PRELIMINARY REPORT ON

COPPER, LEAD, ZINC, AND MOLYBDENUM IN WYOMING

by

W. Dan Hausel
Senior Economic Geologist

WYOMING STATE GEOLOGICAL SURVEY
Mineral Report MR95-1

1995

This field report has not been reviewed for conformity with the editorial standards of the Wyoming State Geological Survey.

Mineral Report MR95-1

PRELIMINARY REPORT

ON

COPPER, LEAD, ZINC, AND MOLYBDENUM IN WYOMING

by

W. Dan Hausel

WYOMING STATE GEOLOGICAL SURVEY
P.O. Box 3008, University Station
Laramie, Wyoming 82071
(307)766-2286

1995

TABLE OF CONTENTS

INTRODUCTION

Near the close of the 1800s, optimism was very high that Wyoming would become an important producer of copper and other base metals. This dream was short-lived when 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. However, by 1908, the Ferris-Haggarty mine closed due to 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 was probably due to the lack of infrastructure in the high Absaroka Mountains east of Yellowstone: and more recently due to much of the area falling within or adjacent to areas designated as wilderness by Congress.

The possibility of Wyoming becoming a major copper producer again in the foreseeable future, except in a national emergency, is remote. Even though the State has significant base metal deposits; restrictive Federal land use policies have essentially eliminated any possibility of a major copper mining industry thriving again in Wyoming. Although, small quantities of copper, zinc, and lead could be recovered as by-products of polymetallic deposits in the future, the regions with the most favorable geology fall within the Federally withdrawn lands.

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 Range 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 red bed deposits in the Overthrust Belt of western Wyoming. It is important to note that all of these deposits are polymetallic and host several other metals in addition to copper, lead, zinc, and/or molybdenum.

USES

Copper, molybdenum, zinc, and lead are necessary ingredients in a modern society. Without the mining, production, and recovery of these metals, modern civilization could not exist. Only a small amount of the world demand for these metals can be met through recycling, and much of the world demand has to be met by the mining of new resources. These metals are used extensively in our automobiles, airplanes, homes, buildings, appliances, and bridges. To imagine a modern society without these products, and the thousands of other products produced from these metals, is unrealistic.

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 electrical wires, switches, and other electrical equipment in our homes, cars, airplanes, appliances, and buildings. Copper is also 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 is also used in the manufacture of brass shell casings for ammunition, and we even find the metal in our food. Copper has literally thousands of applications in our modern society.

Molybdenum has many important metallurgical applications. The metal also has important applications as a lubricant, and is also an important ingredient in the manufacture of stainless steel. But much of molybdenum's usefulness is in the manufacture of 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 utilsiles.

Lead is consumed principally in lead-acid storage batteries in automobiles, and in other products that require energy storage. Other important and common uses include alloys in bearings for the transportation industry, solder, sound barrier partitions in the walls of buildings, and in leaded glass windows to 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 to protect building and highway structures, and is also used in 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 also used in oil refining and in the manufacture of dyes and adhesives.

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

HISTORICAL PRODUCTION

At the turn of the century, Wyoming was a relatively important producer of copper. Copper was mined and produced from several regions in the State including the Copper Mountain district, the Encampment district, the Hartville uplift, the Lake Alice district, the Silver Crown district, and a few other regions (Figure 1). The available production statistics indicate that Wyoming may have produced a maximum of 63,900,000 pounds of copper from 1882 to 1946 (Figure 2) (Table 1) (Hausel, 1989). The majority of the metal was recovered from the Ferris-Haggarty mine, which was the 27th largest copper producer in the world, by the first decade of the 1900s. Lead production in the State was minor and amounted to only about 30,000 pounds.

No statistics are available for zinc or molybdenum; however, other metals production in the State included 384,633 ounces (12 tons) of gold, 29,800 ounces of silver, 16,900 ounces of palladium, 910 ounces of platinim, 135,000,000 tons of iron

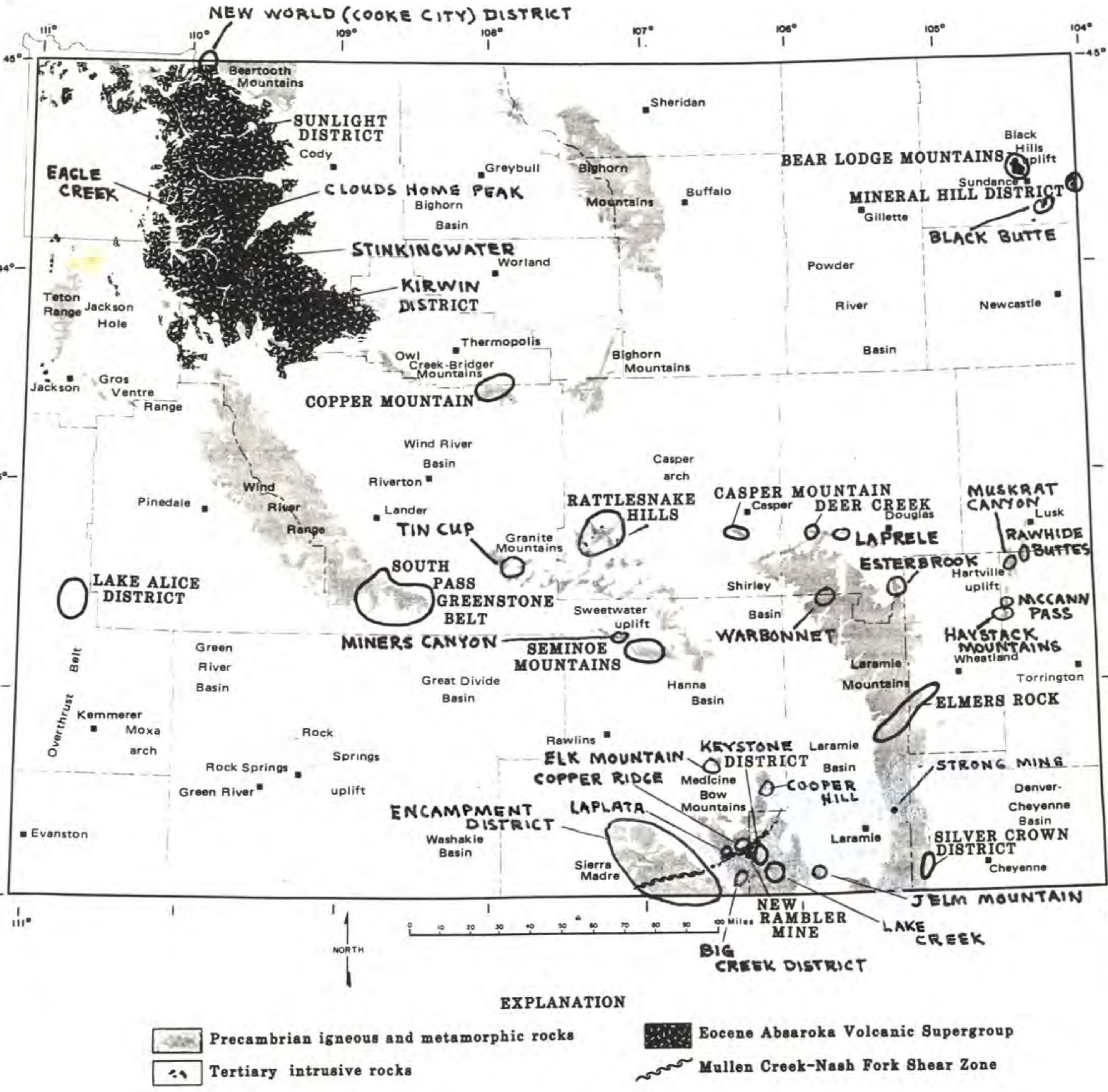


Figure 1. Copper districts and mineralized areas in Wyoming.

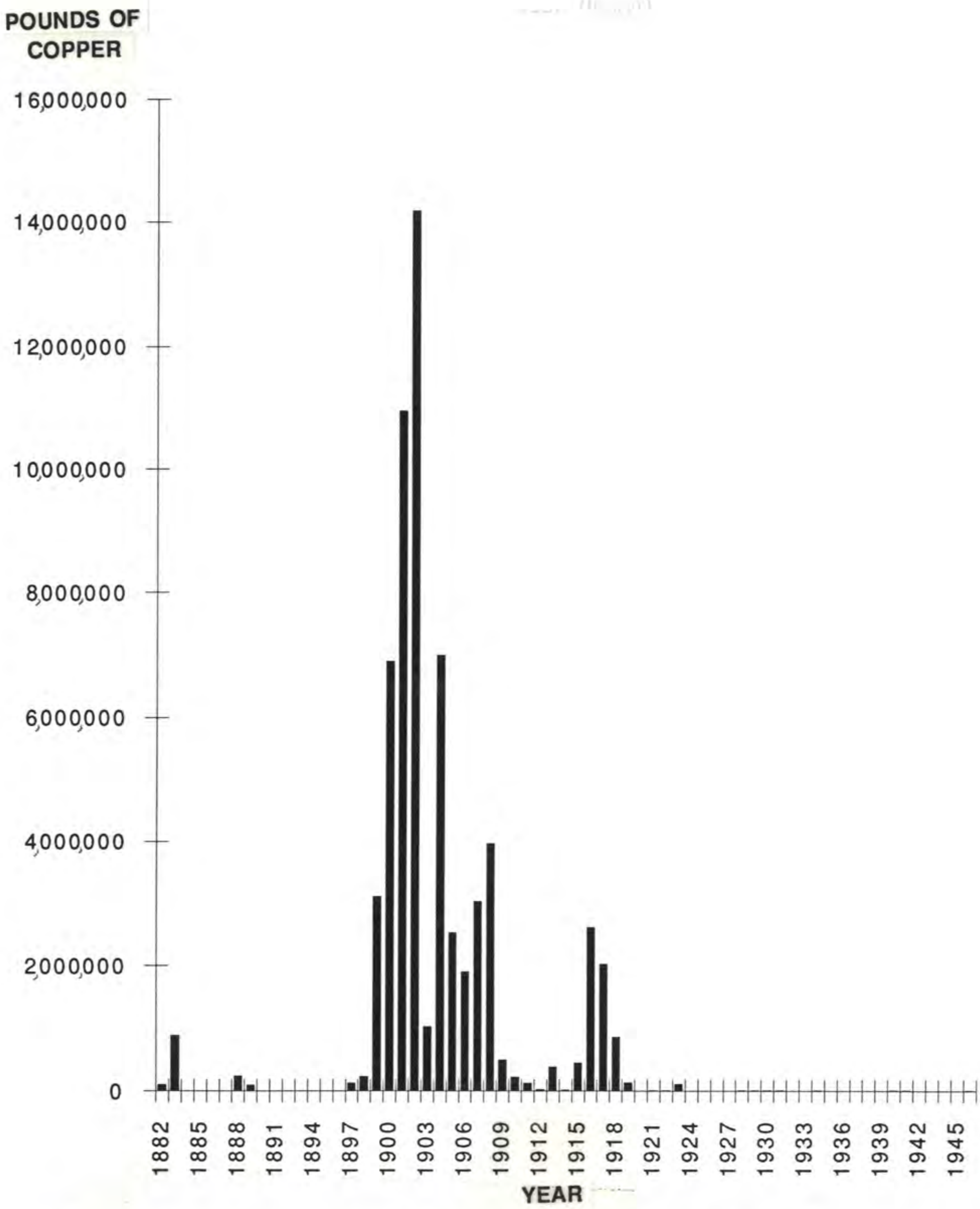


Figure 2. Historical copper production in pounds per year for Wyoming. The production peak in 1902 corresponds to the Ferris-Haggarty mine operations (Boston-Wyoming mill and smelter) reaching maximum capacity. The drop in copper production after 1908 was due to the destruction of the mill and smelter by fire.

Table 1. Wyoming copper and lead production compiled from, U.S. Bureau of Mines Yearbooks, Wyoming Industrial Journal, H.C. Beeler, and Hausel (1989).

Year	Copper (lbs)	Lead (lbs)
1882	104,206	0
1883	962,468	0
1884	0	0
1885	0	0
1886	0	0
1887	0	0
1888	240,113	0
1889	100,000	0
1890	0	0
1891	0	0
1892	0	0
1893	0	0
1894	0	0
1895	0	0
1896	0	0
1897	127,409	0
1898	233,204	0
1899	3,104,827	0
1900	6,904,540	0
1901	10,958,900	0
1902	14,166,700	0
1903	1,023,189	0
1904	7,000,000	0
1905	2,530,531	0
1906	1,905,260	0
1907	3,026,004	0
1908	3,961,540	0
1909	492,539	0
1910	222,339	0
1911	130,499	0
1912	27,570	0
1913	385,239	0
1914	17,421	0
1915	447,246	0
1916	2,610,622	0
1917	2,027,857	0
1918	852,777	0
1919	139,900	0
1920	0	0
1921	10,000	0
1922	4,296	0
1923	111,280	0
1924	0	0
1925	0	0
1926	0	0
1927	0	0

1928	2,604	0
1929	4,301	0
1930	11,600	0
1931	9,000	0
1932	397	9,800
1933	0	0
1934	3,500	2,000
1935	1,000	5,000
1936	0	0
1937	0	0
1938	0	0
1939	0	0
1940	4,000	0
1941	8,000	0
1942	0	6,977
1943	0	0
1944	0	0
1945	0	6,000
1946	2,000	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 Range 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. A few of the volcanic centers are mineralized (Figure 3). These deposits are recognized by their disseminated, stockwork, and vein mineralization with accompanying hydrothermal alteration haloes. 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 the hundreds of millions of tons.

The known mineralized centers in the Absaroka Mountains are characterized by a central intrusive complex surrounded by vent-facies autoclastic flow breccias, lava flows, mudflows, avalanche debris, and tuffs. The vent-facies rocks are commonly 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 NNW structural trend located several miles east of the Yellowstone National Park border. This trend extends north into the New World district of Montana.

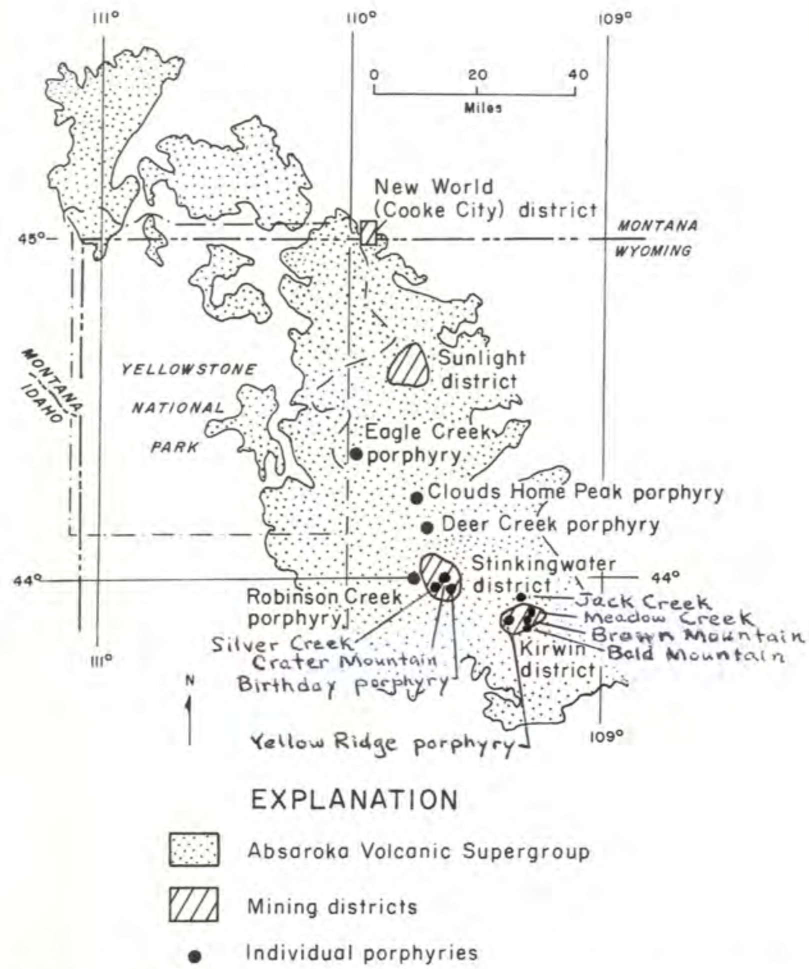


Figure 3. Principal known mineralized porphyries and mining districts in the Absaroka Mountains.

The mineralized and the barren intrusive centers are the source of the great pile of volcanic rock that forms the Absaroka Mountains. The Absaroka volcanics extend over a surface area of more than 8,000 mi^2 and compositionally consists of calc-alkaline flows, flow breccias, breccias, and reworked sedimentary facies. A small volume of flows in the northern Absarokas is shoshonitic.

The Absaroka volcanics and volcaniclastics are termed the Absaroka Supergroup and averages more than 5,000 feet thick (Smedes and Prostka, 1972), and is locally as much as 6,500 feet thick (Wilson, 1963). The Supergroup is divided into three groups that are, from oldest to youngest, the Washburn, Sunlight, and Thorofare Creek Groups. The Washburn Group is restricted to the northern portion of the mountains and represents the oldest volcanic rocks of the Absaroka Mountains. Rocks of the Washburn Group are unconformably overlapped 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 Geological Survey, recognized the potential of the 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 a few localities, in country rock adjacent to mineralized stocks; (2) fracture-filled veins and veinlets 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 portions of the complexes and give way to zinc, lead, and silver laterally away from the center of the complex.

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

Propylitic altered rock grades into phyllic altered (quartz-sericite-pyrite) rock as the mineralized center is approached. The phyllic zone lies adjacent to the disseminated copper deposits in all of the known mineralized areas except the Sunlight Basin, where it is absent. Argillic alteration, which produces secondary clays, has been identified at several of the 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 of the districts, although the potassic halo is generally 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 a large resource of (potentially auriferous) unexplored gravel downstream from the mineralized porphyries and veins. Early development of the district occurred near the turn of the century, and the available records indicate that

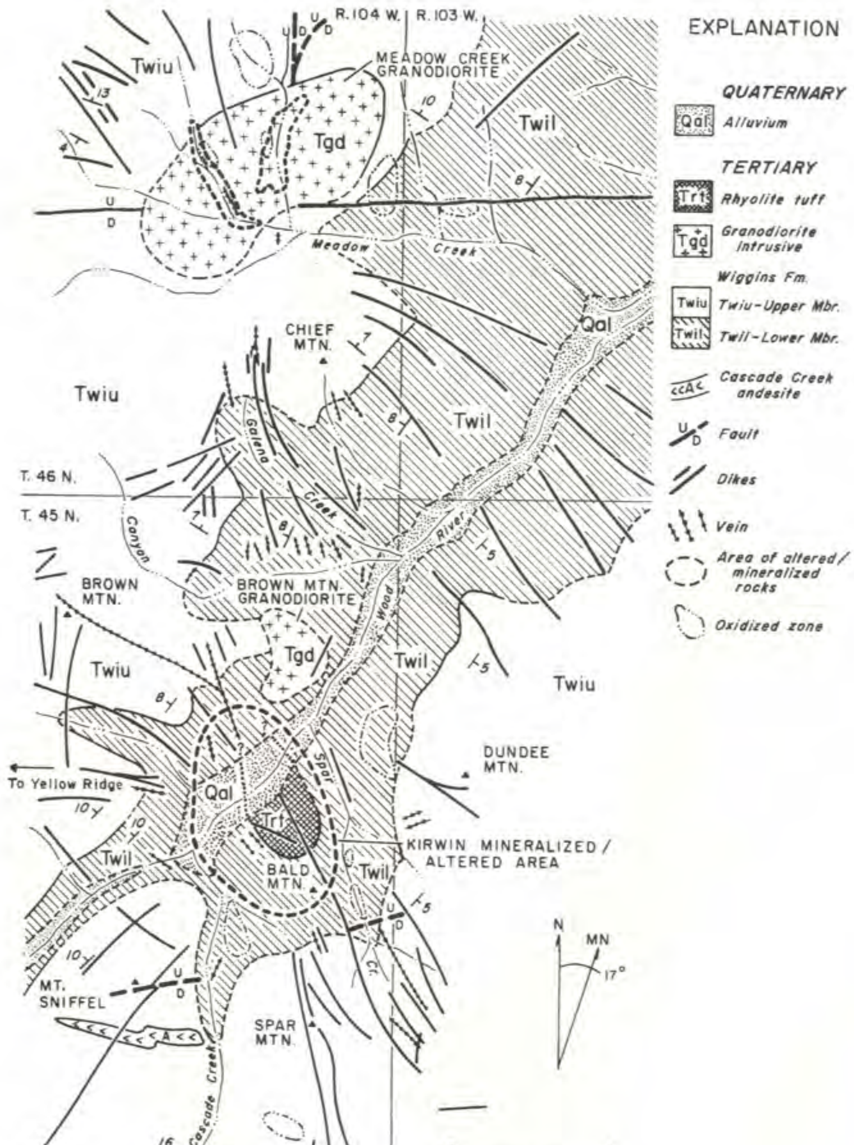


Figure 4. Generalized geologic map of the Kirwin-Wood River area (modified from Wilson, 1964, 1975; and Nowell, 1971).

12,000 to 15,000 feet of drifts, shafts, and adits were driven on veins in the district. Production, however, was 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 volcanics of the Wiggins Formation (Eocene). The Wiggins Formation is one of a group of 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-northwesterly-trending fractures. With few exceptions, the mineralized veins also occur in north-northwesterly-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.

Many veins in the district have only been explored for limited distances along strike, even though some of the veins appear to be as much as 2,500 feet long 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 values of 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.

The Mendota vein also yielded ore grade values. A select sample across 0.5 feet of the Mendota vein in the Galena Ridge tunnel averaged 101.35 opt Ag and 0.283 opt Au. This high-grade portion of the 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 a strike length of 98 feet on the Bryan vein on Spar Mountain averaged 0.13 opt Au, 29.5 opt Ag, and 0.73% Cu (Rostad, 1982). Based on these samples, there are significant vein deposits in the district of possible economic interest for a small mining operation.

Table 2. Assay results from samples collected from various mines in the Kirwin district (from Rostad, 1983 and Wilson, 1964).

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 ft 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 ft of vein.
Oregon	0.07	15.85	-	-	-	-	Dump-ore.
Smuggler	0.06	8.1	0.8	-	-	-	Opencut-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 ft down.
Anaconda shaft	0.03	3.87	-	9.7	-	-	9 ft down.
Anaconda shaft	0.01	1.37	-	-	-	-	19 ft down.
Black Prince	0.06	6.0	0.2	3.1	-	-	Outcrop.
Black Prince	0.10	1.22	-	-	-	-	Average 44 ft 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 ft 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	-	-	-	-	2nd cut.
Mendota	0.04	2.38	-	-	-	-	Face-upper tunnel.
Mendota	0.28	101.0	-	-	-	-	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 ft north of shaft.

The mineralized area continues southeast of Kirwin and into the Stratified Primitive area. Samples collected in the Stratified Primitive area yielded anomalous copper, molybdenum, zinc, lead, and silver (Ketner and others, 1966).

Alluvial gravel is also abundant in the Wood River downstream from the old ghost town of Kirwin. The gravels are reported to range from 60 to 150 feet in depth. It is estimated that the Wood River has a potential for more than 100,000,000 yds^3 of unexplored gravel for gold. Little evidence exists that the gravel has ever been explored, even though geologic evidence suggests some of the gravel has to be mineralized (Rostad, 1982).

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 rhyolitic tuff breccia (Wilson, 1964; Nowell, 1971) which has been informally named the Kirwin Formation. The brecciation appears to be more intense along the edge of the vent.

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 1,500 feet of the mineralized center, Wiggins Formation 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 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 molybdenum. 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-molybdenum-quartz veins (Wilson, 1960). The mineralized porphyry is about 3,900 feet across (Rostad, 1983).

The Bald Mountain porphyry was explored by AMAX in the 1960s, 70s and 80s (Rostad, 1983). 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 totalling of 86,861 feet. The project outlined geologic reserves totalling 196,000,000 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 (Table 3). Open pitable reserves were calculated at 160,800,000 short tons with a favorable stripping ratio of 0.57:1 of waste to ore (Rostad, 1983). Feasibility studies also 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).

Table 3. Copper reserves reported for the Bald Mountain porphyry at Kirwin (Rostad, 1983).

Mineable Reserves (Open Pit)	Cut Off Grade		
	0.3% Cu	0.4%Cu	0.5% Cu
Geologic	196 million	125.3 million	64.2 million
Pit	160.8 million	-	-
% Cu (total)	0.505	0.56	0.7
% Cu (sulfide)	0.467	-	-
% MoS_2	0.022	-	-
Waste: Ore ratio	0.57:1	-	-
Pre-production stripping	8.5 million	-	-

There are unexplored targets in the immediate area of Bald Mountain which could greatly expand the identified reserves. For example, the explosive conditions evidenced by the Kirwin Formation are favorable for mineralized breccia pipes. AMAX's 300 foot drill hole 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. There is also a potential for skarn and replacement deposits in the underlying sediments where the veins project downdip into the underlying sedimentary rock. 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 mineralization are associated with north-northwesterly 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 forming the western third of the intrusive mass, is propylitized, weakly pyritized, and relatively unmineralized. The later 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 is delineated by phyllic alteration with disseminated copper mineralization and corresponds well with a copper geochemical anomaly that yields values from 200 ppm to 700 ppm Cu. A second intensely altered zone is localized along the contact between the two granodiorite intrusives. This zone is approximately 5,000 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 as 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 occur as 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. The 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 is also accessible from the Kirwin district. From Kirwin, the Greybull River trail crosses Greybull Pass and lies within three miles west-northwest of Kirwin. The porphyry lies within wilderness designated lands.

The Yellow Ridge porphyry consists of two stocks intruding Wiggins breccias and flows (W.H. Wilson, personal communication, 1982). The stocks include rhyolite and a composite stock formed 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 2,500 foot northeasterly trend in the southeastern portion of the stock. Malachite is abundant and occurs as fracture coatings and disseminated grains. Pyrite, with minor chalcopyrite, bornite(?), and molybdenite(?), are also 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

Located in T58N, R109W along the Montana-Wyoming border adjacent to Cooke City, Montana (Figure 1). The district lies in Montana and extends to the Wyoming border (Figure 5).

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 of the other mineralized centers in the Absaroka Mountains. Precambrian gneiss, Paleozoic sediments, 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 unconformably rest on Paleozoic sediments (Nelson and others, 1980).

The Goose Lake and Henderson Mountain stocks, located north of Cooke City in Montana, are the principal centers of mineralization. With few exceptions, the major

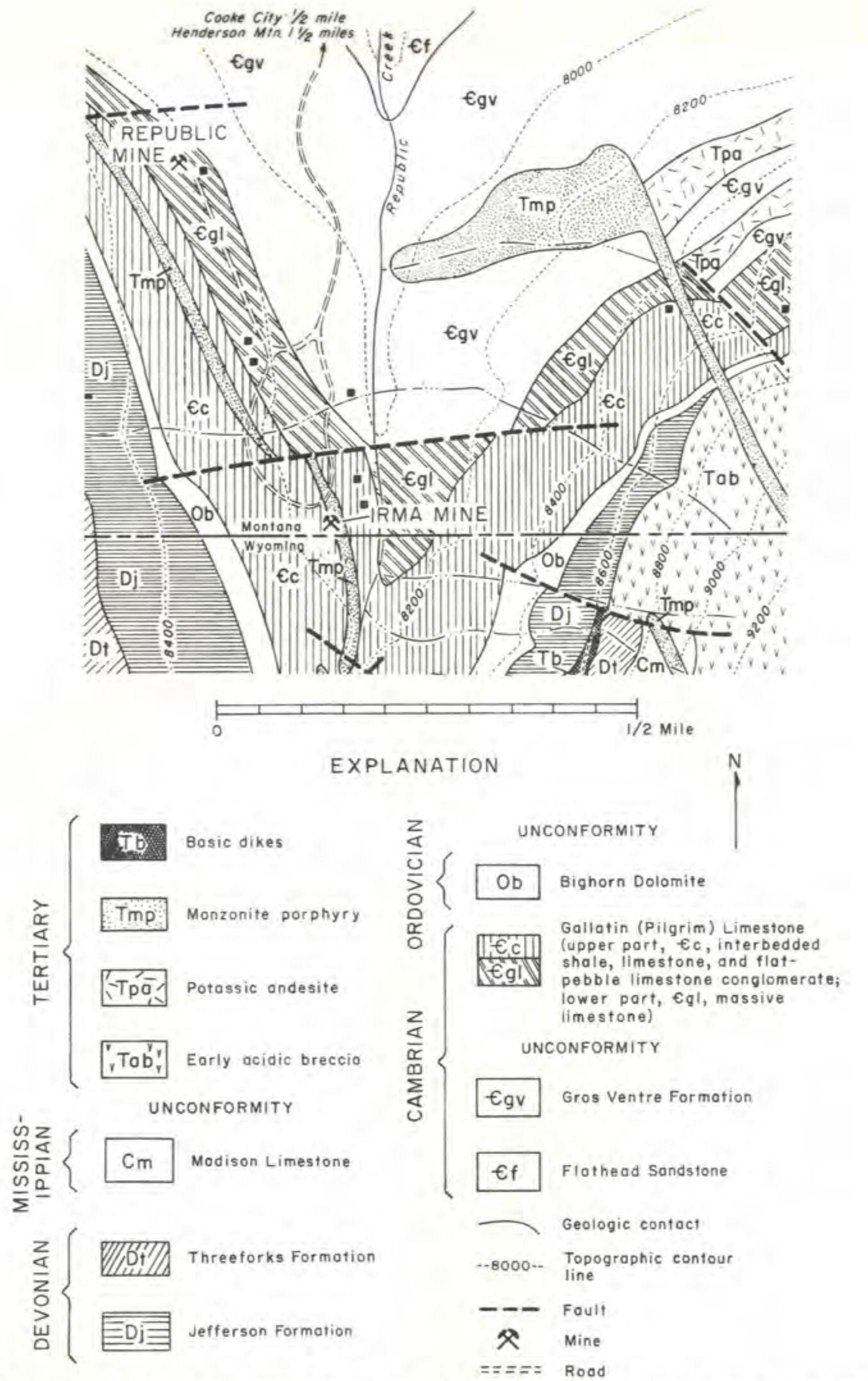


Figure 5. Generalized geologic map of the southern New World district (Wyoming portion in T.58N., R.109W.) (modified from Lovering, 1929).

ore bodies 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 is also reported in the district. The combined reserves of the replacement deposits total more than 12,000,000 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 occur adjacent to the stock and these grade outward to copper-lead deposits. The copper-lead mineralization is further zoned to copper-lead-zinc. At greater distances 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 at greater distances from the stock. The better deposits are developed where the veins cut limestone beds and form replacement deposits in the Pilgrim Limestone (Gallatin Formation equivalent) of upper 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 of the copper and gold production came from the McLaren gold mine, and a large portion of the lead and silver was produced from the Irma-Republic mines (Kirk and others, 1993).

Irma-Republic mines. The Irma-Republic deposits occur as 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, and was formed by fracture filling and replacement of the host oolitic beds of the Pilgrim Limestone. The oolitic beds are overlain by a hanging wall shaley member that is interpreted to have 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.

The 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. Wallrock 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 3,000 feet of open cuts, 1,500 feet of tunnels with a 225 foot deep shaft developed in fissures that are heavily-stained by psilomelane (manganese oxide). The manganese staining is characteristic of the complex lead-silver-zinc ores of the district. Oxidized ore in some stopes assayed as high as 1,000 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 mine 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 2,700 feet (Nelson and others, 1980).

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, totalling 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, 1929).

Recorded production from the Irma-Republic properties included 18,400 tons of concentrates which 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). The 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 ore body.

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 three 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 wilderness designated lands.

The stock sporadically crops out over an area of less than one-half square mile. 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 is also 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 of the dikes in the Birthday region. Oxidation is prominent, and zones of limonite, malachite, and azurite have 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 hydrothermal altered zones are recognized. The propylitic altered rocks are characterized by the development of chlorite, calcite, epidote, saussurite, and pyrite. Phyllic altered rocks are present in scattered patches, and are mainly found 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 is present in two localized areas 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 (sections 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 road's end at Valley along eleven miles of the South Fork pack trail to the mouth of Silver Creek. The intrusive is within one-quarter 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 2,000 by 1,000 foot stockwork complex near the center of the intrusive. This mineralized zone contains disseminated malachite, chalcopyrite, bornite, and minor molybdenum, 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 the rock 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 ore body 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; section 18, T47N, R106W; Located on the confluence of Needle Creek and the South Fork of the Shoshone River near the center of the southern Absaroka volcanic field (Figure 6). Layered, pre-mineral volcanic rocks in the district include (from oldest to youngest): the Wapiti Formation, the Trout Peak Trachyandesite, and the Wiggins Formation. These consist of basalt flows, andesite flows, volcanic breccias, and flow breccias, that are intruded locally by the Needle Mountain granodiorite, the Crater Mountain dacite, and numerous dikes which extend outward from the intrusive complex in a radial pattern. The Crater Mountain dacite intrudes the Needle Mountain granodiorite.

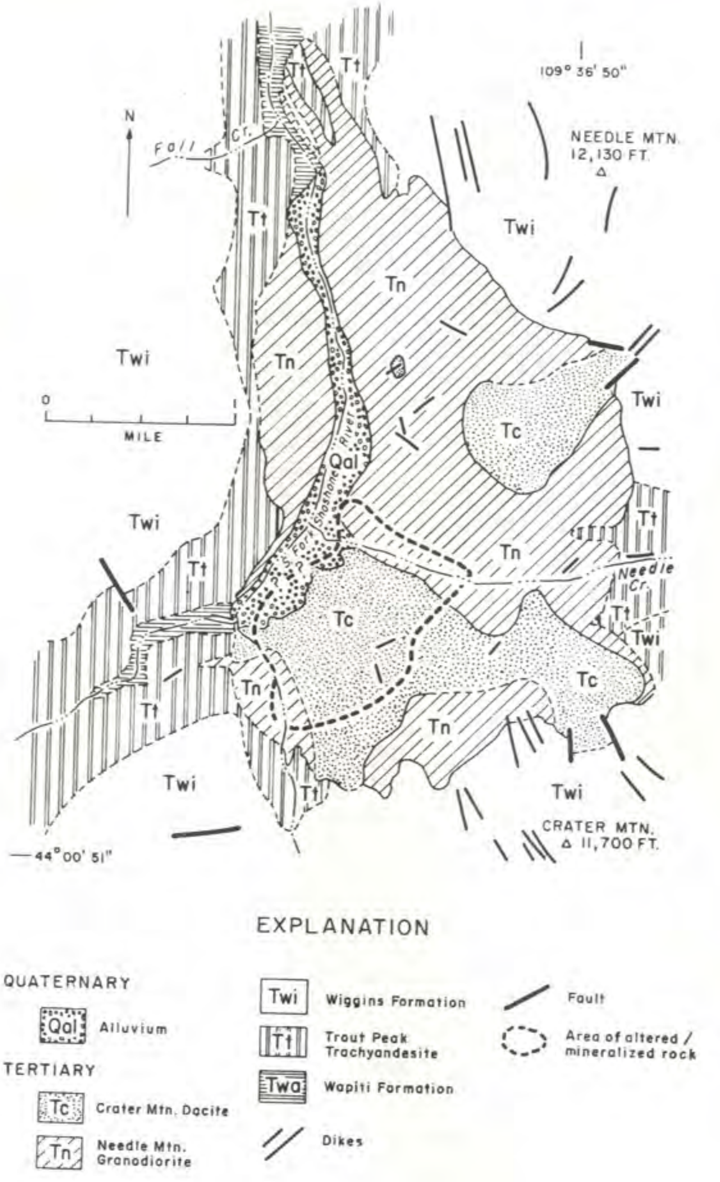


Figure 6. Generalized geologic map of the Stinkingwater mineralized area (after Fisher, 1972).

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 the hydrothermal solutions.

Propylitization of both the intrusive and layered rocks is common throughout the district. The intensity of the propylitic alteration increases around the fringe area of disseminated sulfide minerals. Propylitic alteration gives way to phyllic alteration towards the center of 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, there 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 three-quarters of a square mile) of disseminated copper-molybdenum near the southwestern edge of the intrusive complex. 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 and bleached, and altered to varying degrees. Narrow, steeply dipping veins occur near, and as much as a mile away, 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 one to two inches wide and reach a maximum of one foot in width, locally. These 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 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 -1 ppm in pan concentrates) and mercury (Fisher, 1972).

A supergene enriched chalcocite blanket, as much as 200 feet thick, 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 since the porphyry has only been partially explored. However, drilling results from several companies indicated 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 the drilling results from Bear Creek Mining Company, Newkirk (1980) reported the deposit to host 61 million tons of ore at an average grade of 0.31% Cu. Identified reserves by Phelps Dodge, totaled 96,378,267 tons of ore at an average grade of 0.35% Cu + MoS_2 (Table 4). Phelps Dodge Corporation estimated the deposit to have a potential for 131,657,200 tons of ore at 0.35% Cu + MoS_2 (Lukanuski, 1969).

Table 4. Cu + MoS2 reserves for the Needle Creek porphyry (from Lukanuski, 1969).

Cutoff (Cu + MoS_2)	Tonnage	Grade
0.2%	96,378,267	0.35%
0.3%	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).

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.

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 7). The stockworks consists of less than one inch wide veins and veinlets containing chalcopyrite, bornite, covellite, and chalcocite in quartz and calcite gangue. Disseminated copper is also reported in the northeastern plug of the East Galena Creek Syenite intrusive (Rich, 1974). The veins are zoned and form 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) included 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 a trace of silver (Parsons, 1937).

Copper Creek adit; Located about 44°40', 109°50', 1.5 miles due north of Stinkingwater Peak (Figure 7). 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 a trace to 0.02% Cu, 0.02 to 0.04% Pb, 0.04 to 0.05% Zn, a trace to 0.10 opt Ag, and trace to 0.02 opt Au (Nelson and others, 1980).

Copper Lake prospects; This includes a group of prospects (including the Kodiac claim) in the vicinity of the three Copper Lakes one mile east of Stinkingwater Peak (Figure 7). Samples from the Copper Lake prospects yielded a trace to 0.08% Cu, 0.035% to 0.76% Pb, 0.02% to 0.30% Zn, 0.17 ppm to 2.06 ppm Au, and a 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 a Au-Ag-W vein near Lower Copper Lake that assayed 0.54 opt Au and 13.46 opt Ag.

Within this same area, a 5,000 foot long metasomatically mineralized contact zone was identified in the Wapiti Formation. The zone is enriched is gold and silver and is well developed at the southeast end of Lower Copper Lake (R. Carrington, personal communication, 1991).

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 and 4.2 opt Ag, with a 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 in the basin ranged from a trace to 0.01% Cu, 0.02 to 0.26% Pb, 0.05 to 0.12% Zn, a 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 (section 19, T54N, R107W) that assayed 5% Cu, 5% As, 0.15% Pb, 1,500 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.

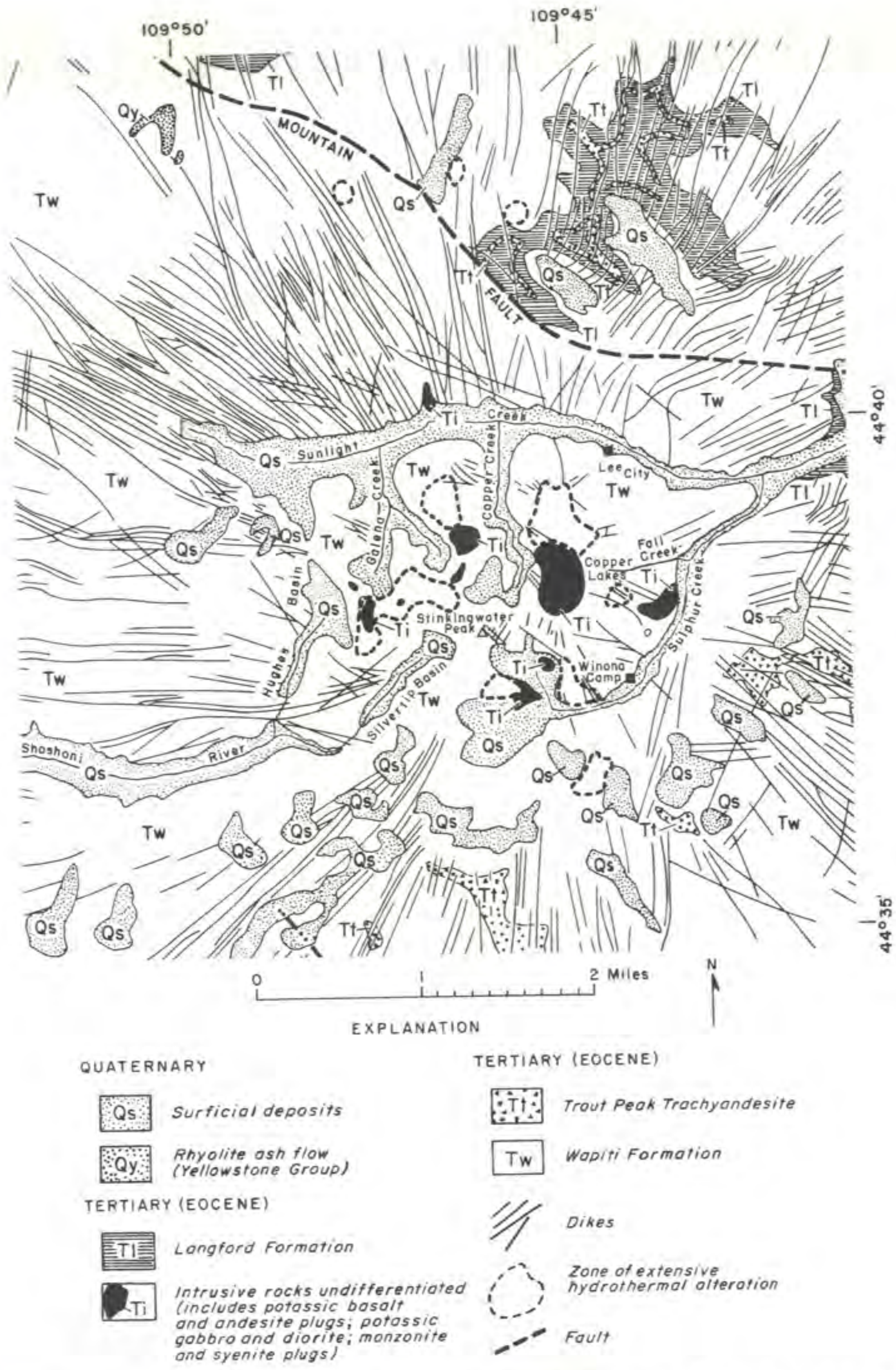


Figure 7. Geologic map of the Sunlight district (modified from Nelson and others, 1980).

