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FORM, DISTRIBUTION, AND GEOLOGY OF GOLD, PLATINUM, PALLADIUM AND SILVER IN WYOMING

by

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ABSTRACT

Significant precious metal deposits in Wyoming include metamorphogenic Au in shear zones and veins in Archean greenstone belts and related supracrustal terranes. These deposits typically contain trace amounts of Au with sporadic, rich, steeply plunging ore shoots.

Magmatic Au, Ag, Pt and Pd deposits also occur in Wyoming. These include Au, Pt, and Pd mineralization in layered Proterozoic mafic complexes, a Proterozoic Cu-Au porphyry, Tertiary Cu-Ag porphyries with associated Mo, Au, Pb, and Zn, and Ag-veins, and disseminated Au and Au-Ag vein mineralization in Tertiary alkalic intrusives.

Other deposits with significant precious metal content include Proterozoic stratabound Cu-Ag-Au quartzites, Jurassic Cu-Ag-Zn-Pb red beds, Tertiary Au paleoplacers, and associated modern placers.

INTRODUCTION

Precious metal mineralization in Wyoming includes a variety of deposits. Historically, the most important have been metamorphogenic shear zone deposits. These deposits should continue to attract attention in the future, simply because they have only been partially explored. Wyoming also has a number of other types of precious metal deposits, most of which are also poorly explored and essentially untapped. These include magmatic Pt, Pd, and Au associated with layered mafic intrusions, Cu-Ag and Cu-Au porphyries, and disseminated and vein epithermal Au. Tertiary paleoplacers host large, but low-grade precious metal values, and some sedimentary-affiliated, stratabound metal deposits contain significant precious metals. Additionally, dozens of unexplained anomalies reported by NURE geochemical surveys (Albert, 1986) may indicate the presence of undiscovered gold deposits.

METAMORPHOGENIC GOLD DEPOSITS

Metamorphogenic deposits originate from processes of metamorphism. During regional or contact metamorphism, fluids released during elevated temperatures and pressures may leach metals from the surrounding rocks and transport to dilational zones. Such a genesis is proposed for gold mineralization in the Lewiston and South Pass-Atlantic City districts in the South Pass granite-greenstone belt in the southern Wind River Mountains.

Shear Zone gold Wyoming's most productive gold deposits where mined from shear zones in the South Pass greenstone belt. During the initial stages of deformation (D1) of this Archean supracrustal belt, regional shortening produced isoclinal folding (F1), regional foliation (S1), and shear zones parallel to S1 and to the F1 fold hinges. Many of the shears were formed along or adjacent to lithologic contacts indicating shear development to be in part due to rock competency contrasts during folding. Regional metamorphism during D1 liberated fluids from the supracrustal pile which tended to focus in the shear structures. Precipitation of silica synchronous with D1 produced quartz veins which were stretched, boudinaged, and sheared in the direction of S1.

Wallrock alteration associated with the gold mineralization includes chlorite, hematite, sericite, quartz, biotite, sulfides, and minor tourmaline and microcline which overprints the amphibolite facies rocks. The precious metal occurs as native gold which fills fractures in quartz, occurs in pyrite, pyrrhotite, and arsenopyrite. Scheelite has been reported in a few of the auriferous shears but it is not known if it is related to the gold event or if it represents a later event of mineralization.

Typically, the Au/Ag ratios for gold in the shears are relatively high (6.6 to 30.2), the Au/Cu ratios are relatively low (445 to 6,740) compared to lodes formed at shallower depths (Antweiler and Campbell, 1977). Trace elements associated with these deposits include Bi, Pb, As, Sb, Sn, V, Mo, W, B, Nb, Cr, Zn, Co, Ni (Love and others, 1978). The gold is characteristic of hypothermal (high P,T) mineralization.

Shear zone mineralization occurs in a variety of rock types including metagreywacke, amphibolite, mica schist, graphitic schist, meta-andesite porphyry, actinolite schist, leucodacite porphyry, metabasalt, metagabbro, greenschist, and greenstone. The source rock for the gold was proposed by Bow (1986) to have been a belt of carbonated tremolite/actinolite schists with basaltic to peridotitic komatiite compositions. Spry and McGowan (1989) proposed the gold originated from the metagreywacke suite based on fluid inclusion and stable isotope studies. However, the variety of host rock types suggests an influence by more than one source rock. And the temporal association of regional metamorphism (2.8 Ga, whole rock isochron of metasediments from the South Pass greenstone belt) and mineralization (~2.8 Ga, model lead age date of ore from the Snowbird mine in the greenstone belt) supports that the gold originated by metamorphic secretion from the supracrustal pile (independent of rock type) during the regional metamorphic event. The shears then acted as conduits to focus the auriferous solutions (Hausel, 1991).

