LARGE DISTAL-DISSEMINATED PRECIOUS-METAL DEPOSITS, BATTLE MOUNTAIN MINING DISTRICT, NEVADA

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ABSTRACT

Apparent transitions between two major classes of metal deposits in the Battle Mountain Mining District, porphyry Cu and stockwork Mo deposits, on the one hand, and high level distal-disseminated Ag–Au deposits, on the other hand, reflect a contrast in paleodepths of deposit formation on either side of the Miocene Oyarbide fault. This fault, a significant northeast-striking, post-mineral fault in the mining district, displaces downwards its northwestern block at least 700 m—geologic relations suggest that final displacements along this fault only can be constrained geologically to sometime during the last 17 to 14 m.y., possibly at roughly the same time as the less-than-9–Ma displacements recorded along the similarly trending Midas, Nev., trough, which is approximately 40 km to the north.

INTRODUCTION

The extraordinarily varied and copious metal endowment of the Battle Mountain Mining District (fig. 1) results from the location of the mining district in a shallow-seated geologic environment at the intersection of regional-scale metallotects of several ages (Roberts and Arnold, 1965; Theodore, 1992; see also, Doebrich and others (1996) for a summary). The term Battle Mountain Mining District used in this report differs from that used by Tingley (1992) by expanding the area to include the Buffalo Valley Mining District and the northern part of the Buffalo Mountain Mining District, which includes mineralized rock in the general area of Lone Tree Hill (fig. 1). Recent precious-metal discoveries in the northern part of the Battle Mountain Mining District have resulted in recognition of a fundamental difference between deposits in the northwest and southeast parts of the district. The discoveries generally are not closely associated genetically with intrusive rocks, and include approximately 1 million oz Au near the Eight South deposit, a probable 1 million oz Au in three other deposits (Trenton, Valmy, North Peak; Felder, 1997), and approximately 5 million oz Au in the Lone Tree deposits (fig. 1; see also, Bloomstein and others, 1998). However, in the southeast parts of the mining district many exposed metal-bearing plutons of Late Cretaceous and middle Tertiary ages contribute significantly to the overall metal endowment of the mining district, and result in at least seven porphyry Cu and stockwork Mo systems being present (Theodore and others, 1992; Doebrich and others, 1996). The economically most significant area of precious metal-mineralized rock in the southeast part of the mining district is at Copper Canyon, where approximately 5 million oz Au have been delineated (Theodore, 1998; see also section below entitled "Multilevel Geochemical Anomalies at the Fortitude Gold Skarn, Battle Mountain Mining District, Nevada"). At Copper Canyon, gold-bearing skarns are present in a widespread 39–Ma skarn-related, porphyry copper system, including the Fortitude gold skarn (approximately 2 million oz Au, Wotruba and others, 1986; Myers, 1994).

The Late Cretaceous and middle Tertiary intrusive rocks, which are present throughout the southeast part of the mining district, are calc-alkaline and shallow seated—they were emplaced into a complex array of Paleozoic rocks that subsequently were broken by a number of post-mineral faults during the late Tertiary. The middle Tertiary magmatism also roughly coincides temporally with initiation of extension in the region, although much extension in north-central Nevada culminated somewhat later when a shift from calc-alkaline to bimodal magmatism occurred about 17 my ago (Seedorff, 1991; see also, Doebrich and Theodore, 1996). The mining district includes the prominent northeast-striking, northwest-dipping post-mineral Oyarbide fault, which displaced its hanging wall approximately 700 m (fig. 1). The Oyarbide fault is classified by Dohrenwend and Moring (1991) as a young, post-17–Ma, deeply penetrating block fault that, in part, juxtaposes Quaternary alluvium against bedrock.

DISTRIBUTION PATTERNS OF ORE DEPOSITS

Several metallized district-scale northwest and north-south structural trends characterize the known major orebodies and their genetically related granitic, *sensu lato*, rocks (Blake and others, 1979; Doebrich, 1995; Doebrich and others, 1996), and the major clusters of orebodies are present at their intersections.

