GEOLOGICAL SURVEY OF WYOMING

GEOLOGICAL RECONNAISSANCE REPORT OF METALLIC DEPOSITS FOR *IN SITU* AND HEAP LEACHING EXTRACTION RESEARCH POSSIBILITIES

by

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

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PURPOSE

Cursory reconnaissance and literature research were implemented during the 1982 summer field season in order to gather basic geological data on several mineral deposits in the State of Wyoming that hosted strategic metals. Some of the strategic metals that were searched for included copper, lead, molybdenum, platinum, silver, titanium, zinc, and cobalt. The purpose of this report and research project was only to provide basic background geological information on several different deposits hosting strategic minerals such that, at a later date, if a Center for Hydrometallurgy and In Situ Extraction is established at the University of Wyoming (Gunn, 1982), the initial steps would have been taken to locate a metallic deposit amenable to hydrometallurgical or in situ extraction research.

This report is preliminary in nature and is not intended as a final report. With a period of only three months working time, it was impossible to complete all geological assessments required for extraction research.

INTRODUCTION

Recent discussions relating to various aspects of leaching of mine dump and in situ metallic deposits are reported in anonymous (1981), Clem (1982), D'Andrea and others (1977), Murr, (1980), and Potter (1981). The reader is referred to these papers in that no discussion of the engineering aspects of leaching is intended in the following text.

Several "hard rock" metal deposits were examined during the 1982 summer. For the most part, these deposits were only briefly examined and more detailed work is necessary before a favorable geological site or sites can be selected for hydrometallurgical, or in situ, extraction research.

Prior to the final selection of a deposit for the extraction research, much more detailed geological research will be necessary. This research should include detailed petrographic studies of the host rock; ore mineralogy and alteration characteristics; detailed geophysical surveys and drilling programs; and detailed geological maps. These studies are recommended as an extension of this project, if a Research Center is established.

The examined areas include gold-platinum deposits in the Centennial Ridge and Douglas Creek (New Rambler Mine) districts of the Medicine Bow Mountains (Albany and Carbon counties), copper-gold-silver deposits in the Silver Crown District of the Laramie Range (Laramie County), titaniferous black sands of the Sheep Mountain area (Albany County), copper-zinc-silver deposits in the Lake Alice District of the Thrust Belt (Lincoln County), and copper-molybdenum deposits in the Sunlight Basin and Kirwin areas of the Absaroka volcanic plateau (Park County) (Figure 1).

CENTENNIAL RIDGE DISTRICT

Location

The Centennial Ridge District is located southwest of Centennial, within T.15N., R.78W. of the Medicine Bow Mountains (Figure 1). Access to the district is by four-wheel-drive and logging roads along the Middle Fork Canyon of the Little Laramie River (Figure 2).

General Geology

The district encompasses several inactive mines that were first developed for gold and platinum in the late 1800's and early 1900's. The largest mine dump in the district is that of the Cliff Gold Mine, which is located less than ½ mile south of the Independence Mine. The Cliff Gold Mine workings are caved and inaccessible. During examination of this district by the Wyoming Geological Survey from 1980 to 1982, only four mines had accessible workings--the Empire, the Columbine, the unnamed portal in SW¼ sec. 17, and the Independence mines. Of these mines, only the Empire Mine was not entered and mapped because of its narrow workings.

Although bedrock exposures in the district are predominately Precambrian in age, Pleistocene to Recent alluvial, colluvial, and talus deposits are present, but sparsely distributed. The bedrock has been subdivided into six general units by McCallum (1968) (Figure 3):

(1) Mafic Series (p€ms) rocks consisting of amphibolite-biotite schists and gneisses.

(2) Lime-silicate rocks which include: pyroxene gneiss (p€pg), lime-silicate marble (p€lms), and skarn-like rock (p€sk).

(3) Felsic gneisses which consist of cataclastic biotite augen gneiss (p€ag), mylonitic biotite-epidote-plagioclase gneiss (p€mg), and quartz monzonite gneiss (p€qmg).

(4) Amphibolitized metaigneous rocks (p€a).

(5) Granitic intrusive rocks (p€sq; p€ai) and

(6) Shear zone tectonites.

The dominant foliation and schistosity in the district trends northeasterly and dips steeply. Intrusive rocks are essentially concordant

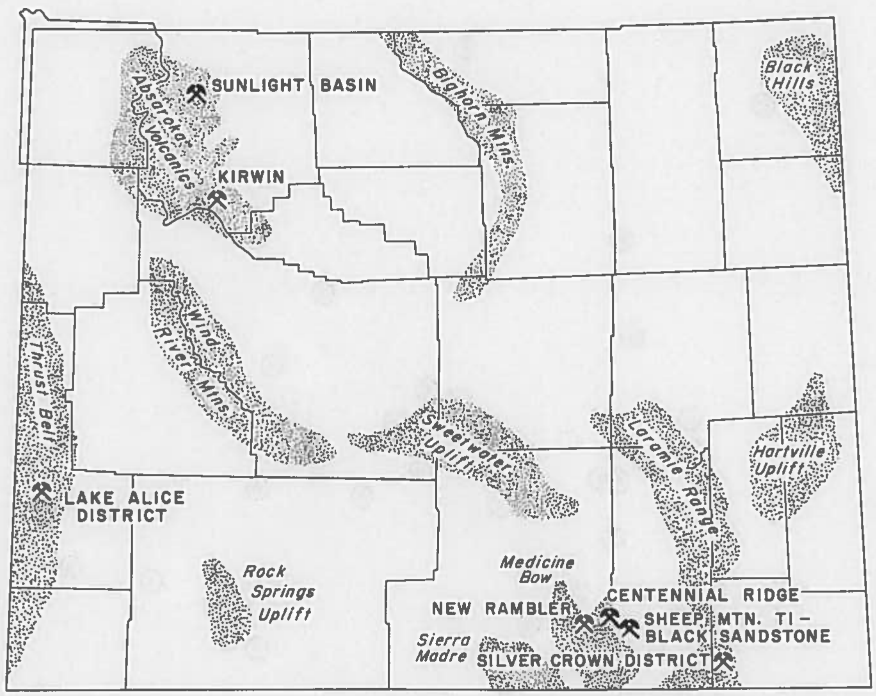

Figure 1. Location map of metallic mineral deposits examined for in situ-heap leaching extraction possibilities.

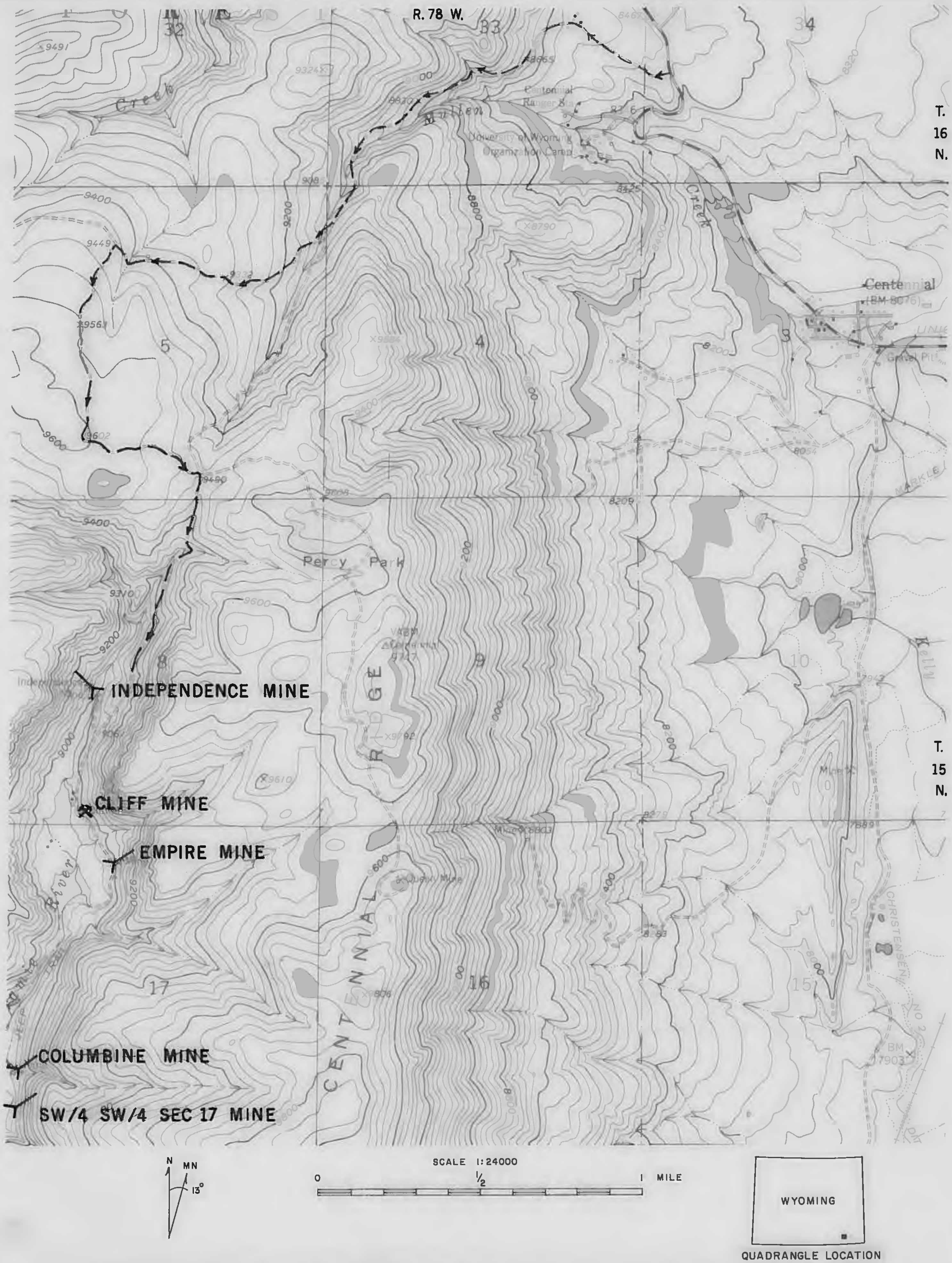

Figure 2. Access map to the Middle Fork Canyon, Centennial Ridge District (T.15N., R.78W.), Albany County.

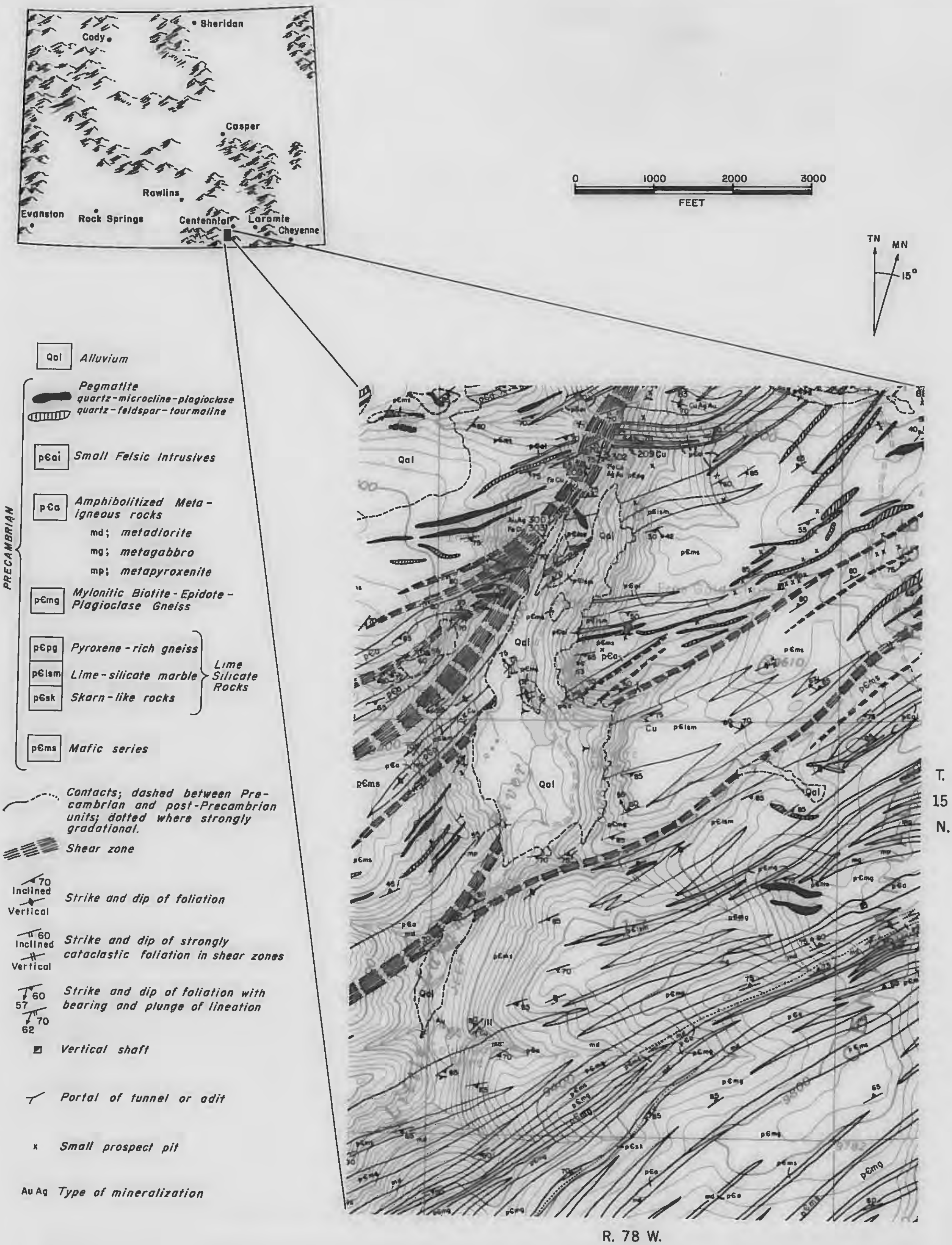

Figure 3. Geologic map of the Middle Fork Canyon area of the Centennial Ridge District (after McCallum, 1968).

with their host metamorphic rocks. Although the shear zones, which trend northeasterly, are concordant in most places, they are disconcordant at other localities (McCallum, 1968).

Mineral Deposits

Potential economic mineralization in the Centennial Ridge District is reported as gold-silver metals with platinum values in intensely-sheared rocks. Platinum group metal values generally are associated with sulfides and/or arsenides in shear zones, quartz veins, and pods within Mafic Series rocks. Secondary mineralization occurs as placer gold in alluvial deposits along the Middle Fork.

The primary mineral deposits occur as fracture and breccia fillings where shears or faults cut amphibolitized Mafic Series metaigneous rocks. This intimate association of mineralization with the Mafic Series rocks suggests that their genesis is related. The metals occur predominately as sulfides associated with graphitic fault gouge, brecciated mafic mylonites and strongly chloritized wall rock. Pyrite is the common sulfide with lesser amounts of arsenopyrite and cobaltian pyrite. Most of the deposits show some degree of sulfide alteration to limonite. Chalcopyrite may occur locally along with small amounts of malachite, azurite, and chrysocolla.

As to how, or as to which mineral specie platinum occurs, is not known. The presence of arsenic in these ores and the identification of platinum arsenide (sperrylite, $PtAs_2$) at the New Rambler Mine a few miles to the southwest suggest that the platinoid minerals may occur as disseminations in sulfides (McCallum, 1968).

Because of the extensive shearing in the district, excursion of leach solutions through these permeable fractures would cause problems. The high permeability of the shear zones is demonstrated by the constant dripping of water from the fractures in the Independence Mine through much of the year. Mine dump tonnages are limited and may not provide sufficient volume for a feasible heap leaching test site.

The accessible mines were mapped by Hausel (1980) although only the Independence Mine was examined in the field during this study (Figure 4).

Independence Mine

The Independence Mine is located along the Middle Fork of the Little Laramie River and within 200 feet of that river. The mine workings were developed on a N35^{o}W trend into sheared amphibolite schist and intersected five separate shears within 80 feet of the adit (Figure 4). At 30 feet into the primary drift, a second drift followed a N68^{o}E trending shear for 110 feet to the southwest. The face of this drift is highly fractured.

