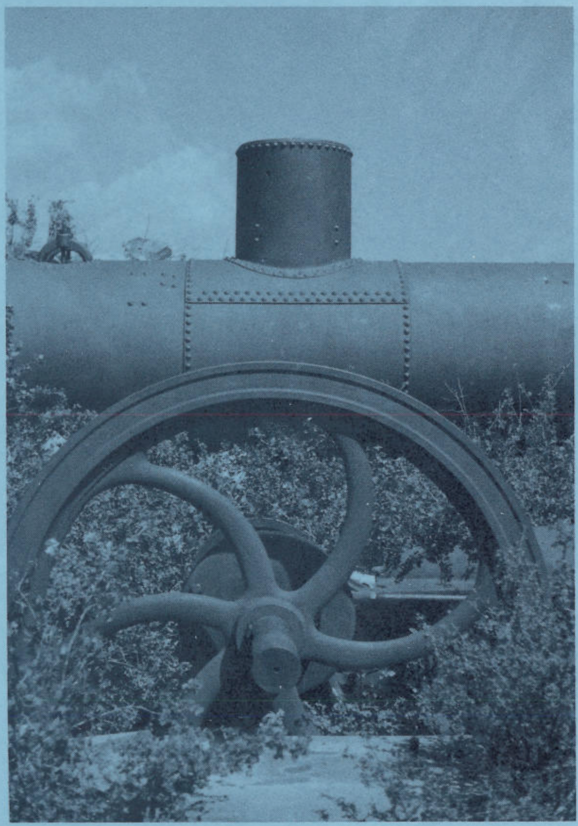
THE GEOLOGICAL SURVEY OF WYOMING

DANIEL N. MILLER, JR., State Geologist

Geology and Mineral Deposits of the Silver Crown Mining District, Laramie County, Wyoming

BY

TERRY KLEIN



PRELIMINARY REPORT NO. 14

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OCTOBER, 1974

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Preliminary Report #3. The Keystone gold-copper prospect area, Albany County, Wyoming: Donald R. Curry, 1965. (Price 75¢)

Preliminary Report #7. The Centennial Ridge Gold-Platinum District, Albany County, Wyoming: M. E. McCallum, 1968. (Price 75¢)

Preliminary Report #8. The New Rambler Copper-Gold-Platinum District, Albany and Carbon Counties, Wyoming: M. E. McCallum and C. J. Orback, 1968. (Price 75¢)

Mines and Minerals Map of Wyoming: colored 1970 Edition; Scale 1:500,000 (approx. 1 in. equals 8 mi.). Rolled or folded copies available for $2.00, or $2.50 if ordered by mail.

THE GEOLOGICAL SURVEY OF WYOMING

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PRELIMINARY REPORT NO. 14

GEOLOGY AND MINERAL DEPOSITS OF THE SILVER CROWN MINING DISTRICT, LARAMIE COUNTY, WYOMING

BY TERRY KLEIN

Box 3008 University Station
Laramie, Wyoming 82071
In cooperation with Mineral Division,
Department of Economic Planning and Development

OCTOBER 1974

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PHOTOGRAPHS

LIST OF PLATES

FOREWORD

Although Wyoming has not been a prolific producer of metallic minerals, many of the old metal mining districts in the state are now being examined and re-evaluated in light of changing economic conditions. Among these is the Silver Crown Mining District in the southern Laramie Range.

In this report Mr. Terry Klein describes the geological characteristics of the copper and precious metal mineral deposits in the Silver Crown district, offers geological interpretations for the origin of these deposits, and describes the results and effectiveness of geochemical and geophysical exploration methods used in the district.

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Laramie, Wyoming
October 21, 1974

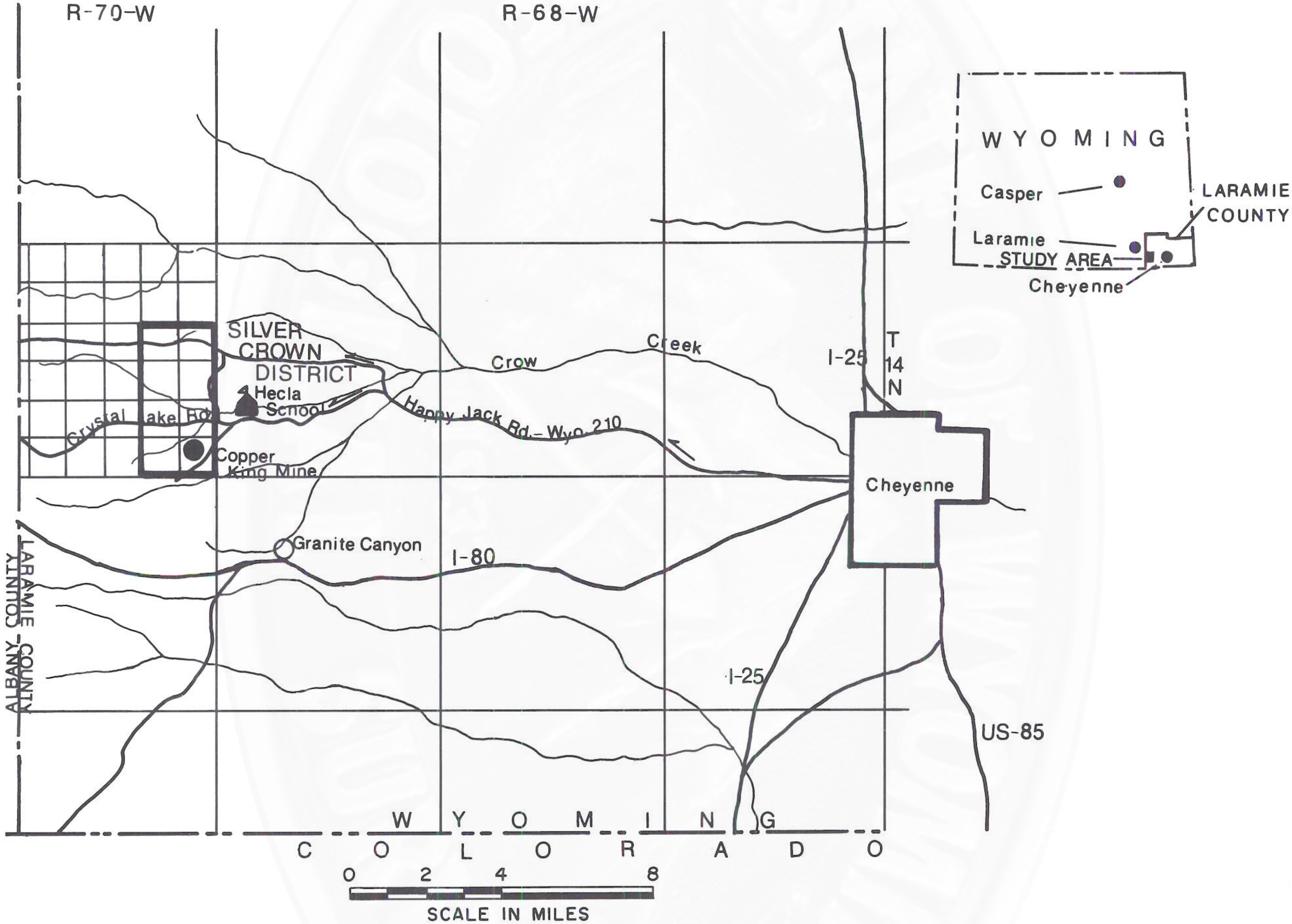


FIGURE 1. Index map of the study area.

GEOLOGY AND MINERAL DEPOSITS OF THE SILVER CROWN MINING DISTRICT, LARAMIE COUNTY, WYOMING

BY TERRY KLEIN

INTRODUCTION

Geography

The Silver Crown Mining District is located approximately twenty miles west of Cheyenne, Wyoming, in the eastern foothills of the Laramie Range. This area lies in the western part of Laramie County, Wyoming, in the Hecla 7.5 minute quadrangle, about four miles north of Interstate 80 at Granite Canyon (Fig. 1).

Evaluation of the district was restricted to sections 13-14, 23-26, 35-36, T. 14 N., R. 70 W., which includes the bulk of the mineralized area.

The region is characterized by rolling hills ranging in elevation from 6,800 to 7,500 feet (Photo 1). Two major streams, the Middle and South Forks of Crow Creek, provide drainage. Vegetation consists of range grasses and brush on lower, drier slopes and scattered coniferous trees on upland surfaces.

Access to the area is attained by traveling 18 miles west on Happy Jack Road from Cheyenne.

Methods of Investigation

The field study included a stream sediment geochemical survey and geologic mapping.

Stream sediment sampling began in the fall of 1971 and was concluded in the spring of 1972. These samples provided coverage of the major drainages.

Geologic mapping and geophysical studies were conducted during the summer and fall of 1972. Geology was recorded on a 1:12,000 enlargement of the U. S. Geological Survey (USGS) 7.5 minute Hecla quadrangle.

Thin sections were prepared from 68 rock samples and feldspar composition was determined by the Michel-Levy method (Kerr, 1959, p. 257-260). Rock slabs were stained to determine the potash feldspar content using the technique described by Bailey and Stevens (1960, p. 1020).

Previous Investigations

An investigation of the Arizona Mine, now known as the Copper King, was conducted in 1912 by C. E. Jamison, the Wyoming State Geologist (open file report, Wyoming Geological Survey). Jamison's report contains an underground map with assay locations and results.

The United States Bureau of Mines evaluated the Copper King property in 1953 and results are discussed in Report of Investigations #5139 (J. H. Soulé, 1955). The area adjacent to the Copper King was core drilled and geology was mapped at a scale of 1 inch = 400 feet in an attempt to delineate extensions of the deposit. McGraw (1954, M. A. theses, University of Wyoming) mapped the Copper King area at 1 inch = 500 feet with a plane table base and did a thin section petrographic analysis of local rock types.

The flanking sediments, Paleozoic through Tertiary in age, adjacent to the eastern portion of this study area have been mapped and correlated by Brady (1949), Loeffler (1939) and Gray (1947).

Granitic rocks of the Sherman batholith to the west and south have been studied

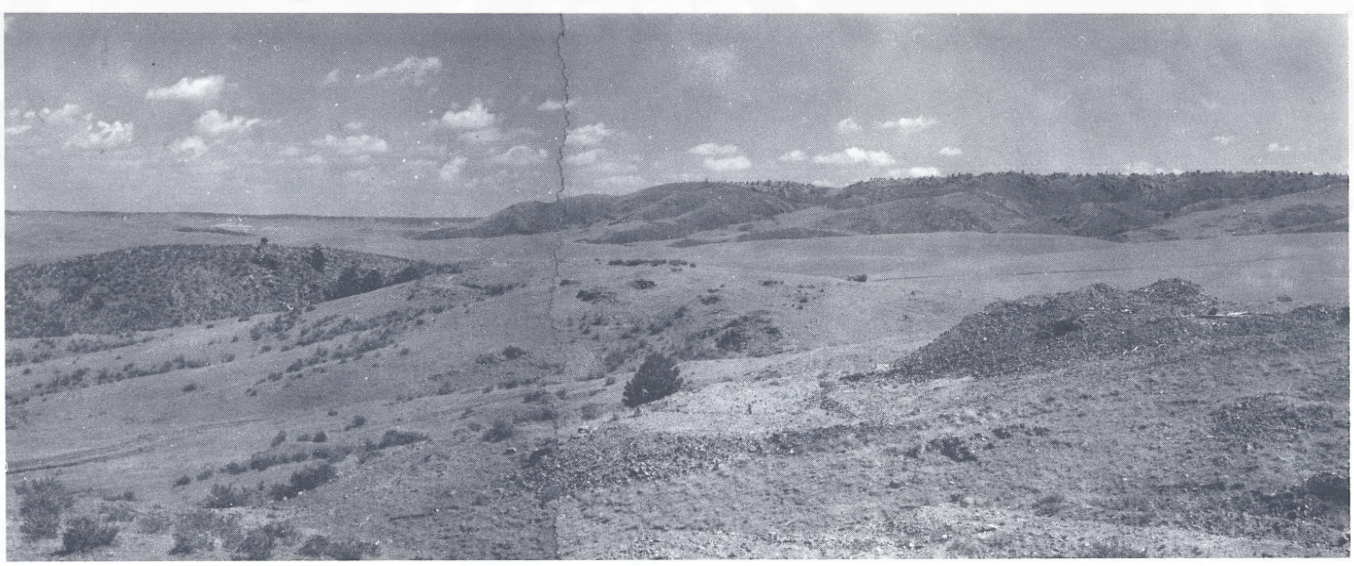


PHOTO 1. View of central part of Silver Crown district with Crystal Lake Reservoir in background and the Sherman erosion surface in the foreground.

PHOTO 2.

The Silver Crown District had a mill - concentrating plant - smelter near Hecla that operated on a small scale for a few years sometime between 1880 and 1900. A 1911 State Geologist's Report says of the operation: "Mining in a small way has been carried on in the district for many years, but operations have been confined principally to prospect holes, and no work of any magnitude, intelligently directed, has been attempted. Some years ago a concentrating plant and a small smelter were erected, but as the supply of ore was not sufficient, the concentrator not adapted to the ores, and the smelter equipped with needless expensive apparatus, operations were not successful."

PHOTO 3.

PHOTO 2. All that is left of the retaining wall and foundation of the mill. View is from the west.

PHOTO 3. A hodge-podge of "needless expensive apparatus" scattered around the old steam boiler. These lie in front of the wall seen in Photo 2.

PHOTO 4. The mill as viewed from the Crystal Lake Road to the south. The Copper King Mine is located on the hill opposite the mill, across the road. Ore was transported by horse-drawn wagons from the mines to the mill, distances of up to 2 miles.

PHOTO 5. Almost buried in berry bushes is part of the milling equipment used to grind the copper ores prior to smelting. The operation was steam-powered.

PHOTO 4.

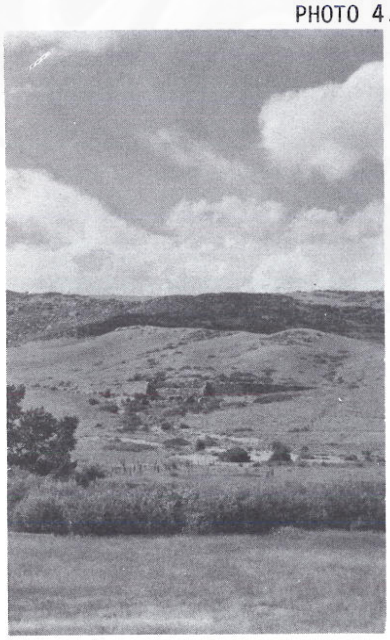


PHOTO 5.

TABLE I. SUMMARY OF EXPLORATION, COPPER KING MINE

Year	Drilling by:	Number of Holes	Total Footage	Additional Information
1938	ASARCO	5	1,400	
1952	Copper King Mining Co.	5	2,630	
1953	U. S. Bureau of Mines	3	2,630	geologic map
1970	ASARCO	8	3,050	geological map, soil geochemical I. P., aeromagnetic surveys
1972	Henrietta Mines	11	*a)1,518 b)1,899	geologic map, soil geochemical I. P., ground magnetic survey, petrography

*a) percussion drilling, b) core drilling

by Harrison (1951), and Eggler (1968). Age determinations made in the Sherman batholith are reported by Ferris and Krueger (1965) and others are included in the discussion by Peterman, Hedge and Braddock (1968) of the age of Precambrian events in the northeastern Front Range.

History of Production and Exploration

The Silver Crown Mining District was organized on April 4, 1879. The greatest amount of underground development was done from 1881 to 1910 on the Comstock and Copper King. An unpublished report by Harry Ferguson (1965), president of the Copper King Mining Company, discusses the history of the district. (See Photos 2-5, opposite page.)

Production records for the district are minimal with none available for the Copper King Mine. Records of several carloads of ore shipped from the Comstock Mine during a period from 1914 to 1917 are summarized in Ferguson's report. Indicated values in copper, silver, and gold were calculated by Ferguson at 1965 prices, to be about $50 per ton for ore shipped.

