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Precious Metal, Base Metal, and Gemstone Deposits of Wyoming

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PRECIOUS METAL, BASE METAL, AND GEMSTONE DEPOSITS OF WYOMING

by
W. Dan Hausel

ABSTRACT

Archean rocks in Wyoming host shear zone and vein Au deposits. Some Au anomalies also occur in banded iron formation. Proterozoic rocks host stratabound Cu-Ag-Au quartzites, a Au-Cu porphyry, volcanogenic Cu-Ag-Zn sulfides, Pt-Pd associated with layered mafic complexes, and radioactive metaconglomerates with isolated Au anomalies.

Phanerozoic rocks host a variety of base and precious metal deposits including Au-REE conglomerates, Cu-Ag-Zn red beds, Au paleoplacers, and Au-Th-REE and Cu-Ag porphyries. During the 1990 field season, these deposits received only a moderate amount of exploration interest.

INTRODUCTION

The available production statistics for iron ore and copper in Wyoming are probably relatively accurate. However, records for other metals (particularly precious metals) are far from accurate in that few production records were ever archived, and in many cases, production from the historic Wyoming and Dakota territories was typically incorporated into neighboring regions and mining districts. But based on the scattered reports, it appears that sufficient quantities of metals were recovered from Wyoming during past years to warrant further exploration of the State. The available records indicate that at least 135,000,000 tons of iron ore, 63,850,000 pounds of copper, 385,000 ounces of gold, 157,000 ounces of silver, 16,900 ounces of palladium, 900 ounces of platinum, 29,000 pounds of lead and some manganese, tungsten, titaniferous magnetite, chromite, rare earths, tantalite, jade, diamond, sapphire, ruby, aquamarine, beryl, onyx, agate, jasper, amazonite, zinc, aluminum (as anorthosite), vanadium, and graphite were recovered in the past.

Although metal deposits are scattered throughout the stratigraphic record, the greatest concentrations are in rocks of Precambrian and Tertiary age. Within the Precambrian, Archean (> 2.5 Ga) metal deposits include gold and iron ore in greenstone belts and in related supracrustal terranes that are found in several of the State's mountain ranges. Additionally, these terranes host scattered deposits of chromite, scheelite, copper, jade, other gemstones, feldspar, asbestos, and rare earths.

In southeastern Wyoming, thick Proterozoic (<2.5 Ga) metasedimentary successions crop out as miogeosynclinal wedges unconformably overlying the Archean basement. These rocks include quartzite-hosted stratabound Cu-Ag-Au deposits, Au-Ag veins, and radioactive Witwatersrand-type metaconglomerates with isolated gold anomalies. This miogeoclinal terrane is separated from a predominantly metavolcanic Proterozoic terrane to the south by a major Precambrian suture, or shear zone. The suture includes scattered Cu-Au-Ag-Pt-Pd deposits in shear zone cataclastics.

South of the shear, metavolcanics host scattered volcanogenic Zn-Cu-Ag massive sulfide deposits, at least one Cu-Au porphyry, and two large layered mafic complexes. The northern edge of one of these layered intrusives yielded some Pt and Pd to miners at the beginning of the 20th century.

Phanerozoic sediments host many precious metal anomalies and some Cu-Zn deposits. Au-REE mineralization occurs in Cambrian conglomerates in northern Wyoming, Ag-Cu-Zn stratabound deposits are found in bleached Jurassic redbeds in western Wyoming, and the broad Wyoming basins include many enigmatic gold occurrences and anomalies that can only partially be explained by detrital transport in fluvial systems. Rocks of Late Cretaceous age along the flanks of some uplifts include black sand deposits with detrital heavy minerals containing resources and occurrences of titanium, zirconium, rare earths, and in some cases gold.

Base and precious metal deposits are associated with scattered composite intrusives in the Absaroka Mountains of northwestern Wyoming. This deeply incised volcanic plateau includes several Tertiary age porphyry copper deposits with Cu, Ag, Mo, Ti, Pb, Zn, and Au resources.

In the Black Hills of northeastern Wyoming, Au-Th-REE mineralization is found associated with fenitized alkalic igneous rock. In addition to disseminated mineralization, scattered fluorite-Au-Cu-REE veins; Pb-Zn-Ag replacement lodes; and Sn pegmatites are found in this region. Similar alkalic intrusives disrupted Archean greenstone belt rocks in the Rattlesnake Hills in central Wyoming. Some gold occurs in this region.

The Tertiary of Wyoming was not only a time of volcanism, but was also an important time of paleoplacer development. Laramide uplifts were dissected by erosion which resulted in deposition of large volumes of fluvial conglomerate and fanglomerate along the flanks of the uplifts. In the vicinity of some greenstone belts and other supracrustal terranes, these conglomerates are often mineralized in gold.

Some modern placers in the State have been productive. Most commercial placers have been mined for gold, although some cassiterite, Pt, Pd, scheelite, monazite, diamonds, chromite, and tantalite have also been recovered from Recent placers.

THE ARCHEAN

Introduction

The ancient geology of Wyoming has been compared to some of the richest precious metal regions of the world including South Africa, Western Australia, and the Superior Province of Canada. These areas are all underlain by ancient Archean cratons with some of the oldest rocks on the surface of the earth. But unlike these other cratons, the Wyoming craton (termed the Wyoming Province) has been greatly modified by Laramide tectonics which thrust slices of the ancient craton through younger Phanerozoic sedimentary rocks. Due to the unfortunate nature of the Laramide tectonics, vast regions of the Wyoming craton remain at the bottom of the Tertiary basins unavailable to direct observation.

The Wyoming Province is not confined to the State of Wyoming, but extends into northern Utah, extreme northeastern Nevada, the eastern edge of Idaho, portions of Montana, and the northwestern corner of South Dakota. According to Condie (1976), the Wyoming craton may have once been part of the Superior Province of Canada. Within and along the margin of the Wyoming craton are vast mineral resources which include the Stillwater complex (Pt, Pd, Cr), Jardine (Au), Homestake (Au), and South Pass (Au, Fe).

The Province is formed of a vast region of high-grade gneiss and migmatite intruded by granite and granodiorite plutons that contain scattered blocks, fragments, and belts of supracrustal terranes that include greenstone belts, eugeoclinal successions, layered mafic complexes, and high-grade supracrustal belts. Mineral occurrences in the granite-gneiss terrane are uncommon, but the supracrustal belts have hundreds of gold, base metal, and related mineral deposits and prospects.

Houston (1983) noted the Province contained supracrustal successions of low-rank metamorphosed rock in the southern portion of the craton that exhibited similarities to greenstone belts in other cratons of the world. However, in the northern region of the craton, the rank of the supracrustal belts generally increases and the belts are lithologically distinct (Hausel and others, 1991). These northern supracrustal belts are typically formed of intercalated amphibolite and gneiss with subordinate metasedimentary successions of quartzite, metapelite, BIF (banded iron formation), amphibolite, and minor metacarbonate. Exceptions occur, such as the Jardine belt of the Snowy Range block of the Beartooth Mountains in the northern portion of the Wyoming craton, which was reported by Thurston (1986) to exhibit similarities to the South Pass greenstone belt to the south. It was Houston's (1983) opinion that the greenstone belts represented the greatest potential for Archean mineralization in the Province. These belts are concentrated along the southern margin of the craton in Wyoming.

Greenstone Belts

In general, the Wyoming greenstone belts form tripartite successions of low-rank metamorphosed (upper greenschist to middle amphibolite facies) sedimentary, volcanic, and plutonic rock, folded into a regional synclinorium. Bedding and most structural elements (i.e., foliation, isoclinal fold axes, auriferous shears) parallel the principal axis of the synclinorium. Although amphibolite facies metamorphism presides in these terranes, the rank is relatively low resulting in the preservation of some primary textures. Pillow structures, and porphyritic, amygdaloidal, spinifex, and cumulus textures have been preserved in some igneous rocks. Graded bedding, quartz pebbles, cross-bedding, and cut and fill channels occur in some metasedimentary rocks.

The lower successions of the belts are typically formed of mafic to ultramafic metavolcanic rocks described as hornblendic amphibolite, serpentinite, tremolite-talc-chlorite schist, mica schist, and metabasalt. These rocks have compositions that suggest their precursors were high-magnesian tholeiitic basalts and tuffs, and komatiitic basalts and peridotites.

The character of the greenstone successions changed through time and the underlying successions were replaced by calc-alkaline metavolcanics (meta-andesite, metadacite, felsic schist), high-iron tholeiitic basalts (amphibolite, greenstone, and metabasalt), and metakomatiite (actinolite schist, hornblende-plagioclase amphibolite, tremolite-talc-chlorite schist, and minor serpentinite). Metasedimentary rocks are prominent in the upper succession and include metagreywacke, BIF, with lesser quartzite, graphitic schist, metaconglomerate, and metapelite.

Several greenstone belts and fragments are recognized in Wyoming and include South Pass in the Wind River Mountains; Barlow Gap, the Rattlesnake Hills, and Tin Cup in the Granite Mountains; the Seminoe Mountains; Casper Mountain, Sellers Mountain, Esterbrook, and Elmers Rock in the Laramie Range; as well as other fragments in the Laramie, Medicine Bow, and Sierra Madre ranges (Condie, 1967; Houston, 1983). Of these, the South Pass, Seminoe Mountains and the Rattlesnake Hills regions have received the greatest exploration interest in recent years.

