WYOMING STATE GEOLOGICAL SURVEY
Gary B. Glass, State Geologist

COPPER, LEAD, ZINC, MOLYBDENUM, AND ASSOCIATED METAL DEPOSITS OF WYOMING

by

W. Dan Hausel

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Front Cover: Part of Boston-Wyoming Copper Company's copper mill and smelter at Riverside, Wyoming as it appeared in 1902, shortly after construction. Copper ore produced from the Ferris-Haggarty and other mines in the Grand Encampment district was sent by aerial tramway some 16 miles to this mill and smelter. Most of the structures shown were destroyed by fire in 1906 and 1907. Photograph from the J.E. Stimson collection, courtesy Wyoming Division of Cultural Resources, Department of Commerce. Reproduced with permission.

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Preface

During the nearly 20 years that the author has worked for the Wyoming State Geological Survey, several potentially economic base metal deposits have been identified in Wyoming. But because of one factor or another, no development of any base metal deposit occurred during this period. This is unfortunate, as I have seen several excellent targets in the State, that with additional exploration, could possibly lead to development.

Similar optimism was also shared by some of my predecessors, such as Henry Beeler and Authur Spencer. However, these two geologists had the advantage of living during the development of a significant copper industry in Wyoming in the early 1900s. In the first decade of the 20th Century, considerable excitment about the development of the Ferris-Haggarty mine in the Sierra Madre of southeastern Wyoming led to much of their optimism. From the information in this book, some company might discover, or rediscover, significant base metal resources in the State, and we will once again see a base metal industry in Wyoming.

This book is intended to give important descriptions about the State's base metal deposits and should be considered a companion to Wyoming State Geological Survey Bulletin 68, *The geology of Wyoming's precious metal lode and placer deposits.* In addition to base metal deposits, this new publication also contains data on several precious metal occurrences.

I would like to thank Richard W. "Dick" Jones of the Wyoming State Geological Survey for his editoral review of this publication and also Wayne Sutherland and Dick for their critical reviews of the manuscript. I also acknowledge the contributions made by the following personnel of the Wyoming State Geological Survey: Janet A. Van Nuys for composition and layout of the manuscript, Phyllis A. Ranz and Fred H. Porter, III, for their nice job on many of the graphics, and Peggy Hopkins for assistance with final production.

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April, 1997

Introduction

Near the close of the 1800s, optimism was very high that Wyoming would become an important producer of copper and other base metals. The Ferris-Haggarty mine in the Grand Encampment district of the Sierra Madre became one of the 30 most important copper mines in the world during the first decade of the 1900s. This dream was short-lived, however, when in 1908 the Ferris-Haggarty mine closed as a result of financial problems. Wyoming never again gained stature as an important copper-producing state. Only minor amounts of zinc, lead, and molybdenum were ever produced in Wyoming.

The fact that Wyoming never again became an important copper producer is somewhat of an enigma. Wyoming hosts several large-tonnage copper-silver porphyry deposits with associated values in lead, zinc, molybdenum, titanium, and gold, which received considerable exploration interest in the 1950s, 60s, 70s, and 80s, but never were exploited. The lack of mining activity on these porphyries probably was due to the lack of infrastructure in the high Absaroka Mountains east of Yellowstone and, more recently, because much of the area lies within or adjacent to areas designated as wilderness by Congress.

Major base metal production elsewhere in the world is derived from porphyry copper deposits, massive sulfides, and bedded stratigraphically controlled deposits. The major world producers are the United States, Chile, Zambia, Canada, the former Soviet Union, Zaire, Peru, Australia, South Africa, and Japan.

Significant base metal resources in Wyoming are found in large copper-silver porphyries in the Absaroka Mountains of the northwestern part of the State; a disseminated Precambrian copper-gold porphyry intrusive complex in the Silver Crown district of the Laramie Mountains in southeastern Wyoming; a cupriferous mafic dike at DePass in the Copper Mountain district in central Wyoming; copper-zinc volcanogenic massive sulfides, and disseminated and high-grade remobilized stratabound copper deposits in quartzites in the Sierra Madre of southeastern Wyoming; and copper-silver-zinc-lead redbed deposits in the Overthrust Belt of western Wyoming (**Figure 1**). It is important to note that all of these deposits are polymetallic and host other metals in addition to copper, lead, zinc, and/or molybdenum.

Uses

Copper, molybdenum, zinc, and lead are necessary ingredients in a modern society. Only a small amount of the world demand for these metals can be met through recycling; consequently, much of this demand must be met by the discovery and mining of new resources. These metals are used extensively in automobiles, airplanes, homes, buildings, appliances, and bridges.

Copper derives much of its importance from its high electrical conductivity, chemical stability, and plasticity. In addition, copper is capable of forming alloys with many metals; two common alloys are brass (copper-zinc) and bronze (copper-tin). Copper is used extensively in wiring, switches, and other electrical equipment in our homes, cars, airplanes, appliances, and buildings. Copper also is used in coaxial cables and microwave tubes. Because of its resistance to corrosion, copper is found in brake-line tubing, in tanks and piping, and in roofing. Copper also is used in the manufacture

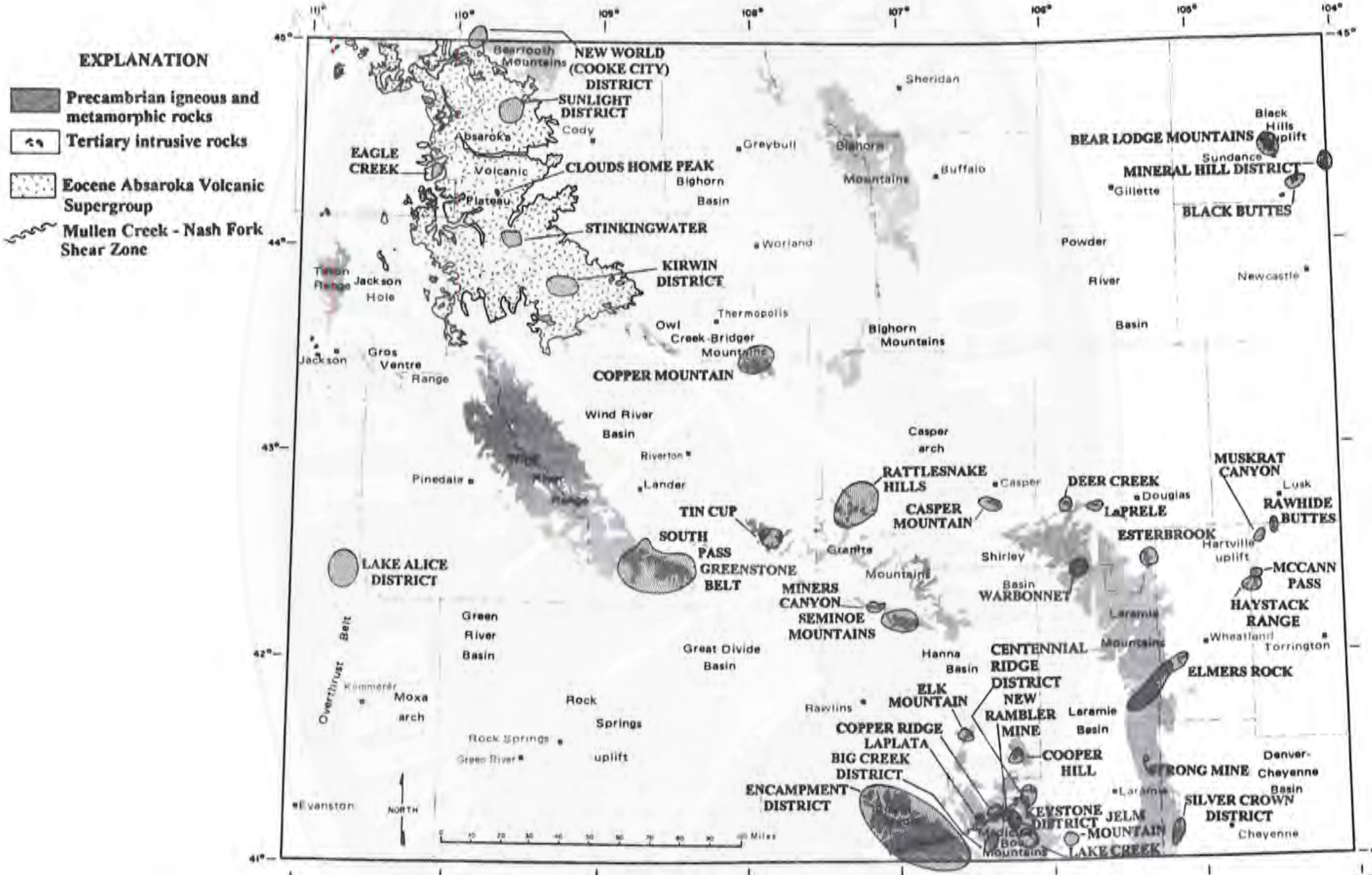


Figure 1. Copper districts and mineralized areas in Wyoming. Map compiled by W.D. Hausel, 1989; modified 1997.

of brass shell casings for ammunition, and the metal is even found in our food. Copper has literally thousands of applications in our modern society.

Molybdenum has many important metallurgical applications. Besides its use as a lubricant, the metal is an important ingredient in the manufacture of stainless steel. By adding molybdenum to steel, an alloy of extreme hardness and toughness is created that is resistant to abrasion and corrosion. Molybdenum steel is necessary for building supports, frameworks, automobiles, bridges, bearings, and stainless steel utensils.

Lead is consumed principally in lead-acid storage batteries for automobiles and in other products that require energy storage. Other important and common uses include alloys in bearings for the transportation industry, solder, soundproofing in buildings, and in leaded glass windows that prevent X-ray leakage in hospitals and research laboratories. Sheet lead is used in the transportation and storage of toxic wastes, and corrosion-resistant lead oxide paint is used for protection of building and highway structures, as well as safety markings on highways. Some lead is also used to manufacture bullets and fishing weights. Lead foil is used to contain radioactivity, and lead is used in oil refining and in the manufacture of dyes and adhesives.

Because zinc has a low melting point and high electrical conductivity, it has many important uses. It is used to galvanize steel for cathodic and corrosion protection. Zinc also is used in paints to provide protection from corrosion. Zinc oxide has excellent photoconductive properties, which are advantageous in photocopying. Zinc die casts are used in making automobiles, furniture, cabinets, doors, locks, and keys. Zinc, like the other base metals, actually has hundreds of uses, and like copper and molybdenum, is essential for human nutrition.

Ore genesis

Studies related to the genesis of Wyoming's copper deposits are notably lacking. However, field studies, textural relationships of the mineral deposits to host rocks, and replacement mineral assemblages have provided a general understanding of the processes which formed many of the State's deposits. In general, most of Wyoming's base metal deposits fall within the categories of magmatic, magmatic hydrothermal, metamorphogenic, and stratiform and stratabound deposits of sedimentary affiliation.

Magmatic deposits

Magmatic deposits show an intimate association of mineralization to the host igneous rock linking the mineralization and host rock to a common heritage. Typically, the mineralization in such deposits is interpreted to have crystallized directly out of the magma of a layered mafic complex.

Although the known Wyoming magmatic deposits do not contain abundant copper and other base metals, copper has been found associated with deposits classified as magmatic. Where cumulate-textured rocks contain disseminated sulfides, textural evidence indicates the sulfides crystallized directly from the host magma. Later deformation and hydrothermal alteration may have occurred, resulting in the remobilization of some of the metals and redeposition in deformation zones associated with hydrothermal alteration assemblages.

In the Mullen Creek mafic complex in the Medicine Bow Mountains of southeastern Wyoming, for example, intense shearing related to the Mullen Creek-Nash Fork shear zone contributed to the deformation of the complex. Copper mineralization, with some platinum and palladium, occur in shear zones in hydrothermally altered metadiorite, metagabbro, metapyroxenite, and metaperidotite (McCallum and others, 1975). Two hydrothermal alteration assemblages have been recognized in this complex at the New Rambler mine that are overprinted by supergene assemblages. These are a propylitic alteration assemblage of secondary chlorite, epidote, clinozoisite, albite, magnetite, and pyrite, and a phyllic alteration assemblage of sericite, quartz, and pyrite.

Mineralization at the New Rambler mine was exposed in a leached cap of malachite and azurite, with subordinate cuprite, tenorite, chalcotrychite, and chalcopyrite. Native copper, atacamite, chalcanthite, tetrahedrite, and bornite were found sparsely distributed with rare orpiment, realgar, and lorandite. At a shallow depth, (75 to 100 feet), the oxidized cap graded into a supergene-enriched blanket of platiniferous covellite and chalcocite. The supergene assemblage graded into primary mineralized rock at 100 feet which included quartz-pyrite-chalcopyrite veins with minor sperrylite (McCallum and Orback, 1968).

In contrast to the Mullen Creek complex, the Lake Owen complex several miles to the south contains cumulate sulfides in at least 12 stratigraphic horizons, with some zones showing elevations of gold and platinum ± palladium. Four horizons exhibit laterally persistent precious metal anomalies of a few hundred to a few thousand parts per billion with Au-Ag alloys, Pt-arsenides, Pt-Pd tellurides and sulfides associated with disseminated chalcopyrite, pentlandite, pyrrhotite, pyrite, gersdorffite, bornite, millerite, and PGE (platinum group elements)-bearing carrollite. The mineralized zones are generally lensy and spotty but include zones up to 15 feet thick with strike lengths of more than 1 mile (Loucks, 1991).

Mineralization in the Lake Owen complex is clearly magmatic, being associated with cumulate layers. In the New Rambler district of the Mullen Creek complex, mineralization occurs in hydrothermally altered mafic cataclastic rocks. Apparently, the New Rambler ore was leached from discrete mafic rock units by hydrothermal solutions, or remobilized from the deformed layered complex (McCallum and Orback, 1968).

Magmatic hydrothermal deposits

Several of Wyoming's base metal deposits are classified as magmatic hydrothermal deposits (Hausel, 1993d). These were formed from high-temperature fluids during igneous activity, producing zoned alteration and mineral assemblages as the temperature gradients decreased outward from the centers of the igneous activity. The metals either accompanied the magma, were leached from the surrounding country rock, or were derived from both sources. The recognized magmatic hydrothermal deposits in Wyoming include (1) porphyry copper deposits, (2) volcanogenic massive copper-zinc sulfide deposits, and (3) associated veins.

Porphyry copper deposits

These deposits include copper-silver mineralization in the Absaroka Mountains of northwestern Wyoming, and a copper-gold deposit in the southern Laramie Mountains of southeastern Wyoming. The porphyries in the Absarokas are associated stocks beneath deeply-dissected stratovolcanoes. These are characterized by a central zone of either potassic or phyllic alteration mineral assemblages that grade outward into argillic and propylitic altered zones. Zoned mineralization includes copper-molybdenum-trace gold surrounding the stocks which gives way laterally to zinc-lead-silver mineralization.

The Bald Mountain porphyry in the Absarokas is surrounded by deuterically altered andesite containing secondary calcite, chlorite, and clay. The andesite gives way to hydrothermally propylitized (quartz-epidote-montmorillonite-calcite-chalcopyrite with chalcopyrite-calcite-quartz veinlets) andesite within 1500 feet of the intrusive center. Near the intrusive center, phyllically altered assemblages are overprinted by argillic assemblages (quartz-sercite-pyrite-biotite-kaolinite-chlorite-illite/montmorillonite). This phyllic-argillic altered zone encloses a poorly defined potassic zone represented by secondary orthoclase, quartz, and veinlet sulfides (Wilson, 1964; Nowell, 1971).

Drill hole data show a pyrite-chalcopyrite-molybdenite stockwork at Bald Mountain with a secondary enriched blanket of chalcocite, digenite, and covellite overlying a stockworks (Wilson, 1964). Veins in the altered area are chalcopyrite-pyrite-molybdenite-quartz veins (Wilson, 1960). Estimated amounts of metals contained in the porphyry include 1.23 billion pounds of copper, 121,000 ounces of gold, 5.6 million ounces of silver, and significant lead, zinc, molybdenum, and anomalous titanium (Pay Dirt, 1985) worth more than $1.5 billion (1989 prices).

In the Silver Crown district of the southern Laramie Mountains, copper and gold are disseminated in the Proterozoic quartz monzonite and foliated granodiorite known as the Copper King porphyry. Near the center of the deposit, a zone of intense silicification extends outward into a narrow potassically altered zone containing secondary biotite and K-spar. This zone is enclosed by a propylitically altered zone that includes secondary epidote, chlorite, sulfides, and quartz. Drilling by the U.S. Bureau of Mines established a 35-million-ton ore body with average grades of 0.21% Cu and 0.755 ppm Au. A higher grade zone (4.5 million tons averaging 1.51 ppm Au) was later outlined by company drilling (Hausel, 1989).

Volcanogenic massive copper-zinc sulfide deposits

Several of these deposits have been identified in the southern Sierra Madre of southeastern Wyoming. The deposits are interpreted to have formed by sulfide precipitation in mounds near volcanic vents on a Proterozoic sea floor. The mineralizaton is associated with epidote-actinolite-magnetite exhalites in differentiated calc-alkaline metarhyolites and meta-andesites of the Green Mountain Formation. Wall rock alteration consists of localized secondary sericite and pyrite zones with broad zones of sausseritization (epidote ± chlorite ± garnet ± calcite ± actinolite). These form stratabound deposits of pyrite, chalcopyrite, and sphalerite, with secondary tenorite, and marmatite spatially associated with volcaniclastics containing clasts up to several inches in length. Locally, samples of colloform pyrite mantled by chalcopyrite in a magnetite matrix occur near some vent breccias.

Associated vein deposits

Quartz veins are common in both volcanic and metamorphic terranes. In Tertiary volcanic rocks, the veins are clearly associated with hydrothermal activity and often show ore zonation. For example, quartz veins associated with the Sunlight stock in northwestern Wyoming are copper rich with trace gold near the porphyry center; the quartz veins grade into lead-silver and barren veins away from the stock. Similar characteristics have also been reported in some of the Proterozoic-age veins in the Encampment district of southeastern Wyoming. For example, precious metal zonation in the Bridger vein was described by Spencer (1904) as exhibiting decreasing gold and increasing silver with depth. However, in the Archean craton, the association is often not clear, and many veins are undoubtedly related to metamorphic secretion during regional metamorphism and deformation, rather than to magmatic hydrothermal processes.

Metamorphogenic deposits

During regional metamorphism, fluids released at elevated temperatures and pressures may leach metals from the surrounding country rock and transport them to dilational zones, forming shear zone and vein deposits. Another type of metamorphogenic deposit is formed by contact metamorphism during the intrusion of an igneous magma into country rock, leading to the recrystallization and replacement of the country rock. Veins related to metamorphic processes are characteristically unzoned.

In addition to localized replacement lead-zinc-silver mineralization at Black Buttes in the Black Hills, a few skarns have been identified in metalimestone of Proterozoic age associated with gabbroic and basaltic intrusives in the Cooper Hill district of the Medicine Bow Mountains. These include (1) garnet (hydrogrossular)-epidote-actinolite-chlorite-idocrase(?)-calcite-limonite-(±)magnetite hornfels, (2) epidote-pyrite-calcite-quartz hornfels, (3) magnetite hornfels, (4) calcite-epidote-actinolite-pyrite-magnetite marble, (5) actinolite-calcite-quartz-chlorite-(±)chalcopyrite hornfels, (6) tremolite-calcite-quartz marble, and (7) uvarovite-magnetite-calcite hornfels.

Stratiform and stratabound deposits of sedimentary affiliation

Stratiform and stratabound base metal deposits of sedimentary affiliation have also been identified in the State. Typically, the stratiform deposits contain mineralization that is concordant to stratification; the stratabound deposits are confined stratigraphically with mineralization that is either concordant or disconcordant to stratification. In particular, two types of deposits have been recognized–cupriferous quartzites and copper-silver-zinc redbeds.

Cupriferous quartzites

Cupriferous quartzites are typified by those at the Ferris-Haggerty mine in the Encampment district of the Sierra Madre. The Ferris-Haggerty deposit is a stratabound massive sulfide hosted by a contact breccia in quartzite formed between a hanging-wall schist and the footwall quartzite of the Magnolia Formation (Proterozoic). The massive sulfide is as much as 20 feet thick and grades into laminated disseminated sulfides in the nonbrecciated quartzite. The source of the mineralization is unknown, but was possibly from a mafic igneous source at depth. In addition to the Ferris-Haggarty deposit, similar quartzite-hosted deposits are described at some other locations in the Sierra Madre.

Copper-silver-zinc redbeds

Another prominent type of stratabound deposit occurs as copper-silver-zinc redbed mineralization. The mineralizaton associated with this type of deposit is widespread in the Overthrust Belt of western Wyoming (Hausel and Harris, 1983). Several of these deposits occur along the contact of the Nugget Sandstone (Triassic-Jurassic) and the overlying Gypsum Spring Member (Jurassic) of the Twin Creek Limestone (Boberg, 1986). Some of the deposits show evidence of both structural and stratigraphic control, and the redbeds are bleached where mineralized, indicating that the mineralizing fluids were reducing.

The best example of this type of deposit occurs at the Griggs mine in the Lake Alice district of western Wyoming. Fluid inclusion studies at the Griggs deposit indicate that the mineralizing fluids were emplaced at less than 100°C (Loose and Boberg, 1987), suggesting that the fluids may have been derived from interformational fluids generated during deformation of the thrust belt (Boberg, 1986), or derived from metalliferous hydrocarbons (Love and Antweiler, 1973). From their points of origin, the ore fluids migrated into anticlinal traps along permeable fault and breccia zones (Loose and Boberg, 1987; Loose, 1988), producing mineralized zones up to 300 feet thick (Love and Antweiler, 1973).

Historical production

At the turn of the century, Wyoming was a relatively important producer of copper. Copper was mined from several regions in the State including the Copper Mountain district, Encampment district, Hartville uplift, Lake Alice district, Silver Crown district, and several other regions (**Figure 1**). Available production statistics indicate that Wyoming may have produced a maximum of 63.9 million pounds of copper from 1882 to 1946 (**Figure 2** and **Table 1**) (Hausel, 1989). The majority of the metal was recovered from the Ferris-Haggarty mine, which was the world's 27th largest copper producer (Short, 1958) by the first decade of the 1900s. Lead production in the State was minor and amounted to only about 30,000 pounds (**Figure 2** and **Table 1**).

No statistics are available for zinc or molybdenum; however, other metals produced in the State included 384,633 ounces (12 tons) of gold, 29,800 ounces of silver, 16,900 ounces of palladium, 910 ounces of platinum, and 135 million tons of iron

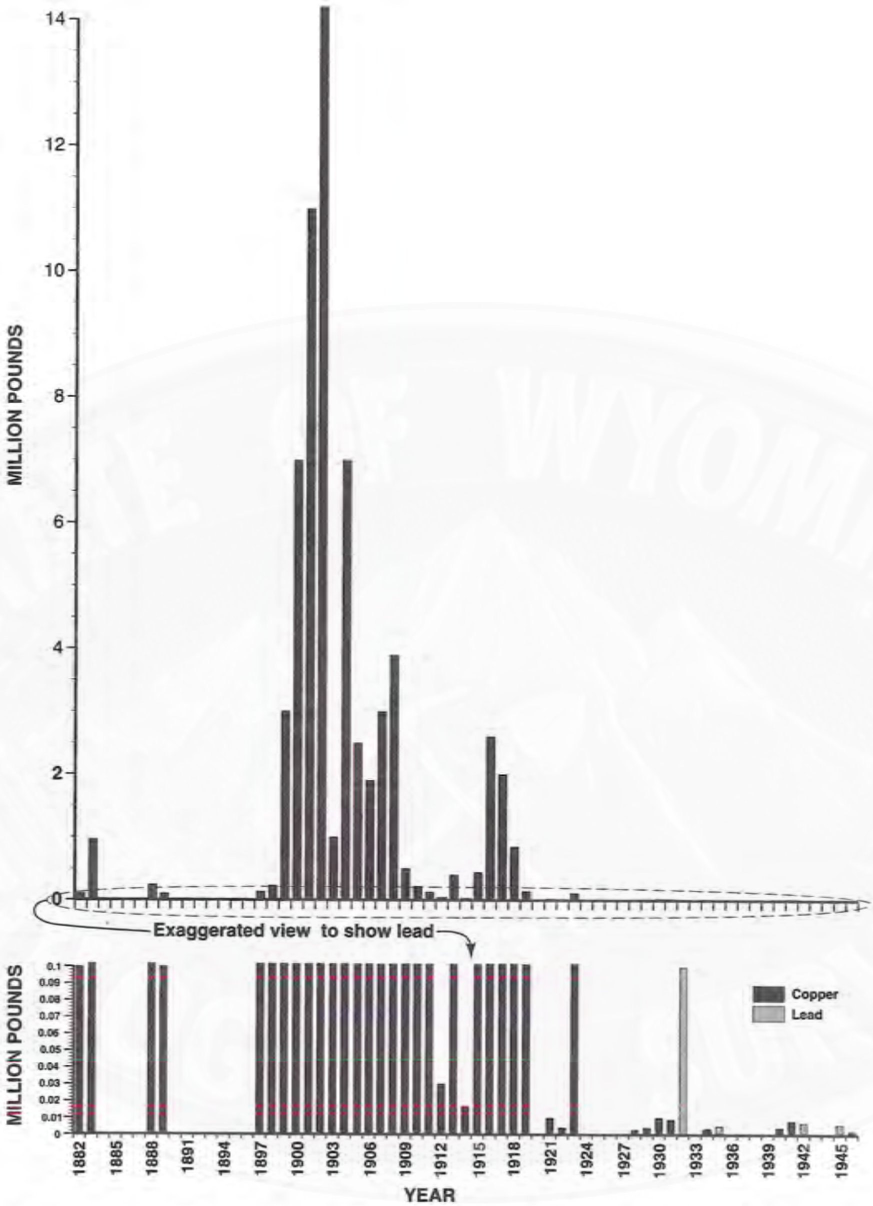


*Figure 2. Historical copper and lead production in million pounds per year for Wyoming. The production peak in 1902 corresponds to the Ferris-Haggarty mine operations (Boston-Wyoming mill and smelter) reaching maximum capacity. The drop in copper production after 1908 was due to the destruction of the mill and smelter by fire. See **Table 1** for the data used to plot this graph.*

Table 1. Wyoming copper and lead production, in pounds. Compiled from U.S. Bureau of Mines Mineral Yearbooks, the Wyoming Industrial Journal, Hausel (1989), and various reports by H.C. Beeler.

Year	Copper	Lead	Year	Copper	Lead	Year	Copper	Lead
1882	104,206	0	1904	7,000,000	0	1926	0	0
1883	962,468	0	1905	2,530,531	0	1927	0	0
1884	0	0	1906	1,905,260	0	1928	2,604	0
1885	0	0	1907	3,026,004	0	1929	4,301	0
1886	0	0	1908	3,961,540	0	1930	11,600	0
1887	0	0	1909	492,539	0	1931	9,000	0
1888	240,113	0	1910	222,339	0	1932	397	9,800
1889	100,000	0	1911	130,499	0	1933	0	0
1890	0	0	1912	27,570	0	1934	3,500	2,000
1891	0	0	1913	385,239	0	1935	1,000	5,000
1892	0	0	1914	17,421	0	1936	0	0
1893	0	0	1915	447,246	0	1937	0	0
1894	0	0	1916	2,610,622	0	1938	0	0
1895	0	0	1917	2,027,857	0	1939	0	0
1896	0	0	1918	852,777	0	1940	4,000	0
1897	127,409	0	1919	139,900	0	1941	8,000	0
1898	233,204	0	1920	0	0	1942	0	6,977
1899	3,104,827	0	1921	10,000	0	1943	0	0
1900	6,904,540	0	1922	4,296	0	1944	0	0
1901	10,958,900	0	1923	111,280	0	1945	0	6,000
1902	14,166,700	0	1924	0	0	1946	2,000	0
1903	1,023,189	0	1925	0	0	TOTAL	63,878,878	29,777

ore, as well as significant titanium ore, some chromium, manganese, tungsten, and minor amounts of other metals.

Currently, copper resources are known in the Absaroka Mountains of northwestern Wyoming, the Laramie Mountains in southeastern Wyoming, at Copper Mountain in central Wyoming, in the Sierra Madre of southeastern Wyoming, and in the Overthrust Belt of western Wyoming. These deposits are polymetallic and host several other metals in addition to copper.

Absaroka Mountains

The Absaroka Mountains of Park County, northwestern Wyoming, are formed of several volcanic centers and associated flows and flow breccias. Several volcanic centers are mineralized (**Figure 3**). These deposits are recognized by their disseminated, stockwork, and vein mineralization and accompanying hydrothermal alteration halos. Most of the significant deposits in this region are classified as porphyry copper-silver deposits. In general, porphyry copper deposits form large-tonnage, low-grade, polymetallic mineral deposits that are measured in the millions to hundreds of millions of tons.

Each of the known mineralized centers in the Absaroka Mountains is characterized by a central intrusive complex surrounded by vent-facies autoclastic flow breccias, lava flows, mudflows, avalanche debris, and tuffs. Vent-facies rocks commonly are domed, altered, and radially fractured and grade laterally into volcaniclastics. The appearance of these volcanic complexes is that of a deeply dissected stratovolcano or shield volcano.

The principal districts and mineralized intrusives in the Absaroka Mountains lie along a prominent deep-seated north-northwest structural trend located several miles east of the Yellowstone National Park border. This trend extends north into the New World district of Montana.

Both the mineralized and the barren intrusive centers are the source of the great pile of volcanic rocks that forms the Absaroka Mountains. The Absaroka volcanics extend over a surface area of more than 8000 square miles and compositionally consist of calc-alkaline flows, flow breccias, breccias, and reworked sedimentary facies. A small volume of flows in the northern Absarokas is shoshonitic.

The Absaroka volcanic and volcaniclastic rocks are termed the Absaroka Supergroup, which averages more than 5000 feet thick (Smedes and Prostka, 1972) and is locally as thick as 6500 feet (Wilson, 1963). The Supergroup is divided into three groups (from oldest to youngest)–Washburn, Sunlight, and Thorofare Creek. The Washburn Group is restricted to the northern mountains and represents the oldest volcanic rocks of the Absaroka Mountains. Rocks of the Washburn Group are unconformably overlain in most places by the Sunlight and Thorofare Creek Groups. Rocks of the Thorofare Creek Group overlie rocks of the Sunlight Group.

William H. Wilson, formerly with the Wyoming State Geological Survey, recognized vent complexes in the Absaroka Mountains as potential hosts for large-tonnage porphyry copper deposits. These deposits contain (1) disseminated and stockwork mineralization in intensely altered stocks or composite stocks, and, at several localities, in country rock adjacent to mineralized stocks; (2) fracture-filled veins and vein–

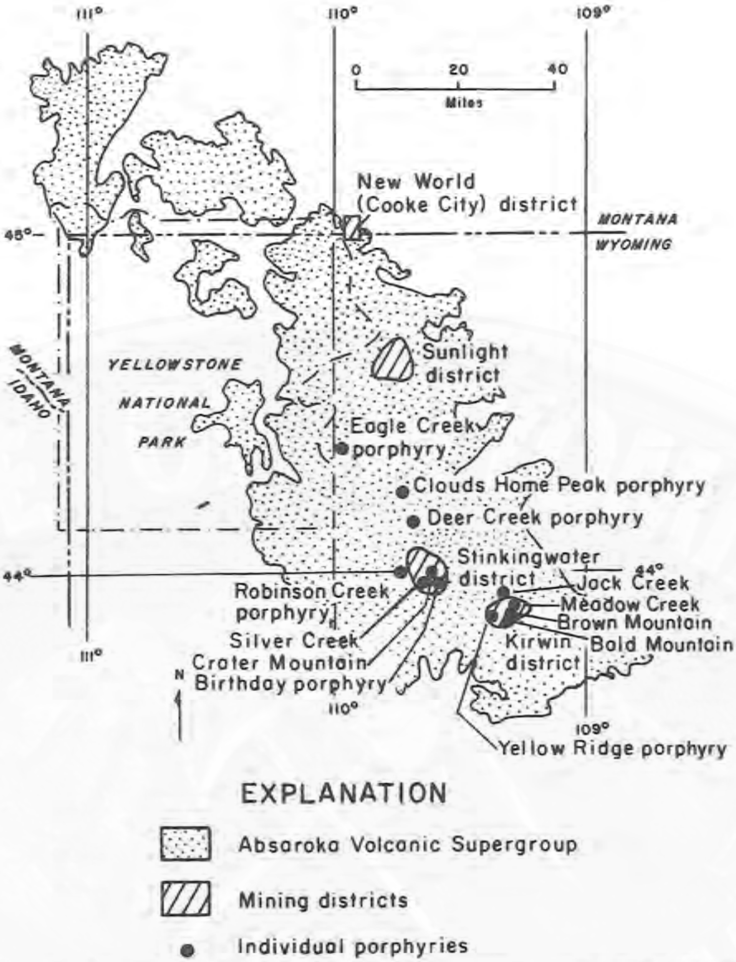


Figure 3. Principal mineralized porphyry copper deposits and mining districts in the Absaroka Mountains, Park County, Wyoming.

lets extending outward from the mineralized centers; (3) fracture- and fissure-filled veins and replacement deposits hosted by Paleozoic carbonates (recognized only in the New World district); (4) supergene enriched deposits; and (5) placer gold deposits below porphyry districts. Generally, copper, molybdenum, and trace gold occupy the central parts of the complexes and give way laterally to zinc, lead, and silver away from the center of the complex.

The mineralized stocks are surrounded by rocks hydrothermally altered at varying intensities (Wilson, 1971; Fisher, 1981). All the districts exhibit widespread deuteric propylitic altered rock; however, as the intrusive centers are approached, the deuterically altered volcanics take on the appearance of hydrothermal propylitic alteration, characterized by secondary chlorite, epidote, calcite, and sulfides.

Propylitic altered rock grades into phyllic altered (quartz-sericite-pyrite) rock toward the mineralized center. The phyllic zone lies adjacent to the disseminated copper deposits in all the known mineralized areas except Sunlight Basin, where it is absent. Argillic alteration, which produces secondary clays, has been identified at several intrusive centers. However, in many cases, the argillic alteration appears to be the result of supergene processes rather than hypogene alteration. Potassic alteration (secondary biotite or orthoclase) has been identified in some districts, although the potassic halo generally is poorly defined.

Kirwin district

The Kirwin mining district is located near the headwaters of the Wood River (T45-46N, R104W), 33 miles southwest of the town of Meeteetse, in the southern Absaroka Mountains (**Figure 4**). The district includes three mineralized porphyries, numerous veins, and potentially auriferous unexplored gravel downstream from the mineralized porphyries and veins. Early development of the district occurred near the turn of the century, and available records indicate that 12,000 to 15,000 feet of drifts, shafts (**Figure 5**), and adits were driven on veins in the district. Production was, however, limited to only one carload of ore with a net value of $65 per ton after smelter and transportation charges were deducted (Hewett, 1912).

Ore minerals identified in the district include pyrite, chalcopyrite, sphalerite, galena, tetrahedrite, molybdenite, stephanite, limonite, malachite, azurite, cuprite, and native gold. Gangue minerals include specular hematite, siderite, barite, calcite, quartz (amethystine), and dolomite (Hewett, 1912).

The three intrusive complexes in the district (Bald Mountain, Brown Mountain and Meadow Creek) penetrate volcanic rocks of the Wiggins Formation (Eocene). The Wiggins Formation is one of several formations belonging to the Thorofare Creek Group (Smedes and Prostka, 1972). In this area the Wiggins Formation forms a series of deuterically propylitized hornblende-biotite and pyroxene andesite porphyry flows, tuffs, breccias, and volcaniclastics. The vent facies layered volcanics have been domed, hydrothermally altered, and radially fractured. Andesite porphyry dikes occupy radial fractures and north-northwest-trending fractures. With few exceptions, the mineralized veins also occur in north-northwest-trending fractures. These veins are predominantly lead-silver-zinc veins. In the altered zone on the northern flank of Bald Mountain, the veins are copper-molybdenum dominant (**Plate 1A**).

Many veins in the district have been explored only for limited distances along strike, even though some veins appear to be as long as 2500 feet with zones of strong mineralization over mineable widths (**Table 2**). The Oregon vein, for example, yielded ore-grade values (17.8 opt Ag and 0.08 opt Au) across 3-foot widths. The Little Johnnie vein yielded 64.7 opt Ag and 0.12 opt Au across widths of 1.5 feet. According to Rostad (1982), the best values on these veins were obtained at or next to the mine face of the adits, where work had stopped. Vein specimens yielded as much as 156 opt Ag.

The Mendota vein also yielded ore grade values. A select sample across 0.5 foot of the Mendota vein in the Galena Ridge tunnel averaged 101.35 opt Ag and 0.283 opt Au. The Galena Ridge tunnel was a crosscut driven 2327 feet to the west from the Wood River valley to test several veins north of the Brown Mountain granodiorite. This high-grade zone of the Mendota vein is enclosed by an untested lower grade segment that brings the vein width to 4.3 feet. The average of 31 samples taken over

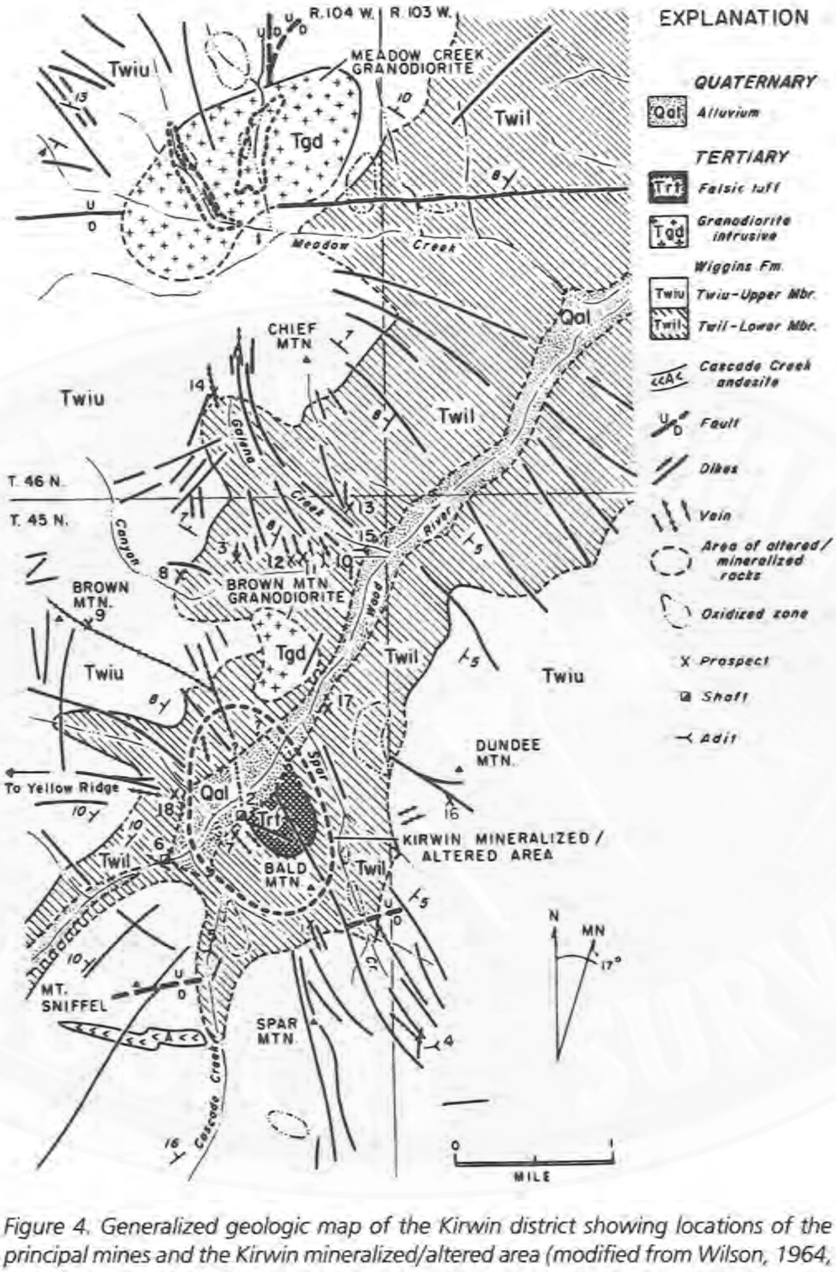


Figure 4. Generalized geologic map of the Kirwin district showing locations of the principal mines and the Kirwin mineralized/altered area (modified from Wilson, 1964, 1975; Nowell, 1971). Named and numbered prospects, shafts, or adits include: 1. Bryan, 2. Wolf shaft, 3. Oregon, 4. Smuggler, 5. Pickwick, 6. Tumlum, 7. Illonies, 8. Anaconda, 9. Black Prince, 10. Little Johnnie, 11. Mendota, 12. Manilla, 13. Iowa, 14. Krachy, 15. Galena Ridge tunnel, 16. Elkton, 17. Long Horn, and 18. Molly Logan.

a strike length of 98 feet on the Bryan vein on Spar Mountain averaged 0.13 opt Au, 29.6 opt Ag, and 0.73% Cu (Rostad, 1982). Based on these samples, significant vein

Figure 5. The Wolf headframe near the Kirwin ghost town as it appeared in 1982. The Wolf mine was one of several historical mines in the district.

deposits of possible economic interest for a small mining operation exist in the district.

The mineralized area continues southeast of Kirwin into the Stratified Primitive Area, samples from which yielded anomalous copper, molybdenum, zinc, lead, and silver (Ketner and others, 1966).

Alluvial gravel is also abundant in the Wood River downstream from the ghost town of Kirwin. The gravels reportedly range from 60 to 150 feet in depth. Little evidence exists that the gravel has ever been explored, even though geologic evidence suggests some of it should be mineralized (Rostad, 1982). It is estimated that the Wood River has a potential for gold in more than 100 million cubic yards of unexplored gravel.

Table 2. Assays of samples collected from mines in the Kirwin district (from Rostad, 1983; Wilson, 1964). Analyses in weight percent (%) or ounces per ton (opt); dashes indicate not analyzed; tr= trace; nd= not detected.

Claim	Au (opt)	Ag (opt)	Cu (%)	Pb (%)	Zn (%)	Mo (%)	Sample type
Bryan	0.04	4.2	–	–	–	–	Dump-grab
Bryan	0.25	30.5	2.33	tr	–	tr	Dump-grab
Bryan #2	0.13	29.6	0.73	–	–	–	Average 98 feet of vein in portal
Wolf shaft	tr	tr	–	tr	–	0.55	Dump-grab
Oregon	0.03	10.8	–	0.1	–	–	Vein-channel
Oregon	0.11	28.9	0.2	2.5	–	–	Dump-grab
Oregon	0.05	9.32	–	–	–	–	Average 120 feet of vein
Oregon	0.07	15.85	–	–	–	–	Dump-ore
Oregon	0.08	17.8	–	–	–	–	3 feet of vein
Smuggler	0.06	8.1	0.8	–	–	–	Open cut-grab
Smuggler	0.07	4.8	0.2	–	–	–	Dump-grab
Pickwick	0.09	1.5	–	–	–	–	Dump-grab
Pickwick	0.04	4.3	–	–	–	–	Vein-channel
Pickwick	0.03	2.2	–	–	–	–	Vein-channel
Pickwick	0.15	28.0	tr	tr	–	–	Large general sample
Tumlum	0.02	17.6	–	3.2	–	–	Dump-grab
Tumlum	0.07	41.1	–	31.9	–	–	Dump-grab
Illonies	0.02	0.2	–	–	–	0.51	Dump-grab
Illonies	tr	tr	0.5	tr	–	0.14	Dump-grab
Anaconda shaft	0.03	1.4	–	20.6	–	–	Dump-grab
Anaconda shaft	0.04	11.9	–	61.8	–	–	Shaft-grab
Anaconda shaft	0.02	7.3	tr	39.9	–	–	Dump-grab
Anaconda shaft	0.03	6.71	–	23.4	–	–	1 foot down
Anaconda shaft	0.03	3.87	–	9.7	–	–	9 feet down
Anaconda shaft	0.01	1.37	–	-	–	–	19 feet down

Table 2 continued.

Claim	Au (opt)	Ag (opt)	Cu (%)	Pb (%)	Zn (%)	Mo (%)	Sample type
Black Prince	0.06	6.0	0.2	3.1	–	–	Outcrop
Black Prince	0.10	1.22	–	–	–	–	Average 44 feet of vein
Little Johnnie	0.01	1.5	–	1.1	–	–	Vein-grab
Little Johnnie	0.19	111.8	0.03	–	1.2	–	Dump-bulk
Little Johnnie	0.07	29.5	–	–	–	–	Average 82 feet of vein in portal
Little Johnnie	0.12	64.7	–	–	–	–	Mine face
Little Johnnie	nd	156.0	–	–	–	–	Specimen from dump
Little Johnnie	0.09	43.1	–	–	–	–	Shipment-(small lot)
Mendota	0.04	14.7	–	0.55	–	–	Dump-grab
Mendota	0.08	21.2	–	–	–	–	Second cut
Mendota	0.04	2.38	–	–	–	–	Face-upper tunnel
Mendota	0.28	101.35	–	–	–	–	High grade
Manilla	0.06	5.86	–	–	–	–	Face-upper tunnel
Iowa	0.06	3.84	–	–	–	–	Lower cut
Iowa	0.02	2.66	–	–	–	–	Main adit at face
Iowa	0.12	8.76	–	–	–	–	Second cut
Krachy	0.10	7.10	–	–	–	–	Ore dump
Krachy	0.10	4.14	–	–	–	–	Cut
Krachy	0.10	0.64	–	–	–	–	Outcrop on summit north of shaft
Krachy	0.15	4.55	–	–	–	–	Outcrop on summit north of shaft
Krachy	0.15	17.68	–	–	–	–	Outcrop 100 feet north of shaft

Bald Mountain (Kirwin) porphyry

The Bald Mountain mineralized porphyry is located along the northwestern flank of Bald Mountain near the southern edge of the Kirwin district (**Figure 4**). The complex is expressed by an oval-shaped, intense zone of hydrothermal alteration. The mineralized area is associated with a volcanic vent complex containing intrusive felsic tuff breccia (Wilson, 1964; Nowell, 1971) that has been informally named the Kirwin formation by Nowell (1971). Brecciation appears to be more intense along the edge of the vent. According to Nowell (1971), this felsic tuff is rhyolitic. Mapping by Cooper (1974) indicates the felsite is a complex of quartz latite porphyry, vent facies conglomerate, and granodiorite (**Figure 6**).

Hydrothermal alteration increases in intensity toward the center of the Bald Mountain altered zone. Outside the altered zone, Wiggins Formation andesites are deuterically altered and exhibit characteristic propylitic alteration minerals, i.e. calcite, chlorite, and clays. Within 1500 feet of the mineralized center, these andesites are hydrothermally altered to quartz, calcite, epidote, and montmorillonite with disseminated chalcopyrite and chalcopyrite-bearing quartz-calcite veinlets. Closer to the volcanic center, the rocks take on the characteristics of argillic and phyllic alteration and contain secondary sericite, mixed-layer illite-montmorillonite, quartz, and biotite

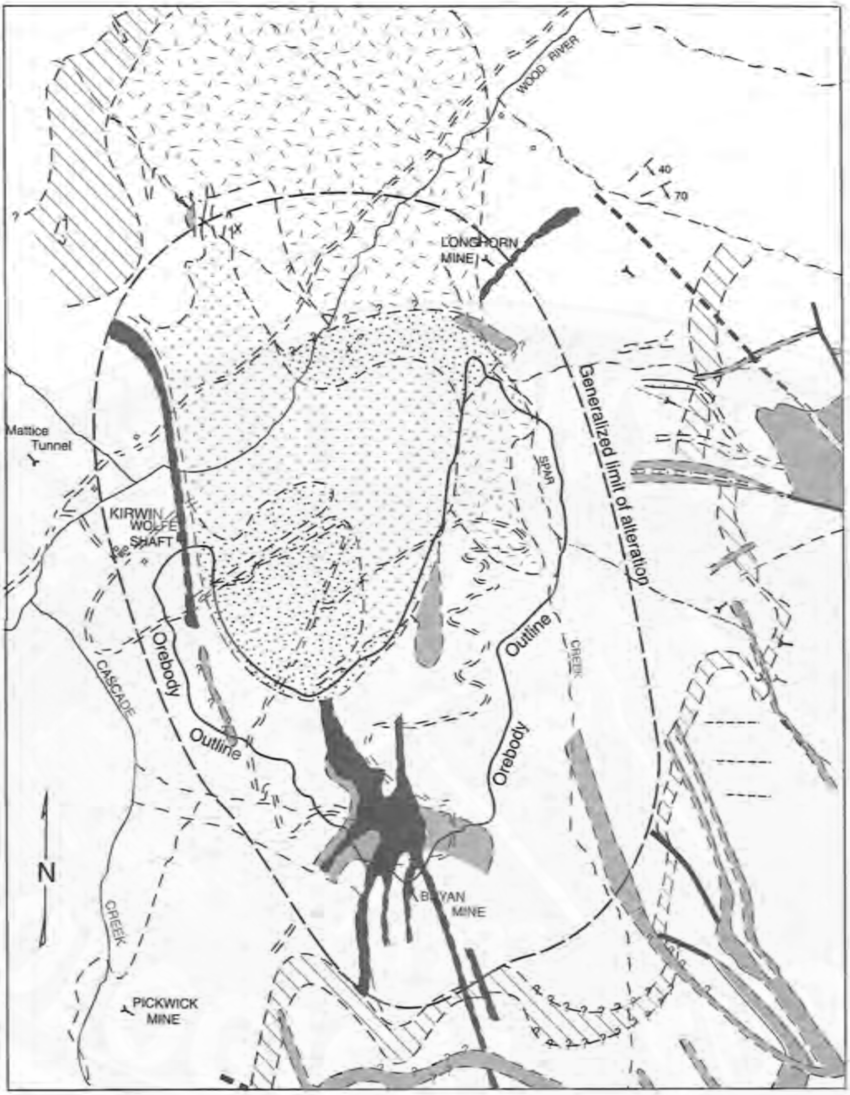


Figure 6. Geologic map of the Kirwin mineralized area showing extent of alteration (modified from AMAX Exploration, Inc. map by J.J. Cooper, 1974). Map explanation on page 17.

with lesser kaolinite and chlorite. Epidote and calcite are nonexistent in this zone. A central potassic altered zone is not well-defined but is suggested by the presence of secondary orthoclase with quartz and veinlet sulfides (Nowell, 1971).

Drill hole data for the Bald Mountain complex show stockwork mineralization with pyrite, chalcopyrite, and molybdenite. Weathering of the stockwork produced a leached cap over a blanket-like deposit of supergene copper. Chalcocite is the principal sulfide with some covellite and digenite. Veins in the altered area are pyrite-chalcopyrite-molybdenite-quartz veins (Wilson, 1960). The mineralized porphyry is about 3900 feet across (Rostad, 1983).

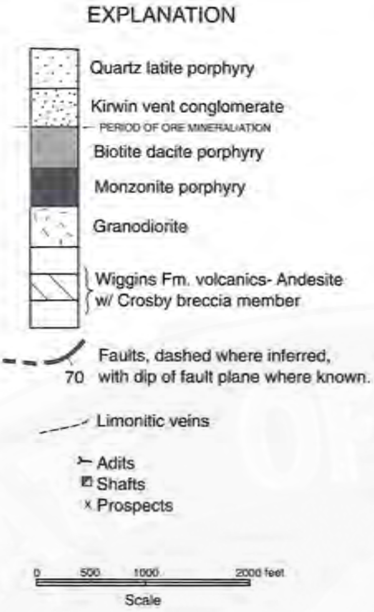


Figure 6. continued.

The Bald Mountain porphyry was explored by AMAX in the 1960s, 70s, and 80s. AMAX began drilling at Kirwin in 1963, and significant secondary-enriched porphyry-copper mineralization was intersected (Rostad, 1983). Drilling over the next several years included 150 holes totaling 86,861 feet. The project outlined in place (geologic) reserves totaling 196 million tons of ore averaging 0.505% Cu and 0.022% MoS_2 with by-product credits in silver and gold at a 0.3% Cu cutoff grade. In place reserves at a cutoff grade of 0.4% Cu were 125.3 million tons of ore averaging 0.56% Cu and in place reserves at a cutoff grade of 0.5% Cu were 64.2 million tons of ore averaging 0.70% Cu. Open pit mineable reserves at a cutoff grade of 0.3% Cu were calculated at 160.8 million short tons of ore with a favorable stripping ratio of 0.57:1 of waste to ore (Rostad, 1983). Feasibility studies indicated that the deposit was amenable to *in situ* leaching. A 1991 study indicated that copper could be recovered at a cost of only $0.309/pound by *in situ* leaching (Ora Rostad, personal communication, 1992).

Unexplored targets exist in the immediate area of Bald Mountain that could greatly expand the identified reserves. For example, the explosive volcanic conditions evidenced by the Kirwin formation are favorable for mineralized breccia pipes. AMAX's 300-foot drillhole spacings could easily have missed potential breccia pipes. Additionally, Spar Mountain, south of Bald Mountain, could represent a separate mineralized center with possible secondary-enriched copper. This is supported by widespread limonitic alteration on the pervasively talus-covered Spar Mountain and by samples of native copper that have been recovered downstream from the divide between Smuggler Basin and Spar Creek. Potential also exists for skarn and replacement deposits where the veins project down dip into the underlying sedimentary rocks. For example, an aeromagnetic high detected by AMAX north of Kirwin formation outcrops is interpreted to be a response to a high-grade skarn below the surface (**Figure 7**). These conditions are similar to the lead-copper-zinc-silver-gold replacement deposits at Camp Bird, Colorado, and the lead-silver-zinc ores of the Irma-Republic mine in the New World district, Montana-Wyoming. Such deposits could be mined relatively cheaply by room-and-pillar methods (Rostad, 1982).

Brown Mountain granodiorite

The Brown Mountain granodiorite appears to be the least mineralized of the three intrusive complexes in the Kirwin district (**Figure 4**). The intrusive consists of fine- to medium-grained equigranular granodiorite that grades into porphyritic granodiorite near its northern margin. Hydrothermal alteration is expressed as weak propylitization with disseminated pyrite. Although the strongest manifestations of

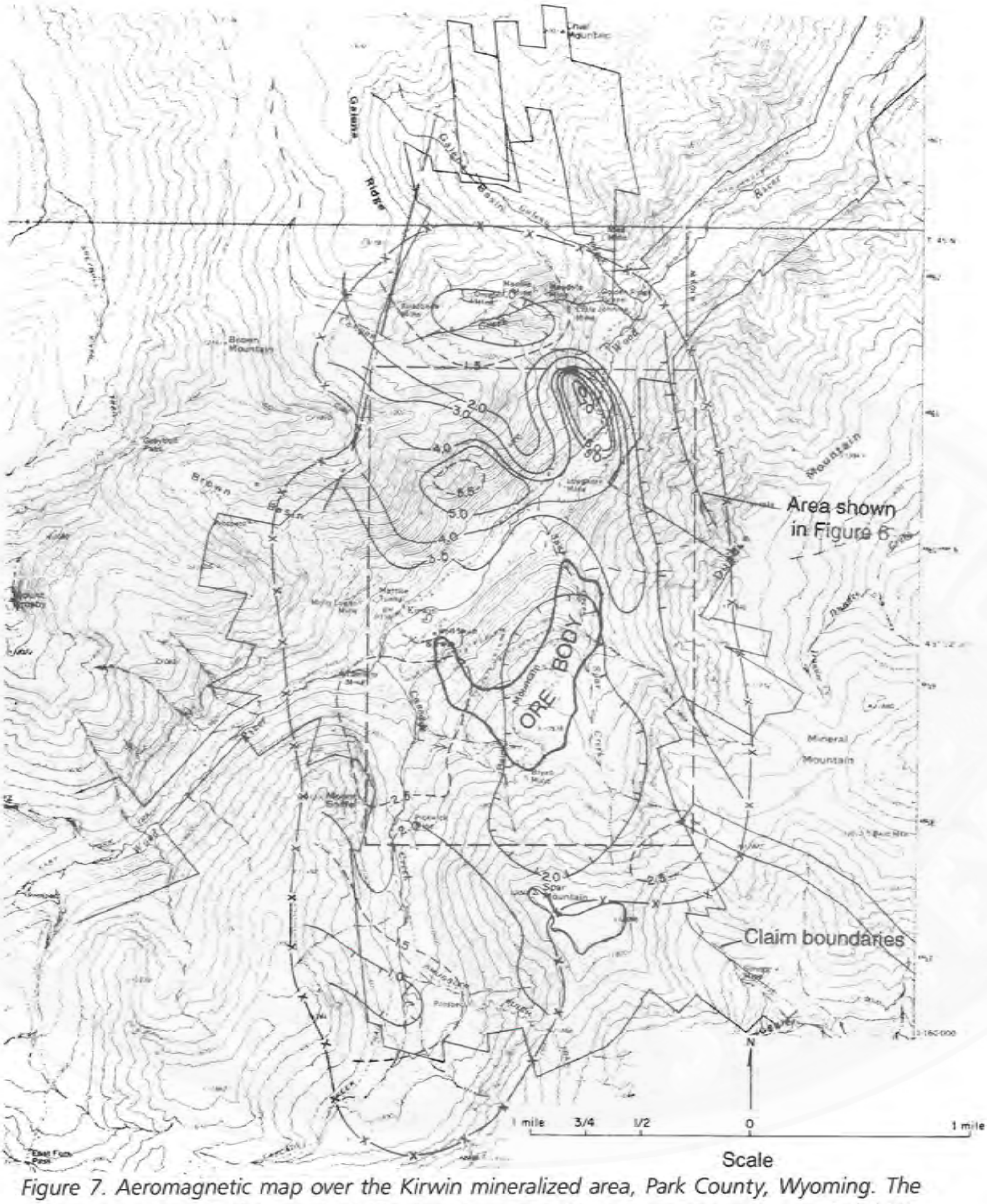


Figure 7. Aeromagnetic map over the Kirwin mineralized area, Park County, Wyoming. The prominent magnetic high north of Kirwin is interpreted to be a response to a buried, high-grade skarn (modified from AMAX Exploration Inc. map, Wyoming State Geological Survey files). Terrain clearance = 1000 feet approximate. Contours are x100 gammas; x'ed line indicates outline of area surveyed.

mineralization are associated with north-northwest-trending veins along Galena Ridge north of the intrusion (Wilson, 1960), it is not known if these veins are an expression of the Brown Mountain granodiorite or of the Bald Mountain mineralized porphyry (Nowell, 1971).

Meadow Creek granodiorite

The Meadow Creek granodiorite is a composite of at least two separate intrusives that average granodiorite in composition (**Figure 4**). The older granodiorite, which forms the western third of the intrusive mass, is propylitized, weakly pyritized, and relatively unmineralized. The younger granodiorite (on the east) is propylitized with more intense alteration along two elongated zones. The intensely altered zone in the eastern portion of the complex extends across the intrusive parallel to the projected trend of a north-south fault. This zone, delineated by phyllic alteration with disseminated copper mineralization, corresponds well with a copper geochemical anomaly that yielded values of 200 to 700 ppm Cu. A second intensely altered zone is localized along the contact between the two granodiorite intrusives. This zone is approximately 5000 feet long with an average width of 300 feet that is outlined by intense silicification, iron staining, and disseminated pyrite. The contact corresponds to induced polarization and resistivity anomalies but does not show a significant copper geochemical anomaly. Samples from the zone average only 50 to 60 ppm Cu (Wilson, 1975).

Spotty chalcopyrite and malachite occur as disseminations and fracture fillings in limited exposures in both the altered granodiorite and in adjacent Wiggins Formation rocks. Other expressions of mineralization include copper, lead, and molybdenum geochemical anomalies within the intrusive, and mineralized quartz veins both north and south of the intrusive. These veins contain galena (argentiferous), sphalerite, tetrahedrite, minor pyrite, and chalcopyrite mineralization in quartz-carbonate gangue (Wilson, 1975).

The Meadow Creek granodiorite is located at the intersection of two faults. Emplacement of the intrusive complex undoubtedly was controlled by this intersection. Dikes form rough radial patterns around the intrusive, and vein mineralization occurs in a north-northwest-trending zone between the Brown Mountain and Meadow Creek intrusives (Wilson, 1964, 1975).

Yellow Ridge porphyry

Located on the Francs Peak 7.5-minute Quadrangle approximately 22 miles from the end of the Greybull River road (**Figure 3**). A pack trail follows the Greybull River to the base of Yellow Ridge. The intrusive also is accessible from the Kirwin district. From Kirwin, the Greybull River trail crosses Greybull Pass and lies within 3 miles west-northwest of Kirwin. The porphyry lies within designated wilderness lands.

The porphyry consists of two stocks intruding Wiggins breccias and flows (W.H. Wilson, personal communication, 1982). The stocks include rhyolite and a composite stock of granodiorite, diorite, andesite porphyry, and hornblende andesite porphyry. Much of the mineralization is associated with the andesite porphyry, although the other intrusive masses are weakly mineralized.

A narrow, 200- to 300-foot-wide mineralized zone is exposed along a 2500-foot northeasterly trend in the southeastern portion of the stock. Malachite is abundant as fracture coatings and disseminated grains. Pyrite, with minor chalcopyrite, bornite(?), and molybdenite(?), also are found in the mineralized zone.

Hydrothermal alteration consists of an outer propylitic zone along the intrusive margin and in the adjacent extrusive rocks. Near the intrusive center, the propylitic-altered rock grades into phyllically altered rock. Near heavily mineralized zones, potassically altered rock predominates (Fisher and others, 1977).

New World (Cooke City) district

This district is located in T58N, R109W, along the Montana-Wyoming border adjacent to Cooke City, Montana (**Figure 1**), and extends to the Wyoming border (**Figure 8**).

Ore deposits in the New World district are related to a deeply dissected intrusive-volcanic complex. Due to uplift, this complex has been more deeply eroded than any other mineralized center in the Absaroka Mountains. Precambrian gneiss, Paleozoic sedimentary rocks, and Tertiary intrusives (diorite to syenite) are exposed throughout much of the district. On the western and southern edges of the district, andesitic flows are still preserved and rest unconformably on Paleozoic sedimentary rocks (Nelson and others, 1980).

Centers of mineralization

The Goose Lake and Henderson Mountain stocks, located north of Cooke City, are the principal centers of mineralization. With few exceptions, the major orebodies are localized adjacent to these stocks. For example, the Como, Fisher Mountain, McLaren, Miller Creek, and Homestake deposits are largely replacement deposits in Cambrian limestone adjacent to the Tertiary intrusive complexes. One breccia pipe also is reported in the district. The combined reserves of the replacement deposits total more than 12 million tons of ore with an average grade of 0.22 opt Au, 0.87 opt Ag, and 0.75% Cu (Kirk and others, 1993).

Mineralization from Henderson Mountain extends outward in irregular metallogenic zones. Contact metamorphic gold-copper deposits adjacent to the stock grade outward into copper-lead deposits. The copper-lead mineralization is further zoned to copper-lead-zinc. Farther from the stock, the mineralization takes on the characteristics of complex lead-silver-zinc deposits. These grade into an aureole of silver-bearing sideritic calcite veins and finally into barren carbonate veins still farther from the stock. The better deposits (replacements) are developed where the veins cut limestone beds in the Pilgrim Limestone (Gallatin Formation equivalent) of Late Cambrian age (Lovering, 1929a; Reed, 1950; Butler, 1965).

Reported production from the district totals 62,311 ounces of gold, 692,386 ounces of silver, 1,963,800 pounds of copper, 3,242,615 pounds of lead, and 920,200 pounds of zinc. Nearly all the copper and gold production came from the McLaren gold mine, and a large proportion of the lead and silver was produced from the Irma-Republic mines (Kirk and others, 1993).

Irma-Republic mines

The Irma-Republic deposits are part of a mesothermal vein system of the Henderson Mountain complex, adjacent to the Montana-Wyoming border. The vein is near vertical and strikes N30°W to N40°W. It was formed by fracture filling and replacement of host oolitic beds of the Pilgrim Limestone. The oolitic beds are overlain by a hanging

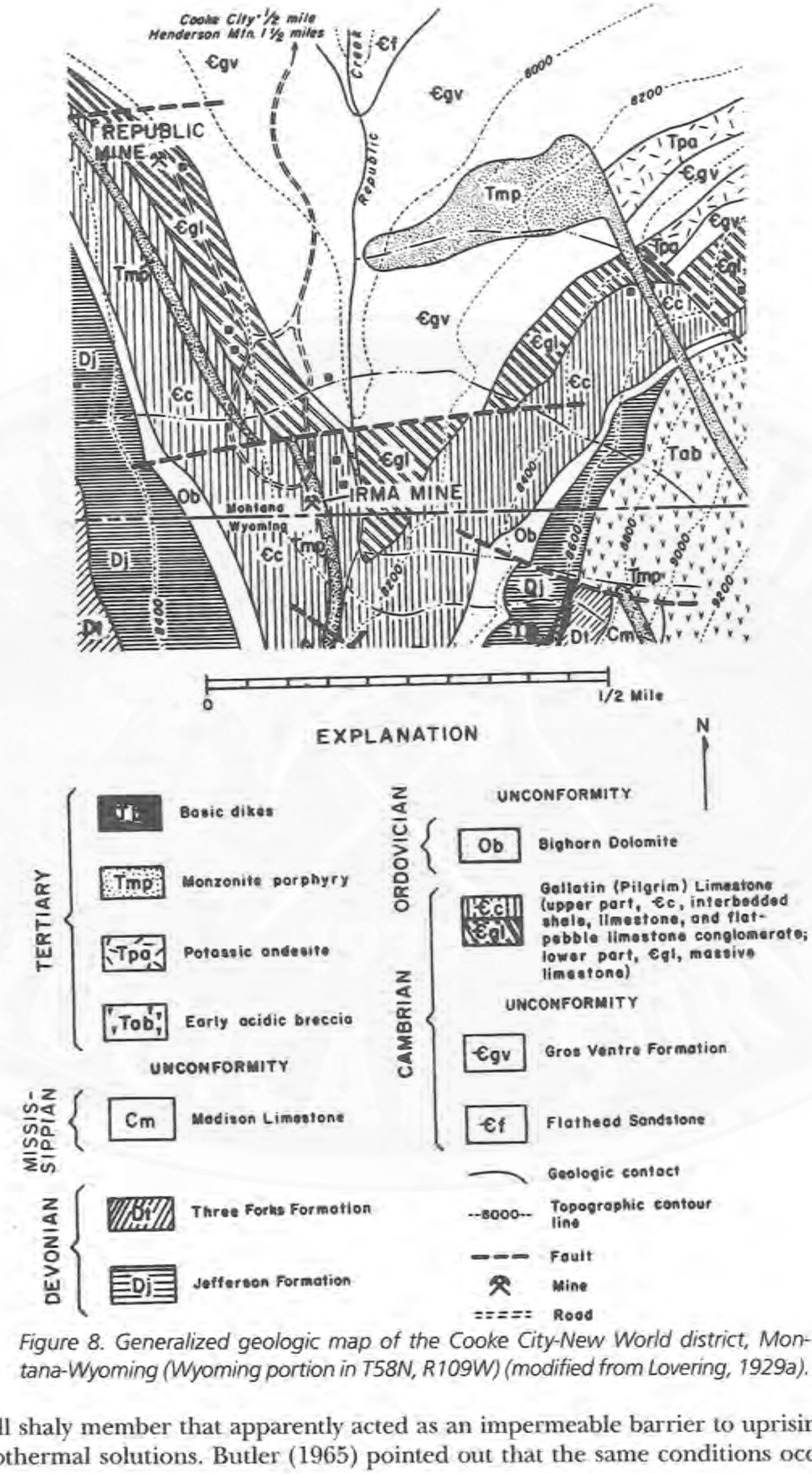


Figure 8. Generalized geologic map of the Cooke City-New World district, Montana-Wyoming (Wyoming portion in T58N, R109W) (modified from Lovering, 1929a).

wall shaly member that apparently acted as an impermeable barrier to uprising hydrothermal solutions. Butler (1965) pointed out that the same conditions occur in the underlying Gros Ventre Formation (Middle to Upper Cambrian) which should offer an attractive exploration target.

Ore mineralogy consists of galena, sphalerite, pyrargyrite, chalcopyrite, polybasite(?), anglesite, cerussite, proustite, native silver, freibergite, argentite, and rhodochrosite. Gangue minerals include quartz, jasperoid, calcite, dolomite, manganian ankerite, arsenopyrite, pyrite, marcasite, pyrolusite, psilomelane, and iron oxides. Wall rock alteration consists of dolomitization and silicification (Butler, 1965).

The Republic deposit, the northernmost of the two mines, was discovered in 1869 by a group of fur trappers. The mine consists of 3000 feet of open cuts and 1500 feet of tunnels with a 225-foot-deep shaft developed in fissures heavily stained by psilomelane (manganese oxide). Manganese staining is characteristic of the complex lead-silver-zinc ores of the district (**Figure 9**). Oxidized ore in some stopes assayed as high as 1000 opt Ag (Lovering, 1929a).

In 1920, exploration led to the discovery of a southern extension of the Republic vein, which became known as the Irma mine. The Irma shaft lies in Wyoming on the Snowslide claim, but most of the workings lie on the Blackrock claim in Montana. The shaft reached a depth of 250 feet with several hundred feet of workings, including a 740-foot-long drainage adit that emptied into Republic Creek. In total, the mine workings in the Irma-Republic lode amounted to more than 2700 feet (Nelson and others, 1980).

Figure 9. Strong manganese stains and replacement deposits in the Pilgrim (Gallatin) Limestone along the Irma-Republic vein. The limestone outcrop in the center of the photograph is barren of manganese stains, but the dark outcrop immediately to the left is strongly altered.

From 1922 to 1959, the Irma mine was a small but consistent producer of lead, zinc, and silver (Butler, 1965; Nelson and others, 1980). Several carloads, totaling more than 200 tons of ore averaging 12% Pb, 13% Zn, and 34.5 opt Ag, were shipped from the mine. The ore was mined from the lower Pilgrim beds in the same horizon as in the Republic mine. The ore consisted of coarse- to fine-grained argentiferous galena and sphalerite with small amounts of pyrite and native silver (Lovering, 1929a).

Recorded production from the Irma-Republic properties included 18,400 tons of concentrates that contained gold, silver, lead, copper, and zinc (Nelson and others, 1980). Direct shipping grade ore averaged about 40 opt Ag, 20% Pb, and 6% Zn. Mill-grade ore contained about 12 opt Ag, 4% Pb, and 5% Zn (Butler, 1965).

Stinkingwater district

Three separate mineralized porphyries in the Stinkingwater district are known as the Birthday, Silver Creek, and Crater Mountain porphyries (**Figure 3**). Crater Mountain porphyry is commonly referred to as the Stinkingwater mineralized area. According to Wells (1982), this deposit has a potential for a 300-million-ton orebody.

Birthday porphyry

The Birthday stock is located on the Needle Mountain and Emerald Lake 7.5-minute Quadrangles about 45 miles southwest of Cody, 12 miles south of Valley, and about 3 miles south-southeast of Crater Mountain. Access is from the South Fork Shoshone River pack trail to Saddle Creek. The intrusive lies at the headwaters of Saddle Creek within designated wilderness lands.

The stock sporadically crops out over an area of less than 0.5 square miles. The main intrusive has granodioritic to dacitic composition and intrudes Wiggins Formation andesites and breccias.

Pyrite and chalcopyrite are widespread. Pyrite is disseminated, coats fractures, and occurs in quartz-pyrite veinlets. In some areas, pyrite comprises as much as 10% of the mineralized rock. Chalcopyrite also is disseminated and occurs in veinlets that form the stockworks. These stockworks are northwest-trending zones from 10 to 14 feet wide developed in andesite dikes(?) and, to a lesser extent, in dacite. Quartz-pyrite-calcite veins and altered rock occur adjacent to many dikes in the Birthday region. Oxidation is prominent, and zones of limonite, malachite, and azurite replace hypogene minerals.

Samples collected in the mineralized area range from 0 to 15,000 ppm Cu, 0 to 500 ppm Pb, 0 to 200 ppm Zn, 0 to 200 ppm Mo, 0 to 10 ppm Ag, and no gold (Fisher and Antweiler, 1980). Propylitic, phyllic, and potassic hydrothermally altered zones are recognized. Propylitically altered rocks are characterized by development of chlorite, calcite, epidote, saussurite, and pyrite. Phyllic altered rocks are present in scattered patches and are found mainly in fractured zones adjacent to dikes and veins and along faults. Variable amounts of sericite, pyrite, and secondary quartz are present in the matrix, replace phenocrysts, and are found in veinlets in the phyllic altered rock. Potassic altered rock present in two localized areas is expressed by veinlet clusters containing actinolite/tremolite, potassium feldspar, magnetite, quartz, and chalcopyrite and is associated with high copper concentrations and mineralized stockworks (Fisher and Antweiler, 1980).

