WYOMING STATE GEOLOGICAL SURVEY
Gary B. Glass, State Geologist

# GEOLOGY AND MINERALIZATION OF THE COOPER HILL MINING DISTRICT, MEDICINE BOW MOUNTAINS, SOUTHEASTERN WYOMING

by

W. Dan Hausel

Report of Investigations No. 49
1994

Laramie, Wyoming

People with disabilities who require an alternative form of communication in order to use this publication should contact the Editor, Wyoming State Geological Survey at (307) 766-2286. TDD Relay Operator 1(800) 877-9975.

This and other publications available from: Wyoming State Geological Survey
Box 3008, University Station
Laramie, Wyoming 82071-3008
(307) 766-2286 • FAX (307) 766-2605

Text and cover printed on 50% recycled fiber paper. First printing of 600 copies by Pioneer Printing and Stationery Company, Cheyenne, Wyoming.

The composition and layout of this publication were done entirely with a voice-activated computer system.

Geology and Mineralization of the Cooper Hill mining district, Medicine Bow Mountains, southeastern Wyoming: by W. Dan Hausel

ISBN 1-884589-04-9

**Front Cover:** Entrance to the Rip Van Winkle adit, circa 1900. This mine, located near the crest of Cooper Hill, was driven about 750 feet into the hillside and reportedly intersected several gold-bearing quartz veins. Photograph courtesy Wyoming State Museum. Reproduced with permission.

WYOMING STATE GEOLOGICAL SURVEY
Gary B. Glass, State Geologist

Report of Investigations No. 49

# GEOLOGY AND MINERALIZATION OF THE COOPER HILL MINING DISTRICT, MEDICINE BOW MOUNTAINS, SOUTHEASTERN WYOMING

by

W. Dan Hausel

Laramie, Wyoming

1994

# Table of contents


Page

- Abstract ... 1
- Introduction ... 1
- Acknowledgments ... 1
- Location and access ... 1
- Mining history ... 3
  - Introduction ... 3
  - Cooper Hill ... 3
- Geology ... 4
- Structure and metamorphism ... 5
- Rock units ... 6
  - Amphibolite ... 6
  - Metalimestone ... 8
  - Quartzite and metaconglomerate ... 8
  - Mica schist ... 9
- Economic geology ... 12
  - Mineralization ... 12
    - Skarns ... 12
    - Veins ... 12
  - Mines and occurrences ... 13
    - Albion mine ... 13
    - Clara B. [Morgan] prospect ... 15
    - Cooper Creek adit ... 15
    - Copper Queen mine ... 16
    - Croesus tunnel ... 16
    - Emma G. mine ... 16
    - Little Ella-Senator Stewart mine ... 17
    - Little Johnnie tunnel ... 18
    - North Star mine ... 18
    - Richmond mine ... 18
    - Rip Van Winkle mine ... 18
    - Silver King prospect ... 19
    - Silver Queen mine ... 19
    - Quartz pebble conglomerate ... 19
    - Placers ... 20
- Summary ... 20
- References cited ... 21


## Illustrations

### Figures


1. Location map of Cooper Hill ... 2
2. Isoclinally folded metalimestone from the hilltop in the NE NE section 34 of Cooper Hill ... 8
3. Quartz pebble conglomerate bed in quartzite near the top of Cooper Hill ... 9

Page

4. Albion mine map .................... 14

5. Mine map of the Cooper Creek adit .................... 15

6. Partial claim map of the Cooper Hill district .................... 16

7. Mine map of the Emma G. incline
showing quartz vein with schist xenoliths .................... 17

8. Gold panned from Cooper Creek in 1991 .................... 20

## Tables

1. Whole rock and trace element analyses of
selected rock samples from the Cooper Hill district .................... 7

2. Geochemical analyses of rock samples from the Cooper Hill district .................... 10

## Plate (back pocket)

1. Geologic map of the Proterozoic rocks of the Cooper Hill mining district, Wyoming

# Abstract

The Cooper Hill mining district, located along the northeastern flank of the Medicine Bow Mountains in southeastern Wyoming, consists of an allochthonous block of amphibolite grade metasedimentary and metavolcanic rock of Proterozoic age. Metamorphic rocks include metalimestone, mica schist, quartzite, metabasalt, amphibolite, and metaconglomerate, which are intruded by mafic sills and dikes. These rocks have been affected by at least three episodes of deformation.

Mineral deposits include skarns, veins, and placers. Past production included some gold, silver, lead, and copper ore.

# Introduction

The Cooper Hill mining district lies along the northeastern edge of the Medicine Bow Mountains in Carbon County of southeastern Wyoming (**Figure 1**). Cooper Hill, a prominent treeless "bald" hill is clearly visible from Interstate 80 in the vicinity of Cooper Cove. The district was an active mining district during the last decade of the Nineteenth Century and the first decade of the Twentieth Century. Some gold, silver, copper, and lead were recovered from this district, but the amount of ore mined is unknown and believed to have been minimal.

Cooper Hill, which is located along the northeastern edge of the Medicine Bow Mountains, has been interpreted as an allochthonous block of Proterozoic crystalline rock. Structurally, the Arlington thrust placed these ancient Precambrian rocks of Cooper Hill on top of younger Phanerozoic sedimentary rocks (King, 1963; Blackstone, 1973).

The rocks comprising Cooper Hill are typical of the miogeosynclinal metasedimentary succession found throughout much of the northern Medicine Bow Mountains and includes quartzite, mica schist, metaconglomerate, metalimestone, and amphibolite. Mineralization is associated with veins, skarns, and placers (Hausel, 1992). Sulfides include chalcopyrite, pyrite, galena, and polybasite (Schoen, 1953).

# Acknowledgments

Field mapping was completed in the summer of 1991. Eric Neilsen provided support work which included the collecting of panned sample concentrates from Cooper Creek and the North Fork of Cooper Creek in the search for placer gold. In the summer of 1992, the author was assisted by Jamie Clemons in mapping an abandoned mine immediately south of Cooper Hill.

I would like to thank Ron Kuhn, Steve Palmer, and Chuck Szekula for granting access to mining claims on Cooper Hill, and Mike McGill for limited access across private property to reach Cooper Hill. I would especially like to thank Audrey Cofferman and Chuck and Ester Szekula for their hospitality. Their friendship will always be remembered. This project was recommended by Dan Dowers, formerly with Union Pacific Resources, and the manuscript was reviewed by Robert S. Houston, Professor Emeritus of Geology at the University of Wyoming. Financial support was provided by grants from Union Pacific Resources.

# Location and access

The Cooper Hill mining district, which includes Cooper Hill and the adjacent gold placers in Dutton and Cooper Creeks, is located along the northeastern edge of the Medicine Bow Mountains in T18N, R78W, about 7 miles southeast of Arlington (**Figure 1**). The district is accessible from Interstate 80 at the Cooper Cove road exit via two dirt roads across private property. The northern road leads to Woodedge, and the southern road leads to Morgan. Morgan and Woodedge are villages with a few summer cabins.

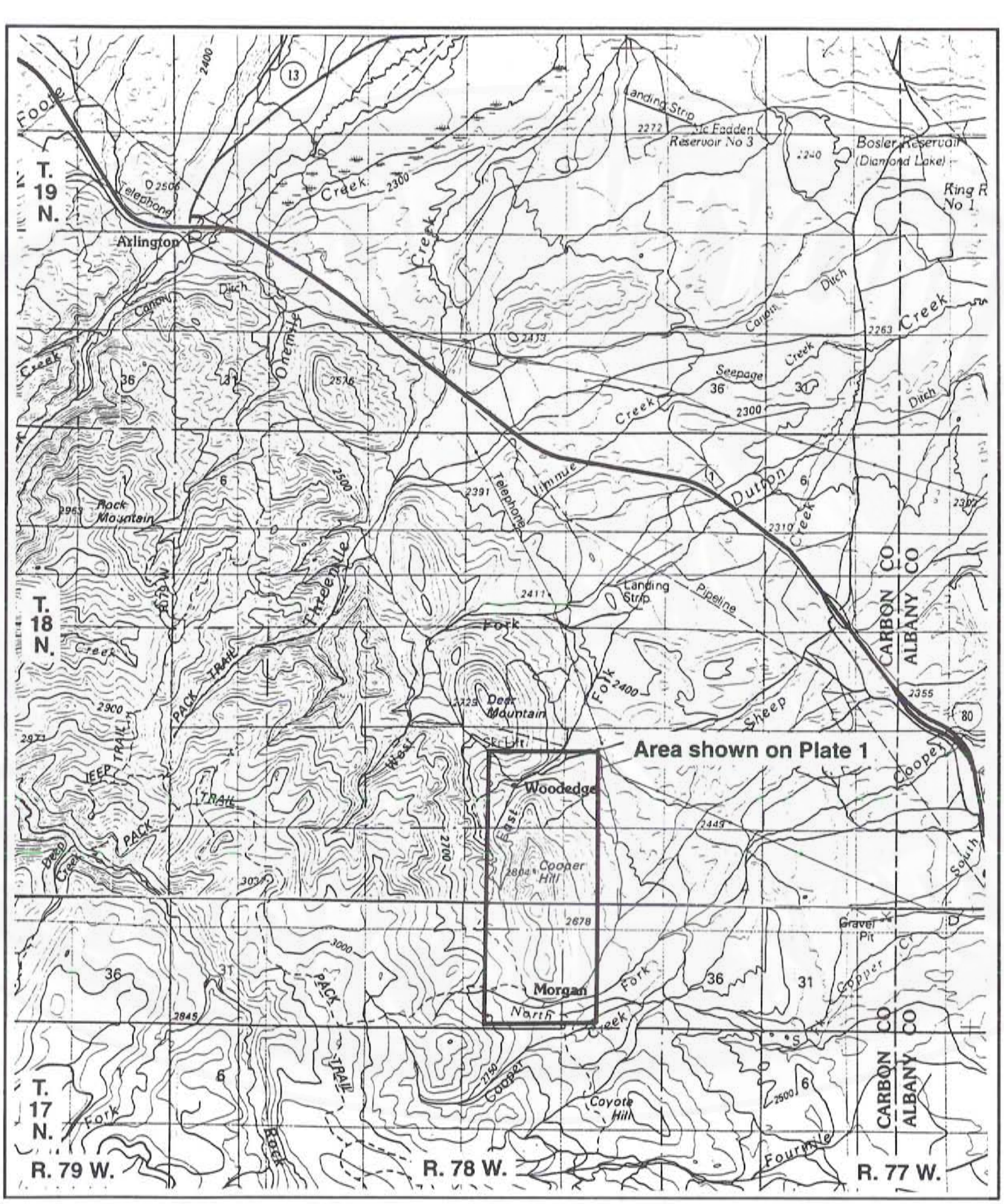


Figure 1. Location map of Cooper Hill.

# Mining history

## Introduction

Cooper Hill and the surrounding drainages lie within what is currently referred to as the Cooper Hill mining district. Historically, the district was flanked by the Herman mining district on the northwest, and the Bald Mountain and Mill Creek districts on the south. The Cooper Hill district has also been called the Cooper Creek mining district, has been included in the Herman mining district (Duncan, 1990, p. 180), and has erroneously been called the Bald Mountain district. The Herman district (T19N, R78W) northwest of Cooper Hill consisted mostly of placer deposits with a few lodes on Foote and Rock Creeks (*Laramie Mining and Stock Exchange*, 1896, p. 12). The *Engineering and Mining Journal* [*EMJ*] (v. 57, June 16, 1894, p. 567) reported that a few scattered lode and placer deposits were located in the Mill Creek and Bald Mountain districts (T16N, R78W) south of Cooper Hill.