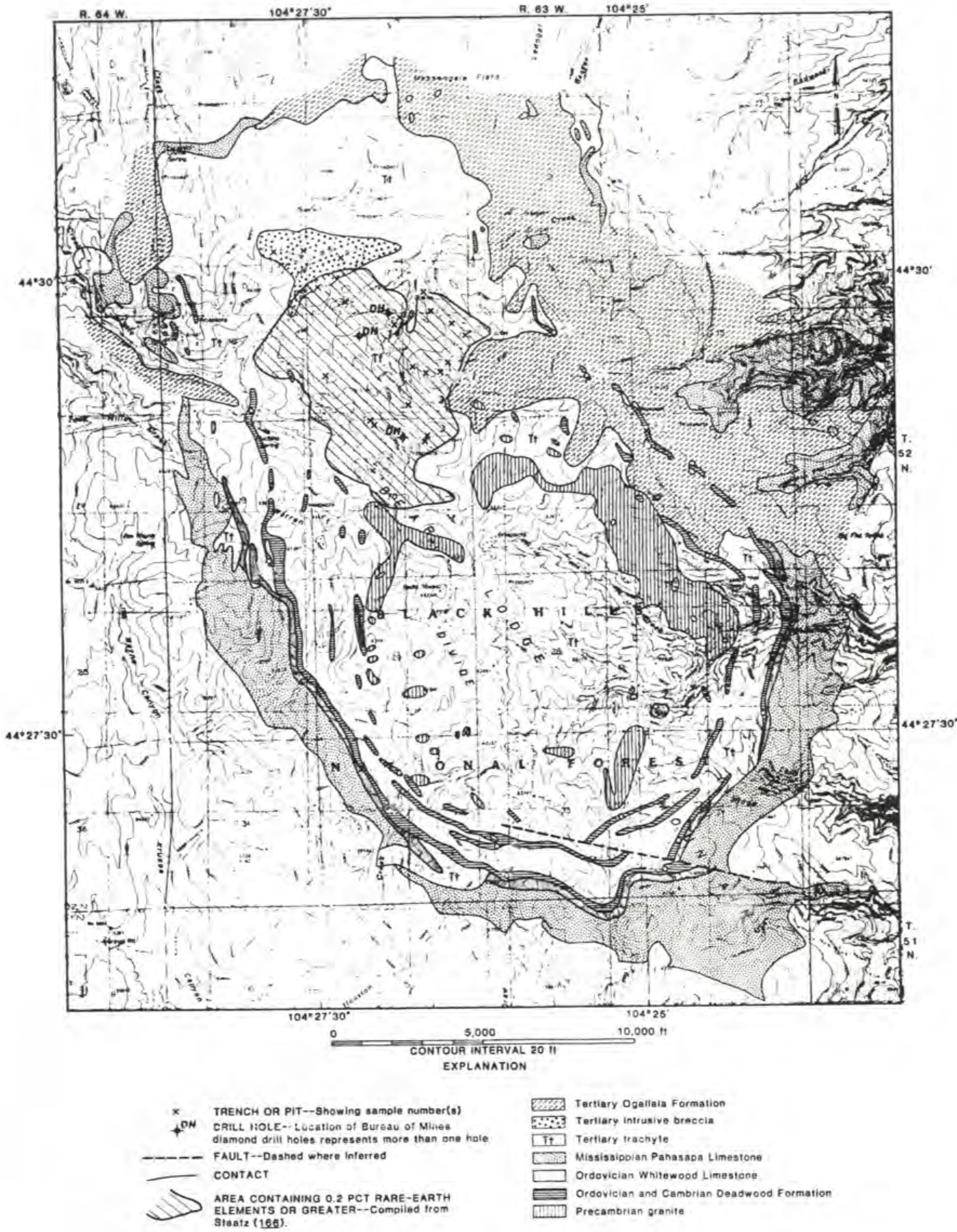


FIGURE 13. - Generalized geologic map of the core of the Bear Lodge Mountains alkaline intrusive complex showing sample locations. (Modified from Staatz (1983).

Hardees Claim; Location unknown. A vein sample collected by Parsons (1937) assayed 62.23% Pb, a trace of 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 wallrock minerals with coarse argentiferous galena in iron carbonate gangue. One sample of ore from the mine dump yielded a trace of 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 Horseshoe Hill 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 7). 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 a trace of gold (Nelson and others, 1980).

Malachite vein; Located 1,500 feet southwest of the Joe vein, on the divide between Fall and Sulphur Creeks. The vein is 6 and 12 feet wide and contains an 18-inch-wide streak of high-grade chalcocite. The vein was traced 2,100 feet on the surface (Osterwald and others, 1966).

Marvin prospect; Location unknown; A 250 x 2,200 x 1,000 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°W to N15°W, 83°E dipping syenite dike (Figure 8). 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, a 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.

Newton prospect; Located on the east side of Silvertip Basin at 9,226 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

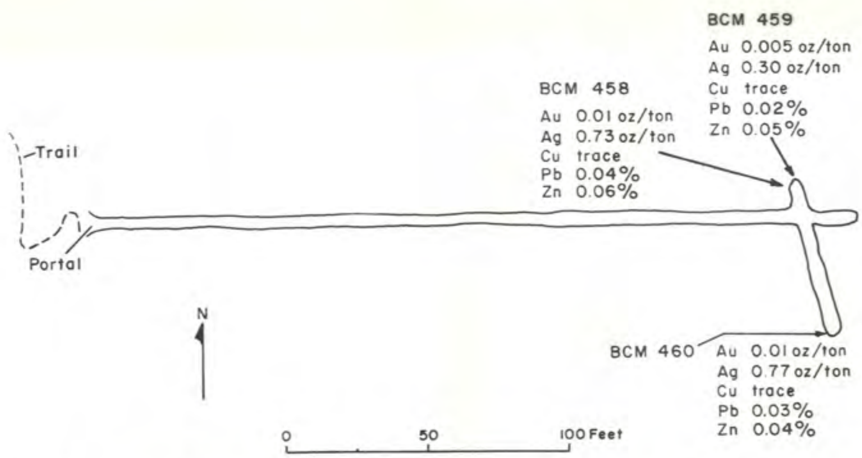


Figure 8. Sample location map of the Morning Star adit in the Hughes Basin of the Sunlight district (modified from Nelson and others, 1980).

0.03% Cu, 0.04% Pb, 0.02% Zn, a trace of gold, and 0.49 opt Ag (Nelson and others, 1980).

Novelty adit; Located at 9,204 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 is sheared along the contact (Figure 9). The mineralized shear trends N24°E and dips 82° SE. Samples of the sheared rock assayed a trace to 0.03% Cu, 0.02 to 0.88% Pb, 0.05 to 0.20% Zn, a trace to 1.5 opt Ag, and a trace to 0.02 opt Au (Nelson and others, 1980). Material from the mine dump 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 9,370 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, a trace to 0.07 opt Au, and 0.47 to 3.03 opt Ag (Nelson and others, 1980). Some other reported assays 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 smelter in Nebraska 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 section 33, SW section 28, NW section 34, and SW section 27. Samples collected by Dreier (1967) in a altered zone at the head of Sulfur Creek yielded 2 ppm to 320 ppm Cu, and none to 10 ppm Mo. Samples collected from veins in the area yielded 20 ppm to 5,600 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 wallrock. Some dump material assayed 0.02 opt Au, 7.14 opt Ag, 0.60% Pb, and a trace of copper (Parsons, 1937). In 1938, approximately one ton of rock was shipped to the Bunker Hill smelter at Kellog, 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).

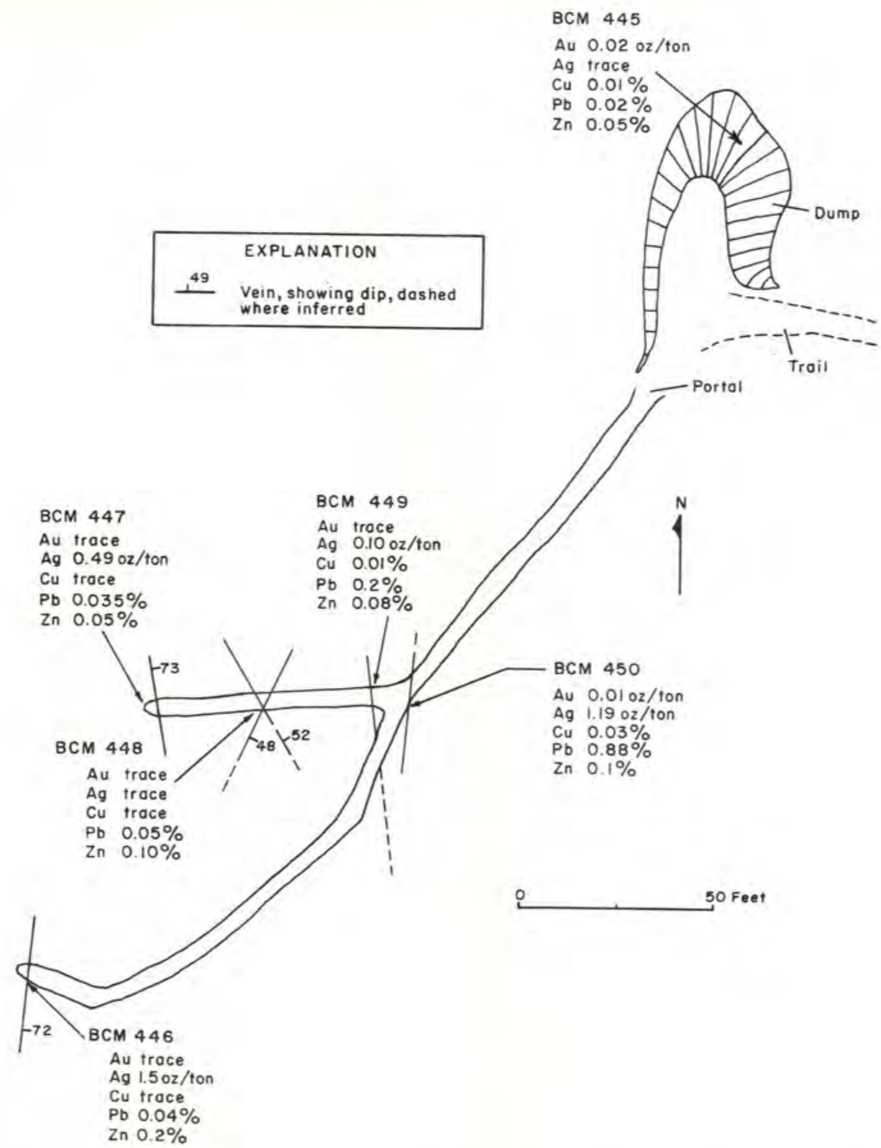


Figure 9. Sample location map of the Novelty adit, Galena Basin, Sunlight mining district (modified from Nelson and others, 1980).

Winona claims group; A group of claims including 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 5). These claims are located near Winona Camp at the head of Sulphur Creek Basin.

Parsons (1937) reported ore from the Winona group was localized in shear zones along dike contacts in volcanic breccias. The ore mineralogy was 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 a foot to more than 12 feet wide (Beeler, 1907e).

Table 5. Reported assays from the Winona group.

Claim Name	Cu (%)	Pb (%)	Zn (%)	Au (opt)	Ag (opt)	Comments and 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).
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 ft 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	-	
Malachite	34.8	-	-	0.08	30.5	(Rich, 1974).
Malachite 1	44.7	-	-	0.12	25.46	(Rich, 1974).

Miscellaneous Porphyries & Prospects in the Absaroka Mountains

Big Wind prospect. SE SW section 3, T50N, R104W; Autunite and anomalous molybdenum occur in a stratiform deposit hosted by carbonaceous shale in the 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 pack trail which 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 eight miles to the south. From the Ishawooa Creek trail head, the base of Clouds Home Peak lies nearly ten 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 one-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 (two inches and less, in width) that cut granodiorite rocks in a three 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 5,000 ppm Cu, 0 to 1,500 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). An 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. 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 from 12 miles of pack trail (Eagle Creek trail) into the wilderness, and lies within sections 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 10). The only recorded production was two ore shipments delivered to the Denver Mint in the 1930's valued at $1,000 in gold (28 to 50 ounces)(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 the emplacement of an irregularly-shaped intrusive (post-Oligocene?) with average latite composition. This latite porphyry was selectively fractured and mineralized, and exhibits stockwork mineralization near the east-central edge of the intrusive, in a topographic saddle. 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 as well as into relatively fresh latite porphyry on the northwestern edge of the saddle.

The mineralization occurs as pyrite disseminations and narrow pyrite, galena, sphalerite, chalcopyrite quartz veinlets (less than one 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).

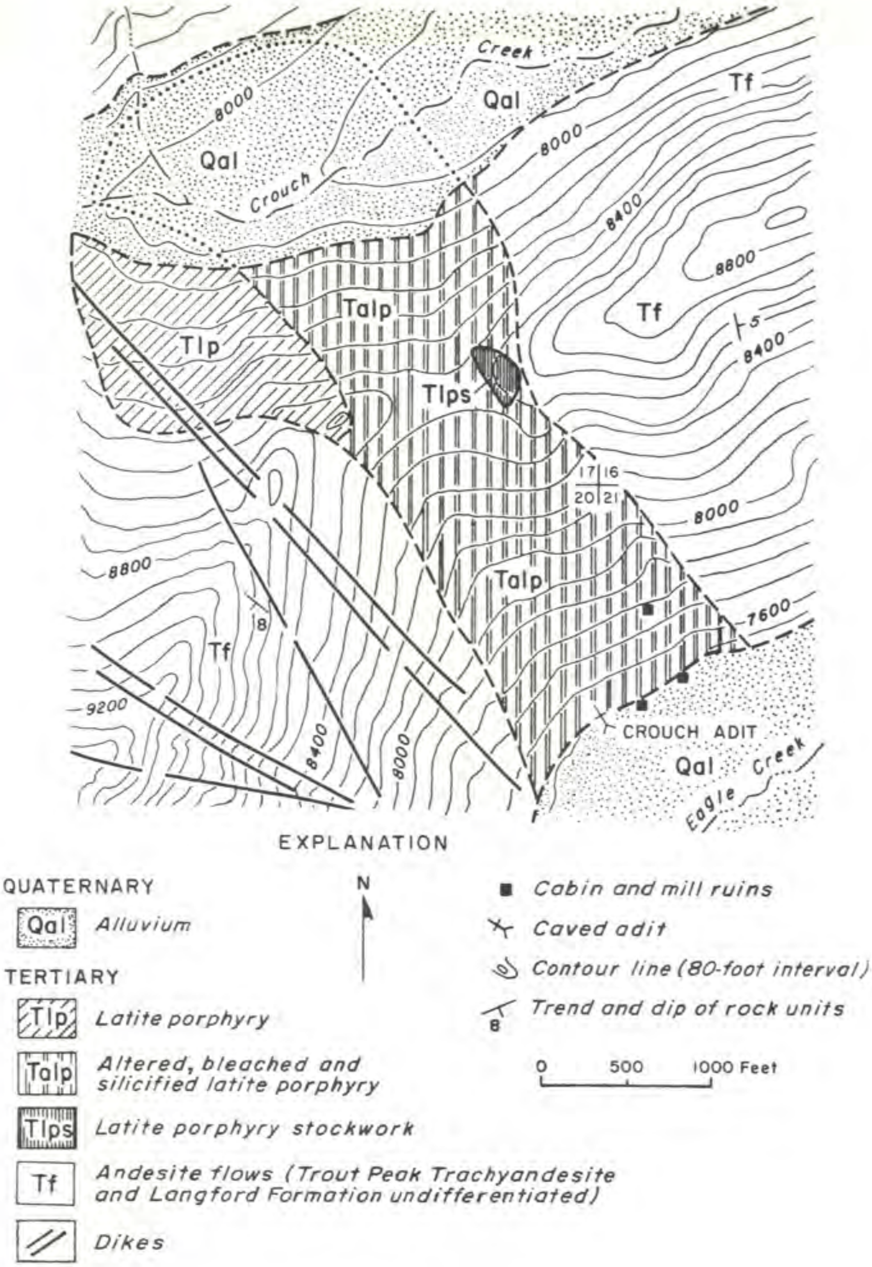


Figure 10. Generalized geologic map of the Eagle Creek porphyry, T.51N., R.109W., (after Galey, 1971). Base metal deposits of the Eagle Creek region are associated with intrusive latite porphyry. There is little evidence for supergene enrichment.

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 section 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 8 to 10 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. 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 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 bleached and limonite-stained rocks.

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 is found as fracture coatings with malachite. The mineralized rocks are shattered with fracture zones trending N20°W to N60°W. Less developed fractures trend to the northeast. Samples collected in the mineralized area ranged from 0 to 1,000 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. The strata on the western flank have relatively gentle, low-angle (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 and culminate at Cloud Peak (13,175 ft above sea level). 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 1,000 square miles.

Osterwald (1959) separated the main body of Precambrian rock of the Bighorns into northern granitic and southern gneissic terranes (Figure 11). The northern granitic terrane is largely composed of pink to gray medium- to coarse-grained plutonic rock of granitic to quartz dioritic composition. The gneissic southern terrane is composed of gray quartzofeldspathic gneiss with minor tonalite and numerous concordant and disconcordant 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).

Rubidium-strontium isochron ages of the northern granites and southern gneisses are essentially the same (2,850 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 2,750 Ma ago. However, more recent work by Arth and others (1980) indicates a more complex Archean history for the Bighorn Mountains. This 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 were 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 occur 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 1,910 to 2,110 Ma (Condie and others, 1969).

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

There are scattered base and precious metal deposits in the Bighorn Mountains, but 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 can not be easily dismissed (Hausel, 1993, 1994). The known mineral deposits are associated with mafic dikes, veins, and shear zones in the granites and gneisses.

Figure 11. Regional geologic map of the Precambrian core of the northern Bighorn Mountains, showing locations of principal precious metal areas (modified from Heimlich, 1971).

Reported mines and occurrences

Bull Camp Group: Section 26, T47N, R84W, located seven 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 section 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; Section 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 (Hopskins, 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 (Hopskins, 1920). A tunnel was also 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 of gold, 0.15 opt Ag, and no detectable Pt (Hopskins, 1920).

North Fork claim group: N/2 section 6, T48N, R84W, located 30 miles southwest of Buffalo, 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 which intrudes gneissic country rock. Chalcopyrite, bornite, malachite, and hematite-bearing mafic rock was 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 section 4, T48N, R85W, on a ridge north of U.S. Highway 16 at Powder River Pass. A 6-inch wide quartz vein cut strongly foliated, isoclinally folded, oligoclase-biotite-hornblende gneiss. The vein contains malachite at scattered intervals, and isolated anhedra of pyrite 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; Section 15, T49N, R83W, located 17 miles from Buffalo. Dark colored dike rock cuts red granite. The dike contains quartz, limonite, hematite, and a few 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 six miles (Darton, 1906).

Taylor mine; SW section 5, T54N, R87W. A 15-foot-wide altered diabase dike at the crest of a ridge trends N80°E and dips 85°N. 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 of 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 northwesterly-trending diabase dike that contains numerous quartz stringers. About 2,000 feet to the northwest, a 1,500 foot tunnel was driven towards 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 a trace of silver (Hopkins, 1920).

Sections 1 and 12, T55N, R85W; Located on a low ridge one-half 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 section 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 section 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. Some 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, forms 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 12).

The Bear Lodge Mountains includes disseminated gold and rare earth (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 in only accessory amounts. Pseudoleucite alkali trachyte porphyry in the Bear Lodge Mountains also carries accessory chalcopyrite, sphalerite, and galena. In the Black Butte area, replacement deposits are dominated by argentiferous silver and 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.

Bear Lodge Mountains

The Bear Lodge Mountains were first prospected in 1875, following the discovery of gold in feldspar porphyry near Warren Peak. The Bear Lodge Mountains form a core of multiple alkalic intrusives of Eocene age which have domed the surrounding Paleozoic and Mesozoic sediments (Figure 13). 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 core of the intrusive complex has been fenitized, in other words, alkalis (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 13).

Mineral deposits in the Bear Lodge Mountains consist of vein-, disseminated-, carbonatite-, and replacement-type deposits within a six mi^2 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 included 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,

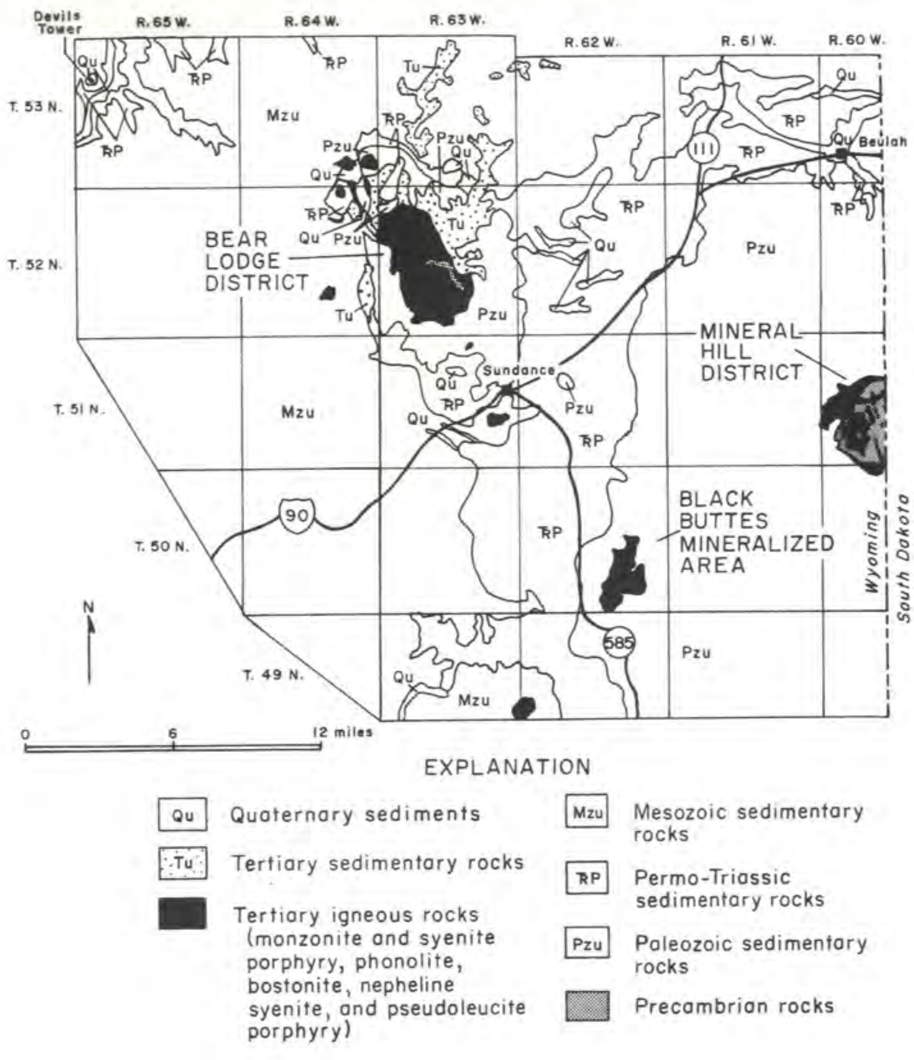


Figure 12. General geology of the Bear Lodge, Black Buttes, and Mineral Hill districts, Black Hills uplift, Wyoming (after Love and Christiansen, 1985; and Lisenbee, 1985).

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, 3.5 ppm Ag.

Replacement deposits occur in inliers of 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, 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 some 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 84,000,000 tons at an average grade of 1.5% REO (rare earth oxides) (Gersic and others, 1990).

Reported occurrences and mines

Copper Prince mine; NW section 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 are also 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.

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

Smith Ridge: section 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 2,000 feet long by 120 feet wide. The breccia averaged 0.021 opt Au. Reserves are estimated at 2,000,000 tons of ore containing 42,000 ounces of gold (Gersic and others, 1990).

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

Sections 16, 18, 22, 27, 33, 34, T52N, R63W; Samples collected from the Deadwood Formation quartzite and from a limestone xenolith, yielded low 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).

Sections 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 core holes and 42 shallow and 2 deep rotary holes were drilled (Gersic and others, 1990). The results are not known.

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

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

NE section 18, T52N, R63W; A sample of intrusive breccia yielded 1,028 ppm Mo, and 1,826 ppm Zn. In 1988, American Copper and Nickel Company drilled four holes into Deadwood Formation conglomerate and trachyte in this section. The recovered samples yielded low gold values (Gersic and others, 1990).

Section 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 Butte

The Black Butte mineralized area, also known as the Hurricane district, lies 12 miles west of Mineral Hill and 8 miles south of Sundance (Figure 1). Black Butte is a Tertiary alkalic igneous complex similar to Mineral Hill and the Bear Lodge Mountains. The Black Butte 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).

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 sections 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 Butte, but sphalerite was not found (Hausel, 1988c). Hayden (1871, p. 215) reported cuprite was also found 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 6,977 pounds of lead (Henderson, 1943).

Black Butte prospect; NE section 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 none to 5.8 opt Ag, 80 ppm to 452 ppm Cu, 130 ppm to 0.79% Mn, 48 ppm to 0.51% Pb, and 61 ppm to 8.3% Zn (Table 6)(Hausel, 1988c). The mineralization is very localized in outcrop.

Table 6. Assay result of samples collected from the Black Butte prospect (after Hausel, 1988c).

Sample Description	Au (ppm)	Ag (ppm)	Cu (ppm)	Mn (ppm)	Pb (ppm)	Zn (ppm)
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 principally known 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 rock. 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 semi-circular 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 alkali trachyte porphyry, a pyroxenite inner ring dike, and a core of feldspathic breccia intruded by diorite (Figure 14). Alkalic lamprophyre and pseudoleucite porphyry dikes are scattered over a wide area (Welch, 1974).

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.

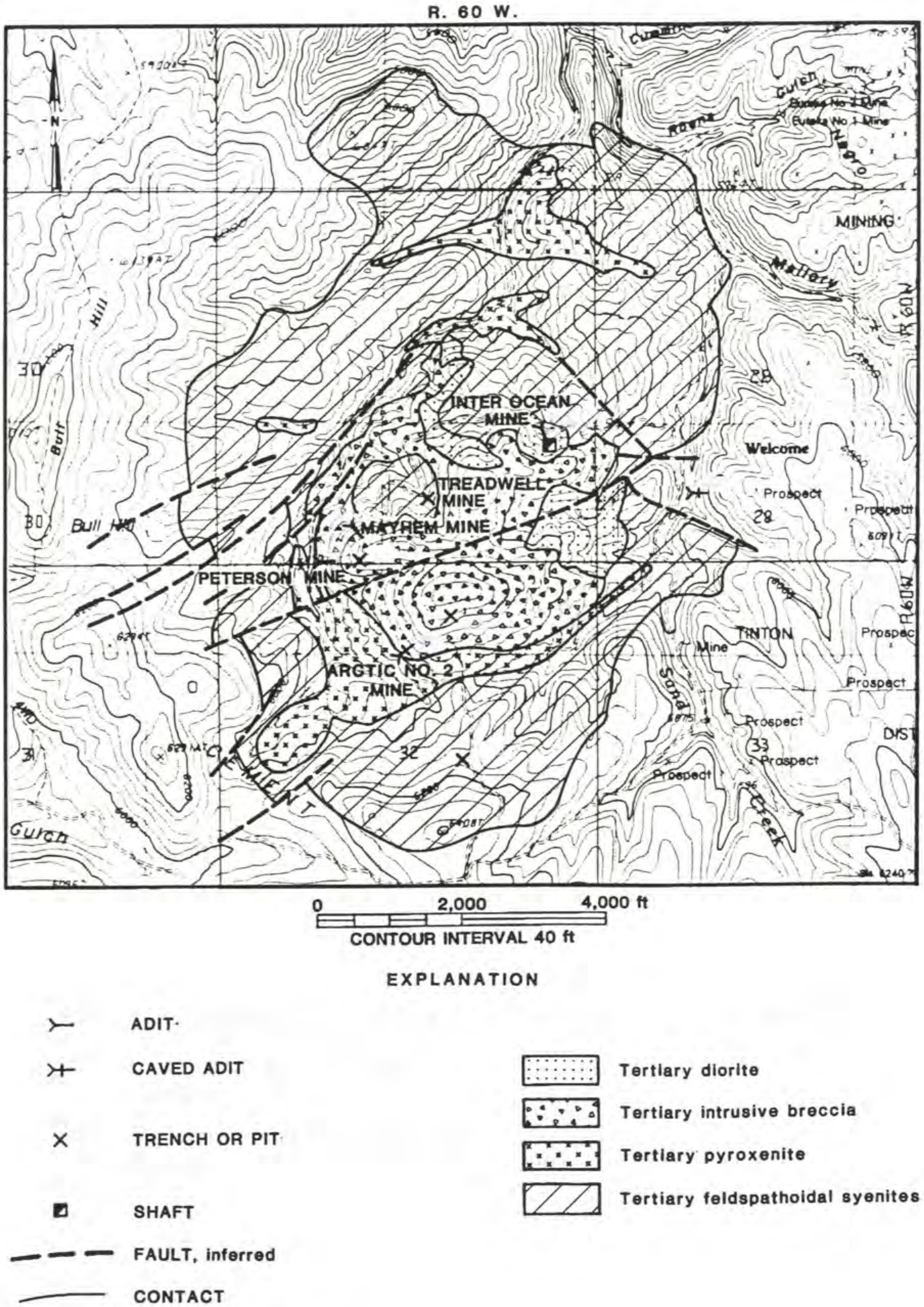


FIGURE 14. - Generalized geologic map of the Mineral Hill area showing sample locations. (Modified from Welch, 1974).

The complex exhibits varying degrees of alteration that Welch (1974) attributed to deuteric processes. Although some bleached rocks are completely replaced by K-spar 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 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 9,000 ounces of placer gold prior to 1893 (Knight, 1893). Minor production from the Interocean mine and the Treadwell claim in 1904 and 1907 totalled 14.25 ounces of gold and 43 ounces of silver (Gersic and others, 1990).

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

Samples collected from the Artic 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 Artic 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 were also poorly mineralized (Table 7) (Hausel, 1990c).

Table 7. Assay results of samples collected from the Artic mine dump (Hausel, 1990c).

Sample Description	Au (ppm)	Ag (ppm)
Chalcedony-bearing trachyte (#2 adit).	0.019	-
Chalcedony-rich trachyte (#1 adit).	0.029	-
Chalcedony-rich trachyte (#1 adit).	0.060	2.4

Birdsnest mine; SE SW section 29, T51N, R60W. Four samples collected from the Birdsnest mine yielded anomalous metal values (Table 8).

Table 8. Assay results of samples collected from the Birdsnest mine (Hausel, 1988c; 1990c).

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 section 30, T51N, R60W. A sample of brown jasperoid in pulaskite assayed 470 ppm Cu, 4,300 ppm Pb, 5 ppm Au, and 7 ppm Ag (Welch, 1974).

Interocean mine; S/2 section 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 ore body with an average gold content between 0.08 and 0.14 opt Au (Welch, 1974).

Two samples of silicified trachyte breccia were collected from the mine dump by the author. These yielded no detectable gold and 0.43 ppm Au; no detectable silver and 2.5 ppm Ag; 622 ppm Cu and 0.12% Cu; 0.19% Mn and 0.83% Mn; no detectable lead and 88 ppm Pb; and 100 ppm and 146 ppm Zn (Hausel, 1988c). A one 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).

Peterson mine: located on the line between sections 29 and 32, T51N, R60W on the west side of Mineral Hill. The Peterson mine was driven 1,450 feet in 1932 by Mineral Hill Gold Properties, Inc. A grab sample of silicified and limonite-stained intrusive breccia from the dump yielded 1,367 ppm Pb, 1,041 ppm Zn, 396 ppm As, 65 ppm Sb, 0.04 ppm Au, and 2.5 ppm Ag (Gersic and others, 1990).

Treadwell mine; S/2 section 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 one-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 9).

Table 9. Assay results of samples collected from the Treadwell mine (Hausel, 1990d).

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 high wall.	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 high wall.	-	-	0.36	<5.0
Vertical fracture vein from high wall.	-	-	0.056	<5.0
Limonitic quartz vein from high wall.	0.19	1.47	21.0	65.0

NE section 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 section 32, T51N, R60W. A quartz vein in altered igneous rock assayed 65 ppm Cu, 3,000 ppm Pb, 0.9 ppm Au, and 3 ppm Ag (Welch, 1974).

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

Section 32, T51N, R60W. Humble Oil and Refining Company drilled Mineral Hill and intersected large intervals of disseminated pyrite and chalcopyrite, locally. One of the holes spudded in pyroxenite and was drilled to a depth of 740 feet and averaged 380 ppm Cu. Some 10 foot intervals in this 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 section 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 3,000 feet of drill core.

NE section 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 section 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 section 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).

Southern Flank of the Black Hills uplift

NW section 27, T44N, R60W; Copper and gold occur in a heavy mineral suite sampled from a breccia 37 feet below the top of the Permian portion 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 rock 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 rock 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 metasediments with minor ultramafic schist (Bowers, 1992) with some 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 are part of a BLM roadless area. The eastern edge of the range, which includes the Miners Canyon, falls outside the roadless area.

Babbs (Weidemeir) mine; SE section 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 the second strikes N5°E and dips 66°W. 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 a 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% WO_3; 0.01 opt Au; and 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 none to 0.05 opt Au, none to 0.5 opt Ag, 0.10% to 6.2% Cu.

Traces of scheelite and weak radioactivity due to allanite were also 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 of 2.4 ppm Au, 6.0 ppm Ag, and 115 ppm WO_3 with an average copper content of 0.32% (BLM, 1983).

SE section 26, T27N, R88W; Six chip samples taken from a disseminated sulfide deposit averaged 0.18% Cu. A northwesterly-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 WO_3. The copper occurs as chalcopyrite with some malachite, bornite, and covellite (Master, 1977).

SW section 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 section 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 was also 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 section 36, T27N, R88W; A 5-foot-wide, malachite-stained vein was selectively sampled by (Master, 1977). The sample assayed 3,000 ppm Cu, 0.30 ppm Au, 7 ppm Ag, and 7,000 ppm WO_3.

SE section 4, T26N, R87W; A sample from a 3-foot-wide quartz-sulfide vein assayed 1,500 ppm Cu and a trace of cobalt (100 ppm Co) (Master, 1977).

SE section 32, T27N, R87W; A sample of a 4-foot-wide, 75°W dipping vein assayed >1.0% Cu, 3,000 ppm As, 100 ppm Pb, 5 ppm (0.15 opt) Ag, and 0.20 ppm Au (Master,1977).

NW section 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

The Spanish mines occur in Miners Canyon near the eastern edge of the Ferris Mountains (Figure 15). 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 none to 6.51 ppm (0.19 opt) Au, none to 147 (4.29 opt) ppm Ag, a maximum of 28% As, a maximum of 4.8% Cu, a maximum of 2.8% Pb, and a maximum of 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 section 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).

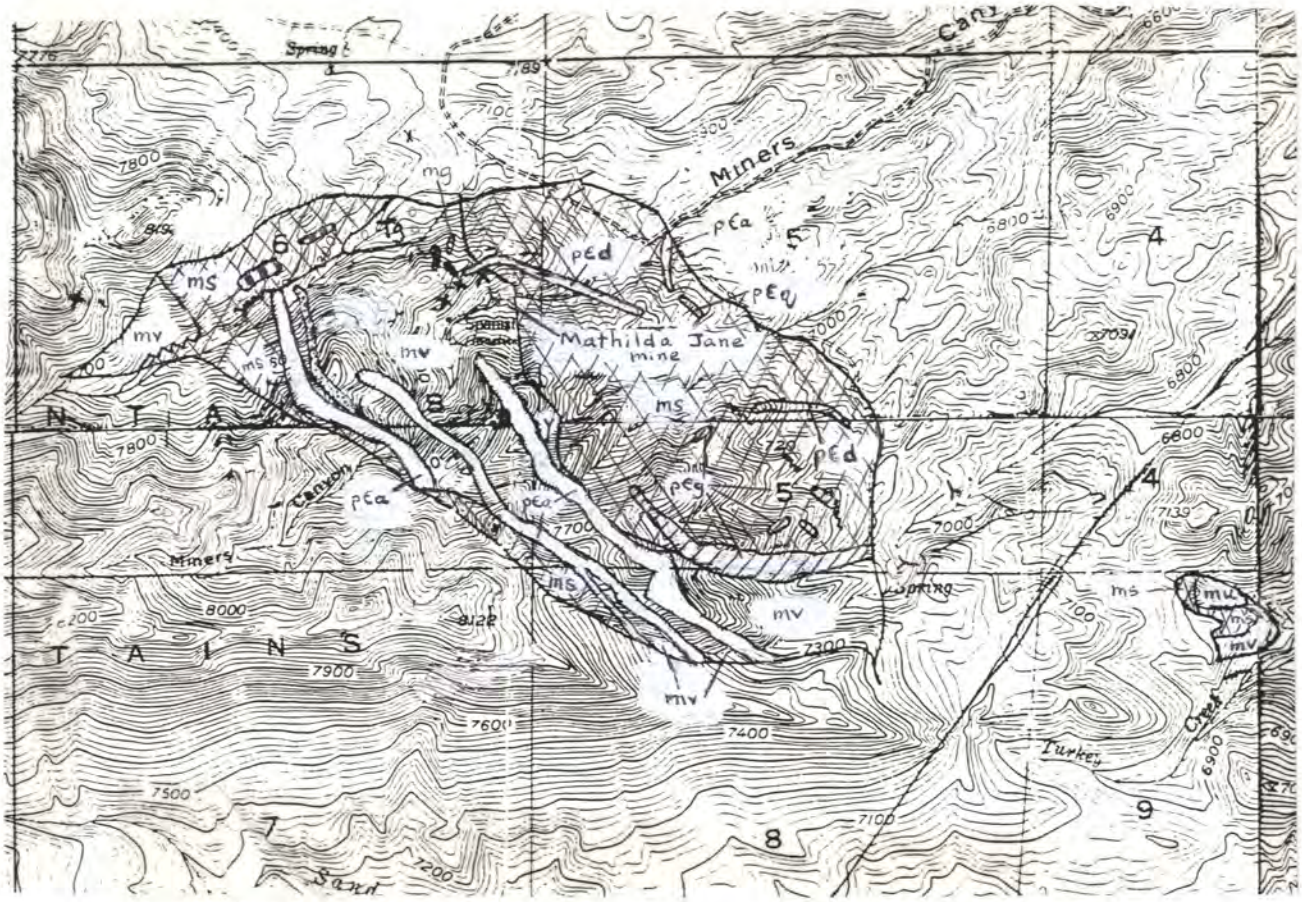
Mathilda Jane adit; E/2 E/2 section 6, T26N, R86W. The Mathilda Jane adit was driven 450 feet along a northwesterly trend. Near the mine face, a 120 foot drift was cut along a S70°W trend (Haff, 1944d). Samples collected in the mine by the author included chloritic schist from the rib in the drift that yielded no detectable gold or silver, and arsenopyrite-bearing quartz from a muck pile that assayed no gold, 4.1 ppm Ag, and 1,330 ppm As (Hausel, 1992c).

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

Spanish Trails #4 adit; E/2 E/2 section 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 section 6, T26N, R86W; Haff (1944d) reported a small pit with a shallow shaft cut in the ridgetop 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)



EXPLANATION

pЄg	granodiorite (orthogneiss)
pЄd	diorite dike
mg	gabbro dike
pЄq	quartzite
mu	ultramafics
if	iron formation
ms	metasediments
pЄa	amphibolites
mv	metavolcanics
ʌʌʌʌ	shear zone
≻	mine
x	prospect

Figure 15. Geological map of the Miners Canyon district, Ferris Mountains (T26-27N, R86W) (by N. Bowers, 1992)

Spanish Trails #8 prospect; W/2 W/2 SW section 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 section 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 (2,640 and 2,600 Ma) exposed in the center of the uplift; and (3) late intruding tholeiitic basaltic 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 (Pekerek, 1977).

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 and 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 16). These rocks have been subjected to several episodes of deformation. According to Hausel (1994c), three episodes of folding are recorded in the Precambrian

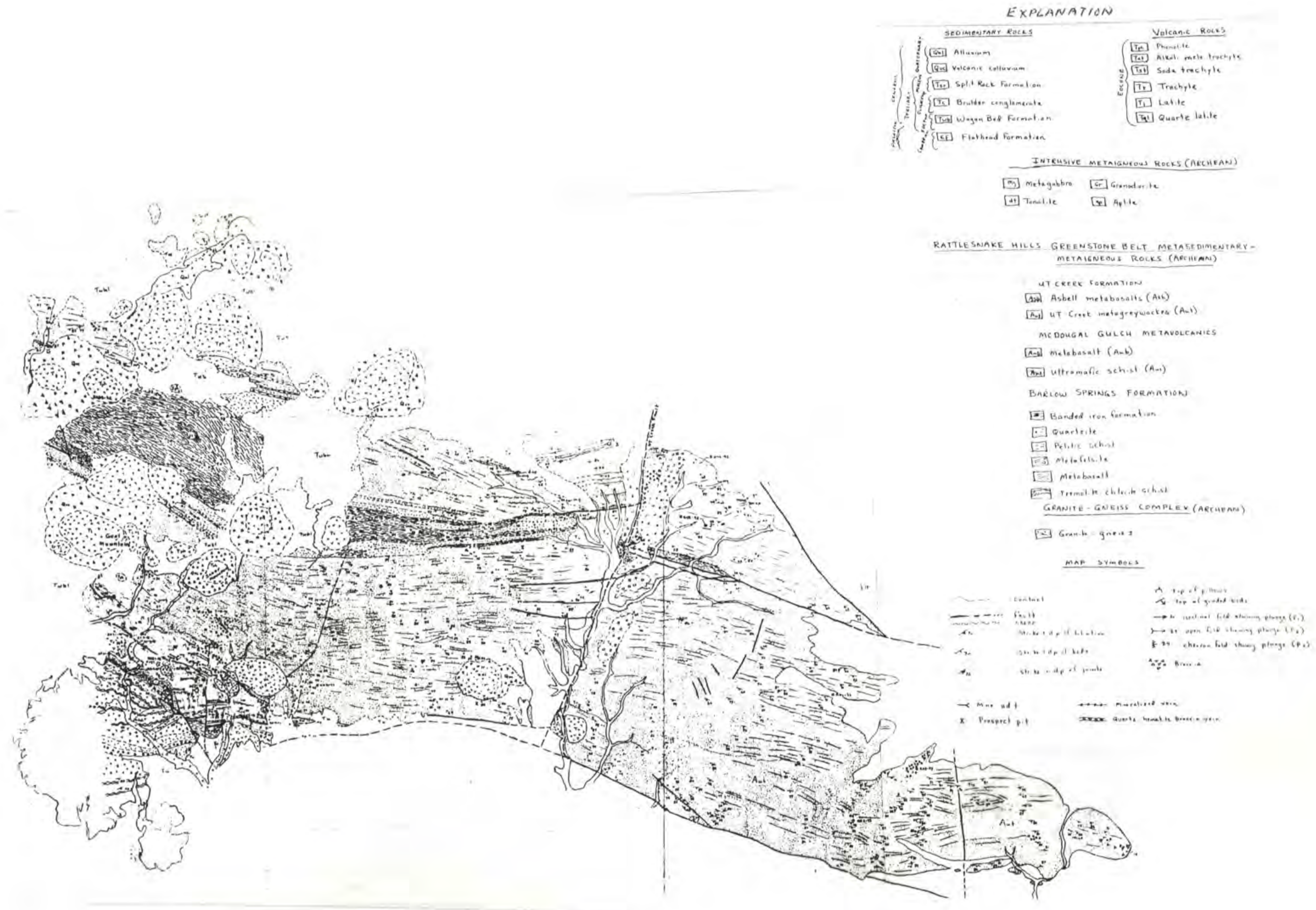


Figure 16. Geological map of the Rattlesnake Hills (after Hausel, 1994c).

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 which encloses 2,000 to 5,000 feet of metatholeiitic volcanics with minor metasediments including metagabbro, metabasalt, and uncommon graphitic schist and metachert. The metagreywackes are underlain by 2,500 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, Sandy Mountain, and a unnamed plug in sections 23, 24, and 25, T32N, R88W, the metatholeiites and metagreywackes have been brecciated and are locally gossaniferous.

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 ppm to 0.078 ppm Hg. Samples of a breccia vein within this disrupted succession yielded 92 ppb to 367 ppb Au. The Tertiary volcanics which disrupted the Precambrian rocks are also anomalous. Composite chip samples of volcanic rock collected along the flank of Sandy Mountain, a phonolitic plug, yielded 44 ppb and 370 ppb Au (Table 2A).

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 which has been fractured and rehealed producing a stockwork-like network of veinlets. A sample of the iron-stained gneiss yielded 300 ppb Au (Hausel, 1994c).

Reported occurrences

<u>Cowpie prospect</u>; SW NE section 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).

<u>Lost Muffler prospect</u>: Section 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 ppm to 0.021 ppm Hg (Hausel, 1993a, 1994c)(Table 2A).

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 T30 and 31N, R92 and 93W. The district is underlain by amphibolite-grade gneiss, schist, and amphibolite metamorphosed at 2,860 Ma. The supracrustal complex was intruded by granite at 2,550 Ma, which was followed by intrusion of diabase dikes a short time later (Peterman and Hildreth, 1978). 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 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.

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, none 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, none to 0.351 ppm Hg, none to 0.9 ppm Ag, and none to 10 ppb Au (Hausel, personal field notes, 1994).

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 on 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.

GROS VENTRE MOUNTAINS

The Gros Ventre Mountains 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 Mountains (Harris and others, 1985).

