooved or striated. Some of the grooves are parallel, while others form complete trigonal patterns. Generally, crystals are black, but some have a bluish iridescence. Compact masses of intergrown crystals are common (Arthur Smith, 2008).

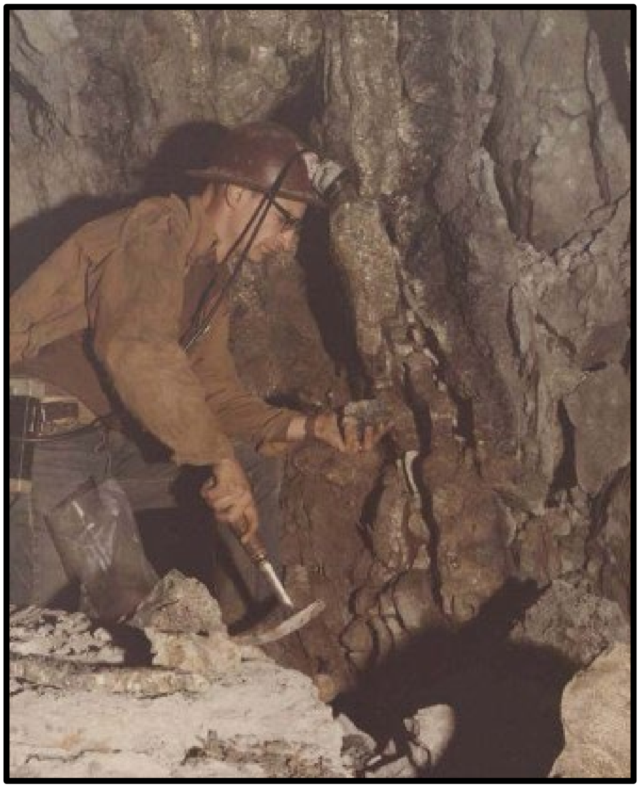
Pyrargyrite Ag_3SbS_3 (silver antimony sulfosalt)

Small amounts of crystallized and massive pyrargyrite are found in the rich silver ore of the Bulldog Mountain Mine. Pyrargyrite occurred in quartz and baryte as small masses of tiny individual crystals and is almost always associated with botryoidal iron sulfide. Crystals and masses are typically black or dark gray and sometimes exhibit a reddish overtone. Larger crystals, usually in the range of 5 to 12 mm, were observed, but are rare (Raines, 1988; Plumlee and Whitehouse-Veaux 1994, Kosnar, 1979a). Microscopic bundles of elongated black crystals with a reddish cast to 2 mm long were observed intergrown with crystalline masses of polybasite-pearcite and acanthite (Arthur Smith, 2008). Most of the crystals have distorted habits. Some crystals have a thin coating of pyrite and are not recognized until broken, thereby exposing the internal red color. Pyrargyrite associated with wire silver is illustrated in Kosnar and Miller (1976).

Megascopic pyrargyrite and chalcopyrite, and microscopic tetrahedrite, bornite, miargyrite, famatinite, and various Ag-Pb sulfosalts form the bulk of the transitional D-E stage mineral assemblage.

Stage E was dominated by the deposition of botryoidal pyrite and lesser marcasite, with minor pyrargyrite and other sulfides and sulfosalts. The pyrargyrite reportedly occurred as euhedral crystals up to about 1 cm in diameter.

Pyrite FeS_2 (iron sulfide)



Pyrite follows galena and sphalerite in abundance among the sulfide minerals. Parts of the Puzzle vein consisted of massive pyrite as much as two feet thick. Pyrite was most abundant where baryte was minor or absent (Hull, 1970; Raines, 1988).

Pyrite was deposited in a number of forms and habits. It could form large botryoidal masses or layers, with a radial structure resembling marcasite, which coated older minerals. (It is possible this material is pyrite after marcasite (Raines, 1988).) Other forms included: columnar veinlets, cavity linings, euhedral crystals with cubic, octahedral and pyritohedral habits, fibrous masses, and sheets. Well-formed crystals are not particularly common. However, cubic, octahedral, and pyritohedral crystals from 0.5 mm to 2.0 cm were present in some of the ore. Small “sunbursts” to 1 cm across with a radiating structure were reported (Arthur Smith, 2008).

Figure 48 (left): Bulldog Mountain Mine geologist examining Stage E botryoidal layers and masses of pyrite in the Puzzle vein. Photo credit: Hull, 1970

Stage E mineralization was dominated by the deposition of botryoidal pyrite with lesser amounts of marcasite and other minerals. The botryoidal pyrite typically occurred in sections ranging in thickness from 1 to 6 cm, although sections up to 10 to 20 cm thick occurred in a few localities. In many hand samples from the mine, concentric layers of radiating fibrous pyrite crystals were easily observed.

Figure 49 (left): Pyrite crystal with octahedral habit to 2.0 cm across with massive pyrite and marcasite. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Anonymous collection. Photo credit: Author.

Megascopic growth zones in stage E pyrite could be recognized by characteristic colors and associated minerals. The earliest pyrite growth zones were bronze to copper colored in hand samples and polished sections and had intergrown stibnite, pyrargyrite, miargyrite, and minor acanthine. The middle pyrite stratigraphy generally appeared brassy and had intergrown marcasite that was typically coarser grained and more euhedral than the intergrown pyrite. The pyrite stratigraphy was capped by bronze-colored growth zones having some intergrown sphalerite (Plumlee and Whitehouse-Veaux, 1994).

An interesting association is the botryoidal iron sulfide (pyrite and marcasite) with pyrargyrite. This "ruby silver" mineral is almost never found without pyrite/marcasite from ores from the Bulldog Mountain Mine (Raines, 1988).

Figure 50 (above): Layering of bronze-colored pyrite (after marcasite?) with gray galena and dark-red pyrargyrite. Specimen dimensions: 8.5 cm x 8 cm x 6.5 cm. Bulldog Mountain Mine, Creede Mining District, Mineral County Colorado. Anonymous collection. Photo credit: Phil Persson.

Figure 51 (above): Plate of large pyrite crystals to about 2 cm with massive pyrite and marcasite. Vertical FOV 14 cm. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Anonymous collection. Photo credit: Author.