South Pass

The South Pass greenstone belt in the southern Wind River Mountains crops out over a 150 to 250 mi^2 surface area, but a large portion of the belt is projected under a thin (<1 ft to > 2,000 ft thick) blanket of Tertiary arkosic sandstone, siltstone, and conglomerate. During the past few years, this region has received minor exploration interest for lode, paleoplacer, and placer gold, yet the terrane undoubtedly offers the greatest potential of all of the greenstone belts in the Wyoming craton for the discovery of significant mineralization. Mineralization includes auriferous shear zones and veins, associated Tertiary paleoplacers and modern placers, Ag- and Au-bearing cupriferous veins, cupriferous stockworks, and vein and disseminated scheelite.

Shear zones in the greenstone belt are narrow, foliation-parallel, cataclastic zones, that exhibit both brittle and ductile deformation and have strike lengths of dozens of feet to more than 11,000 ft (Hausel and Hull, 1990). Widths are typically between 2 to 15 ft, although greater widths occur in some mines. Typically, these structures are weakly mineralized along much of their trend with localized ore shoots. The shoots occur at pinches, swells, fold closures, attitude changes, and at intersections of shears and faults.

Historic reports indicate the tenor of the shoots ranged from a trace to as much as 3,100 opt Au. Average ore grades varied from 2.06 ppm (0.06 opt) to 68.6 ppm (2.0 opt) Au with minor Ag (Hausel, 1989). The continuation of these structures downdip has not been fully tested since the deepest gold mine is only 400 ft deep, and drilling has penetrated the mineralized structures to depths of only 930 ft below the surface (deQuadros, 1989).

Many of the shears and veins are localized in metagreywacke and hornblendic amphibolite with fewer in graphitic schist, meta-andesite, greenstone, greenschist, metatonalite, and tremolite/actinolite schist. A large proportion of the shears are found along or adjacent to lithologic contacts of rocks with contrasting competency (Bayley, 1968; Hausel, 1987).

The source of the shear zone gold was suggested by Bow (1986) to have been rocks of komatiite affinity. But recent stable isotope and fluid inclusion studies by Spry and McGowan (1989) are redolent of a greywacke source. Hausel (1991), however, was impressed by the ubiquitous occurrence of structurally controlled gold anomalies throughout the greenstone belt independent of rock type and proposed the gold was derived by metamorphic secretion during a 2.8 Ga regional metamorphic event, and the shears served to focus the auriferous fluids.

In addition to narrow mineralized structures, the possibility exists for large-tonnage, low-grade, precious metal deposits in this greenstone belt. Five deposits investigated by the Wyoming Geological Survey as possible large tonnage deposits included the Carissa, Duncan, Lone Pine, Tabor Grand, and Wolf properties.

At the Carissa mine near South Pass City along the northern flank of the greenstone belt, a well-developed, narrow (1 to 50 ft wide) shear is enveloped by a broad zone (100 to 200 ft) of weakly mineralized wallrock with rehealed fractures. Beeler (1908) reported the ore in the shear averaged 10.29 ppm Au. A 1.5 ft channel taken across the shear on the surface assayed 5.2 ppm Au (Hausel, 1989). Composite chip samples collected in the wallrock adjacent to the shear also yielded anomalous gold. Over a 97 ft width, the wallrock averaged 0.80 ppm Au (Hausel, 1989) (Table 1).

At the Duncan mine, the foliation-parallel shear is folded and splayed. Within the fold closure, the gold values are enhanced (33 ppm Au over 2 ft). Surrounding the fold closure, the splayed wallrock averaged 2.5 ppm Au over a 37 ft (Table 1).

The Tabor Grand mine to the east of the Duncan, was driven on a 1 to 5 ft wide shear in hornblendic amphibolite. Chip and channel samples in the shear yielded 0.06 to 58.0 ppm Au over a 350 ft length. During mapping, a second shear parallel to the first was discovered 20 ft south of the primary shear. Two samples taken in this shear yielded 1.7 and 7.0 ppm Au. Surface mapping extended the length of the shear another 800 ft to the east where an 8 ft channel assayed 3.8 ppm Au (Hausel, 1991).

At the Lone Pine mine in the Lewiston district along the southeastern margin of the greenstone belt, a hidden shear was discovered under a thin veneer of Tertiary sediments. The discovery trench exposed a minimum 17 ft wide shear which yielded gold values of 0.47 to 3.5 ppm (Table 1). The maximum mineralized width and strike length of this structure have not been determined.

North of the Lone Pine mine, representative samples from the Wolf mine yielded 23.3 ppm Au (Hausel, 1989). This property was later examined by U.S. Borax who determined the shear contained low-grade mineralization over a width of more than 100 ft. Currently, the property is being explored by Barnhart Drilling Company which has extended the mineralized zone over a 250 ft width (Finch, 1993).

Table 1. Chip channel and channel sample analyses in the South Pass greenstone belt (Hausel, 1989).

SAMPLE DESCRIPTION	Au (ppm)	Ag (ppm)
Carissa Mine		
0 to 10 ft north of shear	0.4	--
10 to 20 ft north of shear	1.05	--
20 to 37 ft north of shear	2.5	--
0 to 10 ft south of shear	0.65	--
10 to 20 ft south of shear	0.25	--
20 to 30 ft south of shear	0.30	--
30 to 60 ft south of shear	0.35	--
30 ft composite north of shear	2.4	--
Duncan Mine		
0 to 2 ft west of fold closure in shear	3.0	2.2
2 ft channel across fold closure	33.0	6.0
0 to 5 ft east of closure	1.8	1.8
5 to 15 ft east of closure	6.6	2.7
15 to 25 ft east of closure	0.71	7.4
25 to 35 ft east of closure	0.53	1.0
Lone Pine Mine		
0 to 4 ft (E to W) in shear	0.47	2.5
4 to 7 ft (E to W) in shear	0.69	1.9
7 to 11 ft (E to W) in shear	3.5	4.3
11 to 17 ft (E to W) in shear	1.6	2.9

In addition to auriferous shears, cupriferous veins with Au and Ag values are found at several locations in the belt. These veins have little economic value because of the lack of tonnage. They are seldom greater than 2 ft wide and pinch and swell over short distances along strike. However, one unexplored Cu-Ag stockwork along the northwestern flank of the belt may offer some potential. The stockwork is buried under soil in a aspen grove. Grab samples of the mineralized rock yielded 3.23 % Cu, 3.2 ppm Ag, and 0.16 ppm Au (Hausel, 1991).

The South Pass greenstone belt also has extensive iron deposits in the limbs of the South Pass synclinorium. The BIF along the northern flank of the belt was structurally thickened by internal folding and plication and by repetition along faults. This deposit was reported by Bayley (1968) to have indicated reserves of 300 million tons of 30% Fe. From 1962 to 1983, U.S. Steel Corporation mined more than 90 million tons of iron ore. Recent mapping indicates a sizable resource is remains in place (Hausel, 1991).

The possibility of gold in the iron formation was not considered during the 20 year operating lifetime of the mine. However, samples collected a short distance southwest in the BIF by the Wyoming Geological Survey, yielded gold anomalies (maximum of 1.3 ppm). Other anomalies were detected in BIF along the southeastern margin of the greenstone belt. Only a small number of sulfide-bearing oxide facies BIF were collected by the Survey in the open pit mine before it was flooded in 1983. None of these samples contained detectable gold (minimum detection limit 0.02 opt).

Seminoe Mountains

The supracrustal rocks of the Seminoe Mountains greenstone belt, in south-central Wyoming, yielded an age of approximately 2.7 Ga. The relative volume of metagreywacke and metapelite in the Seminoe Mountains is minor, BIF is abundant, and the belt includes a thick section of spinifex-textured basaltic komatiite and cumulate- and spinifex-textured serpentinite and metaperidotite (Klein, 1981; Snyder and others, 1989).

Gold is concentrated in a 1/4 mile diameter altered zone of metagabbro and metabasalt near the western margin of the belt (Klein, 1981). Samples of quartz collected in this region were highly anomalous and yielded gold values as high as 98.4 ppm. BIF is also locally anomalous in Au and Ag (Hausel, 1992). Amphibolites in the altered zone have been overprinted by chlorite, carbonate, quartz, and sulfide alteration assemblages (Klein, 1981). The zone is transected by narrow quartz-calcite veins and stockworks containing minor pyrite and chalcopyrite. Ore shoots often yield visible gold and exhibit control by folding.

The Seminoe Mountains greenstone belt contains ubiquitous BIF. The predominantly oxide facies BIF is interlayered with metabasalt and metasediments. A portion of the BIF examined by the U.S. Bureau of Mines contained an estimated 100,000,000 tons which varied from 28% to 68.7% Fe (Harrer, 1966).

Copper deposits are sporadic and appear to be unimportant in the belt. The recent discovery of anomalous Zn- and Pb-bearing shears, and several pyrope garnets and chromian diopsides in a Tertiary gold paleoplacer are intriguing (Hausel, 1992). The Seminoe Mountains were last explored by Kerr McGee and Timberline Minerals in the early to mid 1980s.