In general, the shears occur as relatively narrow (generally 2 to 15 feet wide), foliation-parallel, zones with brittle and ductile deformation. They are traceable for hundreds of feet to more than 11,000 ft along strike, and are continuous to depths of at least 930 ft based on drilling and in all probability continue to much greater depths (deQuadros, 1989).

Mineralization in the shears is not evenly distributed. Instead the shears contain trace amounts of gold along much of their trend with sporadic ore shoots containing enhanced gold values (Hausel,1987). Not all ore controls have been identified, but where recognized, fold closures, shear-fault and shear-shear intersections have localized some ore shoots.

The Hidden Hand shaft in the Lewiston district was sunk on the intersection of coalescing shears in metagreywacke. The chloritizied-hematized shear intersection is many feet wide with a gold tenor of a trace to 10% gold by (3,100 opt) weight (Pfaff, 1978). At the Bullion mine on Strawberry Creek north of the Hidden Hand mine, a shoot was mined at the intersection of an Archean shear and a Laramide(?) tear fault. The localization of this latter shoot suggests some gold may have been mobilized synchronous or subsequent to the Laramide deformation (D3). My impression is the intersection produced a zone of high permeability and the ore shoot was produced by supergene processes. Thus this shoot may only be surficial and not extend below groundwater.

Tight to open fold closures control shoots at several mines including the Alpine, Carissa, Diana, Duncan, and Miners Delight. Some shears are also enveloped by broader zones of rehealed wallrock mineralized with low-grade gold. This is interpreted as a result of the metamorphic fluids permeating the penetrative fabrics. This is especially characteristic of the Carissa mine in the South Pass-Atlantic City district where a 100 to 200 foot wide weakly mineralized envelope encloses the Carissa shear.

The Carissa shaft was sunk on a narrow 5 to 50 ft wide shear that is enveloped by a broad, 100 to 200 ft zone of weakly mineralized wallrock with rehealed fractures. A 1.5 ft channel sample taken across the shear assayed 5.2 ppm (0.15 opt) Au (Hausel, 1989), and Beeler (1908) reported the average ore ran 10.29 ppm (0.3 opt) Au. Composite chip samples collected in the adjacent wallrock also yielded anomalous gold over a 97 ft width (Hausel, 1989) (Table 1).

At the Duncan mine located west of the Carissa shaft, the foliation-parallel shear is folded and splayed. The splay has a aggregate width of more than 40 feet adjacent to the shaft, and is mineralized across its entire width. Within the fold closure, the gold values are enhanced, and the nose of the steeply plunging drag fold averages nearly ten times the amount of gold in the fold limbs (Table 1).

Some other relatively wide gold deposits include the Lone Pine, Tabor Grand, and Wolf gold mines. The Lone Pine and Wolf mines occur in the Lewiston district along the southeastern margin of the South Pass greenstone belt. A few years ago, the Geological Survey of Wyoming discovered a hidden shear buried under a thin veneer of Tertiary South Pass Formation near the Lone Pine mine. The discovery trench exposed a 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. At the Wolf mine, representative samples from the mine dump yielded 23.3 ppm (0.68 opt) Au (Hausel, 1989). This property was later examined and reported to include a mineralized shear with more than 100 feet of width.

The Tabor Grand mine west of the Duncan in the South Pass-Atlantic City district was developed on a 1 to 5 ft wide shear in hornblendic amphibolite. Samples of the shear yielded 0.06 to 58.0 ppm Au over a 350 ft length. During mapping of the mine, 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 sample assayed 3.8 ppm Au (Hausel, 1991).

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

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

Veins There are a variety of quartz veins in the South Pass region that are considered hypothermal veins. Whether these are magmatic or metamorphogenic, is not known, however, no distinct wall rock alteration is associated with these veins.

These veins generally have high Au/Ag and include the Mary Ellen, Alpine, and Diana veins. The Mary Ellen vein consists of a 6 inch to 4 foot wide cross-cutting milky quartz vein in a metatonalite plug that intrudes a shear zone. Gold values in the vein are found to increase where the vein pinches. According to historic reports the average tenor of the vein was 0.4 opt Au.

Both the Alpine and Diana veins are light grey to translucent quartz with ore shoots in fold closures. The Alpine vein is hosted by metagreywacke. The vein is low-grade except for a steeply plunging ore shoot in the nose of an open fold. For instance, several samples taken in the Alpine vein ranged from 0.08 ppm to 2.3 ppm, but two samples collected in the fold assayed 9.8 and 101.0 ppm Au (Hausel, 1989). The Diana vein lies along a lithologic contact between actinolite schist and quartzofeldspathic gneiss, and is folded. Samples collected in the vein varied from no detectable gold to 24 ppm Au (Hausel, 1989). The better samples were taken in folds.