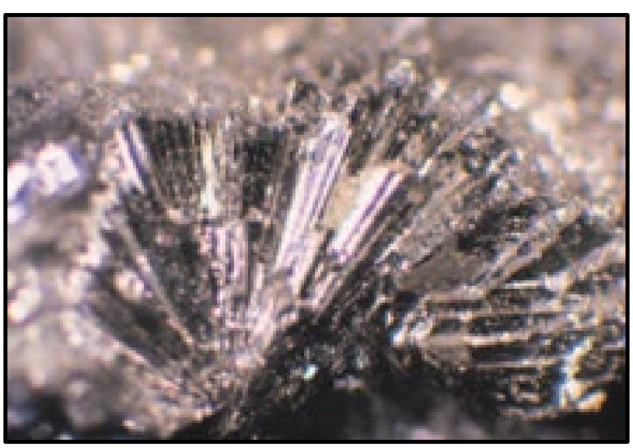


Figure 52 (left): Radiating pyrite crystals, FOV about 4 mm across, Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Photo credit: Rocks & Minerals "Collecting Microminerals in the Creede Mining District", Volume 83, September/October 2008, by Arthur E. Smith.

Pyromorphite $Pb_5(PO_4)_3Cl$ (lead chloro-phosphate)

Small, yellow to brown acicular crystals of pyromorphite were reported. Pyromorphite was associated with mimetite (Arthur Smith, 2008).

Figure 53 (right): Delicate needles of yellow pyromorphite on colorless mimetite. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Horizontal FOV 8.8 mm. Photo credit: Rocks & Minerals "Collecting Microminerals in the Creede Mining District", Volume 83, September/October 2008, by Arthur E. Smith.

Pyrostilpnite Ag_3SbS_3 (silver antimony sulfosalt)

Long, slender crystals generally up to 7 mm were recovered from the mine. The crystals were coated with an epitaxic overgrowth of polybasite and associated minor pyrite and are often grouped in subparallel clusters of 5 to 7 crystals (Raines, 1988). Small pyrostilpnite crystals with pyrargyrite, sphalerite, and pyrite were identified by XRD (C.F. Lewis, written communication, 1980; Eckel, 1997).

Stage E had minor pyrostilpnite-xanthoconite occurring in intergrowths with the ruby silvers (Plumlee and Whitehouse-Veaux, 1994).

Figure 54 (above): A rare specimen of pyrostilpnite partially coated with pyrargyrite. Specimen dimensions 2.5 cm x 5.5 cm. Puzzle vein, Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Ex-George Robertson specimen, now in the Dave Bunk collection. Photo credit: Jesse La Plante.

Quartz SiO_2 - varieties clear, milky, amethystine, and chalcedony (silicon dioxide)

Quartz is an abundant gangue mineral in the Puzzle vein, although subordinate in amount to baryte. Quartz occurs in several varieties: clear, milky, amethystine, and chalcedony. In addition to the chalcedonic variety, quartz occurred as well-developed crystals of clear, white and amethystine varieties. In some stopes at the Bulldog Mountain mine, well-formed amethystine quartz gave the veins a cockscomb texture. Amethyst was a common cementing agent holding breccias together and was found in association with many other minerals in the mine. Isolated individuals or groups of amethyst crystals on matrix are sometimes seen. See Figures 25 and 26.

Depending on the context, the term "chalcedony" can have different meanings. In this context, it refers to the general term for all varieties of quartz that are made of microscopic or submicroscopic crystals, the so-called microcrystalline varieties of quartz.

The Puzzle vein contains several varieties of chalcedonic quartz or chalcedony. The chalcedony varies in color from light grey to yellow green. At several localities the chalcedony occurs as thin layers at the vein walls which grade outward over distances of a few inches through silicified wall-rock into unaltered wall-rock. At other localities, the chalcedony occurs as crusts, as well as in vuggy veinlets coated with sulfide minerals (Hull, 1970).

Figure 55 (left): Large specimen of stage C quartz variety amethyst crystals to about 1.5 cm deposited on banded stage B epithermal white baryte, and dark-gray sphalerite and galena ore. Specimen dimensions 18 cm x 9.5 cm x 8.5 cm. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Anonymous collection. Photo credit: Phil Persson.

Chalcedony and locally inter-banded amethystine quartz were the earliest hydrothermal minerals deposited in the veins. Their deposition overlapped temporally to some extent with subsequent rhodochrosite deposition of stage A mineralization. A massive gray silica surrounded breccia fragments of stage A rhodochrosite and stage B baryte sulfide ore. Fine-grained white to yellow chalcedony, similar to that observed at vein outcrops on the surface, as well as microscopic quartz crystals, commonly coated baryte blades in stage B ores (Plumlee and Whitehouse-Veaux, 1994).

Stage B quartz and chalcedony occurred locally in the lower Bulldog vein system. Interlocking quartz grains commonly coated and filled voids around sulfides. Some of the fine-grained silica was colored black or gray due to included sulfides.

Stage C quartz typically occurred as euhedral comb crystals ranging from 0.4 cm to 2 cm in size. Vugs and bands commonly contained beautiful groups of lavender to deep purple-red amethyst crystals associated with sulfides and native silver. Drusy quartz crystals lined small irregular cavities in some parts of the vein system. In other places, quartz formed epimorphs of crystals of minerals deposited earlier. In the upper part of the ore zone, the quartz was typically finer grained (less than 1 mm) and occurred as interlocking anhedral grains. Stage B sulfides commonly occurred as fragments or blocks surrounded by stage C quartz - the leaching of the overlying and underlying baryte probably removed most of the support for the sulfide minerals (Plumlee and Whitehouse-Veaux, 1994).

