THE GEOLOGICAL SURVEY OF WYOMING
Gary B. Glass, State Geologist

REPORT OF INVESTIGATIONS No. 28

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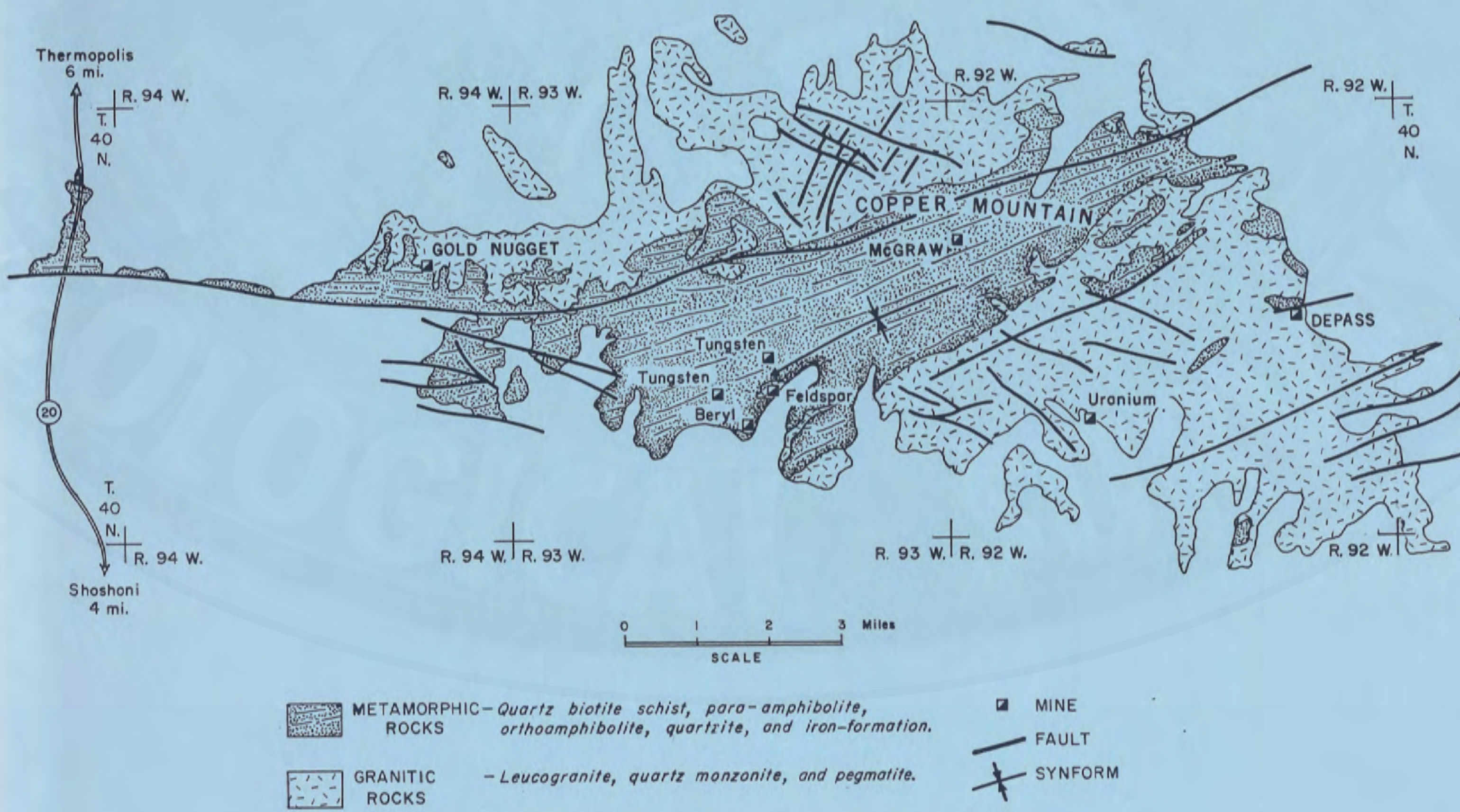
W. Dan Hausel, Paul J. Graff, and Karl G. Albert



LARAMIE, WYOMING
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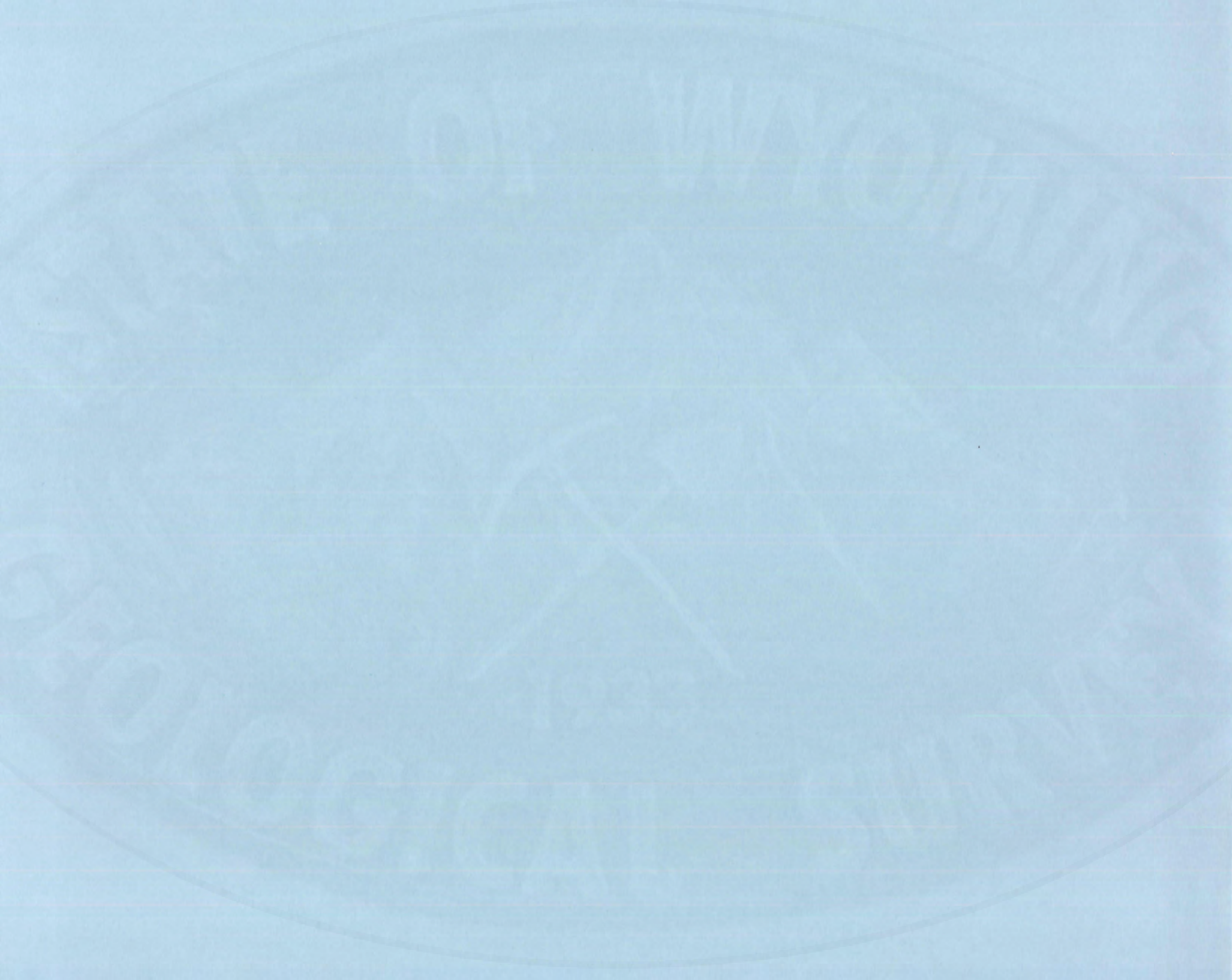
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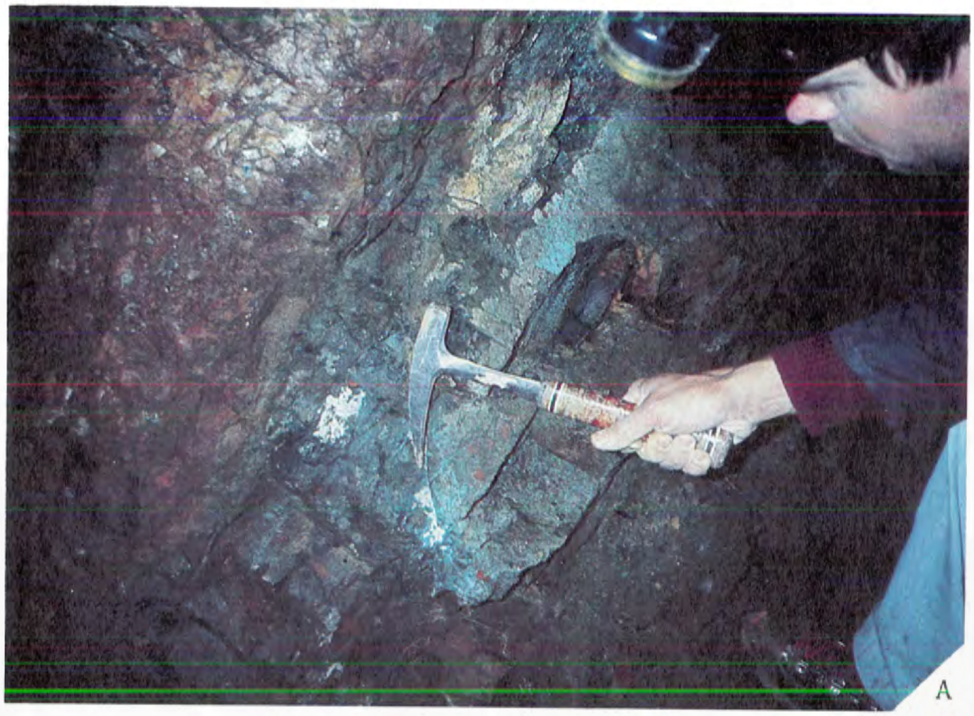

Frontispiece. Mineralization in the DePass Mine. Photographs taken in the hoist room of the main haulage level (see Plate 2). [A] Copper-stained mafic dike. Copper staining is blue. [B] Quartz vein (white) with hematite-limonite alteration (red-brown, yellow) enclosed within the mafic dike (gray).

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First printing, of one thousand, by Pioneer Printing and Stationery Company, Cheyenne. Plate 1 printed by Pikes Peak Lithographing Company, Colorado Springs.

Copies of this publication may be ordered from

The Geological Survey of Wyoming
P.O. Box 3008, University Station
Laramie, Wyoming 82071

Front cover. Generalized geologic map of Copper Mountain.

CONTENTS

ILLUSTRATIONS

Figure

TABLES

Table

PLATES

Plate

PREFACE

This report and the accompanying geologic maps have resulted from a reconnaissance study of a complex metamorphic belt. We have drawn upon our preliminary field work and extensively upon published data for a reinterpretation of this Archean complex. Since we cannot draw upon detailed geologic mapping, extensive petrographic work, abundant whole rock analyses, and isotope geochemical analyses, we consider our conclusions tentative and subject to revision as more data are collected and published.

During the 1982 and 1983 field seasons, the Geological Survey of Wyoming investigated the Archean stratigraphy and associated mineral deposits at Copper Mountain to determine if this supracrustal belt has potential commercial mineral deposits. The history of Copper Mountain includes two facts of interest: it has varied and scattered occurrences of Cu, Au, Ag, Fe, W, Be, Li, and U, and it has been classified as a greenstone belt by two earlier workers.

However, we conclude that Copper Mountain lacks the stratigraphic and structural character of a classical greenstone belt, exhibits higher metamorphic grade, and may be better classified as a "high-grade" terrain. "High-grade" terrains consist of layered quartzofeldspathic gneiss-amphibolite-mica schist sequences with some orthoquartzite and iron formation, and generally are poorly mineralized.

By calling Copper Mountain a "high-grade" terrain, we may be "damning" exploration interest. But it should be pointed out that since the metamorphic grade at Copper Mountain is not the extreme granulite to upper amphibolite facies seen in portions of many classical "high-grade" terrains, some potential for commercial deposits must be considered.

In particular, we noted the potential for stratiform Au associated with iron formation, stratiform W associated with gneiss, and the Cu-Au mineralization in strike veins (metachert?). Post-Archean epigenetic Cu-Au-Ag-U occurrences in unmetamorphosed tholeiitic dikes are also of interest.

ACKNOWLEDGMENTS

Many individuals working and living in the Copper Mountain region and in nearby Thermopolis, Shoshoni, and Lysite were very cordial and provided access to the area. In particular, we wish to acknowledge Mr. and Mrs. Forrest Baskett, employees of the George Fuller ranch, George Fuller, Mr. and Mrs. John Herbst, Jr. and family, John Philp, Dan Phillips, and Mr. and Mrs. Frank Smith, as well as Lee, the ranch employee who rescued the mud saturated senior author and vehicle at the beginning of the 1983 field season, and also Joe, the sheepherder, who provided us with many cups of coffee and nostalgic stories.

Robert C. Berry, Gary B. Glass, Robert S. Houston, and William T. Parry reviewed the manuscript and provided helpful comments and critisims. We would also like to thank Dave Copeland for his editorial review.

Finally, we wish to thank Rocky Mountain Energy Company and Cary Voss for providing us with aerial photographs of the southeastern edge of Copper Mountain.

INTRODUCTION

Copper Mountain forms a major segment of the Owl Creek Mountains in north-central Wyoming (Figure 1). The Owl Creek Mountains are low-lying ridges (6,000-8,000 feet in elevation) which trend east-west and separate the Bighorn Basin to the north from the Wind River Basin to the south.

The Copper Mountain supracrustal belt is one of several fragmented Archean volcanogenic terrains located within the Wyoming Province (Engel, 1963; Karlstrom, 1979). The Wyoming Province (Figure 1) includes several greenstone belts that are relatively enriched in mineral deposits compared with the vast granite-gneiss terrain that surrounds them (Hausel, 1982; Hausel and Harris, 1983). During the last decade, these Archean volcanogenic terrains have received increased attention not only because of their mineral potential, but also because they contain some of the oldest preserved volcanogenic sequences on the surface of the earth. Studies of these ancient terrains may help unravel the early geological history of our planet.

The Copper Mountain area hosts important resources of petroleum, significant tonnages of low-grade uranium resources, and deposits of base, precious, ferrous, and industrial metals and minerals. Uranium and small tonnages of copper, gold, silver, tungsten, feldspar, and beryl have been produced during the past 100 years.

REGIONAL GEOLOGY

The major portion of the State of Wyoming lies within the boundaries of an Archean cratonic block known as the Wyoming Province (Karlstrom, 1979). The limits of this block are, for the most part, not precisely known. Exposed Precambrian rocks of the Wyoming Province represent only about ten percent of its areal extent and occur in widely separated uplifts of Laramide age. The boundaries of the Province are not clear, and are determined from radiometric ages and lithologic assemblages in outcrop, then interpolated between the Laramide blocks, where wide basins of Phanerozoic rocks cover the Precambrian.

Copper Mountain is located in the central part of the Wyoming Province. Rocks of the central part of the Province are divisable into three main suites: early quartzofeldspathic gneiss, granite, and metamorphic supracrustal sequences.