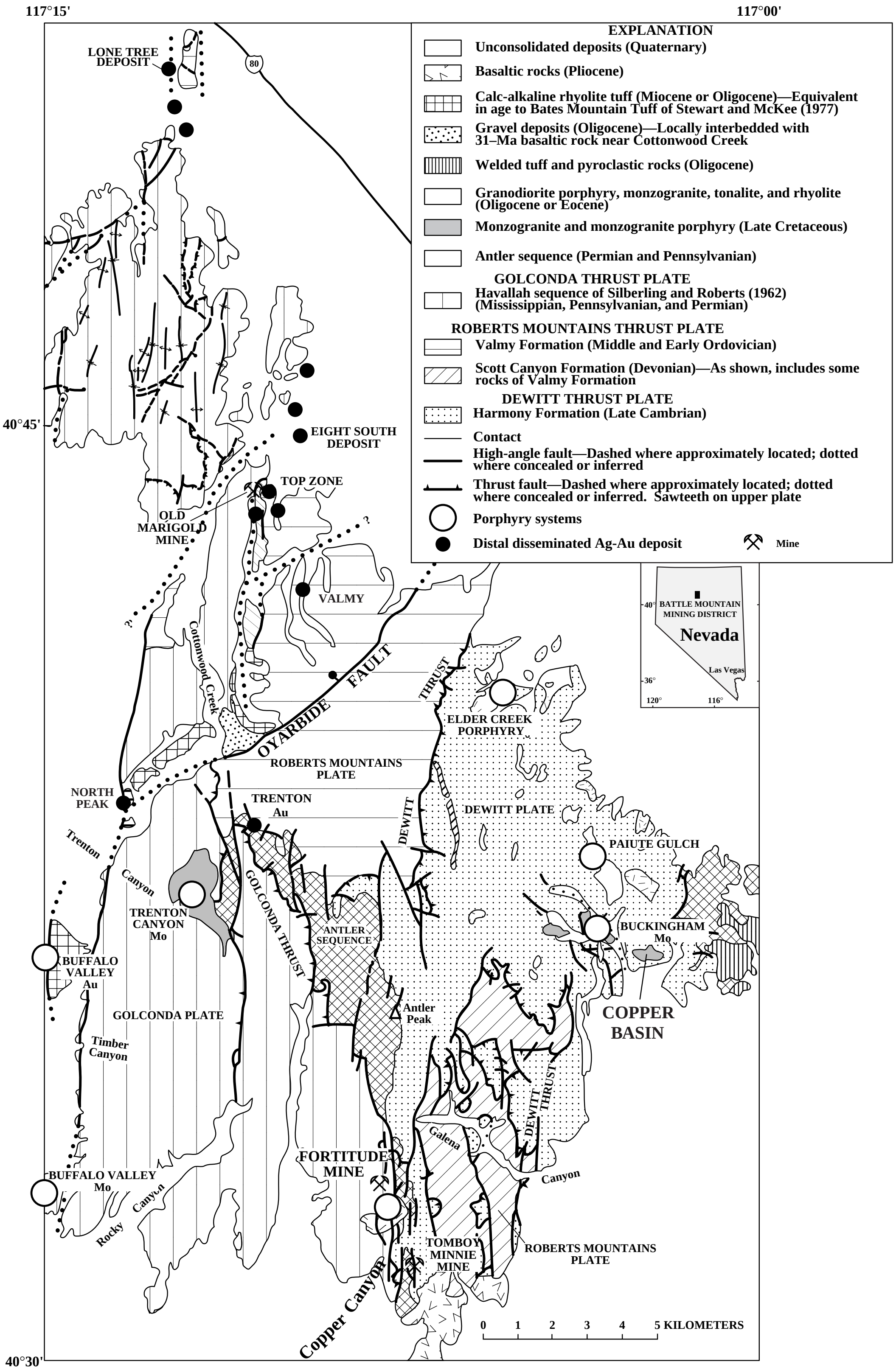

Figure 1. Geology of the Battle Mountain Mining District. Modified from Roberts (1964), Theodore (1991), and Doebrich (1995).

Other important regional-scale metallotects also impact the mining district, and these include: (**1**) a Late Cretaceous magmatic arc resulting from trench-related magmatism in a continental margin mobile belt (for example, Westra and Keith, 1981), (**2**) a highly mineralized trend, the northwest-trending Eureka mineral belt of Shawe and Stewart (1976), previously termed the "Eureka-Battle Mountan mineral belt" by Roberts (1966) and also referred to as the "Battle Mountain gold belt " by Madrid and Roberts (1991), and (**3**) an apparently 5– to 8–km-wide, loosely constrained, north-south mineralized trend, termed the "Rabbit Creek-Marigold mineral belt," that includes the large number of Au–Ag deposits in the general area of the Eight South deposit. The latter metallized trend essentially extends about 50 km farther to the north where it terminates in the Twin Creeks Au–Ag deposit (Bloomstein and others, 1991) northeast of the Carlin-type (Berger, 1986) precious-metal deposits at Getchell.

The geology and geochemistry of a number of precious-metal deposits in the northwest part of the Battle Mountain Mining District (fig.1) also provide specific insight into inferred regional patterns of their distribution, as well as their ages, even though many of these deposits apparently do not have clear-cut spatial and genetic ties to felsic plutons and have not been dated radiometrically. The dominant theme, however, that is repeated through all of the deposits in the northwest part of the mining district is the importance of faults and fractures as major contributing components to their overall genesis. Nonetheless, large volumes of rock in many of these precious-metal deposits contain disseminated ore which results from a bleeding out from mineralized faults and fractures that act as feeders to deliver metal–bearing fluids to chemically and (or) physically receptive sites.