In the early part of 1876, placer gold was discovered near the Overland Trail on Rock Creek northwest of Cooper Hill. The discovery was made by prospecting loose dirt in the trail. In May, 1877, ditches were constructed to supply water for hydraulic mining operations in the area, but apparently the activity subsided within a few years (*Wyoming Industrial Journal* [*WIJ*], v. 9, no. 4, 1907, p. 4).

Years later, in 1897, placer operations began again in the Rock Creek area. By June of 1897, the Overland Gold Mining Company (reported to have held about 11,000 acres of placer ground near Rock Creek) had constructed at least three miles of ditches with 800 feet of flume with iron riffles that led from Foote and Wagonhound Creeks to Rock Creek. The placer gravel was 4 to 9 feet deep with widely dispersed and granular gold (*EMJ*, v. 63, June 5, 1897, p. 583).

Later in June, 1897, an additional 500 feet of flume had been added to accommodate the large quantity of gravel being mined at Rockdale (Arlington?). Two Giants (hydraulic nozzles) were operating day and night washing 20,000 cubic yards of gravel in a 20-foot-high face on the east bank of Emigrant Gulch (NW section 24, T19N, R79W). The gravel reportedly averaged $0.75/yd$^3$ (0.036 oz/yd$^3$) gold, and additional Giants were planned (*EMJ*, v. 63, June 26, 1897, p. 673). Gravel samples along Rock Creek, Wagonhound Creek, and Foote Creek, recently panned by the Wyoming State Geological Survey, yielded anomalous amounts of gold.

Some lode deposits were also developed in the region. The *Laramie Mining and Stock Exchange* (1896) reported considerable work was done on Threemile Creek a few miles west of Cooper Hill. The ore bodies were described as "strong and well-defined," carrying gold and silver, and hosted by granite.

At Bald Mountain to the south, it was reported that some ore recovered from the 50-foot level of a mine contained $54 (2.6 ounces) in gold, 3 ounces of silver, and 4 percent copper (*EMJ*, v. 60, October 5, 1895, p. 332). At the head of Mill Creek between Bald Mountain and Cooper Hill, the *Laramie Mining and Stock Exchange* (1896) reported "immense" veins. Recent samples panned from Mill Creek by the Wyoming State Geological Survey contained pinhead colors of gold.

## Cooper Hill

Placer gold may have been found in Cooper Creek as early as 1854, but no accurate records exist to verify this. In 1877, the King Survey of the 40th Parallel reported rumors of gold in Cooper Creek, but, apparently, no verification was made (Hague and Emmons, 1877). By 1896, placer gold had been discovered in the Cooper Hill district. According to *EMJ* (v. 62, July 4, 1896, p. 15) several thousand acres of placer ground were staked along the North and South Forks of Cooper Creek and on the South Fork (East Fork?) of Dutton Creek.

Lode mineralization on Cooper Hill was first reported in the early summer of 1893, when claims were staked following the discovery of gossaniferous outcrops. A short time later, small scale mining began (Duncan, 1990).

Over the next few years, high-grade ore was mined and stockpiled in anticipation of construction of a mill and smelter in the district. In 1896, *EMJ* (v. 62, November 21, 1896, p. 495) reported that the Carbon County and Gold Coin Mining Company had contracted for construction of a 10-stamp mill (to be built in Denver) with concentrating tables, a large boiler and engine, and a 5-ton jacket smelter. In the following year, a 10-stamp mill was delivered and placed at the south end of Cooper Hill, and 300 tons of the stockpiled ore from the Albion and Emma G. mines were processed, yielding an average of $17.50 per ton (Duncan, 1990). According to Duncan (1990), the smelter was not delivered; thus, the base metals (lead and copper) and refractory precious metals of the stockpiled ore could not have been recovered unless the ore had been shipped.

In 1906, Henry C. Beeler, Wyoming State Geologist, visited the Cooper Hill district. His report noted that the Emma G. mine produced the richest float in the district, the Albion mine produced the greatest body of gold and galena, the Richmond mine produced the greatest amount of free-milling gold, and the Cooper Hill mine [location unknown] produced the greatest amount of copper in the district (Beeler, 1906). He also mentioned that an "immense" vein of sugar quartz along the west side of Cooper Hill carried free-milling gold which consistently averaged 0.1 to 0.2 opt (ounce per ton) of gold. Beeler also mentioned some ore (undoubtedly some rare and selected specimen-grade material) assayed as high as $84,000 per ton.

A detailed study on the geology and mineralization of the Cooper Hill district did not take place until Schoen (1953) characterized Cooper Hill as a folded succession of layered metasedimentary and metaigneous rocks which had been subjected to two episodes of mineralization. Later, King (1963) mapped the northeastern Medicine Bow Mountains with emphasis on Cooper Hill and concluded that Schoen's (1953) stratigraphic succession could not be "rigorously demonstrated." In contrast to Schoen's earlier mapping, King's (1963) remapping of Cooper Hill interpreted the district as a large block of quartzite cut by amphibolite with scattered floating marble reefs. A later study by Karlstrom and others (1981) incorporated King's mapping into their regional study of the stratigraphy of the Medicine Bow Mountains and Sierra Madre.

The current investigation began with detailed geologic mapping of Cooper Hill at a scale of 1:12,000 in the summer of 1991 (**Plate 1**), followed by a search of historical literature in the winter of 1992. In conjunction with mapping, samples for assay were collected from most mine dumps and prospects; additional samples were collected for whole rock, hand specimen, thin section, and XRD (x-ray diffraction) studies. Schoen (1953) had the advantage of access to some underground workings which were not accessible during this present study.

# Geology

Cooper Hill is an allochthonous block of Precambrian rock that has been interpreted as either a gravity slide originating from the west in the main body of the Medicine Bow Mountains (King, 1963), or as an eastward klippe or salient on the Arlington thrust. The district is underlain by Proterozoic metasedimentary and metaigneous rocks deposited in a miogeoclinal basin along the margin of the Wyoming craton (Archean) possibly 2.5 to 1.7 Ga (billion years) ago (Karlstrom and others, 1981). Archean rocks, however, do not crop out at Cooper Hill.

The regional geologic map of the Medicine Bow Mountains (Karlstrom and others, 1981) shows the northern portion of Cooper Hill is underlain by Vagner Formation metasedimentary rocks and the southern portion is underlain by older rocks of the Cascade Quartzite. Typically, the Vagner Formation consists of diamictite, marble, chlorite-biotite-quartz schist, and quartzite; whereas, the Cascade Quartzite consists of quartz-arenite with quartz and black chert pebble conglomerate. These formations comprise part of the Deep Lake Group (Proterozoic).

Some inconsistencies with the earlier studies began to evolve as mapping of Cooper Hill proceeded during this study. Quartz-pebble conglomerate with quartz and black chert pebbles, typical of Cascade Quartzite conglomerate (P.J. Graff, verbal communication, 1991), was found by the author on the northern half of the hill near the 9,198-foot elevation point (**Plate 1**). This conglomerate is underlain by metalimestone, mica schist, and quartzite typical of the younger Vagner Formation, which suggests the units are overturned. However, it is also possible that the conglomerate is not in the Cascade Quartzite, but instead is an upper portion of the Vagner Formation that is not preserved in the mountains to the west (R.S. Houston, verbal communication, 1992). Since no facing indicators could be found to differentiate tops of beds from bottoms of beds (thus indicating relative stratigraphic position), formation names were eliminated in favor of lithologic descriptions in this report.

The present mapping study generally agrees with Schoen (1953) rather than King (1963), and interprets the district as a folded succession of Proterozoic metasedimentary and metaigneous rock with a minimum exposed thickness of 800 feet. The stratigraphic succession is dominated by quartzite containing local quartz-pebble conglomerate, underlain by metalimestone, mica schist, amphibolite, and quartzite. The steep hillsides are scree-covered with few rock exposures. However, there is enough exposure to confidently confirm much of Schoen's stratigraphic succession.

# Structure and metamorphism

With only a few good exposures over a relatively small area, the structural history of Cooper Hill could not be unraveled with any confidence. Precambrian rocks on Cooper Hill appear to be complexly folded and to have been subjected to more than one episode of deformation. Complex folding was also indicated in the metasedimentary succession to the west in the Herman district (King, 1963). The attitude of the lithologic units on Cooper Hill is different from the miogeoclinal metasedimentary rocks to the west in the main body of the Medicine Bow Mountains (R.S. Houston, verbal communication, 1991). The lithologic units on Cooper Hill have relatively flat dips, whereas in the adjacent uplift, they dip comparatively steeply to the southwest.

Between 2.5 Ga and 1.7 Ga, the sediments and mafic volcanics of Cooper Hill were deposited in a miogeoclinal basin near the margin of the Wyoming craton. These sediments were later lithified and folded into a series of small-scale isoclinal folds with northeast-southwest trending axial plane traces.

Refolding produced northwesterly trending open antiforms and synforms. The principal Proterozoic structure on the northern segment of Cooper Hill is a synformal basin cored by quartzite. This synform is separated from a similar quartzite-cored synform in the southern portion of Cooper Hill by a horst (?) composed of amphibolite (metabasalt) and capped by an erosional remnant of folded metalimestone. The bedding in the limestone is isoclinally folded and has been refolded into an open synform. The trace of the axial plane of the antiforms between the synforms has been cut by east-west trending Laramide faults. The Albion vein near the northwestern flank of Cooper Hill apparently predated the refolding event. The mine map of Schoen (1953) indicates open folds in this vein as well as ore shoots in fold closures.

Regional amphibolite-grade metamorphism probably accompanied the initial folding event at Cooper Hill. Schoen (1953, p. 27) more specifically characterized this event as albite-epidote-amphibolite facies metamorphism. During regional metamorphism, the supracrustal succession acquired foliation which is now displayed in most rocks in the district. Mica in quartzite and metaconglomerate is parallel to foliation, pebbles are stretched in the plane of foliation, mica schists are strongly foliated, and several amphibolites exhibit weak to distinct foliation.

Following regional metamorphism, the rocks of Cooper Hill were intruded by gabbroic and basaltic dikes and sills. Hydrothermal alteration accompanied the intrusion of some of the mafic sills producing localized skarns in metalimestone.

Brittle deformation during the Laramide orogeny resulted in eastward thrusting of the Medicine Bow Mountains on the Arlington fault, followed by the breaking of the thrust sheet into a series of fault blocks. The eastern flank of the Medicine Bow Mountains (including Cooper Hill) has been thrust over Phanerozoic sedimentary rocks along the western flank of the Laramie/Cooper Lake Basin. This overthrust has been verified in petroleum exploration drill holes by Union Pacific Resources and Exxon. The drill holes, which were spudded northwest and south of Cooper Hill in sections 10 and 11, T17N, R78W, and section 36, T19N, R79W, cut from 2,000 to 5,000 feet of Precambrian crystalline rock in the upper plate (hanging wall) of the thrust before intersecting overturned sedimentary rocks of the Mesaverde Group in the footwall below the thrust sheet (P.J. Graff, verbal communication, 1991).

Cooper Hill projects east of the trace of the thrust and may represent either a salient on the thrust, or a gravity slide east of the thrust plate. In the latter case, the trace of the thrust would be located west of Cooper Hill in the Dutton Creek valley. King (1963, 1964) interpreted Cooper Hill as a gravity slide which *originated from the west during thrusting along the Arlington thrust.* Blackstone (1973, plate 2) mapped the trace of the Arlington thrust 1/4 mile west of Cooper Hill and indicated the hill was a rootless klippe lying on the Cretaceous Steele Shale and Mesaverde Group and the Tertiary Hanna Formation.