Rhodochrosite $MnCO_3$ (manganese carbonate)

Rhodochrosite is relatively rare at the mine. Multiple generations of rhodochrosite deposition dominated stage A mineralization at the Bulldog system (Wetlaufer, 1977; Plumlee and Whitehouse-Veaux, 1994; Raines, 1988). Rhodochrosite forms or habits varied from massive to banded, rhombohedral crystals, scalenohedral crystals to 6 mm, skeletal, chalky, crusts and botryoidal growths, brecciated, and bladed. Some forms showed partial resorption. The colors of rhodochrosite deposited vary from generation to generation: dark and light pink to buff, orange, or brown. See Figure 20. Microscopically, nearly all forms except the gemmy variety, consist of many fine (1 mm) rhombohedra. Gemmy rhombohedra range in size from several millimeters to 1 cm in size and are rarely represented in Colorado collections. Periodic leaching of rhodochrosite occurred during stage A. This created multiple generations of partially leached crystals that were filled in varying degrees by subsequently deposited rhodochrosite (Wetlaufer, 1977). Large, “leached” crystals up to 2 cm are known. See Figure 56 below.

By early stage B, rhodochrosite was typically deposited only in minor amounts, as thin layers on baryte or sulfides.

Figure 56 (right): Unusual specimen of light pink Rhodochrosite replacing sharp crystals of a carbonate mineral. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Field of view: 6.5 cm x 4.5 cm. Each crystal has been replaced and hollowed out as seen in the photo. Small, light pink rhodochrosite rhombohedral crystals are also observed. Anonymous collection. Photo credit: Author.

Rosasite $(Cu,Zn)_2(CO_3)(OH)_2$ (copper, zinc carbonate hydroxide)

Botryoidal crusts of microscopic-sized fibers of felt-like, pale blue-green rosasite were found on native silver, associated with an unknown green crystalline mineral and acanthite on quartz (Rosemeyer, 2010; A.G. Hampton, written communication, 1992; Eckel, 1997).

Rozenite $Fe^{2+}SO_4 \bullet 4H_2O$ (iron sulfate)

Rozenite was identified by XRD by the Colorado School of Mines Research Foundation in a sample from the Puzzle vein of the Bulldog Mountain Mine (Hull, 1970).

Serpierite $Ca(Cu,Zn)_4(SO_4)_2(OH)_6 \cdot 3H_2O$ (hydrated sulfate)

Occurs as blue crystals to 5 mm in vugs in the ore. Associated minerals include quartz, sphalerite, galena, chalcopyrite, and tetrahedrite-tennatite (Eckel, 1997; C.F. Lewis, written communication, 1980).

Siderite $FeCO_3$ (iron carbonate)

Not a common mineral at the mine. Wetlaufer (1977), reported tan to milk-chocolate brown siderite rhombohedra about 2 mm in size in vugs or as infillings in small interstitial spaces. These crystals overlaid sphalerite, galena, fluorite, quartz, and chalcopyrite. Siderite was also found as intergrowths with hematite platelets. See Figure 27.

Silver Ag (native element)

Massive native silver was commonly deposited as distinct bands up to 15 cm wide (6 inches) in the rich "banded" ores along with galena, acanthite (after argentite), quartz, bartye, and polybasite (Raines, 1988). In other localities, native silver replaced acanthite (after argentite), which had previously replaced galena. The richest grade silver-ore in the Bulldog mine, a nearly vertical zone along the 67 stope, was composed primarily of stage B native silver, baryte, and sulfides. Due to the extremely high grade of this ore (up to several thousand ounces of silver per ton), limited numbers of samples have been available for study.

Silver specimens noted by Smith (1974), Raines (1988), Raines (1992), Hull (1970), and Smith (2008), were found in a wide variety of habits and associations. These included single wires, dense groups of wires resembling "steel wool" and

"bird nests", "ropes" formed of composite subparallel wires, leaves, thin sparkling "spangles", blebs/grains, euhedral crystals many with spinel twinning, arborescent growths, and solid masses of thick vein material.

Figure 57 (left): Attractive dense mats of bronze-colored, stage F "steel wool" wire silver on acanthite and baryte matrix. Horizontal FOV about 14 cm. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Anonymous collection.

Figure 58 (right): "Rope" silver (composite subparallel wires) to 1.7 cm in length growing from corroded acanthite. Horizontal FOV 6.5 cm. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Anonymous collection. Photo credit: Author.

The Bulldog Mountain Mine has produced exceptional examples of wire silver. Silver wires, often associated with and growing directly from acanthite (after argentite), have been found extensively in the zones of secondary sulfide enrichment. Individual wires can be as thin as a hair, but are commonly 1 mm in diameter, and can range up to 50 mm in length (Raines, 1988). One famous single wire specimen was approximately 5 mm in diameter and over a meter long. An exceptional specimen of a silver "rope" was 20 cm long by 2 cm in diameter (Raines, 1988; Raines, 1992). Wires often form complex "bird nests" or growths resembling "steel wool". See Figures 3 and 57. The vugs hosting these nests range up to several centimeters across and can contain just a few curled wires, or tightly packed masses of wires. Many silver wires, in their final crystallization, form beautiful curved "ram's horns" in the open spaces. Arguably, the most aesthetic occurrence of wire silver, and the best preserved in collections, includes nests of silver wires in vugs of beautiful amethyst crystals. See Figure 18.

Arborescent growths of silver are fairly rare at the mine, but they are considered one of its remarkable forms of silver. The growths are usually no more than 2 cm in length and 1 cm across, resembling the branches and trunk of a tree. They can be interlayered with sulfides and crystallized amethystine quartz or white baryte. Their beauty and delicacy rival the fine herring-bone silver growths at Batopilas in Mexico. See Figure 62.

The rarest habit exhibited by primary silver is that of euhedral crystals. Both euhedral cubic crystals and highly modified forms are seen (Raines, 1992). Both types of crystals are associated with amethystine quartz and typically measure 1 to 2 mm across. Some are elongated and resemble spear-like growths, showing spinel twinning. See Figure 8.

Specimens of leaf silver can be up to 10 cm across and only 0.5 mm in thickness, but most found are 2 to 3 cm across. See Figure 59. Being so thin, some with ribbon-like habits can take on a shimmering or sparkling appearance when moved. They can be found in complex intergrowths or clusters not more than 6 cm across (Raines, 1988; Raines, 1992).

Figure 59 (left): Leaf silver with a beautiful patina, 3.5 cm x 2.5 cm with a thickness of about 1 to 2 mm. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Anonymous collection. Photo credit: Author.