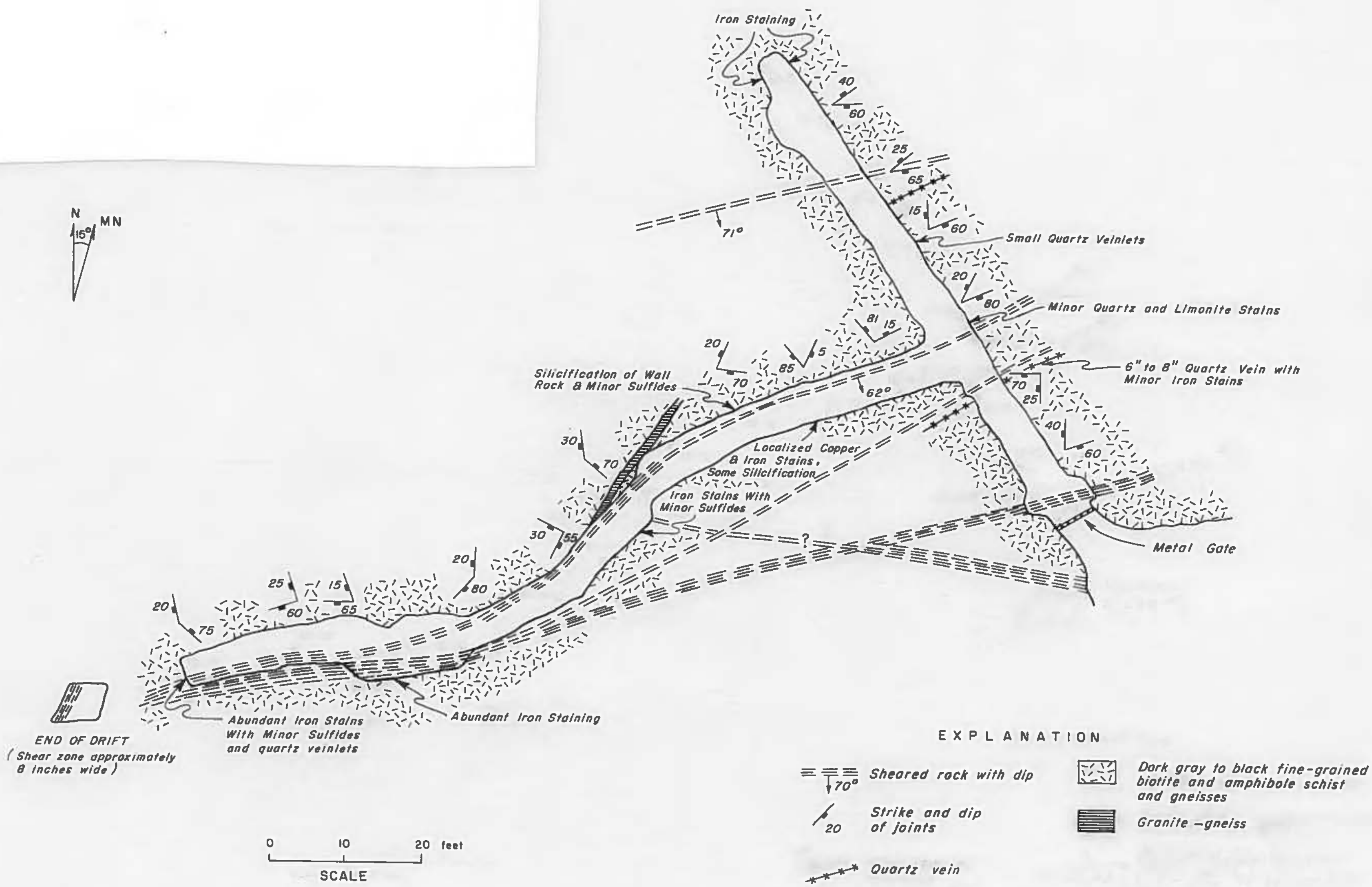

Figure 4. Geologic map of the Independence Mine, Centennial Ridge District (after Hausel, 1980). See Figure 2 for location.

Source	Au oz	Ag oz	Pt oz	Ir oz	Pd oz	Os oz	Ru oz	Rh oz	Cu	Ni
Private comm. to M.E. McCallum	0.31	n.d.	?	?	?	?	n.d.	0.41	n.d.	n.d.
Private comm. to M.E. McCallum	0.36	n.d.	?	?	?	?	n.d.	0.45	n.d.	n.d.
Geol. Survey Wyo. files	0.08	0.22	0.27	0.46	--	0.10	--	0.03	n.d.	n.d.
McCallum, 1968	0.01	0.08	--	--	--	--	--	--	+	+
P. Theobald, U.S. Geol. Survey	n.d.	n.d.	0.01	n.d.	0.02	n.d.	n.d.	n.d.	n.d.	n.d.
Private comm. to W.D. Hausel	n.d.	n.d.	0.50	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Wyo. Analytical Labs.	0.03	n.d.	tr.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Wyo. Analytical Labs	0.03	n.d.	tr.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Wyo. Analytical Labs	0.01	n.d.	tr.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Wyo. Analytical Labs.	0.01	n.d.	tr.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

n.d. = not determined
\+ = present
? = questionable assay, not listed
tr. = trace ($\leq$0.01 oz./ton)

Table 1. Reported assays from the Independence Mine.

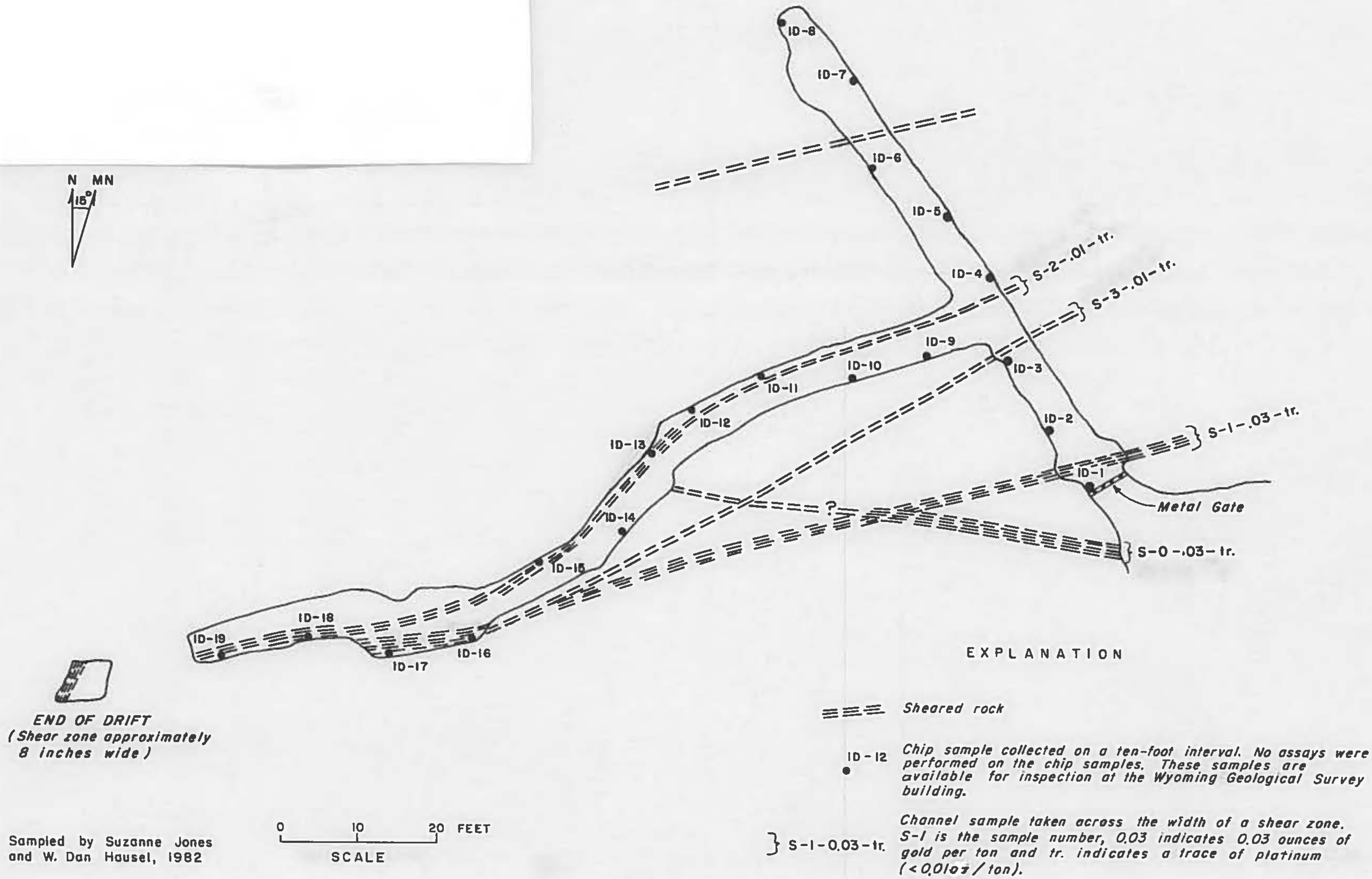

Figure 5. Assay and sample location map of the Independence Mine, Centennial Ridge District.

The shears are very permeable as is evidenced by the persistent flow of water through these fractures into the mine workings during the late spring and early summer months. The nonsheared, fine-grained biotite-amphibolite schist exposed throughout much of the workings is a competent, non-permeable rock, except (of course) where it is fractured.

Reported assays by McCallum (1968, Table 1) suggest that the Independence may contain low-grade gold-platinum resources. However, channel samples collected perpendicular to the strike of the shear zones (Figure 5) show only trace amounts of these metals, and are not encouraging. Samples collected by the authors are combined with reported assays by McCallum in Table 1.

In addition to the channel samples, chip samples were collected on a 10-foot spacing (Figure 5). These samples were not assayed and remain at the Wyoming Geological Survey for public inspection. In general, these show only trace amounts of sulfides.

Two additional mines were mapped: the Columbine (Figure 6), and the unnamed mine in SW¼ SW¼ sec. 17 (Figure 7).

The Columbine Mine (sec. 17, T.15N., R.78W.) was opened on a N45°E shear zone trend and extended 50 feet into the biotite-amphibolite schist (Figure 6). Fracture surfaces contain weak limonite and sulfide stains and disseminations. Overall, the workings expose very poorly mineralized rock. One assay, reported by McCallum (1968 , Table 1) indicated the presence of copper, but not the concentration.

The unnamed mine in SW¼ SW¼ sec. 17 (T.15N., R.78W.) (Figure 7) was drifted 145 feet on a N35°W trend following two weakly mineralized shears. The only indication of mineralization was weak iron and sulfide stains in shear zone fractures. The drift intersected several small barren quartz veins. No samples were collected for assay because of the weak appearance of mineralized rock.

A sketch map of the Empire Mine was published by Finch (1925). This map is shown in Figure 8 and suggests that the workings extended more than 150 feet on a N82°E trend. Although the map reports a limestone country rock, the country rock is actually a lime-silicate marble. Assays show some low-grade platinum and palladium (Table 2).

Sample No.	Platinum (oz./ton)	Palladium (oz./ton)
1	0.0	0.0
2	0.0	0.0
3	0.0	0.0

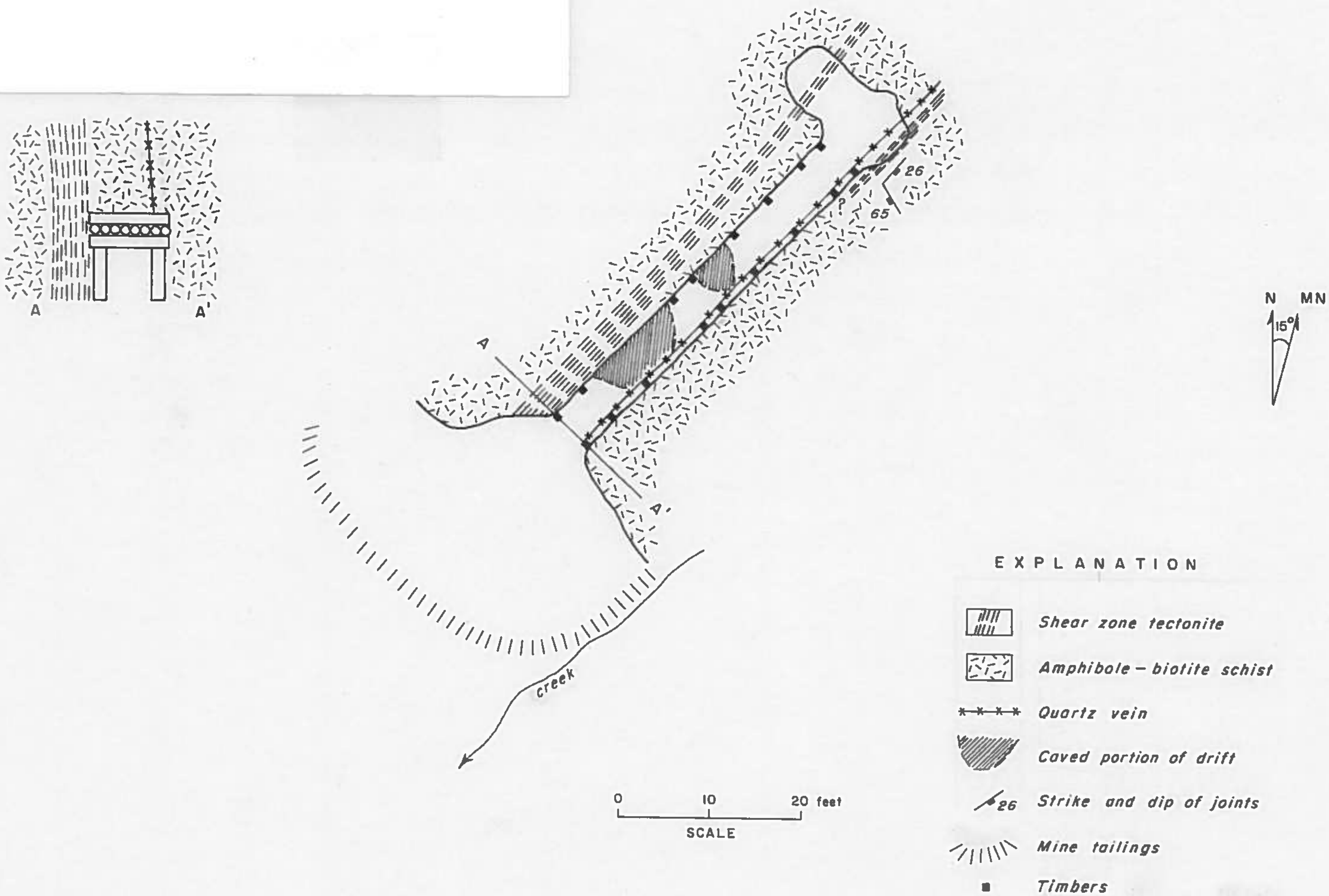

Figure 6. Geologic map of the Columbine Mine, Centennial Ridge District (after Hausel, 1980). See Figure 2 for location.

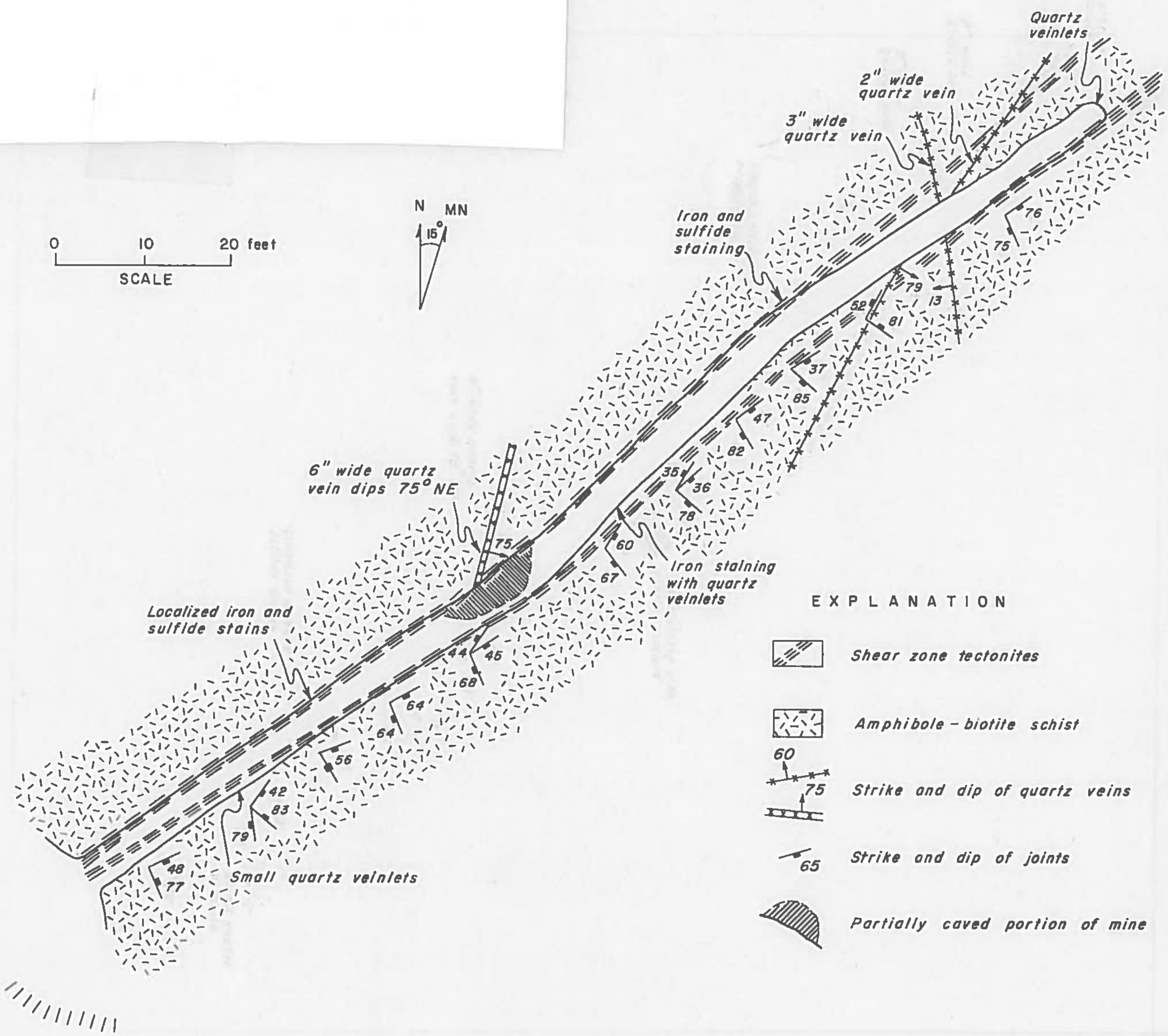

Figure 7. Geologic map of the unnamed mine in the SW¼ SW¼ sec. 17, T.15N., R.78W., Centennial Ridge District (after Hausel, 1980). See Figure 2 for location.