# Rock units

Cooper Hill consists of Proterozoic age metamorphic rocks surrounded by a widespread skirt of scree. Quaternary age colluvium and pediment gravels and Hanna Formation conglomerates occur along the flanks of Cooper Hill (Blackstone, 1973). For this report, only the contiguous block of Proterozoic rocks exposed on Cooper Hill were mapped. Quaternary and older rocks surrounding Cooper Hill were not mapped but instead, are shown on **Plate 1** as "Quaternary undivided and (or) other unmapped rock units."

Four general rock types were mapped on Cooper Hill during this study. These are amphibolite, metalimestone, quartzite and metaconglomerate, and mica schist.

## Amphibolite

Amphibolite on Cooper Hill includes mafic rocks with a variety of textures. All of the mafic rock types examined during this project are assumed to be of igneous origin and can be texturally separated into amphibolite, metagabbro, metabasalt, and chlorite schist. These rocks are fine- to coarse-grained, dark gray, green, and black rocks that range from foliated to weakly foliated to nonfoliated varieties on the megascopic scale.

Petrographic descriptions by King (1963) describe coarse-grained amphibolite to consist of amphibole of variable size with irregular patches of xenoblastic quartz and some corroded crystals of plagioclase in the amphibole matrix. Biotite is found as small irregular patches associated with amphibole, rutile, and an opaque mineral. Sphene and epidote are reported in some samples. Fine-grained amphibolite is described as fine-grained to granoblastic, consisting of ubiquitous epidote, randomly oriented biotite, and small acicular amphibole set in a matrix of xenoblastic quartz (King, 1963).

Coarse-grained hornblende gneiss (metagabbro) described by Schoen (1953) consisted of 75 percent hornblende, 15 percent quartz (with sutured boundaries), 8 percent magnetite, and 2 percent chlorite (replacing hornblende). Medium-grained hornblende gneiss (metadiabase) was described as having 62 percent hornblende, 30 percent quartz, 5 percent chlorite, and 3 percent magnetite. Schoen (1953) also reported metabasalt to exhibit periodic columnar jointing. The presence of columnar joints was not confirmed by the present author.

A prominent coarse-grained, foliated metagabbro sill with blasto-subophitic texture was sampled from the synformal basin a short distance north of Morgan on top of the hill surrounding the 9,214-foot elevation benchmark (**Plate 1**). This probably is the same rock described above by Schoen (as the coarse-grained hornblende gneiss), although it does not contain as much magnetite. Whole rock analysis of this metagabbro (sample CH42-91, **Table 1**) is comparable to a high-iron tholeiitic magma. The rock contains 6.22 percent MgO, 51.3 percent $SiO_2$, 1.51 percent $TiO_2$, and has a Ti/V ratio of 15.

Fine-grained amphibolite (metabasalt and mica schist) dikes are found a short distance north of the metagabbro as well as farther north near the 9,198-foot elevation point (**Plate 1**). These rocks contain abundant chlorite, biotite, and hornblende with plagioclase and minor quartz in blasto-subophitic and schistose rock fabrics.

Fine-grained mafic schist (sample CH3-91, **Table 1**) from the Silver Queen mine area yielded a geochemical analysis comparable to the metagabbro sill. This schist is slightly more MgO-rich (7.06 percent MgO) than the metagabbro, and falls within the high-magnesian tholeiite field of Jensen (1976). The rock is interpreted to be a metamorphosed basalt.

Whole-rock geochemical analysis of a sample of fine-grained amphibolite (metabasalt) collected near the apex of the hill above the Silver Queen mine (sample CH9-91, **Table 1**) yielded unusually high MgO. The high MgO (11.29 weight percent), high chromium (2,500 ppm $Cr_2O_3$), and high $CaO/Al_2O_3$ ratio (1.2) of the rock places it within the basaltic komatiite field of Jensen (1976).

A sample collected immediately north of Morgan and described as metabasalt in the field (sample CH22-91, **Plate 1**) was analyzed for whole rock geochemistry. This rock had a high magnesium content (12.39 percent MgO; 14.88 percent MgO on a volatile-free-basis), very low silica (43.52 percent $SiO_2$), high chromium (1,700 ppm $Cr_2O_3$), and high nickel (387 ppm Ni) values. The MgO, $Cr_2O_3$, and Ni are too high for a tholeiitic magma and fall, instead, within the compositional field of basaltic komatiite. The $CaO/Al_2O_3$ ratio of 1.2 is also consistent with basaltic komatiite chemistry; however, the lack of any spinifex or cumulate textures characteristic of komatiite suggests that it is possibly a pyroxenite sill rather than a flow.

Table 1. Whole rock and trace element analyses of selected rock samples from the Cooper Hill district. LOI = loss on ignition, ppm = parts per million, ppb = parts per billion. Analyses by Bondar-Clegg. (Dashes indicate not analyzed.)

| | CH3-91 | CH9-91 | CH12-91 | CH17-91 | CH22-91 | CH24-91 | CH27-91 | CH42-91 | CH43-91 | CH3-92 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | **Whole rock analyses (weight percent except where noted)** | | | | | |
| **Oxide** | | | | | | | | | | |
| $SiO_2$ | 50.42 | 50.53 | — | 89.63 | 43.52 | 90.79 | 22.71 | 51.30 | 89.47 | — |
| $Al_2O_3$ | 15.82 | 10.07 | — | 4.11 | 7.32 | 3.10 | 3.79 | 14.31 | 5.26 | — |
| $Fe_2O_3$ | 10.90 | 10.34 | — | 0.85 | 10.24 | 0.33 | 1.27 | 13.47 | 0.57 | — |
| MgO | 7.06 | 11.29 | — | 0.34 | 12.39 | 0.09 | 0.89 | 6.22 | 0.23 | — |
| CaO | 7.91 | 11.59 | — | 0.12 | 9.11 | 0.04 | 40.49 | 10.01 | 0.10 | — |
| $Na_2O$ | 2.94 | 1.50 | — | 1.70 | <0.01 | 0.18 | 1.29 | 2.21 | 0.43 | — |
| $K_2O$ | 1.36 | 0.64 | — | 0.61 | <0.10 | 2.15 | 0.91 | 0.11 | 2.50 | — |
| $TiO_2$ | 0.60 | 0.55 | — | 0.11 | 0.51 | 0.04 | 0.12 | 1.51 | 0.08 | — |
| MnO | 0.13 | 0.17 | — | <0.01 | 0.15 | <0.01 | 0.11 | 0.21 | <0.01 | — |
| BaO | 0.012 | 0.012 | — | 0.005 | 0.001 | 0.024 | 0.012 | 0.005 | 0.028 | — |
| $P_2O_5$ | 0.03 | 0.03 | — | 0.04 | <0.01 | 0.02 | 0.04 | 0.09 | 0.05 | — |
| $Cr_2O_3$ | 0.05 | 0.25 | 0.12 | 0.04 | 0.17 | 0.04 | 0.03 | 0.02 | 0.02 | — |
| LOI | 2.46 | 1.14 | — | 0.69 | 16.59 | 0.43 | 30.11 | 1.01 | 0.54 | — |
| Total | 99.69 | 98.11 | 0.12 | 98.25 | 100.00 | 97.23 | 101.77 | 100.47 | 99.28 | — |
| $CaO/Al_2O_3$ | 0.5 | 1.2 | — | — | 1.2 | — | — | 0.7 | — | — |
| Ti/V | 35 | 60 | — | 15 | — | — | — | 15 | — | — |
| S (%) | <0.02 | 0.02 | — | <0.02 | <0.03 | <0.02 | <0.02 | <0.02 | <0.02 | — |
| | | | | | **Trace element analyses (ppm except where noted)** | | | | | |
| **Element** | | | | | | | | | | |
| Ag | — | — | <0.1 | — | — | — | — | 0.1 | <0.1 | <0.1 |
| Au (ppb) | — | — | <5 | — | — | — | — | <5 | <5 | 6 |
| Cu | — | — | 29 | — | — | — | — | — | — | — |
| Ni | 114 | 63 | — | — | 387 | — | — | 33 | — | — |
| Pd (ppb) | — | — | — | — | — | — | — | 17 | — | — |
| Pt (ppb) | — | — | — | — | — | — | — | 21 | — | — |
| Sc | — | — | — | — | — | — | — | — | — | 1.5 |
| Sn | — | — | 8 | — | — | — | — | — | — | — |
| V | 101 | 55 | — | — | 201 | — | — | 574 | — | — |
| W | — | — | <2.0 | — | — | — | — | — | — | — |
| Ce | — | 11 | 10 | — | — | — | — | — | — | 25 |
| Dy | — | 1.9 | 3.6 | — | — | — | — | — | — | — |
| Er | — | <5 | 2 | — | — | — | — | — | — | — |
| Eu | — | 0.5 | 0.6 | — | — | — | — | — | — | 1.5 |
| Gd | — | <5 | 4 | — | — | — | — | — | — | — |
| Ho | — | 0.5 | 0.7 | — | — | — | — | — | — | — |
| La | — | 6.9 | 5 | — | — | — | — | — | — | 13 |
| Lu | — | 0.15 | 0.19 | — | — | — | — | — | — | 0.8 |
| Nd | — | 7 | 5 | — | — | — | — | — | — | 10 |
| Pr | — | <6 | <4 | — | — | — | — | — | — | — |
| Sm | — | 1.6 | 1.4 | — | — | — | — | — | — | 5.2 |
| Tb | — | <0.5 | 0.6 | — | — | — | — | — | — | 3 |
| Tm | — | <0.5 | <0.5 | — | — | — | — | — | — | <10 |
| Yb | — | 1.1 | 1.4 | — | — | — | — | — | — | 7 |

Sample CH3-91, mafic schist; CH9-91, metabasalt; CH12-91, quartz pebble conglomerate; CH17-91, quartzite; CH22-91, metabasalt; CH24-9, quartzite; CH27-91, metalimestone; CH42-91, metagabbro; CH43-91, quartzite with minor sericite and fuchsite; CH3-92, quartz pebble conglomerate (see **Plate 1** for sample locations).

The amphibolites examined during this study probably represent pyroxenites, gabbros, basalts, and norites. Similar high-magnesian amphibolites were reported in the Sierra Madre west of the Medicine Bow Mountains by Houston and others (1975). The Sierra Madre amphibolites were classified as gabbos, norites, and pyroxenites based on petrography and geochemistry.

## Metalimestone

Relatively thin beds of metalimestone crop out on Cooper Hill. The rock is gray-white to brown, laminated and contorted, metamorphosed carbonate or calc-schist. Thin quartz-rich layers in the carbonate produce distinct recumbent isoclinal folds (**Figure 2**). Typically, the rock is massive to recrystallized, has a fine-grained crystalline texture, and is reactive to dilute hydrochloric acid. Based on its response to hydrochloric acid and its fine-grained to massive texture, the rock is referred to as a metalimestone, although there are local pockets of marble.

In hand specimen, the rock includes abundant calcite, minor quartz, and minor to accessory chlorite and biotite. Schoen (1953) described some samples with nearly equivalent amounts of quartz and calcite. Petrographically, the rock is dominated by calcite with inclusions of quartz and feldspar. Large poikiloblasts of biotite are common, and the abundance of muscovite in some specimens locally gives the rock a schistose texture (King, 1963).

A sample of metalimestone collected in the NE section 34 (**Plate 1**) yielded 40.49 percent CaO, 22.71 percent $SiO_2$, and 30.11 percent LOI (sample CH27-91, **Table 1**). The relatively high silica content reflects the presence of quartz and minor amounts of mica.

## Quartzite and metaconglomerate

Quartzites crop out over large areas of Cooper Hill. The quartzites are quartz-arenites and micaceous quartzites. The quartz-arenites are massive, white to buff, granoblastic quartzites with about 5 percent or less laminated pink feldspar (microcline), accessory plagioclase, minor to trace amounts of mica (muscovite and/or chlorite), and trace to

Figure 2. Isoclinally folded metalimestone from the hilltop in the NE NE section 34 of Cooper Hill.

accessory fuchsite and opaques. Micaceous quartzites are light green to brownish foliated quartzites with 70 to 90 percent quartz, minor feldspar, minor chlorite, and lesser sericite.