About 15 precious-metal deposits are mostly present south of the Eight South deposit in the hanging wall of the Oyarbide fault (fig. 1). All of these deposits are probably best classified as distal-disseminated Ag–Au deposits (Cox and Singer, 1992), and owe their origins to relatively far-traveled, hypogene Au–bearing fluids emanating from buried porphyry Cu systems somewhat akin to the evolution of immiscible fluids described for porphyry systems (Hedenquist and Lowenstern, 1994; Albino, 1994). The Eight South Au deposit (Graney and McGibbon, 1991; McGibbon and Wallace, 1997) was the first of these recent discoveries near the Old Marigold Mine (fig. 1). The Eight South deposit is completely oxidized and, compared to most pluton-related systems, apparently has a relatively high Au/Ag ratio of 1 in its ore, as well as anomalous concentrations of As, Sb, Hg, Tl, and especially Ba—geochemical signatures that suggest that this deposit may be a Carlin-type precious-metal system (Graney and McGibbon, 1991). However, Au/Ag ratios prior to oxidation may have been different. Oxidation in the general area of the Eight South deposit may have been taking place for as long as approximately 23 m.y. (Theodore, 1998)—possibly enhanced by the fact that the site of the deposit, at one time, was elevated approximately 700 m relative to its present position (D.H. McGibbon, oral commun., 1996). Classification of these deposits as distal-disseminated Ag–Au, nonetheless, is provisional and assumes that Carlin-type deposits are not pluton-related. Recent discovery of Au–mineralized rock associated with abundant oxide Cu at the Mike deposit along the Carlin trend, Nev. (Teal and Jackson, 1997)—approximately 75 km east of the Battle Mountain Mining District—may require a revision of classification schemes involving Carlin type deposits and distal disseminated Ag–Au deposits, particularly if it is demonstrated that evolved magmatic fluids are the dominant fluids involved in generation of the bulk of the Carlin-type deposits. However, if it turns out that Cu in the Mike deposit is unrelated temporally to the Au, then the Cu may be associated with some type of system other than a Carlin type.

The distal-disseminated Ag–Au deposits in the Battle Mountain Mining District cluster in sedimentary rocks and represent mineral occurrences at various levels vertically in large magmatic-hydrothermal systems as described by Albino (1994) (fig. 1). These 15 deposits—not all shown on figure 1—have many notable differences, some as described above, compare to the deposits used by Cox and Singer (1992) to construct the original distal-disseminated Ag–Au model. This deposit model, regardless, definitely belongs to the porphyry Cu or pluton-related mineralizing environment, and this model has a strong affiliation with upper crustal magmatism. An underestimation of base-metal contents of mineralized systems in the hanging wall of the Oyarbide fault also has contributed to their problematic classification. Nonetheless, the Lone Tree deposits appear to have an increase in base-metal content in the lower benches so that they are now (1998) beginning to display chemical and physical attributes—as well as fluid-inclusion signatures (Theodore, 1998)—characteristic of distal-disseminated Ag–Au deposits. Many of the deposits have elevated contents of K_2O (sericite) associated with Au–mineralized rock (Bloomstein and others, 1991)—large-scale additions of K_2O are not as common in most classic Carlin-type deposits. Some difficulty of classifying Au deposits in the Lone Tree and Marigold areas involves the protracted oxidation, probably lasting as long as 23 m.y., which may have altered significantly base- and precious-metal ratios from their preoxidation values.

The best evidence to assign these deposits to a pluton-related environment includes (**1**) the setting of the deposits in the pluton-related geologic environment of the Battle Mountain Mining District, (**2**) sericitically altered dikes in direct association with sericitically altered and Au–mineralized rock in some of the deposits, and (**3**) magmatic isotopic signatures of hydrothermal barite associated with Au–mineralized rock (Howe and others, 1995; Theodore, 1998). Sulfur isotopic ratios of hydrothermal barites—values of $\delta^{34}S$ clustering tightly at approximately +10 per mil—that are associated with several of these Au deposits clearly indicate a significant magmatic component to ore-forming fluids (Howe and others, 1995). This contrasts to well-studied Carlin-type systems elsewhere (Hofstra and others, 1988, 1989; Arehart, 1996; Ilchik and Barton, 1997).