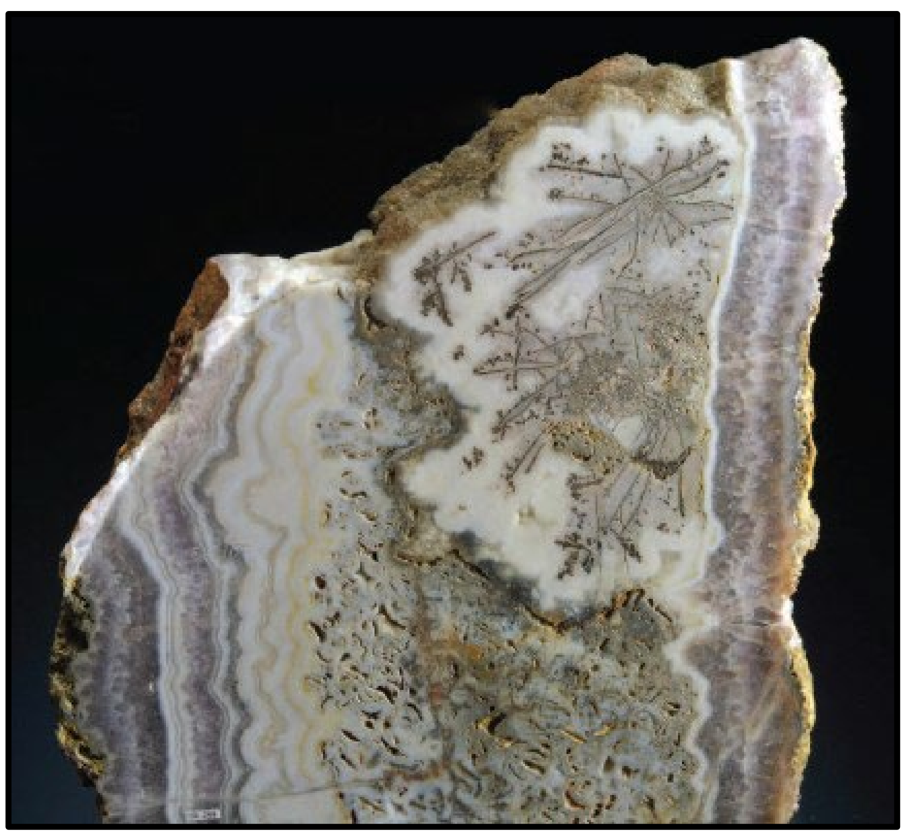
These types of silver habits have different mineral associations, different tarnishing characteristics, and different origins (Hull, 1970). “Spangles” (leaves and ribbons) and arborescent crystals are found in intensely oxidized parts of the vein where they tend to be associated with cuprite, limonitic jasper and the arborescent variety of native copper. See Figure 60. This type of silver tends to resist tarnishing in situ. Native silver can form clusters and dense nests of wires. The wire silver habit was abundant and commonly tarnishes to black or dark gray in situ. Wire silver was found in veinlets of massive native silver and/or acanthite after argentite. On a freshly polished surface the massive variety of native silver has a distinctly yellowish cast.

Figure 60 (left): “Spangles” of silver, to 7 mm, partially encrusting quartz microcrystals. The silver is the thickness of aluminum foil and shimmers with the slightest air movement. The specimen was collected in 1975 by Al Birdsey in the oxidized zone of the Puzzle vein, Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Tom Rosemeyer specimen. Dan Behnke photo in Rocks & Minerals article “Creede – The Last Wild West Silver Mining Camp in Colorado”, Volume 85, September/October 2010.

Figure 61 (left): Large cabinet-sized example of rich spongy wire silver on white baryte and black acanthite matrix. Horizontal FOV 12.0 cm. Specimen Dimensions: 18 cm x 12 cm x 7.5 cm. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Anonymous collection. Photo credit: Phil Persson.

Many desirable native silver specimens, from hand-sized to micro-mounts, were preserved in the 1970's. In particular, massive native silver in the form of delicate arborescent designs interlayered with sulfides and crystallized amethystine quartz or white baryte (often seen slabbed and partially polished) are sought after Bulldog mine specimens (J.A. Murphy, written communication, 1989; Eckel, 1997). See Figure 62 below. This type of crystallization may have been the result of rapid crystallization from super-saturated solutions (Raines, 1992).

Figure 62 (right): Cut slab showing dendritic arborescent growths of hypogene silver enclosed in chalcedony in an interlayered vug of amethystine quartz and sulfides. Specimen dimensions 14 cm x 16 cm. This particular specimen is from the Last Chance Mine, Creede Mining District, Mineral County, Colorado. Dave Bunk collection. Jesse La Plante photo.



Stage B silver ores became progressively richer in baryte and native silver toward the southern portions of the Bulldog vein system, with alternating generations of baryte and fine-grained sphalerite and galena. Massive native silver plus/minus acanthite after argentite assemblages are locally abundant (Plumlee and Whitehouse-Veaux, 1994).

Stage F was the final stage of mineralization along the Bulldog vein system and was characterized by the widespread formation of native silver and coincident leaching of earlier galena and silver-bearing sulfides and sulfosalts. Wire silver was the dominant silver morphology in stage F. The wires grew from or coated corroded sulfides and sulfosalts of all mineralogical stages. Massive blebs of native silver also occur in some localities and generally appear to have replaced earlier sulfides of all stages. In some localities, both wire and massive native silver grew at the expense of, and obtained their silver from, silver-bearing substrates of acanthite or silver-rich sulfosalts that were corroding. In other areas, the native silver appears to have formed as a result of the progressive replacement of earlier silver-poor sulfides such as galena. This silver grew from microscopic acanthite within the galena, which in turn had replaced the earlier sulfides (Plumlee and Whitehouse-Veaux, 1994). Secondary arborescent crystals of acanthite formed on composite silver wires (Smith, 2008).

Sphalerite ZnS (zinc, iron sulfide)

Sphalerite was an important ore mineral and was present throughout the Bulldog Mountain vein system. It occurred as alternating layers with baryte and galena, as individual crystals in vugs, and intermixed with galena.