Drilling at the Copper King property has been extensive; companies, total footage, and additional exploration techniques are summarized in Table I. A map of the Copper King area (Plate II) shows drill hole locations, types, and average metal values for copper, silver and gold, in addition to results from an induced polarization (I. P.) and vertical intensity magnetometer survey.

In 1953-54 the United States Bureau of Mines, under the Defense Minerals Exploration Administration, drilled three diamond drill holes, results of which are described in U. S. Bureau of Mines Report of Investigations #5139. The Bureau's report includes drill hole locations and assays on all previous drilling, the results of their own drilling and a geologic map of the mine and adjacent area.

In 1956, the Good Venture Mining Company obtained the lease on the Comstock property, dewatered the shafts and drifts and installed track, air lines, and a hoist. Some ore was mined, but quantities were insufficient to maintain an operation.

Geologic Setting

The Silver Crown district is on the eastern flank of the Laramie Range, a north-south trending asymmetrical anticline, extending from the Colorado-Wyoming border northward for a distance of 125 miles. Precambrian rocks comprising the core of the range are flanked on either side by Paleozoic and younger sediments. The sediments on the western flank have relatively low dips, whereas those on the eastern side have very steep dips and may be overturned or faulted. Overlying the older sediments are nearly horizontal Tertiary deposits, which locally overlap the Precambrian core.

The oldest rocks in the Precambrian core of the range consist of a metasedimentary sequence of quartzite, dolomite, and hornblende schist (Hagner, 1953, p. 111). In the west central portion of the range, anorthosite and related rocks occur. The Sherman Granite is the youngest major Precambrian unit in the range and composes the bulk of the exposed crystalline rock types.

The Silver Crown district is located in a belt of northeast-trending, foliated, igneous rock types of intermediate composition which form the border of the Sherman batholith. Structural trends generally parallel this border. Paleozoic and Mesozoic sediments are in fault contact with the Precambrian rocks on the eastern border of the district. Tertiary arkosic sediments blanket a large portion of the area.

PETROGRAPHY

Precambrian Rocks

Quartz-Biotite Schist and Quartzite

Outcrops of quartz-biotite schist and quartzite occur east of the Copper King Mine, along the boundary of sections 25 and 36 (Plate I). Contacts with pegmatites, aplitic quartz monzonites, and foliated granodiorites appear to be quite sharp, and inclusions of quartz-biotite schist in pegmatite and aplite dikes are agmatic and intruded by felsic veinlets.

The schists are generally fine-grained, whereas the quartzites are fine- to medium-grained. Outcrops are distinctly to poorly foliated for schists and massive and unfoliated for the quartzites (Photo 6). Both lithologies range from dark gray to black in color.

Xenoliths of quartz-biotite schists occur in the foliated granodiorite throughout the map area and are generally irregular in shape, small in size, and exhibit

PHOTO 6. Outcrop of biotite schist exhibiting well developed foliation northeast of the Copper King Mine.

sharp contact relationships. These are especially numerous in the Copper King Mine area, because of the proximity of granodiorite and metasedimentary rock contacts (Plate I).

Microscopically, the texture of the schist is lepidoblastic, developed by biotite alignment in discontinuous-parallel arrangement. Quartz and feldspar exhibit granoblastic-polygonal textures. Modal analyses are given in Table II.

Amphibolitized Mafic Rocks

Amphibolitized mafic rocks occur in small outcrops with obscure contact relationships. Lithologies include diorite, gabbro, diabase, and pyroxenite. Macroscopic textures include equigranular, porphyritic and diabasic, with grain size ranging from medium to coarse. Colors range from dark gray to black.

Microscopic textures are widely varied. These may be relict igneous, or lepidoblastic and nematoblastic developed from the orientation of metamorphic biotite and amphiboles. The felsic material, plagioclase, quartz and some potash feldspar, may be recrystallized forming granoblastic textures. Modal analyses are given in Table III.

Hornblende (pleochroism: light blue-green, green, blue-green) is usually slightly to moderately poikiloblastic with quartz inclusions, and is commonly shattered. Plagioclase has usually undergone extensive alteration to sericite and to a lesser extent saussurite. It may occur as well developed laths or as large, euhedral, relict phenocrysts. Biotite is often observed as an alteration product of hornblende. Hornblende may form rims on the relict pyroxene (augite) phenocrysts and usually completely replaces them either as optically continuous crystals or as smaller crystalline aggregates. Locally, tremolite-actinolite is observed rimming augite in a dense nematoblastic intergrowth.

Foliated Granodiorite

Foliated granodiorite comprises the bulk of outcropping crystalline rocks in the Silver Crown district. Much of the granodiorite has undergone potassium enrichment. The potassium-rich varieties are generally in outcrops close to the boundary with the Sherman Granite but may occur close to aplitic quartz monzonite intrusions. Compositions range from granodiorite to quartz monzonite. Most of the potash feldspar appears to have been introduced after the initial crystallization of the granodiorite. Outcrops are angular and well jointed where potash is abundant, but tend to be more spheroidal in un-enriched areas. (Photo 7)

The granodiorite is fine- to coarse-grained, and macroscopic textures range from well developed igneous to extremely well foliated gneissic. The rocks are generally equigranular to slightly porphyritic and range from dark gray to red brown.

TABLE II. MODAL ANALYSES (VOLUME PERCENT) FOR QUARTZ-BIOTITE SCHIST

Mineral	Sample Number 21-19	21-57
Quartz	64.0	59.5
Biotite	32.0	32.0
Plagioclase	1.0	1.5
	An 20	An ?
Potash Feldspar	1.0	2.0
Magnetite	0.7	1.5
Apatite	0.5	0.5
Sphene	tr	tr
Muscovite	tr	-
Hematite	tr	tr

TABLE III. MODAL ANALYSES (VOLUME PERCENT) FOR AMPHIBOLITIZED MAFIC ROCKS

Mineral	Sample Number 0-2	21-15[1]	21-29A	21-173A
Hornblende	60.0	14.0	36.0	79.0
Plagioclase	17.0	21.0	25.0	11.0
	An 38	An 39	An 34	An 54
Biotite	3.0	16.4	8.0	tr
Quartz	-	33.6	-	8.0
Potash Feldspar	-	11.5	-	-
Sphene	4.0	1.0	-	tr
Magnetite	7.0	1.6	19.0	2.0
Epidote	-	1.0	-	-
Apatite	-	tr	-	-
Chlorite (incl. penninite)	-	tr	8.0	tr
Sericite	1.0	tr	1.0	2.0
Chalcopyrite and pyrite	-	-	tr	-
Tremolite-Actinolite	-	-	-	2.0

[1]Potash-enriched amphibolitized mafic xenolith

TABLE IV. MODAL ANALYSES (VOLUME PERCENT) FOR FOLIATED GRANODIORITE

Minerals	Sample Number							
	21-8A*	21-16	21-26*	21-74	21-83	21-107	21-118*	21-152
Plagioclase	26.0 An 28	42.0 An 30	25.0 An 23	35.0 An 26	26.0 An 24	29.0 An 26	20.5 An 15	36.0 An 30
Quartz	25.0	12.5	14.0	26.0	30.0	26.0	20.0	23.0
Potash-Feldspar	43.5	15.0	32.0	15.0	13.0	18.0	33.0	13.0
Hornblende	-	18.0	16.0	-	-	14.0	8.0	13.0
Biotite	37.0	6.0	10.0	19.0	27.0	11.0	15.0	11.0
Epidote	tr	3.0	2.0	tr	tr	tr	0.5	2.0
Sphene	-	tr	-	1.0	tr	1.3	1.5	tr
Magnetite	4.0	1.6	1.5	1.0	tr	1.0	1.8	1.0
Hematite	1.0	-	tr	tr	-	-	0.5	tr
Apatite	tr	1.0	tr	tr	tr	tr	0.5	tr
Chlorite	-	-	-	tr	4.0	tr	1.0	-
Sericite	tr	tr	tr	tr	tr	tr	tr	tr

*Potash-rich varieties

Hornblende and biotite often form large, distinctive aggregates. Other primary minerals include quartz and plagioclase, with variable amounts of potash feldspar.

Contact relationships are variable. Sharp contacts are observed with some of the crosscutting aplitic quartz monzonite dikes, much of the Sherman Granite, and all pegmatite dikes. Gradational or indefinite contacts are observed with most aplitic quartz monzonite, amphibolitized mafic rocks and hybrid felsic rocks.

Microscopically, the granodiorite is hypidiomorphic granular, allotriomorphic granular, lepidoblastic, or nematoblastic with granoblastic quartz, potash feldspar, and plagioclase. Plagioclase and quartz may be present as relict phenocrysts. Hornblende (pleochroism: light blue-green, yellow-green, green) is commonly poikiloblastic, containing quartz and plagioclase inclusions (Photo 8). In non-foliated phases, hornblende may be glomeroporphyritic or intergrown with biotite. Overgrowths of one hornblende crystal on another of slightly different optic orientation have been observed. Modal analyses are given in Table IV.

Perthite is present in many sections. Plagioclase is slightly to strongly altered to sericite and saussurite and may locally contain inclusions of quartz, epidote, chlorite, and apatite. Some myrmekitic intergrowths of quartz in plagioclase are observed. Albite twinning is common with Carlsbad-albite twins occurring less often. Zoning is widespread in plagioclase with more sodic plagioclase rimming more calcic cores. Microcline may form overgrowths on plagioclase or replace irregular portions of the plagioclase. Quartz may exhibit undulatory extinction.

The lithology can be divided into two categories based upon the potash feldspar

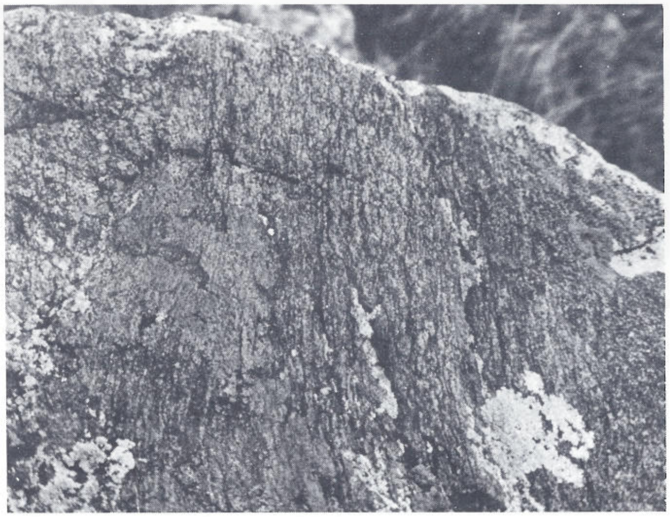


PHOTO 7. Outcrop of unenriched, spheroidally weathered, well-foliated granodiorite.

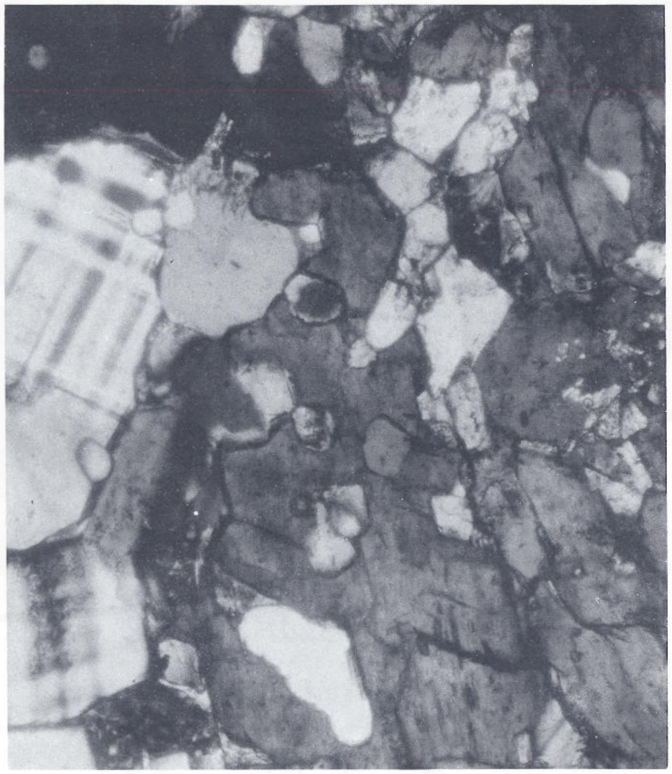


PHOTO 8. Photomicrograph of foliated granodiorite showing poikiloblastic hornblende in subparallel orientation with granoblastic quartz and microcline. Magnification 140 times with crossed nicols.

content. The average content is less than 20% potash feldspar, but may grade up to about 40%. Those with approximately 30% or more show evidence of potassium enrichment in hand sample. Thin sections show potassium feldspar replacement, overgrowths of relict plagioclase phenocrysts, and exhibit a granoblastic groundmass containing large volumes of potash feldspar. An increase in potash feldspar content generally accompanies an apparent decrease in ferromagnesian content. Biotite and hornblende are generally ragged, broken and in string-like elongations.

Where foliation is well developed, various stages of recrystallization may be recognized. Lepidoblastic and nematoblastic textures predominate; whereas intergranular quartz and feldspar are granoblastic. Relict quartz and plagioclase phenocrysts are partially polygonized or completely recrystallized. These rocks might be classified as gneissic, or in some cases mylonitic, but are gradational with non-foliated varieties.

TABLE V. MODAL ANALYSES (VOLUME PERCENT) FOR SHERMAN GRANITE.

Mineral	Sample Number			
	21-13A	21-13B	21-38[1]	21-70[2]
Quartz	39.5	36.4	39.0	26.0
Potash Feldspar	46.5	35.4	34.0	41.5
Plagioclase	12.3 An 14	22.0 An 16	17.0 An 14& An 10	3.0 An 16
Biotite	2.0	3.0	4.5	tr
Hornblende	-	5.0	-	-
Epidote	tr	-	2.0	22.0
Magnetite	1.0	1.5	2.0	tr
Apatite	tr	tr	tr	tr
Chlorite	-	-	2.0	6.0
Hematite	tr	tr	tr	1.0
Sphene	-	-	tr	-
Fluorite	tr	-	-	-
Zircon	tr	tr	-	-
Sericite	tr	tr	tr	2.0

1Sherman Granite dike
2Epidotized Sherman Granite

Sherman Granite

The Sherman Granite is a major rock unit in the Silver Crown district. Outcrops are confined to gullies and spheroidally weathered, low hills. The outcrops are locally well jointed. Most of the Sherman Granite is covered by a layer of grus which ranges up to 20 feet or more in thickness. The grus covers a gently undulating, rather flat, east sloping surface.

The granite is typically buff to pink and very coarse-grained with textures ranging from porphyritic-phaneritic to equigranular. Pink potash feldspar may occur as large phenocrysts up to two cm. in length. Mineralogy is simple, consisting of quartz, potash feldspar, plagioclase and biotite, with local occurrences of hornblende and epidote. Outcrops have a distinctive, rough, breccia-like appearance resulting from the decomposition of coarse feldspar crystals (Photo 9).

Contact relationships with the foliated granodiorite appear to be gradational over a distance of from five to twenty feet. Several dikes of Sherman Granite cut the foliated granodiorite, but are generally small and rare in occurrence.

Microscopically, the Sherman Granite ranges from allotriomorphic granular to hypidiomorphic granular. It is generally equigranular, but may locally be porphyritic. Modal analyses are given in Table V.

Plagioclase with good albite twinning is usually slightly sericitized and may exhibit some myrmekitic intergrowths with quartz. The potash feldspars include minor amounts of perthite, both rod and irregular patch varieties. Small quartz inclusions may also be present in the somewhat poikiloblastic potash feldspars.

Hybrid Felsic Rocks

Hybrid felsic rocks occur exclusively in the south central portion of the area (Plate I). These crop out as an irregular, somewhat ovoid, body in the foliated granodiorite. Exposures are characterized by moderately spher-

PHOTO 9. View of a typical Sherman Granite outcrop exhibiting breccia-like appearance as the result of weathering.

oidal weathering and expressed as elongate masses parallel to the foliation direction. The term hybrid is used here to indicate that the unit was derived from potassic and sodic replacement of foliated granodiorite.