Vertically stacked, large porphyry Cu systems contain peripheral distal-disseminated Ag–Au deposits in the northwest part of the Battle Mountain Mining District, similar to deposits elsewhere referred to as distal epithermal gold deposits (Jones, 1992). These deposits represent the predominantly structurally controlled, high level parts of porphyry Cu systems, probably inboard from the more common Ag–rich deposits. Metal zoning in the most outermost parts of these systems is complicated because absolute differences in precious-metal abundances are difficult to quantify due to intense oxidation (see above). The distal-disseminated Ag–Au deposits are analogous to polymetallic vein deposits, and may be considered to be variants of them (Cox and Singer, 1992); however, distal-disseminated Ag–Au deposits differ from polymetallic veins in their disseminated nature whose style of ore can be dispersed sufficiently to have generated deposits as large as approximately 83 million tonnes as at Cove, Nev. (Cox and Singer, 1992). They differ, as well, in absence of concentrations of Pb and Zn comparable to that found in most polymetallic veins, although the Ag–rich Cove deposit includes relatively high contents of Pb.

Changes in elemental ratios brought about by oxidation in these deposits cause high-level occurrences to have Carlin-type geochemical signatures. Indeed, Albino (1993) points out that the common enrichment of As, Sb, and Hg in both Carlin-type systems and distal-disseminated Ag–Au deposits partly results from these elements having the ability to be transported as bisulfide complexes. In addition, Albino (1993) points out that many distal-disseminated Ag–Au deposits are enriched in Mn, whereas some Carlin-type deposits, in fact, may be leached of Mn. The Au deposits in the down-faulted terrane north of the Oyarbide fault represent high-level parts of large mineralized hydrothermal systems, which formed mostly in calcareous sedimentary rocks near the paleosurface. The two clusters of Au deposits near Lone Tree Hill and the Eight South deposit (fig. 1) result probably from two separate porphyry Cu centers buried beneath them.

I do not mean to imply, however, that distal-disseminated Ag–Au deposits cannot be present south of the Oyarbide fault—actually the Trenton Canyon Au deposits (fig. 1) probably are examples of such deposits (Felder, 1998). Any pluton-related mineralizing system, which is similar geologically to those previously described, and which is emplaced at somewhat greater overall paleodepths south of the Oyarbide fault, also should have the potential of forming distal-disseminated Ag–Au deposits. However, Sillitoe (1994) suggests that the two types gold deposit, distal-disseminated Ag–Au as well as Carlin type, should instead be considered as two broad, genetic varieties of a single category of deposits. Previously, Sawkins (1990) also suggested that Carlin-type deposits result from fluids that emanated from buried felsic to chemically intermediate intrusive rocks and were channeled along deeply penetrating faults to sites where metal deposition occurred. These suggestions disregard the apparent different geologic processes that currently are envisioned by many to have been involved in generation of the two types of deposits: largely magma-equilibrated fluids associated with the former, and mostly evolved meteoric and (or) metamorphic fluids associated with the latter (Arehart, 1996; Ilchik and Barton, 1997), as well as major differences in salinity of the ore-forming fluids. Further, Carlin-type deposits commonly may have formed at paleodepths greater than the distal-disseminated Ag–Au deposits—400 to 800 bars (Peters and others, 1996)—the latter form typically in high-level parts of a Au–enriched pyritic envelope surrounding a porphyry Cu system. Intensely fractured rocks with abundant Au–bearing iron oxides along fractures are present in many of the distal-disseminated Ag–Au deposits in the Battle Mountain Mining District.

Even the age of Carlin deposits, including those that have been investigated intensely for as many as 30 years, remains enigmatic, both along the Carlin trend and along the Getchell trend. Perhaps, the deposits along the Carlin trend owe their origins to long-lived circulation of hot, Au–bearing fluids—perhaps as long as 100 m.y. Post-14–Ma hot fluids deposited quartz-adularia assemblages along joints and fractures in the Miocene Carlin Formation in the northern part of the Carlin trend (Fleck and others, this volume). Similar mineral assemblages (plus Hg) are present in highly recrystallized outcrops near the headframe of the Meikle Mine, one of the economically most important Au deposits along the Carlin trend (Teal and Jackson, 1997).

CONCLUSION

The seeming transition between two major classes of deposits in the Battle Mountain Mining District, porphyry Cu and stockwork Mo deposits, on the one hand, and distal-disseminated Ag–Au deposits, on the other hand, reflects a contrast in paleodepths of deposit formation on either side of the Oyarbide fault. This fault is a significant northeast-striking, post-mineral fault in the mining district (fig. 1). It displaces downwards its northwestern block at least 700 m—geologic relations suggest that final displacements along this fault only can be constrained geologically to sometime during the last 17 to 14 m.y., possibly at roughly the same time as the less-than-9–Ma displacements recorded along the similarly trending Midas, Nev., trough, which is approximately 40 km north of the mining district (Wallace and Hruska, 1991; see also Doebrich and Theodore, 1996).

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