Silver Creek porphyry

The Silver Creek area (secs. 14, 15, 22, and 23, T47N, R107W) lies within the Washakie Wilderness on the Fall Creek 7.5-minute Quadrangle and is accessible from the end of the road at Valley along 11 miles of the South Fork pack trail to the mouth of Silver Creek. The intrusive is within 0.25 mile of the mouth of Silver Creek within the Silver Creek stream valley (approximately 1.5 miles southwest of Crater Mountain).

Copper and molybdenum occur in altered rocks of the intrusive complex. The complex is formed by dacites and rhyodacites that intrude volcanics of the Wapiti Formation, Trout Peak Trachyandesite, and Wiggins Formation. The intrusive and the adjacent volcanic rocks are hydrothermally altered (Fisher and others, 1977).

Two intrusive phases are present. One has a fine-grained quartz-feldspar matrix with feldspar phenocrysts and distinctive bipyramidal quartz phenocrysts. Copper and molybdenum mineralization is restricted to this phase. This rock also has high amounts of magnetite. The other intrusive phase is compositionally similar, but lacks the distinctive quartz phenocrysts and contains common mafic minerals. Structural relationships indicate the latter intrusive phase predates the mineralized rock (Cox, 1979).

Hydrothermal alteration has affected the stock and adjacent host volcanics and generally preceded mineralization. Widespread propylitic alteration gives way laterally to localized phyllic and potassic altered rock near the intrusive center. The phyllic altered rock is expressed by sericite, quartz, and pyrite, which grades inward into quartz-potassium feldspar veinlets with secondary biotite and magnetite. Alteration boundaries are indistinct and overlap. The major sulfides are localized within the phyllic and potassic altered zones.

A well-developed pyrite halo is localized in the phyllic zone and encloses a highly mineralized 2000-by-1000-foot stockwork complex near the center of the intrusive. This mineralized zone contains disseminated malachite, chalcopyrite, bornite, and minor molybdenite, along with chalcopyrite-pyrite-magnetite-quartz veinlets. Fractures in the stockwork trend N35°W to N80°W and dip steeply. These are commonly stained by malachite (Fisher and others, 1977). The total sulfide content is as high as 2% in the phyllic zone and as much as 0.5% in the potassium-silicate zone. The highest copper grades (>0.1%) occur in the potassium-silicate zone.

Surface values of molybdenum do not exceed 0.01% (Hanbury, 1982). The molybdenum is poorly expressed in outcrops; however, core recovered from a 280-foot-deep hole showed molybdenite and chalcopyrite throughout the rock (Cox, 1979). Estimates of resources in the Silver Creek porphyry, based on sparse drilling, suggest that an orebody of at least 27 million tons of 0.5% Cu is enclosed by the complex (John Wells, personal communication, 1982).

Crater Mountain (Needle Creek) porphyry

Located on the confluence of Needle Creek and the South Fork of the Shoshone River (sec. 18, T47N, R106W) near the center of the southern Absaroka volcanic field (**Figure 10**). Layered, premineral volcanic rocks in the district include (from oldest to youngest) Wapiti Formation, Trout Peak Trachyandesite, and Wiggins Formation (**Figure 11**). These consist of basalt flows, andesite flows, volcanic breccias, and flow breccias intruded locally by Needle Mountain granodiorite, Crater Mountain dacite, and numerous dikes that radiate from the intrusive complex. Crater Mountain dacite intrudes the Needle Mountain granodiorite.

The layered volcanic rocks adjacent to the intrusive complex are slightly domed and dip gently (maximum to 10°) away from the intrusive center (Fisher, 1972; Osterwald and others, 1966). Two major lineaments are recognized in the district; these trend northwesterly and east to northeasterly, intersecting at the intrusive complex. The fracture sets probably controlled the emplacement of the intrusive and the migration of hydrothermal solutions.

Propylitization of both the intrusive and layered rocks is common throughout the district. The intensity of propylitic alteration increases around the fringe area of dis-

Figure 10. View looking south along the South Fork of the Shoshone River which leads to Crater Mountain in the background.

seminated sulfide minerals. Propylitic alteration gives way to phyllic alteration toward the center of the complex, and the phyllic zone produces highly altered, bleached, and silicified rock. In places, the original porphyritic texture of the stock is preserved by sericitic pseudomorphs; however, the texture is completely destroyed where pervasive phyllic alteration dominates. Within areas of supergene enrichment is evidence of argillic alteration of probable supergene origin. Potassic alteration (characterized by development of secondary biotite) is expressed in irregular ill-defined zones in the disseminated mineralized area.

Mineralization in the district includes an altered area (approximately 0.75 square mile) of disseminated copper-molybdenum near the southwestern edge of the intrusive complex (**Figure 12**; **Plate 1B** and **1C**). The greater mineralization is associated with a zone of intense hydrothermal alteration centered in the Crater Mountain dacite. The Needle Mountain granodiorite is poorly mineralized except along the northern edge of Needle Creek. All of the outcrops in the mineralized area are highly fractured, bleached, and altered to varying degrees. Narrow, steeply dipping veins occur near, and as far as a mile from, the intrusive complex. Chalcopyrite is the major disseminated ore mineral in the intensely altered zone, followed in abundance by molybdenite and minor bornite. Beyond the central chalcopyrite-molybdenite zone, pyrite is dominant and associated with low copper-molybdenum values. Chalcopyrite and molybdenite also occur in narrow quartz veinlets and coat fractures in the area of disseminated sulfide minerals.

Vein mineralization extends outward from the altered zone. The veins are commonly 1 to 2 inches wide and reach a maximum of 1 foot locally. They contain galena, chalcopyrite, sphalerite, pyrite, and minor arsenopyrite and tetrahedrite in quartz, calcite, dolomite, and minor siderite gangue. The veins are commonly crustiform and banded and considered simple fracture fillings (Fisher, 1972). High gold and

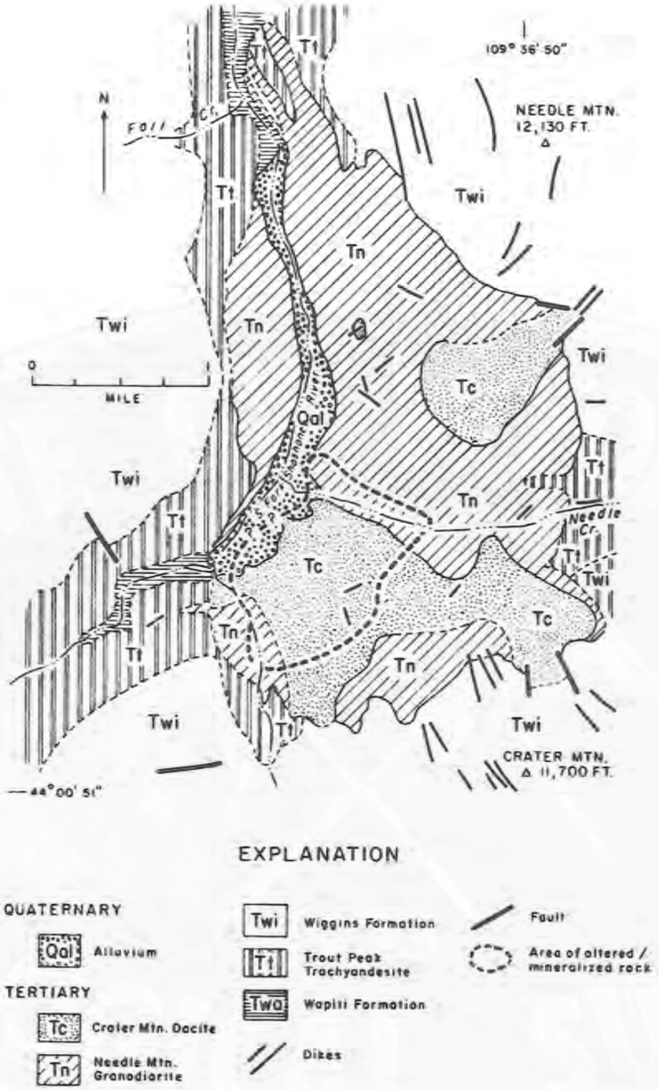


Figure 11. Generalized geologic map of the Stinkingwater mineralized area (after Fisher, 1972).

silver values have been reported from the peripheral zone (Lukanuski, 1969). Streams in the vicinity of the Crater-Needle Mountain mineralized area carry traces of gold (0.5 to 1 ppm in pan concentrates) and mercury (Fisher, 1972).

A supergene-enriched chalcocite blanket as thick as 200 feet was intersected by drilling near the center of the alteration zone at Crater Mountain. The extent of the supergene zone is not known. This zone is overlain by a leached and oxidized cap (Fisher, 1972).

The size of the deposit is not accurately known because the porphyry has only been partially explored. However, drilling results from several companies indicate that the porphyry hosts a sizable copper reserve. For instance, Timberline Minerals, Inc. (1982), identified a reserve of at least 65 million tons of 0.35% Cu. Based on drilling results from Bear Creek Mining Company, Newkirk (1980) reported that the deposit hosted 61 million tons of ore at an average grade of 0.31% Cu. Identified reserves, as determined by Phelps Dodge Corporation, totaled 96,378,267 tons of ore at an average grade of 0.35% Cu + MoS_2 (**Table 3**). Phelps Dodge estimated that the deposit has a potential for 131,657,200 tons of ore at 0.35% Cu + MoS_2 (Lukanuski, 1969).

Figure 12. Crater Mountain oxidized zone is seen near the center of photograph.

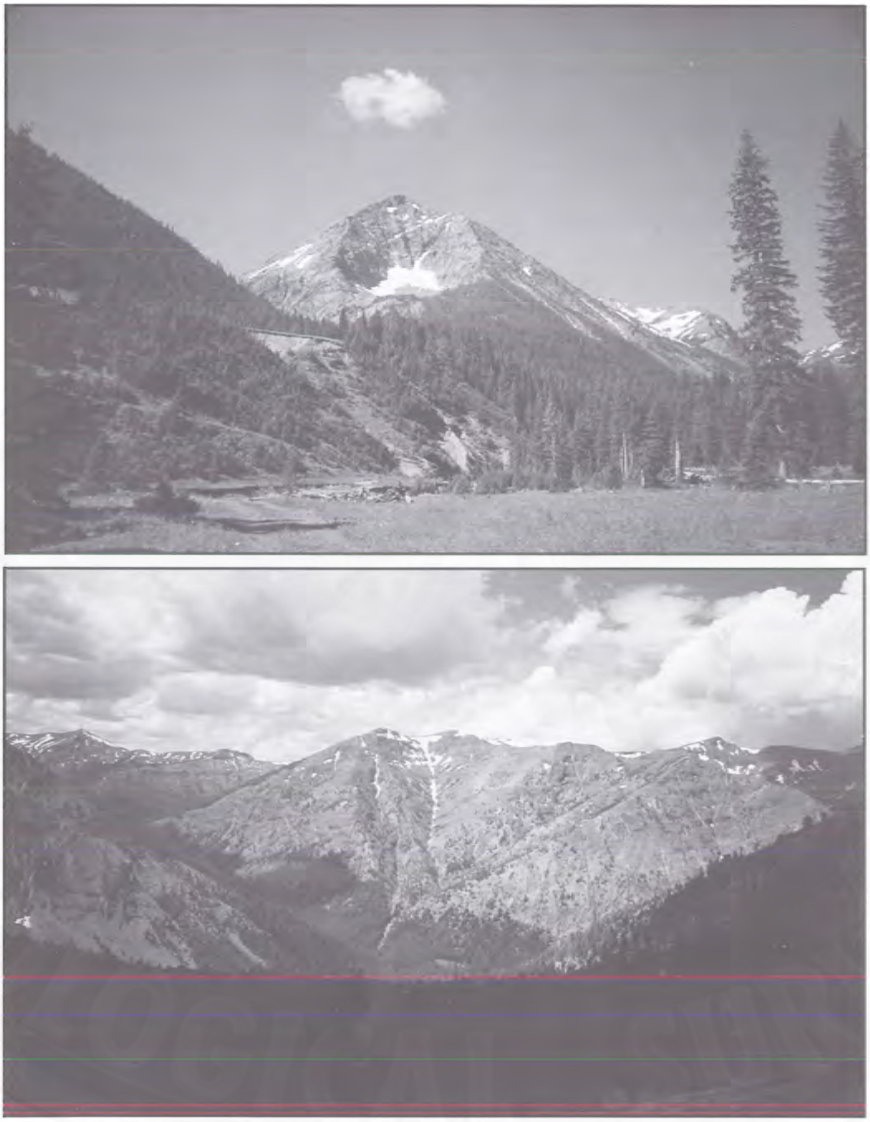
Table 3. Identified copper and molybdenite reserves for the Needle Creek porphyry (from Lukanuski, 1969).

Cutoff grade Cu + MoS_2 (%)	Short tons	Average grade Cu + MoS_2 (%)
0.20	96,378,267	0.35
0.30	50,205,867	0.44
0.35	30,043,467	0.51
0.40	19,376,800	0.58
0.50	14,596,800	0.62
0.60	4,720,000	0.76

Sunlight district

The Sunlight district is located on the Dead Indian Peak (1956) and Sunlight Peak (1956) 15-minute topographic maps. The nearest population center is Cody, Wyoming, 40 miles east of the mineralized area, although the Sunlight Basin area houses numerous private cabins and summer homes (**Figure 1**). This region is typical of much of the Absaroka Mountains with rugged mountains and spectacular volcanic features (**Figure 13**).

The first reported prospecting in the district occurred in 1890. The only report of production was 100 tons of gold, silver, and copper ore mined in 1903 (Nelson and others, 1980). However, Parsons (1937) reported that ore was discovered in 1893, and 25 tons of high-grade ore was extracted over the next few years. Several hundred feet of exploratory workings were developed at several mine sites in the district.



a

b

Figure 13. The rugged topography of the Sunlight district includes spectacular geology such as (a) this peak on the west side of Galena Creek which contains a prominent snow-filled cirque, and (b) Dike Mountain which is intruded by pyroxene andesite dike swarms emplaced in rocks of the Wapiti Formation.

Mineralization

Two types of mineralization are recognized in the district–disseminated and vein mineralization. The disseminated porphyry copper deposits consist of (1) pyrite in altered zones in all rock types, (2) chalcopyrite in intrusive rocks, and (3) copper-bearing stockworks (Nelson and others, 1980). Well-developed stockworks occur in a syenite stock at the headwaters of Sulfur Creek (Drier, 1967; Rich, 1974) and in andesites in contact with the syenite (W.H. Wilson, personal communication, 1982) (**Figure 14**). The stockworks consists of less than 1-inch-wide veins and veinlets containing chalcopyrite, bornite, covellite, and chalcocite in quartz and calcite gangue. Disseminated copper also is reported in the northeastern plug of the East Galena Creek syenite intrusive (Rich, 1974). The veins are zoned, forming copper-rich deposits near the mineralized centers and lead-silver or barren deposits away from the stocks (Parsons, 1937; Nelson and others, 1980). Disseminated mineralization is localized in and around intrusives, and veins are controlled by joint sets and shear zones (Nelson and others, 1980).

Ore minerals reported by Parsons (1937) include chalcopyrite ($CuFeS_2$), pyrite (FeS_2), galena (PbS), tetrahedrite ($Cu_{12}Sb_4S_{13}$), sphalerite (ZnS), gold (Au), sylvanite ($AgAuTe_4$), bornite (Cu_5FeS_4), famatinite (Cu_3SbS_4), enargite (Cu_3AsS_4), wolframite [$(Fe,Mn)WO_4$], proustite (Ag_3AsS_3), stromeyerite (AgCuS), bournonite ($CuPbSbS_3$), magnetite (Fe_3O_4), limonite ($FeO \cdot OH$), malachite [$Cu_2CO_3(OH)_2$], azurite [$Cu_3(CO_3)_2(OH)_2$], covellite (CuS), anglesite ($PbSO_4$), cerussite ($PbCO_3$), cerargyrite (AgCl), and chalcocite (Cu_2S). Common gangue minerals in the veins include quartz, siderite ($FeCO_3$), ankerite [$Ca(Fe,Mg)(CO_3)_2$], calcite ($CaCO_3$), adularia, and barite ($BaSO_4$).

Three alteration types are recognized in the district–propylitic, argillic, and potassic. Propylitic alteration is widespread and increases in intensity near the intrusive stocks and veins, while potassic alteration is localized and restricted in the stocks. Argillic alteration appears to be supergene in origin and overprints the other two alteration phases.

Individual mines and prospects

Big Goose claim. A sample of vein material collected from this claim assayed 0.82 opt Au and trace silver (Parsons, 1937).

Copper Creek adit. Located about 44°40'N, 109°50'W, 1.5 miles due north of Stinkingwater Peak (**Figure 14**). The adit was driven into a cliff in Copper Creek basin. The workings are 200 feet in length and were driven in andesite to intersect a sheared syenite dike. Three samples collected from the sheared syenite assayed trace to 0.02% Cu, 0.02 to 0.04% Pb, 0.04 to 0.05% Zn, trace to 0.10 opt Ag, and trace to 0.02 opt Au (Nelson and others, 1980).

Copper Lake prospects. This group of prospects (including the Kodiac claim) is situated in the vicinity of the three Copper Lakes 1 mile east of Stinkingwater Peak (**Figure 14**). Samples from the prospects yielded trace to 0.08% Cu, 0.035 to 0.76% Pb, 0.02 to 0.30% Zn, 0.17 to 2.06 ppm Au, and trace to 834.18 ppm (24.32 opt) Ag (Nelson and others, 1980). The better mineralized sample was selected high-grade material from a small stockpile located about 80 feet north of the northwestern end of Upper Copper Lake. Parsons (1937) reported a sample from an Au-Ag-W vein near Lower Copper Lake that assayed 0.54 opt Au and 13.46 opt Ag.

Within this same area, a 5000-foot-long metasomatically mineralized contact zone was identified in the Wapiti Formation. The zone is enriched in gold and silver and is well developed at the southeast end of Lower Copper Lake (R. Carrington, personal communication, 1991).

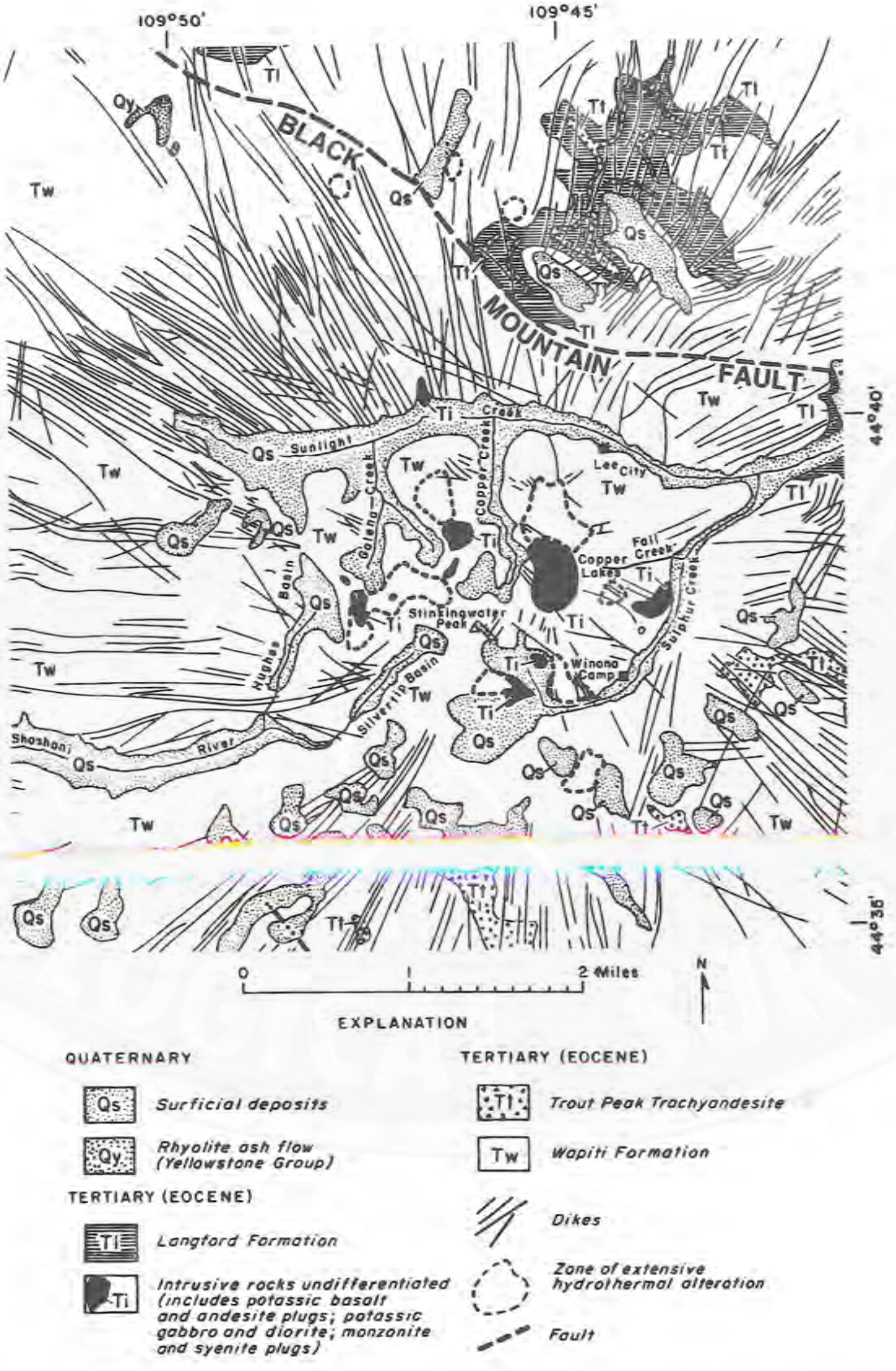


Figure 14. Geologic map of the Sunlight intrusive center (modified from Nelson and others, 1980).

Evening Star claims. The Evening Star claims are a group of patented claims located along the southern ridge of the 11,040-foot peak between Hughes and Silvertip basins. The property was developed by a shallow shaft and two tunnels. A select sample of vein material collected by Parsons (1937) assayed 1.4% Cu, 1.3% Pb, 91.44 opt Ag, and 0.02 opt Au. Two grab samples from the mine dump assayed 0.02% and 0.025% Cu, 0.04% and 0.06% Pb, 0.03% and 0.05% Zn, 3.19 opt and 4.2 opt Ag, with trace and 0.01 opt Au (Nelson and others, 1980).

Galena Creek Basin prospects. Several prospects in the Galena Creek Basin were developed in contact zones of syenite dikes in andesite country rock. Samples collected by the U.S. Bureau of Mines from various prospects ranged from trace to 0.01% Cu, 0.02 to 0.26% Pb, 0.05 to 0.12% Zn, trace to 0.01 opt Au, and 0.29 to 0.80 opt Ag (Nelson and others, 1980). Pedersen (1967) collected a sample of mineralized talus on the Galena Creek rock glacier (sec. 19, T54N, R107W) that assayed 5% Cu, 5% As, 0.15% Pb, 1500 ppm (43.7 opt) Ag, 0.10 ppm Au, 0.1% Bi, 30 ppm Hg, 30 ppm Mo, 1.0% Sb, and 0.7% Zn. The source of the talus was not determined.

Hardees claim. Location unknown. A vein sample collected by Parsons (1937) assayed 62.23% Pb, trace copper, 20.24 opt Ag, and 0.04 opt Au.

Hargrave-Newton-Lafond mine. Located on Sunlight Creek. A fissure cuts porphyritic rock that contains some malachite, chalcocite, and chalcopyrite (Osterwald and others, 1966, p. 59).

Hoodoo claim. Location unknown. Calcite and pyrite occur as secondary wall rock minerals with coarse argentiferous galena in iron carbonate gangue. One sample of ore from the mine dump yielded trace copper, 9.4% Pb, 0.02 opt Au, and 1.98 opt Ag (Parsons, 1937).

Horseshoe Hill. Located between Sunlight and Stinkingwater Peaks. A mineralized intrusive was explored by Skyline Corporation in the 1960s. Skyline drove a 316-foot tunnel in ore that averaged 1.62% Cu with gold and silver credits. The estimated tonnage for the deposit was 23 million tons of low-grade copper ore. In addition, a 7.5-foot-wide, 213-foot-long, high-grade chalcopyrite vein was discovered during exploration (Thomas, 1960).

Joe vein. Located on the divide between Fall Creek and Sulphur Creek. The vein crops out for 900 feet and contains copper, lead, and silver sulfides (Osterwald and others, 1966).

Lee City adit. Located at the former site of Lee City (**Figure 14**). This adit was driven into the hillside along a N20°E trend. Material from the dump assayed 0.01% Cu, 0.02% Pb, 0.02% Zn, 0.20 opt Ag, and trace gold (Nelson and others, 1980).

Malachite vein. Located 1500 feet southwest of the Joe vein on the divide between Fall and Sulphur Creeks. The vein is 6 to 12 feet wide and contains an 18-inch-wide streak of high-grade chalcocite. The vein was traced 2100 feet on the surface (Osterwald and others, 1966).

Marvin prospect. Location unknown. A 250-by-2200-by-1000-foot area exhibits east-west- and north-south-trending, low-grade, mineralized stockwork veinlets (Osterwald and others, 1966). The veinlets carry copper, silver, and gold (East, 1911).

McClung mine. At the base of Stinkingwater Peak and Beartooth Mountain, a 150-foot tunnel intersected a fissure vein in quartz porphyry. The vein carried galena, chalcopyrite, gold, and silver (East, 1911; Osterwald and others, 1966).

Morning Star adit. Located on the northeast wall of Hughes Basin just south of the saddle between Hughes and Galena Creeks at 10,650 feet elevation. A 273-foot adit was driven east in andesite to intersect a N10°–15°W, 83°E dipping syenite dike (**Figure 15**). The dike was intersected 254 feet from the portal. Samples chipped from a shear in crosscuts near the face of the main tunnel assayed trace Cu, 0.02 to 0.04% Pb, 0.04 to 0.06% Zn, trace to 0.01 opt Au, and 0.30 to 0.77 opt Ag (Nelson and others, 1980). A sample of vein material collected by Parsons (1937) assayed 0.01 opt Au and 0.23 opt Ag.

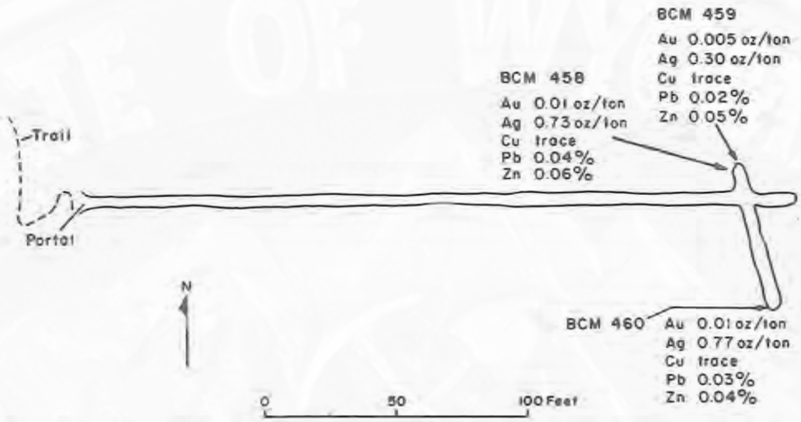


Figure 15. Sample location map of the Morning Star adit, Hughes Basin, Sunlight district (modified from Nelson and others, 1980).

Newton prospect. Located on the east side of Silvertip Basin at 9226 feet elevation; about one mile south of the Painter mine. A 67-foot adit followed a N85°E-trending, vertical shear zone in andesite porphyry. A grab sample from the mine dump assayed 0.03% Cu, 0.04% Pb, 0.02% Zn, trace gold, and 0.49 opt Ag (Nelson and others, 1980).

Novelty adit. Located at 9204 feet elevation on the west fork of Galena Creek near the base of the Galena Glacier. The adit was driven to a syenite dike in andesite country rock; the dike is sheared along the contact (**Figure 16**). The mineralized shear trends N24°E and dips 82°SE. Samples of the sheared rock assayed trace to 0.03% Cu, 0.02 to 0.88% Pb, 0.05 to 0.20% Zn, trace to 1.5 opt Ag, and trace to 0.02 opt Au (Nelson and others, 1980). Material from the mine dump collected 43 years earlier assayed 0.75% Cu, 13.1% Pb, 19.0 opt Ag, and 0.06 opt Au (Parsons, 1937).

Painter mine (Silvertip group). Located on the western flank of the upper Silvertip basin, east and below the Evening Star claim, at 9370 feet above sea level. The Painter vein trends N20°W to N15°E and was tested by two adits. The upper adit is 94 feet long, and the lower adit is 806 feet long. Eight samples collected from the mine dump ranged from 0.12 to 3.53% Cu, 0.02 to 0.08% Pb, 0.04 to 0.10% Zn, trace to 0.07 opt Au, and 0.47 to 3.03 opt Ag (Nelson and others, 1980). Other reported assays

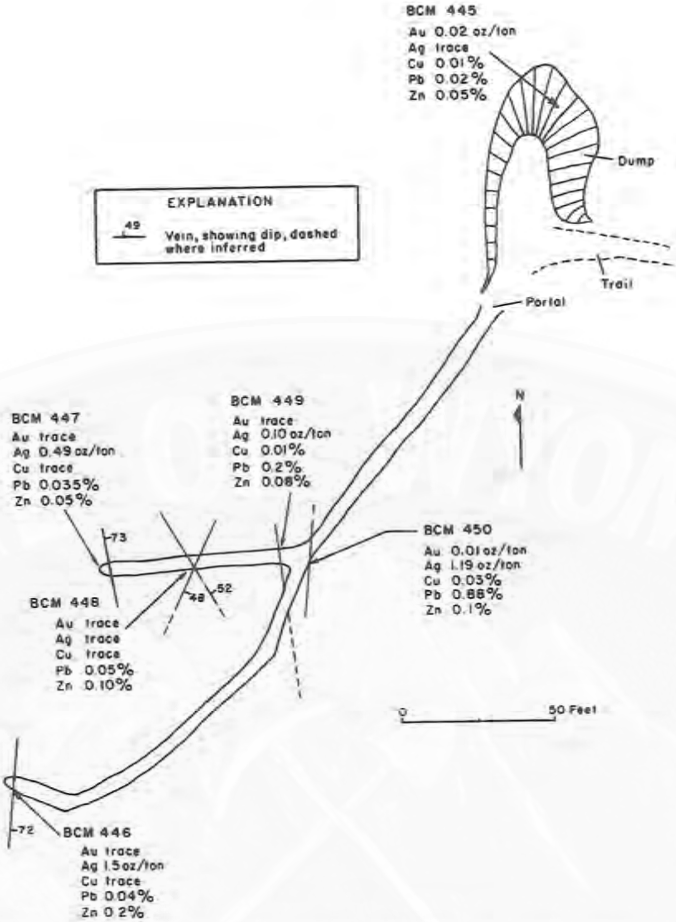


Figure 16. Sample location map of the Novelty adit, Galena Basin, Sunlight district (modified from Nelson and others, 1980).

include (1) dump material tested in 1935 that ran 3.85% Cu, 0.06 opt Au, and 4.62 opt Ag; (2) a sample collected in 1966 that assayed 14.9% Cu, 10.6% Pb, and 5.6 opt Ag; and (3) an average of eight random dump samples collected in 1969 that ran 5.16% Cu, 0.06 opt Au, and 6.1 opt Ag (Rich, 1974).

Rich (1974) estimated the 1-foot-thick vein hosted a minimum of 182,000 tons of ore. Some ore (approximately 100 tons) was shipped from the mine to the Omaha, Nebraska, smelter in 1903.

Silvertip claim. A sample of ore from the dump assayed 3.85% Cu, 0.06 opt Au, and 4.62 opt Ag (Parsons, 1937).

Sulfur Creek altered zone. NW sec. 33, SW sec. 28, NW sec. 34, and SW sec. 27, T54N, R107W. Samples collected by Dreier (1967) in an altered zone at the head of Sulfur Creek yielded 2 to 320 ppm Cu and 0 to 10 ppm Mo. Samples collected from veins in the area yielded 20 to 5600 ppm Cu.

Tip Top claim. (location unknown). Gangue minerals include calcite, ankerite, siderite, and barite. Ore minerals include galena and argentiferous tetrahedrite associated with proustite and stromeyerite. Small amounts of chalcopyrite and pyrite are present in sericitized wall rock. Some dump material assayed 0.02 opt Au, 7.14 opt Ag, 0.60% Pb, and trace copper (Parsons, 1937). In 1938, approximately 1 ton of rock was shipped to the Bunker Hill smelter at Kellogg, Idaho. This ore assayed 0.7% Cu, 2.3% Pb, 0.01 opt Au, and 39.9 opt Ag (Hausel, 1989).

Upper Silvertip Basin prospects. At an elevation of 10,000 feet in the upper end and along the eastern side of Silvertip Basin, is a 52-foot-long adit that trends N85°W. The adit was cut in andesite. One selected sample of dump material was poorly mineralized (Nelson and others, 1980).

Wild Goose group. Along the north side of Sulphur Creek near its headwaters, an 18-inch zone of copper sulfides in quartz and trachyte porphyry was exposed in an open cut. A similar zone was uncovered about 300 feet above the first cut. Still farther above, copper sulfides and black copper oxides were found in loose surface material (Beeler, 1906k).

Winona claims group. This group of claims includes the Greenhorn, Uncle Frank, Malachite, Copper Queen, Copper King, Mohawk, Copperopolis, Granite Mountain, Butte, Doubtful, Gopher, Hidden Treasure, and B & S (Rich, 1974; Nelson and others, 1980) (**Table 4**). These claims are located near Winona Camp at the head of Sulphur Creek Basin.

Parsons (1937) reported that ore from the Winona group was localized in shear zones along dike contacts in volcanic breccias. Ore mineralogy is dominated by chalcopyrite and pyrite with microscopic amounts of tetrahedrite, galena, and sphalerite. Gold was reported in sylvanite and as rare native grains in veinlets in chalcopyrite. Beeler (1907e) reported a 6-foot-wide vein on the Malachite claim contained a high-grade streak of chalcocite. The Bluff vein, located on the north side of Sulphur Creek, was described as a network of stringers and veins ranging in size from 1 foot to more than 12 feet wide (Beeler, 1907e).

Table 4. Reported assays from the Winona group. Analyses in weight percent (%) or ounces per ton (opt); dashes indicate not analyzed.

Claim name	Cu (%)	Pb (%)	Zn (%)	Au (opt)	Ag (opt)	Comments and/or reference
B&S	25.8	–	–	0.08	16.4	Rich (1974)
Butte	4.43	–	–	0.22	3.14	Vein outcrop (Parsons, 1937)
Copper King	3.35	–	–	0.04	0.62	Average ore found on dump (Parsons, 1937)
Doubtful	29.2	–	–	0.28	19.0	Rich (1974)
Gopher	6.7	–	–	0.24	1.76	Rich (1974)
Greenhorn	–	–	–	0.58	0.88	Average ore found on dump (Parsons, 1937)

Table 4 continued.

Claim name	Cu (%)	Pb (%)	Zn (%)	Au (opt)	Ag (opt)	Comments and/or reference
Winona adit	0.01	0.04	0.02	0.01	0.06	Composite sample of dump material. The adit was reported to have 1,135 feet of workings (Nelson and others, 1980)
Winona mine	–	–	–	0.58	0.88	Ore from dump (Parsons, 1937)
Hidden Treasure	47.8	–	–	0.16	11.64	Rich (1974)
	12.4	–	–	0.05	–	Rich (1974)
Malachite	34.8	–	–	0.08	30.5	Rich (1974)
Malachite 1	44.7	–	–	0.12	25.46	Rich (1974)

Miscellaneous porphyries and prospects

Big Wind prospect. SE SW sec. 3, T50N, R104W. Autunite and anomalous molybdenum occur in a stratiform deposit hosted by carbonaceous shale in the Jurassic upper Morrison Formation (Kopp, 1978).

Clouds Home Peak porphyry. Located on the Lake Creek and Clouds Home Peak 7.5-minute Quadrangles (**Figure 3**). The area is accessible by a pack trail that intersects a paved and graded road that services Cody and Valley. Cody is 25 miles to the northeast of the trail head, and Valley is 8 miles to the south. From the Ishawooa Creek trail head, the base of Clouds Home Peak lies nearly 10 miles to the west. The intrusive complex is located near the top of the peak.

The intrusive crops out over an area of more than one square mile. Mineralization and alteration occur sporadically along a 1-mile, north-south trend located within the composite intrusive. According to Fisher and Antweiler (1980), about 5% pyrite and traces of chalcopyrite occur as disseminations and as fracture coatings in the intrusive and in some dikes.

Other expressions of mineralization include small pyrite, chalcopyrite, rhodochrosite, quartz veins (2 inches and less in width) that cut granodiorite rocks in a 3-foot-wide zone; and a 300-foot-wide stockwork hosting malachite, azurite, chalcopyrite, quartz, pyrite, chlorite, and epidote. Samples collected in the mineralized area yielded 0 to 5000 ppm Cu, 0 to 1500 ppm Pb, 0 to 300 ppm Zn, 0 to 70 ppm Mo, 0 to 7 ppm Ag, and no gold.

Alteration includes both propylitic and phyllic assemblages. The phyllic altered rock is restricted and closely associated with veins, fractures, and dikes. Propylitic alteration is widespread. Oxidation has produced limonite stains, minor malachite stains, and bleaching of the rocks (Fisher and Antweiler, 1980).

Deer Creek porphyry. Located 9 to 10 miles north of the Stinkingwater district (**Figure 3**), this intrusive complex of granodiorite, porphyritic dacite, and andesitic dikes intrude vent-facies flows and breccias of the Wiggins Formation. The complex exhibits local patches of propylitically altered rock, with phyllically altered rock restricted to the margins of fractures. The mineralized rocks contain some pyrite with minor cupriferous geochemical anomalies in outcrop (Fisher, 1981).

Eagle Creek porphyry. This area is located near the western boundary of the Washakie Wilderness east of Yellowstone Park, about 40 air miles west of Cody, Wyoming (**Figure 3**). The district is accessible by 12 miles of pack trail (Eagle Creek trail) into the wilderness and lies within secs. 16, 17, 20, and 21, T51N, R109W on the Eagle Peak 15-minute Quadrangle.

The region was prospected in 1911. By 1955, 640 feet of drifts and 50 feet of shaft were developed on what is called the Crouch prospect, located near the southern edge of the intrusive complex (Osterwald and others, 1966; Wilson, 1955c) (**Figure 17**). The only recorded production was two ore shipments valued at $1000 in gold (28 to 50 ounces) and delivered to the Denver Mint in the 1930s (Wilson, 1955c).

The country rock is formed of andesite flows and flow breccias of the Trout Peak Trachyandesite (Sunlight Group). Mineralization is directly related to emplacement of an irregularly shaped intrusive (post-Oligocene?) with average latite composition. This latite porphyry was selectively fractured and mineralized, and it exhibits stockwork mineralization near the east-central edge of the intrusive, in a topographic saddle (**Plate 2A**). The stockwork is expressed by narrow N32°E- and N64°W-trending quartz veinlets. A further expression of mineralization extends out from the stockwork and into silicified and altered latite porphyry (**Plate 2B**) as well as into relatively fresh latite porphyry on the northwestern edge of the saddle.

The mineralization occurs as pyrite disseminations and pyrite, galena, sphalerite, and chalcopyrite in narrow quartz veinlets (less than 1 inch wide) in the altered-silicified latite and as pyrite and chalcopyrite(?) disseminations in the gray latite porphyry. Supergene enrichment appears to be insignificant (Galey, 1971). Some placer gold is reported along Eagle and Crouch Creeks (Wilson, 1955c).

Hydrothermal alteration is intense near the central portion of the stockworks and is characterized by phyllic and potassic alteration assemblages. The intense alteration gives way laterally to regional propylitic alteration mineral assemblages (Galey, 1971).

Jack Creek. Located about 3 miles northwest of the Meadow Creek stock near the Kirwin district (**Figure 3**). N40°W- and N60°W-trending fractures in vent-facies flows and breccias of the Wiggins Formation are poorly mineralized with sparse chalcopyrite, galena, and pyrite (Fisher, 1981).

Jamax claim. NE NE sec. 23, T51N, R104W. Significant molybdenum with uranium is exposed in a short adit cut in the upper Morrison Formation south of Castle Rock, along the eastern edge of the Absaroka Mountains in the Bighorn Basin. Locally, ferrimolybdite occurs in a carbonaceous shale associated with woody material. Samples collected from the Morrison-Cloverly contact contained visible molybdite and had eight to ten times background radioactivity (Kopp and Cohenour, 1978).

Robinson Creek porphyry. This porphyry lies nearly 50 miles southwest of Cody and 15 miles southwest of Valley (**Figure 3**). Access to the intrusive complex is by pack trail along the South Fork Shoshone River to Robinson Creek.

The mineralized area lies at the headwaters of Robinson Creek and includes a one-square-mile hydrothermally altered and mineralized rhyodacite to dacite composite

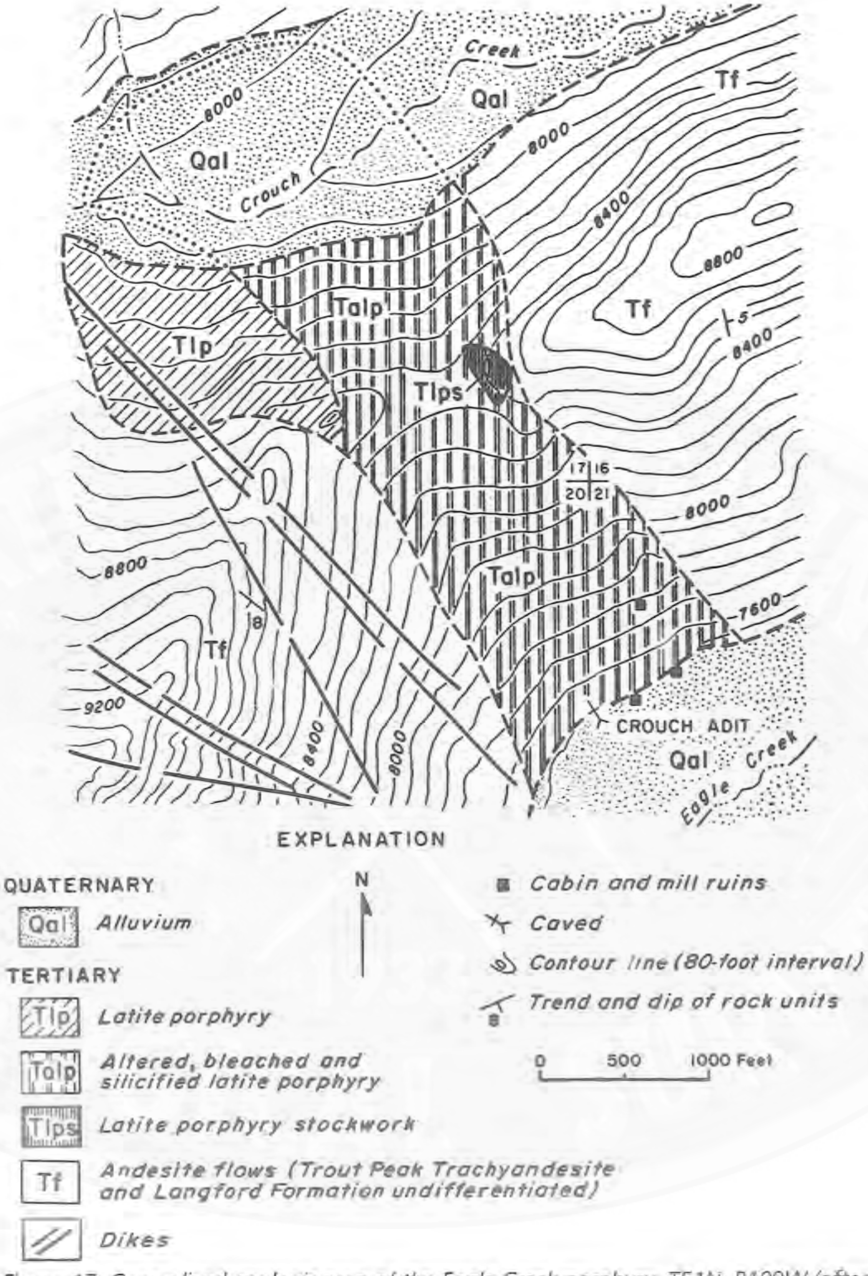


Figure 17. Generalized geologic map of the Eagle Creek porphyry, T51N, R109W (after Galey, 1971).

stock emplaced in flows and flow breccias of the Wiggins Formation. Texturally, the intrusive has both porphyritic and phaneritic phases.

Wiggins Formation andesites adjacent to the Robinson Creek intrusive are propylitized. Selectively pervasive propylitic alteration resulted in chlorite and lesser epidote replacing hornblende. Where propylitization is more intense, calcite, epidote, and minor chlorite are widespread. Secondary quartz, sericite, and pyrite form phyllic altered zones near the intrusive center. Some clay minerals replace phyllic zone minerals and are apparently of supergene genesis. Other manifestations of supergene alteration are bleaching and limonite staining.

Mineralization is coextensive with the phyllic altered zone and exposed as discontinuous outcrops of chalcopyrite, pyrite, and malachite stockworks. Chalcopyrite also occurs as disseminated grains and as fracture coatings with malachite. The mineralized rocks are shattered with fracture zones trending N20°–60°W. Less developed fractures trend to the northeast. Samples collected in the mineralized area ranged from 0 to 1000 ppm Cu, 0 to 100 ppm Pb, 0 to 700 ppm Zn, 0 to 100 ppm Mo, 0 to 2 ppm Ag, and no gold (Fisher and Antweiler, 1980).

Bighorn Mountains

The Bighorn Mountains form an elongate north-south-trending uplift in north-central Wyoming cored by Precambrian granite and gneiss that are unconformably overlain by Paleozoic sedimentary rocks along its flanks. Strata on the western flank have relatively gentle, low-angle (but locally steep) dips into the Bighorn Basin compared to the strata on the eastern flank, which are overturned in places and dip steeply into the Powder River Basin. Precambrian rocks are exposed throughout much of the uplift.

The highest peaks in the range are located west of Buffalo, Wyoming, where several peaks rise above 10,000 feet in elevation and culminate at Cloud Peak (13,175 feet). Several peaks in this area have spectacular cirques and other glacial features.

At the southernmost tip of the range, northeast of Lysite, schists crop out over a fairly large region, but little is known about the geology of the area. Farther north, the Precambrian core is buried by Cambrian sedimentary rocks of the Flathead and Gros Ventre Formations. Still farther north, the Precambrian core is exposed over a large area totaling more than 1000 square miles.

Osterwald (1959) separated the main body of Precambrian rocks of the Bighorn Mountains into northern granitic and southern gneissic terranes (**Figure 18**). The northern granitic terrane is largely composed of pink to gray, medium- to coarse-grained plutonic rocks of granitic to quartz dioritic composition. The gneissic southern terrane is composed of gray quartzofeldspathic gneiss with minor tonalite and numerous concordant and discordant pods and lenses of amphibolite. At least one ultramafic complex has been identified in the southern gneissic complex west of Buffalo along Clear Creek (Luth, 1960).

Rb-Sr isochron ages of the northern granites and southern gneisses are essentially the same (2850 Ma) (Heimlich and Banks, 1968; Stueber and Heimlich, 1977). This age is interpreted as the time of regional metamorphism and metasomatism that produced the gneissic and granitic rocks. Potassium-argon dating reported by Heimlich and Armstrong (1972) indicates that the event responsible for the formation of the Precambrian crystalline rocks ended at 2.75 Ga. However, more recent work by Arth and others (1980) indicates a more complex Archean history for the Bighorn Mountains. Their study of the southwestern portion of the range near Lake Helen indicates the gneisses in that region were older than previously reported and were affected by at least two episodes of magmatism, deformation, and metamorphism. The first event occurred at about 3.0 Ga, and the second event occurred at about 2.8 Ga. At 3.0 Ga, a bimodal suite of tonalitic to trondhjemitic and mafic (amphibolite) magmas was derived from an isotopically primitive source. These orthogneisses and amphibolites, which formed a primitive crust, were intruded by calc-alkaline rocks including quartz diorite, tonalite, granodiorite, and granite during the second episode at 2.8 Ga. The calc-alkaline rocks are isotopically distinct from the earlier bimodal suite (Arth and others, 1980).

More than one generation of mafic dikes occurs in the Bighorn Mountains. One group of dikes is approximately the same age as the granites and gneisses (Stueber and Heimlich, 1977) while a younger, relatively unmetamorphosed generation of tholeiitic dikes yielded K-Ar dates of 1910 to 2110 Ma (Condie and others, 1969).

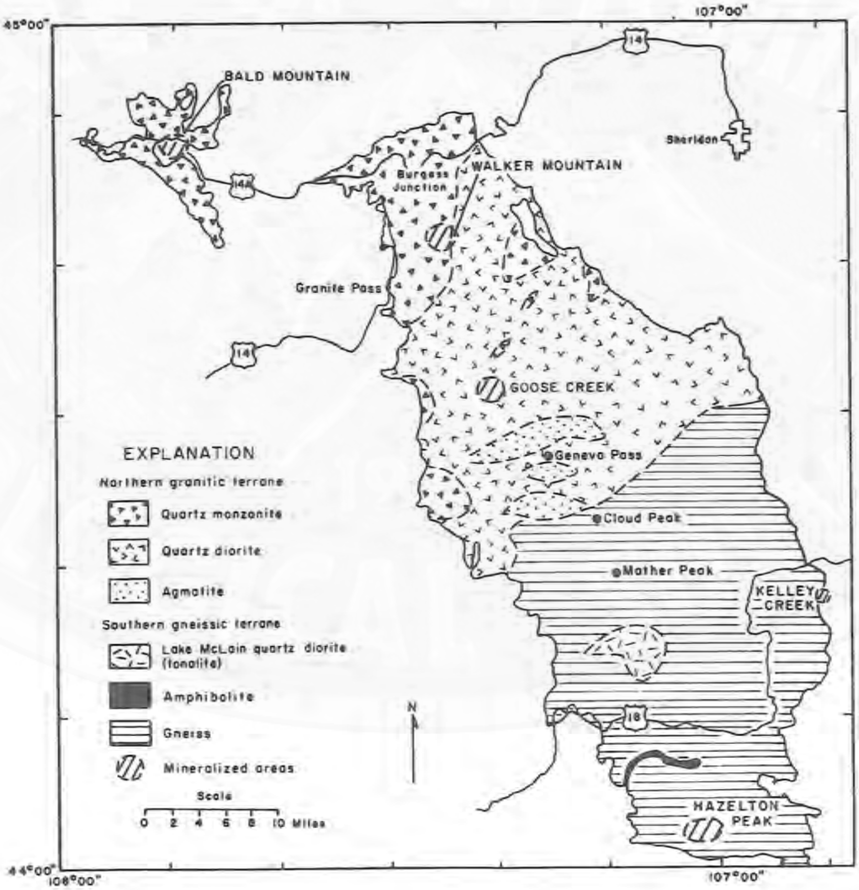


Figure 18. Regional geologic map of the Precambrian core of the northern Bighorn Mountains (modified from Heimlich, 1971). The southernmost schist terrane north-east of Lysite remains unmapped and relatively unexplored.

Mineralization

The Precambrian granites and gneisses of the Bighorn Mountains are not considered likely hosts for major metal deposits. However, this region is part of an Archean craton and may be attractive for diamond exploration.

Although base and precious metal deposits are scattered throughout the Bighorn Mountains, no major metal deposit has ever been recorded. The legend of the Lost Cabin gold mine is enticing to treasure hunters and prospectors, and the possibility of a small, rich, metal deposit somewhere in the range cannot be easily dismissed (Hausel, 1993a, 1994a). The known mineral deposits are associated with mafic dikes, veins, and shear zones in the granites and gneisses.

Reported mines and occurrences

Named mines, claims, and prospects

Bull Camp group. Sec. 26, T47N, R84W, located 7 miles south of Hazelton. Red and gray granites are intruded by dikes. One quartz vein has a 60°N dip and follows the contact between red granite on the north and gray granite on the south. The vein is 14 to 20 inches wide and joined by several small stringers from the south. The north side of the vein is stained by limonite and copper carbonate at the surface. Small bunches of chalcopyrite and bornite occur at a depth below 46 feet, and a small amount of pyrite is distributed in veinlets, lenses, and specks in the footwall granite (Beeler, 1904k). Darton (1906) reported minute veins were widely scattered throughout this area.

Dutch Oven Pass prospect. SE sec. 19, T52N, R87W. A 2- to 5-foot-wide, N60°E-trending quartz vein crops out over a distance of 700 feet. The vein is formed of white quartz stained by iron. In one prospect pit the vein contains malachite and chalcopyrite. One sample assayed 0.15% Cu and 2.5 ppm Ag (Kiilsgaard and others, 1972).

Edelman prospect. Sec. 13, T52N, R87W. Several prospects along Edelman Creek were dug to test a major fault zone. The fault strikes N35°E to N55°E, dips vertically, is up to 50 feet wide, and occurs in sheared biotite granite and quartz diorite. A sample of quartz with pyrite contained 0.2% Cu (Kiilsgaard and others, 1972).

Iron Dike. Located about 35 miles west of Ranchester and 7 miles southwest of the Wirlwind prospect. Two shafts were sunk to a depth of about 50 feet. The footwall of the dike is granite gneiss, and the hanging wall is granite. Samples collected from sorted ore yielded gold and traces of silver with no detectable copper or lead (Hopkins, 1920).

Nickel Plate. Located about 50 miles from Ranchester. The property was developed by a 200-foot shaft. Based on the size of the mine dump, there may have been extensive underground drifting (Hopkins, 1920). A tunnel also was driven into the side of the hill to intersect the dike.

The shaft was sunk in a northwest-trending peridotite dike with quartz stringers. Samples from the dump were heavily copper-stained and assayed 2.75% Cu, trace gold, 0.15 opt Ag, and no detectable Pt (Hopkins, 1920).

North Fork claim group. N/2 sec. 6, T48N, R84W, located 30 miles southwest of Buffalo. The claims are immediately north of Highway 16 near the North Fork of Crazy Woman Creek on a hillside overlooking the creek. A 50-foot shaft was sunk in a mafic dike that intrudes gneissic country rock. Chalcopyrite, bornite, malachite, and hematite-bearing mafic rocks were intersected at the 35- to 50-foot level. One reported assay from the mine tailings yielded 0.005 opt Au and 0.6 opt Ag (Edwards, 1990).

Powder River Pass. SE sec. 4, T48N, R85W, located on a ridge north of U.S. Highway 16 at Powder River Pass. A 6-inch-wide quartz vein cuts strongly foliated, isoclinally folded oligoclase-biotite-hornblende gneiss. The vein contains malachite at scattered intervals and isolated pyrite anhedra up to 3/8 inch in diameter. Fold axes and lineation in the gneiss plunge N30°E and N60°E; the vein strikes N65°E, parallel to gneissic layering (Osterwald and others, 1966, p. 54).

Roe Brothers group. Sec. 15, T49N, R83W, located 17 miles from Buffalo. Dark-colored dike rock cuts red granite. The dike contains quartz, limonite, hematite, and isolated green stains (copper carbonate?). Assays show small amounts of gold (Beeler, 1904j).

South Fork of Wolf Creek. Southwest of Walker Mountain. A 56-foot shaft was sunk on a 15-foot-wide, malachite-stained quartz vein in granite. Cupriferous vein samples assayed 0.18 to 0.2 opt Au. Some galena also occurs in the vein. The vein was traced for nearly 6 miles (Darton, 1906).

Taylor mine. SW sec. 5, T54N, R87W. A 15-foot-wide altered diabase dike at the crest of a ridge trends N80°E and dips 85°NW. The footwall of the dike is red pegmatitic granite with narrow (<3/8 inch wide) epidote veins. A shaft sunk on the dike exposed altered diabase with fracture fillings of magnetite, hematite, limonite, malachite, chrysocolla, quartz, and a little chalcocite (Osterwald and others, 1966, p. 61).

Top Hand group. Located east of the Bull Camp group in T47N, R84W. Red granite and lesser gray granite contain layers of gneiss, schist, and mafic dikes. A mica schist layer strikes northwest and dips northeast. All the rocks are cut by quartz veins with sporadic limonite and malachite stains (Beeler, 1904l).

Walker mine. Located southwest of Walker Mountain. The mine was developed on a 15- to 25-foot-wide vein. The vein was prospected for copper. Pyrite in the vein is auriferous (Darton, 1906).

Wirlwind and Winner. Two historical mining claims located by the Black Mountain Mining Company were examined by Hopkins in 1920. The location of the prospect was not given but is presumably located somewhere near Bald Mountain.

A 60-foot-deep shaft was sunk in a northwest-trending diabase dike that contains numerous quartz stringers. About 2000 feet to the northwest, a 1500-foot tunnel was driven toward the mineralized zone but stopped short of intersecting the mineralized horizon. A sample of copper-stained ore from the dump yielded 4.4% Cu and trace silver (Hopkins, 1920).

Unnamed mines and prospects

Secs. 1 and 12, T55N, R85W. Located on a low ridge 0.5 mile south of the Bear Lodge Resort. A prospect hole was dug in a large siliceous crushed zone in granite. The crushed zone trends north-northeast. Fractures in the siliceous material contain chalcocite and malachite (Osterwald and others, 1966, p. 61).

NE sec. 24, T55N, R88W. A shaft was sunk on a zone of silicified and epidotized crushed granite a short distance northwest of the Madalynna claim. The shear zone trends N40°W and at the shaft intersects a diabase dike trending N80°W. The dump consists of altered diabase containing irregular masses of siliceous material and fracture fillings with a little chalcocite and malachite (Osterwald and others, 1966, p. 61–62).

NW sec. 28, T56N, R88W. A shaft sunk at the intersection of a large east-west-trending altered porphyritic diabase (leopard rock) dike with a north-northeast-trending silicified shear zone, exposed massive pyrite. The diabase contains stringers and masses of quartz with occasional chrysocolla and disseminated pyrrhotite. Other prospects in the vicinity exposed similar mineralization (Osterwald and others, 1966, p. 122).

T56N, R88W. A shaft, prospect pits, and an adit with possibly as much as 500 feet of workings exposed quartz, minor pyrite, malachite, and azurite. The vein trends northeasterly and is associated with granite and a peridotite dike (King, 1952).

Black Hills

The Black Hills in Wyoming form a dome-shaped uplift that extends into South Dakota and is cored by a 2.6-Ga Precambrian basement complex surrounded by Paleozoic and Mesozoic limestone, shale, and sandstone. Tertiary alkalic and peralkalic igneous rocks intrude older rock units at a number of locations. The principal intrusive centers range in age from 30 Ma to 55 Ma and include the Bear Lodge Mountains complex, Black Buttes, Devils Tower-Missouri Buttes, Inyan Kara Mountain, Mineral Hill, and Sundance Mountain (Lisenbee, 1985). Of these, mineralization has been reported in the Bear Lodge Mountains, Black Buttes, and the Mineral Hill district (**Figure 19**).

The Bear Lodge Mountains include disseminated gold and rare earth element (REE) mineralization, in addition to copper. Copper appears to be relatively widespread but in uneconomic concentrations. For example, chalcopyrite is reported with fluorite in trachytes and leucosyenites but only in accessory amounts. Pseudoleucite alkali trachyte porphyry in the Bear Lodge Mountains also carries accessory chalcopyrite, sphalerite, and galena. In the Black Buttes area, replacement deposits are dominated by galena and argentiferous hemimorphite with subordinate fluorite and wulfenite. Copper is uncommon. In the Mineral Hill district, disseminated gold and gold- and silver-rich veins dominate, with some scattered REE, copper, lead, zinc, and tin.

The Bear Lodge Mountains in the northwestern Black Hills of Wyoming form a large multiple intrusive complex of alkalic igneous rocks ranging in age from 38.0 to 50.0 Ma (Staatz, 1983; Lisenbee, 1985). Staatz (1983) described the complex as a porphyry-type intrusive containing one of the largest, low-grade, disseminated and vein-type REE and thorium deposits in the United States. Disseminated gold mineralization is also associated with feldspathic breccia in the complex (Jenner, 1984). One mineralized zone discovered in an elongate intrusive breccia (2000 by 120 feet) was recently drilled yielding gold values of 0.343 to 1.72 ppm (International Curator

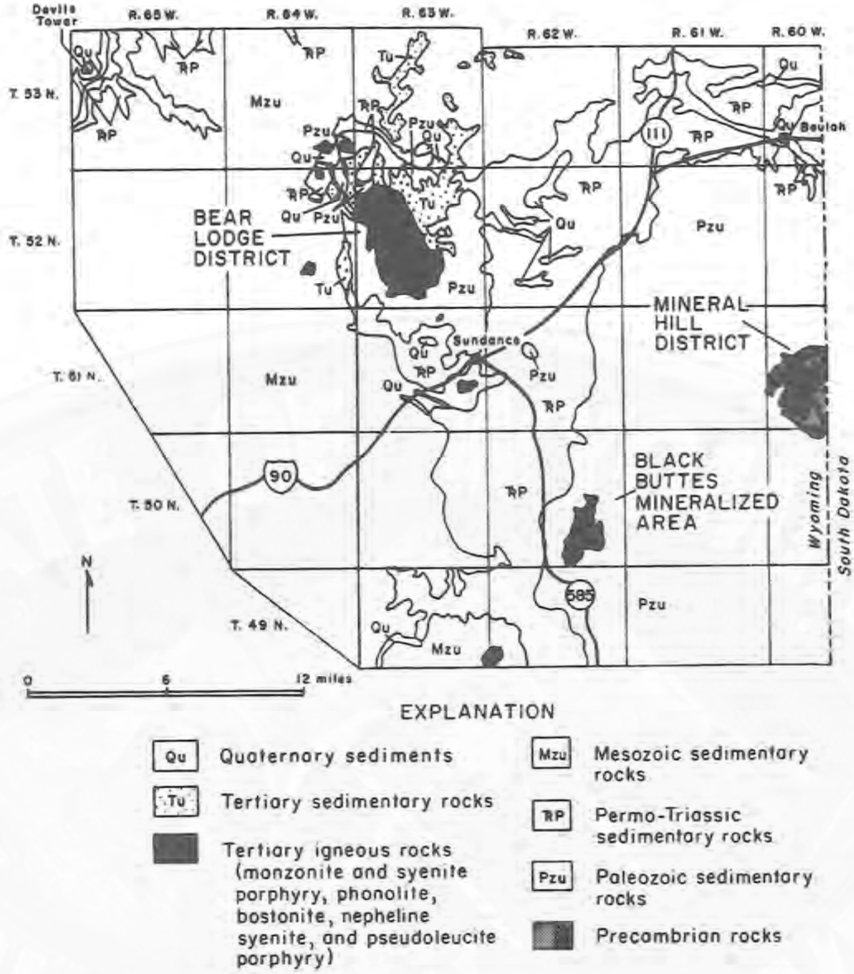


Figure 19. General geologic map of the Black Hills region of Wyoming (after Love and Christiansen, 1985; Lisenbee, 1985).

Resources, 1988). Current geologic resource estimates for the intrusive breccia are 8.2 million tons averaging 0.686 ppm gold (*Engineering and Mining Journal*, April, 1991).

Twelve to 15 miles southeast of the Bear Lodge Mountains, another Tertiary alkalic intrusive at Mineral Hill shows similar mineralization. Anomalous gold is reported in feldspathic breccia, quartz veins, and in jasperoid (Welch, 1974). Welch (1976) reported breccias with 6 ppm Au and 115 ppm Ag, and jasperoids with 5 ppm Au and 7 ppm Ag. The possibility for similar mineralization at Black Buttes, 6 miles to the southwest, is indicated by the presence of epithermal replacement galena, wulfenite, fluorite, and hemimorphite in altered Pahasapa Limestone (Mississippian) along a contact with Tertiary alkalic igneous rock (Hausel, 1989).

Bear Lodge Mountains

The Bear Lodge Mountains were first prospected in 1875, following the discovery of gold in feldspar porphyry near Warren Peak. These mountains form a core of multiple alkalic intrusives of Eocene age that have domed the surrounding Paleozoic and Mesozoic sedimentary rocks (**Figure 20**). The U.S. Geological Survey rated the Bear Lodge Mountains as high mineral resource potential for small- to medium-size vein and replacement-type deposits containing gold, silver, manganese, REE, lead, and thorium; and high potential for large disseminated-type deposits containing REE, thorium, manganese, and barium, with by-product fluorite, uranium, gold, silver, and phosphate (DeWitt and others, 1986). The Bear Lodge district appears to have potential for massive sulfides. One hole drilled in hornblende schist (located in 44°32'24"N, 104°26'24"W) cut through 40 feet of massive sulfides containing sphalerite and minor chalcopyrite (Houston and others, 1992).

Mineralization

The core of the intrusive complex has been fenitized; in other words, alkalies (particularly potassium) were introduced and silica was removed during alteration. The intrusive core consists of trachyte with a large (0.9 by 0.4 mile) intrusive breccia pipe in the northern half of the complex (Gersic and others, 1990) (**Figure 20**).

Mineral deposits in the Bear Lodge Mountains consist of vein-, disseminated-, carbonatite-, and replacement-type deposits within a 6-square-mile area. The deposits are indicative of the upper part of a carbonatite system. The first three types of deposits occur together in the trachyte core, and the replacement deposits occur primarily in the surrounding Paleozoic sedimentary rocks (Gersic and others, 1990).

Thirty-five samples collected from veins within the complex contained 0.011 to 1.2% ThO_2, and 21 samples contained 0.23 to 9.81% REE. Associated trace metals include manganese, barium, zinc, lead, niobium, copper, and uranium (Staatz, 1983).

Disseminated REE and gold-bearing stockworks and intrusive breccia-hosted deposits occur in the trachyte stock. In addition to having significant low-grade thorium, REE, and gold, samples from the stockwork contained as much as 1.5% Ba, 1.0% Cu, 0.7% Sr, 0.5% Pb, 0.2% Nb, 0.2% Zn, and 700 ppm Mo (Staatz, 1983). Samples collected by the U.S. Bureau of Mines in this same region averaged 3.5% total rare earth oxides, 0.26 ppm Au, and 3.5 ppm Ag.

Replacement deposits occur in inliers of Cambrian Deadwood Formation quartzite and Pahasapa Limestone within and on the periphery of the trachyte stock. These types of deposits consist of fluorite, chalcedony, and minor potassium feldspar. They occur as irregular and discontinuous veins, fractures, and brecciated zones and as disseminated streaks and blebs. Samples from carbonatite dikes yielded 1.5 to 3.37% REE and 0.1 to 0.334 ppm Au.

Although the Bear Lodge Mountains contain gold, copper, and other base metals, the greatest resource potential for the district appears to be for disseminated gold and rare earth metals. The estimated identified resource for rare earth elements is 84 million tons of ore at an average grade of 1.5% REO (rare earth oxides) (Gersic and others, 1990).

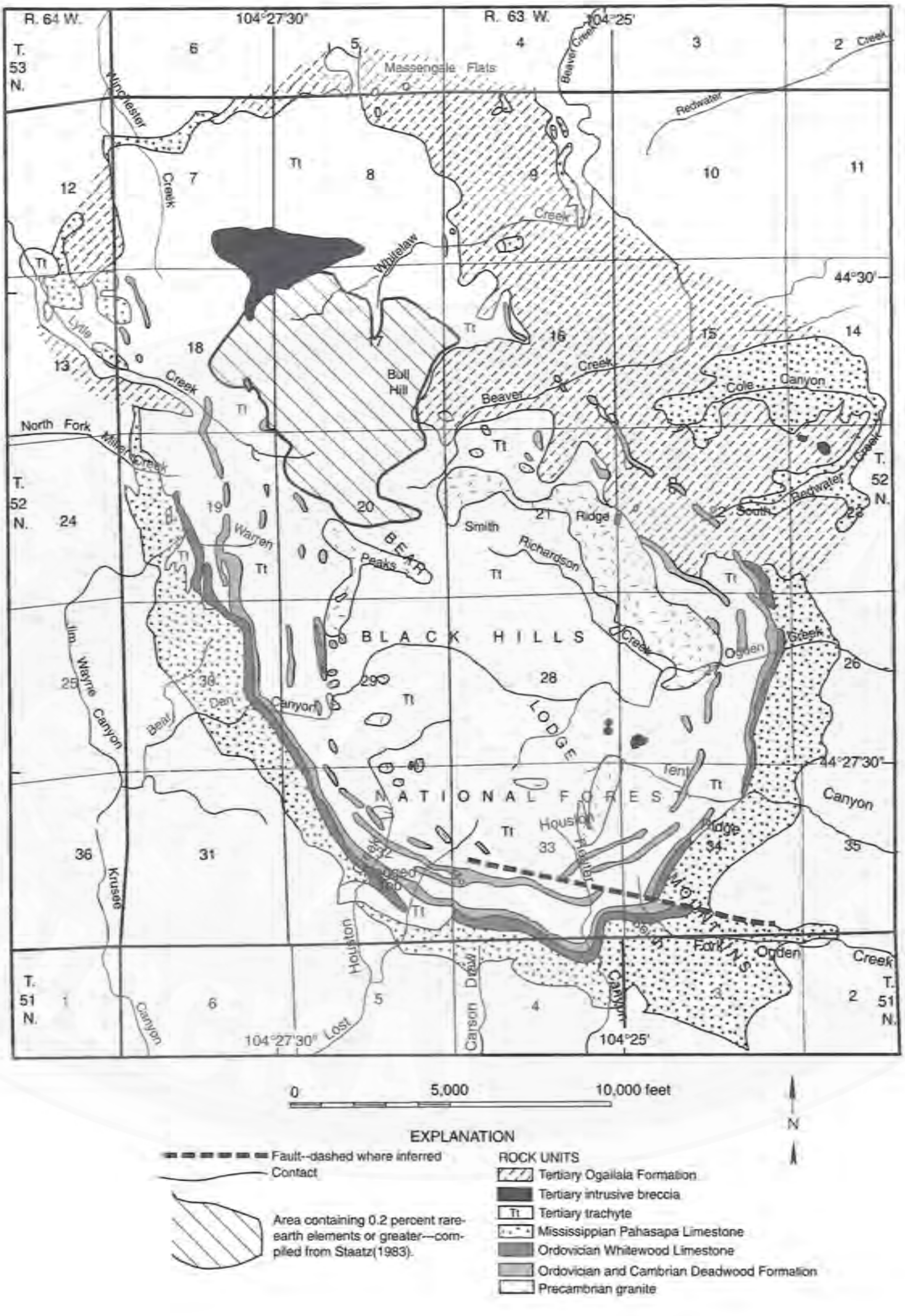


Figure 20. Generalized geologic map of the core of the Bear Lodge Mountains alkaline intrusive complex (modified from Staatz, 1983).

Reported occurrences and mines

Copper Prince mine. NW sec. 17, T52N, R63W. Located adjacent to the Warren Peaks road about 1.25 miles north of the peaks. Mine workings include an incline with a 50-foot vertical shaft. Dump material from the mine contains malachite and chrysocolla with small scattered particles of native gold (Jamison, 1912a) and some cuprite(?) (Chenoweth, 1955). Widely scattered copper carbonate and copper oxide deposits also are reported northwest of Sundance on Warren Peak (Sanford and Stone, 1914). A pyritized intrusive breccia from the Copper Prince yielded >2.0% Cu (Gersic and others, 1990). Jenner (1984) reported chalcopyrite locally approaches ore grade concentrations in the subsurface, and low-grade gold occurs in oxidized samples of intrusive breccia. Trachyte breccias in the vicinity of the mine are cemented with manganese oxide (**Figure 21**).

Prospect. A 150-foot shaft was sunk adjacent to the Bear Lodge truck trail about 1.5 miles northeast of its intersection with the Warren Peaks road. The dump contains malachite, iron oxide, cuprite(?), and chrysocolla (Chenoweth, 1955), which is found as fracture fillings in altered kaolinitized porphyritic syenite(?). The copper minerals are associated with light green and white opal in veinlets.

Smith Ridge. Sec. 21, T52N, R63W. From 1983 to 1988, FMC and International Curator explored the central portion of the intrusive stock and intersected a tabular intrusive breccia approximately 2000 feet long by 120 feet wide. The breccia averaged 0.021 opt Au. Reserves were estimated at 2.0 million tons of ore containing 42,000 ounces of gold (Gersic and others, 1990). Later drilling by Coca Mines increased geologic resources to 8.2 million tons averaging 0.02 opt Au (*Engineering and Mining Journal*, April, 1991).

Figure 21. Trachyte breccia collected near the Copper Prince mine. The fractures of the breccia are rehealed by pyrolusite.

NW NW sec. 17, T52N, R63W. A prospect pit exposed some copper oxide mineralization (Jenner, 1984).

Secs. 16, 18, 22, 27, 33, and 34, T52N, R63W. Samples collected from Deadwood Formation quartzite and from a limestone xenolith yielded minor amounts of gold, silver, REE, and fluorine. Values as high as 0.180 ppm Au, 2.0 ppm Ag, 350 ppm Ce, 150 ppm La, and 1.19% F were detected (Gersic and others, 1990).