Rattlesnake Hills

The Rattlesnake Hills form a supracrustal belt of Archean metasedimentary and metavolcanic rock along the northern edge of the Granite Mountains. The belt was intruded by more than 40 Tertiary alkalic plugs and dikes. Recent mapping by the Wyoming Geological Survey shows the supracrustal belt to consist of a refolded, isoclinally folded greenstone belt fragment with a lower (?) metasedimentary succession of metapelite, quartzite, banded iron formation, and amphibolite overlain (?) by pillowed metatholeiites, which in turn is overlain (?) by metagreywacke with intercalated metacherts. Farther north, the metagreywackes lie in contact with amphibolite and metabasalt. Alkalic plugs intruding the Precambrian succession include phonolite and quartz latite. Precambrian rock adjacent to phonolite is typically unaltered and coherent. Supracrustals adjacent to quartz latites usually are iron-stained and brecciated.

Exploration targets in the district include quartz breccia veins, metachert, BIF, jasperoid, breccias, and stockworks. One 2,500 ft long pyritiferous vein (metachert) with minor galena and jasperoid sampled in 1982 yielded composite chip samples that assayed 7.5 and 4.5 ppm Au (Hausel and Jones 1982). Samples collected from this same trend in 1992 included a jasperoid which yielded 52 ppb Au, 2.0 ppm Ag, 123 ppm Cu, 61 ppm Pb, 59 ppm Zn, 12 ppm Mo, 20 ppm As, 1.4 ppm Sb, and 0.021 ppm Hg. Another sample of jasperized quartz breccia collected a few miles west assayed 86 ppb Au, 0.3 ppm Ag, 122 ppm Cu, 239 ppm As, and 5.1 ppm Sb. Nearby, scorodite-stained quartz in metabasalts assayed 925 ppb Au, 1.2 ppm Ag, 524 ppm Cu, 42 ppm Pb, 1.65% As, 8.2 ppm Sb, and 0.028 ppm Hg. This latter sample was taken along a more than one mile long mineralized trend. Samples collected at several locations along this trend yielded anomalous metal content. To the south, a sample of brecciated BIF along the southwestern margin of the supracrustal belt yielded 5.0 ppm Au, and 0.28 ppm Ag. A sample of iron-stained stockwork in amphibolite gneiss in this same general region yielded 0.30 ppm Au with no detectable Ag.

American Copper and Nickel explored the Rattlesnake Hills from 1983 to 1987. ACNC identified several gold anomalies in structurally prepared Archean metamorphics (John Ray, pers. comm., 1991). The area is currently being explored by Canyon Resources and being mapped by the author.

Other Supracrustal Belts

In addition to greenstone terranes, the Wyoming Province encloses medium- to high-rank metamorphosed supracrustal belts. These belts occur in the Tobacco Root Mountains, and the Ruby and Gravelly Ranges of Montana, and the Copper Mountain district of the Owl Creek Mountains, Wyoming. Another supracrustal belt, the Hartville uplift in the southeastern corner of the Province, is a relatively low-rank metamorphosed eugeoclinal belt.

Copper Mountain

The Copper Mountain district in the eastern Owl Creek Mountains is interpreted as a high-grade supracrustal belt of intensely metamorphosed and isoclinally folded intercalated amphibolite and quartzofeldspathic gneiss, with BIF, metapelite, and quartzite. Scattered mineral deposits in the district include stratiform scheelite, vein Cu and Au, and REE-Ta pegmatites with uncommon aquamarine. Along the eastern edge of the district, the DePass mine was developed by more than 11,000 ft of workings in the early 1900s. This mine is located in a 50 ft wide Proterozoic mafic dike hosted by Archean granite. The mine yielded a minimum of 568,000 lbs of concentrates with receipts for Cu, Au, and Ag (Hausel and others, 1985).

Hartville uplift

The Hartville uplift is interpreted as an Archean eugeoclinal terrane formed of a succession of hematite schist, metadolomite, metabasalt, and pelitic schist unconformably overlain by Paleozoic carbonates. Past production amounted to more than 45 million tons of iron ore, more than 5 million lbs of Cu, and some silver and uranium. Mineral deposits in the region include the McCann Pass pyritiferous massive sulfide deposit, scattered Cu-Ag-Au-U unconformity deposits, iron schist, and Mexican onyx. The Silver Cliff mine near the northern edge of the uplift was initially developed for gold and silver in the 1870s and later mined for uranium in the early and mid 1900s (Hausel, 1989). Mineralization is localized in fault gouge and along a Precambrian-Cambrian unconformity.

The Hartville uplift is principally known for its massive hematite ores, although copper was mined and smelted in the district for more than a decade beginning in 1888. In 1899, with the copper deposits near depletion, the hematite became the object of mining. For many decades, the hematite was mined by C.F.&I. Corporation at the Sunrise, Good Fortune, and Chicago mines until operations ceased in 1981. The Michigan mine to the north of the Sunrise mine in the central portion of the uplift is subdivided into two unexploited deposits. The northern ore body contains 75,000,000 tons of 25% Fe, and the southern deposit contains 41,000,000 tons of 24% Fe (Wilson, undated). At the surface, the hematite is cupriferous and anomalous in gold (Woodfill, 1987). The hematite is secondary in origin and interpreted to have originated from groundwater oxidation and enrichment of originally ferruginous beds (Bayley and James, 1973; Snyder and others, 1989).

Unconformity deposits also occur in the Hartville region. In the northern portion of the uplift, the Silver Cliff shaft was driven on a Precambrian-Phanerozoic unconformity and in fault gouge. Available assay reports indicate the ore contained none to 10.88 % Cu, none to 15.04 opt Ag, 0.001 to 3.39% U_3O_8, and anomalous gold (Wilmarth and Johnson, 1954). In the southern portion of the uplift, Kerr McGee explored a Cu-stained Precambrian-Paleozoic unconformity recovering samples with cerargyrite, unmangite, electrum, and native gold (Kerr McGee Corp., 1988).

South of the Silver Cliff mine, a contact between hanging wall dolomite and footwall schist is mineralized over a 1 to 15 ft thickness at the Copper Belt Group. Lenses from the Group assayed 2 to 8% Cu and the adjacent altered iron-stained schist contained 0.05 to 0.58 opt Au and 2 to 5 opt Ag (Ball, 1907).

In the southern portion of the uplift, an extensive gossan at "gossan hill" along the McCann Pass fault was prospected by Mine Finders in the 1970s, later by Exxon Minerals, and recently by Phelps Dodge. Outcrop and shallow drill holes recovered samples with elevated Cu, As, and Zn. Deeper drilling intersected thick zones of anomalous mineralization including 10 ft of 0.8% Zn, and 2 ft of 1.2% Zn and 0.08 opt Au (Woodfill, 1987). Currently, Cominco American Inc., Doe Run, and Phelps Dodge are exploring the Hartville uplift for metasedimentary-hosted massive sulfide deposits.

THE PROTEROZOIC

Nearly all of the Proterozoic rocks in Wyoming are restricted to the southeastern corner of the state in the Laramie, Medicine Bow, and Sierra Madre Mountains. The Sierra Madre and Medicine Bow Mountains are bisected by a prominent Precambrian suture known as the Mullen Creek-Nash Fork shear zone, or Cheyenne Belt. This shear is projected into the Laramie Range where it was intruded by a 350 mi^2 anorthosite batholith at about 1.4 Ga. To the north of the Cheyenne Belt, Proterozoic miogeosynclinal metasedimentary rocks exposed in the Medicine Bow Mountains and Sierra Madre form a thick wedge lying on the Archean basement. South of the suture are volcanogenic schists and metasediments of the Green Mountain terrane that represent a Proterozoic island arc accreted to the craton nearly 1.7 Ga ago. Archean basement rocks are absent from this region.

Miogeoclinal Terrane

North of the Cheyenne Belt, precious metals occur in narrow veins, shear zones, and in thick quartzites associated with copper. Gold has also been detected in quartz pebble conglomerate (Houston, 1992).

The Proterozoic rocks contain some rich vein deposits. In the Gold Hill district of the Medicine Bow Mountains, and the Purgatory Gulch district of the Sierra Madre, the veins are narrow, with common visible gold. Specimen samples taken out of the districts each year testify to the richness of the veins. Historic reports claim some specimen grade material taken from the Acme mine at Gold Hill assayed 2,100 opt Au. Unfortunately, these veins are narrow (0.5-4 ft wide) and the mineralization is spotty. Samples recently collected in Purgatory Gulch included specimens of quartz with visible gold. One select sample yielded 40.63 ppm Au and 3.62 ppm Ag.

The Proterozoic terrane also hosts some mineralized shear zones. One structure in the Lewis Lake area of the Medicine Bow Mountains is greater than 100 ft wide and has a minimum strike length of 2,000 ft. The shear is in limonitic quartz-mica schist. Samples of the sheared pyritized schist yielded 0.063 ppm to 4.8 ppm Au (Dersch, 1990; Wyoming Geological Survey Geo-notes, 1991, no. 30, p. 49).

Mineralized quartzites occur at several localities in the Sierra Madre north of the Cheyenne Belt. Gossans in quartzites prospected in the late 1800s led to the development of some important copper mines. Two prominent mines were the Ferris-Haggerty and the Doane-Rambler. During the operation of the Ferris-Haggarty (1902 to 1908), the mine was one of the more important copper mines in the West (Houston, 1992). This mine still offers some potential in that the low-grade ore was left in place.

