Economic Geology — An Invited Commentary on Journal Papers

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Distal-Disseminated and Carlin-type Gold Deposits: Are They Fundamentally Different?

In an exciting recent paper, "Formation of a paleothermal anomaly and disseminated gold deposits associated with the Bingham Canyon porphyry Cu-Au-Mo system, Utah," Cunningham et al. (2004) add serious weight to the claim that the Barneys Canyon and Melco sedimentary rock-hosted Au deposits on the northern fringe of the giant Bingham Canyon district, Utah, are genetically linked to the porphyry Cu-Au-Mo deposit and flanking skarn Cu-Au and carbonate-replacement Zn-Pb-Ag deposits in and around the core of the district (Sillitoe and Bonham, 1990; Babcock et al., 1995; Gunter and Austin, 1997). Cunningham et al. (2004) use an innovative combination of techniques, including patterns of apatite and zircon fission-track data, conodont color alteration indices, solid bitumen reflectivity, and stable isotope data, in conjunction with district-scale metal zoning (Babcock et al., 1995). Their results support formation of the Au deposits near the low-temperature (~100°C), outer limits of the Bingham Canyon hydrothermal system, as recorded by the resultant paleothermal and Au-As anomalies in the sedimentary host rocks. They further propose that the sedimentary rock-hosted Au deposits and geochemically similar, fault-controlled Au mineralization cutting the core of the district resulted from admixture of shallowly derived, oxidized, acidic water and upwelling, reduced, Au-bearing fluid during terminal collapse and telescoping of the Bingham Canyon hydrothermal system.

Classificatory issues

The peripheral (and late-stage overprinted) Au mineralization in the Bingham Canyon district has a characteristic Au-As signature reflecting the association of submicron-sized Au with arsenian pyrite, marcasite, and arsenopyrite. Antimony, Hg, Tl, and Ba are accompanying elements, whereas base and lithophile metals are notably absent (Babcock et al., 1995; Gunter and Austin, 1997). The Au mineralization is similar to that hosted by carbonate-bearing rocks on the peripheries of a number of other intrusion-centered mineral districts, the interiors of which contain porphyry Cu-Mo, Cu-Au, or Mo, skarn Cu, Cu-Au, or Au, and carbonate-replacement Zn-Pb-Ag ± Au deposits. Instructive examples include Lone Tree, Marigold, and smaller deposits in the late Eocene Battle Mountain district (Theodore, 1998), West Archimedes in the Early Cretaceous Eureka district (Margolis, 1997), and Rat and other deposits in the Late Jurassic Bald Mountain district (Nutt et al., 2000), all in Nevada, along with deposits in the Miocene Bau district of Sarawak, East Malaysia (Percival et al., 1990; Sillitoe and Bonham, 1990), Miocene Gualcamayo district, Argentina (Lynch et al., 2000), and Late Carboniferous Sepon district, Laos (R.H. Sillitoe, unpub. report, 1994; Manini et al., 2001).

Notwithstanding the notable geologic and geochemical similarities to classic Carlin-type Au deposits (see Cline, this issue, p. 1), the clear intrusive affiliation of the sedimentary rock-hosted Au deposits in the Bingham Canyon and these other zoned districts led to creation by Cox and Singer (1990) of the distal-disseminated deposit class, subsequently perpetuated by several investigators (e.g., Theodore, 1998; Hofstra and Cline, 2000; John et al., 2003). These obvious similarities provided the rationale for assigning all sedimentary rock-hosted Au deposits, irrespective of their observed proximity to coeval intrusions or other related ore deposit types, to a single, albeit broad, intrusion-related category (Sillitoe and Bonham, 1990; see Johnston and Ressel, this issue, p. 12). Whereas the distal-disseminated Au deposits are generally accepted to be zoned around high-level stocks and any associated porphyry, skarn, and carbonate-replacement deposits, Carlin-type deposits, lacking any obvious progenitor intrusions, are commonly believed to be amagmatic in origin: products of either leaching by deeply circulated meteoric water (e.g., Ilchik and Barton, 1997) or metamorphic dehydration of deeply buried sedimentary rocks (e.g., Seedorff, 1991; see Seedorff and Barton, this issue, p. 14). Perhaps tellingly, sedimentary rock-hosted Au deposits assigned to both the distal-disseminated and classic Carlin types in northern Nevada share the main Au trends as well as helping to define the preeminent late Eocene Au epoch (Sillitoe and Bonham, 1990; Henry and Ressel, 2000; John et al., 2003).