Secs. 7, 8, 17, and 18, T52N, R63W. From 1970 to 1985, Duval Corporation explored the northern portion of the Bear Lodge intrusive complex for porphyry copper. Thirteen coreholes and 42 shallow and two deep rotary holes were drilled (Gersic and others, 1990). The results are not known.

S/2 sec. 17, T52N, R63W. A carbonatite yielded 0.21% Pb, 0.12% Zn, 766 ppm Th, and 714 ppm Y (Gersic and others, 1990).

SE sec. 7, T52N, R63W. A sample of intrusive breccia yielded 0.1% Mo and 0.18% Zn (Gersic and others, 1990).

NE sec. 18, T52N, R63W. A sample of intrusive breccia yielded 1028 ppm Mo and 1826 ppm Zn. In 1988, American Copper and Nickel Company drilled four holes into trachyte and Deadwood Formation conglomerate. The recovered samples yielded low gold values (Gersic and others, 1990).

Sec. 16, T52N, R63W. In 1988, American Copper and Nickel Company drilled 16 holes in an intrusive breccia and identified low gold concentrations (Gersic and others, 1990).

Black Buttes area

The Black Buttes mineralized area, also known as the Hurricane district, consists of a group of low-lying hills (**Figure 22**) 12 miles west of Mineral Hill and 8 miles south of Sundance (**Figure 1**). Black Buttes is a Tertiary alkalic igneous complex similar to Mineral Hill and the Bear Lodge Mountains. The complex consists of several separate intrusives, including trachyte porphyry, nepheline syenite porphyry, alkali trachyte porphyry, aegirine-augite trachyte porphyry, phonolite, and nordmarkite (Elwood, 1978, 1979). These magmas intruded and domed the Paleozoic cover at about 54 Ma (Lisenbee, 1985).

Locally, lead-silver-zinc mineralization occurs in a tabular zone along steeply dipping joints of the Mississippian Pahasapa Limestone a few feet above the contact with a Tertiary trachyte porphyry sill. The mineralization replaces limestone, fills cavities, and cements limestone breccia, and was accompanied by strong silicification (Elwood, 1978; Hagner, 1942e).

Figure 22. The topographic features known as Black Buttes form a group of rolling hills south of Sundance.

The most abundant ore mineral present is white hemimorphite, which occurs in cavities and as replacements of algal structures in the limestone. Galena, sphalerite, and fluorite also occur in less abundance. A 25-pound grab sample collected by Elwood (1978) assayed 6% Zn, 0.05% Pb, 0.09% Mn, and 10 ppm Ag. Hagner (1942e) and Osterwald and others (1966) reported galena and cerussite were common ore minerals. One assay of ore collected from secs. 23 and 26, T50N, R62W, yielded 0.002 opt Au, 2.0 opt Ag, 13.9% Pb, 0.02% Cu, and 5.7% Zn (Hagner, 1942e). Some galena in the area also assayed as high as 200 opt Ag (Knight, 1893). The author found hemimorphite and galena and uncommon fluorite and wulfenite at Black Buttes but no sphalerite (Hausel, 1988c). Hayden (1871, p. 215) reported cuprite also was associated with carbonate ore in the district.

Some ore was shipped from the district in the 1880s, and one carload was shipped to the East Helena, Montana, smelter in 1942. The ore shipped in 1942 yielded 51 ounces of silver and 6977 pounds of lead (Henderson, 1943).

Black Butte prospect. This prospect is the only named prospect in the area. Located in NE sec. 26, T50N, R62W. This is probably the same prospect described by Elwood (1978, 1979). Mineralization was accompanied by silicification in contact breccia in the Pahasapa Limestone (Mississippian) where it has been intruded by trachyte (Tertiary). The breccia consists of limestone clasts cemented by massive galena. The galena is accompanied by hemimorphite, minor fluorite, jasperoid, and wulfenite. Elwood (1978) also reported sphalerite. Samples collected for assay ranged from 0 to 5.8 opt Ag, 80 to 452 ppm Cu, 130 ppm to 0.79% Mn, 48 ppm to 0.51% Pb, and 61 ppm to 8.3% Zn (**Table 5**) (Hausel, 1988c). The mineralization is very localized in outcrop.

Table 5. Assays of samples from the Black Butte prospect (after Hausel, 1988c). All values in parts per million (ppm) except for three zinc assays in weight percent (%); nd= not detected.

Sample description	Au	Ag	Cu	Mn	Pb	Zn
Silicified limestone, minor fluorite	nd	nd	85	245	185	115
Fluorite-bearing carbonate	nd	nd	80	130	48	61
Jasperoid, minor fluorite	nd	110	403	2,060	2,810	8.3%
Jasperoid	nd	nd	452	7,870	3,500	6.4%
Galena-bearing limestone breccia with hemimorphite	nd	200	296	3,080	5,100	7.4%

Mineral Hill district

The Mineral Hill district lies within Wyoming adjacent to the Tinton mining district in South Dakota (**Figure 1**). Tinton was known for tin (cassiterite), and Mineral Hill was known principally for placer gold. In addition to placer gold, other potentially valuable heavy minerals were found in the surrounding drainages of Mineral Hill. The district also contains lode and disseminated gold, some copper, and minor amethyst.

Mineral Hill is dominated by a Tertiary alkalic complex that intrudes Precambrian biotite-quartz schist, minor amphibolite and pegmatite, and Paleozoic sedimentary rocks. The Paleozoic rocks are domed and dip gently away from the center of the alkalic complex.

The Deadwood Formation (Cambrian), the lowermost Paleozoic unit exposed in the Mineral Hill area, forms a semicircular outcrop around the Mineral Hill ring-dike complex. The Deadwood Formation crops out as conglomerate and quartzite overlain by laminated carbonate-rich siltstone, sandstone, and flat-pebble conglomerate. Isolated pods and veins of jasper have been identified in these rocks (Welch, 1974).

The Mineral Hill alkalic complex has an outer ring dike of feldspathoidal syenite, a pyroxenite inner ring dike, and a core of feldspathic breccia intruded by diorite (**Figure 23**). Alkalic lamprophyre and pseudoleucite porphyry dikes are widespread (Welch, 1974).

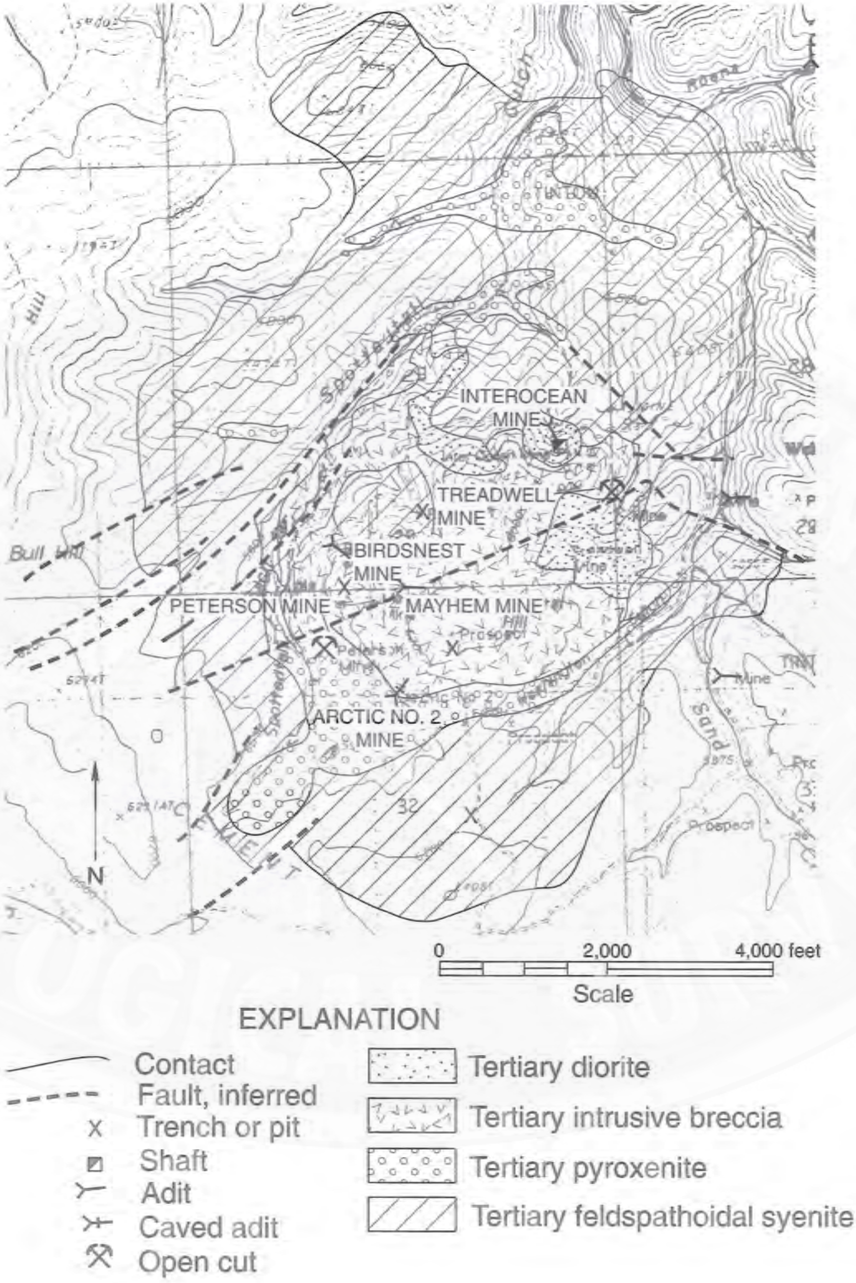


Figure 23. Generalized geologic map of the Mineral Hill district, T51N, R60W (modified from Welch, 1974 and 1:24,000-scale topographic map of the Old Baldy Mountain 7 1/2-minute Quadrangle, South Dakota and Wyoming).

On the west side of Mineral Hill the alkali trachyte porphyry forms extensive sills at the base of the Deadwood Formation, intrudes various horizons of the Deadwood Formation, and occurs locally in younger Paleozoic rocks. East of Mineral Hill the trachyte porphyry forms vertical sills conformable to the schistosity of the Precambrian schist. The central portion of the complex is crudely circular in outcrop and consists of pyroxenite and feldspathic breccia.

The complex exhibits varying degrees of alteration that Welch (1974) attributed to deuteric processes. Although some bleached rocks are completely replaced by potash feldspar and clay, Welch insisted that fenites do not occur in the complex.

The Mineral Hill igneous complex was emplaced during the Laramide orogeny. A crustal fracture is believed to have tapped alkalic peridotitic magma from the mantle, which produced pyroxenitic magma (Welch, 1974). Welch also postulated that a second magma, generated by partial melting of the crust by the pyroxenitic magma, was responsible for the alkalic trachyte porphyry.

Mineralization in the district includes disseminated and vein-type deposits. Anomalous copper, gold, silver, lead, manganese, and zinc occur throughout the ring complex. Precambrian pegmatites contain columbite-tantalite as well as tin. Reported production for the district included 9000 ounces of placer gold prior to 1893 (Knight, 1893). Minor production from the Interocean mine and the Treadwell claim in 1904 and 1907 totaled 14.25 ounces of gold and 43 ounces of silver (Gersic and others, 1990).

Named mines and prospects

Arctic mine. N/2 sec. 32, T51N, R60W. Two adits, the Arctic 1 and Arctic 2, are located along the southwestern edge of Mineral Hill. One of the Arctic adits was driven 400 feet in 1932 by Mineral Hill Gold Properties, Inc. (Gersic and others, 1990).

Samples collected from the Arctic 1 and 2 mines by the author in 1990 contained common crusts of lavender to purple drusy quartz. One sample of amethyst was found in the back of the Arctic 2 adit. A sample of silicified limonite-stained intrusive breccia collected by Gersic and others (1990) from the mine dump yielded 0.023 ppm Au and 1.6 ppm Ag. Other samples collected by the author also were poorly mineralized: a chalcedony-bearing trachyte collected from the #2 adit contained 0.019 ppm Au; a chalcedony-rich trachyte from the #1 adit contained 0.029 ppm Au; and another chalcedony-rich trachyte also from the #1 adit contained 0.060 ppm Au and 2.4 ppm Ag (Hausel, 1990c). Hopkins (1982) reported that samples from the property contained 0.014 to 14.82 opt Au, 0 to 2.15 opt Ag, 0.8 % Pb, and 0.06 % Cu.

Birdsnest mine. SE SW sec. 29, T51N, R60W. Four samples collected from the Birdsnest mine yielded anomalous metal values (**Table 6**).

Table 6. Assays of samples collected from the Birdsnest mine (from Hausel, 1988c, 1990c). Analyses in weight percent (%) or parts per million (ppm); dashes indicate not analyzed; nd= not detected.

Sample description	Cu (%)	Au (ppm)	Ag (ppm)	Mn (%)	Pb (ppm)	Zn (ppm)
Pyroxenite with minor pyrite	–	0.168	–	–	–	–
Pyritiferous mafic breccia	–	0.002	–	–	–	–
Copper-stained quartz w/ pyrite	0.29	15.0	120.0	–	–	–
Altered trachyte	0.04	nd	nd	0.42	471	441

Bull Hill. E/2 SE sec. 30, T51N, R60W. A sample of brown jasperoid in pulaskite assayed 470 ppm Cu, 4300 ppm Pb, 5 ppm Au, and 7 ppm Ag (Welch, 1974).

Interocean mine. E/2 sec. 29, T51N, R60W. The Interocean mine is located on the Interocean #1 patent. The mine consists of a collapsed shaft sunk in diorite and a 35-foot adit driven below the shaft in schist (Gersic and others, 1990). Mineralized diorite assayed 0.2% Cu, 29 ppm Pb, 3 ppm Au, and 1 ppm Ag. Preliminary tests indicated the presence of an orebody with an average gold content between 0.08 and 0.14 opt (Welch, 1974).

Two samples of silicified trachyte breccia were collected from the mine dump by the author. Respectively, these yielded no detectable gold and 0.43 ppm Au; no detectable silver and 2.5 ppm Ag; 622 ppm and 0.12% Cu; 0.19% and 0.83% Mn; no detectable lead and 88 ppm Pb; and 100 ppm and 146 ppm Zn (Hausel, 1988c). A 1-foot chip sample taken across the intersection of two veinlets at the portal of the adit by the U.S. Bureau of Mines yielded 0.13 opt Au, 0.09 opt Ag, and 0.29% Cu. Another sample from an 8-inch-wide pegmatite yielded 0.028 ppm Au and 0.7 ppm Ag (Gersic and others, 1990).

Mayhem mine. Samples from this property yielded values of 0.008 to 0.54 opt Au, 0 to 10.95 opt Ag, 0.4 to 1.45 % Pb, and 0.06 to 0.47 % Cu (Hopkins, 1982).

Peterson mine. Sec. 29, T51N, R60W on the west side of Mineral Hill. In 1932, the Peterson mine was driven 1450 feet by Mineral Hill Gold Properties, Inc. A grab sample of silicified and limonite-stained intrusive breccia from the dump yielded 1367 ppm Pb, 1041 ppm Zn, 396 ppm As, 65 ppm Sb, 0.04 ppm Au, and 2.5 ppm Ag (Gersic and others, 1990).

Treadwell mine. E/2 sec. 29, T51N, R60W. The Treadwell open cut is located on the Gold Coin patent. The cut consists of a small open cut with high walls and two parallel adits driven on 1-foot-wide horizontal veins. The pit was developed to recover ore from two horizontal quartz veins in altered feldspathic syenite and trachyte and possibly from the altered host rock. Welch (1974) collected a sample of silicified intrusive breccia from the pit that assayed 0.17 opt Au, 3.36 opt Ag, 1.1% Cu, and 0.57% Pb. A few samples collected by Hausel (1990d) were mineralized (**Table 7**).

Table 7. Assays of samples collected from the Treadwell mine (from Hausel, 1990d). Analyses in weight percent (%) or parts per million (ppm); dashes indicate not analyzed.

Sample description	Cu (%)	Pb (%)	Au (ppm)	Ag (ppm)
Feldspathic breccia from mine dump	–	–	<0.005	<5.0
Breccia	–	–	<0.005	<5.0
Graphitic sulfide-bearing nodule	–	–	<0.05	<1.0
Limonitic quartz vein from highwall	0.29	2.32	130.0	330.0
Limonite-stained syenite	–	–	0.06	<1.0
Silicified trachyte	–	–	1.39	9.0
Silicified porphyry	–	–	<0.05	<1.0
Quartz vein from highwall	–	–	0.36	<5.0
Vertical fracture vein from highwall	–	–	0.056	<5.0
Limonitic quartz vein from highwall	0.19	1.47	21.0	65.0

Unnamed mines and prospects

NE sec. 29, T51N, R60W. A sample collected in this area in 1960 assayed 3% Pb and 17 opt Ag. Welch (1974) resampled the area but was unable to repeat the results.

N/2 NW sec. 32, T51N, R60W. A quartz vein in altered igneous rock assayed 65 ppm Cu, 3000 ppm Pb, 0.9 ppm Au, and 3 ppm Ag (Welch, 1974).

N/2 sec. 32, T51N, R60W. Samples collected from trenches dug in intrusive breccia yielded 0.027 and 0.005 ppm Au and 0.7 and 1.7 ppm Ag (Gersic and others, 1990).

E/2 sec. 32, T51N, R60W. A sample of feldspathic syenite contained 0.016 ppm Au and 0.4 ppm Ag (Gersic and others, 1990).

Sec. 32, T51N, R60W. Humble Oil and Refining Company drilled Mineral Hill and locally intersected large intervals of disseminated pyrite and chalcopyrite. One of the drill holes spudded in pyroxenite, was drilled to a depth of 740 feet, and averaged 380 ppm Cu. Some 10-foot intervals in this drill hole averaged 900 ppm Cu. A few zones in the pyroxenite contained as much as 25% titanomagnetite (Gersic and others, 1990).

W/2 W/2 sec. 22, T51N, R60W. A hole drilled in pyroxenite along the southwestern margin of Mineral Hill by Exxon in 1970 yielded anomalous copper. According to Welch (1974), trace chalcopyrite was observed throughout much of the 3000 feet of core.

NE sec. 29, T51N, R60W. A sample of bleached breccia collected along the edge of Spottedtail Gulch on the north side of Mineral Hill yielded 220 ppm Cu, 61 ppm Pb, 1.0 ppm Ag, and no gold (Welch, 1974). A sample of brown limonite collected nearby yielded 600 ppm Cu, 23 ppm Pb, 1.0 ppm Ag, and no gold (Welch, 1974).

Center sec. 29, T51N, R60W. A sample of a gray igneous dike with abundant pyrite collected along Spottedtail Gulch by Welch (1974) yielded 280 ppm Cu, 38 ppm Pb, 2 ppm Ag, and no gold.

SW sec. 28, T51N, R60W. A sample from the dump of a caved adit consisted of silicified, pyritized and brecciated biotite schist. The sample assayed 0.335 ppm Au, and 0.7 ppm Ag (Gersic and others, 1990).

Placers. Several placers in the district have yielded varying amounts of gold (Hausel, 1989). Reeves (1980) reported that the Spottedtail and Sand Creek placers contained 0.06 to 0.14 ounces per cubic yard (oz/yd^3) Au, 0.31 to 1.34 pounds per cubic yard (lb/yd^3) Ta, 1.70 to 2.5 lb/yd^3 Sn, and 165 to 800 lb/yd^3 magnetite. The total amount of gravel was estimated at 1,305,000 cubic yards. Tests conducted by TRYCO suggested that these estimates were exaggerated (Rick Parent and Cheryl Parent, personal communication, 1989).

Southern flank of the Black Hills uplift

An occurrence of copper and gold is reported in NW sec. 27, T44N, R60W. The metals occur in a heavy mineral suite sampled from a breccia 37 feet below the top of the Permian part of the Minnelusa Formation (Epstein, 1958).

Ferris Mountains

The Ferris Mountains form a spectacular east-west-trending, Precambrian-cored anticlinal uplift of Laramide age near central Wyoming. Two blocks of Precambrian rocks are separated by a tightly folded syncline formed of Paleozoic and Mesozoic rocks. The southern flank of the range consists of Paleozoic and Mesozoic rocks that dip steeply to the south. Along the northern flank, the Paleozoics are truncated by faulting. Near the eastern extent of the range, the Precambrian complex is onlapped by Tertiary strata.

The Precambrian terrane is dominated by igneous rocks, including tonalite, granite, granodiorite, orbicular quartz diorite, monzonite, syenite, pegmatite, and mafic dikes. Many of these rocks are cut by calcite, quartz, and quartz-sulfide veins (Master, 1977). In the Miners Canyon area to the east, the section is dominated by metasedimentary rocks and minor ultramafic schist (Bowers, 1992) with impressive gossans in the vicinity of the Spanish mine (Hausel, 1992c).

Two types of sulfide mineralization were recognized in the Ferris Mountains by Master (1977). These are quartz-sulfide veins and disseminated sulfide mineralization in granodiorite porphyry associated with quartz veins. Much of the Ferris Mountains is part of a BLM roadless area. However, the eastern edge of the mountains, which includes Miners Canyon, is outside the roadless area.

Mines in the western Ferris Mountains

Babbs (Weidemeir) mine. SE sec. 26, T27N, R88W. The mine consisted of two adits, three open cuts, and a few prospect pits located on the headwaters of Cherry Creek. Discontinuous, north-trending, steeply dipping quartz veins occur within and adjacent to diabase dikes. The country rock granite and granodiorite has two prominent joint sets, one that strikes north and dips 80°E and a second striking N5°E and dipping 66°NW. Mineralized veins have the same attitude as the first set of joints (Wilson, 1955a).

Two types of mineralization are present–copper-quartz veins and disseminated pyrite-chalcopyrite in brecciated and silicified matrix (Wilson, 1955a). The veins carry scattered malachite, chalcopyrite, azurite, and bornite. One of the adits was driven 100 to 125 feet along a quartz-sulfide vein hosted by a mafic dike. The vein is 2 to 2.5 feet wide and can be followed on the surface for 350 feet before pinching out. Samples collected from the deposit assayed >1.0% Cu, 50 ppm to >1.0% $W0_3$, 0.01 opt Au, 1.5 to 15 ppm Ag, 10 to 50 ppm Sn, and 20 to 100 ppm Pb (Master, 1977). Samples collected by Neubert (1985) yielded 0 to 0.05 opt Au, 0 to 0.5 opt Ag, and 0.10 to 6.2% Cu.

Traces of scheelite and weak radioactivity due to allanite also were reported (Wilson, 1955a). Four samples collected by the Bureau of Land Management averaged 0.19% Cu. The maximum tungsten content was reported as 37 ppm WO_3. Samples collected from a dozer cut above the Babbs adit yielded a maximum 2.4 ppm Au, 6.0 ppm Ag, and 115 ppm WO_3 with an average copper content of 0.32% (U.S. Bureau of Land Management, 1983).

SE sec. 26, T27N, R88W. Six chip samples taken from a disseminated sulfide deposit averaged 0.18% Cu. A northwest-trending, 1.5-foot-wide vein cuts through this disseminated deposit. A sample of the vein assayed 32% Cu, 0.17 opt Au, 10 ppm Ag, and 100 ppm $W0_3$. The copper occurs as chalcopyrite with some malachite, bornite, and covellite (Master, 1977).

SW sec. 33, T27N, R87W. A sample collected from a 5-foot-wide quartz-sulfide vein at this locality assayed 300 ppm Cu and 20 ppm Co (Master, 1977).

SE sec. 24, T27N, R88W. A sample from a 5-foot-wide, steeply dipping vein assayed 0.15% Cu and 70 ppm Pb. Sheared granodiorite porphyry in the same area also was sampled. The sample from the 30-foot-wide shear was poorly mineralized and yielded only 30 ppm Mo, 150 ppm La, 70 ppm Ni, and 70 ppm Cu (Master, 1977).

W/2 sec. 36, T27N, R88W. A 5-foot-wide, malachite-stained vein was selectively sampled by Master (1977). The sample assayed 3000 ppm Cu, 0.30 ppm Au, 7 ppm Ag, and 7000 ppm WO_3.

SE sec. 4, T26N, R87W. A sample from a 3-foot-wide quartz-sulfide vein assayed 1500 ppm Cu and trace cobalt (100 ppm) (Master, 1977).

SE sec. 32, T27N, R87W. A sample of a 4-foot-wide, 75°W-dipping vein assayed >1.0% Cu, 3000 ppm As, 100 ppm Pb, 5 ppm (0.15 opt) Ag, and 0.20 ppm Au (Master, 1977).

NW sec. 30, T27N, R88W. A 1- to 2-foot-wide quartz-sulfide vein was sampled. The chip sample yielded >1.0% Cu, 10 ppm (0.29 opt) Ag, 200 ppm Ni, 100 ppm Co, and 0.03 ppm Au (Master, 1977).

Miners Canyon district

Mineralization

The Spanish mines occur in Miners Canyon near the eastern edge of the Ferris Mountains (**Figure 24**). Free-milling gold was found in oxidized quartz-pyrite veins in the Mathilda Jane adit on the Spanish Trails #2 claim around 1870, and a stamp mill was constructed on Sand Creek south of the mines (Haff, 1944d). The adits were driven on gossans in graphitic schist. Samples from the mines contained pyrite, chalcopyrite, arsenopyrite, bornite, galena, pyrrhotite, and malachite (Hausel, 1992c). In addition, Neubert (1985) reported sphalerite.

More than 100 samples were collected by Neubert (1985). These contained 0 to 6.51 ppm (0.19 opt) Au, 0 to 147 ppm (4.29 opt) Ag, maximum 28% As, maximum 4.8% Cu, maximum 2.8% Pb, and maximum 2.0% Zn. Some select ore samples collected in 1927 were reported by Osterwald and others (1966) to assay 31.7% Pb, 18.2 opt Ag, and 0.01 opt Au, and some very rich silver samples were reportedly found in this region prior to 1871 (Hausel, 1994a).

Miscellaneous mines and prospects

Done Moving prospect. S/2 NW sec. 5, T26N, R86W. Samples of cupriferous shear cataclastics collected from a mine dump near the remains of an old cabin yielded 0.87% Cu, 0.12% Pb, 0.03% Zn, 2.9 ppm Ag, and <5 ppb Au (Hausel, 1992c).

Mathilda Jane adit. E/2 E/2 sec. 6, T26N, R86W. The Mathilda Jane adit was driven 450 feet along a northwesterly trend (**Figure 25**). Near the mine face, a 120-foot drift was cut along a S70°W trend (Haff, 1944d). Samples collected in the mine by the author included chloritic schist from the rib (**Plate 2C**) in the drift that yielded no detectable gold or silver, and arsenopyrite-bearing quartz from a muck pile that assayed no gold, 4.1 ppm Ag, and 1330 ppm As (Hausel, 1992c).

Spanish Trails #1 prospect. E/2 E/2 sec. 6, T26N, R86W. Samples of graphitic schist with quartz-pyrite veins were sampled. Three of the samples assayed <5 to 6 ppb Au and 1.5 to 5.4 ppm Ag (Hausel, 1992c).

Spanish Trails #4 adit. E/2 E/2 sec. 6, T26N, R86W. Located a short distance upstream from the Mathilda Jane in the east bank of Miners Canyon. An adit was driven 260 feet along a S80°E trend (Haff, 1944d).

Spanish Trails #4 prospect. E/2 E/2 sec. 6, T26N, R86W. Haff (1944d) reported that a small pit with a shallow shaft in the ridge top east of Miners Canyon (probably on the Spanish Trails #4 claim) exposed several narrow N30°W-trending quartz veins in sheared amphibolite. Some galena was found on the surface.

In the bottom of the shaft, the vein is 2 feet wide and consists of massive galena with some pyrite, chalcopyrite, limonite, and traces of malachite and azurite in a gangue of quartz, epidote, and actinolite (Haff, 1944d). A sample collected from the dump yielded 164 ppb Au, 313.9 ppm (9.15 opt) Ag, 2.72% Cu, 7.67% Pb, and 0.58% Zn (Hausel, 1992c).

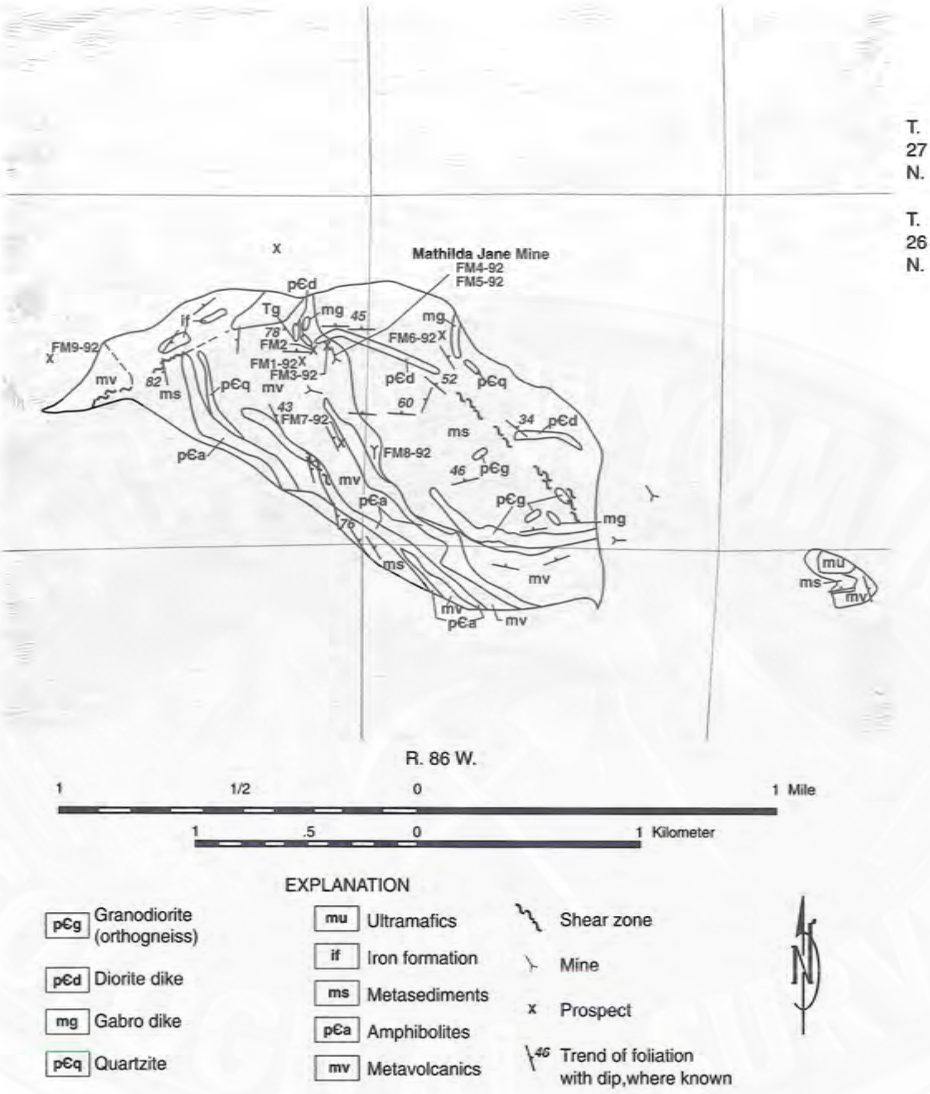


Figure 24. Geologic map of the Miners Canyon district, Ferris Mountains (T26-27N, R86W)(modified from Bowers, 1992).

Spanish Trails #8 prospect. W/2 W/2 SW sec. 5, T26N, R86W. Probably on the Spanish Trails #8 claim. A sample of pyrrhotite-bearing metavolcanic rock from a mine dump of an adit driven in the southeastern wall of the southern branch of Miners Canyon assayed 6 ppb Au and 0.9 ppm Ag (Hausel, 1992c).

NE sec. 6, T26N, R86W. A sample of copper-stained granodiorite collected from an inclined shaft yielded 6.65% Cu, 0.004% Pb, 0.02% Zn, 26.4 ppm Ag, and 390 ppb Au (Hausel, 1992c).

Granite Mountains

The Granite Mountains of central Wyoming form an east-west-trending belt of Archean rocks immersed in Cenozoic sedimentary rocks and associated unconsolidated sediments. The Precambrian terrane is divided into three major units (1) a complex belt of amphibolite-grade metamorphic rocks exposed along the northwestern and northern margins of the Granite Mountains in the Tin Cup and Rattlesnake Hills-Barlow Gap areas; (2) granites (2640 and 2600 Ma) exposed in the center of the uplift; and (3) late intruding tholeiitic basalt dikes that cut both the granites and metamorphic rocks. The dominant trend of the dikes is northeast (Stuckless and Peterman, 1977). Along the northern edge of the Granite Mountains, Tertiary (40 to 44 Ma) alkalic phonolites, latites, and related volcanics cut Precambrian rocks in the vicinity of the Rattlesnake Hills (Pekarek, 1977).

Figure 25. Limonite-stained mylonite in the Mathilda Jane adit, Miners Canyon district, Ferris Mountains.

The metamorphic belt in the Granite Mountains consists of a group of metavolcanic schists and gneisses that were metamorphosed to amphibolite grade at about 2.9 Ga (Peterman and Hildreth, 1978). However, the Sr^{87}/Sr^{86} ratios are unusually high for rocks of this age. To explain these high ratios, it is assumed that these rocks may have formed as much as 3.2 to 3.3 Ga ago (Peterman and Hildreth, 1978). These rocks also exhibit local effects of retrograde metamorphism.

The metamorphic rocks have steep, southerly dipping, northeasterly to easterly foliation trends. The complex consists of quartzofeldspathic gneiss, augen gneiss, epidote gneiss, biotite gneiss and schist (metagreywacke), amphibolite and minor serpentinite, and banded iron formation (Peterman and Hildreth, 1978). In the Barlow Gap-Rattlesnake Hills area, both oxide- and silicate-facies banded iron formation have been reported (Bickford, 1977). In the Tin Cup supracrustal belt, massive sulfides occur in hematitic iron formation.

Mineralization in the Granite Mountains includes copper, gold, and iron occurrences and a number of exotic ornamental stones and gemstones. Agates, jade, sapphires, and rubies occur at scattered localities in the uplift (Love, 1970; Sutherland, 1990).

Rattlesnake Hills

The Rattlesnake Hills greenstone belt consists of refolded Archean metamorphic rocks intruded by several Tertiary (42 Ma) alkalic plugs and dikes (Pekarek, 1977) (**Figure 26**). These rocks have been subjected to several episodes of deformation. According to Hausel (1996), three episodes of folding are recorded in the Precambrian rocks, and at least two later episodes of brittle deformation disrupted the greenstone terrane during the Phanerozoic.

The Precambrian greenstone belt is dominated by a thick metagreywacke succession that encloses 2000 to 5000 feet of metatholeiitic volcanics with minor metasediments including metagabbro, metabasalt, and uncommon graphitic schist and metachert. The metagreywackes are underlain by 2500 feet of metavolcanics dominated by well-preserved pillow metabasalts and amphibolites with minor intercalated ultramafics and intermediate metavolcanic schists. In the vicinity of three Tertiary alkalic plugs–Goat Mountain (**Figure 27**), Sandy Mountain, and Oshihan Hill, in secs. 23, 24, and 25, T32N, R88W–the metatholeiites and metagreywackes have been brecciated and are locally gossaniferous (**Figure 28**).

Mineralization

Samples of brecciated Precambrian rock along the flanks of the Tertiary plugs yielded 37 ppm to 0.14% Cu, <5 ppb to 925 ppb Au, 25 ppm to 1.65% As, and 0.012 to 0.078 ppm Hg. Samples of a breccia vein within this disrupted succession yielded 92 to 367 ppb Au (**Appendix A**). The Tertiary volcanics that disrupted the Precambrian rocks also are anomalous. Composite chip samples of volcanic rock collected along the flank of Sandy Mountain, a phonolitic plug, yielded 44 ppb and 370 ppb Au (Hausel, 1996). This area is considered to have good potential for low-grade, high-tonnage gold mineralization and is reported to contain a large gold resource with an average grade of 0.042 opt.

The mafic metamorphic rocks are underlain by a succession dominated by metasedimentary rocks containing banded iron formation, metapelite, and amphibolite. Samples of the banded iron formation yielded <5 ppb to 5.0 ppm Au. Other iron formation samples collected for whole-rock analysis yielded 15.62 to 64.74% Fe_2O_3 with 23.13 to 79.12% SiO_2.

The supracrustals lie in contact with gneiss along the southwestern flank of the belt; the gneiss has been fractured and rehealed producing a stockwork-like network of veinlets. A sample of the iron-stained gneiss yielded 300 ppb Au (Hausel, 1996). Based on field studies by the author, the Rattlesnake Hills has good potential for commercial gold deposits. The copper, lead, zinc, and molybdenum potential are considered poor.

Reported occurrences

Cowpie prospect. SW NE sec. 21, T32N, R87W. Along UT Creek, a sample of copper-stained brecciated schist yielded 1.5% Cu, 800 ppm Pb, and 8.0 ppm Ag (Pekarek, 1977).

Lost Muffler prospect. Sec. 16, T32N, R87W. The Lost Muffler prospect consists of several prospect pits dug in a 1.5-mile-long, sulfide-bearing metachert exposed in UT Creek near the center of the Rattlesnake Hills. The vein is hosted by metatholeiitic and graphitic schist and consists of quartz, metachert, minor jasperoid, pyrite, and uncommon galena. Samples collected in the vein yielded <0.2 to 2.0 ppm Ag, <5 ppb to 7.55 ppm Au, 38 ppm to 0.04% Cu, 11 ppm to 0.13% Pb, and <0.010 to 0.021 ppm Hg (Hausel and Jones, 1982; Hausel, 1993a, 1994c, 1996) (**Appendix A**).

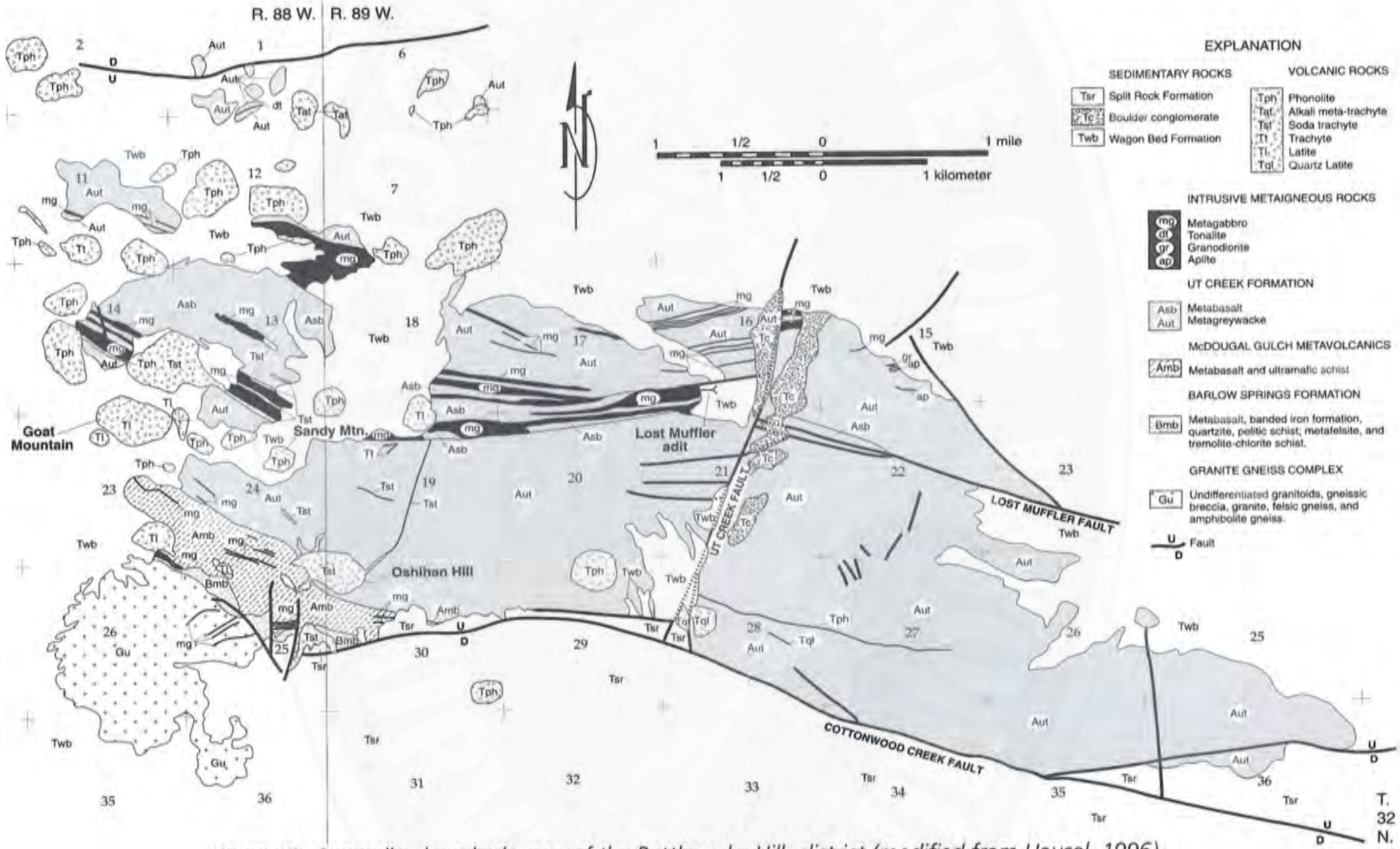


Figure 26. Generalized geologic map of the Rattlesnake Hills district (modified from Hausel, 1996).

Figure 27. The Goat Mountain alkalic plug is one of several volcanic features in the Rattlesnake Hills.

Figure 28. Brecciated and limonite-stained metagreywacke located near Sandy Mountain in the Rattlesnake Hills.

Tin Cup district

The Tin Cup district (also referred to as the Black Rock-Long Creek district) is located in the northwestern part of the Granite Mountains in Ts30 and 31N, Rs92 and 93W (**Figure 29**). The district is underlain by amphibolite-grade gneiss, schist, and amphibolite, all metamorphosed at 2860 Ma. The supracrustal complex was intruded by granite at 2550 Ma, which was followed by intrusion of diabase dikes a short time later (Peterman and Hildreth, 1978).

Mineralization

The principal development in the district occurred at the Sutherland (Red Boy) mine in the southeastern part of the district. The Sutherland contains massive pyrite (Hausel, 1989). Beeler (1907a) reported several gold prospects and one copper prospect in the district, which yielded gold values from 0.08 to 3.5 opt and up to 15% Cu. The mineralization was reported in schist, diorite, quartz veins, and jasper. The Tin Cup district includes three parallel faults with common jasperoids that are poorly mineralized. In addition to the jasper, the district encloses some localized prospects with minor copper stains, some massive pyrite, several jade deposits, and a 4000-foot-long ruby schist (**Figure 30** and **Plates 2D** and **2E**). A group of samples recently collected from the district included hematite-stained quartz, cupriferous schist, low-grade banded iron formation, and limonite-stained quartz breccia veins. These samples yielded 188 ppm to >2.0% Cu, 0 to 551 ppm Pb, 20 to 253 ppm Zn, 5 to 14 ppm Mo, 20 to 342 ppm As, 0.6 to 14 ppm Sb, 0 to 0.351 ppm Hg, 0 to 0.9 ppm Ag, and 0 to 10 ppb Au (W.D. Hausel, personal field notes, 1994) (**Appendix B**).

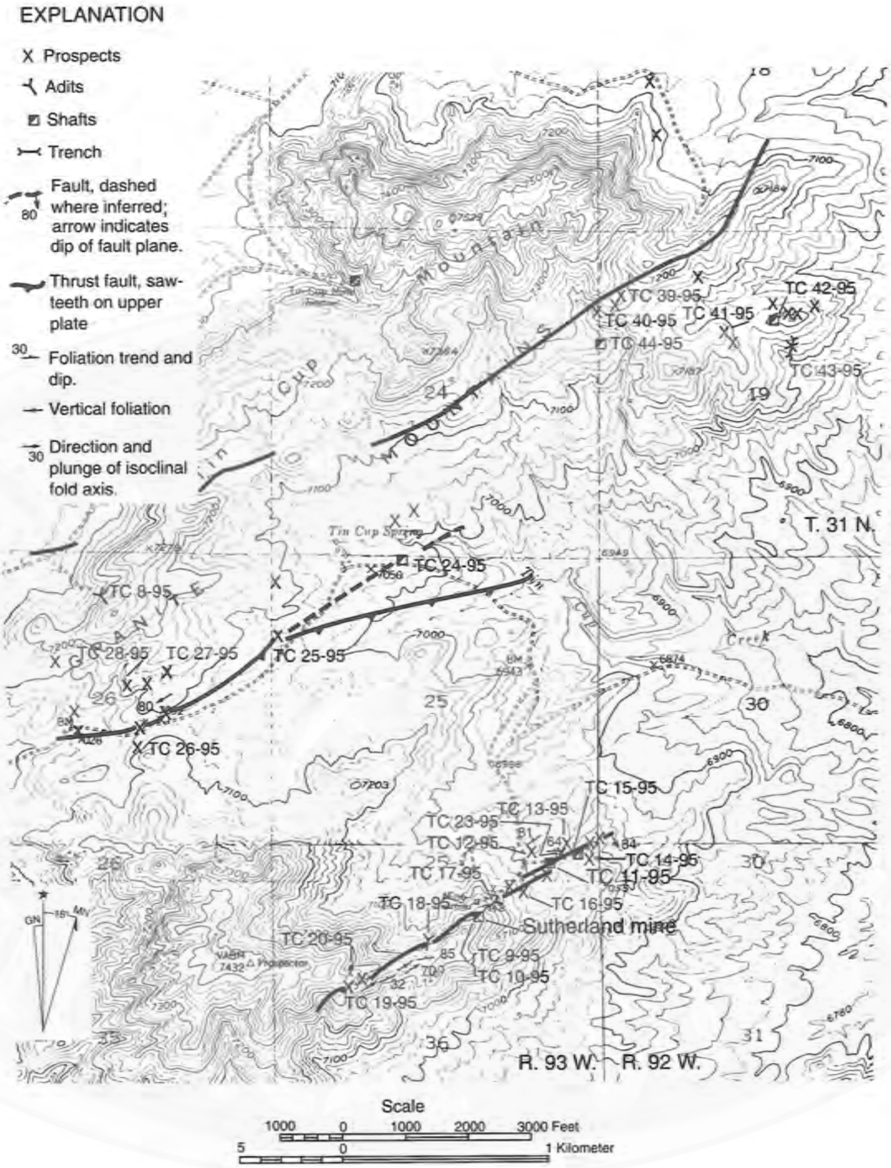


Figure 29. Map of the Tin Cup district showing sample locations and numbers, prospects, mines, and geologic structures. Analyses of samples collected are given in ***Appendix B.***

Reported occurrences

Lone Tree claims. Located east of the Queen Sheba claims (no legal description given). A shallow shaft cut a wide ledge of oxidized iron and quartz. Both copper and iron sulfides were noted in the 20- to 30-foot-wide ledge. One sample assayed 15.0% Cu and 3.5 opt Au (Beeler, 1907a).

Queen Sheba claims. Beeler (1907a) reported this property to lie somewhere at the west end of the district. A shallow shaft was sunk on a huge copper- and iron-stained quartz ledge. No assays were given by Beeler.

Prospect Pit TC19-95. NW section 36, T31N, R93W. This prospect lies along a prominent northeast-trending fault in Archean gneiss that has been traced on the surface for 5500 feet by the author (**Figure 29**). To the northeast of the prospect, the same structure contains jasperoid and massive sulfides at the Sutherland shaft. Copper mineralization is uncommon along the structure, although weakly copper-stained jasper in the prospect pit contains some malachite, azurite, tenorite, and uncommon chalcocite. A select sample yielded 1.71% Cu, 3.6 ppm Ag, 7 ppb Au, 74 ppm Zn, and 10 ppm Pb.

Figure 30. In addition to scattered copper occurrences in the Tin Cup district, there are common jasperoids, nephrite jade, and rubies. Although many of the jasperoids are red, some spectacular banded agates as shown also occur in the district. Width of view is approximately six inches.

Prospect Pit TC27-95. NE section 26, T31N, R93W. Samples of fault breccia from this prospect pit contain goethite, limonite, trace azurite, and minor jasper with calc-silicate veinlets. A sample of the breccia assayed 0.48% Cu, 0.5 ppm Ag, and trace lead and zinc.

Prospect Pit TC28-95. NE section 26, T31N, R93W. A short distance to the west of TC27-95, traces of copper stains were found in the breccia. A select sample yielded 0.29% Cu and trace lead and zinc.

Prospect Pit TC41-95. NW section 19, T31N, R92W. Butterscotch and red jasper contain vugs filled with botroyoidal quartz in a graphitic schist. A sample of the schist with jasper yielded 0.13% Cu, 694 ppm Zn, 43 ppm Pb, 11 ppm Mo, and 86 ppm As.

Prospect Shaft TC42-95. NW section 19, T31N, R92W. One thousand feet to the northeast, a shallow (8 feet deep) shaft exposed granular quartz in an iron-stained schist. A sample of the schist yielded 0.22% Cu, 336 ppm Zn, 26 ppm Pb, 38 ppm Mo, and 65 ppm As.

Gros Ventre Range

The Gros Ventre Range was uplifted during the Laramide orogeny and consists of a core of Precambrian rock overlain by Phanerozic sedimentary rocks. Scattered base metal occurrences are reported in the Gros Ventre Range (Harris and others, 1985). Molybdenum and gold were reported from two occurrences.

NW sec. 34, T40N, R113W. Molybdenite is reported in pods and fracture fillings in Precambrian granite near Swift Creek (Osterwald and others, 1966).

Bartlett mine. Located in T38N, R111W. Auriferous pyrite was apparently recovered from the Bartlett mine on Bartlett Creek in the early 1900s. The adit was driven in Chugwater Formation sedimentary rocks. Samples of pyrite from the ore bin stockpile were assayed and yielded up to 2.8 ppm Au (Antweiler and others, 1977).

Hartville uplift

The Hartville uplift of Platte, Goshen, and Niobrara Counties contains resources of copper, zinc, silver, iron, and beryl (**Figures 1** and **31**). Copper occurs in vein deposits, associated with hematite in Precambrian schists, as replacement deposits along unconformities between the underlying Precambrian schists and overlying Paleozoic limestones, and associated with zinc in metasedimentary-hosted massive sulfide deposits and unconformity deposits.

The uplift is formed of eugeoclinal metasedimentary and metavolcanic rocks. Excellent pillow basalts are exposed in a canyon wall east of the Michigan mine in Goshen County, and stromatolitic dolomites occur east of the Guernsey Stone Company quarries and south of the Sunrise iron mine in Platte County (Snyder and others, 1989). The supracrustal rocks are Archean in age (Snyder, 1980), although previous investigators reported the metamorphics to be Proterozoic (Millgate, 1965a).

According to Ball (1907), lenses of copper in Precambrian metacarbonate were generally localized within 50 feet of the base of the overlying Devonian-Mississippian Guernsey Formation but usually gave out within the first 20 feet. This ore occurred in veinlets along bedding planes accompanied by brecciation. Its close association with iron-stained rock or hematite suggests that the iron acted as a precipitant.

Other copper lenses were found in schist, quartzite, and jaspery rocks. This ore also was limited at depth and often extended downward from the blanket deposits in the Guernsey Formation. Copper also occurred in lenses in iron ore (hematite) deposits and in heavily iron-stained jasper. Copper in the hematite and jasper was developed at the Sunrise iron mine, which was initially mined for copper during the 1880s until the copper was mined out. Later, in the early 1900s, the mine became the largest iron ore producer west of the Mississippi River for many years (Dyck and others, 1994).

The blanket deposits at the base of the Guernsey Formation occur as lenticular to tabular masses in sandstone. These extend horizontally but have no appreciable vertical extent and do not extend into the overlying limestone beds of the Guernsey Formation. In many places, stringers of ore extend down from the Guernsey sandstone at the Guernsey-Precambrian unconformity, into the Precambrian crystalline rocks. These deposits are generally less than 3 feet thick but locally are as thick as 20 feet where copper extends down into Precambrian limestone and dolomite. At some localities, the copper was concentrated and enriched in pockets along a paleokarst surface (Ball, 1907). Copper-zinc-silver and minor gold occur in some metasedimentary, massive sulfide deposits.

Ore minerals reported by Ball (1907) include malachite, azurite, chrysocolla, chalcocite, tennantite(?), native copper, bornite, covellite, cuprite, and chalcopyrite. Ball (1907) also reported that gold values from iron-stained schist were closely associated with copper at several localities in the uplift.

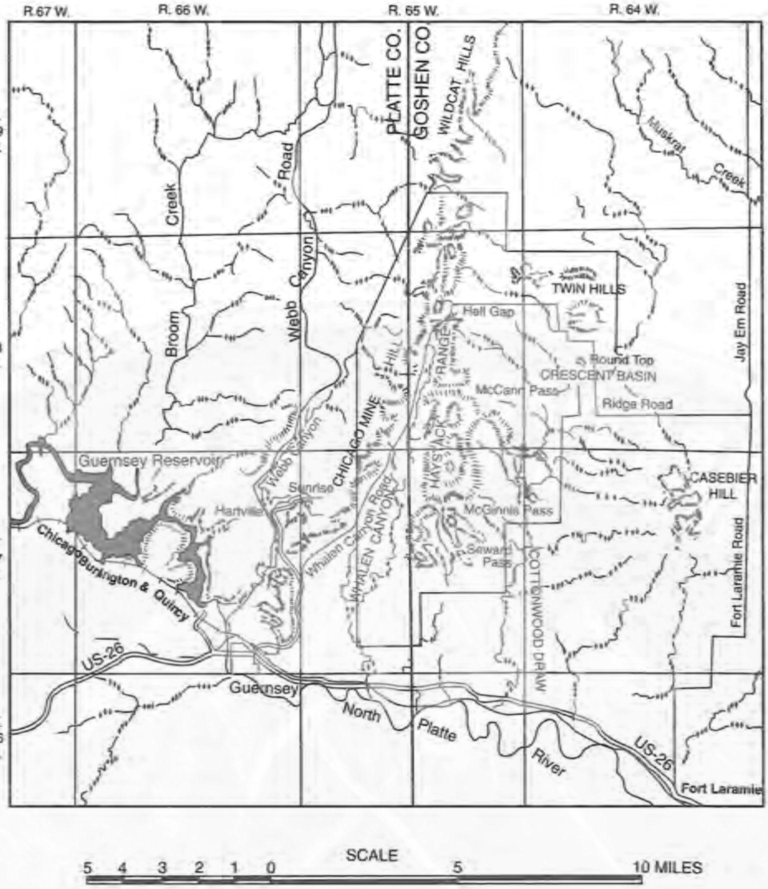


Figure 31. Index map showing geographic features in the southern Hartville uplift (from Millgate, 1965a).

Haystack Range

Mineralization

Copper was mined from the Haystack Range in the southern portion of the Hartville uplift, principally from the massive hematite deposits found in the region. Copper is widely distributed throughout the Precambrian terrane, in faults, along unconformities, and in the basal arkose of the Guernsey Formation. Much of the area surrounding the hematite orebodies became known as the Hartville mining district. The Hartville district includes four iron ore mines–Sunrise, Central, Chicago, and Good Fortune (**Figure 32**) (Hausel, 1989).

Mines and prospects

Green Mountain Boy. Located 0.5 mile east of the town of Guernsey at the head of a broad valley. According to Ball (1907), production from the Green Mountain Boy

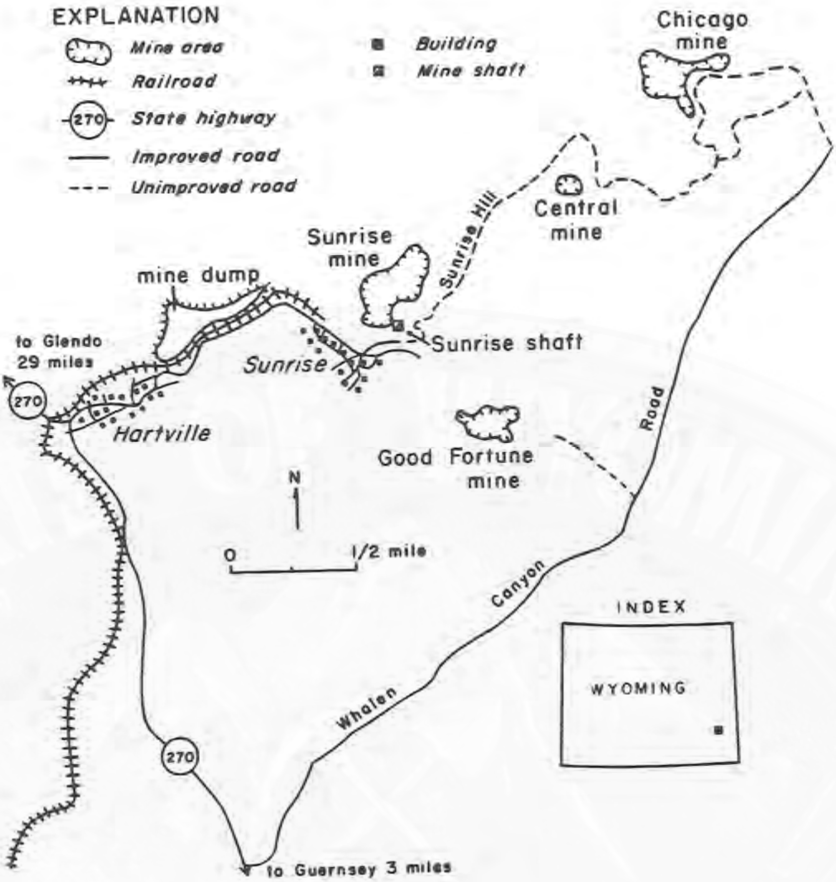


Figure 32. The Sunrise, Central, Chicago, and Good Fortune mines near Hartville. These were initially developed as copper prospects. At shallow depth, the copper values disappeared, leaving high-grade hematite ore which was mined for nearly one hundred years.

amounted to 300 to 500 tons of ore containing an estimated 60,000 to 100,000 pounds of copper. Ore produced prior to 1907 averaged 37% Cu with 0.3 to 0.5 opt silver for each percent of copper

Mineralization is localized in the upper part of a limestone in the Guernsey Formation. The copper occurs as low-temperature replacement deposits in the limestone. Where mineralized, the limestone contains lenticular masses of brown flint nodules 2 inches to 4 feet long and up to 6 inches wide.

The chalcocite lens mined on the Green Mountain Boy property was reported to have originally been 60 feet long, 30 feet wide, and 5 to 9 feet thick. A few stringers led out from the main orebody, but no other ore was noted except for scattered patches of malachite in limestone. The deposit is distinctly limited at depth and scarcely a copper stain is visible 20 feet beneath the chalcocite blanket (Ball, 1907; Osterwald and others, 1966, p. 60).

Native copper nuggets were found in sand and gravel near the deposit. Some nuggets weighed as much as 25 to 30 pounds. In the shaft, Hagner (1942b) found 28 feet of sand and gravel, 6 to 7 feet of quartzite and phonolite(?), with occasional pockets of ore. Dump material included chrysocolla, malachite, cuprite, and chalcocite.

Sunrise mine. Sec. 7, T27N, R65W. The Sunrise mine initially was developed for copper in the 1880s. Later, mine operations exploited the vast hematite resources associated with the copper mineralization, and the mine became the leading iron ore producer west of the Mississippi River until 1944. Iron ore continued to be mined until 1981, when operations terminated.

Hematite was localized in a steeply plunging synform within the Silver Springs Schist (Archean) near its contact with the overlying Wildcat Hills Dolomite (Archean) (Snyder and others, 1989). The orebody continued to a depth of 1000 feet and covered a surface area of 2100 feet by 50 to 600 feet (Engineering and Mining Journal, 1974). The hematite was preferentially localized where the overlying dolomite was thinnest and the schist was silicified, suggesting that the hematite formed by groundwater leaching (Snyder and others, 1989).

Copper was found in lenticular masses in the overlying Guernsey Formation, which lies unconformably on Archean rocks. The mineralization continued downward into the underlying Precambrian hematite schist to shallow depths (less than 60 feet below the surface). Chrysocolla, malachite, azurite, chalcocite, and native copper filled lenticular or pear-shaped masses in the Precambrian hematite and jasper beneath a blanket of Guernsey limestone. The copper occupied joint planes and irregular fractures and cavities (Ball, 1907).

The copper mineralization disappeared at shallow depths, but the hematite persisted. As the copper was exhausted, hematite was mined for iron. Between 1880 and 1887, the mine yielded a total of 1,395,287 pounds of copper from ore that averaged 15% Cu and typically carried 2 to 3 opt Ag (Hausel, 1989). By 1900 the property was converted to an iron mine because of the exhaustion of the copper. However, between 1907 to 1919, an additional 6.4 million pounds of copper was shipped to the smelter at Fairbank, near Guernsey. The renewed production was the result of a discovery of a new copper orebody (Dyck and others, 1994).

Iron production from 1900 to 1981 totaled more than 45 million tons of hematite ore (Hausel, 1989; Dyck and others, 1994). At the termination of mine operations in 1981, the shaft was 860 feet deep, and ore haulage was on the 700-feet level. In 1974 the mine contained about 25 million tons of iron ore reserves (Engineering and Mining Journal, 1974), suggesting that possibly as much as 22 million tons of reserves remained *in situ* following closure of the mine in 1981.

Johosephat prospect. Sec. 12, T27N, R66W. A small amount of malachite was found mixed with siliceous dolomite enclosing hematite schist (Osterwald and others, 1966).

NE sec. 36, T27N, R66W. Ball (1907) reported sandstones in the Pennsylvanian Hartville Formation were locally stained by malachite.

SW NW sec. 13, T27N, R66W. A small prospect pit exposed a copper-stained unconformity between underlying Precambrian dolomites and overlying quartzite and limestone of the Devonian-Mississippian Guernsey Formation. In the early 1980s, Kerr-McGee Corporation explored the unconformity and intersected some local silver-rich zones. Cerargyrite (AgCl), umangite (Cu_3Se_2), electrum, and native gold were all identified from samples (Leedy, 1988).

Center of NE sec. 26, T27N, R65W. This could possibly be located in T28N, R65W near Haystack Peak. Chalcopyrite and chalcocite cement breccia are found in a schist. The mineralized breccia also carries trace silver. Neither gold, cobalt, nor nickel were detected (Ball, 1907, p. 97).

McCann Pass

A number of copper prospects occur in the McCann Pass area. McCann Pass is located within 5 miles northeast of the Hartville district and forms an east-west-trending fault valley that hosts some impressive gossans (**Figure 33**). The northern side of the pass contains outcrops of granite intruding mica schist; steeply dipping mica schists crop out on the southern side of the pass (Millgate, 1964). Several prospects associated with the gossans are found at the pass.

Charter Oak mine. According to Ball (1907), this mine is located near the center of SE sec. 26, T27N(?), R65W on the south side of McCann Pass. However, McCann Pass lies within T28N, R65W.

The Charter Oak shaft was sunk in a cupriferous gossan in muscovite schist and quartzite. Malachite, chrysocolla, and chalcocite occur in fractures and in a 4-foot-wide vein that crosscuts the vertically dipping schist. The altered schist adjacent to the vein yielded values of 0.04 to 1.4 opt Au and 2 to 5 opt Ag (Ball, 1907). Two samples collected in 1988 from a mine dump, assumed to be the Charter Oak mine, in McCann Pass assayed 8.6% and 1.4% Cu, 11 ppm and 50 ppm Zn, and no detectable Au or Ag (Hausel, 1990b).

Figure 33. "Gossan Hill" at McCann Pass contains some impressive gossans and massive sulfides exposed in shafts and prospect pits. The shaft in the foreground contains abundant sulfides on the mine dump.

Gossan Hill area. SW sec. 23, NW sec. 26, and E/2 sec. 27, T28N, R65W. A widespread gossan is localized along the McCann Pass fault (**Figure 34**). The largest exposed gossan (in sec. 27) is a 3000-foot-long by 300-foot-wide lens-shaped area consisting of various rock fragments cemented by spongy to massive iron oxides. The other two gossans are smaller and less brecciated, but likewise are stratabound in character (Zahony, 1976). Another extensive gossan in sec. 26, nicknamed "gossan hill" because of the pronounced gossan derived from the oxidation of massive sulfides (principally iron sulfides), has been tested by a group of shafts (Hausel, 1989).

Outcrop and shallow drillhole samples from the largest gossan in McCann Pass yielded 20 to 300 ppm Cu, 200 to 900 ppm Zn, and 500 to 7000 ppm As (Zahony, 1976). At one locality, massive pyrrhotite, disseminated pyrite, and malachite were found in graphitic schist.

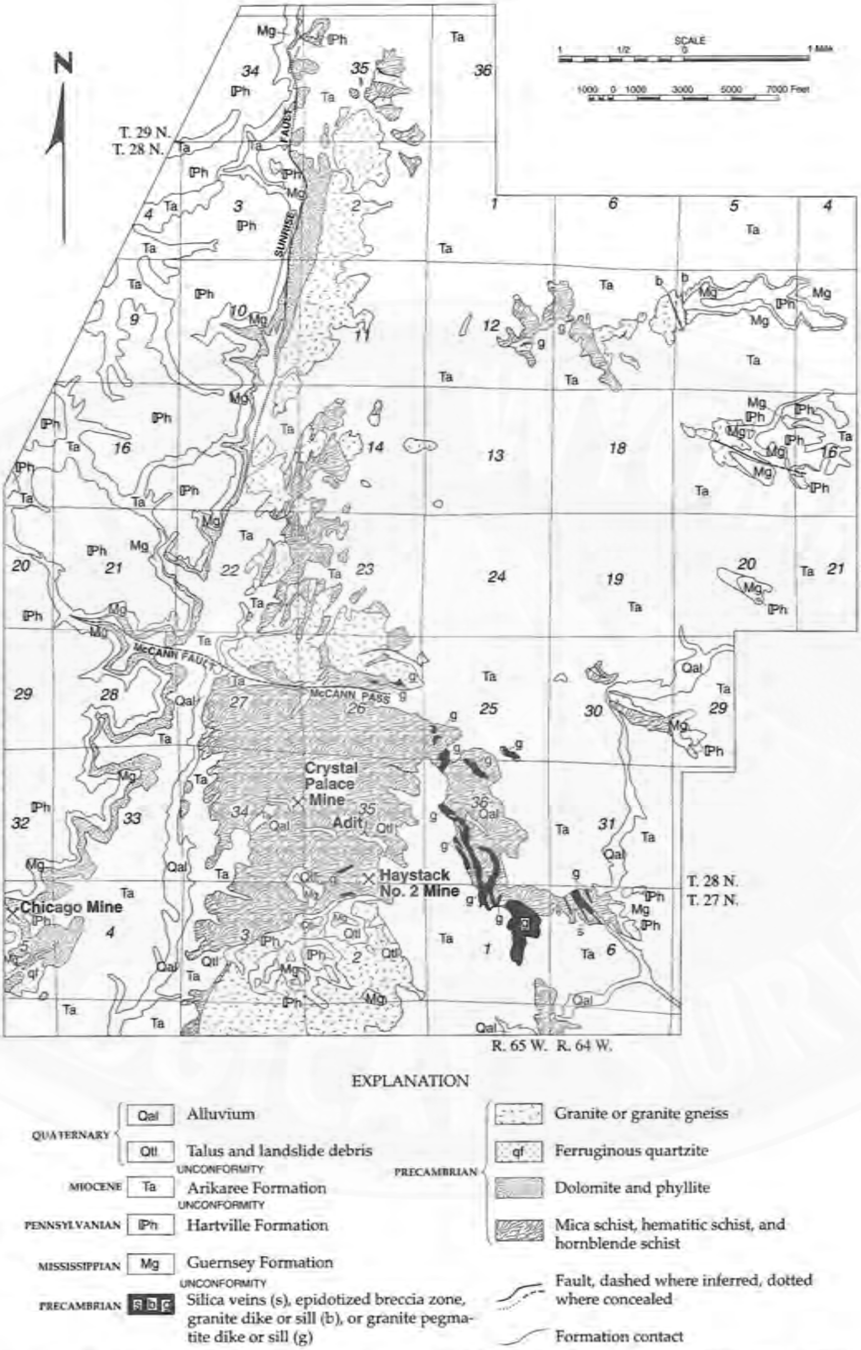


Figure 34. Geology of McCann Pass, Hartville uplift, Wyoming (T28N, R65W)(modified and adapted from Millgate, 1965a).

Two strong electromagnetic anomalies were detected parallel to the McCann Pass fault with one of the anomalies overlying the fault. Exxon Minerals Company drilled the anomalies and intersected a 10-foot zone averaging 0.8% Zn. Another hole cut through a 2-foot mineralized zone that averaged 1.2% Zn and 0.08 opt Au (Woodfill, 1987). The geophysical, geochemical, and geological evidence available on the McCann Pass prospects indicate the presence of a massive sulfide deposit hosted by metasedimentary rocks. Such a massive sulfide could contain significant amounts of zinc, copper, silver, lead, and gold (Zahony, 1976; Woodfill, 1987).

Rawhide Buttes

A group of mines known as the Copper Belt mines was developed in the Rawhide Buttes area in the northern portion of the Hartville uplift. The mines were the Gold Hill, Omaha, and Lucky Henry mines and the Emma open cut. Country rock in this area consists of Precambrian dolomite interbedded with mica schist and quartz sills, all unconformably overlain by tuffaceous rocks of the Miocene Arikaree Formation (Tertiary). The mines are located along the flanks of a synform in Precambrian metasedimentary rocks (Millgate, 1965a) (**Figure 35**).

Emma open cut. Exact location unknown. A fracture zone exposed in the Emma open cut contains quartz lenses parallel to the regional schistosity. The quartz stringers are mineralized with malachite, chrysocolla, azurite, chalcocite, and chalcopyrite. Samples from the open cut averaged 3 to 30% Cu. Masses of chalcocite weighing up to 47 pounds were also found (Ball, 1907).

Gold Hill and Omaha shafts. Probably located in the S/2 sec. 2, T30N, R64W. These shafts were sunk on a 7- to 20-foot-wide band of schist between two limestone(?) beds (probably metadolomite). A well developed "S" fold lies between the two shafts.

The Gold Hill workings exposed a 6-foot vein with 2 feet of iron-stained footwall schist. *The Mining Reporter* (October 26, 1905, p. 431) reported the ore assayed 6% Cu and 0.3 opt Au. The iron-stained schist assayed 0.2 opt Au (Ball, 1907). Veinlets of malachite, chrysocolla, and lesser chalcocite were found within the vein. Fractures in a shattered quartz vein parallel to the schistosity contained stringers and masses of chalcocite and bornite partially altered to malachite, chrysocolla, and azurite.

The Omaha shaft has malachite, azurite, chalcocite, and chrysocolla, with barite gangue in stringers both parallel and crosscutting the foliation of the schist. The zone of stringers is about 4 feet wide and assays as high as 2% Cu. The mineralized zone was traced for more than 200 feet on the surface (Ball, 1907).

Lucky Henry incline. N/2 sec. 11, T30N, R64W. The Lucky Henry incline was reported by Ball (1907) to be 288 feet deep. In 1909, the Copper Belt Mining Company reported the shaft to be 640 feet deep with 3500 feet of underground workings (Hall, 1909; Osterwald and others, 1966). The hanging wall of the mine is dolomite, and the footwall is iron-stained schist. The dolomite strikes N20°–30°E and dips 50°–70°SE.

Ore is localized in the schist adjacent to the hanging wall dolomite in two lens-shaped masses separated by barren schist. The lenses are 1 to 6 feet thick and continue from the surface downward to the bottom of the incline, at which point the mineralized zone is at least 15 feet thick.