The Ferris-Haggerty deposit is interpreted as a remobilized stratabound copper deposit (Hausel, 1986). Massive chalcocite minor chalcopyrite ore fills irregular quartzite breccias along the contact between hanging wall schist and the underlying quartzite (Spencer, 1904). Ore shoots greater than 20 ft thick were high-graded for the rich (30-40 % Cu) ore, and much of the lower grade material was left as waste. The ore averaged 6 to 8 % Cu and carried some Au and Ag (Beeler, 1905; Spencer, 1904). Beeler (1905) reported the ore contained 3.4 to 15 ppm Au. The mine was mapped during World War II, and according to Ralph E. Platt (pers. comm., 1988), the steeply dipping quartzite flattens out in the lower mine workings where large blocks of "low grade" ore (~ 5% Cu) remain in place. The property was last explored for stratiform Cu-Au-Ag mineralization by Exxon Minerals in the early to mid 1980s.

Proterozoic age quartz pebble conglomerate occurs in the thick miogeoclinal wedge in the northern Medicine Bow Mountains and Sierra Madre. These conglomerates were of considerable interest in the late 1970s after it was discovered that they were radioactive (Houston and Karlstrom, 1979). During mapping of these conglomerates some samples were tested for precious metal content. Gold values as high as 10 ppm were detected from a conglomerate near Dexter Peak in the Sierra Madre. Even though similarities to the Witwatersrand conglomerates have been noted (e.g. Houston and others,1983; Hutchison and Viljoen, 1988; Karlstrom and others, 1981), these rocks still have received only minor attention for gold. Exxon explored and drilled some of the conglomerates in the late 1970s in search of U and Th. In the early 1980s, Superior Minerals initiated a project to prospect for Au. Recently, BHP-Utah International has shown some interest.

Green Mountain Terrane

Precious and base metals south of the Cheyenne Belt occur in quartz veins, massive sulfides, a porphyry, and in layered mafic intrusions. In the Keystone district of the Medicine Bow Mountains, N60°W-trending shears are loci for narrow veins. These veins are gold- and copper-bearing, pyritic, quartz-carbonate veins in tensional faults subsidiary to the Mullen Creek-Nash Fork shear zone (Currey, 1965). Mineralization is accompanied by silicification in the form of small, irregular quartz veinlets and the wallrock is enriched in epidote.

At the Keystone mine, gold was found in quartz, and in pyrite and pyrrhotite masses in mylonite selvages adjacent to the vein. The vein lies in sheared diabase that intrudes quartz-biotite gneiss country rock (Currey, 1965). The shear is 2 to 6 ft wide, locally splays to 300 ft, and continues 4,500 ft to the southeast to the Florence mine. Available information indicates the Keystone ore averaged 1.2 opt Au. When the mine ceased operations in 1893, 100,000 tons of reserves were reported in site. Eight samples collected from the mine dump by Loucks (1976) yielded 6.5 ppm to 300 ppm Au and averaged 117 ppm Au. Samples recently collected by the author yielded none to 22.0 ppm Au, and none to 2.6 ppm Ag.

At the the southeastern end of the Keystone trend, the Florence mine was developed in sheared quartz diorite. The ore occurred as 'kidneys' of auriferous pyrite which assayed from 7.5 to 48 opt Au (Currey, 1965). Samples collected from the mine dump by Loucks (1976) yielded values ranging from 2.06 ppm to 799 ppm Au. One sample collected by the author in 1990 consisted of limonite boxwork after pyrite with abundant visible gold. Other samples collected for assay yielded none to 45.0 ppm Au, and none to 2.3 ppm Ag.

Volcanogenic massive sulfide deposits occur in the Green Mountain Formation of the southern Sierra Madre. This unit consists of relatively low-grade metamorphosed calc-alkaline metavolcanics and associated metasedimentary rocks and volcaniclastics. The massive sulfides are copper or zinc dominated with silver and traces of gold. Between 1979 and 1982, Conoco Minerals Company explored this region for massive sulfides (Conoco Minerals Company, 1982). Mineralized exhalites were discovered in metarhyolite and meta-andesite, and colloform-textured, pyrite-chalcopyrite was found associated with volcaniclastics (mill rock) (Hausel, 1986). Recent exploration in this region was reported by BHP-Utah International in the Pearl district of Colorado, and by Noranda to the north in Wyoming. No major discoveries have been reported.

In the same general region, the Wyoming Geological Survey investigated a cupriferous shear in Sierra Madre granite at the historic Kurtz-Chatterton mine on Copper Creek. The Kurtz-Chatterton deposit exhibits widespread copper mineralization over a width of 800 to 1,000 ft and a minimum strike length of 2,500 ft and possibly as much as 4,000 ft. Ten samples collected from the deposit were highly mineralized and averaged 4.43% Cu, 5.96 ppm Au, and 2.1 ppm Ag.

At least one deposit in the Laramie Range south of the shear zone has been classified as a low-grade, Au-Cu porphyry. The Copper King mine in the Silver Crown district west of Cheyenne (Klein, 1974) was developed in weakly foliated and hydrothermally altered quartz monzonite and granodiorite. A shaft sunk in a potassium-silicate altered zone is surrounded by propylitically altered rock.

The Copper King was initially drilled by the U.S. Bureau of Mines in the 1950s, later by Asarco, and more recently by Caledonia Resources and Royal Gold. Drilling has outlined a 35,000,000 ton ore body averaging 0.755 ppm Au and 0.21 % Cu (Nevin, 1973). Recent work by Caledonia Resources outlined a higher grade zone consisting of 4,500,000 tons averaging 1.5 ppm Au. The Copper King porphyry is mineralized along a 600 to 700 ft strike length and a 300 ft width that is open at depth (Stockwatch, 1987).

A few years ago, American Copper & Nickel, Chevron Resources, International Platinum, and Vanderbilt Gold explored two layered mafic complexes (1.8 Ga) in the Medicine Bow Mountains. The 60 mi^2 Mullen Creek complex abuts against, and is sheared by, the Mullen Creek-Nash Fork shear zone. This complex is highly deformed and metamorphosed, and along its northeastern corner is a historic Cu-Pt-Pd mine. The New Rambler shaft was collared in sheared and hydrothermally altered mafic rock and sporadically operated from 1900 to 1918 producing at least 6,100 tons of copper ore with values in Au, Ag, Pt, and Pd. Production has been estimated at 1,750,000 lbs of Cu, 170 oz of Au, 7,350 oz of Ag, 16,870 oz of Pd, and 910 oz of Pt. The source of the platinoids has not been determined, although one possibility suggested by McCallum and Orback (1968) is hydrothermal remobilization from a platinum reef hidden at depth.

Six miles east of the Mullen Creek mafic complex is a second layered intrusive known as the Lake Owen complex. This intrusive is of similar size, but is essentially unmetamorphosed. Cumulus sulfides have been identified in 12 horizons, four of which have laterally persistent precious metal anomalies of a few hundred to a few thousand ppb. The mineralized zones contain Au-Ag alloys, Pt-arsenides, Pt-Pd tellurides and sulfides associated with disseminated chalcopyrite, pendlandite, pyrrhotite, pyrite, gersdorffite, bornite, millerite, and PGE-bearing carrollite. The mineralized zones are lensey and spotty, although they are up to 15 ft thick and more than a mile long (Loucks, 1991; Robert Loucks, pers. comm., 1991). Currently, Chevron Resources are maintaining their holdings in the complex (Paul J. Graff, pers. comm., 1993).

The Mullen Creek-Nash Fork shear zone is a major Precambrian suture formed of mylonite, shear cataclastics, and breccia that separates the Archean craton to the north from the Proterozoic basement to the south. Several mineral deposits in the Medicine Bow Mountains occur in this zone (Houston, 1992).

Anorthosite Complex

The Cheyenne Belt was intruded by a 350 mi^2 anorthosite complex in the Laramie Mountains at about 1.4 Ga. The complex contains massive pods and disseminated titaniferous magnetite that have been the subject of numerous investigations. Union Pacific investigated the deposits in the 1950s 60s and 70s and determined that these deposits could be successfully be mined and milled for iron, titanium dioxide, and vanadium pentoxide.

However, the titaniferous magnetite has been mined only as a heavy aggregate. Production of massive titaniferous magnetite during the late 1950s to early 1970s amounted to 1,091,452 tons (Hausel, 1990). Magnetite Products Corporation mined the Cobar deposit (Sybille pit) from 1957 to 1963. The Heviwate Corporation mined 94,000 tons of ore from the Cobar mine between 1967 to 1969. From 1963 to 1969 Plicoflex Inc. recovered approximately 675,000 tons of ore from the Iron Mountain deposit, and from 1972 to 1974, U.S. Aggregate Company mined 14,500 tons of ore from the Shanton mine. In 1983 and 1984, U.S. Chrome drilled the Strong Creek disseminated titaniferous magnetite deposit.

Hagner (1968) reported more than 30 deposits of massive titaniferous magnetite occurred in the anorthosite complex. In addition to the massive ore, the complex contains huge resources of disseminated titaniferous magnetite. The massive ore is concentrated near the fold axis of a antiform in the anorthosite. In addition to titanium and iron, these deposits also contain anomalous vanadium and chromium. Published analyses indicate the ore to range from 26.26% to 83.43% Fe_2O_3, 10.75% to 28.0% TiO_2, 0.03% to 2.45% Cr_2O_3, and 0.07 to 0.46% V_2O_5. The deposits are assumed to have formed either by magma unmixing or as cumulates (Frost and Simons, 1991).