Reported occurrences

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

Bartlett mine: 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 sediments. 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 extends into Niobrara and Platte Counties and contains resources of copper, zinc, silver, iron, and beryl (Figure 17). Copper occurs in vein deposits, associated with hematite in the 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 stromatilitic dolomites occur east of the Guernsey Stone Company quarries and south of the Sunrise iron mine in Platte County (Snyder and others, 1989). The

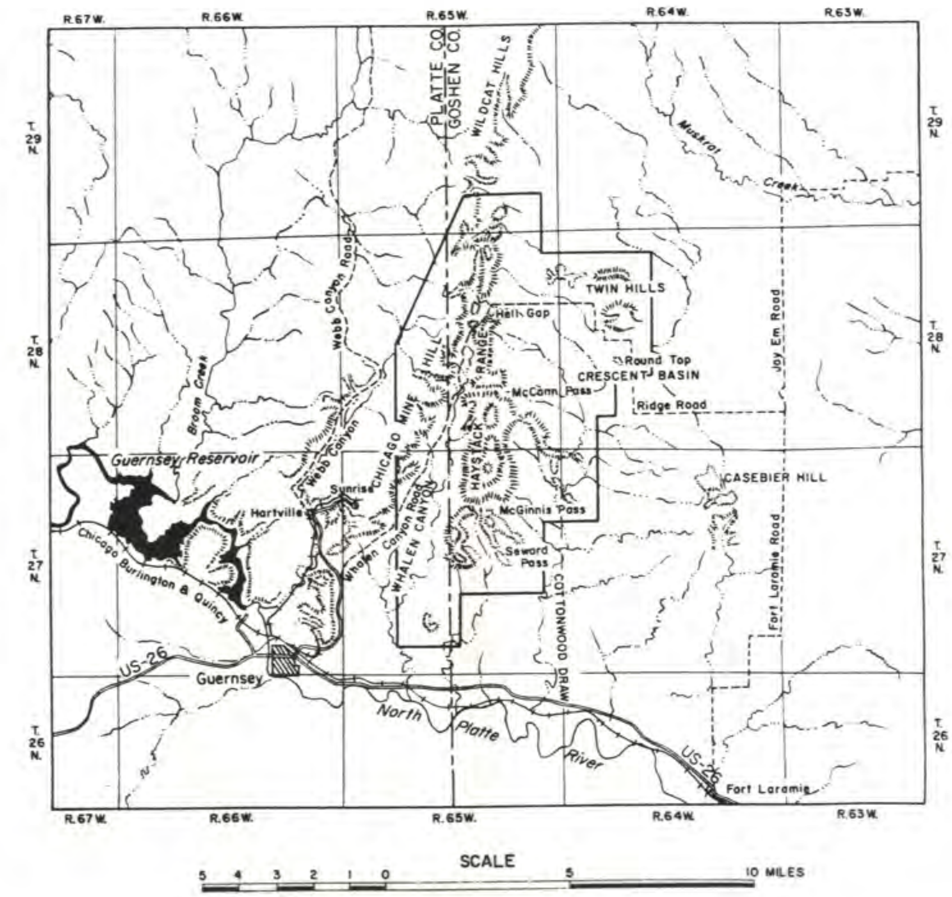


Figure 17. Index map showing geographic features in the southern Hartville uplift (from Millgate, 1964).

supracrustal rocks are Archean in age (Snyder, 1980), although previous investigators reported the metamorphics to be Proterozoic (Millgate, 1965a).

According to Ball (1907a), lenses of copper in Precambrian metacarbonate were generally localized within 50 feet of the base of the overlying Guernsey Formation, and gave out within the first 20 feet. This ore occurred in veinlets along bedding planes accompanied by brecciation, and is closely associated with iron-stained rock or hematite suggesting 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. This type of ore was developed at the Sunrise iron mine which was initially mined for copper in 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 (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 from the Guernsey sandstone, at the Guernsey-Precambrian unconformity, down into the Precambrian crystalline rocks. These deposits are generally less than 3 feet thick but locally are as much as 20 feet thick 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 gold values from iron-stained schist were closely associated with copper at several localities in the uplift.

Haystack Mountains

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 (Paleozoic). Much of the area surrounding the hematite ore bodies, became known as the Hartville mining district. The Hartville district included four iron ore mines known as the Sunrise, Central, Chicago, and Good Fortune mines (Figure 18) (Hausel, 1989).

Mines and prospects

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

The mineralization was localized in the upper part of the Guernsey limestone. The copper occurs as low-temperature replacement deposits in the limestone. Where

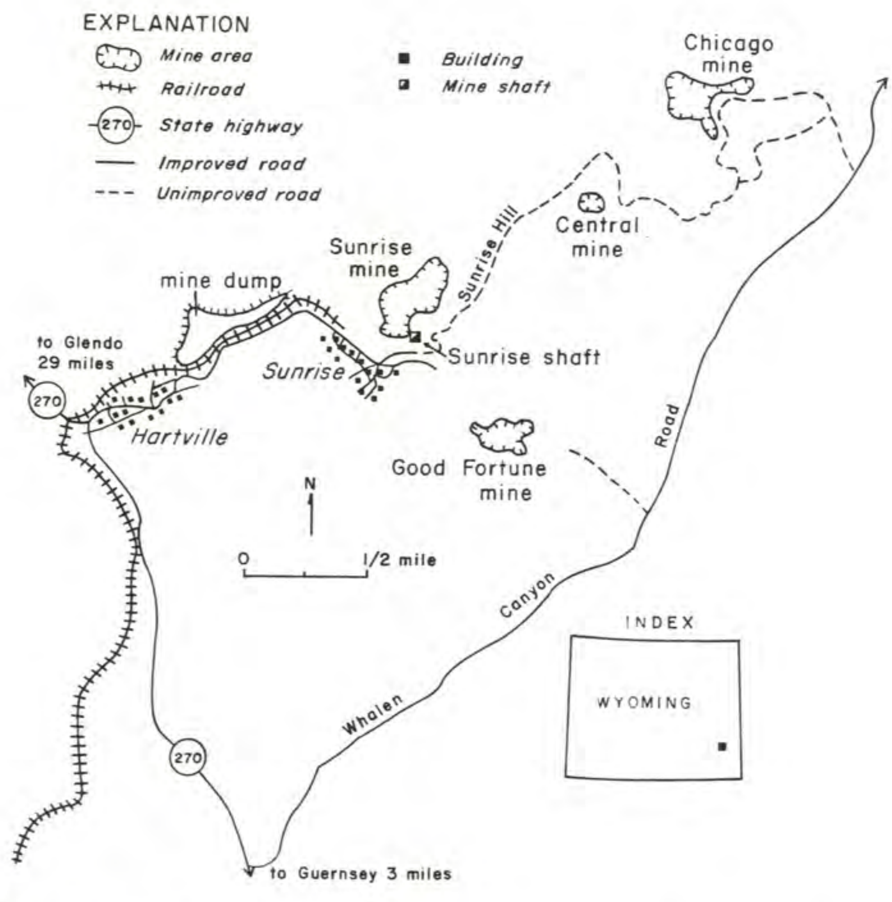


Figure 18. The Sunrise, Central, Chicago and Good Fortune mines were developed by spectacular open pits outside of the towns of Hartville and Sunrise. This historic mining district is located about 15 miles east of Interstate 25. Many of the iron mines were initially opened as copper prospects.

mineralized, the limestone contains lenticular masses of brown flint nodules two inches to four feet long, and up to six 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 the main ore body, but there was no other ore 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, six to seven feet of quartzite, and phonolite(?), with occasional pockets of ore. The dump material included chrysocolla, malachite, cuprite, and chalcocite.

Sunrise mine; section 7, T27N, R65W. The Sunrise mine was initially 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 mine operations terminated.

The 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 ore body continued to a depth of 1,000 feet, and covered a surface area of 2,100 feet by 50 to 600 feet (Anonymous, 1974). The hematite was preferentially localized where the overlying dolomite was thinnest and the schist was silicified suggesting that the hematite formed by ground-water leaching (Snyder and others, 1989).

Copper was found in lenticular masses in the overlying Guernsey Formation (Paleozoic), which lies unconformably on the 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, the hematite was mined for iron. Between 1880 to 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 6,400,000 pounds of copper was shipped to the smelter located at Fairbank, near Guernsey. The renewed production was the result of a discovery of a new copper ore body (Dyck and others, 1994).

Iron ore production from 1900 to 1981, totaled more than 45,000,000 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 the ore haulage level was on the 700 foot level. In 1974, the mine contained about 25 million tons of iron ore reserves (Anonymous, 1974), suggesting that possibly as much as 22 million tons of reserves remained *in situ* following the closure of the mine in 1981.

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

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

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

Center of NE section 26, T27N, R65W (possibly T28N, R65W) near Haystack Peak. Chalcopyrite and chalcocite cement breccia in a schist. The mineralized breccia also carries a trace of silver. Gold, cobalt, and nickel were not detected (Ball, 1907, p. 97).

McCann Pass

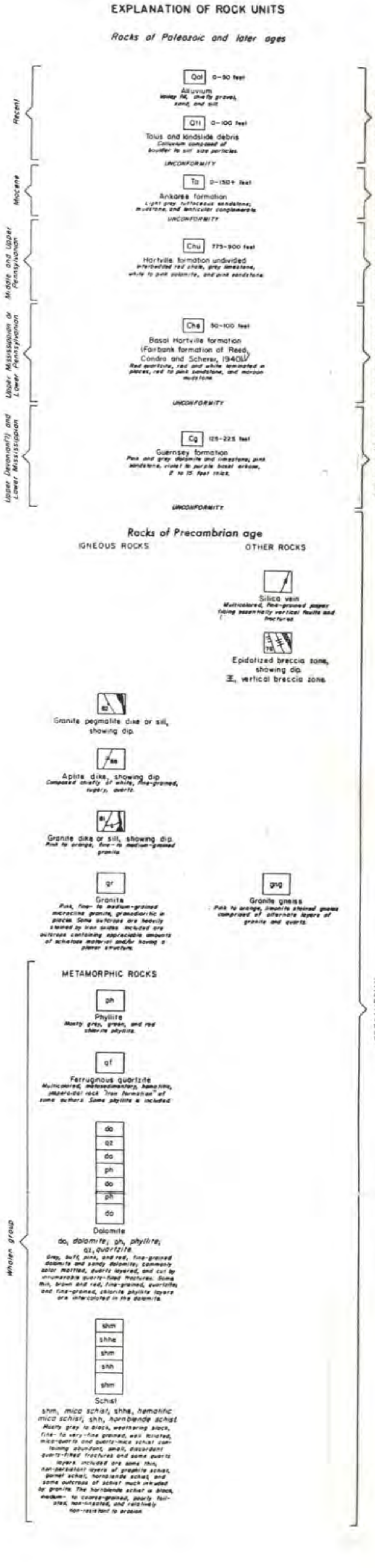
A number of copper prospects occur in the McCann Pass area. McCann Pass is located within five miles northeast of the Hartville district, and forms an east-west trending fault valley that hosts some impressive gossans (Figure 19). The northern side of the pass contains outcrops of granite intruding mica schist; whereas steeply dipping mica schists crop out on the southern side of the pass (Millgate, 1964). Several prospects are found in the pass associated with the gossans.

Charter Oak; According to Ball (1907), the Charter Oak mine is located near the center of SE section 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 of 0.04 to 1.4 opt Au and 2 to 5 opt Ag (Ball, 1907). Two samples collected from a mine dump in McCann Pass in 1988 assumed to be the Charter Oak mine, assayed 8.6% and 1.4% Cu, 11 ppm and 50 ppm Zn, and no detectable Au or Ag (Hausel, 1990b).

Gossan Hill; SW section 23, NE section 26, and E/2 section 27, T28N, R65W; A widespread gossan is localized along the McCann Pass fault. The largest exposed gossan (in section 27) is a 3,000 foot long by 300 foot wide lens-shaped area consisting of various fragments of rock cemented by spongy to massive iron oxides. The other two gossans are smaller, less brecciated, but likewise are stratabound in character (Zahony, 1976). Another extensive gossan in section 26, nick-named "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 drill hole samples from the largest gossan in McCann Pass yielded 20 to 300 ppm Cu, 200 to 900 ppm Zn, and 500 to 7,000 ppm As (Zahony, 1976). At one locality, massive pyrrhotite, disseminated pyrite, and malachite were found in graphitic schist.



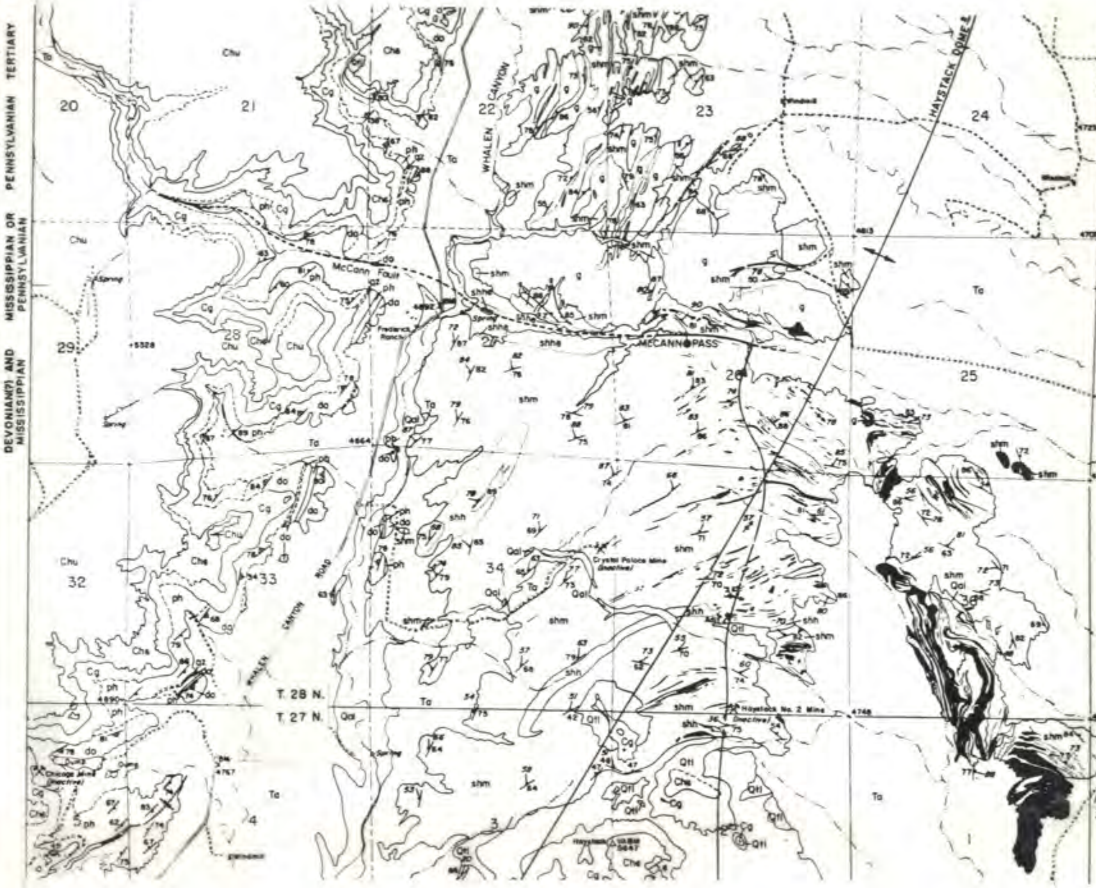


Figure 19. Geology of McCann Pass, Hartville uplift, Wyoming (T28N, R65W) (from Millgate, 1964).

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 which 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 possible presence of a hidden 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 were 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. The country rock in this area consists of Precambrian dolomite with interbedded mica schist and quartz sills unconformably overlain by Arikaree Formation (Tertiary) tuffaceous sediments. The mines are located along the flanks of a synform in Precambrian metasedimentary rocks (Millgate, 1965a) (Figure 20).

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 in the S/2 section 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 to assay 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 that occurs in stringers both parallel and crosscutting the foliation of the schist. The zone of stringers is about 4 feet wide and assay 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 section 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 3,500 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°E to N30°E and dips 50°SE to 70°SE.

The ore is localized in the schist adjacent to the hanging wall dolomite in two lense-shaped masses separated by barren schist. The lenses are 1 to 6 feet thick and

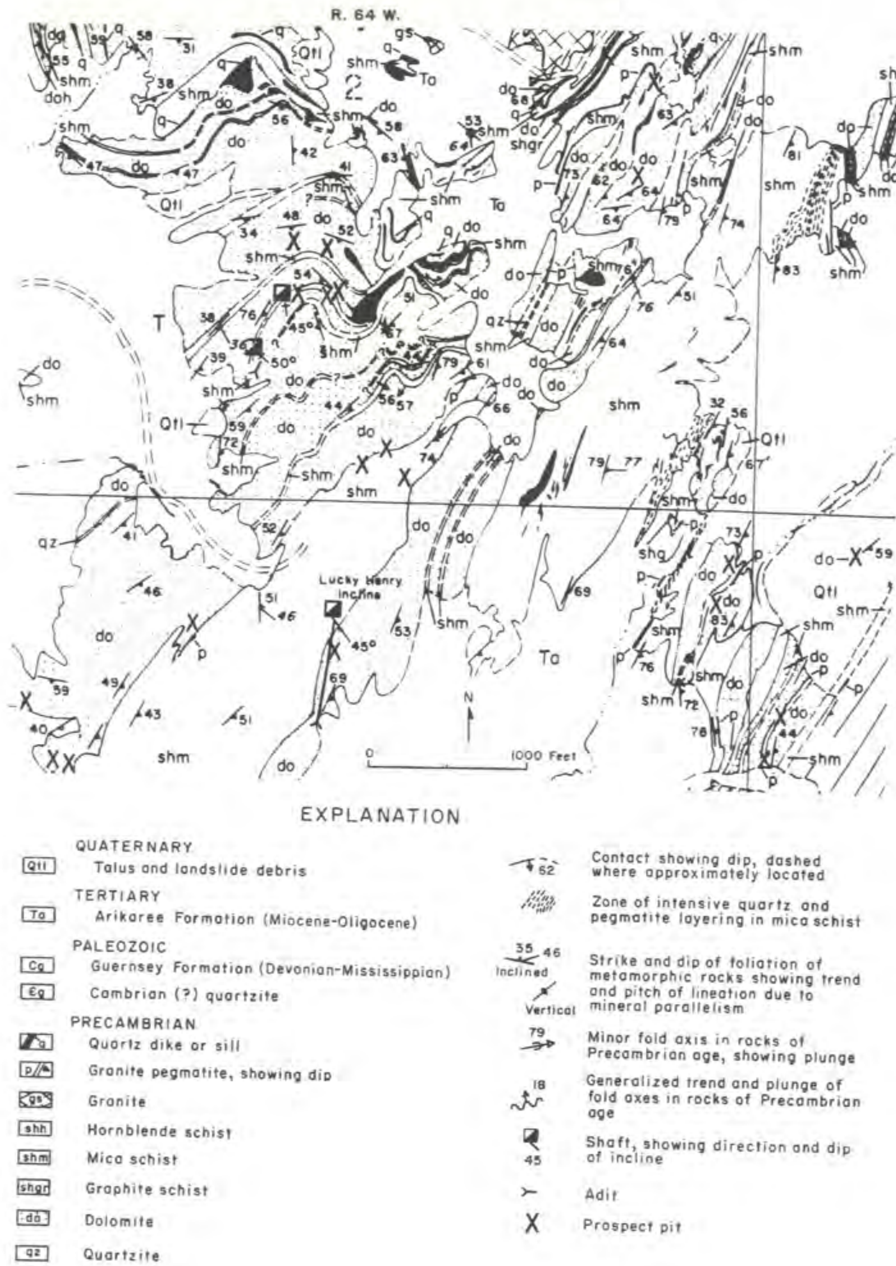


Figure 20. Geologic map of the Rawhide Buttes district (modified from Millgate, 1964).

continue from the surface downward to the bottom of the incline. At the bottom of the incline, the mineralized zone is at least 15 feet thick.

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 (averages 0.15 opt) and from 2 to 5 opt Ag (Ball, 1907).

Wild Cat 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. The copper occurs in fissure veins in the Precambrian rocks and is found in unconformity deposits associated with paleokarst surfaces in Mississippian dolomites.

Copper Bottom; SE section 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 a trace of gold, 2 opt Ag, and 24.64% Cu. The principal copper minerals are chrysocolla and some malachite. Some irregular masses of tennanite [$(Cu, Fe)_{12} As_4 S_{13}$] were found (Ball, 1907).

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

The 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 paleo-surface. Tufted crystal aggregates of malachite, and botryoidal masses of chrysocolla are found in the solution cavities. White or yellowish calcite incrusts 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 exposed a cupriferous iron formation near the western end of canyon at what is known as the Michigan mine. The iron formation is part of a grey to red crossbedded siliceous to ferruginous quartzite near the base of the Muskrat Canyon Formation (Archean). This unit is overlain by a grey 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) limestones and dolomites, which in turn are overlain by Hartville Formation sandstone and quartzite (Pennsylvanian or Mississippian) (Snyder, 1980).

Michigan mine; NW section 24, T30N, R65W; A 300- to 350-foot-thick hematitic iron formation is structurally overlain by sericitic metachert at the Michigan mine. The 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 21).

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 samples of the cupriferous iron-formation were assayed and 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 ore bodies by Colorado Fuel and Iron Corporation. The northern ore body was estimated to contain 75.5 million tons of ore averaging 25.3% Fe, and the southern ore body 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 ore bodies 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 an 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 along the western edge of the Lusk townsite, produced some uranium in the 1920s and again later in the early 1950s. Some copper, silver, and gold were also recovered from this area in 1879 and the early 1880s.

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

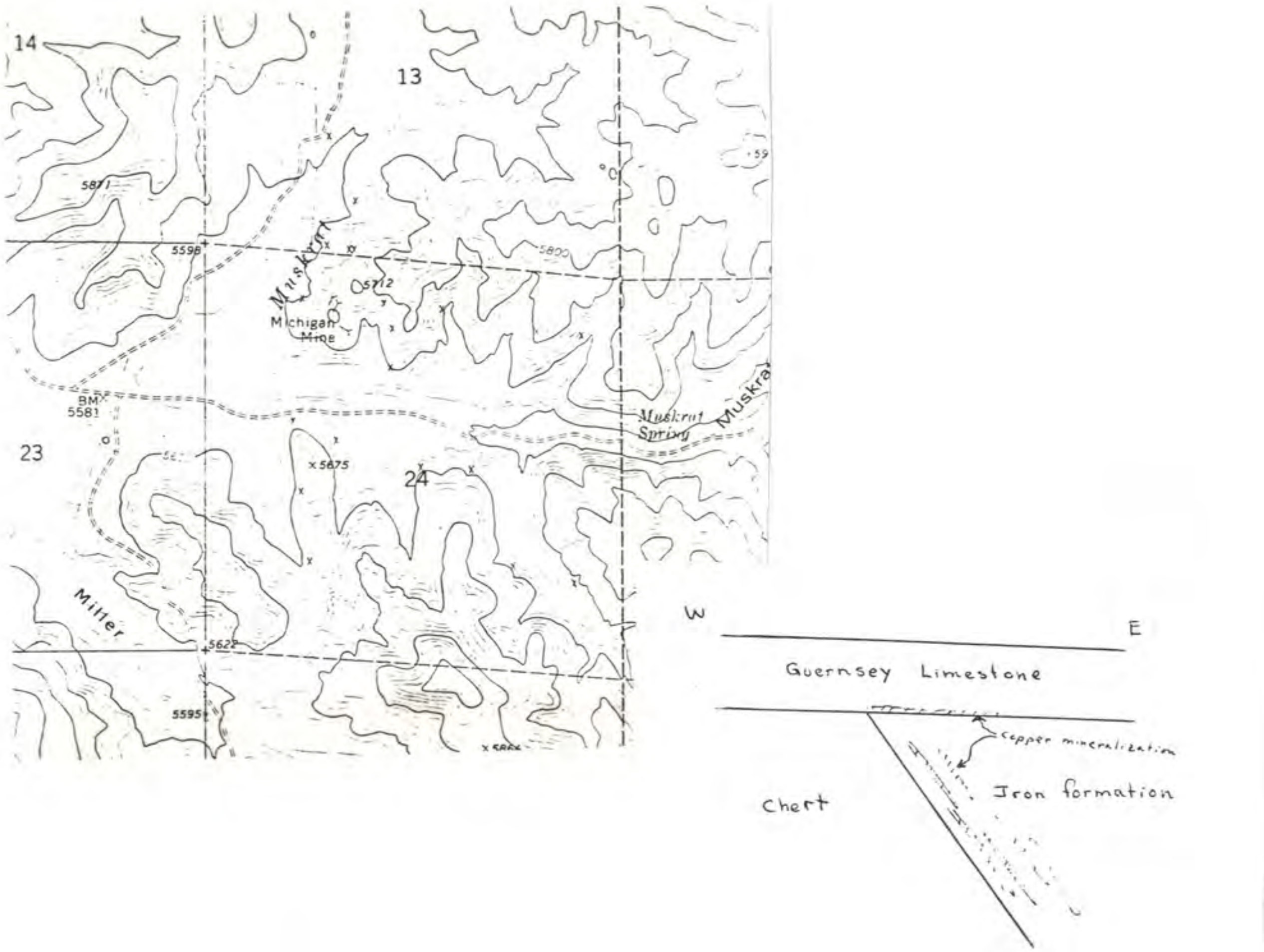


Figure 21. Location map and generalized cross section of the Michigan mine (T30N, R65W).

Following the discovery of silver-copper-gold mineralization in 1879, a 285 foot deep shaft was sunk, and a 1,200 foot inclined adit was driven to the bottom of the shaft. Five levels were established with at least 1,600 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 with a strike trend of N15°E (Wilmarth and Johnson, 1978), and also occurs in a blanket deposit in iron-stained sandstone at the base of the Paleozoic sediments 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 greater than 3% U_3O_8 were shipped to the Radium Company of Denver, Colorado. Following this period of mining, a haitus occurred until 1951. From 1951 to 1953, minor amounts of uranium were recovered (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 section 6, T33N, R63W; Foliated mica schists intruded by several pegmatite sills, strike N4°E and dip 70°SE to 80°SE. A 30-foot-thick mineralized zone, conformable to 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 is preferentially more common 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; sections 26, 27, and 34, T32N, R64W; and section 3, T31N, R64W. In 1984, Exxon Minerals drilled a gossan in the Silver Springs Schist and intersected anomalous zinc between a depth of 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 rock that is flanked by upwarped Phanerozoic sedimentary rocks. Along the western flank of the range, the Phanerozoic rocks unconformably overlie the 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 Basin, and in places are overturned and locally overthrust by Precambrian crystalline rocks. Locally, the 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 and include Casper Mountain, Deer Creek district, Elmers Rock greenstone belt, Esterbrook district, Garrett (Sellers Mountain), LaPrele, Silver Crown district, and the Warbonnet district.

The Precambrian rocks of the Laramie Mountains are divisible into a southern Proterozoic province (Green Mountain terrane) and a northern Archean terrane (Wyoming Province). These two 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 Green Mountain terrane to the south 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).

Rocks in the central and northern Laramie Range are part of the Wyoming Province and include Archean 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 Range 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 granites and gneiss intruded by mafic (diabase) dikes. Probably the most significant base metal deposits 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 Range, and lies immediately south of the city of Casper. This portion of the Laramie Mountains 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 22). 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 Phanerozoic rocks overlying the Precambrian terrane, 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 of the 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 schists collected by the author yielded 16.5% to 35% MgO, 0.6% to 17.01% Cr_2O_3, and 225 ppm to 1,456 ppm Ni (W.D. Hausel, personal field notes, 1992). Drilling by the U.S. Bureau of Mines identifed 575,000 tons of 8.7% chromite ore with a resource of 4,160,000 tons of 2.5% chromite ore (Hausel, 1987a).

Blue Cap: 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 nor 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 40 foot wide mineralized zone which yielded some rock that assayed as high as 0.2 to 0.77 opt Au.

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 outcrops of ultramafic schist, quartzite, and amphibolite occur in the area (Figure 23). The serpentinites in the region are reported to be chromite and asbestos-bearing. Nearly 2,300 tons of chromite ore were produced in 1908 and during the first World War (Hausel, 1987a). The reported copper occurrences in the area appear to be minor.

Smith copper prospect; Section 29, T32N, R75W; Located about 9 miles south of Glenrock near the head of a tributary of Hutton Creek on the U.S. Geological Survey 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, 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 for decorative stone on a small scale.

Swede Boy vein; NE section 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°E. The vein at the main shaft was six feet wide, and at some 600 to 800 feet from the primary shaft, the vein pinched to four feet wide. Some ore was shipped (Spencer, 1916, p. 75-76).

NE NE section 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 24). The belt extends across the width of the Laramie Range and is bounded on the north by an Archean granite-gneiss complex. The belt is truncated along the south by Proterozoic syenites.

The 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 schists, metapelite, banded iron formation, quartzites, metaconglomerate, and marble intruded by granites and gabbroic rocks. Mineralization in the greenstone belt includes some low-grade chromite, asbestos, copper, and uranium.

Mines and prospects

Bell Prospect: N/2 SW section 20, T23N, R69W; Located at 5,415 feet elevation in the Cooney Hills along the eastern flank of the Laramie Mountains near the eastern extent of the greenstone belt. The Bell 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°E-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; section 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 was also 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 crops out for 500 feet along the surface with a width of four to seven 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 two feet of the vein is mineralized (Beeler, 1903i).

Precious Honor No.1; NW SE section 20, T23N, R69W, at 5,491 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 samples of pyritiferous quartz collected from the dump by the author yielded 0.25 and 0.49 ppm Au, and 2.5 and 5.3 ppm Ag (Hausel, 1990a).

Whippoorwill mine; NE SW section 20, T23N, R69W; Located at an elevation of 5,836 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 mine shafts and locally

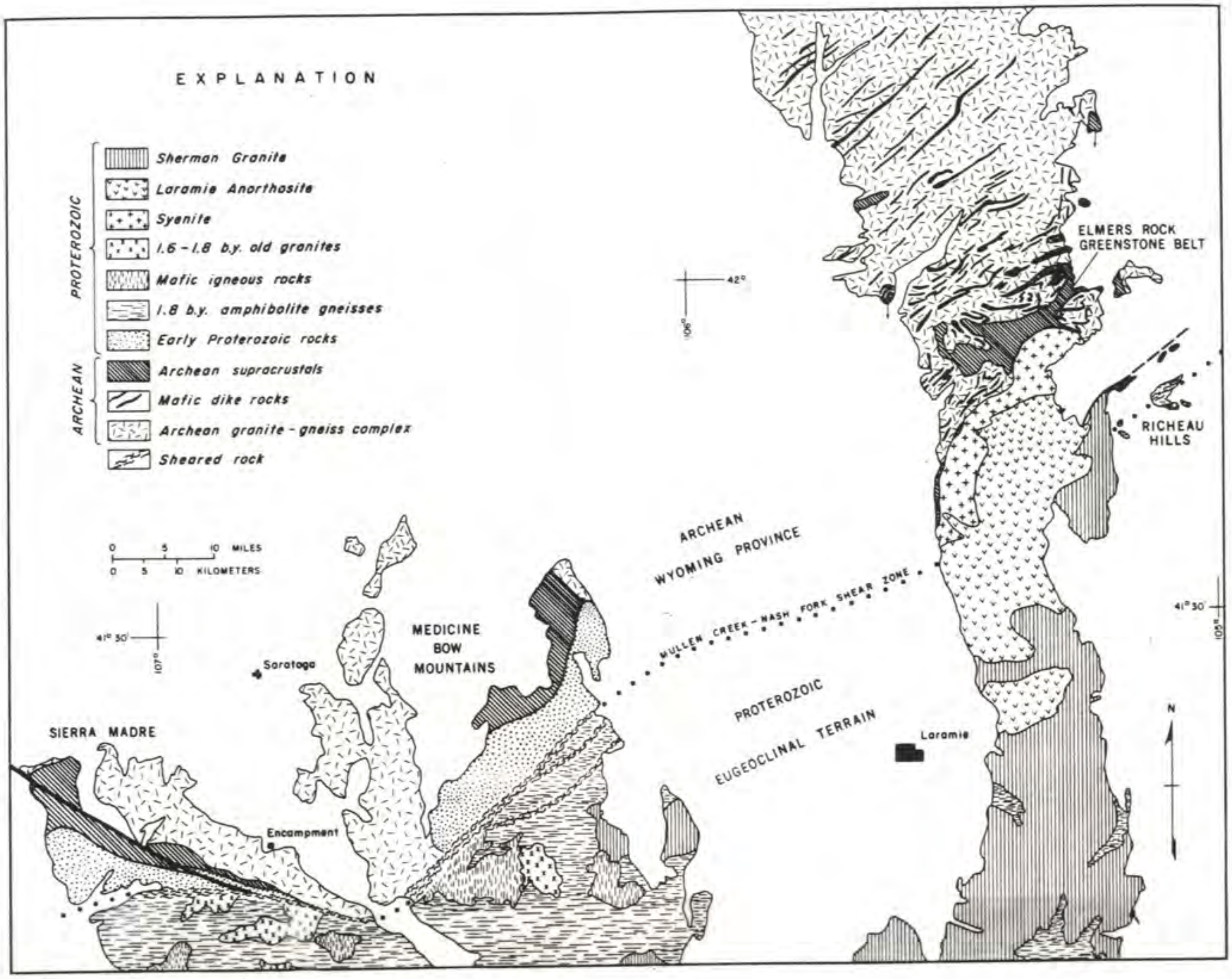


Figure 24. Location of the Elmers Rock greenstone belt in the central Laramie Mountains, southeastern Wyoming (after Graff and others, 1982).

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 0.05 ppm Au, no silver, and 0.08% Cu (Hausel, 1990a).

<u>NW section 28, T23N, R69W</u>; A shallow shaft was dug on a N80°E trending, 78°S 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 section 28 in which he reported the presence of uranium in addition to copper.

<u>NW NE section 18, T23N, R69W</u>; A vertical shaft cut red quartzite and quartz pegmatite. Some malachite and azurite was found (Bothner, 1967).

<u>SW SW section 8, T23N, R69W</u>; Minor amounts of copper sulfide were found at this location (Bothner, 1967).

<u>Emerald Group</u>: Section 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).

<u>Independence Group</u>; Located on Slate Creek (a tributary of the Laramie River) about 22 miles west of Wheatland. A one 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.

<u>Rattlesnake Den prospect</u>; S/2 section 26, T23N, R70W. Located on the east edge of Squaw Mountain at 5,604 feet elevation. An iron-stained breccia trends N22°W and dips 71° to the west. The zone is six to eight feet wide and was tested by a short tunnel and intersecting shaft. The host rock is gneiss. No obvious mineralization was recognized.

Esterbrook district

The Esterbrook district (also known as the North Laramie Peak district) is located north and west of Laramie Peak in the northern Laramie Range of Converse County and partially extends into Albany County. Archean metasediments and metavolcanics in this district were intruded by Late Archean granites. The supracrustal rocks host several fissure veins and possibly some replacement deposits. Four groups of mineral deposits were described by Greeley (1962). These are: (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 was discovered in the district in 1953 and is genetically related to other metallic deposits. The mineralization is spatially associated with the contacts between granite and schist (Guilinger, 1956).

Mines and prospects

Al Mahoney prospect; Section 14, T27N, R71W (Albany County). The Al Mahoney prospect was developed by a 60 foot adit which followed 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, with 0.1 opt Ag (Segerstrom and others, 1977).

Ashenfelder prospect; Section 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 mine dump and nearby prospect pits.

The copper and lead contents of these samples were minor and ranged from 80 ppm to 160 ppm Cu, and none to 0.2% Pb. One sample contained significant gold. This was a piece of hematite-stained granite which assayed 0.17 opt Au (Segerstrom and others, 1977).

Big Five prospect; SW SW section 10, T28N, R71W; Located 2,500 feet north-northeast of the Three Cripples mine. The dump near a 50-foot shaft contained rock with mostly pyrrhotite and bunches of chalcopyrite 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 with 100 ppm Pb, and 0.1 opt Ag (Figure 25).

East of Esterbrook; Section 9 and 10, T28N, R71W. Anomalous copper was detected in eight samples collected from prospects immediately east of the Esterbrook townsite (Segerstrom and others, 1977). These samples yielded 160 ppm to 0.3% Cu, none to 200 ppm Pb, and none to 0.1 opt Ag.

Esterbrook mine; SE section 9, T28N, R71W; Galena was found in tabular open space fillings in hornblende schist in the Esterbrook mine on the Douglas claim (Figure 25). The mineralized body is 2 to 6 feet wide, trends N30°E, and dips vertically. In addition to galena, pyrite, calcite, quartz, cerrusite, minor limonite, covellite, chalcopyrite, and

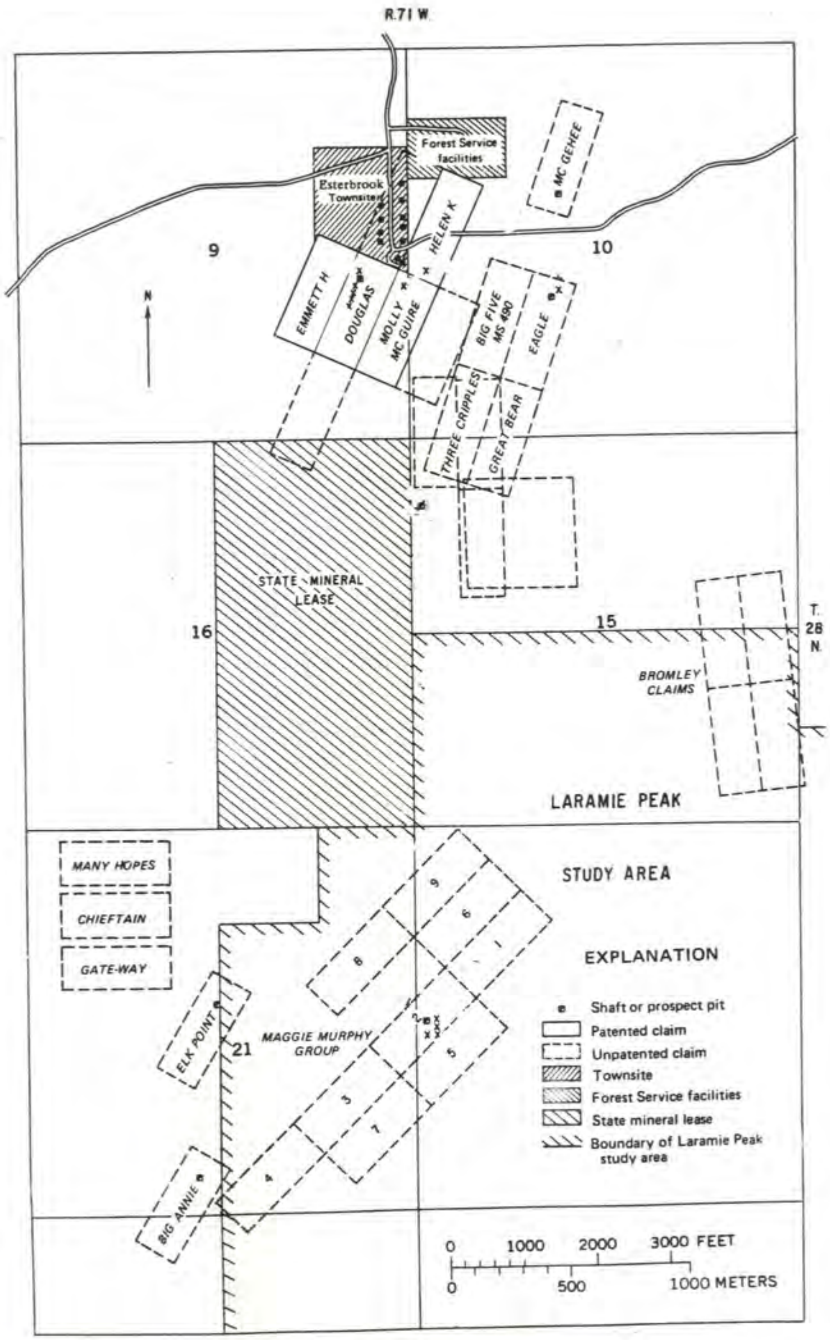


Figure 25. Mining claims near Esterbrook (from Segerstrom and others, 1977).

traces of malachite were found (Beeler, 1904c; Greeley, 1962). 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 foot level) 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 six-foot-wide, solid shoots of galena in the mine workings. Samples collected by Segerstrom and others (1977) yielded 600 ppm to 0.3% Cu, 0.6% to 10% Pb, 0.1 to 0.4 opt Ag, none to 0.03 opt Au, 0.5% to 2.0% Zn, and no detectable Pt or Pd.

Eureka prospect; sections 9 and 16, T28N, R71W; A 8 to 20 foot wide, north-trending quartz vein along a contact between schist with diabase is stained with limonite. Masses, disseminations, and streaks of pyrrhotite 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; SE section 36(?) T28N, R73W. This property is located about ten miles southwest of Esterbrook. The Hoosier Boy 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 Hoosier Boy shaft carries small amounts of chalcopyrite (Spencer, 1916, p. 71).

Kentucky Belle; SE section 36(?) T28N, R73W. The Kentucky Belle 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 only 40 feet. The quartz vein is about two feet wide, and carries considerable chalcopyrite and some chalcocite (Spencer, 1916, p. 71).

Kreisley prospect; SW section 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 section 22, T28N, R71W; The Maggie Murphy mine is located about two miles south Esterbrook along the north side of Horseshoe Creek (Figure 25). The Maggie Murphy property consisted of nine claims staked in 1903 that crossed the section line to the west into the eastern-most part of section 21. A 107-foot shaft was sunk adjacent to the section line in the center of the W/2 W/2 of section 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 five-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) were also found. Eight samples collected for assay from the dump and nearby prospect pits contained weakly anomalous copper. The samples ranged from 160 ppm to 600 ppm Cu, none to 200 ppm Pb, and none to 5.6 opt Ag (Segerstrom and others, 1977).

Maverick; section 22 and 23, T29N, R71W; A 50 foot shaft was sunk on irregular, 3 to 10 foot wide, quartz veins that trend N45°W to N55°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; SW section 10, T28N, R71W; Minor chalcopyrite and traces of sphalerite occur in quartz-pyrrhotite mineralized zones. These strike northeasterly and dip vertically (Greeley, 1962).

Northeast of Ashenfelder; section 5, T27N, R71W; Four samples were collected from a caved adit about one mile northeast of the Ashenfelder prospect. All of the samples were poorly mineralized. The assays ranged from 0.016 to 0.06% Cu, none to 0.04% Pb, and none to 0.2 opt Ag (Table 1, sample numbers 19-22) (Segerstrom and others, 1977).

Northwest of Ashenfelder; section 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 (Table 1, samples numbers 16-18)(Segerstrom and others, 1977).

Sauls Camp; NE SE section 22, T29N, R71W; The country rock at Sauls 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 1,000 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 section 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 section 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 2,000 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 section 15, T28N, R71W; The Three Cripples prospect was developed on a northeast trending limonite-stained zone in schist southeast of Esterbrook (Figure 25). 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 a trace of cobalt (Spencer, 1916). Segerstrom and others (1977) assayed five samples which yielded only traces to 0.3% Cu. One sample yielded a trace of nickel (40 ppm). Hall (1909) reported pyrrhotite-bearing samples from the mine yielded 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 section 10, T29N, R71W, about 25 miles south of Douglas near the head of Trail Creek. Interlayered granites and schists 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 fresh unaltered hornblende schist wallrock was discovered eight feet below the adit floor at the junction of two north- and northeast-trending, vertical-dipping shear zones in 1954. Both shear zones are radioactive where cut by the adit. The uraninite, coated by crythrite (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 mineralization 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; section 36, T27N, R73W, and section 1, T26N, R73W; Six samples collected from six different mine 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 the LaPrele reservoir located 12 miles southwest of Douglas. The area includes parts of land located on the Hermit Rock and the LaPrele Reservoir 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 section 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 schists and underlies massive limestone of the Casper Formation. These sediments dip north-northeast and are broken by a north-south trending fault along Cottonwood Creek. The 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; section 25, T32N, R74W; Prospect pits were dug on a vertical quartz vein in hornblende schist. The quartz contains some copper carbonate (Smith, 1953).

Hazenville prospect; section 30, T32N, R73W; Located about 2 miles east of the 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 (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 section 23, T29N, R73W; According to Beeler (1903e) this prospect was located on West LaBonte Creek; however, the legal description places it on French Joe Ceek. 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).

Mormon Canyon

The Mormon Canyon area is a small supracrustal fragment of amphibolite, sillimanite-quartz-mica schist, and gneiss with several 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 section 13, T32N, T76W; Chalcocite and chalcopyrite in white quartz was discovered near the head of Dry Creek, eight miles south of Glenrock (Spencer, 1916, p. 79). In the N/2 SW section 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 the Curt Gowdy State Park along the eastern flank of the Laramie Range (Figure 26). 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 the mill 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 deposit.