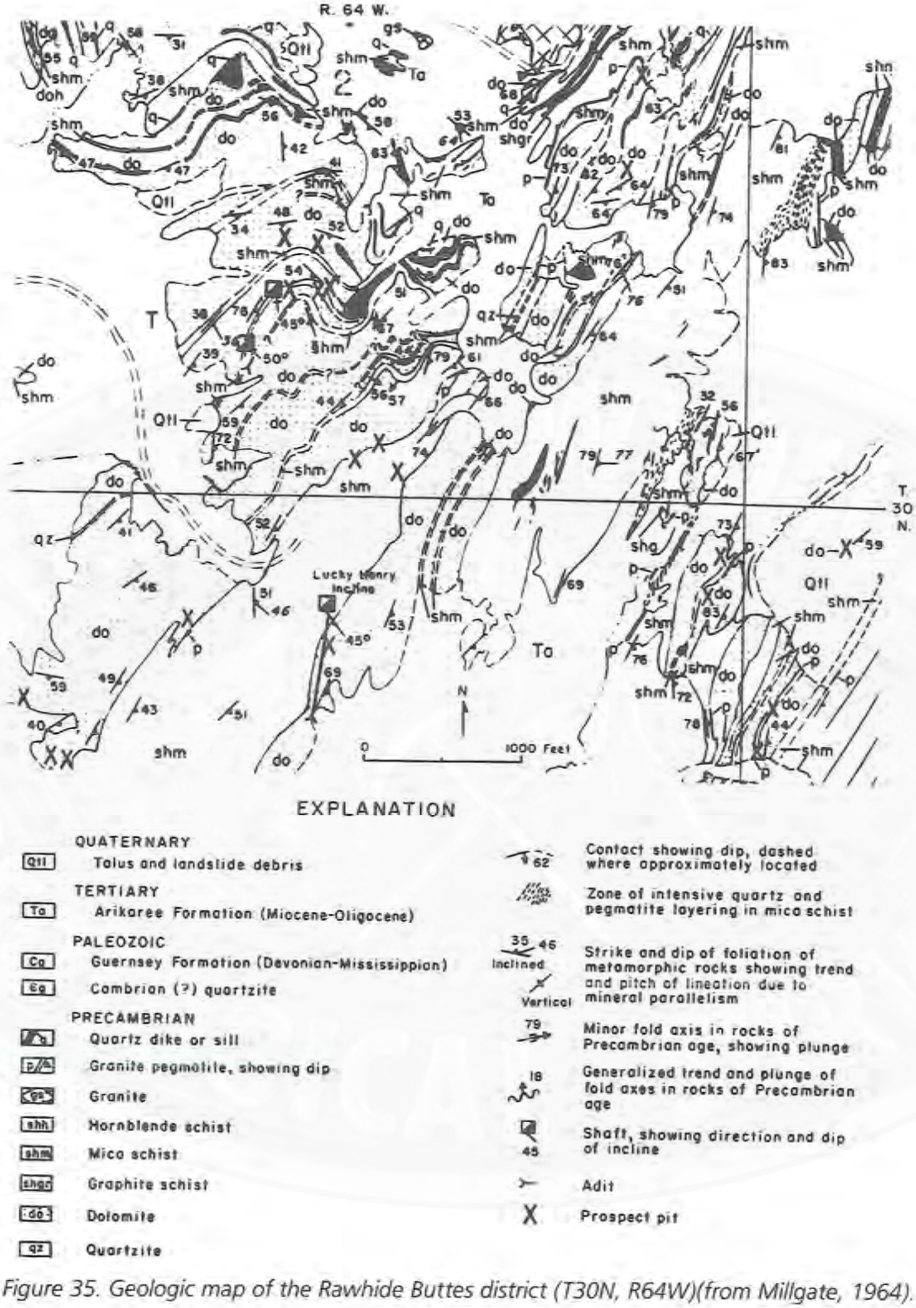


Figure 35. Geologic map of the Rawhide Buttes district (T30N, R64W)(from Millgate, 1964).

The mineralized lenses consist of ramifying veinlets and stringers of malachite, chrysocolla, and minor chalcopyrite. Chalcopyrite occurs only below 50 feet. Samples from the lenses are reported to assay from 2% to 8% Cu. The iron-stained schist surrounding the lenses assayed 0.05 to 0.58 opt Au (average 0.15 opt) and from 2 to 5 opt Ag (Ball, 1907).

Wildcat Hills area

Mineralization in the Wildcat Hills area is found in carbonates. Both Precambrian and Mississippian dolomites are reported to carry localized shows of copper. Copper occurs in fissure veins in the Precambrian rocks and is found along unconformities associated with paleokarst surfaces in Mississippian dolomites.

Copper Bottom claim. SE sec. 23, T29N, R65W. A claim was staked on a fissure vein in Precambrian dolomite cut by thin seams of hematite. The vein is vertical, strikes N20°W, is 4 inches wide at the surface, and swells to 22 inches wide at 15 feet below the surface. Assays yielded trace gold, 2 opt Ag, and 24.64% Cu. The principal copper minerals are chrysocolla and some malachite. Some irregular masses of tennantite [$(Cu, Fe)_{12} As_4 S_{13}$] were found (Ball, 1907).

Green Hope mine. NW sec. 26, T29N, R65W. A coarse, conglomeratic hematitic-stained sandstone at the base of the Guernsey Formation (Mississippian) overlies an uneven paleokarst surface on Precambrian dolomite that exhibits enlarged joint planes, sinkholes, and other solution features. Malachite, chrysocolla, azurite, and chalcocite replaced the cement in the sandstone and locally replaced carbonate pebbles. These minerals, as well as olivenite ($Cu_2AsO_4 \cdot OH$), fill fractures.

Mineralized sandstone and conglomerate average 3 feet thick, but in places the mineralization extends 20 feet below the normal contact into solution features on the Precambrian paleosurface. Tufted crystal aggregates of malachite and botryoidal masses of chrysocolla are found inside the solution cavities. White or yellowish calcite encrusts these minerals, and films of bluish-white chalcedony commonly cover the calcite. Thin stringers of malachite, chrysocolla, and azurite extend downward into the Precambrian dolomite (Ball, 1907).

A sample of cupriferous conglomerate assayed 9.74% Cu, 0.93 opt Ag, 0.04% Zn, and <0.01 opt Au (Hausel, 1983a). Mine production was estimated at 400 to 500 tons of ore at an average grade of 17% Cu. The ore ranged from 15 to 27% Cu (Ball, 1907).

Muskrat Canyon

Muskrat Canyon is an east-west-trending valley cutting through Archean and Phanerozoic rocks near the northern margin of the Hartville uplift. The canyon exposes a cupriferous iron formation near its western end at what is known as the Michigan mine. The iron formation is part of a gray to red, cross-bedded, siliceous to ferruginous quartzite near the base of the Muskrat Canyon Formation (Archean). This unit is overlain by a gray tremolite dolomite member of the formation. Amphibolites and metabasalts of the Mother Featherlegs Metabasalt (Archean) crop out above the Muskrat Canyon Formation, and near the eastern end of the canyon these rocks are well exposed and include well-preserved pillow metabasalt. The Archean rocks in this area are unconformably overlain by Guernsey Formation (Mississippian) limestone and dolomite, which in turn are overlain by Hartville Formation sandstone and quartzite (Pennsylvanian or Mississippian) (Snyder, 1980).

Michigan mine. NW sec. 24, T30N, R65W. A 300- to 350-foot-thick hematitic iron formation is structurally overlain by sericitic metachert. Iron deposits form part of the Muskrat Canyon Formation (Archean). The Archean complex, in turn, is unconformably overlain by Guernsey Formation limestone, which dips gently to the west (**Figure 36**).

Copper is found in both the Archean iron formation and in the overlying Guernsey limestones. The iron formation progressively becomes more sheared, cupriferous, and silicified to the west in the direction of the metachert, where malachite and chrysocolla stain the iron formation. Two assayed samples of cupriferous iron formation yielded 0.76 to 1.08% Cu, 14.0 to 21.0% Fe, and no detectable gold or silver (Hausel, 1983a).

The iron formation was separated into two orebodies by Colorado Fuel and Iron Corporation. The northern orebody was estimated to contain 75.5 million tons of ore averaging 25.3% Fe, and the southern orebody was estimated to contain 41 million tons of ore averaging 24% Fe (Wilson, undated).

Significant magnetic and conductivity anomalies were identified in association with this deposit, and according to Woodfill (1987), the deposit exhibits similarities to the Broken Hill and Black Mountain massive sulfide orebodies in South Africa. The Broken Hill and Black Mountain deposits are giant, stratiform, lead, silver, zinc, and copper massive sulfides associated with isoclinally folded Proterozoic quartz schists and iron formation. The apparent similarities between the South African and the Michigan mine deposits should make this area an attractive exploration target.

The overlying Guernsey limestone near the Michigan mine is cupriferous along the unconformable contact with the underlying iron formation. The mineralized zone is narrow and ranges from less than 1 inch to 1 foot wide where the limestone has been replaced by malachite and chrysocolla. Copper production from the Michigan mine is estimated at 200,000 to 400,000 pounds of copper. Only a small amount of iron was produced.

Lusk area

This area lies near the extreme northern margin of the Hartville uplift adjacent to the town of Lusk. The Silver Cliff mine at the western edge of the town site produced uranium in the 1920s and again in the early 1950s. Some copper, silver, and gold also were recovered from this area in 1879 and the early 1880s.

Silver Cliff mine. Sec. 7, T32N, R63W. Located at the top of a hill on the west edge of Lusk. Most of the hill consists of Precambrian metamorphic rocks (muscovite schist interbedded with thin lenses of limy schist) unconformably overlain by calcareous Flathead(?) Sandstone or possibly Guernsey(?) Formation sandstone. The sandstone dips southeast.

Following the discovery of silver-copper-gold mineralization in 1879, a 285-foot-deep shaft was sunk, and a 1200-foot inclined adit was driven to the bottom of the shaft. Five levels were established with at least 1600 feet of drifts.

The ore consisted of native copper, native silver, chalcocite, malachite, azurite, cuprite, chrysocolla, metatorbernite, uranophane, gummite, and pitchblende in calcite, limonite, and clinozoisite gangue. The mineralization lies within and adjacent to a high-angle reverse fault that strikes N15°E (Wilmarth and Johnson, 1978). It also

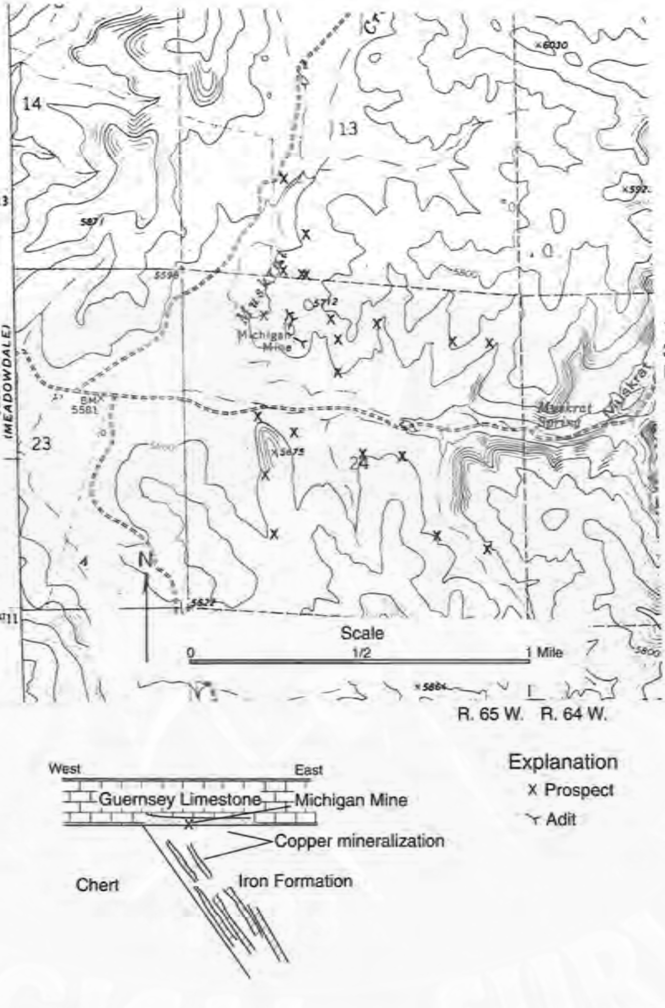


Figure 36. Location map and generalized cross section of the Michigan mine (T30N, R65W).

occurs as a blanket deposit in iron-stained sandstone at the base of the Paleozoic rocks adjacent to the mineralized fault.

The mine was opened in 1880 and worked on a small scale for copper and silver until 1884. Later, uranium was discovered. Between 1918 and 1922, six carloads containing more than 3% U_3O_8 were shipped to the Radium Company of Denver, Colorado. Following a period of inactivity, minor amounts of uranium were recovered from 1951 to 1953 (Bromley, 1953).

Osterwald (1950) reported some select samples from the mine contained 0.5 opt Au. Wilmarth and Johnson (1953) collected several samples that yielded <0.02 to 10.88% Cu, 0.16 to 15.04 opt Ag, and 0.001 to 3.39% U_3O_8.

Fred Sullivan mine. NW sec. 6, T33N, R63W. Foliated mica schists intruded by several pegmatite sills strike N4°E and dip 70°–80°SE. A 30-foot-thick mineralized zone, conformable with the attitude of the schists, was exposed in several prospect pits and shafts over a strike length of 150 feet. Abundant malachite with sparse chrysocolla, azurite, and chalcocite occur as fracture coatings and disseminations in the pegmatite and schist. Malachite is most abundant along the pegmatite-schist contacts and preferentially occurs more commonly in coarsely grained schist. Gangue minerals include limonite, quartz, chlorite, epidote, dravite, hematite, and schorlite. Mineralized samples from the property are weakly radioactive (Berosi, 1953).

About 300 feet north of this zone, an adit was driven near a granite-schist contact. The adit trends N6°E parallel to the foliation of the mica schist (Osterwald and others, 1966, p. 56).

Silver Springs prospects. Secs. 26, 27, and 34, T32N, R64W; and sec. 3, T31N, R64W. In 1984, Exxon Minerals drilled a gossan in the Silver Springs Schist and intersected anomalous zinc at depths between 244 and 425 feet. One 5-foot zone averaged 950 ppm Zn and 0.03 opt Au. The mineralization is closely associated with a strong electromagnetic anomaly (Woodfill, 1987).

Laramie Mountains

The Laramie Mountains form an elongate north-south anticlinal uplift cored by Precambrian rocks and flanked by upwarped Phanerozoic sedimentary rocks. Along the western flank of the range, the Phanerozoic rocks unconformably overlie Precambrian basement and dip at low angles into the Laramie and Shirley Basins. On the eastern flank, pre-Tertiary sedimentary rocks generally dip steeply into the northern Denver-Cheyenne Basin and in places are overturned and locally overthrust by Precambrian crystalline rocks. Locally, Phanerozoic rocks contain scattered low-temperature copper-silver replacement deposits (Harris and Hausel, 1984). Within the Precambrian core, several mining districts and mineralized areas are recognized, including Casper Mountain, Deer Creek district, Elmers Rock greenstone belt, Esterbrook district, Garrett (Sellers Mountain), LaPrele, Silver Crown district, and Warbonnet district.

Precambrian rocks of the Laramie Mountains are divisible into a southern Proterozoic province (Colorado Province) and a northern Archean terrane (Wyoming Province). These terranes meet near the center of the Laramie Mountains where a 350-square-mile anorthosite batholith intrudes the projected trend of the Mullen Creek-Nash Fork shear zone. The anorthosite is dated at 1.42 Ga (Subbarayudu, 1975) to 1.53 Ga (Smithson and Hodge, 1972).

The Colorado Province consists of amphibolite-grade mafic to intermediate metavolcanic and associated metasedimentary rocks that are about 1.8 Ga (Peterman and others, 1968). These rocks were intruded by 1.39 to 1.25 Ga granite, which includes the Sherman Granite and related felsic phases (Peterman and others, 1968).

Archean rocks in the central and northern Laramie Mountains (Wyoming Province) include gneiss, migmatite, granite, and supracrustal successions of metasedimentary and metavolcanic rock. Gneisses and migmatites in this region have been radiometrically dated at about 2.9 to 3.0 Ga (Johnson and Hills, 1976). Granites in this terrane typically date between 2.54 and 2.65 Ga. The metavolcanic and metasedimentary supracrustal successions are interpreted to overlie the gneisses and were intruded by granite. Thus the ages of the supracrustal belts are bracketed by the older gneisses and the younger granites (Graff and others, 1982). Granites that fold and dome the supracrustal belts have been dated at 2.54 Ga (Hills and Armstrong, 1974).

Copper and associated metals in the northern Laramie Mountains are found near Esterbrook on the north flank of Laramie Peak. These deposits include several copper-pyrrhotite deposits and some lead and zinc occurrences. The principal deposits are located in pendants of Archean metasediments and metavolcanics.

The Deer Creek, LaPrele, and Warbonnet districts occur principally in potassic granite and gneiss intruded by mafic (diabase) dikes. Probably the most significant base metal deposits in the Laramie Mountains are located in the Silver Crown district in the southern part of the range.

Casper Mountain

Casper Mountain forms the northernmost tip of the Laramie Mountains immediately south of the city of Casper. This portion of the range consists of a supracrustal belt of mica-quartz-feldspar gneiss, quartz-feldspar gneiss, amphibolite, quartzite, serpentinized cumulate peridotite, magnetite-talc-chlorite schist, and related metamorphic rocks (**Figure 37**). These rocks are intruded by mafic sills and dikes and granodiorite, granite, and granite pegmatites. Casper Mountain was affected by amphibolite-grade metamorphism at 2.7 to 2.8 Ga (Burford and others, 1979). Mineralization includes beryl and feldspar pegmatites, copper-stained sandstone and limestone in the overlying Phanerozoic rocks, gold and silver in the Precambrian rocks, and magnetite and chromite associated with the serpentinized peridotite cumulates (Hausel, 1989, 1993d). Overall, copper, zinc, lead, and molybdenum are lacking on Casper Mountain, and the greatest economic potential appears to be related to mineralization associated with the peridotites.

Some peridotites on Casper Mountain are chromite bearing, with local lenses of 2 to 25% Cr_2O_3. Samples of the cumulate peridotite and talc-chlorite schist collected by the author yielded 16.5 to 35% MgO, 0.6 to 17.01% Cr_2O_3 and 225 to 1456 ppm Ni (W.D. Hausel, personal field notes, 1992). Drilling by the U.S. Bureau of Mines identified 575,000 tons of 8.7% chromite ore, with a resource of 4.16 million tons of 2.5% chromite ore (Hausel, 1987a).

In 1892, the Zahn Syndicate sunk a 28-foot-deep shaft in copper-stained limestone on the south flank of Casper Mountain on the Blue Cap and Cross Fox properties (Molker, 1923). No information was given on the grade or extent of the mineralization. Examination of a copper-stained limestone (assumed to be the Blue Cap deposit) by the author showed only localized mineralization. According to the *Wyoming Industrial Journal* (1906, v. 7, p. 21), the Blue Cap was developed by a 215-foot shaft with drifts and intersected a 40-foot-wide mineralized zone, which yielded some rock that assayed as high as 0.2 to 0.77 opt Au.

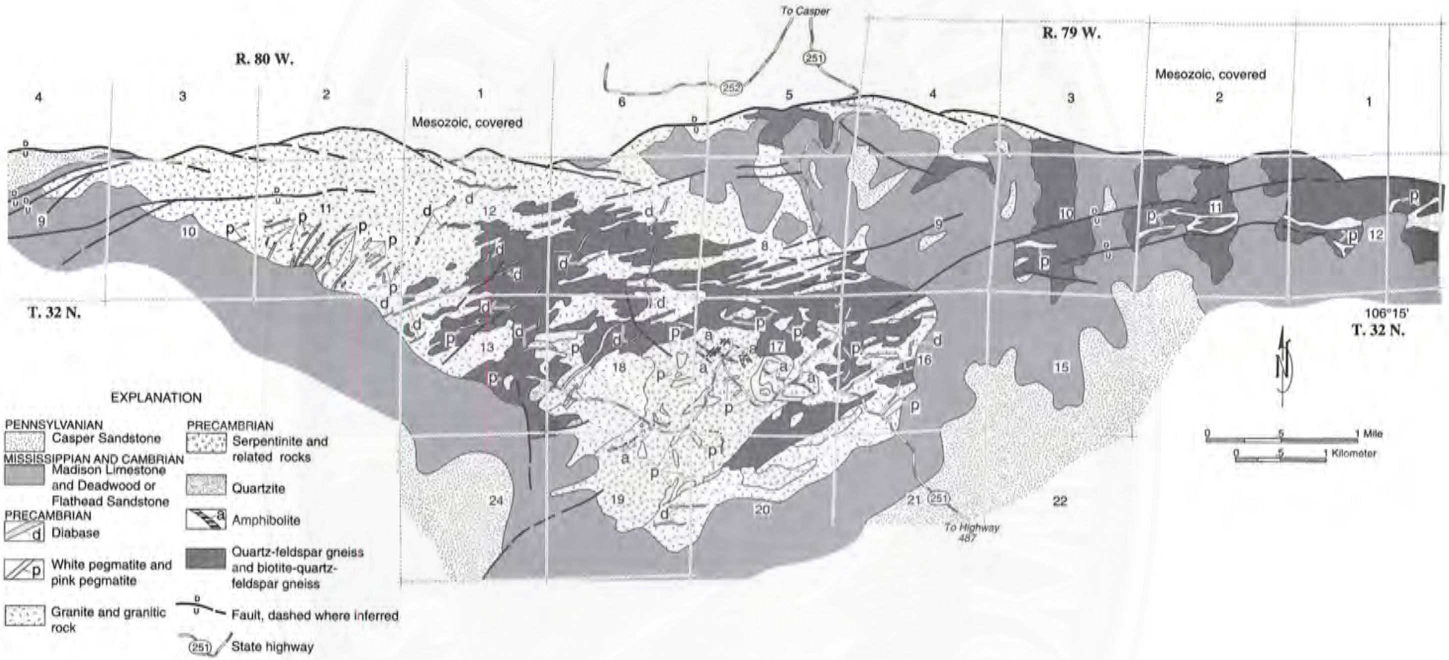


Figure 37. General geologic map of the Casper Mountain area (modified and adapted from Burford and others, 1979).

Deer Creek area

The Deer Creek area of Converse County lies between Boxelder Creek and the western boundary of the county. The area is underlain by schist and gneiss intruded by Late Archean potassic granite. Minor ultramafic schist, quartzite, and amphibolite crop out in the area. Serpentinites in the region are reported to be chromite and asbestos bearing. Nearly 2300 tons of chromite ore were produced in 1908 and during World War I (Hausel, 1987a). Reported copper occurrences appear to be minor.

Smith copper prospect. Sec. 29, T32N, R75W. Located about 9 miles south of Glenrock near the head of a tributary of Hutton Creek on the Root Creek 7.5-minute Quadrangle. The rocks in the area consist of hornblende schist, granite, and serpentinite. At a point about 100 feet above the canyon bottom, copper carbonate was discovered. A 30-foot shaft was sunk on the mineralized rock, and an adit was driven to intersect the shaft, but no significant mineralization was encountered (Spencer, 1916, p. 79). The area was examined by the author (Hausel, 1988b), and no significant copper was found. Serpentinites in the area have been quarried on a small scale for decorative stone.

Swede Boy vein. NE sec. 32(?), T31N, R76W. Located 16 miles south of Glenrock and 4 miles southwest of Boxelder Creek and Deer Creek. A cupriferous quartz vein in granite strikes N5°W and dips 60°NE. The vein at the main shaft was 6 feet wide, and at 600 to 800 feet from the primary shaft, the vein pinched to 4 feet wide. Some ore was shipped (Spencer, 1916, p. 75-76).

NE NE sec. 14, T32N, R76W. A 30- to 40-foot-wide vein parallels regional foliation and is stained with copper near its apex. A grab sample from the vein assayed 0.67% Cu, 0.2% Mn, 1.6 ppm Ag, and 0.58 ppm Au (Hausel, 1988b). The host rock is Archean quartzite (Gable, 1987).

Elmers Rock greenstone belt

The Elmers Rock greenstone belt consists of an amphibolite-grade synformal supracrustal belt in the central Laramie Mountains (**Figure 38**). The belt extends across the width of the Laramie Mountains and is bounded on the north by an Archean granite-gneiss complex. The belt is truncated along the south by Proterozoic syenites.

Supracrustal rocks

Supracrustal rocks of the greenstone belt were subdivided by Graff and others (1982) into a lower group of ultramafic and mafic amphibolites with chemistries similar to komatiites and tholeiitic basalts. This lower metaigneous group is overlain by metasedimentary rocks, including mica schist, metapelite, banded iron formation, quartzite, metaconglomerate, and marble intruded by granites and gabbroic rocks. Mineralization in the greenstone belt includes some low-grade chromite, asbestos, copper, and uranium.

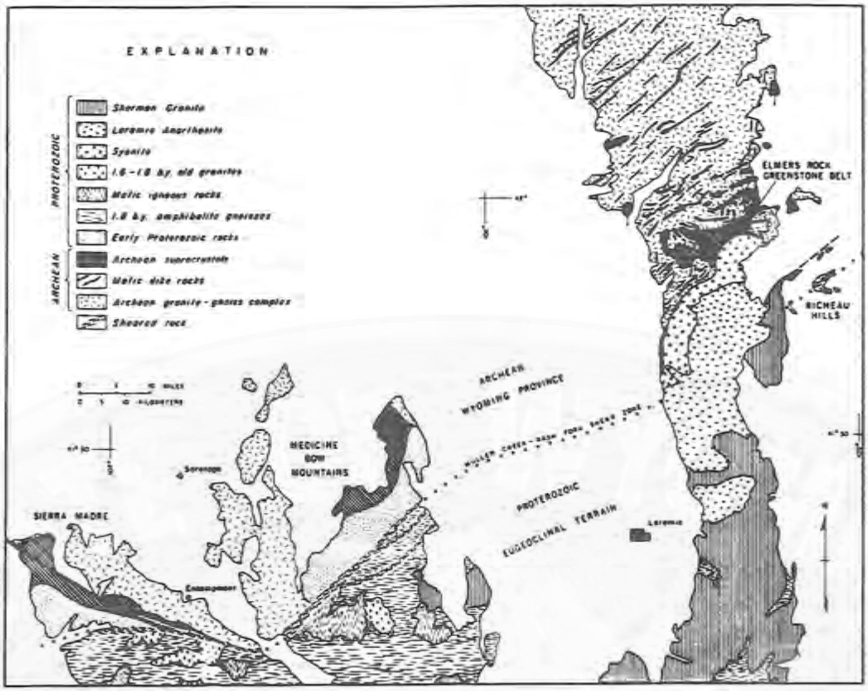


Figure 38. Location of Elmers Rock greenstone belt in the central Laramie Mountains, southeastern Wyoming (after Graff and others, 1982).

Mines and prospects

Bell prospect. N/2 SW sec. 20, T23N, R69W. Located at 5415 feet elevation in the Cooney Hills along the eastern flank of the Laramie Mountains near the eastern extent of the greenstone belt. The prospect was developed by a short 120-foot adit known as the Bell No. 1 mine (Springer and Donna Jones, personal communication, 1985). The adit was driven into a N5°W-trending, 50°NE-dipping muscovite schist. The schist is stained by limonite and encloses small quartz lenses. No sulfides were found on the property when visited by the author, and three samples collected in 1989 yielded no detectable gold or silver (Hausel, 1990a).

Big Mac claim. Sec. 19, T23N, R69W. A small prospect pit dug in Precambrian graphitic schist in the Cooney Hills area exposed some pyrite, chalcopyrite, malachite, and azurite. Anomalous radioactivity also was detected (Smith, 1954; Osterwald and others, 1966, p. 217).

Lucky Gus prospect. (This may be the Precious Honor No. 1.) Located 12 miles west of Wheatland in the South Cooney Hills area. Quartz veins in red granite strike east-west and dip gently to the south. One vein 4 to 7 feet wide crops out for 500 feet. The quartz contains limonite and copper carbonates associated with bunches and streaks of pyrite, chalcopyrite, chalcocite, bornite, and a small amount of native copper. In the bottom of the shaft the vein encloses a horst of barren rock. Only 2 feet of the vein is mineralized (Beeler, 1903i).

Precious Honor No. 1. NW SE sec. 20, T23N, R69W. Located at 5491 feet elevation in the South Cooney Hills along the eastern edge of the Elmers Rock greenstone belt. Two shafts were sunk on a N61°W-trending vertical shear in granite gneiss. The shear is 6 feet wide at the collar of the shaft and stained with limonite and copper carbonate.

At a depth of 155 feet, the mineralized zone is 4 feet wide and impregnated with chalcopyrite and bornite. Approximately 65 tons of ore were produced in 1901 that averaged $9.00 per ton (1901 prices). The ore also contained small amounts of gold (Osterwald and others, 1966). Two dump samples of pyritiferous quartz collected by the author yielded 0.25 ppm and 0.49 ppm Au and 2.5 ppm and 5.3 ppm Ag, respectively (Hausel, 1990a).

Whippoorwill mine. NE SW sec. 20, T23N, R69W. Located at an elevation of 5836 feet. Two shafts were sunk in a 15-foot-wide pyritized quartzite in mica schist country rock. The massive sulfide is stratiform and well developed at the shafts and locally stained by malachite. At a depth of 40 feet, the shafts cut primary sulfides (pyrite and chalcopyrite). Reported assays yielded anomalous copper, silver, and 0.32 opt Au (Beeler, 1905k; Osterwald and others, 1966). Bothner (1967) reported some arsenopyrite.

Samples collected in 1989 yielded only trace silver, gold, and copper. Two of four samples contained no detectable base or precious metal values. One sample of gossaniferous quartz yielded 0.05% Cu, 1 ppm Ag, and no detectable gold. Another 20-foot composite chip sample taken across the gossan yielded 0.08% Cu, 1.1 ppm Ag, and 0.06 ppm Au. A sample of gossaniferous quartz collected from an outcrop west of the Whippoorwill yielded 0.08% Cu, 0.05 ppm Au, and no silver (Hausel, 1990a).

NW sec. 28, T23N, R69W. A shallow shaft was dug on a N80°E-trending, 78°SE-dipping, 4- to 5-foot-wide shear in granite. The shear encloses brecciated mafic rock and mica schist with masses of weakly copper-stained quartz. Two samples from the shear yielded 1.6% and 0.62% Cu, 4.6 ppm and <1.0 ppm Ag, and no detectable gold. The shear pinches out to the west (Hausel, 1990a). This may be the same shaft reported by Bothner (1967) in the SW SW of sec. 28 in which he noted the presence of uranium in addition to copper.

NW NE sec. 18, T23N, R69W. A vertical shaft cut red quartzite and quartz pegmatite. Some malachite and azurite was found (Bothner, 1967).

SW SW sec. 8, T23N, R69W. Minor amounts of copper sulfide were found at this location (Bothner, 1967).

Emerald group. Sec. 8, T23N, R70W. The Emerald group is located on Sturgeon Gulch. Folded hornblende and biotite schists host a quartz and calcite vein at a point where the strike of foliation changes from northeast to northwest. Folding in this area was accompanied by fracturing, and quartz-calcite stringers in fractures pitch northwest.

The vein contains limonite and copper carbonates near the surface and chalcopyrite, bornite, and chalcocite at depth. The main shaft was sunk to a depth of 50 feet (Beeler, 1905j).

Independence group. Located on Slate Creek (a tributary of the Laramie River) about 22 miles west of Wheatland. A 1-mile-wide layer of schist in granite trends northeast and dips 30° to 40°NW. The schist consists of fine-grained biotite schist, garnet-mica schist, muscovite schist, and hornblende schist. Several quartz veins conform to the foliation of the schist and contain limonite, malachite, azurite, and bornite, as well as marcasite and pyrrhotite. Assays reportedly detected anomalous copper, nickel, gold, and silver (Beeler, 1904d). A short tunnel, about 40 feet long, was driven on the prospect.

Rattlesnake Den prospect. S/2 sec. 26, T23N, R70W. Located on the east edge of Squaw Mountain at 5604 feet elevation. An iron-stained breccia in gneissic host rock trends N22°W and dips 71°SW. The zone is 6 to 8 feet wide and was tested by a short tunnel and intersecting shaft. No obvious mineralization was recognized (Hausel, 1990a).

Esterbrook district

The Esterbrook district (also known as North Laramie Peak district) is located north and west of Laramie Peak in the northern Laramie Mountains of Converse County and northern Albany County. Archean metasedimentary rocks and metavolcanics in this district were intruded by Late Archean granites.

Mineralization

The supracrustal rocks host several fissure veins and possibly replacement deposits. Four groups of mineral deposits were described by Greeley (1962): (1) pyrrhotite-quartz-minor chalcopyrite and sphalerite veins, (2) galena-pyrite-calcite-quartz veins, (3) quartz-pyrite veins, and (4) quartz-feldspar-mica-beryl pegmatites.

According to Beeler (1904c), copper ores in the district generally carried only minor gold and silver, although rare assays as high as 23 opt Au and 30 opt Ag were reported. Additionally, uranium mineralization, genetically related to other metallic deposits, was discovered in the district in 1953. The mineralization is spatially associated with the contacts between granite and schist (Guilinger, 1956).

Mines and prospects

Al Mahoney prospect. Sec. 14, T27N, R71W (Albany County). The Al Mahoney prospect was developed by a 60-foot adit along a 5-foot-wide limonite-stained gouge zone in granite. Four chip samples and two grab samples were collected for assay. The highest assay was from a fault gouge sample inside the tunnel. This sample yielded 0.13% Cu, 0.07% Pb, and 0.1 opt Ag (Segerstrom and others, 1977).

Ashenfelder prospect. Sec. 8, T27N, R71W. The Ashenfelder property was active during the later part of the 19th century and again in 1932. The prospect was developed by a 70-foot tunnel driven north into a limonite-stained shear. At the face of the tunnel, a winze was sunk and a drift driven north from the winze. Of ten samples collected for assay, five were taken from the mine, and the remaining five from the dump and nearby prospect pits.

The copper and lead contents of these samples were minor and ranged from 80 to 160 ppm Cu and 0 to 0.2% Pb. One sample containing significant gold was hematite-stained granite, which assayed 0.17 opt Au (Segerstrom and others, 1977).

Big Five prospect. SW SW sec. 10, T28N, R71W. Located 2500 feet north-northeast of the Three Cripples mine. The dump near a 50-foot shaft contained rock with mostly pyrrhotite and chalcopyrite bunches in quartz and feldspar gangue (Spencer, 1916). Traces of sphalerite were also detected (Greeley, 1962). One dump sample collected by Segerstrom and others (1977) assayed 0.3% Cu, 100 ppm Pb, and 0.1 opt Ag (**Figure 39**).

East of Esterbrook. Secs. 9 and 10, T28N, R71W. Anomalous copper was detected in eight samples collected from prospects immediately east of Esterbrook (Segerstrom and others, 1977). These samples yielded 160 ppm to 0.3% Cu, 0 to 200 ppm Pb, and 0 to 0.1 opt Ag.

Esterbrook mine. SE sec. 9, T28N, R71W. Galena was found in tabular open space fillings in hornblende schist in the Esterbrook mine on the Douglas claim (**Figure 39**). The mineralized body is 2 to 6 feet wide, trends N30°E and dips vertically. In addition to galena, pyrite, calcite, quartz, cerussite, and minor limonite, Beeler (1904c) and Greeley (1962) found covellite, chalcopyrite, and traces of malachite. Ore shipped from the property averaged 34.65% Pb, 1.3 opt Ag, and 0.035 opt Au (Beeler, 1902f).

Three shafts were sunk along the 500-foot mineralized trend. One shaft was sunk to a depth of 350 feet. On the main level (335 feet) two drifts were developed. One was driven 300 feet to the south, and the other was driven 100 feet to the north (Greeley, 1962).

Very little ore remains on the dump (which has been converted to the village landfill), even though Spencer (1916) reported 6-foot-wide solid shoots of galena in the mine workings. Samples collected by Segerstrom and others (1977) yielded 600 ppm to 0.3% Cu, 0.6to 10% Pb, 0.1 to 0.4 opt Ag, 0 to 0.03 opt Au, 0.5 to 2.0% Zn, and no detectable Pt or Pd.

Eureka prospect. Secs. 9 and 16, T28N, R71W. An 8- to 20-foot-wide, north-trending quartz vein along a contact between schist and diabase is stained with limonite. Pyrrhotite masses, disseminations, and streaks were discovered below the limonitic gossan at a depth of 12 feet. Chalcopyrite also occurs in the vein, and some gold was recovered from the gossan (Beeler, 1902h).

Hoosier Boy claims. SE sec. 36(?), T28N, R73W. This property is located about 10 miles southwest of Esterbrook. The claims lie in a high grassy valley at the head of a tributary of LaBonte Creek. Two exploratory shafts were developed on a silicified N70°E-trending diabase dike intruded into granite country rock. In both places, quartz veins pinch and swell over a strike distance of several hundred feet. Some vein material from the shaft carries small amounts of chalcopyrite (Spencer, 1916, p. 71).

Kentucky Belle claims. SE sec. 36(?), T28N, R73W. These claims are southeast of the Hoosier Boy claims beyond a divide between LaBonte and Horseshoe Creeks. The Kentucky Belle shaft was developed to a depth of 40 feet. The quartz vein is about 2 feet wide and carries considerable chalcopyrite and some chalcocite (Spencer, 1916, p. 71).

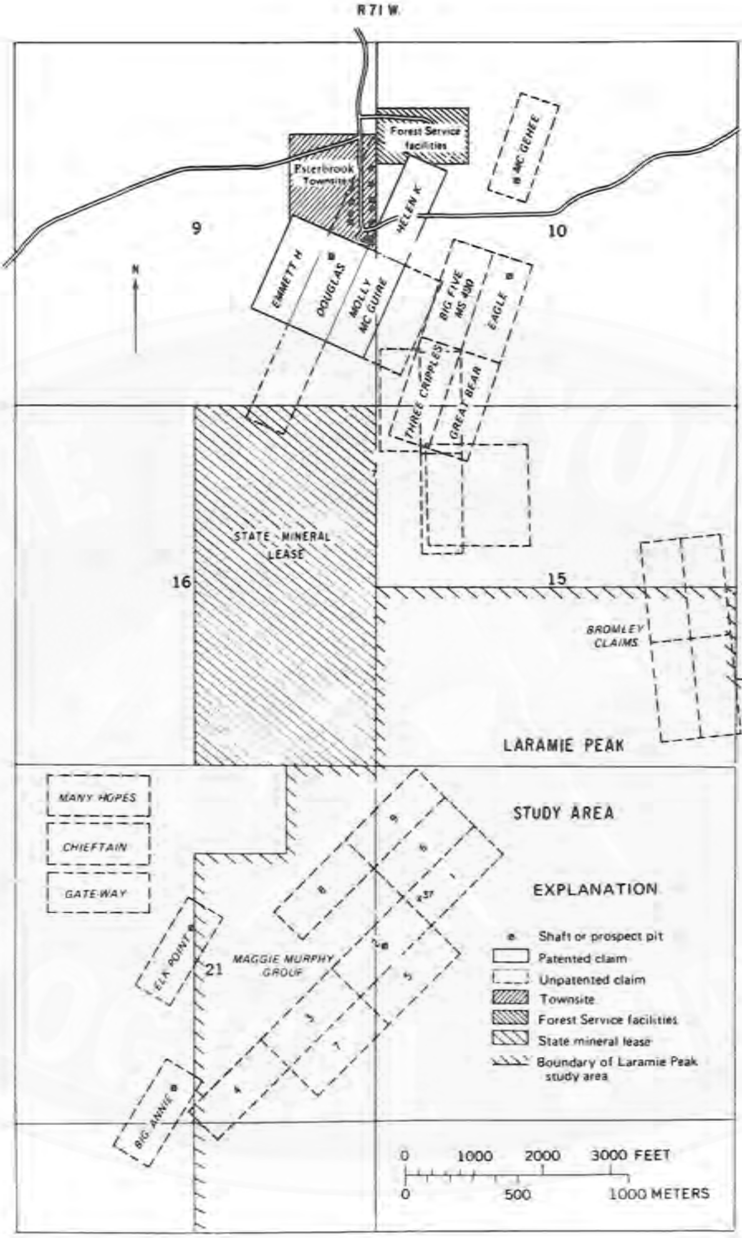


Figure 39. Mining claims near Esterbrook (from Segerstrom and others, 1977).

Kreisley prospect. SW sec. 35, T29N, R71W. Minor amounts of chalcopyrite and traces of sphalerite occur in this pyrrhotite-bearing quartz vein. The vein trends north-northeast and has a vertical dip (Greeley, 1962). One of the veins was traced more than 600 feet along outcrop. In places, the vein may be 50 feet wide (Spencer, 1916, p. 65).

Maggie Murphy mine. W/2 W/2 sec. 22, T28N, R71W. The Maggie Murphy mine is located about 2 miles south of Esterbrook along the north side of Horseshoe Creek (**Figure 39**). The property consisted of nine claims staked in 1903 that crossed the section line to the west into easternmost sec. 21. A 107-foot shaft was sunk adjacent to the section line in the center of the W/2 W/2 of sec. 22.

The Maggie Murphy shaft was sunk on a northeast-trending limonite-, minor malachite-, and azurite-stained gossan in amphibolite schist. The gossan crops out for several hundred feet along strike over a width of 10 to 20 feet. A few feet below the gossan, the shaft cut a 5-foot-wide pyrrhotite-rich vein. At about 50 feet, the vein was quartz dominant and pyrrhotite poor (Spencer, 1916, p. 60–61). Traces of sphalerite (Greeley, 1962) and some coffinite (Guilinger, 1956) also were found. Eight samples collected for assay from the dump and nearby prospect pits contained weakly anomalous copper. The samples ranged from 160 to 600 ppm Cu, 0 to 200 ppm Pb, and 0 to 5.6 opt Ag (Segerstrom and others, 1977).

Maverick. Secs. 22 and 23, T29N, R71W. A 50-foot shaft was sunk on irregular, 3- to 10-foot-wide quartz veins that trend N45°–55°W and dip vertically. The quartz veins are closely associated with pegmatitic veins. The veins are vuggy, pyritic, stained with iron, and hosted by granite (Spencer, 1916, p. 66). One 2- to 6-foot-wide quartz vein is stained by limonite and malachite. A few "kidneys" of chalcopyrite were found in this vein (Beeler, 1904m).

McGhee. Sec. 10, T28N, R71W. Minor chalcopyrite and traces of sphalerite occur in quartz-pyrrhotite mineralized zones. These zones strike northeasterly and dip vertically (Greeley, 1962).

Northeast of Ashenfelder. Sec. 5, T27N, R71W. Four samples were collected from a caved adit about 1 mile northeast of the Ashenfelder prospect. All the samples were poorly mineralized. Assays ranged from 0.016 to 0.06% Cu, 0 to 0.04% Pb, and 0 to 0.2 opt Ag (Segerstrom and others, 1977, table 1, samples 19–22).

Northwest of Ashenfelder. Sec. 31, T28N, R71W. Three samples selected from a prospect pit were assayed for base and precious metals. The highest copper value was 0.13%. This sample also contained 0.2 opt Ag. Another sample ran 0.2% Pb with 0.2 opt Ag (Segerstrom and others, 1977, table 1, samples 19–22).

Saul's Camp. NE SE sec. 22, T29N, R71W. The country rock at Saul's Camp is predominantly hornblende schist with a dominant foliation trend of N45°E. The schist is intruded by diabasic dikes conformable to foliation.

Shafts and drifts were dug on a copper-stained gossan in the schist and intersected lenses of chalcocite, chalcopyrite, pyrite, pyrrhotite, magnetite, and native copper. Some high grade ore with as much as 30% Cu, 6 to 8 opt Ag, and 0.03 opt Au was found on the property, and about 100 tons of ore containing 9% Cu were mined.

Four hundred feet east of the main shaft, a highly magnetic zone was traced for 1000 feet along a southeasterly trend. The anomaly is strong enough to disturb a compass needle (Spencer, 1916, p. 66–67). It is not known if this anomaly has ever been explored.

Snowbird group. NW NE sec. 21, T29N, R71W. Located on the north slope of Elkhorn Mountain east of LaBonte Creek. Red granite hosts two narrow greenish schist layers interpreted as sheared diabase dikes. The schist strikes north-south and is 150 feet thick at the Snowbird group. Quartz veins, 6 to 8 feet wide in the schist, contain limonite, specular hematite, spots of copper carbonates, and some gold. At the bottom of the 75-foot shaft, pyrite and chalcopyrite were found filling fractures, seams, and gouge zones in the quartz and schist (Beeler, 1907j; Spencer 1916, p. 68–69; Osterwald and others, 1966).

Tenderfoot group. S/2 sec. 3, T28N, R71W. The Tenderfoot group consists of several claims staked at the turn of the century. According to Spencer (1916, p. 65), the Tenderfoot group included a 2000-foot-wide belt of prospect pits and shafts developed in scattered limonite-stained gossans. Near the west side of the belt, a 150-foot exploratory shaft was sunk, and a southeast-trending crosscut was dug that terminated in barren rock without intersecting any mineralization. The principal ore mineral found is pyrrhotite (Greeley, 1962). Some chalcopyrite with gold and silver was found below the gossan (Beeler, 1903d).

Three Cripples prospect. NW sec. 15, T28N, R71W. This prospect was developed on a northeast-trending limonite-stained zone in schist southeast of Esterbrook (**Figure 39**). A 96-foot shaft was sunk on the limonite zone. Dump samples contain pyrrhotite with some chalcopyrite.

A composite sample of 25 chips taken from different areas on the mine dump ran 41.80% Fe, 0.23% Cu, and trace cobalt (Spencer, 1916). Segerstrom and others (1977) assayed five samples that yielded only traces to 0.3% Cu. One sample yielded trace nickel (40 ppm). Hall (1909) reported pyrrhotite-bearing samples from the mine yielding values in copper, gold, silver, and traces in nickel. Beeler (1904c) also reported the presence of nickel. Traces of sphalerite are also reported (Greeley, 1962).

Trail Creek mine. NW SE sec. 10, T29N, R71W, about 25 miles south of Douglas near the head of Trail Creek. Interlayered granite and schist strike northeasterly and dip gently to the northwest. The country rock is intruded by diabasic dikes that lie conformable to foliation of the granite and schist.

The granite is siliceous and often grades into quartz veins. The veins are fractured and contain limonite, hematite, and schist inclusions. Locally the veins show masses of azurite and malachite and small amounts of copper- and iron-sulfides (Beeler, 1903f). Spencer (1916) reported malachite and chalcocite on the outcrops but found little mineralization in the tunnel. Beeler (1904c) reported the property was developed by a 60-foot-deep shaft and a 360-foot crosscut tunnel.

A small lens of uraninite in unaltered hornblende schist wall rock was discovered in 1954, 8 feet below the adit floor at the junction of two north- and northeast-trending, vertical shear zones. Both shear zones are radioactive where cut by the adit. The uraninite, coated by erythrite (cobalt arsenate), occurs as botryoidal and sooty coatings along shear zones and as disseminations in the hornblende schist (Guilinger, 1956). Guilinger (1956) reported that quartz, galena, pyrite, and arsenopyrite intergrown with disseminated chalcopyrite are found near the uranium mineralization but in completely separate lenses and shear zone fillings. This suggests that the uranium represents a separate episode of mineralization. According to Bromley (1955), production from the mine included 8 tons of ore that averaged 0.24% U_3O_8.

West of Eagle Peak. Sec. 36, T27N, R73W, and sec. 1, T26N, R73W. Six samples collected from six different dumps west of Eagle Peak yielded a maximum of 0.7% Pb from one sample (Segerstrom and others, 1977).

LaPrele mineralized area

The LaPrele area includes several prospects in the vicinity of LaPrele Reservoir, located 12 miles southwest of Douglas on the Hermit Rock and LaPrele Reservoir 7.5-minute Quadrangles. The bedrock geology consists of hornblende schist with lesser granite. The area is limited on the north by onlapping Paleozoic and Tertiary strata (Spencer, 1916).

Cottonwood Creek (Mewis) prospects. SE sec. 14, T32N, R74W. Located along a tributary of Cottonwood Creek about 3 to 4 miles northwest of LaPrele Reservoir. A sandstone bed 20 to 40 feet thick overlies Precambrian schist and underlies massive limestone of the Casper Formation. These rocks dip north-northeast and are broken by a north-south-trending fault along Cottonwood Creek. Vertical displacement on the fault is about 100 feet with the eastern block downthrown. Shallow workings intersected malachite, azurite, and chalcocite within 50 feet of the fault (Spencer, 1916, p. 79–81).

Cross prospect. Sec. 25, T32N, R74W. Prospect pits were dug on a vertical quartz vein in hornblende schist. The quartz contains copper carbonate (Smith, 1953).

Hazenville prospect. Sec. 30, T32N, R73W. Located about 2 miles east of LaPrele Reservoir. A shaft and tunnel were developed on a small copper-bearing quartz vein in schist (Spencer, 1916, p. 81).

Horace Greeley group. Located about 18 miles southwest of Douglas on a branch of LaPrele Creek. Broad, interlayered lenses of granite, gneiss, and schist strike north-south and are cut by diorite dikes and quartz veins. A vein intersected in the tunnel varied from 1 to 2 feet wide and had considerable iron oxide and lesser copper stains. Rocks in the area are locally sheared (Beeler, 1903g).

Jasper mine. Location unknown. Malachite, azurite, and cuprite occur as fracture fillings and replacement bodies near the top of the Cambrian Deadwood (or Flathead) Formation on the west side of a hill (Hagner, 1942c). The Cambrian rocks underlie the Madison Limestone, which dips 26°N. Eleven carloads of copper ore were produced from this mine during World War I.

French Joe prospect. W/2 sec. 23, T29N, R73W. According to Beeler (1903e), this prospect was located on West LaBonte Creek; however, the legal description places it on French Joe Creek. The prospect consisted of two lodes known as the Eureka and Copper King, developed by a 60-foot shaft with open cuts. Beeler (1903e) described a series of northeast-trending quartz stringers in altered silicified schist, which, in turn, was enclosed by granite. The altered zone is stained by limonite, with heavy stains of malachite and azurite. Some disseminated pyrite and copper sulfides also occur in the quartz stringers (Beeler, 1903c).

Laramie anorthosite batholith

The Laramie Mountains anorthosite batholith forms a 350-square-mile complex in the central Laramie Mountains. The batholith is dated at approximately 1.5 Ga.

In the past, massive titaniferous-magnetite deposits have been mined at several localities in the batholith, and some exploration of disseminated to massive deposits has occurred. Sulfides are reported in trace to minor amounts in the batholith and include pyrrhotite, chalcopyrite, pyrite, and sphalerite which are found in norite, hypersthene syenite, and anorthosite. Recently, pentlandite has also been recognized (Ron Frost, personal communication, 1997).

Strong Creek (Greaser Ranch). Secs. 24 and 26, T19N, R72W. This is a large disseminated titaniferous magnetite deposit with associated sulfides (pyrite, chalcopyrite, and pyrrhotite) containing pods of massive titaniferous magnetite (Kling, 1986). Based on drilling, about 300 million tons of titaniferous magnetite are present (John Simons, personal communication, 1990). In 1983 and 1984, U.S. Chrome drilled in the Strong Creek area north of the Buttes near Albany County Road 12, and recovered core containing abundant sulfides (principally pyrrhotite) (Hausel, 1990g).

Strong mine. NW NW sec. 4, T16N, R71W, located near the head of Horse Creek. From 1900 to 1915, the Strong Mining Company produced some copper (Beeler, 1942). The shaft was reopened in 1942, and some tungsten ore was shipped. The shaft was closed again in 1944 (Troyer, 1946). The Strong mine is a polymetallic ore deposit containing a variety of metals.

A shaft with five levels was sunk 360 feet deep and included at least 1308 feet of tunnels by 1907 (**Figure 40**) (Beeler, 1907d). Beeler (1942) later suggested that the total amount of development in the mine was considerably greater. The shaft was sunk into fractured diabasic and gabbroic dikes hosted by layered gneiss and schist in granite and anorthosite. Many of the fractures were rehealed with quartz.

The vein, described as 6 feet wide at the surface, swelled to 14 feet at a depth of 50 feet. On the 100-foot level, the vein was 7 feet 8 inches wide. On the 150-foot level, the width varied from 1 to 9 feet. On the 250-foot level, a drift driven to the south cut 125 feet of crushed quartz containing chalcocite, bornite, and chalcopyrite. Another drift intersected 30 feet of chalcopyrite streaks and masses in a cross vein. On the 350-foot level, a drift cut to the north intersected streaks and spots of chalcocite, including a 15-foot-wide zone of chalcopyrite that had apparently replaced granite. Assays for gold and silver were higher in the north drift than elsewhere in the mine. Minute quantities of molybdenum and lead also were found on this level (Beeler, 1906c).

The vein changed dip with depth. Above the 150-foot-level the vein dipped steeply to the east. Below the 150-foot-level, the vein reversed dip to the west. Troyer (1946) indicated the main ore shoot was 100 feet long, 3 to 5 feet wide, and carried an average 0.45% WO_3 and 0.5% Cu. In the upper level of the mine, the chief minerals were copper carbonates with lesser amounts of chrysocolla, cuprite, and native copper. Below this level, the ore minerals were chalcopyrite and bornite, with some chalcocite.

In 1942, the mine reopened for scheelite under a Reconstruction Finance Corporation loan (Osterwald and others, 1966). A second scheelite deposit was located on the nearby Yellow Pine property. The scheelite was localized at the intersections of granitic dikes in the anorthosite on the 350-foot level of the mine. One hundred tons of tungsten ore were shipped from the property to the Metals Reserve Company stockpile (Osterwald and others, 1966). The shipments yielded 0.2 to 0.6% WO_3. Assays of ore shipped to the Boulder tungsten mills in Boulder, Colorado, in 1943 are given in **Table 8** (Troyer, 1946).

Beeler (1942) reported a number of assays for the Strong mine (**Table 9**). Four pounds of ore from a depth of 70 feet were assayed for nickel. The sample assayed

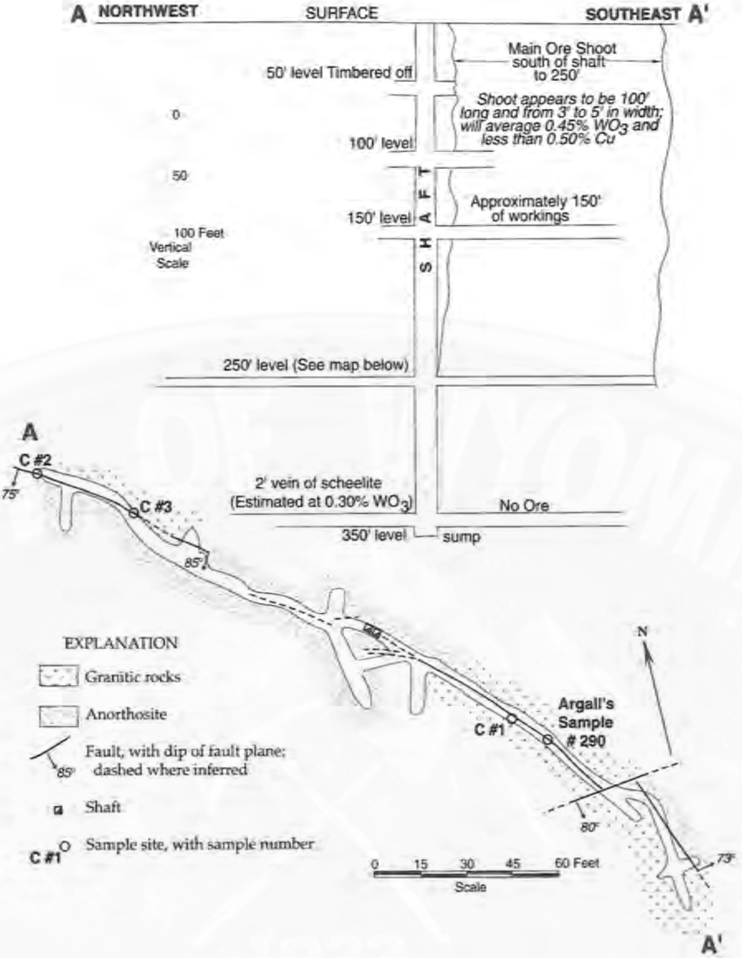


Figure 40. Sketch cross section and geologic map of the 250-foot level of the Strong mine (after Troyer, 1946).

0.75 opt Au, 9.5 opt Ag, and 1.0% Ni. A one-ton sample from the 100-foot level assayed no gold, 3.0 opt Ag, and 16.6% Cu (Beeler, 1942). The mine was closed in 1944, and the dump was handpicked for scheelite.

Ulcahoma. Located a short distance from the Strong mine. A 150-foot shaft was sunk on a quartz vein containing copper and iron sulfides that produced remarkable gold values. In addition to copper, silver, and nickel, some samples assayed as much as 50 opt Au (Beeler, 1906l, p. 63).

Table 8. Assays of tungsten ore shipped from the Strong mine in 1943 to the Boulder tungsten mills, Colorado (from Troyer, 1946).

Weight (pounds)	Tungsten content (WO_3)
10,650	0.44
16,660	0.49
10,250	0.44
14,840	0.49
11,980	0.44

Table 9. Copper, gold, and silver assays of mineralized rock reported from various depths in the Strong shaft (from Beeler, 1942). Analyses in weight percent (%) or ounces per ton (opt); dashes indicate not analyzed; tr= trace.

Depth (feet)	Cu (%)	Au (opt)	Ag (opt)	Depth (feet)	Cu (%)	Au (opt)	Ag (opt)
9	19.3	0.68	0.88	50	16.03	tr	2.90
9	19.85	tr	7.86	50	22.00	–	–
11	5.08	tr	13.72	54	25.26	tr	2.50
11	13.33	0.01	3.20	58	26.02	tr	tr
13	38.81	0.04	6.86	58	26.24	tr	3.70
15	32.91	tr	7.70	58	36.82	tr	2.95
15	43.12	tr	tr	80	68.00	–	–
15	35.48	tr	4.00	80	68.50	–	–
21	7.55	0.08	3.68	85	26.64	–	–
25	19.93	tr	5.30	85	45.50	–	–
25	39.96	tr	5.10	90	20.50	–	–
26	34.76	tr	5.40	92	29.50	–	–
28	30.37	0.04	6.76	100	22.80	–	–
38	20.56	0.16	3.60	100	42.00	–	–
49	51.56	0.18	3.50				

Mormon Canyon

The Mormon Canyon area is a small supracrustal fragment of amphibolite, sillimanite-quartz-mica schist, and gneiss with small bodies of ultramafic schist and serpentinite (Gable, 1987). Several prospects in the area are located in the ultramafic schist and serpentinite.

Mormon Canyon prospect. W/2 sec. 13, T32N, R76W. Chalcocite and chalcopyrite in white quartz was discovered near the head of Dry Creek, 8 miles south of Glenrock (Spencer, 1916, p. 79). In the N/2 SW sec. 13, an adit was driven on a N53°W-trending vein in amphibolite. The vein is nearly 20 feet wide and conformable to regional foliation. A grab sample of the vein was collected for assay and yielded no detectable gold or silver. No copper-bearing minerals were found (Hausel, 1988b).

Silver Crown district

The Silver Crown district (also known as the Hecla district) lies 20 miles west of Cheyenne and immediately east of Curt Gowdy State Park along the eastern flank of the Laramie Mountains (**Figure 41**). Most of the mining activity in the district centered on the Copper King and Comstock mines.

The foundation of the old Silver Crown mill is located south of Highway 210 (Happy Jack Road) at Hecla on Middle Crow Creek. Available reports indicate the mill was poorly designed, and mill tailings often assayed higher than concentrates (Ferguson, 1965).

Several copper-gold-silver deposits in the district occur as permeable fracture fillings and as rehealed silicified fractures. The Copper King deposit, however, is a large-tonnage, low-grade copper-gold porphyry.

Mineralization

Regional retrogressive metamorphism produced widespread greenschist alteration throughout the district, but near the Rambler prospect and at the Copper King mine, alteration is more intense and associated with sulfides, suggesting that a later propylitic hydrothermal event overprinted the regional retrogressive metamorphic event. Potassic alteration also occurs in association with the Copper King deposit.

The major orebody at the Copper King mine is hosted by calc-alkaline intrusives that average granodiorite and quartz monzonite in composition. These were emplaced into 1.6- to 1.9-Ga mafic to intermediate metavolcanics and associated volcanogenic metasedimentary rocks. The entire volcanogenic succession was extensively invaded by Sherman Granite at about 1.4 Ga. The Copper King stock may have been emplaced at about the same time.

Mineralization is generally low grade, although supergene ores mined during the past often contained rich masses of chalcocite ore (Ferguson, 1965). Such large masses of supergene ore were selectively mined.

Modern exploration in the district has been confined to the large-tonnage, low-grade copper-gold deposit at the Copper King mine. Potentially, the limits of the

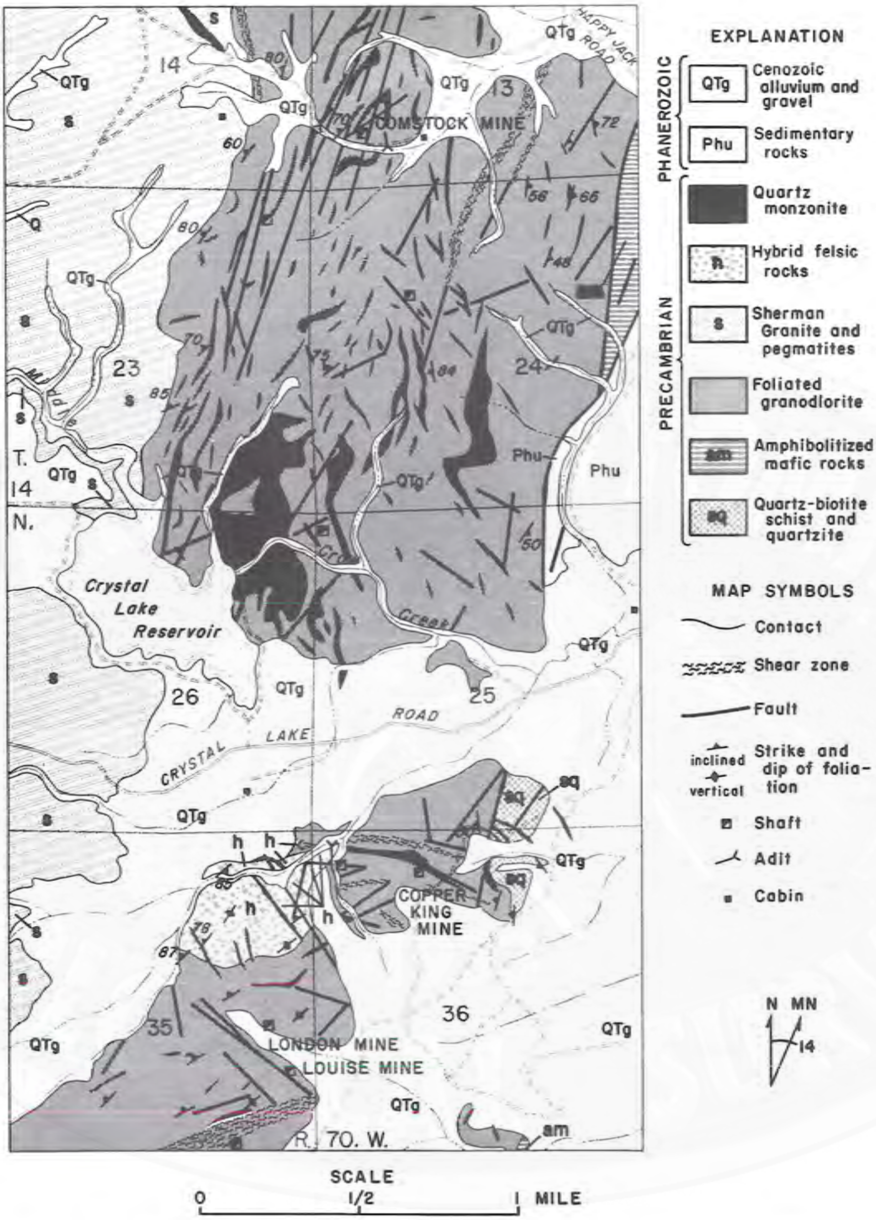


Figure 41. Geologic map of the Silver Crown district (modified from Klein, 1974).

deposit could be increased by drilling and exploring nearby geochemical and geophysical anomalies (Klein, 1974; Hausel and Jones, 1982; Hausel, 1989).

Named mines and prospects

Agate prospect. Located 0.25 mile northwest of the Julian lode. Samples supposedly yielded 1 to 2 opt Au and an exceptionally rich sample assayed 13.5 opt Au and about 14.0 opt Ag (Aughey, 1886, p. 4).

Bon Brothers mine. Location unknown. A shaft sunk on a gossan encountered copper sulfides at 20 feet. The ore contained 6% Cu and minor values in gold and silver (Osterwald and others, 1966, p. 55).

Carbonate Belle. NE sec. 24, T14N, R70W. This is the site of the infamous salting incident, which allegedly involved the Wyoming Territorial Geologist, Samuel Aughey. Historic reports indicate that Aughey and associates may have obtained bonds on a number of claims on the Carbonate Belle and attempted to promote the property (*Wyoming Industrial Journal*, 1899, v. 1, no. 5, p. 98-99).

Comstock (King David) mine. SW sec. 13, T14N, R70W. The Comstock mine was developed at a fracture intersection in foliated granodiorite. The main N20°E-trending mineralized fissure was traced for nearly 0.75 mile on the surface. The vein has an average width of about 2 feet (Jamison, 1911) (**Plate 3A**).

The Comstock lode was located in 1882 by William M. Ferguson. A 240-foot-deep shaft was sunk on the fracture intersection, and 200 feet of drifts were developed on the 172-foot level, and 400 feet of drifts on the 205-foot level (Ferguson, 1965). In 1981 and 1982 the Wyoming State Geological Survey mapped the accessible workings, which consisted of 500 feet of drifts (**Figure 42**) (Hausel and Roberts, 1981; Hausel and Jones, 1982). This may have been Ferguson's 205-foot level; however, a flooded winze mapped in the eastern drift probably intersects another level below the main adit level.

The mine was driven in foliated granodiorite and biotite schist and intersected several mineralized and nonmineralized mylonites. The majority of the mineralized faults are permeable and contain localized secondary copper silicates and oxides (Hausel and Jones, 1982). The available assays indicate the presence of high-grade copper as well as anomalous gold and silver (**Table 10**).

Pockets of rich chalcocite ore were periodically encountered and selectively mined. One massive piece of chalcocite as large as a cook stove was lifted out of the shaft with ropes. The amount of ore produced from the property is unknown; however, Ferguson (1965) reported that several hundred tons of ore were mined that yielded credits in copper, gold, and silver.

Copper King mine. NW sec. 36, T14N, R70W. Historically, the Copper King (Arizona) mine was located in 1881 and developed by Adams Copper Mining and Reduction Company. The property was later worked by Hecla Mining Company.

A shaft was sunk 157 feet with 102 feet of crosscuts on the 80-foot level, and 260 feet of drifts and crosscuts and three large rooms on the 130-foot level. A 100-foot adit was driven near the shaft but stopped short of intersecting the shaft. Some ore was shipped, although the total amount of production is unknown (Ferguson, 1965).

The Copper King deposit is a deeply dissected Proterozoic age copper-gold porphyry deposit with disseminated sulfides, a small stockwork, and propylitic and potassic alteration zones. Fourteen samples collected by Jamison (1912b) varied from 0.22 to 2.43% Cu, 0.06 to 0.42 opt Au, and 0.4 to 0.8 opt Ag. Mineralization at the

Figure 42. Geologic map of the Comstock mine (adapted from Hausel and Jones, 1982).

surface occurs as malachite and chrysocolla, and at depth as chalcopyrite, pyrite, minor bornite, pyrrhotite, and native copper (McGraw, 1954; Soule, 1955).

Primary hypogene mineralization was intersected at a depth of 150 to 180 feet in drilling by the U.S. Bureau of Mines. The primary ore is overlain by an oxidized and leached zone extending from the surface down to depths of 30 to 150 feet (Soule, 1955). Near the shaft, a zone of intense silicification consists of intersecting quartz veins and veinlets. Extending out from the shaft is a zone of potassium silicate alteration expressed by secondary enrichment of biotite and microcline-quartz intergrowths with muscovite, sericite, epidote, and sulfides. This potassic altered zone is enclosed by a propylitic altered zone consisting of secondary chlorite and epidote with sulfides (**Figure 43**) (Hausel and Jones, 1982).

The available drilling data indicate that the maximum metal concentrations were on the order of 1.5% Cu and 0.2 opt Au (Klein, 1974). Drilling by the U.S. Bureau of Mines showed the mineralization continued to a depth of at least 1024 feet. Spectrographic analyses also showed traces of lead, zinc, tungsten, and 0.5 to 3.0% TiO_2

Table 10. Assays of samples from the Comstock mine, Silver Crown district (from Ferguson, 1965). Analyses in weight percent (%) or ounces per ton (opt); dashes indicate not analyzed.

Sample description	Cu (%)	Au (opt)	Ag (opt)
Assay sample	66.6	0.0	0.0
Assay sample	4.8	0.3	0.66
Assay sample	6.0	0.12	7.08
Assay sample	41.35	0.02	9.7
Assay sample	2.01	0.02	0.5
Assay sample	14.7	0.04	0.7
Assay sample	3.10	0.08	1.6
Assay sample	6.50	0.04	11.56
Assay sample	6.90	trace	2.80
Assay sample	4.0	0.02	1.2
Assay sample	6.0	0.02	1.0
Assay sample	3.5	0.02	1.0
Assay sample	5.85	0.04	1.02
North drift, cross section of vein	9.70	0.05	5.15
South drift, winze	8.70	0.07	1.93
North drift, wall rock	1.70	0.0	0.4
Bottom of shaft, 240 feet	12.9	0.04	2.66
North drift, 20 feet from shaft	18.2	trace	14.0
South drift	0.98	0.0	0.2
Shaft, 210 feet	0.78	0.0	0.5
No sample description	8.8	0.07	1.13
48,217 pounds	0.74	0.83	11.02
25,113 pounds	8.0	0.0	1.35
Car control	5.74	0.04	1.25
Concentrates	31.26	0.2	21.8
Selected ore	21.41	–	–
Selected ore	19.34	–	–
Selected ore	45.0	3.75	–

(Soule, 1955). An estimate of *in situ* ore reserves was made by Nevin (1973) based on drilling (**Table 11**).

In 1987, Caledonia Resources Ltd. of Canada leased the mine to test the property as a large-tonnage, low-grade disseminated gold deposit. The company reported preliminary estimates of 4.5 million tons of ore averaging 0.044 opt Au (or about 200,000

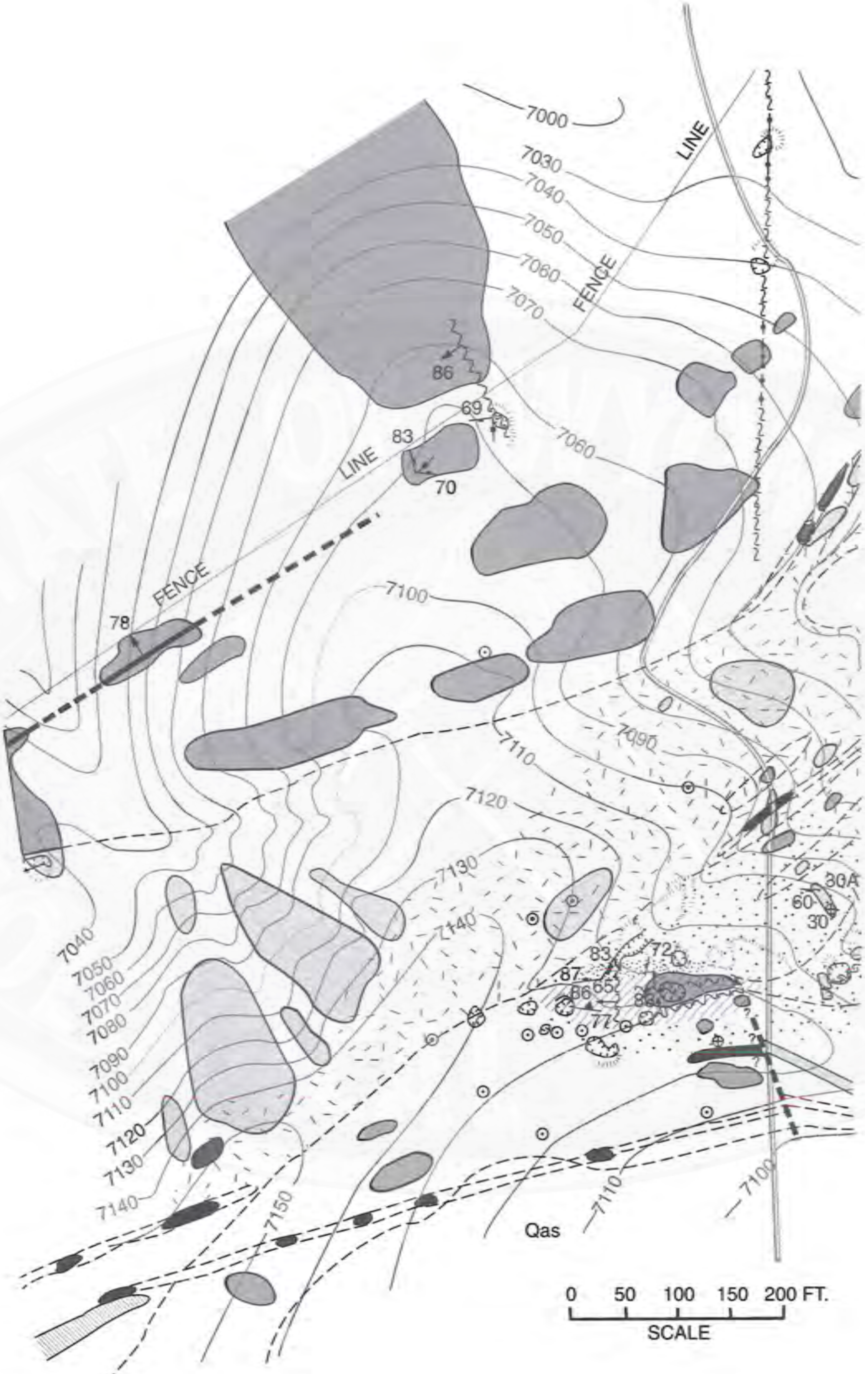


Figure 43. Rock alteration and outcrop map of the Copper King mine (adapted from Nevin, 1973, and Hausel and Jones, 1982). Map is divided into two pieces.