Early quartzofeldspathic gneiss of the Province has not been studied in great detail, and our understanding of its role in the history of the Province is limited. However, we can generally characterize the gneiss as (potassium-poor) quartz tonalite. Recent studies have revealed complex histories for early quartzofeldspathic gneiss. For example, B.R. Frost at the University of Wyoming (personal communication) recognizes two imposed granulite events in some of the early gneiss of the Wind River Mountains. Peterman and Hildreth (1978) identify a gneissic complex in the Granite Mountains which is invaded by granite batholiths and yields an age of 2,860 million years before present. This age is a minimum whole rock age,

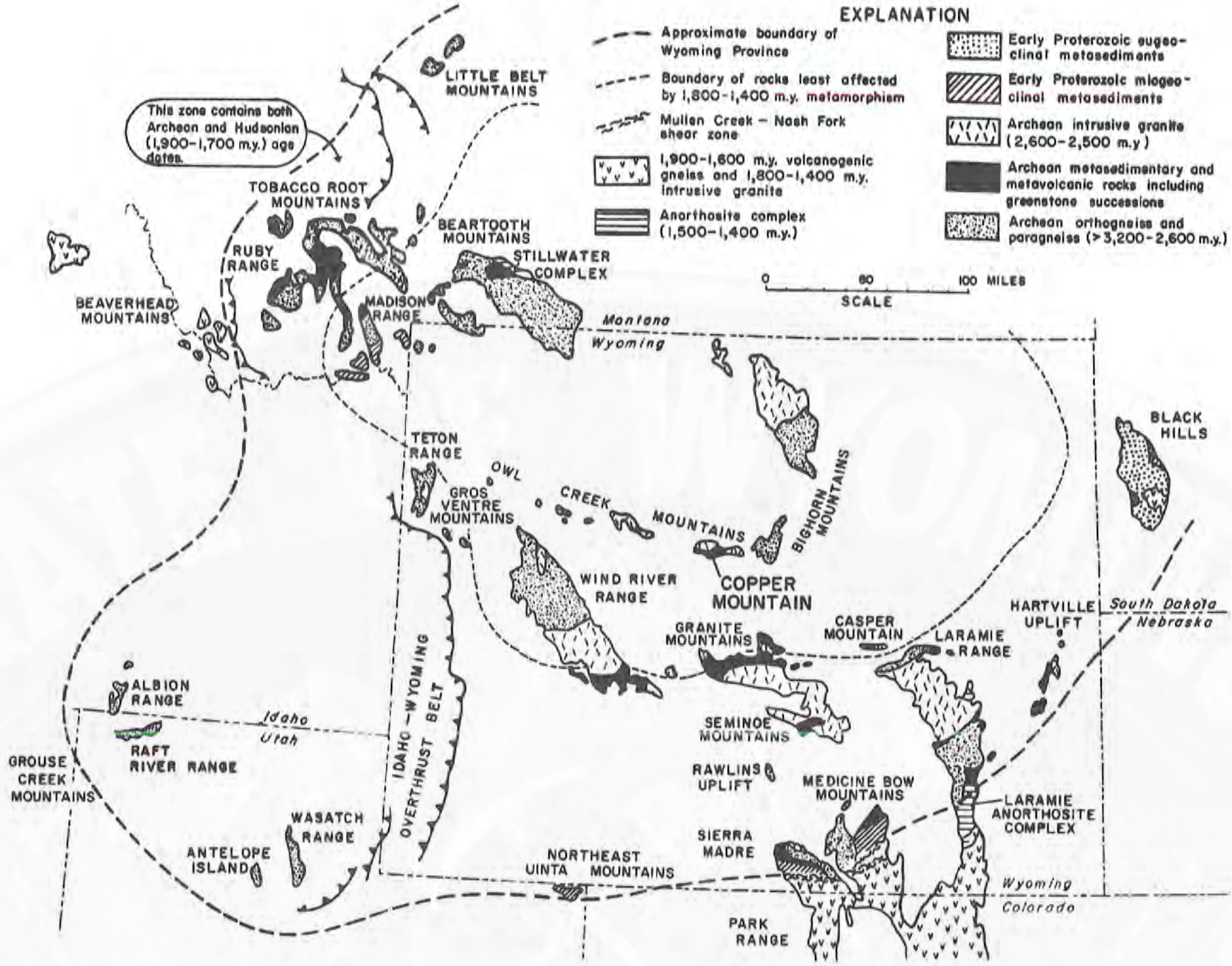


Figure 1. Generalized sketch map of the Wyoming Province (after Karlstrom and others, 1981).

for the samples studied had very high Sr^{87}/Sr^{86} ratios which suggest that these gneisses are the recrystallized product of rocks originally formed as early as 3,200 or 3,300 million years ago. Divis (1977) calculates a similar age of 2,800-2,900 million years for quartz-plagioclase (leucocratic) gneiss in the northern Sierra Madre. Hills and others (1968), Hills and Armstrong (1974), and Johnson and Hills (1976) cite gneiss across the southern Wyoming Province as being older than 2,750 million years, and Henry and others (1982) have identified a 3,390 million year old granulite metamorphic event in the Beartooth Mountains of Montana. In describing these rocks, the terms "leucogranite" and "gray gneiss" are used, terms which suggest low potassium values for rocks of those suites. In the Laramie Range, Hills and Armstrong (1974) divide the Precambrian basement section into gneissic complexes which are 2,800-3,000 million years old and pink to red granites which are 2,600-2,750 million years old.

Throughout the Wyoming Province these 2,750+ million-year-old gneisses are apparently products of potassium-poor, early crustal differentiates. They have experienced at least one major period of anatexis or other high-grade metamorphic event -- note Frost's evidence for two granulite gneisses and Peterman and Hildreth's evidence for first crystallization of 3,200 or 3,300 million years ago -- before the craton-wide intrusion of red granite. All current evidence suggests that the protoliths for these early gneisses were the products of chemically immature, early crustal differentation. Whether these early differentiates were emplaced on or in a primitive basic crust (e.g., see Anhaeusser, 1973; Anhaeusser and others, 1969; Glickson, 1976; Cloud, 1972) or were primary sialic material (e.g., see Windley, 1973; McGregor, 1973; Moorbath, 1975; Goldich and Hedge, 1974), they formed proto-continental masses (Goodwin, 1968). These masses may have grown by accretion, agglomeration, collision, or proto-plate tectonic activity, and, during growth, formed both intraprotolithic and interprotolithic depositional basins. The sedimentary piles deposited on the gneisses varied with their individual environments of deposition, but are generally grouped as stable shelf, greenstone belt, or high-grade supracrustal sequences.

High-grade supracrustal belts and greenstone belts are most common in the center of the Wyoming Province. In the Copper Mountain area, both Condie (1967) and Granath (1975) have described the metamorphic rocks as a greenstone belt on the basis of limited exposures in Wind River Canyon to the west of the main body of supracrustal rocks. But on the basis of our examination of the volcanogenic sequence exposed at Copper Mountain, the rocks seem more representative of assemblages that Windley (1977) describes as "high-grade supracrustal belts." These belts are formed from layered gneiss-amphibolite-mica schist sequences containing quartzite and iron formation. They lack the stratigraphic character and structural morphology of the classic greenstone belt, and show higher metamorphic grade. At Copper Mountain this sequence occurs as intercalated quartzofeldspathic gneiss, biotite schist, amphibolite, metapelite, quartzite, iron formation, and local marble.

The supracrustals are intruded, and locally consumed, by potassium-rich plutonic rocks including granite, two-mica granite, monzonite, syenite, and granodiorite. Similar potassium-rich plutonic rocks intruded the older gneisses, doming and folding greenstone belts throughout the Wyoming Province, between 2,650 and 2,550 million years ago (Graff and others, 1982).

During the Laramide Orogeny, the Copper Mountain block was uplifted and thrust to the south over Phanerozoic sediments of the Wind River Basin (see Plate 3). Brittle deformation of Precambrian rocks during thrusting resulted in intense fracturing and faulting of the thrust plate. The toe of the thrust is a structurally complex terrain: coalescing thrust faults and grabens developed immediately behind the leading edge of the thrust.

Along the northern flank of Copper Mountain, Precambrian rocks are unconformably overlain by Cambrian sediments. These sediments contain numerous bedding-plane faults (as a result of the southward directed thrust) expressed as slickensides in the plane of dip of the Cambrian strata. Tertiary rocks onlap the Precambrian rocks along the southern edge of the uplift.

STRATIGRAPHY

The Copper Mountain metamorphic complex can be divided into three general rock types, of different ages: supracrustals, granite, and mafic dikes. The oldest are the high-grade metamorphic supracrustal rocks, more than 2,700 million years old. The supracrustals were intruded, folded, and metamorphosed about 2,700 million years ago, according to Rb-Sr dates of 2,640 and 2,720 million years before present obtained from the late-intruding granite (Giletti and Gast, 1961). The youngest Precambrian rocks recognized in the district are mafic dikes that show no evidence of prograde metamorphism. These dikes have tholeiitic affinities and are similar to dikes found in Precambrian terrain in the Bighorn Mountains to the east of Copper Mountain and to dikes located west of Copper Mountain in the Owl Creek Mountains. The dikes on Copper Mountain have not been dated, but are assumed to be similar in age to those in the Bighorns emplaced about 2,200 million years ago (Armbrustmacher, 1977) and those in the Owl Creeks emplaced 1,910 to 2,110 million years ago (Condie and others, 1969).

All three of these general rock types are considered in the following discussion, but the greatest emphasis is placed on the supracrustal rocks because of their importance in understanding Archean geology and because they are important hosts for mineral deposits. Interpretation of the depositional environments of these rocks is ambiguous because intense metamorphism has destroyed nearly all primary sedimentary features, and because the Laramide block that forms Copper Mountain is fragmented. Complex tectonic interleaving may have occurred during both Archean and Laramide times. Such activity may have resulted in only the partial exposure of the original sequence and the stratigraphic juxtaposition of different parts of the sequence.

SUPRACRUSTAL ROCKS

On the basis of the age of intrusive granites, the supracrustal sequence of the Copper Mountain area is interpreted to be more than 2,700 million years old. The supracrustal rocks consist of an amphibolite-grade terrain which was modified by a later, weaker, retrogressive greenschist event.

The regional structural grain of the metamorphic complex (Plate 1) is N.50°E. to N.80°E. Regionally, the complex forms a belt which dips very steeply to the south and is apparently a homoclinal succession with a recumbent, southwest-plunging synform along its southeastern margin (see Plate 1).

We separate the supracrustal rocks into the three mappable units proposed by Hamil (1971). These units are identified, from south to north, as Metamorphic Unit I, Unit II, and Unit III (Plate 1). Gliozzi (1967) suggests that the southernmost unit, Unit I, is older than rocks to the north. Although that suggestion is supported by such evidence as some poorly preserved cross-beds(?) and stretched pebbles(?) at the base(?) of some quartzites, it is contradicted by other cross-beds(?). We feel that more detailed mapping is necessary (although it may not be sufficient) to establish an unequivocal stratigraphic top of the supracrustal belt. The possibility that this belt is a steeply dipping and tightly folded synform is also possible, as Unit I and Unit III have many lithologic similarities, although Unit III is more mafic.

Metamorphic Unit I

Unit I, the southernmost unit, is at least 5,000 feet thick as measured in continuous exposure. Several small remnants of this unit are located as far as five miles south of the contact of Unit I with Unit II. To the north, near its contact with Unit II, rocks of Unit I become progressively more dominated by quartzofeldspathic gneiss. To the south, Unit I is dominantly amphibolitic. In the vicinity of Hoodoo Creek, the contact between Unit I and Unit II is slightly angular and appears to represent an angular unconformity (Gliozzi, 1967).

Amphibolite and intercalated quartzofeldspathic gneiss are the two principal rock types which form Unit I. Epidote schist and chlorite-biotite schist occur to a lesser extent. Where Unit I rocks have been extensively invaded by granitic magma, veining and migmatitic textures are present.

The quartzofeldspathic gneiss is a strongly foliated, layered rock that shows shades of light gray on weathered surfaces. It consists of varying amounts of plagioclase, quartz, biotite, and potassium feldspar. The chief feldspar is oligoclase which is partially altered to clay with minor sericite. Quartz is present in mortar structure of well sutured, rectangular grains. Biotite often shows limited replacement by chlorite. The potassium feldspar is orthoclase and minor microcline. Microcline, which is late in the paragenetic sequence, exhibits ragged crystal edges and occurs as interstitial grains. A whole-rock analysis of fairly fresh and relatively unaltered gneiss shows that these rocks are silica rich and chemically similar to dacite or rhyolite (Table 1). In the vicinity of Hoodoo Creek, some of the gneisses contain tungsten, beryl, tourmaline, and local copper sulfide mineralization (Robert C. Berry, personal communication, 1984) indicating that these units are either magmatic or hydrothermally altered. Frey and Wilson (1950) essentially describe the tungsten mineralization as stratiform. Stratiform mineralization would favor a volcanogenic origin for some of these gneissic units.

Amphibolite is of two varieties, para-amphibolite and orthoamphibolite, which have distinctive mineralogies and textures. The para-amphibolite (or amphibolite schist) is a finely foliated schist containing hornblende, cummingtonite, relatively large amounts of quartz, and relatively small amounts of plagioclase (An_{36}-An_{42}). These rocks were not analyzed chemically. Their mineralogy implies a sedimentary origin, and they were probably deposited as greywackes (Condie, 1967) although they could easily have been mafic tuffs.

The orthoamphibolite is massive, dark gray to black rock that locally exhibits weak foliation and diabasic texture. At least two generations of orthoamphibolite are present. The older generation often shows weak foliation and is conformably intercalated with adjacent rock types. A second generation orthoamphibolite with diabasic texture lacks foliation and forms nonconformable (angular) contacts with the host metasedimentary and metavolcanic rocks. The mineralogies of the two orthoamphibolites are similar. Their mineralogy shows that they were derived from mafic flows and gabbroic dikes or sills.

In thin section, the orthoamphibolite consists of euhedral to subhedral plagioclase and hornblende with decussate to subophitic texture. Plagioclase is saussuritized and partially replaced by epidote, clay, and white mica (identified by microprobe analysis as sericite by

Table 1. Chemical composition of quartzofeldspathic gneiss and orthoamphibolite from Copper Mountain. Analysis of sample CUMTN-25-83 by Bondar-Clegg Inc., and of sample CUMTN-17-83 by Gordon Marlatt.

OXIDE	SAMPLE CUMTN-25-83 (quartzofeldspathic gneiss)	SAMPLE CUMTN-17-83 (amphibolite)
SiO_2	71.00%	55.60%
TiO_2	0.16	-
Al_2O_3	13.50	13.57
Fe_2O_3	3.61	10.72
MnO	0.06	0.19
MgO	0.36	7.86
CaO	2.61	10.52
Na_2O	4.31	1.75
K_2O	2.17	1.38
P_2O_5	0.18	-
TOTAL	97.96%	101.59%

Hamil, 1971, p.16). The plagioclase is An_{46} to An_{54}. Minor constituents include quartz, mica, epidote, magnetite, and ilmenite, with accessory apatite, zircon, and locally fibrous anthophyllite.

The orthoamphibolite is different mineralogically and texturally from the para-amphibolite (Condie, 1967). Plagioclase is more calcic in the orthoamphibolite, and quartz occurs in minor amounts. The mineralogy and texture, as well as a chemical analysis, favor an igneous origin for these rocks (Table 1). Chemically, these rocks are tholeiitic.

The lithologic character of Metamorphic Unit I suggests a rapidly sinking depositional basin fed by a quasi-stable headland. The orthoamphibolite and para-amphibolite are interpreted as mafic submarine flows, mafic sills, and greywacke. Important to the interpretation of the geologic setting of Unit I, as well as the entire supracrustal belt, is the quartzofeldspathic gneiss. Bayley and others (1973, p. 25) favored basement gneiss as an interpretation. However, in similar Archean regions elsewhere, such gneiss has been considered as greywacke, arkose, andesite, dacite, granite, or as reworked basement gneiss.

Metamorphic Unit II

Metamorphic Unit II contains several distinct metasedimentary units and apparently is conformable with Unit I at most localities (Gliozzi, 1967). Metamorphic Unit II consists of para-amphibolite, orthoamphibolite, quartzite, iron formation, and metapelite (Plate 1), and is 50 to 60 percent, or more, metasedimentary.

The metapelite is predominantly three varieties of light-gray to dark-gray, quartz-mica pelitic schist with a distinctive nodular texture formed by porphyroblasts of alumino-silicates. The varieties are chlorite-muscovite schist, cordierite-muscovite schist, and andalusite muscovite schist. Other minerals in the schist include garnet, quartz, sillimanite, cummingtonite, anthophyllite, quartz, and feldspar (Hamil, 1971). Gliozzi (1967) reported porphyroblasts of kyanite in thin section and in the field but kyanite was not observed during this study nor reported by Hamil (1971). Gliozzi identified all three of the polymorphic alumino-silicates in Metamorphic Unit II. Andalusite is the most common of the three and generally occurs as large porphyroblasts pervasively altered to muscovite. Kyanite also is altered to muscovite. Near mafic dikes which have been thermally metamorphosed, kyanite is altered to fibrous sillimanite and sillimanite forms rims around biotite. Textural evidence indicates that the "triple point" assemblage was not in equilibrium and was produced during local thermal events (Gliozzi, 1967).