Regional retrogressive metamorphism produced widespread greenschist alteration throughout the district, but near the Rambler prospect and at the Copper King mine, the 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 ore body 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 deposit could be increased by drilling and exploring nearby geochemical and geophysical anomalies (Klein, 1974; Hausel and Jones, 1982; Hausel, 1989).

<u>Agate Prospect</u>: Located 0.25 mile northwest of the Julia 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).

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

<u>Carbonate Belle</u>: NE section 24, T14N, R70W; This is the site of the infamous salting incident which purportedly involved the Wyoming Territorial Geologist, Samual Aughey. Historic reports indicate that Aughey and associates obtained bonds on a number of claims on the Carbonate Belle and attempted to promote the property by salting samples with gold (Hausel, 1993a, 1994a).

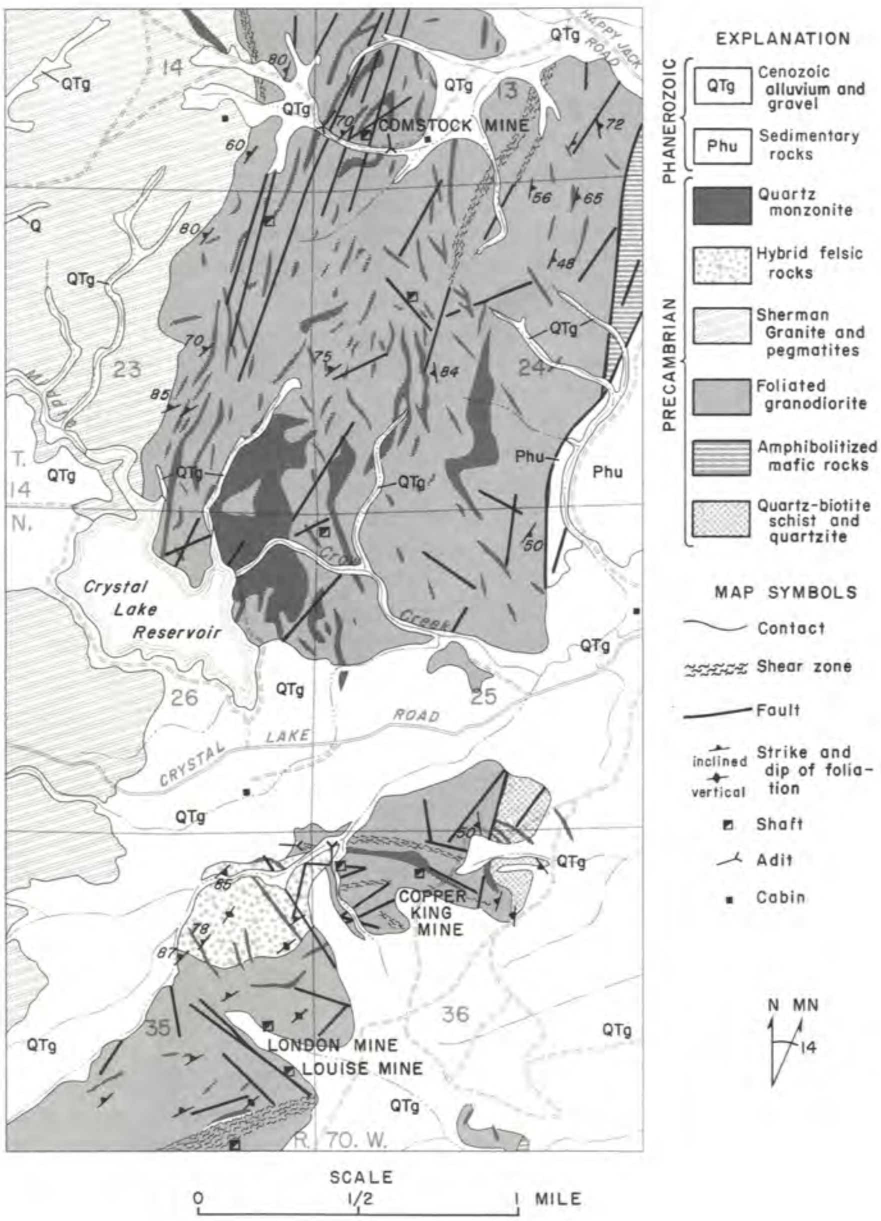


Figure 26. Geologic map of the Silver Crown district (modified from Klein, 1974).

Comstock (King David) mine; SW section 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).

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 Geological Survey mapped the accessible workings of the Comstock mine which consisted of 500 feet of drifts (Figure 27) (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 11).

Table 11. Assays of samples from the Comstock mine, Silver Crown district (from Ferguson, 1965)

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, wallrock	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 lbs	0.74	0.83	11.02
25,113 lbs	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	-

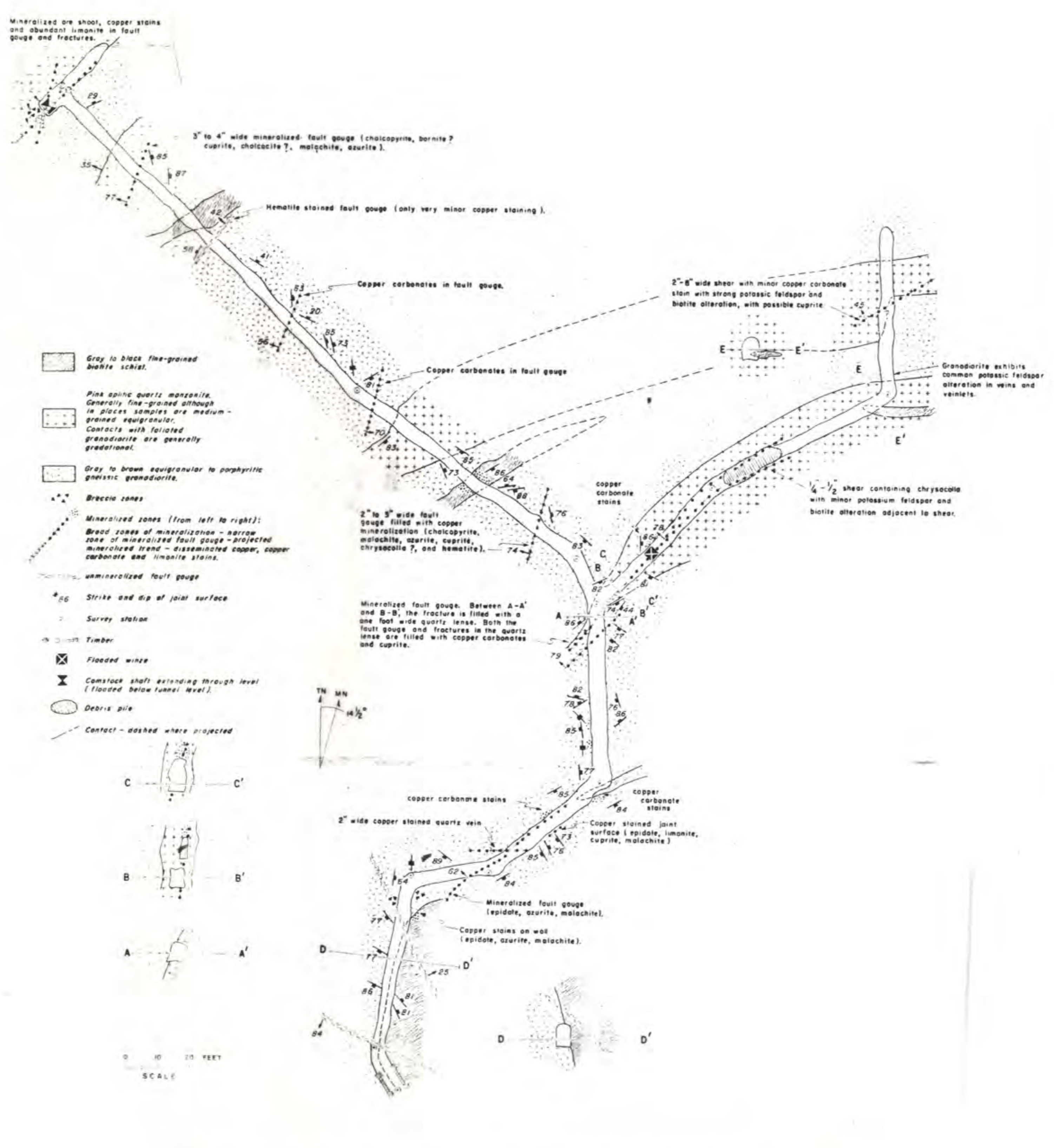


Figure 27. Geological map of the Comstock mine (from Hausel and Jones, 1982).

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 section 36, T14N, R70W; Historically, the Copper King (Arizona) mine was located in 1881 and developed by the Adams Copper Mining and Reduction Company. The property was later worked by the 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 surface occurs as malachite and chrysocolla: at depth as chalcopyrite, pyrite, minor bornite, pyrrhotite, and native copper (McGraw, 1954; Soule, 1955).

Primary hypogene mineralization was intersected by drilling at a depth of 150 to 180 feet by the 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 Copper King 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 some 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 28) (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 1,024 feet. Spectrographic analyses also showed traces of lead, zinc, tungsten, and 0.5 to 3.0% TiO_2 (Soule, 1955). An estimate of the *in situ* ore reserves were made by Nevin (1973) based on drilling:

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

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 gold estimates to be of the order of 4.5 million tons of ore averaging 0.044 opt Au (or about 200,000 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).

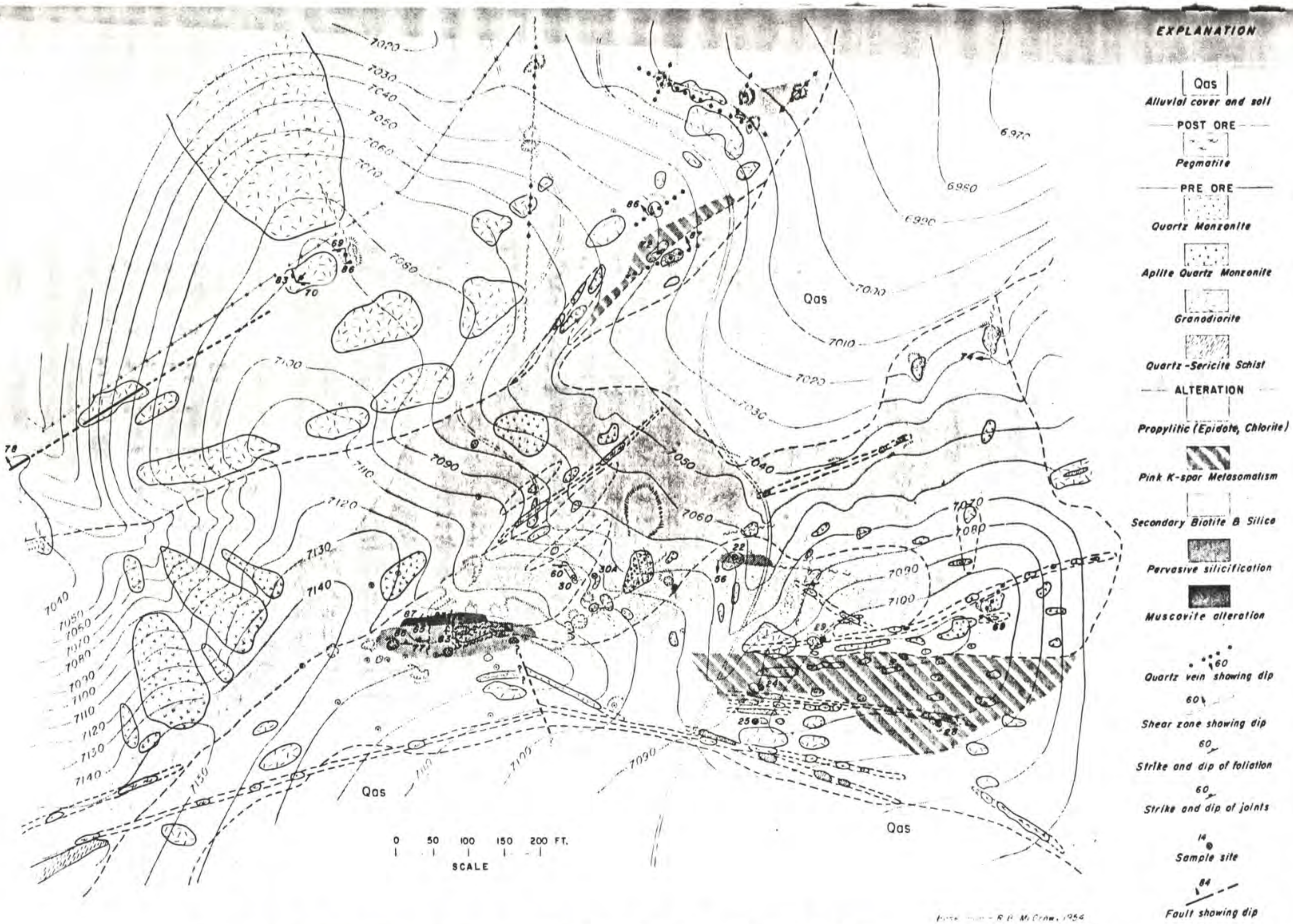


Figure 28. Rock alteration and outcrop map of the Copper King mine (from Hausel and Jones, 1982).

Geochemical and geophysical anomalies suggest the known resource could be increased. For example, a large magnetic anomaly (1,000 ft wide x 2,000 ft long, 450 gamma magnitude), almost identical to that reflected by the Copper King deposit (800 ft wide x 1,500 ft long, 500 ft gamma magnitude), was identified in a gravel covered area 4,500 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 shallow metal factor anomaly trending east-northeast of the principal mineralized area (Klein, 1974).

Dan Joe (Adams) prospect; N/2 section 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 section 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 1903-1904.

Globe prospect; section 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, four-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; section 1, T13N, R70W; and section 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 section 1, and the Good Hope in section 35. The Good Hope abuts against the Louise mine on the north (Beeler, 1906e).

The dominant rock type is foliated granodiorite; however, metadiorite and amphibolite are common in section 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 section 1 as well as a gossan in the E/2 SE section 1.

Great Standard group: This Group consisted of 17 lode claims including the Jolly Rover, Madeline no. 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 a trace of silver.

Hecla; section 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 four-foot-wide vein on one of the claim groups. A leasor shipped 20 tons of ore in March, 1916, and received $413.00 after the 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).

Lenox mine; section 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 ore body was intersected which trends north-northwest and dips to the northeast. The vein is 6 inches wide at the surface and 2.5 feet wide at 40 feet below the ground. 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 ficticous ore, highly selected specimens, or erroneous assays).*

London mine; E/2 section 35, T14N, R70W. In 1915, a shaft was sunk on a pyritized gossan in foliated granodiorite to a depth of about 60 feet. The ore was too low grade 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 section 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, with 143 feet of drifts on the 80-, 110-, and 160-foot levels (Beeler, 1907c). The shafts were sunk on a one-foot-wide northerly striking cupriferous vein.

A well-developed stockworks 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 bornite, chalcopyrite, chalcocite, malachite, azurite, and pyrite were found in the mine. The country rock is granodiorite with a small lense of garnet schist to the east.

Monte Cristo mine; SE section 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 section 36, T14N, R70W; A 500 foot adit was driven into granodiorite about 1,500 feet west of the Copper King mine in a tributary valley of Middle Crow Creek (Figure 29). 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, the mineralization was poor.

Rambler prospect; E/2 E/2 SE NE section 22, T14N, R70W; Located within Curt Gowdy State Park between the Granite Springs and Crystal Lake reservoirs (see Hecla). The Rambler prospect was developed by an 80 foot deep shaft on a 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, 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 due to retrogressive metamorphism. But at the Rambler prospect, propylitization is much more intense and associated with sulfides. Within a few feet of the mineralized fractures, the mafic minerals are completely replaced by chlorite and the feldspars are relatively unaffected, megascopically. More intense alteration adjacent to the vein, is expressed as pervasive propylitic alteration and the mafic minerals and feldspar are altered to chlorite, epidote, and calcite (Hausel, 1981a; Hausel and Jones, 1982).

Roberts Ranch copper prospect; S/2 section 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. The 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; section 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).

NE section 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,

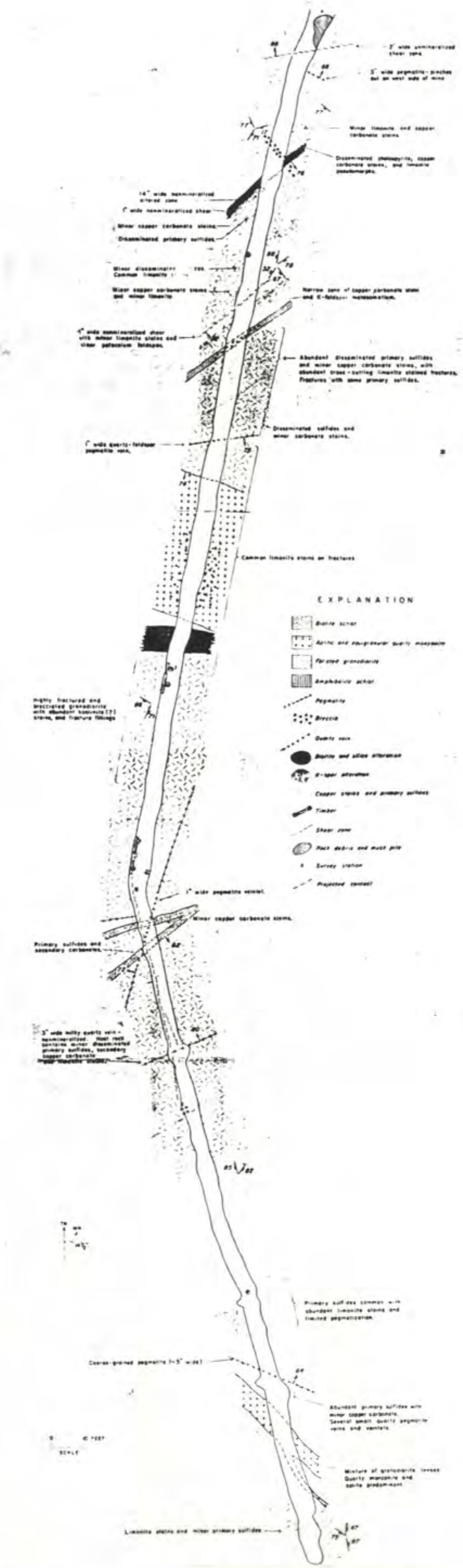


Figure 29. Geological map of the Orenogo Mine (from Hausel and Jones, 1982).

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 section 6, T13N, R69W; A shaft located on the U.S. Geological Survey 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 section 1, T13N, R70W; A 20 foot shaft was sunk on N80°E striking, 67°N dipping copper carbonate stained quartz veins. The largest vein is two 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.

Julian Lode. Located 0.5 mile from the Lenox mine near the bank of the 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 in the bottom of the shaft (Aughey, 1886, p. 4).

Warbonnet district

The Warbonnet district, bearing the name of a prominent peak situated in section 35, T29N, R75W of Converse County, is described by Spencer (1916) to include 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 section 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 section 12, T29N, R75W. 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 adits are located on the U.S. Geological Survey Warbonnet Peak 7.5 minute topographic map.

The Copper King vein is hosted by a diabase dike with schistose texture. The vein and dike trend N30°E to N40°E in granite country rock, and can be traced for 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 two miles southwest, a small deposit of massive magnetite was discovered (Spencer, 1916).

LaBonte Prospect; NE section 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 sections 27 and 28, T28N, R74W. A 50 foot wide quartz vein is traceable on the surface for at least 2,000 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 was sunk on the property and exposed some chalcocite.

Oriole mine; E/2 SE section 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°W, 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, 0.055% and 0.086% Mn, 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 much as 20 to 30 feet wide.

Pyramid shaft; NW NW section 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 three 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 1,000 feet of drifts and cross-cuts which exposed weakly pyritized rock (Spencer, 1916, p. 73).

Olin mine: SW NW section 5, T29N, R75W; A shallow, 12 foot deep shaft, was dug for copper in granite. No other information is available.

Miscellaneous Localities in the Laramie Mountains

Bucaneer group; section 10, T12N, R71W. Located six 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 section 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 section 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 underlying Sherman Granite (Precambrian).

Native copper, cuprite, and malachite locally stain sand grains and pebbles in the arkose and replace the 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 was later filled with dump material and log cabin home constructed over the workings.

Percis claims; sections 1 & 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 the Casper limestone (Hagner, 1942d).

Sawmill Canyon; E/2 section 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 was probably mobilized by groundwater along the fault. This deposit is similar to the Copper Float and King Solomon prospects further to the south.

Sherman group; section 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).

Strong mine; Located in the NW NW section 4, T16N, R71W, near the head of Horse Creek. From 1900 to 1915, the Strong Mining Company produced some copper (Beeler, 1942). The shaft was later 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 1,308 feet of tunnels by 1907 (Figure 30) (Beeler, 1907d). Beeler (1942) later suggested that the total amount of development in the mine was considerably greater. The shaft was sunk in 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 50 feet deep. On the 100-foot-level, the vein was seven feet eight inches wide. On the 150-foot-level, the width varied from one to 9 feet. On the 250-foot-level, a drift driven to the south cut 125 feet of a crushed quartz which contained chalcocite, bornite, and chalcopyrite. Another drift intersected 30 feet of streaks and masses of chalcopyrite 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 were also 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 of 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 ores were chalcopyrite and bornite, with some chalcocite.

In 1942, the mine was reopened under a Reconstruction Finance Corporation loan for scheelite (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 below (Troyer, 1946):

Weight (lbs)	Tungsten (WO_3)(%)
10,650	0.44
16,660	0.39
10,250	0.44
14,840	0.49
11,980	0.44

Beeler (1942) reported the following assays for the Strong mine:

Depth (feet)	Copper (%)	Gold (opt)	Silver (opt)
9	19.3	0.68	0.88
9	19.85	tr	7.86
11	5.08	tr	13.72
11	13.33	0.01	3.20

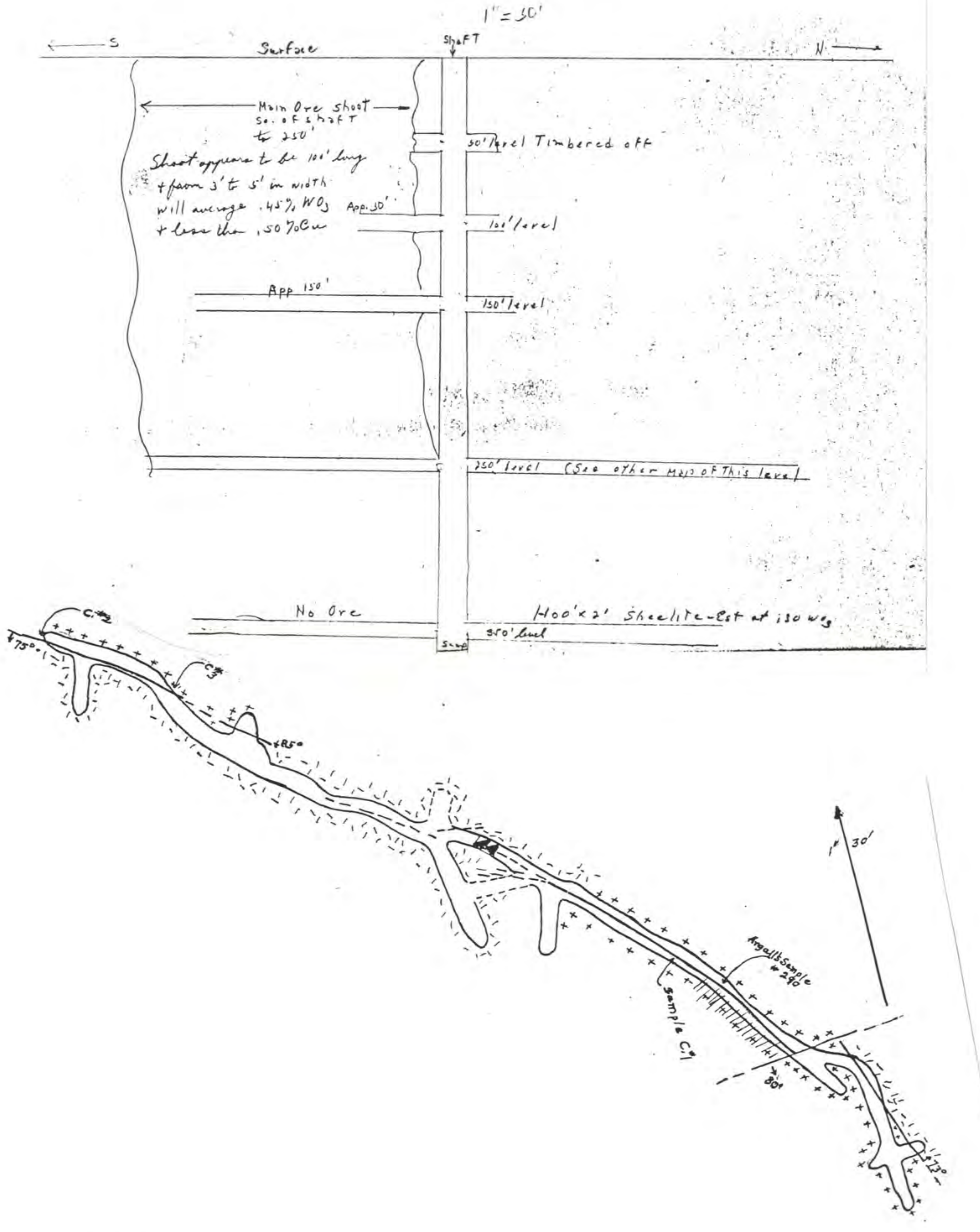


Figure 30. Sketch cross-sectional map and geological map of the 250 foot level of the Strong mine (after Troyer, 1946)

13	38.81	0.04	6.86
15	32.91	tr	7.70
15	43.12	tr	tr
15	35.48	tr	4.00
21	7.55	0.08	3.68
25	19.93	tr	5.30
25	39.96	tr	5.10
26	34.76	tr	5.40
28	30.37	0.04	6.76
38	20.56	0.16	3.60
49	51.56	0.18	3.50
50	16.03	tr	2.80
50	22.00	--	--
54	25.26	tr	2.50
58	26.02	tr	tr
58	26.24	tr	3.70
58	36.82	tr	2.95
80	68.00	--	--
80	68.50	--	--
85	26.64	--	--
85	45.50	--	--
90	20.50	--	--
92	29.50	--	--
100	22.80	--	--
100	42.00	--	--

Four pounds of ore from a depth of 70 feet were assayed for nickel. The sample assayed 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 some remarkable gold values. In addition to copper, silver, and nickel, some samples assayed as much as 50 opt Au (Beeler, 1906l, p. 63).

Wallrock Canyon; section 36, T19N, R73W. Chrysocolla and chalcocite occur as replacement veins lining small fractures and also 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; Located in sections 10, 15, and 22, T16N, R72W. Copper occurs in limestone of the Casper Formation several hundred feet (stratigraphically) above the granite-limestone contact. Three mineralized bodies occur as small, irregular, replacement veins that line fractures. In section 22, copper was found in loose angular blocks and fragments of limestone. Copper minerals include malachite, chalcocite, chrysocolla, brochanite, and bornite. The 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 metasedimentary rocks to the north, are separated from younger metavolcanic and metasedimentary rocks to the south. These contrasting rock successions are separated by a major east-west trending crustal suture that divides the Medicine Bow Mountains in two. The suture is known locally as the Mullen Creek-Nash Fork shear zone and 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 age subduction zone separating cratonic rocks to the north from 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 to the 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 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 1,750 ppb Pt plus Pd, and 17 mineralized samples from five different mines averaged 3,050 ppm Cu (Houston and others, 1975).

Historically, the Medicine Bow Mountains were initially swarmed 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 along the southwestern flank of the Medicine Bow Mountains within the foot hills at the North Platte River. 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 some narrow quartz veins containing gold and minor copper (Hausel, 1989).

The area is underlain by interlayered Precambrian feldspar-quartz-biotite gneiss and hornblende gneiss and schist folded 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 rock 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).

Mines and prospects

<u>Big Creek (Bonanza, Cox) mine</u>: sections 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 $2,300 worth of copper ore (about 11,500 lbs) 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 which intrudes Precambrian schists and gneisses. The dike is conformable to 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 the 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. Samples collected from the dike in 1934 included:

Sample Description	Cu(%)	Au(opt)	Ag(opt)
15 ft sample, 100 ft from portal.	4.1	0.005	0.6
14 ft sample, from small stope.	4.6	0.005	0.7
18 ft sample in drift.	3.9	trace	0.1
27 ft sample, hanging wall side of drift.	4.2	trace	0.2
66 ft sample, south side of drift.	4.3	trace	0.3
12 ft sample, north side of drift in small stope.	4.8	trace	0.5
19 ft sample, crosscut, northwest face.	6.0	trace	0.1
12 ft sample, east wall of same crosscut.	5.1	trace	0.1
12 ft sample, footwall, 150 ft 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, some native copper and copper carbonates were found. Below the surface, chalcopyrite, chalcopyrite, and covellite were encountered (Beeler, 1903h).

Natures Mint mine; section 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 some 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 age metasedimentary rocks with minor mafic intrusives (Figure 31). 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. Many years 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).

The activity in the district was short-lived in that the veins were narrow with no possibility of extending minable reserves at depth, i.e., Cooper Hill is an allochtonous block of layered Proterozoic metamorphic rock thrust over much younger unmineralized

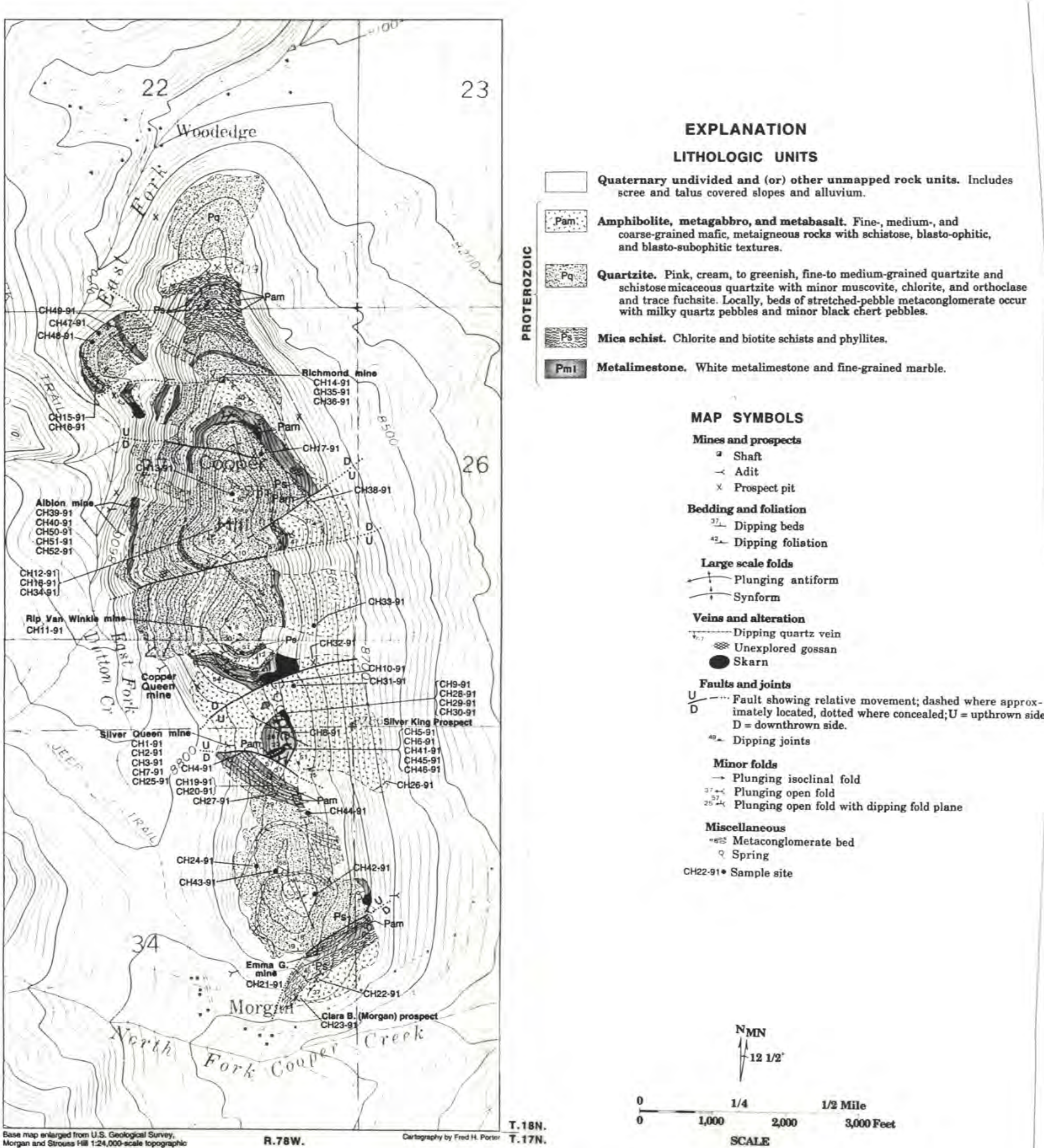


Figure 31. Geological map of the Cooper Hill district (From Hausel, 1994b).

Cretaceous sedimentary rock. Therefore, the Proterozoic-age veins can have no appreciable depth. 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, cerrusite, and limonite.

Albion mine: W/2 section 27, T18N, R78W; The Albion vein was developed by two tunnels on a horizontal vein (Figure 32). The vein consists of frayed quartz in metalimestone which cuts across lithologies into a footwall quartzite. Where hosted by metalimestone, the vein carried pyrite, chalcopyrite, chalcocite, and bornite. Where hosted by quartzite, the vein carried argentiferous galena. Samples collected from the deposit range from 0.62% to 1.12% Pb, 0.05 opt to 0.7 opt Au, 1.66 opt 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 to run as high as 350 opt Ag, 9 opt Au, and 40% Pb (Hausel, 1994a).

Cooper Creek adit: SW section 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 33). The vein was poorly mineralized. Samples collected from the vein and dump ranged from none to >2.0% Cu, none to 0.71 ppm Au, none to 1.9 ppm Ag, and none to 128 ppm Pb (Table 12) (Hausel and others, 1994).

Croesus tunnel: The mine was reported to be on the east side of Cooper Hill about a half mile from the Albion mine. The claim was apparently located on a large vein of silicious gold, copper, and silver ore. Historical reports also indicate the ore body was 18 feet wide and carried gold and copper pyrites that averaged 0.4 opt Au and 14% Cu. In 1902, the tunnel was 1,236 feet long, and it was reported that ore from one of the drifts assayed as high as 2.1 opt Au (Hausel, 1992d, 1994b).

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

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 section 27, T18N, R78W, 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 which intersected a vein reported to have free milling gold at a depth of 20 feet. Mill runs of ore from the mine were reported to average 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,

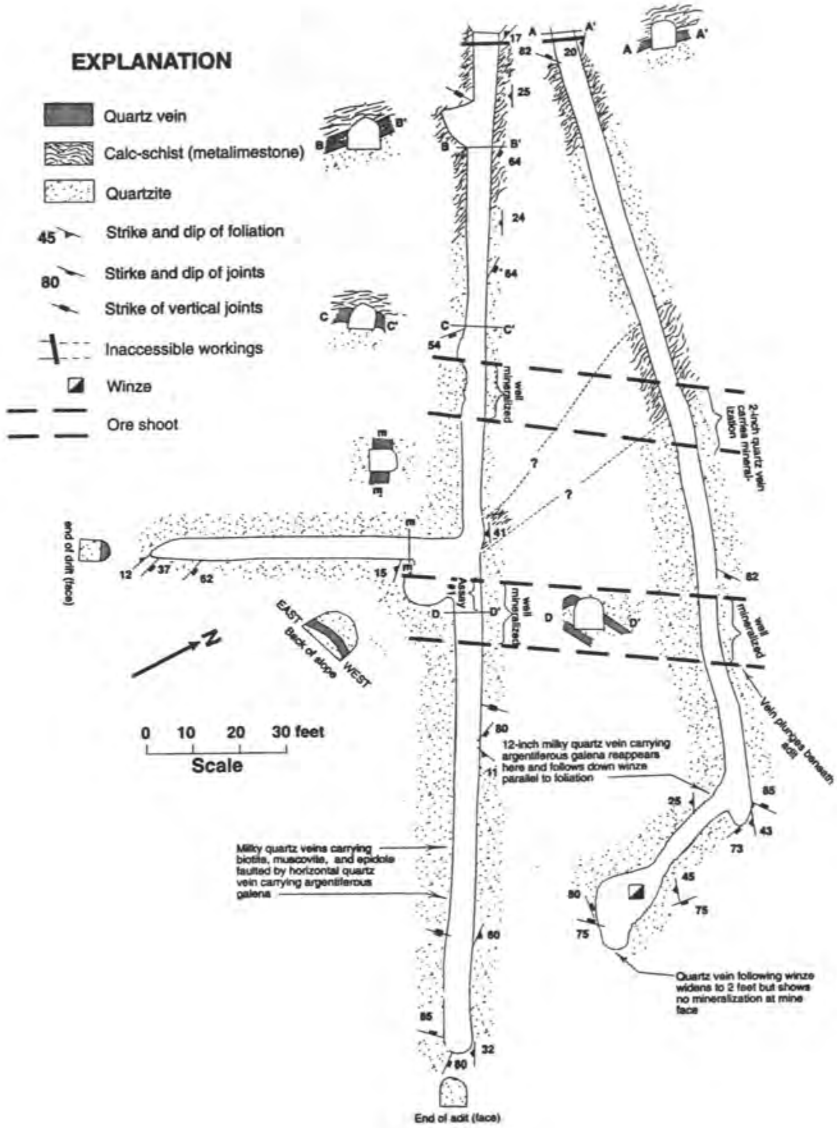


Figure 32. Geological map of the Albion mine (after Schoen, 1953).

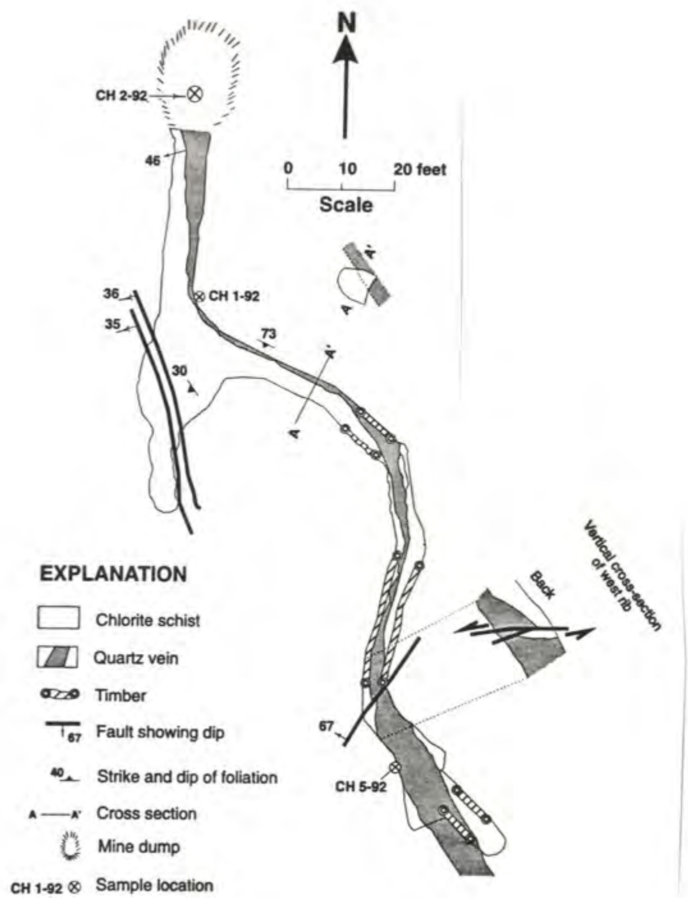


Figure 33. Geological map of the Cooper Creek adit (after Hausel, 1994b).

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 12) (Hausel, 1994b).

Silver King prospect: N/2 NE section 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. A narrow quartz vein in the prospect carries some chalcopyrite, chalcocite, and minor malachite.

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 12) (Hausel, 1992d).

Silver Queen adit: N/2 N/2 section 34, T18N, R78W. Ore minerals found on the mine dump included chalcopyrite, cuprite, malachite, chrysocolla, and limonite. Chalcopyrite-bearing amphibolite schist from the mine 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 12) (Hausel, 1994b).

Table 12. Assays from the Cooper Hill district (from Hausel, 1994b) (Refer to Figure 31 for sample locations).

Sample #	Description	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-ft 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

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 were in this region were developed on copper shows in granite.

American mine; SW section 16, T12N, R78W; This mine is located one-half 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 section 9, T12N, R79W; Located near Pelton Creek. The mine consisted of a sixty-foot shaft sunk in quartz monzonite gneiss. No ore minerals were found on the dump, but the shaft was presumably sunk to intersect a chalcopyrite-molybdenite-bearing pegmatite which crops out a short distance to the northwest (Swetnam, 1961).

Elk Mountain district

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

Cumberland group; 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. Another similar deposit known as the Camperdown group was located north of the Cumberland (Beeler, 1905a).

M & M's Elk Mountain mine; Sections 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 with 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 4,380.21 pounds of copper (14% Cu).

French Creek district

The French Creek district includes some massive pyritiferous sheared graphitic schists that have been the focal point of some recent gold scams. Beeler (1905a) reported some silicious 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 oxides of iron and manganese and exposed some graphitic schist. The nearby Raven group showed similar rock.

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

Lorain Group: Sections 11 and 12, T15N, R80W; Iron sulfides (pyrrhotite) occur in graphitic schist (Beeler, 1904i).

Raven Group ; sections 15, 21, 22, T14N, R80W; Located on Iron Creek. A siliceous zone stained by limonite and hematite lies along the contact of 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 some 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 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 34). 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.

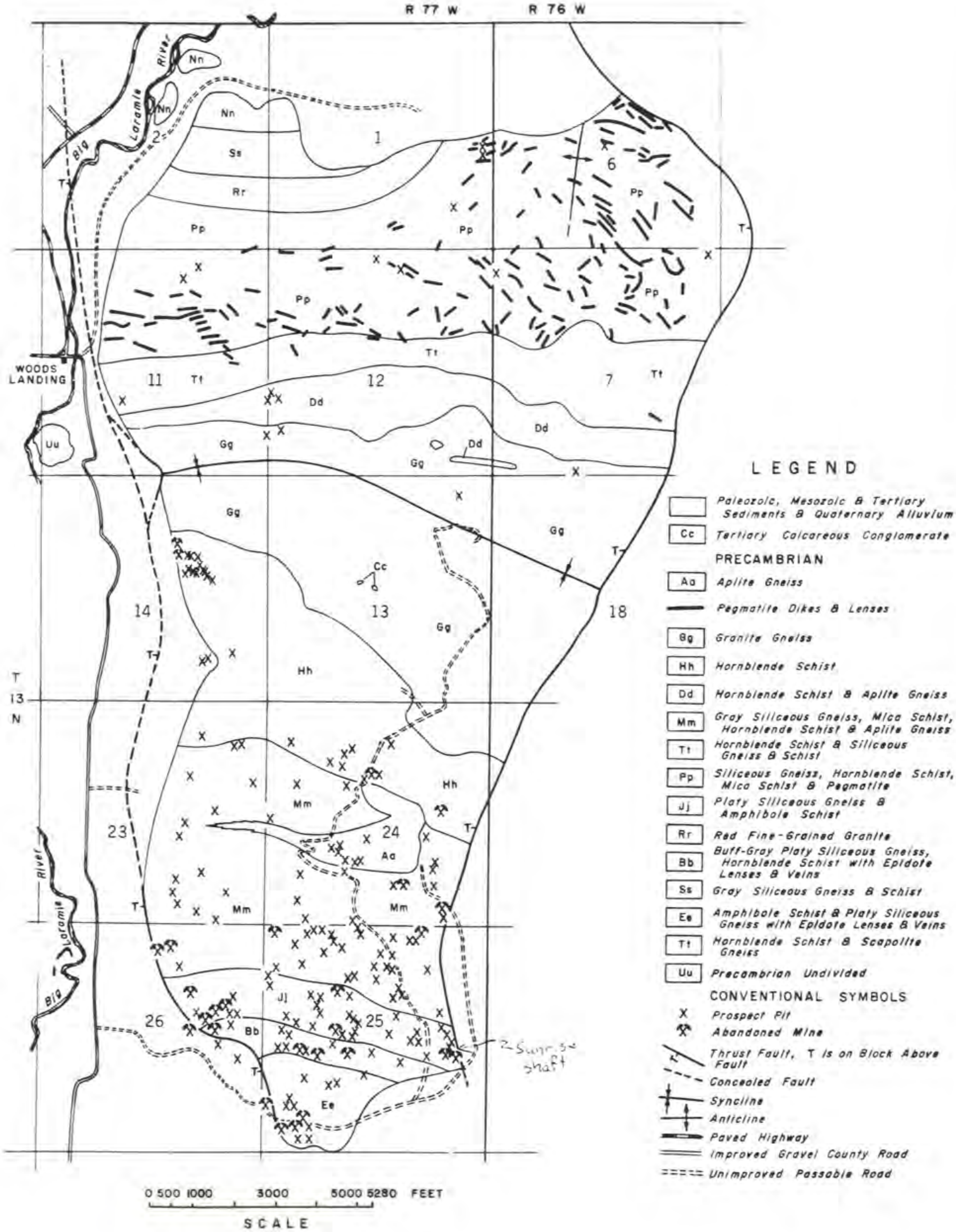


Figure 34. Geological map of the Jelm Mountain district, Wyoming (after Michalek, 1952).