These hybrid rocks are medium to coarsely crystalline, slightly porphyritic and range from light tan to light gray. The minerals quartz, potash feldspar, plagioclase and biotite are visible in hand sample. Foliation is generally well developed by the parallel orientation of biotite.

Contacts with foliated granodiorite are extremely gradational, the mineralogic changes taking place gradually over a distance of up to 500 feet. Across the contact, ferromagnesian content declines and as a result the rock appears to become less foliated.

PHOTO 10. Outcrop showing foliated granodiorite (G) intruded by aplitic quartz monzonite dike (M). The contact (above hammer) shows some evidence of assimilation of the granodiorite country rock.

Microscopically, the hybrid rocks range from hypidiomorphic granular to allotriomorphic granular. Parallelism is weakly developed in the biotite and hornblende (pleochroism: light blue-green, green, blue-green), which occur as elongate strings of shattered crystals, with associated magnetite and epidote. Quartz, microcline, and plagioclase (An 30 and An 15) are the essential minerals (Table VI). In one thin section (21-171) near the contact with foliated granodiorite, narrow veins of fine-grained quartz, microcline and sodic plagioclase (An 14) penetrate and surround plagioclase (An 27) and biotite. The plagioclase and biotite may be altered extensively to sausserite and chlorite respectively.

Quartz usually shows undulatory extinction. Microcline is present as discrete crystals and partially rims altered plagioclase. Perthite exsolution lamellae are also present in the potash feldspar. Two distinct compositions of plagioclase may be evident. The more calcic plagioclase (An 27-32) is usually zoned with albite rimming the more calcic cores, which are extensively altered to sericite and sausserite. The more sodic plagioclase (An 14-15) may also appear as smaller, less altered, subhedral crystals in the groundmass or in smaller phenocrysts.

TABLE VI. MODAL ANALYSES (VOLUME PERCENT) FOR HYBRID FELSIC ROCKS.

Mineral	Sample Number				
	21-124	21-139	21-142	21-171	21-172[1]
Potash Feldspar	21.0	39.5	45.5	17.0	43.5
Quartz	25.0	21.0	20.0	25.0	21.8
Plagioclase	43.0 An 15	29.0 An 14	25.5 An 15 & 32	38.0 An 27 & 14	4.0 An ?
Biotite	4.3	5.0	3.0	7.0	-
Hornblende	6.3	-	-	4.1	-
Epidote	1.5	2.0	1.5	5.0	1.5
Chlorite	tr	tr	1.0	3.0	1.5
Muscovite	1.0	1.0	tr	-	25.0
Magnetite	3.0	tr	tr	1.5	-
Hematite	-	1.0	-	tr	2.4
Sericite	tr	tr	0.5	0.5	-
Zircon	tr	tr	tr	-	-
Apatite	tr	tr	-	tr	-

[1]Altered variety of hybrid felsic rock

Aplitic Quartz Monzonite

Aplitic quartz monzonite occurs predominantly in narrow dikes cutting all crystalline rock types and ranging in width from a few feet to about 30 feet (Photo 10). These may be up to 800 feet in length and are widely distributed. One large irregularly shaped body occurs near the center of the study area. Outcrops range from angular and well jointed to rounded and slightly spheroidal.

The aplitic rocks are finely crystalline and range from slightly porphyritic to equigranular with colors ranging from light to medium brown. Locally, a weak foliation may parallel dike walls, but is not readily apparent because of low mica content.

Contact relationships range from very sharp in smaller dikes to extremely gradational in larger ones. Contact zones of potash enrichment in the foliated granodiorite may range up to 40 feet in width.

Microscopically, the aplitic quartz monzonite is allotriomorphic granular, but ranges to hypidiomorphic granular. It is generally equigranular, but may be slightly porphyritic. Essential minerals

TABLE VII. MODAL ANALYSES (VOLUME PERCENT) FOR APLITIC QUARTZ MONZONITE.

MINERAL	Sample Number				
	21-21	21-24	21-54	K-8[1]	K-12
Potash Feldspar	37.0	35.0	39.0	25.0	36.0
Quartz	29.0	39.0	23.0	30.0	32.0
Plagioclase	32.0	25.5	31.0	25.0	27.0
	An 12	An 14	An 10	An 15	An 6
Biotite	3.5	0.5	4.5	-	1.0
Chlorite	tr	-	1.0	5.0	-
Epidote	0.5	tr	0.5	7.0	tr
Sphene	tr	-	tr	-	-
Apatite	-	tr	tr	-	tr
Magnetite	1.0	-	-	-	0.5
Hematite	-	-	tr	tr	tr
Sericite	-	tr	tr	1.0	tr

[1]Slightly cataclastic epidotized aplitic quartz monzonite

include quartz, microcline and plagioclase (An 10-14) (Table VII).

Plagioclase usually exhibits good albite twinning, is generally euhedral, and may exhibit poikilitic texture, containing small crystals of muscovite, biotite and pale green chlorite. It may exhibit some patchy zonation with the more calcic zones exhibiting moderate to strong sericitic alteration. Untwinned plagioclase may be present in amounts up to 10% of the total plagioclase.

Pegmatites

Coarsely crystalline pegmatites occur throughout the area as small veins and dikes cutting all rock types. They range in size from less than one foot to approximately ten feet in width and up to 200 feet in length. Where associated with shear zones, some pegmatites are intensely deformed whereas others were apparently intruded post-tectonically. Contacts with all rock types are sharp.

Quartz, plagioclase and potash feldspar crystals range up to about two cm. in diameter. Tourmaline may be a locally abundant accessory mineral.

Shear Zone Tectonites

The shear zones in the Silver Crown district occur in elongate, fairly continuous, outcrops that range up to 400 feet in width and approximately 4,000 feet in length. Included in these zones are cataclasites, mylonites, blastomylonites, and mylonite gneisses. Locally, fault gouge and breccia may be present in crosscutting or concordant faults of smaller size. The shear zones locally are expressed as topographic highs reflecting the greater resistance of the annealed zones.

Grain sizes vary as a function of the degree of cataclasis, parent lithology, and extent of recrystallization, and range from extremely fine to finely crystalline. Colors are widely varied ranging from white, light gray to dark gray, buff and green-brown or red-brown. Outcrops typically have a massive blocky appearance which varies as a function of the amount of annealing and jointing which has occurred. The rocks range from unfoliated to well foliated. Contacts with surrounding lithologies are poorly defined to gradational, especially the contacts with the foliated granodiorite and hybrid felsic rocks.

Response to cataclasis varies according to lithology. The pegmatites and aplitic quartz monzonites tend to develop classic mylonite fabrics, whereas the foliated granodiorite shows a more gneissic texture.

Epidote and quartz veinlets are commonly present parallel to the cataclastic foliation. Fractures are commonly coated with hematite, manganese oxides, and less

PHOTO 11. Photomicrograph showing elongate grains of recrystallized quartz in a blastomylonite. Magnification 30 times with crossed nicols.

often, copper carbonates.

Microscopically, most of the tectonites exhibit a high degree of recrystallization and/or neomineralization (Photos 11, 12) although one mylonitic texture was observed. Textures range from mylonitic gneissic to blastomylonitic as defined by Higgins (1971). The majority of the mineral grains are in granoblastic layers with very fine crystal size. Larger porphyroclasts of quartz and plagioclase may show augen structures with elongation in the primary cataclastic foliation direction. Micas are lepidoblastic and may define a conspicuous cataclastic foliation.

Essential minerals include quartz, potash feldspar, and plagioclase, all of which may exhibit

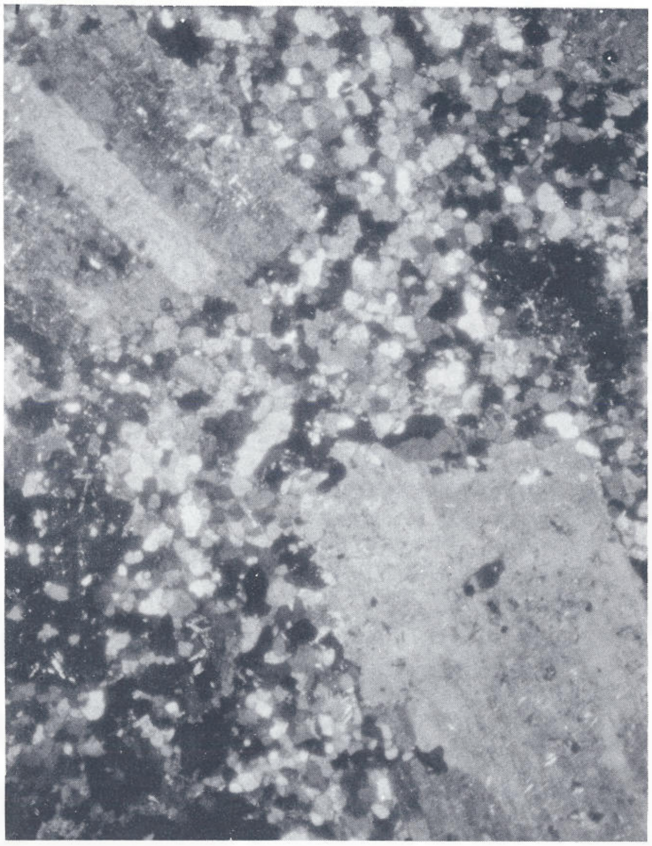


PHOTO 12. Photomicrograph of a recrystallized cataclasite showing equigranular granoblastic texture from the Copper King shear zone with relict, sericitized plagioclase phenocrysts. Magnification 35 times with crossed nicols.

strain. Quartz and plagioclase comprise most of the porphyroclasts which may be either strained or polygonized. Plagioclase, which usually exhibits sericitic and saussuritic alteration, varies in composition depending on original rock type and amount of recrystallization. Composition was observed to range from An 16 to An 24. Recrystallized and/or neomineralized material is predominantly quartz with smaller amounts of potash feldspar and plagioclase. Microcline is the most common potash feldspar.

Accessory minerals are, in order of decreasing abundance, epidote, chlorite (including penninite), biotite, muscovite, titaniferous (?) magnetite, sphene, apatite, hematite, chalcopyrite, pyrite, and leucoxene. Epidote is generally abundant, locally up to 60%, and occurs either in veinlets or in varying degrees of dissemination. Chlorite is common as an alteration product of biotite or may be intergrown with it. Titaniferous (?) magnetite is locally abundant, and may be replaced by varying amounts of chalcopyrite and pyrite or be oxidized to hematite and leucoxene. Sphene is present as a rare accessory.

Outcrop characteristics vary with respect to parent rock type. Aplitic quartz monzonite and pegmatite are sheared to a finely crystalline, generally mylonitic rock with variable amounts of biotite or chlorite. Outcrops are extremely angular and are generally red-brown or green-brown in color.

Intensely foliated, dark mylonitic gneissic rocks have been produced by shearing of the foliated granodiorite and hybrid felsic rocks. Foliated granodiorite may be silicified in zones of sulfide mineralization or may appear in schist-like outcrops when silicification is absent. Texture of the sheared hybrid felsic rock may range to well developed mylonites.

Sedimentary Rocks

Sedimentary rocks ranging in age from Paleozoic through Tertiary are exposed on the eastern border of the study area. The Paleozoic sediments are in fault contact with Precambrian crystalline rocks. A detailed discussion of the stratigraphy and structure of the flanking sediments is provided by Brady (1949). Many of the less resistant lithologies are covered by Tertiary sediments and Quaternary alluvial and colluvial deposits.

STRUCTURE

General Regional History

The Laramie Range, a northern extension of the Colorado Front Range, apparently experienced its earliest known period of deformation more than 1800 million years (m.y.) ago, which resulted in the low grade metamorphism of a Precambrian sedimentary rock sequence (Peterman and others, 1968, p. 2279, 2294).

A second deformation episode, at from 1700-1800 m.y. ago, involved the medium to high grade regional metamorphism of the metasediments and the intrusion of the Boulder Creek Granite (Peterman and others, 1968, p. 2277, 2279, 2294).

The Sherman batholith and, further south, the Silver Plume Granite were intruded into the metasedimentary sequence from 1390-1450 m.y. ago. This was followed by a period of faulting and cataclasis which probably occurred about 1300 m.y. ago (Peterman and others, 1968, p. 2277).

The Laramie Orogeny and the earlier uplift of the Ancestral Rockies probably produced a rejuvenation of Precambrian faults, the development of new joints and fractures in the Precambrian rocks, and faulting of the local Paleozoic and Mesozoic sedimentary sequence.

Foliations

Metamorphic foliations are well developed in the shear zone tectonites, hybrid felsic rocks, quartz-biotite schists, some of the foliated granodiorite, and locally in the aplitic quartz monzonite dikes. Foliation is produced by the parallel alignment of biotite, muscovite, and/or amphibole grains; and the segregation of dark and light minerals in the gneissic varieties of granodiorite and some shear zone tectonites.

Poles normal to foliation planes were plotted on a Lambert meridional equal area projection (Schmidt net) for 45 gneissic foliations (Fig. 2), 30 cataclastic foliations (Fig. 3), and 65 fault trends (Fig.4).

Plots were made using the standard percent area method described by Dennison (1968, p. 122-130).

A prominent trend of approximately N 25°E dipping 70°W to 80°E is observed in the gneissic foliations, the cataclastic foliations and the fault plane plots. A second trend of approximately N75°E dipping 80°W is reflected to a great extent in the cataclastic and fault plane plots and to a lesser extent the gneissic foliations. The mineralized shear of the Copper King Mine is manifested on the cataclastic foliation and fault plane plots by a subordinate trend of N60°W with generally vertical dip. This agrees with trends observed by McGraw (1954, p. 35).

FIGURE 2. Contoured pole-plot diagram (% per 1% area) of 45 gneissic foliation measurements in the Silver Crown area.

FIGURE 3. Contoured pole-plot diagram (% per 1% area) of 30 cataclastic foliation measurements in the Silver Crown area.

The N25°E trend in the northern two-thirds of the study area roughly parallels the Sherman Granite boundary, whereas a N75°E trend is found generally in the southern one-third. Gneissic foliations are nearly parallel to cataclastic foliations and fault planes, indicating a similarity in stress parameters. Gneissic foliations were probably produced during the regional metamorphic event of 1700 m.y. ago (Peterman and others, 1968, p. 2294) and apparently controlled the emplacement of the Sherman Granite. The cataclastic foliations may be a direct result of the intrusion of the Sherman Granite or slightly later Precambrian stresses and dislocative deformation along the trends of existing gneissic foliations.

Shear Zones

Intensive shearing affected the area some time during (1380 m.y.) or after (1300 m.y.) the emplacement of the Sherman Granite, quartz monzonite dikes and some pegmatites (Peterman and others, 1968, p. 2277). Major shearing is manifested by the occurrence of cataclasites, mylonites, blastomylonites and mylonite gneisses with generally well developed cataclastic foliations.

The major trends are N25°E in the northern two-thirds of the area and N 60°E to N80°W in the southern one-third. No evidence of directions of movement was observed.

Faults

A large number of faults of various sizes exist in the Silver Crown Mining District. There is a marked tendency for the faults to parallel metamorphic foliation, especially near the Sherman Granite boundary. (See Photo 13, p. 15.)

The clay-rich fault zones, ranging in width from a few inches to about 10 feet and up to one half mile in length, are generally linear in trace and may be mineralized with hematite, manganese oxides, biotite, garnet (almandine 78%, pyrope 18%, grossularite 5%), or sulfides. Garnet and most biotite is considered to have developed during Precambrian cataclastic deformation before the introduction of other mineralizers.