Unit II contains some quartzofeldspathic gneiss and quartzite. The gneiss is a minor constituent in this unit, and is similar mineralogically and texturally to the gneiss of Unit I. The quartzite is nearly equigranular, and contains fractures, filled with massive quartz, that show that some silica remobilization has occurred. Locally, some of these fractures are lens shaped and have the appearance of stretched pebble conglomerate. The quartzite is massive, and varies from milky white to reddish brown to light green. The milky quartzite is nearly pure silica, whereas the reddish brown rock is stained by iron from the oxidation of opaques. The greenish quartzite contains varying proportions of fuchsite.

Possible quartz pebbles elongated or stretched in the plane of foliation occur at the base(?) of some quartzite sequences (Gliozzi, 1967). However, these units have undergone intense deformation and metamorphism, and features which appear to be stretched pebbles, or quartz lenses, may have resulted from more than one mechanical process. These rocks also exhibit fractures and weathered surfaces that are filled, or coated, by cryptocrystalline and fine acicular quartz suggestive of remobilized silica. No clearly recognizable sedimentary structures have been preserved, but the occurrence of possible stretched pebbles near the base(?) of some quartzites and the presence of possible cross-bedding(?) at a few localities suggest that the stratigraphic top may be to the north. However, other cross-beds(?) indicate that the top lies to the south.

Metamorphic Unit II contains para-amphibolite and orthoamphibolite similar to that in Unit I and Unit III. While some para-amphibolite in Unit II is similar mineralogically to Unit I para-amphibolite, a second type of amphibolite contains a significant amount of iron-rich amphibole. This second type contains quartz, ferroamphibole, and minor plagioclase. The prominent amphibole is grunerite with lesser amounts of hornblende, anthophyllite, actinolite, and cummingtonite (Gliozzi, 1967). This grunerite-rich amphibolite is mineralogically similar to the silicate-facies iron formation reported by Granath (1975) in the Wind River Canyon.

Four prominent, thin, oxide-facies iron formations are mappable throughout much of exposed Metamorphic Unit II. Individual rock units exhibit complex drag folds which indicate structural thickening. There is some lateral variation in these units, and the iron tenor evidently decreases outward from the center of the complex. These iron formations consist of banded magnetite-ferroamphibole-quartz layers.

Unit II also contains several thin veins of limited extent. Historically, these have been interpreted as veins even though they exhibit no recognizable hydrothermal alteration and conform to regional foliation. Furthermore, many of these veins are hosted by orthoamphibolite and are located adjacent to iron formation.

These veins are generally only a few feet thick, and can be traced for several hundred feet along strike. At least two types of strike veins are recognized. One type, here called the "McGraw-type," consists of massive milky quartz, or chert. The "McGraw-type" often contains copper sulfides with gold values and is predominately hosted by orthoamphibolite and para-amphibolite closely associated with iron formation. Similar Archean rocks of the Onverwacht Series of the Barberton greenstone belt, southern Africa, have been interpreted as chemically precipitated chert deposited during periods of quiescence between outpourings of lava (Anhaeusser and others, 1968).

A second variety of strike vein, typified by the Gold Nugget deposit, is hosted by metapelite rather than amphibolite. The "Gold Nugget type" vein is fundamentally different from the "McGraw-type" vein in that the "Gold Nugget type" vein is hosted by aluminous schist, and is generally micaceous. The Gold Nugget vein is massive to granular, and contains greasy-luster to milky white quartz. Both the "McGraw type" and "Gold Nugget type" veins form a sharp contact with adjacent host rocks and exhibit little or no evidence of hydrothermal alteration, but the dominant sulfide in the "Gold Nugget type" is pyrite rather than chalcopyrite. At the entrance to the north adit on the East Fork of Birdseye Creek (see page 21), a "Gold Nugget type" vein grades laterally into quartzite over a distance of a few feet. Field evidence suggests that the "Gold Nugget type" veins may be quartzite that has undergone intensive silica remobilization.

Metamorphic Unit III

The lithologies of Unit III rocks are generally similar to those of corresponding Unit I rocks, but the bulk chemistry of Unit III is more mafic. Metamorphic Unit III is dominantly epidotized amphibolite schist, with lesser amounts of orthoamphibolite, scattered outcrops of quartzofeldspathic gneiss, and localized outcrops of fuchsitic quartzite and metapelite. This unit has been extensively invaded and migmatized by granitic rock. Because of the numerous granitic intrusives, hydrothermal alteration is more prevalent in Unit III. Where hydrothermal alteration is evident, plagioclase is partially altered to epidote and lesser sericite, and amphiboles exhibit biotite rims and included grains of magnetite. In places, the quartzofeldspathic gneiss contains replacement of primary feldspar by microcline.

The rock types of Unit III indicate that these rocks were originally sporadic mafic flows which were erupted during periods of relative quiescence. Erosion resulted in the breakdown and decomposition of mafic flows and the deposition of volcaniclastic greywackes.

Depositional Environment

The stratigraphy of the exposed supracrustal rocks provides evidence that these rocks were deposited in a submarine volcanogenic setting. Available evidence for determining the stratigraphic tops of these rocks is inconclusive, and the interpretation of the evolution of this supracrustal belt is questionable.

If the stratigraphic top lies to the north, as suggested by Gliozzi (1967), the quartzofeldspathic gneiss in Unit I may represent tectonically interleaved slices of the original gneissic basement. But if the top is to the south, Unit III may be considered as a mafic volcanogenic sequence deposited on an Archean basement. Further volcanic activity and periods of quiescence represented by Unit II would follow. Finally, Unit I would then represent further development in the evolution of the belt with a return to predominately volcanic activity producing mafic flows, greywackes, and intermediate calc-alkaline volcanics. Some quartzofeldspathic gneiss on Copper Mountain resembles volcanic flows and tuffs in its textural patterns and facies variations (Robert C. Berry, personal communication, 1984). In other words, the quartzofeldspathic gneiss may be envisioned as intermediate volcanics and tuffs and their metamorphosed erosional products.

GRANITIC ROCKS

The margin of the supracrustal belt has been invaded by a suite of granitic stocks, plutons, and associated pegmatites and aplites. These are biotite granite, muscovite granite, two-mica granite, quartz monzonite, syenite, granodiorite, and numerous aplites and pegmatites. Nearly all of the pegmatites are simple pegmatites containing muscovite, quartz, and potassium feldspar; however, along Hoodoo Creek on the southern edge of Copper Mountain, a number of complex pegmatites have been identified (McLaughlin, 1940). Lepidolite, tourmaline, and beryl have been recognized in some of these.

MAFIC DIKES

Proterozoic mafic dikes intrude both the supracrustal and granitic rocks on Copper Mountain. Armbrustmacher (1977) dates similar dikes in the Bighorn Mountains at about 2,200 million years before present. Mafic dikes located within the Owl Creek Mountains to the west of Copper Mountain have yielded dates of 1,910 to 2,110 million years before present (Condie and others, 1969). The Copper Mountain dikes are probably of similar age.

The mafic dikes at Copper Mountain exhibit no foliation and are basaltic. In hand specimen, they are black, aphanitic rocks. In thin section, dike rocks consist of microphenocrysts of plagioclase and pyroxene in a fine-grained matrix of randomly oriented plagioclase, pyroxene, opaques, and hematite. Both augite and pigeonite are pervasively uralitized. Labradorite, the dominant plagioclase, is partially altered to scapolite(?).

STRUCTURE AND METAMORPHISM

The Copper Mountain supracrustal belt was regionally metamorphosed to almandine-amphibolite facies. The mineral assemblages produced by the amphibolite-grade event are obscured by local retrograde and hydrothermal overprinting from the intrusion of mafic dikes and hydrous granitic solutions.

Fold patterns in the rocks of Copper Mountain show that Precambrian supracrustal rocks were initially folded sometime prior to the intrusion of the late Archean orogenic granites. About 2,700 million years ago, a second phase of folding occurred which corresponded with the invasion of these felsic intrusives. A third recognizable episode of folding followed the waning stages of retrograde metamorphism. These last two stages of deformation are recorded in the granites (Granath, 1975).

Later, during Laramide time, the Precambrian rocks of Copper Mountain were uplifted and thrust southward over Phanerozoic basin rocks. Laramide tectonics produced thrust sheets, complex gravity faults, and keystone-type grabens (Wise, 1963).

Available information on mineral assemblages and textures indicates that the supracrustal rocks were regionally metamorphosed to the almandine-amphibolite facies. Both Gliozzi (1967) and Hamil (1971) recognize the dominant subfacies as staurolite-quartz, the lowest metamorphic grade of the almandine-amphibolite facies.

Locally, regional metamorphism was modified by the emplacement of late-intruded mafic dikes and by hydrous solutions produced during the final stages of crystallization of the 2,700-million-year-old granites. Both microcline and sericite were produced at the expense of plagioclase feldspar in reaction with the hydrothermal solutions from the granitic rocks. The emplacement temperature of the mafic dikes was higher than the temperatures produced during regional metamorphism, and thermal haloes were developed in the intruded rocks. Where these post-prograde metamorphic dikes intruded mafic metamorphic rocks, amphibole was altered to epidote and chlorite, and plagioclase was replaced by scapolite and epidote. In metapelite terrains, kyanite was replaced by fibrous sillimanite (Gliozzi, 1967).

TECTONIC SETTING AND GEOLOGIC HISTORY

The Copper Mountain area has been likened in its geologic and tectonic setting to an Archean greenstone belt (Condie, 1967; Granath, 1975). The Copper Mountain supracrustal belt is similar in some respects to greenstone belts of the Wyoming Province such as the South Pass (Bayley and others, 1973), the Seminoe Mountains, (Klein, 1981), and the Elmers Rock (Graff and others, 1982) greenstone belts. There are, however, a number of important features of Wyoming greenstone belts that are missing from Copper Mountain. These features may have been removed by erosion or faulting; they may be present but unrecognized; or they may never have been present.

To interpret the early tectonic setting, it is necessary to understand the geologic setting of the depositional basin in which the supracrustal sequence was deposited.

Currently, the supracrustal rocks are the oldest group recognized in the Copper Mountain area. Without knowing the nature of the rocks upon which the supracrustals were deposited, the tectonic environment of the depositional basin cannot be determined. Only granite, and not older leucocratic gneiss, has been mapped in this area. The dominant rock type immediately adjacent to the supracrustals is potassium-feldspar-bearing granite which intrudes, and is therefore younger than, the supracrustals. We suppose, by analogy to other terrains in the Wyoming Province, that the supracrustals were most likely deposited between 2,740 and 3,000 million years ago on sialic basement gneiss which had been formed by recrystallization of volcaniclastic and volcanogenic rocks during a major high-grade metamorphic event or events about 3,000 to 3,400 million years ago. As proposed earlier in this paper, deposition probably occurred between or at the margins of sialic protoliths which coalesced to form the major portion of the Wyoming Province. Growth of the cratonic mass by collision, accretion, and underplating may have formed depositional environments similar to those which formed greenstone belts. But, because of rapid plate movement and rapid changes in heat flow patterns, downwarping mechanisms failed or shifted to the new margin of the accreted mass and left behind starved basins, or formed new, fairly shallow basins in the interior of the new craton. In this setting, volcanics would have been deposited during the early history of the basins while high heat flow and downwarping were active. The coarse clastic and pelitic portions of the supracrustal sequence were deposited late in the depositional history of these basins. We propose that, in this respect, the depositional and tectonic histories of the clastic metasedimentary portions of greenstone belts and high-grade supracrustal sequences such as Copper Mountain are very similar. Following deposition, the supracrustal sequence was deformed and intruded by granitic bodies about 2,650 to 2,700 million years ago. This deformation may have been accompanied by brittle fracture and tectonic interleaving of basement and granitic slabs. Contacts between metasediments and gneisses are sharp and define apparent differences in metamorphic grade between the juxtaposed lithologies.

The character of the stratigraphic sequence at Copper Mountain also supports its classification as a high-grade supracrustal belt. While recognized greenstone belts display a three-part stratigraphic assemblage (Graff and others, 1982) consisting of a lower group of ultramafic-mafic flows and sills, a middle group of mafic and andesitic flows, and an upper group of metasediments, Copper Mountain supracrustals do not contain a clearly mafic to felsic trend in their amphibolite sequences, nor is a clear fining-upward trend seen in the clastic metasediments. No definite metakomatiites, or metaperidotites have been recognized in Unit I or Unit III at Copper Mountain; rather, both units are dominated by similar amphibolites having characteristics compatible with tholeiitic basalts.

The lack in Unit II of a thick, coarse conglomerate-greywacke facies indicates that downwarping and accompanying rapid deposition was short-lived. Unit II is dominated by metapelite with thin orthoquartzite layers, a lithology typical of a period of quiescence during deposition of a slowly, gradually deepening basin. At least some of the veins and banded iron formation within Unit II are most likely exhalative in origin. Silica-rich exhalite interlayered with pelite may indicate the later stages of volcanic and tectonic activity associated with the formation of the Archean cratonic mass which makes up the Wyoming Province.

The intrusion of granite 2,650 million years ago (Nkomo and others, 1978) was the last major tectonic event in the formation -- and thickening -- of the Wyoming Province. The granite intruded the upper crust throughout the Province between 2,550 and 2,650 million years ago.

Proterozoic events represent a fundamental change in the character of the craton. Rather than deform ductilely, as it had in the Archean, the cratonic slab was thick, rigid, and cool enough to deform in a brittle manner in response to large-scale stresses. Thus, fracturing is evident in the emplacement of the mafic dikes. At Copper Mountain, these dikes exhibit no evidence of metamorphism (Condie, 1969).

ECONOMIC GEOLOGY

Copper Mountain has a history of minor production from metal deposits and is an area that should be explored in greater detail because the geological environment appears to be favorable for low-grade stratiform deposits. In recent years, the greatest exploration interest has been in uranium and petroleum resources. But because the focus of this paper is the Precambrian geology, petroleum and uranium resources, which were generated much later in geologic time, are examined only briefly.

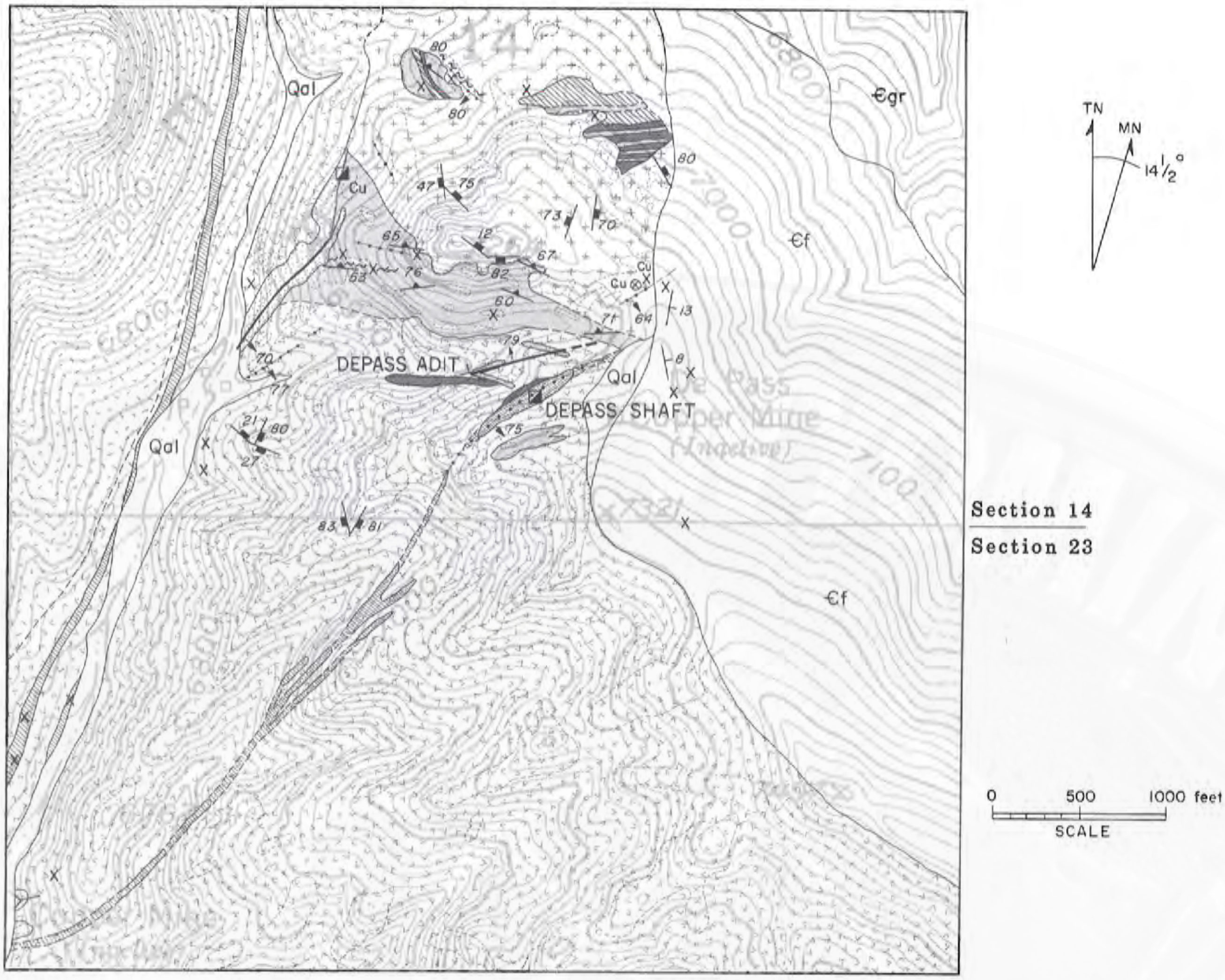
The Copper Mountain supracrustal belt has been affected by more than one episode of mineralization. There is evidence that mineralizing events occurred in the Archean, the Late Archean, the Early Proterozoic, and the Phanerozoic. But until detailed geochemical, isotope, and mapping studies are completed, discussions about these events at Copper Mountain will be speculative.