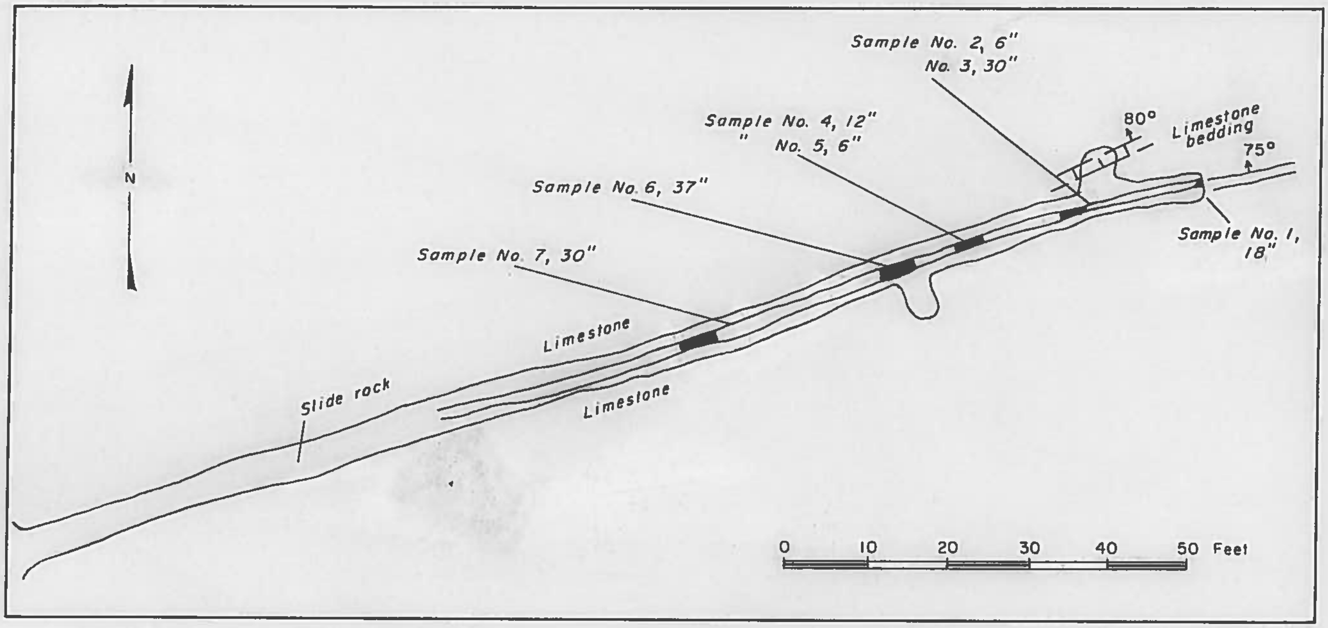

Figure 8. Sketch map of the Empire Mine, Centennial Ridge District (after Finch, 1925). The limestone outcrops mapped by Finch are lime-silicate marble. See Figure 2 for location.

Sample No.	Platinum (oz./ton)	Palladium (oz./ton)
4	0.264	0.100
5	0.0	0.0
6	0.030	0.245
7	0.0	0.0

Table 2. Reported platinum group metal assays from the Empire Mine (After Finch, 1925).

The Mother Lode prospect pit (not shown on Figure 2) (SE¼ sec. 1, T.15N., R.79W.) was briefly examined. This prospect is developed by a small 50 by 100 feet pit in alluvial and possible eluvial material located on the northern bank of the Middle Fork of the Little Laramie River.

The mineralized rock occurs as pyritized quartz and pyritized amphibolite (?) in alluvial boulders and stream bank deposits. The pyritized rock extends several hundred feet upslope from the pit, suggesting that the Mother Lode material either originated from that slope, or is eluvial.

One selected pyritized sample from the pit was assayed and gave <0.01 ounces per ton in gold and platinum.

Several other mines are located in the district, and the reader is referred to McCallum (1968) for a discussion on these properties.

NEW RAMBLER MINE

Introduction

The New Rambler Mine is included in the Douglas Creek mining district of the Medicine Bow Mountains of southeastern Wyoming. The property lies adjacent to the western shore of the Rob Roy Reservoir within the SW¼ sec. 33, T.15N., R.79W. (Figure 9).

The discovery of the rich ore deposits at the New Rambler took place during the 1880's. Prior to a fire in 1918 that destroyed most of the mine records and terminated the mining operations, more than 3,000 feet of workings were developed on four levels (Figure 10). Production reports indicate that the New Rambler Mine produced more than 6,500 tons of ore from which copper, gold, silver, and some platinum and palladium were recovered (Kasteler and Frey, 1949). Of this tonnage, more than 4,000 tons of 25 to 30 percent copper ore were

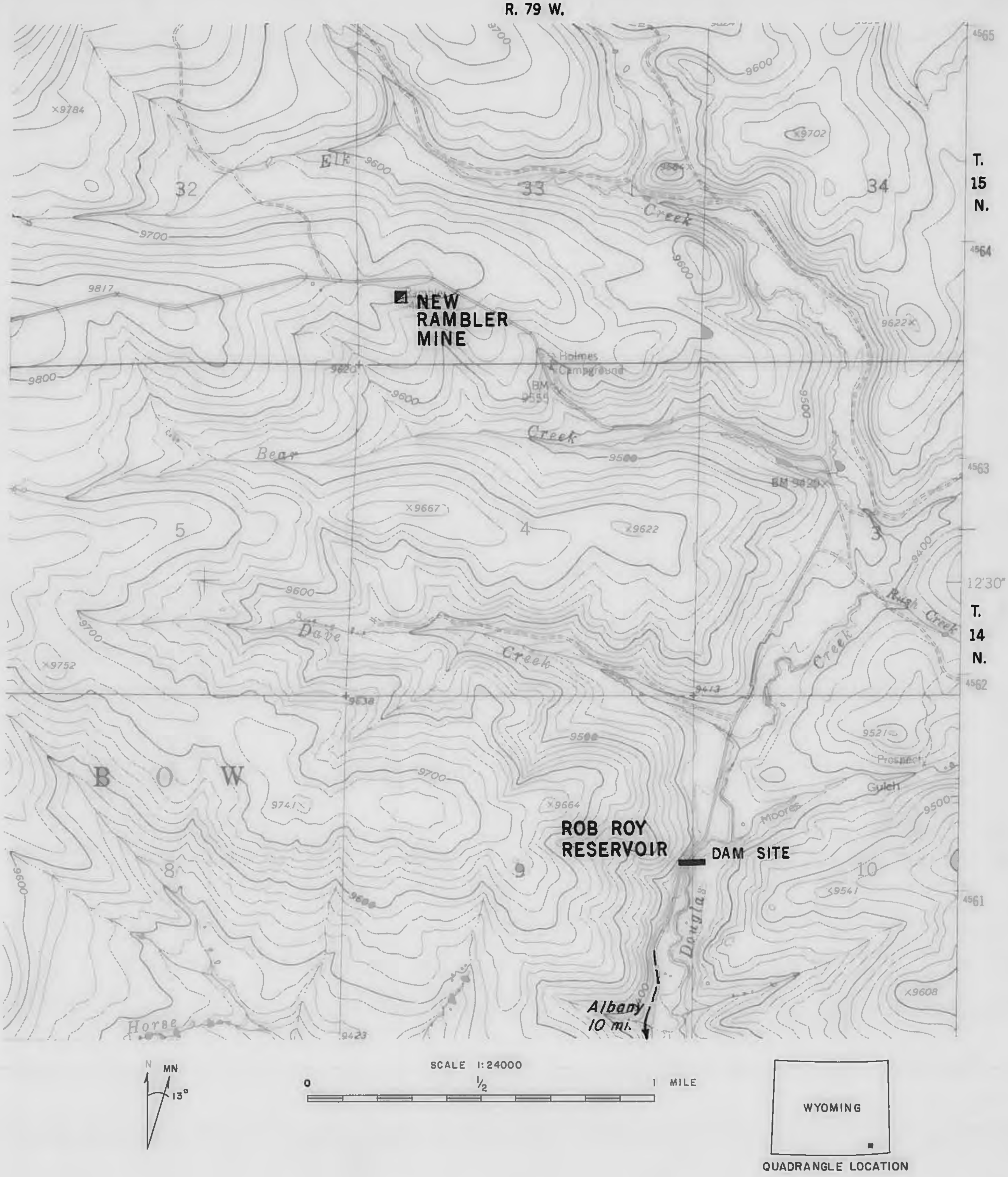

Figure 9. Location map for the New Rambler Mine (sec. 33, T.15N., R.79W.), Albany County.

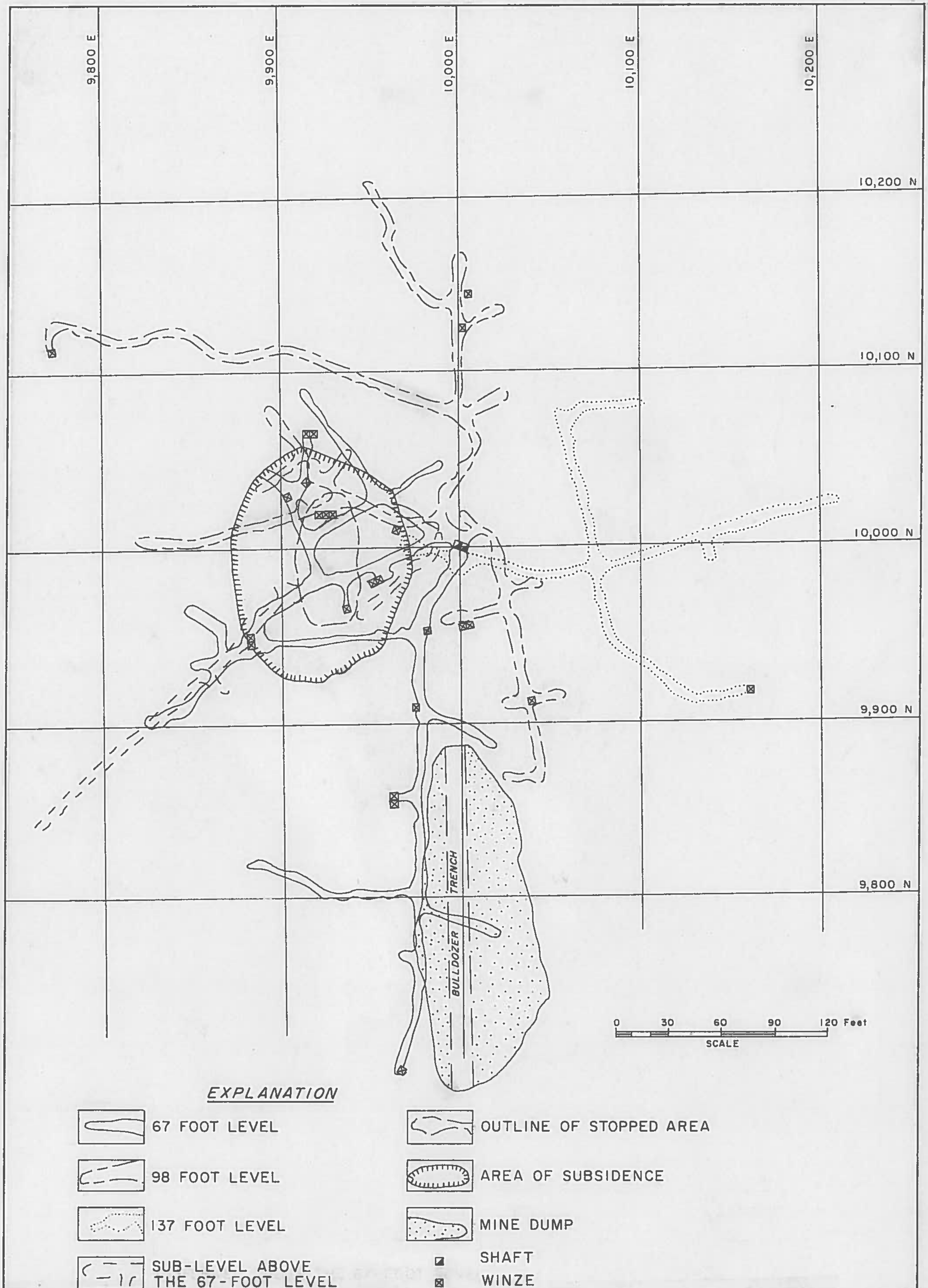

Figure 10. Mine workings of the New Rambler Mine (after Kasteler and Frey, 1949).

milled prior to the discovery of platinum group metals in the ore (McCallum and Orback, 1968).

The mine workings presently are inaccessible due to caving and flooding. The mine dump covers a surface area of about 50,000 square feet and is estimated to contain a waste rock tonnage between 30,000 tons (authors' estimate) and 50,000 tons (Theobald and Thompson, 1968) (Figure 11). The mill tailings cover a similar sized area, although the volume of waste material is considerably less.

Geology

The New Rambler Mine property lies six miles southwest of the Cliff Gold and the Independence mines of the Centennial Ridge District. Both the Rambler Mine and the Centennial Ridge Districts lie on northeast trending shears of the Mullen Creek-Nash Fork shear zone.

The New Rambler Mine area is developed in amphibolitized rock of Precambrian age which is part of a large layered tholeiitic Mullen Creek mafic complex. The more abundant rock type in the mine area is medium- to coarse-grained metadiorite and metagabbro that grades downward at shallow depths, into metapyroxenite and metaperidotite. Other rocks found in the mine area are diabasic dikes, and a granitic stock, although neither is abundant within the boundaries of the property (McCallum and others, 1976).

Structurally, an intense regional shearing is dominant and responsible for high permeability of the host rock and, in turn, to the emplacement of the ore body. An east-west branch of the Mullen Creek-Nash Fork shear zone intersects a northwest trending shear (McCallum and Orback, 1968; plate 1).

Old mine reports indicate that the mine workings intersected four well-defined northwest trending fault planes (Kasteler and Frey, 1949). These presumably are intersected by a broad east-west zone of shear tectonites (McCallum and others, 1976). Apparently, structural control of the ore body is poor because the ore body occurs as an irregular mass with no obvious trend or trends.

Hydrothermal alteration

In addition to supergene alteration, two hydrothermal alteration types are recognized at the New Rambler. Greenschist propylitic alteration is evident throughout much of the country rock, and becomes more intense in proximity to the ore body, suggesting that the alteration products in the mine area are dominantly hydrothermal rather than retrogressive metamorphic products. Propylitic alteration assemblages incompletely replaced much of the hornblende, and calcic plagioclase. Biotite, generally, was unaffected. The alteration produced varying amounts of secondary chlorite, epidote, clinozoisite, albite, magnetite, and pyrite, at the expense of the hypogene mineral assemblages.

Phyllic alteration pervasively replaced both plagioclase and albite, whereas the mafic minerals generally were not as greatly affected. Sericite and quartz are prominent replacements, with pyrite found as disseminations, veinlets, and occasionally as magnetite overgrowths (McCallum and others, 1976).

Mineral deposits

The New Rambler deposit contains complex assemblages of ore minerals and exhibits classic features of an oxidized and supergene enriched deposit with a leached limonitic gossan cap.

The oxidized mineral assemblages are reported to continue to a depth of 75 feet. Reported oxidized ore minerals include abundant chrysocolla ($CuSiO_3 \cdot 2H_2O$), malachite ($Cu_2CO_3(OH)_2$), and azurite ($Cu_3(CO_3)_2(OH)_2$), with lesser amounts of native copper, cuprite (Cu_2O), tenorite (CuO), chalcotrichite (Cu_2O), chalcopyrite ($CuFeS_2$), and accessory amounts of atacamite ($Cu_2Cl(OH)_3$), chalcanthite ($CuSO_4 \cdot 5H_2O$), tetrahedrite ($Cu_{12}Sb_4S_{13}$), and bornite (Cu_5FeS_4) (McCallum and Orback, 1968).

The supergene enriched zone lies below the oxidized ore and was intersected at a depth of 75 to 100 feet. The principal supergene ore minerals are covellite (CuS) and chalcocite (Cu_2S) with minor to trace amounts of orpiment (As_2S_3), realgar (AsS), and lorandite ($TlAsS_2$) (McCallum and Orback, 1968). Covellite, in the supergene zone, was reported to carry up to 1.4 ounces of platinum and lesser palladium per ton. Knight (1902) first recognized this relationship, and reported nearly equal amounts of platinum and palladium with traces of iridium and osmium. The mineral sperrylite ($PtAs_2$) occurs in association with covellite (Wells and Penfield, 1902).

The primary hypogene zone, lying beneath the zone of supergene enrichment, contains pyrite (FeS_2), magnetite (Fe_3O_4), chalcopyrite ($CuFeS_2$), and pyrrhotite ($Fe_{0.8-1}S$) with traces of pentlandite ($(Fe,Ni)_9S_8$), sphalerite (ZnS), mackinawite ($(Fe, Ni)_9S_8$), electrum (auriferous silver), and five hypogene palladium and platinum minerals. The platinoid minerals include: michenerite ($PdBiTe$), merenskyite ($(Pd,Pt)(Te,Bi)_2$), kotulskite ($Pd(Te, Bi)$), and two unknown minerals with the following chemical formulas--$Pd_5(Bi,Sb)_2Te_4$ and $Pd_5(Te,Bi,Sb)_2$ (McCallum and others, 1976).

Assays

The U.S. Bureau of Mines sampled the Rambler Mine dump. The samples were collected from five-foot channel samples from a bulldozer cut (Table

3) (Kasteler and Frey, 1949).

Table 3. Copper-platinum assays of five-foot mine dump channel samples, New Rambler Mine (After Kasteler and Frey, 1949).