In the Seminoe Mountains greenstone belt near central Wyoming, gold-chalcopyrite-pyrite-quartz veins occur in a 1/4-mile diameter chlorite-calcite-sulfide alteration halo in metagabbro and metabasalt (Klein, 1981). These veins are generally narrow (0.5 to 2.5 ft), but commonly yield specimen samples with visible gold. Samples collected from this area by the author have yielded gold values as high as 98.4 ppm.

Gold-bearing quartz veins in Precambrian terranes have been less productive than the shear structures. These veins are dominated by milky to translucent, to grey (tourmaline-bearing) quartz and may contain appreciable amounts of calcite.

MAGMATIC DEPOSITS

Disseminated and cumulate mineralization provide direct textural evidence of crystallization from the host magma. This intimate association links mineralization to the host igneous rock implying the mineralization and host rock have a common heritage. Such magmatic deposits include platinum and palladium in layered mafic complexes, chrome in serpentinites, chrome and nickel in ultramafic schists, titaniferous magnetite in anorthosite, and diamonds in kimberlite and lamproite.

Other than nickeliferous schists and diamondiferous lamproite, all of the remaining magmatic deposits have been recognized in Wyoming in one form or another. And since a major lamproite field occurs in southwestern Wyoming and high-magnesian schists with peridotitic komatiite composition occur in more than one mountain range in the state, it is possible these latter deposits may also some day be found. However, only those deposits with precious metal anomalies will be discussed.

Platinum Group Mineralization Worldwide, platinum-group metals show a strong affinity for large, intracontinental, layered, mafic complexes of tholeiitic affinity. The platinum-group metals occur as sulfides in stratiform layers spatially associated with cyclic cumulus pyroxenite, dunite, anorthosite, and troctolite. Sulfides include cooperite, sperrylite, braggite, and laurite (Edwards and Atkinson, 1986).

In southeastern Wyoming, platinum-group mineralization is intimately associated with two (~1.8 Ga) Precambrian layered mafic intrusives (Lake Owen and Mullen Creek) in the Medicine Bow Mountains. A third gabbroic complex (Elkhorn intrusion) extends south from the Wyoming border into the North Park Range of Colorado, although no platinum anomalies are known to be associated with it.

Typically, platinum-group metals are found in cyclic cumulus layers of undisturbed layered tholeiitic complexes. In the Lake Owen intrusive, anomalous platinum is syngenetic and found in labradorite-bearing gabbroic norite (Loucks and Glasscock, 1990). In the Mullen Creek mafic complex, however, platinum mineralization is epigenetic and in hydrothermally altered metaigneous rock (McCallum and others, 1975). The nearby Centennial Ridge district shows similar evidence for epigenesis in that minor platinum and palladium occur with gold in shear zones in discontinuous mafic intrusives. Elsewhere, platinum nuggets have been recovered from placers of the Douglas Creek district downstream from the Mullen Creek mafic complex.

The layered complexes of the Medicine Bow Mountains intrude Proterozoic schist and gneiss of the Green Mountain terrane. This terrane is interpreted as part of a Precambrian island arc which was accreted to the Wyoming craton about 1,770 Ma. The terrane was intruded by the Mullen Creek mafic complex at about the time of accretion (Loucks and others, 1988).

The effects of deformation on the Lake Owen and Mullen Creek complexes differ greatly. The Lake Owen complex, which lies south of the Mullen Creek-Nash Fork suture zone, is virtually unaffected by deformation and metamorphism. Whereas, the Mullen Creek complex is intensely deformed. The northern edge of the 60 mi^2 Mullen Creek complex is truncated by the Mullen Creek-Nash Fork shear zone which contributed greatly to the deformation of the complex.

Rocks are intensely sheared along the northeastern edge of the Mullen Creek complex. Platinum and palladium occur in shear zones in hydrothermally altered metadiorite, metagabbro, metapyroxenite, and metaperidotite (McCallum and others, 1975). Sporadic mining operations between 1900 and 1918 at the New Rambler mine in these mineralized shears, produced at least 6,100 tons of copper ore with credits in gold, silver, platinum, and palladium. The U.S. Bureau of Mines (1942) reported mine production at 1.75 million lbs of Cu, 170 oz of Au, 7,350 oz of Ag, 170 oz of Pt, and 451 oz of Pd. Silver Lake Resources (1985), indicated, platinum and palladium production may have been as much as 910 oz of Pt and 16,870 oz of Pd.

McCallum and others (1975) recognized two hydrothermal alteration assemblages overprinted by supergene assemblages at the New Rambler mine. Hydrothermal propylitic mineral assemblages include chlorite, epidote, clinozoisite, albite, magnetite, and pyrite. Phyllic alteration assemblages consist of secondary sericite, quartz, and pyrite.