BASE AND PRECIOUS METALS

DEPASS (WILLIAMS-LUMAN) MINE

The DePass Mine lies on a tributary of the East Fork of Dry Creek along the eastern edge of the Copper Mountain complex (Figures 2 and 3; Plate 1). The DePass Mine contains the most extensive underground workings of any of the mines on Copper Mountain. Estimates are that more than 11,000 feet of workings were developed on the property (Osterwald and others 1966, p. 52). At the intersection of the DePass Mine tributary with the East Fork of Dry Creek are the remains of a mill which was used to process and concentrate the DePass ores prior to shipment to the American Smelting and Refining smelter in Omaha, Nebraska. The historic records of ore shipped from the property may be incomplete (Table 2).

Figure 2. The DePass Mine dump. Off-road vehicle gives scale.



EXPLANATION

Qal **Stream gravels, alluvium, and talus slopes.**

CAMBRIAN SEDIMENTS

€gr **Gros Ventre Formation.**

€f **Flathead Sandstone.**

PROTEROZOIC ROCKS

Massive Chert. Milky quartz.

Mafic Dike. Aphanitic dark grey to black tholeiite. Cupriferous and silicified near DePass Mine.

ARCHEAN INTRUSIVE ROCKS

Grey Granodiorite.

Muscovite Granite. Coarse to medium grained hypidiomorphic granular. Dominant mica is muscovite.

Biotite Granite. Coarse to medium grained hypidiomorphic granular. Dominant mica is biotite.

ARCHEAN SUPRACRUSTALS

Quartzofeldspathic Gneiss. Grey quartz, biotite, feldspar-bearing rocks with gneissic texture.

Amphibolite. Predominately schistose rocks of sedimentary genesis.

Metapelite. Muscovite schist.

SYMBOLS

70 **Fault with dip. Dashed where projected.**

75 **Quartz vein. Dashed where projected.**

⊗ **Copper float.**

Shaft.

Adit.

x **Prospect pit.**

68 **Foliation trend with dip.**

30 **Joint trend with dip.**

Contact. Dashed where projected.

Outcrop boundary.

Cu **Copper mineralization.**

Figure 3. Geologic map of the DePass Mine area, east flank of Copper Mountain, S1/2 section 14 and N1/2 section 23, T.40N., R.92W.

Table 2. Historic records of smelter returns on ore concentrates shipped from the DePass Mine. From Beeler (1906) and Bowdin (1918).

Date shipped	Pounds shipped	Percent copper or copper value	Ounces per ton or value of gold	Ounces per ton or value of silver
8/14/1906	31,209	$874.67*	$65.54*	$61.21*
1906	809	$127.89*	$ 3.64*	none
2/17/1917	40,485	11.26%	0.07 oz/ton	0.43 oz/ton
4/13/1917	36,358	8.94%	0.09 oz/ton	none
5/ 2/1917	28,343	8.90%	1.05 oz/ton	0.34 oz/ton
6/ 6/1917	28,739	7.25%	0.11 oz/ton	0.39 oz/ton
7/19/1917	6,565	9.14%	0.11 oz/ton	0.42 oz/ton
7/19/1917	30,261	10.84%	1.45 oz/ton	0.60 oz/ton
12/10/1917	92,912	2.52%	none	none
12/11/1917	783	49.50%	none	none
2/ 6/1918	85,410	2.30%	none	0.08 oz/ton
2/ 8/1918	80,488	2.62%	none	none
2/ 8/1918	62,499	1.10%	none	0.40 oz/ton
7/27/1918	21,484	3.40%	none	none
7/27/1918	21,265	0.65%	none	none

*1906 prices.

The geology of the DePass Mine area is shown in Figure 3. The DePass area consists of sparsely scattered, fragmented, and intruded outcrops of metamorphic rock assumed to be part of the metamorphic Unit I sequence. The emplacement of the granite here, as well as throughout the metamorphic belt, was passive -- inclusions of metamorphic rocks have foliation trends consistant with those of the remainder of the belt. There is no evidence of rotation or tilting of any of these metamorphic xenoliths. Mafic dikes intrude both granitic and metamorphic rock, and the mafic dike at the DePass Mine is an important host to the DePass mineral deposits. After the dike was emplaced, it was fractured and silicified. The mineral deposits at the DePass Mine occur as fracture-fillings and disseminations in the silicified, northeast-trending mafic dike. Both the veins and the host dike are mineralized.

The DePass Mine discovery point (see glory hole on Figure 4) was developed in two separate milky quartz veins (three to five feet wide) that occur within a mafic dike 30 to 50 feet wide. These veins consist of fractured, copper-stained milky quartz. The host mafic dike is dark brown to black aphanitic rock that is also copper stained. The copper minerals occur as fracture fillings in the veins and in the mafic rock, and as disseminations in the mafic dike.

Hydrothermal alteration is recognizable in both the mafic dike and the adjacent quartzofeldspathic gneiss. A zone of gray gneiss approximately one foot wide adjacent to the mafic dike is stained pink. Rocks collected from this stained zone and from three feet into the gray gneiss were sampled and thin-sectioned. The sample of pink-stained gneiss adjacent to the mineralized mafic

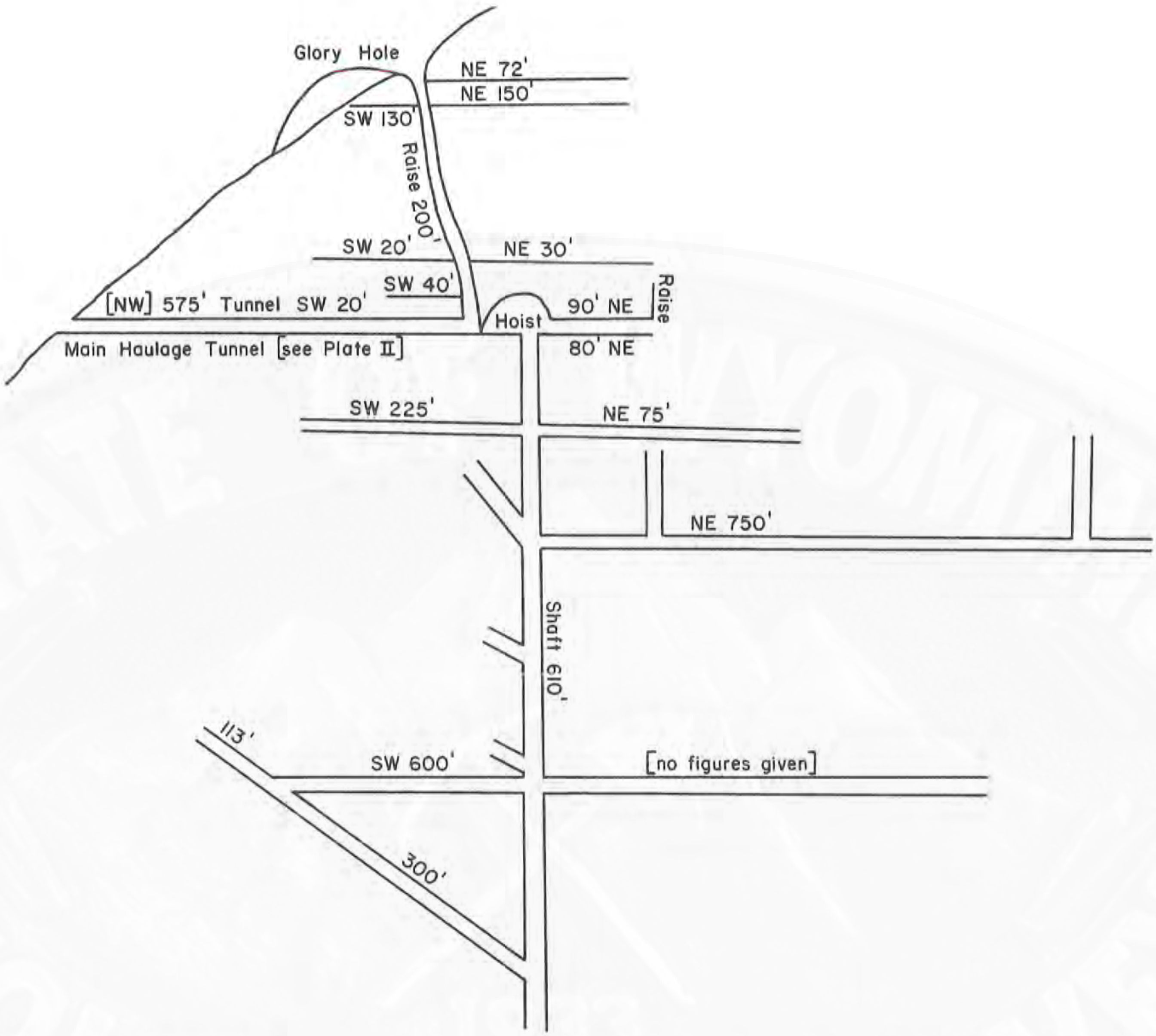


Figure 4. Schematic cross section of the historic DePass Mine workings (modified from Bowdin, 1918).

dike shows replacement of plagioclase grains by sericite and illite. Microcline occurs as interstitial grains, often with ragged grain boundaries, and several grains contain sericitized plagioclase cores. The pink gneiss samples contain 50 to 60 percent microcline, and the plagioclase shows intense alteration to sericite. Samples of the gray gneiss collected within a few feet of the pink gneiss show a distinct decrease in the volume percent of sericite and microcline. The relatively unaltered gray gneissic rocks average about 10 percent microcline.

Samples of relatively unaltered dike rock exhibit subophitic to microporphyritic texture in thin-section. Plagioclase and pyroxene grains exhibit partial replacement by chlorite, and some plagioclase grains show minor sericite replacement. Opaques are generally unaltered except near quartz veins where they are progressively altered to hematite. Adjacent to one vein in the hoist room of the main haulage level, hematite occurs as fracture filling, and in places pervasively replaces the dike rock (Frontispiece). Near other areas of silicification, the dike rock is pervasively replaced by chlorite and quartz. Apparently, the mafic dike was emplaced along a northeast-trending fracture that was reactivated during mineralization.

Ore minerals recognized at the DePass Mine include chalcopyrite, malachite, azurite, cuprite, chalcocite, native copper, and chrysocolla and other copper silicates. Although primary sulfides were only rarely observed during this investigation, Bowdin (1918) reported localized chalcopyrite in the hoist room and in the lower workings (which are now inaccessible). Gangue minerals include milky quartz, pyrite, specular hematite, earthy hematite, limonite, goethite, and siderite. Love (1954) also reported radioactive minerals on the mine dump.

The quartz veins are confined within the mafic dike (Plate 2). A chip sample of milky quartz vein material collected from the easternmost vein exposed in the glory hole (Figure 4) assayed 0.96 percent copper with no detectable gold or silver. Immediately south of the glory hole, a composite sample from material collected every two feet over the 30-foot width of the exposed dike assayed 1.79 percent copper, 74 ppm nickel, and no detectable gold, platinum, or silver. This sample included both vein and dike material. A chip sample of mineralized dike with only minor silicification ran 0.7 percent copper. Although gold and silver were not detected in these three assay samples, historic smelter returns identified both precious metals.

The extent of the dike is not known, but early records indicate that the mine workings were developed to a depth (from the glory hole) of at least 810 feet. Mine reports also suggest that many of the drifts were in ore grade material. The extent of the mineralized dike along strike is also unknown. The dike can be traced on the surface for about 500 feet to the northeast of the glory hole, where it disappears under talus and the Flathead Sandstone. To the southwest, the dike can be traced a few hundred feet on the surface to where it pinches to a narrow altered zone. Further down the valley (Figure 3), the dike again widens, but is poorly silicified and mineralized. A historic cross section of the mine workings (Figure 4) shows a northeasterly drift of 750 feet and a southwesterly drift of 600 feet. On the basis of Bowdin's (1918) report and cross section, we estimate that the dike was mineralized over a strike distance of at least 1,350 feet and a vertical depth of at least 810 feet.

The authors mapped the accessible portion of the DePass Mine during field examination (Plate 2). The main haulage level was driven through 410 feet of pegmatite, biotite granite, biotite schist, and quartzofeldspathic gneiss along a S.70°E. trend to intersect the mafic dike. At the dike intersection, a hoist room was developed from which a winze projected downward to the lower levels. The lower workings are presently flooded to the collar of the winze. An exploratory drift ran southeast for about 20 feet from the hoist room and terminated in quartzofeldspathic gneiss. Another drift was developed northeast along the trend of the dike. A few feet into this northeast drift, a raise extends up to the glory hole. About 40 to 50 feet to the northeast of the raise is a stoped area that rises about 80 to 100 feet. The northernmost extent of the drift is still in mineralized ground (Frontispiece; Plate 2).

The quartzofeldspathic gneiss, which hosts the mafic dike in the main haulage level workings, has a foliation trend running roughly east-west. The dike does not follow the trend of foliation, but cuts the foliation at about a 40-degree angle.

According to Bowdin (1918), the De-

Pass Mine workings were well mineralized in copper, but apparently only sporadic samples contained gold and silver. At the bottom of the glory hole (Figure 4), a drift was developed along the northernmost vein in a northeasterly direction. This drift followed a five-foot-wide vein for 72 feet. Samples from this vein averaged 2.32 percent copper. Twenty-five feet above the main haulage tunnel, a drift to the southwest intersected a five-foot-wide vein. A sample collected from the back of this drift ran 3.10 percent copper, and a second sample, taken along the entire length (40 feet) of the drift, carried 2.02 percent copper. This later sample was taken from mafic dike rock (Bowdin, 1918).

Commencing from the haulage level hoist station, 72 feet to the northeast of the hoist station in the drift, Bowdin collected an eight-foot sample of cupriferous mafic rock with vein material that assayed 3.48 percent copper. In the drift southwest from the station, the vein was six feet wide and hosted primary sulfides (pyrite and chalcopyrite). This is where the first primary sulfides were encountered in the mine. Three samples were collected from this drift. The first sample was from the footwall of the vein and assayed 1.30 percent copper from a one-foot sample width. The second sample was taken from a five-foot width of the vein and assayed 1.6 percent copper. The third sample was from the floor of the drift across a six-foot width and ran 3.46 percent copper. No samples were collected from the lower mine workings, although Bowdin reported that visual examination indicated that the veins and mafic dike in these lower levels were as well, if not better, mineralized than the workings that he had sampled for assay.