Whole-rock geochemical analysis of three quartzite samples (CH17-91, CH24-91, and CH43-91, **Table 1**) yielded 89.47 to 90.79 percent $SiO_2$, 0.61 to 2.50 percent $K_2O$, 0.18 to 1.70 percent $Na_2O$, and 3.10 to 5.26 percent $Al_2O_3$. The potassium and alumina contents reflect minor amounts of mica and feldspar in the rocks.

Quartzites in the northern portion of Cooper Hill contain thin beds of metaconglomerate. These conglomerates are foliated and consist of abundant, stretched, translucent to milky, quartz pebbles up to 5 inches in length with uncommon black chert pebbles in a fine-grained matrix dominated by quartz grains with minor mica and feldspar, and accessory opaque minerals (**Figure 3**). The quartz pebbles may be stretched as much as three to four times in the plane of foliation. Fuchsite and sericite occur in minor to accessory amounts. These conglomerates are characteristic of the Cascade conglomerate found elsewhere in the Medicine Bow Mountains. None of the collected samples were radioactive and all were poor in rare earth elements (samples CH12-91 and CH3-92, **Table 1**) and gold. One sample (CH34-91, **Table 2**) did yield a weak gold anomaly (see **Economic geology** section).

The quartzites and conglomerates are interpreted as fluvial and are assumed to have been deposited as sediments in Proterozoic streams draining from a highland to the north in the Wyoming craton. Similar quartzite and conglomerate elsewhere in the Medicine Bow Mountains have been interpreted as being deposited on part of a widespread braided drainage that ran to an ancient sea located to the south of the Cheyenne belt (Karlstrom and others, 1981).

## Mica schist

The mica schists on Cooper Hill are strongly foliated muscovite-chlorite-schists with crenulated cleavage. Porphyroblasts are rare. This unit also includes minor beds of metagreywacke. The schists and metagreywacke beds represent metamorphosed siltstones, claystones, and sandstones.

King (1963) described mica schist in thin section to consist of a very fine matrix of quartz with sinuous and bifurcating bands of mica and subparallel bands of quartz with rare plagioclase augen. Muscovite and chlorite are the dominant minerals with subordinate biotite. A ubiquitous opaque mineral in the schists occurs as fine, dust-like inclusions and as large, elongate grains parallel to foliation.

Poorly preserved porphyroblasts occur in mica schist near the Emma G. mine at the south end of Cooper Hill. These consist of small grains of quartz and feldspar, and possibly represent aluminosilicate replacements. No primary aluminosilicate porphyroblasts were recognized.

Figure 3. Quartz pebble conglomerate bed in quartzite near the top of Cooper Hill.

Table 2. Geochemical analyses of rock samples from the Cooper Hill district (ppm = parts per million, ppb = parts per billion). Refer to **Plate 1** for sample locations. Analyses by Bondar-Clegg. (Dashes indicate not analyzed.)

| Sample number | Description | Ag (ppm) | As (ppm) | Au (ppm) | Cr (ppm) | Cu (%) | Ga (ppm) | Hg (ppm) | Mo (ppm) | Ni (ppm) | Pb (ppb) | Pd (ppb) | Pt (ppm) | Sb (ppm) | Sn (ppm) | Tl (ppm) | W (ppm) | Zn (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CH1-91 | Limonite after siderite from Silver Queen mine dump | 0.6 | — | <0.005 | — | — | 23 | — | — | — | — | — | — | — | — | — | — | — |
| CH2-91 | Limonite after sulfides in chloritized mafic rock, Silver Queen dump | 0.3 | — | 0.034 | 500 | — | 30 | — | — | 264 | — | — | — | — | — | — | — | — |
| CH4-91 | Marble from prospect pit (N/2 NE/4 sec. 34) | 1.6 | — | <0.005 | — | — | — | — | — | — | 22 | — | — | — | — | — | — | 5 |
| CH5-91 | Cupriferous quartz in meta-limestone from prospect pit (N/2 NE/4 sec. 34) | 0.8 | — | 0.187 | 400 | 0.065 | — | — | — | — | 10 | — | — | — | — | — | — | — |
| CH7-91 | Cupriferous quartz from Silver Queen mine dump | <0.2 | — | >10.0 | — | 2.27 | — | — | — | — | <2 | — | — | — | — | — | — | 12 |
| CH8-91 | Pyrite-actinolite-epidote-garnet hornfels (N/2 N/2 NE/4 sec. 34) | <0.2 | — | <0.005 | — | 0.014 | — | — | — | — | 7 | — | — | — | — | — | — | 1 |
| CH11-91 | Milky quartz with limonite boxworks after siderite from Rip Van Winkle mine | <0.2 | — | 0.006 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| CH13-91 | Massive limonite and hematite in quartz vein (E/2 sec. 27) | <0.2 | — | 0.24 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| CH14-91 | Boxwork-filled quartz from Richmond mine dump | 0.2 | — | 0.041 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| CH15-91 | Limonite boxworks from mine dump along East Fork Dutton Creek (NE/4 NW/4 sec. 27) | <0.2 | — | 0.013 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| CH16-91 | Limonite boxworks after siderite in quartz from mine dump | 0.8 | — | 0.037 | 700 | 0.08 | — | — | — | — | 56 | — | — | — | — | — | — | 46 |
| CH18-91 | Limonite- and hematite-stained quartz pebble conglomerate (NW/4 SE/4 sec. 27) | <0.2 | — | <0.005 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| CH19-91 | Milky quartz breccia with massive limonite after siderite (E/2 NE/4 sec. 34) | 0.5 | — | <0.005 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| CH20-91 | Milky quartz in mafic schist selvage in quartzite, with minor limonite after sulfide | <0.2 | — | 0.022 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| CH21-91 | Limonite-stained quartz from Emma G. mine dump | 1 | — | 0.089 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| CH23-91 | Limonite boxworks after sulfides in quartz from Clara B. prospect | 1.4 | — | >10.0 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| CH25-91 | Limonite-stained chalcopyrite-bearing schist from Silver Queen dump | 0.7 | — | 0.046 | — | 0.35 | — | — | — | — | <2 | — | — | — | — | — | — | 20 |

*Table 2 continued.*

| Sample number | Description | Ag (ppm) | As (ppm) | Au (ppm) | Cr (ppm) | Cu (%) | Ga (ppm) | Hg (ppm) | Mo (ppm) | Ni (ppm) | Pb (ppm) | Pd (ppb) | Pt (ppb) | Sb (ppm) | Sn (ppm) | Ti (ppm) | W (ppm) | Zn (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CH26-91 | Milky quartz breccia vein from mine dump (W/2 NW/4 sec. 35) | 0.5 | — | <0.005 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| CH28-91 | Limonite-stained skarn (S/2 SE/4 sec. 27) | <0.2 | — | 0.012 | — | 0.04 | 44 | — | — | — | 34 | — | — | — | 31 | — | <2.0 | 21 |
| CH30-91 | Limonite boxworks from skarn | <0.2 | 363 | 0.17 | — | 0.09 | — | 0.101 | 9 | — | <2 | — | — | 2.4 | — | — | — | 10 |
| CH31-91 | Limonite boxworks from skarn (SE/4 SE/4 sec. 27) | — | — | <0.05 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| CH32-91 | Limonite-stained, gray-black quartz (SE/4 sec. 27) | <1.0 | — | 0.19 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| CH34-91 | Quartz pebble conglomerate with hematite pseudomorphs after magnetite (?) or pyrite (?) | <0.2 | — | 0.04 | — | — | — | — | — | — | — | — | — | — | <5 | <50 | <2.0 | — |
| CH35-91 | Select sample of quartz from ore sack at Richmond mine | <0.1 | — | 0.012 | — | 0.1 | — | — | — | — | 25 | — | — | — | — | — | — | 63 |
| CH36-91 | Twenty-foot composite chip sample across Richmond breccia vein | 1.2 | — | 0.08 | — | 0.07 | — | — | — | — | 11 | — | — | — | — | — | — | 50 |
| CH38-91 | Limonite boxworks in quartz from mine dump (E/2 sec. 27) | 1.8 | — | 0.16 | — | — | — | — | — | — | 72 | — | — | — | — | — | — | 48 |
| CH39-91 | Grab sample of galena-bearing quartz, Albion mine (W/2 sec. 27) | 56.9 | — | 7.5 | — | 0.04 | — | — | — | — | 11,242 | — | — | — | — | — | — | 2.6 |
| CH40-91 | Boxwork quartz from Albion mine | 1.4 | — | <0.05 | — | 0.03 | — | — | — | — | 134 | — | — | — | — | — | — | 45.5 |
| CH41-91 | Epidote-calcite-actiolite-sulfide-skarn (N/2 NE sec.34) | 0.6 | — | 0.108 | — | 1.88 | — | — | — | — | 14 | 11 | 4 | — | — | — | 5 | 19 |
| CH45-91 | Weak skarn from prospect pit (NW/4 NE/4 sec. 34) | 3.5 | — | <0.05 | — | 0.003 | — | — | — | — | 60 | — | — | — | — | — | — | 15.8 |
| CH46-91 | Skarn from pit | 2.5 | — | <0.05 | — | 0.004 | — | — | — | — | 31 | — | — | — | — | — | — | 7.3 |
| CH50-91 | Galena-bearing quartz from Albion mine dump | 97.2 | — | 1.7 | — | — | — | — | — | — | 6,193 | — | — | — | — | — | — | <0.005 |
| CH51-91 | Decalcified pyritiferous metalime-stone from Albion mine | 1 | — | 0.6 | — | 0.003 | — | — | — | — | 93 | — | — | — | — | — | — | 36.7 |
| CH52-91 | Boxwork quartz with pyrite from Albion mine | <0.1 | — | 0.2 | — | 0.003 | — | — | — | — | 12 | — | — | — | — | — | — | 12.7 |
| CH1-92 | Chip of quartz from rib, Sawmill Creek adit | <0.1 | — | <0.005 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| CH2-92 | Selected samples of quartz from dump | <0.1 | — | <0.005 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| CH4-92 | Milky quartz with boxworks | <0.1 | — | 0.005 | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| CH5-92 | Selected sample from rib, Sawmill Creek adit | 1.9 | — | 0.071 | — | >2.0 | — | — | — | — | 128 | — | — | — | — | — | — | 55 |

# Economic geology

## Mineralization

Cooper Hill has not been developed to any great extent. According to Duncan (1990), Cooper Hill had a short-lived prospecting and mining history between 1893 to 1897, following the economic collapse of the U.S. economy in 1893 (set off by Congressional repeal of the Sherman Silver Purchasing Act). Mining continued into the early 1900s and possibly some activity occurred during the Great Depression. In recent years, a few Laramie residents continue to prospect in the district. Most of the accessible mines were recently closed under the State of Wyoming's Federally-funded Abandoned Mine Land Reclamation Program.

Ore minerals reported in veins in the district include pyrite ($FeS_2$), chalcopyrite ($CuFeS_2$), chalcocite ($Cu_2S$), argentiferous galena [(Pb, Ag)S], polybasite [$(Ag, Cu)_{16}Sb_2S_{11}$], and gold (Au) (Schoen, 1953). Secondary ore minerals derived from the oxidation of the primary sulfides include malachite, cerrusite, and limonite. During this study, two forms of limonite [FeO(OH)] were recognized. One variety, a reddish-brown to tawny limonite, is typically derived from oxidation of sulfides and can be used as an indicator of gold and sulfide mineralization; a second variety, a sugary, yellow-orange limonite after siderite, is of no apparent economic value. Lode mineralization includes skarns and veins.