U.S. Bureau of Mines sample number	Copper (percent)	Platinum metals (oz./ton)
1	0.92	0.10
2	1.22	0.02
3	0.15	tr
4	0.18	tr
5	0.67	tr
6	0.12	tr
7	0.24	tr
8	0.15	tr
9	0.09	none
10	0.08	tr
11	0.10	tr
12	0.05	none
13	0.31	0.01
14	0.80	0.04
15	0.81	0.02
16	0.85	0.05
17	0.75	0.04
18	0.47	tr
19	0.47	0.01
20	0.37	tr
21	0.40	tr
22	0.54	0.02
23	0.24	tr

Samples collected from diamond drill holes at various localities on the mine property were also assayed for copper and platinum (Table 4) (Kasteler and Frey, 1949).

Table 4. Copper-platinum drill-hole assays reported by Kasteler and Frey (1949).

U.S.B.M. hole #	Sample description	Copper (%)	Platinum metals (oz./ton)
1	Composite of 270 feet of sludge	0.05	none
1	Core 190 to 220 feet	0.05	do
2	Composite of 54 feet of sludge	0.05	do
3	Composite of 234 feet of sludge	0.05	do
4	Composite of 150 feet of sludge	0.05	do
5	Sludge from 116 to 126 feet	0.05	do
5	Sludge from 126 to 127 feet	0.05	do
5	Sludge from 149 to 159 feet	0.05	do
5	Composite of 174 feet of sludge	0.05	do
6	Composite of 66 feet of sludge	0.05	do
1	Spectrographic analysis of representative sections of core	0.13	do

Almost 20 years later, in 1968, the U.S. Bureau of Mines again sampled the mine waste rock from the New Rambler Mine. Their results are presented in Table 5.

Other reported assays in the literature include:

(1) various copper minerals from the mine carried from 0.10 to 0.70 ounces of platinum per ton, and several carloads of covellite ore contained from 0.40 to 1.40 ounces of platinum per ton (Knight, 1902).

(2) Composite samples of dump materials gave values of 0.06 ounces of platinum, 0.04 ounces of iridium, 0.04 ounces of palladium, 0.10 ounces of silver, and a trace of gold.

Genesis

The New Rambler deposit has characteristics that are attributable to one of two possible origins. One possible genesis is that the deposit is the product of hydrothermal processes. In this case, the metals are derived from hydrothermal leaching of the mafic rock and deposited in permeable fractures in cataclastics and as replacements.

Table 5. Analyses of mine waste from the New Rambler Mine--see Figure 11 for sample locations (Analyses reported in parts per million) (After Thompson and Theobald, 1968).

Sample No	Copper	Silver	Platinum plus palladium	Gold 2-g sample	Gold 10-g sample	Arsenic	Tellurium	Molybdenum	Lead	Zinc
Coarse mine tailings in main mine area										
AAE 651	2,000	7.8	3.5	<0.1	1.3	40	8	15	<25	25
652	1.200	55	3	.9	3.0	10	25	15	50	<25
654	>6.000	1.5	.1	.3	.4	60	1	<5	25	50
655	2,000	1.0	.4	<.1	.2	30	2.5	<5	<25	25
656	1,000	14	1.7	.9	2.5	30	2	10	<25	25
662	3,000	2.0	.5	.8	.5	40	20	<5	<25	25
667	1.200	1.8	6	.7	.2	30	2.5	5	25	50
Coarse mine tailings in outlying piles and mines										
664	80	1.0	0.2	0.2	0.04	10	0.25	<5	25	25
649	>6.000	2.8	.4	.9	1.0	30	2.5	<5	<25	50
Millsite debris										
666	2.000	7.2	1.0	2.6	0.3	120	13	5	750	25
680	2.000	4.2	1.6	.1	.5	160	15	<5	25	25
Mill tailings										
668	2.000	4.5	2.5	0.3	0.9	80	13	10	<25	25
669	2.000	2.2	.3	1.6	.2	30	4	5	25	25
670	1,000	2.8	1.0	.6	.3	60	7	5	<25	25
Outwash from mill tailings										
675	2.000	1.8	0.8	0.8	0.3	40	7	<5	<25	50
678	1.000	.5	.4	.5	.02	10	.1	<5	<25	25
Slag										
679	>6.000	3.8	0.7	1.5	0.08	<10	1.3	5	<25	75
Average	3.000	7	1.1	.8	.7	----	----	----	----	----
Outwash from mill tailings on Bear Creek flood plain										
737	600	0.8	0.6	0.3	0.06	20	0.5	<5	<25	50
738	2,000	4.8	2.0	.1	1.0	80	7	5	<25	50

A magmatic segregation genesis of the deposits would suggest that the ore body was tectonically translated into the present location in the shear zone and hydrothermally reworked by fluids introduced along the cataclastics (McCallum and others, 1976).

Although both modes of genesis are possible, most of the known facts support a genesis by hydrothermal solutions.

Summary

The New Rambler deposit contains interesting amounts of copper and platinoid metals. These rocks are highly fractured and permeable and contain a complex assemblage of oxidized and hypogene metals. The large mine dump volume with rock hosting minor amounts of copper and platinoid metals may be available for heap leaching research. Much of the supergene high-grade ore undoubtedly has been exploited although assays of mine dump samples (Table 5) suggest some high grade material still remains on the property. This deposit is recommended for further study.

SILVER CROWN DISTRICT

Location

The Silver Crown District is located on the eastern flank of the southern Laramie Range between Laramie and Cheyenne (Figure 1). The district is accessible from Cheyenne (Figure 12) by driving 20 miles west, or from Laramie by driving 30 miles to the east, along I-80. The district lies west of Granite, and extends a few miles south and six miles to the north of the Interstate. Most of the mining activity in the district was centered on the Copper King and Comstock mines, which are located immediately east of Curt Gowdy State Park. A small amount of copper and gold was also prospected within one to two miles north and south of the Interstate.

Development

The Silver Crown District has had a fairly active exploration and development history. More than 3,000 feet of workings were developed on the numerous mines and glory holes (Ferguson, 1965). The more extensive mines were the Copper King, Orenogo, Comstock, and Fairview (Figure 12), although the Fairview was not accessible because of caving and will not be discussed in this study.

In addition to the mine workings, several thousand feet of drill hole information has been accumulated and is available in the Geological

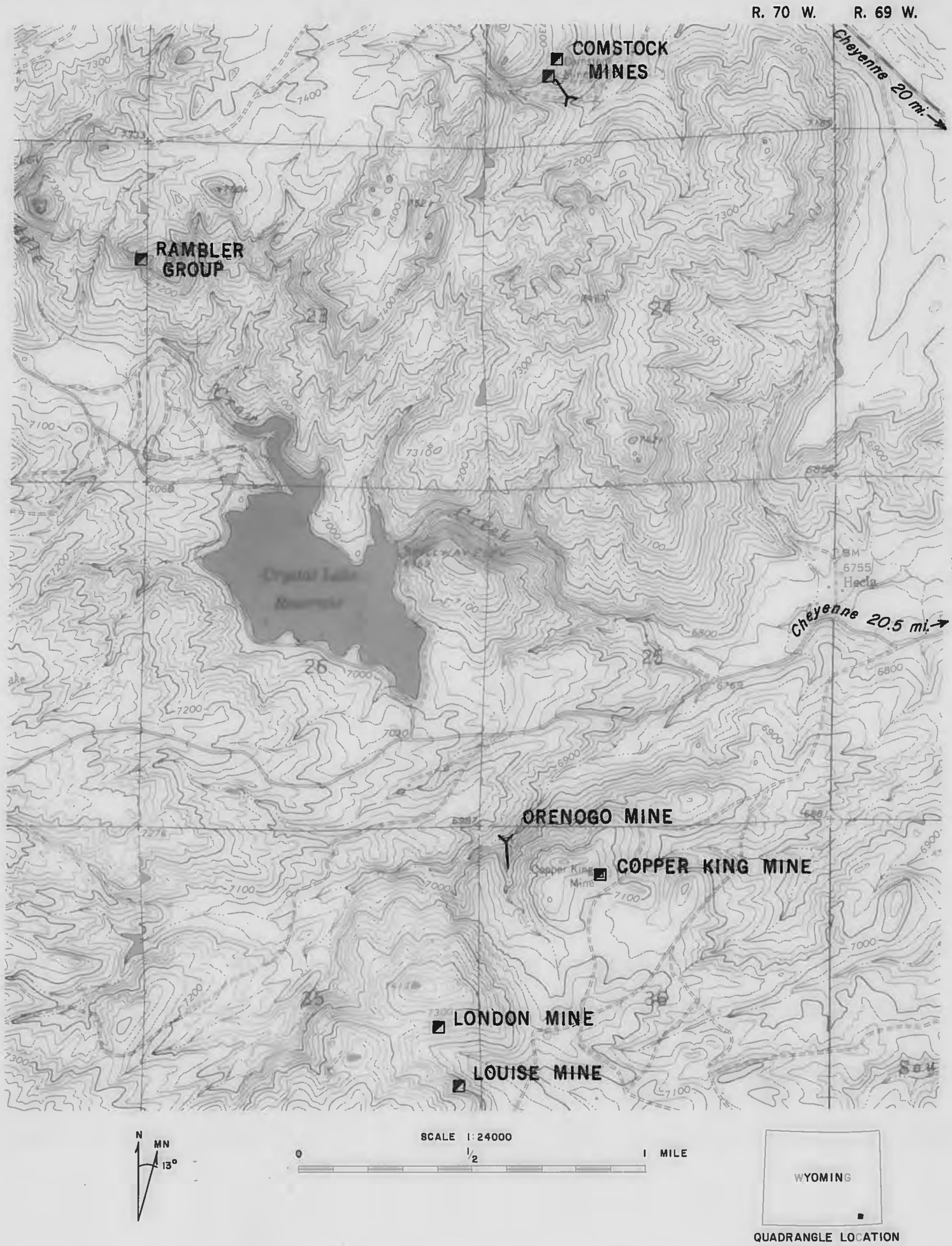

Figure 12. Location map of a portion of the Silver Crown District (T.14N., R.70W.), Laramie County.

Survey of Wyoming files. Most of the drilling has been centered on the Copper King Mine.

The remains of the old Silver Crown mill are located south of Highway 210 (Happy Jack Road) immediately north of the Copper King at Hecla. Reports suggest that this mill was poorly designed and that the tailings often assayed better than the mill concentrates (Ferguson, 1965).

Geologic Setting

Several copper-gold-silver deposits are found within the district occurring as nonhealed permeable fracture fillings, and as quartz veining in relatively impermeable fracture zones. Regional retrogressive metamorphism produced widespread propylitic alteration. But near some deposits, in particular the Rambler group in Curt Gowdy State Park and the Copper King Mine, the alteration is more intense suggesting hydrothermal genesis for the propylitic minerals adjacent to the ore bodies. Potassic alteration is evident in the Copper King area. Both secondary potassium feldspar and biotite are apparent, although more detailed petrographic analysis will be necessary before these conclusions can be verified. Silicification is obvious at several deposits. At the Copper King, numerous fractures have been rehealed by quartz veins and veinlets. The rocks adjacent to the veins are highly siliceous.

The major ore bodies are hosted by calc-alkaline intrusives of average composition approximating granodiorite and quartz monzonite. The remaining rocks are mafic to intermediate calc-alkaline metavolcanics with lesser metasediments. These rocks form part of an Early to Middle Proterozoic basement province that is also exposed in the southern Medicine Bow and Sierra Madre ranges. The metamorphic rocks were intruded at about 1.4 b.y. by the Sherman Granite batholith.

Mineralization associated with the respective deposits generally is low-grade, although supergene ores, mined during the past, reportedly contained some rich ore masses. At the Comstock Mine, one mass of pure supergene chalcocite ore extracted from the primary shaft was reported to be as large as a wood stove (Ferguson, 1965). Large masses of enriched ore, however, are uncommon, and the major ore bodies are low grade. An example is the Copper King, which contains a low grade resource of 35 million tons that averages 0.21 percent copper and 0.022 ounces of gold per ton (Nevin, 1973).

A few of the prospects and mines are discussed below. The reader should refer to Klein (1974) and Osterwald and others (1966) for discussions on several remaining deposits not mentioned herein.

Deposits that are discussed include a few minor prospects not previously mentioned in the literature. The Comstock, Orenogo, and Copper King are described in greater detail because of potential interest for this project.

Copper prospect ($S\frac{1}{2}$ section 23, T.13N., R.71W.)

This prospect is located on the Granite 7½-minute quadrangle, to the south of Figure 12. It is exposed as a northwest trending shear with quartz stringers in Sherman Granite. The mine workings are small and restricted to a shallow shaft and a caved adit along an adjacent drainage. Mineralized rock consists of secondary chrysocolla and cuprite with disseminated pyrite and chalcopyrite. The extent of the mineralized zone appears to be restricted to the immediate area.

One sample (GQ 82-1) was selected from the ore pile and assayed 2.37 percent copper and 0.01 ounces per ton in gold. No further evaluation of the prospect was considered necessary for this report because of the apparent low tonnage of mineralized rock.

Wilson's gold placer prospect

Located east of the Wilson Ranch along the South Fork of South Crow Creek on the eastern half of section 10, T.13N., R.70W. (not located on Figure 12). The Wilson gold placer was operated prior to the Great Depression. Evidence of limited dredging is present in the creek, and the remains of some old placer equipment (frame for a sluice and a trommel) are preserved on the north flank of the South Fork.

According to Mr. Wilson the present ranch operator, his father often found small gold nuggets in chicken gizzards while cleaning the fowls. These discoveries led his father to begin prospecting and resulted in the discovery of a gold placer east of their ranch house. The rocks in the immediate area are amphibolite schists.

During the examination of the property, Wilson identified two old barrels of concentrates that were apparently run through the sluice. Samples of the concentrate weighing 125.7 ounces were processed in the Wyoming Geological Survey's sluice to reduce the bulk. The samples were examined for gold with a binocular scope. From all of this concentrate, only one color was identified.

The possibility that the gold was removed from the concentrates prior to our examination must be considered. However, if this sample represents material that was processed and the gold not removed, then the value of the placer appears to be very poor.

London and Louise mines

The Louise and London mines are similar to many of the copper prospects in the Silver Crown District. The host rock is fractured granodiorite.

At the Louise Mine, the fractured granodiorite forms a small stockwork system of intersecting limonite-stained fractures. Selected samples were collected from both the Louise and the London mines for assay.

Sample SCLD-1 was a limonitic stained quartz vein with disseminated pyrite collected from the London mine dump. The sample assayed 0.02 ounces of gold per ton.

Two selected samples collected from the Louise mine dump were assayed. Sample SCLS-1 was a copper carbonate-stained biotite schist and produced 0.59 percent copper and 0.01 ounces of gold per ton. Sample SCLS-2 was a chunk of pyrite impregnated quartz vein. The sample assayed 0.01 ounces per ton in gold and 0.22 ounces per ton in silver.

These deposits are not recommended for additional study.

Orenogo Mine

The Orenogo Mine is located in section 36 approximately 1500 feet west of the Copper King shaft. A tunnel was driven nearly 500 feet into granodiorite and intersected two narrow quartz monzonite zones (Plate 2). Mineralization occurred as sulfide and secondary copper carbonate disseminations and stains along joint surfaces and in host granodiorite. Overall, the mine was poorly mineralized and the control of mineralization is poorly defined.

It remains somewhat of an enigma as to why the Orenogo was developed. The mineralization throughout the mine is very weak and the mine entrance showed little evidence of mineralization other than limonite-stained shears. There is no mine dump associated with the workings. The waste was hauled off for some unknown reason. No samples were collected for assay from this mine that is typified by its more than appropriate name.

Rambler prospect

The Rambler prospect is located within the Curt Gowdy State Park between the Granite Springs and Crystal Lake reservoirs (Figure 12). Ferguson (1965) reports that the Rambler prospect was developed to a depth of 80 feet.

During field reconnaissance, Hausel (1981) briefly examined the property and the workings. A shaft was developed at the intersection of two fractures trending N60^{o}W and N75^{o}E in the Sherman Granite country rock. Thirty to 40 feet below the collar of the shaft, the workings were intersected by an adit drifted westerly along the N60^{o}W fracture.

The ore shoot was formed at the fracture intersections. Sulfides occurred as disseminations and lenses of pyrite, chalcopyrite with minor sphalerite and specularite. The sulfides appear, in hand specimen, to occur principally as replacements of mafic minerals. Secondary metals recognized in dump samples include copper silicates, copper carbonates, and limonitic boxworks. Oxidation is restricted to a narrow gossan zone at the ore shoot. One selected sample of mineralized granite assayed 0.28 percent copper and a trace of gold.

Alteration is expressed as hydrothermal propylitization. The granites in the general area of the Rambler Mine are weakly propylitized by retrogressive metamorphism. Near the Rambler ore shoot, the propylitization is much more intense. Within a few feet of the fractures, the mafic minerals are completely replaced by chlorite, although, in hand specimen, the feldspars appear to be unaffected. More intense alteration, adjacent to the vein, is expressed by increased amounts of epidote and pervasive alteration of mafic minerals and feldspar to chlorite, epidote, and calcite.

Summary--Rambler

The Rambler prospect occurs as a classic example of an ore shoot development at the intersection of two mineralized fractures. Surface expressions of the ore shoot suggest that associated tonnages are small.

The limited tonnages of metallic ore, the small mine dump waste, and the location of this deposit within a State Park make this deposit unattractive for *in situ* or heap leaching research.

COMSTOCK MINE

The Comstock Mine is located near the northern edge of the Silver Crown District within the SW¼ section 13, T.14N., R.70W. (Figure 12). The deposit occurs as both quartz vein copper and unhealed fracture fillings. The main mineralized fissure can be traced along a N20^{o}E trend for nearly three-quarters of a mile.

A shaft was sunk to a depth of 240 feet at the intersection of two fractures. The primary mineralization occured as a copper-bearing quartz vein adjacent to permeable sheared granodiorite. Drifts were developed 200 feet on the 172-foot level and 400 feet on the 205-foot level (Ferguson, 1965).