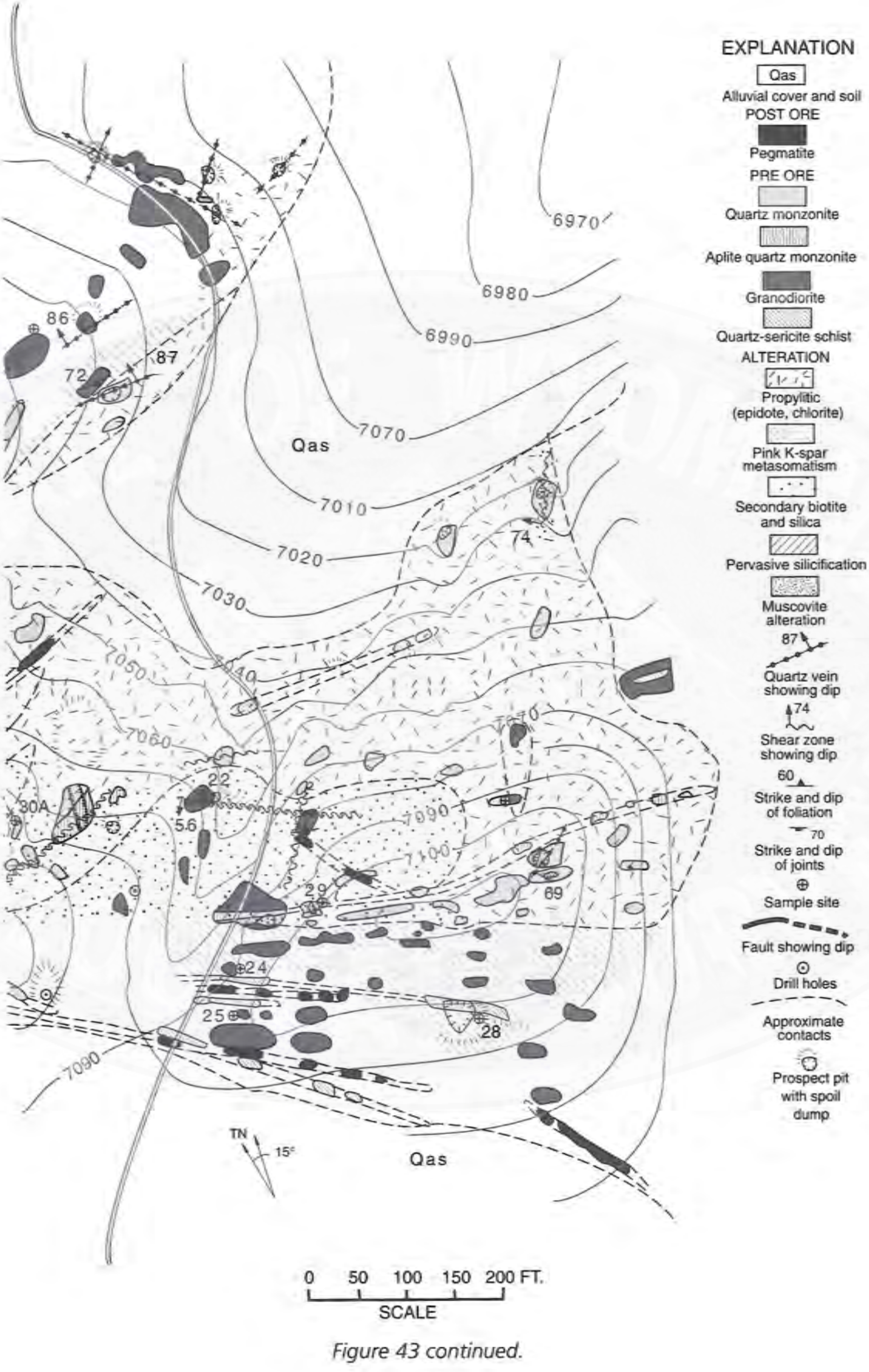


Figure 43 continued.

Table 11. Average grades and resources of copper and gold ore calculated for the Copper King mine (after Nevin, 1973). Grades expressed in weight percent (%) or ounces per ton (opt).

Average grade Cu (%)	Average grade Au (opt)	Ore short tons (millions)	Stripping ratio (waste/ore)
0.36	0.044	2.8	0.5
0.32	0.038	6.0	1.2
0.26	0.028	13.5	1.8
0.21	0.022	35.0	2.0

ounces of contained gold). Sampling suggests the deposit has a minimum strike length of 600 to 700 feet with a 300-foot width that is open at depth (Stockwatch, 1987).

Geochemical and geophysical anomalies suggest the known resource could be increased. For example, a large magnetic anomaly (1000 feet wide by 2000 feet long, 450 gamma magnitude), almost identical to that reflected by the Copper King deposit (800 feet wide by 1500 feet long, 500 gamma magnitude), was identified in a gravel-covered area 4500 feet to the southeast. Soil samples over this anomaly returned some anomalous values for the pathfinder elements mercury, zinc, and arsenic. Geological and geophysical evidence also suggests the presence of sulfides down plunge to the southwest and to the east of the Copper King. An I.P. (induced polarization) survey identified a moderate to weak metal-factor anomaly trending east-northeast of the principal mineralized area (Klein, 1974). More recently, Compass Minerals, Ltd., of Reno, Nevada, has been drilling and sampling the property and reportedly has expanded the gold-copper resource (Paul Graff, personal communication, 1995).

Dan Joe (Adams) prospect. N/2 sec. 24, T14N, R70W. Located across the valley (Jaw Bone Gulch) from the Comstock mine. The Dan Joe prospect is reported to have produced $500 in silver (Ferguson, 1965). Jamison (1911) reported that the property included three fault-controlled veins. Samples from one of the veins assayed 5% Cu with traces of gold. Copper mineralization includes malachite, azurite, and tenorite.

Eureka lode. Located north of the King David mine (the location of the King David mine is unknown). The Eureka vein contains chalcopyrite, which assayed as high as 0.58 opt Au. One ore specimen from the property yielded 8% Pb and 3.0 opt Au (Aughey, 1886).

Fairview mine. SW sec. 13, T14N, R70W. An 8- to 14-foot-wide fissure with argentiferous chalcocite and other copper minerals was intersected at the bottom of a 20-foot shaft (Aughey, 1886). Drifts were driven north-northeast from the shaft on a quartz vein in aplitic quartz monzonite. According to Ferguson (1965), the shaft is 70 feet deep. Some ore was shipped from the property in the winter of 1903-04.

Globe prospect. Secs. 13 and 14, T14N, R70W. This prospect, examined by Beeler (1902e), is probably the Comstock or the Fairview mine. Beeler (1902e) reported the property contained a northerly trending, 4-foot-wide quartz vein with a westerly dip that cut layered granitic rocks. The vein pinched and swelled along strike and was mineralized with chalcopyrite and lesser "white iron pyrites" (pyrrhotite?). The quartz gangue was reported to contain "bunches" and stringers of chalcopyrite, and the "white pyrites" and chalcopyrite were disseminated in granite near the small fissures. Outcrops of quartz were stained with malachite.

Good Hope-Teddy Roosevelt group. Sec. 1, T13N, R70W, and sec. 35, T14N, R70W. This group consists of six claims known as the Teddy Roosevelt, Ray Rock #1, Ray Rock #2, Comstock, and Mountain Rose in sec. 1 and the Good Hope in sec. 35. The Good Hope abuts the Louise mine on the north (Beeler, 1906e).

The dominant rock type is foliated granodiorite; however, metadiorite and amphibolite are common in sec. 1 to the southeast. The amphibolites represent metamorphosed mafic flows and contain some thin felsites that probably represent either metamorphosed andesites or rhyolites.

A number of prospects in this region expose east-west-trending veins with northerly dips stained by copper carbonate and impregnated with chalcopyrite (Beeler, 1906e). Six localized zones exhibiting potassic alteration were mapped by the author in sec. 1 as well as a gossan in the E/2 SE sec. 1.

Great Standard group. This group consisted of 17 lode claims, including the Jolly Rover, Madeline Nos. 1, 2, 3, and 4, Virginia Boy, Hustling Dick, Doctor Bill, Boston Boy, Catalina, Molly O, Colonial, Columbian, Florence, Independence, Washington, and Charlotte. Beeler (1904e) collected three samples of copper-stained quartz from the Colonial prospect that assayed 0.03 to 0.04 opt Au and 0.12 to 0.14 opt Ag. Samples from the Boston Boy prospect yielded 0.03 opt Au, 0.12 and 0.14 opt Ag, and 0.25% Cu. A sample of sulfide-bearing quartz from the Florence prospect assayed 0.1% Cu, 0.02 opt Au, and trace silver.

Hecla. Sec. 24, T14N, R70W. The Hecla property consisted of the Rambler, Coming Day, Big Elephant, and Monte Cristo groups. Copper minerals were found associated with gold and silver in a 4-foot-wide vein on one of the claim groups. A lessor shipped 20 tons of ore in March, 1916 and received $413.00 after freight and smelter fees were deducted (Osterwald and others, 1966, p. 55).

Samples from another group (probably the Rambler) assayed 0.62% Zn, 0.08% Cu, 0.01% Pb, 0.15 opt Au, and $2.40 in silver (price prior to 1927). Other average assays were reported to yield 5.2% Zn with lesser amounts of silver, lead, and copper. The Monte Cristo group was reported to contain molybdenum (Osterwald and others, 1966).

Julian lode. Located 0.5 mile from the Lenox mine near the bank of Middle Crow Creek. A 2.5- to 3-foot-wide vein yielded some free-milling gold. Samples assayed 0.5 opt Au. The vein was 20 feet wide at the bottom of the shaft (Aughey, 1886, p. 4).

Lenox mine. Sec. 24, T14N, R70W. Located on the west side of Red Canyon Road. The Lenox tunnel was driven 375 feet into Hecla Mountain (Ferguson, 1965). An orebody was intersected that trends north-northwest and dips northeast. The vein is 6 inches wide at the surface and 2.5 feet wide at 40 feet below the surface. Mineralization consisted of cerussite and argentiferous galena. Assays showed 10 to 60% Pb, 40 to 60 opt Ag, and 0.3 opt Au (Aughey, 1886). Aughey (1886) also reported wulfenite crystals were found. *(Author's note: These values are highly unlikely and in all probability represent highly selected specimens, or erroneous assays).*

London mine. E/2 sec. 35, T14N, R70W. In 1915 a shaft was sunk on a pyritized gossan in foliated granodiorite to a depth of about 60 feet. Ore grade was too low to ship to a smelter (Ferguson, 1965). Jamison (1911) reported an inclined shaft intersected an 11-foot-wide vein, which assayed as high as 11.0% Cu, 0.05 opt Au, and 1.0% Ni.

No copper minerals were present when examined by the author in 1982, and a select sample of quartz with disseminated pyrite collected at that time assayed 0.02 opt Au.

Louise mine. SE sec. 35, T14N, R70W. The Louise mine was part of the Kopper Krown group (Osterwald and others, 1966, p. 56). The mine consists of two shafts, 160 and 110 feet deep respectively, with 143 total feet of drifts on the 80-, 110- and 160-foot levels (Beeler, 1907c). The shafts were sunk on a 1-foot-wide northerly striking cupriferous vein.

A well-developed stockwork extends 10 to 20 feet outward on either side of the vein (Hausel and Jones, 1982). According to Ferguson (1965), some copper ore was mined from the property and milled at the Copper King mill.

Two grab samples of dump material were collected from the property by the author for assay. A copper carbonate stained schist assayed 0.59% Cu and 0.01 opt Au, and a second sample of pyritized quartz vein assayed 0.22 opt Ag and <0.01 opt Au (Hausel, 1982c). A chip sample of cupriferous quartz from the south shaft assayed 4.2% Cu and no gold (Gordon Marlatt, personal communication, 1982). Beeler (1907c) reported that bornite, chalcopyrite, chalcocite, malachite, azurite, and pyrite were found in the mine. The country rock is granodiorite with a small lens of garnet schist to the east.

Monte Cristo mine. SE sec. 8, T14N, R70W. A 90- to 100-foot-deep shaft was sunk in hornblende granite that reportedly contained stringers of molybdenite (Hagner, 1942a). Hagner, however, noted that no molybdenite was found on the mine dump during his examination of the property.

Orenogo mine. NW NW sec. 36, T14N, R70W. A 500-foot adit was driven into granodiorite about 1500 feet west of the Copper King mine in a tributary valley of Middle Crow Creek (**Figure 44**). The adit was developed in granodiorite with a few poorly mineralized fractures containing copper carbonates and sulfides and cut two quartz monzonite dikes (Hausel and Jones, 1982). In general, mineralization exposed in the mine was poor (**Figure 45**).

Rambler prospect. E/2 E/2 SE NE sec. 22, T14N, R70W. Located in Curt Gowdy State Park between Granite Springs and Crystal Lake Reservoirs (see Hecla). The Rambler prospect was developed by an 80-foot-deep shaft on an ore shoot formed at the intersection of N60°W and N75°E fractures in Sherman Granite. Thirty to 40 feet below the collar of the shaft, the workings were intersected by an adit driven to the west on the N60°W fracture. Sulfides occur as disseminated pyrite and chalcopyrite, with minor sphalerite and specularite. The sulfides occur principally as replacements of mafic minerals in altered granite. Secondary mineralization includes copper silicates and carbonates. Limonitic boxworks are also present. One select sample of sulfide-bearing granite assayed 0.28% Cu and <0.01 opt Au (Hausel, 1981a).

The granite in the general vicinity of the prospect is weakly propylitized as a result of retrogressive metamorphism. But at the Rambler prospect, propylitization is much

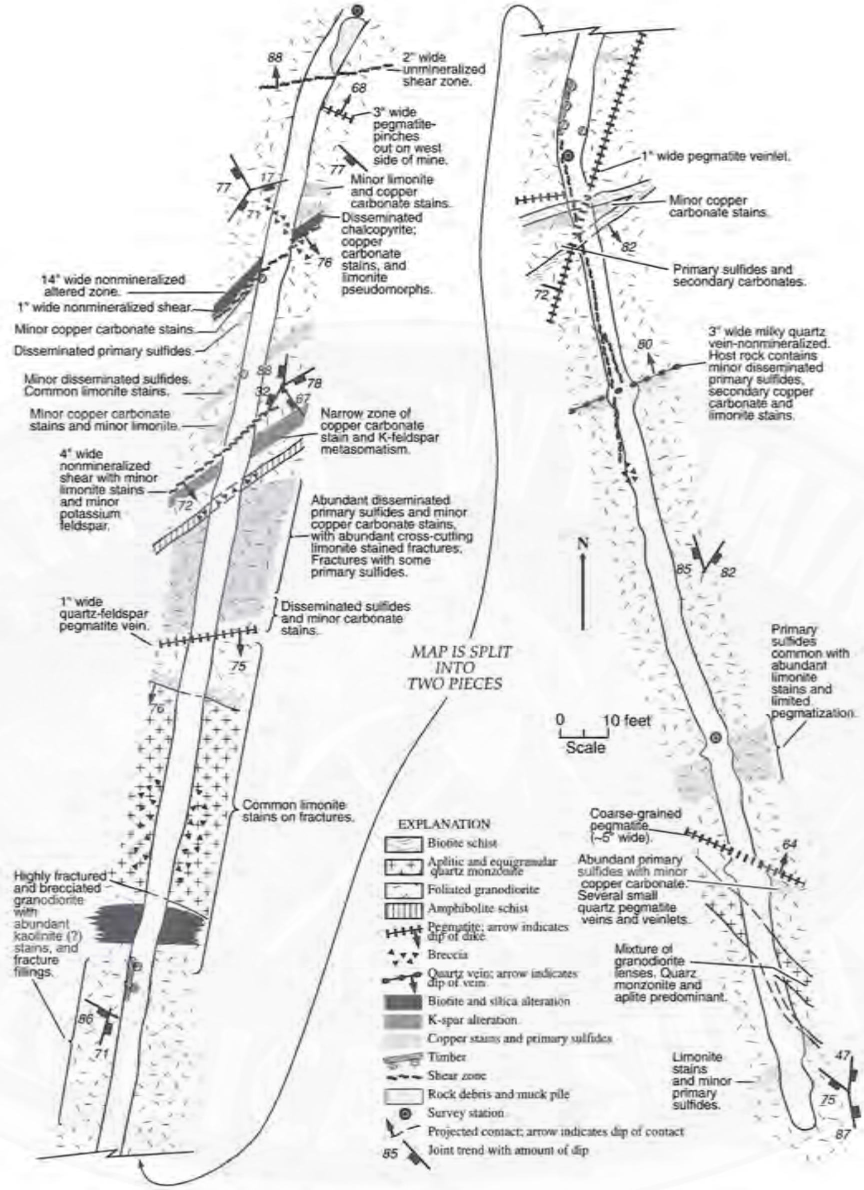


Figure 44. Geologic map of the Orenogo mine (from Hausel and Jones, 1982). Due to length and configuration of mine, this map has been split into two pieces.

more intense and associated with sulfides. Within a few feet of the mineralized fractures, mafic minerals are completely replaced by chlorite, and feldspars are relatively unaffected, megascopically. More intense alteration adjacent to the vein is expressed as pervasive propylitic alteration, and mafic minerals and feldspar are altered to chlorite, epidote, and calcite (Hausel, 1981a; Hausel and Jones, 1982).

Roberts Ranch copper prospect. S/2 sec. 23, T13N, R71W. Northwest-trending cupriferous shears and quartz stringers occur in the Sherman Granite. The mine workings are small and restricted to a shallow shaft and collapsed adit along the Duck Creek drainage. Mineralized rock consists of secondary chrysocolla and cuprite with disseminated pyrite and chalcopyrite. One sample from the mine dump assayed 2.37% Cu and 0.01 opt Au (Hausel, 1982d; Hausel and Jones, 1982).

Steadman tunnel. Sec. 26, T14N, R70W. Located on the north side of the canyon above the Crystal Lake dam (Ferguson, 1965).

Yellow Bird mine. No location given. A shaft was sunk in hornblende granite, and some pyrite was visible on the dump (Hagner, 1942a). According to Ferguson (1965), the shaft was sunk 200 feet. Traces of gold have been reported (Hagner, 1942a).

Figure 45. Geological mapping in the Orenogo mine by the Wyoming State Geological Survey. Although the tunnel was cut through about 500 feet of rock, very little mineralization was evident.

Unnamed mines and prospects

NE sec. 12, T13N, R70W. A select sample of silicified copper-bearing amphibolite collected from a prospect pit on the South Fork of South Crow Creek assayed 0.86% Cu, 0.02 opt Ag, and <0.01 opt Au (Hausel, 1983b). The mineralized rock appears to be limited to a narrow mylonitic zone.

S/2 SW sec. 6, T13N, R69W. A shaft located on the Granite 7.5-minute Quadrangle was sunk to a depth of 10 to 20 feet on a narrow epidote-filled shear in chlorite amphibolite schist. Minor malachite and chrysocolla were found in fractures with minor limonite pseudomorphs after pyrite.

SE sec. 1, T13N, R70W. A 20-foot shaft was sunk on N80°E-striking, 67°NW-dipping copper carbonate-stained quartz veins. The largest vein is 2 feet wide at the surface and has limonitic boxworks. A shear in the host amphibolite separates the primary vein from a smaller vein to the south. The small vein (6 to 8 inches wide) is stained by copper carbonate and limonite. Samples from the mine dump contain quartz vein material with abundant epidote-stained calcite veinlets.

Warbonnet district

The Warbonnet district, bearing the name of a prominent peak situated in sec. 35, T29N, R75W, Converse County, is described by Spencer (1916) as including lands drained by the headwater tributaries of LaPrele Creek and the West Fork of LaBonte Creek to the north, and by tributaries of Sheep Creek and Little Medicine Bow River to the south. The country rock is Archean granite with minor schist cut by northeast-trending diabase dikes with schistose texture. The schists are apparently older than the granite, and the diabase dikes are younger.

Mines and prospects in the district are found in both Albany and Converse Counties, and most are developed on quartz veins principally in the diabase dikes. No major copper occurrences have ever been reported in this district, and historic production was minimal.

Brenning prospect. N/2 sec. 2, T28N, R76W. Two shafts were sunk on epidotized hornblende schist. The shafts intersected chalcocite-bearing schists (Spencer, 1916, p. 76-77).

Copper King mine. W/2 SW sec. 12, T29N, R75W, Warbonnet Peak 7.5-minute Quadrangle. The Copper King mine was developed by two 600-foot tunnels and a shallow discovery shaft located on the north bank of Crazy Horse Creek about 35 miles southwest of Douglas.

The Copper King vein is hosted by a diabase dike with schistose texture. The vein and dike trend N30°–40°E in granite country rock and can be traced at least 2.5 miles along strike. The vein pinches and swells over short distances, and at one point in the upper Copper King adit, the vein swells to a 12-foot-wide ore shoot enriched in chalcopyrite. Gangue minerals include siderite and feldspar (Spencer, 1916).

Spencer estimated that 50 tons of ore were shipped from the mine, and the ore remaining on the dump contained more than 15% Cu. Assays of this material were reported to yield as much as 0.35 opt Au. To the southwest, the vein has scattered patches and seams of magnetite. At one point, about 2 miles southwest, a small deposit of massive magnetite was discovered (Spencer, 1916).

LaBonte prospect. NE sec. 14, T28N, R74W. Copper and pyrite were found in quartz veins hosted by a northeast-trending diabase dike. The dike has well-developed schistosity (Spencer, 1916, p. 73). According to Beeler (1904c), the property was developed by a 360-foot crosscut tunnel.

Mammoth vein. Located on the line between secs. 27 and 28, T28N, R74W. A 50-foot-wide quartz vein is traceable on the surface for at least 2000 feet. At one point along the vein, a shaft exposed iron-stained quartz (Spencer, 1916, p. 73). Beeler (1904c) reported that a 60-foot shaft sunk on the property exposed some chalcocite.

Oriole mine. E/2 SE sec. 10, T29N, R75W. Located on the Warbonnet Peak Quadrangle in the upper valley of LaPrele Creek at its confluence with Roaring Fork Creek. Two shafts were sunk to a depth of about 250 feet on a fractured and silicified Proterozoic mafic dike in Archean granite, and drifts were developed on four levels (Beeler, 1904g; Hausel, 1988a). The dike trends N40°E and dips 86°NW, parallel to the Copper King trend to the east.

Prominent ore minerals found on the mine dump included pyrite, chalcopyrite, and malachite. A select sample assayed 1.11% Cu, and two other mineralized samples assayed 1.14% and 1.18% Cu, respectively, 0.055% and 0.086% Mn, respectively, and no detectable gold or silver (Hausel, 1988a).

Spencer (1916, p. 76) reported several hundred tons of rock carrying as much as 3% Cu had been produced from this property. The vein is as wide as 20 to 30 feet.

Pyramid shaft. NW NW sec. 23, T28N, R74W. A N53°E-trending quartz vein in granite was prospected for copper on LaBonte Creek. Quartz from the dump of a 30-foot-deep shaft sunk on the vein was estimated by Spencer (1916, p. 72) to contain 5% Cu. About 70 feet northeast of this shaft, another shaft was sunk to a depth of about 100 feet on the same vein. Nearly 300 feet northeast of this second shaft, a short tunnel was driven to intersect a 3-foot-wide quartz vein stained with limonite.

A short distance northwest of the Pyramid prospects, hornblende schist cuts across the north-south-trending Corduroy Creek valley. Beyond a bluff on the east side of the valley, prospect pits have disclosed recurring lenses of quartz constituting an interrupted vein. Some of the quartz carries copper. This vein was prospected by about 1000 feet of drifts and crosscuts, which exposed weakly pyritized rock (Spencer, 1916, p. 73).

Olin mine. SW NW sec. 5, T29N, R75W. A shallow, 12-foot-deep shaft was dug for copper into granite. No other information is available.

Miscellaneous localities in the Laramie Mountains

Bucaneer group. Sec. 10, T12N, R71W. Located 6 miles south of Sherman Siding on the north and east side of Dale Creek. A 35-foot-deep shaft was sunk on an 8-foot-wide quartz vein cutting granite. The vein crops out for several hundred feet along strike. The granite is associated with schist and gneiss and is intruded by diabase dikes. Locally the vein contains malachite and azurite with masses of iron and copper sulfides. This prospect is a part of the Portland group (Beeler, 1906d).

Copper Float group. SW sec. 29, T13N, R72W. The Copper Float and other copper prospects were discovered east of Boulder Ridge following the discovery of several masses of native copper float (Darton and Siebenthal, 1909). Some shipments of copper boulders and fragments were made from the property (Beeler, 1906f).

The Copper Float group is located at the base of the Pennsylvanian Fountain Formation where it unconformably overlies Precambrian diorite. Native copper and malachite occur in the matrix of the arkosic basal conglomerate of the Fountain Formation. The deposit was tested by a few prospect pits and open cuts at the Precambrian-Pennsylvanian contact. The deposit is very limited in extent (Harris and Hausel, 1984).

King Solomon shaft. NE sec. 15, T12N, R73W. Located along the eastern flank of Boulder Ridge. Pieces of native copper float, weighing as much as 20 pounds, were discovered on talus slopes of the Fountain Formation prior to 1909 (Darton and Siebenthal, 1909). The source of the copper was later discovered to be arkosic sandstones of the Fountain Formation (Pennsylvanian) along the unconformity with the Sherman Granite (Precambrian).

Native copper, cuprite, and malachite locally stain sand grains and pebbles in the arkose and replace carbonate matrix of the Fountain conglomerate. A shaft was sunk in the mineralized rock but the extent of the workings is unknown (Harris and Hausel, 1984). The shaft later was filled with dump material, and a log cabin was constructed over the workings.

Percis claims. Secs. 1 and 12, T18N, R73W. Copper was reported replacing chert in Casper Formation limestone near the mouth of Wallrock Canyon. The mineralization is erratic and consists of chalcocite, cuprite, and malachite. According to Hagner

(1942d), some ore was hand picked from this property and from another deposit 5 miles to the north and shipped. The property to the north also contains copper veinlets and replacements in limestone of the Casper Formation (Hagner, 1942d).

Sawmill Canyon. E/2 sec. 18, T14N, R72W. Located in the vicinity of Red Buttes south of Laramie. A couple of prospect pits were dug along a fault in the Casper Formation. Samples of limestone contain minor malachite and hematite as fracture fillings (Alan Ver Ploeg, personal communication, 1994). One sample assayed by the Wyoming State Geological Survey yielded 0.4% Cu, 9.7 ppm Ag, 0.2 ppm Au, 39 ppm Pb, and 8.7 ppm Zn.

The limestone shows no evidence of hydrothermal alteration, and the copper probably was mobilized by groundwater along the fault. This deposit is similar to the Copper Float and King Solomon prospects further to the south.

Sherman group. Sec. 23, T13N, R71W. Some samples of limonite-stained veins from the Sherman group assayed 0.10 opt Au. A 140-foot-deep shaft dug on the property cut 2 feet of quartz containing disseminated copper sulfides at a depth of 75 feet. Three hundred feet to the south, a 25-foot-wide "heavily mineralized" mafic dike crops out (Beeler, 1906d; 1907f).

Wallrock Canyon. Sec. 36, T19N, R73W. Chrysocolla and chalcocite occur as replacement veins lining small fractures and as coatings on Casper Formation limestone. A select sample yielded 44.0% Cu and 11 opt Ag (Hausel, 1983d).

Welcome mine. Located northeast of Frederick at the base of a granite hill. The granite contains banded and intermingled chalcopyrite (Osterwald and others, 1966, p. 120).

Rogers Canyon prospects. Secs. 10, 15 and 22, T16N, R72W. Copper occurs in Casper Formation limestone several hundred feet (stratigraphically) above the granite-limestone contact. Three mineralized bodies occur as small, irregular replacement veins that line fractures. In sec. 22, copper was found in loose angular blocks and fragments of limestone. Copper minerals include malachite, chalcocite, chrysocolla, brochanite, and bornite. Mineralization appears to pinch out at a shallow depth (Wilson, 1951).

Medicine Bow Mountains

Within the Medicine Bow Mountains, older quartzofeldspathic gneiss unconformably overlain by a succession of metasedimentary rocks occur to the north and are separated from a succession of younger metavolcanic and metasedimentary rocks to the south by a major east-west-trending crustal suture known locally as the Mullen Creek-Nash Fork shear zone. It is part of the larger and more extensive Cheyenne Belt that continues to the east through the Laramie Mountains and to the west through the Sierra Madre.

The Mullen Creek-Nash Fork shear zone is interpreted as a Proterozoic subduction zone separating older cratonic rocks to the north from younger cratonized oceanic and island-arc rocks to the south. Platinum-bearing mafic and ultramafic rocks (i.e. the New Rambler area and the Lake Owens complex) are found south of the shear zone in the eugeoclinal terrane and may represent ophiolite remnants stacked against the main subduction zone. Samples collected from this terrane in the Medicine Bow Mountains yielded anomalously high platinum values compared to both crustal abundances and to similar rocks in the nearby Sierra Madre (Houston and others, 1975). Nine mineralized samples collected from the New Rambler mine averaged 1750 ppb Pt plus Pd, and 17 mineralized samples from five different mines averaged 3050 ppm Cu (Houston and others, 1975).

Historically, the Medicine Bow Mountains were initially swarmed over by gold prospectors. Some copper and platinum was later found in the region, but production was minor (Hausel, 1993c).

Big Creek district

The Big Creek district lies on the southwestern flank of the Medicine Bow Mountains within the foothills along the North Platte River. The area is underlain by interlayered Precambrian feldspar-quartz-biotite gneiss and hornblende gneiss and schist deformed into a series of northeast-trending folds with near-vertical limbs. The folds are displaced along east-west- and northeast-trending faults and shears.

The layered rocks were intruded by mafic rocks in the northeastern portion and by foliated granite in the northwestern portion of the district. Tertiary rocks of the North Park Formation unconformably overlie the Precambrian crystalline rocks in the southwestern part of the district (Houston, 1961).

Mineralization

A few small mines and prospects were developed on cupriferous and rare-earth-bearing pegmatites. The pegmatites are hosted by layered gneiss and schist. Farther to the north, along Boat Creek, are narrow quartz veins containing gold and minor copper (Hausel, 1989).

Mines and prospects

Big Creek (Bonanza, Cox) mine. Secs. 8 and 9, T13N, R81W. In 1932, 30 tons of ore averaging 38% Cu and 50 tons of ore averaging 10% Cu were shipped from the Big Creek mine. Later, approximately $2300 worth of copper ore (about 11,500 pounds) was recovered from two tunnels during the Second World War (Platt, 1942). Assays of the ore were reported to range from 2.3 to 74.5% Cu plus some silver and as much as 0.85 opt Au (Beeler, 1903a; Osterwald and others, 1966, p. 46).

The Big Creek mine is located on a 20- to 30-foot-wide granite pegmatite dike that intrudes Precambrian schists and gneisses. The dike is conformable with the foliation of the metamorphic rocks (Kennedy, 1927).

Mineralization is erratic and includes chalcopyrite, bornite, chalcocite, pyrite, azurite, native copper, and malachite (Beeler, 1903a; Haldane, 1934). Some ore was reported by American Smelting and Refining Company to contain 18.65% Cu, 1.0% Zn, 0.3% As, 0.015 opt Au, and 0.6 opt Ag. Assays of samples collected from the dike in 1934 are listed in **Table 12**.

Table 12. Copper, gold, and silver assays reported by the American Smelting and Refining Company in 1934 for mineralized rock in the Big Creek mine (from Beeler, 1942). Analyses in weight percent (%) or ounces per ton (opt).

Thickness and location of sample	Cu (%)	Au (opt)	Ag (opt)
15-foot sample, 100 feet from portal	4.1	0.005	0.6
14-foot sample, from small stope	4.6	0.005	0.7
18-foot sample in drift	3.9	trace	0.1
27-foot sample, hanging wall side of drift	4.2	trace	0.2
66-foot sample, south side of drift	4.3	trace	0.3
12-foot sample, north side of drift in small stope	4.8	trace	0.5
19-foot sample, crosscut, northwest face	6.0	trace	0.1
12-foot sample, east wall of same crosscut	5.1	trace	0.1
12-foot sample, footwall, 150 feet from portal	2.4	trace	0.4

Gibraltar prospect. Located on the north and west side of Big Creek. A shaft was sunk on quartz in iron-stained schist. At the surface, native copper and copper carbonates were found. Below the surface, chalcocite, chalcopyrite, and covellite were encountered (Beeler, 1903h).

Golden Clover mine. Located in section 26, T14N, R82W. The Golden Clover shaft was sunk 100 feet into a narrow quartz vein in sheared quartzofeldspathic gneiss. The vein has a strike length of 2000 feet with widths of 6 inches to 6 feet. According to Ralph Platt (personal communication, 1995), the vein and some of the sheared wall rock contains gold, although the wall rock is only weakly mineralized. Assay certificates in the possession of Mr. Platt ranged from 0.2 to 20 opt Au. The higher gold values tend to occur where the vein pinches.

A sample of milky quartz float with limonite after sulfides collected by the author yielded 9.65 ppm Au. More recent samples yielded 3 ppb to 49.85 ppm Au, <0.02 to 37.4 ppm Ag, 248 ppm to 1.8% Cu, and trace Pb and Zn. According to Ralph Platt, several float samples from the area as well as a nearby vein (that is cut by Highway 230) also yield anomalous gold. A nearby copper prospect contains some silver values but no gold.

Natures Mint mine. Sec. 30, T14N, R80W. The mine was developed on a northwest-trending quartz vein in metagabbro in Boat Creek valley. Donnelly (1979) reported the vein carried chalcopyrite, arsenopyrite, and visible gold. A sample collected by Kluender (1982) yielded 1.0% Cu, 2.46 opt Au, 1.2 opt Ag, 0.2% V, and 0.2% As. Another sample collected by McCallum and Kluender (1983) assayed 23.3 opt Au and 24 ppm Ag. The nearby Golden Eagle prospect has produced specimens with visible gold (Hausel, 1989).

Cooper Hill district

The Cooper Hill district is located along the northeastern edge of the Medicine Bow Mountains and consists of Proterozoic metasedimentary rocks with minor mafic intrusives (**Figure 46**). The district was initially prospected for gold. In addition to gold, minor amounts of copper, lead, and silver were mined in the district.

Placer gold may have been found in Cooper Creek as early as 1854. Later, in 1877, the King Survey of the 41st Parallel also reported rumors of gold in Cooper Creek, but no apparent verification was made. In 1893, claims were staked following the discovery of gossans on Cooper Hill, and lode mining began. Three years later (1896) several thousand acres of placer ground were staked along the North and South Forks of Cooper Creek and on the East(?) Fork of Dutton Creek (Hausel, 1993a, 1994a).

Activity in the district was short-lived in that the veins were narrow and little possibility existed of finding minable reserves at depth. Because Cooper Hill is an allochthonous block of layered Proterozoic metamorphic rocks thrust over younger unmineralized Cretaceous sedimentary rocks, the Proterozoic veins can have no appreciable depth.

Mineralization

Mineral deposits in the district include veins, breccia veins, replacement veins, and skarns (Hausel, 1992d, 1994b). Minor amounts of gold, silver, copper, and lead were recovered from the district.

Ore minerals reported in the district include pyrite, chalcopyrite, chalcocite, argentiferous galena, polybasite [$(Ag,Cu)_{16}Sb_2S_{11}$], and gold (Schoen, 1953). Secondary ore minerals derived from the oxidation of the primary sulfides include malachite, cerussite, and limonite.

Mines and prospects

Albion mine. W/2 sec. 27, T18N, R78W. The Albion vein was developed by two tunnels on a horizontal vein (**Figure 47**). The vein consists of frayed quartz in metalimestone and cuts across lithologies into a footwall quartzite. Where hosted by metalimestone, the vein carried pyrite, chalcopyrite, chalcocite, and bornite. Where hosted by quartzite, it carried argentiferous galena. Samples collected from the deposit range from 0.62 to 1.12% Pb, 0.05 to 0.7 opt Au, 1.66 to 2.83 opt Ag, 0.003 to 0.04% Cu, and trace amounts of zinc (Schoen, 1953; Hausel, 1994b). Some historical assays were reported as high as 350 opt Ag, 9 opt Au, and 40% Pb (Hausel, 1994a).

Cooper Creek adit. SW sec. 3, T17N, R78W. Located south of Cooper Hill along Cooper Creek. The adit was driven 140 feet along a 5- to 6-foot-wide quartz vein hosted by chlorite schist (**Figure 48**). The vein was poorly mineralized. Samples collected from the vein and dump ranged from <0.005 to 0.71 ppm Au and <0.1 to 1.9 ppm Ag, with >2.0% Cu and 128 ppm Pb (**Table 13**) (Hausel and others, 1994).

Croesus tunnel. The mine was reported to be on the east side of Cooper Hill about 0.5 mile from the Albion mine. The claim apparently was located on a large vein of

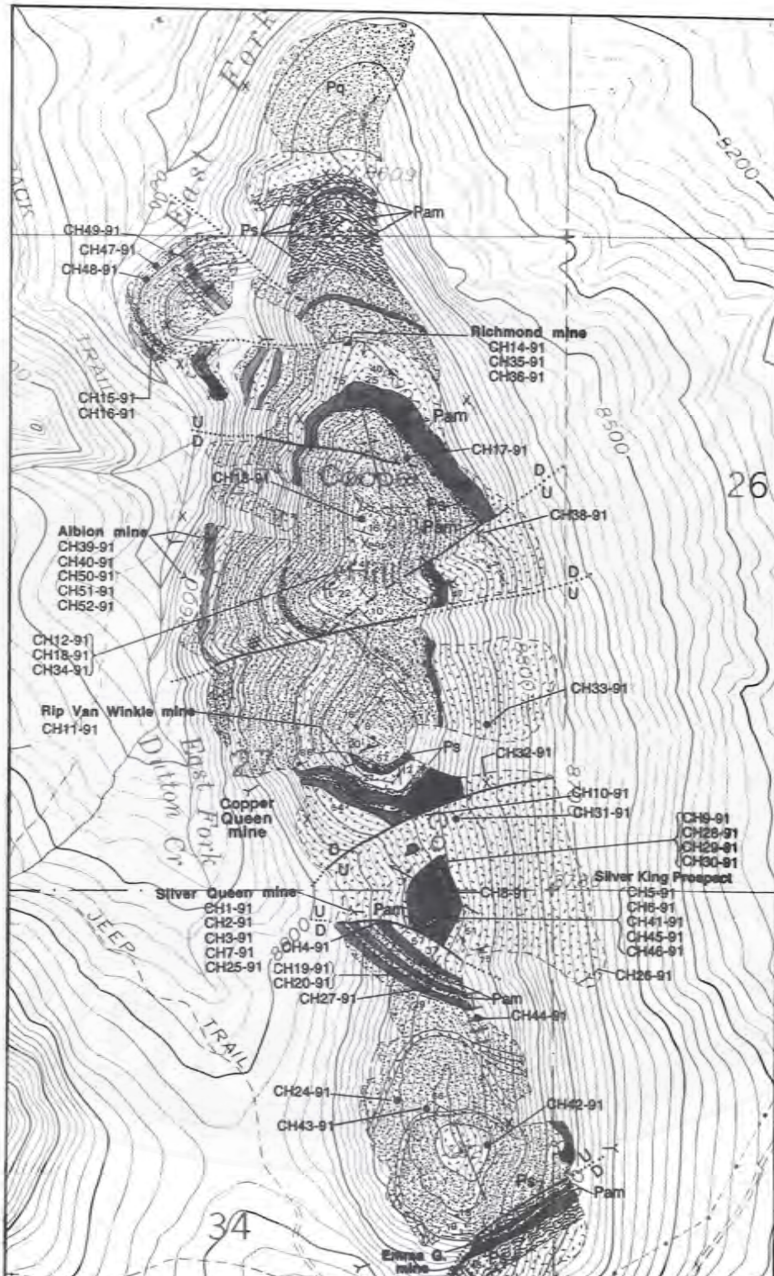


Figure 46. Geologic map of the Cooper Hill district, T18N, R78W (from Hausel, 1994b). Explanation for map is on page 108.

EXPLANATION

LITHOLOGIC UNITS

Quaternary undivided and (or) other unmapped rock units. Includes scree and talus covered slopes and alluvium.

PROTEROZOIC

Pam **Amphibolite, metagabbro, and metabasalt.** Fine-, medium-, and coarse-grained mafic, metaigneous rocks with schistose, blasto-ophitic, and blasto-subophitic textures.

Pq **Quartzite.** Pink, cream, to greenish, fine-to medium-grained quartzite and schistose micaceous quartzite with minor muscovite, chlorite, and orthoclase and trace fuchsite. Locally, beds of stretched-pebble metaconglomerate occur with milky quartz pebbles and minor black chert pebbles.

Ps **Mica schist.** Chlorite and biotite schists and phyllites.

Metalimestone. White metalimestone and fine-grained marble.

MAP SYMBOLS

Mines and prospects

- Shaft
- Adit
- Prospect pit

Bedding and foliation

- 37 Dipping beds
- 42 Dipping foliation

Large scale folds

- Plunging antiform
- Synform

Veins and alteration

- 57 Dipping quartz vein
- Unexplored gossan
- Skarn

Faults and joints

- U D Fault showing relative movement; dashed where approximately located, dotted where concealed; U = upthrown side, D = downthrown side.
- 49 Dipping joints

Minor folds

- Plunging isoclinal fold
- 37 Plunging open fold
- 25 57 Plunging open fold with dipping fold plane

Miscellaneous

- Metaconglomerate bed
- Spring
- CH22-91 Sample site

N MN

12 1/2°

0 1/4 1/2 Mile

0 1,000 2,000 3,000 Feet

SCALE

Figure 46 continued.

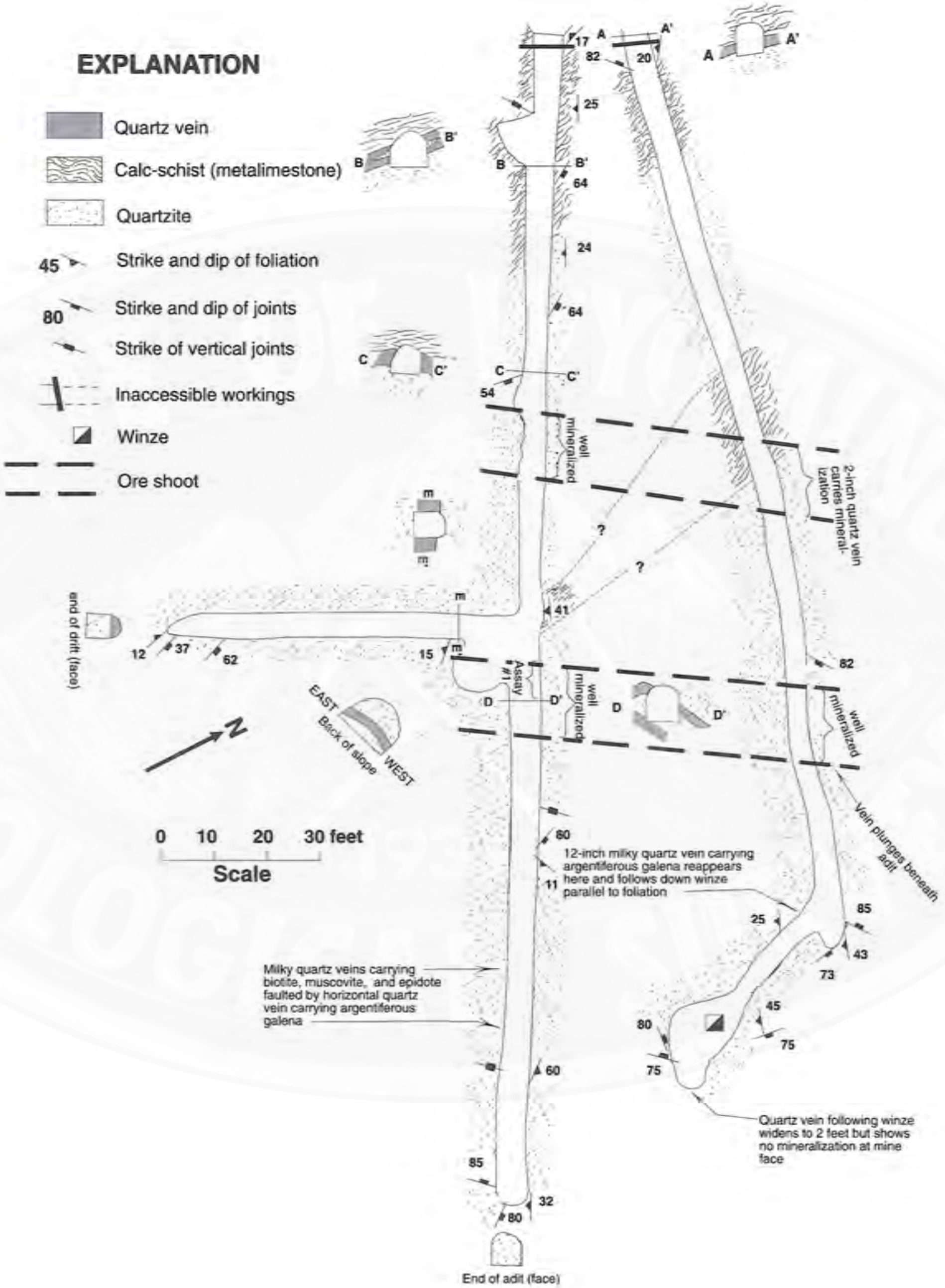


Figure 47. Geologic map of the Albion mine (after Schoen, 1953).

siliceous gold, copper, and silver ore. Historical reports also indicate the orebody was 18 feet wide and carried gold and copper pyrites that averaged 0.4 opt Au and 14% Cu. In 1902 the tunnel was 1236 feet long, and ore from one of the drifts reportedly assayed as high as 2.1 opt Au (Hausel, 1992d, 1994b).

Little Ella-Senator Stewart mine. SW sec. 16 and NW sec. 21, T18N, R78W. Historical reports indicate the Little Ella mine included 700 feet of development work with two shafts 70 feet and 100 feet deep (Hausel, 1992d, 1994b). The Little Ella shaft was connected by a 150-foot tunnel to the Senator Stewart shaft.

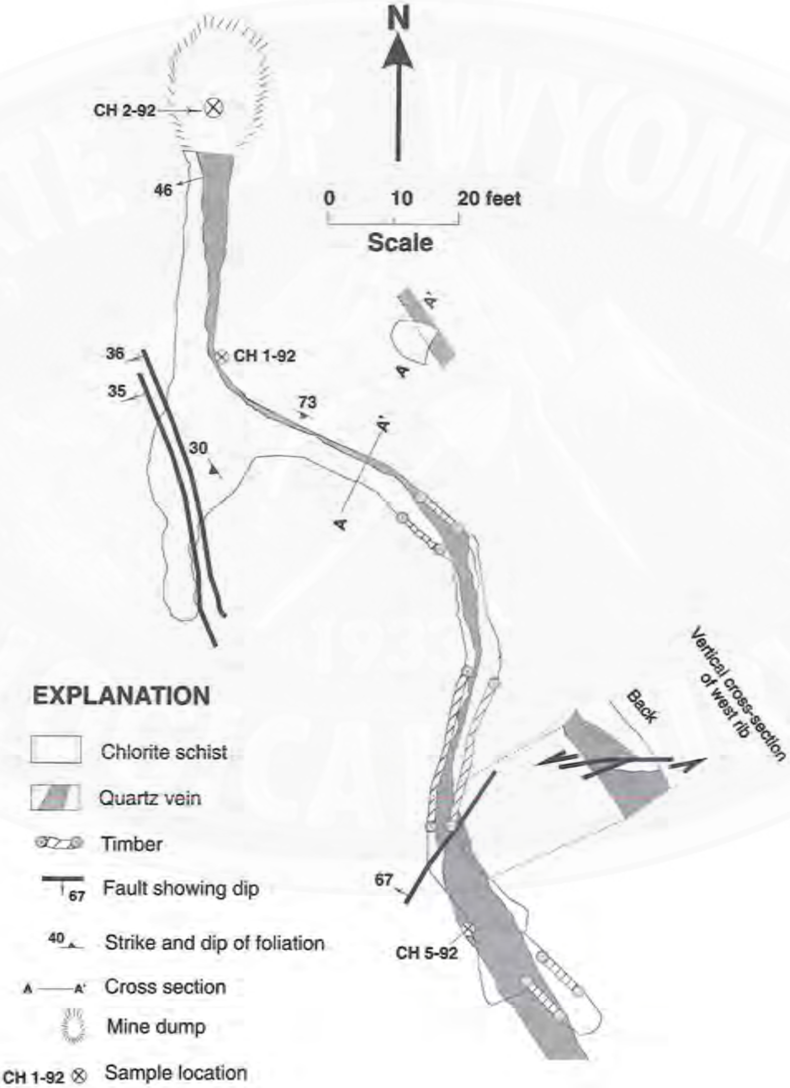


Figure 48. Geologic map of the Cooper Creek adit (after Hausel, 1994b).

*Table 13. Assays from the Cooper Hill district (from Hausel, 1994b). Refer to **Figure 46** for sample locations; locations are all in T18N, R78W. Analyses in weight percent (%) or parts per million (ppm); dashes indicate not analyzed.*

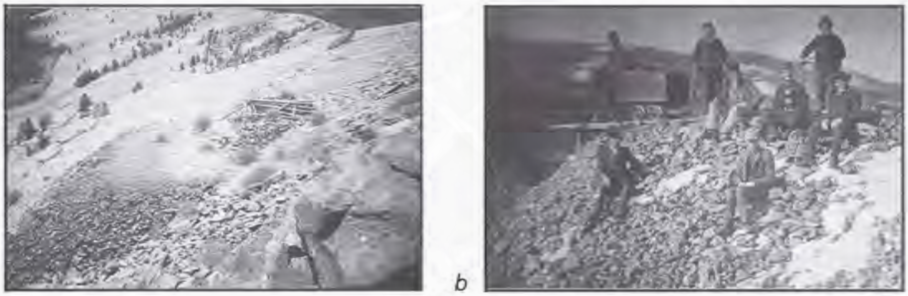
Sample number	Description and location	Au (ppm)	Ag (ppm)	Cu (%)	Pb (ppm)	Zn (ppm)
CH1-91	Limonite, Silver Queen	<0.005	0.6	–	–	–
CH2-91	Limonite, Silver Queen	0.034	0.3	–	–	–
CH4-91	Marble (N/2 NE sec. 34)	<0.005	1.6	–	22	5
CH5-91	Quartz (NW NE sec. 34)	0.187	0.8	0.065	10	–
CH7-91	Quartz, Silver Queen	>10.0	<0.2	2.27	<2	12
CH8-91	Hornfels (N/2 NE sec. 34)	<0.005	<0.2	0.014	7	1
CH11-91	Milky quartz, Rip Van Winkel	0.006	<0.2	–	–	–
CH13-91	Limonite, quartz vein (E/2 sec. 27)	0.240	<0.2	–	–	–
CH14-91	Quartz from Richmond mine	0.041	0.2	–	–	–
CH15-91	Limonite (NE NW sec. 27)	0.013	<0.2	–	–	–
CH16-91	Limonite in quartz	0.037	0.8	0.08	56	46
CH18-91	Conglomerate (SE sec. 27)	<0.005	<0.2	–	–	–
CH19-91	Quartz breccia (E/2 NE sec. 34)	<0.005	0.5	–	–	–
CH20-91	Quartz with limonite	0.022	<0.2	–	–	–
CH21-91	Quartz, Emma G mine	0.089	1.0	–	–	–
CH23-91	Quartz, Clara B prospect	>10.0	1.4	–	–	–
CH25-91	Cupriferous schist, Silver Queen	0.046	0.7	0.35	<2	20
CH26-91	Quartz breccia (W/2 NW sec. 35)	<0.005	0.5	–	–	–
CH28-91	Skarn (S/2 SE sec. 27)	0.012	<0.2	0.04	34	21
CH30-91	Limonite from skarn	0.170	<0.2	0.09	<2	10
CH31-91	Skarn (SE SE sec. 27)	<0.05	–	–	–	–
CH32-91	Quartz (SE sec. 27)	0.190	<1.0	–	–	–
CH34-91	Quartz pebble conglomerate	0.040	<0.2	–	–	–
CH35-91	Quartz, Richmond mine	0.012	<0.1	0.10	25	63
CH36-91	20-foot composite, Richmond vein	0.080	1.2	0.07	11	50
CH38-91	Limonitic quartz, (E/2 sec. 27)	0.160	1.8	–	72	48
CH39-91	Galena quartz, Albion mine	7.5	56.9	0.04	11,242	2.6
CH40-91	Boxwork quartz, Albion mine	<0.05	1.4	0.03	134	45.5
CH41-91	Skarn (N/2 NE sec. 34)	0.108	0.6	1.88	14	19
CH45-91	Skarn (NW NE sec. 34)	<0.05	3.5	0.003	60	15.8
CH46-91	Skarn	<0.05	2.5	0.004	31	7.3
CH50-91	Galena quartz, Albion mine	1.7	97.2	–	6,193	<0.005
CH51-91	Metalimestone, Albion mine	0.6	1.0	0.003	93	36.7
CH52-91	Quartz, Albion mine	0.2	<0.1	0.003	12	12.7
CH1-92	Quartz, Cooper Creek adit	<0.005	<0.1	–	–	–
CH2-92	Quartz, Cooper Creek adit	<0.005	<0.1	–	–	–
CH4-92	Quartz, Cooper Creek adit	0.005	<0.1	–	–	–
CH5-92	Cooper Creek adit	0.071	1.9	>2.0	128	55

The main vein in the mine was 9 to 12 feet wide with gold- and copper-bearing sulfides in quartz. On the 100-foot level, the vein was interpreted to be 50 feet wide The vein averaged 1.1 opt Au with pay streaks running from 2 to 2.4 opt Au. Some select ore was reported by Knight (1893) to have assayed 32.17 opt Au, 4 to 10 opt Ag, and 10 to 12% Cu.

Richmond mine. NE sec. 27, T18N, R78W, located along the crest of Cooper Hill. According to Beeler (1906l), the Richmond mine produced the largest amount of free-milling gold of the Cooper Hill mines. The mine was developed by a 40-foot shaft with a 94-foot drift that intersected a vein reported to have free-milling gold at a depth of 20 feet. Mill runs of ore from the mine averaged nearly 1.0 opt Au according to the available historical reports.

The Richmond shaft was sunk in a quartz breccia vein in a fine-grained hornblendic amphibolite. The vein is more than 20 feet thick and consists of fractured, iron-stained quartz with angular clasts of amphibolite country rock. A 20-foot composite chip sample collected across the vein width assayed 0.08 ppm Au, 1.2 ppm Ag, 0.07% Cu, 11 ppm Pb, and 50 ppm Zn (**Table 13**) (Hausel, 1994b).

Silver King prospect. N/2 NE sec. 34, T18N, R78W. A small prospect pit in the saddle of Cooper Hill on the Silver King claim exposed epidote-calcite-actinolite skarn with some chalcopyrite (**Figure 49**). A narrow quartz vein in the prospect carries chalcopyrite, chalcocite, and minor malachite.



a b

Figure 49. The Silver King mine dump as it appeared in (a) 1993 (photograph by the author), and (b) about 1900 (photograph from the S.H. Knight Collection, American Heritage Center, University of Wyoming. Reproduced with permission).

Five samples collected from the dump in 1991 were poorly mineralized. The maximum assay was cupriferous quartz which yielded 0.187 ppm Au, 0.8 ppm Ag, and 0.065% Cu (**Table 13**) (Hausel, 1992d).

Silver Queen adit. N/2 N/2 sec. 34, T18N, R78W. Ore minerals found on the mine dump included chalcopyrite, cuprite, malachite, chrysocolla, and limonite. Chalcopyrite-bearing amphibolite schist from the dump assayed 0.046 ppm Au, 0.7 ppm Ag, and 0.35% Cu. Cupriferous quartz yielded 0.16 opt Au, <0.2 ppm Ag, and 2.27% Cu (**Table 13**) (Hausel, 1994b).

Plates 1-4

Plate 1A. Looking east from Brown Basin toward Bald Mountain, the symmetrical hill near the center of the photograph.

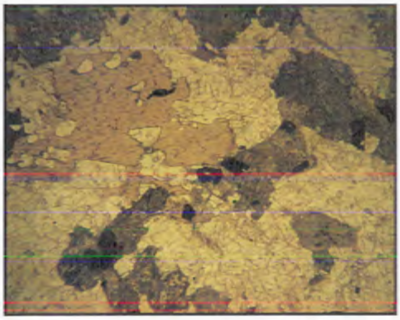


Plate 1B. Thin section of mineralized dacite from the Stinkingwater district shows selective partial replacement of mafic (green) minerals by sulfides (black).

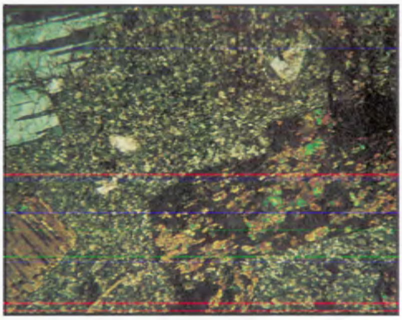


Plate 1C. Under cross polars, a thin section of granodiorite from the Stinkingwater district shows partial replacement of biotite by epidote typical of propylitic alteration (bright stained-glass colors) and sulfides (black).

Plate 1.

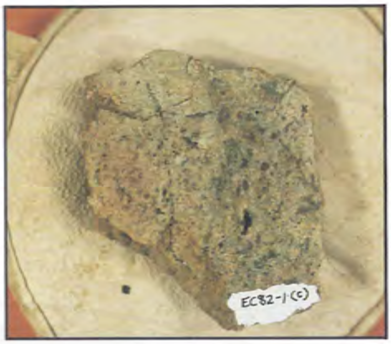


Plate 2A. The topographic saddle in the center of the photograph encloses the Eagle Creek stockworks in the Eagle Creek district.

Plate 2B. The stockworks in the Eagle Creek district include intensely phyllically altered (bleached) latite with abundant pyrite.

Plate 2C. Manganese and sulfide-stained rib in the Mathilda Jane adit, Miners Canyon district, Ferris Mountains.

Plate 2D. Besides copper, jade also occurs in the Tin Cup district. This is a photograph of a rare piece of hexagonal nephrite (jade) pseudomorphing quartz.

Plate 2E. Rubies are also found in the Tin Cup district. This specimen collected by Eric Hausel shows a ruby enclosed by a reaction rim of fuchsitic mica.

Plate 2.

Plate 3A. The Comstock vein in the Silver Crown district as seen in the back of the mine, above the geologist, is about 2.5 feet wide at this point.

Plate 3B. Massive chalcocite-cuprite-chalcopyrite with minor malachite and chrysocolla filling fracture in milky quartz vein from the Kurtz-Chatterton mine, Encampment district.

Plate 3C. View of Nugget Sandstone hosted mineralization in the Griggs mine, Lake Alice district.

Plate 3.

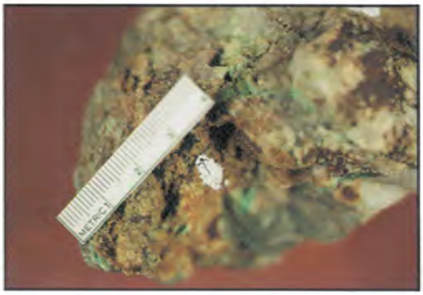


Plate 4A. Copper-stained limonitic quartz from the Penn mine area, Seminoe Mountains. Arrow points at small rod of visible gold.

Plate 4B. Altered and brecciated banded iron formation collected near Bradley Peak, in the Seminoe Mountains.

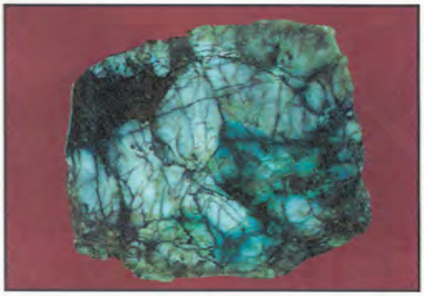


Plate 4C. Cupriferous milky quartz from the Sunday Morning prospect, Seminoe Mountains. Fractures in the quartz are filled with cuprite with minor chrysocolla.

Plate 4D. Botryoidal chalcopyrite ore collected from the Itmay mine dump, Encampment district.

Plate 4.

Copper Ridge district

The Copper Ridge district was located near Mountain Home and the Pelton Creek area in the southern Medicine Bow Mountains. A few small prospects and mines in this region were developed on copper shows in granite.

American mine. SW sec. 16, T12N, R78W. This mine is 0.5 mile east of Mountain Home and south of State Highway 230. The property was developed on silicified, rehealed N15°W-trending fractures in granite. Mineralization includes malachite and azurite. A sample of altered copper-stained granite assayed 1.37% Cu, 2.9 opt Ag, and no detectable gold (Hausel, 1983c).

Copper King mine. SE sec. 9, T12N, R79W, located near Pelton Creek. The mine consisted of a 60-foot shaft sunk in quartz monzonite gneiss. No ore minerals were found on the dump, but the shaft presumably was sunk to intersect a chalcopyrite-molybdenite-bearing pegmatite that crops out a short distance to the northwest (Swetnam, 1961).

Elk Mountain district

Copper was found in limestone breccia and along the unconformity between Paleozoic limestone and the underlying Precambrian granite along Elk Mountain. Production was minor.

Cumberland group. These claims are located at the south end of Coad Mountain. A 12-foot-wide ledge of cupriferous quartzose material was discovered. The mineralized zone is conformable to regional foliation. A similar deposit known as the Camperdown group was located north of the Cumberland group (Beeler, 1905a).

M & M's Elk Mountain mine. Located in secs. 22, 23, and 26, T19N, R82W. Operated by the Elk Mountain Mining and Milling Company, the property was discovered as a copper- and iron-stained gossan (Beeler, 1905a). The deposit lies on the north side of Pass Creek in a series of north-trending fractures along the contact between Madison Limestone and Precambrian schist and granite. Two feet of limestone breccia containing iron oxides, copper oxides, and copper carbonates were discovered. Bunches and streaks of gold- and silver-bearing chalcocite varied from mere specks to masses weighing several hundred pounds (Beeler, 1906l, 1902g). Chalcopyrite was discovered below the chalcocite (Beeler, 1902g; Osterwald and others, 1966).

According to Beeler (1902g), more than 300 feet of drifts and shafts were dug by 1902, and smelter returns showed a shipment of 15.75 tons of ore yielded 4380.21 pounds of copper (14% Cu).

French Creek district

The French Creek district includes massive pyritiferous sheared graphitic schists that have been the focus of some recent gold scams. Beeler (1905a) reported that siliceous hematite schists on Iron Creek yielded small amounts of copper. One shaft sunk to a depth of 80 feet on the Ak-Sar-Ben group cut into the schist and exposed a ledge with considerable black iron and manganese oxides as well as some graphitic schist. The nearby Raven group showed similar rocks.

Ak-Sar-Ben group. Secs. 14 and 15, T14N, R80W. Situated near the head of Iron Creek (a tributary of French Creek). The mineralized zone consists of a limonite- and hematite-stained siliceous zone along the contact between altered graphitic schist and quartzite (Beeler, 1906h).

Lorain group. Secs. 11 and 12, T15N, R80W. Iron sulfides (pyrrhotite) occur in graphitic schist (Beeler, 1904i).

Raven group. These claims are located in secs. 15, 21, and 22, T14N, R80W, on Iron Creek. A siliceous zone stained by limonite and hematite follows the contact between altered graphitic schist and quartzite. The altered schist contains secondary silica and the quartzite is iron stained. The belt of siliceous material trends northeast for about 2 miles, is 30 to 70 feet wide, and contains specks of copper (Osterwald and others, 1966). A 200-foot shaft cut a 5-foot-wide vein in the footwall quartzite that exposed pyrrhotite with minor chalcopyrite. The hanging-wall schist also has disseminated sulfides (Beeler, 1907i). Some samples (apparently selected) yielded as much as 6% Cu (Beeler, 1903j). Beeler (1903j) suggested there were similarities between the Raven group and the Ferris-Haggarty and Doane Rambler properties in the Encampment district.

Gold Hill district

The Gold Hill district in the central Medicine Bow Mountains was organized in 1889 following the discovery of several narrow auriferous quartz veins in quartzites and orthoamphibolites (Hausel, 1989, 1993c). The district produced some spectacular gold-quartz specimens; however, the ore was spotty and only minor production was realized from the district. Copper was unimportant in the district and reported at one locality.

Waterloo prospect. SE part of T16N, R80W. An outcrop of limonite- and copper carbonate-stained quartzite has some copper sulfides (Beeler, 1902i).

Jelm Mountain district

The Jelm Mountain district, located along the southeastern flank of the Medicine Bow Mountains, is centered on T13N, R76–77W (**Figure 50**). The district extends across the Laramie River to the Boswell Creek area west of Jelm Mountain and continues northwest to the southern portion of Sheep Mountain.

In the 1870s, copper and gold were discovered at Jelm Mountain, but the district gained much of its reputation through various mining scams and frauds (Duncan, 1990). Actual production was minimal.

The district includes numerous prospect pits and a few small, scattered mines. The prominent host rock is amphibolite schist (Proterozoic), which has been intruded by granite and pegmatite (Michalek, 1952; King, 1961). The majority of the mineralized deposits occur as quartz veins or as epidotized rehealed fractures conformable with regional foliation (Michalek, 1952). Many of the mines and prospects were initially developed for gold, but gold values declined at shallow depths below surficial gossans. Below the gossans, copper mineralization was prevalent.

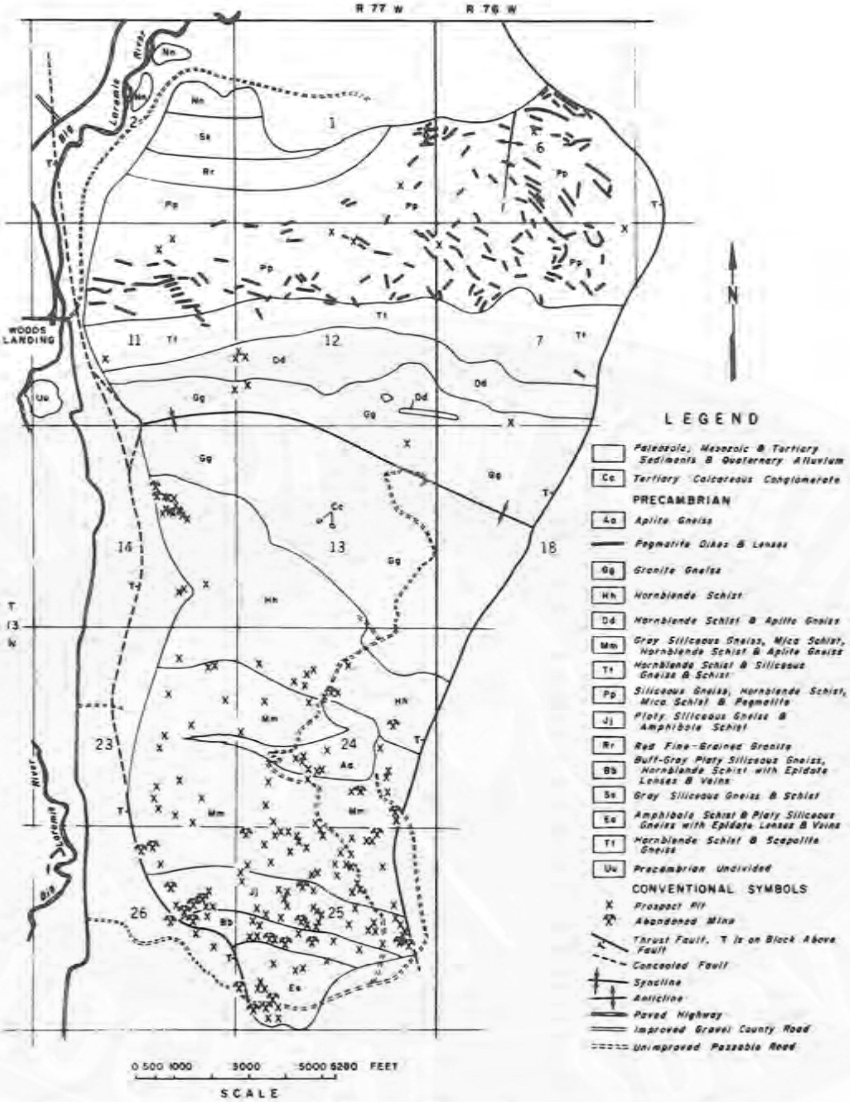


Figure 50. Geologic map of Jelm Mountain, Wyoming (after Michalek, 1952).

Gangue minerals include limonite, hematite, and quartz. The ore assemblage included malachite, cuprite, chalcopyrite, pyrite, and native copper with minor azurite, native gold, and local galena.

According to Michalek (1952), the Jelm Mountain deposits probably formed from hydrothermal leaching of amphibolites followed by transportation of metals to nearby dilation zones. The hydrothermal solutions were suggested to have emanated from late intruding granites.

Named mines and prospects

Annie mine. NE sec. 26, T13N, R77W. Three quartz veins in granite contain chalcopyrite. The veins are separated by 150 feet–one dips 60°N, and the other two dip 70°S. The veins average 3 to 6 feet wide and can be followed 2250 to 3000 feet on an east-west strike conformable to regional foliation. In 1906, development work included a 140-foot shaft intersected by an adit with 138 feet of drifts. The host granite is intercalated with diorite, hornblende schist, and tourmaline schist. Limonite, hematite, malachite, and azurite stain the veins at the surface, and according to Beeler (1906l), "red talcose material" borders the veins, and some of the quartz is auriferous.

Five hundred pounds of ore from 100 feet deep yielded 6.3% Cu. A 2-foot streak of high-grade material at a depth of 135 feet assayed 29% Cu and 0.07 opt Au (Knight, 1942). Beeler (1906l) reported two assays of select ore from the mine yielded 15.53% and 28.83% Cu.

Barber mine. W/2 SE sec. 15, T14N, R77W. The Barber mine is well hidden in a forested area at the headwaters of two unnamed drainages along the southeastern flank of Sheep Mountain. In 1911 the shaft was sunk to a depth of 150 feet (Mining and Engineering World, 1911, v. 35, Aug. 5, p. 259).

When examined in 1991, the property included the caved mine shaft and the remains of three mine support buildings (Hausel, 1991a). Since the portal also was caved, it was not possible to determine the extent of the workings; however, based on the size of the dump, the workings probably were in the range of several hundred feet. In all probability some ore had been shipped from the mine, but no production records are available.

The mine was developed on a quartz vein in Sherman Granite. Mineralized samples collected from the property included (1) hypidiomorphic granular granite with traces of malachite with accessory fluorite replacing biotite; (2) malachite-stained quartz with fracture filling ilsemannite ($MoO_8 \cdot xH_2O$); (3) fractured quartz filled with malachite-stained chalcopyrite, chalcocite, and bornite, with minor disseminated molybdenite; (4) quartz with fractures filled by malachite-stained chalcopyrite, minor cuprite, and traces of copper sulfate. Results of five assays are summarized in **Table 14**.

Table 14. Assays of samples from the Barber mine. Analyses in weight percent (%), parts per million (ppm), or parts per billion (ppb); dashes indicate not analyzed.

Sample number	Au (ppb)	Ag (ppm)	Cu (%)	Pb (ppm)	Zn (ppm)	Mo (ppm)
SPM3-91	52	16.3	>2.0	192	<1	870
SPM4-91	6	5.0	>2.0	672	60	99
SPM5-91	10	23.2	>2.0	47	<1	114
SPM6-91	40	26.8	>2.0	–	–	–
SPM7-91	13	23.8	>2.0	83	<1	–

Boston shaft. The Boston shaft lies 3000 feet north of the Colorado shaft. The prospect was developed by an 80-foot shaft in an auriferous vein (Beeler, 1906l, p. 56).

Colorado shaft. A body of chalcopyrite with stringers of native copper was discovered in gneiss and schist at the bottom of the 250-foot shaft (Beeler, 1906l, p. 54–56).

Copper Queen. Located about 0.5 mile southwest of the former Cummins City settlement. A 24-foot-thick fissure strikes northwest and dips southwest. The Copper Queen mine was developed by an 80-foot shaft sunk on the chalcocite-, cuprite-, tenorite-, and chalcopyrite-bearing fissure. At the bottom of the shaft, native copper was found. One streak of ore 18 inches thick assayed 65% Cu with some gold and lead (Aughey, 1886, p. 8).

Rising Sun. The Rising Sun claim is located northeast of the Boston shaft. This vein parallels the strike and dip of the Boston and Colorado veins and carries some galena with gold and silver values in addition to copper (Beeler, 1906a, p. 56).