### Skarns

Skarns were identified at some sites on Cooper Hill (Hausel and others, 1992) (**Plate 1**). The skarns occur in metalimestone in contact with mafic schist (amphibolite), and range from one foot to more than 100 feet thick. One of the more extensive skarns was mapped north of the Silver King prospect in the extreme southeastern corner of section 27. Skarns are undoubtedly more widespread than mapped simply because portions of the metalimestone are buried by colluvium and scree on the steep hillsides.

Most skarns on Cooper Hill were prospected in the past. Other than shallow prospect pits, no tunnels were driven in skarn. Typically, the skarns are erratic and contain some pyrite, chalcopyrite, and magnetite. Because of the presence of magnetite, the skarns should be susceptible to magnetometer prospecting where they continue under colluvium.

Skarn samples were examined in hand specimen. Megascopically, the skarns are varied and include: (1) dark green to black garnet (XRD pattern best fits goldmanite and hydrogrossular), epidote, actinolite, chlorite, calcite, limonite, and ± magnetite hornfels; (2) epidote, pyrite, calcite, and quartz hornfels; (3) magnetite hornfels; (4) calcite, epidote, actinolite, pyrite, and magnetite marble; (5) actinolite, calcite, quartz, chlorite, and ± chalcopyrite hornfels; (6) tremolite, quartz, and calcite marble; and (7) calcite, light yellow-green garnet (identified as uvarovite by XRD), and magnetite hornfels.

Skarn exposed in the Silver King prospect pit in the saddle of the hill above the Silver Queen mine shows clear association to amphibolite (metabasalt). The prospect cut exposes a narrow amphibolite dike intruding metalimestone that is replaced by skarn along both margins of the dike. A short distance from the dike, the skarn grades into metalimestone. All other skarns found in the district also lie in contact with amphibolite. Skarn samples collected for assay are weakly anomalous in silver, gold, and copper.

### Veins

More than one vein type occurs in the district. At the portal of the Albion mine along the western flank of Cooper Hill, pyrite-sericite-limonite-calcite altered metalimestone (calc-schist) wallrock encloses a fractured and frayed pyritiferous milky quartz vein. The calc-schist is stained by limonite and contains abundant cubic limonite pseudomorphs after pyrite(?) over the exposed width of the outcrop. The vein cuts across lithologies into an underlying footwall quartzite where it is a relatively well-defined quartz vein with galena. Later-stage silicification is evident where small fractures in some quartz are partially rehealed by minor translucent quartz and jasper, often accompanied by galena.

Additionally, some classic, well-defined quartz vein deposits occur in the district that are either conformable or crosscut foliation and bedding. According to Schoen (1953), the crosscutting veins are typically barren. Another type of vein found at the Richmond mine is a strike-trending (conformable), limonite-stained, several-foot-wide, quartz breccia vein with open vugs filled with radiating actinolite prisms, pyrite, and chlorite.

## Mines and occurrences

None of the mines or prospect pits located on Cooper Hill were developed to any great extent, and unfortunately, only the workings of one mine were accessible during this study. Therefore, only mine dump samples were collected. It is the author's experience that mine mineralization is somewhat characterized by the ore in mine dumps, although in some cases, mine dump samples will not be indicative of the mineralization within the mines simply because of high-grading by prospectors over many years.

During mapping, most mine and prospect pit dumps on Cooper Hill were sampled. In many cases, the names of the mines and pits were unknown. Stream-sediment samples were also collected in the North Fork of Cooper Creek and Cooper Creek to test for placer gold.

### Albion mine

Located in W/2 section 27, T18N, R78W. The Albion mine workings were inaccessible during this study since the portals had recently been reclaimed. Therefore, it was necessary to rely on the available literature to describe the mine workings.

The Albion mine was developed by two adits driven into a near-horizontal vein near the contact between altered hanging wall metalimestone (calc-schist) and footwall quartzite (**Figure 4**).

The portals were cut into a frayed quartz vein hosted by the altered, limonite-stained, calc-schist. Twenty to 30 feet into the tunnel, the vein cut across lithologies into a footwall quartzite. Where hosted by calc-schist, the vein carried disseminated pyrite, chalcopyrite, chalcocite, and bornite; where hosted by quartzite, the vein carried argentiferous galena and was well-defined (Schoen, 1953). A short distance from the end of the tunnel (near the mine face), the vein abruptly changed attitude from near horizontal to an 80° dip (*EMJ*, v. 61, January 11, 1896, p. 47).

Two ore shoots were intersected about 70 and 100 feet, respectively, from the mine portals (see heavy dashed lines on **Figure 4**). The shoots are localized where the vein rolls from an easterly to a southerly dip (Schoen, 1953). According to *EMJ* (September 12, 1896, p. 255), the No. 1 tunnel was 270 feet long and the No. 2 tunnel was 185 feet long. This agrees fairly well with Schoen's (1953) map.

At the northern portal (No. 2 tunnel), the vein consists of relatively narrow, frayed, quartz veinlets (less than 6 inches wide) enclosed by a broad zone of altered, limonite-stained, calc-schist with abundant cubic, limonite pseudomorphs after pyrite(?) over the width of the exposed outcrop. At this point, the footwall quartzite is buried.

Based on Schoen's (1953) study, the adit for the No. 2 tunnel was driven 80 feet east into calc-schist and cut across the dipping contact of the schist before continuing another 85 feet east in the footwall quartzite. From here, the tunnel turns southeast another 40 feet down an incline where the mine tunnel terminates in quartzite. Near the mine portal, the vein is 2 feet thick. Farther in the tunnel, it pinches down from 2 to 18 inches but swells again to 2 feet thick near the face of the incline. A winze was sunk at the face, but was full of water at the time of Schoen's investigation.

The southern portal (No. 1 tunnel) is presently covered by quartzite scree that buries the calc-schist and vein. According to Schoen (1953), the vein is 2 to 5 feet thick a short distance into the southern portal. Farther into the hillside, the vein cuts across lithologies into the lower quartzite. At about 40 feet into the tunnel, the schist-quartzite contact was intersected and the tunnel continued another 160 feet east into the footwall quartzite before terminating in quartzite. At about 100 feet from the portal, a 50-foot-long crosscut was driven south. The face of the crosscut is also in quartzite. Schoen (1953) reported the primary vein in the crosscut disappeared below the mine workings near the face of the main tunnel, and that the workings continued to follow another galena-bearing vein to the face.

Samples of the vein and altered calc-schist were collected from the outcrop at the northern portal during this study; galena-bearing quartz was collected from the dump since it is not exposed at the portal. The pyritiferous quartz collected at the portal is weakly anomalous in gold and silver (samples CH40-91 and CH52-91, **Table 2**), as is the calc-schist wallrock (sample CH51-91, **Table 2**). Samples of galena-bearing quartz were relatively well mineralized and assayed 0.62 and 1.12 percent Pb, 0.05 and 0.22 opt Au, and 2.83 and 1.66 opt Ag (samples CH50-91 and CH39-91, respectively, **Table 2**). Schoen's (1953) sample of galena-bearing quartz from the second roll (ore shoot) in the mine yielded 0.83 percent Pb, 0.7 opt Au, and 2.2 opt Ag.

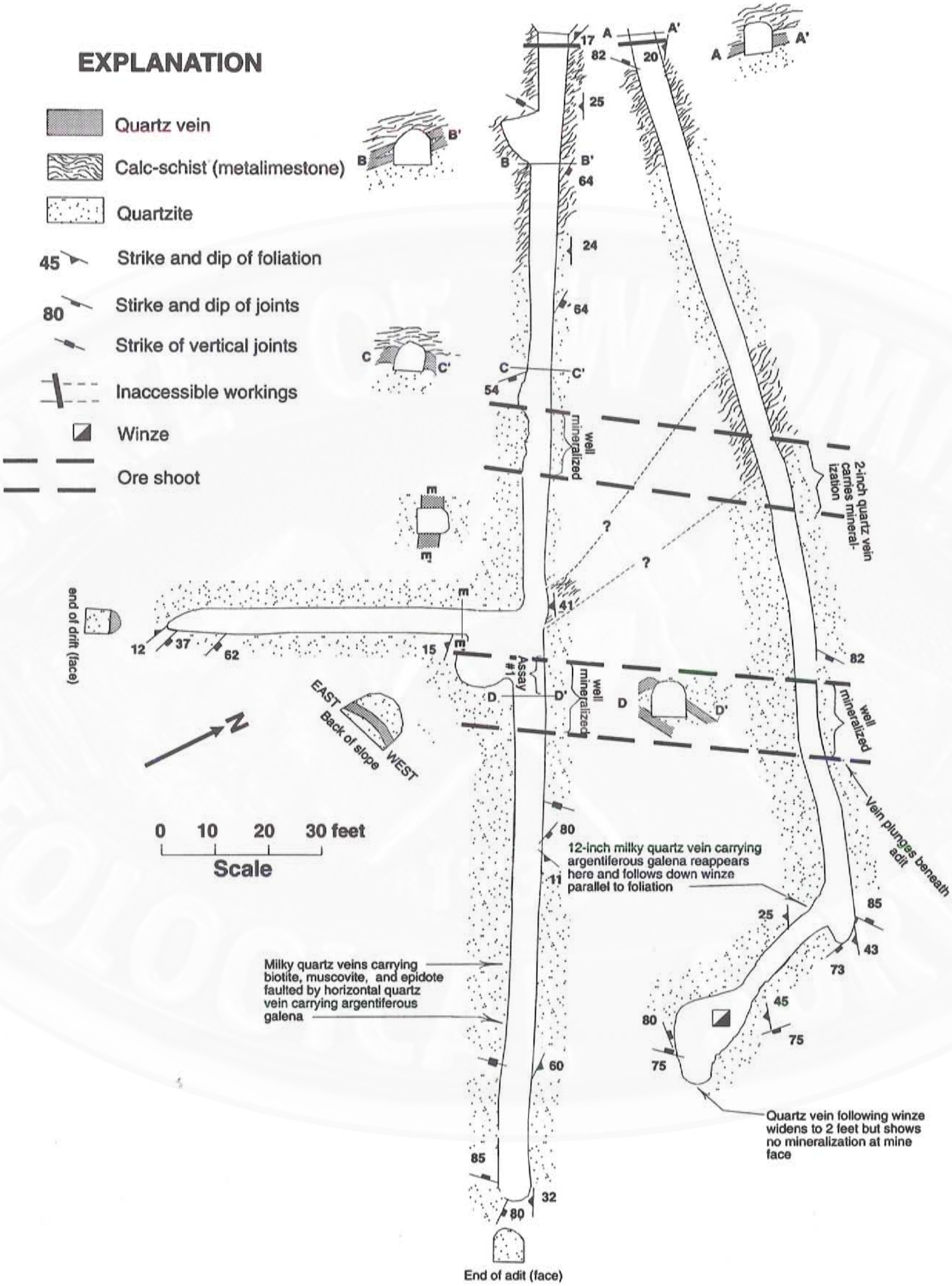


Figure 4. Albion mine map (after Schoen, 1953).

Assay values reported in historic documents are much higher than the samples reported by Schoen (1953) or in **Table 2**. The discrepancy is either due to the assaying of selected ore for the historic reports, or due to exaggeration by the early reports. For example, the *EMJ*, v. 60, (October 19, 1895, p. 380) reported a narrow pay streak in the Albion mine that assayed 350 ounces of silver, 9 ounces of gold, and 40 percent lead.

An 1895 mill run of ore from the Albion mine and from the adjacent Smuggler (No. 2 adit ?) yielded $101 and $69 worth of metals, respectively (*EMJ*, v. 60, October 19, 1895, p. 380). The Smuggler Gold Mining and Milling Company reported a carload of argentiferous galena had a value of $18.40 per ton (*EMJ*, v. 63, January 9, 1897, p. 51).