The New Rambler shaft was sunk in a 75 ft thick oxidized cap of malachite and azurite, with subordinate cuprite, tenorite, chalcotrychite, and chalcopyrite. Native copper, atacamite, chalcanthite, tetrahedrite, and bornite are sparsely distributed with rare orpiment, realgar, and lorandite. From 75 to 100 ft deep, the oxidized cap grades into a supergene enriched blanket of platiniferous covellite and chalcocite. The supergene assemblages grade into primary mineralized rock at 100 ft deep. Primary ore includes quartz-pyrite-chalcopyrite veins with minor sperrylite (McCallum and Orback, 1968).

Loucks and others (1988) recognized more than 21 cyclic units in the Mullen Creek complex. It is not known if syngenetic platinum is associated with these units, but the association of platinum and palladium with shear zones in the layered complex suggests possible remobilization of the metals from the complex.

In contrast to the Mullen Creek complex, the Lake Owen complex is relatively undeformed. It is a 20 to 25 mi^2 funnel-shaped intrusion tilted 75° on its side exposing a cross-section of 18 cyclic units (Loucks and Glasscock, 1990).

Cumulus sulfides occur in several stratigraphic horizons in the complex, with some zones containing elevated gold and platinum. Titanomagnetite cumulates also occur near the tops of some cyclic units (Loucks and Glasscock, 1990).

North of the Lake Owen complex in the Centennial Ridge district, late 19th century vintage mine developments cut mafic metaigneous rock in search of gold associated with platinum-group metals. The mineralization is spotty and found in shears and veins. The richest ores were found in sulfide-rich zones in mafic mylonites, graphitic fault gouge, and in strongly chloritized zones (McCallum, 1968).

It is apparent some Wyoming platinum is magmatic as well as hydrothermal. Platinum in the Lake Owen complex is clearly magmatic and associated with cumulus layers. In the New Rambler district, the platinum is in hydrothermally altered mafic cataclastics. Possibly, the New Rambler ore was leached from discrete mafic rock units by hydrothermal solutions, or remobilized from the deformed layered complex (McCallum and Orback, 1968). Platinum in the Centennial Ridge district is restricted to narrow zones of altered, mafic, metaigneous schist and gneiss and appears to have been remobilized from the mafic country rock (McCallum, 1968).

MAGMATIC HYDROTHERMAL DEPOSITS

Hydrothermal alteration often accompanies many magmatic metalliferous deposits. Temperature gradients associated with the deposits results in zoned alteration and mineralization. The classic magmatic hydrothermal deposits are the porphyry copper deposits and their associated vein systems. Spatially associated with some porphyries with relatively high average Au/Ag ratios are large tonnage, disseminated, gold deposits. Porphyries, veins, and disseminated gold mineralization have all been recognized in Wyoming.

Porphyry Deposits Several large Cu-Ag porphyries (with high Ag/Au ratios) occur in the Absaroka Mountains of northwestern Wyoming. This region includes one of North America's great copper districts, but limited accessibility has precluded development and extensive exploration of these deposits. Total copper, molybdenum, lead, zinc, silver, and gold resources are unknown, but the available drilling records indicate ore tonnages exceed a hundred million tons.

The Absaroka Mountains form a deeply dissected Tertiary volcanic plateau of calc-alkaline flows and flow breccias. Some eruptive centers possess classical hydrothermal alteration mineral assemblages and zonation typically seen in many porphyry copper deposits in the southwestern United States.

In the southern Absaroka Mountains, the Bald Mountain porphyry in the Kirwin district is surrounded by deuterically altered andesite containing secondary calcite, chlorite, and clay. The andesite gives way to hydrothermally propylitized (quartz-epidote-montmorillonite-calcite-chalcopyrite with chalcopyrite-calcite-quartz veinlets) andesite within 1,500 feet of the intrusive center. Near the intrusive center, phyllically altered assemblages are overprinted by argillic assemblages (quartz-sercite-pyrite-biotite-kaolinite-chlorite-illite/montmorillonite). Near the intrusive center, a potassic zone is represented by secondary orthoclase, quartz, and veinlet sulfides (Wilson, 1964; Nowell, 1971).

Drill hole data show a pyrite-chalcopyrite-molybdenite stockwork at Bald Mountain with a secondary enriched blanket of chalcocite, digenite, and covellite overlying a portion of the stockworks (Wilson, 1964). Veins in the altered area are chalcopyrite-pyrite-molybdenite-quartz veins (Wilson, 1960). Wilson (1964) reported vein and mine dump samples to assay a trace to 0.25 opt Au, and a trace to 111.8 opt Ag. A portion of the ore body was drilled outlining a minimum resource of 70 million tons of 0.75% Cu (Rosenkranz and others, 1979). Estimated contained metals in the porphyry includes 1.23 billion lbs of Cu, 121,000 oz of Au, 5.6 million oz of Ag with significant Pb, Zn, and Mo (Pay Dirt, 1985).