Recent interest has been shown for the Strong Creek deposit, which is a disseminated deposit hosted by gabbroic to noritic rocks of the complex. The deposit consists of disseminated ore, about 5% Fe-Ti oxides with layers up to 2 inches thick of massive Fe-Ti oxides (Kling, 1986: Frost and Simons, 1991). The deposit has a width of about 500 feet and a strike length of nearly 1 mile, and extends to a depth of at least 650 feet based on drilling. Drilling has identified at least 100,000,000 tons of disseminated ore of an average grade of 6.0% TiO_2, 14% FeO, and 0.25% V_2O_5 (Frost and Simons, 1991).

THE PHANEROZOIC

Gold anomalies are scattered throughout the Phanerozoic in the State. Many of these anomalies are enigmatic with no definite source terrane. In Paleozoic and Mesozoic rocks, gold deposits and anomalies are much less common than in the Cenozoic. Whereas, in the Cenozoic, there is a significant increase in anomalies compared to the earlier Eras. The increase in gold anomalies is partially due to the Cenozoic section being better preserved, but also because the Cenozoic Era represented a period of gold redistribution from Precambrian sources and an influx from volcanic sources.

Paleozoic Mineralization

The Paleozoic record is not well preserved in Wyoming. However, thick limestones and dolomite crop out along the flanks of the uplifted mountain ranges. Gold-bearing Cambrian Flathead Formation (Deadwood-equivalent) conglomerates occur at a few localities in the state. The better known of these is the "Deadwood conglomerate" (basal Flathead Conglomerate) at Bald Mountain west of Burgess Junction in the northern Bighorn Mountains. In southeastern Wyoming and northern Colorado more than 100 Early Devonian kimberlite diatremes, blows, and dikes intrude the Precambrian terrane, more than a dozen of which have yielded diamonds.

Bald Mountain

During the Bald Mountain rush near the turn of the century, more than 1,500 miners occupied the short-lived town of Bald Mountain and prospected the conglomerate and associated modern placers for gold. However, the grades were too low to sustain commercial operations and the district was deserted. The gold occurred as flat, fine-grained flakes with jagged edges.

In addition to gold, the conglomerate carries black sands with ilmenite, magnetite, zircon, and monazite (Wilson, 1951; Mckinney and Horst, 1953; King and Hausel, 1991). Interest in the monazite resulted in a U.S. Bureau of Mines drilling project which outlined a 20,000,000 ton low-grade resource averaging 2.5 lbs/ton of monazite with a higher-grade resource of 675,000 tons averaging 13.2 lbs/ton of monazite including a resource of 22,000 tons of contained ilmenite (Borrowman and Rosenbaum, 1962; King and Hausel, 1991).

During testing of the Bald Mountain conglomerate, the Bureau of Mines ran gold assays of material recovered from six drill holes in the better-grade monazite areas. The assays showed gold contents to range from 0.034 ppm to 0.172 ppm, and to average 0.103 ppm (McKinney and Horst, 1953). The actual gold content of the conglomerate is undoubtedly higher than that reported by the U.S. Bureau of Mines, in that the samples were composited from the entire depth of dry rotary-drilled holes. Darton (1906) reported gold assays to run as high as 0.1 opt. Although it is not known if Darton's assays are from reworked placers, or from the Cambrian paleoplacers.

Kimberlites

Southeastern Wyoming includes more than 100 Early Devonian kimberlite dikes, blows, and diatremes. Nearly every intrusive that has been tested in the State Line district to date, has yielded diamonds. More than 40 kimberlites occur in the State Line district of Colorado and Wyoming (Hausel and others, 1985).

Diamonds were first discovered in this region in 1975 (McCallum and Mabarak, 1976). In 1979, the State of Wyoming and Union Pacific Resources attracted several companies to this region to search for commercial diamond deposits. Cominco American Inc., constructed a diamond recovery plant initially in Spokane, and later in Ft Collins and tested several intrusives in the Wyoming portion of the State Line district. The recovered diamonds ranged from microscopic to 0.86 carat. Approximately one-half of the diamonds were gem in character.

To the south in Colorado, Superior Minerals Company constructed a plant adjacent to the Sloan 1 diatreme in the Prairie Divide area. The plant was later sold to the Mobile-Lac Minerals joint venture. Currently the plant is owned by Dia Met (Waldman, 1991).

To date, more than 100,000 diamonds have been recovered from the Colorado-Wyoming State Line district. The largest reported diamond was a 2.6 carat industrial (McCallum, 1991).

Recently, the great diamond rush in the Northwest Territories has had a dramatic effect on interest in the State Line district. Several new companies have been obtaining property positions in the Colorado-Wyoming kimberlite province. Additionally, some Australian interests are still operating in the district. Recently, Diamond Company, N.L. permitted a diamond recovery plant in Wyoming (Howard Coopersmith, pers. comm., 1992).

Many exploration targets remain unexplored or only partially explored. These include possible diamond placers within the State Line district. McCallum and Mabarak (1976) suggested that the State Line diatremes represent deeply dissected structures. Since better diamond grades usually occur near the surface in the intrusives, it would suggest that a significant volume of diamonds have been eroded from the intrusives and carried downstream. Additionally, several untested airborne EM, magnetic, and remote sensing anomalies occur in the district (Paterson and McFadyen, 1984; Marrs and others, 1984).

Numerous heavy mineral anomalies have also been identified and extend outside the known districts (Hausel and others, 1988). Other heavy mineral anomalies reported in

Wyoming include diamonds from Cortez Creek and pyrope garnet from Iron Creek in the Medicine Bow Mountains; pyrope garnet, chromian diopside, and rare picro-ilmenite from the Green River Basin (McCandless, 1984); and pyrope garnet and chromian diopside from the Seminoe Mountains (Hausel, 1992).

Phosphoria Formation

Precious metal anomalies are also reported in black shales and phosphorites of the Phosphoria Formation (Permian) in the Overthrust Belt of western Wyoming. These rocks host anomalous Ag, Au, Cr, Zn, Cu, and V (Love, 1984). The U.S. Bureau of Mines and the U.S. Geological Survey report rocks from the Phosphoria Formation to have high silver values (as much as 2,600 ppm) and anomalous gold (0.2 ppm) (Allsman and others, 1949; Love, 1984). It has recently been suggested that anomalous platinum may also occur in association with some of these deposits (Lechler, 1991).

Mesozoic Mineralization

Several argentiferous Cu-Zn redbed occurrences are located in Mesozoic rocks in the Overthrust Belt of western Wyoming. The majority of these are in the Nugget Sandstone (Triassic-Jurassic). Similar mineralization has been identified in the Twin Creek Limestone (Jurassic), and in the Wells Formation Sandstone (Permo-Pennsylvanian). Cretaceous age sandstones at several locations in the State contain titaniferous black sandstones that are potential sources of Ti, Zr, and Au (Hausel, 1990; Hausel and others, 1992).

Lake Alice district

The better known of these deposits are located in the Lake Alice district in Wyoming near the Idaho-Wyoming border. The Lake Alice deposits are localized in an anticline formed of bleached redbeds of the Nugget Sandstone capped by the Gypsum Spring Member of the Twin Creek Limestone. The Lake Alice deposits were drilled by Bear Creek Exploration in the 1970s.

At the Griggs mine in the northern part of the district, the mineralized sandstone is at least 300 feet thick. Samples collected by Love and Antweiler (1973) ranged from 0.02 to 6.7% Cu, a trace to 0.5% Pb, a trace to 3.2% Zn, and a trace to 1,200 ppm Ag. The average mine ore ran 3.5% Cu and 254 ppm Ag (Allen, 1942). The mineralizing fluids are interpreted as interformational or derived from a similar low temperature source and were structurally trapped (in anticlines and faults) during thrusting and folding of the Overthrust Belt (Boberg,1986; Loose and Boberg, 1987). Boberg (1984) suggested that the Lake Alice district has potential for a deposit or series of deposits containing over 100,000,000 tons of ore with a grade of 0.5 to 1.0% Cu, and 2 to 5 opt Ag.

Grass Creek

Grass Creek in the Bighorn Basin contains one of many Cretaceous age titaniferous black sandstone deposits in Wyoming. This paleobeach placer occurs in the Mesaverde Formation along the flanks of the Grass Creek anticline west of Thermopolis and is divided into two adjacent deposits. The northern deposit crops out over a length of 5,600 feet with an average thickness of 10 to 12 ft, and the southern deposit crops out for more than 1,600 feet with an average thickness of 5 ft (Hausel, 1990). Drilling and outcrop sampling of the northern deposit has delineated a 3,000,000 ton ore body with an average of 21.0% TiO_2 and 4.8% $ZrSiO_4$ (William H. Graves, pers. comm., 1990).

Cenozoic Mineralization

The Cenozoic of Wyoming includes many poorly studied and unexplored gold and silver deposits and anomalies. Only a few are discussed here and the reader is referred to Hausel (1989) for information on some other occurrences and anomalies.