## Clara B. [Morgan] prospect

Located in SE section 34, T18N, R78W. A shallow prospect pit on the Clara B. claim on the south-sloping hillside north of the village of Morgan, exposed a narrow quartz vein with common limonite boxworks after pyrite. The sample from the vein assayed greater than 10 ppm Au and 1.4 ppm Ag (sample CH23-91, **Table 2**). The sample was reassayed and yielded 0.53 opt (18.2 ppm) Au.

## Cooper Creek adit

Located in SW section 3, T17N, R78W (south of **Plate 1**). Locally known as the Sawmill Creek adit. This is a short adit located immediately south of Cooper Hill, but considered a part of the mining district. The adit was driven in on a S5°E-trending, milky quartz vein in chlorite schist. The vein is about 5 to 6 feet wide at the portal.

The tunnel followed the vein 140 feet to the southeast, and terminated in the quartz (**Figure 5**). A select sample of quartz from the mine dump (CH2-92, **Table 2**) yielded no detectable gold or silver. A sample of quartz (CH1-92) collected from the eastern mine rib in a open fold closure also contained no detectable gold or silver. A third sample (CH5-92) of boxwork quartz with some chalcopyrite, collected 20 feet from the mine face, yielded greater than 2 percent Cu, 71 ppb Au, 1.9 ppm Ag, and 128 ppm Pb. This was the only place in the mine where mineralization was observed.

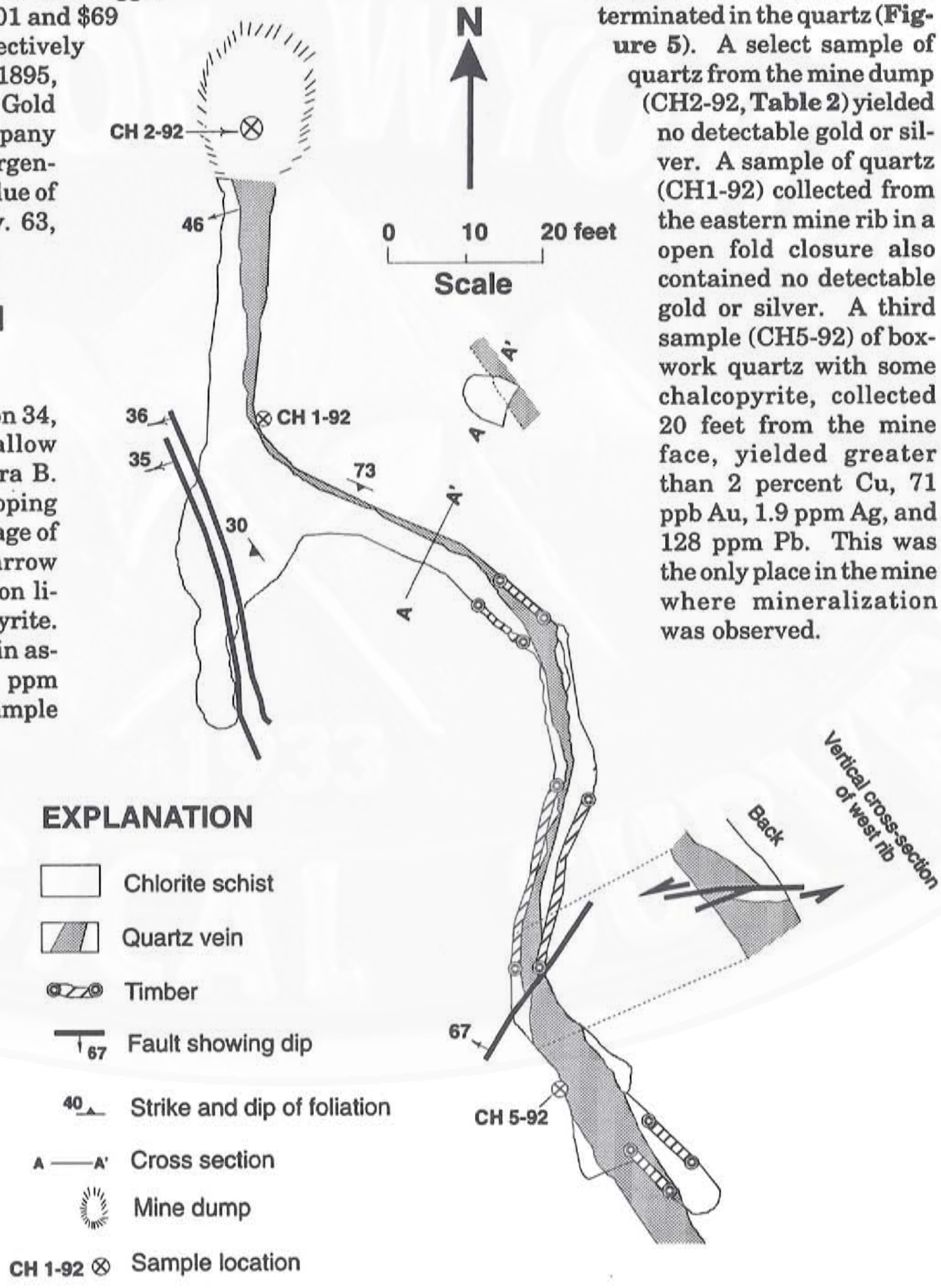


Figure 5. Mine map of the Cooper Creek adit. By W. Dan Hausel and Jamie Clemons, 1992.

## Copper Queen mine

Located in S/2 S/2 section 27, T18N, R78W. Previously known as the Rip Van Winkle tunnel. Located about 400 feet below the Rip Van Winkle adit on the Wyoming claim (**Figure 6**, and **Plate 1**). Duncan (1990, p. 193) indicated this was the Rip Van Winkle tunnel; however, Schoen (1953, p. 7, figure 2) published a photograph of (apparently) the same mine and labeled it as the old Copper Queen mine. The adit was driven in quartzite scree but the workings were inaccessible to the author. Based on the rock types found on the mine dump, the tunnel intersected amphibolite somewhere near the mine face. Very little evidence of mineralization could be found on the dump other than a few specimens of quartz with minor limonite after siderite.

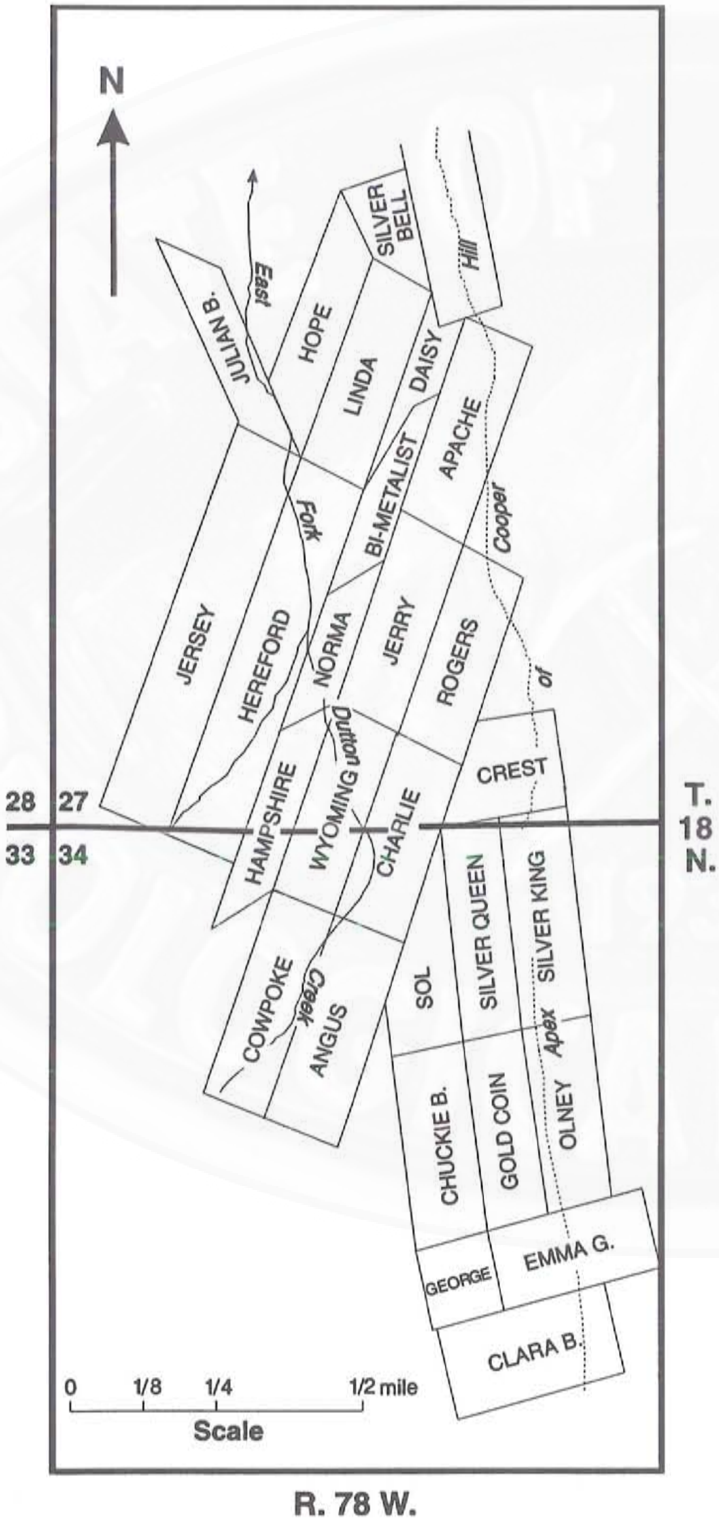


Figure 6. Partial claim map of the Cooper Hill district (after Schoen, 1953).

## Croesus tunnel

Location unknown. The Croesus tunnel was reportedly located on the east side of Cooper Hill about half a mile from the Albion mine (*EMJ*, May 22, 1897, p. 523). The Croesus claim was reported to be on a large vein of siliceous gold, copper, and silver ore that averaged $27 per ton. The *EMJ* (September 12, 1896, p. 255) reported the ore body was 18 feet wide and carried gold and copper pyrites averaging $8 in gold (0.4 opt) and 14 percent Cu. In 1902, the *Mining Reporter* (1902, p. 565) reported the tunnel was 1,236 feet long, and that ore from one of the drifts assayed as high as $44 (2.1 opt) in gold. The ore was also reported to be an excellent smelting flux (*Laramie Mining and Stock Exchange*, 1896).

The only mines that might fit this description are in section 35. The first mine is at sample locality CH26-91, about three-quarters of a mile southeast of the Albion mine; the second mine is located about a quarter of a mile south of CH26-91 (**Plate 1**). However, no evidence of an 18-foot-wide ore body was found on the surface, nor was there much evidence of mineralization on the mine dumps.

## Emma G. mine

Located at the southern end of Cooper Hill above the village of Morgan in N/2 SE section 34, T18N, R78W. In 1894, a gold strike was made at the Emma G. mine during the driving of a 135-foot tunnel which cut a 20-foot-wide vein 60 feet below the surface (*EMJ*, v. 57, March 17, 1894, p. 257). A shaft was later sunk to 60 feet and the tunnel was extended to 300 feet. The ore was reported to carry $12 per ton (0.58 opt) gold, and to be free milling (*EMJ*, v. 62, September 12, 1896, p. 255).

The Emma G. mine consists of three different portals. Two portals consist of a shaft with an adit driven into metalimestone and amphibolite. The third portal is an inclined shaft (**Figure 7**) cut into mica schist that intersected a vein a short distance to the north (**Plate 1**).