Another porphyry occurs in the Laramie Mountains of southeastern Wyoming. This is a Cu-Au porphyry in Proterozoic rocks known as the Copper King mine.

The Copper King porphyry in the Silver Crown district is a composite stock formed by quartz monzonite and foliated granodiorite. The granodiorite was intruded by quartz monzonite and hydrothermally altered and both the quartz monzonite and granodiorite are mineralized. The stock intruded Early Proterozoic (>1.7 Ga) crystalline rocks in the southern Laramie Mountains that are rafted in the Sherman Granite batholith (1.4 Ga).

Hydrothermal alteration is expressed by a narrow zone of K-silicate alteration (K-spar, biotite, quartz) extending from the quartz monzonite into the granodiorite. This zone is surrounded by widespread propylitic alteration consisting of secondary chlorite, epidote, and disseminated sulfides. Sulfides include chalcopyrite, pyrite, and minor bornite. Near the old shaft, a zone of intense silicification is expressed by a poorly developed stockwork of intersecting quartz veins and veinlets.

An oxidized cap, according to Soule (1955) may extend to a depth of 100 to 150 feet. Below this depth, sulfides predominate. The ore body extends to a minimum depth of 1,024 feet and is 300 ft wide by 600 to 700 ft long. Drilling by the Bureau of Mines established a 35 million ton ore body with average grades of 0.21% Cu and 0.022 opt Au. A higher grade zone (4.5 million tons averaging 0.044 opt Au) was later outlined by company drilling (Stockwatch, 1987; Hausel, 1989).

Disseminated and vein gold. Disseminated magmatic gold deposits do not appear to be widespread in Wyoming, although the numerous gold anomalies reported in the Absaroka Mountains of northwestern Wyoming (i.e., Albert, 1986) suggests this region deserves a serious look. Precious metals associated with Tertiary alkalic complexes have been mapped in the Bear Lodge Mountains, Black Buttes, and the Mineral Hill district in the Black Hills, and also in the Rattlesnake Hills of the Granite Mountains.

In the Black Hills, gold occurs in feldspathic breccia, veins, and jasperoids. Silver occurs in veins and replacement deposits.

The Bear Lodge Mountains in the northwestern Black Hills of Wyoming, form a large multiple intrusive complex of alkalic igneous rock that ranges in age from 38.0 to 50.0 Ma (Staatz, 1983; Lisenbee, 1985). Staatz (1983) described the complex as a porphyry-type intrusive containing one of the largest, low-grade, disseminated and vein-type REE and Th deposits in the United States. This terrane also includes disseminated and vein Au associated with feldspathic breccias (Hausel, 1989).

Recent exploration in the district has outlined 120 by 2,000 foot breccia with an average grade of 0.72 ppm Au. The tenor varies from 0.34 ppm to 1.7 ppm Au (International Curator Ltd, annual report, 1988). Historic reports also indicate the presence of auriferous fluorite veins in the district (Hall, 1911). However, several samples of fluorite-limonite-vein material collected by the author in 1988 contained no detectable gold, suggesting the fluorite may represent a separate mineralizing event (Hausel, 1989).

The Mineral Hill district is described as a alkalic ring dike complex (Welch, 1974). Gold mineralization was reported in the district to occur in silicified feldspathic breccia, diorite, and in jasperoid (Welch, 1974). The Mineral Hill district yielded some placer gold prior to 1893. According to Knight (1893), more than 9,000 ounces of gold were recovered from the Mineral Hill district. Reports of walnut-size nuggets from the district include a 2.45 oz recovered in 1890 (E&MJ, 1890, v.50, p. 555), and some nuggets recovered in modern times. Recent placer exploration in the district reported discouraging results for all heavy minerals including gold (Rick and Cheryl Parent, 1989, pers. comm.).

Welch described a sample of jasperoid to contain 5 ppm Au and 7 ppm Ag. East of the jasperoid, a diorite at the Interocean mine was described to host an ore body of unknown size, averaging 0.08 to 0.14 opt Au. Welch also described a feldspathic breccia to have assayed 6 ppm Au and 115 ppm Ag. These results were supported by Hopkins (1982) who reported samples from the Mayhem mine to range from 0.008 to 0.54 opt Au. Samples from the Artic mine contained from 0.014 to 14.82 opt Au, and none to 2.15 opt Ag.