Some gold and silver were reported in the workings. A sample collected in the main haulage tunnel assayed approximately 0.14 ounces of gold per ton. Bowdin indicated that the gold values were continuous. At the bottom of the shaft (possibly at the bottom of the raise, since Bowdin apparently did not sample the lower workings), the ore carried 0.08 to 0.10 ounces of gold per ton. In addition to gold, the ore reportedly carried no silver to 0.80 ounces per ton in silver (Bowdin, 1918).

Three samples collected during our field examination of the DePass Mine were assayed, but no gold or silver was detected. Our assay results and those reported by Bowdin (1918) point to gold and silver occurring sporadically, and not evenly distributed throughout the mineralized dike.

Bowdin (1918) reports that at least thirteen different lots of ore concentrates were shipped from the DePass Mine and Mill to the American Smelting and Refining company in Omaha during 1917 and 1918. Table 2 summarizes the smelter returns.

Beeler (1906) reported that ore shipped from the Copper Glance Group (part of the DePass property) included 31,209 pounds of ore concentrate shipped on August 4, 1906, which yielded \$847.67 in copper, \$65.54 in gold, and \$61.21 in silver. Another lot of 809 pounds of ore returned \$3.64 in gold, no silver, and \$127.89 in copper (all 1906 prices). The mine apparently terminated operations after Bowdin's visit in 1918, following the death of three miners by carbon monoxide poisoning (Henry Jensen, personal communication, 1984).

In summary, the DePass Mine is developed in a 30 to 50 foot wide mafic dike containing quartz veins. Both the dike and veins are mineralized in copper, gold, and silver. The extent of the mineralized dike is not known, but apparently continues to the northeast of the mine workings under Cambrian sedimentary rocks. To the southwest, the dike pinches to a small, narrow altered zone in granite. The dike has not been tested to the northeast or southwest from the DePass workings, nor has it been tested below a depth of 810 feet.

There is no question that the property is well mineralized in copper; but economically, the continuity and amount of gold and silver are critical. The DePass Mine appears to be a viable exploration target and will require detailed drilling and sampling for precious metals.

McGRAW MINE AREA

The McGraw Mine area, which includes several small mines and prospects located within one mile of the McGraw Mine, is hosted by Metamorphic Unit II. Important recognized deposits in this vicinity include iron deposits and cupriferous strike veins. South of the McGraw Mine, in the West Fork of Dry Creek valley, are several tungsten claims which were not examined during this investigation. All samples collected from the McGraw Mine area were examined with short-wavelength ultraviolet light for scheelite, but none contained visible tungsten mineralization.

McGraw Mine

The McGraw Mine is located in the central portion of the Copper Mountain supracrustal belt (Plate 1). Access to the mine is by rough dirt road through private property, either along the West Fork of Dry Creek from the south or along the West Bridger Basin from the the north.

The McGraw Mine consists of two shafts in SW1/4SW1/4 sec. 7, T.40N.,R.92W. The property occurs within Metamorphic Unit II (see Plate 1), which consists of intercalated quartzite, para-amphibolite, orthoamphibolite, metapelite, quartzofeldspathic gneiss, localized veins (or metacherts?), and iron formation, as well as amphibolite dikes or sills (Figure 5). The McGraw primary shaft is collared into an oxide-facies iron formation. The McGraw Mine dump consists of fragments of iron formation and amphibolite with only minor fragments of cupriferous quartz vein material. Because the iron formation is a low-grade iron resource, it is doubtful that this historic mine was developed for iron. The secondary or ventilation shaft located to the east of the primary shaft (Figure 5) was developed into a cupriferous vein which follows the country rock foliation. This vein trends to the southwest from the primary shaft and in all probability was the primary target for mining.

The "McGraw vein" is a milky quartz vein, or metachert(?), that trends parallel to the regional foliation of N.50°E. to N.70°E. and dips 76°S. Copper occurs as fracture filling and surface coatings. Like the majority of the veins examined on Copper Mountain, this deposit is intercalated in the metamorphic succession and exhibits no evidence of cross-cutting or distinct wallrock alteration. The vein at the McGraw Mine is enclosed by orthoamphibolite, lies adjacent to an iron formation, and carries copper. The close association of the vein with volcanogenic rocks suggests that this and similar veins could be siliceous exhalites.

Two samples of the McGraw vein were assayed. The first sample, copper-stained milky quartz selected from the mine dump adjacent to the McGraw primary shaft, assayed 0.29 percent copper and no detectable gold or silver. The second sample, a grab sample from the McGraw secondary mine dump, ran 0.12 percent copper with 0.04 ounces per ton gold and no detectable silver.

A sample of typical iron formation collected from the McGraw primary shaft assayed 33.9 percent iron with no detectable gold (sample number A1630, Table 3). A second sample (sample number A1307, Table 3) was assayed for copper and gold and yielded 0.02 percent copper with no gold. The iron formation at the McGraw primary shaft contained no visi-

*Table 3. Analyses of oxide facies iron-formation, Copper Mountain District, Fremont County, Wyoming (- implies no analysis; * implies sample stained with chrysocolla).*

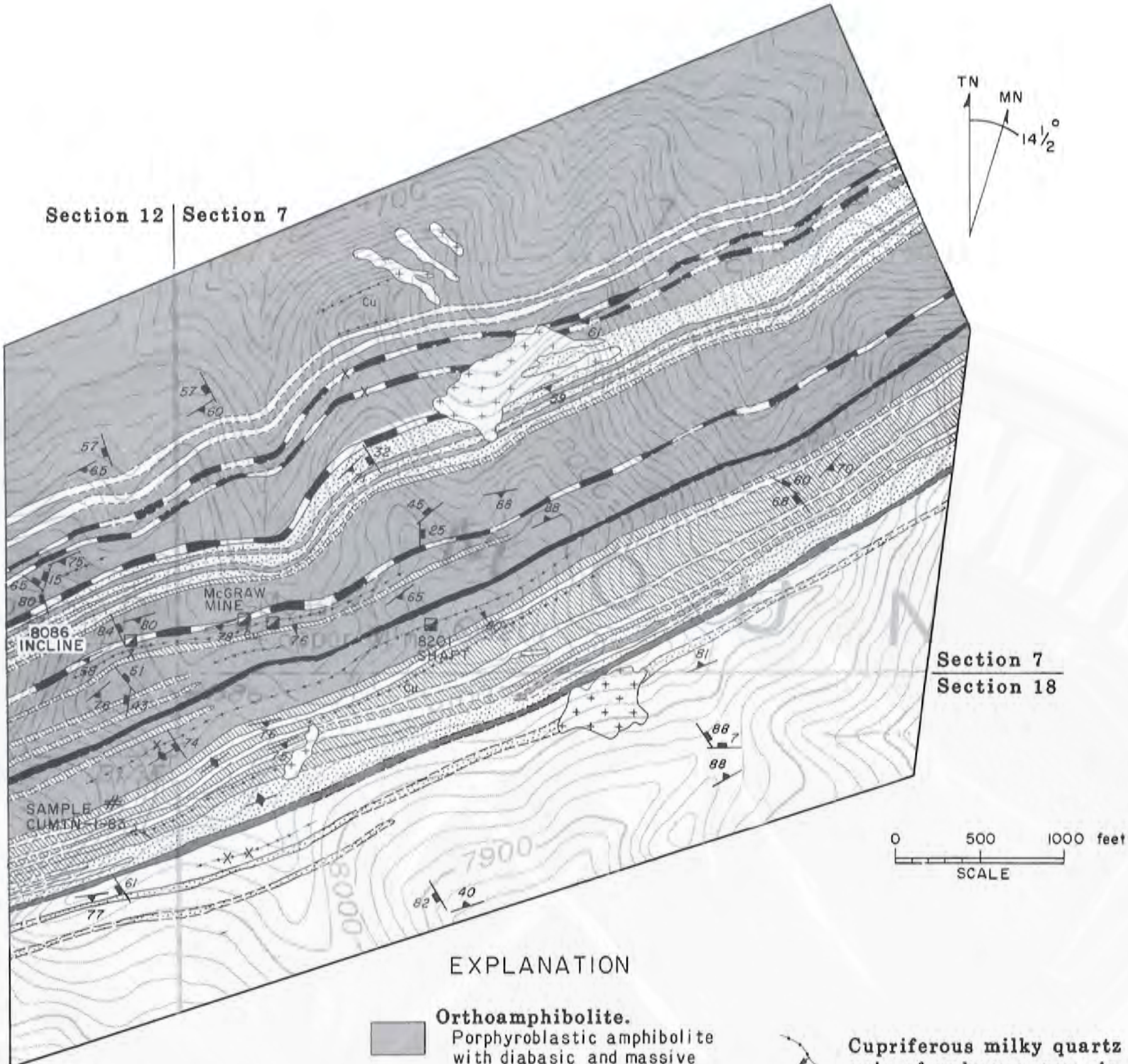
		Analyses (reported as oxides or elements)									
Sample number or description	Location (Section-Township-Range)	Fe (%)	FeO (%)	SiO_2 (%)	Mn (%)	TiO_2 (%)	P (%)	S (%)	Cu (%)	Trace elements detected†	Source
Birdseye Pass	15-40-94	36.8	-	48.9	0.005	0.16	0.07	0.03	-	Al,Ca,Mg,Cu,	1
Birdseye Pass	15-40-94	23.1	-	52.2	0.009	0.25	0.075	0.04	-	Ni,Cr,V,Zr	1
Hoodoo Creek	14,15,22,23-40-93	33.4	-	48.8	0.060	0.11	0.03	0.03	*	-	1
Hoodoo Creek	14,15,22,23-40-93	31.0	-	46.3	0.042	0.29	0.04	0.03	*	-	1
Dry Creek	13,14-40-93	32.3	-	49.5	0.009	0.19	0.05	0.03	-	-	1
Dry Creek	13,14-40-93	31.1	-	50.4	0.013	0.19	0.055	0.03	-	-	1
McGraw Mine	7-40-92	33.7	-	45.6	0.012	0.20	0.05	0.03	0.25	Al,Ca,Mg,Cu	1
Composite sample††	unknown	32.4	-	50.1	0.016	0.19	0.06	0.03	-	Ni,Cr,V,Zr	1
IF-100-32	12-40-93	28.17	-	-	-	-	-	-	-	Mn	1
IF-100-33	12-40-93	25.86	-	-	-	-	-	-	-	-	2
IF-100-34	12-40-93	30.40	-	-	-	-	-	-	-	-	2
IF-100-51	13-40-93	20.06	-	-	-	-	-	-	-	Mn	2
IF-100-7	13-40-93	22.09	-	-	-	-	-	-	-	-	2
IF-100-8	13-40-93	24.94	-	-	-	-	-	-	-	-	2
IF-100-13	23-40-93	25.23	-	-	-	-	-	-	-	Mn	2
IF-100-52	unknown	21.62	-	-	-	-	-	-	-	Mn	2
CM-16&17-11-22	15-40-94	-	15.6	-	-	-	-	-	-	-	2
CM-14&15-11-11	15-40-94	-	10.1	-	-	-	-	-	-	-	2
CM-12-11-11	15-40-94	-	6.6	-	-	-	-	-	-	-	2
CM-11-11-11	15-40-94	-	9.8	-	-	-	-	-	-	-	2
CM-10-11-11	15-40-94	-	9.8	-	-	-	-	-	-	-	2
CM-9-11-11	15-40-94	-	8.1	-	-	-	-	-	-	-	2
CM-8-11-11	15-40-94	-	10.6	-	-	-	-	-	-	-	2
CM-7-11-11	15-40-94	-	12.0	-	-	-	-	-	-	-	2
CM-6-11-11	15-40-94	-	6.9	-	-	-	-	-	-	-	2
CM-5-11-11	15-40-94	-	19.1	-	-	-	-	-	-	-	2
CM-4-11-11	15-40-94	-	7.8	-	-	-	-	-	-	-	2
CM-3-11-11	15-40-94	-	10.9	-	-	-	-	-	-	-	2
CM-2-11-11	15-40-94	-	16.3	-	-	-	-	-	-	-	2
CM-1-11-11	15-40-94	-	19.1	-	-	-	-	-	-	-	2
A1307 McGraw Mine	7-40-92	-	-	-	-	-	-	-	0.02	<0.01Au	3
CUMTN-2-83, 8086 incline	12-40-93	36.9	-	-	-	-	-	-	0.059	<0.01Au	3
A1630 McGraw Mine	7-40-92	33.9	-	-	-	-	-	-	-	<0.01Au	3

†Trace elements detected in semi-quantitative spectrographic analysis.

††Composite metallurgical sample, Owl Creek taconite

Sources: 1, Harrer, 1966; 2, Millgate and Gliozzi, 1966; 3, Hausel and Albert, 1983b

Figure 5 (opposite). Geologic map of the McGraw Mine area, in sections 7 and 18, T.40N., R.92W., and sections 12 and 13, T.40N., R.93W.



EXPLANATION

ARCHEAN INTRUSIVE ROCKS

Muscovite granite. Medium-grained hypidiomorphic granular granite with simple pegmatite phases.

Diabasic amphibolite. Small sill-like diabasic rocks exhibiting cross-cutting relations with adjacent rocks.

ARCHEAN SUPRACRUSTAL ROCKS

Quartzite. Orthoquartzite and fuchsite-bearing quartzite.

Iron formation. Banded oxide facies magnetite, quartz, amphibole rocks.

Orthoamphibolite. Porphyroblastic amphibolite with diabasic and massive texture, exhibiting weak foliation. May include some silicate facies iron formations.

Para-amphibolite. Fine-grained amphibolite with well developed schistosity.

Metapelite. Porphyroblastic muscovite schists. Common andalusite porphyroblasts. Includes some chlorite schist.

Quartzofeldspathic gneiss. Grey quartz, biotite, feldspar gneiss

Phyllite. Fine-grained brown to grey schistose rocks.

45 **Cupriferous milky quartz vein of unknown genesis, showing strike and dip of contact.**

Shaft.

Adit.

Prospect pit

80 **Strike and dip of foliation.**

Vertical foliation.

70 **Strike and dip of joints.**

Contact, dashed where projected and dotted where projection is unsure.

ble copper or sulfides, and consisted of banded magnetite, minor hematite, quartz, and amphibole. Harrer (1966) reported that a characteristic iron-formation sample from the McGraw Mine contained 33.7 percent iron, 0.012 percent manganese, 0.20 percent TiO_2, 0.05 percent phosphorous, 0.03 percent sulfur, 45.6 percent SiO_2, and 0.25 percent copper (see Table 3).

8201 Shaft

The 8201 shaft lies east of the McGraw Mine in S1/2SW1/4 sec. 7. T.40N., R.92W., 50 to 100 feet west of the 8201-foot bench mark (Figure 5). The property is located within Metamorphic Unit II (Plate 1).

The 8201 shaft was developed into a cupriferous milky quartz vein four to five feet wide that follows the regional foliation and is hosted by orthoamphibolite. This deposit trends N.60°E. and dips 80°S. The vein material is fractured and contains visible copper silicates and oxides as fracture filling and stains. Malachite, chrysocolla, and cuprite were all identified in hand specimen. One selected mine dump sample assayed 6.8 percent copper and no detectable gold.

8086 Incline

Shaft 8086 is an incline, estimated to be less than 100 feet deep. The incline is located in SE1/4 sec. 12, T.40N., R.93W., about 700 feet west of the McGraw primary shaft and within 100 yards of the 8086-foot bench mark (Figure 5).

The iron formation at the 8086 incline is the same iron formation as at the McGraw Mine, but here it contains visible copper silicates and, in places, limonite boxworks after sulfides. One selected sample of the cupriferous iron-formation assayed 36.9 percent iron, 0.059 percent copper, and no detectable gold (Sample No. CUMTN-2-83, Table 3).

Sample No. CUMTN-1-83

This sample was collected from mine dump material at a collapsed adit in NE1/4NE1/4 sec. 13, T.40N., R.93W. (Figure 5). The sample represents material from a cupriferous quartz vein hosted by pelitic and chloritic schists and minor amphibolite. The vein follows regional foliation. A grab sample from the mine dump assayed 1.58 percent copper, 0.26 ounces per ton gold, and no detectable silver.