According to Schoen (1953), the ribs of the incline(?) are in porphyroblastic biotite schist. These porphyroblasts were described as granulated quartz developed during regional metamorphism (Schoen, 1953, p. 28). A brief field examination of these metacrysts (?) showed them to be quartz-mica augen. Possibly, they are the alteration products of aluminosilicates. Schoen further described the vein as a thick, barren, milky white, quartz-breccia vein conformable to foliation. At 15 feet from the bottom of the shaft, the vein is reportedly 15 feet thick. Fault gouge was intersected at the bottom of the shaft (Schoen, 1953).

The southern shaft was sunk on the contact between metalimestone and amphibolite. No evidence of mineralization was found on the dump. Possibly, this was an exploration shaft in search of skarn or to explore gossaniferous metalimestone. The limonite here is after carbonate (siderite) rather than after sulfide. One sample of limonite-stained quartz from the mine dump assayed only 0.089 ppm Au and 1.0 ppm Ag (sample CH21-91, **Table 2**).

## Little Ella-Senator Stewart mine

Located in SW section 16 and NW section 21, T18N, R78W (northwest of **Plate 1**). The Little Ella mine was reported 2 miles north of Cooper Hill on the north branch (West Fork?) of Dutton Creek (*EMJ*, May 22, 1897, p. 523). However, an earlier report located the mine 3 miles north of the Richmond mine (*EMJ*, v. 60, October 19, 1895, p. 380). County courthouse records indicate the Senator Stewart claim was staked in sections 16 and 21, which would place it along the West Fork, west of Cooper Hill (E.L. Neilsen, verbal communication,

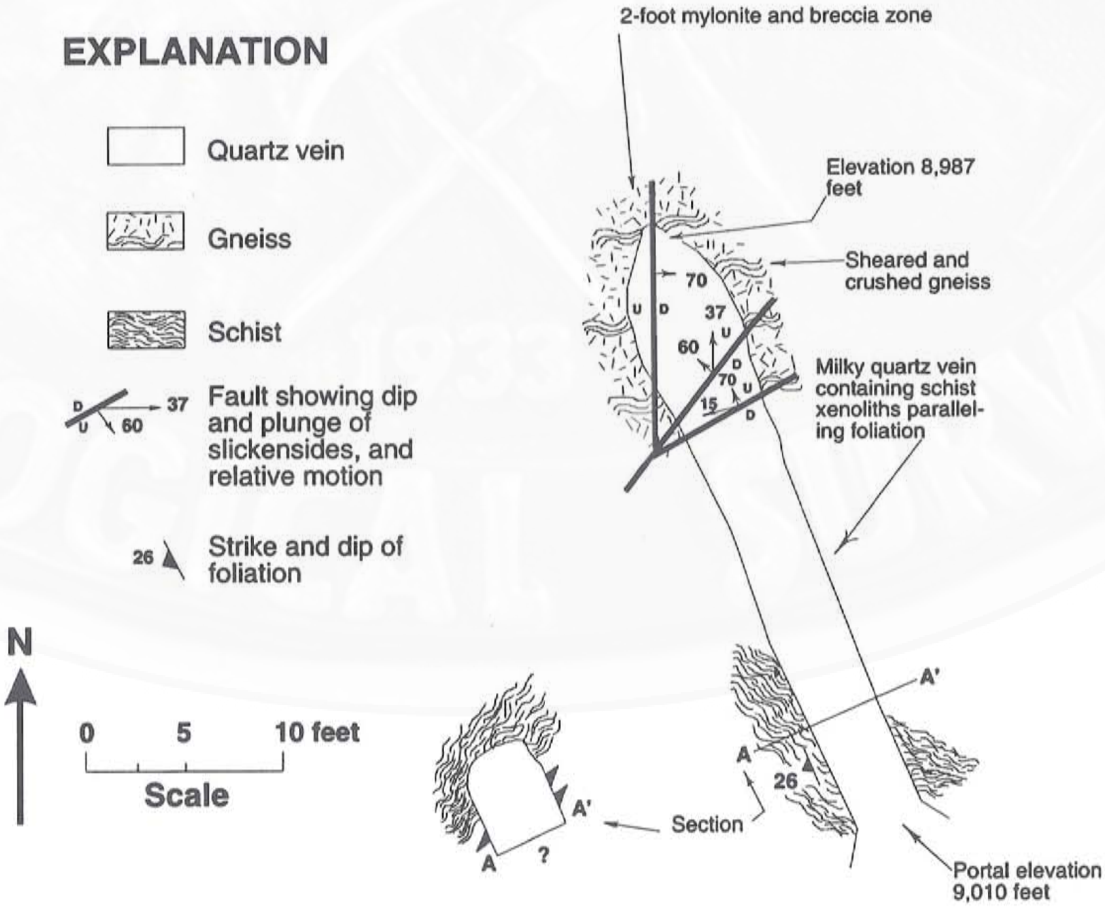


Figure 7. Mine map of the Emma G. incline showing quartz vein with schist xenoliths (after Schoen, 1953).

1992). Since this mine could contribute gold to the West Fork of Dutton Creek along the flank of the Cooper Hill district, it is mentioned in this report.

The Little Ella mine included 700 feet of development work with two 70-foot-deep shafts (*EMJ*, May 22, 1897, p. 523). Another report indicated that the Little Ella shaft was sunk to a depth of at least 100 feet and connected to the Senator Stewart shaft by a 150-foot-long tunnel (*EMJ*, v. 61, April 11, 1896, p. 359).

The main vein cut by the drifts was reportedly 9 to 12 feet wide with gold- and copper-bearing sulfides in quartz (*EMJ*, May 22, 1897, p. 523). However, the vein cut at the 100-foot level was reported as 50 feet wide (*EMJ*, v. 61, June 13, 1896, p. 575). The vein was reported to average $23 per ton (1.1 opt) (*EMJ*, v. 61, April 11, 1896, p. 359) with pay streaks running from $40 to $50 (2 to 2.4 opt) in gold (*EMJ*, v. 60, October 19, 1895, p. 380; *Laramie Mining and Stock Exchange*, 1896). Some select ore from the mine was reported by Knight (1893) to have assayed 32.17 opt Au, 4 to 10 opt Ag, and 10 to 12 percent Cu.

## Little Johnnie tunnel

Location unknown. The Cooper Hill Deep Mining Company reported plans to run a 1,300-foot tunnel into Cooper Hill from the Little Johnnie claim (*EMJ*, v. 62, September 12, 1896, p. 255). It was later reported that the company was working on a group of claims north of the Rip Van Winkle mine, and a tunnel had been started at the base of the hill to penetrate to its center, a distance of 1,400 feet (*EMJ*, May 22, 1897, p. 523).

## North Star mine

Location unknown (see also Rip Van Winkle adit). The *Laramie Mining and Stock Exchange* (1896) reported the North Star consisted of three claims located on a blowout of quartz on the apex of the hill. Based on the description, this probably is the Richmond mine. The formation was described as quartz and black granite (amphibolite?). Across the gulch from the same group, a peculiar black quartz was reported to carry from $8 to $19 in free gold.

## Richmond mine

Located in the NE section 27, T18N, R78W, along the crest of Cooper Hill (**Plate 1**). According to Beeler (1906), the Richmond mine produced the largest amount of free-milling gold of the Cooper Hill mines. The Richmond mine was developed by a 40-foot-deep shaft with a 94-foot drift (*Laramie Mining and Stock Exchange*, 1896) which intersected a vein reported to have free-milling gold at a depth of 20 feet (*EMJ*, v. 58, September 22, 1894, p. 280). Mill runs of ore from the mine were reported to average nearly $20 per ton gold (approximately 1.0 opt) (*EMJ*, v. 60, October 19, 1895, p. 380).

The Richmond shaft was sunk in a quartz breccia vein in a fine-grained hornblendic amphibolite (metabasalt). The vein lies near the bottom of the amphibolite outcrop near the contact of the host amphibolite with underlying quartzite. The vein disappears a short distance southeast and southwest under colluvium and does not reappear, indicating the vein is very limited in strike length.

The vein is more than 20 feet thick at the Richmond shaft and consists of fractured, iron-stained quartz with angular clasts of amphibolite country rock. The quartz is pitted with open vugs filled with well-developed radiating actinolite prisms on a fine-grained mass of chlorite, actinolite, and calcite. Uncommon sulfides occur as chalcopyrite and chalcocite blebs with small (1mm) pyritohedrons and octahedral pyrite grains. Minor stains of malachite occur on some fracture surfaces in the quartz.

Three samples for assay were collected from the Richmond mine by the Wyoming State Geological Survey (samples CH14-91, CH35-91, and CH36-91, **Table 2**). Two samples of boxwork quartz contained 0.012 and 0.041 ppm Au, and less than 0.1 and 0.2 ppm Ag; and one sample had traces of lead, zinc, and copper. One 20-foot composite chip sample (CH 36-91) chipped across the vein width assayed only 0.08 ppm Au (0.002 opt), 1.2 ppm Ag (0.035 opt), 0.07 percent Cu, 11 ppm Pb, and 50 ppm Zn.

## Rip Van Winkle mine

Located in S/2 S/2 section 27, T18N, R78W (**Plate 1**). Two photographs in Duncan (1990, p. 192) indicate the mine near the crest of the hill is the Rip Van Winkle mine. This is supported by the description in the *Laramie Mining and Stock Exchange* (1896) which reported the Rip Van Winkle and North Star claims occupied the apex of the mountain.

The available historical reports conflict as to the amount of development in the mine. For instance, the Rip Van Winkle adit was reportedly driven 750 feet into the hillside by 1906, and cut several minor leads. The first lead was intersected 200 feet farther in the tunnel than expected, and a sample from this vein reportedly assayed $650 in gold (31 opt) (*WIJ*, v. 7, no. 12, May, 1906, p. 20). Beyond the 500-foot point, quartz from the whole breast of the tunnel reportedly yielded visible gold when panned (*WIJ*, v. 6, no. 12, May, 1905, p. 7).

In another report, the mine was described as two 25-foot-deep shafts with a 250-foot tunnel and a 100-foot tunnel (*WIJ*, v. 8, no. 2, July, 1906, p. 8-9). No evidence of the shafts was found in 1991. In 1908, another lead intersected in the mine carried $6 of gold (0.3 opt) to the ton (*WIJ*, v. 10, no. 1, June, 1908, p. 22).

The portal of the adit assumed to be the Rip Van Winkle was cut in amphibolite and the tunnel intersected mica schist and metagreywacke a short distance into the hillside. Only a few fragments of quartz were found on the mine dump in 1991 and these contained uncommon limonite boxworks after siderite. One sample of the limonite-stained quartz (sample CH11-91, **Table 2**) yielded only 0.006 ppm Au and less than 0.2 ppm Ag.

## Silver King prospect

N/2 NE section 34, T18N, R78W. This is a small prospect pit dug in skarn in the saddle of Cooper Hill on the Silver King claim (**Figure 6** and **Plate 1**). The open cut exposes a narrow mafic sill in metalimestone. The metalimestone adjacent to the sill is altered to skarn, producing an epidote-calcite-actinolite skarn with some chalcopyrite. A narrow quartz vein exposed in this pit carries some chalcopyrite, chalcocite, and minor malachite.

Five samples (CH 5-91, CH 6-91, CH 41-91, CH 45-91, and CH 46-91, **Plate 1** and **Table 2**) collected from the dump in 1991 were poorly mineralized. CH6-91 was used for petrographic studies. The highest assayed gold content of the remaining four samples was of cupriferous quartz, which yielded 0.187 ppm Au (sample CH5-91, **Table 2**).

## Silver Queen mine

Located in N/2 N/2 section 34, T18N, R78W (**Plate 1**). The location of this mine suggests it is on the Silver Queen claim (**Figure 6**), although it is possible the mine lies on either the Sol or Charlie claims. The mine portal is located about 1,200 feet southeast of the Copper Queen mine and was sealed by a locked wooden door. Thus, it was inaccessible when visited in 1991.