Recent investigations in the district by the author found only traces of gold in some breccias, and recovered highly mineralized samples of two near horizontal limonitic quartz veins in the Treadwell open cut along the northwestern edge of Mineral Hill. Samples from the Treadwell open cut included silicified trachyte and quartz vein material. These assayed from 0.05 ppm to 130 ppm Au and none to 330 ppm Ag. A sample of pyroxenite from the Birdsnest mine contained 0.17 ppm Au, and a sample of quartz from the mine dump assayed 15 ppm Au and 120 ppm Ag.

The Black Butte (Hurricane) district contains some localized contact metasomatic mineralization in the Pahasapa Limestone along a contact with Tertiary trachyte. The mineralization does not appear to be extensive, but exposures are poor. Samples of the limestone contain argentiferous galena, hemimorphite, fluorite, and wulfenite. Some lead and silver ore was shipped from this area prior to 1943. According to the U.S. Bureau of Mines, 51 oz of Ag and 6,977 lbs of Pb were recovered from this deposit (Henderson, 1943).

Widespread disseminated gold is hosted by hypabyssal alkalics (Tertiary) and disrupted metagreywacke (Archean) in the Rattlesnake Hills (Figure 1). Drilling intersected thick zones with low grade mineralization. One hole cut 255 ft averaging 0.823 ppm Au. Another 145 ft intercept averaged 1.0 ppm Au. Breccia veins assayed as high as 3.77 ppm Au.

Veins Quartz veins are common in both volcanic and metamorphic terranes. In Tertiary volcanics, veins are clearly associated with hydrothermal activity and often show classical ore zonation.

Quartz veins associated with the porphyry stocks of the Absaroka Mountains are zoned. In the Sunlight district, Cu-rich veins with trace Au occur near the porphyry center and grade into Pb-Ag and barren veins away from the stock.

Some Proterozic veins are also zoned. Spencer (1904) described precious metal zonation in the Bridger vein of the Sierra Madre. Gold decreased and silver increased with depth. In the Cooper Hill district of the Medicine Bow Mountains, Schoen (1953) described zonation at the Albion vein to be dependant on the host rock lithology. The vein is cupriferous where hosted by calc-schist and Pb-Ag-bearing where hosted by quartzite.

Several factors may cause ore shoots in hydrothermal veins. In the Mineral Hill district, veins in the Treadwell open cut are relatively narrow, contain abundant limonite after pyrite, and yield strong Au and Ag anomalies with some Pb, Cu, and Zn. The strongly mineralized, near horizontal, pyritiferous veins are reported to form ore shoots at intersections with a series of vertical fractures.

STRATIFORM DEPOSITS OF SEDIMENTARY AFFILIATION

Cupriferous Quartzite The Ferris-Haggerty mine in the Sierra Madre was Wyoming's premier copper mine. The Ferris-Haggerty ore body is a massive sulfide hosted by a contact breccia in quartzite formed between a hanging wall schist and the footwall quartzite of the Magnolia Formation (Proterozoic). The massive sulfide is as much as 20 ft thick and grades into disseminated sulfides oriented parallel to foliation in the quartzite.

Beeler (1905) described ore shoots containing from 30 to 40% Cu with some Ag and 3.43 to 12.7 ppm Au. The mine operated from 1902 until operations terminated in 1908 following the destruction of the Riverside smelter at Encampment by fire. The ore body was not exhausted and large blocks of 'low-grade' ore remained unmined (Ralph Platt, personal communication, 1988). The low-grade ore typically ran 6 to 8% Cu.

Copper-Silver-Zinc Redbeds. Copper-silver-zinc redbed mineralization is widespread in the Overthrust Belt of western Wyoming (Hausel and Harris, 1983). Many of these deposits and occurrences lie along the contact of the Nugget Sandstone (Triassic-Jurassic) and the overlying Gypsum Spring Member (Jurassic) of the Twin Creek Limestone (Boberg, 1986) Some deposits show evidence of both structural and stratigraphic control.

The best exposure of this type is at the Griggs mine in the Lake Alice district. Several adits were driven into mineralized sandstone at the Griggs mine. The mineralized rock is 300 ft thick (Love and Antweiler, 1973). Ore shipped from the district between 1914 and 1920, and ore recovered from the mine in 1942 averaged 3.5% Cu and 254 ppm Ag (Allen, 1942). Samples collected by Love and Antweiler (1973) contained 180 ppm 6.7% Cu, a trace to 0.5% Pb, 26 ppm 3.2% Zn, and a trace to 1,200 ppm Ag. The redbeds are bleached indicating the mineralizing fluids were reducing.