The sphalerite varied in color from specimen to specimen, and from core to rim in single crystals. Some sphalerite shows a bright yellow-green color (low iron content) and other specimens show a blackish-brown color (high iron content).

Ore microscopic study revealed a variety of textures in the sphalerite. Of particular interest are the arborescent forms of sphalerite and galena along the cleavages of baryte, and the pelletal forms (small rounded, spherical, or cylindrical bodies) of sphalerite (Hull, 1970). Partial resorption of sphalerite leaves an irregular fluted texture (Raines, 1988).

Figure 63 (right): Beautiful twinned, orange sphalerite crystal to 7 mm with galena on pale amethystine quartz. Bulldog Mountain Mine, Creede Mining District, Mineral County, Colorado. Anonymous collection. Photo credit: Author.

Sphalerite crystals are not common. As with massive varieties, crystals can vary greatly in color, depending upon their iron content. The lighter-colored crystals, which are generally shades of yellow-green to orange are lower in iron, while some can be reddish to brown and have a higher iron content. Single crystals can reach 2 cm in size and show a complex habit with spinel law twinning, while others show minor polysynthetic twinning (Raines, 1988; Arthur Smith, 2008).

Sulfide minerals in the Bulldog Mountain vein system were dominated by multi-generational, fine-grained and in some areas, course-grained sphalerite and galena. Even though sphalerite could be deposited as discrete euhedral crystals, it could also occur as continuous layers coating earlier mineralization. Large pockets or layers of massive stage B sphalerite occurred along the southernmost parts of the vein system. The sphalerite was fine grained (grains to 0.5 mm), commonly coated a bladed baryte generation, and formed veins up to several inches wide. Blebs of chalcopyrite and tetrahedrite are a common alteration product within early-stage B sphalerite in the Bulldog Mountain vein system (Plumlee and Whitehouse-Veaux, 1994).

In stage B, all sphalerite generations had well-developed microscopic growth bands marked by strong color variations, morphology, and types of intergrown associated minerals. Primary sphalerite textures varied from fibrous and anisotropic to isotropic and sector-zoned. In the far south reaches of the vein system, the sphalerite generations became more massive, with a muddy looking "schalenblende" texture. Galena was generally present as inter-bands within or replacements of sphalerite bands (Plumlee and Whitehouse-Veaux, 1994).

Most of stage D mineralization was dominated by coarse-grained (0.5 - 2 cm) sphalerite and galena crystals generally occurring on top of stage C quartz. The larger sphalerite crystals usually had abundant interpenetrating twins. The sphalerite was generally a greenish shade in color in hand samples, but in some localities where the crystals are small, the color could range from orange to brown or red. See Figure 28. Growth banding was readily apparent in thin sections. In some localities, etch pits were readily visible on sphalerite crystal surfaces.

Stage E was dominated by the deposition of botryoidal pyrite and lesser marcasite, with minor amounts of sphalerite and other sulfides and sulfosalts.

Stibnite Sb_2S_3 (antimony sulfide)

Stage E mineralization contained minor amounts of stibnite with other sulfides and sulfosalts. The stibnite occurs as acicular crystals up to several millimeters long in drusy quartz cavities (Plumlee and Whitehouse-Veaux, 1994; Arthur Smith, 2008).

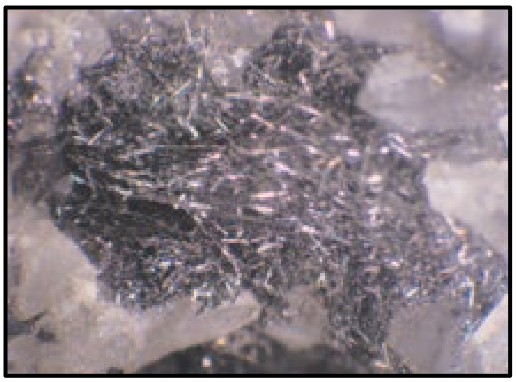


Figure 64 (left): Small, stibnite mass of tangled acicular crystals with quartz in a 3-mm area. Bulldog Mountain Mine. Creede Mining District, Mineral County, Colorado. Photo credit: Rocks & Minerals "Collecting Microminerals in the Creede Mining District", Volume 83, September/October 2008, by Arthur E. Smith.

Tetrahedrite $Cu_6(Cu_4C^{2+}_2)Sb_4S_{12}S$ and **Tennantite** $Cu_6(Cu_4C^{2+}_2)As_4S_{12}S$ (copper, iron, zinc, antimony/arsenic sulfosalts)

"Tetrahedrite Subgroup"

Tetrahedrite and other sulfosalts were fairly widespread in the Bulldog Mountain Mine, although euhedral crystals are rare (Barton and others, 1977; Raines, 1988; Bethke and Rye, 1979). As massive material, they were typically present in the banded ores as black masses with acanthite and other sulfides; as alternating botryoidal growth layers with chalcopyrite; disseminated or included with chalcopyrite or sphalerite; and, as grains coating vugs in rhodochrosite (Hull 1970; Plumlee and Whitehouse-Veaux 1994). Early in the mine's development, X-ray diffraction patterns for a "grey copper" mineral in the Puzzle vein were much closer to tetrahedrite reference patterns than to either tennantite or freibergite patterns (Hull, 1970).

Stage B crystals of tetrahedrite, although quite rare, grew contemporaneously with fibrous sphalerite. Crystals of tetrahedrite to approximately 1 cm are reported from the Bulldog mine by Kosnar (1979a) and Eckel (1997).

Growth bands in stage B tetrahedrite reflected compositional variations in silver, arsenic, and antimony. Silver occurred in trace amounts (Plumlee and Whitehouse-Veaux 1994).

Microscopic tetrahedrite, as well as bornite, miargyrite, famatinite, and various Ag-Pb sulfosalts formed the bulk of the transitional D-E stage mineral assemblage.

Thuringite (see chamosite)

Wulfenite $PbMoO_4$ (lead molybdate)

Hull (1970) reportedly found a single yellowish-gray crystal of wulfenite in a vug in a galena-pyrite vein on the 9700 level of the mine. The same vug contained a cerussite crystal. Wulfenite was not recognized anywhere else in the Bulldog Mountain mine. Wulfenite is the only molybdenum bearing mineral noted in the Puzzle vein.