The adit was driven into amphibolite. Mine dump material consists of chloritized mafic schist and amphibolite. A few samples of quartz and silicified amphibolite that were collected from the dump contained secondary chlorite, sericite, and biotite with minor sulfides. Ore minerals included chalcopyrite, cuprite, malachite, chrysocolla, and limonite after sulfides. Samples collected from the mine dump included a sample of limonite after siderite, which assayed less than 0.005 ppm Au, 0.6 ppm Ag, and 23 ppm Ga (gallium) (sample CH1-91, **Table 2**). A sample of limonite-stained mafic rock (sample CH2-91) assayed 0.034 ppm Au, 0.3 ppm Ag, and 30 ppm Ga. Chalcopyrite-bearing schist (sample CH25-91) assayed 0.046 ppm Au, 0.7 ppm Ag, and 0.35 percent Cu; cupriferous quartz (sample CH7-91) yielded greater than 10 ppm Au, less than 0.2 ppm Ag, and 2.27 percent Cu. The latter sample was reassayed and yielded 0.16 opt Au.

## Quartz pebble conglomerate

Located in W/2 E/2 section 27, T18N, R78W. Quartz pebble conglomerate crops out as thin beds at a couple of different localities at the crest of the hill. At sample location CH12-91, three samples were collected for analysis. This quartz pebble conglomerate contained milky quartz and uncommon black chert pebbles in a quartz matrix with some fuchsitic mica and hematite pseudomorphs after magnetite(?) or pyrite(?) (**Figure 3**). None of the samples were radioactive. One of the three samples contained detectable gold (0.04 ppm Au) (sample CH34-91, **Table 2**).

Samples of quartz pebble conglomerate collected a short distance southwest of Cooper Hill were poorly mineralized. Sample CH3-92 (**Table 1**), a quartz pebble conglomerate with accessory fuchsite and disseminated limonite, was collected from a prospect pit in the NE section 3, T17N, R78W. The sample yielded no precious metal or rare earth element anomalies. Sample CH4-92 (**Table 2**) was collected from a prospect pit nearby in the NE NE section 4, T17N, R78W. This sample was milky quartz with boxworks hosted by diabase adjacent to quartz pebble conglomerate. The assay indicated no unusual gold or silver values.

## Placers

Placer gold had been discovered in the district by 1896. According to *EMJ* (v. 62, July 4, 1896, p. 15) several thousand acres of placer ground were located along the North and South Forks of Cooper Creek and the South Fork of Dutton Creek. This article reported that the gravel contained gold values from \$0.50 to \$0.75/yd³ (0.02 to 0.04 oz/yd³).

Samples collected by the Wyoming State Geological Survey confirmed the presence of anomalous gold in Cooper Creek (Hausel and others, 1992). Every panned sample collected from Cooper Creek by Eric Nielsen of the Wyoming State Geological Survey was anomalous and contained visible gold (**Figure 8**). One sample collected from the West Fork of Dutton Creek also yielded visible gold and was highly anomalous (Hausel and others, 1993).

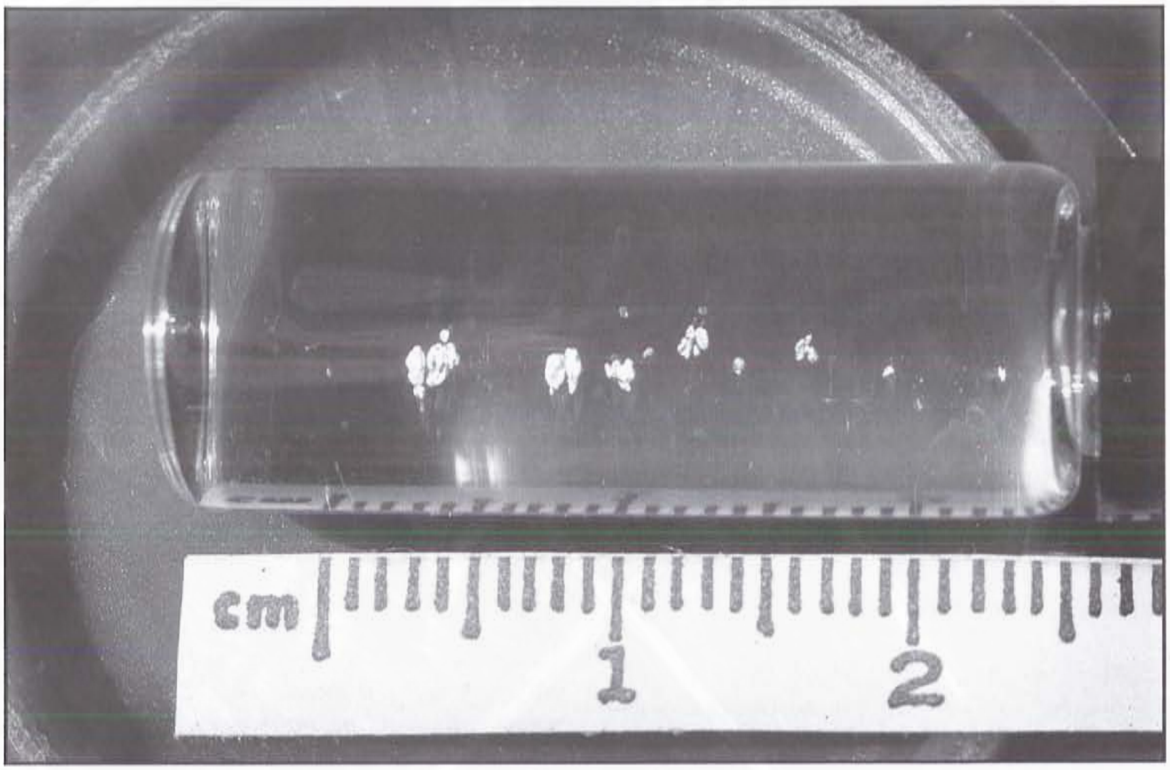


Figure 8. Gold panned from Cooper Creek in 1991.

# Summary

The Cooper Hill mining district produced minor amounts of lead, silver, gold, and copper ore near the turn of the century. Mineral deposits in the district include skarns and veins in Proterozoic age rocks, and gold in Quaternary placers.

The historical literature describes several impressive ore deposits that were not apparent during the 1991 mapping project. Unfortunately, nearly all of the mine workings were inaccessible in 1991, which made it difficult to properly assess the early reports. The assays reported in the early, historical literature in many cases are probably exaggerations, based on either selected ore samples or samples of supergene enriched ore, and are not consistent with the samples collected by Schoen (1953) and Hausel and others (1992). This is not unusual, but it leaves the geologist with the problem of sorting out fact from fiction.

When a mining district receives recognition for specimen grade ore, as Cooper Hill may have because of Beeler's (1906) report, many of the mine dumps become thoroughly picked over by specimen collectors. Possibly this has happened at Cooper Hill, and sampling on the surface and from the mine dumps may not do justice to the district. Because of this problem, it would be highly advantageous to anyone exploring Cooper Hill to reopen the historic mines and sample and map the mines in detail. Nevertheless, the historical literature does suggest this area has some interesting mineralization.

It has been erroneously suggested by some historians that the Cooper Hill district may require deep exploration to find extensions of some of the ore deposits. This proposal directly conflicts with the geological facts for the following reasons: (1) Cooper Hill is a rootless block of Precambrian rock overlying relatively undeformed Cretaceous sedimentary rocks located at relatively shallow depths. 'Deep' vertical mining would ultimately enter the underlying Cretaceous and Tertiary sedimentary rock units (possibly only 800 to 1,000 feet below the highest point of Cooper Hill) which are geologically too young to host extensions of Precambrian mineralization. (2) The rocks on Cooper Hill are relatively flat lying and most of the examined mineral deposits appear to be strata-bound or stratiform. Thus, exploration seeking the continuation of mineralization exposed at the surface would logically have to follow the attitude of the rock units. And if King's (1963) theory that Cooper Hill is a gravity slide is correct, then exploration for the source terrane could be beneficial and lead to the discovery of similar deposits to the west.

After reviewing the geochemical data produced during this study, one may conclude that the greatest potential for this area may be the source of the placer gold found in the streams and stream banks. Although the gold source is presently unknown, it appears to be widespread in that most streams sampled along the northeastern flank of the Medicine Bow Mountains yielded anomalously high gold values (Hausel and others, 1992, 1993). The most probable source is the widespread quartz pebble conglomerates. The author also recommends further exploration for the low-grade, "immense" quartz veins reported by various sources. Although none of these veins were found during this study, further research may lead to their rediscovery.

# References cited


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

Blackstone, D.L., Jr., 1973, Structural geology of the eastern half of the Morgan Quadrangle, James Lake Quadrangle, Albany and Carbon Counties, Wyoming: Geological Survey of Wyoming Preliminary Report 13, 45 p.

Duncan, Mel, 1990, The Medicine Bow mining camps: Jelm Mountain Publications, Laramie, Wyoming, 244 p.

Hague, Arnold, and Emmons, S.F., 1877, Descriptive geology: Report of the geological exploration of the Fortieth Parallel (King), v. 2, 890 p.

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

______, 1992, Economic geology of the Cooper Hill mining district, Medicine Bow Mountains, Carbon County, Wyoming: Wyoming Geological Association 43rd Field Conference Guidebook, p. 303-314.

Hausel, W.D., Marlatt, G.G., Nielsen, E.L., and Gregory, R.W., 1992, Preliminary study of precious metals and stones along the Union Pacific right-of-way of southern Wyoming: Geological Survey of Wyoming Open File Report 92-5, 79 p.

______, 1993, Study of metals and precious stones in southern Wyoming: Geological Survey of Wyoming unpublished Mineral Report MR 93-1, 25 p.

Houston, R.S., Schuster, J.E., and Ebbett, B.E., 1975, Preliminary report on distributions of copper and platinum group metals in mafic igneous rocks of the Sierra Madre, Wyoming: U.S. Geological Survey Open File Report 75-85, 129 p.

Hyden, H.J., King, J.S., and Houston, R.S., 1967, Geologic map of the Arlington Quadrangle, Carbon County, Wyoming: U.S. Geological Survey Geological Quadrangle Map GQ-643, scale 1:24,000.

Jensen, L.S., 1976, A new cation plot for classifying subalkalic volcanic rocks: Ontario Department of Mines Miscellaneous Paper 66, 22 p.

Karlstrom, K.E., Houston, R.S., Flurkey, A.J., Coolidge, C.M., Kratochvil, A.L., and Sever, C.K., 1981, Volume 1, A summary of the geology and uranium potential of Precambrian conglomerates in southeastern Wyoming: U.S. Department of Energy NURE Open File Report GJBX-139(81), 541 p.

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

______, 1964, Cooper Hill—A gravity slide in the northeastern Medicine Bow Mountains, Wyoming: University of Wyoming Contributions to Geology, v. 3, no. 1, p. 33-37.

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

Laramie Mining and Stock Exchange, 1896, Albany County, Wyoming, mineral resources: The Laramie Republican Book and Job Print, 42 p.

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

Schoen, Robert, 1953, Geology of the Cooper Hill district, Carbon County, Wyoming: M.A. thesis, University of Wyoming, Laramie, 41 p.

STATE OF WYOMING
1933
GEOLOGICAL SURVEY

GEOLOGY AND MINERALIZATION OF THE COOPER HILL MINING DISTRICT, MEDICINE BOW MOUNTAINS, SOUTHEASTERN WYOMING

RI 49

STATE OF WYOMING GEOLOGICAL SURVEY 1933

*Geology -- Interpreting the past to provide for the future*

ISBN 1-884589-04-9