The accessible workings on the Comstock property consist of 500 feet of drifts which intersect the Comstock shaft at its farthest northwestern point (Plate 3).

These workings were developed into foliated granodiorite and biotite schist and intersect several nonmineralized and mineralized mylonites.

The majority of the mineralized faults are permeable and contain localized secondary copper silicates and oxides.

The dominant rock type is a porphyritic to foliated grey granodiorite formed of plagioclase and minor potassium feldspar, quartz, biotite and minor amphibole. Quartz monzonite occurs as fine-grained equigranular to aphanitic rock.

Although no samples were collected for assay during this study, Ferguson (1965) reported assays of material collected from the Comstock (Table 6). Much of the high grade ore reported in the assays presumably has been mined out. Remaining mineralization exposed in the mine workings occurs as narrow zones of copper-bearing quartz veins and fracture fillings. None of the mineralized zones observed by the authors contain high-grade material.

Summary--Comstock

The Comstock Mine is accessible although the shafts are filled with water, and much of the drifts also lie under one to two feet of water. Overall, the exposed mineralization in the mine workings appears to be limited and localized into a few small, permeable fractures. The better ore apparently has been mined out, although it is not known if it continues at depth. If this deposit is proposed for further research, it would be recommended that the lower workings and shafts be drained and mapped.

COPPER KING MINE

The Copper King Mine was initially prospected in 1881. A shaft was sunk 157 feet with levels at 80 feet and 130 feet. At the 80 foot level, three rooms were developed, running south, northeast, and northwest from the main shaft. A total of 13,296 feet of drilling has also been done on the property (Nevin, 1973).

Pre-ore rocks in the Copper King area include metasediments, granodiorite, and quartz monzonite intrusive rock (Figure 13). The metasedimentary rocks in the immediate vicinity of the Copper King occur as pendants surrounded by the intrusive masses. The granodiorite is the principal host rock in the vicinity of the Copper King.

Collected granodiorite hand specimens are equigranular to porphyritic with varying degrees of foliation. Some specimens show strong foliation and other specimens show weak to no observable foliation. Porphyritic granodiorite exhibits phenocrysts of plagioclase up to ¼ inch in length and lesser pink potassium-feldspar set in a fine-grained groundmass

Sample Description		Gold Oz.	Silver Oz.	Copper %
2-3-11	Assay Sample	.00	.00	66.60
4-18-15	" "	.03	.66	4.80
4-6-15	" "	.12	7.08	6.00
4-7-15	" "	.02	9.70	41.35
6-7-15	" "	.02	.50	2.01
7-25-17	" "	.04	.70	14.70
5-6-18	" "	.08	1.60	3.10
5-3-18	" "	.04	11.56	6.50
5-16-18	" "	trace	2.80	6.90
6-13-49	" "	.02	1.20	4.00
6-13-49	" "	.02	1.00	6.00
6-13-49	" "	.02	1.00	3.50
5-13-55	" " from dump	.04	1.02	5.85
Samples assayed by AS&R Co. Omaha plant				
North drift, cross section of vein		.05	5.15	9.70
South drift winze		.07	1.93	8.70
North drift, wall rock		.00	.40	1.70
Bottom of shaft, 240 feet		.04	2.66	12.90
North drift, 20 feet from shaft		trace	14.00	18.20
South drift		.00	.20	.98
Shaft, 210 feet		.00	.50	.78
No description		.07	1.13	8.80
7-19-15	48,217 lbs. to AS&R Co.	.83	11.02	.74
3-14-16	25,114 lbs. to AS&R Co.	.00	1.35	8.00
10-11-18	Car Control	.04	1.25	5.74
6-29-20	Concentrates	.20	21.80	31.26
7-10-56	Selected Ore			21.41
8-31-56	Selected Ore			19.34
11-16-63	Selected Ore	3.75		45.00

Table 6. Gold, silver, and copper assays reported for the Comstock Mine, Silver Crown District (From Ferguson, 1965).

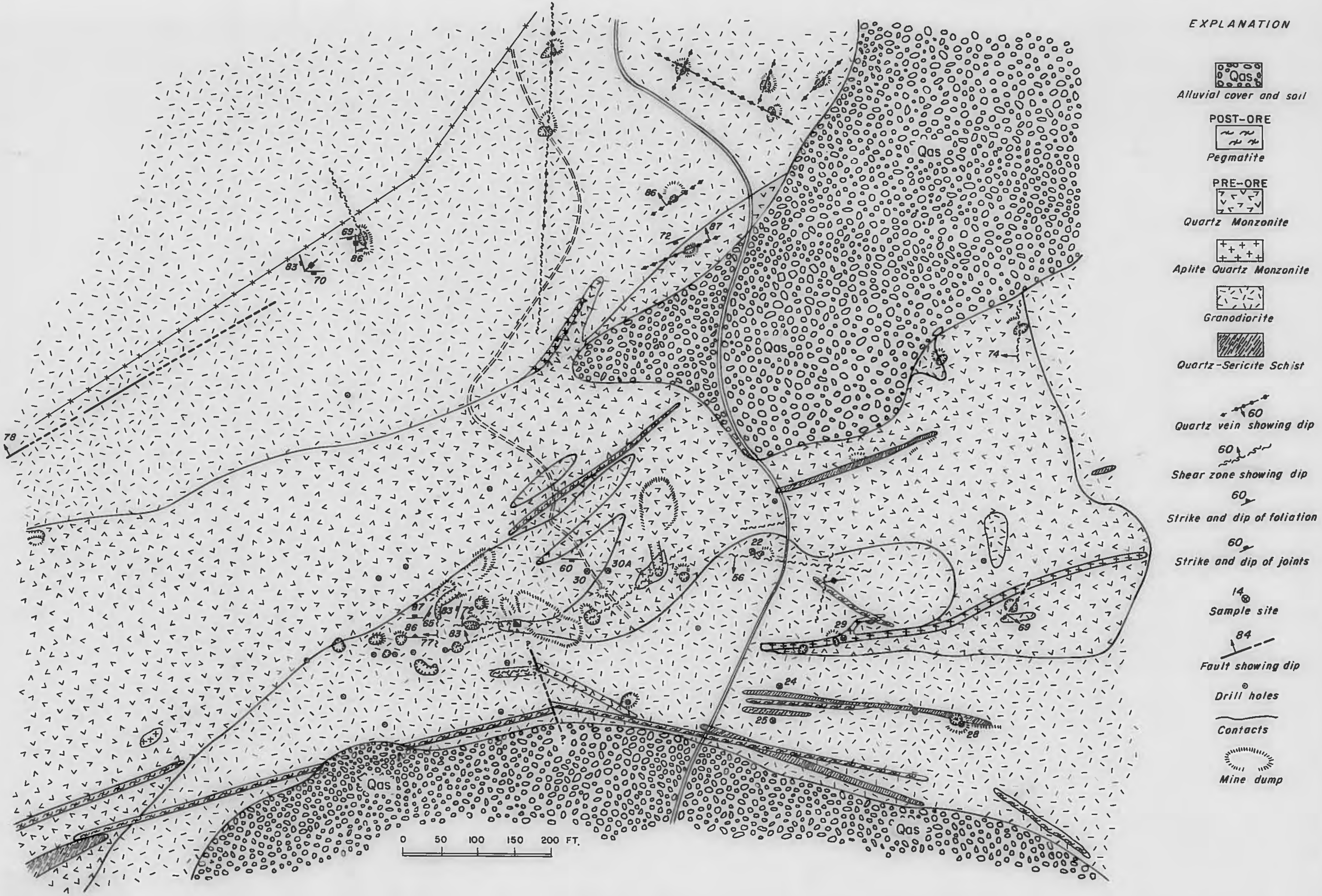

Figure 13.

GEOLOGIC MAP OF THE COPPER KING MINE (Sec. 16, T. 14 N., R. 70 W.) SILVER CROWN DISTRICT

Base map - R.B. McGrow, 1954

TN 15°

of biotite, quartz, and feldspar (?). Many specimens exhibit many cross-cutting rehealed fractures. The fractures generally are filled with quartz, biotite, with minor chalcopyrite. Specimens with stockwork fabric also are characterized by disseminated chalcopyrite and limonite pseudomorphs after pyrite(?) in the groundmass. Foliated and equigranular specimens have similar mineralogy as the porphyry, and foliation is developed by micaceous minerals.

The pink quartz monzonite exhibits fine-grained aplitic to equigranular fine- to medium-grained texture and occures as a dike-like intrusive with the granodiorite. Rocks generally are composed of K-feldspar and fine-grained aggregates of biotite and lesser quartz. The rocks generally exhibit porphyritic texture.

Post-ore rocks in the vicinity of the Copper King property are pegmatite and aplite veins.

Mineralization and Alteration

Mineralization on the surface is, for the most part, oxidized and occurs as malachite and chrysocolla. Based on mine dump samples, primary mineralization occurs as chalcopyrite, pyrite, and minor bornite.

The primary hypogene mineralization was intersected at a depth of 150 to 180 feet. An oxidized and leached zone extends from the surface down to depths of 30 to 150 feet. A zone of mixed oxide and hypogene ore occupies the central portion of the dominant hypogene and oxidized ore (Nevin, 1973).

Hydrothermal alteration is evident (Nevin, 1973) (Figure 14). Near the Copper King shaft, a zone of intense silicification is expressed by two intersecting quartz veins and veinlets. Extending outward from the shaft are two zones of apparent potassic alteration expressed as secondary metasomatic pink K-feldspar and secondary biotite enrichment. These potassic zones are enclosed by propylitic alteration. A small zone of medium-grained muscovite was mapped on the eastern flank of the deposit and also was intersected by a small adit located 175 feet east of the Copper King shaft (Figure 15). This zone was assumed to be a hydrothermal by-product.

Although several metasedimentary rocks in the vicinity exhibit similar mineralogy to the muscovite zone on the eastern flank of the Copper King deposit, these metasediments are composed almost entirely of coarse-grained muscovite and milky quartz. The mineralogy of these metasediments is interpreted as a greissen-like alteration and is considered to be a product of hydrous metamorphism of aluminous and siliceous metasediments and was not mapped as a hydrothermal alteration product, but rather as an individual rock type.

Supergene alteration expressed as kaolinite and limonite stains is

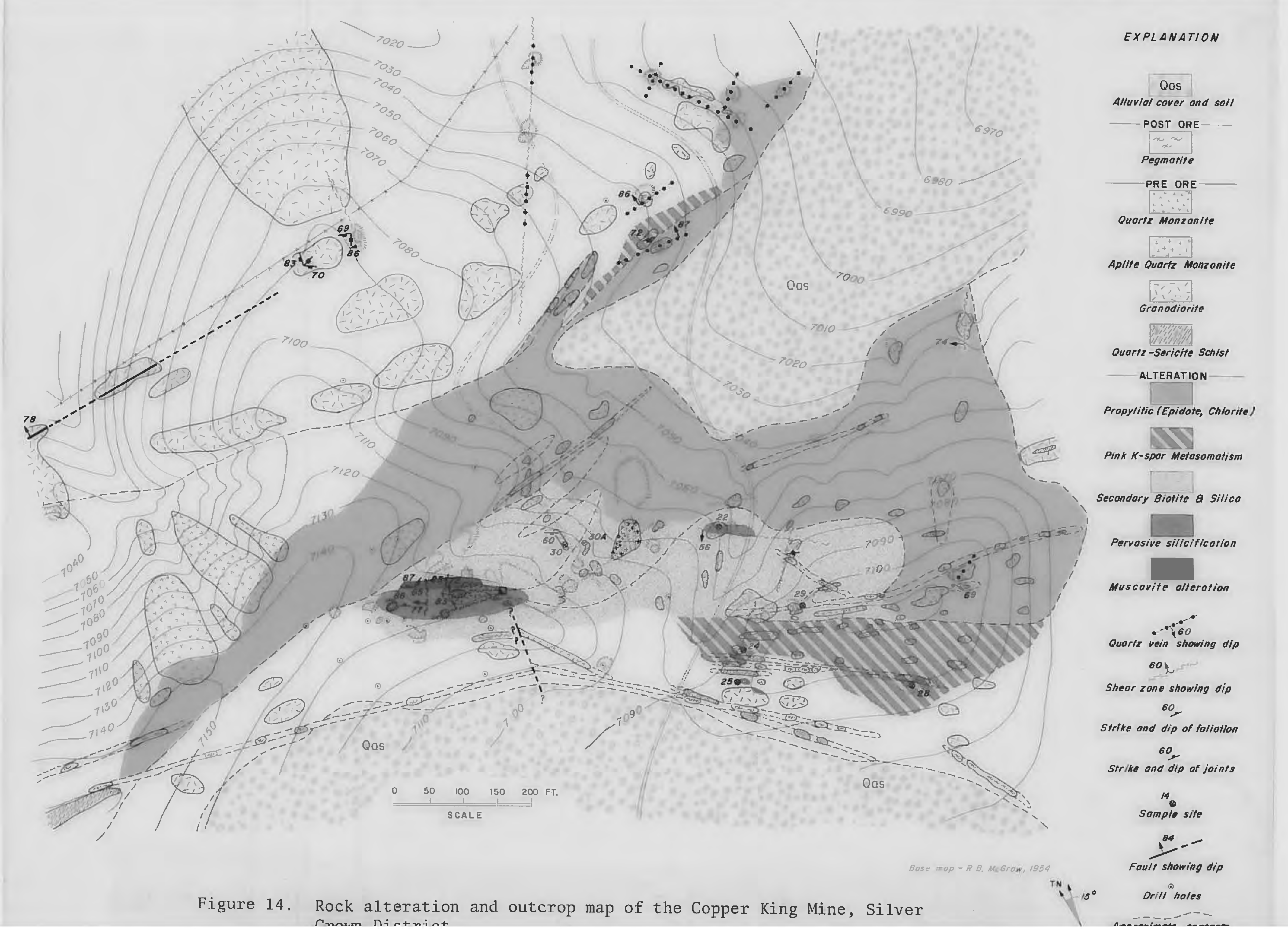

Figure 14. Rock alteration and outcrop map of the Copper King Mine, Silver Crown District

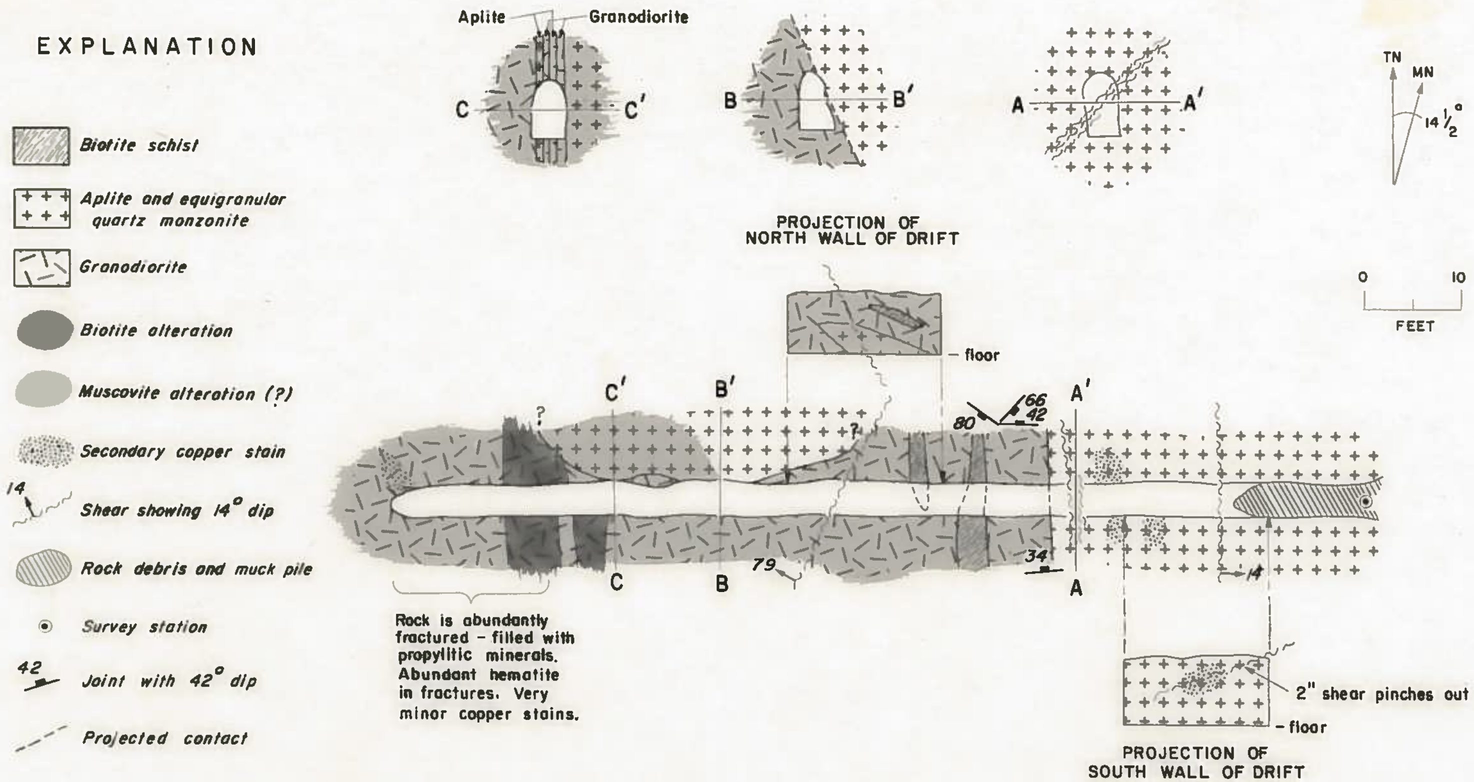

Figure 15. Geologic map of an adit located 175 feet east of the Copper King shaft, Silver Crown District.

evident throughout much of the exposed country rock. This secondary alteration was not mapped.