One large high angle reverse fault on the eastern edge of the area (Plate I) brings the Triassic Chugwater Formation into contact with Precambrian rocks. The vertical displacement is estimated at a minimum of 1,200 feet since the Fountain, Casper, and lower Permo-Triassic Red Beds are absent. The Casper Formation (Plate I) is vertical and in fault contact with Precambrian rocks, indicating a nearly vertical attitude of the fault plane. The west, hanging wall of this eastern flanking fault in section 24 (Plate I) exhibits cataclasites and mylonites. This indicates the presence of a Precambrian shear zone which was apparently faulted later to form a fine-grained gouge material. Time relationships indicate that the youngest faulting probably occurred during the Laramide Orogeny. The Precambrian trend (N25°E) of this fault is continued through the north half of section 24 and establishes the contact between the foliated granodiorite and the amphibolitized mafic rocks (Plate I). The younger Laramide fault swings east, departing from the older fault trend near the middle of section 24 (Plate I). The presence of faulted, cohesive cataclastic rock types and the linear continuity between the younger fault and the older fault trend indicate a Laramide or later rejuvenation of the Precambrian structural trend.

Other faults in the area probably represent shallow depth rejuvenation of Precambrian structures although no direct evidence has been observed. Faults may be concordant with shear zone trends or, less commonly, discordant. These faults were definitely formed after the major Precambrian shearing at lower pressure and temperature conditions, as evidenced by lack of cohesion and recrystallization in the faulted material, and are probably Laramide or younger in age.

FIGURE 4. Contoured pole-plot diagram (% per 1% area) of 65 fault plane measurements in the Silver Crown area.

PETROGENESIS OF IGNEOUS ROCKS

Quartz-Biotite Schist and Quartzite

The limited exposure of quartz-biotite schist and quartzite in the study area makes petrologic interpretations difficult and highly speculative. On the west flank of the Laramie Range, a sequence including quartzites and schists is considered metasedimentary by Hagner (1953, p. 111). In northern Colorado, Eggler (1968, p. 1547) observed hornblende and biotite gneisses and quartzites bordering the Sherman batholith, but made no interpretation as to their origin. These lithologies are similar to the quartzite and schist in the Silver Crown area. A metasedimentary origin for the schist and quartzite in this district is favored on the basis of a speculative regional correlation with the quartzites and schists described by Hagner (1953).

Amphibolitized Mafic Rocks

This rock unit consists of a group of meta-igneous rock types including metadiorite, metadiabase, metagabbro and metapyroxenite. The igneous origins of these rocks are evidenced by relict igneous textures. Original igneous rocks were subjected to metamorphism, with most of the pyroxene being converted to poikiloblastic amphibole containing small quartz crystals. This reaction indicates increased P_{H_2O} and decreased temperature, which probably occurred during an episode of amphibolite grade metamorphism, after crystallization of these intermediate to mafic igneous rocks (Spry, 1969, p. 301).

Figure 5 shows the modal composition of all igneous and meta-igneous lithologies in the Silver Crown district in terms of quartz, plagioclase and potash feldspar. Most amphibolitized mafic rock plots occur along the quartz-plagioclase side of the diagram, although one sample exhibits significant potash enrichment. Metasomatic interaction with a later, more felsic intrusive probably caused this enrichment.

The persistence of igneous textures in regionally metamorphosed igneous rocks is considered by Spry (1969, p. 273) to result from low ionic mobility, favored by low stress and the absence of intergranular fluids. These conditions were evidently present during the amphibolitization of the mafic rocks.

Later retrogressive metamorphism of greenschist facies grade resulted in the

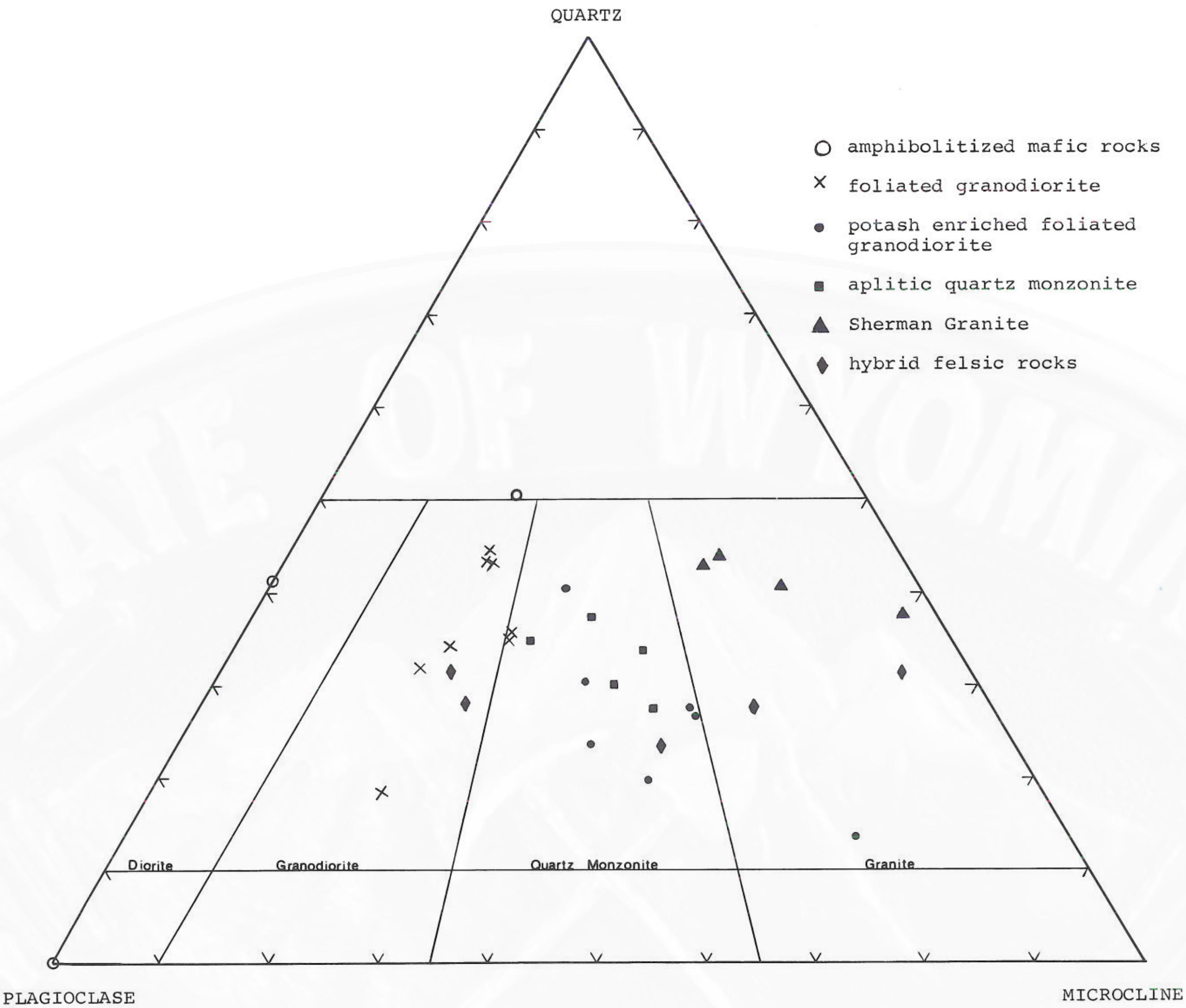


FIGURE 5. Modal composition diagram for samples of igneous and meta-igneous rock samples of the Silver Crown area. Solid lines delineate the indicated compositional fields.

conversion of some biotite to chlorite, and hornblende to biotite and epidote. These mineralogic changes were probably induced by continued increase in P_{H_2O} and decrease in temperature. Foliation planes, defined by the biotite and chlorite, were evidently developed in the presence of a dynamic stress component of at least moderate intensity. Shattering of the pretectonic hornblende is seen to parallel the surrounding syntectonic biotite and chlorite. The groundmass plagioclase and quartz forms a well developed granoblastic texture, indicating metamorphic recrystallization.

Poorly exposed contact relationships make interpretation of origin difficult, but three genetic interpretations have been considered for the mafic rocks. These rocks could have been xenoliths of older country rock included in a granodioritic magma, primary segregations of a more mafic character within the granodioritic magma, or later intrusions of mafic material into the granodiorite.

Based on regional relationships as discussed in Fowler (1930), Ramarathnam (1962), and Eggler (1968), it is suggested that the amphibolitized mafic rocks in the Silver Crown district represent xenolithic inclusions of older gabbros, pyroxenites and diabases in the foliated granodiorite. These mafic rocks show the effects of the same amphibolite grade metamorphism which affects the foliated granodiorite. This metamorphism may be related to the regional deformation occurring about 1700 m.y. ago (Peterman and others, 1968, p. 2294). Subsequent to the amphibolite grade metamorphism, these rocks were subjected to a period of retrogressive metamorphism to the greenschist facies with local development of gneissic fabric.

Foliated Granodiorite

The foliated granodiorite of the Silver Crown district is probably of igneous origin, even though it locally exhibits distinctly metamorphic textures resulting from amphibolite grade regional metamorphism.

The following evidence is given for an igneous origin:

1) crosscutting contacts with the older quartz-biotite schist and quartzites which are considered to be metasedimentary;
2) common occurrences of the sphene-magnetite association suggestive of igneous origin (Moorhouse, 1959, p. 459);
3) locally well developed igneous textures gradational with adjacent gneissic phases; and
4) complex twinning of plagioclase (Carlsbad-albite) in the less gneissic phases (Williams, Turner, and Gilbert, 1954, p. 243).

The presence of a single characteristic is not a positive indication of igneous origin; however, the presence of all four substantiates this origin.

Amphibolite grade metamorphism in the foliated granodiorite is indicated by the presence of poikiloblastic hornblende porphyroblasts and two generations of hornblende overgrowths. Metamorphic textures produced in the granodiorite during this metamorphic episode include gneissic foliation and parallel orientation of the hornblende phenocrysts. During this same metamorphic episode is probably when amphibolitization of the mafic igneous rocks in the area occurred.

Dense intergrowths of biotite and chlorite surrounding some hornblende phenocrysts indicate a later retrogressive metamorphic episode. The shattering of pretectonic hornblende and the development of syntectonic biotite and chlorite are evidence of a dynamic component of moderate intensity. The granoblastic groundmass characteristic of the foliated phases of granodiorite was apparently formed by recrystallization, with the preservation of some relict aggregates of plagioclase and quartz as augen structures parallel to foliation planes.

The retrogressive metamorphism is evidently of the greenschist facies, probably of quartz-albite-epidote-biotite grade as evidenced by the presence of this assemblage. Although microcline is not common in most rocks of this facies, it is present in quartzo-feldspathic assemblages (Fyfe, Turner, and Verhoogen, 1958, p. 233).

The intrusion of the Sherman Granite may have occurred at, or slightly before, this period of greenschist facies retrogressive metamorphism. (1) The general parallelism of biotite and chlorite foliation planes with the Sherman contact, and (2) the occurrence of this greenschist metamorphic assemblage in hybrid felsic rocks (interpreted as products of granodiorite-Sherman Granite interaction) strongly supports this interpretation of the age relationships. Narrow shear zones parallel to gneissic foliations may have developed at this time in response to the Sherman intrusive event. Earlier zones of shearing may have been rejuvenated by the Sherman intrusion.

As observed in Figure 5, the foliated granodiorite exhibits varying degrees of potash enrichment. The potash-enriched phases range to granite in composition. Potash enrichment appears in the form of microcline overgrowths and patchy microcline replacements of relict phenocrysts of plagioclase (An 25-30). Microcline is also present in granoblastic intergranular areas, probably as a replacement in the crushed zones. Some albitic rims on oligoclase suggest local sodic enrichment.

Field observations show that potash enrichment usually occurs near contacts of the granodiorite with aplitic quartz monzonite, and more rarely with Sherman Granite. This strongly suggests that the alkali-rich fluids were derived from the aplitic quartz monzonite and, locally, the Sherman Granite.

Evidence seems to support the following sequence of development for the foliated granodiorite:

1) An intermediate magma intruded into a metasedimentary sequence and the crystallization of granodiorite. The exact age of the intrusion is uncertain, but it is older than 1450 m.y., the oldest reported date of the Sherman Granite (Peterman and others, 1968, p. 2287) which cuts the granodiorite. The granodiorite may be equivalent in age to the Boulder Creek Granite described by Peterman and others, (1968, p. 2285) as having intruded the Colorado Front Range metasediments at about 1700 m.y. ago. This correlation is based on similarities in gross lithology, on field relationships with the Sherman-Silver Plume intrusives, and on the fact that the Boulder Creek Granite and the Silver Crown district granodiorite show similar metamorphic histories.
2) Dynamothermal metamorphism of the granodiorite to amphibolite grade resulted in the formation of poikiloblastic hornblende porphyroblasts, nematoblastic texture, and gneissic foliation. Relict igneous textures were preserved locally.
3) Retrograde metamorphism to greenschist facies probably synchronous with widespread cataclastic deformation formed augen structures, shattered hornblende porphyroblasts and generally recrystallized quartzo-feldspathic groundmass material. Intrusion of the Sherman Granite and local alkali enrichment near granodiorite-Sherman Granite contacts appear to also have occurred at this time, forming the hybrid felsic rocks. The intrusion of the Sherman Granite is dated at 1390 to 1450 m.y. ago. Narrow shear zones generally formed parallel to the Sherman batholith boundary.
4) The intrusion of aplitic quartz monzonite, apparently controlled by pre-existing foliations and shear zones, produced local potash enrichment of the granodiorite near contacts.

Sherman Granite

The Sherman Granite has been considered by most workers to be igneous in origin. Field evidence in the Silver Crown district, such as sharp contacts of dikes of Sherman Granite cutting the foliated granodiorite, and the presence of sharp angular xenoliths of foliated granodiorite in these dikes would seem to favor an igneous origin.

The Sherman Granite in the study area falls well within the granite compositional field (Fig. 5). Eggler (1967) indicates that phases of the Sherman Granite, in the Virginia Dale area to the south, range from granite to quartz monzonite in composition.

Eggler (1967, p. 78-82) suggests that the Sherman Granite may have been derived from partial remelting in the lower crust rather than by differentiation. He also concludes that the magma was high in water and volatile content, and crystallized at rather low temperatures. A low temperature of intrusion is supported in the Silver Crown district by the general lack of apparent interaction between the Sherman Granite and the foliated granodiorite and is manifested by sharp contacts. Eggler (1967, p. 82) also suggests that cataclastic contacts with associated mafic rocks may have been a late stage phenomenon associated with high temperature (600°C) hydrous phases.

The age of the Sherman Granite has been established to be 1390-1450 m.y. (Peterman and others, 1968, p. 2295).

Hybrid Felsic Rocks

The hybrid felsic rocks retain varying degrees of texture from the parent foliated granodiorite. Modal compositions range from granodioritic to granitic (Fig. 5), a distribution that reflects enrichment of original granodiorite by potash. Secondary potash feldspar is present in the groundmass and also rims sericitized calcic oligoclase. Soda enrichment is demonstrated by sodic oligoclase (An 14) rimming calcic oligoclase (An 27) phenocrysts, and occurring as a secondary constituent of the groundmass.

Contacts with the foliated granodiorite are gradational, with biotite content decreasing and potash enrichment apparently increasing toward the north and west (Plate I). This may indicate the approach toward the source of the metasomatic fluids, the Sherman Granite.

The Sherman Granite appears to be the only local rock type with enough available potash and sodium to act as the source for metasomatic components (see Fig. 5). Based on field evidence, it appears highly probable that the Sherman Granite is present under the grus cover north and west of the hybrid quartz monzonite and may be gradational with it (Plate I). It is suggested, therefore, that the Sherman Granite is the most logical source for the cations involved in the alkali metasomatism of the granodiorite unit to form the hybrid quartz monzonite.

Aplitic Quartz Monzonite and Pegmatites

Aplitic quartz monzonite occurs as dikes and in several large, irregularly shaped bodies. Crosscutting relationships indicate that it is younger than the Sherman Granite.