Fluid inclusion studies indicate the mineralizing fluids were deposited at less than 100°C (Loose and Boberg, 1987). The source of these fluids may have been interformational fluids generated during deformation of the Overthrust Belt (Boberg, 1986), or possibly could have originated from metalliferous hydrocarbons (Love and Antweiler, 1973). The ore fluids migrated into anticlinal traps along permeable fault and breccia zones (Loose and Boberg, 1987; Loose, 1988).

Banded Iron Formation. Significant resources of Archean banded iron formation (BIF) occur in the Copper Mountain, South Pass, and Seminoe Mountains supracrustal belts, and additional BIF is found in the Barlow Gap, Sellers Mountain, and Elmers Rock belts. In the Hartville uplift of southeastern Wyoming, giant resources of hematite schist occur in an eugeoclinal belt of Archean (?) age.

BIF in the South Pass greenstone belt occurs in a metasedimentary-metaigneous unit containing quartzite, metapelite, and amphibolite. The BIF typically shows well-developed banding expressed by alternating magnetite-rich and metachert-rich layers with subordinate amphibole (principally hornblende and grunerite), chlorite, and locally sulfides (pyrite and chalcopyrite). The rock averages 33.0% iron (Bayley, 1963).

Sulfides are uncommon, but locally may form up to 5% of the rock. The sulfides (pyrite with subordinate chalcopyrite) are principally stratiform with some crosscutting veinlets. The BIF has been structurally thicken by internal folding and plication and by repetition by slippage along faults.

Gold distribution has been incompletely examined. Available records indicate one mine was developed in a crosscutting quartz vein adjacent to BIF at the Atlantic City iron mine. The ore averaged 2.06 ppm Au (Bayley, 1963). Elsewhere, samples of BIF have assayed 1.1 ppm Au with some quartz stingers containing 0.4 ppm Au.

BIF in the Copper Mountain district crops out as four, relatively continuous, narrow beds along a 8 mile strike. These rocks contain both quartz and magnetite but also have abundant grunerite (Hausel and others, 1985). Near the center of the district, a shaft was sunk (McGraw mine) in copper-stained magnetite-rich iron formation. No production history is available for the mine, but it is suspected the shaft was sunk to test a nearby cupriferous strike vein.

BIF in the Seminoe Mountains greenstone belt forms a large resource in the Bradley Peak thrust sheet (Blackstone, 1965). The iron formation is intercalated in metasediments, follows schistosity in metabasalt and metagabbro, and occur as interflow sediments between basaltic komatiite flows. Locally, the BIF is structurally thickened producing a giant iron ore resource. Harrer (1966) indicated the north slope of Bradley Peak contains a resource of 100 million tons. The iron deposits continue beyond the north slope suggesting the total resource to be much greater. Chemical analyses of the Seminoe BIF give iron contents of 28.7% Fe to 68.7% Fe (Harrer, 1966). Local gold and silver anomalies have been detected (Hausel, 1989).

BIF and metachert in the Barlow Gap supracrustal belt of the Granite Mountains, is found in a metavolcanic-metasedimentary sequence. A metachert in this region is auriferous. Composite chip samples across the metachert contained 4.46 ppm and 7.55 ppm Au (Hausel, 1989, p.60). A nearby 4,700 ft anomalous zone was drilled with 3 of 20 intercepts containing anomalous gold (2.7 to 10.98 ppm) (Ray, 1988).

Iron deposits in the Hartville uplift were commercially mined until 1981. About 45 million tons of ore were mined from the Sunrise deposit. The ore occurs as hematite schist in the Silver Springs Schist (Snyder and others, 1989). Gold anomalies have also been detected in some hematite schists in the Hartville uplift (Woodfill, 1987).

PLACERS

Wyoming has extensive paleoplacer gold deposits, particularly in Tertiary conglomerates. Some paleoplacers are also reported in Proterozoic, Cambrian, and

Cretaceous conglomerates and sandstones. Recent placers are concentrated near known mining districts, and nuggets, flakes, and colors of gold, platinum, and silver have been recovered.

Paleoplacers Paleoplacers are widespread in the State. To date, production from paleoplacers and their associated reworked placers has been minimal, although the shear volume of paleoplacer material would imply that these deposits may become important sources of gold and other heavy minerals in the future.

The oldest paleoplacers occur in the Proterozoic miogeoclinal terrane of the Sierra Madre and Medicine Bow Mountains in southeastern Wyoming. Little exploration has occurred on these deposits, even though the succession includes thick sequences of quartzite with basal conglomerates. During the 1970s, it was discovered that several of these paleoplacers were radioactive and contained resources of thorium and uranium (Houston and Karlstrom, 1979). An investigation of the energy resources of the metasediments, also led to a discovery of anomalous gold in some samples. For instance, a sample of Magnolia Formation conglomerate from the Dexter Peak area of the Sierra Madre contained 10 ppm Au (Houston and Karlstrom, 1979). No systematic studies on the gold potential of these deposits have occurred, possibly because of the lack of nearby modern placers.