Reserves

An estimate of in place reserves was made by Nevin (1973). These are as follows:

Tons	Gold (oz.)	Copper (%)	stripping ratio (waste to ore)
2.8×10^6	0.044	0.36	0.5
6.0×10^6	0.038	0.32	1.2
13.5×10^6	0.028	0.26	1.8
35.0×10^6	0.022	0.21	2.0

The entire ore body has not been delineated and additional drilling could extend these reserves.

Summary--Copper King

The Copper King property contains a large tonnage of low-grade copper-gold ore disseminated throughout the host granodiorite country rock. It is recommended that this deposit be examined in greater detail for continued research. The rock generally should be impermeable except along a few fractures and shears. Fracturing of the host rock would be required to make this deposit amenable to *in situ* leaching.

SHEEP MOUNTAIN TITANIFEROUS BLACK SANDSTONE

Location

The titaniferous black sandstone deposit at Sheep Mountain lies within the basal(?) part of the Upper Cretaceous Mesaverde Formation. It is exposed as a low lying, northwest trending dark hill located within one mile south of the junction of State Highways 11 and 130 (Figure 1). The black sand is accessible by dirt road, three-quarters of a mile east of the highway junction. This road runs south and enters the Sheep Mountain Federal game refuge. The deposit is located in the SE¼ section 10, and extends southeast into the NW¼ section 14, T.15N., R.77W. (Figure 16).

Geology

The University of Wyoming Mining and Mineral Resource Research Institute recommended that the Wyoming Geological Survey examine this

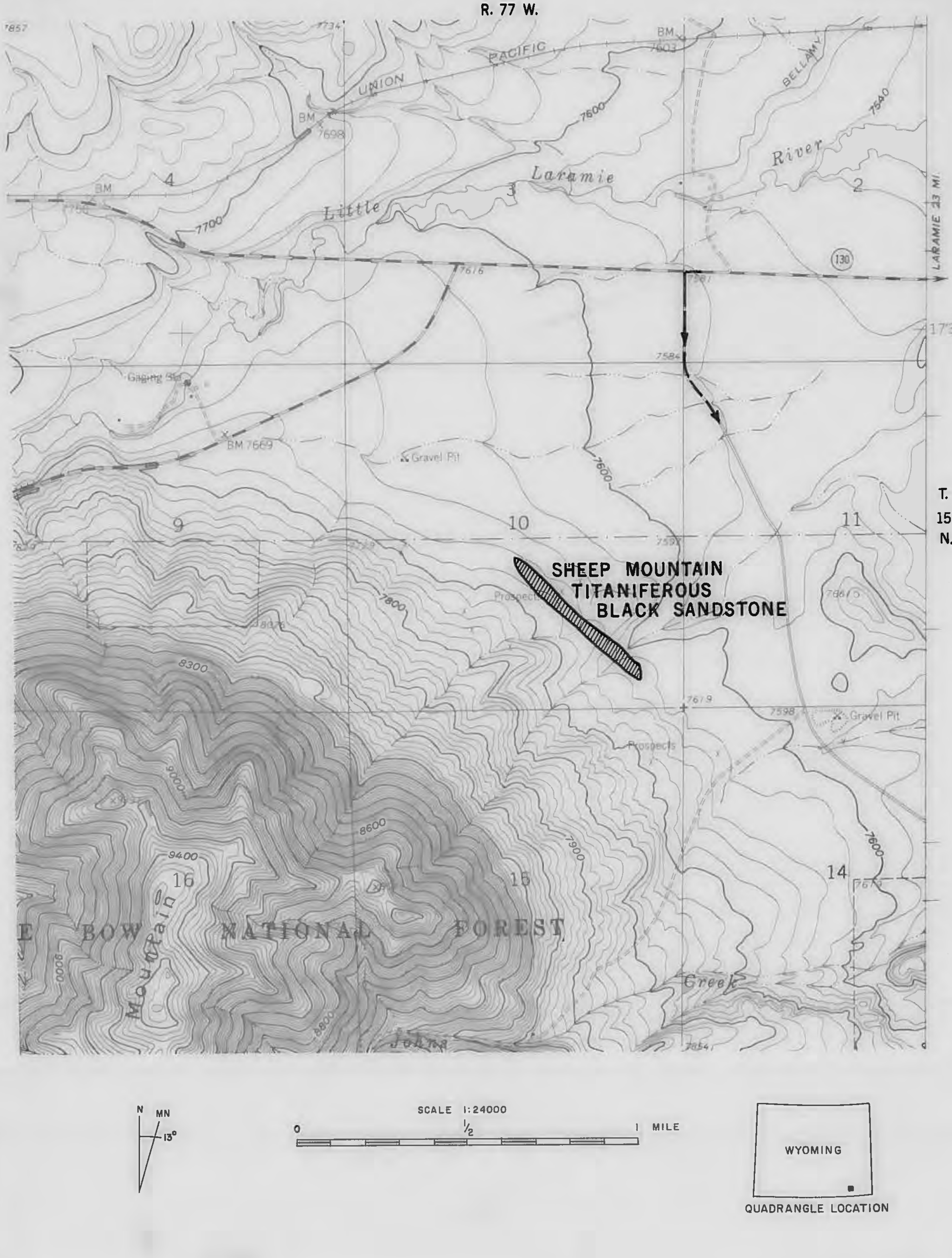

Figure 16. Location map of the Sheep Mountain titaniferous black sandstone (T.15N., R.77W.), Albany County.

prospect because of the potential metals commonly associated with these paleo-beach placers. Of economic interest are opaque minerals that contain titanium dioxide and iron oxide; rutile that contains titanium dioxide; zircon that contains zirconium, hafnium, and uranium; monazite that contains thorium and rare earth elements; and a radioactive opaque mineral that contains niobium. A summary of the use of the metals and their markets is presented by Houston and Murphy (1962, p. 75-77).

These types of deposits are generally considered to be formed in a backshore beach environment along the shorelines of a large body of water, presumably a sea. The source of the heavy minerals is assumed to be crystalline rock that, through geologic time, was weathered and many of the mineral constituents transported seaward to the beach environment. It is postulated that wave action along the beach during storm turbulence is the mechanism that separated light minerals and concentrated the heavier mineral species. The greater the storm activity, the greater the concentration of the heavy minerals.

The Sheep Mountain deposit is sporadically exposed along a N45^{o}W strike trend over a distance of nearly 4,300 feet. The strata dips northeasterly between 25 and 30 degrees. On the northwestern edge of the exposure, near MAG I (magnetic profile line) (Figure 17), the black sands have a maximum thickness of 17 feet and outcrop exposure of 50 feet in width. To the southeast, the deposit thins considerably (Houston and Murphy, 1962).

Magnetic profiles (Figure 18) that were run perpendicular to the strike trend of the deposit suggest that the ferromagnetic heavy minerals do not continue down the dip of the strata.

The petrographic analysis of six samples collected from the Sheep Mountain deposit are reported by Houston and Murphy (1962). These samples contained an average of 22 percent acid soluble matrix, 15 percent light minerals, and 63 percent heavy minerals of which 28 percent were ferromagnetic. The identified heavy minerals were: zircon - 10.3 percent; garnet - 3.0 percent; epidote - 1.0 percent; tourmaline - 1.0 percent; monazite - 1.0 percent; staurolite - 1.0 percent; amphibole - 1.0 percent; sphene - 1.0 percent; biotite - 1.0 percent; spinel - 1.0 percent; and opaques - 84.2 percent. The individual chemical analyses of nine samples are reported in Table 7. The last two chemical analyses were from low-grade samples collected near the southeast end of the deposit.

Summary

The Sheep Mountain black sandstone contains large percentages of heavy minerals. Overall, the sandstone appears to contain very small tonnages with no appreciable overburden. Two representative samples (SM-1 and SM-2, see Figure 17) were collected during reconnaissance by the authors and are available for inspection at the Geological Survey of

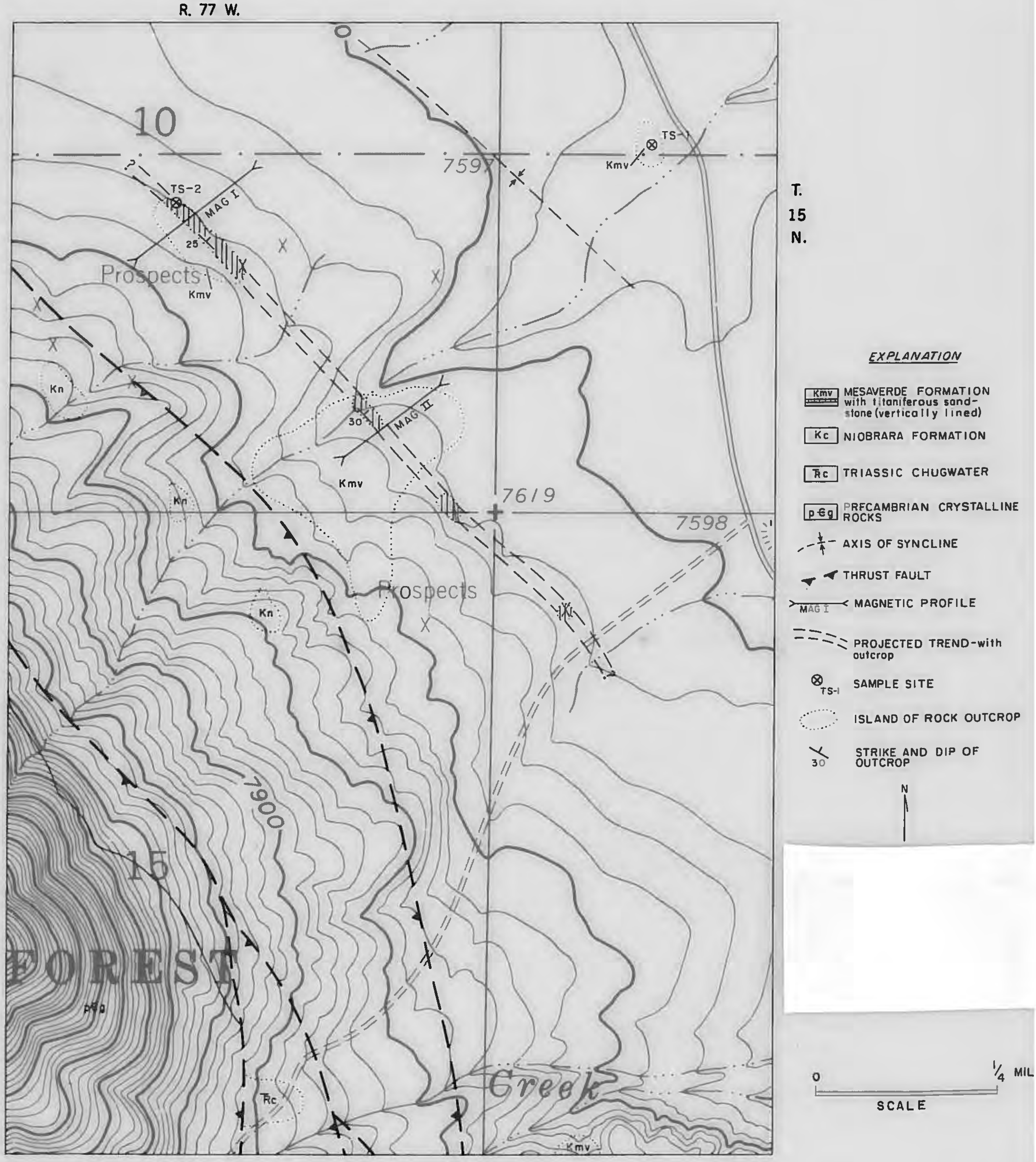

Figure 17. Geologic map of the Sheep Mountain black sandstone deposit (modified from Houston and Murphy, 1962).

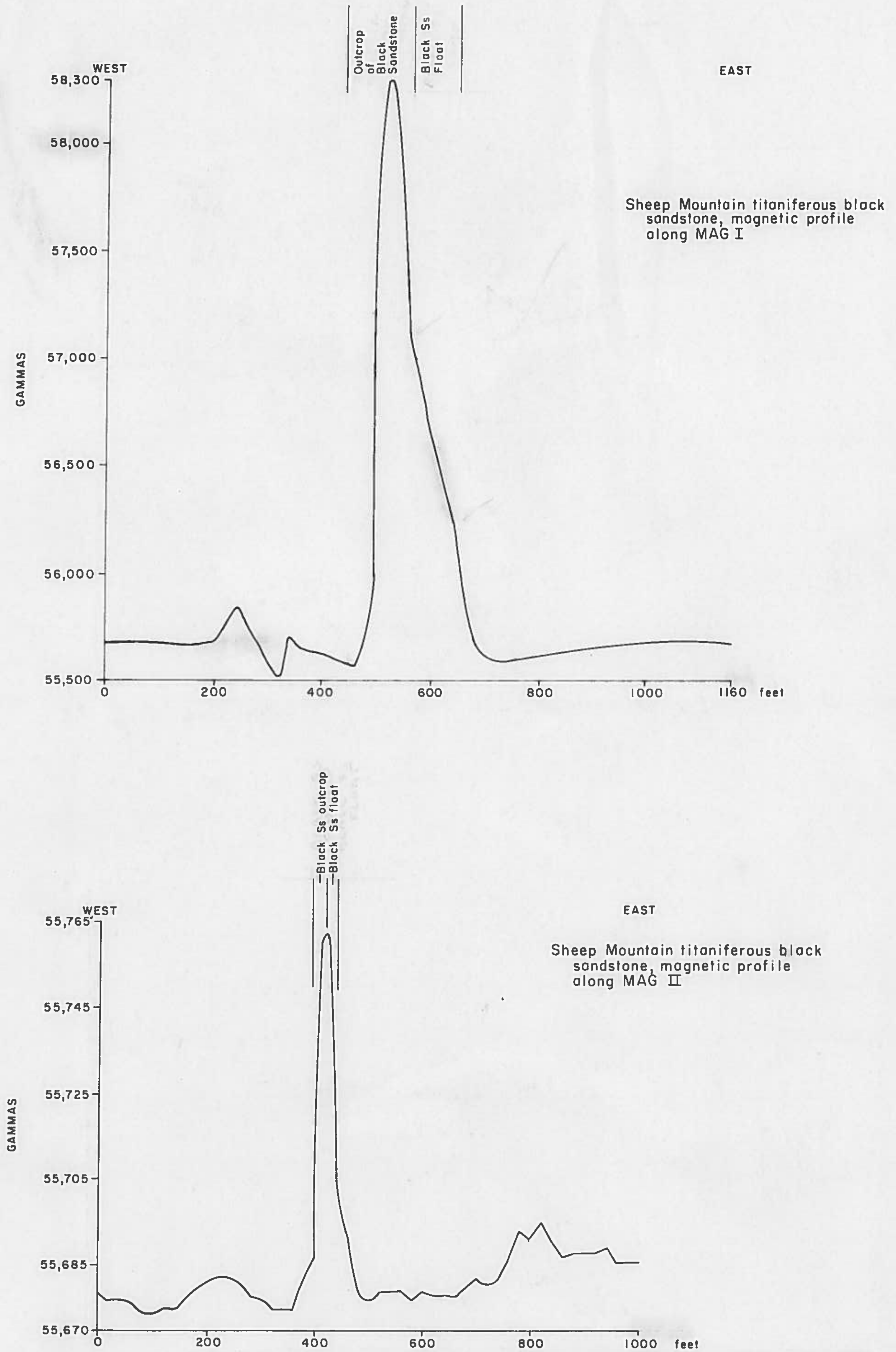

Figure 18. Magnetic profiles across the Sheep Mountain titaniferous black sandstone. See Figure 17 for location of profiles.

Wyoming minerals laboratory. This deposit is not recommended for further examination.

Chemical Analyses			Equivalent			Heavy Minerals	
TiO_2	Iron as Fe_2O_3	Uranium	Uranium eU	Cement	Light Minerals	Total	Ferro-magnetic
3.77	13.53	<0.001	0.004	--	--	--	--
14.18	28.32	<0.001	0.008	--	--	--	--
3.94	16.27	--	0.002	--	--	--	--
23.68	45.64	<0.001	0.007	40.0	17.6	42.4	26.0
22.86	59.19	<0.001	0.011	30.2	5.4	64.4	23.6
20.85	58.22	<0.001	0.010	--	--	--	--
19.18	61.27	0.006	0.016	22.5	0.10	77.4	44.6
0.70	9.01	--	0.001	--	--	--	--
0.26	13.32	--	0.001	--	--	--	--

Table 7. Analyses of Sheep Mountain black sand (in percent). Percent of total heavy minerals separated by an electromagnet designed to separate magnetite from ilmenite (After Houston and Murphy, 1962, table 13).

LAKE ALICE DISTRICT

The Lake Alice District is located 20 miles northeast of Cokeville in Lincoln County. The mineralized region is accessible by State Highway 232 from Cokeville. Highway 232 converts to a Forest Service dirt road at Button Flat. The major mineralized zone is accessible by following Forest Service markers to the Lake Alice campground along Hobble Creek. From the Lake Alice campground, the Griggs Mine area lies an additional two miles north at road's end (Figure 19).

The district is within the Tunp Range of the Bridge National Forest (Figure 1).