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 to regional foliation (Michalek, 1952). Many of the mines and prospects were initially developed for gold, but the gold values declined at shallow depths below surficial gossans. Below the gossans, copper mineralization was prevalent.

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 the metals to nearby dilation zones. The hydrothermal solutions were suggested to have emanated from late intruding granites.

Mines and prospects
<u>Annie mine</u>; NE section 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 2,250 to 3,000 feet on an east-west strike conformable to regional foliation. In 1906, development work included a 140 foot shaft which was 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 (1906a) reported two assays of select ore from the mine yielded 15.53% Cu and 28.83% Cu.

<u>Barber mine</u>: W/2 SE section 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 was caved when examined in 1991, it was not possible to determine the extent of the mine workings; however, based on the size of the dump the workings were probably in the range of several hundred feet. In all probability some ore had been shipped from the mine, although 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.

Five samples were assayed and yielded the following metal contents:

Sample no.	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 3,000 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 one half mile southwest of the former Cummins City settlement. A 24 foot thick fissure strikes northwest and dips to the southwest. The Copper Queen mine was developed by an 80 foot shaft sunk in 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).

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

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

E/2 section 26, T13N, R77W; 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 wallrock 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 in at the mouth of a narrow canyon along the southwestern margin of Jelm Mountains was sampled by the author in 1993. A 4 foot composite chip sample collected in 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, 4,306 ppm (0.43%) Zn, and no gold (Hausel, personal field notes, 1993).

W/2 section 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 a minor pyrite and a trace of 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 section 25, T13N, R77W; A shallow shaft was sunk on a shear zone along the contact between pink felsite and grey 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 section 25, T13N, R77W; At another shaft, select samples of milky quartz in amphibolite contained minor chalcopyrite, malachite, and cuprite.

W/2 section 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 section 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 section 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, and the Keystone district was established. In the following year of 1877, 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 35).

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

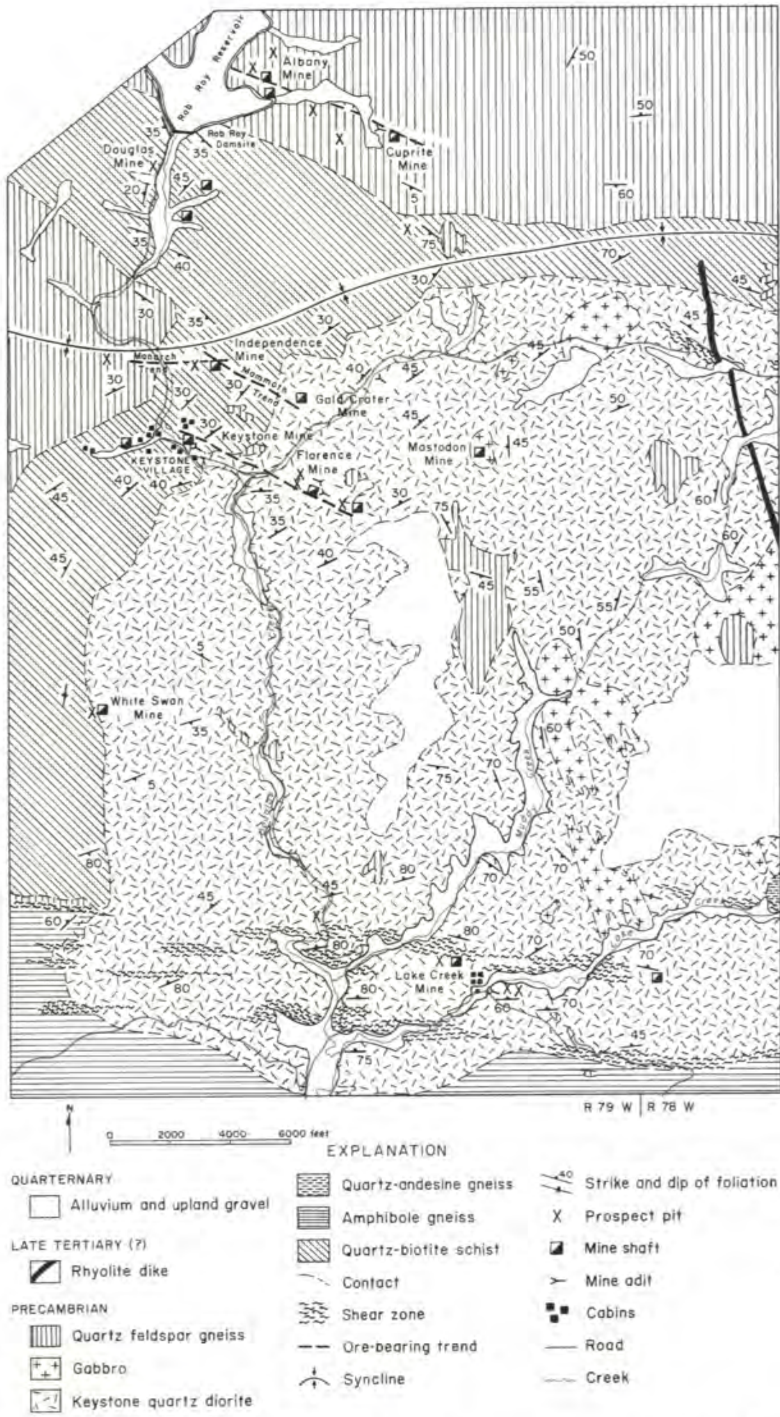


Figure 35. Geologic map of the Keystone district (modified from Currey, 1965).

principal ore bodies 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).

The Keystone district surrounds the village of Keystone in the Medicine Bow Mountains and is considered to include all the lode deposits related the Keystone quartz diorite. Most base and precious metals deposits in the Keystone region consist of gold- and copper-bearing pyritic quartz-carbonate veins that occur in northwest-trending tensional faults subsidiary to the Mullen Creek-Nash Fork shear zone. Some sparse mineralization also occurs within major northeast-trending shears (Currey, 1965).

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

Cuprite mine; NW section 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, a trace to 2.56 opt Au, and a trace to 2.0 opt Ag. Trace cobalt and chromium were also detected. The veins 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 section 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 seven-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, 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; section 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 section 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 (EMJ, 1890, Jan. 25, v. 49, 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 no gold to 0.03 opt Au and no silver 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 2,500 ounces of gold.

<u>Gold Crater group</u>; SE section 15, NE section 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 section 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 fifty 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 none to 0.03 opt Au, and none 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).

<u>Hamilton Group</u>; section 36, T14N, R80W, 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).

<u>Independence mine</u>; S/2 SW section 15, T14N, R79W. This prospect was originally called the Mammoth. In the early 1900's, 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 of a 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).

<u>Keystone mine</u>: NW section 22, T14N, R79W. The Keystone mine was principally a gold property and it's not known if any copper was recovered from the mine. The shaft was sunk to a depth of 365 feet with 5,000 feet of drifts on an oreshoot in the Keystone-Florence trend. The Keystone-Florence trend is a N60°W-trending shear zone in diabase that intrudes quartz-biotite gneiss 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 5,000 to 10,000 ounces of gold. For instance, EMJ (1890, Jan. 25, v. 49, p. 118) reported production at 10,000 ounces of gold from ore that averaged 0.84 opt Au. However, several months later, EMJ (1890, Nov. 22, v. 50, p. 607) reported the Keystone mine produced only

3,750 ounces of gold up to 1889. Gold production continued after these reports as was indicated in 1891, when the EMJ (1891, Apr. 18, v. 51, p. 480) reported the Otras Mining Company was recovering about 50 ounces of gold per week. In 1893, mining operations ceased with 6,000 tons of ore on the dump, and another 100,000 tons of reserves identified underground (Currey, 1965).

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 no silver 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, 1900).

SE section 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 (T13N-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 of the schist 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; section 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 section 12 and Beeler's location would be only about two 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 section 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 section 1, T13N, R79W. Located on Lake Creek, three 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 owners 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 1,000 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 greatly 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 2,000 feet. Recent samples collected from the shear yielded 0.063 ppm to 4.8 ppm Au (Dersch, 1991; Hausel, 1993c).

Bellamy Lake mine: section 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 36). The Mullen Creek complex is a 60 mi^2, highly deformed, 1.8 Ga (billion year old), layered tholeiitic intrusive. The complex includes more than 21 cyclic units (Loucks and others, 1988).

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

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

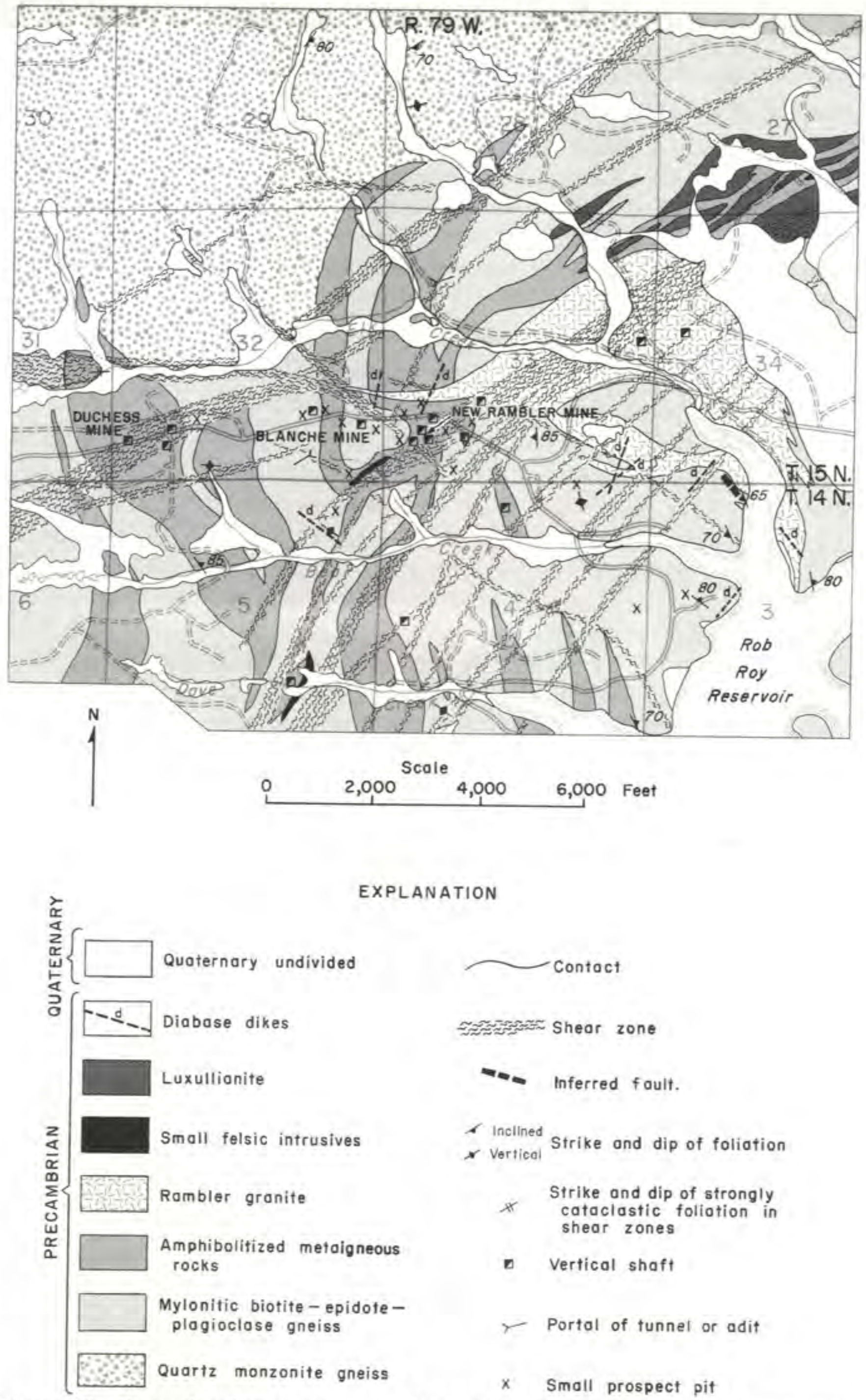


Figure 36. Generalized geologic map of the New Rambler district, Albany and Carbon Counties (modified from McCallum and Orback, 1968).

calcic plagioclase are partially altered, but biotite is unaltered. Magnetite and epidote veinlets are common.

Phyllic alteration resulted in the pervasive replacement of calcic plagioclase and albite, whereas the mafic minerals are 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).

Blanche mine; SE section 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 (Kleunder, 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 and 17.0 ppm Pt, 30.0 and 20.0 ppm Pd, and 20.0% and 17.0% Cu (Loucks, 1976).

Duchess mine; SW section 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: section 5, T13N, R79W and section 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, silver, with traces of platinum. Assays were reported to run as high as 1.94% 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 a trace of copper.

A nearby placer property was reported to yield values of 0.04 opt Au with assays as high as 0.21 opt Au. The gravel also contained recoverable amounts of native mercury worth about $0.4 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: section 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 section 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, 1942).

The New Rambler shaft was sunk to a depth of 170 feet and more than 5,000 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 37). Coarsely crystalline, sheared, epidotized granite (Rambler

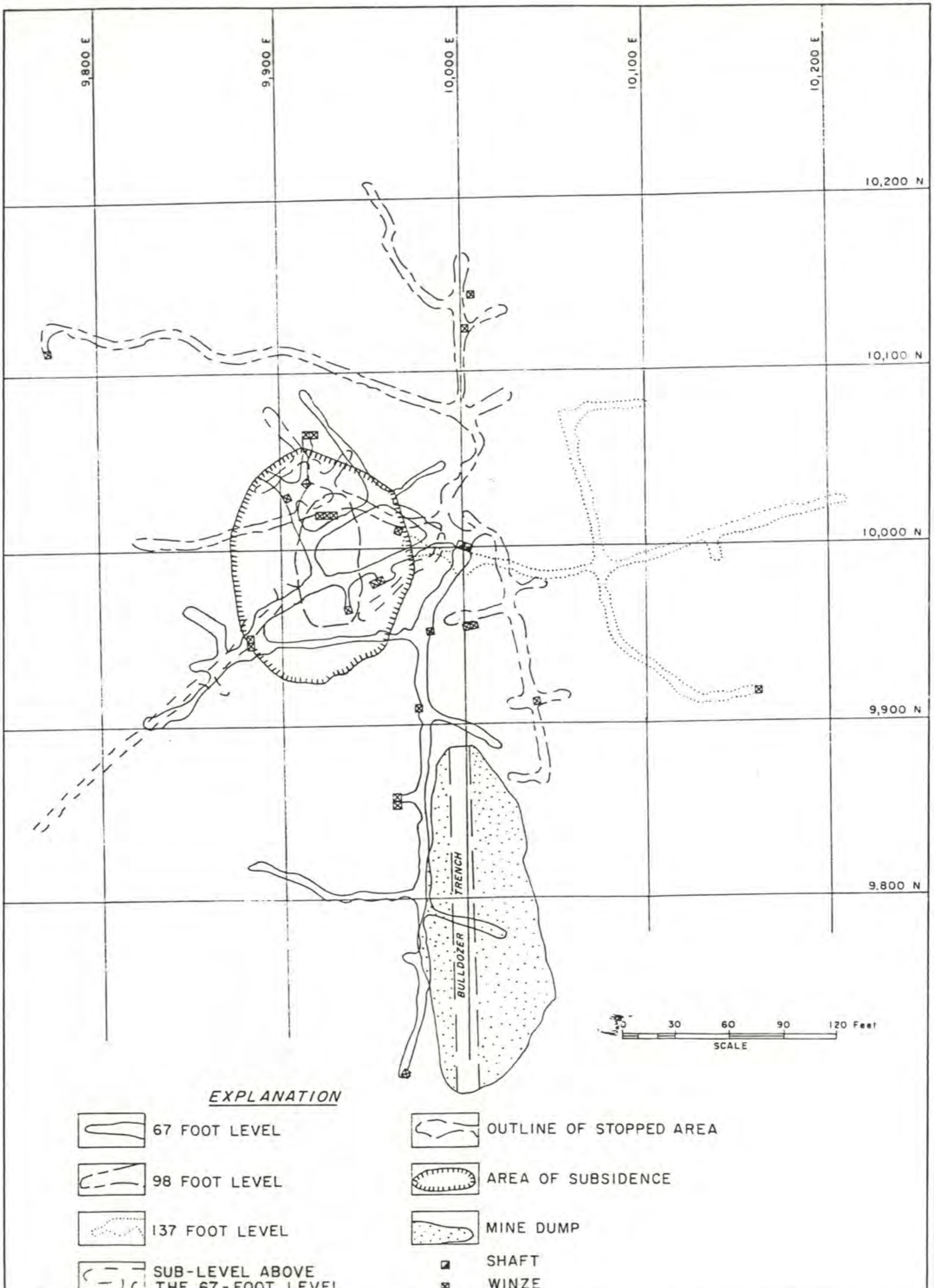


Figure 37. Mine workings of the New Rambler Mine (after Kasteler and Frey, 1949).

granite) was encountered at a relatively shallow depth. Both diorite and peridotite were also reported in the main shaft (McCallum and Orback, 1968; McCallum and others, 1976).

The New Rambler ore body 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) are probably 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 ore bodies 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 7,000 tons of 7 to 8% Cu, 0.25 opt Pt, with some gold and silver (Needham, 1942). The mine dump was estimated to contain 7,900 tons of waste rock.

Mine production is estimated at about 6,100 tons of copper ore with values in gold, silver, platinum, and palladium. Before any platinum group metals were identified, approximately 4,000 tons of high-grade 25% to 30% copper ore was mined and processed for which no payments were received for the platinum.

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 to range from 3.24% to 61.37% Cu, 0.0007 opt to 1.4 opt Au, 1.01 opt to 7.5 opt Ag, 0.047 opt to 3.2 opt Pt, and 0.33 opt 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, 7,346 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 was probably much higher than reported by Needham, and was on the order of 16,870 ounces of palladium and 910 ounces of platinum.

A series of assays ran 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 13). Theobald and Thompson (1968) also sampled the tailings and obtained similar results. Their samples yielded 80 ppm to >6,000 ppm Cu, 0.5 ppm to 55 ppm Ag, <0.03 ppm to 1.3 ppm Pt, 0.3 ppm to 9.2 ppm Pd, 0.02 ppm to 3.0 ppm Au with traces of arsenic, tellurium, molybdenum, lead, and zinc (Figure 38).

Table 13. Copper-platinum assays of 5-foot channel samples from the New Rambler mine dump (from Kasteler and Frey, 1949).

Sample number	Cu (%)	Platinum metals (opt)

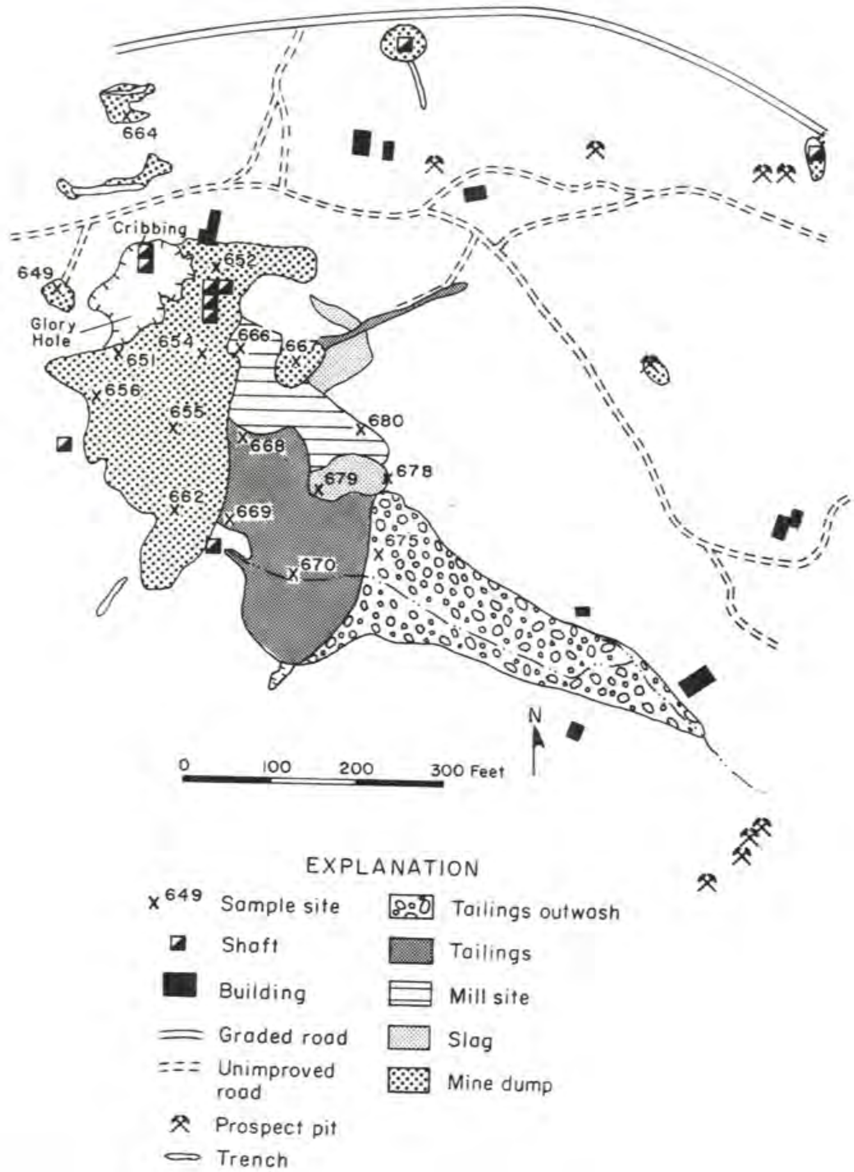


Figure 38. Plan of mine waste and sample locations from the New Rambler mine area (after Theobald and Thompson, 1968).

Appendix - Table 1A. Geochemical analyses of mineralized samples and related rocks from the Seminoe Mountains.

Sample No.	Description	Au (ppm)	Ag (ppm)	Cu (%)	Pb (ppm)	Zn (ppm)	Cr (ppm)	Ni (ppm)
42A	Milky quartz stockworks in chlorite schist	1.3	4.0	0.14	14	43	- -	- -
43A	Weakly iron-stained schist	<0.05	2.1	- -	- -	- -	- -	- -
44A	Limonite-cemented fault breccia w/goethite	<0.05	1.1	- -	- -	- -	- -	- -
45A	Cupriferous felsite from prospect pit	<0.05	<1.0	4.4	16	39	- -	- -
46A	1 ft channel, across Cu-stained shear	0.07	45.4	1.8	220	47	- -	- -
47A	Cu-stained quartz, Sunday Morning prospect	2.1	26.9	5.8	1,970	140	- -	- -
48A	10 ft composite, mafic wallrock, Junk Creek	<0.05	1.7	0.78	- -	- -	- -	- -
49A	Azurite-malachite-tenorite-limonite-quartz	0.05	1.4	1.2	- -	- -	- -	- -
50A	Cu-stained quartz	0.15	2.7	3.7	66	2,920	- -	- -
51A	Quartz from mine dump	<0.05	<1.0	- -	- -	- -	- -	- -
52A	Quartz in fold closure from prospect pit	4.6	5.2	0.12	54	22	- -	- -
53A	Cu- Fe-stained fracture in metatholeiite	12.0	55.0	3.75	25	250	- -	- -
54A	Limonite-stained metatholeiite	9.8	12.0	0.81	10	85	- -	- -
55A	Vein quartz, south of Emeletta mine	2.2	3.5	0.11	5.4	28	- -	- -
56A	Wallrock adjacent to stockwork	0.12	<1.0	0.09	3.0	120	- -	- -
57A	Cu-stained quartz w/ minor pyrite	8.8	6.8	0.37	23	120	- -	- -
58A	Cu-stained quartz w/ minor pyrite	11.0	9.3	0.94	75	480	- -	- -
59A	Quartz with chalcopyrite, covellite, and pyrite	2.2	26.0	1.61	11	110	- -	- -
60A	Banded metachert	<0.05	3.3	0.03	3,890	43,000	- -	- -
61A	Cu-stained boxworks	0.05	8.1	0.28	2,180	25,000	- -	- -
62A	Boxwork quartz, Deserted Treasure #2 mine dump.	28.0	18.0	0.39	- -	- -	- -	- -
63A	Boxwork quartz, Deserted Treasure #2 mine dump.	20.0	18.0	0.38	- -	- -	- -	- -
64A	Quartz w/ chalcopyrite & bornite.	0.87	<2.0	0.06	- -	- -	- -	- -
65A	Selected quartz, Deserted Treasure #1 dump.	1.2	3.6	- -	- -	- -	- -	- -
66A	Limonite-stained quartz in fold closure, King mine.	6.8	4.2	- -	- -	- -	- -	- -
67A	Sulfide-bearing amphibolite.	35.4	- -	- -	- -	- -	- -	- -
68A	Select sample quartz, Deserted Treasure #2 dump.	89.3	- -	- -	- -	- -	- -	- -
69A	Select boxwork quartz breccia, Apex mine.	0.004	4.0	0.53	9,530	2,330	- -	- -
70A	3 ft composite, quartz breccia, Apex dump.	0.003	0.5	0.14	175	108	- -	- -
71A	Cu-stained mafic schist, Apex mine.	0.013	63.8	3.81	92	68	- -	- -
72A	Cu-stained schist, Apex mine dump.	0.001	0.3	0.49	61	131	- -	- -
73A	Cupriferous, amphibolite-hosted, quartz vein.	0.038	3.6	3.43	3	11	- -	- -
74A	Stockwork in ultramafic schist.	0.010	<0.1	- -	- -	- -	2,771	1,379

75A	Metagabbro	--	--	--	--	--	27	65
76A	Cu-stained schist from prospect pit.	0.14	0.2	4.7	10	622	--	--
77A	Milky quartz with boxworks.	0.027	1.7	--	--	--	206	15
78A	Quartz w/ limonite boxworks.	<0.010	<0.5	--	--	--	--	--
79A	Serpentinite w/asbestos & minor chromite.	<0.010	<0.5	--	--	--	6,000	1,700
80A	Talc serpentine schist, disseminated limonite.	<0.010	<0.5	--	--	--	1,900	2,400
81A	Limonite-stained milky quartz.	<0.010	0.8	--	--	--	--	--
82A	Limonite-stained serpentinite.	--	--	--	--	--	7,600	627
83A	Cu-stained quartz, Charlie's glory hole.	<0.05	0.33	0.52	30.1	106	--	
84A	Gossan adjacent to spinifex metakomatiite.	<0.05	<1.0	--	--	--	66	43
85A	Iron-stained schist.	<0.05	<1.0	--	--	--	--	46
86A	Banded amphibolite.	<0.05	<1.0	--	--	--	--	--
87A	Massive gossan with boxworks.	<0.05	<1.0	--	--	--	--	--
88A	Gossan cut by quartz & carbonate vein stockwork.	<0.05	<1.0	--	--	--	--	--
89A	Iron-rich gossan at serpentinite base.	<0.05	<1.0	--	--	--	202	23
90A	Limonite-cemented milky quartz breccia.	<0.05	<1.0	--	--	--	--	--

Appendix - Table 2A. Geochemical analyses of mineralized samples from the Rattlesnake Hills district, Granite Mountains, Wyoming.

sample no	Ag (ppm)	Au (ppb)	Zn (ppm)	As (ppm)	Sb (ppm)	Cu (ppm)	Pb (ppm)	Hg (ppm)	
RH1-92	1.2	114	35	88	38.6	38	197	<0.01	
RH2-92	1.8	21	90	124	2	432	1307	<0.01	
RH3-92	2	52	59	20	1.4	123	61	0.021	
RH9-92	<0.2	8	33	75	3.3	57	16	<0.01	
RH11-92	0.9	26	25	213	1.8	614	<2	0.139	
RH13-92	1.1	29	253	110	1.6	423	9	0.013	
RH15-92	0.2	157	18	1080	11	263	41	<0.01	
RH18-92	0.5	16	53	68	4.6	22	11	<0.01	
RH20-92	1.2	925	12	16500	8.2	524	42	0.028	
RH22-92	0.6	<5	37	91	1.5	37	16	0.012	
RH23-92	0.2	92	4	131	0.4	125	8	0.372	
RH29-92	0.5	300	-	-	-	-	-	-	
RH30-92	1.8	<5	-	-	-	-	-	-	
RH31-92	<0.2	367	52	4720	2.5	835	12	0.101	
RH32-92	1.7	109	4	8820	3.1	37	<2	<0.01	
RH33-92	0.56	164	17	543	0.8	163	55	0.083	
RH35-92	<0.2	800	-	-	-	1000	-	-	
RH36-92	0.28	300	-	-	-	-	-	-	
RH37-92	<0.2	5000	-	-	-	-	-	-	
RH43-92	<0.2	<5	-	-	-	-	-	-	
RH44-92	1.5	10	-	-	-	-	-	-	
RH3-93A	<0.2	<5	34	-	-	49	7	-	
RH6-93	<0.2	28	42	290	7	285	17	0.043	
RH8-93	<0.2	103	78	222	6	128	67	0.04	
RH9-93	-	11	-	-	-	-	-	-	
RH13-93	<0.2	9	297	36	8	62	11	0.078	
RH14-93	<0.2	29	95	25	7	1369	14	0.015	
RH19-93A	<5	370	<200	345	11	-	-	-	
RH20-93	<5	44	<200	103	4.1	-	-	-	
RH21-93	<0.2	31	309	95	<5	167	13	<0.010	
RH23-93	<0.2	<5	137	<5	7	130	11	<0.010	
LMP82-1	-	7550	-	-	-	-	-	-	
LMP82-2	-	4460	-	-	-	-	-	-	
LMP82-3	1.03	1030	-	-	-	-	-	-	
LMP82-4	-	1370	-	-	-	-	-	-	

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	none
10	0.08	trace
11	0.10	trace
12	0.05	none
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

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 a trace of 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, none and 0.007 opt Pt, 0.4 and 1.2 opt Ag, and none and 0.4% Mo.

Skylark shaft: The Skylark shaft was located immediately north of the New Rambler mine. A 47-foot 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.

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

Section 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 section 35, T15N, R81W; A sample sheared rock collected from an adit yielded 0.5% Cu, 0.4% Mo, 0.5% Ti, and 0.4 opt Ag (Kluender, 1982).

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

N/2 NE section 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 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 several sites of potential economic interest where anomalous values in P_2O_5, V, Au, Ag, Cr, Mo, Zn, Cu, and Ni.

Lake Alice district

The Lake Alice district is situated near the center of the Overthrust Belt at the northernmost tip of the Fossil Basin and lies entirely in the upper plate of the Tunp Thrust, a prominent north-south trending thrust fault (Figure 39). Metal occurrences of the Lake Alice district are contained entirely within the uppermost portion of the 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, associated bleaching of the typically red host sediments. Prospect pits in the area are concentrated along this contact between the underlying Nugget Sandstone and the overlying Gypsum Spring Member.

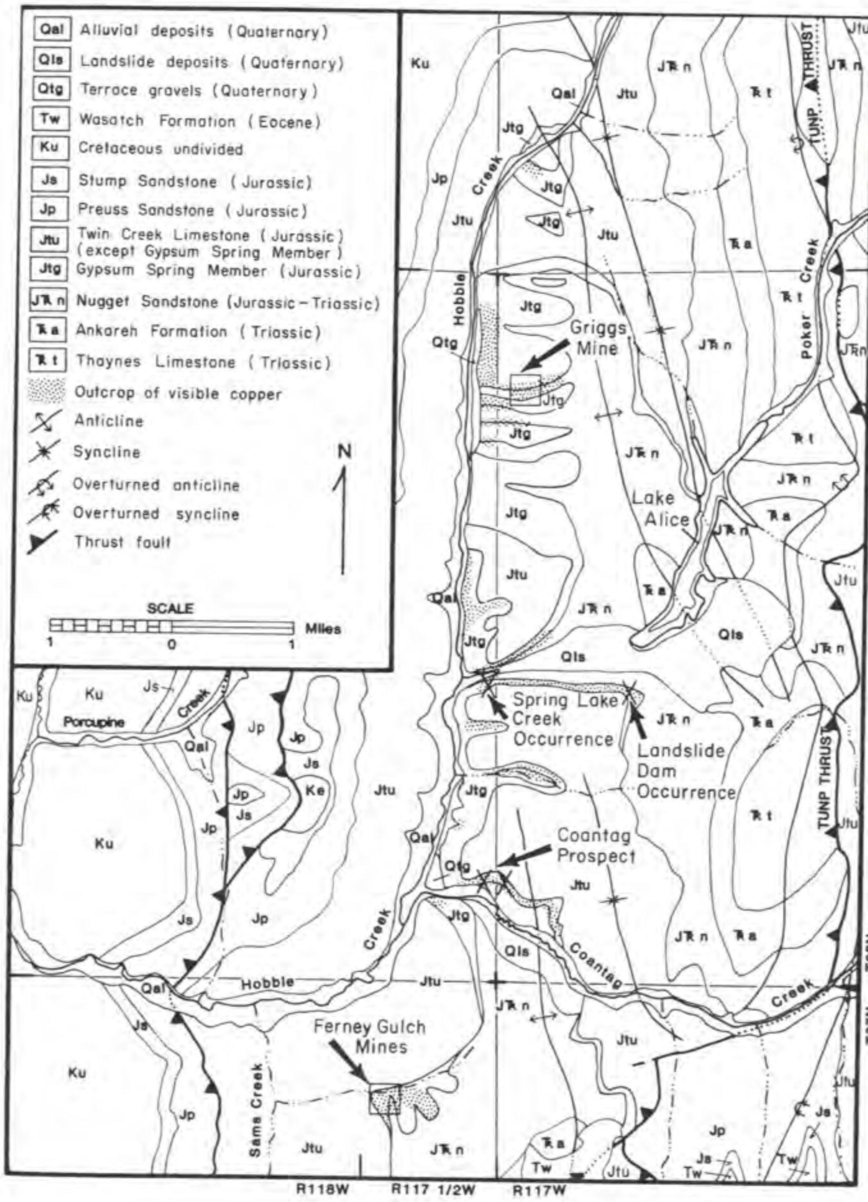


Figure 39. Geologic map of the Lake Alice district (modified from Loose and Boberg, 1987).

Generally, the most highly mineralized areas occur where significant structural preparation of the host rocks has occurred. Normal faults and an associated co-axial planar, joint-system which parallels the crest 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 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 Lake Alice district (Boberg, 1984; Loose and Boberg, 1987; Loose, 1988, 1990).

The mineralization most common at the Lake Alice district is disseminated sulfides which occur in various forms including interstitial pore fillings, poikioblasts, and clastic sand-grain replacements. The mineralization can also 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. Some 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 core hole drilled in the highly mineralized area at the Griggs mine in the district yielded mineralized zones from depths of less than 40 feet that ran 5 feet 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) indicates there is potential for discovery of a 100 million ton deposit with grades of 0.5 to 1.0% Cu, 2 to 5 opt Ag at depths of only 20 to 150 feet below the surface.

Big Park prospect; E/2 section 12, T27N, R117W; Copper-stained sandstone was reported at this locality by Love and Antweiler (1973).

Contag prospect; NE section 36, T28N, R117W; Malachite and azurite were exposed in a adit driven along the contact between the underlying Nugget Sandstone with 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; section 1, T27N, R118W; Some ore was shipped from the Ferney Gulch 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 a trace (63 ppm) cobalt (Hausel and Harris, 1983).

Griggs mine; section 7, T28N, R117W; bleached sandstone of the 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. The deposit occurs in a structurally prepared zone along the flank of a anticline (Boberg, 1983) over a vertical thickness of about 300 feet (Love and Antweiler, 1973). A locally continuous, 2 to 3 feet thick gray silty sandstone of Gypsum Spring Member contains some mineralization 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, a trace to 5,000 ppm Pb, 26 to 31,000 ppm (3.1%) Zn, and a trace to 1,200 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 40).

The Griggs mine contains three adits which 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 of the Twin Creek Limestone. 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 1,000 tons of ore on the mine dumps (Thomas, 1943).

Landslide dam prospect; section 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 section 24, T28N, R117W; A short 110 foot adit was driven into bleached Nugget Sandstone and intersected malachite and pyrite. Two samples collected from the ribs of the mine ran 500 ppm and 2,100 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).

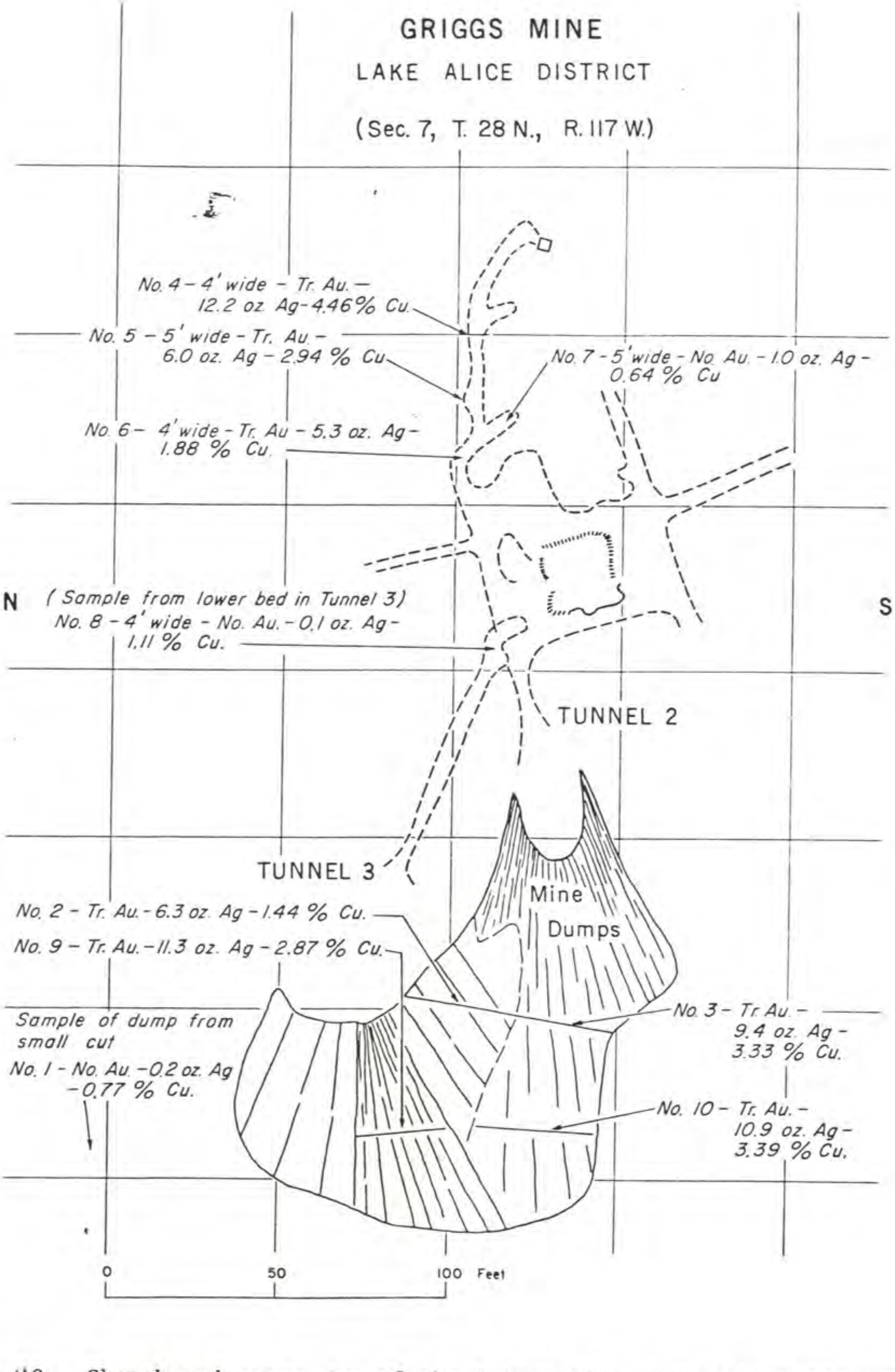


Figure 40. Sketch and assay map of the Griggs Mine, Lake Alice District (after Allen, 1942). North is assumed to be to the left hand side of the illustration.

Other Prospects in the Overthrust Belt

Cabin Creek; SW 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 was observed at the top of the Nugget Sandstone at this locality 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 a trace of silver.

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

East Gros Ventre Butte: SW NE section 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' 109°51'; Copper carbonate-stained Nugget Sandstone was reported along Mill Creek at this locality by Harris (1983).

Halfturn Creek; NE 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 recovered from a well (BELCO Petroleum Holback #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 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 ten 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 section 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 section 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 from 0.1 to 7.5% Cu, 70 to 360 ppm Zn, and 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 1,000 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 section 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. The Tertiary rocks along the southern margin of the Owl Creek Mountains conceal Paleozoic and Mesozoic rocks that overthrust by Precambrian rocks.

The Precambrian core of the Owl Creek Mountains has been subdivided into three different rock groups based on age. The oldest rocks are supracrustal metamorphics exposed within the Copper Mountain district (Figure 41). These formed about 2.9 Ga and were metamorphosed at about 2,750 Ma (Mueller and others, 1985). The metamorphic rocks were intruded by granites at 2,640 and 2,720 Ma (Gilletti and Gast, 1961). Later, both the supracrustals and granites were intruded by Proterozoic mafic dikes (1,190 to 2,100 Ma) with tholeiitic basalt compositions (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 is located within the Owl Creek Mountains of north central Wyoming. The district lies southeast of Thermopolis and northeast of Shoshoni.

The 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

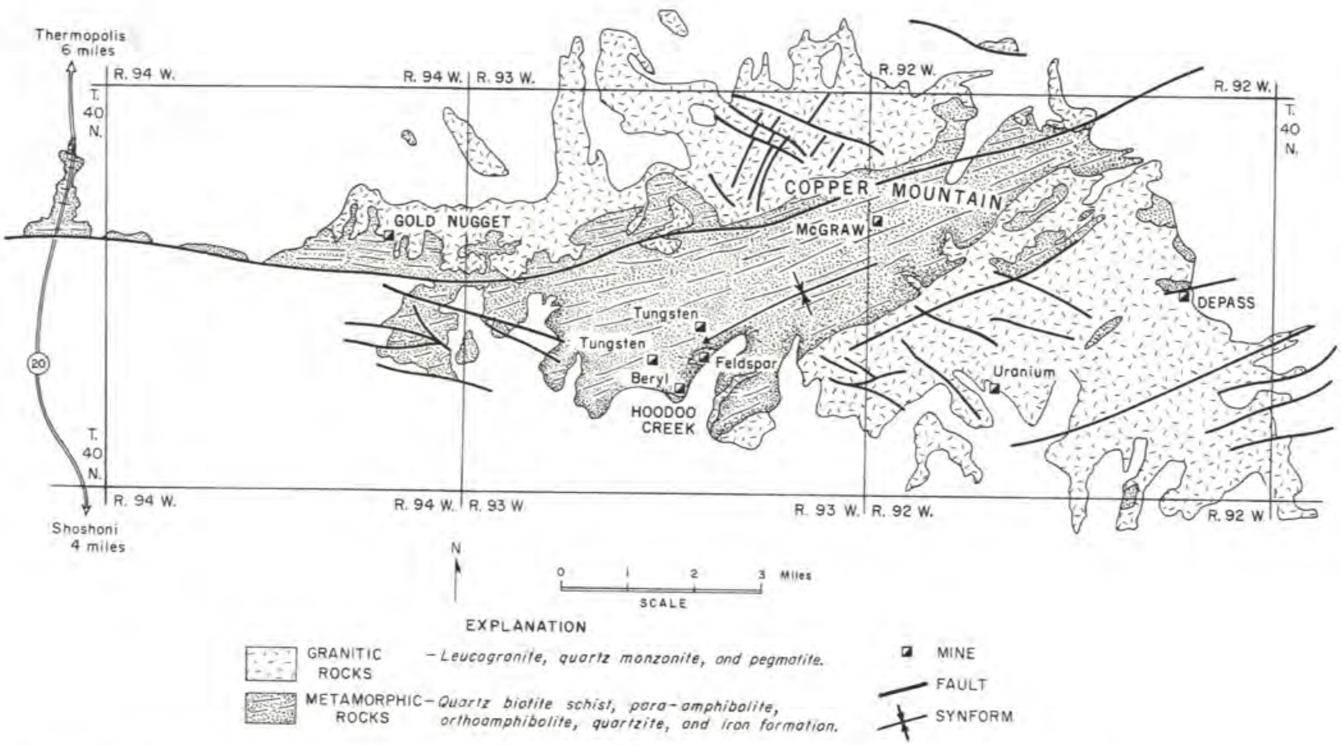


Figure 41. Generalized geologic map of Precambrian rocks in the Copper Mountain district, Fremont County (modified from Hausel and others, 1985).

gneiss, and mica schist. The central unit consists of banded iron formation, metapelite, quartzite, and amphibolite, and the northern unit is dominated by amphibolite with subordinate quartzofeldspathic gneiss.