Xanthoconite Ag_3AsS_3 (silver arsenic sulfosalt)

Minor xanthoconite-pyrostilpnite is intergrown with "ruby silver" minerals in stage E of mineralization (Plumlee and Whitehouse-Veaux, 1994, Eckel, 1994). Flat, elongated, dark-colored crystals with pointed terminations occurred with pyrargyrite-proustite and reportedly could be either xanthoconite or pyrostilpnite (Arthur Smith, 2008).

Figure 65 (left): A gated and closed Bulldog Mountain Mine. Image credit: Codastory, 2023.

Figure 66 (below): Downtown Creede in 2016. Image credit: unknown.

Future Prospects for the Bulldog Mountain Mine

Today, nearly forty years after the Bulldog Mountain Mine was shuttered, Creede's mining industry might soon come alive again and add a new chapter to its vibrant history. Bulldog Mountain still holds a large quantity of untapped silver. Last year, Hecla Mining, the largest silver mining company in the United States, confirmed plans for a targeted exploration program centered on the Bulldog Mountain Mine, through its subsidiary, Rio Grande Silver (Codastory, 2023). With Hecla's purchase of the mineral rights to 21 square miles of land in the Creede Mining District, the company has been working to make Bulldog Mountain Mine's old infrastructure accessible again. In some circles, it's believed that potential exists for the discovery of an additional 100 million ounces of silver (Rosemeyer, 2010). The company planned an exploration program for 2022 to determine how much silver was left in the mountain and how best to access the metal. Stay tuned.

"The cliffs are solid silver with wondrous wealth untold
And the beds of running rivers are lined with glittering gold
While the world is filled with sorrows and hearts must break and bleed
It's day all day in the day-time and there is no night in Creede"

Cy Warman

Appendix

“Quick Read”: Geology and Mineralogy of the Creede Mining District

The geology and mineralogy of the Creede Mining District and the Bulldog Mountain Mine have been described in detail in numerous excellent sources.

- For detailed information about the geology and geochemistry, interested readers are referred to the following references: (Bethke et al, 1976), (Barton, Bethke, and Roedder, 1977), (Bethke and Rye, 1979), (Robinson and Norman, 1984), (Plumlee, 1994), and (Plumlee and Whitehouse-Veaux, 1994).
- For detailed information about mineralogy, readers are referred to the following references: Emmons and Larson (1923), Smith (1974, 2008), Holmes and Kennedy (1983), Raines (1988, 1992), and Plumlee and Whitehouse-Veaux (1994).

Over a period of 94 years (1891-1985), the Creede Mining District produced an estimated 85.7 million ounces (more than 2,600 tons) of silver, 169,000 short tons of lead, and 54,000 short tons of zinc. All of this from an estimated 5.0 million tons of ore and 182 miles of mine workings (modified from Huston, 2005; Meeves and Darnell, 1968; Boppe, 2001; Ridge, 1933-1967; Jackson, 2001 and 2002**).**

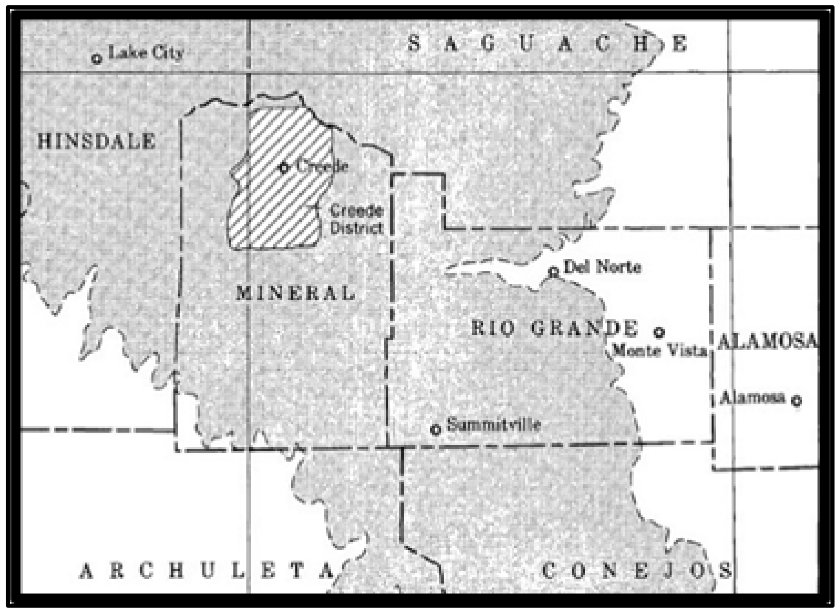


Figure 67 (right): The Creede Mining District is situated near the confluence of Willow Creek and the Rio Grande River in the northern half of Mineral County, in the San Juan Mountains of southwestern Colorado. District shown in hatching.

The Creede district is in the central portion of the San Juan volcanic field, in a complex set of nested calderas. These calderas were formed by the eruption of seven major ash flow sheets during the period 28.25 to 26.15 million years ago (Lipman et al, 1978).

As geologic movement caused fractures and zones of fractures in the surrounding rhyolitic country rocks, hydrothermal solutions rich in silica, silver, lead, and zinc ascended toward the surface. Because of the decreased temperatures and pressures encountered by solutions as they moved upward along the fault zones, the solutions solidified to form massive veins with epithermal banding and crustified open-space fillings of minerals. These epithermal veins contained banded agate, amethystine quartz, native silver, and a variety of silver, lead, and zinc sulfides and sulfosalts. Erosion later carved and shaped the area into present topography and exposed some of the mineralized veins.

The district’s vein deposits occur primarily as fillings in fractures of a graben extending between the Creede caldera and San Luis caldera to the northwest. The majority of Creede ores occur in the Bachelor caldera, the third caldera to form in the nested caldera complex, situated between the Creede and San Luis calderas. See Figure 68 on next page. The geologic movement that caused the formation of the graben created six major fault zones. The two fault zones forming the west side of the graben are the Bulldog Mountain and Alpha-Corsair faults. The eastern side of the graben is bounded by the Amethyst and Solomon-Holy Moses fault zones. See Figure 70 on next page. The OH and P fault zones occupy the center of the district. The bulk of the production to date has come from four veins or fault systems, including the Bulldog Mountain, Amethyst, OH, and P. Lesser production has come from the Solomon-Holy Moses and Alpha-Corsair veins.