Unnamed mines and prospects

NW sec. 10, T13N, R77W. A cupriferous quartz vein occurs in a quartz-hornblende gneiss (Orback, 1960).

SE sec. 21, T14N, R77W. A quartz-copper vein lies along the contact of pink aplite granite with pink coarse-grained granite (Orback, 1960).

E/2 sec. 26, T13N, R77W. Located about 500 feet north of the Jelm Mountain observatory road along a southerly drainage. A now collapsed adit was driven into a N56°W-trending, near vertical, silicified, epidotized, cupriferous breccia in amphibolite schist. The wall rock adjacent to the breccia is locally potassically altered. The adit trends in the direction of a shaft and probably connects to the shaft about 200 feet west of the portal.

Ore minerals found on the dump and in the breccia include malachite, tenorite, and minor azurite and pyrite. A copper-stained chip sample from the breccia assayed 0.23% Cu, 0.09 opt Ag, and <0.01 opt Au (Hausel, 1983e). A chip sample of cupriferous shear assayed 0.63% Cu, 9.7 ppm Pb, and 286 ppm Zn (Hausel, personal field notes, 1993).

Section 26, T13N, R77W. A short adit mapped at the mouth of a narrow canyon along the southwestern margin of Jelm Mountain was sampled by the author in 1993. A 4-foot composite chip sample collected in a limonite-stained vein in the back of the mine yielded 1.9 ppm Ag, 65 ppm Cu, 116 ppm Pb, 884 ppm Zn, and no gold. A second sample of fault gouge at the hanging wall of the vein yielded 137 ppm (3.99 opt) Ag, 36 ppm Cu, 24 ppm Pb, 201 ppm Zn, and no gold. A 1-foot chip sample of limonite-stained micaceous quartzite(?) in the mine yielded 26 ppm Cu, 8.3 ppm Pb, 59 ppm Zn, and no gold or silver. A sample of a narrow limonite- and copper-stained zone at the face of the main tunnel yielded 904 ppm Cu, 5.8 ppm Ag, 276 ppm Pb, 4306 ppm (0.43%) Zn, and no gold (Hausel, personal field notes, 1993).

W/2 sec. 25, T13N, R77W. A select sample of copper-bearing amphibolite schist was collected from a prospect pit on a N83°W-trending vertical shear zone. The sample contained visible chalcopyrite, cuprite, malachite, and azurite and assayed 0.22% Cu, 0.07 opt Ag, and <0.01 opt Au (Hausel, 1983e). A sample of milky quartz with minor pyrite and trace copper staining assayed 0.7 ppm Au, 51.0 ppm (1.5 opt) Ag, 889 ppm Cu, 989 ppm Pb, and 103 ppm Zn (Hausel, personal field notes, 1993).

NW sec. 25, T13N, R77W. A shallow shaft was sunk on a shear zone along the contact between pink felsite and gray quartz biotite gneiss. A sample collected from the mine dump was highly silicified with milky quartz, black tourmalinized quartz, and minor pyrite. The sample assayed 32 ppm Cu, 29 ppm Zn, and no detectable gold, silver, or lead (Hausel, personal field notes, 1993).

NW sec. 25, T13N, R77W. At another shaft, select samples of milky quartz in amphibolite contained minor chalcopyrite, malachite, and cuprite.

W/2 sec. 25, T13N, R77W. Weakly copper-stained mafic schist assayed 52 ppm Cu, 5.4 ppm Pb, 54 ppm Zn, and 12.0 ppm Ag. Two other samples were collected from this location by the author. One sample assayed 0.18% Cu, 955 ppm Pb, 184 ppm Zn, 88.0 ppm (2.57 opt) Ag, and 2.3 ppm (0.067 opt) Au. The other sample yielded 1.39% Cu, 16 ppm Pb, 110 ppm Zn, 12 ppm Ag, and no Au (Hausel, personal field notes, 1993).

NW sec. 27, T14N, R77W. A small prospect pit occurs on a southeasterly trending fault in the Fence Creek valley. A short distance east of that prospect, at the confluence of two unnamed intermittent drainages, is a shaft with a small dump and a decaying cabin.

SE sec. 21, T14N, R77W. A prospect pit was dug in pink sericitized granite. Very little evidence of mineralization was found here with the exception of minor malachite stains on the granite (Hausel, 1991a).

Keystone district

The Keystone lode was staked along the bank of Douglas Creek on October 31, 1876, establishing the Keystone district. In the following year, a five-stamp mill was moved from the Centennial Ridge district to the Keystone mine (Duncan, 1990). By 1890, a 40-ton stamp mill was operating on the property crushing gold-bearing quartz.

In addition to several gold mines, a few copper prospects were developed in the district. The principal lode was the Keystone-Florence trend which ran from the village of Keystone to the Florence mine nearly a mile to the southeast (Hausel, 1989) (**Figure 51**).

The geology of the district is dominated by a large, circular, 5-mile-diameter quartz diorite pluton that intrudes quartz biotite schist and amphibole gneiss. The principal orebodies are found in tensional shears (faults) subsidiary to the Mullen Creek-Nash Fork shear zone (Currey, 1965). These mineralized shears range from a few feet wide with local splays over 300 feet (Loucks, 1976).

Mineralization

The Keystone district surrounds the village of Keystone in the Medicine Bow Mountains and is considered to include all lode deposits related to the Keystone quartz diorite. Most base and precious metal deposits consist of gold- and copper-bearing pyritic quartz-carbonate veins that occur in northwest-trending tensional faults subsid-

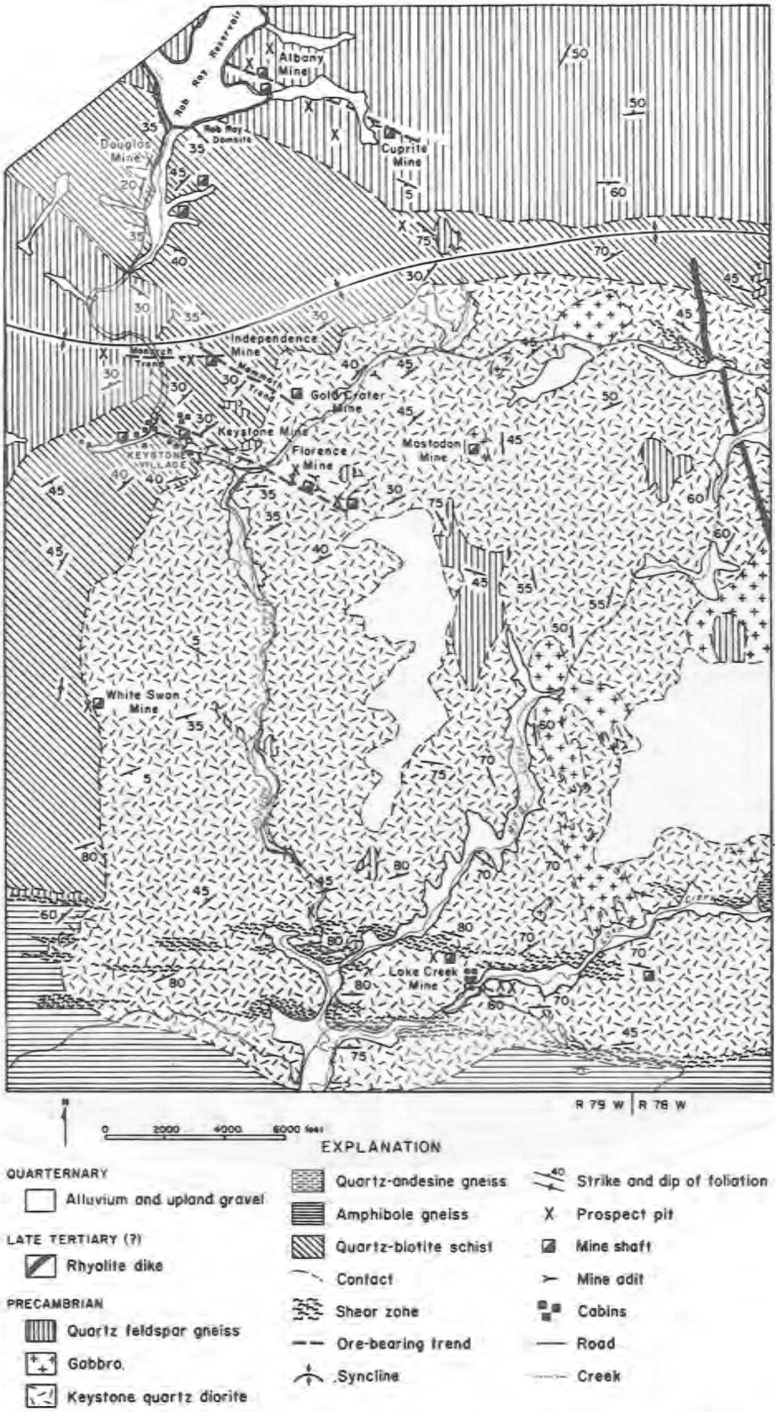


Figure 51. Geologic map of the Keystone district (from Currey, 1965).

iary to the Mullen Creek-Nash Fork shear zone. Some sparse mineralization also occurs within major northeast-trending shears (Currey, 1965).

Mines and prospects

Albany mine. N/2 sec. 10, T14N, R79W. In 1903, a 360-foot shaft was sunk on a west-northwest-trending vein and shear. Covellite was found 150 feet below the collar (Curry, 1965).

Cuprite mine. NW sec. 11, T14N, R79W. In 1900, a 954-foot drift driven off a 65-foot shaft followed a west-northwest-striking vein in chlorite schist. The width of the mineralized zone is slightly less than the width of the drift and has native copper, cuprite, pyrite, chalcopyrite, chalcocite, gold, and silver (Anonymous, 1903; Curry, 1965).

Vein material from the mineralized zone reportedly assayed 3 to 28% Cu, trace to 2.56 opt Au, and trace to 2.0 opt Ag. Trace cobalt and chromium also were detected. The vein coincides with the trend of the Albany vein and probably is the eastern extent of that vein (Curry, 1965). Some float rock found near the Cuprite mine was reported to assay as high as 870 opt Au (Anonymous, 1903).

Douglas mine. SE sec. 9, T14N, R79W. This mine was originally located as the Morning Star claim in 1868. The property consisted of a 150-foot inclined shaft with 80 feet of drifts and crosscuts. A 7-foot-wide mineralized zone was encountered at the 35-foot level that contained native copper, copper carbonates, chalcopyrite, chalcocite, cobaltite, silver, and gold. Three veins, 6 inches to 2 feet, 2 to 3 feet, and 1 foot wide, respectively, were encountered at deeper levels. The surface workings were obliterated when the present road was constructed along the west bank of Douglas Creek (Osterwald and others, 1966).

Fairview claim. Sec. 6, T13N, R79W. Located near Devil's Gate southwest of Keystone. Material from a 3.5-foot-wide vein assayed 28.5% Cu and 0.8 opt Au. The sample was taken 8 feet below the surface (Osterwald and others, 1966, p. 81).

Florence mine. SE sec. 22, T14N, R79W. The Florence shaft was sunk in a shear zone in Keystone quartz diorite near the southeastern extent of the Keystone-Florence shear. The property was principally a gold property and ore from the mine was reported to average 0.82 opt Au (Engineering and Mining Journal, 1890, v. 49, Jan. 25, p. 118). The ore consisted of low-grade mineralized rock with sporadic pockets of gold-bearing pyrrhotite.

Some of the pyrrhotite pockets were rich and yielded 7.5 to 48 opt Au (Currey, 1965). Samples collected by Loucks (1976) assayed 0.06 to 23.3 opt Au. Samples collected by the author yielded 0 to 0.03 opt Au and 0 to 0.06 opt Ag (Hausel, 1990e); however, some auriferous boxwork specimens were collected that were not assayed. Gold production from the mine was estimated by Currey (1965) at 2500 ounces.

Gold Crater group. SE sec. 15 and NE sec. 22, T14N, R79W. Located a short distance northeast of the Keystone ranger station. Several copper-stained quartz veins and stringers occur in quartz diorite. The Gold Crater mine in the NE sec. 22 was developed along the Mammoth trend. The Mammoth trend strikes northwesterly and was tested by both the Independence and Gold Crater mines (Currey, 1965).

Limonite and copper-carbonates stain quartz. A vein 10 to 12 inches wide was cut by a 370-foot tunnel at the Gold Crater mine. The vein carried bunches and spots of pyrite and chalcopyrite with free gold. The material varied in tenor but averaged "one foot of $20.00 ore" (Beeler, 1905a). An additional 50 feet of drift were driven in 1937 (Currey, 1965).

The Gold Crater lode consists of several sheared quartz veins containing pyrite, chalcopyrite, and free gold. Seven samples collected from mines in the Gold Crater group by the author contained 0 to 0.03 opt Au and 0 to 0.55 opt Ag. Two samples yielded 0.04% and 0.2% Cu, and two other samples had 0.025% and 0.032% Co. The assays indicate the rock is weakly, although anomalously, mineralized (Hausel, 1993c).

Hamilton group. Sec. 36, T14N, R80W, located near Devils Gate 6 miles southwest of Keystone. A "huge 2 mile long ledge of altered diorite" hosted by granite trends west-east. At several locations, the diorite encloses limonite- and copper-stained quartz (Beeler, 1907g).

Independence mine. S/2 SW sec. 15, T14N, R79W. This prospect was originally called the Mammoth. In the early 1900s, an 80-foot shaft with 100 feet of crosscuts was driven near the intersection of an east-west-trending quartz vein with a northwest-striking shear zone in quartz biotite schist country rock. The ore shoot contained auriferous pyrite and chalcopyrite. One-quarter mile west of the shaft, an adit driven to the east encountered chalcanthite-bearing ore on the east-west-trending vein, which averaged 13.5% Cu with 0.97% Bi (Currey, 1965). Weathered slope material from the vein panned in gold (Beeler, 1906j).

On either side of the principal vein, several small rich gold veins were encountered. These vary from 6 to 18 inches wide and carry 0.5 to 14.5 opt Au (Loucks, 1976).

Keystone mine. NW sec. 22, T14N, R79W. The Keystone mine was principally a gold property and it is unknown if any copper was recovered from the mine (**Figure 52**). The shaft was sunk to a depth of 365 feet with 5000 feet of drifts on an ore shoot in the Keystone-Florence trend. The Keystone-Florence trend is a N60°W-trending shear zone in diabase that intrudes quartz-biotite schist country rock (Currey, 1965). The shear is traceable for more than a mile.

Gold is found in quartz, pyrite, and pyrrhotite in the shear zone and in mylonite selvages adjacent to the shear. The shear is 2 to 6 feet wide with local splays up to 300 feet (Loucks, 1976; Hausel, 1990f). Ore produced from the mine was reported to average 1.2 opt Au (Currey, 1965).

Production statistics suggest that the Keystone mine produced 5000 to 10,000 ounces of gold. For instance, *Engineering and Mining Journal* (1890, v. 49, Jan. 25, p. 118) reported production at 10,000 ounces of gold from ore that averaged 0.84 opt Au. However, several months later, the journal (1890, v. 50, Nov. 22, p. 607) reported the Keystone mine had produced only 3750 ounces of gold up to 1889. Gold production continued after these reports, as was indicated in 1891 when the journal (1891, v. 51, Apr. 18, p. 480) reported the Otras Mining Company was recovering about 50 ounces of gold per week. In 1893 mining operations ceased with 6000 tons of ore on the dump, and another 100,000 tons of reserves identified underground (Currey, 1965).

Figure 52. The historical Keystone mine along Douglas Creek as it appeared about 1905 (Photograph from the S.H. Knight Collection, American Heritage Center, University of Wyoming. Reproduced with permission).

During field examination of this property, ore specimens were difficult to find, indicating the ore stockpile had been beneficiated sometime after the mine closure. Eight samples collected from the mine by Loucks (1976) yielded 0.19 to 8.75 opt Au. Samples collected by the author ranged from no detectable gold to 0.64 opt Au and 0 to 0.08 opt Ag (Hausel, 1990e).

Rosebud claim. Located on Muddy Creek about 1.5 miles southwest of Tenderfoot Mountain. Material found in a 55-foot shaft assayed a maximum of 50% Cu and 1 opt Ag (Anonymous, 1903).

SE sec. 19, T14N, R79W. A high-grade sample collected from an ore bin adjacent to a shaft at this location yielded 0.2% Cu, 0.2% As, 0.2% Ti, 0.4 opt Ag, and 0.604 opt Au (Kluender, 1982).

Lake Creek district

The Lake Creek district included a group of small mines and prospects along Lake Creek south of the Keystone district. Immediately east of the district is the Lake Owen layered mafic complex (T13–14N, R77–78W) which has significant potential for platinum group metals.

Albatross claim. A 7-foot-wide vein of "jasper-iron quartz" yielded 0.32 opt Au and 4% Cu. A 30-foot shaft was sunk on the property (Anonymous, 1900).

Cumberland group. Located near the head of the South Fork of Lake Creek on the south end of Coad Mountain. A series of quartz-biotite schists, hornblende schists, and tourmaline-garnet-mica schists dip 15°NW. A 15-foot-wide quartz vein conforms to the schistosity and contains limonite and malachite with some chalcocite. Some quartz contains a little gold and silver. Much of the vein is crushed and broken (Beeler, 1903m; Osterwald and others, 1966, p. 43).

Kansas group. Sec. 12, T13N, R79W. Located on Lake Creek about 6 miles southeast of Keystone and about 4 miles above the junction of Lake Creek with Douglas Creek. Based on Beeler's description, this group may be mislocated because Lake Creek does not flow through sec. 12, and Beeler's location would be only about 2 miles above the junction.

A 40-foot shaft and a 150-foot adit were dug to test a 6-foot-wide quartz vein in "diorite granite" (probably Keystone quartz diorite). The vein trends S70°E with a southerly dip. The vein is "heavily mineralized" and stained by limonite and copper with trace amounts of gold (Beeler, 1907h).

Lake Creek mines. SE sec. 2, T13N, R79W. Copper-gold mineralization occurs in silicified mylonite associated within broad east-west-striking shears. Underground workings included a 75-foot shaft with 715 feet of crosscuts and drifts and a 35-foot adit. Contemporary assays from this area reported combined values in gold, silver, and copper ranging from $4 to $140 per ton (date of prices not given) (Curry, 1965).

Maudem group. SW sec. 1, T13N, R79W. Located on Lake Creek, 3 miles above its junction with Douglas Creek. Biotite and hornblende granite and gneiss interlayered with schist are cut by a quartz vein. The vein shows heavy limonite and copper stains. Mine dump samples contain chalcocite and chalcopyrite. The owner's assay sheets showed "considerable gold values" (Beeler, 1904f).

LaPlata district

The LaPlata district was developed from a small group of copper, silver, and gold prospects and mines immediately east of Gold Hill in the Snowy Range–none of which yielded much ore. Historical reports indicate 1000 pounds of ore were shipped from the Big Strike prospect in the district. The reports indicated the ore contained as much as 40% Pb, 31.7 opt Ag, and 0.9 opt Au *(Author's note: either these values were from very select ore or the values were probably exaggerated).* Other properties in the district included the Telephone, North American, Brooklyn, Red Bird, and Gray Copper prospects.

The LaPlata district lies at the top of the Snowy Range in the Medicine Bow Mountains and is underlain by metacarbonates and quartzites. Many of the mines and prospect pits were developed on shears that yielded traces of silver and copper. The known mineral deposits are weakly mineralized with the possible exception of the Billie Class deposit. The Billie Class consists of an impressive gossaniferous shear zone, 100 to 200 feet wide, with strike length of 2000 feet. Recent samples collected from the shear yielded 0.063 to 4.8 ppm Au (Dersch, 1991; Hausel, 1993c).

Bellamy Lake mine. Located in sec. 19, T16N, R79W. This adit was located on a contact between quartzite and a mafic dike (chlorite schist). Samples from the mine dump contained minor amounts of quartz with some chalcopyrite. A sample of mineralized schist yielded 0.04% Cu, 0.02 opt Ag, and no detectable gold (Hausel, 1993c).

New Rambler district

The New Rambler district lies along the northeastern edge of the Mullen Creek layered mafic complex in the north-central Medicine Bow Mountains (**Figure 53**). The Mullen Creek complex is a 60-square-mile, highly deformed, 1.8-Ga, layered tholeiitic intrusive. The complex includes more than 21 cyclic units (Loucks and others, 1988).

The principal property is the New Rambler mine located west of Douglas Creek and Rob Roy Reservoir. The former Holmes town site was established adjacent to the New Rambler mine in about 1893.

Mineralization

Rocks within the district have been hydrothermally altered and locally overprinted by supergene alteration. Greenschist propylitic alteration assemblages are widespread throughout the district but intensify at the New Rambler mine site. This assemblage includes chlorite-epidote-clinozoisite-albite-magnetite (±pyrite). In most propylitically altered samples from the New Rambler mine dump, hornblende and calcic plagioclase are partially altered, but biotite is unaltered. Magnetite and epidote veinlets are common.

Phyllic alteration resulted in pervasive replacement of calcic plagioclase and albite, whereas mafic minerals were only partially affected. Sericite and quartz dominate as replacement minerals with lesser amounts of pyrite as disseminations, veinlets, and magnetite overgrowths (McCallum and others, 1976).

Named mines

Blanche mine. SE sec. 32, T15N, R79W. A shaft was sunk west of the New Rambler mine to a depth of 160 feet and intersected copper carbonates, chalcocite, and chalcopyrite at 120 feet (Kluender, 1982). The host rock is sheared felsic gneiss, metagabbro, and metadiorite. The copper minerals occur in quartz veins and in shear gouge with some pyrite, hematite, and limonite (McCallum and Orback, 1968).

Two samples collected from the dump contained limonite, abundant malachite, and cuprite, with traces of chalcocite and sperrylite. These samples assayed 6.0 ppm and 17.0 ppm Pt, 30.0 ppm and 20.0 ppm Pd, and 20.0% and 17.0% Cu, respectively (Loucks, 1976).

Duchess mine. SW sec. 32, T15N, R79W. This mine lies west of the Blanche mine and consists of several exploratory shafts sunk in shear zone tectonites and strongly sheared metagabbro and metadiorite. Traces of copper associated with pyrite, hematite, limonite, and gold-bearing tetrahedrite were detected in the cataclastics (McCallum and Orback, 1968; Loucks, 1976).

Henry lode. Sec. 5, T13N, R79W, and sec. 32, T14N, R79W. The property was reported to be a possible extension of the New Rambler deposit (Stoll, 1929). A shaft was sunk 88 feet and exposed an 18-inch iron-stained quartz vein hosted by gabbro. The vein carried values in gold and silver, and the gabbro carried values in copper, gold, and silver, with traces of platinum. Assays were reported to run as high as 1.94%

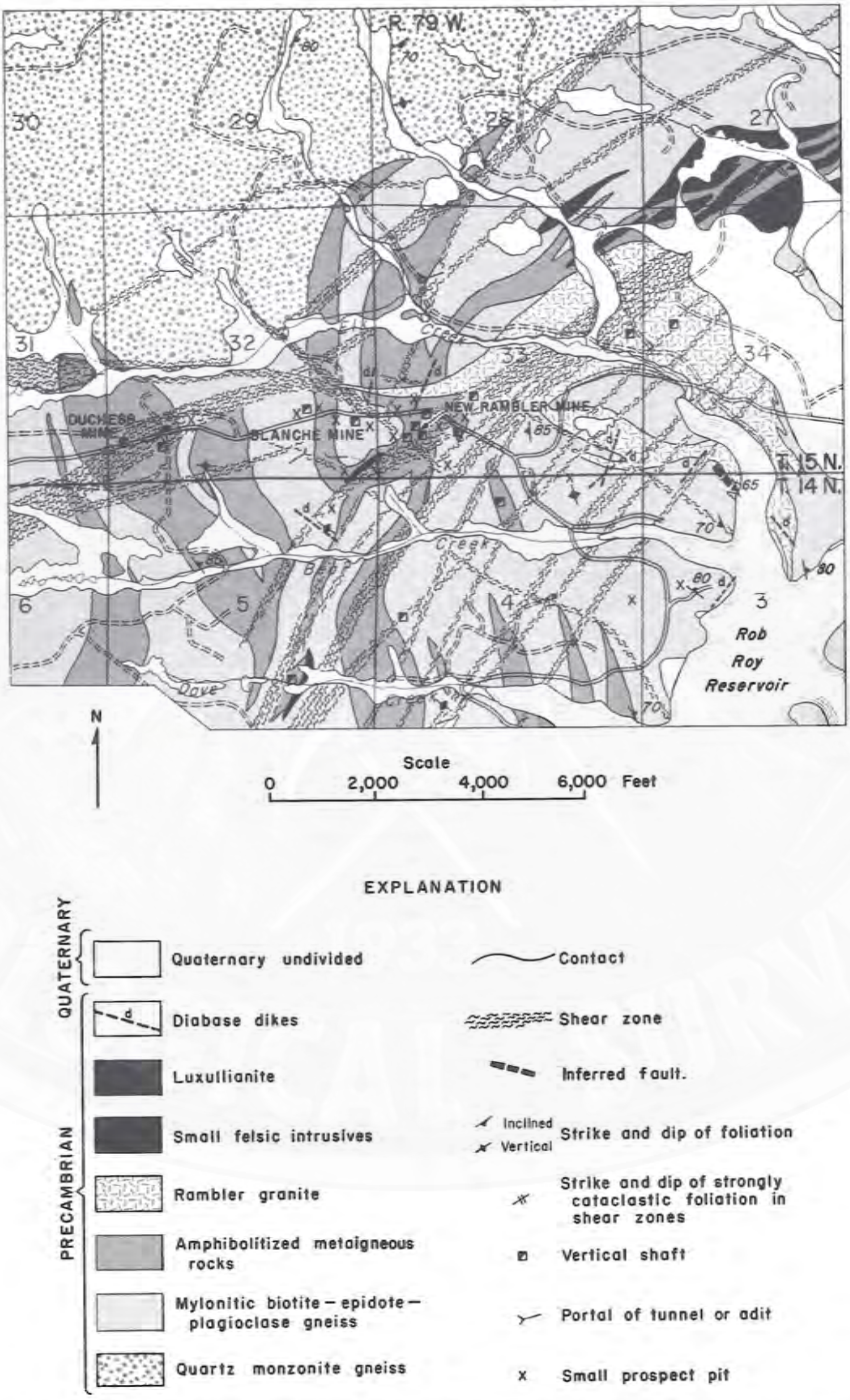


Figure 53. Generalized geologic map of the New Rambler district, Albany and Carbon Counties, Wyoming (modified from McCallum and Orback, 1968).

Cu, 0.16 opt Au, 0.22 opt Ag, and 0.0054 opt Pt. A qualitative analysis of 8 feet of gabbro collected on either side of the quartz vein yielded detectable silver and gold. A sample from the 18-inch vein assayed 0.54 opt Au, 0.70 opt Ag, and trace copper.

A placer property nearby reportedly yielded assay values of 0.04 opt Au with values as high as 0.21 opt Au. The gravel also contained recoverable amounts of native mercury worth about $0.40 per ton (1929 prices). The placers were estimated to contain 12,196,800 cubic yards (18,295,200 tons) of material (Stoll, 1929).

Jupiter group. Sec. 5, T14N, R79W. Beeler (1904h) reported iron-stained fractured granite on the property. No other information was given.

Medicine Bow Mines Company. Located somewhere in the New Rambler district. A 954-foot tunnel cut a number of mineralized zones containing anomalous copper, gold, and cobalt (Beeler, 1906l).

New Rambler mine. SW sec. 33, T15N, R79W. The New Rambler mine was originally located as a gold prospect in 1870. Copper was later discovered at 65 feet below the surface (Kasteler and Frey, 1949).

The New Rambler shaft was sunk to a depth of 170 feet, and more than 5000 feet of drifts and crosscuts were driven in hydrothermally altered metapyroxenite and metagabbro in shear zone tectonites and mylonitic gneiss of the Mullen Creek layered mafic complex (**Figure 54**). Coarsely crystalline, sheared, epidotized granite (Rambler granite) was encountered at a relatively shallow depth. Both diorite and peridotite also were reported in the main shaft (McCallum and Orback, 1968; McCallum and others, 1976).

The New Rambler orebody is considered to be a classical supergene enriched deposit with an overlying porous spongy limonite and jaspilite gossan capping a 75-foot-thick oxidized zone. Oxidized ore minerals form a diverse mineral assemblage that includes abundant malachite and azurite with lesser cuprite, tenorite, chalcotrichite, and chalcopyrite. Dendrites and nuggets of native copper with atacamite, chalcanthite, tetrahedrite, and bornite are sparsely distributed. This oxidized assemblage grades downward from 75 to 100 feet into the supergene enriched zone consisting of platinum-bearing covellite and chalcocite. Orpiment, realgar, and lorandite ($TlAsS_2$) reported by Rogers (1912) probably are products of supergene enrichment. Below 100 feet, the supergene minerals grade into the primary mineralized rock containing quartz-pyrite-chalcopyrite veins with minor sperrylite (McCallum and Orback, 1968). The ore occurred in three orebodies in fissure veins localized on the footwall of the fissures (Needham, 1942).

The mine sporadically operated from 1900 to 1918, and ore was shipped nearly every year until the mine support buildings were destroyed by fire. After the fire, the mine manager estimated probable mine reserves at 7000 tons of 7% to 8% Cu, 0.25 opt Pt, with some gold and silver (Needham, 1942). The mine dump was estimated to contain 7900 tons of waste rock (**Figure 55**).

Mine production is estimated at about 6100 tons of copper ore with values in gold, silver, platinum, and palladium. Before any platinum group metals were identified, approximately 4000 tons of high-grade 25 to 30% copper ore was mined and processed, for which no payments were received for the platinum.

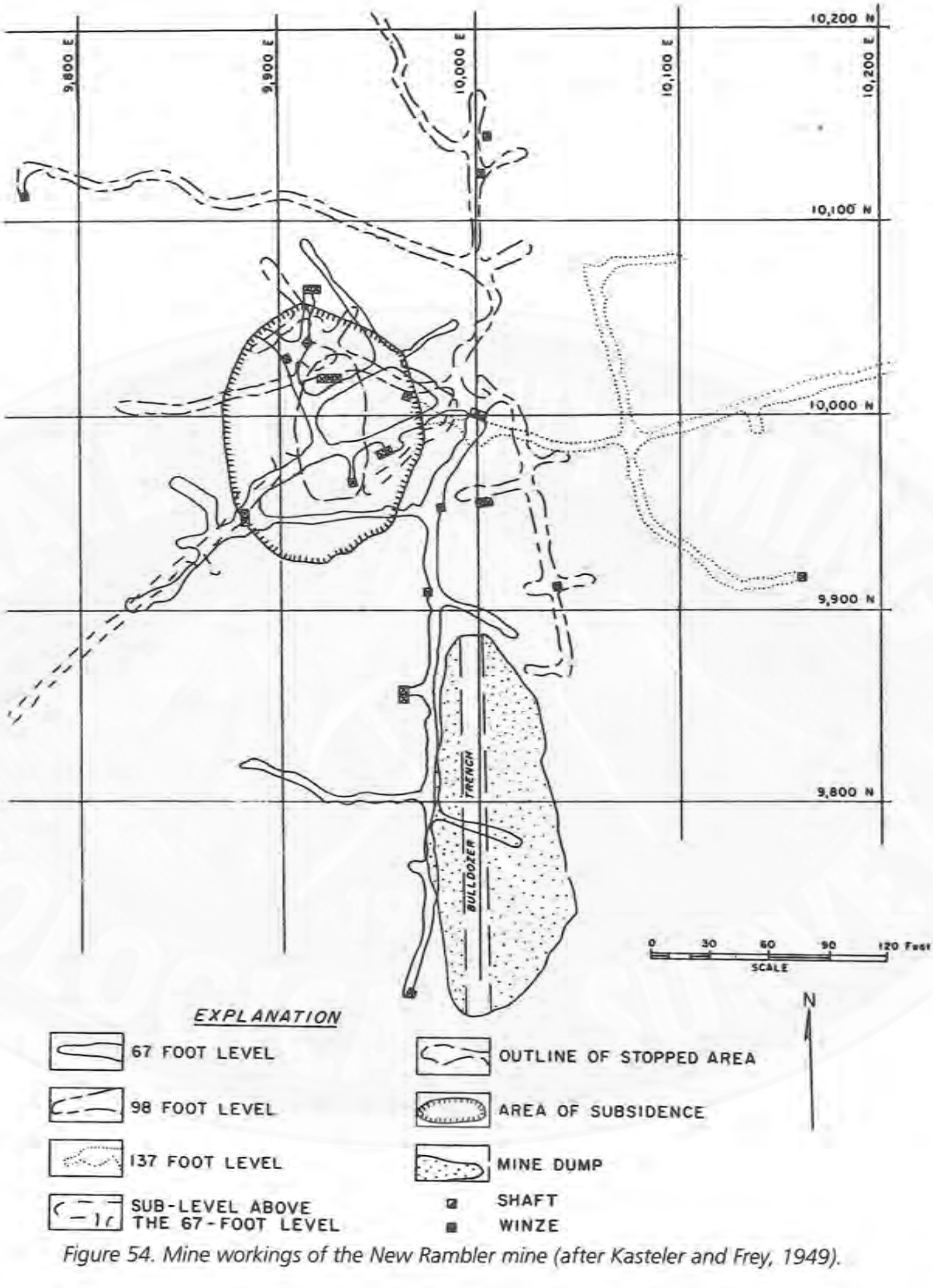


Figure 54. Mine workings of the New Rambler mine (after Kasteler and Frey, 1949).

Concentrates shipped from the mine in 1910 contained 13.2 to 13.7% Cu and 8.64 to 15.2 opt Pt (Needham, 1942). Production records of the last ore shipped from the mine following the 1918 fire showed values ranging from 3.24 to 61.37% Cu, 0.0007 to 1.4 opt Au, 1.01 to 7.5 opt Ag, 0.047 to 3.2 opt Pt, and 0.33 to 12.3 opt Pd (Anonymous, 1942a).

Needham (1942) reported metal production from the mine at 1,753,924 pounds of copper, 171.35 ounces of gold, 7346 ounces of silver, 170.16 ounces of platinum, and 451.4 ounces of palladium. Silver Lake Resources (1985) later estimated that platinum group metal production probably was much higher than reported by Needham–on the order of 16,870 ounces of palladium and 910 ounces of platinum.

Figure 55. View of the New Rambler mine tailings.

A series of assays run in 1910 on various grades of ore showed 0.6 to 5.8 opt precious metals and 0.5 to 31.07% Cu (Anonymous, 1911). In 1949, the U.S. Bureau of Mines sampled the mine waste with 5-foot channel samples and low-grade copper and platinum were detected (**Table 15**). Theobald and Thompson (1968) also sampled the tailings and obtained similar results. Their samples yielded 80 to >6000 ppm Cu, 0.5 to 55 ppm Ag, <0.03 to 1.3 ppm Pt, 0.3 to 9.2 ppm Pd, 0.02 to 3.0 ppm Au, and traces of arsenic, tellurium, molybdenum, lead, and zinc (**Figure 56**).

Other assays of the New Rambler ore include (1) composite samples of dump material that assayed 0.06 opt Pt, 0.04 opt Ir, 0.04 opt Pd, 0.10 opt Ag, and trace gold; (2) various copper minerals from the mine that contained 0.10 to 0.70 opt Pt; and (3) seven carloads of covellite ore that contained 0.40 to 1.4 opt Pt (Knight, 1902). Two grab samples collected by Kluender (1982) yielded 0.85% and 1.54% Cu, 0 and 0.007 opt Pt, 0.4 ppt and 1.2 opt Ag, and 0 and 0.4% Mo, respectively.

Skylark shaft. The Skylark shaft was located immediately north of the New Rambler mine. A shaft was sunk to a depth of 47 feet and cut talc schist at a depth of 20 feet (Beeler, 1903l). No ore minerals were encountered.

Unnamed mines and prospects

Prospects. SE SE sec. 34, T15N, R80W. McCallum and Kluender (1983) reported that several galena-bearing samples collected from prospect pits in this area contained significant silver. The samples ranged from 1.17 to 46.6 opt Ag, 1.0 to 2.0% Pb, and 0.05 to 0.5% Zn. One sample also contained 0.13 opt Au.

Sec. 35, T15N, R80W. Two shafts and several trenches exposed 1- to 3-foot-wide veins in granite that strike nearly east-west and dip vertically. The vein material consists of quartz, sparse orthoclase, dolomite(?), malachite, azurite, hematite, limonite, and chrysocolla (Millgate, 1965b).

E/2 E/2 sec. 35, T15N, R81W. A sample of sheared rock collected from an adit yielded 0.5% Cu, 0.4% Mo, 0.5% Ti, and 0.4 opt Ag (Kluender, 1982).

Table 15. Assays of copper and platinum metals in 5-foot channel samples from the New Rambler mine dump (from Kasteler and Frey, 1949). Analyses in weight percent (%) or ounces per ton (opt).

Sample number	Cu (%)	Platinum metals (opt)
1	0.92	0.10
2	1.22	0.02
3	0.15	trace
4	0.18	trace
5	0.67	trace
6	0.12	trace
7	0.24	trace
8	0.15	trace
9	0.09	0
10	0.08	trace
11	0.10	trace
12	0.05	0
13	0.31	0.01
14	0.80	0.04
15	0.81	0.02
16	0.85	0.05
17	0.75	0.04
18	0.47	trace
19	0.47	0.01
20	0.37	trace
21	0.40	trace
22	0.54	0.02
23	0.24	trace

SW sec. 35, T15N, R80W. Poorly exposed, 1- to 3-foot-wide copper veins occur in Precambrian granite. The vertical veins were exposed in several trenches and two shafts and strike several degrees north of west. In one vein, the mineralized zone consisted of malachite, azurite, and chrysocolla(?). Gangue minerals included potassium feldspar, dolomite(?), hematite, and limonite (Millgate, 1965b). This prospect lies a short distance west of the New Rambler district.

NW sec. 5, T18N, R78W. Malachite-impregnated quartzite is found on the mine dump of a caved adit at this location (King, 1963).

N/2 NE sec. 7, T12N, R81W. A short 60- to 80-foot-long adit was dug into a N81°W-trending, near-vertical shear zone in mafic gneiss. The shear is stained with limonite

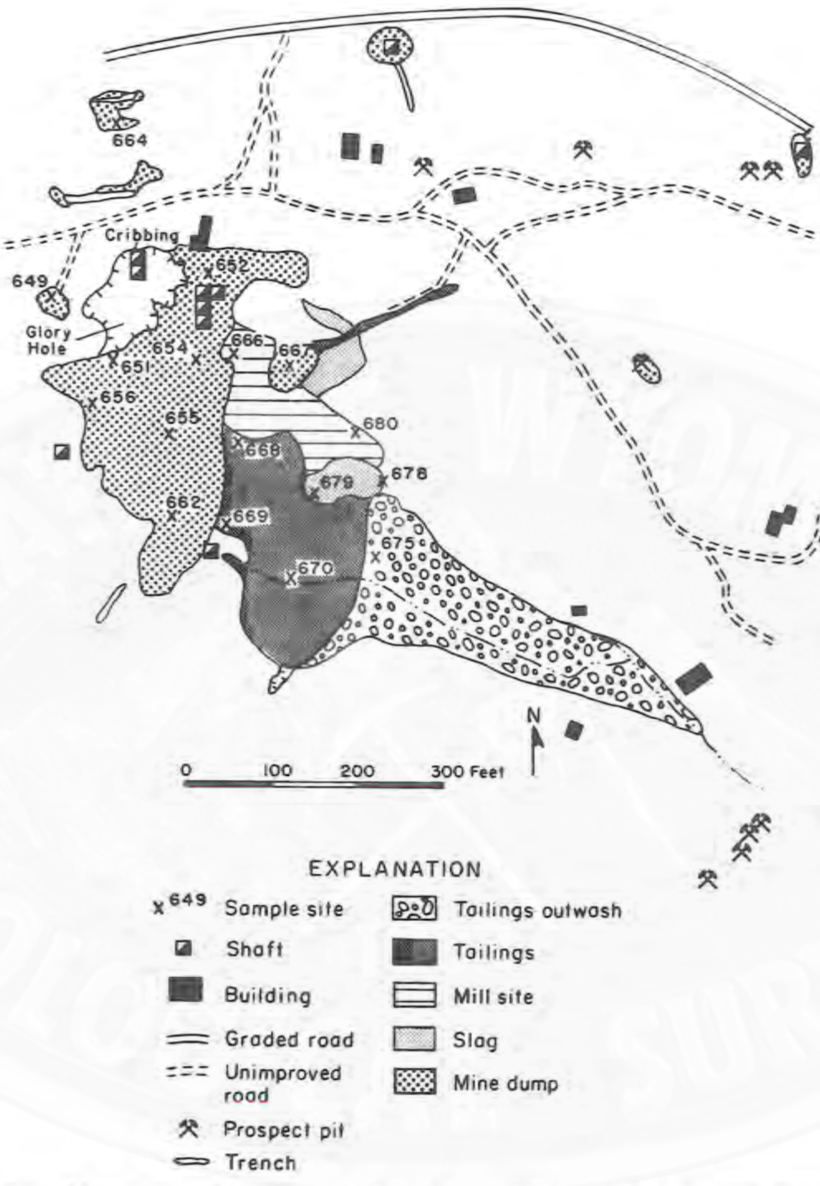


Figure 56. Plan map of the New Rambler mine showing location of mine waste, tailings, and sample sites (after Theobald and Thompson, 1968).

and malachite and ranges from 2 to 3 feet wide. A sample of quartz material collected on the mine dump contained covellite, chalcocite, chalcopyrite, pyrite, and malachite. A shallow shaft, only 40 feet deep, is located on the ridge above the adit (W.D. Hausel, personal field notes, 1984).

Overthrust Belt

The Overthrust Belt in western Wyoming is formed of several thrust wedges of Phanerozoic sedimentary rocks. Mineralization in this region includes scattered copper-zinc-lead-silver redbed deposits, metalliferous phosphorites, and black shales. The principal mineralized district is the Lake Alice redbed deposits near Cokeville.

Metal resources in the Overthrust Belt are not well understood, nor are they well explored. It is known that where copper mineralization is found, it appears to be stratabound and associated with a host of other metals. Because of the stratabound nature of the ore, the resource potential for this region is considered to be high. The Nugget Sandstone and the overlying Twin Creek Limestone are the principal hosts for stratabound mineralization.

Copper, silver, zinc, and lead mineralization has been detected at scattered localities in bleached redbeds of the Nugget Sandstone and less often in other sandstone units. Within the Lake Alice district, mineralization is locally well developed in the Nugget Sandstone and in the Gypsum Spring Member of the Twin Creek Limestone. The source of the mineralization may have been metalliferous petroleum or interformational fluids.

Another source of anomalous base and precious metals are the phosphorites and phosphatic black shales of the Mead Peak Member of the Phosphoria Formation. Love (1984) reported finding several sites of potential economic interest where anomalous values in phosphate, vanadium, gold, silver, chromium, molybdenum, zinc, copper, and nickel.

Lake Alice district

The Lake Alice district is situated near the center of the Overthrust Belt at the northernmost tip of Fossil Basin and lies entirely in the upper plate of the Tunp Thrust, a prominent north-south-trending thrust fault (**Figure 57**). Metal occurrences in the district lie entirely within the uppermost Nugget Sandstone (Triassic/Jurassic) and the lowermost sandstone and carbonate units of the overlying Gypsum Spring Member of the Twin Creek Limestone (Jurassic). Wherever significant mineralization is found, it is associated with bleaching of the typically red host sedimentary rocks. Prospect pits in the area are concentrated along this contact between the Nugget Sandstone and the Gypsum Spring Member.

Generally, the most highly mineralized areas occur where significant structural preparation of the host rocks has occurred. Normal faults and an associated coaxial planar joint-system, which parallels the crests of the anticlinal folds are common. These structures may have served as conduits for at least part of the mineralizing fluids (Loose, 1990).

Hydrocarbons are associated with the metal occurrences in the most highly mineralized areas (Boberg, 1984; Loose, 1988). However, a sandstone immediately beneath a petroliferous limestone in the Gypsum Spring Member does carry ubiquitous copper mineralization. Low-grade blanket-type mineralization is confined to this particular sedimentary unit and is common throughout the district (Boberg, 1984; Loose and Boberg, 1987; Loose, 1988, 1990).

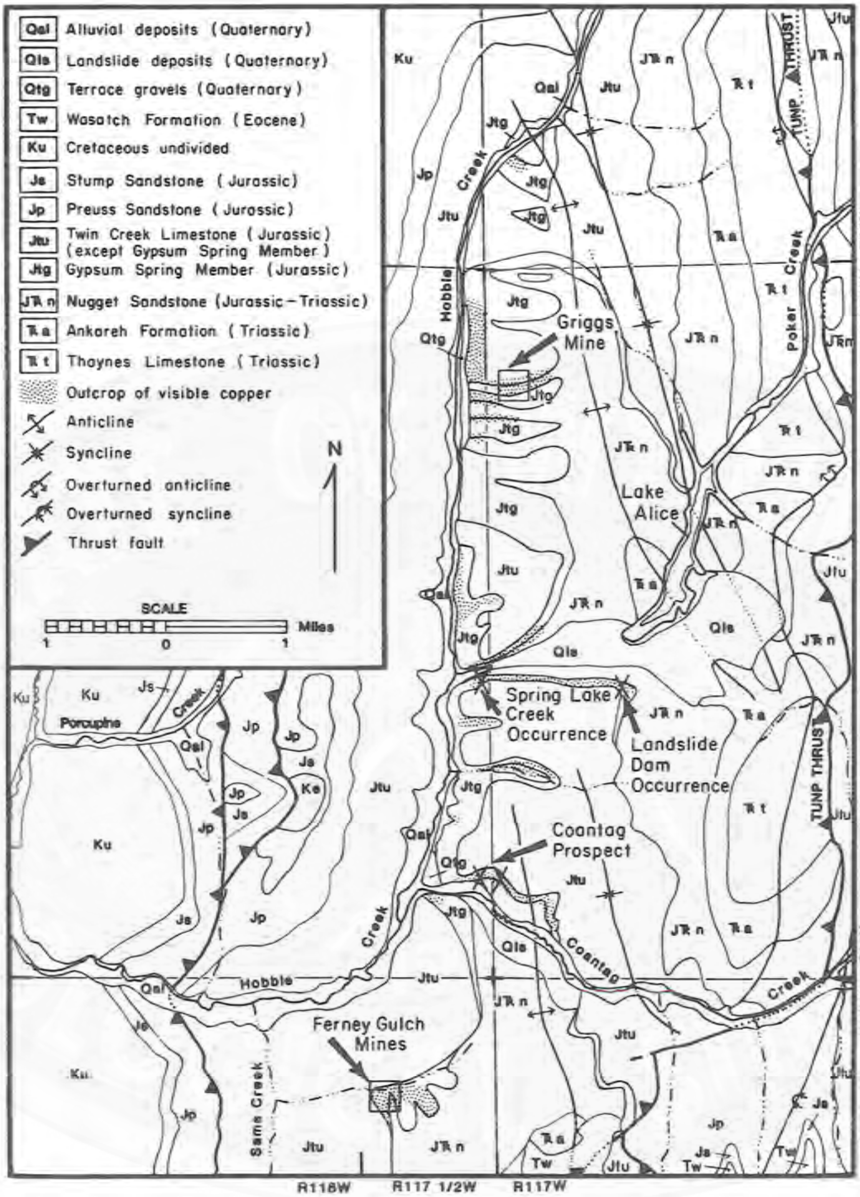


Figure 57. Geologic map of the Lake Alice district (from Loose and Boberg, 1987).

The mineralization most common at the Lake Alice district is disseminated sulfides, which occur in various forms, including interstitial pore fillings, poikiloblasts, and sand-grain replacements. Mineralization also can occur as sulfide veinlets and fracture fillings. Ore minerals include chalcopyrite, chalcocite, digenite (Cu_2S), bornite, sphalerite, idaite (Cu_3FeS_4), loellingite ($FeAs_2$), tennantite [$(Cu,Fe)_{12}As_4S_{13}$], covellite, pyrite, arsenopyrite, galena, malachite, azurite, cerussite (Loose, 1990), and an unidentified black cupriferous oxide. Gangue oxides include jarosite and neotocite ($Mn_2Fe_2Si_4O_{13} \cdot 6H_2O$) (Loose, 1990). Silver is contained within some of the sulfides.

A general vertical zonation, from bottom to top, consists of Fe-Cu to Ag-Pb-Zn. This zonation pattern is somewhat typical with that observed in most major stratiform sulfide deposits worldwide. Overall, these redbed deposits have characteristics similar to numerous major ore deposits including the Largentiere, Laisvall, McArthur River, Redstone River, and Kupperschiefer (Loose, 1990).

The principal deposits in the district occur at the Griggs and Ferney Gulch mines. Mining occurred on these properties between 1914 and 1920. In 1914, it was reported that high-grade ore was intersected 532 feet from one of the mine portals. The ore was reported to be in excess of 6 feet thick and to have yielded assays as high as $400 per ton. In 1915, 12,000 tons of ore were hauled from the Lake Alice mines to Cokeville, Wyoming, for shipment to Murray, Utah. Records indicate some ore continued to be shipped to the Utah smelter until at least 1920. Assayed samples were reported to give as much as 0.175 opt Au, 79.60 opt Ag, and 33.6% Cu (Lloyd, 1970).

Selected grab samples from the district assayed as high as 24% Cu, 1.5% Pb, 7.25% Zn, and 45 opt Ag (Loose and Boberg, 1987). A corehole drilled in the highly mineralized area at the Griggs mine yielded mineralized zones from depths of less than 40 feet that ran 5 feet of 0.26% Cu, 10 feet of 0.48% Cu, and 13 feet of 0.37% Cu; 3 feet of 0.77% Zn and 5 feet of 0.37% Zn; 2 feet of 0.21% Pb and 5 feet of 0.24% Pb; and 3 feet of 1.3 opt Ag and 5 feet of 4.5 opt Ag (Boberg, 1984; Loose and Boberg, 1987).

Because of limited exploration and drilling in the area, no reserve or resource estimates are available. However, Boberg (1984) indicated there is potential for discovery of a 100-million-ton deposit with grades of 0.5 to 1.0% Cu and 2 to 5 opt Ag at depths of only 20 to 150 feet.

Big Park prospect. E/2 sec. 12, T27N, R117 1/2W. Copper-stained sandstone was reported at this locality by Love and Antweiler (1973).

Contag prospect. NE sec. 36, T28N, R117 1/2W. Malachite and azurite were exposed in an adit driven along the contact between the Nugget Sandstone and overlying limestone and dolomite breccia of the Gypsum Spring Member of the Twin Creek Limestone. A sample of mineralized sandstone from the rib of the 50-foot tunnel assayed 0.39% Cu, 32 ppm Zn, and 2.0 ppm Ag (Love and Antweiler, 1973).

Ferney Gulch mine. Sec. 1, T27N, R117 1/2W. Some ore was shipped from the mine during the early 1900s. A selected sample collected by Love and Antweiler (1973) from the mine dump assayed 50,000 ppm (5%) Cu, 15 ppm Ag, 26,000 ppm (2.6%) Zn, 700 ppm Co, 500 ppm Pb, and 70 ppm Mo. Another sample collected by the author in 1982 contained 1.11% Cu, 0.52 opt Ag, 137 ppm Zn, and trace (63 ppm) cobalt (Hausel and Harris, 1983).

Griggs mine. Sec. 7, T28N, R117W. Bleached Nugget Sandstone and gray silty sandstones and petroliferous cherty dolomites of the Gypsum Spring Member of the Twin Creek Limestone contain variable copper, silver, zinc, and lead values (**Plate 3C** and **Figure 58**). The deposit occurs in a structurally prepared zone along the flank of an anticline (Boberg, 1983) over a vertical thickness of about 300 feet (Love and Antweiler, 1973). A locally continuous, 2- to 3-foot-thick gray silty sandstone of the Gypsum Spring Member is mineralized and averages 0.2% Cu and 0.1 opt Ag (Boberg, 1983). Samples of Nugget Sandstone collected by Love and Antweiler (1973) assayed 180 to

67,000 ppm (6.7%) Cu, trace to 5000 ppm Pb, 26 to 31,000 ppm (3.1%) Zn, and trace to 1200 ppm (35 opt) Ag. Allen (1942) reported the face of one of the tunnels was located in a block of ore 7 feet thick and 50 feet long, which averaged 3.5% Cu and 7.4 opt Ag (**Figure 59**).

Figure 58. The stratiform nature of the ore in the Nugget Sandstone at the Griggs mine is evident in the banding of the copper-zinc-lead-silver ore seen in the mine rib.

The Griggs mine contains three adits that were driven as far as 600 feet into the upper bleached Nugget Sandstone, and two adits that were driven approximately 100 feet into the lowermost sandy units of the Gypsum Spring Member. The two adits in the Gypsum Spring Member are connected by a stope. One of the adits in the Nugget Sandstone is connected to one of the overlying adits in the Gypsum Spring Member by a near-vertical raise (Loose, 1990).

Some ore was shipped from the property in 1916. Ten thousand tons of copper ore were blocked out in the mine, with 1000 tons of ore on the mine dumps (Thomas, 1943).

Landslide dam prospect. Sec. 20, T28N, R117W. A sample of copper-stained sandstone from this locality assayed 0.086% Cu, 22 ppm Zn, and 1.0 ppm Ag (Love and Antweiler, 1973).

Spring Lake Creek adit. SE sec. 24, T28N, R117 1/2W. A short 110-foot adit was driven into bleached Nugget Sandstone and intersected malachite and pyrite. Two samples from the ribs of the mine ran 500 ppm and 2100 ppm Cu with traces of silver and zinc (Love and Antweiler, 1973). A malachite-stained sample collected in 1982 by the author contained 0.25% Cu, 46 ppm Zn, and traces of silver (Hausel, 1982f; Hausel and Harris, 1983).

Other prospects in the Overthrust Belt

Cabin Creek. SW part of T37N, R114W. Near the headwaters of Cabin Creek. Copper-stained Nugget Sandstone was reported by Love and Antweiler (1973).

Cabin Creek campground. 43°14'N, 110°47'W. Copper mineralization here was observed at the top of the Nugget Sandstone by the author. One sample reported by Harris (1983) assayed 6.8% Cu, 0.56% Pb, 30 ppm Co, 150 ppm Zn, 340 ppm Ni, and 0.9 ppm Ag. A select sample of bleached Nugget Sandstone, collected at the upper contact with the overlying Twin Creek by Hausel (1982f), yielded 0.15% Cu, 23 ppm Zn, and trace silver.

Cockscomb prospect. T19N, R120W. Located 25 miles north of Evanston and 5 miles from Bear River (this would place the deposit about 20 miles south of Watercress Canyon). Copper carbonates stain gray sandstone at three locations along the axis of an overturned anticline. The copper occurs in organic-rich sandstones of the Beckwith Formation (Veatch, 1907; Schultz, 1914; Osterwald and others, 1966, p. 56).

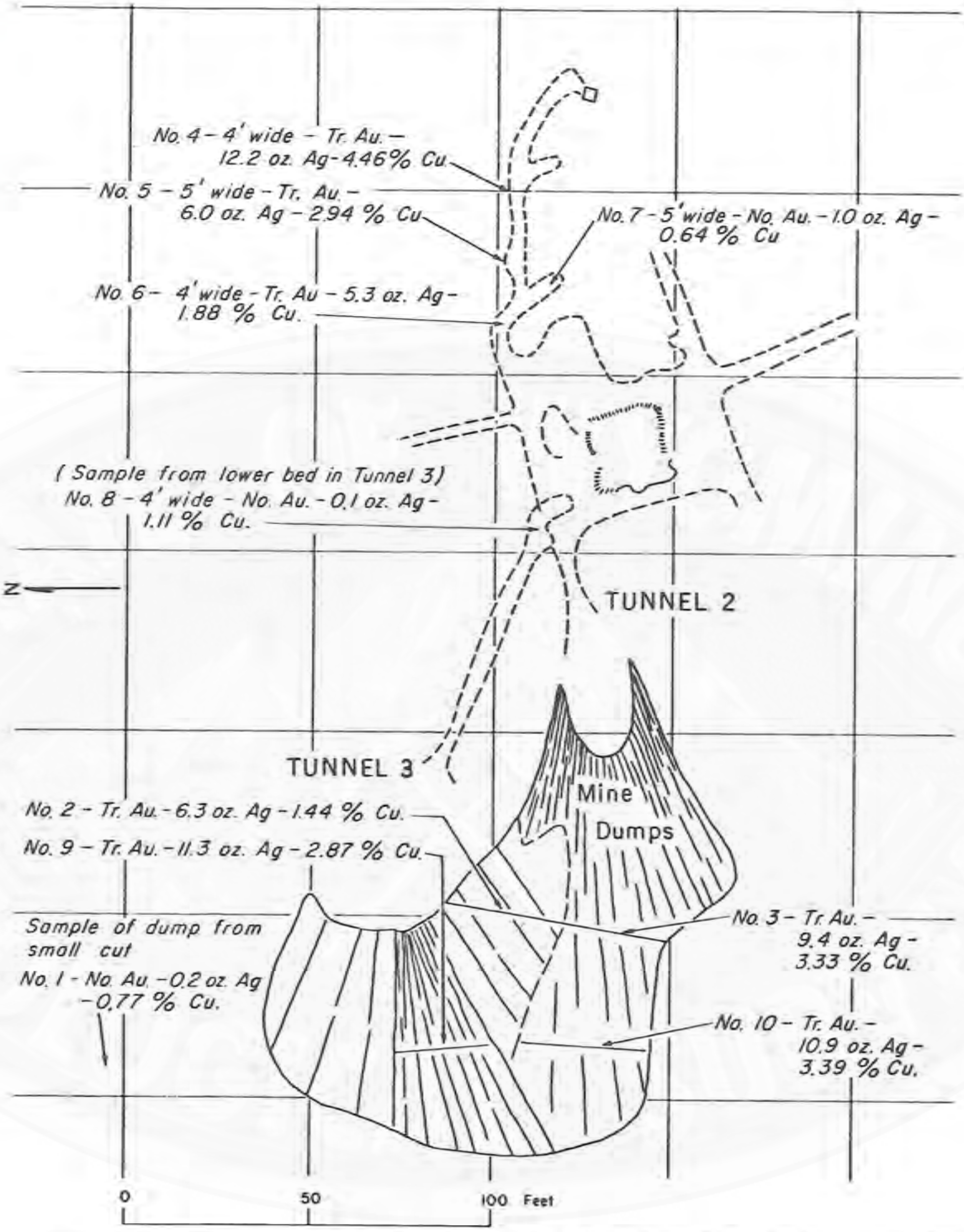


Figure 59. Sketch and assay map of the Griggs mine (after Allen, 1942). North is assumed to be to the left side of the illustration.

East Gros Ventre Butte. SW NE sec. 15, T41N, R116W. A 1.4-foot-thick phosphatic unit in the Mead Peak Member of the Phosphoria Formation was sampled and yielded 0.2% Cr, 0.05% Cu, and 0.1 ppm Au. The basal 4.5-foot-thick phosphatic shale averages 20 ppm Ag (Love, 1978).

Green River Lakes (Mill Creek). 43°19'N, 109°51'W. Copper carbonate-stained Nugget Sandstone was reported along Mill Creek at this locality by Harris (1983).

Halfturn Creek. NE part of T37N, R115W. Copper carbonate stains Nugget Sandstone near the Headwaters of Halfturn Creek. A few miles south, similar stains were found at the headwaters of Cabin Creek in Sublette County. A sample of mineralized rock from the Halfturn Creek prospect assayed 3.0% Cu, 70 ppm Pb, and 150 ppm Ag (Love and Antweiler, 1973).

Hoback Oil Field. Section 15, T28N, R115W. A core sample from a depth of 543 feet from a well (BELCO Petroleum Hoback #3-15) drilled in the Hoback field approximately 12 miles east of the Lake Alice district contained galena- and sphalerite-bearing Nugget Sandstone (Loose, 1990).

LaBarge Creek. NW part of T27N, R115W. A west-facing dip slope on the east bank of LaBarge Creek is stained by malachite (Gordon Marlatt, personal communication, 1984). This area is located about 10 miles east-southeast of the Lake Alice district.

Mill Creek. 43°18'N, 109°51'W. Copper mineralization was observed at the top of the Nugget Sandstone at this locality (Harris, 1983).

Snow King Mountain. NE NE sec. 9, T40N, R116W. Samples of a 7.5-foot-thick phosphatic black mudstone collected from a bulldozer trench yielded anomalous metal values. The mudstone is part of the Meade Peak Member of the Phosphoria Formation. The samples yielded values of 0.05% Mo, 0.7% Cr, 0.07% La, 0.07% Ni, 0.3% Sr, 0.3% V, 0.07% Y, 0.6 ppm Hg, and 50 to 70 ppm Ag (Love, 1984).

Squaw Flat. 43°09'N, 110°55'W. Copper mineralization was observed at the top of the Nugget Sandstone at this locality (Harris, 1983).

Watercress Canyon (Rock Creek Valley). SE NW sec. 4, T22N, R118W. The Wells Formation (Pennsylvanian-Permian) is mineralized along the Rock Creek fault on the western limb of a north-trending anticline about 6 miles north of Nugget Station (Veatch, 1907, p. 163; Schultz, 1914, p. 131). Stratigraphically, the Wells Formation is overlain by the Grandeur Limestone, which in turn is overlain by black shales of the Phosphoria Formation. Samples of the mineralized sandstone assayed 0.1 to 7.5% Cu, 70 to 360 ppm Zn, 0.6 to 2.7 ppm Ag, <0.02 to 0.03 ppm Au, 30 to 700 ppm Pb, 200 to 700 ppm As, 30 to 50 ppm Mn, 8 to 150 ppm Mo, 10 to 20 ppm V, and 5 to 50 ppm Ni (Rubey and others, 1975).

The mineralized zone was traced over a distance of about 1000 feet during field investigations in 1992 (Hausel and others, 1994). Nine samples collected for assay yielded 0.02 to 3.35% Cu, 0.01 to 1.38% Zn, 0.24 to 15.1 ppm Ag, and 12 ppm to 0.12% Pb. One sample yielded anomalous gold (300 ppb Au).

West Gros Ventre Butte. NW NE sec. 17, T41N, R116W. Samples from the basal phosphorite in the Mead Peak Member yielded 20 ppm Ag, 0.02 ppm Au, 0.7% V, 0.15% Cr, and 1.0% Zn (Love, 1984).

Owl Creek Mountains

The Owl Creek Mountains form a narrow, linear, east-west-trending asymmetrical anticlinal uplift in north central Wyoming. The northern flank of the range is unconformably overlain by Paleozoic sedimentary rocks that dip to the north. The southern flank is onlapped by Tertiary strata, which conceal Paleozoic and Mesozoic rocks that are overthrust by Precambrian rocks.

The Precambrian core of the Owl Creek Mountains has been subdivided into three rock groups based on age. The oldest rocks are supracrustal metamorphics exposed within the Copper Mountain district (**Figure 60**). These formed about 2900 Ma and were metamorphosed at about 2750 Ma (Mueller and others, 1985). The metamorphic rocks were intruded by granites at 2640 and 2720 Ma (Gilletti and Gast, 1961). Later, both the supracrustals and granites were intruded by Proterozoic mafic dikes (1190 to 2100 Ma) of tholeiitic basalt composition (Condie and others, 1969).

The Owl Creek Mountains contain scattered cupriferous fissure veins in granites and in mafic dikes. However, the fairly extensive supracrustal terrane within the Copper Mountain district along the eastern edge of the range contains a diversified assemblage of mineral deposits.

Copper Mountain district

The Copper Mountain district lies southeast of Thermopolis and northeast of Shoshoni. Supracrustal metamorphic rocks of the district have been subdivided into three mappable units by Gliozzi (1967), Hamil (1971), and Hausel and others (1985). The southernmost unit consists of amphibolite, intercalated quartzofeldspathic gneiss, and mica schist; the central unit consists of banded iron formation, metapelite, quartzite, and amphibolite; the northern unit is dominated by amphibolite with subordinate quartzofeldspathic gneiss.

The amphibolites consist of both orthoamphibolites (igneous) and para-amphibolites (sedimentary). Orthoamphibolites are interpreted as metamorphosed tholeiitic basalts and basaltic andesites (Mueller and others, 1985), and the para-amphibolites as metamorphosed greywackes (Condie, 1967). Quartzofeldspathic gneisses in this succession are interpreted to represent dacites.

The supracrustal rocks of Copper Mountain have been subjected to relatively intense metamorphism and deformation, such that essentially all primary textures have been destroyed. Structurally, the succession appears to be a homocline, but lithologic similarities between the northern and southern units, and the presence of small-scale isoclinal folds in the belt, may indicate that the Copper Mountain belt is a synformal high-grade supracrustal belt.

Mineralization

Copper, gold, silver, iron, tungsten, feldspar, lithium, beryl, tantalum, uranium, and petroleum have been reported in the region. Production included minor amounts of tungsten during the Second World War, some feldspar, minor aquamarine beryl, minor amounts of gold and silver, and some copper. Available production reports indicate that at least 568,000 pounds of copper with some gold and silver were shipped from the district between 1906 and 1918.

Mines and prospects

Charter Oak shaft. A vein with copper oxides and carbonates swelled from 1 foot thick at the surface to 7 feet at the bottom of a 100-foot shaft. The vein assayed 25% Cu at 3 feet from the surface (Aughey, 1886).

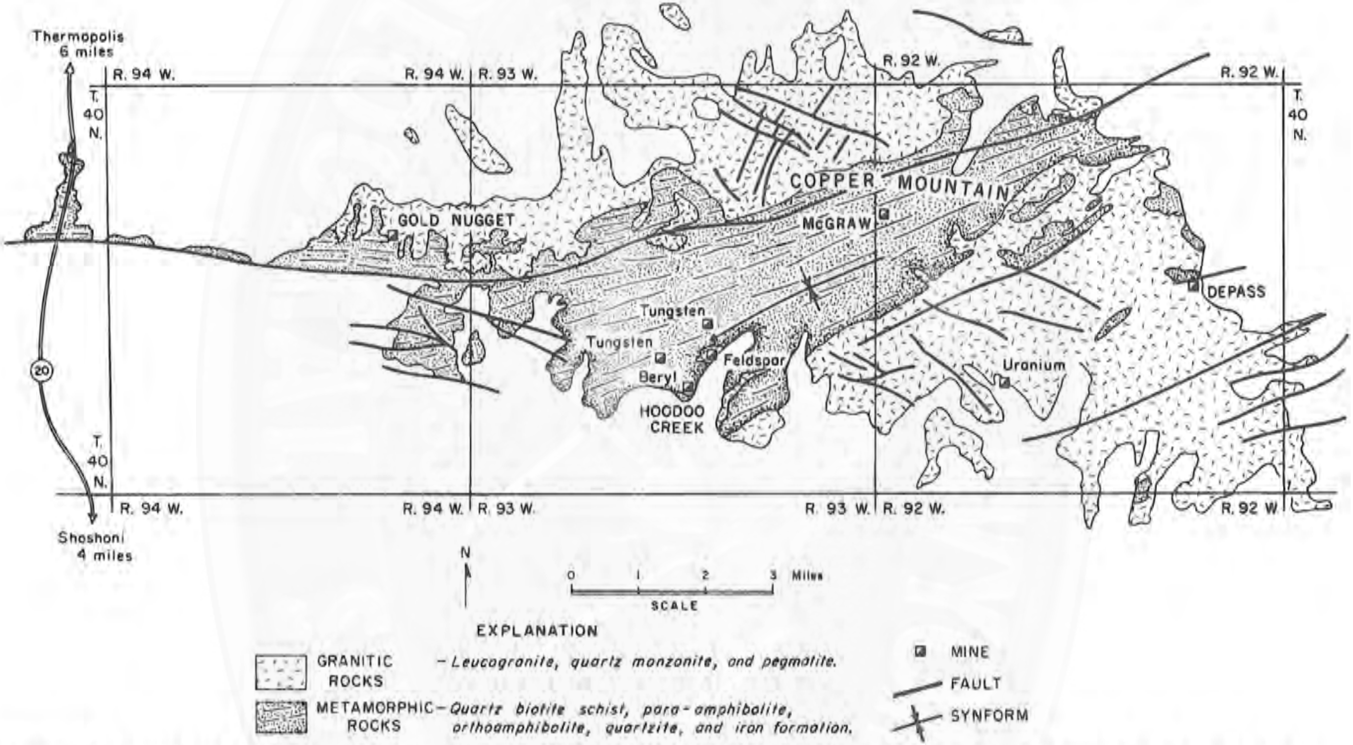


Figure 60. Generalized geologic map of Precambrian rocks in the Copper Mountain district (modified from Hausel and others, 1985).

Copper Glance group. The Copper Glance group was located somewhere in the vicinity of the Depass mine. The ore consisted of iron-stained quartz with copper minerals. The ore assemblage included chalcocite with some azurite, malachite, cuprite, chrysocolla, and chalcopyrite. The quartz also contained free gold. Two shipments of ore in 1906 included 39,303 pounds of ore that yielded values in gold, silver, and copper (Beeler, 1906a).

Cumtn-1-83. NE sec. 13, T40N, R93W. This sample was collected from dump material at a collapsed adit. The sample of copper-stained quartz assayed 1.58% Cu and 0.26 opt Au (Hausel and others, 1985).

Depass (Williams-Luman) mine. Sec. 23, T40N, R92W. The DePass mine was developed in a 30- to 50-foot-wide Proterozoic mafic (basalt) dike (≈2.0 Ga) (**Figure 61**). The dike trends northeasterly under the Flathead Sandstone (Cambrian) to the north and pinches out to the south.

The dike has been fractured and rehealed by several milky quartz veins that were accompanied by hematitic and chloritic alteration (Hausel and Albert, 1983a). Copper appears to be relatively evenly distributed throughout the dike, and ore minerals include chalcopyrite, malachite, azurite, cuprite, chalcocite, native copper, and chrysocolla. Gangue minerals include milky quartz, pyrite, earthy and specular hematite, limonite, goethite, and siderite (Hausel and others, 1985). Uraninite was recovered from a 3-foot-wide radioactive zone within in the mine several hundred feet from the portal and on the dump (Love, 1954).

A composite chip sample across a 30-foot width of the dike assayed 1.79% Cu and no detectable gold, platinum, or silver (Hausel and others, 1985). Although no precious metals were detected in the sample, other workers (i.e., Beeler, 1906i; Bowdin, 1918) have reported gold and silver from the area. For example, Bowdin (1918) reported samples from the mine assayed 0.08 to 0.14 opt Au and 0 to 0.8 opt Ag. Beeler (1908b) reported a gold streak was intersected that was several feet wide and yielded specimen-grade gold samples.

Mine production records appear to be incomplete, although production reported during 1906, 1917, and 1918 include 567,610 pounds of copper with some gold and silver (Hausel and others, 1985). The DePass mine (**Figure 62**) includes more than 11,000 feet of workings (Bowdin, 1918). During field investigations by the Wyoming State Geological Survey in 1983, only 600 feet of drifts were accessible, and the lower workings were flooded. The mine was developed to a depth of 810 feet on several levels (**Figure 63**) (Bowdin, 1918).

East Fork Birdseye Creek mines. NE NW sec. 13, T40N, R94W. Two portals occur along the East Fork of Birdseye Creek. The northernmost adit was driven in quartzite. No copper was observed in this mine; however, a select sample of boxwork quartz from the mine dump assayed 0.77 opt Au.

The southernmost drift was driven 160 feet on a pegmatite dike. Twenty-five feet into the portal, the drift cut a narrow, 1-foot-wide, crosscutting copper- and iron-stained vein (Hausel and others, 1985).