Paleoplacers

The Tertiary of Wyoming was a time of intense erosion, and large volumes of fanglomerate and conglomerate were shed from the mountain ranges into the adjacent valleys. Where the source terrane included greenstone belts and other mineralized regions, the alluvial fans and fluvial sedimentary rocks often carried detrital gold. For example, the Twin Creek paleoplacer on the northeastern margin of the South Pass greenstone belt is estimated to exceed one billion cubic yards of gold-bearing gravel (Antweiler and others, 1980). The Oregon Buttes paleoplacer along the southern margin of the greenstone belt is estimated to contain more than 28,500,000 ounces of gold (Love and others, 1978). Other significant paleoplacers occur in and along the margins of the greenstone belt, but for the most part remain unexplored. In the late 1980s, spurred on by an earlier report of recovery of auriferous core from an oil well along the southern edge of the South Pass greenstone belt, Hecla Mining drilled and flew airborne magnetic and IP surveys over the buried southern edge of the belt. Distinct magnetic and IP anomalies were identified, but the project was never completed.

Recent exploration of a previously unreported paleoplacer in the South Pass region was conducted by Sawatch Gold Placers Inc. and Goldstake Mining. Gold anomalies were found within a few feet of the surface (Fred Groth, pers. comm.).

In northwestern Wyoming, paleoplacers and associated reworked modern placers cover an extensive region. These auriferous quartzitic conglomerates and sandstones range in age from Late Cretaceous to Miocene and include associated Quaternary placers. The average gold content for these paleoplacers is anomalous but low, and the gold is very fine grained (Table 2) (Antweiler and Love, 1967). Most past prospecting activities have been confined to reworked alluvial and bench placers primarily along the Hoback and Snake Rivers.

Table 2. Reported gold content of conglomerates in northwestern Wyoming (Antweiler and Love, 1967).

Stratigraphic unit	Average Au (ppb)	Maximum assay (ppb)
Quaternary alluvium	103	2,000
Miocene(?) conglomerate	65	290
Pass Peak Fm(Eocene)	47	250
Wind River Fm(Eocene)	222	2,000
Early? Eocene conglomerate	94	400
Pinyon Conglomerate (Paleocene)	86	6,000
Ft Union Fm (Paleocene)	35	300
Harebell Fm (Late Cretaceous)	65	1,000

In this region, 16 claims held by Gold West Corporation on Cottonwood Creek, a tributary of the Gros Ventre River, were drilled by Falcona Exploration & Mining N.L. in

1992. Exploration was conducted as a follow-up to a 1963 report that the Cottonwood Creek deposit contained a widespread gold resource of 2.25 million ounces within 30 feet of the surface.

The Cottonwood Creek deposit consists of gravels from the Harebell Formation and Pinyon Conglomerate. Twenty holes were drilled by Falcona and the recovered gravels were analyzed by Hazen Research. Visible gold was not observed in any of the samples, and the gold analyses of the samples differed greatly from the 1963 results: the gold content was considerably lower and not widespread (Reid, 1992).

Tertiary volcanism

During the Tertiary, Wyoming was affected both directly and indirectly by volcanism. In northwestern Wyoming, the Yellowstone and Absaroka regions were inundated by calc-alkaline flows, flow breccias, and ash falls generated from nearby composite volcanoes. In the Black Hills of northeastern Wyoming, several alkalic volcanic centers erupted. Local alkalic volcanoes erupted in the Rattlesnake Hills of central Wyoming, and basalts erupted from cinder cones in the Baggs area in southern Wyoming. In southwestern Wyoming, volcanoes ejected rare leucite- and olivine-lamproites with chemical and mineralogical similarities to the Kimberly diamondiferous lamproites of northwestern Australia (Carmichael, 1968).

Black Hills

In the Black Hills, mineralization is reported in the Tertiary alkalic complexes of the Bear Lodge Mountains, Mineral Hill, and Black Buttes. In recent years, this area has been explored by Hecla Mining, Molycorp, FMC Gold, International Curator, Coca Mines, and Canyon Resources. In the Bear Lodge Mountains, gold was reported in fluorite veins, pegmatites, and in feldspathic breccia. Recent exploration led to the discovery of an elongate intrusive breccia (120 by 2,000 ft) containing disseminated gold varying from 0.34 to 1.7 ppm (International Curator Resources Ltd, 1988 Ann. Rept.). The deposit contains a geologic resource of 8,200,000 tons averaging 0.72 ppm (Hahn and Bauer, 1991). According to the U.S. Geological Survey, the Bear Lodge Mountains also includes one of the largest, low-grade, rare earth and thorium deposits in the United States (Staatz, 1983).

The Mineral Hill district to the east has had a history of placer gold and tin production. Placers in the area have been relatively productive and have yielded nuggets up to wallnut size. Preliminary work by the Wyoming Geological Survey in cooperation with TRYCCO identified two horizontal pyritiferous quartz veins at the Treadwell open cut along the northwestern flank of Mineral Hill that yielded maximum gold values of 130 ppm and silver values as high as 330 ppm. Previous work in the district by Welch (1974) identified several gold anomalies including a jasperoid that assayed 5 ppm Au and 7 ppm Ag.

Black Buttes, 8 miles west of Mineral Hill, is formed of Tertiary phonolites and trachytes intruded into Paleozoic limestone. Contact replacement mineralization (Zn, Pb, Ag, Mo, F) occurs in the Pahasapa Limestone (Mississippian), but the surface exposures are very limited (Hausel, 1989).

Porphyry copper

The Absaroka Mountains in northwestern Wyoming include several Cu-Ag porphyry complexes, several of which are located within wilderness designated land. However, the two largest known porphyries-Kirwin and Sunlight Basin, lie outside of wilderness within the National Forest. These two porphyries contain anomalous Cu, Mo, Pb, Zn, Ag, Au, and Ti, and include disseminated, stockwork, and vein mineralization (Hausel, 1982). The Sunlight porphyry has been receiving exploration interest over the past few years.

The Kirwin porphyry in the southern Absaroka Mountains was explored by AMAX in the 1960s, 70s and 80s (Rostad, 1985). The property was sold to the Mellon Foundation which then donated it to the U.S. Forest Service. The property is now held within Acquired Land Status meaning that it could either be withdrawn or possibly leased at some later date.

AMAX began drilling at Kirwin in 1963, and significant secondary-enriched porphyry-copper mineralization was intersected (Rostad, 1983a). Drilling over the next several years proved a significant porphyry deposit. AMAX's drilling program resulted in 150 holes totaling 86,861 feet. The project outlined geologic reserves totalling 196,000,000 tons of ore averaging 0.505% Cu and 0.022% MoS_2 at a 0.3% Cu cutoff grade with by-product credits in silver and gold. Pitable reserves were calculated at 160,800,000 short tons with a very favorable stripping ratio of 0.57:1 of waste to ore (Rostad, 1983b). Feasibility studies have also indicated the deposit is amenable to *in situ* leaching. A recent 1991 study on *in situ* leaching indicated possible recovery costs of $0.309/pound Cu (Ora Rostad, pers. comm., 1992).

The Kirwin mineralized area is expressed by a roughly oval-shaped zone of intense hydrothermal alteration. The mineralized area is associated with a volcanic vent complex containing exposures of intrusive rhyolite tuff breccia (Wilson, 1964; Nowell, 1971). Weathering of the stockwork produced a leached cap over a blanket-like deposit of supergene copper. Chalcocite is the principal sulfide with some covellite and digenite. The deposit is about 3,900 feet across (Rostad, 1983a).

There are several unexplored targets in the district. Explosive conditions occurred in the district as is evidenced by the Kirwin Formation. Thus there is a possibility of breccia pipes missed by AMAX's 300 foot drill spacing. Spar Mountain south of Bald Mountain, could also represent a separate mineralized center with possible secondary enrichment, however the mountain is pervasively talus covered. But there is widespread limonitic alteration on Spar Mountain, and samples of native copper have been recovered from the divide between Smuggler Basin and Spar Creek. The possibility of skarn and replacement deposits in the underlying sediments should also be addressed (Rostad, 1982).

Veins have received only limited exploration in the district, although some are traceable for more than 2,500 ft along strike. The veins are narrow, but some have ore grade values. Some of the better assays in two adits were obtained from samples collected at or adjacent to the mine face. For example, in the Oregon mine, a 3 ft wide sample at the face yielded 17.8 opt Ag, and 0.08 opt Au, and a 1.5 ft wide channel in the Johnnie mine assayed 64.7 opt Ag, and 0.12 opt Au.

Alluvial gravel is abundant in the Wood River downstream from Kirwin. The gravels range in depth from 60 ft to 150 ft. It is estimated that the Wood River has a potential for more than 100,000,000 cubic yards of unexplored gravel. Little evidence exists that the gravel has ever been explored for gold, even though geologic evidence suggests some has to be mineralized (Rostad, 1982).

Aspen Mountain silicified zone

The Geological Survey of Wyoming recently investigated a 20 to 30 mi^2 silicified zone south of the town of Rock Springs (Hausel and others, 1992). Strong silicification of sandstones and siltstones of the Rock Springs and Blair Formations (Cretaceous) and Bishop Conglomerate (?) (Oligocene) resulted in the preservation of Quaking Asp Mountain (Aspen Mountain). The feature stands as a prominent hill south of Rock Springs.

The silicification continues to a minimum depth of 3,700 feet based on past drilling for oil and gas at Aspen Mountain. Other interesting features of the silicified zone include alunite (Love and Blackmon, 1962), travertine (Kirschbaum, 1986), native sulfur (Tom Sharps, pers. comm., 1993), kaolinite alteration, arsenic anomalies, banded chert (jasperoid

?), and trace gold (Hausel and others, 1992, 1993). Most of the seventy-nine samples collected in the area contained no detectable gold. However, a few chip samples yielded a trace to a maximum of 115 ppb Au (Hausel and others, 1992). No bulk samples were taken. Similar deposits have recently been identified elsewhere in the Greater Green River Basin (Hausel and others, 1993).