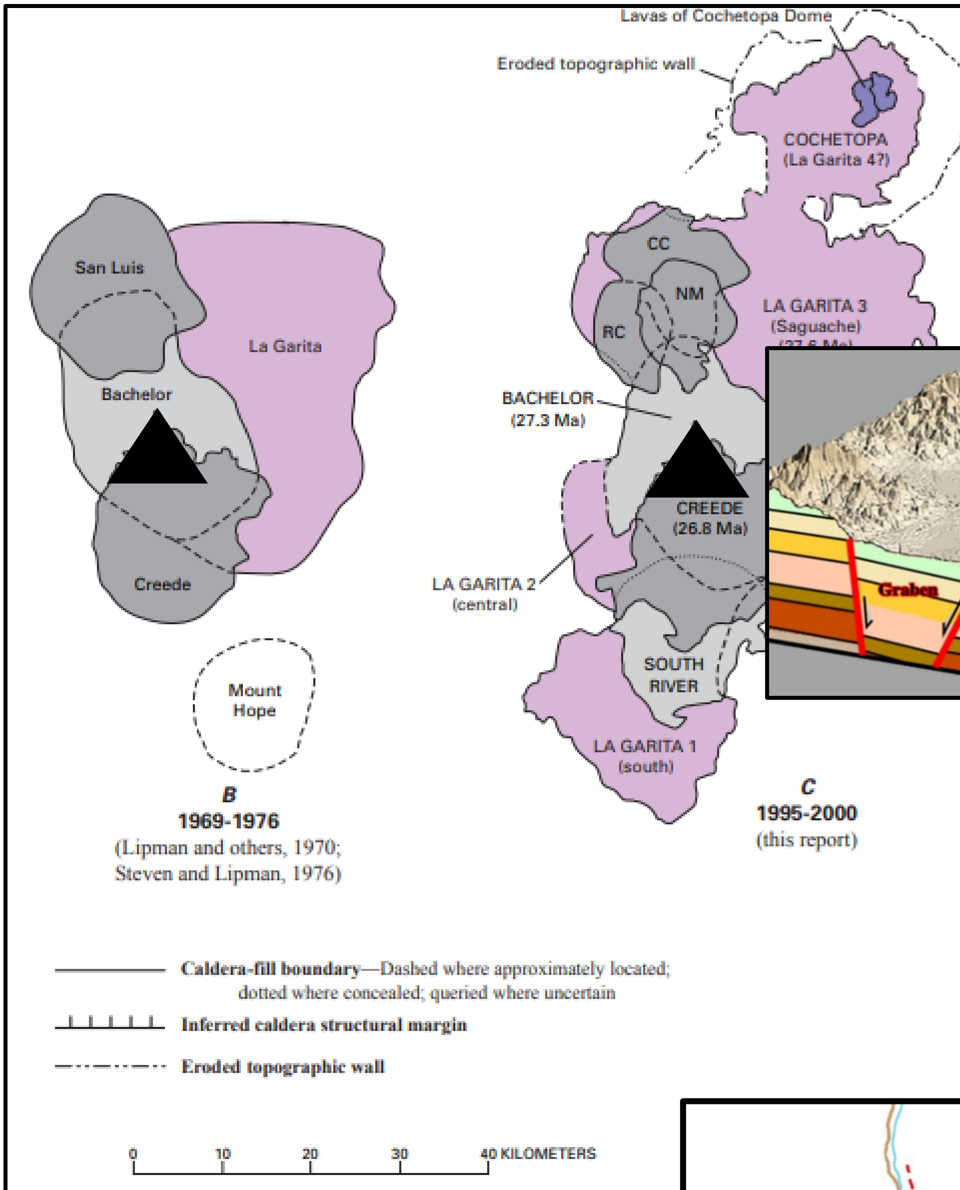


Figure 68 (left): Maps showing successive interpretations (1969-2000) of the locations and geometry of central San Juan caldera: Creede caldera, Bachelor caldera and San Luis caldera (CC=Cebolla Creek, NM=Nelson Mountain, RC=Rat Creek). Diagram B represents the caldera geometries of 1969-1976. Diagram C represents the contemporary interpretation 1995-2000. Black triangle represents location of the Town of Creede. (Lipman, 2006)

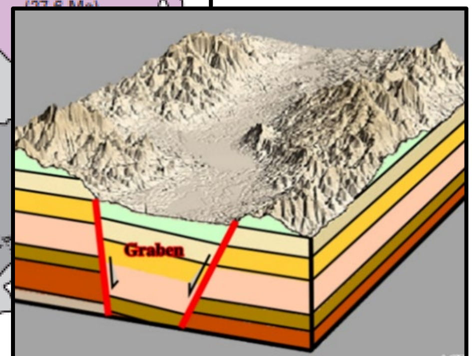
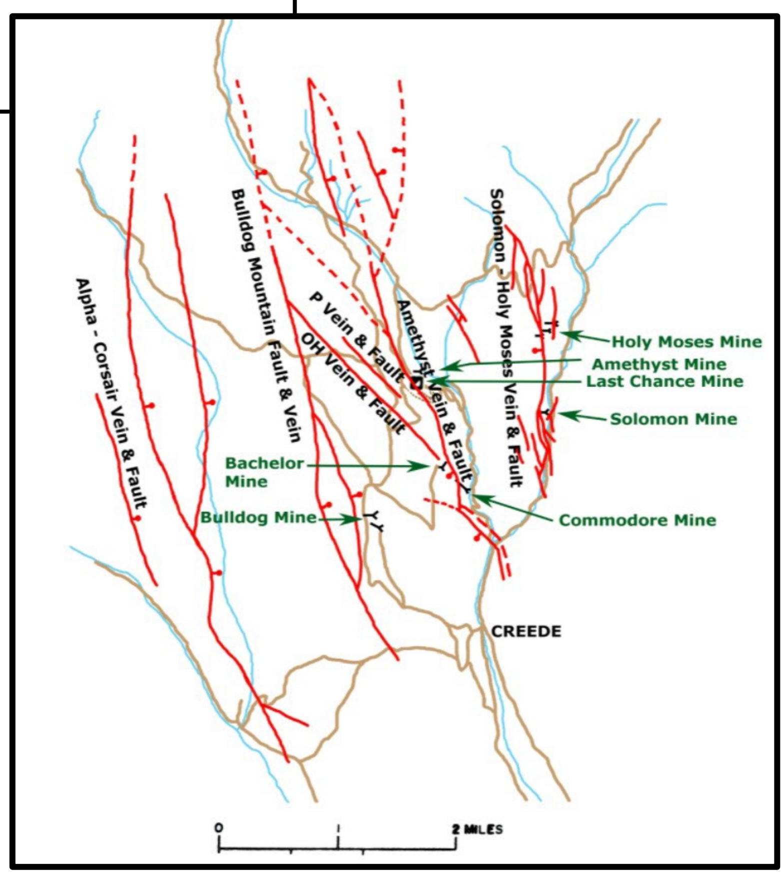