Geology

Copper-zinc-silver deposits are reported from several sedimentary red bed sandstones ranging in age from Pennsylvanian to Cretaceous in this

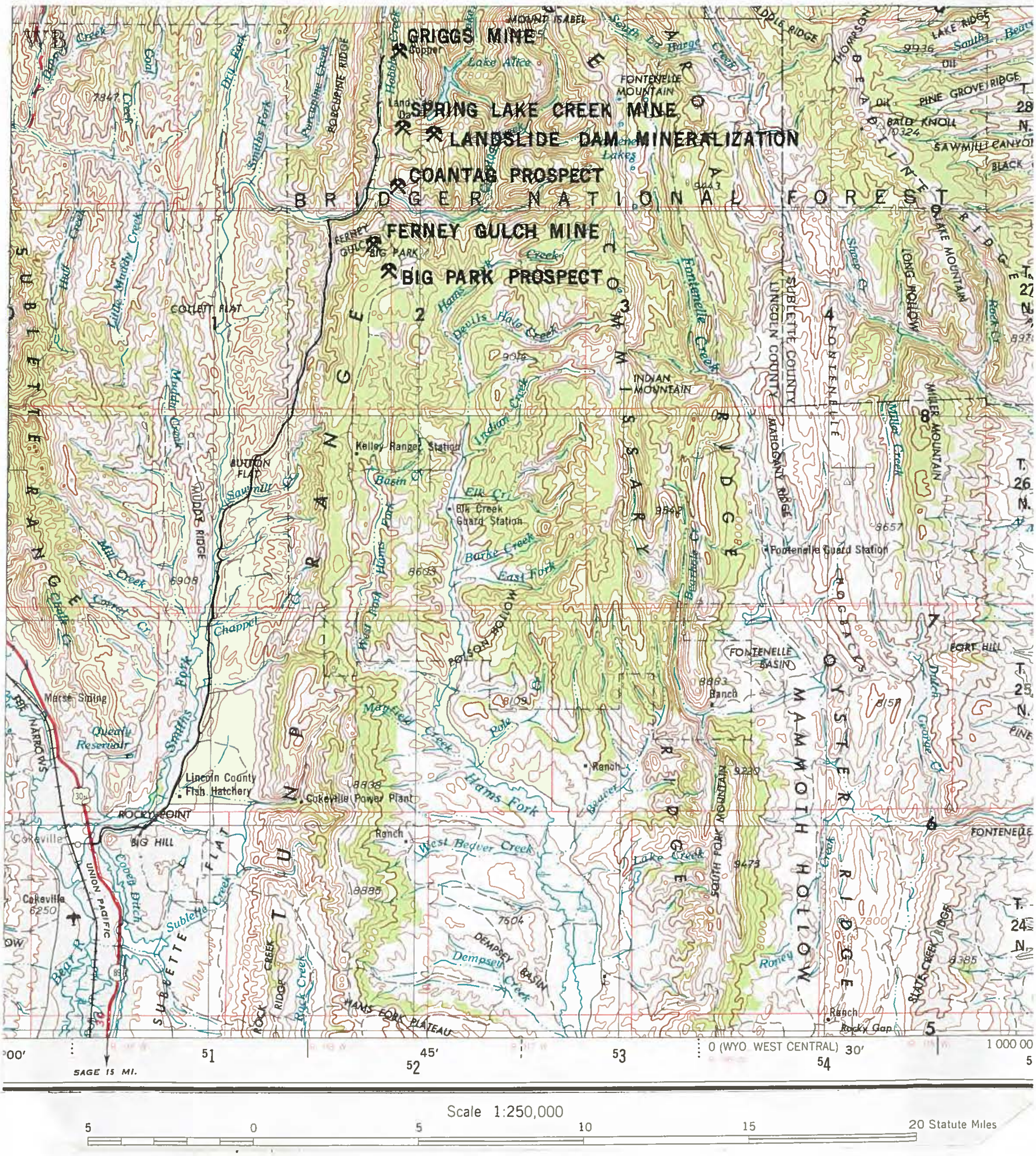

Figure 19. Location map of the Lake Alice District, Lincoln County.

region of the Thrust Belt (Hausel, 1982a). These deposits are reported at several localities in the Nugget Sandstone, Wells Formation, and Beckwith Formation (also referred to as Gannet Group).

Copper deposits in the Nugget Sandstone are localized near the top of the formation where it is overlain by the Gypsum Springs Member of the Twin Creek Limestone, and are intimately associated with green to white, altered sandstone as opposed to the dull red unaltered rock. The origin of the mineralization is not known and the lack of Precambrian and younger igneous rocks in this part of the Overthrust Belt would complicate a hydrothermal genesis. However, Love and Antweiler (1973) suggest that the metals may have been derived from metal-bearing oil, or possibly from the leaching of overlying tuffaceous sediments (long since removed by erosion) and localized by petroleum, or some other reducing agent. It is known that some oils in north central Wyoming are metalliferous, and that similar bleaching (or similar alteration) occurs in oil-saturated Triassic red beds in central Wyoming (Love and Antweiler, 1973).

The largest mine in the Lake Alice District--the Griggs Mine (sec. 7, T.28N., R.117W.)--was developed by several adits and stull-type stoping in a bleached zone of the Nugget Sandstone. These adits occur over a vertical distance of more than 300 feet from top to bottom, suggesting the potential thickness of the ore body. Assays from old mine maps show good mineralized rock ranging from as little as 0.64 percent copper and 0.1 ounces of silver per ton to as high as 4.46 percent copper and 12.2 ounces per ton in silver from one of the adits (Allen, 1942) (Figure 20). Recognizable ore minerals include malachite, azurite, chalcopyrite, and tenorite. Samples collected by Love and Antweiler (1973) ranged from 0.05 to 6.7 percent copper, a trace to 36 ounces of silver per ton, a trace to 0.5 percent lead, and 0.02 to 0.81 percent zinc. Allen (1942) suggested that ore emplacement was structurally controlled. He reported that the ore occurred in shoots developed along northeasterly and northwesterly fissure intersections.

At the Ferney Gulch Mine (sec. 1, T.27N., R.118W.), also in the Lake Alice District, a selected sample of mineralized rock assayed five percent copper, a trace of silver, 2.6 percent zinc, 0.7 percent arsenic, 0.5 percent barium, 0.07 percent cobalt, 0.05 percent lead, and a trace of molybdenum (Love and Antweiler, 1973).

One selected sample collected from the Ferney Gulch Mine assayed 1.11 percent copper, 0.52 ounces per ton in silver, 137 ppm in zinc, and 63 ppm cobalt.

A sample collected from the Nugget Sandstone from the Spring Lake Creek Mine dump (E½ sec. 24, T.28N., R.117½W.) assayed 0.25 percent copper, <0.01 ounces per ton in silver, and 46 ppm zinc.

A mineralized fragment of Nugget Sandstone collected from the Cabin

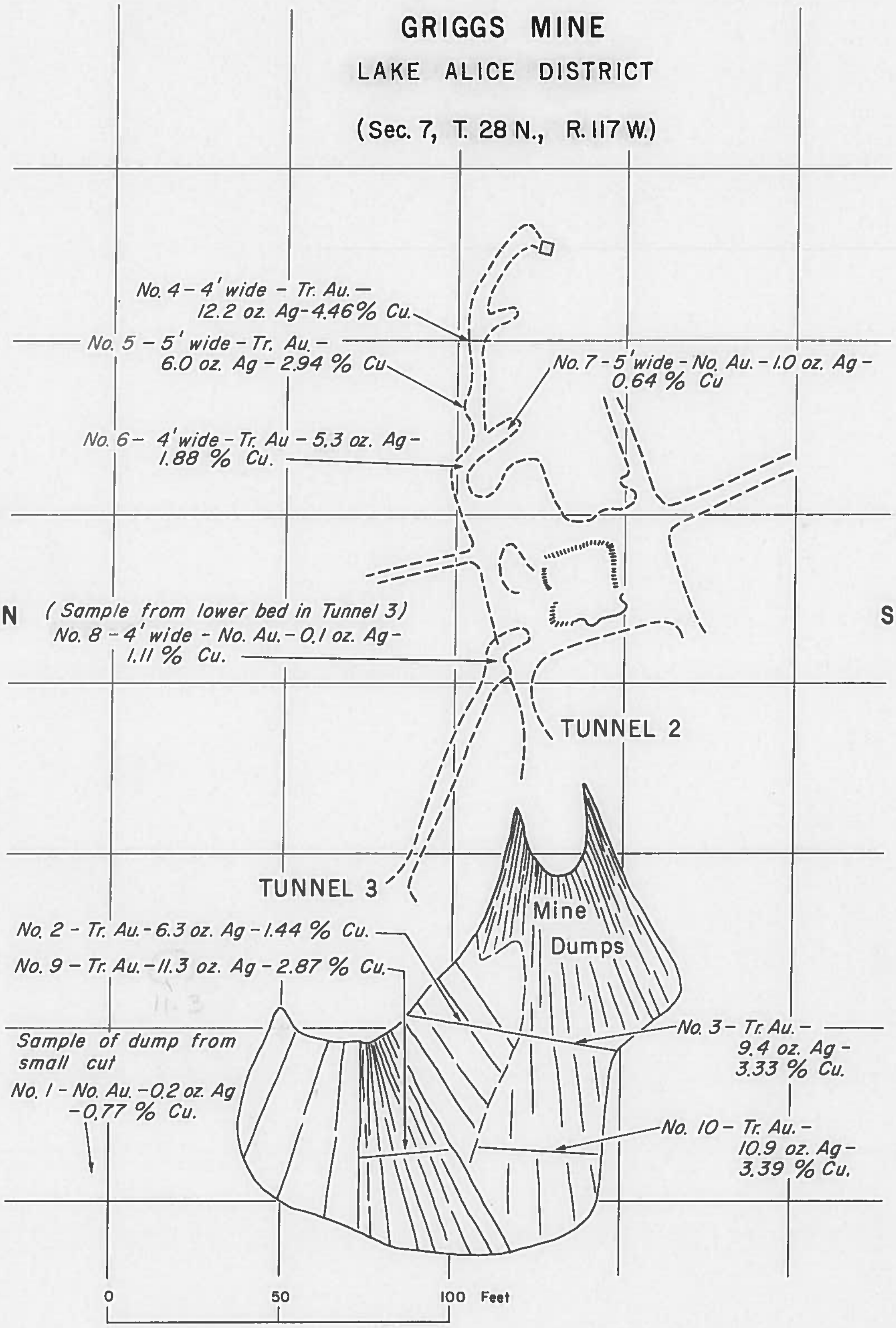

Figure 20. Sketch and assay map of the Griggs Mine, Lake Alice District (after Allen, 1942). North is assumed to be to the left hand side of the illustration.

Creek area (43°15'; 110°47') assayed 0.15 percent copper, 0.01 ounces per ton silver, and 23 ppm zinc.

The Nugget Sandstone is between 500 to 700 feet thick, and is relatively homogeneous , evenly bedded to cross-bedded, slightly limy (except where bleached and mineralized, hard and brittle. It is fine-grained but has sporadic larger rounded frosted quartz grains. Many of the quartz grains show secondary growth that has reduced porosity and permeability.

The Nugget is overlain by the Gypsum Spring member of the Twin Creek Limestone. The Gypsum Spring, in outcrop, forms an excellent marker identifying the contact between the two formations. In outcrop, it forms a residual breccia composed of dolomite and limestone fragments. The breccia is the result of leaching of the gypsum. At depth, it forms a massive, bedded gypsum unit.

Summary

Mineral deposits in the Nugget Sandstone, more specifically, those associated with the Griggs Mine, are of potential interest for *in situ* leaching research. These deposits contain interesting amounts of copper, zinc, and silver, along with trace amounts of cobalt. The Griggs deposit lies a few hundred feet above the present water table and within a sandstone of low permeability. This deposit is recommended for additional research.

PORPHYRY COPPER-MOLYBDENUM DEPOSITS

A reconnaissance program designed to examine several porphyry copper-molybdenum deposits in the Absarokas was initiated. The summary of this reconnaissance was published by Hausel (1982b).

Overall, these porphyry mineralized centers host disseminated copper-molybdenum mineralization with associated zinc, lead, gold, and silver. Research related to these deposits would be restricted because they are located in rugged terrain of the Absaroka plateau, and many are within Wilderness boundaries. Both the Sunlight Basin and the Kirwin intrusives are recommended for further study in that these two mineralized centers are accessible and lie outside of the Wilderness (Figure 1).

Kirwin

The Kirwin mineralized area, located on the northwest flank of Bald Mountain, is expressed by a rough ovel-shaped intense zone of hydrothermal alteration (Figure 21). The mineralized area is associated with a volcanic vent complex with exposures of intrusive rhyolitic tuff breccia (Wilson, 1964 ; Nowell, 1971). Brecciation appears more commonly along the edge of the vent.

This mineralized area exhibits hydrothermal alteration with increasing intensity toward the center of alteration. Outside of the alteration zone, Wiggins Formation andesites are deuterically altered and exhibit propylitic alteration products--calcite, chlorite, and clays. Within 1,500 feet of the mineralized center, Wiggins andesites exhibit hydrothermal propylitic alteration characteristics and, in addition to the typical alteration minerals--quartz, calcite, epidote, and montmorillonite, these rocks contain chalcopyrite-bearing quartz-calcite veinlets and disseminated chalcopyrite blebs. Nearer to the volcanic center, alteration assemblages are more characteristic of argillic and phyllic hydrothermal alteration. Major alteration products include sericite, mixed-layer illite-montmorillonite, quartz, and biotite with lesser kaolinite and chlorite. Epidote and calcite are nonexistent in this zone.

The potassic zone is not well-defined, but is suggested by the presence of secondary orthoclase with quartz and veinlet sulfides. This zone lies near the mineralized center (Nowell, 1971).

Drill hole data in the Kirwin area show stockwork mineralization of pyrite, chalcopyrite, and molybdenum. A secondary enriched blanket of chalcocite, digenite, and covellite overlies a portion of the stockworks, which, in turn, is overlain by a barren leached cap (Wilson, 1964). Veins in the altered area are pyrite-chalcopyrite-molybdenum-quartz veins (Wilson, 1960).

The U.S. Bureau of Mines reports that the Kirwin mineralized-altered area at Bald Mountain hosts a resource of at least 70 million short tons of 0.75 percent copper (Rosenkrantz and others, 1979).

Sunlight Mineralized Area

The Sunlight mineralized area is located on U.S. Geological Survey 15-minute topographic quadrangles Dead Indian Peak (1956) and Sunlight Peak (1956). The nearest population center is Cody, Wyoming, located 40 miles east of the mineralized area, although the Sunlight Basin area houses numerous private cabins and summer homes. Osterwald and others (1966), Parsons (1937), Williams (1980), Elliott (1980), and Hausel (1980, 1982a, b) provide overviews of the Sunlight deposits. Rich (1974), Pedersen (1968), and Dreier (1967) conducted thesis investigations in the area.

The first report of prospecting in the Sunlight area occurred in 1890 and the only report of ore production was 100 tons of gold, silver, and copper ore mined in 1903 (Williams, 1980, p. 34). Several hundred feet of exploratory workings have been developed by shaft and adits at several mine sites. All of these historic workings were developed along vein mineralization.

Two types of mineralization are recognized in the district; these are disseminated deposits and vein mineralization. The disseminated

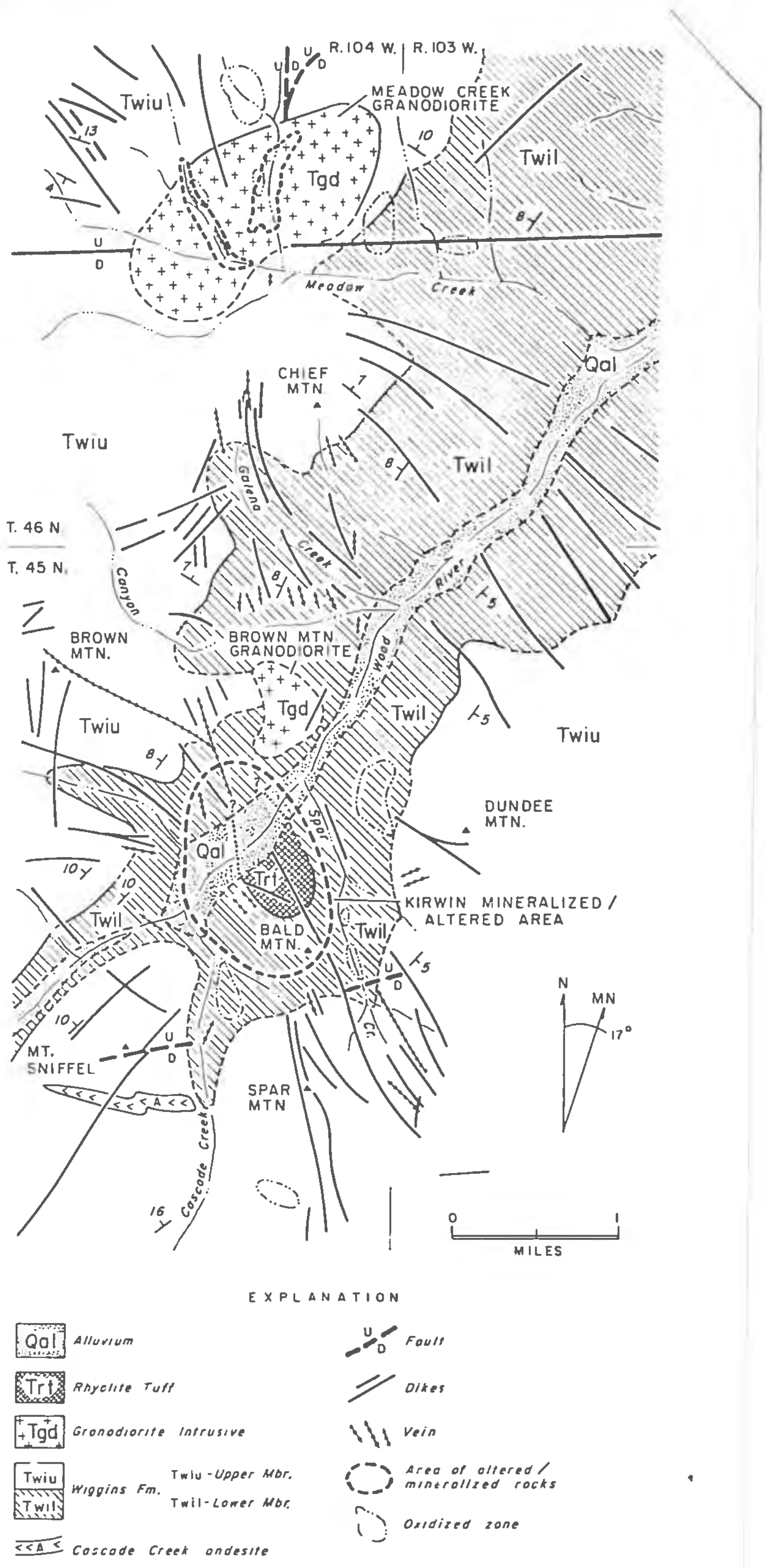

Figure 21. Generalized geologic map of the Kirwin-Wood River area (modified from Wilson, 1964, 1965; Nowell, 1971).

deposits consist of (1) pyrite in altered zones in all rock types, (2) chalcopyrite in intrusive rocks, and (3) copper-bearing stockworks (Elliott, 1980). Fairly well-developed stockworks are developed in a syenite stock at the headwaters of Sulfur Creek (Dreier, 1967), and in andesites in contact with syenite (Wilson, personal comm., 1982). The stockworks consist of less than one inch wide veins and veinlets hosting chalcopyrite, bornite, covellite, and chalcocite in quartz, calcite gangue (Figure 22).