West Bridger Mine

The West Bridger Mine consists of two adits in the West Bridger Basin located in N1/2 sec. 8, T.40N., R.92W. (Plate 1). The northern adit was developed in amphibolite and metapelite, and intersected iron formation. The southern adit was developed in amphibolite.

Both adits are caved and inaccessible. While the lower adit occurs in Metamorphic Unit II, the upper adit lies near the contact of Unit II with Unit III. Two samples were collected from the lower dump. An iron-formation sample yielded 0.06 percent copper and no gold. A selected cupriferous vein sample ran 9.0 percent copper and no gold.

GOLD NUGGET MINING REGION

The Gold Nugget mining region is located along the west flank of Copper Mountain (Figure 6). Rocks in the region are para-amphibolite, orthoamphibolite, quartzite, metapelite, and quartzofeldspathic gneiss. This region has characteristics of both Metamorphic Unit II and Metamorphic Unit III. Because of the predominance of metapelite at the Gold Nugget Mine, we include this region in Metamorphic Unit II (Plate 1).

Mineral deposits occur in quartz veins containing iron sulfides and sporadic gold. This district was developed by several small adits and prospects and serviced by a small mill in a tributary of Birdseye Creek (Hausel, 1982, p. 5). Since there is no evidence of tailings or waste rock near the mill, the mill apparently had only limited use. We examined only three mines in some detail during field reconnaissance. All three appear to have limited potential.

Gold Nugget Mine

The Gold Nugget Mine (SE$^{1/4}$SE$^{1/4}$ sec. 11, T.40N., R.94W.) was developed on a 30°SE to 40°SE dipping, three-foot-wide strike vein hosted by muscovite schist. The vein carries some sulfides (principally pyrite) and sporadic gold values.

The Gold Nugget Mine workings are now inaccessible. Bregy (1935) reported that the property was developed to a maximum depth of 400 feet with 1,190 feet of total workings. Access to the portal was through a northeast-trending adit at the southern edge of the vein, and this was intersected by two ventilation shafts located further up the hill. At the base of the mine dump near the adit are the remains of a trestle which apparently was constructed to run ore cars south from the Gold Nugget portal across the Birdseye Creek tributary to the Gold Nugget stamp mill, a distance of more than 300 yards.

The Gold Nugget vein is traceable on the surface to the northeast for about 700 feet to where it terminates against muscovite granite. At its northern extent, the vein is intruded and assimilated by granite. The vein is again found about 500 feet to the east; here it is hosted by the same metapelite, and has a dip of 60 to 65°S. It is visible eastward for only about 200 to 300 feet before it again disappears against the muscovite granite. Although this vein often produces interesting gold assays, the available gold resource is limited in tonnage. The Gold Nugget Mine area map (Figure 6) shows that the Gold Nugget vein lies within a roof pendant completely engulfed by granite. The vein most likely continues down dip for only a few hundred feet before it terminates against the granite.

Production reports on the Gold Nugget area are probably incomplete. Reported production was 1,700 tons of gold ore, mined prior to 1935. In 1935, the Gold Nugget Mine contained reserves of 16,500 tons averaging 0.42 ounces of gold per ton. An additional resource of 14,000 tons (no average grade given) was also indicated. Samples (presumably chip samples) taken in the mine drifts assayed from a trace to 2.37 ounces of gold per ton (Bregy, 1935).

In conclusion, the Gold Nugget vein is conformable to the foliation of the host metapelite sequence and may represent a reworked quartzite in which the silica has undergone intensive remobilization. Although gold values are reported in these rocks, geological relationships indicate that the reserve base in this property is limited.

East Fork Birdseye Creek Mines (Section 13 Mines)

Two portals located within 100 yards of one another (Figure 6) are shown in Figures 7 and 8. They are located in NE$^{1/4}$NW$^{1/4}$ sec. 13, T.40N.,R.94W., east of the Gold Nugget mill. The northern mine enters on a thin quartzite (Figure 7) which is, at the portal, a vein apparently resulting from silica remobilization. Thirty-five feet in, the tunnel splits into two parallel drifts. The northern drift follows a quartzite-metapelite contact and cuts a few small quartz stringers and sulfide stains. The south drift follows a contact between hanging wall amphibolite and footwall quartzite. A narrow vein continues only a short distance into this drift and terminates against a pegmatite.

A selected sample of limonite-stained quartz vein material with boxworks was collected from the mine dump. It yielded 0.77 ounces of gold per ton. The vein appears to be limited in size and extent.

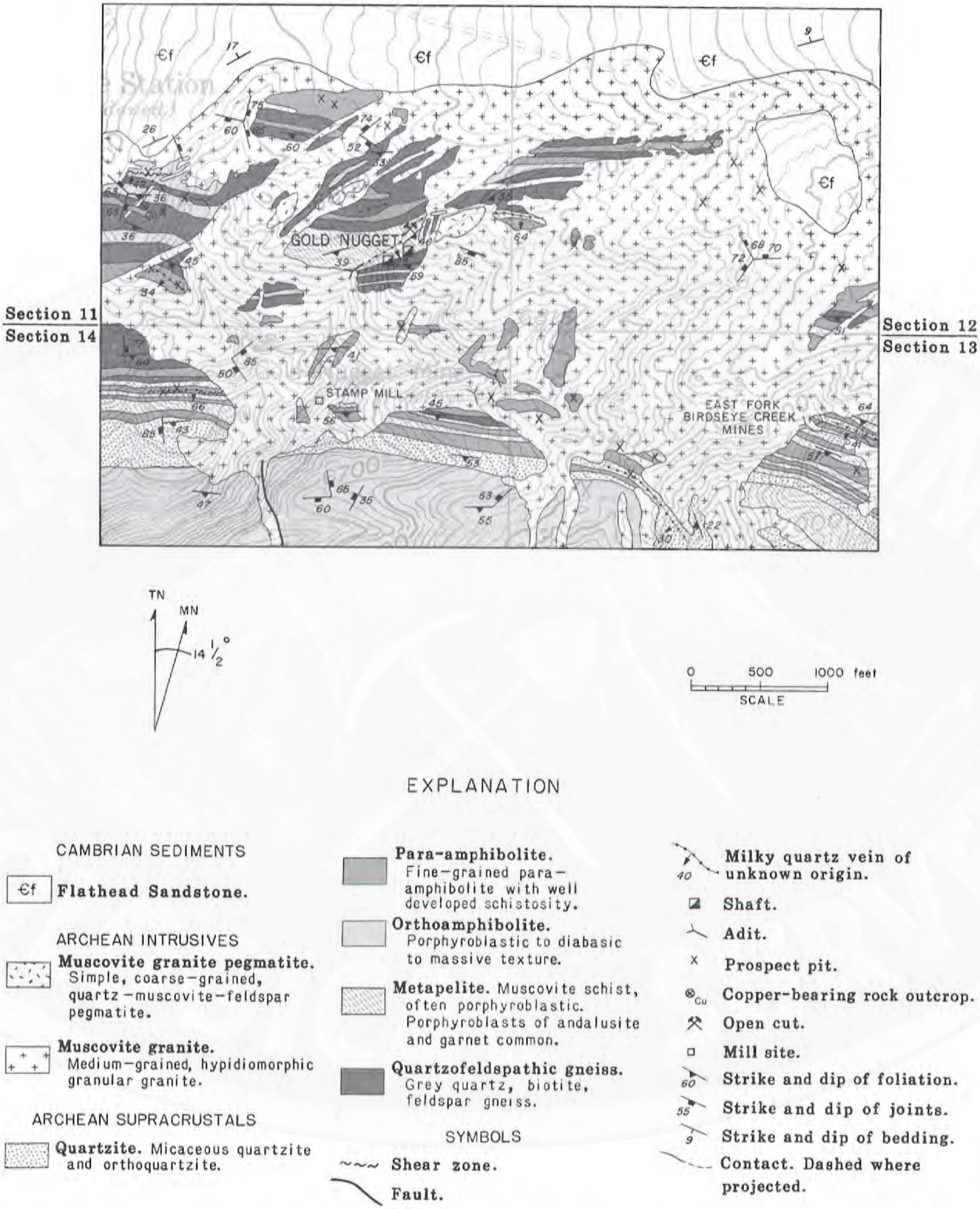


Figure 6. Geologic map of the Gold Nugget area, in sections 11, 12, 13, and 14, T.40N., R.94W.

The southern adit (Figure 8) lies a few hundred feet down drainage from the northern adit. This mine enters a muscovite granite pegmatite along a S.60°E. trend and continues for 160 feet. Twenty-five feet into the portal, the drift cuts a narrow, one-foot-wide, copper- and sulfide-stained vein that strikes N.12°E. and dips 65°NW. This was one of the few veins located in Copper Mountain that is not controlled by regional foliation. Unlike the Gold Nugget vein, this vein is hosted by granite and formed later than the Gold Nugget and similar veins. The mine terminates in amphibolite with very little indication of mineralization.

IRON FORMATION

Two types of iron formation are reported in the Copper Mountain region. An oxide-facies iron formation extends through Metamorphic Unit II of the metamorphic belt and forms fairly continuous units for eight to ten miles (Plate 1). Silicate-facies iron formation is reported in exposures along Wind River Canyon (Granath, 1975) and in Metamorphic Unit II.

Available assays report oxide-facies iron formation to run from 20 to 37 percent iron (Table 3). The silicate-facies iron formation was not assayed, and is assumed to contain less total iron. The reported assays indicate that the Copper Mountain iron formations constitute a low-grade iron resource, but the individual units of oxide facies rock are too thin (generally less than 20 feet thick) for economic mining at the present time. By adding the silicate facies to the oxide facies iron-formations, the available tonnage is greater, but average grade is significantly lower. Copper stains and limonite pseudomorphs observed at some iron-formation localities indicate that these units should be examined in detail for potential low-grade stratiform gold deposits.

The oxide facies iron formation is banded, with alternating magnetite and quartz-rich layers. The mineralogy of the rocks is simple: magnetite, quartz, and amphibole. The amphibole is principally grunerite, with minor riebeckite, cummingtonite, actinolite, and local hornblende (Gliozzi, 1967).

The silicate facies banded iron formation consists of dark green amphibolitic layers interbedded with gray to pale green, more siliceous layers. Weathered surfaces show characteristic iron staining. Mineralogically, these units consist of amphibole and quartz, with small amounts of garnet, pyroxene, opaques, and feldspars. In the Wind River Canyon, amphibole is 90 percent iron-rich hornblende with lesser amounts of grunerite (Granath, 1975), whereas grunerite is the predominant amphibole in Metamorphic Unit II (Gliozzi, 1967).

TUNGSTEN DEPOSITS

Scheelite ($CaWO_3$) was discovered on the Romur property in December 1941 by the use of ultraviolet light. The Romur property includes the Comet and Stardust Mines (sec. 22, T.40N., R.93W.).

Only minor production of tungsten has been reported. In 1942, a few tons of ore, averaging approximately two percent WO_3, were shipped; in the following year, 40 tons of ore, averaging three percent WO_3, were produced. This ore was produced from the Romur property. Production is also reported from the Whippet Mine. Three carloads of ore were shipped which averaged 1.47 percent, 0.16 percent, and 2.56 percent WO_3 (no date in Frey and Wilson, 1950).

The tungsten occurs as crystals and disseminated grains of scheelite in lenses and pods that lie parallel to the foliation of metamorphic rocks. The host rock is quartzofeldspathic gneiss with epidotite bands. The epidotite is associated with the gneiss and occurs as lenses and layers within the gneiss. Other deposits are reported in quartz veins and in schist (Frey and Wilson,

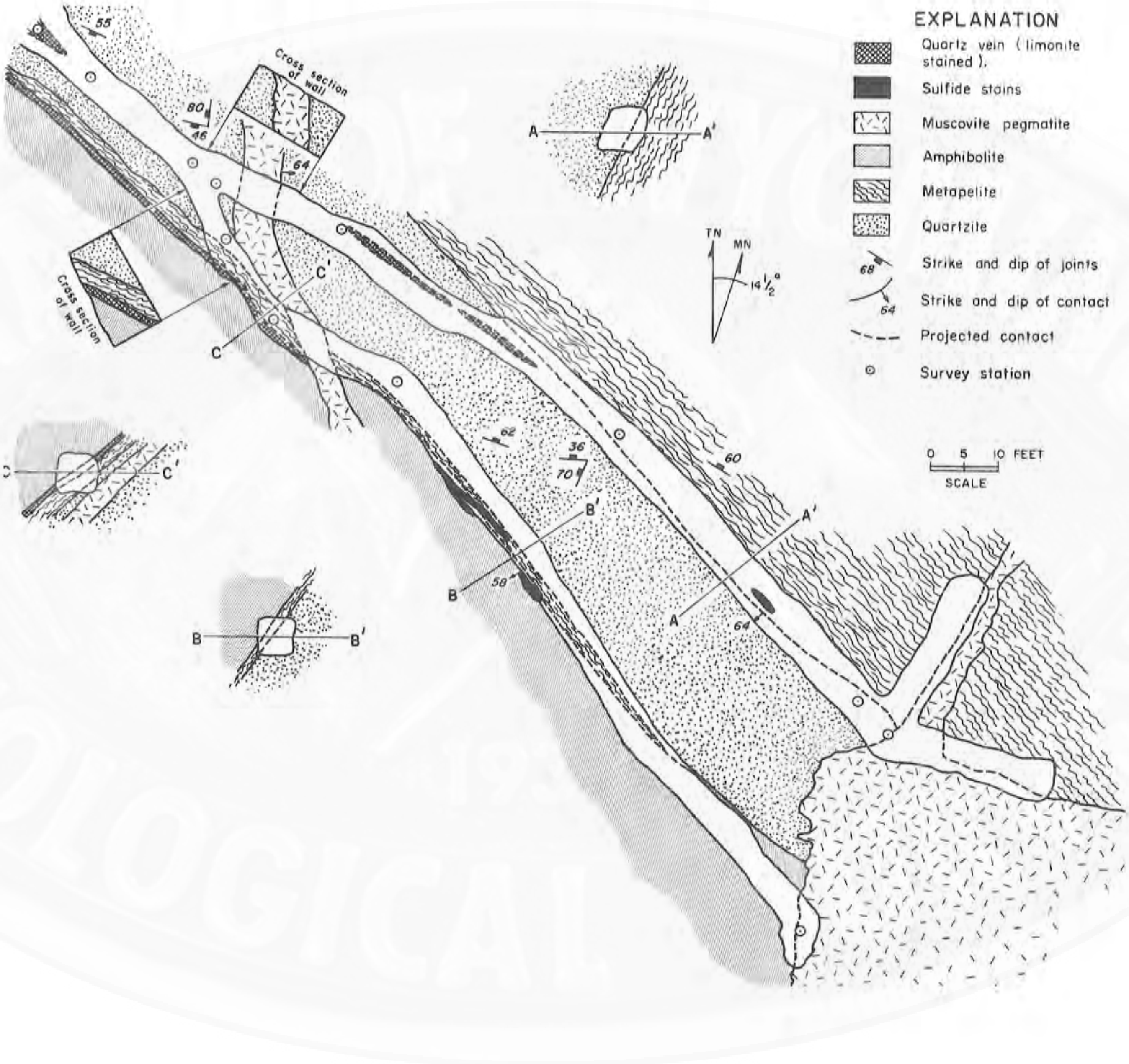


Figure 7. Geologic map of the north adit, East Fork Birdseye Creek, NE1/4NW1/4 sec. 13, T.40N., R.94W.

1950). The scheelite-bearing units have a foliation trend of N.70°E. to N.80°E. and dip 50°S.

Scattered outcrops of scheelite, which form an east-northeast trending zone, occur in a belt 2-1/2 miles long and 1/4 mile wide in sections 20, 21, 22, 23, 27, 28, and 29, T.40N., R.93W. These mineral deposits consist of numerous small shoots or pods composed of scheelite crystals in quartz gangue.

It is interesting to note that the tungsten in some of the quartzofeldspathic gneiss has essentially been described as being stratiform (Frey and Wilson, 1950). Additionally, some of the quartzofeldspathic gneiss contains sulfides, beryl, and tourmaline (Robert C. Berry, personal communication, 1984). Whether these minerals are syngenetic or metasomatic is not known. If syngenetic, such minerals would suggest an igneous genesis, but the presence of adjacent beryl- and tourmaline-bearing pegmatites suggests possible metasomatic replacement.