The amphibolites consist of both orthoamphibolites (igneous) and para-amphibolites (sedimentary). The 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 intercepted 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 the 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.

The Copper Mountain district lies within the Owl Creek Mountains of central, Wyoming. Copper, gold, silver, iron, tungsten, feldspar, lithium, beryl, tantalum, uranium and petroleum have been reported in this 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. The available copper 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.

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

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 which yielded values in gold, silver, and copper (Beeler, 1906a).

CUMTN-1-83; NE section 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; section 23, T40N, R92W; The DePass mine was developed in a 30 to 50 foot wide Proterozoic mafic (basalt) dike (~2.0 Ga) (Figure 42). The dike trends northeasterly under Flathead sandstones (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 the 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 mine portal, and on the mine dump (Love, 1954).

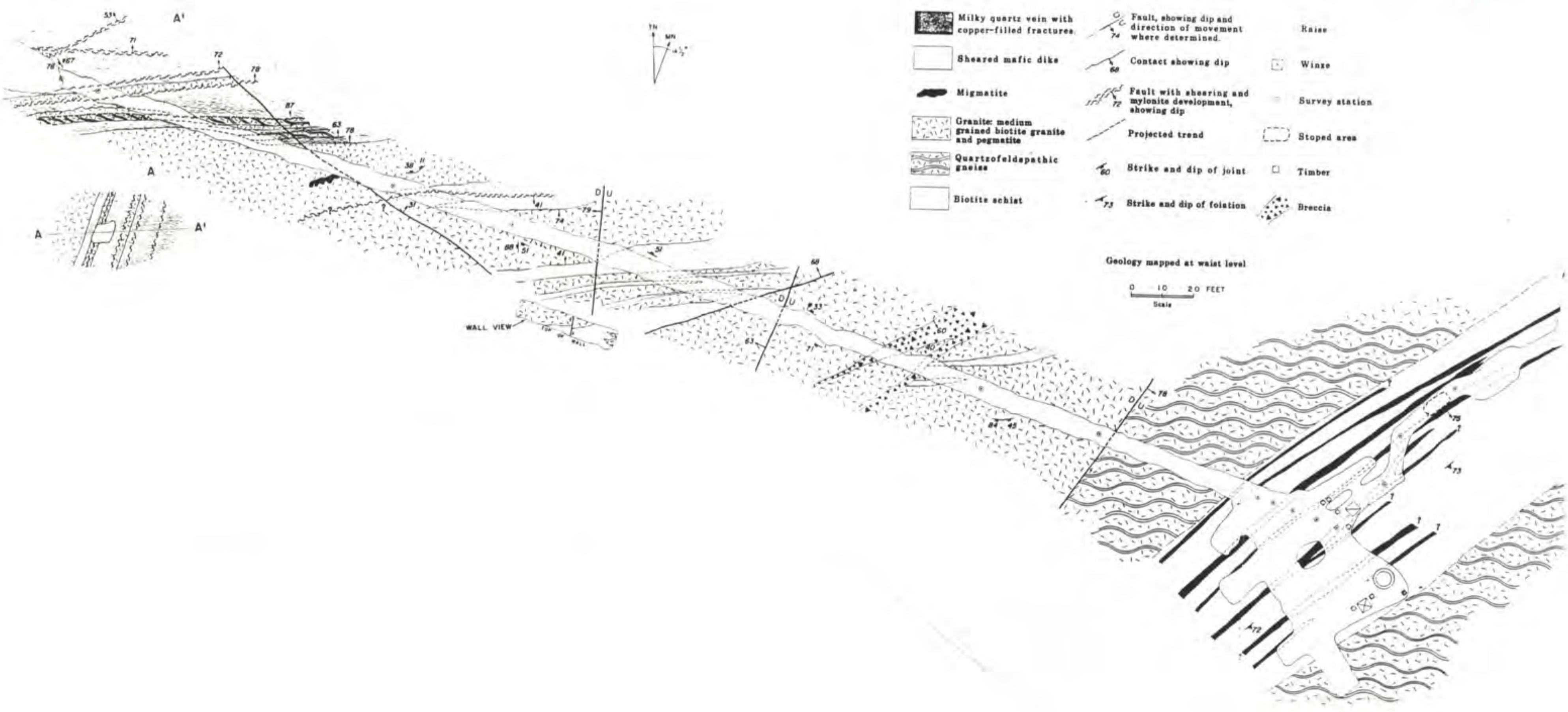


Figure 42. Geologic map of the main haulage level of the DePass mine (after Hausel and others, 1985).

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 none to 0.8 opt Ag. Beeler (1908b) reported a gold streak was intersected that was several feet wide which yielded specimen grade gold samples.

Mine production records appear to be incomplete, although production reported during portions of 1906, 1917 and 1918 include 567,610 pounds of copper with some gold and silver (Hausel and others, 1985). The DePass mine includes more than 11,000 feet of workings (Bowdin, 1918). During field investigations of the mine in 1983 by the Wyoming Geological Survey, only 600 feet of drifts were accessible, and the lower workings were flooded. The mine was developed to a depth of 810 feet with several levels (Figure 43) (Bowdin, 1918).

East Fork Birdseye Creek mines; NE NW section 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, one-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, one to two miles wide with interlayered quartzite, strikes east-west. Quartz veins cut the schist, some at an acute angle, and some more nearly 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, 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).

McGraw mine; SW section 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 mine 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).

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

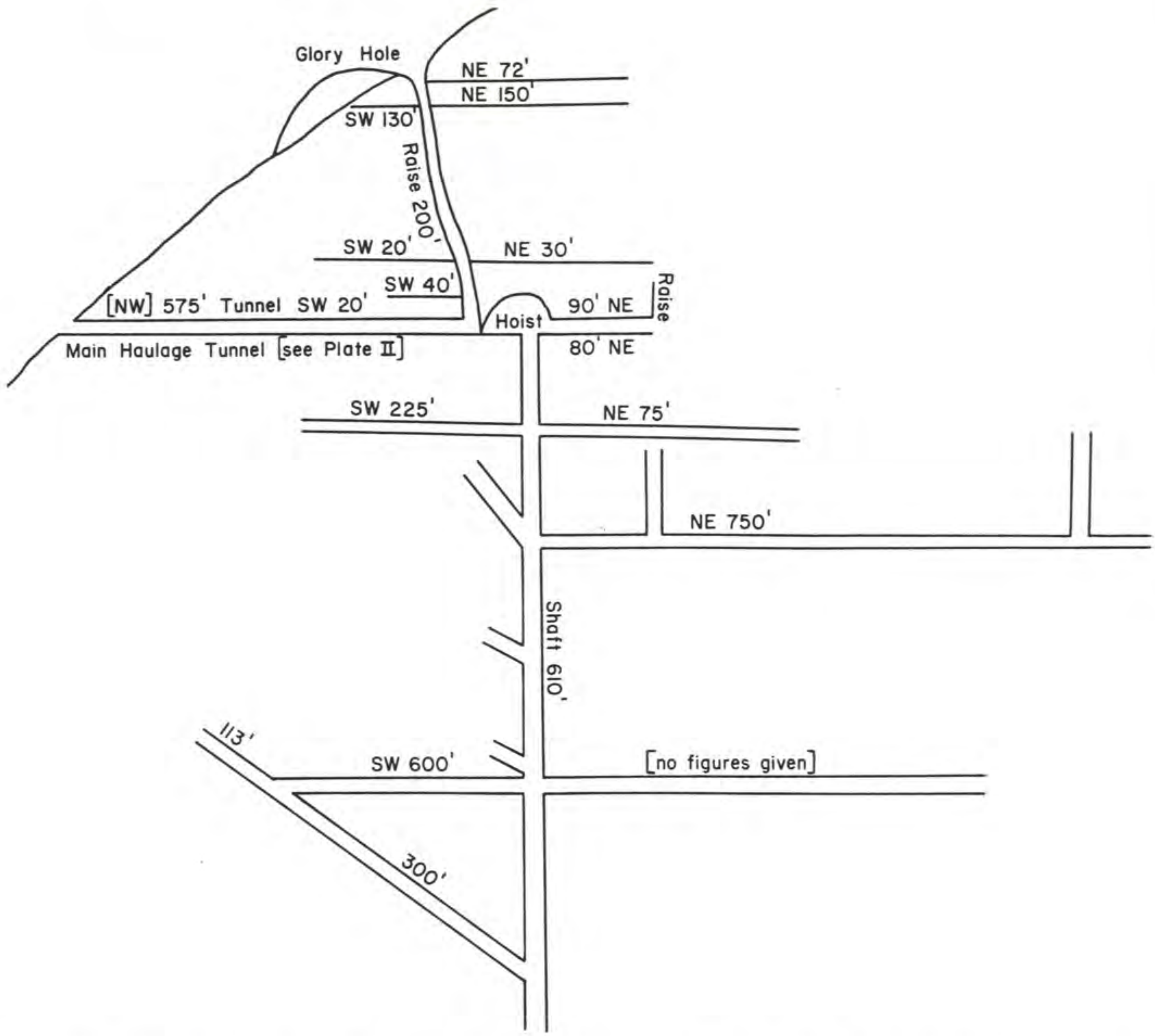


Figure 43. Schematic cross section of the historic DePass Mine workings (modified from Bowdin, 1918).

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) suggest 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.

Mascotte claim; A 1 foot thick vein with 2 feet of hard slaty shale strikes to the northwest and dips southwest and carries limonite and copper oxides. The vein contains 20 opt Ag (Aughey, 1886).

Riverton group; sections 20 and 21, T40N, R93W 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 a trace of gold to 0.04 opt Au, and a trace to 1.5 opt Ag.

West Bridger Mine; N/2 section 8, T40N, R92W; Two caved adits in the West Bridger Basin lie within a 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 section 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 vein quartz is fractured in 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 section 12, T40N, R93W; This incline was sunk in the McGraw iron formation and lies about 700 feet southwest of the McGraw shaft. The iron formation is 15 feet thick and is 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 the 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; Section 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 a 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; section 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 a sheared serpentinite(?) with quartz stringers. The hanging wall is formed by granite. The quartz at the surface contains copper and 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 rock (> 2.7 Ga) exposed in a broad, vertically plunging fold (Figure 44). 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 rock that form a spectacular steeply dipping precipice along the southern flank of the range.

The metamorphic rocks of the greenstone belt are subdivided into three mappable units (Hausel, 1993b, 1994d). 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 1,000 feet of mafic and ultramafic schists informally named the Bradley Peak Ultramafics by Klein (1981, 1982). The Bradley Peak Ultramafics consist of massive to highly foliated amphibolites, serpentinites, and tremolite-talc-chlorite schists. Some ultramafic rocks in this unit are similar to nickeliferous komatiites in Western Australia (Hausel,

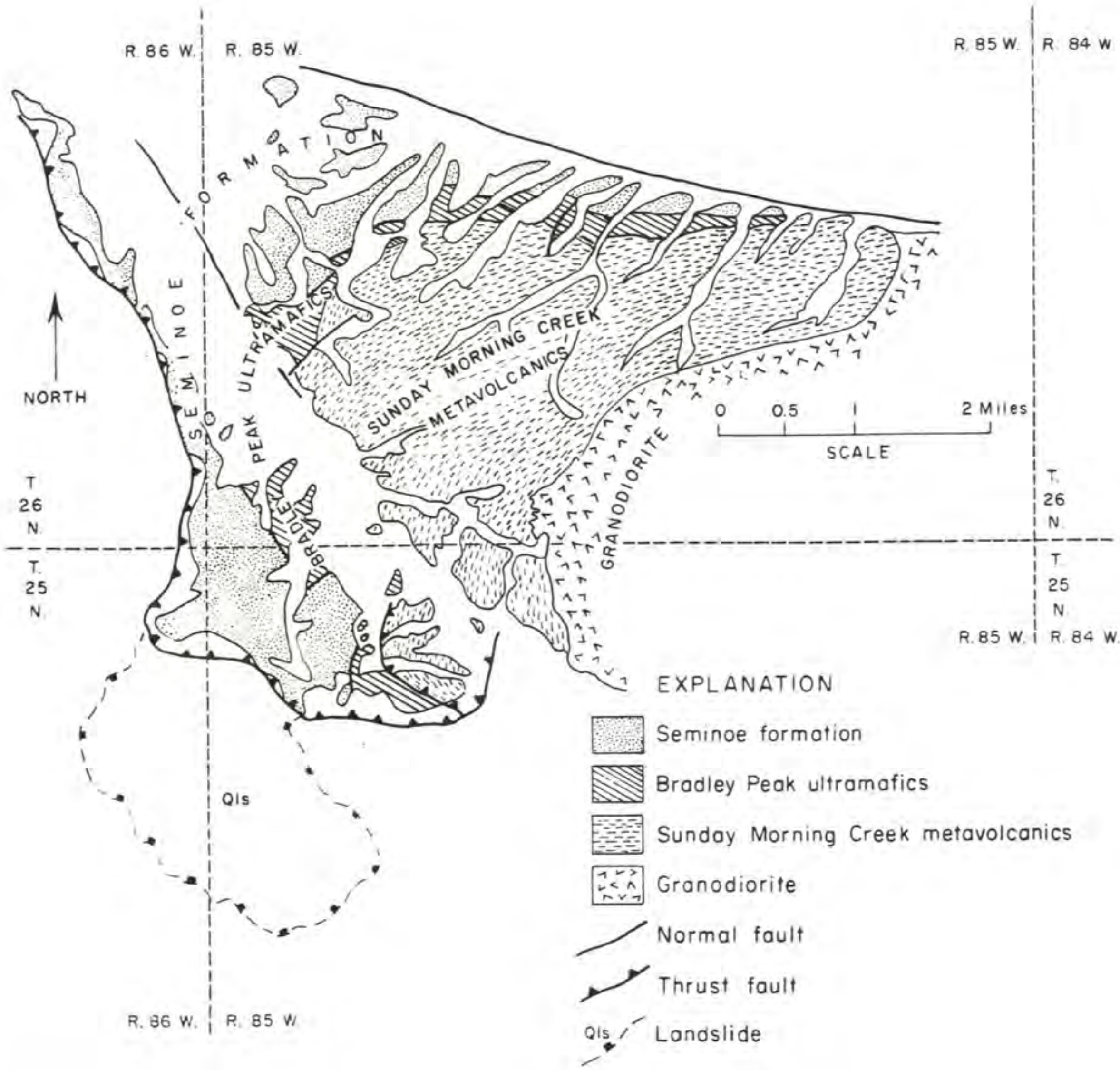


Figure 44. Generalized geologic map of the Seminoe Mountains greenstone belt.

1993b). The Bradley Peak Ultramafics are overlain by 2,000 to 4,000 feet of interlayered metasedimentary and metavolcanic rock named the Seminoe Formation (Lovering, 1929b). These rocks include quartz-magnetite-grunerite iron formation, chlorite schist, metagreywacke, metapelite, metabasalt, metatuff, and felsic schist.

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 3,000 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 in a nearby placer with detrital gold (Hausel, 1994d).

Vein samples collected around Bradley Peak generally are narrow (< 3 feet wide), quartz-carbonate veins with pyrite and chalcopyrite, that 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 ppm to 89.3 ppm (2.6 oz/ton) Au, <1.0 to 55.0 ppm (1.6 oz/ton) Ag, 0.03 to 3.75% Cu, 3.0 ppm to 0.39% Pb, and 22 ppm to 4.3% Zn (Table 1A).

Several samples collected in altered banded iron formation have 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 Cu to 0.045% Cu, 7.2 ppm to 220 ppm Pb, 90 ppm to 2,820 ppm Zn, <1.0 ppm to 15.33 ppm Ag, and < 0.01 ppm to 42.3 ppm Au (Table 14).

Table 14. Geochemical analyses of banded iron formation and host veins and veinlets, Seminoe Mountains district, Wyoming (from Hausel, 1994d).

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 & 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	--

Apex adit; N/2 N/2 section 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 ppm to 63.8 ppm Ag, 0.001 ppm to 0.013 ppm Au, 61 ppm to 0.95% Pb, and 68 ppm to 0.23% Zn (Hausel, 1994d). Bishop (1964) identified bornite, chalcopyrite, and pyrite.

Deserted Treasure adits; NE section 6, T25N, R85W; Two tunnels were driven along the northeastern flank of Bradley Peak on a narrow quartz vein hosted by metabasalt. The vein trends N67°E. 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 ppm to 89.3 ppm Au, and <2.0 to 18.0 ppm Ag (Hausel, 1993b).

Junk Creek mine; SW section 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 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, a caved prospect with malachite, bornite and covellite occur as fracture coatings in altered granite (Bishop, 1964). A 10-foot composite chip sample of copper-stained mafic schist wallrock yielded 0.78% Cu, and 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 section 6, T25N, R85W; Located downslope from the Deserted Treasure adits. A select sample yielded 6.8 ppm Au and 4.2 ppm Ag (Hausel, 1994d).

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, and chrysocolla, and native copper. The host rock is altered amphibolite.

Sunday Morning mine: E/2 E/2 section 21, T26N, R85W. This property was staked in 1882, and a 60 foot shaft with a 146 foot tunnel driven from a adit at Sunday Morning Creek. Three crosscuts of 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, 1994d).

Sunday Morning prospect: SE section 29, T26N, R85W; The Sunday Morning 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 (Hausel, 1993b).

SIERRA MADRE MOUNTAINS

The Sierra Madre Mountains are similar to the Medicine Bow Mountains, and were also uplifted during Laramide time. The Precambrian core of the Sierra Madre consists of rock from two provinces separated by a major east-west trending suture known locally as the Mullen Creek-Nash Fork shear zone (Figure 45) (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 Early Proterozoic (2.5-1.8 Ga) miogeoclinal and epicontinental metasediments. These Early Proterozoic metasediments include quartzite, metaconglomerate, metalimestone, metadolomite, and phyllite, with lesser metvolcanics. South of the shear zone, late Early Proterozoic eugeoclinal schists and gneisses form a thick suite of metavolcanics and volcaniclastics. These rock are calc-alkaline affinity and include metabasalts, meta-andesites, and metarhyolites. At several localities, these schists and gneisses retain relic volcanic textures (Divis, 1976, 1977).

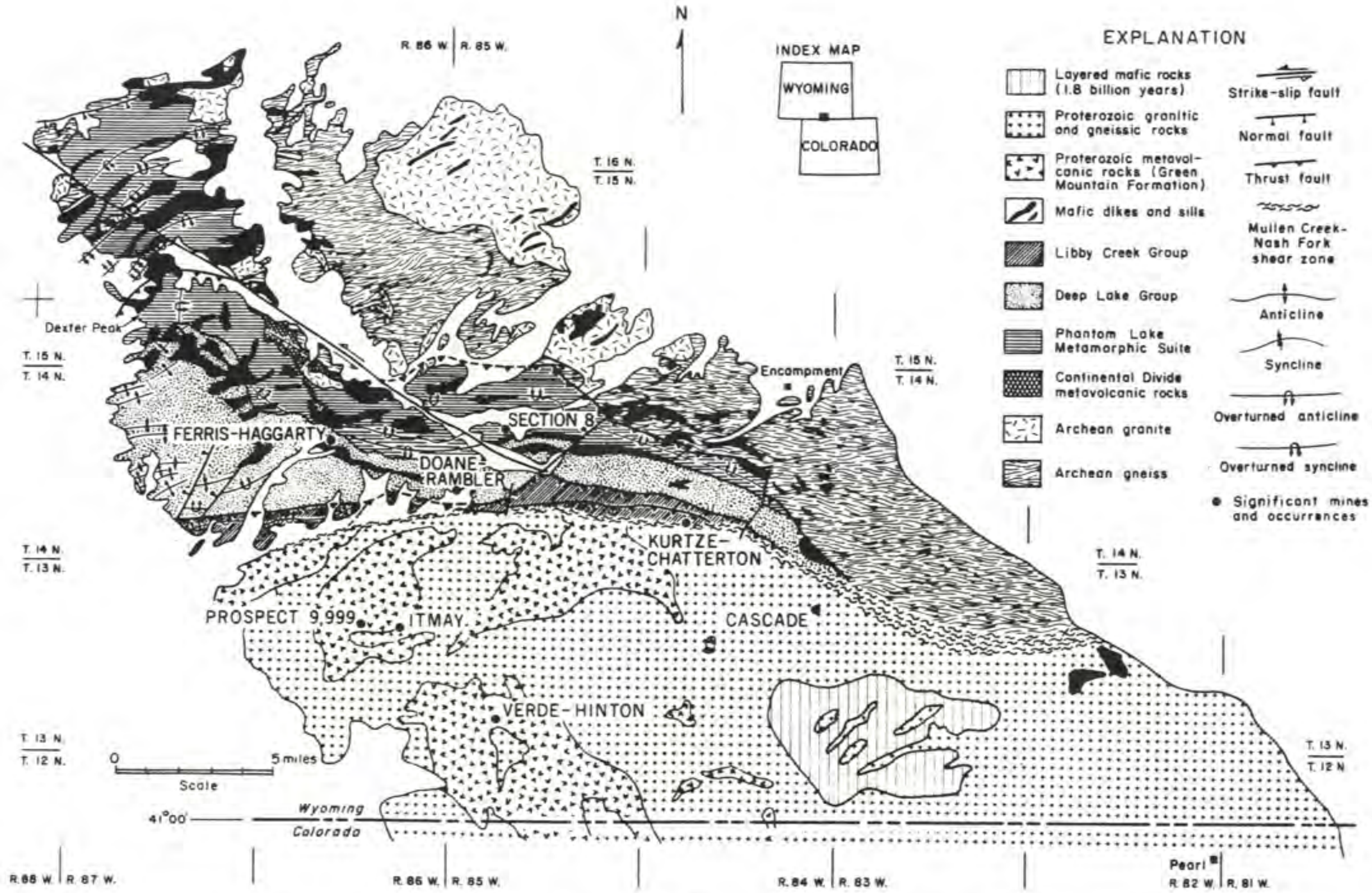


Figure 45. Generalized geologic map of the Sierra Madre, Wyoming (modified from Karlstrom and others, 1981).

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.

The Grand Encampment district

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 townsite of Rambler. This discovery led to the 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 was sunk on the gossan and 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. 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 averaging about 550,000 pounds of copper per month (Hausel, 1993a).

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 which included 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, crossed over continental divide at a elevation of 10,690 feet, and ran east to the Boston-Wyoming smelter at Riverside 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 1,000 pounds carrying capacity (Beeler, 1905a; Vandenberge, 1906).

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, a portion of the mill was destroyed by fire, and in 1907, a large segment of the mill and smelter complex were destroyed by fire. These disasters were followed by a 35% drop in the copper price which resulted in the closure of the Ferris-Haggarty mine and the layoff of more than 200 miners in 1908 (Hausel, 1993a, Short, 1958). Production records indicate more than 21,000,0000 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).

It was reported by 1901, that 2,500 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 and was 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, Winona Rex, with hundreds of other mines in the initial stage of development (Armstrong, 1970). Many of the deposits yielded very rich ores. Beeler (1905a) reported shipping ore from some of the mines often yielded 35% to 49% copper in car load lots. The gold and silver values associated with the ores were uniformly low, although some rich gold samples were discovered in oxidized ores at Purgatory Gulch, the Charter Oak mine, and others.

The Encampment district includes the entire Sierra Madre and is divisible into a Northern and Southern regions (Hausel, 1986a). These two regions are 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 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 Recent gold placers. South of the shear zone, rocks are 1.6 to 1.9 Ga Proterozoic metavolcanics and metasediments. These include 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).

Mineral deposits in this region include veins, shear zone deposits, and volcanogenic massive sulfides (Hausel, 1986a, b: Houston and others, 1992). According to Spencer (1904), five types of deposits characterized 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 the intersection of fractures 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 these deposits 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, Spencer 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 of the metasedimentary and metavolcanic rocks in the district, Houston and others (1975) suggested that a more likely source of the metals was the 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°N to 60°N. The vein cuts schist, diorite, quartzite, and alaskite dikes, and contains some galena, chalcopyrite, and siderite (Spencer, 1904, p. 99).

Anaconda mine (see also North group): Sections 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; section 18, T14N, R86W; Located near the historic Dillon townsite. A series of quartzite, schist, and diorite layers strike 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 much as 10 feet wide. The mine contains approximately 1,000 feet of workings (Beeler,1905b).

Beaver group; Located in sections 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 (the 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 mine 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 section 18, T14N, R85W, and sections 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 45°S to vertically. 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 one foot zone next to the gouge (Beeler, 1902a).

Bonita prospect; sections 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 1,800 pounds of copper, 1 ounce of gold, and 23 ounces of silver.

Bridger mine; N/2 NW section 2, T15N, R87W; The Bridger vein is conformable to regional foliation and trends northwest with a 25°SW to 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 and 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 a 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. The gold values were noted to decrease with depth while the silver values increased (Spencer, 1904).

Broadway mine; The Broadway property is located on the East Fork Creek in the SW section 32, T14N, R83W of the Dudley Creek 7.5 minute quadrangle. The 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). Osterwald reported that the ore zone dipped 50°SE to 50°NW and covered a surface area of 1,000 feet by about 50 feet and continued under a heavily wooded area (Figure 46). Later soil geochem dispersion studies by Amselco suggested that the ore zone was more extensive.

The ore minerals included massive sphalerite and minor galena with local disseminated chalcopyrite, chalcocite, and covellite. Small amounts of secondary malachite and chrysocolla were also 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), the 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).

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 was identified by spectrographic analysis.

Sample#	Zn(%)	Pb(%)	Cu(%)	S(%)
(1)	12.5	1.9	0.02	7.65

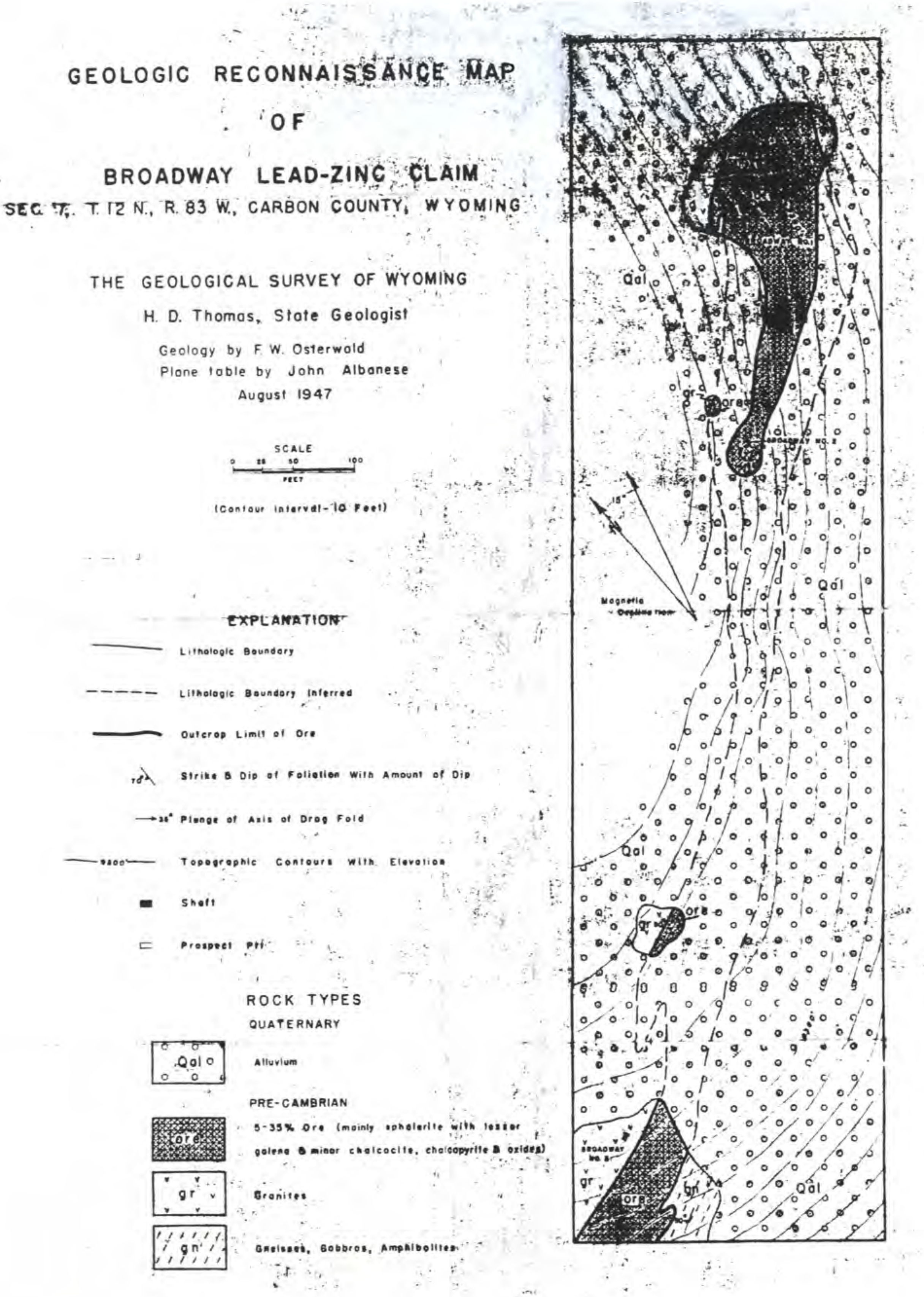


Figure 46. Reconnaissance map of the Broadway property, Encampment district (from Osterwald, 1947).

(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	--	--

Grab samples collected by Osterwald (1947) were also highly anomalous:

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 drill holes totaling 850 feet were completed, two of which intersected significant mineralization. The best drill intercept was near the No. 2 shaft, and encountered 20.5 feet of 8% Zn. Based on the limited amount of data, it was estimated the ore in sight over a surface area of 150 feet by 8 feet to a depth of 100 feet, totalled 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 of 1977, they drilled and completed zinc, lead, and copper soil geochem surveys over a relatively large area. The survey identified a 3,000 foot long copper soil geochem anomaly, a 2,200 foot long, 100 to 1,000 foot wide zinc soil anomaly, and a 1,500 foot long lead anomaly. The mineralization was reported as massive zinc, lead, and copper sulfide associated with a lens of tightly folded pyroxene-garnet rock. The pyroxenite was traced for nearly 1,400 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 a trace of galena. The samples were highly anomalous in zinc, lead, copper, gold, and silver:

Sample#	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	--	--

<u>Buckeye lode</u>; The Buckeye claim is located on Mill Creek in section 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 one mile north of Battle. Altered schists strike east-west, dip 45°N to 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 section 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 Cascade 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 a similar outcrop of cupriferous pegmatite was discovered 6,000 feet to the northwest that may have been a northern extension of the Cascade deposit.

Century mine; sections 32 and 33, T13N, R85W; on Harrison Creek seven 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; section 24, T15N, R85W; Located 6.5 miles northwest of Encampment on Puzzler Hill. Puzzler Hill appears as a 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 (W. D. Hausel, personal field notes, 1994).

Oxide/Element	Sample number	
(Weight percent)	CO1-94	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
Au (ppb)	3	14
Pt (ppb)	8	<5
Pd (ppb)	15	8
Cu (ppm)	159	248
Ni (ppm)	343	178
Co (ppm)	29	28

Other amples collected in the massif from a small group of mines and prospects on Puzzler Hill contained anomalous metal values. These samples included limonite-stained breccia (CO2-94) from a mine dump in the S/2 section 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 Charter Oak mine dump (CO3-94 and CO4-94) yielded anomlous 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 section 26, was poorly mineralized (Table 15).

Table 15. Assays from the Puzzler Hill massif (Analyses by Bondar-Clegg).

Sample No	Cu (ppm)	Ni (ppm)	Co (ppm)	Cr (ppm)	Au (ppb)	Pt (ppb)	Pd (ppb)	Ag (ppm)	Pb (ppm)	Zn (ppm)
CO2-94	>20000	>20000	831	244	95	828	4042	2.9	57	55
CO3-94	>20000	66	27	71	>10000	<5	11	3.8	10	14
CO4-94	>20000	127	82	64	9862	<5	14	6.6	9	9
CO6-94	135	162	21	294	14	<5	5	<0.1	-	-

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).

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), although I was unable to verify these high values. The Charter Oak shaft was sunk to a depth of 488 feet (Beeler, 1905a). In total, more than 1,570 feet of shafts and tunnels were dug on the property (Beeler, 1906g).

Colorado Belle group; 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; section 18, T14N, R85W; 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 which dip at a low angle. Copper-carbonate and limonite-stained quartz veins cut the dikes but conform to the country rock foliation (Beeler, 1908a). Samples taken at a 30 foot depth assayed as high as $50 per ton (1899 prices) (Armstrong, 1970).

<u>Copper Gem prospect</u>; On Dunkard Creek in Purgatory Gulch eight miles south of Encampment. An incline was driven into a gouge zone in granite and mica schist that varies from one inch to more than one 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).

<u>Copper Rock group</u>; sections 27, 28, T14N, R85W; about eight miles west of Encampment. A mafic dike cut 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).

<u>Copper Schist mine</u>: SW section 12, T14N, R84W. A shallow shaft was sunk on a narrow cupriferous quartz vein along a fault contact between Cascade Quartzite and 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).

<u>Creede property:</u> N/2 section 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 to the south. Trace nickel and cobalt were reported by Spencer (1904, p. 54, 86).

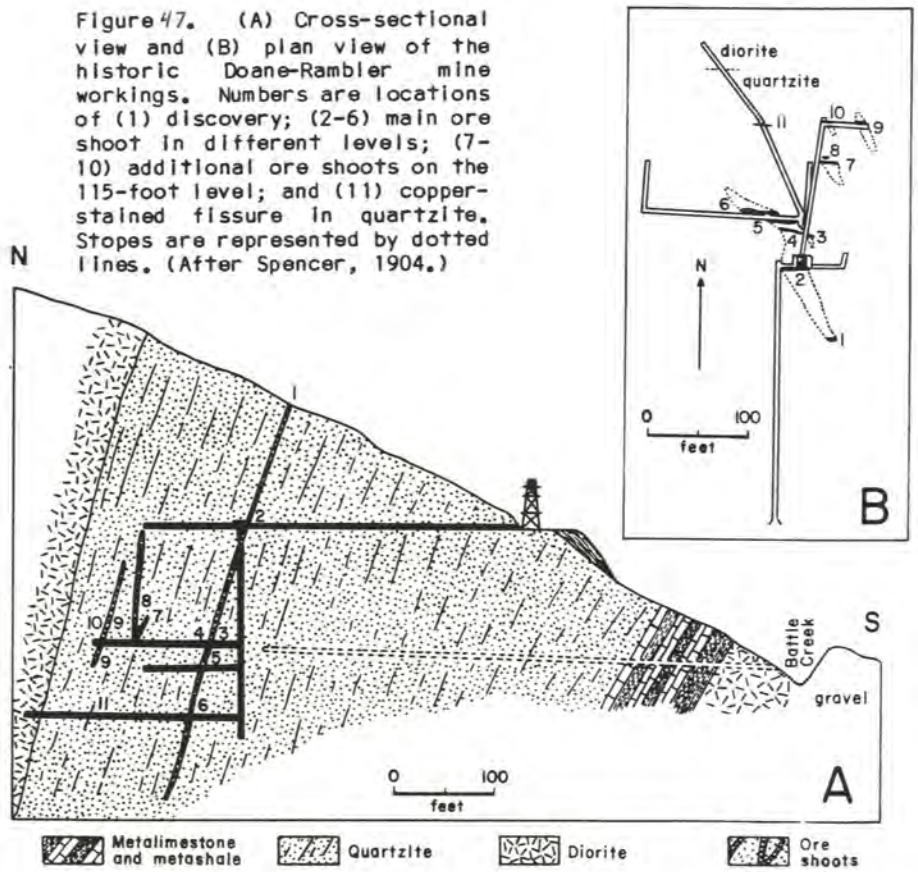
<u>D & L group</u>; sections 27, 28, T14N, R85W. About 2 miles east of Battle. Small amounts of chalcocite and a considerable amount of hematite were discovered underlying a gossan at this locality (Beeler, 1905d).

<u>Doane-Rambler mine</u>; NE section 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 in 1881 (Messerschmidt, 1972). The quartzite was part of the steeply dipping Cascade Quartzite (Proterozoic) which trends east-west and dips 65 to 75°N.

The property was developed from an adit driven to the north from Battle Creek (Figure 47). A total of 1,880 feet of drifts, crosscuts, and shafts were developed in the ore body 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). And at one time (1905) the construction of a two-mile tramway spur was considered for the Doane-Rambler mine to run to the northeast to the Ferris-Haggarty tramway (Armstrong, 1970).

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.

Figure 47. (A) Cross-sectional view and (B) plan view of the historic Doane-Rambler mine workings. Numbers are locations of (1) discovery; (2-6) main ore shoot in different levels; (7-10) additional ore shoots on the 115-foot level; and (11) copper-stained fissure in quartzite. Stopes are represented by dotted lines. (After Spencer, 1904.)



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 mine dump by McCallum and Menzer (1982) yielded 25 ppm Cu to 2.1% Cu and none to 6.8 ppm Ag.

The ore was localized at fracture plane intersections with bedding planes in the quartzite. Some ore was also reported to be stratiform (Spencer, 1904). On the 400 foot level, the main ore body was 14 feet wide. On the 500 foot level, the ore body 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), based on smelter receipts (Vandenberge, 1906). It was estimated that 25,000 tons of ore were recovered from the underground workings that averaged 10% Cu (Menzer, 1981). In other words, as much as 5,000,000 pounds of copper may have been produced.

Dreamland King group; sections 1, 2, T14N, R86W, on South Spring Creek. Layers of quartzite and schist interlayered with occasional gabbro lenses, strike east-west and dip to the 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; Sections 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 section 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. The wallrock 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-Haggerty mine; center section 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 the Ferris-Haggarty. 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).

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

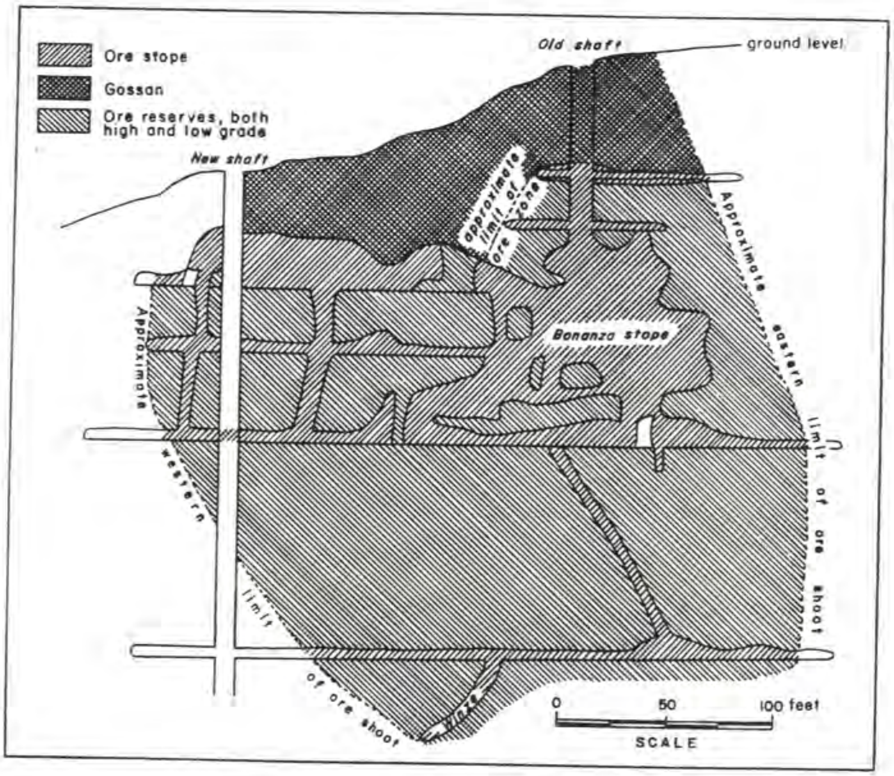


Figure 48. Cross section of the Ferris-Haggarty ore body. The sketch is of a vertical plane parallel to the strike of the ore body (from Spencer, 1904).

0.1 to 0.4 opt Au (Lakes, 1904; Beeler, 1905a). The ore body was 250 to 300 feet long and was opened to a depth of 300 feet in 1903 (Figure 48) (Spencer, 1904), and the workings may have ultimately extended to a vertical depth of 560 feet prior to termination of the mine operations in 1908 (DEQ, 1985). The host quartzite dips 30 to 60° south, and trends east-west.

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 mine dump samples collected in 1984 yielded 3.95% Cu with a trace of 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 assayed 3.95% Cu, trace Ag, and no Au, and 4.6% Cu, 0.03 opt Ag, and no Au (Anonymous, 1942b).

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.

<u>Finley mine</u>; NE section 22, T14N, R84W; The Finley shaft was sunk in quartzite. At a depth of 170 feet below the collar, mineralization was intersected (Armstrong, 1970).

<u>Gertrude mine</u>; E/2 E/2 section 28, T14N, R85W; The Gertrude mine was developed on an outcrop of massive earthy hematite in quartzite with a east-west trend and a 40°S dip. Three shafts (50, 80, and 90 feet deep) 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 some specularite and minor copper stains, in addition to the earthy hematite.

Samples of the hematite were reported to assay 0.37 opt Au (Spencer, 1904, p. 92-93). Spencer suggested that the Gertrude deposit was probably a gossan capping an underlying copper deposit.

<u>Gold Coin prospect</u>; SW section 11, T15N, R87W; This claim was staked south of the Bridger mine on the Continental Divide. A one-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).

<u>Great Lakes claims</u>; S/2 section 30, T14N, R84W; 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).

<u>Hercules mines</u>; W/2 SW section 29, T14N, R85W; south of Battle along the Huston-Standard Park jeep trail. The Hercules mine was developed by a 80 foot shaft (Beeler, 1905a) in a sheared contact between granite, and metadolomite and phyllitic schist of the Slaughterhouse Formation. The metadolomite and phyllitic 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 none to 0.9 ppm Ag. Other samples from the mine yielded 0.001 ppm to 1.0 ppm Au and none to 0.30 ppm Pt, and 0.002 ppm to 0.020 ppm Pd (Menzer, 1981).

Hidden Treasure mine; section 28, T14N, R85W; one mile east of the old town of Battle and one-half mile from the Gertrude claim. A 1,000 foot tunnel was driven to intercept a N70°E trending vein that dips steeply to the south. The country rock strikes northeast and dips to the south and 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 lessor 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 section 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 3,000 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 1,780 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 on 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 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 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 5,000 to 7,000 feet along strike. A group of prospects dug in the NW SW section 33 exposed an epidote-magnetite exhalite. The rock contained disseminated sphalerite, chalcopyrite, and bornite (Lawrence, 1982).

Homestake: Sections 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 six inch streak on the hanging wall side of the vein yielded 19% Cu with some gold and silver (Pease, 1905).

Hub prospect; E/2 NW section 6, T15N, R87W; Located on the Divide Peak Quadrangle. A sample with visible gold collected from the dump assayed 10 opt Au (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 sections 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 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. The Pease properties also included the Parallel group and the North Fork group (Pease, 1905).