Based on textures and field relationships, McGraw (1954, p. 41) considered this unit to be of replacement origin. However, angular inclusions of wall rock exhibiting sharp contacts within these rocks would seem to indicate an igneous origin. The contacts of the dikes and bodies with the foliated granodiorite are sharp in some outcrops. Other contacts with granodiorite are sharp with respect to ferromagnesian content, but potash enrichment transects the ferromagnesian "contact", grading outward into unaffected rock.

Pegmatites in the Silver Crown district are considered to be igneous. Forceful emplacement is indicated by angular migmatites exhibiting rotation of blocks. Contacts with all rock types are generally extremely sharp and some fine-grained chilled borders have been observed.

The pegmatites crosscut aplitic dikes and are clearly the youngest intrusive rock type in the area. Pegmatitic solutions may have been related to a final gaseous phase of the Sherman intrusion.

Shear Zone Tectonites

The shear zone tectonites in the Silver Crown district are typically recrystallized or neomineralized varieties. These consist mainly of blastomylonites and mylonite gneisses as defined by Higgins (1971, p. 11).

McGraw (1954, p. 40-41) in his evaluation of the Copper King Mine area, concluded that the cataclastic rocks resulted from granulation (cataclasis) and replacement of granulated material by silica and potash. He cites evidence of a mortar texture with the groundmass displaying sutured contacts. His observations may be correct, but recrystallized granular material could exhibit similar sutured contacts with slight postcrystalline movement (Spry, 1969, Plate VIId). Most cataclastic rock types observed during this study exhibit granoblastic groundmass textures which are indicative of crystallization under low shearing stress or of abundant post-tectonic crystallization (Spry, 1969, p. 263).

Elsewhere in the Silver Crown district, narrow fault zones occur parallel to the Sherman batholith boundary and may have formed during or prior to the Sherman Granite intrusion. These narrow fault zones locally control the emplacement of aplitic quartz monzonite dikes, presumed to be a late stage Sherman-related intrusive episode.

The association of the Sherman emplacement with cataclasis near contacts with mafic country rocks was observed by Eggler (1967, p. 80-82) in the Virginia Dale ring dike complex. He suggests the shearing was a late stage phenomenon associated with high temperature hydrous phases. Some shearing observed in the Silver Crown district may be a feature of the late stage Sherman emplacement.

A later episode of shearing occurred after the emplacement of the Sherman Granite as evidenced by the shearing of the aplitic quartz monzonite dikes which cut the Sherman Granite. This shearing episode may be related to the regional cataclastic event which, according to Peterman and others (1968, p. 2295), occurred about 1300 m.y. ago, post-dating the Sherman intrusion.

MINERAL DEPOSITS

The mineral deposits of the Silver Crown district are structurally controlled base-precious metal concentrations. Gold and copper have the greatest value, but silver may also be present in recoverable quantities. Copper values are contained in copper sulfides, oxides, carbonates and in native copper. Gold and silver have not been observed as native metals and are evidently present in solid solution in sulfides or as very fine particles in rock matrix.

Two types of structure localize the mineralization. The Comstock deposits occur in narrow fault gouge zones, which may be associated with massive quartz veins. The Copper King deposits occur in larger Precambrian shear zones, consisting of mylonites, blastomylonites, mylonite gneisses, and cataclasites. Mineralization is greatest in silicified zones within the cohesive sheared material.

PHOTO 13. Fault zone at the Louise Mine (SE ¼ Sec. 35); illustrates the nature of the Comstock-type, clay-rich, fault group. Scale is provided by 6" x 6" mine timber in upper right.

General Description

Deposits of the Comstock type are especially common in the north central half of the district where they exhibit a strong N 20°W trend. The fault zones themselves consist predominantly of non-cohesive fault gouge material which is generally altered to clay or may consist of intensely foliated biotite-rich zones (Photo 13). Locally, they may be filled with quartz veins of a variety of sizes which may contain sulfides.

The Copper King Mine is located in the northwest ¼ of section 36 (Plate I). Mineralization consists of disseminated sulfides in a silicified, cataclastic foliated granodiorite. Cataclastic foliations trend from N64°W east of the mine area to N80°W at the mine. Younger faults similar to those of the Comstock-type structures occur as discordant features, trending from N20°E, or as concordant structures parallel to cataclastic foliation and probably represent later brittle zone cataclasis.

Mineralogy and Paragenesis

Sulfides are usually absent at the surface as the result of oxidation and leaching. Hematite, limonite, manganese oxides, malachite, azurite, and chrysocolla are present at both mines, with native copper and cuprite at the Copper King. These minerals are usually present as fracture fillings in zones of supergene enrichment.

Unoxidized minerals are sometimes present in prospect pits, mine dump materials and in a few outcrops. Pyrite, chalcopyrite, molybdenite, bornite and covellite are the predominant sulfides in hand sample. Magnetite is usually abundant. Chalcocite has been reported by Harry Ferguson (1965), from the Comstock mine, but none was observed during this study.

The opaque minerals, magnetite, pyrite, chalcopyrite, sphalerite, and hematite were identified in polished section in material from both types of deposits, whereas covellite and cuprite were also identified at the Comstock.

Magnetite is generally present in subhedral to euhedral disseminated crystals which locally may be moderately fractured or shattered. The formation of martite appears to have occurred around magnetite boundaries, and in irregular intragranular arrangement probably along fractures. It may occur parallel to cleavage or fractures. Locally, magnetite may be completely oxidized to martite (hematite). Conversion to red translucent hematite occurs as the result of a veining process, possibly caused by post depositional oxidation. Magnetite may also be invaded and replaced to varying degrees by pyrite, chalcopyrite, and possibly sphalerite along fractures and grain boundaries. In the Copper King deposit, magnetite is commonly concentrated parallel to cataclastic foliation in biotite and/or chlorite-rich layers.

Pyrite is subhedral to euhedral and fractured or broken crystals are common. Pyrite may locally replace biotite and magnetite and be oxidized to hematite. In the Copper King type deposit, elongate masses of pyrite and chalcopyrite may result from replacement of elongate biotite and/or chlorite segregations by these sulfides. McGraw (1954, p. 48-49), at the Copper King, observed that chalcopyrite and pyrite replace biotite and chlorite. McGraw also indicates that pyrite content in the Copper King type deposits has no appreciable relationship to copper and gold values. More recent drilling results appear to substantiate this earlier observation.

Chalcopyrite, the predominant copper-bearing sulfide, is usually present in anhedral masses replacing magnetite, pyrite and biotite. Locally, crystals may be slightly shattered. It may be present as small exsolution blebs in sphalerite which appear to have no relationship to crystallographic or cleavage direction. Covellite was observed to replace chalcopyrite in veinlets and in small irregular patches in Comstock samples. In the Copper King deposit, chalcopyrite is present in finely disseminated (0.1-1.0 mm in diameter) anhedral grains and irregular masses. Replacement of pyrite, magnetite and biotite is evidenced by rims and patchy areas of chalcopyrite in magnetite and pyrite and as elongate masses along biotite cleavages. Replacement of cubic pyrite by chalcopyrite was also observed.

Anhedral sphalerite is of minor abundance. It occurs as rims on chalcopyrite or in masses within it. Sphalerite generally exhibits exsolution of chalcopyrite as previously described.

Covellite in the Comstock deposits is present in veinlets and as patchy replacement of chalcopyrite. It may locally rim some pyrite grains. It has been observed in veinlets which have feathery dendritic intergrowths with chalcopyrite. Covellite was observed in hand sample at the Copper King Mine.

Bornite and molybdenite have been observed in hand sample in the Copper King deposit, but not in polished section. Bornite occurs as finely disseminated crystals. Molybdenite has been reported in drill logs and was observed in one core sample of uncertain location.

Pyrrhotite was reported by McGraw (1954, p. 49)

PHOTO 14. View of Comstock adit.

but was not observed during the course of this study.

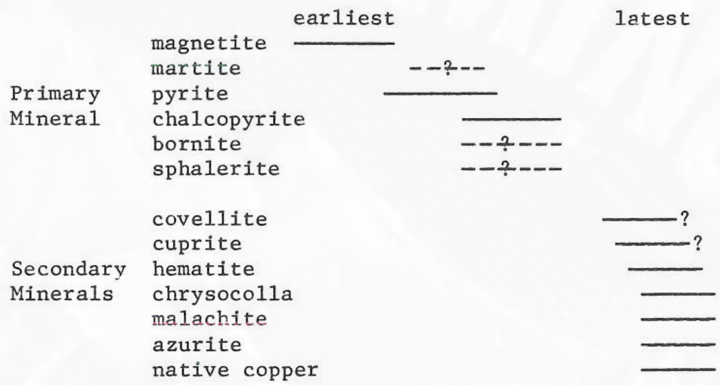
Cuprite is rare in occurrence, but has been observed surrounding and penetrating covellite in polished section probably as the result of an oxidation-replacement reaction.

Native copper may occur with cuprite, as fracture fillings and as disseminated grains which may be the product of replacement of disseminated chalcopyrite.

Hematite occurs in veins, fractures and along grain boundaries with magnetite, biotite, pyrite, and some chalcopyrite. Vein associated varieties may rim sulfides and gangue minerals alike.

The enrichment in the Copper King area is fairly typical of the supergene type. The crude zonation from near the surface to the water table is malachite-cuprite-native copper-sulfides. This sequence probably represents the general decrease in E_h conditions and a decrease in pH with depth.

The suggested paragenetic sequence is as follows:



Quartz and biotite are the predominant gangue minerals. Garnet (predominantly almandine), fluorite, and calcite may be present in small amounts in the Comstock type deposits. In the Copper King deposit, microcline is an additional major gangue mineral, and epidote and apatite are additional minor gangue minerals. Quartz and biotite appear to have formed early in the paragenetic sequence, probably contemporaneously with magnetite. The origin of the garnet in the Comstock deposits is unclear but it may have been a primary constituent of some rock type caught up in the fault zone or, less likely, the result of local metamorphism of high grade in the fault zones. Epidote is very common as a fracture fill and in veinlets in most rock types, especially near the fault zones. Clay forms significant percentages of these mineralized zones on the surface of the Comstock deposits.

Structural and Petrologic Associations

Comstock-Type Deposits

Non-cohesive fault gouge material occurs in zones up to eight feet wide. The gouge is fine-grained clay-rich material with yellow or brown color in surface outcrops. Fault zones are usually concordant with gneissic foliation, but may locally be discordant. The major trend is N20°E and these fault traces tend to be very straight in nature. Faults of this type were observed to cut all rock types except the Sherman Granite where heavy grus cover makes detection difficult.

Sulfides occur in three general associations with fault zone material and country rock:

1) filling intergranular areas in brecciated quartz and fault zones and more rarely disseminated in country rock.
2) as rather massive discontinuous layers at the boundaries of unbrecciated quartz veins and veinlets in fault zones and in country rock. Quartz veins are markedly discordant to foliation, with a general trend of N70°E, and range up to three feet in thickness.
3) as elongate masses with replacement of some biotite in intensely foliated biotite-rich zones in the shear zone. These biotite "schists" may locally contain large amounts of massive quartz or may be interlayered with it. Garnet (almandine 77%, pyrope 18%, grossularite 5%) may be locally abundant.

The intensely foliated zones probably represent narrow zones of cataclasis, as evidenced by their mylonitic to mylonite gneissic textures. Precambrian age is suggested by crosscutting relationships to these zones shown by some Precambrian aplitic quartz monzonite and pegmatite. The latter rocks were not affected by the cataclastic metamorphism. Garnets are rare and sporadic in occurrence in these narrow zones and appear to be unaffected by cataclasis since no rotation or fracturing was observed. Garnet formation was apparently contemporaneous with that of the biotite in the garnet-rich zones.

Poor exposures make interpretation of the garnet-rich zones difficult; however, the writer feels that blocks of garnet-bearing rock were tectonically incorporated into the shear zones and account for the relict, unsheared garnet. No garnets are observed in the surrounding foliated granodiorite, so the garnets are unlikely to be relict minerals from the presently exposed country rock. Xenolithic inclusions of quartz-biotite schist are observed in the foliated granodiorite, however. Although no garnet-bearing xenoliths were observed in the granodiorite, the limited number of exposures do not preclude the so-far undetected existence of such rocks. Incorporation of such xenoliths into the shear zones could account for the masses of biotite and garnet apparently unaffected by the dislocative metamorphism.

The non-cohesive fault gouge of both the Comstock deposits and the Copper King deposit was probably formed by low temperature and pressure brittle shearing during the rejuvenation of existing structures. This is evidenced by the previously mentioned brecciation of the crosscutting late Precambrian pegmatites and aplites in the biotite "schist" zones and shear zones. Many associated quartz veins are also affected by brittle fracture which may represent rejuvenation during either the uplift of the Ancestral Rockies and/or Laramide or later uplifts.

Copper King Deposit

Shear zones occur in elongate outcrops of various widths and are in subparallel orientation in the vicinity of the Copper King Mine. These zones usually contain blastomylonites, with the areas between zones comprised of locally cataclastic hybrid felsic rocks; aplitic quartz monzonite; and intensely foliated, silicified, and locally potash-enriched cataclastic granodiorite. The cataclastic foliations trend approximately N70°W (Plate I).

The foliated granodiorite in this shear zone exhibits mortar texture with oligoclase porphyroclasts. Varying degrees of granulation have occurred in the rock and recrystallization and/or neomineralization has occurred extensively in the granoblastic groundmass. The blastomylonites which are present in the Precambrian shear zones exhibit granoblastic textures, which apparently represent zones of more extensive recrystallization and/or alkali-silica enrichment.

Metallic mineralization is most intense in a highly silicified zone of foliated granodiorite in the immediate area of the Copper King Mine. Biotite and/or chlorite content is lower than in the normal foliated granodiorite. Silica occurs in veinlets or as replacement of original groundmass feldspars. Based on drill core information, altered foliated granodiorite associated with the shear zones contains varying amounts of apatite, fluorite, and calcite, probably indicating the presence of significant amounts of volatiles in the original magma or in the invading fluids. The aplitic quartz monzonite appears to have been localized along general trends of shear zones as evidenced by pronounced parallelism with the cataclastic trend, however, these rocks are also affected by later shearing.

Origins of Mineral Deposits

The two types of base-precious metal occurrences in the Silver Crown district differ in structural association (open vs. healed shears), and structural trends. However, distinct similarities exist in all deposits in the district.

Similarities in ore and gangue mineral paragenesis and replacement phenomena exist. Magnetite was apparently derived from mobilization of the dislocated intermediate (foliated granodiorite) to mafic (amphibolitized mafic rocks) rock types or from initial high temperature hydrothermal fluids. Replacement phenomena are similar in that pyrite replaced magnetite, evidently under the influence of a high sulfur environment. Late stage replacement of pyrite, magnetite, biotite and/or chlorite by chalcopyrite is also evident.

Ground-water solutions were active in oxidation and leaching of sulfides from near surface deposits and redepositing secondary copper and iron oxides along fractures. In the Comstock-type deposits, as a result of the intense granulation, silicates were also

PHOTO 15.

PHOTO 16.

The Copper King Mine of the Silver Crown district was located in October 1881. In an 1885 report to Territorial Governor Francis E. Warren, Territorial Geologist Samuel Aughey writes: "A great deal of prospect work has been done in this camp at different times for many years past. The only prospect, however, that has been developed sufficiently to be called a mine is the Copper King..." Aughey continues to describe the extent ("immense") and good quality of the ore, and notes that "this property is not worked at present."

A 1907 report by Henry C. Beeler, State Geologist, says, "It is evident that this ore carries a low but constant Au and Cu value and that under the proper treatment can be made to show a fair profit, the quantity and mining facilities being favorable."

A 1912 report gave the total underground development of this mine (then called the Arizona Mine) at 619 feet.

Both Aughey and Beeler were overoptimistic about the mine's potential; although the Copper King was one of the largest mines there, the Silver Crown Mining District was never a big producer. The district never became "the financial success... that has characterized mining in the more fortunate camps in the Rockies," that Aughey thought it would in 1885.

PHOTO 15. Waste dump of the Copper King Mine, looking toward hills of Precambrian Sherman Granite.