Vein mineralization is zoned, and forms copper-rich veins near the mineralized centers, and lead-silver or barren veins at a distance from the stocks.

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

Primary controls on the mineralization were the intrusive masses and associated fracture systems. Disseminated mineralization is localized in and around intrusives, and veins are controlled by joint sets and shear zones (Elliott, 1980).

CONCLUSIONS

Of the deposits examined on a reconnaissance nature, five are recommended for additional study and research. These are the Copper King property in the Silver Crown District, the New Rambler Mine in the Douglas Creek District, the Griggs Mine area of the Lake Alice District, and the Kirwin and Sunlight porphyry deposits in the Absaroka plateau.

Figure 22. Geologic map of the Sunlight intrusive center (after Nelson and others, 1980).

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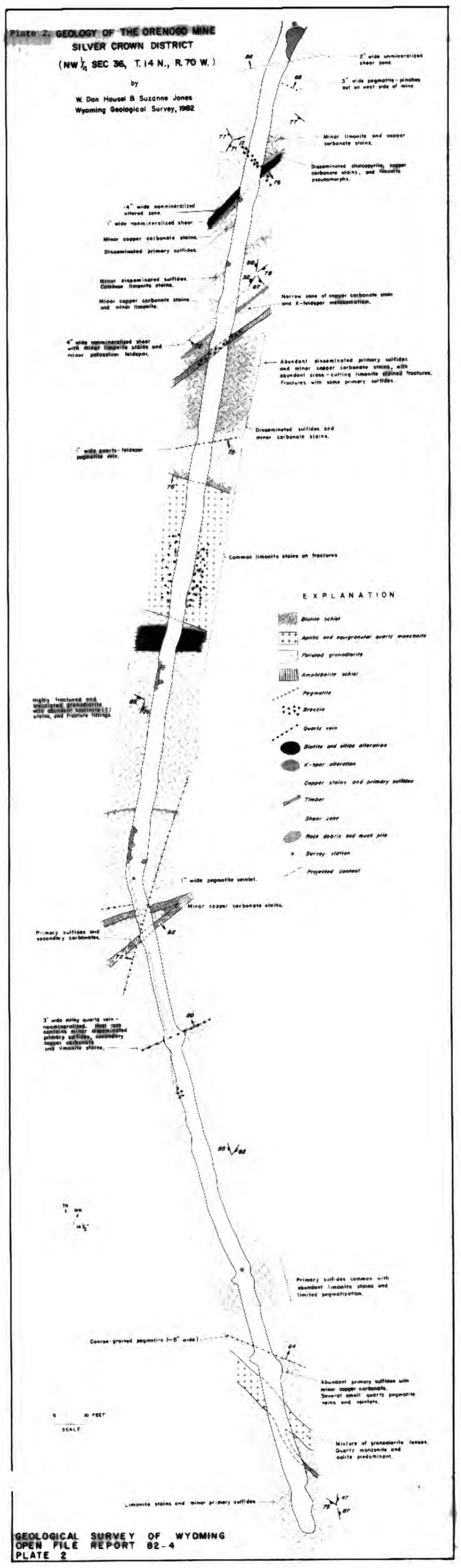
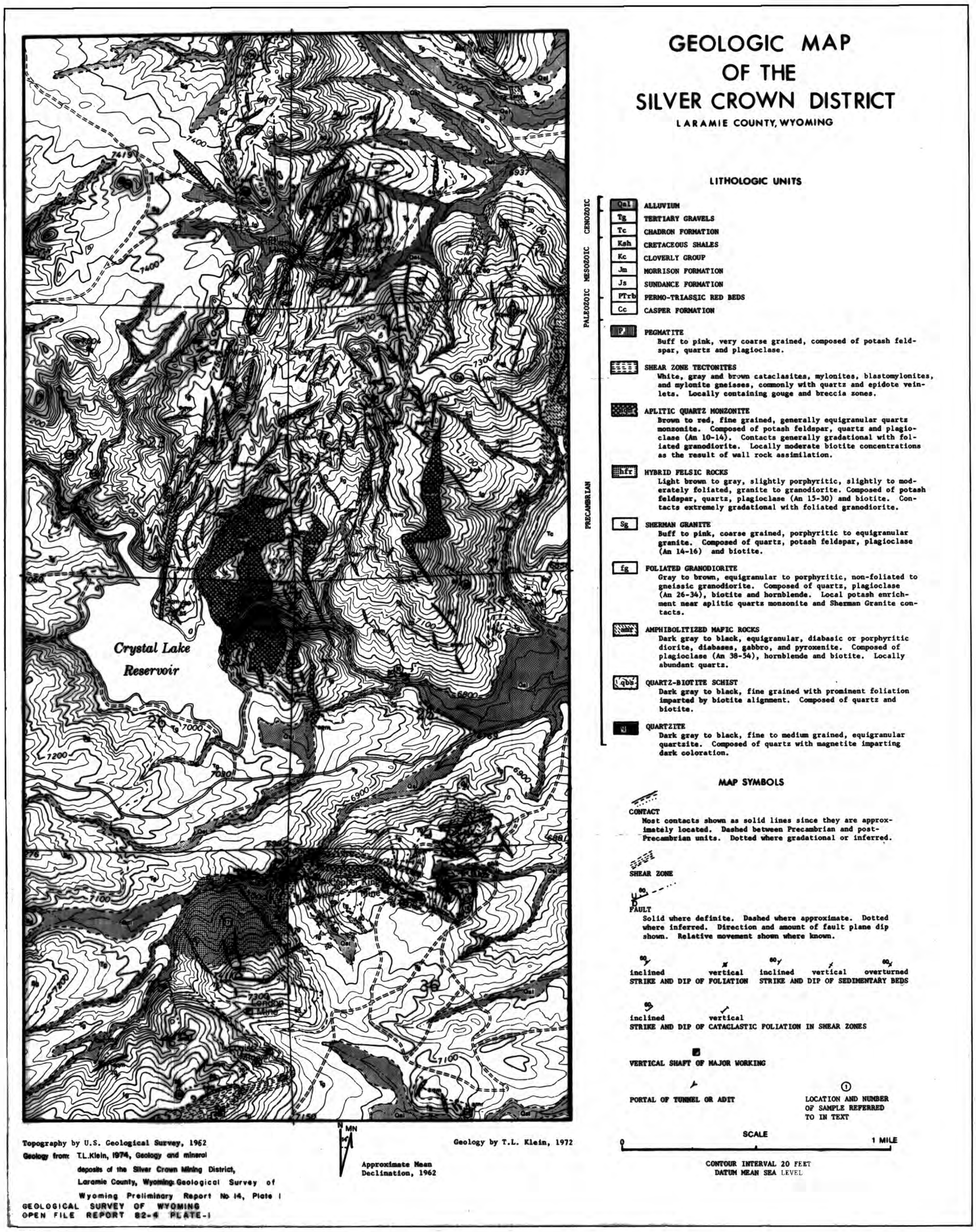
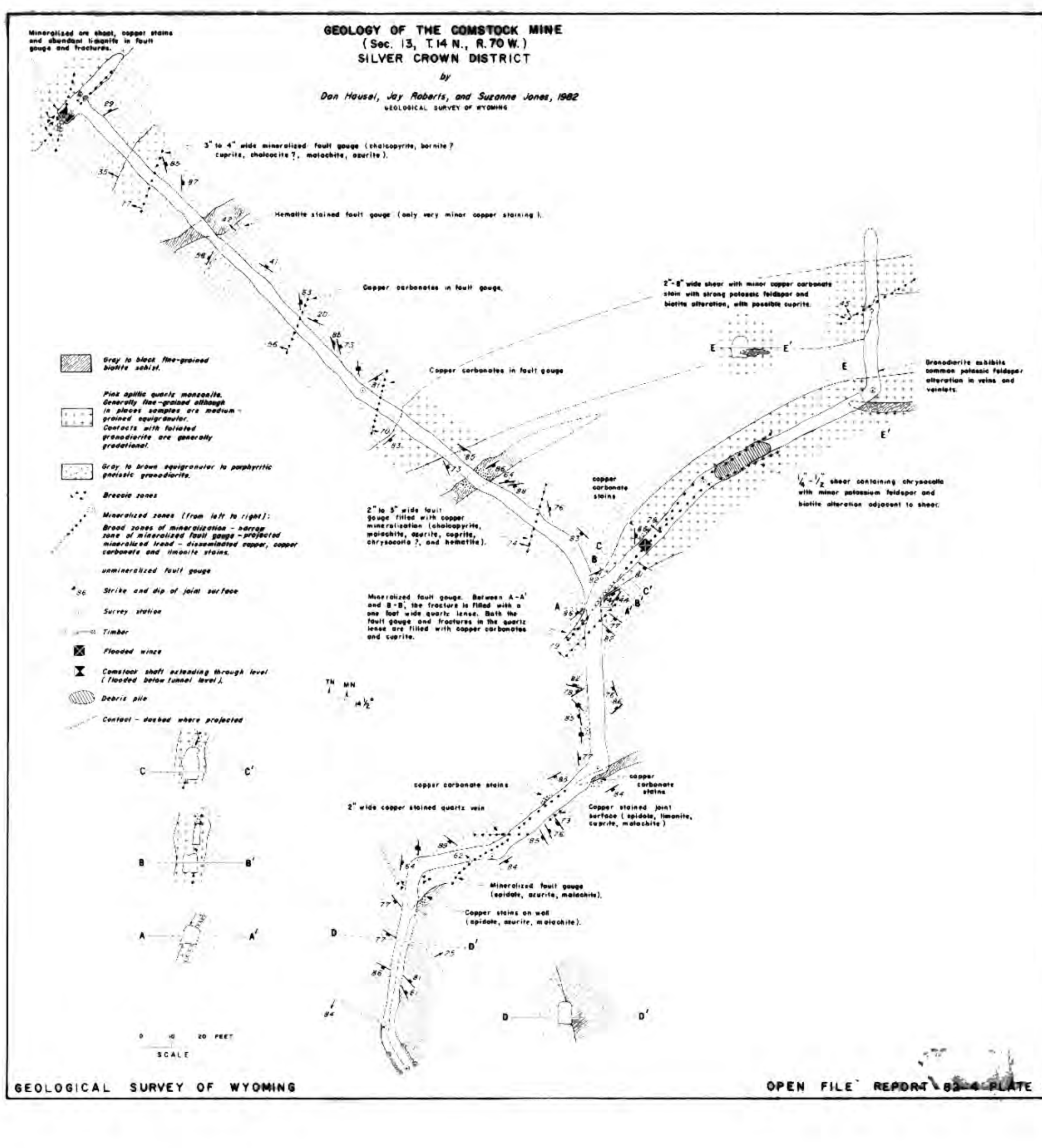


Plate 2. GEOLOGY OF THE ORENOGO MINE
SILVER CROWN DISTRICT
(NW¼ SEC 36, T. 14 N., R. 70 W.)
by
W. Don Hausel & Suzanne Jones
Wyoming Geological Survey, 1982
2" wide unmineralized shear zone.
3" wide pegmatite - pinches out on west side of mine.
Minor limonite and copper carbonate stains.
Disseminated chalcopyrite, copper carbonate stains, and limonite pseudomorphs.
4" wide nonmineralized altered zone.
1" wide nonmineralized shear.
Minor copper carbonate stains.
EXPLANATION
Common limonite stains on fractures
GEOLOGICAL SURVEY OF WYOMING
OPEN FILE REPORT 82-4
PLATE 2


GEOLOGIC MAP
OF THE
SILVER CROWN DISTRICT
LARAMIE COUNTY, WYOMING
Crystal Lake Reservoir
LITHOLOGIC UNITS
CENOZOIC
MESOZOIC
PALEOZOIC
PRECAMBRIAN
Qal ALLUVIUM
Tg TERTIARY GRAVELS
Tc CHADRON FORMATION
Ksh CRETACEOUS SHALES
Kc CLOVERLY GROUP
Jm MORRISON FORMATION
Js SUNDANCE FORMATION
PTrb PERMO-TRIASSIC RED BEDS
Cc CASPER FORMATION
PEGMATITE
Buff to pink, very coarse grained, composed of potash feldspar, quartz and plagioclase.
SHEAR ZONE TECTONITES
White, gray and brown cataclasites, mylonites, blastomylonites, and mylonite gneisses, commonly with quartz and epidote veinlets. Locally containing gouge and breccia zones.
APLITIC QUARTZ MONZONITE
Brown to red, fine grained, generally equigranular quartz monzonite. Composed of potash feldspar, quartz and plagioclase (An 10-14). Contacts generally gradational with foliated granodiorite. Locally moderate biotite concentrations as the result of wall rock assimilation.
hfr HYBRID FELSIC ROCKS
Light brown to gray, slightly porphyritic, slightly to moderately foliated, granite to granodiorite. Composed of potash feldspar, quartz, plagioclase (An 15-30) and biotite. Contacts extremely gradational with foliated granodiorite.
Sg SHERMAN GRANITE
Buff to pink, coarse grained, porphyritic to equigranular granite. Composed of quartz, potash feldspar, plagioclase (An 14-16) and biotite.
fg FOLIATED GRANODIORITE
Gray to brown, equigranular to porphyritic, non-foliated to gneissic granodiorite. Composed of quartz, plagioclase (An 26-34), biotite and hornblende. Local potash enrichment near aplitic quartz monzonite and Sherman Granite contacts.
amr AMPHIBOLITIZED MAFIC ROCKS
Dark gray to black, equigranular, diabasic or porphyritic diorite, diabases, gabbro, and pyroxenite. Composed of plagioclase (An 38-54), hornblende and biotite. Locally abundant quartz.
qbs QUARTZ-BIOTITE SCHIST
Dark gray to black, fine grained with prominent foliation imparted by biotite alignment. Composed of quartz and biotite.
q QUARTZITE
Dark gray to black, fine to medium grained, equigranular quartzite. Composed of quartz with magnetite imparting dark coloration.
MAP SYMBOLS
CONTACT
Most contacts shown as solid lines since they are approximately located. Dashed between Precambrian and post-Precambrian units. Dotted where gradational or inferred.
SHEAR ZONE
FAULT
Solid where definite. Dashed where approximate. Dotted where inferred. Direction and amount of fault plane dip shown. Relative movement shown where known.
inclined
vertical
STRIKE AND DIP OF FOLIATION
inclined
vertical
overturned
STRIKE AND DIP OF SEDIMENTARY BEDS
inclined
vertical
STRIKE AND DIP OF CATACLASTIC FOLIATION IN SHEAR ZONES
VERTICAL SHAFT OF MAJOR WORKING
PORTAL OF TUNNEL OR ADIT
LOCATION AND NUMBER OF SAMPLE REFERRED TO IN TEXT
SCALE
0
1 MILE
CONTOUR INTERVAL 20 FEET
DATUM MEAN SEA LEVEL
Topography by U.S. Geological Survey, 1962
Geology from: T.L.Klein, 1974, Geology and mineral deposits of the Silver Crown Mining District, Laramie County, Wyoming Geological Survey of Wyoming Preliminary Report No 14, Plate I
Geology by T.L. Klein, 1972
Approximate Mean Declination, 1962
GEOLOGICAL SURVEY OF WYOMING
OPEN FILE REPORT 82-4 PLATE-1


GEOLOGY OF THE COMSTOCK MINE
(Sec. 13, T.14 N., R.70 W.)
SILVER CROWN DISTRICT
by
Don Hausel, Jay Roberts, and Suzanne Jones, 1982
GEOLOGICAL SURVEY OF WYOMING
Hematite stained fault gouge (only very minor copper staining).
Copper carbonates in fault gouge.
Copper carbonates in fault gouge
Copper carbonate stains
Breccia zones
Unmineralized fault gouge
Strike and dip of joint surface
Survey station
Timber
Flooded winze
Debris pile
Contact - dashed where projected
SCALE
GEOLOGICAL SURVEY OF WYOMING
OPEN FILE REPORT 82-4 PLATE 3