PEGMATITE DEPOSITS

Pegmatites are scattered throughout the metamorphic complex, and the majority are simple pegmatites consisting of bull quartz, muscovite, and potassium feldspar. A few pegmatites also contain beryl, columbite-tantalite, tourmaline, garnet, petalite, apatite, clevelandite, and lepidolite in addition to quartz, muscovite, and microcline.

At least two simple pegmatites have been mined for their feldspar resources in the recent past: the Quien Sabe and Blue Spar mines along Hoodoo Creek were mined for microcline (Hausel and Holden, 1978).

Two sets of pegmatite dikes intrude

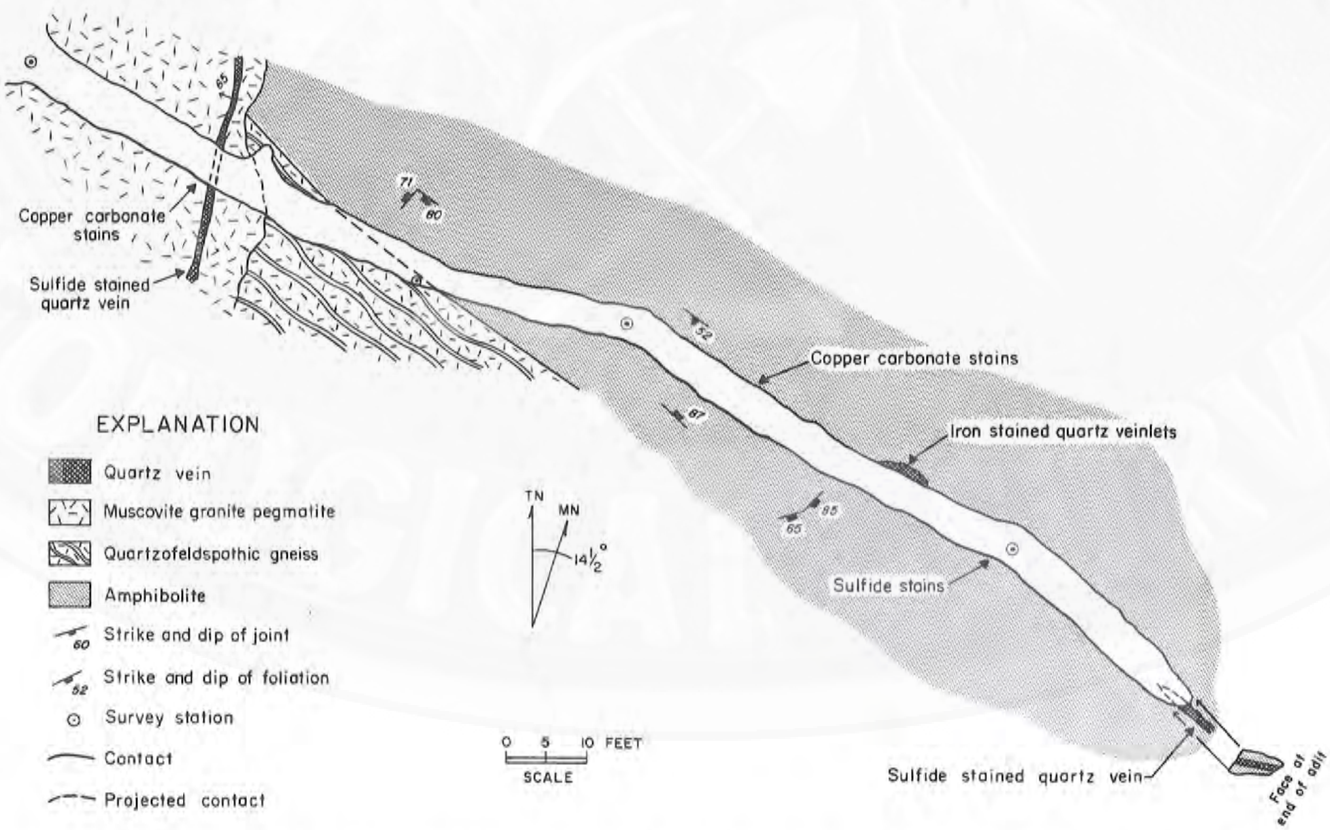


Figure 8. Geologic map of the south adit, East Fork Birdseye Creek, NE1/4NW1/4 sec. 13, T.40N., R.94W.

the country rock in the Copper Mountain area. The older set was intruded along a steeply dipping joint set parallel to regional foliation. The younger dikes follow joint sets that strike subparallel to regional foliation and dip north against the foliation. According to Kopp (1976), many of the dikes have narrow zones of alteration indicated by a hardening of the host schist. The few complex dikes are concentrated in a small area on the south side of the range in sections 21, 27, and 28, T.40N., R.93W.

The melt which formed the older dikes included silica-rich solutions which produced zones of alteration less than one yard wide. The altered zones exhibit additions of quartz and muscovite to the host amphibolite. The younger dikes show minor contact metamorphic effects. The hard, black, massive amphibolite has been altered to a dark greenish, friable material, but little mineralogical change is recognizable.

The younger pegmatites show various degrees of hydrothermal mineralization, ranging from unaltered to completely replaced dikes. The replacement minerals have been deposited in some dikes in distinct zones (McLaughlin, 1940).

URANIUM

The Copper Mountain uranium deposits are localized in outcrops of the Tepee Trail Formation (Eocene) and in propylitized fractures in Precambrian granite. Assays of some uraninite-bearing, brecciated, quartz-carbonate rock from the DePass Mine were reportedly between 0.41 and 1.03 percent U_3O_8 (Yellich and others, 1978; Cramer and others, 1979).

The uranium mineralization occurs (1) disseminated in boulder conglomerate and sandstone of the Tepee Trail Formation, and (2) localized along fractures in Precambrian granite. The genesis of the uranium has been attributed to two possible sources. Some propose that the uranium was leached from overlying Tertiary ash falls and localized where the uranium was reduced by organics (Yellich and others, 1978), and others suggest that the uranium was mobilized out of the Precambrian granite during the Laramide Uplift (Nkomo and others, 1978) and transported to favorable sites of deposition by low-temperature hydrothermal solutions (Shrier and Parry, 1982). These granites exhibit evidence of uranium loss (Nkomo and others). However, Laramide activity and burial by Eocene tuffaceous material are separated by little geologic time. It is possible that both may have contributed to the enriched deposits along the southern flanks of Copper Mountain. The Cambrian Flathead Formation on the northern flank of Copper Mountain may also be a host for unconformity-type uranium deposits, as well as for paleoplacer gold, although none have yet been identified.

PETROLEUM

Emplacement of the Precambrian slab during Laramide thrusting overturned and folded Paleozoic and Mesozoic strata below, and in front of, the thrust wedge (Plate 3). A number of fractures in Precambrian rocks along the southern flank of Copper Mountain are stained by hydrocarbons which have seeped up through the thrust sheet from underlying Phanerozoic rocks. Economic accumulations of oil do occur in fore-thrust and sub-thrust structures within the Madden, Lost Cabin, and Tepee Flats fields along the south edge of the Owl Creek Thrust (Figure 9). Domes and detachments provide interesting exploration plays (Plate 3).

SUGGESTIONS FOR EXPLORATION

The Copper Mountain supracrustal belt has been affected by more than one mineralizing episode. It is apparent that mineralizing events occurred during the Archean, Late Archean, Early Proterozoic, and Phanerozoic. But until detailed geochemical, isotope, and mapping studies can be completed for this region, much of any discussion concerning these mineralizing events will be speculative.

ARCHEAN MINERALIZATION

It is envisioned that the supracrustal pile was deposited during the Archean sometime prior to 2.7 billion years ago. Deposition occurred in a submarine, tectonically active basin and produced a thick succession of volcaniclastic rocks. Such tectonic settings are favorable for stratiform deposits, and, in particular, exhalative mineralization. No clear-cut exhalites have been identified on Copper Mountain, although iron formation is considered by many workers to be of exhalative origin.

Any exploration program at Copper Mountain or any similar supracrustal terrain should examine iron formation for low-grade gold mineralization. Auriferous iron formation in the Seminoe Mountains, nearly 100 miles to the southeast, appears to be closely associated with carbonate and sulfide replacement textures (Hausel, 1981). The association of gold with replacement textures and the presence of gold in adjacent amphibolite and quartz veins in the Seminoe Mountains are suggestive of remobilization or epigenesis (Hausel and Harris, 1983). But, whether gold in iron formation is syngenetic (e.g.

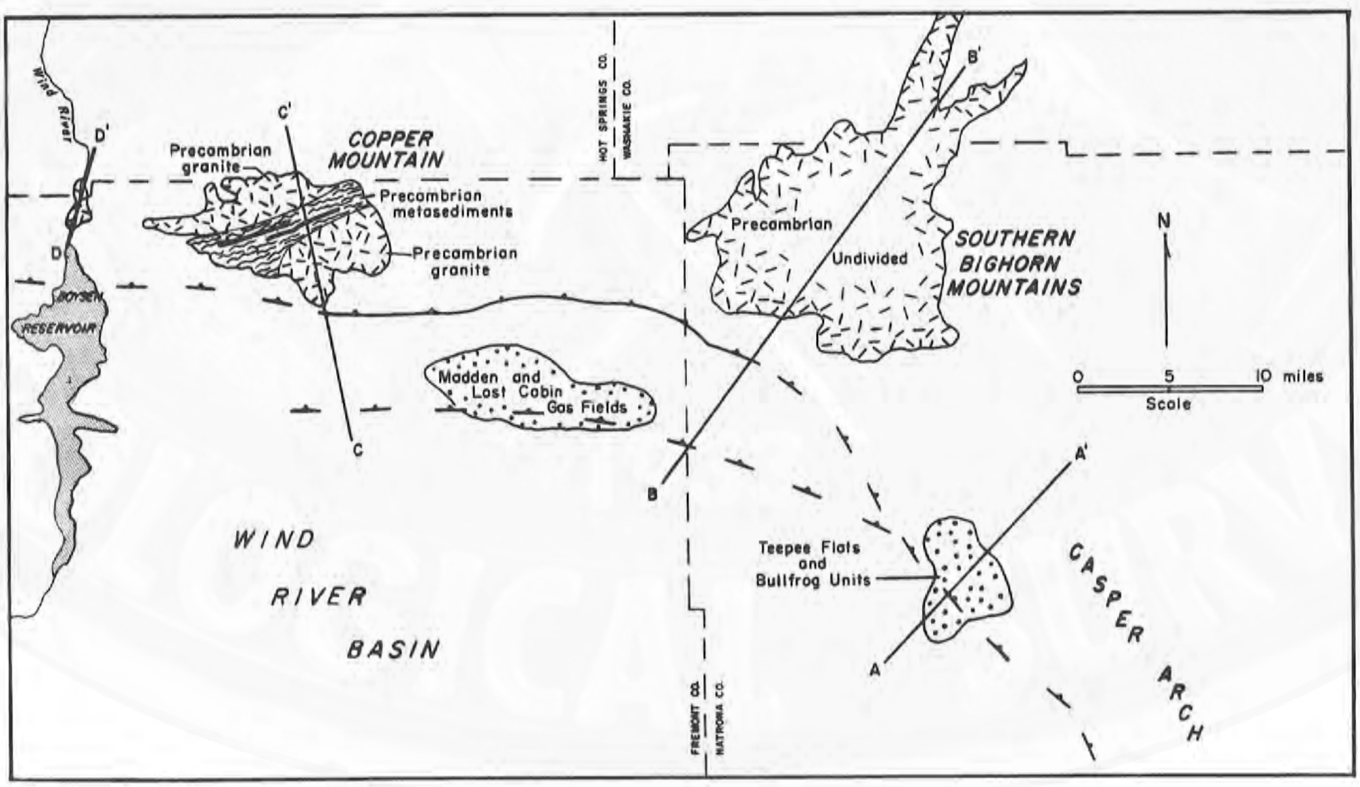


Figure 9. Location of major forethrust and subthrust hydrocarbon accumulations related to Laramide thrusting, Copper Mountain area. Schematic cross sections A-A', B-B', C-C', and D-D' are shown on Plate 3.

Fripp, 1976) or epigenetic (e.g. Phillips and others, 1984), gold has an affinity for iron, and thus iron formations represent a viable exploration target. In the vicinity of the McGraw Mine, boxworks, copper silicates, and copper carbonates were observed in iron formation. This area, and similar regions, should be considered in any sampling program for gold.

Some quartz veins at Copper Mountain follow regional foliation and are closely associated with iron formation and volcanogenic rock. These veins have been intensely metamorphosed, so that any primary textures related to their genesis have been destroyed. The origin of these strike veins may be hydrothermal, although no wallrock alteration has been detected; they may be metamorphic veins produced by dehydration during regional metamorphism; or they may be metacherts and represent highly metamorphosed siliceous exhalites. Many of these strike veins contain high-grade copper and detectable gold.

Similar strike veins in the Gold Nugget region are hosted by metasedimentary successions and contain very little to no copper and sporadic gold values. These veins are believed to represent intensely metamorphosed quartzites and are generally considered poor exploration targets. The Gold Nugget vein has some reported gold resources, but is part of a roof pendant completely surrounded by granite, and in all probability does not continue at depth.

Tungsten deposits in the vicinity of Hoodoo Creek were not examined during this project; however, early reports described many of these deposits as disseminated scheelite localized in layers, conformable to regional foliation and containing abundant zoisite and minor carbonate. The zoisite and carbonate occur as bands in quartzofeldspathic gneiss (Frey and Wilson, 1950). These tungsten deposits may have resulted from hydrothermal activity, as suggested by Frey and Wilson (1950), but the possibility that they are stratiform deposits hosted by metavolcanics should be considered in any exploration program.

LATE ARCHEAN MINERALIZATION

Near the end of the Archean, 2.7 billion years ago, the supracrustal pile at Copper Mountain was intruded by granite. The invading granite migmatized much of the adjacent supracrustal pile and produced hydrothermal alteration assemblages in the supracrustals. At this time, mineralization was introduced into the supracrustal pile along cross-cutting and possibly along strike veins, but only localized sulfides have been found in the granites and pegmatites, and in a few cross-cutting veins.

Microcline-rich, simple pegmatites have been mined in the recent past for their feldspar content (Hausel and Holden, 1978), and complex pegmatites near Hoodoo Creek contain varying amounts of beryl, lepidolite, tourmaline, columbite-tantalite, and chalcopyrite (McLaughlin, 1940).

EARLY PROTEROZOIC MINERALIZATION

Only a few Proterozoic mafic dikes have been mapped at Copper Mountain (Plate 1). They are unmetamorphosed, and are assumed to be about 2.0 billion years old, on the basis of comparison with similar tholeiitic dikes in the Bighorn Mountains to the east of Copper Mountain and in that part of the Owl Creek Mountains to the west of Copper Mountain. Dike exposures along the East Fork of Dry Creek have been heavily prospected. Thaden (1980) reported that many of these prospect pits were developed in radioactive gouge zones. Some prospects were undoubtedly developed to search for deposits similar to those at the DePass Mine.

The DePass Mine was developed into one of the Early Proterozoic dikes and contains more than 11,000 feet of workings, according to historic reports. This deposit generally averages 2.0 percent copper and yields sporadic gold and silver values. It is apparent from historic reports that the extent of the mineralized dike, along both strike and dip, has never been fully evaluated. With a more favorable copper market, this mine should become an important exploration target, not only to determine the extent of copper mineralization, but also to evaluate its associated precious and other metals.

PHANEROZOIC MINERALIZATION

Phanerozoic deposits of greatest interest are uranium and petroleum deposits. Uranium mineralization occurs in the Tepee Trail Formation (Eocene) and localized along propylitically altered fractures in Precambrian rocks. Uranium hosted by the Precambrian fractures is epigenetic and is assumed to have been introduced sometime during late Cretaceous to Early Tertiary time (Cramer and others, 1979). Some historic uranium production at Copper Mountain has been reported (Osterwald and others, 1966), and when the uranium market again becomes favorable, this region will undoubtedly attract some interest.