PHOTO 16. Main shaft (under board cover), waste dump, and debris, looking east.

PHOTOS 17 and 18. Winch used to haul up ore and waste rock while excavating.

PHOTO 17.

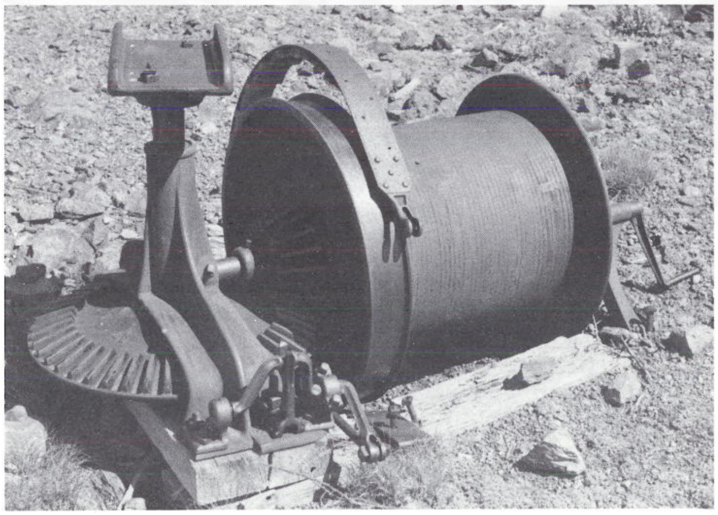
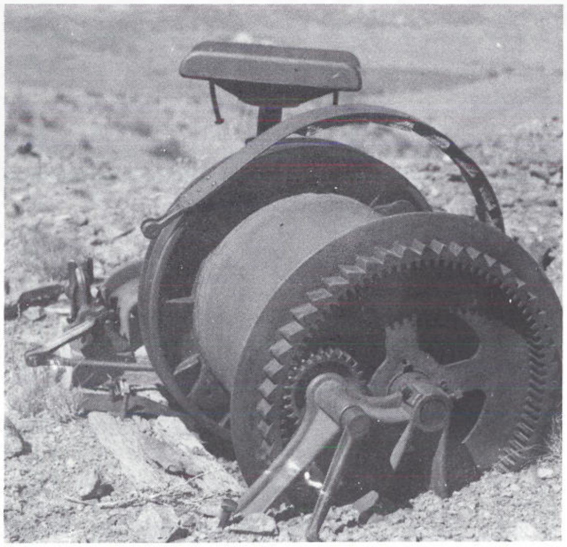


PHOTO 18.



affected, resulting in the formation of clay minerals.

Comstock-Type Deposits

The narrow Comstock-type shears apparently were formed during the Precambrian sometime before the intrusion of many of the pegmatites, and were instrumental in localizing ore solutions.

Base-precious metal deposition in shears was preceded by the deposition of quartz and biotite, with quartz deposition continuing during sulfide deposition.

Rejuvenation of fault zones under low total pressure and lower temperatures probably resulted in the brecciation and fracture of magnetite, pyrite, quartz veins and gangue, allowing passage of ground-water solutions and oxidation of near surface portions of veins. Some local sulfide remobilization may have taken place as evidenced by chalcopyrite filling intergranular areas in some brecciated quartz material.

The origin of the mineralizing fluids is not known, but two sources are postulated: 1) late stage fluids from a nearby intrusive source (e.g. Sherman Granite and related rocks) migrating and depositing along zones of permeability (e.g. shear zones) or, 2) the reconcentration of preexisting metals from country rock.

Parallelism of the Comstock structures with the Sherman batholith suggests that the Sherman intrusion was related to the formation of the narrow shear zones, and the production of mineralizing fluids. Mineralization is younger than the aplitic quartz monzonite, which is interpreted as being a late phase of the Sherman intrusive. Most of these shear zones and the mineralization are, however, older than some pegmatites, which are considered to be a later phase of the Sherman Granite magma.

Rejuvenation of shear zones probably occurred during the Laramide uplift, but may have occurred anytime during or after the uplift of the Ancestral Rockies.

Copper King Deposit

The localization of metallic mineralization in the Copper King deposit apparently involved a combination of structural and lithologic controls. The dominant structure appears to be the nearly east-west trending zone of Precambrian cataclasis. Lithologic control is evidenced by the apparently preferential deposition of sulfides and silica within the silicified, foliated granodiorite, especially near the contact with aplitic quartz monzonite. Mineralization is not confined to the silicified granodiorite, since primary copper minerals are present in lesser quantities in the aplitic quartz monzonite and hybrid felsic rocks.

McGraw (1954, p. 49-50) concludes that the sulfides at the Copper King were "...deposited as disseminated replacements in a zone of granulation", but is uncertain as to the structural control for the enrichment of copper and gold in the immediate area of the Copper King shaft. His basic conclusions are apparently correct, but he did not consider lithologic control as a factor in localizing sulfide deposition.

Textural relationships do not clearly indicate the actual sequence of alteration and sulfide deposition. Biotite, chlorite, and magnetite were probably present in the foliated granodiorite prior to mineralization based on observations of this unit outside the mineralized zone. Initially high pre-mineralization concentrations of biotite and/or chlorite and magnetite may have resulted in preferential deposition of sulfides as replacements in the foliated granodiorite.

Silica replacement of groundmass feldspars, especially plagioclase, is prevalent in the mineralized rocks. The foliated granodiorite was apparently receptive to change as evidenced by the pervasive nature of the alteration in it.

Pyrite in the mineralized zone is commonly fractured or broken, indicating some deformation during or after mineralization. Chalcopyrite may also have been subjected to deformation, but, because of its greater malleability, did not fracture.

Precious metal concentrations occur in direct proportion to sulfide content, especially to chalcopyrite, in some instances in the Copper King area.

The origin of the base and precious metals is highly conjectural since no direct evidence of their origin exists and textures developed from recrystallization and replacement may be similar in appearance.

Two origins are proposed:

1) base-precious metals in residual fluids related to a crystallized igneous pluton were introduced into a cataclastic zone, which provided a suitable depositional environment.
2) remobilization and concentration of metals from previously existing deposit by cataclasis.

Two igneous sources might be considered. The fluids may have originated from a final phase of the Sherman intrusion or they may have been derived from a presently non-exposed pluton.

The Sherman late stage fluids, as previously mentioned, are thought by Eggler (1967, p. 78-82) to have been rich in volatiles, especially H_2O, F, and Cl. The presence of fluorite, calcite and apatite in the mineralized zone may be related to the invasion of these residual fluids. The silica-potash enrichment of the granodiorite immediately west of the Copper King area may be considered evidence of the interaction between silica- and potash-rich fluids from the Sherman and the foliated granodiorite.

If a non-exposed pluton was the source of mineralizing fluids, this pluton must certainly have been of Precambrian age. This age is necessitated by the fact that the Precambrian shear zones, which were the apparent conduits for the mineralizing fluids and the local control for mineralization, were rendered impermeable by extensive recrystallization before the end of the Precambrian.

Meyer and Henley (in Barnes, 1967, p.

228) indicate that the potassium-silicate alterations assemblage observed in this study (potash feldspar, biotite, and some chlorite) are characteristic of alteration as the result of reaction of wall rock with fluids emanating from a crystallizing magma. If pressure and temperatures and wall rock composition are homogeneous, disseminated chalcopyrite, pyrite, and molybdenite may occur in the wall rock adjacent to hydrothermal solution channels. This particular assemblage is apparent in the alteration zone containing the metallic mineralization in the Copper King deposit.

No evidence has been observed to directly link potassic and silicic enrichment in the ore zone to invading "granitic" fluids, since the potassic and silicic enrichment often occurs in shear zones and could be attributed to metamorphic recrystallization. The cataclastic textures of the zone would tend to favor metamorphic processes. Eggler (1967, p. 22-23) observed the occurrence of pyrite and chalcopyrite in the intermediate to mafic rocks surrounding the Virginia Dale Sherman ring dike complex. These rocks are similar in description to the amphibolitized mafic rocks of the Silver Crown district. The diorite described by Eggler (1967, p. 17-19) is considered as a possible equivalent rock type to the foliated granodiorite. The foliated granodiorite and associated amphibolitized mafic rocks of this district may be considered as a logical source of copper.

The original metallic concentrations, in this case, may have existed before Precambrian shearing and developed as a primary igneous segregation or during the amphibolite grade dynamothermal metamorphism which created the foliation of the granodiorite. The original textures and paragenetic sequence probably would have been modified by the recrystallization and/or neomineralization to such an extent as to make them unrecognizable. This textural modification would have especially affected the chalcopyrite and sphalerite, since these are softer and more plastic in their behavior and will recrystallize completely when subjected to moderate to high temperature and pressure conditions (Ramdohr, 1969, p. 80).

Magnetite is observed to be a primary constituent of the foliated granodiorite and associated amphibolitized mafic rock types, since the Sherman Granite has been observed to generally have very little magnetite.

By the comparison of the modes of foliated granodiorite to local and nearby Sherman Granite (Eggler, 1967, p. 131; Ramarathnam, 1962, p. 72), modal volumes for magnetite were generally found to be ten times less in the Sherman Granite than in the foliated granodiorite. Therefore, the foliated granodiorite and amphibolitized mafic rocks are the logical source for the magnetite in this ore zone.

Precambrian deposits of the Front Range (Lovering and Goodard, 1950, p. 64) usually contain values in gold, copper and zinc. Primary minerals include free gold and chalcopyrite, with lesser amounts of bornite, pyrrhotite, pyrite, sphalerite, galena and magnetite. Gangue minerals are high temperature silicates quartz, feldspar, and garnet. Laramide deposits tend to be complex types, with sulfantimonides, sulfarsenides, and tellurides as common ore minerals with values in gold, silver, lead and zinc. Based on high copper and gold values and similarity of gangue minerals, the Copper King deposit seems to be similar to other Precambrian Front Range deposits.

Precambrian mineral deposits of the Front Range, as described by Lovering and Goodard (1950, p. 64-72) include hypothermal replacement, magmatic segregation, pegmatitic quartz vein and pegmatitic deposits. The Copper King deposits do not show any similarities to the pegmatitic quartz veins or pegmatitic type deposits, and are not in the calc-silicate country rock typical of replacement deposits.

Precambrian magmatic segregation and dissemination deposits of the Front Range consist of chalcopyrite, pyrrhotite, magnetite and marmatite ores, and generally occur as lenticular masses of high grade ore or as disseminations. They are usually associated with a hornblende gneiss representing metamorphosed gabbroic dike rocks (Lovering and Goodard, 1950, p. 64). Magnetic anomalies have been described occurring over this type of deposit caused by magnetite and pyrrhotite accumulations.

The exact nature of the metallic mineralization in the Copper King deposits prior to cataclastic redistribution is not known, since textural relationships were destroyed by the later shearing. However, the general features of the Copper King deposit are very similar to those of the magmatic segregation and dissemination deposits of the Front Range. The gross metal and gangue mineralogy, the association of metamorphosed mafic rocks, and the magnetic anomalies associated with the ore zones all are similar.

Mafic dike association is not observed in the Copper King area, but its presence could easily have been obscured by the subsequent cataclasis. The elongate ovoid shape of the proven ore body may reflect the originally tabular shape of an associated dike or could be the result of the later cataclasis. The presence of pyrite in the Copper King deposit may be a function of a greater original sulfur content or an effect of inversion of pyrrhotite under the influence of the later cataclastic event. The locally observed association of chalcopyrite with the amphibolitized mafics and the observations by Eggler (1967, p. 22-23) of chalcopyrite and pyrite in the mafic rocks surrounding the Virginia Dale ring dike complex to the south of the Silver Crown district also support this origin. The later shearing in the Copper King deposition probably modified the original metal distribution through at least partial remobilization and movement of metallics from the foliated granodiorite and amphibolitized mafic rock to the adjoining cataclastic aplitic quartz monzonite and hybrid felsic rocks. The foliated granodiorite must have been a suitable environment for redeposition of the mobilized metals, partially because of its high content of magnetite, biotite, and chlorite which provided depositional sites as replaceable material.

The Copper King deposit is considered originally to have been a Precambrian metallic concentration, possibly of a magmatic segregation or dissemination type, that was subjected to a later Precambrian cataclasis, causing partial redistribution of metal concentrations into the adjacent sheared rocks.

Distribution and Size

Comstock-Type Deposits

The Comstock-type mineral deposits are the most widespread in the district. Those near the Comstock Mine in section 13 (Plate I) consist of six parallel northeast-trending mineralization zones in a distance of less than one-half mile. Three of these zones are traceable in nearly continuous outcrops for about 3/4 of a mile.

Sulfide concentrations are variable, but high grade pods have been reported from the Comstock Mine (Harry Ferguson, 1965). Although dump material substantiates the presence of high grade ore, mineralization appears to be sporadic in occurrence. The Comstock shaft and accessible workings appear to intersect the larger N15°E trending zone which is located slightly to the east.

Good primary sulfide mineralization occurs throughout the area in many prospect pits, shafts, and tunnels. Several of the more notable localities are the Fairview (section 13) and Louise (section 35) mines (Plate I).

Tonnages of ore grade material are probably small and, although possibly very high grade, are sporadically distributed.

Copper King Deposit

The Copper King Mine is the largest known occurrence of its type in the Silver Crown district. Two other similar occurrences are located in the east central part of section 14 and the southwest ¼ of section 35.

A significant amount of drilling has been done on the Copper King property. Maximum concentrations from available drill data indicate copper up to 1.5% and gold up to 0.2 oz. per ton; however, most concentrations are somewhat lower.

The highest metal concentrations lie in a roughly oval shaped zone with approximate dimensions of 300 by 500 feet (Plate II). Drilling has generally been to a depth no greater than 400-500 feet in this zone, but several deeper holes have been completed. In the U.S. Bureau of Mines drill hole B-3, good concentrations of copper and gold extend to approximately 700 feet and then seem to decrease rapidly. Further deep drilling is needed to determine if the decrease is generally prevalent.

Plate II shows the location, depths and average gold and copper concentrations for the indicated hole intervals. No attempt was made to calculate reserves because of variability in methods which might be used.

Reserves indicated by A. E. Nevin (consulting engineer for Henrietta Mines) include 10 million tons of 0.30% copper and 0.038 oz. gold per ton to a depth of 500 feet. This block has a stripping ratio of 1.5 tons waste rock per ton of ore (Carrington, 1973, p. 21).

The Copper King Mine appears to have potential for development by small open pit operation. Further drilling is necessary to determine the extension of the ore zone at depth. This would entail deep drilling, probably to 1,000 feet or more.

SUMMARY OF GEOLOGIC HISTORY

The following is a summary of postulated events leading to the present geology and mineral deposits within this district:

1) A sequence of sedimentary material was deposited and later folded probably before 1700 to 1800 m.y. ago, based on regional studies of Peterman and others (1968, p. 2294).
2) Intermediate to mafic rock types, including granodiorite, quartz diorites, gabbros, diabases and pyroxenites were intruded into the metasedimentary sequence as evidenced by the presence of xenolithic inclusions of metasedimentary biotite schist. This intrusive event may coincide with the Boulder Creek event of the Colorado Front Range before 1700 m.y. ago (Peterman and others, 1968, p. 2294). Original metallic concentrations of copper and gold probably developed as magmatic segregations or disseminations and in narrow shear zones. During a period of dynamothermal metamorphism the metasedimentary rocks and the intermediate to mafic rock types experienced amphibolite grade metamorphism (probably related to regional event 1700 m.y. ago, Peterman and others, 1968, p. 2294) as evidenced by two generations of hornblende and the presence of poikiloblastic hornblende after pyroxene in the granodiorites. Gneissic foliations may have developed in response to this metamorphic episode.
3) Retrograde metamorphism of the metasedimentary sequence and the intermediate to mafic rock types occurred in response to dynamic metamorphism during or slightly after the intrusion of the Sherman batholith at about 1400 m.y. (Peterman and others, 1968, p. 2294). Syntectonic deformation and minor shearing probably occurred, resulting in the development of cataclastic foliation and faults roughly parallel to the batholith boundary. These structures were the controls for the mineralization of the Comstock-type deposits, which are postulated to have formed from remobilization of metallic concentrations

in the foliated granodiorite or as fluids from the late stage Sherman intrusion. Slightly before or contemporaneous with deformation, alkali metasomatism, presumably from Sherman related fluids, locally altered the granodiorite to form the hybrid felsic rocks.