Iron King prospect; section 15, T14N, R85W, located three miles north of Battle on Cow Creek. A 15-foot-wide quartz vein strikes northeast and dips 30°S. 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; sections 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 townsite. 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; section 14, T13N, R86W. The Itmay mine was developed from a shaft and adit. At the shaft, a chloritized mafic dike cuts granodiorite (Schmidt, 1984). About 160 feet north of the shaft, a magnetite iron formation carrying botryoidal pyrite coated by chalcopyrite occurs adjacent to volcaniclastics (mill rock). A sample of the rock from this locality assayed 5% Cu and a trace of gold (W.D. Hausel, personal field notes, 1978). Schmidt (1984) collected a sample of magnetite, pyrite, chalcopyrite, quartz, chlorite, and epidote schist which yielded 1,000 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 ore body. Three holes drilled on the property intersected weak to moderate stratabound and fracture related copper-silver mineralization.

Drill hole IM-1 was drilled to a depth of 383 feet and intersected a strongly chloritized, epidotized unit; however, the exhalite horizon and possible massive sulfide 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.

Drill holes 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 drill holes (Lawrence, 1981).

Drill hole	Depth	Mineralized zone	Values
IM-2	316 feet	34.7 to 41 ft	1.9 % Cu, 0.2 opt Ag
		124.5 to 128 ft	0.12% Cu, 0.03 opt Ag

		293.0 to 302 ft	0.35% Cu, 0.01 opt Ag
IM-3	501 feet	35.7 to 59 ft	0.09% Cu, 0.03 opt Ag
		368.0 to 398 ft	0.17% Cu, 0.04 opt Ag

It was concluded that the Itmay volcanic cycle, which consists of differentiated metarhyolites overlain by an exhalite (which can be traced for 2,500 feet along strike), is a favorable horizon for massive sulfides. The exhalite is coincident with higher copper soil values and 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; section 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 section 29, T14N, R84W; One of the three most productive copper mines in the Encampment district. By 1901, more than 1,700 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 5 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 4,000 feet which 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 none to 28.10 ppm Au, none to 7.24 ppm Ag, 4.0 ppm to 12.55% Cu, 0.0 to 0.8% TiO_2, with trace amounts of lead and zinc. The following assays were obtained:

Sample no.	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	-

Leighton-Gentry (Jack Creek) mine; SW section 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 a 11-foot-thick limy quartzite. Pyrite, pyrrhotite, and chalcopyrite were found along bedding planes and disseminated throughout the limy quartzite. The metalimestone below the quartzite contained no sulfides. The rocks strike N80°W, and dip 30°S. An assay yielded 3.07% Cu, 0.67% Ni and Co, and a trace of zinc (Spencer, 1904). Spencer noted similarities between the Leighton-Gentry mine and the Ferris-Haggarty ore deposit.

Lena Shields group; section 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; sections 24 or 25, T15N, R86W, 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, but at depth 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 to 25°N.

Samples of the vein contain a variety of minerals. The ore consists of massive galena that is probably argentiferous, chalcopyrite, sphalerite, cerrusite, 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 6 to 7 carloads of ore were shipped to Salt Lake City sometime after 1930.

From these accounts, it suggests 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 per ton (1944 prices).

Mohawk prospect; NW section 20, NW section 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; sections 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 4,500 feet. At one point, the vein contained a 4 foot ore zone that average 28.8% Cu (Armstrong, 1970).

Newton group; sections 13 and 24, T14N, R85W, and sections 18 and 19, T14N, R84W; The claims are located on an east-west trending layer of mafic rock sandwiched 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; section 13, T12N, R86W; located 14 miles south of Battle. Granite and "diorite" dikes trend northwesterly and dip to the northeast and 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 the ore to this consist of galena and sphalerite with some wire silver.

Some galena from the property yielded as much as 600 opt Ag. Assays of some 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 1,700 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 cut the North Fork vein. The crosscut vein is 23 feet wide and is mineralized throughout much of its width with pyrite, chalcopyrite, and some galena.

North Spring Creek prospect; section 10, T15N, R86W; Four short adits were driven into a near horizontal milky quartz vein. The vein is 6 to 10 inches wide with a strike of 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 one to two inch wide fine-grained chloritic alteration zone is exposed in the wallrock adjacent to the vein in the northernmost portal, but no other evidence of mineralization was found in this vein (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 and dips 30°SW cutting an altered limy schist. The quartz contains occasional calcite and disseminated and streaky pyrite and chalcopyrite (Beeler, 1901c).

Parallel group (see also North group): Sections 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 section 30, T14N, R85W; 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 feet wide to 12 feet wide. Beeler (1905a) reported the Portland vein was traced for 3,000 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, none to 11.0 ppm Ag, 0.005 ppm to 9.0 ppm Au, none to 0.030 ppm Pt, and 0.002 ppm to 0.060 ppm Pd.

Prospect 9,999; W/2 section 15, E/2 section 16, T13N, R86W; The mineralization and geology of this prospect is similar to the Itmay and Hinton-Verde massive sulfide deposits located 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).

The Fletcher Park area has two recognized volcanic cycles termed the Fletcher Park cycle and the Itmay cycle. These cycles consist of metarhyolites overlain by exhalites.

Two types of alteration occur in the Fletcher Park area: localized sericite-pyrite at the Itmay mine, and a wide zone of sausseritization. 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 9,999.

In 1979 and 1980, Conoco Minerals drilled the Prospect 9,999 exhalite. Drill hole FWDH-2 was collared near the top of the exhalite and intersected alternating tuffaceous metasediments and metatuffs all 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.

Drill hole 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 the rhyolite metatuff with interbedded porphyritic meta-andesite. The exhalite was altered to silica, garnet, epidote, and chlorite.

Two strongly mineralized zones were encountered in the drill hole. 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.

Drill hole FP-3 collared 500 feet to the southeast of FP-2. This hole encountered meta-andesite tuffs, interbedded cherts, siliceous metasediments, calc-silicates, and terminated in metarhyolite tuff with interbedded porphyritic meta-andesite. The 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; section 1, T13N, R84W and section 36, T14N, R84W; Includes the Golden Eagle claim. A group of short adits were driven into limonite-stained shears in gneiss (see also Copper Gem prospect). 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 mine 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 ten 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 section 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 ppm to 400 ppm Cu). The Rambler adit was driven in Cascade Quartzite.

Rex prospect; SE SW section 24, T14N, R86W; A shallow, 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; S/2 SE section 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 dips 52°S. 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 and is associated with chalcopyrite as fracture fillings in a gangue of bull or honeycomb quartz with minor calcite (Wied, 1960).

Standard mine; NE section 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 & Sweet claims; Section 34, T14N, R85W and section 6, T13N, R84W. Located in a series of east-west trending hornblende schists that cross 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, small red garnets, with a little magnetite and chalcopyrite.

Several prospects and small mines occur in an arc extending from section 34 to section 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 section 6 contained chalcopyrite, pyrite, and malachite in a epidote-calcite-hornblende-feldspar-augite lapilli tuff (Schmidt, 1983).

Syndicate mine; section 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 and trends N70°W and dips 65°S. 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 also in some of the quartz fragments (Spencer, 1904).

Tennant property; Located four miles from Encampment in sections 21 and 22, T14N, R84W. A 6-foot-wide fissure vein in section 22 contains copper and some gold. Six tons of ore mined from the claim netted $400.00 in copper (copper at $0.20 per pound) (Osterwald and others, 1966, p. 49). In section 21, three strike veins containing gold, silver, and lead assayed from $15 to $112 per ton (1927 prices). Some of the country rock schist is also 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 sections 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 6,500 feet and extends from the south bank of the North Fork river and continues south into Colorado. The vein trends N25°W and 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) (Pease, 1905). Downslope from the Three Forks group (sections 13 and 14), are the Pease placers. The gravels of the placers contain some gold and silver (Beeler, 1905f).

Umslopagus group; Sections 19 and 30, T14N, R85W, near the old town of Rambler. A series of schists and quartzites are 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 section 9, T12N, R84W; Malachite occurs at the intersection (contact?) of amphibolite and pegmatite. Two shafts were sunk on the mineralized zone (Merry, 1963).

Section 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 section 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 section 24, T14N, R84W; Chalcanthite encrustations occur on the ribs and in the back of an adit driven in gneiss. The gneiss is in contact with an amphibolite dike (Ferris, 1964).

SE section 28, T14N, R83W; Crusts and stains of malachite occur on quartz and amphibolite fragments found in a prospect pit (Ferris, 1964).

SW NE section 11, T12N, R85W; A prospect was developed in a exhalite associated with dacitic metavolcanics (Swift, 1982).

SW NE section 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).

Section 6, T13N, R84W; Several prospect pits and three shafts occur 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), 5,000 ppm Ba, >20,000 ppm Cu, and 200 ppm Pb and Zn.

SW section 25, T14N, R85W; A mine at this locality has its main shaft situated on the contact of a sheared metadolomite and quartz chlorite schist. Hematite gossan and small amounts of malachite occur on the mine dump. A sample of the 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 section 29, T14N, R85W; Six samples collected from the dump of an unnamed mine at this locality by Menzer (1981) yielded 40 ppm Cu to 8.8% Cu. Two of the samples yielded detectable silver values of 0.5 ppm and 1.5 ppm Ag. Samples tested for gold and platinum group metals yielded only 0.005 ppm to 0.010 ppm Au, none to 0.020 ppm Pt, and none to 0.070 ppm Pd.

<u>SW section 25, T14N, R85W</u>; A 100-foot-deep shaft and two portals occur on a hill top. The two portals are short (15 to 20 feet) and do not connect with the shaft. The country rock is felsite, felsite breccia, and lessor 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 one to two 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).

<u>Section 35, T14N, R86W</u>; A mine was sunk along a granite-amphibolite contact. Samples from the dump contain hematite, chalcopyrite, and malachite stringers in quartz (Schmidt, 1983).

<u>Section 11, T13N, R86W</u>; Samples from a small mine situated along the contact of granodiorite with metavolcanic rocks contain pyrite in quartz. An assay of the material contained no detectable anomalous metals (Schmidt, 1983).

<u>SW section 23, T14N, R84W</u>; 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, 2 foot wide, copper-stained fault zone (1,140 ppm Cu, 102 ppm Mn, 15 ppb Au, 2 ppm Pb, and 5 ppm Zn); a grab sample of dump material (8,770 ppm Cu, 200 ppm Mn, and 22 ppm Zn); malachite-stained quartzite (6,980 ppm Cu, 356 ppm Mn, 4 ppm Pb, and 34 ppm Zn); and a grab sample of copper-stained granite and quartz (3,150 ppm Cu, 1,035 ppm Mn, 16 ppm Pb, and 5 ppm Zn) (Ryan, 1988).

<u>SW section 27, T14N, R84W</u>; 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).

<u>N/2 section 34, T14N, R84W</u>; 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 with a 36°N dip.

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.

<u>N/2 SW section 26, T14N, R84W</u>; 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 gold 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).

<u>S/2 SE section 26, T14N, R84W</u>: 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 section 35, T14N, R84W: A grab sample of hematite-stained quartz from a 3 foot deep pit assayed 562 ppm Cu, 1,145 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 section 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 section 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.

Section 21, T13N, R82W; Vein filling chalcopyrite with chalcocite, bornite, and malachite occur 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 section 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 section 33, T13N, R82W; Malachite-stained pegmatite occurs in this vicinity (Huang, 1970).

N/2 N/2 section 19, T13N, R82W; A sample of gossan was analyzed and yielded 0.016% Cu and 0.017% Zn (Huang, 1970).

Section 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 section 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 section 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 Mountains

The Teton Mountains are considered the youngest mountain range in Wyoming. These spectacular peaks enclosed by the Teton National Park, were uplifted only 5 to 13 million years ago along the Teton fault. The fault forms a prominent scarp 150 feet high that is traceable over a distance of 30 miles.

The Tetons consist 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 Tetons and adjacent areas, and only limited information is available on the known deposits.

Reported occurrences
Buffalo Fork of the Snake River; 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, where State Highway 22 cuts through the sandstone (J.D. Love, personal communication, 1982).

Teton Pass: E/2 section 12, T41N, R118W, Samples collected from the basal phosphorite of the Mead Peak Member 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 Mountains

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 which forms the core of the Wind River Range is a high-grade metamorphic and igneous complex of migmatite, 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 2,000 to 2,795 Ma 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). The South Pass greenstone belt consists of a synform of metasedimentary, metavolcanic, and plutonic rocks (Figure 49) (Hausel, 1991b). Very little copper, molybdenum, zinc, and lead mineralization has been reported in the Wind River Mountains. But where found, the copper is generally associated with veins and shear zones that crosscut earlier auriferous shears in the South Pass granite-greenstone terrane (Hausel, 1987b). The South Pass greenstone

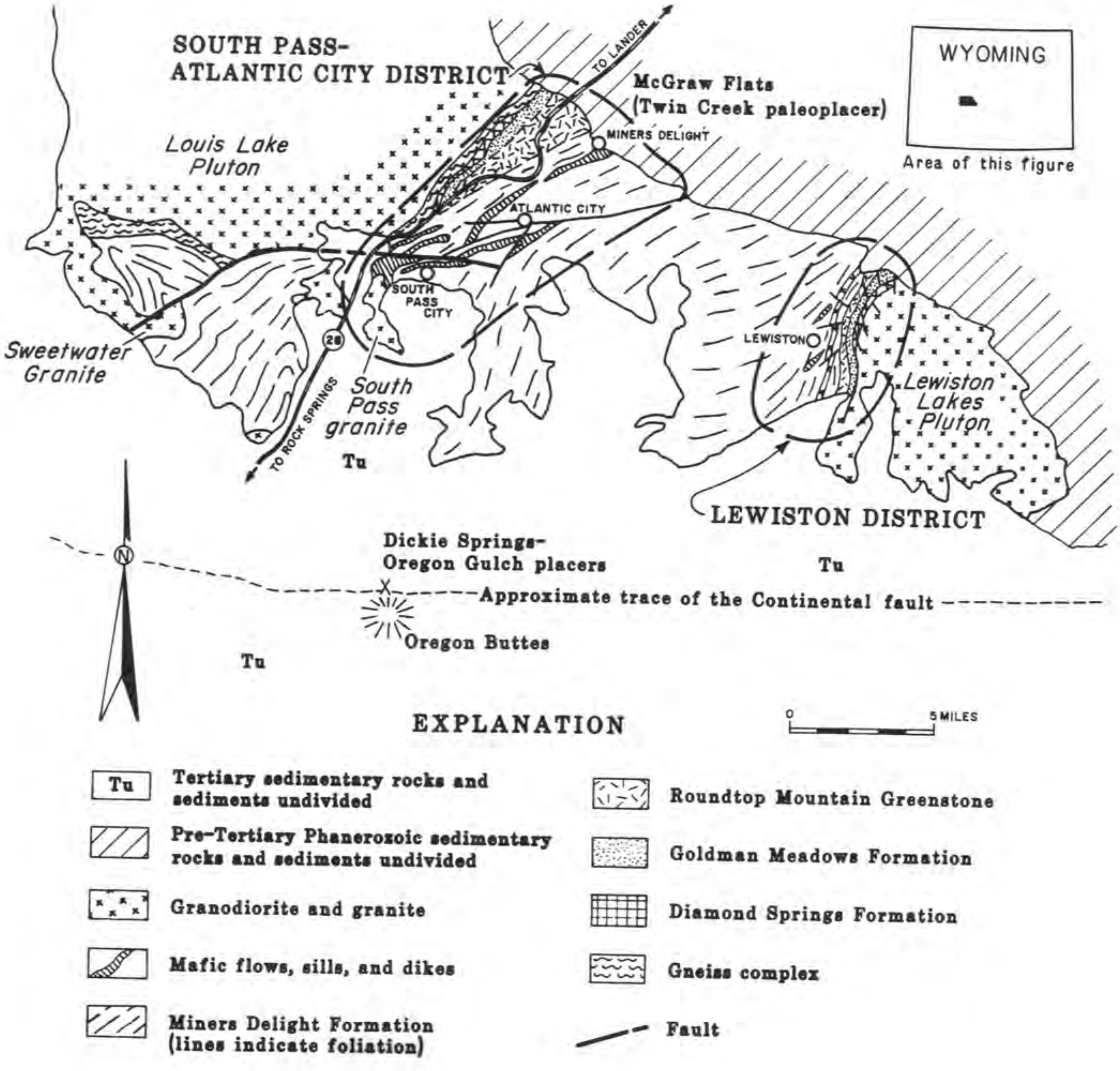


Figure 49. General map of the South Pass greenstone belt, Wind River Mountains (from Hausel, 1991b).

district has been subdivided into the Anderson Ridge area, the Lewiston district, and the South Pass-Atlantic City district. Some molybdenum porphyry and veins are reported in the southern portion of the range

Anderson Ridge

The Anderson Ridge area lies west of South Pass City and is an extension of the South Pass greenstone belt. 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 section 21, T29N, R101W. A shaft with 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 section 17, T29N, R101W. A prospect pit and short adit were developed on a narrow, N20°E, 19°NW dipping shear in Louis Lake granodiorite. One sample of malachite stained granodiorite was selected from the mine dump. The sample assayed 2.75% Cu, 3.03 opt Ag and 4.03 ppm Au (Hausel, 1991b).

PEG claims; section 34, T30N, R101W; On the flank of Rennecker Peak near 10,000 feet above sea level. A westerly trending mafic dike occurs in granitic country rock. Prospect pits expose pyritized dike material and epidotized xenoliths of granite. Portions of the granite wallrock are also pyritized. Some 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 section 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 easterm margin of the South Pass greenstone belt and is dominated by metagreywacke with lessor metapelite, banded iron formation, metabasalt and serpentinite. The eastern edge of the district contains a prominant tonalite dike which 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 in the district.

Lewiston iron formation: N/2 NE section 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 section 9, T28N, R98W; Two parallel quartz veins carry considerable arsenopyrite. Samples collected from the veins assayed 0.26% and 0.28% Cu, 0.85 ppm and 1.73 ppm Au, and 130 ppm and 24 ppm Ag (Hausel, 1991b).

South Pass-Atlantic City district

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 metamorphics 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 billion year old) mafic dikes and in minor shear zones, but these are unimportant for their base metal content.

Diana mine; SW section 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 ppm to 269 ppm Cu, 133 ppm to 2,830 ppm As, 2 ppm to 32 ppm W, <0.02 ppm to 24 ppm Au, and <0.2 ppm to 8.9 ppm Ag (Hausel, 1989;1991b).

Exchange Lode: E/2 section 15, W/2 section 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 cuts the schist and contains pyrite and chalcopyrite. Copper carbonates also occur on outcrops 1,000 feet west of the 40 foot deep shaft (Beeler, 1907k).

Silent Friend prospect: S/2 section 14, T29N, R100W: A reported 10 to 50 foot wide vein contained anomalous copper and gold (Hausel, 1991b).

Snowbird mine: section 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, 1989a).

Tornado Mine: S/2 SE section 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, 0.0 to 1.08 opt Au, and 0.0 to 0.55 opt Ag, 0.0 to 160 ppm Zn, 0.0 to 78 ppm Pb, and 0.0 to 67 ppm Ni (Hausel, 1991b).

Wyoming Copper Mining Company; section 18, T29N, R100W.; A shaft was sunk on 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).

S/2 SE/4 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 silver, and 105 ppb gold.

Southern Wind River Mountains

The southern Wind River Mountains are 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; sections 30 & 31, T32N, R103W, and sections 24 & 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 (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 association with the mineralization is minor and occurs as weak silicification, sausseritization, and sericitization (Benedict, 1982).

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, are confined to the pluton's margin, show weak alteration, and are associated with pyrite and chalcopyrite.

Samples containing molybdenite are generally slightly enriched in silver, copper, lead, and gold. Molybdenite-bearing samples collected by Lee and others (1982) yielded 10 ppm to greater than 2,000 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 rock have been found in glacial debris in the area (Wilson, 1955b).

CONCLUSIONS

Since the early part of the 1900s, Wyoming has not been a significant source for base metals. In the early 1900s, Wyoming was host to one of larger producing copper mines in the world: the Ferris-Haggarty in the Sierra Madre, which incidently may still contain significant unmined resources.

The lack of copper, zinc, lead, and molybdenum production in the state since the early 1900s, is not the result of lack of mineralization in the state. The evidence is overwhelming that the state contains significant copper porphyry resources 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 deposits 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 lack of exploitation of these deposits is not due to unfavorable geologic conditions, as millions of exploration dollars have been spent in the past testing these deposits for commerical mineralization. The lack of interest in these deposits is primarily due to Federal programs which have resulted in the piecemeal withdrawal of

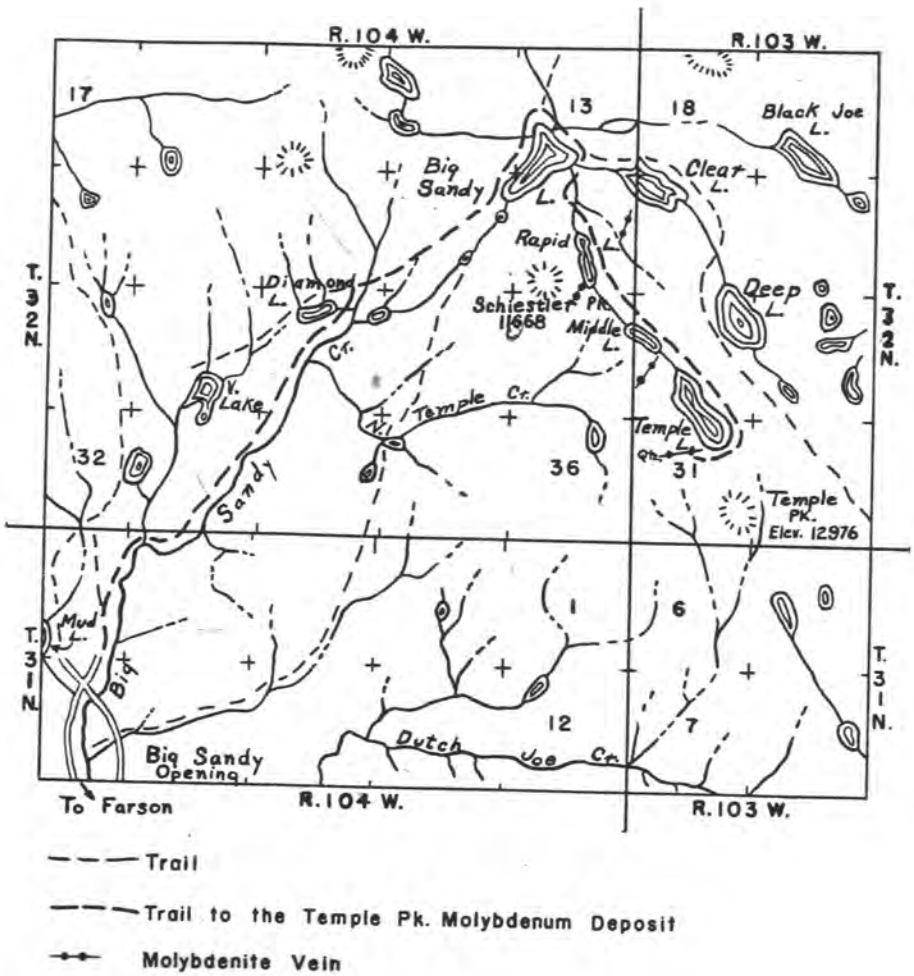


Figure 50. Sketch map of the Temple Peak molybdenum deposit (from Wilson, 1955b).

the state's base metal resources from mineral exploration, i.e., the majority of the prospective deposits have been enclosed by wilderness and roadless areas. Should the Federal programs ever reverse, the State of Wyoming can expect to become an important base metal producer again.

REFERENCES

Allen, F.S., 1942, Letter to the Board of Directors of the Polaris Mining Company: Geological Survey of Wyoming mineral files, 3 p.

Anonymous, 1903, Prospectus on the Medicine Bow's Mines Company: Geological Survey of Wyoming mineral files, 25 p.

Anonymous, 1908, Miscellaneous reports on the copper deposits of the Owl Creek Mountains: Geological Survey of Wyoming mineral files, 8 p.

Anonymous, 1911, Concentration of platiniferous copper ore at the Rambler mine, Wyoming: Journal of Metal and Chemical Engineering, v. 9, no. 2, p. 75-78.

Anonymous, 1942a, Suggestions with reference to "War Minerals Report" #286 Rambler Mine, Albany County, Wyoming, supplement to War Minerals Report #17: Geological Survey of Wyoming mineral files, 5 p.

Anonymous, 1942b, The Ferris-Haggarty mine, Carbon County, Wyoming: Geological Survey of Wyoming mineral report MR42-2, 8 p.

Anonymous, 1974, CF&I's underground Sunrise mine supplies Pueblo mills: Engineering and Mining Journal, Nov., p. 151-152.

Antweiler, J.C., Love, J.D., and Campbell, W.L., 1977, Gold content of the Pass Peak Formation and other rocks in the Rocky Mountain Overthrust Belt, northwestern Wyoming: Wyoming Geological Association 29th annual field conference guidebook, p. 731-749.

Armstrong, J.R., 1970, Grand Encampment 1898-1912: High Country Treasure: Rawlins Newspaper, Inc., Rawlins, Wyoming, 19 p.

Arth, J.G., Barker, F., and Stern, T.W., 1980, Geochronology of Archean gneisses in the Lake Helen area, southwestern Bighorn Mountains, Wyoming: Precambrian Research, v. 11, p. 11-12.

Aughey, S., 1886, Annual report of the Territorial Geologist to the Governor of Wyoming, 61 p.

Ball, S.H., 1907a, Copper deposits of the Hartville uplift, Wyoming: U.S. Geological Survey Bulletin 315B, p. 93-107.

Beeler, H.C., 1901a, Report on the Buelah prospect: Geological Survey of Wyoming Mineral Report MR01-3, 2 p.

Beeler, H.C., 1901b, Report on the Copper Gem prospect: Geological Survey of Wyoming Mineral Report MR01-6, 3 p.

Beeler, H.C., 1901c, Report on the Octivia prospect: Geological Survey of Wyoming Mineral Report MR01-1, 3 p.

Beeler, H.C., 1901d, Report on the Bonita prospect: Geological Survey of Wyoming Mineral Report MR01-5, 3 p.

Beeler, H.C., 1901e, Report on the Iron King prospect: Geological Survey of Wyoming Mineral Report MR01-4, 2 p.

Beeler, H.C., 1901f, Report on the Gertrude mine: Geological Survey of Wyoming Mineral Report MR01-2, 4 p.

Beeler, H.C., 1901g, Report on the Kearns prospect: Geological Survey of Wyoming Mineral Report MR01-7, 3 p.

Beeler, H.C., 1902a, Report on the Big Chief group: Geological Survey of Wyoming Mineral Report MR02-13, 4 p.

Beeler, H.C., 1902b, Report on the Lena Shields group: Geological Survey of Wyoming Mineral Report MR02-22, 2 p.

Beeler, H.C., 1902c, Report on the Mohawk prospect: Geological Survey of Wyoming Mineral Report MR02-17, 3 p.

Beeler, H.C., 1902d, Report on the Monark prospect: Geological Survey of Wyoming Mineral Report MR02-18, 3 p.

Beeler, H.C., 1902e, Report on the Globe prospect: Geological Survey of Wyoming Mineral Report MR02-21, 4 p.

Beeler, H.C., 1902f, Report on the Esterbrook: Geological Survey of Wyoming Mineral Report MR02-12, 6 p.

Beeler, H.C., 1902g, Report on the Elk Mountain prospect: Geological Survey of Wyoming Mineral Report MR02-14, 4 p.

Beeler, H.C., 1902h, Report on the Erueka (sic) prospect: Geological Survey of Wyoming Mineral Report MR02-15, 3 p.

Beeler, H.C., 1902i, Report on the Waterloo prospect: Geological Survey of Wyoming Mineral Report MR02-19, 4 p.

Beeler, H.C., 1902j, Report on the Gold Coin prospect: Geological Survey of Wyoming Mineral Report MR02-20, 4 p.

Beeler, H.C., 1903a, A report on the Cox mine, near Grand Encampment, Carbon County, Wyoming: Report addressed to Governor Fennimore Chatterton from H.C. Beeler, Geological Survey of Wyoming mineral files, 13 p.

Beeler, H.C., 1903b, Report on the Copper Gem property of the Fremont Copper Company: Geological Survey of Wyoming Mineral Report MR03-37, 3 p.

Beeler, H.C., 1903c, Report on the King of the Camp prospect: Geological Survey of Wyoming Mineral Report MR03-28, 3 p.

Beeler, H.C., 1903d, Report on the Tenderfoot group: Geological Survey of Wyoming Mineral Report MR03-23, 5 p.

Beeler, H.C., 1903e, Report on the French Joe prospect: Geological Survey of Wyoming Mineral Report MR03-24, 3 p.

Beeler, H.C., 1903f, Report on the Trail Creek group: Geological Survey of Wyoming Mineral Report MR03-25, 5 p.

Beeler, H.C., 1903g, Report on the Horace Greeley prospect: Geological Survey of Wyoming Mineral Report MR03-26, 3 p.

Beeler, H.C., 1903h, Report on the Gibraltar prospect: Geological Survey of Wyoming Mineral Report MR03-27, 3 p.

Beeler, H.C., 1903i, Report on the Lucky Gus prospect: Geological Survey of Wyoming Mineral Report MR03-30, 3 p.

Beeler, H.C., 1903j, Report on the Raven group: Geological Survey of Wyoming Mineral Report MR03-36, 5 p.

Beeler, H.C., 1903k, Report on the Fremont group: Geological Survey of Wyoming Mineral Report MR03-38, 7 p.

Beeler, H.C., 1903l, Report on the Skylark prospect: Geological Survey of Wyoming Mineral Report MR03-39, 5 p.

Beeler, H.C., 1903m, Report on the Cumberlain group of claims: Geological Survey of Wyoming Mineral Report MR03-34, 5 p.

Beeler, H.C., 1904a, Report on the Island City group, Battle, Carbon County, Wyoming: Geological Survey of Wyoming Mineral Report MR04-50, 3 p.

Beeler, H.C., 1904b, Report on the King of the Camp Mine: Geological Survey of Wyoming Mineral Report MR04-42, 6 p.

Beeler, H.C., 1904c, The North Laramie Peak copper district in Converse, Albany and Laramie Counties, Wyoming: State Geologist report, Cheyenne, Wyoming, 16 p.

Beeler, H.C., 1904d, Report on the Independence prospect: Geological Survey of Wyoming Mineral Report MR04-40, 7 p.

Beeler, H.C., 1904e, Report on the Great Standard group: Geological Survey of Wyoming Mineral Report MR04-41, 13 p.

Beeler, H.C., 1904f, Report on the Maudem group: Geological Survey of Wyoming Mineral Report MR04-43, 3 p.

Beeler, H.C., 1904g, A brief report on the Oriole group: Geological Survey of Wyoming Mineral Report MR04-46, 5 p.

Beeler, H.C., 1904h, Report on the Jupiter group: Geological Survey of Wyoming Mineral Report MR04-47, 3 p.

Beeler, H.C., 1904i, A brief report on the Lorain group: Geological Survey of Wyoming Mineral Report MR04-48, 3 p.

Beeler, H.C., 1904j, Report on the Roe Brothers group: Geological Survey of Wyoming Mineral Report MR04-51, 2 p.

Beeler, H.C., 1904k, Report on the Bull Camp group: Geological Survey of Wyoming Mineral Report MR04-52, 4 p.

Beeler, H.C., 1904l, Report on the Top Hand group: Geological Survey of Wyoming Mineral Report MR04-52, 4 p.

Beeler, H.C., 1904m, Report on the Maverick group: Geological Survey of Wyoming Mineral Report MR04-53, 4 p.

Beeler, H.C., 1905a, Mining in the Grand Encampment copper district, Carbon and Albany counties, Wyoming (2nd edition): Office of the State Geologist, Cheyenne, Wyoming, 31 p.

Beeler, H.C., 1905b, Report on the Batchelder mine, Dillon, Carbon County: Geological Survey of Wyoming Mineral Report MR05-61, 5 p.

Beeler, H.C., 1905c, Report on the Copper Rock group: Geological Survey of Wyoming Mineral Report MR05-63, 5 p.

Beeler, H.C., 1905d, Report on the D & L group, Battle, Carbon County, Wyoming: Geological Survey of Wyoming Mineral Report MR05-62, 3 p.

Beeler, H.C., 1905e, Report on the Dreamland King group, Battle, Carbon County, Wyoming: Geological Survey of Wyoming Mineral Report MR05-59, 3 p.

Beeler, H.C., 1905f, Report on the Pease properties: Geological Survey of Wyoming Mineral Report MR05-66, 8 p.

Beeler, H.C., 1905g, Report on the Newton group near Encampment, Carbon County, Wyoming: Geological Survey of Wyoming Mineral Report MR05-67, 3 p.

Beeler, H.C., 1905h, Report on the North Fork group near Battle, Carbon County, Wyoming: Geological Survey of Wyoming Mineral Report MR05-65, 6 p.

Beeler, H.C., 1905i, Report on the Investors mining and prospecting company property at Rambler, Carbon County, Wyoming: Geological Survey of Wyoming Mineral Report MR05-58, 5 p.

Beeler, H.C., 1905j, Report on the Emerald group: Geological Survey of Wyoming Mineral Report MR05-55, 4 p.

Beeler, H.C., 1905k, Report on the Whippoorwill claim near Wheatland, Laramie County, Wyoming: Geological Survey of Wyoming Mineral Report MR05-56, 5 p.

Beeler, H.C., 1906a, A report on the Copper Glance group at DePass, Fremont County, Wyoming: Geological Survey of Wyoming Mineral Report MR06-77, 7 p.

Beeler, H.C., 1906b, A brief report on the Colorado Belle group near Encampment, Carbon County, Wyoming: Geological Survey of Wyoming Mineral Report MR06-75, 3 p.

Beeler, H.C., 1906c, A report on the Strong mine, Leslie, Albany County, Wyoming: Geological Survey of Wyoming Mineral Report MR06-68,15 p.

Beeler, H.C., 1906d, A brief report on the Portland group, near Sherman, Albany County, Wyoming: Geological Survey of Wyoming Mineral Report MR06-69, 5 p.

Beeler, H.C., 1906e, A brief report on the Teddy Roosevelt-Good Hope group, Hecla, Laramie County, Wyoming: Geological Survey of Wyoming Mineral Report MR06-70, 4 p.

Beeler, H.C., 1906f, A brief report on the Copper Float group, Hermosa, Albany County, Wyoming: Geological Survey of Wyoming Mineral Report MR06-72, 4 p.

Beeler, H.C., 1906g, A brief report on the Charter Oak-Puzzler groups near Encampment, Carbon County, Wyoming: Geological Survey of Wyoming Mineral Report MR06-73, 10 p.

Beeler, H.C., 1906h, A brief report on the Ak-Sar-Ben group, Carbon County, Wyoming: Geological Survey of Wyoming Mineral Report MR06-74, 6 p.

Beeler, H.C., 1906j, A report on the Independence group, near Keystone, Albany County, Wyoming: Geological Survey of Wyoming Mineral Report MR06-78, 6 p.

Beeler, H.C., 1906k, A brief report on the Wild Goose group near Painter, Big Horn (Park) County, Wyoming: Geological Survey of Wyoming Mineral Report MR06-80, 5 p.

Beeler, H.C., 1906l, Mineral and allied resources of Albany County, Wyoming: Office of the State Geologist, miscellaneous printed report, Cheyenne Wyoming, 79 p.

Beeler, H.C., 1907a, Prospecting in the Black Rock-Long Creek vacinity near the Sweetwater River, Fremont County, Wyoming: Wyoming State Geologist Report, Cheyenne, Wyoming, 12 p.

Beeler, H.C., 1907b, A brief report on the Century group near Battle, Carbon County, Wyoming: Geological Survey of Wyoming Mineral Report MR07-97, 4 p.

Beeler, H.C., 1907c, A report on the Kopper Krown group at Hecla, Laramie County, Wyoming: Geological Survey of Wyoming Mineral Report MR07-82, 12 p.

Beeler, H.C., 1907d, A report on the Strong mine, Leslie, Albany County, Wyoming: Geological Survey of Wyoming Mineral Report MR07-87, 16 p.

Beeler, H.C., 1907e, A report on the Winona property: Geological Survey of Wyoming Mineral Report MR07-91, 5 p.

Beeler, H.C., 1907f, A report on the Sherman mine: Geological Survey of Wyoming Mineral Report MR07-92, 3 p.

Beeler, H.C., 1907g, A brief report on the Hamilton group near Devils Gate, Carbon County, Wyoming: Geological Survey of Wyoming Mineral Report MR07-93, 4 p.

Beeler, H.C., 1907h, A brief report on the Kansas group near Keystone, Albany County, Wyoming: Geological Survey of Wyoming Mineral Report MR07-95, 3 p.

Beeler, H.C., 1907i, Supplementary report on the Raven group near Encampment, Carbon County, Wyoming: Geological Survey of Wyoming Mineral Report MR07-95, 5 p.

Beeler, H.C., 1907j, A brief report on the Snowbird group near Douglas, Carbon County, Wyoming: Geological Survey of Wyoming Mineral Report MR07-99, 7 p.

Beeler, H.C., 1907k, A brief report on the Mechanic group near Atlantic, Fremont County, Wyoming: Geological Survey of Wyoming Mineral Report MR07-101, 3 p.

Beeler, H.C., 1907l, A brief report on the McGowan-LeClaire group, Willow Creek, Fremont County, Wyoming: Geological Survey of Wyoming Mineral Report MR07-90, 4 p.

Beeler, H.C., 1908a, Report on the Continental group: Geological Survey of Wyoming Mineral Report MR08-106, 4 p.

Beeler, H.C., 1908b, Wyoming Mines 1907: Office of the State Geologist, Cheyenne, Wyoming, p. 15.

Beeler, H.C., 1909, Report on the Riverton mine: Geological Survey of Wyoming Mineral Report MR09-108, 5 p.

Beeler, H.C., 1942, A brief statement on conditions noted at the Strong mine 16 miles northeast of Laramie, Albany County, Wyoming: Geological Survey of Wyoming Mineral Report MR42-1, 8 p.

Benedict, J.F., 1982, The geology and mineral potential of the Schiestler Peak area, Temple Peak quadrangle, Wyoming: M.S. thesis, University of Wyoming, 119 p.

Berosi, E.P., 1953, Trace elements preliminary reconnaissance report of the Fred Sullivan Mine: U.S. Geological Survey report D-599, 1 p.

Bickford, F.E., 1977, Petrology and structure of the Barlow Gap area, Wyoming: M.S. thesis, University of Wyoming, Laramie, 76 p.

Bishop, D.T., 1964, Retrogressive metamorphism is the Seminoe Mountains, Carbon County, Wyoming: M.S. thesis, University of Wyoming, 49 p.

Boberg, W.W., 1983, Lake Alice copper district, Lincoln County, Wyoming, *in* Hausel, W.D., and Harris, R.E., eds, Genesis and exploration of metallic and nonmetallic mineral and ore deposits of Wyoming and adjacent areas (extended abstracts): Geological Survey of Wyoming Public Information Circular 19, p. 14-15.

Boberg, W.W., 1984, Lake Alice silver-copper district stratiform sulfide deposits, Lincoln County, Wyoming: unpublished consultant's report, Geological Survey of Wyoming mineral files, 11 p.

Bothner, W.A., Jr, 1967, Petrology, structural geology, and economic geology of the Cooney Hills, Platte County, Wyoming: PhD dissertation, University of Wyoming, Laramie, 164 p.

Bowdin, H.C., 1918, Report on Williams-Luman Copper Mine at DePass, Wyoming: Geological Survey of Wyoming Mineral Report MR18-1, 7 p.

Bowers, N.E., 1992, Geologic map of the Ferris Mountain supracrustal block, Carbon County, Wyoming: Geological Survey of Wyoming mineral files (scale 1:6,000).

BLM, 1983, Adobe Town-Ferris Mountains wilderness environmental impact statement: U.S. Bureau of Land Management, draft environmental impact statement, p. 66-67.

Bromley, C.P., 1953, Results on diamond drilling at the Silver Cliff mine, Lusk, Wyoming: U.S. Atomic Energy Commission report RME-1002, 25 p.

Bromley, C.P., 1955, Supplementary to preliminary reconnaissance report: Nuclear Energy Commission report DEB-5-2-1348, 1 p.

Burford, A.E., Corbett, R.G., Franks, P.C., Friberg, L.M., Lorson, R.C., Marsek, F.A., Nanna, R.F., Schumacher, J.C., and Wymer, R.E., 1979, Precambrian complex of Casper Mountain Wyoming-a preliminary paper: Wyoming Geological Association Earth Science Bulletin, v. 12, no. 2, p. 58-69.

Butler, T.A., 1965, Geology of the Irma-Republic mines and vicinity, New World mining district, Montana and Wyoming: M.S. thesis, University of Idaho, 48 p.

Chenoweth, W.C., 1955, The sedimentary and igneous rocks, structure, and mineral deposits of the southeastern Bear Lodge Mountains, Crook County, Wyoming: M.S. thesis, Iowa State University, 220 p.

Condie, K.C, Leach, A.P., and Baadsgaard, H., 1969, Potassium-argon ages of Precambrian mafic dikes in Wyoming: Geological Society of America Bulletin, v. 80, p. 899-906.

Cox, B.E., 1979, Silver Creek, Wyoming Cu/Mo prospect - a preliminary evaluation for Koppen Mining Company: Earthworks Incorporated report, Geological Survey of Wyoming mineral files, 27 p.

Currey, D.R., 1965, The Keystone gold-copper prospect area, Albany County, Wyoming: Geological Survey of Wyoming Preliminary Report 3, 12 p.

Darton, N.H., 1906, Mineral resources of the Bighorn Mountain region, Wyoming: U.S. Geological Survey Bulletin 285, p. 303-310.

Darton, N.H., and Siebenthal, C.E., 1909, Geology and mineral resources of the Laramie Basin, Wyoming: U.S. Geological Survey Bulletin 364, p. 66-67.

DeNault, K.J., 1967, Geology and distribution of copper, lead, and zinc in streams and soil - Broadway mine area, Carbon County, Wyoming: M.S. thesis, University of Wyoming, 45 p.

DEQ, 1985, Mine permit application no. 255C, appendix D, p. 1-4.

Dersch, J.S., 1991, Snowy range withdrawal: U.S. Bureau of Land Management Report WYW-115104, 21 p.

DeWitt, D., Redden, J.A., Wilson, A.B., and Buscher, D., 1986, Mineral resource potential and geology of the Black Hills National Forest, South Dakota and Wyoming: U.S. Geological Survey Bulletin 1580, 135 p.

Divis, A.F., 1976, The Geology and geochemistry of the Sierra Madre Mountains, Wyoming: Colorado School of Mines Quarterly, v. 71, no. 3, p. 1-95.

Divis, A.F., 1977, Isotopic studies on a Precambrian geochronological boundary, Sierra Madre Mountains, Wyoming: Geological Society of America Bulletin, v. 88, p. 96-100.

Donnelly, M.E., 1979, Petrology and structure of a portion of the Precambrian Mullen Creek mafic igneous complex, Medicine Bow Mountains, Wyoming: M.S. thesis, Colorado State University, Fort Collins, 162 p.

Dreier, J.E., Jr., 1967, Economic geology of the Sunlight mineralized region, Park County, Wyoming: M.S. thesis, University of Wyoming, Laramie, 81 p.

Duncan, M., 1990, The Medicine Bow Mining Camps, Jelm Mountain Publications, Laramie, 244 p.

Dyck, H.M., Hausel, W.D., and Dyck, G., 1994, The Sunrise mine near Hartville, Wyoming: Rocks and Minerals, v. 69, Heldref Publications, Washington, D.C., p. 163-168.

East, J.H., Jr., 1911, Sunlight mining district, Wyoming: Engineering and Mining Journal, v. 91, p. 1155-1156.

Edwards, B.E., 1990, Field notes on the North Fork claims, Bighorn Mountains: Geological Survey of Wyoming mineral files, 1 p.

Elwood, M.W., 1978, Geology of the Black Buttes, Crook County, Wyoming: M.S. thesis, South Dakota School of Mines and Technology, Rapid City, 123 p.

Elwood, M.W., 1979, General geology of the Black Buttes, northwestern Black Hills, Crook County, Wyoming: Wyoming Geological Association Earth Science Bulletin v. 12, no. 1, p. 1-16.