Modern placers

Most commercial modern placers in the State have been principally mined for gold, although the Douglas Creek placers in southeastern Wyoming also possess platinum and palladium, the Clarks Camp placers in the northern Wind River Range contain anomalous monazite in addition to gold, and the Mineral Hill placers in northeastern Wyoming also have tin, tantalite, and magnetite. Monazite placers also occur in the Shirley Basin in southeastern Wyoming (J.D. Love, pers. comm., 1990). Several placers and sand and gravel deposits in southern Wyoming were sampled for gold in 1992 and 1993 by the Wyoming Geological Survey. Visible gold was recovered from most placers draining the northern Medicine Bow Mountains suggesting the presence of a widespread gold source or contribution from several individual sources (Hausel and others, 1992, 1993).

Statistics on gold nuggets are incomplete, although walnut-size nuggets have been recovered from the Mineral Hill district, the Douglas Creek district, and the South Pass greenstone belt. The largest nugget found in Wyoming may have been a 24 ounce nugget from Rock Creek in the South Pass greenstone belt, although a boulder with nearly 40 pounds of gold was found in the same area prior to 1905 (Hausel, 1989).

Conglomerates and terrace gravels in the Wind River Basin are reported to contain gold over large regions. In 1910, gold was reported along the Wind River, Little Wind River, and Popo Agie River. The metal was found in terrace gravels capping benches and buttes and in the nearby plains, mesas, and uplands for thousands of feet to a few miles from the present drainages. The deposits were reported to average 12 to 14 feet thick over widths of 3 to 4 miles.

The gold occurred as very fine tablet-like particles smaller than a pinhead. In 1913, gravels were tested and varied from none to 0.016 oz/yd^3 and averaged less than 0.0025 oz/yd^3 Au. Two dredges operated in the Wind River. The Neble Dredge operated in a pay zone that ranged from 0.007 to 0.016 oz/yd^3 and averaged 0.014 oz/yd^3. The gold-bearing gravels averaged 22 feet thick. The Clark Dredge, a few miles west of the Neble Dredge, treated gravels that averaged 0.038 oz/yd^3 (Schrader, 1913). The demise of the district was the gold was too fine to be recovered efficiently.

SUMMARY

Within the State boundaries are numerous gold deposits and anomalies scattered throughout the geologic record. Many examples occur in rocks ranging in age from Archean to Tertiary, and in Quaternary to Recent unconsolidated gravels and sands. Yet, relatively few of these deposits and anomalies have been explored and only a handful have been drilled.

Being that much of Wyoming is underlain by an Archean craton similar to the Superior Province of Canada, the eastern and southern African craton, and to the Pilbara and Yilgarn blocks of Western Australia, one would expect Wyoming to also have significant mineralization.

REFERENCES

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

Allsman, P.T., Majors, F.H., Mahoney, S.R., and Young,W.A.,1949, "Investigation of Sublette Ridge vanadium deposits, Lincoln County, Wyoming," U.S. Bureau of Mines, Report of Investigations 4476, 8 p.

Antweiler, J.C., and Love, J.D.,1967, "Gold-bearing sedimentary rocks in northwest Wyoming-A preliminary report," U.S. Geological Survey, Circular 541, 12 p.

Antweiler, J.C., Love, J.D., Mosier, E.L., and Campbell, W.L.,1980, "Oligocene gold-bearing conglomerate, southeast margin of Wind River Mountains, Wyoming," Wyoming Geological Association, 32nd Annual Field Conference Guidebook., p.223-237.

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

Bayley, R.W.,1968, "Ore deposits of the Atlantic City district, Fremont County, Wyoming," *in* J.D. Ridge (ed), Ore Deposits of the United States, 1933-1967, AIME, New York, N.Y, p. 589-604.

Bayley, R.W., and James, H.L.,1973, "Precambrian iron-formations of the United States," Economic Geology, v. 68, p. 934-959.

Beeler, H.C.,1905, "Mining in the Grand Encampment copper district, Carbon and Albany Counties, Wyoming," Office of the State Geologist, misc. rept., Cheyenne, 32 p.

Beeler, H.C.,1908, "A brief review on the South Pass gold district, Fremont County, Wyoming," Office of the State Geologist, misc. rept., Cheyenne, 23 p.

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

Boberg, W.W.,1986, "Lake Alice copper district, Lincoln County, Wyoming," *in* S. Roberts (ed), Metallic and Nonmetallic Deposits of Wyoming and Adjacent Areas, Geological Survey of Wyoming, Public Information Circular 25, p. 54-55.

Borrowman, S.R., and Rosenbaum, J.B.,1962, "Recovery of thorium from a Wyoming ore," U.S. Bureau of Mines, Report of Investigations 5917, 8 p.

Bow, C.S.,1986, "Structural and lithologic controls on Archean greywacke-hosted gold mineralization within the Sweetwater district, Wyoming, USA," *in* Turbidite-Hosted Gold Deposits, Geological Association of Canada, Spec. Pap. 32, p.107-118.

Carmichael, I.S.E., 1967, "The mineralogy and petrology of the volcanic rocks from the Leucite Hill, Wyoming," Contr. Mineral. and Petrol. 15, p. 24-66.

Condie, K.C., 1976, "The Wyoming Province in the western United States," *in* B.F. Windley (ed), The Early History of the Earth, John Wiley & Sons, New York, p.499-510.

Conoco Minerals Company,1982, "Summary report on the Huston and Fletcher Parks massive sulfide deposits," Geological Survey of Wyoming, mineral files, 82 p.

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

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

deQuadros, A.M.,1989, "Report on the diamond drill program July-August 1989 at the Carissa mine property, South Pass City, Fremont County, Wyoming, for Consolidated McKinney Resources Ltd.," Vancouver, B.C.: (unpublished report), 76 p., plus drill logs and assays.

Dersch, J.S., 1990, "Snowy Range withdrawal," U.S. Bureau of Land Management, Mineral Report WYW-115104, 19 p.

Finch, Ed, 1993, "Meadows Creek Prospect (a preliminary report) Lewiston mining district, South Pass greenstone belt, Fremont County, Wyoming," Barnhart Drilling Company, Inc., report, Geological Survey of Wyoming files, 11 p.

Frost, B.R., and Simons, J.P., 1991, "Fe-Ti oxide deposits of the Laramie anorthosite complex: their geology and proposed economic utilization," in B.R. Frost and Sheila Roberts, editors, Mineral resources of Wyoming, Wyoming Geological Association 42nd Field Conference Guidebook, p. 41-48.

Hagner, A.F.,1968, "The titaniferous magnetite deposit at Iron Mountain, Wyoming," in J.D. Ridge, editor, Ore Deposits of the United States, 1933-1967: AIME, New York, p. 666-680.

Hahn, G.A., and Bauer, C.F., 1991,"The Sundance gold deposit in the Bear Lodge Mountains of northeastern Wyoming,"Wyoming Geological Association 42nd Field Conference Guidebook, p. 15-17.

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

Hausel, W.D.,1982, "General geologic setting and mineralization of the porphyry copper deposits, Absaroka volcanic plateau, Wyoming," Wyoming Geological Association, 33rd Annual Field Conference Guidebook, p.297-313.

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

Hausel, W.D., 1987, "Structural control of Archean gold mineralization within the South Pass greenstone terrain, Wyoming (USA)," *in* R.W. Hurst, T.E. Davis, and S.S. Augustithis (eds), The Practical Applications of Trace Elements And Isotopes to Mineral Resource Evaluation, Theophrastus Publications, Athens, Greece, p.199-216.

Hausel, W.D.,1989, "The Geology of Wyoming's Precious Metal Lode and Placer Deposits," Geological Survey of Wyoming, Bulletin 68, 248 p.

Hausel, W.D., 1990, "Strategic mineral resources in Wyoming-titanium," Geological Survey of Wyoming Open File Report 90-7, 17 p.

Hausel, W.D.,1991, "Economic geology of the South Pass granite-greenstone belt, Wind River Mountains, western Wyoming," Geological Survey of Wyoming, Report of Investigations 44, in press.

Hausel, W.D.,1992, "Preliminary report on the geology, geochemistry, mineralization, and mining history of the Seminoe Mountains mining district, Carbon County, Wyoming," Geological Survey of Wyoming unpublished Mineral Report MR92-6, 50 p.

Hausel, W.D., Edwards, B.R., and Graff, P.J., 1991, "Geology and mineralization of the Wyoming Province," Society for Mining, Metallurgy, and Exploration Preprint 91-72, Littleton, Colorado, 12 p.

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

Hausel, W.D., and Hull, J.M., 1990, "Guide to gold mineralization and Archean geology of the South Pass greenstone belt, Wind River Range, Wyoming," *in* Sheila Roberts (ed), Geologic Field Tours of Western Wyoming, and Parts of Adjacent Idaho, Montana, and Utah: Geological Survey of Wyoming, Public Information Circular 29, p. 178-191.

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

Hausel, W.D., Marlatt, G.G., Nielsen, E.L., and Gregory, R.W., 1993, "Second year study of precious metals and stones along the Union Pacific right-of-way in southern Wyoming," in preparation.

Hausel, W.D., and Jones, Suzanne, 1982, "Field notes-Lost Muffler gold prospect, Rattlesnake Hills," Geological Survey of Wyoming unpublished Mineral Report 82-9, 5 p.