Fremont group. Located about 15 miles north of Shoshoni on the crest of Copper Mountain. A biotite schist layer, 1 to 2 miles wide with interlayered quartzite, strikes east-west. Quartz veins cut the schist, some at an acute angle and some more nearly

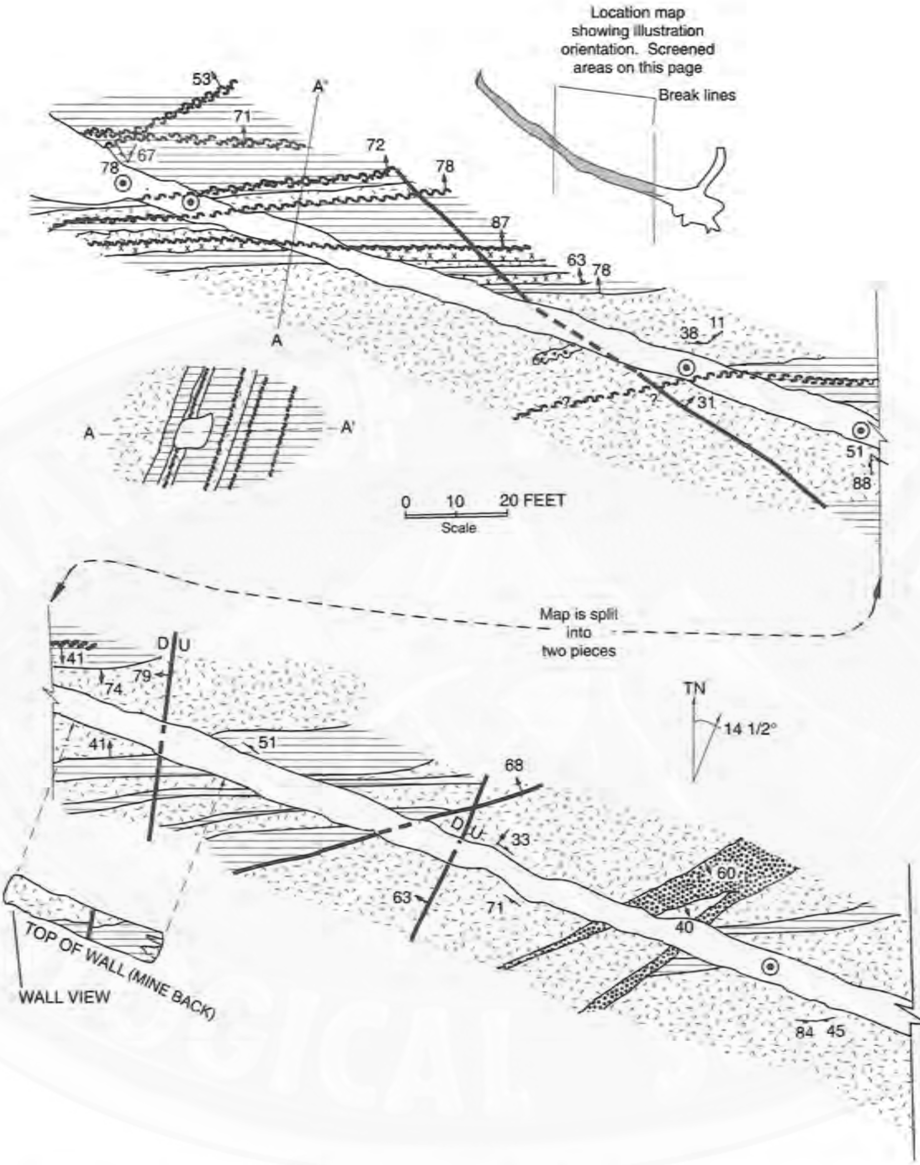


Figure 61. Geologic map of the main haulage level of the DePass mine (after Hausel and others, 1985). Due to length and configuration of mine, this map has been divided into three segments.

perpendicular to the foliation. The acute veins are mineralized and the veins intersecting at a large angle are barren. The Fremont group shaft was sunk on a 4- to 6-foot-wide vein that dips gently south. Forty-three feet below the surface, the vein is 6 to 9 feet wide and contains malachite, azurite, limonite, and hematite, with some chalcocite. All the minerals are found in bunches and streaks. Chalcopyrite was found in a tunnel a short distance downhill from the shaft. The vein carries a slight amount of gold (Beeler, 1903k; Osterwald and others, 1966, p. 52).

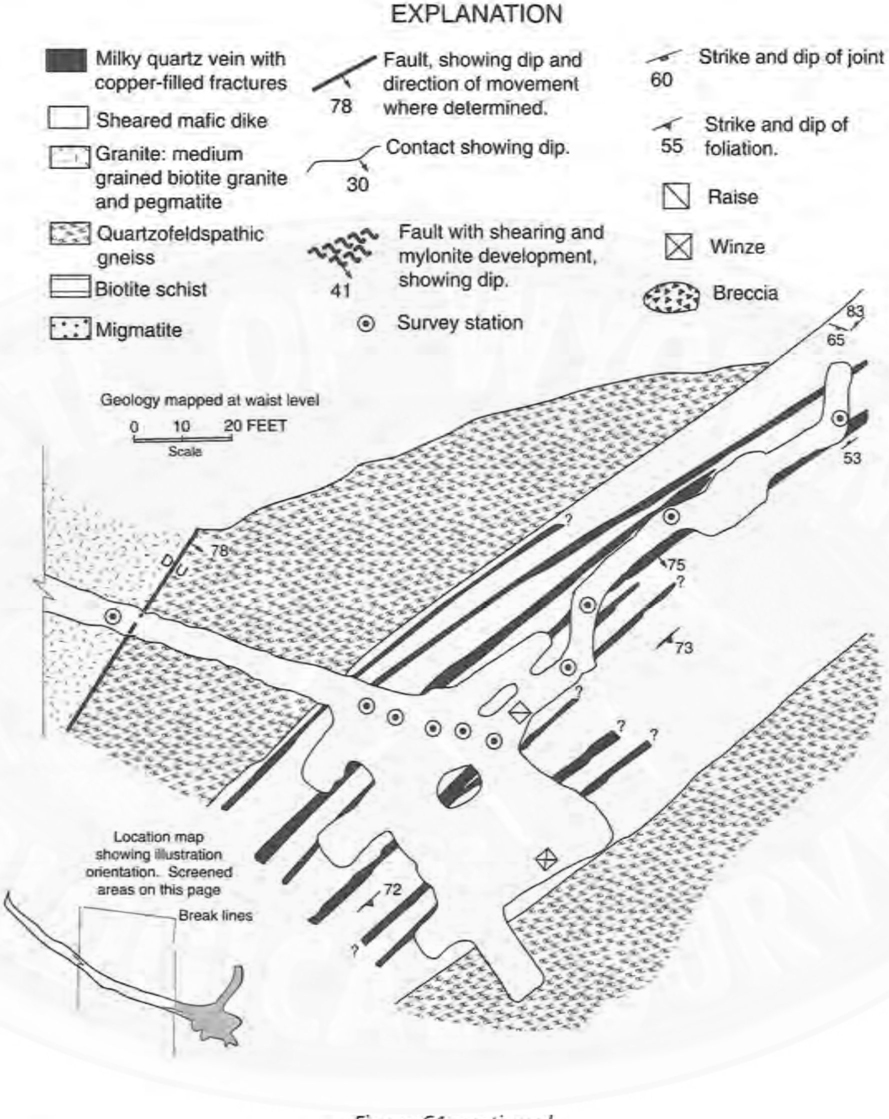


Figure 61 continued.

McGraw mine. SW sec. 7, T40N, R92W. The McGraw mine was developed by two shafts sunk in a belt of metasedimentary-metavolcanic rock. The main shaft lies west of the secondary shaft and is collared in weakly copper-stained, banded iron formation that exhibits secondary silicification (Hausel and Albert, 1983b). The secondary shaft intersected a cupriferous strike vein. The primary shaft probably was designed to intersect the quartz vein from crosscut drifts; however, only a few quartz vein fragments were found on the dump in 1983.

Two samples of copper-stained quartz were collected for assay. The first sample assayed 0.29% Cu with no gold or silver; the second sample ran 0.12% Cu with 0.14 opt Au and no detectable silver (Hausel and others, 1985).

Figure 62. The Depass mine dump shows extensive waste tailings from the extensive mine workings.

Banded iron formation collected from the McGraw mine assayed 33.9% Fe and 0.02% Cu (Hausel and others, 1985). Harrer (1966) reported a sample of iron formation from the mine assayed 33.7% Fe, 0.012% Mn, 0.20% TiO_2, 0.05% P, 0.03% S, 45.6% SiO_2, and 0.25% Cu.

Hausel and others (1985) suggested that this region may be favorable for low-grade stratiform gold deposits. At several localities, the McGraw iron formation has disseminated sulfides or exhibits boxworks after sulfides.

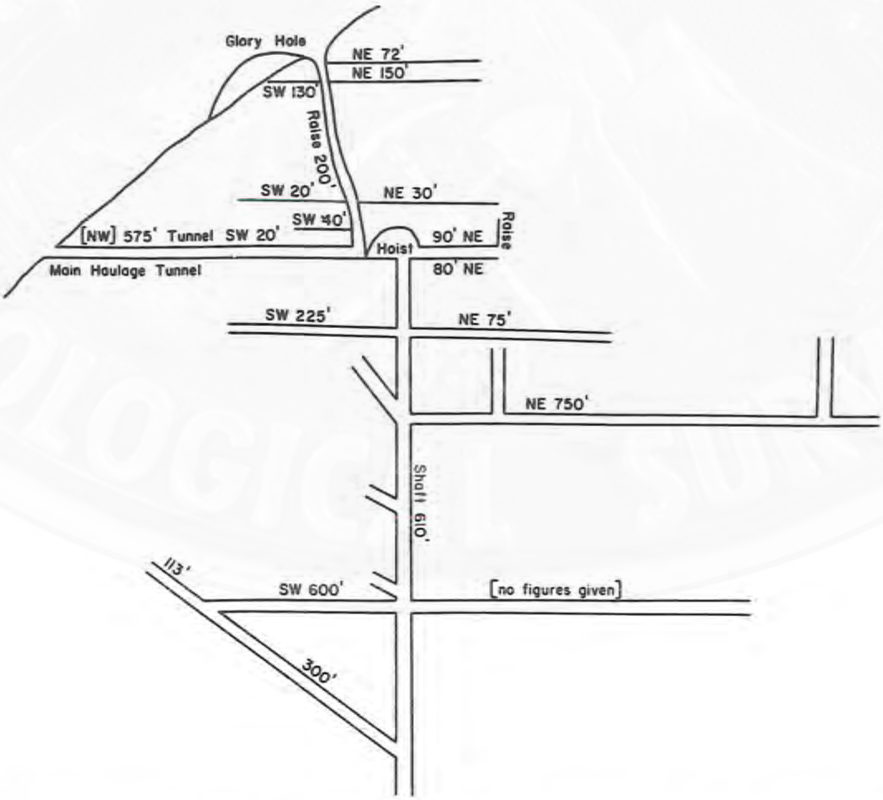


Figure 63. Schematic cross section of the DePass mine workings (modified from Bowdin, 1918).

Mascotte claim. A 1-foot-thick vein with 2 feet of hard slaty shale strikes to the northwest, dips southwest, and carries limonite and copper oxides. The vein contains 20 opt Ag (Aughey, 1886).

Riverton group. Secs. 20 and 21, T40N, R93W, located at the head of Tough Creek. Includes the Copper King, Uncle Sam, and Black Diamond properties. Copper stains and disseminated chalcopyrite are associated with quartz veins in schist that also carry anomalous gold and silver (Osterwald and others, 1966, p. 85). Beeler (1909) reported the schist near the southern end of the property was altered and silicified with numerous quartz veins over a width of 100 feet. Both copper stains and some chalcopyrite were observed in the altered zone. Samples collected by Beeler (1909) yielded trace to 0.04 opt Au and trace to 1.5 opt Ag.

West Bridger mine. N/2 sec. 8, T40N, R92W. Two caved adits in the West Bridger basin lie within an amphibolite-metapelite-banded iron formation succession. Two samples collected from the northernmost mine dump were assayed. The iron formation from the dump yielded 0.06% Cu and no gold, and the copper-stained quartz yielded 9.0% Cu with no gold (Hausel and others, 1985).

8201 Shaft. S/2 SW sec. 7, T40N, R92W. This shaft is located several hundred feet east of the McGraw mine and was sunk on a N60°E-trending strike vein hosted by amphibolite. The fractured vein quartz contains copper silicates and oxides as fillings and coatings. Malachite, chrysocolla, and cuprite were identified in hand specimens. One select sample assayed 6.8% Cu and <0.01 opt Au (Hausel and others, 1985).

8086 Incline. SE sec. 12, T40N, R93W. This incline was sunk in the McGraw iron formation about 700 feet southwest of the McGraw shaft. The iron formation is 15 feet thick and stained by copper silicates. One sample assayed 36.9% Fe, 0.059% Cu, and <0.01 opt Au (Hausel and others, 1985).

Willow Creek district

Little is known about this district located west of Copper Mountain within the Wind River Indian Reservation. One anonymous (1908) report concerning mineralization in the region stated:

> *In a number of instances, altered diorite dikes show replacement by silica and are filled full of small stringers of quartz and the whole mass carries more or less copper and iron. At the Willow Creek Basin section, the diorite dikes show a great deal of alteration, and lying in the diorite or between the granite and diorite are found numbers of parallel ledges of quartz carrying copper and iron, and varying in size from two feet to ten feet wide.*
>
> *These veins all run with the trend of the dikes, east and west, and north of this series of quartz veins a huge altered diorite dike is found very heavily mineralized and showing the replacement above noted, and the whole dike stained with iron oxides. Copper stains and some sulfides are noted here and the whole mass appears to be filled with quartz veins.*

McGowan-LeClaire group. Secs. 3 and 4, T6N, R3E (Wind River Meridian), in the Willow Creek Basin 18 miles southwest of Thermopolis. Limonite and copper stain east-west-trending quartz veins in granite. The veins are associated with mafic dikes and schist and range from a small stringer to a vein several feet wide (Beeler, 1907l).

Minor shaft. Adjoining the Wertz claims on the west was a 100-foot-deep shaft with a 50-foot-long drift at the bottom of the shaft. The workings reportedly intersected an 18-foot vein that yielded assays as high as 9.0 opt Au, 160 opt Ag, and some copper (Wertz, 1913).

Mountain View, Liberty, and Orebin. Sec. 7, T6N, R3E. Located at the crest of the Owl Creek Mountains within the Wind River Indian Reservation. The area is underlain by near-vertical, east-west-trending diorite and granite dikes. A shaft was sunk to a depth of 120 feet in sheared serpentinite(?) with quartz stringers. The hanging wall is formed by granite. Quartz at the surface contains copper, iron oxides, and carbonates. At depth, the shaft exposed copper and iron sulfides in small amounts (Trumbull, 1914).

Wertz mine. The Wertz mine included three claims known as the Dot, Long, and Salvador. The mine was driven into a 100-foot-wide diorite dike with 2- to 20-foot-wide quartz stringers. Development work in 1913 included a 93-foot tunnel with a 90-foot winze. Assays from the mine were reported to average 16% Cu, 0.1 opt Au, and 113 opt Ag. The Minor shaft (see above) adjoined the Wertz claims on the west. To the south was another shaft sunk about 100 feet in granite. The vein in this mine reportedly assayed 12.1% Cu, 0.4 opt Au, and 0.5 opt Ag (Wertz, 1913).

Seminoe Mountains

The Seminoe Mountains mining district near central Wyoming is restricted to a belt of Archean metamorphic rocks cropping out along the western flank of the Seminoe Mountains. The core of the mountains is formed by metasedimentary and metavolcanic rocks (>2.7 Ga) exposed in a broad, vertically plunging fold (**Figure 64**). These rocks are of lower amphibolite grade and were intruded and folded by syntectonic granodiorite (>2.6 Ga, Snyder and others, 1989). The flanks of the Precambrian core are unconformably overlain by Phanerozoic sedimentary rocks that form a spectacular, steeply dipping precipice along the southern flank of the range.

Metamorphic rocks of the greenstone belt are subdivided into three mappable units (Hausel, 1993b, 1994c). The lower portion of the belt consists of 11,000 feet of mafic metavolcanic and volcaniclastic rocks informally named the Sunday Morning Creek metavolcanics. This unit includes amphibolite, metabasalt, metatuff, mica schist, and minor serpentinite intruded by metagabbro sills and plugs, which occur in greater frequency near the top of the unit.

The Sunday Morning Creek metavolcanics are overlain by nearly 1000 feet of mafic and ultramafic schists informally named the Bradley Peak ultramafics by Klein (1981, 1982). They consist of massive to highly foliated amphibolites, serpentinites, and tremolite-talc-chlorite schists. Some ultramafic rocks in this unit are similar to komatiites in Western Australia and southern Africa (Klein, 1981; Hausel, 1993b) (**Figure 65**). The Bradley Peak ultramafics are overlain by 2000 to 4000 feet of interlayered metasedimentary and metavolcanic rocks named the Seminoe forma-

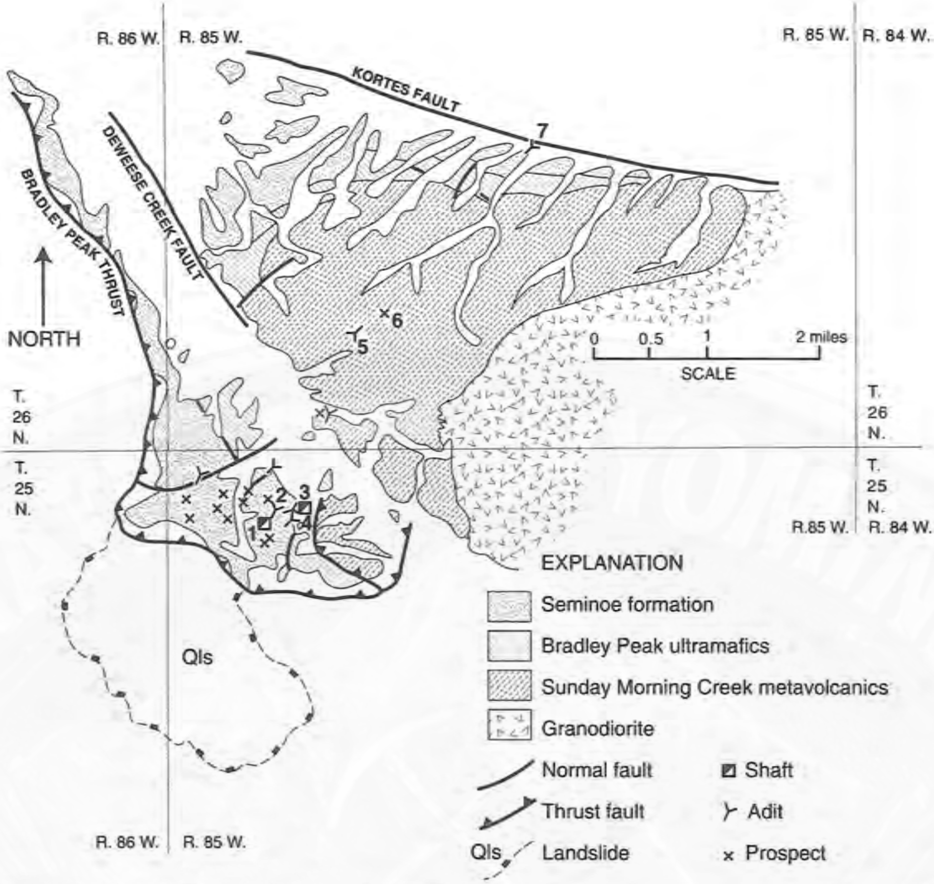


Figure 64. Generalized geologic map of the Seminoe Mountains mining district (modified from Hausel, 1994c). Numbered mines and prospects are named as follows: 1. Emeletta mine, 2. Deserted Treasure #1, 3. Deserted Treasure #2, 4. King mine, 5. Apex mine, 6. Sunday Morning prospect, and 7. Sunday Morning mine.

Figure 65. Spinifex-textured metakomatiite from the Sunday Morning Creek area of the Seminoe Mountains.

tion (Lovering, 1929b). These rocks include quartz-magnetite-grunerite iron formation (**Figure 66**), chlorite schist, metagreywacke, metapelite, metabasalt, metatuff, and felsic schist intruded by metagabbro sills and plugs.

Mineral resources

Available records indicate the district contains more than 100 million tons of low-grade iron resources, and historic gold production from the district is estimated at 3000 ounces. Resources and occurrences of copper, silver, serpentine, asbestos, jasper, jade, leopard rock, lead, and zinc are found in the district, and some pyrope garnets and chromian diopsides ('kimberlitic' indicator minerals) were recently discovered with detrital gold in a nearby paleoplacer in T26N, R84W (Hausel, 1994c).

Mineralization

Vein samples collected around Bradley Peak generally are narrow (<3 feet wide), quartz-carbonate veins with pyrite and chalcopyrite, which occur in a broad zone of altered amphibolite. The amphibolites are moderately to pervasively altered to chlorite, carbonate, actinolite, and epidote. Samples collected from the altered zone ranged from <0.05 to 89.3 ppm (2.6 opt) Au, <1.0 to 55.0 ppm (1.6 opt) Ag, 0.03 to 3.75% Cu, 3.0 ppm to 0.39% Pb, and 22 ppm to 4.3% Zn (**Appendix C**; **Plate 4A**).

Figure 66. Folded banded iron formation from the Seminoe Mountains.

Altered banded iron formation (**Plate 4B**) has yielded anomalous values in copper and other metals. In a study of trace metals associated with iron formation, the author recovered samples that yielded from 30 ppm to 0.045% Cu, 7.2 to 220 ppm Pb, and 90 to 2820 ppm Zn (**Table 16**). In addition, numerous other samples were analyzed for iron, gold, and silver. These yielded values from <1.0 to 15.55 ppm Ag, <0.01 to 42.3 ppm Au, and 9.5 to 33.5% Fe (Hausel, 1994c, table 5).

Table 16. Geochemical analyses of banded iron formation (BIF) and host veins and veinlets, Seminoe Mountains district, Wyoming (from Hausel, 1994c). Analyses in weight percent (%) or parts per million (ppm); dashes indicate not analyzed.

Sample description	Au (ppm)	Ag (ppm)	Cu (%)	Pb (ppm)	Zn (ppm)
Sheared BIF in contact with amphibolite	<0.05	2.9	0.045	12	90
Crosscutting vein in BIF	0.34	<1.0	0.02	7.2	–
Quartz-carbonate breccia vein in BIF	<0.05	<1.0	0.04	170	2,820
BIF with crosscutting carbonate veins and prismatic quartz-filled vug	<0.05	<1.0	0.009	220	–
BIF with limonite-stained carbonate	<0.05	<1.0	0.003	30	–
Pyritiferous carbonate fracture-filling	<0.05	<1.0	0.005	11	–

Mines and prospects

Apex adit. N/2 N/2 sec. 32, T26N, R85W. The Apex adit was driven into a quartz breccia vein containing angular clasts of country rock and more than one generation of quartz. Some visible gold was found near the portal (Charlie Kortes, personal communication, 1989). Samples assayed 0.14 to 3.81% Cu, 0.3 to 63.8 ppm Ag, 0.001 to 0.013 ppm Au, 61 ppm to 0.95% Pb, and 68 ppm to 0.23% Zn (Hausel, 1994c). Bishop (1964) identified bornite, chalcopyrite, and pyrite.

Deserted Treasure adits. NE sec. 6, T25N, R85W. Two tunnels were driven along the northeastern flank of Bradley Peak on a narrow N67°E-trending quartz vein hosted by metabasalt. One sample of limonite-stained quartz from the Deserted Treasure #1 dump yielded 1.2 ppm Au and 3.6 ppm Ag. Samples collected from the Deserted Treasure #2 mine dump yielded 0.06 to 0.39% Cu, 0.87 to 89.3 ppm Au, and <2.0 to 18.0 ppm Ag (Hausel, 1993b).

Junk Creek mine. SW sec. 20, T26N, R85W. Malachite, bornite, chrysocolla, and chalcopyrite occur as fracture fillings and coatings in a brecciated N45°E-trending quartz vein, aplite dike, altered amphibolite schist, and in sheared iron formation (Hausel, 1993b). Both the vein and aplite dike are approximately 1.5 to 3 feet thick (Klein, 1981).

About 650 feet southwest of the Junk Creek shaft is a caved prospect with malachite, bornite, and covellite, which occur as fracture coatings in altered granite (Bishop, 1964). A 10-foot composite chip sample of copper-stained mafic schist wall rock yielded 0.78% Cu, 1.7 ppm Ag, and <0.05 ppm Au. A grab sample of copper-stained quartz assayed 1.2% Cu, 0.05 ppm Au, 1.4 ppm Ag, and 6 ppm Ga (Hausel, 1993b).

The King mine. E/2 SE NE sec. 6, T25N, R85W. Located downslope from the Deserted Treasure adits. A select sample yielded 6.8 ppm Au, and 4.2 ppm Ag (Hausel, 1994c).

Long Creek area. Section 26, T26N, R85W. A shaft sunk into the Kortes fault scarp near Long Creek exposed abundant copper minerals, including malachite, bornite, chalcopyrite, chrysocolla, and native copper. The host rock is altered amphibolite.

Sunday Morning mine. E/2 E/2 sec. 21, T26N, R85W. This property was staked in 1882, and a 60-foot shaft with a 146-foot tunnel was driven from an adit at Sunday Morning Creek. Three crosscuts–15 feet, 40 feet, and 27 feet in length–were driven from the tunnel. A grab sample of quartz from the mine dump contained no anomalous mineralization (Hausel, 1994c).

Sunday Morning prospect. SE sec. 29, T26N, R85W. This prospect was developed on a copper-stained shear in amphibolite of the Sunday Morning Creek metavolcanics (Hausel, 1993b). Both chrysocolla and cuprite are common with uncommon visible gold (Bishop, 1964). Samples of sheared rock yielded 1.8% Cu, 45.4 ppm Ag, and 0.07 ppm Au. A grab sample of cupriferous quartz from the dump yielded 5.8% Cu, 26.9 ppm Ag, 2.1 ppm Au, and 0.2% Pb (**Plate 4C**)(Hausel, 1993b).

Sierra Madre

General geology and rock types

The Sierra Madre are similar to the Medicine Bow Mountains, having been uplifted during Laramide time. The Precambrian core of the Sierra Madre consists of rocks from two provinces separated by a major east-west-trending suture known locally as the Mullen Creek-Nash Fork shear zone (**Figure 67**) (Houston and others 1968, 1983). This structure is part of a major suture known as the Cheyenne Belt (Houston, 1993).

North of the shear zone, Archean (>2.5 Ga) granite, gneiss, and infolded metasedimentary and metavolcanic rocks are unconformably overlain by a thick clastic wedge of Lower Proterozoic (2.5-1.8 Ga) miogeoclinal and epicontinental metasediments (**Figure 68**). These metasediments include quartzite, metaconglomerate, metalimestone, metadolomite, and phyllite, with lesser metavolcanics. South of the shear zone, upper Lower Proterozoic eugeoclinal schists and gneisses form a thick suite of metavolcanics and volcaniclastics. These rock are of calc-alkaline affinity and include metabasalts, meta-andesites, and metarhyolites. At several localities, these schists and gneisses retain relic volcanic textures (Divis, 1976, 1977).

Although several mining districts were established in the Sierra Madre in the later 1800s, the entire uplift became known as one mining district, the Grand Encampment. This district was principally a copper district, but some gold, silver, zinc, and lead were recovered as by-products.

Grand Encampment district

History of exploration and development

The Grand Encampment district (also known as the Encampment district), originally included the Sierra Madre and much of the Medicine Bow Mountains. Several smaller districts were included in the Grand Encampment, including the Battle, Purgatory Gulch, Sandstone, New Rambler, and other districts. The boundaries of the Encampment district are currently interpreted to only include the Sierra Madre.

The Sierra Madre was explored as early as 1868 when the first known mining claims were staked. The first significant discovery of metals in the district was made in 1874 when copper float was found near the historic town site of Rambler. This discovery led to development of the Doane-Rambler mine in 1881.

In 1897 another cupriferous gossan was discovered in quartzite northwest of the Doane-Rambler mine. In the following year, a shaft sunk on the gossan intersected massive copper at a depth of 30 feet. The first 14-ton shipment averaged 33.18% Cu! This led to the development of the greatest copper mine in Wyoming, known as the Ferris-Haggarty. According to Houston (1992), this was also one of the most important copper mines in the West at this time in history, and the mine was ranked as the 27th largest copper producer in the world (Short, 1958).

Ore from the Ferris-Haggarty was mixed chalcocite and bornite, and shipments often yielded more than 35% Cu. By 1900 the Ferris-Haggarty mine was producing an average of about 550,000 pounds of copper per month (Hausel, 1993a).

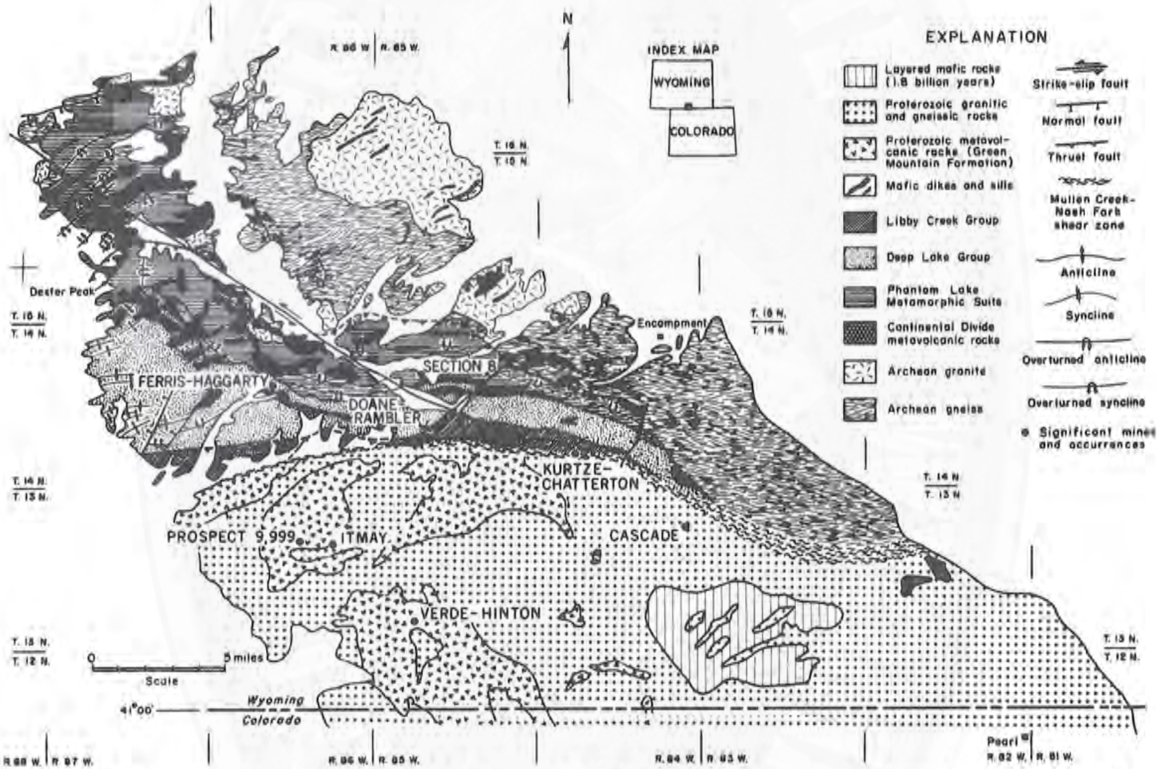


Figure 67. Generalized geologic map of the Sierra Madre, Wyoming (modified from Karlstrom and others, 1981).

Following the discovery of the Doane-Rambler and Ferris-Haggarty, the region experienced a mining boom, and the town of Encampment along the eastern flank of the Sierra Madre blossomed. Other towns were constructed, including Battle, Copperton, Dillon, Elwood, Rambler, and Riverside. To support the district, a 16-mile-long tramway was constructed from the Ferris-Haggarty mine on the western flank of the range, crossing over the Continental Divide at a elevation of 10,690 feet and continuing east to the Boston-Wyoming smelter at Riverside (**Figure 69**), adjacent to Encampment. Both the tramway and smelter were constructed in 1902. The tramway included 304 wooden towers with 985 buckets. Each ore bucket was rated at 700- to 1000-pounds carrying capacity (Beeler, 1905a; Vandenberge, 1906).

Figure 68. Typical folded and deformed gneissic rocks of the Sierra Madre.

The tramway had a 984-ton daily haulage capacity and was the longest aerial tramway in the world at the time of its construction (Short, 1958). The Boston-Wyoming smelter at Riverside operated at a maximum capacity of 500 tons per day (Armstrong, 1970).

In 1906, part of the mill was destroyed by fire and in 1907, a large segment of the mill and smelter complex was destroyed by fire. These disasters were followed by a 35% drop in the copper price, which resulted in closing the Ferris-Haggarty mine and laying off more than 200 miners in 1908 (Hausel, 1993a; Short, 1958). Produc-

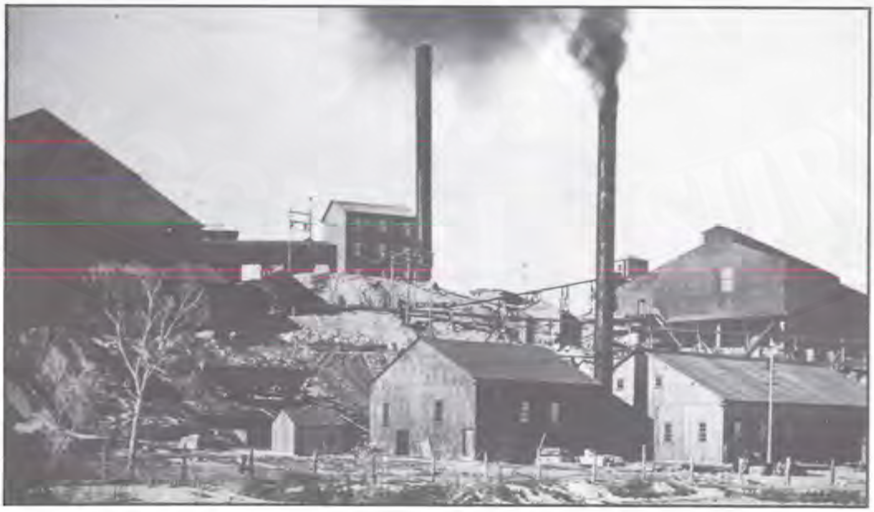


Figure 69. The Boston-Wyoming copper smelter and mill at Riverside as it appeared about 1905. (Photograph reproduced with permission, Wyoming Division of Cultural Resources, Department of Commerce.)

tion records indicate more than 21 million pounds of copper were mined from the district with credits in gold and silver, most of which was produced by the Ferris-Haggarty (Hausel, 1989).

By 1901 it was reported that 2500 prospect holes were dug, several thousand mining claims were staked, and 260 mining companies were operating in the district. The Ferris-Haggarty mine was the largest producer, followed by the Kurtz-Chatterton, Doane-Rambler, Charter Oak, Cold Water, Union, Syndicate, Hercules, Haskins, Elk Mountain, Copper Belt, Com-Stock, Cox, Great Lakes, Big Creek, Eureka, Continental, Philadelphia, Cherokee, Victor, Blackfoot, Wagner-Green, Home Fraction, Isabelle, Molly-Hill, Herring, Portland, Bohemian, Gold-Hill, Gertrude, Copper Glance, International, Jenny-Queen, Headlight, Finley, Illinois, Bimetallic, Black Tiger, Little Robert, Mail Pouch, Crescent, Vulcan, Beaver, Bay Horse, Ruby, Kerns, Aetna, Newsboy, Green Mountain, Hecla, Lone Fisherman, Tip Top, Copper King, Venture, Calmet, and Winona Rex, with hundreds of other mines in initial stages of development (Armstrong, 1970). Many of the deposits yielded very rich ores. Beeler (1905a) reported that ore shipped from some of the mines often yielded 35% to 49% copper in carload lots. Gold and silver values associated with the ores were uniformly low, although some rich gold samples were discovered in oxidized ores at Purgatory Gulch, Charter Oak mine, and others.

The Encampment district includes the entire Sierra Madre and is divisible into northern and southern regions (Hausel, 1986a) separated by a major east-trending shear zone called the Mullen Creek-Nash Fork shear zone. North of the shear zone, the rocks are early Proterozoic to late Archean in age and form a miogeosynclinal wedge. These rocks are metaconglomerate, quartzite, phyllite, and metalimestone with subordinate metavolcanics. Similarities have been drawn between the miogeoclinal successions of the Sierra Madre and those of the Witwatersrand, South Africa and Blind River, Canada basins. Mineralization recognized in the northern region include Blind River-type radioactive and locally auriferous quartz-pebble conglomerates, quartz veins, stratabound copper-bearing quartzite, and Holocene gold placers. South of the shear zone, rocks are 1.6- to 1.9-Ga Proterozoic metabasalt, meta-andesite, metarhyolite, metatuff, and volcanogenic metasediments of apparent island-arc derivation. The rocks were intruded by granitic stocks and plutons at 1.6 to 1.8 Ga (Houston and others, 1975).

Mineralization

Mineral deposits in this region include veins, shear zone deposits, and volcanogenic massive sulfides (Hausel, 1986a, 1986b; Houston and others, 1992). According to Spencer (1904), five types of deposits characterize the Encampment district: (1) disseminated chalcopyrite and magnetite in hornblende schist, (2) pyrrhotite and chalcopyrite in recrystallized hornblende schist near mafic igneous intrusions, (3) fault-controlled sulfide-bearing quartz veins with calcite, siderite, and feldspar gangue, (4) chalcopyrite in pegmatite, and (5) copper sulfides at fracture intersections in quartzite.

The quartzite-hosted deposits were by far the most productive; however, according to Houston and others (1975), the copper deposits associated with mafic intrusives are by far the most common in the district, although they are relatively small. The general association of mafic igneous rocks and sulfide minerals led Spencer (1904) to propose that some of the copper mineralization in the district originated from the mafic magmas, and in particular, he attributed some of the major quartzite-hosted deposits to a mafic source rock.

In a study of potential source rocks in the Sierra Madre, Houston and others (1975) were unable to substantiate that the copper was derived from mafic source rocks. Because of radically different Pt/Cu ratios in the mineral deposits compared to the mafic rocks, and because of the relatively low average metal content of many metasedimentary and metavolcanic rocks in the district, they suggested that a more likely source of the metals was leaching of the metasedimentary-metavolcanic succession during compaction and metamorphism. Twenty mineralized samples from various parts of the Sierra Madre averaged only 2 ppb Pt plus Pd, and 18 mineralized samples averaged 1.7% Cu (Houston and others, 1975).

Mines and prospects

Alma property. On the divide between Spring and South Spring Creek southwest of the Meta mine. A mineralized 18-inch-wide quartz vein trends east-northeast and dips 40°–60°N. The vein cuts schist, diorite, quartzite, and alaskite dikes and contains galena, chalcopyrite, and siderite (Spencer, 1904, p. 99).

Anaconda mine. (See also North group.) Secs. 11, 12, 13, and 14, T12N, R86W. This was part of the Pease properties, which were also known as the North Fork group. A 100-foot tunnel was driven on a vein carrying low-grade gold, copper, and silver (Pease, 1905).

Batchelder mine. Sec. 18, T14N, R86W. Located near the historic Dillon town site. A series of quartzite, schist, and diorite layers strikes east-west. The rock is replaced by "lime and silica" near a gabbro-schist contact. Cupriferous rocks in a drift at the bottom of the 100-foot shaft dip north, while at the surface the rocks dip south. The sulfides are hosted by a quartz vein that is as wide as 10 feet. The mine contains approximately 1000 feet of workings (Beeler, 1905b).

Beaver group. Located in secs. 14 and 23, T13N, R83W, along Beaver Creek about 0.25 mile southeast from its confluence with Camp Creek. The Beaver group of claims include the Red Beaver (discovery lode), Yellow Beaver, Silver Beaver, Golden Beaver, Red Jacket, Tenderfoot, and the Two Tom mine. The property was worked from 1905 to 1911 by the Keystone Copper Company.

Two shafts and one adit were driven in chlorite schist and arkosic conglomerate(?), quartzite(?), or brecciated granite pegmatite(?). When examined in 1944, few mineralized specimens could be found on the dumps. According to Haff (1944a), the dumps were barren of sulfides and only traces of copper carbonate could be found.

Big Chief group. Located in sec. 18, T14N, R85W, and secs. 13 and 24, T14N, R86W, on the flank of Bridger Peak. Copper carbonate-stained quartz veins cut schist and diorite. The schist strikes east-west and dips from 45°S to vertical. One large 15-foot vein with a 4- to 5-inch gouge zone was exposed in the south wall. The strongest mineralization occurred in a 1-foot zone next to the gouge (Beeler, 1902a).

Bonita prospect. Secs. 25 and 36, T15N, R85W. Quartz veins cut mica schist and granite. A 2- to 8-inch-thick limonite-, hematite-, and malachite-stained vein carries a small amount of gold (Beeler, 1901d).

Bonrite mine. Location unknown. The U.S. Bureau of Mines reported 17 tons of ore recovered from the Bonrite mine in 1969 yielded 1800 pounds of copper, 1 ounce of gold, and 23 ounces of silver.

Bridger mine. N/2 NW sec. 2, T15N, R87W. The Bridger vein is conformable to regional foliation and trends northwest with a 25°S–55°SW dip. The vein is hosted by quartzite and lies near a contact with hanging-wall metagabbro. The mineralized zone varies in width from more than 1 foot to 4 feet and consists of a 0.5- to 3-foot-wide quartz vein enclosed by a narrow alteration zone. The quartz contains calcite gangue with galena and chalcocite.

Both the hanging wall and footwall are altered adjacent to the vein. The hanging wall includes a 10-inch-wide zone of altered quartzite that is highly mineralized and reported to assay from trace to 69 opt Au. The footwall zone is 4 to 10 inches wide and yields both gold and silver.

A 100-pound sample taken from the Bridger vein assayed 90 opt Ag and 0.26 opt Au. Gold values were noted to decrease with depth while the silver values increased (Spencer, 1904). The location of the mine is suspect. The author was unable to find any evidence of mineralization at this location.

Broadway mine. The Broadway property is located on East Fork Creek in the SW sec. 32, T14N, R83W, of the Dudley Creek 7.5-minute Quadrangle. Available records indicate that the Broadway has had a long period of exploration activity following the staking of the property in 1904, and sometime in the past, four shallow shafts were sunk into the mineralized zone.

The first geological study of the property was completed by Osterwald (1947), who reported that the ore zone dipped 50°SE to 50°NW and covered a surface area of 1000 feet by about 50 feet and continued under a heavily wooded area (**Figure 70**). Later soil geochemical dispersion studies by Amselco suggested that the ore zone was more extensive.

Ore minerals included massive sphalerite and minor galena with local disseminated chalcopyrite, chalcocite, and covellite. Small amounts of secondary malachite and chrysocolla also were observed. The ore content ranged from 3% to 35% throughout the property, and near the No. 1 shaft, a gray and white gneissic rock hosted 1% to 5% disseminated chalcocite, chalcopyrite, and bornite. Osterwald (1947) suggested that the deposit was zoned based on high concentrations of copper near the Sodder shaft compared to the higher zinc concentrations near the No. 1 shaft.

According to Osterwald (1947), ore was localized along the contact of granite and pegmatite with a complex of gneiss, amphibolite (pyroxenite), gabbro, and diorite. Later petrographic studies by DeNault (1967) showed the host rock was a pyroxenite rather than amphibolite. The host rock consists of diopside with minor enstatite entirely or partially replaced by spessartine. One sample contained 35% olivine, characteristic of a peridotite.

The gneisses and pyroxenites were fractured and recrystallized near the contact with the granite. Where sheared, the pyroxenites were replaced by ore. The replacement was controlled by a set of northwest-trending cross-fractures (Osterwald, 1947).

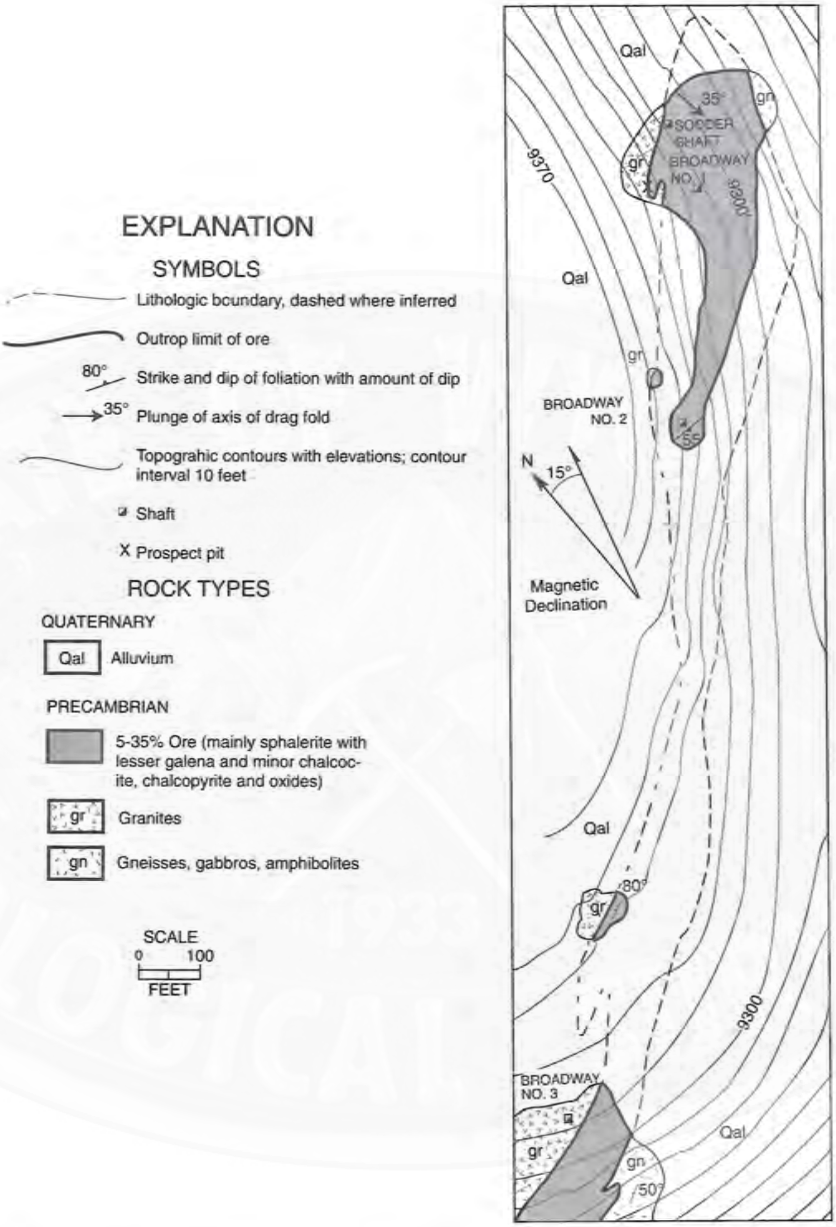


Figure 70. Reconnaissance map of the Broadway property, Encampment district (from Osterwald, 1947).

The U. S. Bureau of Mines collected five character samples and one channel sample in 1942 (Osterwald, 1947). These included: (1) a channel sample along the west side of the No. 1 shaft; (2) a sample from the mine dump of the No. 2 shaft; (3) a sample from the No. 3 shaft; (4) rock chips from an outcrop near the No. 3 shaft; and (5) and (6) select samples from the No. 1 shaft. Anomalous amounts of lead and zinc and a small amount of a platinum group metal were identified by spectrographic analysis (**Table 17**). Grab samples collected by Osterwald (1947) also were highly anomalous (**Table 18**).

Table 17. Zinc, lead, copper, and sulfur assays of samples from the Broadway mine as reported by the U.S. Bureau of Mines (after Osterwald, 1947). Analyses in weight percent (%); dashes indicate not analyzed.

Sample number	Zn (%)	Pb (%)	Cu (%)	S (%)
1	12.5	1.9	0.02	7.65
2	4.2	1.9	–	–
3	0.0	1.0	–	–
4	0.0	0.5	–	–
5	10.2	0.9	–	–
6	5.2	1.5	–	–

Table 18. Copper, lead, zinc, silver, and gold assays of grab samples from the Broadway mine (after Osterwald, 1947). Analyses in weight percent (%), ounces per ton (opt), or parts per million (ppm).

Description	Cu (%)	Pb (%)	Zn (%)	Ag (opt)	Au (ppm)
Above shaft 1	0.82	1.0	0.04	9.1	0.5
Blake #1	0.003	1.2	6.9	0.11	0.1
Lower #1	0.44	1.0	0.031	1.5	0.3
Lower #2	0.065	0.52	2.3	0.35	0.4

Bunker Hill Mining Company explored the property in 1966 and 1967. Nine shallow drillholes totaling 850 feet were completed, two of which intersected significant mineralization. The best drill intercept was near the No. 2 shaft, which encountered 20.5 feet of 8% Zn. Based on the limited data, it was estimated that the ore in sight over a surface area of 150 feet by 8 feet to a depth of 100 feet, totaled 12,000 tons of 10% Zn. This represented only a very small portion of the ore deposit.

Amselco examined the Broadway property in 1976. In the following year, the company drilled and completed zinc, lead, and copper soil geochemical surveys over a relatively large area. The survey identified a 3000-foot-long copper soil geochemical anomaly; a 2200-foot-long, 100- to 1000-foot-wide zinc soil anomaly; and a 1500-foot-long lead anomaly. The mineralization was reported as massive zinc, lead, and copper sulfides associated with a lens of tightly folded pyroxene-garnet rock. The pyroxenite was traced for nearly 1400 feet on the surface.

The author examined the property in 1992 (Hausel, 1992a) and collected samples of banded massive sphalerite with lesser galena in a matrix of tremolite and spessartine, and granodiorite with disseminated chalcopyrite and chalcocite. The host rock of the massive sulfide is a pyroxene-spessartine hornfels typical of skarn.

Five samples collected for assay included BW1-92, a limonite-stained felsite; BW2-92, granodiorite with disseminated chalcopyrite and chalcocite; BW3-92, sphalerite-galena-bearing pyroxenite hornfels; BW5-92, spessartine-calcite-quartz-pyroxene-actinolite hornfels with massive sphalerite and minor galena; and BW6-92, spessartine-calcite-diopside-actinolite hornfels with massive sphalerite and trace galena. The samples were highly anomalous in zinc, lead, copper, gold, and silver (**Table 19**).

Table 19. Zinc, lead, copper, gold, silver, platinum, and palladium assays of samples collected from the Broadway property (from Hausel, 1992a). Analyses in weight percent (%), ounces per ton (opt), or parts per billion (ppb); dashes indicate not analyzed.

Sample number	Zn (%)	Pb (%)	Cu (%)	Au (ppb)	Ag (opt)	Pt (ppb)	Pd (ppb)
BW1-92	0.31	0.30	0.77	3,278	2.0	–	–
BW2-92	0.02	0.75	1.82	1,604	12.18	–	–
BW3-92	4.34	5.66	0.18	156	1.37	–	–
BW5-92	7.66	0.69	0.05	104	0.2	<5	2
BW6-92	8.17	0.62	–	215	0.29	–	–

Buckeye lode. The Buckeye claim is located on Mill Creek in sec. 11, T14N, R87W, in what used to be known as the Sandstone mining district. According to Haff (1944c), the country rock consists of metadiorite (hornblende gneiss?) and quartzite, which grades into micaceous quartz schist. However, McCarty (1927) reported the country rock as metalimestone and gneiss.

The mine workings were developed on a more than 1-foot-wide quartz vein in the quartzite. Traces of copper were reported along fractures in the vein with abundant iron oxides (Haff, 1944c). Samples assayed 7% Cu, 0.05 opt Au, and 1.75 opt Ag (McCarty, 1927).

Buelah prospect. Located 1 mile north of Battle. Altered schists strike east-west, dip 45°–50°N, and have bands and stringers of quartz. A tunnel cut 15 feet of malachite stained quartzite containing spots and streaks of copper and iron sulfides (Beeler, 1901a).

Cascade mine. W/2 NE sec. 12, T13N, R84W. Located on the east bank of the Encampment River. The property was developed by a 425-foot tunnel and a 100-foot shaft by 1902. Spencer (1904, p. 96) reported plans to drive the tunnel 800 feet to intersect the shaft. The mine yielded high-grade copper ore until extensive flooding forced its abandonment (Wied, 1960).

A large zoned pegmatite, which strikes N20°W and dips to the south, carries chalcopyrite with minor malachite and azurite in a breccia along the periphery of the pegmatite (Wied, 1960). The shaft cut the pegmatite at a depth of 80 feet, and a crosscut exposed a 24-foot-wide section of pegmatite with well-marked walls of clay gouge. On the northeast side, the country rock is diorite; on the southwest side, it is granite (Spencer, 1904). Spencer reported that a similar outcrop of cupriferous pegmatite was discovered 6000 feet to the northwest that may have been a northern extension of the Cascade deposit.

Century mine. Secs. 32 and 33, T13N, R85W. Located on Harrison Creek 7 miles south of Battle. A 50-foot shaft was sunk in altered hornblende schist and diorite that contained hematite, bornite, and chalcopyrite. The schist trends northwesterly and stands on end. A cupriferous gossan capped the protore (Beeler, 1907b).

Charter Oak mine. Sec. 24, T15N, R85W. Located 6.5 miles northwest of Encampment on Puzzler Hill. Puzzler Hill is formed from a layered mafic-ultramafic complex hosted by Late Archean gneiss north of the Cheyenne Belt suture zone. The extent of the complex has not been determined as the complex continues to the northeast under sedimentary cover.

Puzzler Hill appears as an ultramafic massif with sporadic mineralization in sections 24, 26, 35, and 36. Based on hand specimens, the host rock is pyroxenitic. Sample CO1-94, described as pyroxenite in the field, and Sample CO5-94, described as actinolite-chlorite schist, yielded relatively high magnesian contents (**Table 20**) (Hausel, 1995).

Other samples collected in the massif from a small group of mines and prospects on Puzzler Hill contained anomalous metal values. The samples yielded 0.01% to 4.43% Cu, 66 ppm to 3.72% Ni, 14 ppb to 0.29 opt Au, <5 ppb to 828 ppb Pt, 5 ppb to 0.12 opt Pd, <0.1 ppm to 0.19 opt Ag, 21 ppm to 831 ppm Co, 64 ppm to 294 ppm Cr, and trace Pb and Zn (**Table 21**). These samples included limonite-stained breccia (CO2-94) from a mine dump in the S/2 sec. 26 that yielded anomalous copper, nickel, platinum, and palladium. Samples of massive specular and earthy hematite with copper carbonate, minor bornite, and chalcopyrite in chlorite-actinolite-talc schist from the mine dump (CO3-94 and CO4-94) yielded anomalous copper and gold. A sample (CO6-94) of quartz breccia cemented by sideritic limonite with fuchsite, collected from a mine dump in the center of sec. 26, was poorly mineralized (**Table 21**).

According to early reports, the mine was located in a northerly trending, easterly dipping quartz vein on the east side of a broad synform in granite-gneiss, schist, and diorite country rock. The vein contains iron and copper sulfides which also impregnate the fractured country rock. Chalcopyrite, chalcocite, bornite, and azurite were identified in a gangue of quartz, jasperoid, schistose wall rock, calcite, and some chalcedony (Spencer, 1904). Some high-grade gold was found on the property (Beeler, 1905a).

Table 20. Whole rock analyses of ultramafic rock samples collected from Puzzler Hill (Hausel, 1995). Oxide analyses in weight percent (%); LOI= loss on ignition; elemental analyses in parts per million (ppm) or parts per billion (ppb).

Oxide	Sample CO1-94	Sample CO5-94
SiO_2	45.5	48.75
TiO_2	0.59	0.44
Al_2O_3	8.48	8.57
Fe_2O_3	11.76	12.09
MnO	0.17	0.19
MgO	19.39	16.43
CaO	8.01	6.65
Na_2O	0.83	0.79
K_2O	0.07	0.09
P_2O_5	0.05	<0.03
Cr_2O_3	0.35	0.28
LOI	3.59	4.24
TOTAL	**98.79**	**98.52**
Element		
Au (ppb)	3	14
Pt (ppb)	8	<5
Pd (ppb)	15	8
Cu (ppm)	159	248
Ni (ppm)	343	178
Co (ppm)	29	28

Table 21. Assays of samples from the Puzzler Hill massif (from Hausel, 1995). Analyses in weight percent (%), parts per million (ppm), or parts per billion (ppb); dashes indicate not analyzed. Analyses by Bondar-Clegg.

Sample number	Cu (%)	Ni (ppm)	Co (ppm)	Cr (ppm)	Au (ppb)	Pt (ppb)	Pd (ppb)	Ag (ppm)	Pb (ppm)	Zn (ppm)
CO2-94	4.43	3.72%	831	244	95	828	4042	2.9	57	55
CO3-94	3.52	66	27	71	>10000	<5	11	3.8	10	14
CO4-94	2.39	127	82	64	9862	<5	14	6.6	9	9
CO6-94	0.01	162	21	294	14	<5	5	<0.1	–	–

The mineralized zone was traced 2 miles on the surface and varied in width from 14 feet at the Charter Oak shaft to 100 feet elsewhere. Where the mineralized structure is widest, the ore apparently consisted of quartz stringers mixed with low-grade material. An open cut near the top of Puzzler Hill showed a "huge ledge of mineralized diorite" stained with copper carbonate (Beeler, 1906g). It has been reported the Charter Oak ores carry some cobalt (as much as 4% to 5% Co) (Armstrong, 1970), but the author was unable to verify these high values. The Charter Oak shaft was sunk to a depth of 488 feet (Beeler, 1905a). According to the Saratoga Sun, three shafts were sunk on the property with more than four levels. In total, the Charter Oak contained more than 2300 feet of shafts, winzes, raises, and tunnels dug on the property (Saratoga Sun, 1907). The Saratoga Sun contradicted Beeler's (1906g) assessment of the ore body and stated that the ore body ranged from 3 to 10 feet thick. The ore reserve was estimated at 680,000 tons to a depth of 300 feet and was reported to be high-grade with a 6-foot thickness.

Colorado Belle group. Located on Miner Creek 4 miles south of Encampment. Fine-grained schists and slates trend northwesterly. Small amounts of copper were found in a fault in the Miner Creek drainage (Beeler, 1906b).

Continental group. Sec. 18, T14N, R85W. Located on Cow Creek 12 miles west of Encampment. A shallow shaft and a 150-foot-long adit were driven to test the property. "Diorite" dikes cut a series of northeast-trending schists and conglomerates that dip at a low angle. Copper carbonate and limonite-stained quartz veins cut the dikes but conform to country rock foliation (Beeler, 1908a). Samples taken at a 30-foot depth assayed as high as \$50 per ton (1899 prices) (Armstrong, 1970).

Copper Gem prospect. Located on Dunkard Creek in Purgatory Gulch 8 miles south of Encampment. An incline was driven into a gouge zone in granite and mica schist that varies from 1 inch to more than 1 foot wide. The gouge zone contains some malachite and a little gold. Nearby, a 1- to 2-foot-wide quartz vein was developed by a 358-foot shaft (Beeler, 1903b). The vein contained small specks and streaks of chalcocite and chalcopyrite. Graphite schist occurs north of the vein, and a "black schist" to the south contains scattered sulfides (Beeler, 1901b).

Copper Rock group. Secs. 27 and 28, T14N, R85W. Located about 8 miles west of Encampment. A mafic dike cuts schist, slate, and quartzite. The country rock trends east-west and dips 45°S. Three shafts were sunk in limonite- and copper-stained outcrops, and the middle shaft intersected copper sulfides at depth (Beeler, 1905c).

Copper Schist mine. SW sec. 12, T14N, R84W. A shallow shaft was sunk on a narrow cupriferous quartz vein along a fault contact between the Cascade Quartzite and the Jack Creek Quartzite. Mine dump samples contain malachite, azurite, massive cuprite, and minor tenorite. A sample of mineralized rock assayed 11.1% Cu, 1.44 ppm Au, 6.4 ppm Ag, 30.8 ppm Pb, and 6.26 ppm Zn (Hausel, 1992b).

Creede property. N/2 sec. 10, T14N, R86W. Magnetite, pyrrhotite, and chalcopyrite are localized along a contact between hornblende schist and a norite intrusive. The schist strikes east-west and dips south. Trace nickel and cobalt were reported by Spencer (1904, p. 54, 86).

D & L group. Secs. 27 and 28, T14N, R85W. Located about 2 miles east of Battle. Small amounts of chalcocite and a considerable amount of hematite were discovered underlying a gossan at this locality (Beeler, 1905d).

Doane-Rambler mine. NE sec. 25, T14N, R86W. Copper float was discovered a short distance east of the present Doane-Rambler mine site in 1874, but the source of the copper was not found until seven years later when George Doane discovered the cupriferous quartzite (Messerschmidt, 1972). The quartzite is part of the steeply dipping Cascade Quartzite (Proterozoic), which trends east-west and dips 65°–75°N.

The property was developed from an adit driven to the north from Battle Creek (**Figure 71**). A total of 1880 feet of drifts, crosscuts, and shafts were developed in the orebody to a depth of 365 feet below the main tunnel (or nearly 600 feet below the surface) (Vandenberge, 1906) on a total of six levels (Beeler, 1905a). At one time (1905) construction of a 2-mile tramway spur was considered for the Doane-Rambler mine; this spur would have extended northeast to the Ferris-Haggarty tramway (Armstrong, 1970).

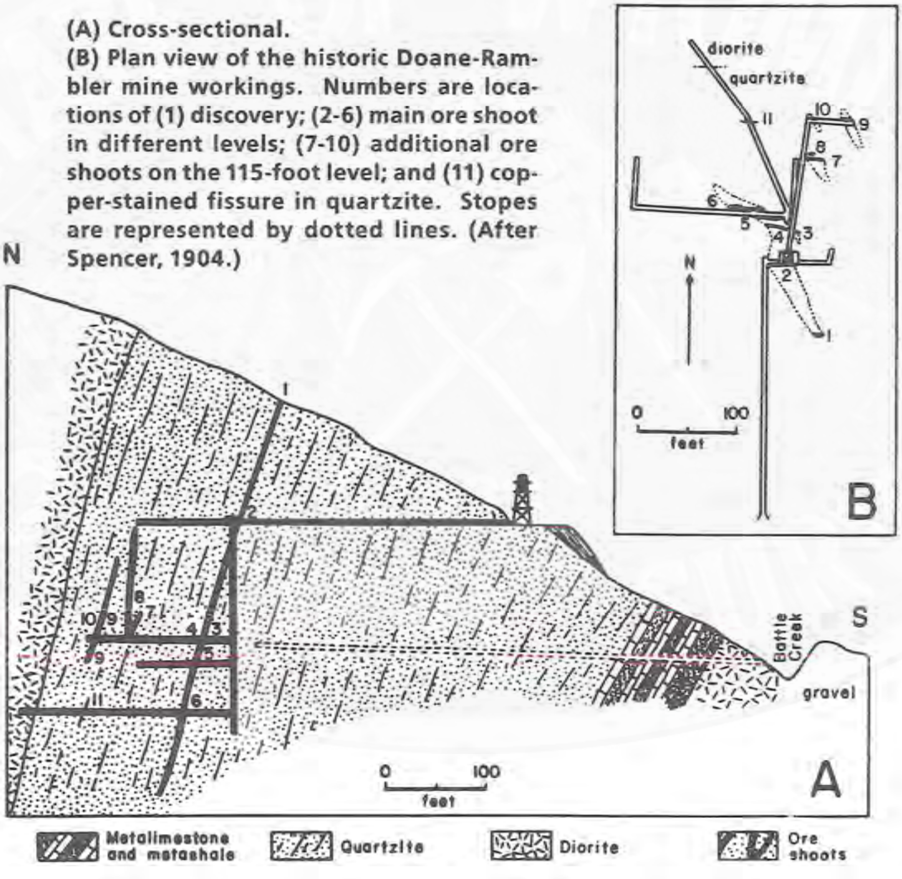


Figure 71. Cross-sectional view (A) and plan view (B) of the historic Doane-Rambler mine workings. The numbers show locations of (1) discovery; (2-6) the main ore shoot on different levels; (7-10) additional ore shoots on the 115-foot level; and (11) copper-stained fissure in the quartzite host rock. Stopes are represented by dotted lines (after Spencer, 1904).

Ore minerals recovered from the mine included chalcopyrite, bornite, chalcocite, covellite, malachite, azurite, cuprite, and chrysocolla (Spencer, 1904). Platt (1947) and Roberts and others (1974) also reported lorandite ($TlAsS_2$) on the dump, and Whalen (1954a) reported that anomalous radioactivity corresponded with greater amounts of copper.

The high-grade ore consisted of brecciated quartzite cemented by chalcopyrite and chalcocite. Mineralization also occurred in siliceous mylonite, mica schist, and brecciated dolomite (Menzer, 1981). According to Armstrong (1970), the Doane-Rambler ores may have contained as much as 4% cobalt, although this has not been confirmed. Samples collected from the dump by McCallum and Menzer (1982) yielded 25 ppm to 2.1% Cu and 0 to 6.8 ppm Ag.

The ore was localized at fracture plane intersections with bedding planes in the quartzite. Some ore also was reported to be stratiform (Spencer, 1904). On the 400-foot level, the main orebody was 14 feet wide. On the 500-foot level, the orebody swelled to 65 feet wide (Vandenberge, 1906).

Actual production figures for the mine are unavailable. However, some of the first ore recovered from the mine included 16 carloads that averaged better than 40% Cu with \$7.00 in gold and silver (1906 prices, units not specified), based on smelter receipts (Vandenberge, 1906). It was estimated that 25,000 tons of ore that averaged 10% Cu were recovered from the underground workings (Menzer, 1981). In other words, as much as five million pounds of copper may have been produced.

Dreamland King group. Secs. 1 and 2, T14N, R86W, located on South Spring Creek. Layers of quartzite and schist, interlayered with occasional gabbro lenses, strike east-west and dip south. Limonite, malachite, and azurite stain a 20-foot-wide quartz vein that cuts the schist and gabbro. The vein contains some pyrite and a little gold (Beeler, 1905e).

Echo property. Secs. 9, 15, and 16, T14N, R86W. Located on the northern edge of the Ferris-Haggarty quartzite. A shaft was sunk 114 feet on a 3-foot-wide copper-stained gossan. The shaft intersected mineralized quartzite in the hanging wall; the footwall consisted of schist (Beeler, 1905a).

Eureka. NW sec. 22, T14N, R84W. A shallow shaft sunk on hematite-, limonite-, and malachite-stained milky quartz contains disseminated and fracture-filling chalcopyrite. The host is diorite. Wall rock adjacent to the vein contains narrow biotite selvages (W.D. Hausel, personal field notes, 1984). Reported assays yielded 11 to 46% Cu and 0.15 to 0.38 opt Au (Armstrong, 1970).

Ferris-Haggarty mine. Center sec. 16, T14N, R86W. In 1897, Ed Haggarty discovered a cupriferous gossan along a drainage that later became known as Haggarty Creek (Spring, 1947). A shaft (initially known as the Rudefeha shaft) was sunk in the gossan and intersected solid bornite at a depth of 39 feet (Lakes, 1904; Beeler, 1905a). The mine name was later changed to Ferris-Haggarty (**Figure 72**). Shortly after the massive ore was intersected, the property was sold to the Penn-Wyoming Copper Company and was capitalized at \$20 million. Within a short time, the property was ranked as the 27th largest copper producer in the world. The ore was transported from the mine portal to a mill and smelter complex at Riverside, Wyoming by way of a 16-mile-long tramway. At the time of construction, the Ferris-Haggarty tramway was the longest aerial tramway in the world (Short, 1958).

a

b

Figure 72. (a) Historical (1902) and (b) recent (1983) views of the Ferris-Haggarty mine. 1902 photograph from S.H. Knight collection, American Heritage Center, University of Wyoming (reproduced with permission); 1983 photograph by W.D. Hausel.

The mine was developed in a flexure fold along a massive quartzite-felsic schist contact where a 20-foot-thick ore shoot was localized in brecciated footwall quartzite. Locally, the shoot was as much as 65 feet thick and averaged 6 to 8% Cu (Messerschmidt, 1972; Vandenberge, 1906). High-grade ore mined from the shoot supplied the Boston-Wyoming smelter at Riverside with an average of 200 to 500 tons of ore per day. Some of the high-grade varied from 30 to 40% Cu with some silver and 0.1 to 0.4 opt Au (Lakes, 1904; Beeler, 1905a). The orebody was 250 to 300 feet long and was opened to a depth of 300 feet in 1903 (**Figure 73**) (Spencer, 1904), although the workings ultimately may have extended to a vertical depth of 560 feet prior to termination of the operations in 1908 (Department of Environmental Quality, 1985). The host quartzite dips 30° to 60° south and trends east-west.

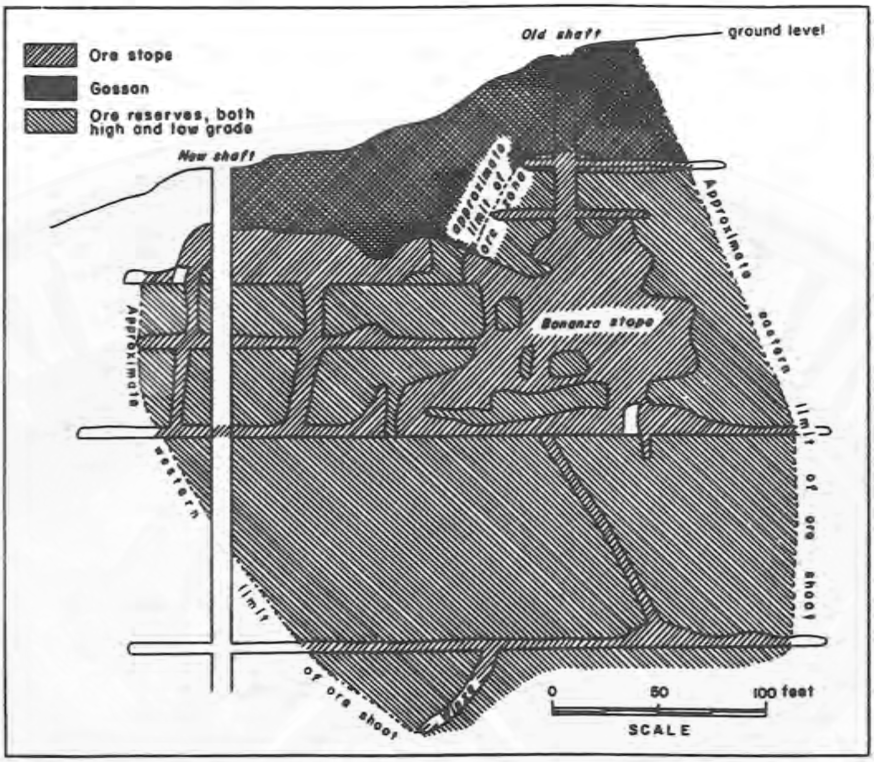


Figure 73. Cross section of the Ferris-Haggarty mine (after Spencer, 1904).

The principal ore minerals were chalcocite and chalcopyrite with minor bornite and covellite (Short, 1958). However, Platt (1947) indicated that covellite was an important constituent of the ore assemblage. Other minerals found on the mine dump included cuprite, pyrite, malachite, and chrysocolla. Additionally, the dump was reported to be slightly radioactive, although no uranium minerals were identified (Whelan, 1954b). Assays of dump samples collected in 1984 yielded 3.95% Cu with trace silver and 4.6% Cu with 0.06 opt Ag. Another sample of cupriferous quartzite contained 3.23% Cu and 0.61 opt Ag (Hausel, 1986a). Two samples collected from ore buckets respectively assayed 3.95% Cu, trace Ag, and no Au; and 4.6% Cu, 0.03 opt Ag, and no Au (Anonymous, 1942b).

Records indicate the mine may have produced as much as 21 million pounds of copper with some gold and silver. The amount of remaining ore in the mine is speculative. Ralph Platt (verbal communication, 1986) reported that large blocks and pillars of low-grade ore with an average composition of 5% Cu remained in the mine. A sampling program in a portion of the underground workings by Exxon Minerals in 1988 yielded 0.10 to 21.3% Cu, 1.1 ppm to 2.34 opt Ag, and 75 ppb to 0.33 opt Au. Reserves were reported to include 928,500 tons of ore averaging 6.5% Cu and containing 116,800 ounces of gold (Wyoming State Geological Survey files).

Finley mine. NE sec. 22, T14N, R84W. The Finley shaft was sunk in quartzite. At a depth of 170 feet below the collar, mineralization was intersected (Armstrong, 1970).

Gertrude mine. E/2 E/2 sec. 28, T14N, R85W. The Gertrude mine was developed on an outcrop of massive earthy hematite in quartzite with an east-west trend and a 40°S dip. Three shafts (50, 80, and 90 feet deep, respectively) were sunk in the mineralized zone (Beeler, 1901f). At the surface, the hematite was 2.5 feet thick; at a depth of 80 feet, the hematite swelled to 9 feet thick. The outcrop contained specularite and minor copper stains, in addition to earthy hematite.

Samples of hematite were reported to assay 0.37 opt Au (Spencer, 1904, p. 92–93). Spencer suggested that the Gertrude deposit probably was a gossan capping a copper deposit.

Gold Coin prospect. SW sec. 11, T15N, R87W. This claim was staked south of the Bridger mine on the Continental Divide. A 1-foot-wide calcite-quartz vein with galena, pyrite, chalcopyrite, and some gold and silver crosscuts regional schistosity (Beeler, 1902j). The mineralization is localized in a N75°E-trending fissure that dips steeply to the south (Spencer, 1904, p. 100–101).

Great Lakes claims. S/2 sec. 30, T14N, R84W. Located east of Willow Creek and immediately west of the Kurtz-Chatterton mine. A 4- to 5-foot-wide vein in gabbro(?) yielded values as high as 30% Cu and 0.13 opt Au (Armstrong, 1970).

Hercules mine. W/2 SW sec. 29, T14N, R85W. This mine is south of Battle along the Huston-Standard Park jeep trail. The Hercules mine was developed by an 80-foot shaft (Beeler, 1905a) in a sheared contact between granite and metadolomite-phyllitic schist of the Slaughterhouse Formation. The metadolomite and schist are hosted by chloritic schist interpreted as metamorphosed basalt.