The northern flank of Copper Mountain is unconformably overlain by the Flathead Sandstone (Cambrian). This region could be favorable for unconformity-related uranium deposits (Ray Harris, personal communication, 1983).

The southern flank of Copper Mountain is formed by an overthrust of Precambrian rock which overlies a thick section of fractured and folded Phanerozoic sediments. Several fractures in the Precambrian on the overthrust plate are stained with asphaltic residue that indicates possible petroleum traps beneath the overthrust plate. Undoubtedly, this area will be subject to continued petroleum exploration for these overthrust-type deposits.

The potential for paleoplacer gold, hosted by the Cambrian Flathead Sandstone, has not been tested to date. Fluvial facies within the Flathead (Cambrian) should be examined for both gold and uranium. Finally, placer gold has been reported along Badwater Creek and the Wind River. These occurrences have never been fully evaluated.

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STATE OF WYOMING

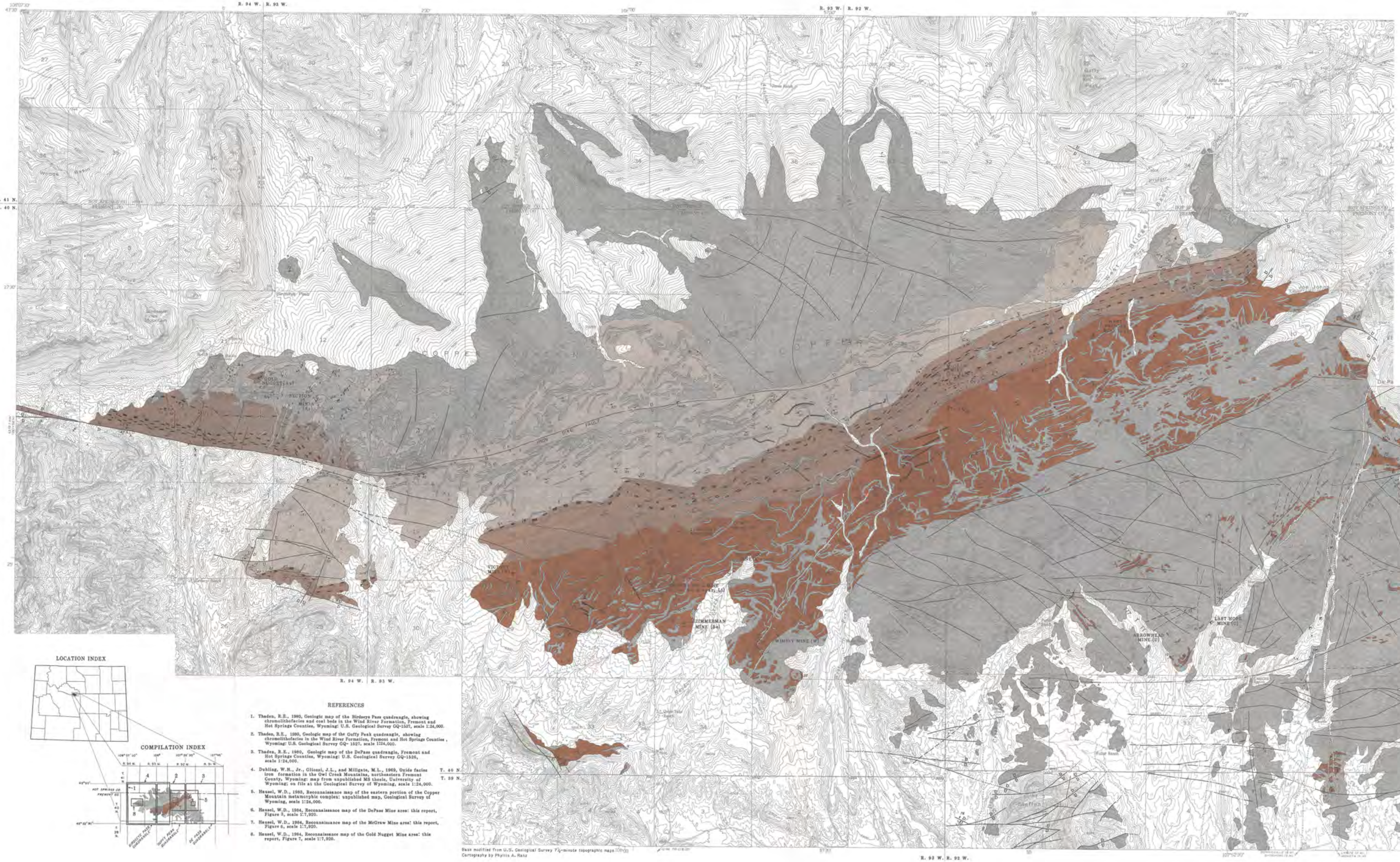
1933

GEOLOGICAL SURVEY

THE GEOLOGICAL SURVEY OF WYOMING
Gary B. Glass, State Geologist

GEOLOGIC MAP OF COPPER MOUNTAIN, OWL CREEK RANGE, WYOMING

Compiled by W. Dan Hausel
1985



Base modified from U.S. Geological Survey 7½-minute topographic maps
Cartography by Phyllis A. Ranz

EXPLANATION

PHANEROZOIC ROCKS

Sedimentary rocks and surficial deposits undivided.

PROTEROZOIC(?) DIKES

Mafic dikes. Finely crystalline greenish black ophitic to subophitic basaltic dikes. Consist of augite, plagioclase (Ab_{45}) and minor magnetite.

ARCHEAN INTRUSIVE ROCKS

Granitic rocks. Predominately quartz-microcline-biotite granite, quartz-microcline-muscovite granite, and quartz-microcline-plagioclase-biotite-muscovite granite. Lesser amounts of quartz monzonite, syenite, and granodiorite, with numerous aplite and pegmatite dikes. Pegmatites generally exhibit coarse-grained potassium feldspar, bull quartz, and mica. Along the southern margin of the range in the vicinity of the Quien Sabe Mine, pegmatites contain beryl, lepidolite, and tourmaline, in addition to feldspar, quartz, and mica.

ARCHEAN AMPHIBOLITE DIKES

Uralitized amphibolitic dikes and sills.

SCALE 1:24,000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Approximate mean magnetic declination = 14½°

ARCHEAN SUPRACRUSTAL ROCKS

METAMORPHIC UNIT I

Consists of alternating quartzofeldspathic gneiss and amphibolite with intercalated biotite schist. Dominantly amphibolitic to the south.

METAMORPHIC UNIT II

Quartzite. Massive brown and greenish fuchsite quartzite. Relict sedimentary structures are poorly preserved.

Iron Formation. Predominately oxide facies with minor silicate facies iron formation. Consists of layered quartz-magnetite and amphibolite-magnetite bands. In the vicinity of Wind River Canyon (to the west of the mapped area), iron formation is predominately silicate facies.

Metapelite. Garnet-biotite schist, andalusite-muscovite schist, and cordierite-muscovite schist.

Amphibolite. Both para-amphibolite and orthoamphibolite. These are hornblende schist, hornblende-quartz-plagioclase schist, cummingtonite schist, and cummingtonite-grunerite schist. Orthoamphibolite exhibits ophitic to subophitic texture. Para-amphibolite exhibits well developed schistosity.

METAMORPHIC UNIT III

Consists predominately of amphibolite schist and gneiss and orthoamphibolite with lesser quartzofeldspathic gneiss and minor iron formation, pelitic schist, and fuchsitic quartzite. Rocks are veined and fractured and exhibit epidote replacement and fracture filling, sericitization, and microcline replacement of plagioclase.

Marble. Local pods of grey calcite marble.

SYMBOLS

Contact, short dashes where indefinite.

Fault, short dashes where indefinite and dotted where concealed. U=upthrown side, D=downthrown side.

Synform, showing direction of plunge.

Strike and dip of foliation

Vertical shaft

Inclined shaft. Tail indicates direction of incline

Adit

Prospect pit

Open cut

Open cut, too small in area to show at this scale.

Ag, Au, Be, Cu, K-spar, Li, Ta, U, W — Type of mineral deposit. Ag=silver, Au=gold, Be=beryl, Cu=copper, K-spar=potassium feldspar, Li=lepidolite (lithium), Ta=tantalite, U=uranium, W=tungsten.

Quartz vein. Arrow indicates direction of dip.

Silicified rock

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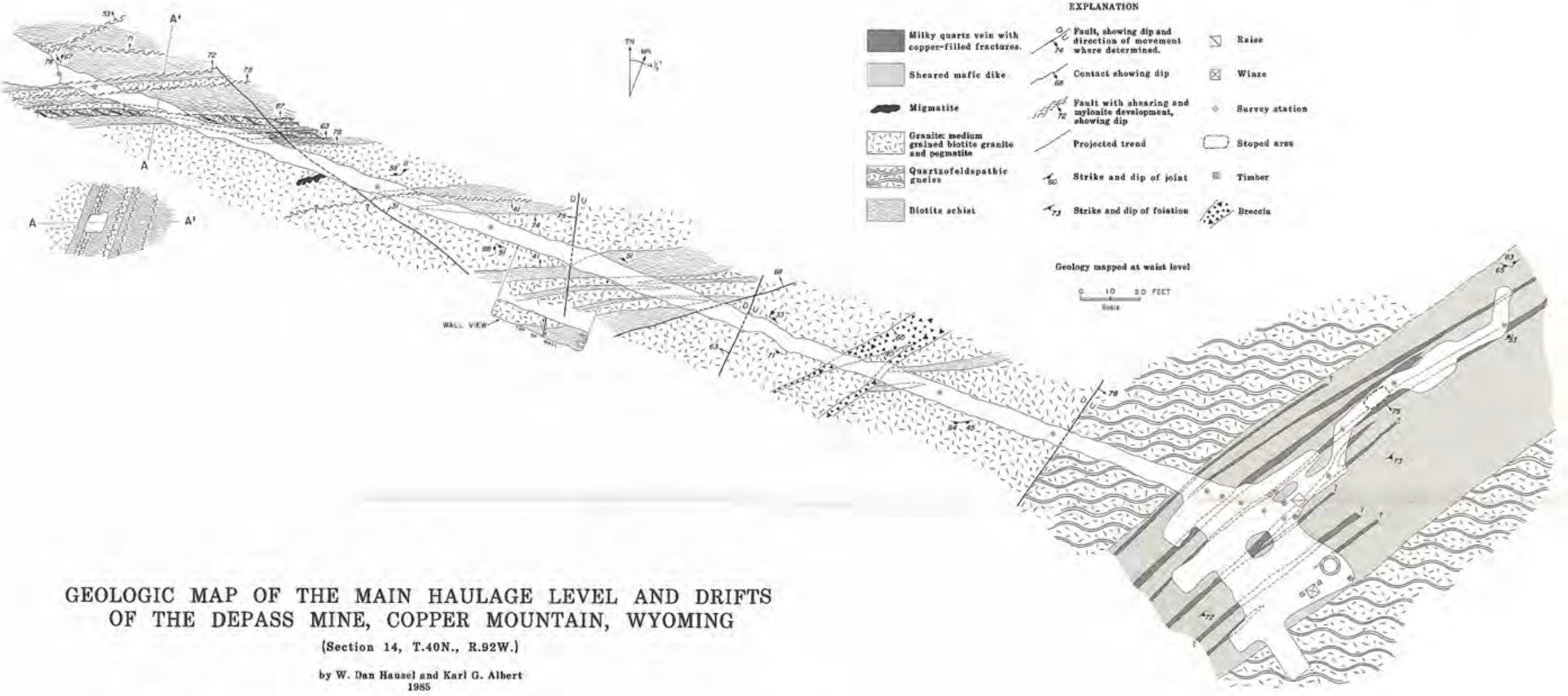
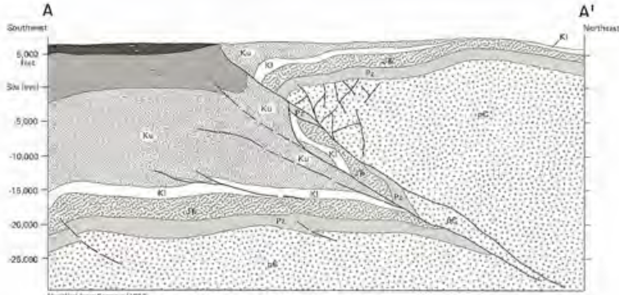


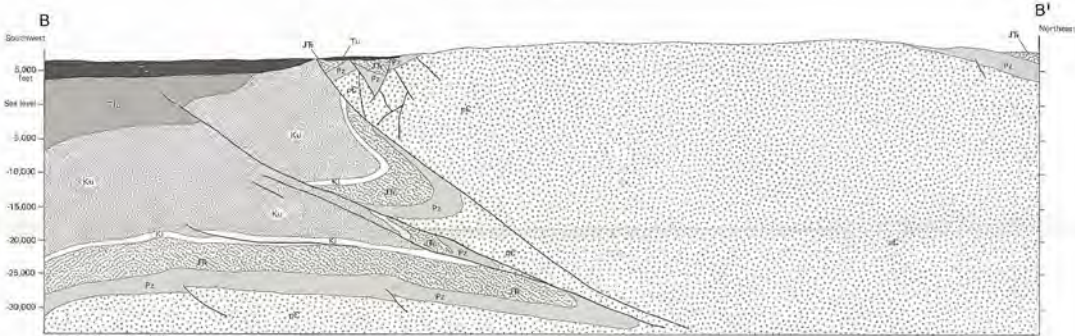
GEOLOGIC MAP OF THE MAIN HAULAGE LEVEL AND DRIFTS OF THE DEPASS MINE, COPPER MOUNTAIN, WYOMING

(Section 14, T.40N., R.92W.)

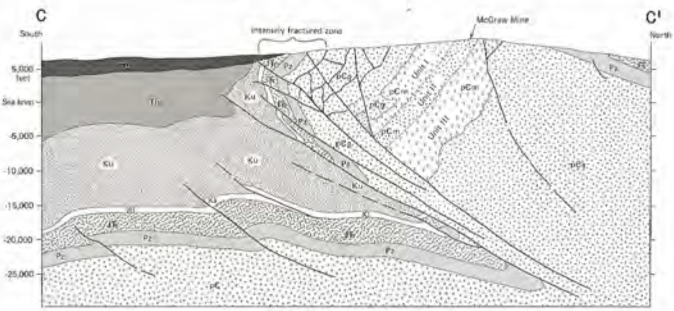
by W. Dan Hausel and Karl G. Albert
1985



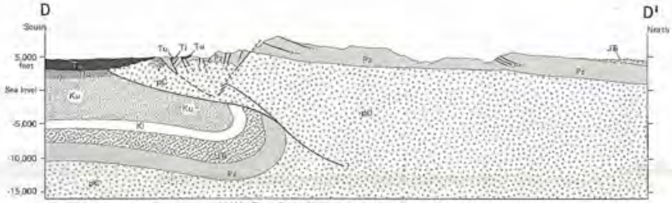
CASPER ARCH



SOUTHERN BIGHORN MOUNTAINS



COPPER MOUNTAIN



WIND RIVER CANYON AREA

EXPLANATION

Tu — **Upper Tertiary rocks**
Includes the Wind River and White River Formations.

Tfu — **Lower Tertiary Fort Union Formation**

Ku — **Upper Cretaceous rocks**
Includes the Lance, Fort Union, Meeteetse, Mesaverde, Cody, Frontier, and Niobrara Formations.

Kl — **Lower Cretaceous rocks**
Includes the Mowry, Thermopolis, and Cloverly Formations.

JR — **Jurassic and Triassic rocks**
Includes the Morrison and Sundance Formations and the Chugwater Group.

Pz — **Paleozoic rocks**
Includes the Phosphoria, Tensleep, Amsden, Madison, Bighorn, Gallatin, Gros Ventre, and Flathead Formations.

pC — **Precambrian undivided**

pCg — **Precambrian granite**

pCm — **Precambrian metasedimentary — metavolcanic rocks; metamorphic units designated I, II, and III.**

Fault, dashed where inferred

SCHEMATIC CROSS SECTIONS ACROSS THE CASPER ARCH, THE SOUTHERN BIGHORN MOUNTAINS, COPPER MOUNTAIN, AND WIND RIVER CANYON

(See Figure 9 for locations of cross sections)