Hausel, W.D., McCallum, M.E., and Roberts, J.T., 1985, "The geology, diamond testing procedures, and economic potential of the Colorado-Wyoming kimberlite province," Geological Survey of Wyoming Report of Investigations 31, 22 p.

Hausel, W.D.,, Sutherland, W.M., and Gregory, E.B., 1988, "Stream-sediment sample results in search of kimberlite intrusives in southeastern Wyoming," Geological Survey of Wyoming Open File Report 88-11, 11 p., 5 plates.

Houston, R.S., 1983, "Wyoming Precambrian Province-example of the evolution of mineral deposits through time?", *in* Sheila Roberts, (ed), Metallic and Nonmetallic deposits of Wyoming and Adjacent Areas, 1983 Conference Proceedings: Geological Survey of Wyoming, Public Information Circular 25, p.1-12.

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

Houston, R.S., and others, 1983, Mineral potential of the Snowy Range Wilderness, Albany and Carbon Counties, Wyoming: U.S. Geological Survey Misc. Field Studies Map MF-1596-1, 15 p.

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

Houston, R.S., and Karlstrom, K.E.,1979, "Uranium-bearing quartz pebble conglomerates-exploration model and United States resource potential," U.S. Department of Energy, Open File Report GJBX-1(80),510 p.

Hutchison, R.W., and Viljoen, R.P., 1988, Re-evaluation of gold source in Witwatersrand ores: South African Journal of Geology 91 (2), p. 157-173.

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

Kerr McGee Corporation, 1988, "Letter and report to W. D. Hausel from W.P. Leedy on the discovery of umangite," Geological Survey of Wyoming, mineral files, 7 p.

King, J.K.,and Hausel, W.D.,1991, "Rare earth elements and yttrium in Wyoming-from oddities to resources," Wyoming Geological Association 42nd Field Conference Guidebook, p. 49-70.

Kirschbaum, M.A., 1986, "Geologic map of the Kappes Canyon Quadrangle, Sweetwater County, Wyoming," U.S. Geological Survey Map GQ 1607, scale 1:24,000.

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

Klein, T.L.,1981, "The geology and geochemistry of the sulfide deposits of the Seminoe district, Carbon County, Wyoming," Ph.D. thesis, Colorado School of Mines, Golden, 232 p.

Kling, J.F., 1986, "Petrology of the Strong Creek prospect, Albany County, Wyoming," M.S. thesis, University of Wyoming, 109 p.

Lechler, P.J., 1991, Potential for hydrothermal platinum mineralization in the Western Wyoming Overthrust Belt," Wyoming Geological Association, 42nd Annual Field Conference Guidebook, p. 39

Loose, S.A., and Boberg, W.W.,1987, "Sedimentary facies control on mineralization at the Lake Alice district in the Wyoming Overthrust Belt," Wyoming Geological Association, 38th Annual Field Conference Guidebook, p. 309-327.

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

Loucks, R.R.,1991, "Platinum-gold and vanadiferous magnetite mineralization in the Early Proterozoic Lake Owen layered mafic intrusion, Medicine Bow Mountains, Wyoming," Wyoming Geological Association, 42nd Annual Field Conference Guidebook, p. 37-38.

Love, J.D.,1984, "Gold, silver, and other selected trace elements in the Phosphoria Formation of western Wyoming," Wyoming Geological Association, 35th Annual Field Conference Guidebook, p.379-391.

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

Love, J.D., Antweiler, J.C., and Mosier, E.L.,1978, "A new look at the origin and volume of the Dickie Springs-Oregon Gulch placer gold at the south end of the Wind River Mountains," Wyoming Geological Association, 30th Annual Field Conference Guidebook, p.379-391.

Love, J.D., and Blackmon, P.D., 1962, "Alunite on Aspen Mountain, southwestern Wyoming," U.S. Geological Survey Professional Paper 450-D, p. 11-15.

Marrs, R.W., Marks. J.E., Hausel, W.D., and Albert, K.G., 1984, "Detection of diamond-bearing kimberlites in Colorado-Wyoming Province," University of Wyoming Remote Sensing Lab report, 70 p.

Marsh, J.A. and Pinnel, B.A., 1954, "Fe-Ti deposits of Iron Mountain,"Union Pacific Railroad Natural Resources Department report, 20 p.

McCallum, M.E., 1991, "The Sloan 1 and 2 kimberlite complex near the southern boundary of the State Line district of the Colorado-Wyoming kimberlite province," Wyoming Geological Association 42nd Field Conference Guidebook, p. 229-250.

McCallum, M.E., and Mabarak, C.D., 1976, Diamond in State-Line kimberlite diatremes, Albany County, Wyoming, Larimer County, Colorado: Geological Survey of Wyoming Report of Investigations 12, 36 p.

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

McCallum, M.E., and Waldman, M.A., 1991, The diamond resources of the Colorado-Wyoming State Line District: kimberlite indicator mineral chemistry as a guide to economic potential: Wyoming Geological Association 42nd Field Conference Guidebook, p. 77-90.

McCandless, T.E., 1984, "Detrital minerals of mantle origin in the Green River Basin, Wyoming," AIME Preprint 84-395, 6 p.

McKinney, A.A., and Horst, H.W.,1953, "Deadwood conglomerate monazite deposit, Bald Mountain area, Sheridan and Big Horn Counties, Wyoming," U.S. Atomic Energy Commission, RME-3128, 40 p.

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

Nowell, W.B., 1971, The petrology and alteration of the Kirwin mineralized area, Park County, Wyoming: M.S. thesis, University of Montana, Missoula, 72 p.

Paterson, N.R., and MacFayden, D.A., 1984, "An airborne EM (INPUT)/magnetometer survey, State Line district, Colorado-Wyoming," AIME Preprint 84-310, 11 p.

Reid, I.W., 1992, Report on drilling at Cottonwood Creek, Wyoming," Falcona Exploration & Mining N.L., unpublished report, Geological Survey of Wyoming mineral files, 9 p.

Rostad, O.H., 1982, "Memo concerning future work at Kirwin, Park County, Wyoming," AMAX Exploration Company, Geological Survey of Wyoming mineral files, 5 p.

Rostad, O.H., 1983a, "The Kirwin porphyry copper deposit, Park County, Wyoming," Geological Survey of Wyoming mineral files, 2 p.

Rostad, O.H., 1983b, "Data Summary, AMAX's Kirwin project, Park County, Wyoming," AMAX Exploration Company report, Geological Survey of Wyoming mineral files, 4 p.

Rostad, O.H., 1985, "History of the discovery of the Kirwin porphyry copper deposit, Park County, Wyoming," Geological Survey of Wyoming mineral files, 4 p.

Schrader, F.C.,1913, "Gold placers on Wind and Bighorn Rivers, Wyoming," U.S. Geological Survey, Bulletin 580, p.127-143.

Snyder, G.L., Hausel, W.D., Klein, T.L., Houston, R.S., and Graff, P.J.,1989, "Precambrian rocks and mineralization, southern Wyoming Province," 28th International Geological Congress, Field Trip Guidebook T332, 48 p.

Spencer, A.C.,1904, "Copper deposits of the Encampment district, Wyoming," U.S. Geological Survey, Professional Paper 25, 107 p.

Spry, P.G., and McGowan, K.I.,1989, "Origin of Archean lode gold mineralization at Atlantic City-South Pass, Wyoming: fluid inclusion stable isotope study," 28th International Geological Congress, Abstracts, v.3. p.3-163.

Staatz, M.H.,1983, "Geology and descriptions of thorium and rare earth deposits in the southern Bear Lodge Mountains, northeastern Wyoming," U.S. Geological Survey, Professional Paper 1049-D, 52 p.

Stockwatch, 1987, "Exploration update on Caledonia Resources Ltd.," September, 1987, Canjex Publishing, Ltd., Vancouver, B.C., p.9

Thurston, P.B.,1986, "Geochemistry and provenance of Archean metasedimentary rocks in the southwestern Beartooth Mountains: M.S. Thesis, Montana State University, Bozeman, 74 p.

Waldman, M.A., 1991, "Guide to Dia Met Minerals diamond recovery plant near Sloan Ranch, Colorado, " Wyoming Geological Association 42nd Field Conference Guidebook, p. 251-257.

Welch, C.M.,1974, "A preliminary report on the geology of the Mineral Hill area, Crook County, Wyoming," M.S. thesis, South Dakota School of Mines, Rapid City, 83 p.

Wilmarth, V.R., and Johnson, D.H.,1954, "Uranophane at Silver Cliff mine, Lusk, Wyoming," U.S. Geological Survey, Bulletin 1009-A, 12 p.

Wilson, W.H., undated, "Muskrat Creek", Geological Survey of Wyoming, mineral files (unpublished), 6 p.

Wilson, W.H.,1951, "A monazite deposit in the Big Horn Mountains, Sheridan and Big Horn Counties, Wyoming," Geological Survey of Wyoming, Mineral Report 51-3 (unpublished), 3 p.

Wilson, W.H., 1964, The Kirwin mineralized area, Park County, Wyoming: Geological Survey of Wyoming Preliminary Report 2, 20 p.

Woodfill, R.D.,1987, "Hartville uplift, southeastern Wyoming", unpublished consultant's report, Geological Survey of Wyoming, mineral files, 20 p.

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