4) Aplitic quartz monzonite dikes and bodies and some pegmatites intruded previously existing rock types. These dikes are considered to be late stage Sherman derivatives. Localization of dikes along previously existing shear zones and foliation trends occurred. Local potassic alteration occurred along granodiorite contacts.
5) A period of cataclasis resulted in the formation of large shear zones, some of which may have been reactivations of earlier shear trends. These shear zones may be correlative with regional cataclasis from 1400 to 1200 m.y. ago (Peterman and others, 1968, p. 2295). Remobilization of metallic elements which were possibly originally present in the pre-cataclastic granodiorites and related mafic rocks occurred during cataclasis. The remobilized metals were redeposited, as sulfides, in zones of chemical favorability (i.e. in granodiorite as replacement of biotite, magnetite and chlorite) and/or greater permeability.
6) Late stage pegmatites were intruded, controlled by foliation planes and shear zones.
7) Paleozoic and Mesozoic sedimentation and lithification occurred with uplift of Ancestral Rockies during mid-Paleozoic time.
8) Reactivation of older shear and fault zones, establishment of new faults and the development of some joint sets evidently formed during the uplift of the earlier Ancestral Rockies and/or the Laramide Orogeny under brittle fracture conditions.

GEOCHEMICAL EXPLORATION INVESTIGATIONS

A study of the concentration of selected mobile, semi-mobile, and immobile elements was undertaken to determine areas of potential mineralization. Investigation was restricted to elements present in stream sediment material.

Sample Collection

Sample locations were established on a 1:12,000 topographic base map with a density of approximately seven samples per square mile and provided uniform coverage of drainage areas (Fig. 6). A total of 57 samples was taken over the eight-square-mile area.

Three-pound samples of alluvial material were collected at most sites. Where no alluvium was available, soil material was collected at a depth of about four to six inches and root material was sorted out by hand.

Twenty-pound samples of rock material were collected from several of the mine dumps in the area. These samples were random in an effort to obtain a representative assemblage of dump material not necessarily representing the content of the mineralized zone.

Chemical Analysis

Analyses were made for total metal content on the mobile element silver, the intermediately mobile element copper, and the relatively immobile element lead. A Perkin-Elmer 290 Atomic Absorption Spectrophotometer was used. Procedures for dissolution were obtained from Wayne Mountjoy of the Analytical Section of the USGS, Denver, Colorado (personal communication). An HF-HNO_3 total digestion procedure was used.

General Results

Lowest concentrations of Cu are present in stream sediment material derived from the Sherman Granite, sedimentary rocks, and areas of thick Tertiary gravels. Average concentrations are about 30 parts per million (ppm) in the gravel and 20-25 ppm in the Sherman Granite. Higher concentrations were recorded in materials from the granodiorite and quartz monzonite units. Average concentrations for these rocks are about 80-90 ppm. Copper concentrations above 200 ppm are observed in drainage segments below known mineralization.

Concentrations of samples in the Sherman Granite area were disregarded as members of a separate population. With these exclusions, the mean is 105 ppm Cu with standard deviation of 63 ppm Cu. The threshold approximation is a value of 230 ppm Cu.

Three stream sediment samples and two dump grab samples were analyzed by the USGS for 36 minor elements (Appendix, Table A-IV). Results showed no elements of sulfide association which were above the concentrations of average igneous rocks except Cu, Mo, and Ag (Hawkes and Webb, 1962, p. 359-377).

Recommendations for Geochemical Exploration

Based on the results of spectrographic and atomic absorption analysis, elements to be analyzed in future work should definitely include copper, molybdenum, and silver. These elements appear to be present in the mineral deposits in anomalous quantities (Appendix, Tables A-I, A-II, A-III) and are sufficiently mobile to provide good dispersion.

Other elements, which were below the DC Arc Spectrometer detection limits, and which may be of use in geochemical exploration are arsenic and zinc. Both elements may be present in this district's mineral deposits in quantities detectable by atomic absorption analytical methods. The intermediate mobility of these two elements in aqueous environments and their general association with base-precious metal deposits suggests a need for further investigation

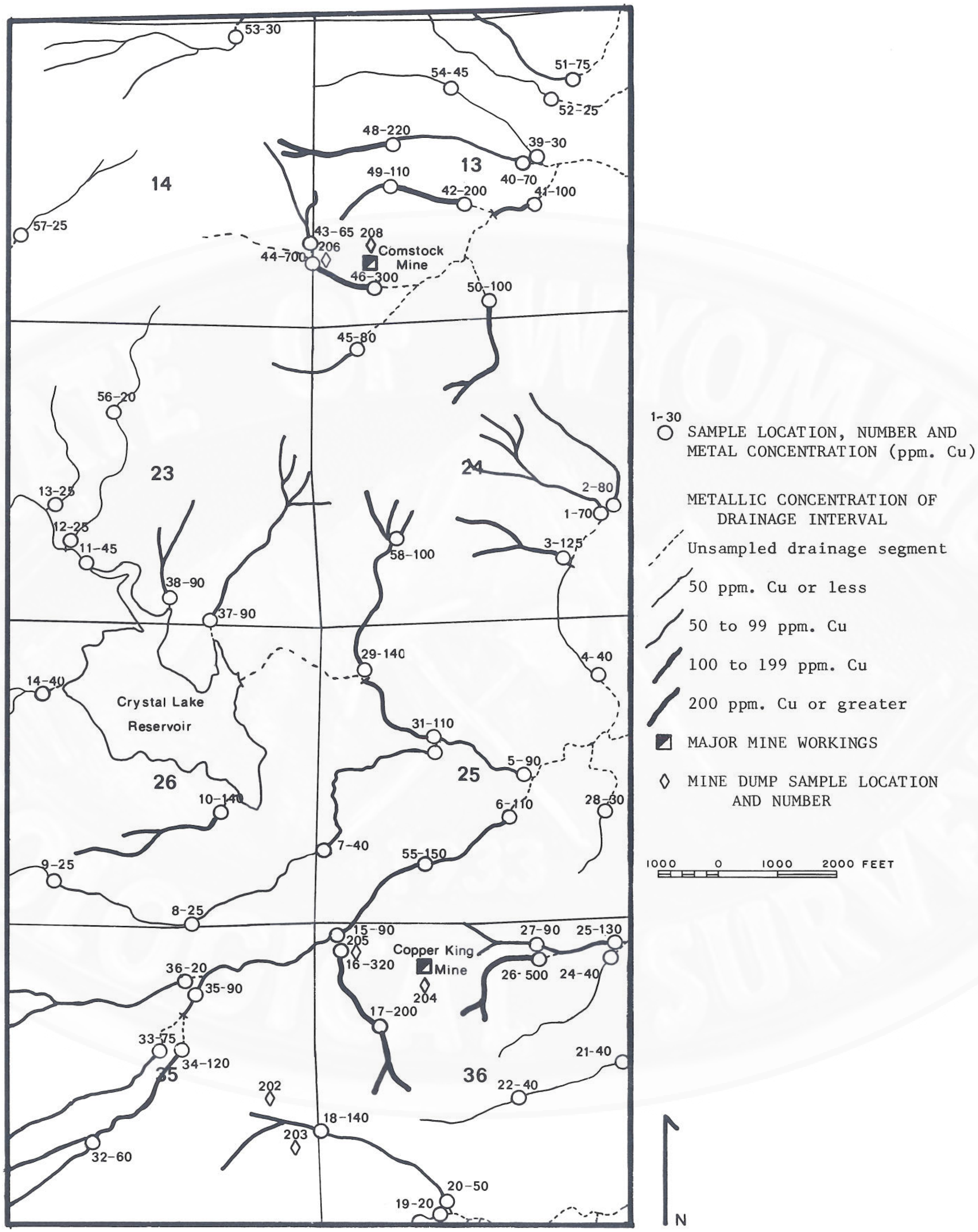


FIGURE 6. Stream sediment geochemical survey map with copper concentrations indicated.

into their desirability as indicator elements for the district's mineral deposits.

Stream sediments do appear to give good anomalies (>200 ppm Cu) near known deposits, and should be of some usefulness in establishing new geochemical targets in the area. Closer sampling intervals are suggested, especially upstream from some of the higher recorded concentrations (>140 ppm Cu). This should be supplemented by outcrop sampling and especially by soil sampling to further delineate target areas. Several soil geochemistry programs have been instituted by ASARCO and Henrietta Mines Inc. near the Copper King Mine (Plate I). These have been somewhat successful in confirming the approximate location of mineralization beneath soil cover areas. This mineralization was confirmed by drilling (C. E. Beverly, ASARCO, and A. E. Nevin, consultant for Henrietta Mines Inc., 1973, personal communications).

GEOPHYSICAL INVESTIGATIONS

Procedure and Instrumentation

Several geophysical exploration programs have been undertaken in the vicinity of the Copper King property. The latest was undertaken by Henrietta Mines, Inc. to assist in evaluation of this property and the surrounding area. Vertical intensity ground magnetometer and induced polarization (I.P.) surveys were conducted.

The magnetometer ground survey conducted by Henrietta Mines Inc. utilized a Jalander vertical intensity fluxgate magnetometer. This survey encompassed sections 35 and 36 and the southern ½ of sections 25 and 26. Traverse lines were at 800-foot spacing, with 200 feet between stations. A more detailed survey was conducted in the vicinity of the Copper King Mine, with a 200-foot spacing of traverse lines and 200 feet between stations. An isogam map of the Copper King area is shown in Plate II, indicating drill hole locations and metal concentrations.

An induced polarization and resistivity survey was conducted by McPhar Geophysics, Inc. for Henrietta over the Copper King area. The survey utilized the frequency-domain method with dipole-dipole electrode configuration. A dipole spacing of 200 feet was used between the two current electrodes and between the two potential electrodes. Metal factor and percent frequency effect anomalies are indicated in Plate II by bars which represent the surface projection of anomalies as interpreted from the location of the current and potential electrodes when anomalous values were measured. Type of anomaly is also indicated as definite, probable, and possible through the use of appropriate line patterns. According to the McPhar Geophysics I.P. report, locations of anomaly boundaries are only approximate, since those boundaries can be located with accuracy no greater than the distance between each electrode of a pair (electrode interval length). Seven lines were run, five in the north-south direction with approximately 2,000 feet of separation between lines. Two very closely spaced lines were also run in a general east-west direction over the highly mineralized area.

General Results

The high content of magnetite generally associated with Precambrian shear zones in the Silver Crown district is manifested as a large positive magnetic anomaly over known zones. Anomalies for the magnetometer surveys are of the magnitude of 900 gammas above the surrounding colluvial gravel cover. The Henrietta isogam map of the Copper King area is shown in Plate II, with reference to drill holes and I.P. anomalies.

A very high anomaly on trend with the anomaly at the Copper King is present to the east as an elongate anomaly of slightly lower magnitude. This apparently corresponds to the eastward extension of the mapped shear zone which apparently extends beneath the gravel cover. The smaller scale map which was done for Henrietta shows another elongate positive anomaly which corresponds approximately to a northeast-southwest trending shear zone located in the east portion of section 35 (Plate I).

Relative magnetic lows for the most part are located in areas of gravel cover. These lows may result from the low magnetite content presumably present in the gravel material derived from the Sherman Granite. Elongate lows are also present on the larger scale map and may correspond to reactivated fault trends which, in some cases contain hematite after magnetite to a depth of 100 feet or more.

Results of the I.P. survey were reported in metal factor (M.F.) and percent frequency effect (f.e.) parameters. A definite M.F. anomaly occurs near the area of proven high mineralization (Plate II). An additional strong M.F. and a weak to moderate f.e. anomaly exist southwest of the proven mineralization zone. The origin of the anomaly is apparently deep, approximately five times the dipole spacing or about 1,000 feet; however, by the nature of the method any depth calculation is unreliable; thus, only the designation "deep" is used. In the case of 200-foot dipoles "deep" generally means 450 to 1,000 feet of depth. Several shallow, narrower anomalies exist to the northeast.

Evaluation of Geophysical Methods

Both the vertical intensity magnetometer and the I.P. methods appear to be applicable to exploration in the Silver Crown district. The methods appear to give similar information since the highly mineralized areas often contain large quantities of magnetite which may also give an I.P. anomaly.

The vertical intensity magnetometer appears to be the most feasible geophysical technique on the basis of cost and time required. Elongate magnetic highs may occur in association with mineralized shear zones as a result of the large quantities of magnetite present. The presence of a magnetic high does not necessarily imply associated sulfides, but the anomalous area should be evaluated with other techniques such as soil and outcrop geochemical sampling.

Both magnetometer and I.P. methods may be of some usefulness in exploration for Comstock-type deposits. Electromagnetic methods might, however, be of more use, since this type of deposit occurs in narrow fault zones as high grade pods and veins.

Recommendations for Further Exploration

Large tonnage deposits, such as the Copper King property, appear to be associated with Precambrian cataclastic rocks in shear zones. Further investigation of known shear zones is warranted. Two instances of sulfides associated with shear zones other than the Copper King have been observed in sections 14 and 35 (Plate I). Suggestions for prospecting for unexposed deposits are as follows:

1) A general reconnaissance vertical intensity magnetometer survey should be completed over the Silver Crown district to delineate areas of high magnetic response.
2) A more detailed stream sediment geochemical program would be useful and would complement the results of the magnetometer survey. Elements in addition to copper and silver which might prove useful in delineating target areas are zinc, molybdenum, arsenic and possibly mercury.

The Copper King Mine property has been subjected to extensive investigation in the past, especially within the last 20 years. A variety of geophysical and geochemical techniques have been used as aids in evaluating the extent of the deposit. Drilling has for the most part been confined to a relatively small area surrounding the Copper King shaft where mineralization occurs close to the surface.

Only one hole, BM-3, has been drilled to a depth of greater than 700 feet. Most holes, even in the known mineralized zone, extend to depths of less than 500 feet. Several good possibilities exist for further drilling, since much information has already been gained from geophysical and geochemical investigations.

1) Drilling should be conducted to determine the southwestward extension of the Copper King deposit. This area is of interest, since a deep I.P. metal factor anomaly (at 450 to 1,000 feet) is present, magnetometer isogam lines seem to indicate a slightly southwestward-dipping magnetic zone, and values in copper and gold in holes A-12, H-3, and A-3 experience a sharp increase at from 160 to 200 feet (Plate II). If the vicinity of holes A-2 and A-8 is arbitrarily taken to be near the top of the mineralized zone and an increase in values related to the previously mentioned zone, the ore body apparently dips toward the southwest at 50° to 60°. Step-out drilling from P-1 to a depth of 400 to 500 feet should indicate the validity of this projection.
2) The extension of the magnetic and metal factor anomalies to the east along with general field relationships indicate that the shear zone extends under the gravel cover (Plate I). Since no significant exploration has as yet been conducted in this area, it should be seriously considered.

ACKNOWLEDGEMENTS

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PHOTO 19. (left) A monument to a silent mill, the words here read: IMPROVED STONE BREAKER MADE BY FARREL FOUNDRY & MACHINE CO. ANSONIA CONN. SIZE 7BY10 No. 132.

PHOTO 20. (below) Back in the days when Hecla was a more viable community, this was part of the schoolhouse, located just south of the old mill on the Crystal Lake Road.