Epstein, J.B., 1958, Geology of part of the Fanny Peak quadrangle, Wyoming-South Dakota: M.S. thesis, University of Wyoming.

Ferguson, H.E., 1965, Silver Crown mining district: Geological Survey of Wyoming Mineral Report MR65-1, 4 p.

Ferris, C.S., Jr., 1964, Petrology and structure of the Precambrian rocks of southeast of Encampment, Wyoming: PhD dissertation, University of Wyoming, Laramie, 74 p.

Fisher, F.S., 1972, Tertiary mineralization and hydrothermal alteration in the Stinkingwater mining region, Park County, Wyoming: U.S. Geological Survey Bulletin 1332C, 33 p.

Fisher, F.S., 1981, Controls and characteristics of metallic mineral deposits in the southern Absaroka Mountains, Wyoming: Montana Geological Society 1981 Field Conference Guidebook, p. 343-348.

Fisher, F.S., and Antweiler, J.C., 1980, Preliminary geological and geochemical results from the Robinson Creek, Birthday, and Clouds Home Peak mineralized areas in the Washakie Wilderness, Wyoming: U.S. Geological Survey Open File Report 80-781, 12 p.

Fisher, F.S., Antweiler, J.C., and Welsch, E.P., 1977, Preliminary geological and geochemical results from the Silver Creek and Yellow Ridge mineralized areas in the Washakie Wilderness, Wyoming: U.S. Geological Survey Open File Report 77-225, 11 p.

Gable, D. J., 1987, Geologic maps of greenstone-granite areas, northern Laramie Mountains, Converse and Natrona Counties, Wyoming: U.S. Geological Survey Map I-1724, scale 1:24,000.

Galey, J.T., Jr, 1971, Mineralization in the Eagle Creek area, Park County, Wyoming: M.S. Thesis, University of Wyoming, Laramie, 51 p.

Gersic, J., Peterson, E.K., and Schreiner, R.A., 1990, Appraisal of selected mineral resources of the Black Hills National Forest, South Dakota and Wyoming: U.S. Bureau of Mines Open File Report MLA 5-90, 225 p.

Giletti, B.J., and Gast, P.W., 1961, Absolute age of Precambrian rocks in Wyoming and Montana: New York Academy of Science Annuals, v. 91, p. 454-458.

Gliozzi, J. 1967, Petrology and structure of the Precambrian rocks of the Copper Mountain district, Owl Creek Mountains, Fremont County, Wyoming: PhD dissertation, University of Wyoming, 141 p.

Graff, P.J., Sears, J.W., Holden, G.S., and Hausel, W.D., 1982, Geology of the Elmers Rock greenstone belt, Laramie Range, Wyoming: Geological Survey of Wyoming Report of Investigations 14, 22 p.

Greeley, M.N., 1962, Geology of the Esterbrook area, Converse and Albany Counties, Wyoming: M.S. thesis, University of Missouri School of Mines and Metallurgy, Rolla, 58 p.

Guilinger, R.R., 1956, Uranium occurrences in the North Laramie Peak district, Albany and Converse Counties, Wyoming: U.S. Atomic Energy Commission Technical Memorandum Report DBO-2-TM-3, 15 p.

Haff, J.C., 1944a, Beaver group of copper claims: Geological Survey of Wyoming Mineral Report MR 44-1, 3 p.

Haff, J.C., 1944b, Field report on the Meta lead-zinc prospect: Geological Survey of Wyoming Mineral Report MR 44-9, 3 p.

Haff, J.C., 1944c, Field report on the Buckeye copper claim: Geological Survey of Wyoming Mineral Report MR 44-2, 2 p.

Haff, J.C., 1944d, Spanish Trails group of lead-zinc claims: Geological Survey of Wyoming Mineral Report MR 44-8, 3 p.

Hagner, A.F., 1942a, The Yellow Bird mine and the Monte Cristo Mine: Geological Survey of Wyoming Mineral Report MR 42-13, 1 p.

Hagner, A.F., 1942b, The Vaughn copper (Green Mountain Boy): Geological Survey of Wyoming Mineral Report MR 42-43, 1 p.

Hagner, A.F., 1942c, Jasper mine (copper): Geological Survey of Wyoming Mineral Report MR 42-7, 1 p.

Hagner, A.F., 1942d, Percis claims-copper: Geological Survey of Wyoming Mineral Report MR 42-8, 1 p.

Hagner, A.F., 1942e, Field examination of Black Butte lead deposit, Crook County, Wyoming: Geological Survey of Wyoming Mineral Report MR 42-47, 5 p.

Haldane, W.G., 1934, Special report on the Big Creek mining property: Consultant's report, Geological Survey of Wyoming mineral files, 10 p.

Hall, E., 1909, Annual report of the State Geologist to the Governor of Wyoming: Office of the State Geologist, Cheyenne, Wyoming, 17 p.

Hamil, M.M. 1967, Metamorphic and structural environment of Copper Mountain, Wyoming: PhD. dissertation, University of Missouri, Rolla, 87 p.

Hanbury, J.B., 1982, Hydrothermal alteration and mineralization of the Silver Creek porphyry copper deposit, Park County, Wyoming: M.S. thesis, Washington State University, 44 p.

Harrer, C.M., 1966, Wyoming iron-ore deposits: U.S. Bureau of Mines Information Circular 8315, 114 p.

Harris, R.E., 1983, Redbed copper: Geological Survey of Wyoming Mineral Report MR83-16, 1 p.

Harris, R.E., and Hausel, W.D., 1984, Mineral resources of the Permian and Pennsylvanian rocks in Wyoming: Wyoming Geological Association 35th annual field conference guidebook, p 369-381.

Harris, R.E., Hausel, W.D., and Meyer, J.E., 1985, Metallic and industrial minerals map of Wyoming: Geological Survey of Wyoming Map Series 14, scale 1:500,000.

Hausel, W.D., 1981a, The Rambler group prospect, Silver Crown district: Geological Survey of Wyoming Mineral Report MR 81-1, 2 p.

Hausel, W.D., 1981b, PEG copper claims, Rennecker Peak (Christina Lake Quadrangle): Geological Survey of Wyoming Mineral Report MR 81-2, 3 p.

Hausel, W.D., 1982a, Assay report on selected dump samples from the Portland mine, Sierra Madre, Wyoming: Geological Survey of Wyoming Mineral Report MR 82-5, 3 p.

Hausel, W.D., 1982b, Reconnaissance notes and assay of banded chert, Sierra Madre range, Carbon County Wyoming: Geological Survey of Wyoming Mineral Report MR 82-6, 3 p.

Hausel, W.D., 1982c, Field notes and assay report on the Louise copper mine, Silver Crown district, Laramie County, Wyoming: Geological Survey of Wyoming Mineral Report MR82-3, 2 p.

Hausel, W.D., 1982d, Robert's Ranch copper prospect, Sherman Mountains, Albany County, Wyoming: Geological Survey of Wyoming Mineral Report MR82-4, 3 p.

Hausel, W.D., 1982e, Assay report on tenorite-stained sample from the Fletcher Park area, Sierra Madre, Wyoming: Geological Survey of Wyoming Mineral Report MR 82-7, 3 p.

Hausel, W.D., 1982f, Miscellaneous field notes and assay report on mineralized red bed Nugget Sandstone in the Overthrust Belt, Wyoming: Geological Survey of Wyoming Mineral Report MR 82-8, 8 p.

Hausel, W.D., 1983a, Field notes on the Michigan iron-copper mine, Hartville uplift, Goshen County, Wyoming: Geological Survey of Wyoming Mineral Report MR 83-4, 5 p.

Hausel, W.D., 1983b, Unnamed copper prospect at Granite, Laramie County, Wyoming: Geological Survey of Wyoming Mineral Report MR 83-15, 3 p.

Hausel, W.D., 1983c, Field notes and assay report for the American mine, Albany County, Wyoming: Geological Survey of Wyoming Mineral Report MR 83-9, 3 p.

Hausel, W.D., 1983d, Wallrock Canyon copper-silver prospect, Albany County, Wyoming: Geological Survey of Wyoming Mineral Report MR 83-10, 3 p.

Hausel, W.D., 1983e, Report on copper samples from the Jelm Mountain district, Albany County: Geological Survey of Wyoming Mineral Report MR 83-8, 3 p.

Hausel, W.D., 1986a, Mineral deposits of the Encampment mining district, Sierra Madre, Colorado-Wyoming: Geological Survey of Wyoming Report of Investigations 37, 31 p.

Hausel, W.D., 1986b, Mineral deposits of the Encampment district, Sierra Madre, Wyoming-Colorado: Rocky Mountain Association of Geologists 1986 Symposium Guidebook, p. 283-288.

Hausel, W.D., 1987a, The geology and occurrence of critical strategic metals (chromium, cobalt, manganese, and platinum) in Wyoming: Geological Survey of Wyoming Open File Report 87-7, 34 p.

Hausel, W.D., 1987b, Structural control of Archean gold mineralization within the South Pass greenstone terrain, Wyoming (USA), *in* The practical applications of trace elements and isotopes to mineral resource evaluation: Theophrastus Publications, Athens, Greece, p. 199-216.

Hausel, W.D., 1988a, Assay report on samples from the Oriel mine, Warbonnet district: Geological Survey of Wyoming Mineral Report MR 88-5, 1 p.

Hausel, W.D., 1988b, Assay report of vein samples from Mormon Canyon: Geological Survey of Wyoming Mineral Report MR 88-2, 3 p.

Hausel, W.D., 1988c, Black Buttes wulfenite ($MoPbO_4$): Geological Survey of Wyoming Mineral Report MR 88-1, 2 p.

Hausel, W.D., 1988d, Assay report on samples collected from Purgatory Gulch and some other locations: Geological Survey of Wyoming Mineral Report MR 88-7, 5 p.

Hausel, W.D., 1989, The geology of Wyoming's precious metal lode and placer deposits: Geological Survey of Wyoming Bulletin 68, 248 p.

Hausel, W.D., 1990a, Cooney Hills copper-massive sulfide, Platte County, Wyoming: Geological Survey of Wyoming Mineral Report MR 90-7, 2 p.

Hausel, W.D., 1990b, Charter Oak mine, McCann Pass, Hartville uplift: Geological Survey of Wyoming Mineral Report MR 90-5, 2 p.

Hausel, W.D., 1990c, Gold analyses for samples from the Treadwell, Birdsnest, and Artic mines, Mineral Hill district, Crook County, Wyoming: Geological Survey of Wyoming Mineral Report MR90-3, 2 p.

Hausel, W.D., 1990d, The Treadwell gold-silver mine, Mineral Hill district, Crook County, Wyoming: Geological Survey of Wyoming Mineral Report MR90-6, 2 p.

Hausel, W.D., 1990e, Keystone district, Medicine Bow Mountains: Geological Survey of Wyoming Mineral Report MR90-4, 4 p.

Hausel, W.D., 1990f, Precious metals of Wyoming *in* D.M. Hausen, ed., Gold '90, Society for Mining, Metallurgy, and Exploration, Inc., Littleton, Colorado, p. 53-63.

Hausel, W.D., 1991a, Sheep Mountain copper mine, Medicine Bow Mountains, Wyoming: Geological Survey of Wyoming Mineral Report MR91-1, 6 p.

Hausel, W.D., 1991b, Economic geology of the South Pass granite-greenstone belt, southern Wind River range, western Wyoming: Geological Survey of Wyoming Report of Investigations 44, 129 p.

Hausel, W.D., 1992a, Zinc-lead-copper-silver-gold-massive sulfide mineralization at the Broadway mine, Sierra Madre, Wyoming: Geological Survey of Wyoming Mineral Report MR92-4, 6 p.

Hausel, W.D., 1992b, Geology and mineralization of the Copper Creek area and nearby prospects, Encampment mining district, Sierra Madre, Wyoming: Geological Survey of Wyoming Mineral Report 92-2, 5 p.

Hausel, W.D., 1992c, Miners Canyon district, Ferris Mountains, Wyoming: Geological Survey of Wyoming Mineral Report 92-5, 5 p.

Hausel, W.D., 1992d, Economic geology of the Cooper Hill mining district, Medicine Bow Mountains, Carbon County, Wyoming: Wyoming Geological Association 43rd field conference guidebook, p. 303-314.

Hausel, W.D., 1993a, Mining history and geology of some of Wyoming's metal and gemstone districts and deposits: Wyoming Geological Association Jubilee Field Conference Guidebook, p. 39-63.

Hausel, W.D., 1993b, Preliminary report on the geology, geochemistry, mineralization, and mining history of the Seminoe Mountains mining district, Carbon County, Wyoming: Wyoming Geological Association Jubilee Field Conference Guidebook, p. 387-409.

Hausel, W.D., 1993c, Guide to the geology, mining districts, and ghost towns of the Medicine Bow Mountains and Snowy Range scenic byway: Geological Survey of Wyoming Public Information Circular 32, 53 p.

Hausel, W.D., 1993d, Metal and gemstone deposits of Wyoming, *in* Snoke, A.W., Steidtmann, J.R., and Roberts, S.M., eds, Geology of Wyoming: Geological Survey of Wyoming Memoir 5, p. 816-835.

Hausel, W.D., 1994a, Mining history of Wyoming's gold, copper, iron, and diamond resources: The Mining History Association 1994 Annual, Denver, CO, p. 27-44.

Hausel, W.D., 1994b, Geology and mineralization of the Cooper Hill mining district, Medicine Bow Mountains, southeastern, Wyoming: Geological Survey of Wyoming Report of Investigations 49, 22 p.

Hausel, W.D., 1994c, Economic geology of the Rattlesnake Hills, Granite Mountains, central Wyoming: Wyoming State Geological Survey Mineral Report MR94-1, 3 p. (map scale 1:24,000).

Hausel, W.D., 1994d, Economic geology of the Seminoe Mountains mining district, Carbon County, Wyoming: Wyoming State Geological Survey Report of Investigations 50, 31 p.

Hausel, W.D. and Albert, K.G., 1983a, Geology and mineralization of the Depass (Williams-Luman) mine located at Copper Mountain, Fremont County, Wyoming: Geological Survey of Wyoming Mineral Report MR83-13, 6 p.

Hausel, W.D. and Albert, K.G., 1983b, Economic geology of the McGraw mine area, Copper Mountain metamorphic complex, Wyoming: Geological Survey of Wyoming Mineral Report MR83-11, 10 p.

Hausel, W.D., and Graff, P.J., 1983, Reconnaissance and economic geology of the Copper Mountain metamorphic complex, Owl Creek Mountains, Wyoming: Wyoming Geological Association 34th Annual Field Conference Guidebook, p. 179-184.

Hausel, W.D., Graff, P.J., and Albert, K.G., 1985, Economic geology of the Copper Mountain supracrustal belt, Owl Creek Mountains, Fremont County, Wyoming: Geological Survey of Wyoming Report of Investigations 28, 33 p.

Hausel, W.D., and Harris, R.E., 1983, Metallogeny of some Wyoming deposits: Colorado Mining Association 1983 Yearbook, p. 46-63.

Hausel, W.D., and Jones, S., 1982, Geological reconnaissance report of metallic deposits for *in situ* and heap leaching extraction research possibilities: Geological Survey of Wyoming Open File Report 82-4, 51 p.

Hausel, W.D., Marlatt, G.G., Nielsen, E.L., and Gregory, R.W., 1994, Study of metals and precious stones in southern Wyoming: Geological Survey of Wyoming Open File Report 94-2, 62 p.

Hausel, W.D., and Roberts, J.T., 1981, Geology of the Comstock mine and lode, Silver Crown district: Geological Survey of Wyoming Mineral Report MR81-3, 9 p.

Hayden, F.V., 1871, Preliminary report of the United States Geological Survey of Wyoming and contiguous territories: Washington, D.C., 511 p.

Heimlich, R.A., and Armstrong, R.L., 1972, Variance of Precambrian K-Ar biotite dates, Bighorn Mountains, Wyoming: Earth and Planetary Science Letters, v. 14, p. 75-78.

Heimlich, R.A., and Banks, P.O., 1968, Radiometric age determination, Bighorn Mountains, Wyoming: American Journal of Science, v. 226, p. 180-192.

Henderson, C.W., 1943, Gold, silver, copper, and lead in Wyoming, *in* Minerals Yearbook 1942: U.S. Bureau of Mines, p. 517-520.

Hewett, D.F., 1912, The ore deposits of Kirwin, Wyoming: U.S. Geological Survey Bulletin 811-A, p. 121-132.

Hills, F.A., and Armstrong, R.L., 1974, Geochronology of Precambrian rocks in the Laramie Range and implications for the tectonic framework of Precambrian in southern Wyoming: Precambrian Research, v. 1, p. 1757-1784.

Hopkins, J.E., 1920, Preliminary report on prospects of Bald Mountain area of Big Horn Mountains, Sheridan County, Wyoming: Tonopah Placers Company report, Philadelphia, PA: Geological Survey of Wyoming mineral files, 16 p.

Houston, R.S., 1961, The Big Creek pegmatite area, Carbon County, Wyoming: Geological Survey of Wyoming Preliminary Report No. 1, 11 p.

Houston, R.S., 1992, Proterozoic mineral deposits near plate margins of the Archean Wyoming Province, USA: Precambrian Research 58 p. 85-97.

Houston, R.S., 1993, Late Archean and Early Proterozoic geology of southeastern Wyoming *in* Snoke, A.W., Steidtmann, J.R., and Roberts, S.M., eds, Geology of Wyoming : Geological Survey of Wyoming Memoir 5, p. 78-116.

Houston, R.S., and others, 1968, A regional study of rock of Precambrian age in that part of the Medicine Bow Mountains lying in southeastern Wyoming-with a chapter on the relationship between Precambrian and Laramide structure: Geological Survey of Wyoming Memoir 1, 167 p.

Houston, R.S., Hausel, W.D., Woodfill, R.D., and Graff, P.J., 1992, Metallogenic map of volcanogenic massive sulfide occurrences in Wyoming: U.S. Geological Survey Map MF-1853-F, scale 1:1,000,000

Houston, R.S., Schmidt, T.G., and Lane, M.E., 1983, Mineral resources potential and geology of the Huston Park roadless area, Carbon County Wyoming: U.S. Geological Survey Miscellaneous Field Studies Map MF-1637, 8 p., scale 1:24,000.

Houston, R.S., Schuster, J.E., and Ebbett, B.E., 1975, Preliminary report on distributions of copper and platinum group metals in mafic igneous rocks of the Sierra Madre, Wyoming: U.S. Geological Survey Open File Report, 128 p.

Huang, Chi-I, 1970, Cataclastic rocks in the Little Beaver Creek area, Carbon County, Wyoming: M.S. thesis, University of Wyoming, Laramie, 63 p.

Jamison, C.E., 1911, Wyoming State Geologist record report no. 110, on the Silver Crown District, Laramie County, Wyoming: Geological Survey of Wyoming Mineral Report MR11-1, 14 p.

Jamison, C.E., 1912a,Report on the property of the Hutchins Consolidated gold mining company, Crook County, Wyoming: Geological Survey of Wyoming Mineral Report MR12-2, 24 p.

Jamison, C.E., 1912b, Wyoming State Geologist record report no. 112, Otego Mining Company, Silver Crown District: Geological Survey of Wyoming Mineral Report MR12-1, 7 p.

Jenner, G.A., Jr., 1984, Tertiary alkalic igneous activity, potassic fenitization, carbonatitic magmatism, and hydrothermal activity in the central and southeastern Bear Lodge Mountains, Crook County, Wyoming: M.S. thesis, University of North Dakota, Grand Forks, 232 p.

Johnson, R.C., and Hills, F.A., 1976, Precambrian geochronology and geology of the Boxelder Canyon area, northern Laramie Range, Wyoming: Geological Society of America Bulletin, v. 87, no. 5, p. 809-817.

Kasteler, J.I., and Frey, E., 1949, Diamond drilling at the Rambler copper mine, Albany County: U.S. Bureau of Mines Report of Investigations 4544, 6 p.

Kennedy, G.A., 1927, Preliminary report on the examination of the Bonanza King mining property, Carbon County, Wyoming: University of Wyoming American Heritage Center, Thayer Lindsley Collection Report No. 6034, 6 p.

Ketner, K.B., Keefer, W.R., Fisher, F.S., Smith, D.L., and Raabe, R.G., 1966, Mineral resources of the Stratified Primitive area, Wyoming: U.S. Geological Survey Bulletin 1230-E, 56 p.

King, J.R., 1961, Geology of the Boswell Creek area, Albany County, Wyoming: M.A. thesis, University of Wyoming, Laramie, 83 p.

King, J.S., 1963, Petrology and structure of the Precambrian and post Mississippian rocks of the northeastern Medicine Bow Mountains, Carbon County, Wyoming: PhD. dissertation, University of Wyoming, Laramie, 125 p.

King, R.U., 1952, Abandoned copper-gold mine, Sheridan County: U.S. Geological Survey trace elements preliminary reconnaissance report, 1 p.

Kiilsgaard, T.H., Dricksen, G.E., Patten, L.L., and Bieniewski, C.L., 1972, Mineral resources of the Cloud Peak Primitive area, Wyoming: U.S. Geological Survey Bulletin 1371-C, 60 p.

Kirk, A.R., Johnson, T.W., and Elliott, J.E., 1993, Geology and mineral deposits of the New World district, Park County, Montana: Society of Economic Geologists Newsletter no. 12, p. 1-16.

Klein, T.L., 1974, Geology and mineral deposits of the Silver Crown mining district, Laramie County, Wyoming: Geological Survey of Wyoming Preliminary Report 14, 27 p.

Klein, T.L., 1981, The geology and geochemistry of sulfide deposits of the Seminoe district, Carbon County, Wyoming: PhD dissertation, Colorado School of Mines, Golden, 232 p.

Klein, T.L., 1982, Archean metavolcanic rocks of the Bradley Peak area, Seminoe Mountains, Wyoming: 1982 Archean geochemistry field conference guidebook, August 15-19, p. 24-49.

Kluender, S.E., 1982, Mineral resources investigation of the Savage Run wilderness, Albany and Carbon Counties, Wyoming: U.S. Bureau of Mines Open File Report MLA 75-82, 8 p.

Knight, S.H., 1942, Known mineral resources of Albany County, Wyoming, part 1, the metallic minerals: Geological Survey of Wyoming Mineral Report 42-45, 24 p.

Knight, W.C., 1893, Notes on the mineral resources of the State: University of Wyoming Experiment Station Bulletin 14, p. 103-212.

Knight, W.C., 1902, Notes on the occurrence of rare minerals at the Rambler mine: Engineering and Mining Journal, v. 73, p. 696.

Kopp, R.S., 1978, Uranium occurrence report for the Big Wind occurrence: U.S. Atomic Energy Commission Preliminary Reconnaissance report, 6 p.

Kopp, R.S., and Cohenour, R.E., 1978, Uranium occurrence report for the Jamax property: U.S. Atomic Energy Commission Preliminary Reconnaissance report, 6 p.

Lackey, L.L., 1965, Petrography of metavolcanic and igneous rocks of Precambrian age in the Huston Park area, Sierra Madre, Wyoming: M.A. thesis, University of Wyoming, Laramie, 78 p.

Lakes, A. 1904, Grand Encampment: Mines and Minerals, v. 25, Nov., p. 200-201.

Lawrence, R., 1981, Itmay drilling program-1981: Interoffice communication in Conoco Minerals Wyoming project summary report, 8 p.

Lee, G.K., Antweiler, J.C., Love, J.D., and Benedict, J.F., 1982, Geologic reconnaissance and geochemical sampling survey of molybdenum mineralization near Schiestler

Peak, Temple Peak Quadrangle, Sublette County, Wyoming: U.S. Geological Survey Open File Report 82-299, 202 p.

Leedy, W.P., 1988, Letter addressed to W. Dan Hausel about the discovery by Kerr McGee Corporation, of umangite, a copper selenite: Geological Survey of Wyoming mineral files, 7 p.

Lisenbee, A.L., 1985, Tectonic map of the Black Hills uplift, Montana, Wyoming, and South Dakota: Geological Survey of Wyoming Map Series 13, scale 1:250,000.

Lloyd, J.E., 1970, The history of Cokeville, Wyoming: M.S. thesis, Utah State University, Logan, Utah, 160 p.

Loose, S.A., 1988, Sedimentary facies, ore mineralogy, and paragenesis of the Lake Alice Cu-Ag-Pb-Zn district in the Wyoming Overthrust Belt: M.S. Thesis, University of Wyoming, Laramie, 177 p.

Loose, S.A., 1990, Ore mineralogy, paragenesis, source of metals, and timing of mineralization of the Lake Alice Cu-Ag-Pb-Zn district in the Wyoming Thrust Belt: Wyoming Geological Association 41st annual field conference guidebook, p. 123-149.

Loose, S.A., and Boberg, W.W., 1987, Sedimentary facies control on mineralization at the Lake Alice district in the Wyoming overthrust belt: Wyoming Geological Association 38th annual field conference guidebook, p. 309-327.

Loucks, R.R., 1976, Platinum-gold-copper mineralization, central Medicine Bow Mountains, Wyoming: M.S. thesis, Colorado State University, 290 p.

Loucks, R.R., 1988, Petrology, structure, and age of the Mullen Creek layered mafic complex and age of arc accretion, Medicine Bow Mountains, Wyoming: Geological Society of America Abstracts w/ Programs, v. 20, p. A73.

Love, J.D., 1954, Memorandum of notes on uranium deposits in the Badwater area, Fremont County, Wyoming: Geological Survey of Wyoming mineral report MR54-1, 3 p.

Love, J.D., 1970, Cenozoic geology of the Granite Mountains area, central Wyoming: U.S. Geological Survey Professional Paper 495-C, 154 p.

Love, J.D., 1984, Gold, silver, and other selected trace elements in the Phosphoria Formation of western Wyoming: Wyoming Geological Association 35th Annual Field Conference Guidebook, p. 383-388.

Love, J.D., and Antweiler, J.C., 1973, Copper, silver, and zinc in the Nugget Sandstone, western Wyoming: Wyoming Geological Association 25th Field Conference Guidebook, p. 139-147.

Love, J.D., and Christiansen, A.C., 1985, Geologic map of Wyoming: U.S. Geological Survey, scale 1:500,000.

Lovering, T.S., 1929a, The New World or Cooke City mining district, Park County, Montana: U.S. Geological Survey Bulletin 811-A, 87 p.

Lovering, T.S., 1929b, The Rawlins, Shirley, and Seminoe iron deposits of Carbon County, Wyoming: U.S. Geological Survey Bulletin 811-D, p. 203-235.

Lukanuski, J.N., 1969, Progress report on the Needle Creek property, Park County, Wyoming: Phelps Dodge Corporation report, Geological Survey of Wyoming mineral files, 62 p.

Luth, W.C., 1960, Mafic and ultramafic rocks of the Trailside area, Bighorn Mountains, Wyoming: M.S. thesis, University of Iowa, Iowa City, 138 p.

Master, T., 1977, Rock and mineral occurrences in the Ferris Mountains, Wyoming: M.S. thesis, University of Wyoming, 147 p.

McCallum, M.E., and Kluender, S.E., 1983, Mineral resource potential of the Savage Run Wilderness, Albany and Carbon Counties, Wyoming: U.S. Geological Survey Miscellaneous Field Studies Map MF1638-A, 10 p.

McCallum, M.E., Loucks, R.R., Carlson, R.R., Cooley, E.F., and Doerge, T.A., 1976, Platinum metals associated with hydrothermal copper ores of the New Rambler mine, Medicine Bow Mountains, Wyoming: Economic Geology, v. 71, p. 1429-1450.

McCallum, M.E., and Menzer, F.J., 1982, Metal distribution in the Battle Lake area, Grand Encampment mining district, Carbon County, Wyoming, with comparisons to deposits in the New Rambler mine district, Albany and Carbon Counties, Wyoming: U.S. Geological Survey Open File Report 82-179, 20 p.

McCallum, M.E., and Orback, C.J., 1968, The New Rambler copper-gold-platinum district, Albany and Carbon Counties, Wyoming: Geological Survey of Wyoming Preliminary Report 8, 12 p.

McCarty, E.P., 1927, Letter to Julia L. Stevenson about the Buckeye mine (September, 12, 1927): Geological Survey of Wyoming mineral files, 2 p.

McGraw, R.B., Jr., 1954, Geology in the vicinity of the Copper King mine, Laramie County, Wyoming: M.A. thesis, University of Wyoming, 68 p.

Menzer, F.J., 1982, Sulfide mineralization in the Battle Lake area, Grand Encampment mining district, Carbon County, Wyoming: M.S. thesis, Colorado State University, Ft. Collins, 129 p.

Merry, R.D., 1963, Precambrian geology, shear zones and associated mineral deposits of the Hog Park area, Carbon County, Wyoming: M.S. thesis, University of Wyoming, Laramie, 44 p.

Messerschmidt, D.A.,1972, The Grand Encampment: The Grand Encampment Museum, Encampment, Wyoming, 44 p.

Michalek, D.D., 1952, Precambrian geology of Jelm Mountain, Albany County, Wyoming: M.A. thesis, University of Wyoming, Laramie, 51 p.

Millgate, M.L., 1964, Geologic map of the beryl-bearing pegmatite area, Niobrara County, Wyoming: Geological Survey of Wyoming Open File Report 64-1, scale 1:24,000.

Millgate, M.L., 1965a, The Haystack Range, Goshen and Platte Counties, Wyoming: Geological Survey of Wyoming Preliminary Report 5, 9 p.

Millgate, M.L., 1965b, Copper prospect, section 35, T15N, R80W, Carbon County, Wyoming: Geological Survey of Wyoming Mineral Report 65-2, 2 p.

Molker, A.J., 1923, History of Natrona County: R.R. Donnelley and Sons, The Lakeside Press, Chicago, p. 99-101.

Mueller, P.A., Peterman, Z.E., and Granath, J.W., 1985, A bimodal Archean volcanic series, Owl Creek Mountains, Wyoming: Journal of Geology, v. 93, p. 701-712.

Neeham, A.B., 1942, Rambler mine, Albany County, Wyoming: U.S. Bureau of Mines War Minerals Report 17, 7 p.

Nelsen, C.J., 1981, Technical report on the Fletcher Park, Wyoming project: Conoco Minerals Wyoming project summary report, 63 p.

Nelson, W.H., Prostka, H.J., Williams, F.E., Elliott, J.E., and Peterson, D.L., 1980, Geology and mineral resources of the North Absaroka wilderness and vicinity, Park County, Wyoming: U.S. Geological Survey Bulletin 1447, 101 p.

Neubert, J.T., 1985, Mineral investigation of the Ferris Mountains wilderness study area (WY-030-407), Carbon County, Wyoming: U.S. Bureau of Mines Open File Report MLA 71-85, 55 p.

Nevin, A.E., 1973, Interim report, Copper King property, Laramie County, Wyoming: Henrietta Mines Ltd. company report, Geological Survey of Wyoming mineral files, 16 p.

Newkirk, S.R., 1980, History of the Needle Creek project, Park County, Wyoming: unpublished report: Geological Survey of Wyoming mineral files, 3 p.

Orback, C.J., 1960, Geology of the Fox Creek area, Albany County, Wyoming: M.S. thesis, University of Wyoming, 98 p.

Osterwald, F.W., 1947, Report of geologic investigation of the Broadway lead-zinc claim, Carbon County, Wyoming: Geological Survey of Wyoming Mineral Report 47-2, 4 p.

Osterwald, F.W., 1950, Notes on the geology at the Silver Cliff mine, Lusk, Wyoming: Geological Survey of Wyoming Mineral Report 50-4, 8 p.

Osterwald, F.W., 1959, Structure and petrology of the northern Big Horn Mountains, Wyoming, Geological Survey of Wyoming Bulletin 48, 47 p.

Osterwald, F.W., Osterwald, D.B., Long, J.S., Jr., and Wilson, W.H., 1966, Mineral resources of Wyoming, Geological Survey of Wyoming Bulletin 50, 287 p.

Parsons, W.H., 1937, The ore deposits of the Sunlight mining region, Park County, Wyoming: Economic Geology, v. 32, no. 6, p. 832-854.

Pease, L. A., 1905, Letter to H.C. Beeler about the Pease properties in the north Fork district of the Sierra Madre, October 24, 1905: Geological Survey of Wyoming mineral files, 8 p.

Pedersen, K., 1967, Sulfide mineralization of the northwestern part-Sunlight mining region, Park County, Wyoming: M.S. thesis, University of Wyoming, 50 p.

Pekarek, A.F., 1977, The structural geology and volcanic petrology of the Rattlesnake Hills, Wyoming: Wyoming Geological Association Earth Science Bulletin, v. 10, no. 4, 30 p.

Peterman, Z.E., Hedge, R.A., and Braddock, W.A., 1968, Age of Precambrian events in the northeast Front Range, Colorado: Journal of Geophysical Research, v. 73, p. 2277-2296.

Peterman, Z.E., and Hildreth, R.A., 1978, Reconnaissance geology and geochronology of the Precambrian of the Granite Mountains, Wyoming: U.S. Geological Survey Professional Paper 1055, 22 p.

Platt, R.E., 1942, Application for a development loan for the Big Creek copper mine: Geological Survey of Wyoming mineral files, 9 p.

Platt, R.E., 1947, Little known Wyoming locality: The Mineralogist, v. 15, no. 5, p. 227-230.

Reed, G.C., 1950, Mines and mineral deposits, Park County, Montana: U.S. Bureau of Mines Information Circular 7546, 68 p.

Rich, D.H., 1974, Economic geology of the Silvertip Basin, Sunlight mining region, Park County, Wyoming: M.S. thesis, University of Miami, Oxford, Ohio, 73 p.

Roberts, W.L., Rapp, G.R., Jr, and Weber, J., 1974, Encyclopedia of minerals: Van Nostrand, New York, 693 p.

Rogers, A.F., 1912, Lorandite from the Rambler mine: American Journal of Science, v. 33, p. 105-106.

Rostad, O.H., 1982, Future work at Kirwin: AMAX Exploration Memorandum, Feb. 10, 1982, Geological Survey of Wyoming mineral files, 5 p.

Rostad, O.H., 1983, Data summary, AMAX's Kirwin project, Park County, Wyoming: AMAX Exploration Memorandum, August 30, 1983, Geological Survey of Wyoming mineral files, 4 p.

Rubey, W.W., Oriel, S.S., and Tracey, J.I., Jr., 1975, Geology of the Sage and Kemmerer 15-minute quadrangles: U.S. Geological Survey Professional Paper 855, 18 p.

Ryan, G.S., 1988, Mineral investigation of the Encampment wilderness study area (WY-030-301), Carbon County, Wyoming: U.S. Bureau of Mines Open File Report MLA-88, 17 p.

Sanford, S., and Stone, R.W., 1914, Useful minerals in the United States: U.S. Geological Survey Bulletin 585, 250 p.

Schmidt, T., 1986, Metavolcanic rocks and associated volcanogenic mineral deposits of the Fletcher Park and Green Mountain areas, Sierra Madre, Wyoming *in* S. Roberts ed., Metallic and nonmetallic deposits of Wyoming and adjacent areas, 1983 conference proceedings: Geological Survey of Wyoming Public Information Circular 25, 23-36.

Schoen, R., 1953, Geology of the Cooper Hill district, Carbon County, Wyoming: University of Wyoming M.A. thesis, 41 p.

Schultz, A.R., 1914, Geology and geography of a portion of Lincoln County, Wyoming: U.S. Geological Survey Bulletin 543, 141 p.

Segerstrom, K., Weisner, R.C., and Kleinkopf, M.D., 1977, Mineral resources of the Laramie Peak study area, Albany and Converse Counties, Wyoming: U.S. Geological Survey Bulletin 1397-B, 35 p.

Short, B.L., 1958, A geologic and petrographic study of the Ferris-Haggarty mining area, Carbon County, Wyoming: M.A. thesis, University of Wyoming, Laramie, 100 p.

Silver Lake Resources, Inc., 1985, Annual report for 1985: Geological Survey of Wyoming mineral files, 27 p.

Smedes, H.W., and Prostka, H.J., 1972, Stratigraphic framework of the Absaroka Volcanic Supergroup in the Yellowstone National Park region: U.S. Geological Survey Professional Paper 729-C, 33 p.

Smith, E.W., 1953, Preliminary reconnaissance report of the William A. Cross ranch, LaPrele district: U.S. Atomic Energy Commission report DEB-RRD-1019, 1 p.

Smith, E.W., 1954, Preliminary reconnaissance report: U.S. Atomic Energy Commission report DEB-RRD-1094, 2 p.

Smith, R.B., Byrd, J.O.D., and Susong, D.D., 1993, The Teton fault, Wyoming: seismotectonics, Quarternary history, and earthquake hazards, *in* Snoke, A.W., Steidtmann, J.R., and Roberts, S.M., eds, Geology of Wyoming: Geological Survey of Wyoming Memoir 5, p. 628-667.

Smithson, S.B., and Hodge, D.S., 1972, Field relations and gravity interpretation in the Laramie anorthosite complex: University of Wyoming Contributions to Geology, v. 11, no. 2, p. 43-59.

Snyder, G.L., 1980, Map of Precambrian and adjacent Phanerozoic rocks of the Hartville Uplift, Goshen, Niobrara, and Platte Counties, Wyoming: U.S. Geological Survey Open File Report 80-779, 10 p.

Snyder, G.L., Hausel, W.D., Klein, T.L., Houston, R.S., and Graff, P.J., 1989, Precambrian rocks and mineralization, southern Wyoming Province: American Geophysical Union 28th International Geological Congress Field Trip Guidebook T332, Washington, D.C., 10 p.

Soule, J.H., 1955, Investigations of the Copper King copper-gold-silver deposits, Silver Crown mining district, Laramie County, Wyoming: U.S. Bureau of Mines Report of Investigations 5139, 37 p.

Spencer, A.C., 1903, Reconnaissance examination of the copper deposits at Pearl, Colorado: U.S. Geological Survey Bulletin 213, p 163-169.

Spencer, A.C., 1904, Copper deposits of the Encampment district, Wyoming: U.S. Geological Survey Professional Paper 25, 107 p.

Spencer, A.C., 1916, The Atlantic City gold district and the north Laramie Mountains: U.S. Geological Survey Bulletin 626, 85 p.

Spring, A.W., 1947, Million dollar gossan: Rocky Mountain Life, May, p. 38-42.

Staatz, M.H., 1983, Geology and descriptions of thorium and rare earth deposits in the southern Bear Lodge Mountains, northeastern Wyoming: U.S. Geological Survey Professional Paper 1049-D, 52 p.

Stockwatch, 1987, Exploration update on Caledonia Resources, Ltd: Canjex Publishing, Ltd., September, Vancouver, B.C., p. 9.

Stoll, E.J., 1929, Prospectus on Platinum Metals Corporation's Henri Lode Claim: Geological Survey of Wyoming mineral files, 8 p.

Stuckless, J.S., Hedge, C.E., Worl, R.G., Simmons, K.R., Nkomo, I.T., and Wenner, D.B., 1985, Isotopic studies of the Late Archean plutonic rocks of the Wind River Range, Wyoming: Geological Society of America Bulletin, v. 96, p. 850-860.

Stuckless, J.S., and Peterman, Z.E., 1977, A summary of the geology, geochronology, and geochemistry of the Archean rocks of the Granite Mountains, Wyoming: Wyoming Geological Association Earth Science Bulletin, v. 10, no. 3, p. 3-10.

Stueber, A.M., and Heimlich, R.A., 1977, Rb-Sr isochron age of the Precambrian basement complex, Big Horn Mountains, Wyoming: Geological Society of America Bulletin, v. 88, p. 441-444.

Subbarayuda, G.V., 1975, The Rb-Sr isotopic composition and the origin of the Laramie anorthosite-mangerite complex, Laramie Range, Wyoming: PhD dissertation, University of New York, Buffalo, 109 p.

Sutherland, W.M., 1990, Gemstones, lapidary materials and geological collectables in Wyoming: Geological Survey of Wyoming Open File Report 90-9, 53 p.

Swift, P.N., 1982, Precambrian metavolcanic rocks and associated volcanogenic mineral deposits of the southeastern Sierra Madre, Wyoming: M.S. thesis, University of Wyoming, 61 p.

Theobald, P.K., Jr., and Thompson, C.E., 1968, Platinum and associated elements at the New Rambler mine and vicinity, Albany and Carbon Counties, Wyoming: U.S. Geological Survey Circular 607, 14 p.

Thomas, H.D., 1943, Letter to Charles Henderson, U. S. Bureau of Mines, about the Griggs mine: Geological Survey of Wyoming mineral files, 1 p.

Thomas, H.D., 1960, September 26, 1960, memo to William H. Wilson: Geological Survey of Wyoming mineral report MR07-91, 2 p.

Timberline Minerals Company, 1982, Report on the Needle Creek copper-molybdenum porphyry deposit: Geological Survey of Wyoming mineral files, 80 p.

Troyer, M.L., 1946, Geology of the Strong mine and vicinity: Geological Survey of Wyoming Mineral Report MR46-1, 6 p.

Trumbull, L.W., 1914, Report number 120 of the State Geologist's office upon the lode claims, Mountain View, Liberty, and Orebin situated in section 7, T6N, R3E, Wind River: Geological Survey of Wyoming Mineral Report MR14-1, 5 p.

Vanderberge, J.H., 1906, An independent engineer's report on the properties of the Penn-Wyoming copper company and the Grand Encampment mining district: Geological Survey of Wyoming Mineral Report MR06-1, 25 p.

Veatch, A.C., 1907, Geography and geology of a portion of southwestern Wyoming: U.S. Geological Survey Professional Paper 56, 178 p.

Welch, C.M., 1974, A preliminary report on the geology of the Mineral Hill area, Crook County, Wyoming: M.S. thesis, South Dakota School of Mines and Technology, Rapid City South Dakota, 83 p.

Wells, John, 1982, Letter to Representative Dick Cheney, March 12, 1982: Geological Survey of Wyoming mineral files, 1 p.

Wertz, J.T., 1913, Letter addressed to J.S. Spur, vice-president of the Tonapah Mining Company, on August 1, 1913: Geological Survey of Wyoming mineral files, 3 p.

Whalen, J.F., 1954a, Preliminary reconnaissance report of the Doane-Rambler mine: U.S. Atomic Energy Commission report DEB-RRD-1375, 1 p.

Whalen, J.F., 1954b, Preliminary reconnaissance report of the Ferris-Haggarty mine: U.S. Atomic Energy Commission report DEB-RRD-1372, 1 p.

Wied, O.J., 1960, Geology of the Encampment area, Carbon County, Wyoming: M.S. thesis, University of Wyoming, Laramie, 51 p.

Wilmarth, V.R., and Johnson, D.H., 1954, Uranophane at Silver Cliff mine, Lusk, Wyoming: U.S. Geological Survey Bulletin 1009A, 12 p.

Wilson, W.H., Undated, Muskrat Creek: Geological Survey of Wyoming Mineral Report, 6 p.

Wilson, W.H., 1951, An occurrence of copper in the Laramie Mountains, Albany County, Wyoming: Geological Survey of Wyoming Mineral Report 51-2, 2 p.

Wilson, W.H., 1955a, Cherry Creek copper prospect, Carbon County: Geological Survey of Wyoming Mineral Report 55-1, 3p.

Wilson, W.H., 1955b, Temple Peak molybdenum deposit, Sublette County: Geological Survey of Wyoming Mineral Report 55-3, 10 p.

Wilson, W.H., 1955c, Crouch gold prospect, Park County, Wyoming: Geological Survey of Wyoming Mineral Report 55-2, 6 p.

Wilson, W.H., 1960, Petrology of the Wood River area, southern Absaroka Mountains, Park County, Wyoming: PhD dissertation, University of Utah, 121 p.

Wilson, W.H., 1964, The Kirwin mineralized area, Park County, Wyoming: Geological Survey of Wyoming Preliminary Report no. 2, 12 p.

Wilson, W.H., 1971, Volcanic geology and mineralization, Absaroka Mountains, northwest Wyoming: Wyoming Geological Association 23rd Field Conference Guidebook, p. 151-155.

Wilson, W.H., 1975, The copper-bearing Meadow Creek granodiorite, upper Wood River area, Park County, Wyoming: Wyoming Geological Association 27th Field Conference Guidebook, p. 235-241.

Woodfill, R.D., 1987, Hartville uplift, southeastern Wyoming: Consultants report, Geological Survey of Wyoming mineral files, 20 p.

Zahony, S., 1976, Report on McCann Pass, Wyoming(Cu-Zn-Ag): Mine Finders Incorporated report: Geological Survey of Wyoming mineral files, 5 p.