Cambrian placers associated with conglomerates and quartzites of the Flathead Formation have been described at a few localities in the State. These placers do not appear to be widespread, but appear to be local phenomenon. They have been reported near Miners Delight in the South Pass-Atlantic City district, in the hematitic conglomerates of the Rawlins uplift, in the Mineral Hill district, and in the Bald Mountain district of the Bighorn Mountains. Only the Bald Mountain deposits have been explored in any kind of detail. These were explored and drilled by the U.S. Bureau of Mines in the search of commercial deposits of monazite.

In 1952, the U.S. Bureau of Mines drilled 92 holes in the Bald Mountain conglomerates and estimated 20 million tons of rock contained an average of 2.5 lbs/ton monazite. A higher grade zone continued 675,000 tons of 13.5 lbs/ton monazite. Gold assays ran on material recovered from six high-grade monazite intersects contained only 0.34 to 0.171 ppm Au (McKinney and Horst, 1953: Borrowman and Rosenbaum, 1962).

Cretaceous paleoplacers include several titaniferous black sandstones in the Mesaverde Formation. The black sandstones are enriched in heavy minerals which include anatase, sphene, rutile, ilmenite, titanomagnetite, magnetite, monazite, zircon, and gold. Minerals of potential economic value include the titanium-bearing assemblage of sphene, rutile, anatase, ilmenite, and titanomagnetite; zircon for zirconium and hafnium; monazite for rare earth metals; a niobium-bearing opaque; and gold (Houston and Murphy, 1962, 1970).

The deposits are widespread and differ greatly in grades and size. The Grass Creek deposit in the Bighorn Basin is the largest, high-grade, deposit in Wyoming (Houston and Murphy, 1962) and includes significant resources of titanium (averages 16% TiO_2), and zircon (3 million tons averaging 4.8% $ZrSi0_4$) (William Graves, personal communication, 1990). However, it is incompletely explored for gold and of two samples collected by the author, no gold was detected.

Some of the younger Cretaceous deposits, such as the Sheep Mountain titaniferous black sandstone in southern Wyoming, and deposits in northeastern Wyoming, are enriched in gold (Madsen, 1978). Values as high as 1.3 ppm gold are reported by Houston and Murphy (1970) and 1.7 ppm by William Graves (personal communication, 1990).

Tertiary paleoplacers are abundant in the State. These consist of fanglomerate and fluvial conglomerates that locally include giant boulders eroded from the nearby uplifts. The more highly mineralized conglomerates lie adjacent to greenstone belts. For example, the South Pass greenstone belt is flanked by two giant paleoplacers known as the Twin Creek (Antweiler and others, 1980) and Oregon Buttes paleoplacers (Love and others, 1978). According to Love and others (1978) as much as 28,500,000 oz of gold is probably contained in the deposit. Other extensive paleoplacers covered vast regions of northwestern Wyoming (Antweiler and Love, 1967).

Modern placers Gold tenors of modern placers in the state range from a trace to more than 1.0 oz/yd^3. Generally, the commercial placers contain pay streaks that average about 0.01 oz/yd^3, although exceptional placers have averaged 0.1 oz/yd^3.

Nuggets recovered from Wyoming placers include walnut size nuggets from Mineral Hill, Douglas Creek, and the South Pass greenstone belt. The largest nugget reported in the state came from the South Pass area and was described as a fist size rock containing 24 oz of Au. Another interesting specimen, that was also found on Rock Creek, was described as a boulder with an estimated 630 oz of Au. Most nuggets in the State are rounded typical of detrital transport, although Day and others (1988) report slivers and hairs of gold from gravels in the Lewiston district. Nuggets encasing sand grains have also been found in the South Pass-Atlantic City district (J.D. Love, personal communication, 1990).

In addition to placer gold, other heavy minerals of potential value have been found in stream placers.

Gold placer or district	Heavy Minerals
Lewiston district, South Pass	Gold, scheelite, cassiterite
South Pass-Atlantic City district	Gold, amalgam, scheelite, cassiterite, chromite
Crows Nest, South Pass	Gold, scheelite.
Mineral Hill district, Black Hills	Gold, cassiterite, tantalite
Douglas Creek, Medicine Bow Mtns	Gold, platinum, palladium
Cortex Creek, Medicine Bow Mtns	Gold, diamond
Clarks Camp, Wind River Mountains	Gold, monazite
Bald Mountain, Bighorn Mountains	Gold, monazite
Nugget Creek, Sierra Madre	Silver, gold
Muddy Creek, Shirley Basin	Monazite

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