APPENDIX

TABLE A-I. USGS SEMI-QUANTITATIVE ANALYSIS (D.C. ARC SPECTROMETER)

Elements		Sample Number* 6	46	50	204A	208
Fe %	(.05)	5	5	5	7	7
Mg %	(.02)	1.5	1	1.5	0.5	1
Ca %	(.05)	1.5	1	1.5	0.5	1.5
Ti %	(.002)	0.5	0.5	0.3	0.1	0.2
Mn	(10)	1,000	700	1,000	500	700
Ag	(.5)	N	N	N	5	15
As	(200)	N	N	N	N	N
Au	(10)	N	N	N	N	N
B	(10)	200	10	L	50	L
Ba	(20)	700	700	700	700	1,500
Be	(1)	2	2	2	1	1
Bi	(10)	N	N	N	L	L
Cd	(20)	N	N	N	N	N
Co	(5)	15	10	10	10	10
Cr	(10)	50	50	70	L	L
Cu	(5)	100	300	70	>20,000	>20,000
La	(20)	30	50	30	N	20
Mo	(5)	N	5	N	5	50
Nb	(10)	L	10	N	N	N
Ni	(5)	30	30	30	7	50
Pb	(10)	15	15	15	15	20
Sb	(100)	N	N	N	N	N
Sc	(5)	15	10	10	L	L
Sn	(10)	N	N	N	N	N
Sr	(100)	300	200	500	150	300
V	(10)	100	100	100	30	50
W	(50)	N	N	N	N	N
Y	(10)	20	20	15	N	L
Zn	(200)	N	N	L	N	N
Zr	(10)	300	500	200	30	70

Fe, Mg, Ca, and Ti reported in %, all other elements reported in ppm. Lower limits of determination are in parentheses. N = not detected at limit of detection, or at value shown. L = detected below limit of determination, or below value shown. Analyst: C. Forn
*See Figure 6 for locations.

TABLE A-II. USGS FIRE ASSAY ANALYSIS

Elements	Sample Number 6	46	50	204A	208
Pt (ppm)	N(0.025)	N(0.005)	N(0.005)	N(0.010)	N(0.005)
Pd (ppm)	N(0.010)	N(0.002)	N(0.002)	0.006	0.004
Rh (ppm)	N(0.010)	N(0.002)	N(0.002)	N(0.004)	N(0.002)
Ru (ppm)	N(0.500)	N(0.100)	N(0.100)	N(0.200)	N(0.100)
Ir (ppm)	N(0.500)	N(0.100)	N(0.100)	N(0.200)	N(0.100)

N = not detected at limit of detection. Analyst: E. F. Cooley

TABLE A-III. USGS ATOMIC ABSORPTION ANALYSIS

Elements	Sample Number 6	46	50	204A	208
Au	N(0.10)	N(0.05)	N(0.05)	6.0	1.0
Cu	ins	400	110	26,000	22,000
Ag	ins	L(.5)	L(.5)	4.0	14.0
Mo*	N(2)	4	N(2)	4	10.0
Te	ins	N(0.5)	ins	1.0	N(0.5)

N( ) = not detected at limit of detection or at value shown. L( ) = detected, but below limit of determination or below value shown. ins = insufficient sample. All values in ppm unless otherwise noted. Analysts: J. G. Frisken and R. B. Carten.
*Molybdenum analysis by colorimetric techniques.

TABLE A-IV. USGS CONCENTRATION OF Cu, Au, AND Ag IN MINE DUMP GRAB SAMPLES*

Sample No.	Mine Name	Cu(ppm)	Au(ppm)	Ag(ppm)
202	London	7,500	—	15
203	Louise	10,000	—	35
204	Copper King	28,000	6	5
205	—	320	—	tr
206	Fairview	12,500	—	10
208	Comstock	19,750	1	25

*Samples taken as random representative samples on dumps, with analysis by A.A. spectrophotometer. See Figure 6 for locations.

STATE OF WYOMING

1933

GEOLOGICAL SURVEY

STATE OF WYOMING
1933
GEOLOGICAL SURVEY

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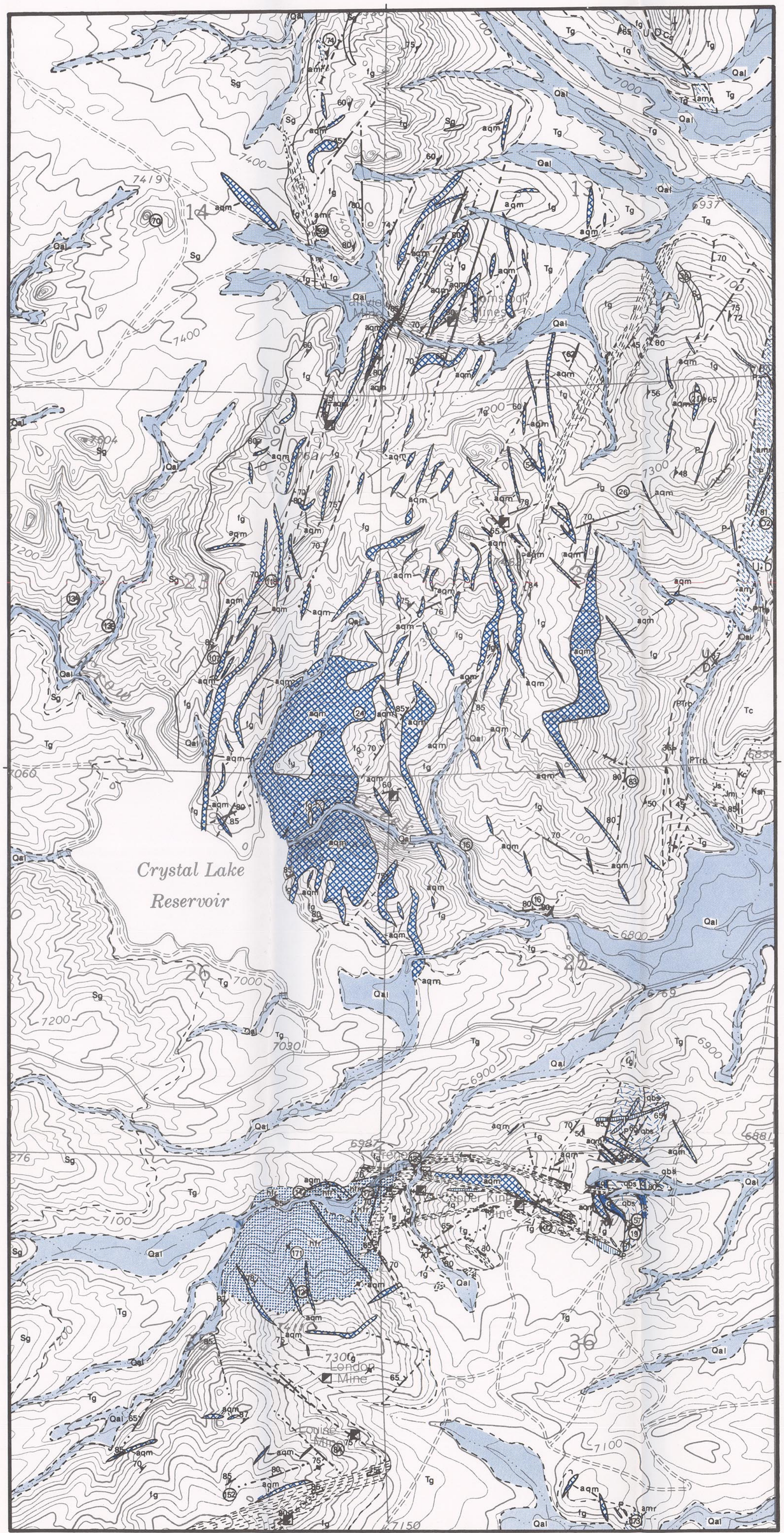
PLATE I

GEOLOGIC MAP OF THE SILVER CROWN DISTRICT

LARAMIE COUNTY, WYOMING

TERENCE L. KLEIN
1973



Topography by U.S. Geological Survey, 1962

N MN 14°

Approximate Mean Declination, 1962

Geology by T.L. Klein, 1972

LITHOLOGIC UNITS

CENOZOIC

- Qal — ALLUVIUM
- Tg — TERTIARY GRAVELS
- Tc — CHADRON FORMATION

PALEOZOIC MESOZOIC

- Ksh — CRETACEOUS SHALES
- Kc — CLOVERLY GROUP
- Jm — MORRISON FORMATION
- Js — SUNDANCE FORMATION
- PTrb — PERMO-TRIASSIC RED BEDS
- Cc — CASPER FORMATION

PRECAMBRIAN

P — PEGMATITE
Buff to pink, very coarse grained, composed of potash feldspar, quartz and plagioclase.

SHEAR ZONE TECTONITES
White, gray and brown cataclasites, mylonites, blastomylonites, and mylonite gneisses, commonly with quartz and epidote veinlets. Locally containing gouge and breccia zones.

aqm — APLITIC QUARTZ MONZONITE
Brown to red, fine grained, generally equigranular quartz monzonite. Composed of potash feldspar, quartz and plagioclase (An 10-14). Contacts generally gradational with foliated granodiorite. Locally moderate biotite concentrations as the result of wall rock assimilation.

hfr — HYBRID FELSIC ROCKS
Light brown to gray, slightly porphyritic, slightly to moderately foliated, granite to granodiorite. Composed of potash feldspar, quartz, plagioclase (An 15-30) and biotite. Contacts extremely gradational with foliated granodiorite.

Sg — SHERMAN GRANITE
Buff to pink, coarse grained, porphyritic to equigranular granite. Composed of quartz, potash feldspar, plagioclase (An 14-16) and biotite.

fg — FOLIATED GRANODIORITE
Gray to brown, equigranular to porphyritic, non-foliated to gneissic granodiorite. Composed of quartz, plagioclase (An 26-34), biotite and hornblende. Local potash enrichment near aplitic quartz monzonite and Sherman Granite contacts.

amr — AMPHIBOLITIZED MAFIC ROCKS
Dark gray to black, equigranular, diabasic or porphyritic diorite, diabases, gabbro, and pyroxenite. Composed of plagioclase (An 38-54), hornblende and biotite. Locally abundant quartz.

qbs — QUARTZ-BIOTITE SCHIST
Dark gray to black, fine grained with prominent foliation imparted by biotite alignment. Composed of quartz and biotite.

q — QUARTZITE
Dark gray to black, fine to medium grained, equigranular quartzite. Composed of quartz with magnetite imparting dark coloration.

MAP SYMBOLS

CONTACT
Most contacts shown as solid lines since they are approximately located. Dashed between Precambrian and post-Precambrian units. Dotted where gradational or inferred.

SHEAR ZONE

U 60 D

FAULT
Solid where definite. Dashed where approximate. Dotted where inferred. Direction and amount of fault plane dip shown. Relative movement shown where known.

60 inclined — vertical — STRIKE AND DIP OF FOLIATION

60 inclined — vertical — 60 overturned — STRIKE AND DIP OF SEDIMENTARY BEDS

60 inclined — vertical — STRIKE AND DIP OF CATACLASTIC FOLIATION IN SHEAR ZONES

VERTICAL SHAFT OF MAJOR WORKING

PORTAL OF TUNNEL OR ADIT

1 — LOCATION AND NUMBER OF SAMPLE REFERRED TO IN TEXT

SCALE
0 — 1 MILE

CONTOUR INTERVAL 20 FEET
DATUM MEAN SEA LEVEL

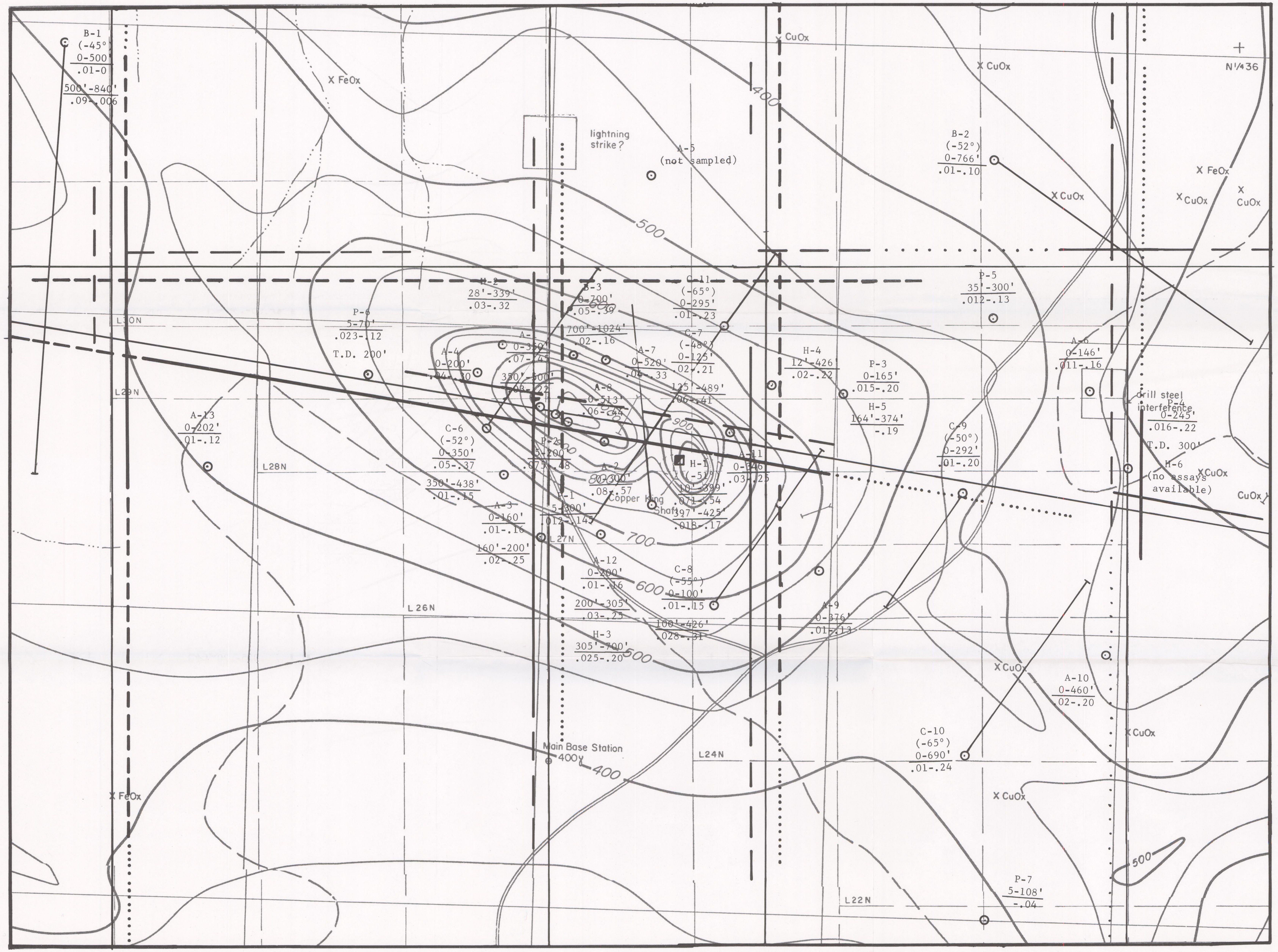


PLATE II

MAP OF THE COPPER KING MINE AREA

LARAMIE COUNTY, WYOMING

DRILL HOLE LOCATION, VERTICAL INTENSITY MAGNETOMETER ISOGAM, INDUCED POLARIZATION SURVEY

(used by permission from surveys for Henrietta Mines Inc.)

T.L. KLEIN
1973

LEGEND

⊙ Diamond Drill Hole

10 – 397' = footage
.071 – .54 = oz Au – % Cu

H — Henrietta — Diamond Drill Hole
A — Asarco 1938 and 1970
B — U.S. Bur. Mines 1953
C — Copper King Mining Co. 1952-3
P — Henrietta Percussion Drill Hole

x prospect pit with most apparent content:

- FeOx limonite
- CuOx copper stain
- Ser sericite
- Qtz quartz
- Epid epidote

Contour Interval 50γ

NOTES:

Jalander Magnetometer no.57106
Adjusted for diurnal variation
All data and culture located via
brunton and tape survey traverses.
Grid control systems as of USBM R.I. 5139

Mc Phar I. P Lines

Anomalous Metal Factor

Anomalous Percent Frequency Effect

N MN 14°

0 100 200ft.