The mine was developed on N65°E-trending crosscutting veins in the metadolomite and chloritic schist. The schist exhibits an east-west regional foliation (Spencer, 1904). The veins are narrow at the surface (a few inches wide) and traceable for several hundred feet. In places, the metadolomite and schist are brecciated and impregnated with chalcopyrite.

Samples collected from the Hercules mine were reported by Menzer (1981) and McCallum and Menzer (1982) to yield 85 ppm to 3.2% Cu and 0 to 0.9 ppm Ag. Other samples from the mine yielded 0.001 to 1.0 ppm Au, 0 to 0.30 ppm Pt, and 0.002 to 0.020 ppm Pd (Menzer, 1981).

Hidden Treasure mine. Sec. 28, T14N, R85W. Located 1 mile east of the old town of Battle and 0.5 mile from the Gertrude claim. A 1000-foot tunnel was driven to intercept a N70°E-trending vein that dips steeply to the south. The country rock, which strikes northeast and dips to the south, is formed of brecciated and mylonitized schist, quartzite, and altered diorite. The vein occurs near the center of the diorite and contains chalcopyrite, chalcocite, malachite, and a small amount of specular hematite in a gangue of quartz, calcite, siderite, and lesser feldspar. The average assay of nine samples from the mine was 0.3 opt Au. One sample assayed 11.0 opt Au (Spencer, 1904, p. 93-94).

Hinton-Verde mine. NE NW sec. 32, T13N, R85W. An average ore sample collected from the mine dump by Spencer (1904) assayed 8.18% Cu and 0.02 opt Au. Spencer indicated that the ore was stratabound. Samples collected by Swift (1982) contained flecks of chalcopyrite, pyrite, and magnetite in a fine-grained hedenbergite matrix.

About 3000 feet of section is exposed near the mine. This metasedimentary-metavolcanic section is wedged between granite on the north and gabbro on the south and east. The volcanogenic section is older than 1780 Ma based on the age of the gabbro. The top of the section lies to the southwest (Swift, 1982).

The Hinton-Verde mine was prospected by Conoco Minerals in 1981. Weak to moderate copper-zinc sulfide mineralization was found: in the mine dump (2% Cu, 0.04% Zn, 0.15 opt Au, and 0.35 opt Ag); in a ferruginous chert cropping out as a reddish gossan traceable for 200 feet along strike; and in a felsic tuff breccia measuring 40 by 50 feet. Associated with these rocks is a chert and actinolite-epidote-garnet exhalite, several pods of metalimestone (possibly travertine), and a tuff breccia containing rhyolite clasts up to 18 inches in length that is interpreted to represent a vent breccia (mill rock).

The entire felsic volcanic exhalite horizon varies from 100 to 400 feet thick and can be traced 5000 to 7000 feet along strike. A group of prospects in the NW SW sec. 33 exposed an epidote-magnetite exhalite. The rock contained disseminated sphalerite, chalcopyrite, and bornite (Lawrence, 1981).

Homestake. Secs. 11, 12, 13, and 14, T12N, R86W. The Homestake prospect was located on the North Fork group cross vein. A 40-foot tunnel cut a 3-foot-wide vein in chalcopyrite-bearing diorite. A 6-inch streak on the hanging wall of the vein yielded 19% Cu with some gold and silver (Pease, 1905).

Hub prospect. E/2 NW sec. 6, T15N, R87W. Located on the Divide Peak 7.5-minute Quadrangle. A sample with visible gold was collected from the dump (Paul Graff, personal communication, 1982). The prospect was developed on a 1.5-foot-wide, steeply dipping quartz vein in a sheared amphibolite. A select sample of cupriferous quartz vein gave 0.41% Cu, <0.01 opt Au, and 4.4 opt Ag (Hausel, 1986a).

Independence group. Located somewhere in secs. 11, 12, 13, and 14, T12N, R86W, about 14 miles from the old town of Battle near the Colorado-Wyoming state line. A quartz vein at the contact between diorite and schist strikes N60°W. Limonite has stained the upper part of the vein, which contained low-grade copper, gold, and silver. The diorite footwall was mineralized with "considerable" pyrite and chalcopyrite (Beeler, 1905f). The Independence group was part of the Pease properties, which also included the Parallel group and the North Fork group (Pease, 1905).

Iron King prospect. Sec. 15, T14N, R85W. Located 3 miles north of Battle on Cow Creek. A 15-foot-wide quartz vein strikes northeast and dips 30°SE. The vein contains copper and iron oxides at the surface and sulfides at depth and cuts altered schist and "diorite dykes" (Beeler, 1901e).

Island City group. Secs. 3 and 10, T14N, R86W. Located on the north side of Bridger Mountain near the head of North Spring Creek, approximately 2 miles northeast of the old Dillon town site. At 60 feet deep, a strong showing of pyrrhotite was intersected at the contact between norite and schist. Limonite and copper carbonates stained the vein, which also contained a small amount of copper sulfide (Beeler, 1904a).

Itmay mine. Sec. 14, T13N, R86W. The Itmay mine was developed from a shaft and adit. At the shaft, a chloritized mafic dike cuts granodiorite (Schmidt, 1986). About 160 feet north of the shaft, magnetite iron formation carrying botryoidal pyrite coated by chalcopyrite occurs adjacent to volcaniclastics (mill rock) (**Plate 4D**). A sample of the rock from this locality assayed 5% Cu and trace gold (W.D. Hausel, personal field notes, 1978). Schmidt (1983) collected a sample of magnetite, pyrite, chalcopyrite, quartz, chlorite, and epidote schist that yielded 1000 ppm Co, 15,000 ppm Cu, and 200 ppm Ni. A sample collected by Spencer (1904) assayed 17.92% Cu and 0.05 opt Au.

In 1981, Conoco Minerals explored the Itmay property searching for a massive sulfide orebody. Three holes drilled on the property intersected weak to moderate stratabound and fracture-related copper-silver mineralization.

Drillhole IM-1 was drilled to a depth of 383 feet and intersected a strongly chloritized, epidotized unit; however, the exhalite horizon and possible massive sulfides were not intersected, although fracture veining with locally strong remobilized chalcopyrite in the lower part of the core suggested the hole was in close proximity to a massive sulfide. The interval from 210 to 211 feet assayed 1.6% Cu and 0.06 opt Ag.

Drillholes IM-2 and IM-3 encountered a southeast-dipping section of siliceous metasedimentary rock with interbedded metatuff, a 15-foot-thick altered exhalite, and a lower metarhyolite crystal tuff. Pyrite and chalcopyrite were found in the metasedimentary-tuffaceous rocks as fine disseminations, in discrete seamlets parallel to bedding, and were locally abundant in epidote-actinolite veinlets. Weak mineralization was found as veinlets in intensely altered actinolite-epidote-magnetite exhalite.

Rhyolite crystal tuff was weakly mineralized with veinlets and disseminations along foliation. Locally strong chlorite-magnetite alteration was identified near the contact with the exhalite. Mineralization was encountered in both of these drillholes (**Table 22**) (Lawrence, 1981).

The Itmay volcanic cycle, characterized by differentiated metarhyolites overlain by an exhalite (which can be traced for 2500 feet along strike), appears to be a favorable

Table 22. Copper and silver assays from samples of mineralized zones intersected in drill holes at the Itmay mine by Conoco Minerals Company (from Lawrence, 1982) Analyses in weight percent (%) or ounces per ton (opt).

Drill hole	Total depth (feet)	Mineralized zone (feet from surface)	Cu (%)	Ag (opt)
IM-2	316	34.7 to 41	1.9	0.2
		124.5 to 128	0.12	0.03
		293.0 to 302	0.35	0.01
IM-3	501	35.7 to 59	0.09	0.03
		368.0 to 398	0.17	0.04

horizon for massive sulfides. The exhalite is coincident with higher copper soil values, anomalous ground magnetics, and with localized pyrite-sericite alteration in the footwall rhyolite crystal tuffs (Nelsen, 1981).

Kearns prospect. Located at the head of Beaver Creek. A 12- to 20-foot-thick silicified, copper-stained banded jaspilite gneiss(?) lies along the contact between gneiss and granite. In 1901, a 460-foot tunnel and a couple of shallow shafts were dug to test the deposit (Beeler, 1901g).

King of the Camp prospect. Located in sec. 36, T14N, R83W, about 5 miles south of Encampment on the South Fork of Encampment River. At the surface, a 5-foot quartz vein in mica schist trends northeast and dips 45°NW. The dip of the vein in the shaft is 20°NW. The quartz was stained with iron oxides and contains pyrite and chalcopyrite below the oxidized zone. Traces of azurite and malachite are scattered throughout the vein with variable amounts of gold (Beeler, 1903c).

A tunnel driven to intersect the vein cut several faults and six 2- to 4-foot-wide quartz veins. The quartz was stained with iron oxides and contained streaks and bunches of iron sulfides and copper sulfides, some of which weighed many pounds. In addition to these veins, another 15-foot vein was cut by the shaft at a depth of 100 feet. This vein assayed 0.2 to 0.3 opt Au (Beeler, 1904b).

Kurtz-Chatterton mine. S/2 sec. 29, T14N, R84W. One of the three most productive copper mines in the Encampment district. By 1901, more than 1700 feet of tunnel and several hundred feet of drifts had been driven on this property, located along Copper Creek, 5 miles southwest of Encampment (Armstrong, 1970).

Widespread copper mineralization was found in veins and in shear zones in Sierra Madre granite. Vandenberge (1906), reported the property contained five distinct veins ranging in width from 18 to 44 feet. The ore consisted of chalcocite and chalcopyrite (Spencer, 1904).

Locally, the granite exhibits potassic alteration (secondary biotite, muscovite, and chlorite) where it has been sheared and rehealed. Reconnaissance of the property in 1991 identified a mineralized zone extending over a strike length of 4000 feet that swelled from a relatively narrow zone to possibly a few hundred feet wide (Hausel, 1992b). Select samples of mineralized rock collected on the property in 1991 and 1993 ranged from 0 to 28.10 ppm Au, 0 to 7.24 ppm Ag, 0 to 12.55% Cu, 0 to 0.8% TiO_2, and trace amounts of lead and zinc (**Plate 3B**). **Table 23** summarizes the assays that were obtained.

Leighton-Gentry (Jack Creek) mine. Located in SW sec. 5, T14N, R86W, near the Continental Divide at the head of Jack Creek. A 3-inch-wide gossan is structurally overlain by 4 feet of black, crumbly mica schist. The schist is overlain by a thick norite sill. The footwall of the gossan is formed by an 11-foot-thick limy quartzite. Pyrite, pyrrhotite, and chalcopyrite were found along bedding planes and disseminated throughout the quartzite. The metalimestone below the quartzite contained no sulfides. The rocks strike N80°W and dip 30°SW. An assay yielded 3.07% Cu, 0.67% Ni and Co combined, and trace zinc (Spencer, 1904)[*Note: the author (Hausel) was not able to confirm these results (W.D. Hausel, unpublished field notes, 1996)*]. Spencer noted similarities between the Leighton-Gentry mine and the Ferris-Haggarty ore deposit.

Table 23. Assays of samples collected from the Kurtz-Chatterton property (from Hausel, 1992b and unpublished data). Analyses in weight percent (%) or parts per million (ppm); dashes indicate not analyzed; nd= not detected.

Sample number	Au (ppm)	Ag (ppm)	Cu (%)	Pb (ppm)	Zn (ppm)	TiO_2 (%)
EN6-91	12.29	3.0	4.51	11.9	nd	–
EN7-91	15.69	7.24	12.55	37.4	1.57	–
EN8-91	0.95	0.94	–	–	–	–
EN9-91	28.10	3.06	4.34	3.1	nd	–
EN11-91	nd	nd	0.7	13.3	1.54	0.8
EN12-91	0.34	nd	3.66	6.8	nd	0.1
EN13-91	0.45	nd	1.21	10.4	nd	0.06
EN14-91	1.45	1.44	3.56	12.6	nd	0.02
EN15-91	0.14	2.56	2.35	150.9	2.20	0.04
EN16-91	0.20	2.56	7.27	26.4	4.45	nd
KC1-93	0.007	<0.2	nd	14.0	6.0	–
KC3-93	<0.005	<0.2	nd	9.0	15.0	–
KC4-93	0.032	1.4	1.13	90.0	16.0	–
KC5-93	0.021	0.7	1.50	16.0	17.0	–
KC7-93	0.170	1.0	1.93	16.0	23.0	–
KC8-93	0.017	<0.2	2.22	15.0	39.0	–
KC10-93	0.176	0.8	0.98	19.0	13.0	–

Lena Shields group. Located in sec. 12, T14N, R86W, near the head of the main fork of Cow Creek. The Lena Shields group encloses a series of fine-grained micaceous schists, abundant schistose conglomerate, and fractured diorite dikes that are altered in many places. At one locality, a N70°W-trending quartz vein with interlaminated schist has an aggregate thickness of 5 to 15 feet. The vein contains limonite, azurite, malachite, and pyrite (Beeler, 1902b).

Meta mine. Located in either sec. 24 or 25, T15N, R86W, and situated at the head of a branch of South Spring Creek, the Meta mine was developed by a 100-foot shaft on a 6-inch- to 6-foot-wide vein. The vein strikes roughly east-west and dips nearly vertical at the surface. At depth, the vein dips about 60°S. Although the foliation of the quartz-biotite gneiss country rock strikes parallel to the Meta vein, the foliation dips only 20°–25°N.

Samples of the vein contain a variety of minerals. The ore consists of massive galena that is probably argentiferous, chalcopyrite, sphalerite, cerussite, anglesite, pyrite, azurite, malachite, chrysocolla, hematite, limonite, hemimorphite, and smithsonite in a gangue of barite (Haff, 1944b). Spencer (1904, p. 99) reported that one carload of silver ore was shipped from the property. Haff (1944b) estimated that six to seven carloads of ore were shipped to Salt Lake City sometime after 1930.

These accounts suggest that 200 to 300 tons of ore were shipped from this mine. Ore mined after 1930 was reported to run 27 to 54% Pb, 8% Zn, and $20 to $22 combined gold and silver values (1944 prices, units not specified).

Mohawk prospect. NW sec. 20 and NW sec. 35, T14N, R85W. Brown iron-stained, siliceous and limy material at the contact between granite and altered schist contains minor malachite (Beeler, 1902c).

Monarch group. Secs. 32 and 33, T14N, R85W. Located 1.5 miles southeast of Battle. Interlayered schist and "quartz diorite" trend east-west and dip vertically. The rocks are altered, silicified, and mineralized with pyrrhotite. Near the surface, the rocks are weathered to hematite and are stained with limonite. No copper was found (Beeler, 1902d).

Newsboy claim. Located 4 miles east of Encampment. A vein was traced over a strike length of 4500 feet. At one point, the vein contained a 4-foot ore zone that averaged 28.8% Cu (Armstrong, 1970).

Newton group. Secs. 13 and 24, T14N, R85W, and secs. 18 and 19, T14N, R84W. The claims are located on an east-west-trending layer of mafic rock situated between metaconglomerate to the south and quartzite schist to the north. A 140-foot shaft was sunk on a vein in the mafic unit located on the Copper Queen claims. The vein contained abundant limonite, hematite, cuprite, malachite, azurite, and chrysocolla near the surface. At depth, chalcopyrite, bornite, and chalcocite were found (Beeler, 1905g).

North Fork group. Sec. 13, T12N, R86W. Located 14 miles south of Battle. Granite and "diorite" dikes trend northwesterly and dip to the northeast; they are cut by a N45°W-trending quartz vein known as the North Fork vein. The vein is 6 to 26 inches wide at 160 feet below the surface. Near the surface, limonite, malachite, and azurite were found; at depth the vein carried pyrite and chalcopyrite (Beeler, 1905h). Pease (1905) however, reported that the ore consisted of galena and sphalerite with some wire silver.

Galena from the property yielded as much as 600 opt Ag. Assays of other oxidized ore yielded 33 to 73 opt Au. The average workable ore yielded $36.39 per ton in gold, silver, and lead (1905 prices) (Beeler, 1905h). A historical prospectus from the Boston Sierra Madre Mine Industry Company reported that a 1700-foot-long pay streak was outlined on the property with a 300-foot-long, 6- to 18-inch-wide ore shoot (Pease, 1905).

A N88°E-trending crosscut vein cuts the North Fork vein. The crosscut vein is 23 feet wide and mineralized throughout much of its width with pyrite, chalcopyrite, and some galena.

North Spring Creek prospect. Sec. 10, T15N, R86W. Four short adits were driven into a near-horizontal, 6- to 10-inch-wide milky quartz vein that strikes N40°W. The country rock is diorite. A second milky quartz vein, located about 150 feet above the workings, is stained by spotty malachite and carries some sulfides.

The deepest penetration of any of the tunnels was only 100 feet. A 1- to 2-inch-wide fine-grained chloritic alteration zone is exposed in the wall rock adjacent to the vein in the northernmost portal, but no other evidence of mineralization was found in this vein (W.D. Hausel, personal field notes, 1986).

Octavia prospect. Located on the West Fork of Savery Creek about 5 miles west of Battle. A quartz vein strikes northwest, dips 30°SW, and cuts an altered limy schist. The quartz contains occasional calcite and disseminated and streaky pyrite and chalcopyrite (Beeler, 1901c).

Parallel group. (See also North group.) Secs. 11, 12, 13, and 14, T12N, R86W. The Parallel group was part of the Pease properties and was also known as the North Fork group. According to Beeler (1905f), a smoky quartz vein "with copper showings" occurs in the dioritic country rock. The vein was 3 feet wide with a dip of 85°NE (Pease, 1905).

Portland mine. E/2 SE sec. 30, T14N, R85W. This mine is south of Battle along the Huston-Standard Park jeep trail. The Portland mine was developed by 370 feet of tunnel with 120 feet of crosscuts and a shallow shaft (Beeler, 1905a). The mine lies a short distance downslope and west of the Hercules mine and exhibits similar geology.

Both the Portland and the Hercules mines lie along a sheared contact between granite to the south and metadolomite and phyllitic schist to the north. The primary target of the Portland mine, like the Hercules, was crosscutting veins in the metadolomite and schist (Spencer, 1904). The veins are narrow at the surface (a few inches wide) and can be traced for several hundred feet. However, according to Vandenberge (1906), the Portland vein was 44 feet wide and included a number of smaller veins ranging from a few to 12 feet wide. Beeler (1905a) reported the Portland vein was traced for 3000 feet. In places, the metadolomite and schist are brecciated and impregnated with chalcopyrite.

Mineralization consists of chalcopyrite, some chalcocite and bornite with hematite, quartz, calcite, and siderite gangue. A select sample of silicified mafic rock with chalcopyrite and chalcocite collected from the Portland dump assayed 2.75% Cu, 81 ppm Zn, and <0.01 opt Au (Hausel, 1982a). Samples collected from the mine by Menzer (1981) and McCallum and Menzer (1982) yielded 25 ppm to 11.5% Cu, 0 to 11.0 ppm Ag, 0.005 to 9.0 ppm Au, 0 to 0.030 ppm Pt, and 0.002 to 0.060 ppm Pd.

Prospect 9999. W/2 sec. 15 and E/2 sec. 16, T13N, R86W. The mineralization and geology of this prospect are similar to the Itmay and Hinton-Verde massive sulfide deposits to the east and southeast. This property lies in the Fletcher Park area of the Sierra Madre within a series of calc-alkaline metavolcanic rocks and volcanogenic metasediments collectively grouped into the Green Mountain Formation. The Green Mountain Formation consists of 1.7- to 1.9-Ga metamorphic rocks interpreted to have been deposited in an island arc (Divis, 1976, 1977).

In the Fletcher Park area two volcanic cycles are recognized–the Fletcher Park cycle and the Itmay cycle. These cycles consist of metarhyolites overlain by exhalites.

Two types of alteration occur–localized sericite-pyrite at the Itmay mine and a wide zone of saussuritization. This second type of alteration occurs as epidote ± chlorite ± calcite ± garnet ± actinolite and is locally intense near the Fletcher Park exhalite in the vicinity of Prospect 9999.

In 1979 and 1980, Conoco Minerals drilled the Prospect 9999 exhalite. Drillhole FWDH-2 was collared near the top of the exhalite and intersected alternating tuffaceous metasediments and metatuffs, all of which showed strong garnet-epidote alteration. Significant zinc-copper mineralization was present and averaged 0.9% Zn, 0.16% Cu, and 0.32 opt Ag over a true thickness of 67 feet.

Drillhole FP-2 cut through a 479-foot section of exhalitives. The hole collared in andesitic lapilli metatuff (which graded downward into rhyodacitic metatuff), intersected the exhalite, and terminated in rhyolite metatuff with interbedded porphyritic meta-andesite. The exhalite was altered to silica, garnet, epidote, and chlorite.

Two strongly mineralized zones were encountered in Drillhole FP-2. In the lower portion of the andesite lapilli metatuffs (between 214.5 and 320 feet deep), the mineralized zone contained up to 2.1% Zn and 0.19% Cu. Within the exhalitive zone (510 to 564 feet deep) copper, zinc, and lead sulfides averaged 1 to 4% of volume and locally reach up to 15% by volume.

Drillhole FP-3 collared 500 feet to the southeast of FP-2. This hole encountered meta-andesite tuffs, interbedded cherts, siliceous metasediments, and calc-silicates, and terminated in metarhyolite tuff with interbedded porphyritic meta-andesite. Mineralization was anomalous over a 200-foot interval. The strongest showing occurred in the lower meta-andesite upper exhalite zone between 197 and 263 feet. In the basal(?) meta-andesite, assays ran as high as 0.55% Cu, 0.11% Zn, and 0.04 opt Ag (Nelsen, 1981). A sample of tenorite- and marmatite-stained altered schist collected from an outcrop yielded 0.14% Cu, 47 ppm Zn, <0.01 opt Au, and <0.01 opt Ag (Hausel, 1982e).

Purgatory Gulch mines. Sec. 1, T13N, R84W, and sec. 36, T14N, R84W. Includes the Golden Eagle claim. A group of short adits was driven into limonite-stained shears in gneiss (also see Copper Gem prospect, above). On the west side of the gulch, two mines were examined by the author in 1984. The southernmost adit was driven into granodiorite gneiss along a narrow shear. Four narrow copper- and limonite-stained veins were intersected in the workings. A short distance north, a short adit was driven less than 100 feet into the country rock. Across the gulch, more extensive workings were found, but the adit was caved.

Some remarkably rich gold specimens were found here (Beeler, 1905a). According to Armstrong (1970), a 10-foot-wide, free-milling gold vein was struck on Purgatory Gulch. Assays ran as high as 6 opt Au. Samples recently collected from the Golden Eagle vein by the author contained visible gold, and one sample of boxwork quartz was assayed yielding 40.63 ppm Au and 3.62 ppm Ag (Hausel, 1989, 1992b). Another sample assayed 0.013% Cu, 4.2 ppm Ag, and 19.0 ppm Au (Hausel, 1988d).

Rambler mine. NW sec. 30, T14N, R85W. Five samples collected from the Rambler mine dump (located east of the Doane-Rambler mine) by Menzer (1981) yielded weak copper anomalies (80 to 400 ppm Cu). The Rambler adit was driven in the Cascade Quartzite.

Rex prospect. SE SW sec. 24, T14N, R86W. A 25-foot-deep shaft was sunk in limonite gossan. Dump samples contained small amounts of pyrite (W.D. Hausel, personal field notes, 1980).

Section 8 mine. Located in S/2 SE sec. 8, T14N, R85W, adjacent to the historic Ferris-Haggarty tramway. Stratiform copper mineralization occurs in a banded pyritized chert. The chert is hosted by amphibolite of the Silver Lake Volcanics, which trend

N81°E and dip 52°SE. A grab sample of the chert contained limonite, chalcopyrite, and bornite and assayed 2.61% Cu and <0.01 opt Au (Hausel, 1982b).

Sierra Madre shaft. Located near the state line about 1.5 miles north of Pearl, Colorado. The shaft was sunk on a 7-foot-wide, N60°E-trending, foliation-parallel mineralized zone in micaceous gneiss. The mineralized zone consists of both unbanded massive hornblende with pyrite, chalcopyrite, sphalerite, and minor galena, and light-colored banded rock with sphalerite and minor pyrite. Sphalerite appears to replace mafic minerals in the gneiss (Spencer, 1903).

Soldier Creek. T14N, R84W. Copper-gold mineralization is present in zones of intense shearing. The gold occurs as free gold associated with chalcopyrite as fracture fillings in a gangue of bull or honeycomb quartz with minor calcite (Wied, 1960).

Standard mine. NE sec. 13, T13N, R86W. Samples from a large dump near a water-filled shaft are dark, fine-grained rocks containing pyrite, chalcopyrite, and traces of bornite. The original rock type is unknown, but large mafic inclusions and mafic dikes crop out in the area (Lackey, 1965).

Sun-Anchor and Sweet claims. Sec. 34, T14N, R85W, and sec. 6, T13N, R84W. Located in a series of east-west-trending hornblende schists that crosses the south branch of the North Fork along the north face of Green Mountain. According to Spencer (1904), the zone contains an appreciable amount of epidote and small red garnets, with a little magnetite and chalcopyrite.

Several prospects and small mines occur in an arc extending from sec. 34 to sec. 6 following a magnetite iron formation. The stratigraphic succession near the Sun-Anchor and Sweet claims includes metabasalt, metadacite, fragmental felsite, laminated siliceous rock, iron formation, banded metasediments, hornblende schist, metadacite tuff, and lapilli tuff. One sample from the mineralized zone in sec. 6 contained chalcopyrite, pyrite, and malachite in an epidote-calcite-hornblende-feldspar-augite lapilli tuff (Schmidt, 1983).

Syndicate mine. Sec. 26, T15N, R87W. Precambrian quartzite strikes east-west and dips to the south. The quartzite is overlain by a 150-foot-thick diorite sill.

A 135-foot shaft was sunk on a fissure vein in the quartzite. The vein crosscuts bedding, trends N70°W, and dips 65°SW. The vein is 3 to 11 feet thick and consists of a calcite-filled breccia zone in the quartzite. Mineralization occurs as disseminated chalcocite in the calcite and in some of the quartz fragments (Spencer, 1904).

Tennant property. Located 4 miles from Encampment in secs. 21 and 22, T14N, R84W. A 6-foot-wide fissure vein in sec. 22 contains copper and some gold. Six tons of ore mined from the claim netted $400.00 in copper (at $0.20/pound) (Osterwald and others, 1966, p. 49). In sec. 21, three strike veins containing gold, silver, and lead assayed from $15 to $112 per ton (1927 prices). Some of the country rock schist also is mineralized and was reported to assay 0.12 to 0.18 opt Au (Osterwald and others, 1966, p. 84).

Three Forks group. This is part of the Pease properties in secs. 11, 12, 13, and 14, T12N, R86W, about 14 miles from Battle. Smoky quartz veins in schist contain argentiferous galena and minor sphalerite and copper. The veins also contain abundant hematite near the surface, and both the quartz and hematite are reported to be auriferous (Pease, 1905). Some cerargyrite is present (Osterwald and others, 1966, p. 49). At least 500 feet of development work occurred on the property.

According to Pease (1905), the Three Forks vein is well-defined and mineralized over a strike length of 6500 feet and extends from the south bank of the North Fork River south into Colorado. The vein trends N25°W, dips 82°NE, and is hosted by diorite. At one point, the vein (or complex of veins) is about 120 feet wide. A 54-inch streak on the footwall side of the vein carried approximately 10% Pb and averaged $30.00 in lead, silver, and gold (1905 prices, units not specified) (Pease, 1905). Downslope from the Three Forks group (secs. 13 and 14) are the Pease placers. The gravels of the placers contain some gold and silver (Beeler, 1905f).

Umslopagus group. Secs. 19 and 30, T14N, R85W, near the old town of Rambler. A series of schists and quartzites is cut by dikes of "diorite or gabbro" that strike northwest. A 9- to 22-foot-wide limonite zone lies between hanging wall schist and footwall quartzite. Malachite and azurite are associated with the limonite, and copper sulfides were found below the gossan (Beeler, 1905i).

SW sec. 9, T12N, R84W. Malachite occurs at the contact between amphibolite and pegmatite. Two shafts were sunk on the mineralized zone (Merry, 1963).

Sec. 24, T14N, R84W. A shaft sunk on the contact of a quartz vein with amphibolite country rock exposed bornite and minor chalcopyrite (Ferris, 1964).

NE sec. 20, T14N, R83W. A 40-foot shaft was sunk on an amphibolite dike. The dike is cut by an 8- to 18-inch-wide quartz-feldspar vein that exposes chalcopyrite and minor bornite near the contact. Most of the mineralization is localized in fractures (Ferris, 1964).

SW sec. 24, T14N, R84W. Chalcanthite encrustations occur on the ribs and back of an adit driven in gneiss. The gneiss is in contact with an amphibolite dike (Ferris, 1964).

SE sec. 28, T14N, R83W. Crusts and stains of malachite occur on quartz and amphibolite fragments found in a prospect pit (Ferris, 1964).

SW NE sec. 11, T12N, R85W. A prospect was developed in a exhalite associated with dacitic metavolcanics (Swift, 1982).

SW NE sec. 15, T12N, R85W. A mine of limited extent was dug in fragmental felsic and mafic rocks and exhalite hosted by a thick metabasalt sequence (Swift, 1982).

Sec. 6, T13N, R84W. Several prospect pits and three shafts were dug along the contact between granite and metabasalt. Quartz vein material from the mine dump contains malachite. One sample collected by Schmidt (1983) yielded 500 ppm Ag (14.6 opt), 5000 ppm Ba, >20,000 ppm Cu, 200 ppm Pb, and 200 ppm Zn.

SW sec. 25, T14N, R85W. The main shaft at this mine is situated on the contact between sheared metadolomite and quartz chlorite schist. Hematite gossan and small amounts of malachite occur on the dump. A sample of chlorite schist yielded 1.5% Cu and 0.1% Ni. A sample of the gossan yielded 300 ppm Cu and 200 ppm Ni (Schmidt, 1983).

SW sec. 29, T14N, R85W. Six samples collected from the dump of an unnamed mine at this locality by Menzer (1981) yielded 40 ppm to 8.8% Cu. Two samples yielded detectable silver values of 0.5 and 1.5 ppm. Samples tested for gold and platinum group metals yielded only 0.005 to 0.010 ppm Au, 0 to 0.020 ppm Pt, and 0 to 0.070 ppm Pd.

SW sec. 25, T14N, R85W. A 100-foot-deep shaft and two portals occur on a hilltop. The two portals are short (15 to 20 feet) and do not connect with the shaft. The country rock is felsite, felsite breccia, and lesser mafic rocks. The shaft was developed to intersect an east-west-trending milky quartz vein that is well exposed on the west flank of the hill.

The vein is 1 to 2 feet wide and located along the contact between footwall mafic schist and hanging wall felsite. The vein contains minor chalcopyrite and malachite in a quartz and calcite gangue (Hausel, 1986a).

Sec. 35, T14N, R86W. A mine was sunk along a granite-amphibolite contact. Samples from the dump contain hematite, chalcopyrite, and malachite stringers in quartz (Schmidt, 1983).

Sec. 11, T13N, R86W. Samples from a small mine situated along the contact of granodiorite with metavolcanic rocks contain pyrite in quartz. An assay of the material showed no detectable anomalous metals (Schmidt, 1983).

SW sec. 23, T14N, R84W. Five samples collected from a group of nearby adits and prospect pits along Miners Creek yielded anomalous metal values. These samples included: a N65°W-trending, 2-foot-wide, copper-stained fault zone (1140 ppm Cu, 102 ppm Mn, 15 ppb Au, 2 ppm Pb, and 5 ppm Zn); a grab sample of dump material (8770 ppm Cu, 200 ppm Mn, and 22 ppm Zn); malachite-stained quartzite (6980 ppm Cu, 356 ppm Mn, 4 ppm Pb, and 34 ppm Zn); and a grab sample of copper-stained granite and quartz (3150 ppm Cu, 1035 ppm Mn, 16 ppm Pb, and 5 ppm Zn) (Ryan, 1988).

SW sec. 27, T14N, R84W. A chip sample of hematite-stained quartz in biotite gneiss yielded 0.16% Cu, 28 ppm Ag, 0.01 ppm Au, 1 ppm Mo, 178 ppm Pb, and 76 ppm Zn (Ryan, 1988).

N/2 sec. 34, T14N, R84W. A narrow shear was cut by two adits and a small pit along the bank of the South Fork of Miner Creek. The host feldspathic mylonite contains numerous quartz veinlets with minor copper stains, including malachite, tenorite, and cuprite. The shear is not well exposed and could be several feet wide. The structure trends east-west and dips 36°N.

A chip sample collected by Hausel (1992b) assayed 0.18% Cu, 11 ppm Pb, 42 ppm Zn, and no detectable gold or silver. A grab sample collected by Ryan (1988) yielded >1.0% Cu, 262 ppm Mn, 20 ppm Pb, 30 ppm Zn, 0.8 ppm Ag, and no detectable gold or molybdenum.

N/2 SW sec. 26, T14N, R84W. A grab sample collected from a mine dump adjacent to a 50-foot-deep shaft assayed 0.14% Cu, 650 ppm Mn, 14 ppm Pb, 26 ppm Zn, 0.01 ppm Au, and no detectable silver or molybdenum (Ryan, 1988). The rocks on the dump were stained with minor malachite and included quartz and mafic igneous rock. A short distance to the southeast, another shaft (25 feet deep) was sunk in malachite- and hematite-stained quartzite. A grab sample assayed >1.0% Cu, 36 ppm Pb, 173 ppm Zn, 107 ppm Mn, 0.17 ppm Au, 20.8 ppm Ag, and no detectable molybdenum (Ryan, 1988).

S/2 SE sec. 26, T14N, R84W. A grab sample of limonite-stained quartzite from a trench overlooking the Encampment River assayed 33 ppm Cu, 120 ppm Pb, 19 ppm Zn, 3 ppm Mo, 115 ppm Mn, 0.2 ppm Ag, and no detectable gold (Ryan, 1988).

NW NE sec. 35, T14N, R84W. A grab sample of hematite-stained quartz from a 3-foot-deep pit assayed 562 ppm Cu, 1145 ppm Mn, 2 ppm Mo, 6 ppm Pb, 27 ppm Zn, 0.6 ppm Ag, and 0.125 ppm Au. The pit exposed a 2-foot-wide quartz pod in gneiss (Ryan, 1988).

SE NW sec. 24, T14N, R84W. Quartz from a mine dump adjacent to a 25-foot-deep shaft contained minor pyrite. The dump also contains mafic igneous rock. A grab sample assayed >1.0% Cu, 80 ppm Mn, 1 ppm Mo, 14 ppm Pb, 5 ppm Zn, 9.8 ppm Ag, and no detectable gold (Ryan, 1988).

W/2 SW sec. 24, T14N, R84W. Two adits along the banks of the Encampment River were sampled (Ryan, 1988). The northern adit was developed on a 23-inch-wide vein stained by malachite and limonite with some minor chalcopyrite in granite gneiss. The 1.9-foot-wide chip sample across the vein assayed >1.0% Cu, 80 ppm Mn, 1 ppm Mo, 14 ppm Pb, 5 ppm Zn, 8.2 ppm Ag, and 1.55 ppm Au.

The southern adit was driven on a quartz pod along a contact between mafic rock and biotite gneiss for 27 feet, and a raise was cut to the surface. A 2-foot chip sample of the vein assayed 0.14% Cu, 96 ppm Mn, 2 ppm Pb, 45 ppm Zn, 0.2 ppm Ag, and no detectable molybdenum or gold.

Sec. 21, T13N, R82W. Vein-filling chalcopyrite with chalcocite, bornite, and malachite occurs on the face of a cliff in the Beaver Creek area. The gangue minerals associated with the mineralization include massive calcite, quartz, and amphibole. The ore minerals are disseminated in fault breccia of the host amphibolite (Huang, 1970).

W/2 W/2 sec. 16, T13N, R82W. A shaft was sunk to a depth of about 15 feet into iron-stained micaceous submylonite. Both malachite and brochantite with minor olivenite were identified at the locality. One sample was analyzed and yielded 0.054% Cu and 0.065% Zn (Huang, 1970).

NE NE sec. 33, T13N, R82W. Malachite-stained pegmatite occurs in this vicinity (Huang, 1970).

N/2 N/2 sec. 19, T13N, R82W. A sample of gossan was analyzed and yielded 0.016% Cu and 0.017% Zn (Huang, 1970).

Sec. 8, T12N, R81W. A sample was collected from a copper-stained, N10°E-trending, narrow shear in amphibolite gneiss. The sample yielded 1.85% Cu, 18.0 ppm Ag, and no gold (Hausel, 1988d).

SW sec. 11, T12N, R82W. A sample of copper-stained amphibolite gneiss yielded 0.97% Cu, 11.0 ppm Ag, and no gold (Hausel, 1988d).

NE SW sec. 11, T15N, R87W. Chlorite schist with minor quartz collected from a mine dump assayed 0.014% Cu, 4.4 ppm Ag, and no gold (Hausel, 1988d).

Teton Range

The Teton Range is considered the youngest mountain range in Wyoming. These spectacular peaks within Grand Teton National Park were uplifted only 5 to 13 million years ago along the Teton fault. The recent movements on the fault have formed a prominent scarp 150 feet high that is traceable over a distance of 30 miles.

The Teton Range consists of Archean igneous and metamorphic rocks that include quartz monzonite, gneiss, and diabase. The Archean rocks are overlain by Paleozoic strata and Quaternary silicic volcanic rocks that form the western dip slope of the range (Smith and others, 1993). Only small amounts of base metal mineralization have been reported in the Teton Range and adjacent areas, and only limited information is available on the known deposits. There are only three reported occurrences of copper, lead, zinc, and molybdenum in this area.

Buffalo Fork of the Snake River. Located about 30 miles southeast of Yellowstone National Park, Precambrian granite, schist, and diorite host veins with copper sulfides. The average value of the material is 4 to 7% Cu. Hundreds of feet of shafts and drifts were dug (Hall, 1909).

Teton Pass. Exposures of Nugget Sandstone at Teton Pass are stained with malachite in a roadcut through the sandstone along State Highway 22 (J.D. Love, personal communication, 1982).

E/2 sec. 12, T41N, R118W, near Teton Pass. Samples collected from the basal phosphorite of the Mead Peak Member of the Phosphoria Formation yielded 25 ppm Ag, 0.2% Pb, >1.0% Zn, >0.05% Cd, 0.1% Cr, 0.1% Cu, and 0.2% V. One sample collected near the top of the phosphorite yielded 70 ppm Ag (Love, 1984).

Wind River Range

The Wind River Range in western Wyoming forms an asymmetrical arch. Along the eastern flank of the range, Paleozoic and Mesozoic strata dip into the Wind River Basin. Along the northern and northeastern flanks, the strata are folded and faulted against the Precambrian basement complex. Major boundary faults along the southern flank continue along the western margin of the range and place Precambrian igneous and metamorphic rocks over younger sedimentary rocks in the Green River Basin.

The Archean basement complex that forms the core of the Wind River Range is a high-grade metamorphic and igneous complex of migmatite, and amphibolite- to granulite-facies felsic orthogneiss and paragneiss, intruded by quartz diorite and granite plutons. Amphibolite-grade orthogneiss is dated at 2.8 to 3.0 Ga, and in the northern part of the range, these gneisses are intruded by 2.0- to 2.795-Ga granite pegmatites (Stuckless and others, 1985).

Near the south end of the range, the 2.6-Ga Louis Lake batholith cuts the South Pass greenstone belt (Stuckless and others, 1985), which is a synform of metasedimentary, metavolcanic, and plutonic rocks (**Figure 74**) (Hausel, 1991b). Very little copper, molybdenum, zinc, or lead mineralization has been reported in the Wind River Mountains. Where found, copper generally is associated with veins and shear zones that crosscut earlier auriferous shears in the South Pass granite-greenstone terrane (Hausel, 1987b). The South Pass greenstone belt has been subdivided into the Anderson Ridge area, the Lewiston district, and the South Pass-Atlantic City district. Molybdenum porphyry and veins are reported in the southern part of the range.

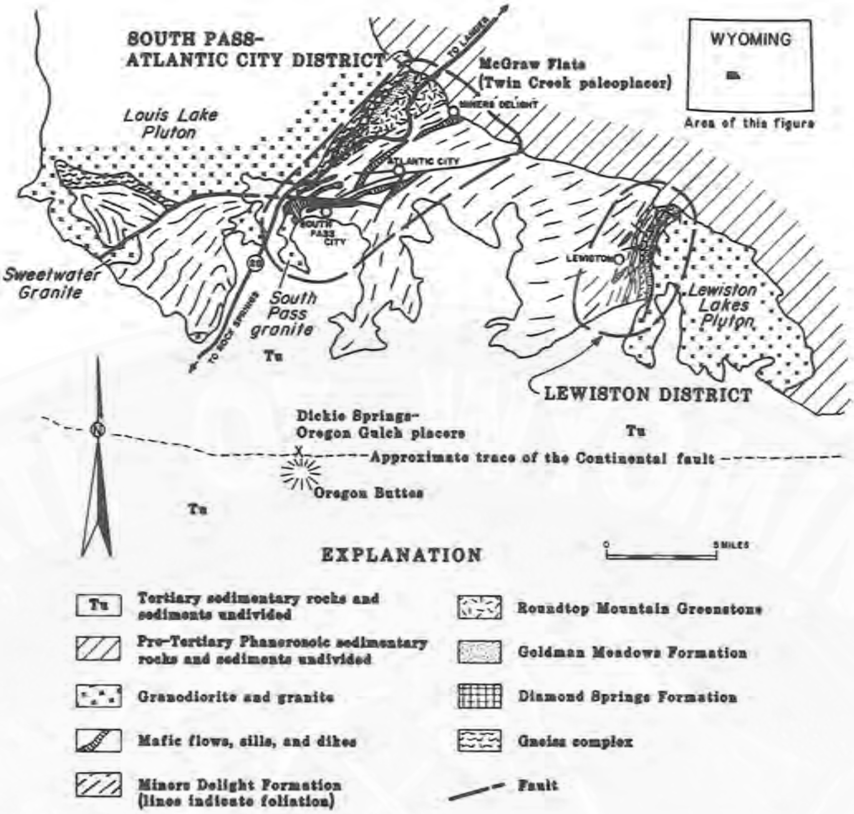


Figure 74. General map of the South Pass greenstone belt, Wind River Mountains (from Hausel, 1991b).

Anderson Ridge area

The area lies west of South Pass City and to the west of State Highway 28. The area is an extension of the South Pass greenstone belt (**Figure 1**). Rock outcrops in this area are dominantly garnet-bearing metagreywackes extensively intruded by granite pegmatites. The pegmatites in the area are simple pegmatites that contain some schorl tourmaline and uncommon beryl.

Anderson Ridge fault. NE sec. 21, T29N, R101W. A shaft and trenches were dug along the Anderson Ridge fault to expose copper stained cataclastics. The breccia zone is 500 to 800 feet wide at this locality. One sample of copper-stained rock assayed 1.86% Cu and 175 ppb Au. Another sample yielded 2.27 ppm Au (Hausel, 1991b).

Burnt Meadow prospect. NW NW sec. 17, T29N, R101W. A prospect pit and short adit were developed on a narrow, N20°E-trending, 19°NW-dipping shear in Louis Lake granodiorite. One sample of malachite-stained granodiorite selected from the mine dump assayed 2.75% Cu, 3.03 opt Ag, and 4.03 ppm Au (Hausel, 1991b).

PEG claims. Located in sec. 34, T30N, R101W, on the flank of Rennecker Peak near 10,000 feet elevation. A westerly trending mafic dike occurs in granitic country rock.

Prospect pits expose pyritized dike material and epidotized xenoliths of granite. Parts of the granite wall rock are also pyritized. Chalcopyrite is disseminated in the dike rock (Hausel, 1981b). The dike was initially prospected near the turn of the century by a Mr. Rennecker (Elmer Winters, personal communication, 1981).

NW sec. 32, T29N, R101W. A shallow incline driven into sheared metagreywacke of the Miners Delight Formation contains minor cupriferous quartz. One selected sample collected from the mine dump yielded 1.54% Cu, 4.4 ppm Ag, and 3.4 ppm Au (Hausel, 1991b).

Lewiston district

The Lewiston district forms the eastern margin of the South Pass greenstone belt and is dominated by metagreywacke with lesser metapelite, banded iron formation, metabasalt, and serpentinite. The eastern edge of the district contains a prominent tonalite dike that intrudes the metagreywackes. Much of the mineralization in the district is shear-zone-controlled gold deposits and associated gold placers. Very little evidence of base metal mineralization has been recognized.

Lewiston iron formation. N/2 NE sec. 25, T29N, R98W. A sample of hematitic iron formation assayed 0.55% Cu, 0.02 opt Au, and 0.05 opt Ag (Hausel, 1991b).

SE sec. 9, T28N, R98W. Two parallel quartz veins carry considerable arsenopyrite. Samples collected from the veins assayed 0.26% and 0.28% Cu, 0.85 and 1.73 ppm Au, and 130 and 24 ppm Ag (Hausel, 1991b).

South Pass-Atlantic City district

South Pass-Atlantic City district is principally a gold and iron province and copper prospects are relatively uncommon (see Hausel, 1987b, 1991b). Copper in the South Pass area occurs in veins that often cut regional foliation. It is apparent the copper prospects become more frequent near the contact of the metamorphic rocks with the Late Archean granites along the margin of the supracrustal belt. In the Lewiston district to the southeast, a similar relationship occurs. Within the bordering granites, copper has been reported in some Proterozoic (approximately 2.0 Ga) mafic dikes and in minor shear zones, but these are unimportant for their base metal content.

Diana mine. SW sec. 1, T29N, R100W. Drifts in the Diana mine cut metagreywacke, graphitic schist, amphibolite, grunerite schist, and actinolite schist of the Miners Delight Formation (Archean). The mineralized zone consists of a complexly folded vein. Samples collected in the mine ranged from 13 to 269 ppm Cu, 133 to 2830 ppm As, 2 to 32 ppm W, <0.02 to 24 ppm Au, and <0.2 to 8.9 ppm Ag (Hausel, 1989, 1991b).

Exchange lode. E/2 sec. 15 and W/2 sec. 14, T29N, R100W. The Exchange lode includes a narrow N63°W-trending shear in Miners Delight Formation amphibolite. A sample of cupriferous milky quartz collected from the property yielded 18.1% Cu, 0.02 opt Au, and 0.79 opt Ag (Hausel, 1991b).

Mechanic (Emerald) lode. Located about 0.5 mile northeast of Atlantic City. Hornblende schist dips north and strikes northeast. A quartz vein that cuts the schist contains pyrite and chalcopyrite. Copper carbonates also occur on outcrops 1000 feet west of the 40-foot-deep shaft (Beeler, 1907k).

Silent Friend prospect. S/2 sec. 14, T29N, R100W. A reported 10- to 50-foot-wide vein contained anomalous copper and gold (Hausel, 1991b).

Snowbird mine. Sec. 6, T29N, R99W. The Snowbird mine was developed in a shear and a carbonate-quartz-sulfide breccia vein hosted by metagreywacke of the Miners Delight Formation. Samples recovered from the breccia vein yielded weakly anomalous copper, silver, and gold (Hausel, 1989).

Tornado mine. S/2 SE sec. 30, T30N, R99W. The inclined adit was developed on a narrow, shallow-dipping, sheared milky quartz vein hosted by greenstones of the Roundtop Mountain Greenstone (Archean). The vein consists of siderite and calcite gangue with chalcopyrite and malachite. A suite of samples taken in the mine yielded 0.01 to 3.5% Cu, 0 to 1.08 opt Au, 0 to 0.55 opt Ag, 0 to 160 ppm Zn, 0 to 78 ppm Pb, and 0 to 67 ppm Ni (**Table 24** and **Figure 75**) (Hausel, 1991b).

*Table 24. Assays of samples collected in the Tornado mine (from Hausel, 1991b). Locality numbers refer to **Figure 75**. Analyses in weight percent (%) or parts per million (ppm); n.d.= not detected; detection limits (in ppm) were: Au<0.1, Ag<1.0, Ni<10, Pb<2.0, and Zn<10.*

Locality number	Au (ppm)	Ag (ppm)	Cu (%)	Ni (ppm)	Pb (ppm)	Zn (ppm)
1	nd	1.7	0.019	34	nd	66
2	nd	nd	0.011	10	nd	37
3	nd	nd	0.022	41	nd	nd
4	0.39	nd	0.31	27	2	40
5	0.23	1.0	0.18	17	nd	50
6	17.0	1.3	0.37	nd	nd	48
7	0.28	nd	0.10	nd	nd	160
a	25.0	6.7	1.8	14	3	93
8	0.13	nd	0.25	34	nd	71
9	8.4	nd	0.174	10	6	16
10	3.4	2.2	3.5	67	78	140
11	37.0	19.0	1.1	nd	26	97
12	9.1	6.1	1.4	26	3	47

Wyoming Copper Mining Company. Sec. 18, T29N, R100W. A shaft was sunk in ubiquitous breccia in Miners Delight Formation metagreywacke. The breccia is locally mineralized with milky quartz impregnated with chalcopyrite (Hausel, 1991b). The mineralized zone was described as 40 feet wide and developed by a 500-foot-deep shaft. Ore samples yielded 4 to 16% Cu, 0.1 to 0.52 opt Au, and 1.5 to 40 opt Ag (Spencer, 1916).

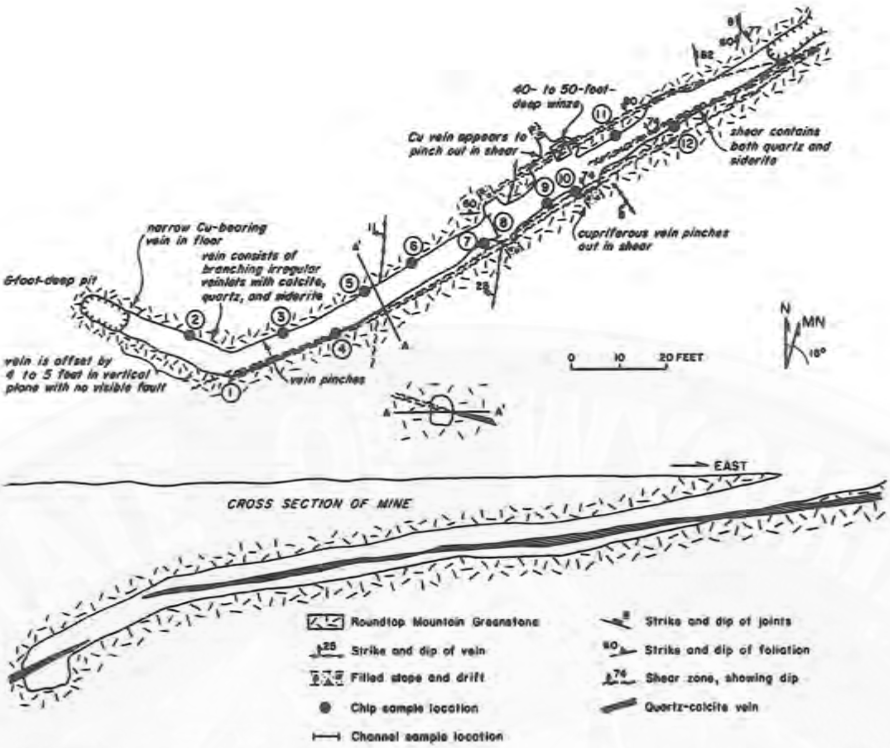


Figure 75. Geologic map of the Tornado mine (from Hausel, 1991b). Refer to ***Table 24*** *for the assay results.*

S/2 SE sec. 18, T29N, R100W. A shaft was sunk in intensely sheared metagreywacke along the Hidden Fault north of South Pass City. One sample of milky quartz with fracture-filling chalcopyrite assayed 2.88% Cu, 320 ppm Zn, 8.4 ppm Ag, and 105 ppb Au.

Southern Wind River Range

The southern Wind River Range is dominated by Archean granites and gneisses intruded by diabasic dikes. Mineralization in this region includes molybdenite associated with quartz monzonite and some minor copper shows associated with diabasic dikes.

Schiestler Peak. Located in secs. 30 and 31, T32N, R103W, and secs. 24 and 25, T32N, R104W. Disseminated molybdenite occurs in rocks ranging in composition from quartz diorite to granite, and in felsic dikes, quartz pegmatites, and quartz veinlets near shear zones in the Schiestler Peak area (**Figure 76**) (Wilson, 1955b; Lee and others, 1982). Prospect pits on the southwestern flank of Schiestler Peak contain marcasite, pyrite, and chalcopyrite in addition to molybdenite. Alteration associated with the mineralization is minor and occurs as weak silicification, saussuritization, and sericitization (Benedict, 1982).

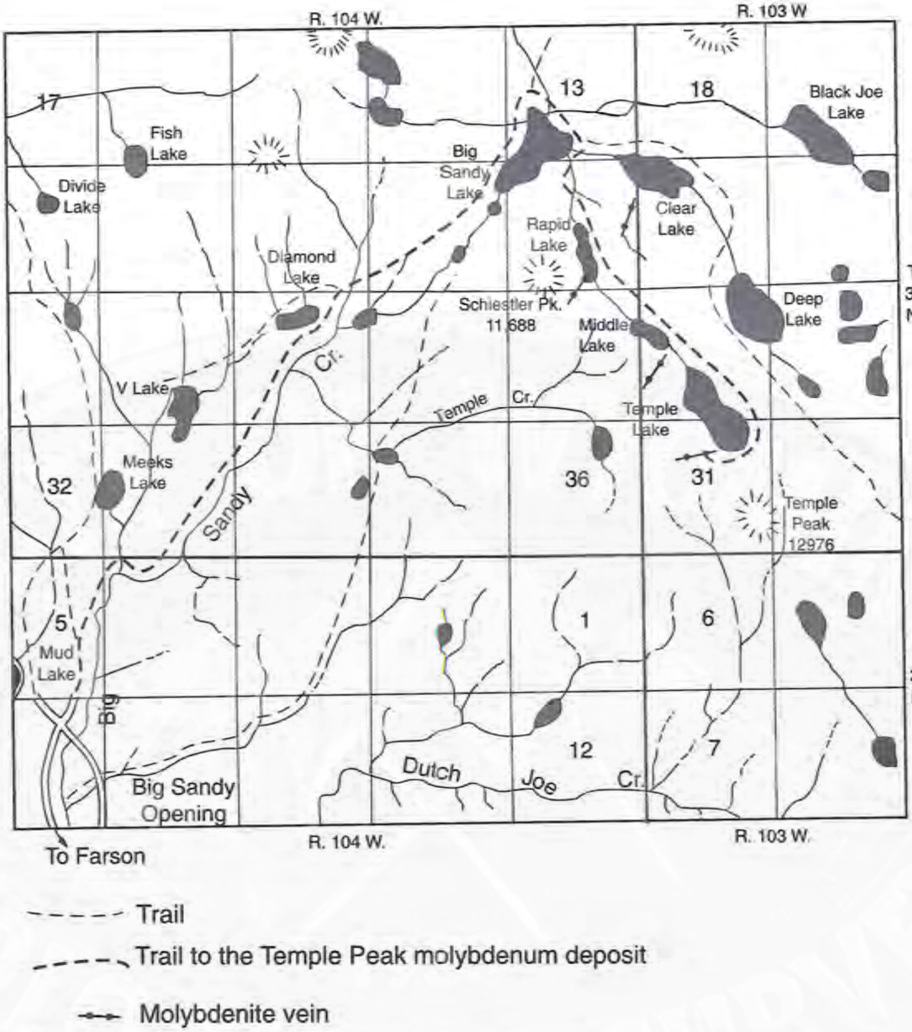


Figure 76. Sketch map of the Temple Peak molybdenum deposit (modified from Wilson, 1955b).

Benedict (1982) found the molybdenum mineralization to be similar to other types of Precambrian plutonic molybdenite deposits in Canada. Typically, these deposits are associated with late stage magma crystallization in felsic plutons, confined to the pluton's margin, show weak alteration, and are associated with pyrite and chalcopyrite.

Samples containing molybdenite generally are slightly enriched in silver, copper, lead, and gold. Molybdenite-bearing samples collected by Lee and others (1982) yielded 10 ppm to greater than 2000 ppm Mo. A chip sample taken by Wilson (1955b) assayed 2.03% Mo.

Schiestler Peak was extensively glaciated during the Pleistocene. As a result, specimens of nearly pure molybdenite in granitic rocks have been found in glacial debris in the area (Wilson, 1955b).

Conclusions

In the early 1900s, Wyoming was host to one of the larger producing copper mines in the world, the Ferris-Haggarty in the Sierra Madre, which, incidentally, may still contain significant unmined resources. Since then, however, Wyoming has not been a significant source for base metals.

The relatively small amounts of copper, zinc, lead, and molybdenum production in the State since the early 1900s does not mean that mineralization is lacking or depleted. Evidence is overwhelming that the State indeed contains significant metallic resources, including: copper porphyries with associated values in molybdenum, zinc, lead, titanium, silver, and gold in the Absaroka Mountains of northwestern Wyoming; significant redbed copper, zinc, lead, and silver in the Overthrust Belt of western Wyoming; and potentially significant copper, zinc, lead, silver, and gold volcanogenic massive sulfides in the Grand Encampment district of the Sierra Madre in southern Wyoming.

The fact that these resources have not been fully exploited is not the result of unfavorable geologic conditions, as millions of exploration dollars have been spent in the past testing the deposits for commercial mineralization. Rather, the lack of development probably stems from the piecemeal withdrawal of the State's base metal resources from mineral exploration (i.e., the majority of prospective deposits have been enclosed by wilderness and roadless areas and rendered inaccessible) as well as changing economic conditions. Should the current programs and policies ever reverse, the State of Wyoming can expect to become an important base metal producer again.

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Appendix A. Selected trace metal analyses of mineralized samples from the Rattlesnake Hills district, Granite Mountains, Wyoming (from Hausel, 1996, table 5; see his plate 1 for sample locations). Analyses in parts per million (ppm) except where noted; ppb = parts per billion; dashes indicate not analyzed.

Element	RH1-92	RH2-92	RH3-92	RH9-92	RH11-92	RH13-92	RH15-92	RH18-92	RH20-92	RH22-92	RH23-92	RH29-92	RH30-92
Ag	1.2	1.8	2	<0.2	0.9	1.1	0.2	0.5	1.2	<0.20	0.6	0.2	0.5
Au (ppb)	114	21	52	8	26	29	157	16	925	<5	92	300	<5
Hg	<0.01	<0.01	0.021	<0.01	0.139	0.013	<0.01	<0.01	0.028	0.012	0.372	-	-
Cu	38	432	123	57	614	423	263	22	524	37	125	-	-
Pb	197	1307	61	16	<2	9	41	11	42	16	8	-	-
Zn	35	90	59	33	25	253	18	53	12	37	4	-	-
Mo	5	6	12	9	10	18	10	16	5	8	5	-	-
As	88	124	20	75	213	110	1080	68	16500	91	131	-	-
Sb	38.6	2	1.4	3.3	1.8	1.6	11	4.6	8.2	1.5	0.4	-	-

Lithologies of samples as follows: RH1-92, Lost Muffler pyritiferous metachert; RH2-92, Lost Muffler pyritiferous metachert; RH3-92, Lost Muffler jasperoid; RH9-92, brecciated and carbonated graphitic schist with quartz breccia and jasperoid; RH11-92, iron-rich quartz-breccia vein; RH13-92, quartz breccia vein; RH15-92, cupriferous quartz vein; RH18-92, breccia; RH20-92, arsenopyrite-bearing quartz; RH22-92, volcanic breccia; RH23-92, banded chert; RH29-92, iron-stained quartz breccia; RH30-92, banded iron formation.

Appendix A continued.

Element	RH31-92	RH32-92	RH33-92	RH35-92	RH36-92	RH37-92	RH43-92	RH44-92	RH3-93A	RH6-93	LMP82-1	LMP82-2	LMP82-3	LMP82-4
Ag	1.8	<0.2	1.7	0.56	<0.2	0.28	<0.2	1.5	<0.2	-	-	-	1.03	-
Au (ppb)	367	109	164	800	300	5000	<5	10	<5	11	7550	4460	1030	1370
Hg	0.101	<0.01	0.083	-	-	-	-	-	-	-	-	-	-	-
Cu	835	37	163	1000	-	-	-	-	49	-	-	-	-	-
Pb	12	<2	55	-	-	-	-	-	7	-	-	-	-	-
Zn	52	4	17	-	-	-	-	-	34	-	-	-	-	-
Mo	19	4	10	-	-	-	-	-	-	-	-	-	-	-
As	4720	8820	543	-	-	-	-	-	-	-	-	-	-	-
Sb	2.5	3.1	0.8	-	-	-	-	-	-	-	-	-	-	-

Lithologies of samples as follows: RH31-92, quartz breccia with pyrite; RH32-92, quartz breccia with arsenopyrite; RH33-92, iron-stained breccia; RH35-92, quartz vein; RH36-92, iron-stained stockwork-like breccia in mylonitic zone in the border gneiss; RH37-92, brecciated iron formation; RH43-92, brecciated metagabbro; RH44-92, gossaniferous brecciated metagabbro; RH3-93A, brecciated metagreywacke; RH6-93, brecciated iron formation; LMP82-1, composite chip sample collected across Lost Muffler pyritiferous metachert; LMP82-2, composite chip sample collected across Lost Muffler pyritiferous metachert; LMP82-3, pyritiferous metachert from Lost Muffler prospect; and LMP82-4, pyritiferous metachert from Lost Muffler prospect.

Appendix B

*Appendix B. Analyses of samples collected in the Tin Cup district (see **Figure 29** for locations). Analyses in parts per million (ppm) or parts per billion (ppb); dashes indicate not analyzed.*

Sample number	Au (ppb)	Ag (ppm)	Cu (ppm)	Pb (ppm)	Zn (ppm)	Mo (ppm)	As (ppm)	Sb (ppm)	Hg (ppm)
TC1-95	<5	0.9	1128	4	20	14	108	1.0	<0.010
TC2-95	<5	<0.2	>20000	87	57	7	78.0	0.6	<0.010
TC3-95	10	<0.2	2116	7	198	6	103.0	3.5	0.027
TC4-95	<5	<0.2	392	<2	27	5	20.0	1.6	<0.010
TC6-95	<5	<0.2	188	551	253	6	342.0	14.0	0.351
TC8-95	9	<0.2	-	-	-	-	-	-	-
TC9-95	<5	<0.2	258	13	27	13	496	<5	0.048
TC10-95	<5	<0.2	276	13	15	17	165	<5	0.016
TC16-95	<5	<0.2	-	-	-	-	-	-	-
TC17-95	<5	<0.2	-	-	-	-	-	-	-
TC18-95	<5	<0.2	-	-	-	-	-	-	-
TC19-95	7	3.6	17121	10	74	-	-	-	-
TC21-95	<5	<0.2	-	-	-	-	-	-	-
TC24-95	<5	<0.2	146	6	3	-	-	-	-
TC25-95	<5	<0.2	-	-	-	-	-	-	-
TC27-95	<5	0.5	4781	18	57	-	-	-	-
TC28-95	<5	<0.2	2889	23	35	-	-	-	-
TC29-95	<5	<0.2	-	-	-	-	-	-	-
TC31-95	<5	<0.2	461	23	25	116	190	<5	0.033
TC40-95	<5	<0.2	-	-	-	-	-	-	-
TC41-95	<5	<0.2	1258	43	694	11	86	<5	<0.010
TC42-95	<5	<0.2	2246	26	336	38	65	9	0.016
TC43-95	10	<0.2	577	28	154	16	69	<5	<0.010
TC44-95	<5	<0.2	-	-	-	-	-	-	-

Sample number	Au (ppb)	Ag (ppm)	Pt (ppb)	Pd (ppb)	Ni (ppm)	Cr (ppm)
TC15-95	2	<0.1	<5	<1	39	220
TC20-95	4	0.3	<5	2	417	704
TC23-95	-	-	-	-	411	1463

Appendix C. Geochemical analyses of mineralized samples and related rocks from the Seminoe Mountains district, Wyoming (from Hausel, 1994c, table 6; see his plate 2 for sample locations). Analyses in weight percent (%), parts per million (ppm), or parts per billion (ppb); dashed indicate not analyzed.

Sample number	Description	Ag (ppm)	Au (ppm)	Cr (ppm)	Cu (%)	Ga (ppm)	Ni (ppm)	Pb (ppm)	Pd (ppb)	Pt (ppb)	Zn (ppm)
42A	Milky quartz stockworks in chlorite schist	4.0	1.3	—	0.14	—	—	14	—	—	43
43A	Weakly iron-stained schist	<0.05	2.1	—	—	—	—	—	—	—	—
42A	Milky quartz stockworks in chlorite schist	4	1.3	—	0.14	—	—	14	—	—	43
43A	Weakly iron-stained schist	2.1	<0.05	—	—	—	—	—	—	—	—
44A	Limonite-cemented fault breccia with goethite	1.1	<0.05	—	—	—	—	—	—		
45A	Cupriferous felsite from prospect pit	<1.0	<0.05	—	4.4	62	—	16	—	—	39
46A	1-foot channel, across Cu-stained shear	45.4	0.07	—	1.8	—	—	220	—	—	47
47A	Grab, Cu-stained quartz, Sunday Morning prospect	26.9	2.1	—	5.8	—	—	1,970	—	—	140
48A	10-foot composite, Cu-mafic wall rock, Junk Creek	1.7	<0.05	—	0.78	—	—	—	—	—	—
49A	Grab, azurite-malachite-tenorite-limonite-quartz	1.4	0.05	—	1.2	6	—	—	—	—	—
50A	Cu-stained quartz	2.7	0.15	—	3.7	—	—	66	—	—	2,920
51A	Quartz from mine dump	<1.0	<0.05	—	—	—	—	—	—	—	
52A	Quartz in fold closure from prospect pit	5.2	4.6	—	0.12	—	—	54	—	—	22
53A	Cu-Fe-stained fracture in metatholeiite	55.0	12.0	—	3.75	—	—	25	—	—	250
54A	Limonite-stained metatholeiite	12.0	9.8	—	0.81	—	—	10	—	—	85
55A	Vein quartz, south of Emeletta mine	3.5	2.2	—	0.11	—	—	5.4	—	—	28
56A	Wall rock adjacent to stockwork	<1.0	0.12	—	0.09	—	—	3.0	—	—	120
57A	Cu-stained quartz with minor pyrite	6.8	8.8	—	0.37	—	—	23	—	—	120
58A	Cu-stained quartz with minor pyrite	9.3	11.0	—	0.94	—	—	75	—	—	480
59A	Quartz with chalcopyrite, covellite, and pyrite	26.0	2.2	—	1.61	—	—	11	—	—	110
60A	Banded metachert	3.3	<0.05	—	0.03	—	—	3,890	—	—	43,000
61A	Cu-stained boxworks	8.1	0.05	—	0.28	—	—	2,180	—	—	25,000
62A	Boxwork quartz, Deserted Treasure #2 mine dump	18.0	28.0	—	0.39	—	—	—	—	—	—
63A	Boxwork quartz,Deserted Treasure #2 mine dump	18.0	20.0	—	0.38	—	—	—	—	—	—
64A	Quartz with chalcopyrite and bornite	<2.0	0.87	—	0.06	—	—	—	—	—	—
65A	Selected quartz, Deserted Treasure #1 mine dump	3.6	1.2	—	—	—	—	—	—	—	—

Appendix C continued.

Sample number	Description	Ag (ppm)	Au (ppm)	Cr (ppm)	Cu (%)	Ga (ppm)	Ni (ppm)	Pb (ppm)	Pd (ppb)	Pt (ppb)	Zn (ppm)
66A	Limonite-stained quartz in fold closure, King mine	4.2	6.8	—	—	—	—	—	—	—	—
67A	Sulfide-bearing amphibolite	—	35.4	—	—	—	—	—	—	—	—
68A	Selected sample quartz, Deserted Treasure #2 mine dump	—	89.3	—	—	—	—	—	—	—	—
69A	Selected boxwork quartz breccia, Apex mine	4.0	0.004	—	0.53	—	—	9,530	—	—	2,330
70A	3-foot composite, quartz breccia, Apex mine dump	0.5	0.003	—	0.14	<10	—	175	—	—	108
71A	Grab, Cu-stained mafic schist, Apex mine	63.8	0.013	—	3.81	—	—	92	—	—	68
72A	Cu-stained schist, Apex mine dump	0.3	0.001	—	0.49	—	—	61	—	—	131
73A	Cupiferous, amphibolite-hosted, quartz vein	3.6	0.038	—	3.43	—	—	3	—	—	11
74A	Stockwork in magnetite-bearing ultramafic schist	<0.1	0.01	2,771	—	—	1,379	—	—	—	—
75A	Metagabbro	—	—	27	—	—	65	—	—	—	—
76A	Cu-stained schist from prospect pit	0.2	0.14	—	4.7	19	—	10	—	—	622
77A	Milky quartz with boxworks	1.7	0.027	206	—	—	15	—	1	<5	—
78A	Grab, quartz with limonite boxworks	<0.5	<0.010	—	—	—	—	—	—	—	—
79A	Serpentinite with asbestos and minor chromite	<0.5	<0.010	6,000	—		1,700	—	—	—	—
80A	Talc serpentine schist, common limonite pits	<0.5	<0.010	1,900	—	—	2,400	—	—	—	—
81A	Limonite-stained milky quartz	0.8	<0.010	—	—	—	—	—	—	—	—
82A	Limonite-stained serpentinite (27.8% MgO)	—	—	7,600	—	—	627	—	—	—	—
83A	Cu-stained quartz, Charlie's glory hole	0.33	<0.05	—	0.52	—	—	30.1	—	—	106
84A	Gossan adjacent to spinifex metakomatiite	<1.0	<0.05	66	—	—	43	—	—	—	—
85A	Iron-stained schist	<1.0	<0.05	—	—	—	46	—	—	—	—
86A	Banded amphibolite	<1.0	<0.05	—	—	—	—	—	—	—	—
87A	Massive gossan with boxworks	<1.0	<0.05	—	—	—	—	—	—	—	—
88A	Gossan cut by quartz and carbonate vein stockwork	<1.0	<0.05	—	—	<5	—	—	—	—	—
89A	Iron-rich gossan at serpentinite base	<1.0	<0.05	202	—	—	23	—	—	—	—
90A	Limonite-cemented milky quartz breccia	<1.0	<0.05	—	—	<5	—	—	—	—	—

Index to areas, districts, mines, and prospects

ABBREVIATIONS AND CONVERSION FACTORS USED IN THIS TEXT

Chemical symbols

Symbol	*Element*	*Symbol*	*Element*	*Symbol*	*Element*
Ag	Silver	Fe	Iron	Rb	Rubidium
Al	Aluminum	Ga	Gallium	S	Sulfur
Ar	Argon	Ge	Germanium	Sb	Antimony
As	Arsenic	H	Hydrogen	Se	Selenium
Au	Gold	Hg	Mercury	Si	Silicon
B	Boron	K	Potassium	Sn	Tin
Ba	Barium	Mg	Magnesium	Sr	Strontium
Be	Beryllium	Mn	Manganese	Ta	Tantalum
Bi	Bismuth	Mo	Molybdenum	Te	Tellurium
C	Carbon	Na	Sodium	Th	Thorium
Cd	Cadmium	Nb	Niobium	Ti	Titanium
Cl	Chlorine	Ni	Nickel	Tl	Thallium
Co	Cobalt	O	Oxygen	U	Uranium
Cr	Chromium	P	Phosphorus	W	Tungsten
Cu	Copper	Pb	Lead	Zn	Zinc
F	Fluorine				

Platinum Group Elements

Symbol	*Element*
Ir	Iridium
Os	Osmium
Pd	Palladium
Pt	Platinum
Rh	Rhodium
Ru	Ruthenium

Rare Earth Elements

Symbol	*Element*	*Symbol*	*Element*
Ce	Cerium	Pm	Promethium
Dy	Dysprosium	Pr	Praseodymium
Er	Erbium	Sc	Scandium
Eu	Europium	Sm	Samarium
Gd	Gadolinium	Tb	Terbium
Ho	Holmium	Tm	Thulium
La	Lanthanum	Y	Yttrium
Lu	Lutetium	Yb	Ytterbium
Nd	Neodymium		

Conversion factors

1 ounce (oz)	=	31.1 grams
1 ounce (oz)	=	20 pennyweights
1 metric ton (tonne)	=	1,000 kilograms
1 short ton	=	0.907 metric ton or 2,000 pounds
1 ounce per ton (oz/ton)	=	34.3 grams per ton
1 ounce per ton (oz/ton)	=	34.3 parts per million (ppm)
1 part per million (ppm)	=	1,000 parts per billion (ppb)
1 percent	=	10,000 ppm
1 ounce per cubic yard	=	40.7 grams per cubic meter

Miscellaneous

$<$ = less than

$>$ = greater than

lbs = pounds

yd^3 = cubic yard

°C = degrees celsius

Age

Ga = billions of years (old)

Ma = millions of years (old)

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