Figure 69 (left): A graben is a depressed block of the earth's crust bordered by parallel normal faults.

Figure 70 (below): Map showing primary fault and vein systems, including the Bulldog Mountain Fault and Vein system in the Creede Mining District. The district's metallic deposits occur primarily as fillings in fractures of a massive graben. The fault zones forming the west side of the graben are the Bulldog Mountain and Alpha-Corsair faults. The eastern side of the graben is bounded by the Amethyst and Solomon-Holy Moses fault zones. Image credit: Mines Museum of Earth Science digital archives.



The most important ore deposits in the district are the silver-lead fissure veins, occupying these fractured zones. Generally, ore bodies do not exhibit pronounced out-crops. Many of these veins have been leached to significant depths, causing the removal of ore minerals from the upper elevations of bodies and redeposition into underlying zones of secondary enrichment (Meeves and Darnell, 1968).

The district's most productive mineral vein and fault system, the three-mile-long Amethyst, is known for its beautiful layered epithermal deposits. These typically have well-defined, concentric, geode-like structures/layers of minerals. Some banded layers consisted of white and bluish chalcedony, masses of dark, mineralized quartz, and a zone of translucent amethystine quartz, in which traces of manganese created pink, violet, and lavender colors. (Hence, the name Amethyst vein.) In some places, the center of veins were filled with solid masses of acanthite after argentite, argentiferous galena, and native silver. During Creede's boom days, this material could assay to several thousand ounces of silver per ton (Voynick, 2020).

The ore deposits in the vein and fault zones of the district are mineralogically complex and spatially zoned.

- The southernmost veins are silver rich and gold poor, with native silver, acanthite after argentite, sulfosalts, sphalerite, galena, and copper sulfides, in a gangue of baryte, rhodochrosite, quartz, pyrite, hematite and adularia. Silver to gold ratios are >1000:1. This is known as the Bulldog Assemblage (Plumlee and Whitehouse-Veaux, 1994).
- Further north along the OH, P, central Amethyst and Bulldog Mountain vein systems, the ores become more base metal rich. This is the OH Assemblage, comprising sphalerite, galena, chalcopyrite and lesser tetrahedrite, in a gangue of quartz, pyrite, chlorite, hematite and lesser adularia and fluorite. Gold is present in slightly greater amounts but is still rare (Plumlee and Whitehouse-Veaux, 1994).
- To the north, the vein systems take on the Northern Assemblage, marked by high precious metal values, with silver to gold ratios below 100:1. Ore minerals include electrum, acanthite after argentite, pyrargyrite, jalpaite, sphalerite and galena, in a gangue of quartz, adularia, calcite, kutnahorite, rhodonite, rhodochrosite, pyrite, fluorite, hematite, magnetite and chlorite. Higher precious metal levels are marked by adularia-rhodonite-kutnahorite gangue. Baryte is rare but increases toward the south (Plumlee and Whitehouse-Veaux, 1994).

Mineralogically, the Creede district is noted for the many fine crystallized and wire silver specimens. Many were recovered from mines along the prolific Amethyst vein system, and more recently from the Bulldog Mountain mine's Puzzle and West Strand veins. As in other mining camps, very few silver specimens survived that can be attributed to the early "boom days". In addition, many fine specimens of crystallized sphalerite, galena, acanthite after argentite, baryte, chalcopyrite, and "sowbelly agate" (banded quartz – varieties amethyst and chalcedony) grace collections around the world.

Figure 71 (left): Supt. Harry Van Horn and miners at the Commodore mine, Creede Mining District, circa 1900. Image credit: Denver Public Library Western History digital collection.

Figure 72 (above): Early Creede saloon with its customers. Date circa late 1890's. Image credit: Denver Public Library Western History digital collection.

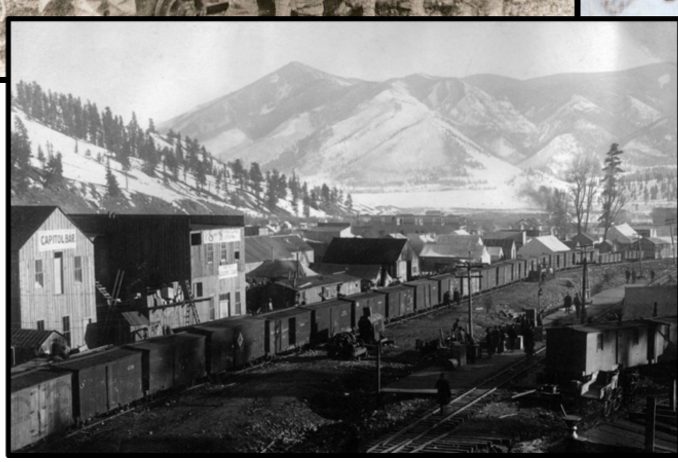


Figure 73 (left): Ore cars on the Denver and Rio Grande Railroad line in Creede circa 1895. Image credit: Denver Public Library Western Digital Archives.

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