Key questions

The distal-disseminated Au deposits, in sharp contrast to those assigned to the Carlin type, are considered to show clear evidence, especially in metal and isotopic signatures, for magmatic input (e.g., Hofstra and Cline, 2000). But is this distinction as clearcut as claimed? Admittedly, minor amounts of one or more base metals, Te, and Ag ± Bi, Mo, W, and Sn accompany Au, As, Sb, Hg, and Tl in the sedimentary rock-hosted Au mineralization at West Archimedes and Bald Mountain, for example (Margolis, 1997; Nutt et al., 2000), but none of these "intrusion-related" metals is reported to be anomalous in such deposits peripheral to the other intrusion-centered districts, including Bingham Canyon (Babcock et al., 1995). Moreover, Te, W, Ag, and relatively minor quantities of Zn, Pb, and Cu occur in several classic Carlin-type deposits (Hofstra and Cline, 2000), although the base metals are usually downplayed or ascribed to pre-Au diagenetic or hydrothermal activity. Nevertheless, detailed lithogeochemical modeling of the Deep Star deposit in the northern Carlin trend reveals that high-grade Au was deposited with As, Sb, Hg, Tl, W, Zn, and Ag, which are flanked by Fe, Mn, Co, Ni, P, Cu, Mo, U, V, and possibly Pb and Bi anomalies (Heitt et al., 2003). Nickel, Co, Mo, W, and Zn are

COMMENTARY

also enriched at the nearby Beast deposit (Ressel et al., 2000). At Getchell, in the eponymous trend, the earliest ore-stage pyrite contains elevated As, Hg, Cu, and Te, as well as the highest Au values (~0.4%; Cline et al., 2003). Classic Carlin-type deposits typically lack isotopic evidence for magmatic input (Hofstra and Cline, 2000; Hu et al., 2002), although recent results from Deep Star, Screamer, and Getchell are consistent with contributions of magmatic volatiles and/or S (Cline et al., 2003; Heitt et al., 2003; Kesler et al., 2003).

Is it possible that the variability in isotopic and metal signatures across the sedimentary rock-hosted Au spectrum is telling us more about distance from source magmas and degree of mixing and dilution of magmatic with meteoric and other fluids rather than distinguishing between mutually exclusive magmatic and amagmatic contributions? If so, then the classic Carlin-type deposits in Nevada and southwestern China could denote even more distal Au precipitation sites than the so-called distal-disseminated deposits. Perhaps the former typically overlie "blind" intrusions, indicated only by outcrops of dike offshoots and aeromagnetic anomalies (e.g., Henry and Ressel, 2000), whereas the latter generally occur alongside exposed stocks. In both situations, however, barren gaps, 3 km wide in the Bingham Canyon district (Babcock et al., 1995), typically separate the sites of distal Au deposition from the nearest coeval base-metal mineralization. In this regard, it should be recalled that certain carbonate-replacement deposits also occur with coeval dikes above buried progenitor stocks (e.g., Ward, Nevada; Hasler et al., 1991). Furthermore, a continuum between carbonate-replacement and sedimentary rock-hosted Au deposits might be anticipated, broadly comparable to the overlap between the carbonate-replacement and skarn environments. Such a hybrid Au deposit could be Jerónimo in the Potrerillos porphyry Cu-Au-Mo district, northern Chile, which contains early arsenopyrite, late orpiment, realgar, and cinnabar, and an overall As-Mn-Zn-Pb-Sb-Ag-Hg-(Te-Sn) signature (Thompson et al., 2004).

Exploration consequences

The classification and origin of sedimentary rock-hosted Au deposits are not just academic concerns, but also of fundamental importance to the explorationist. Clearly, the so-called distal-disseminated type of sedimentary rock-hosted Au deposit may be targeted on the peripheries of intrusion-centered systems, which may or may not be cored by porphyry Cu and/or Mo mineralization (Sillitoe and Bonham, 1990). Such Au mineralization may develop up to ~10 km outboard of intrusive centers as lithologically and/or structurally localized bodies as well as occurring internally as structurally confined overprints to porphyry, skarn, and carbonate-replacement deposits (e.g., Babcock et al., 1995; Cunningham et al., 2004). Nevertheless, prospective district peripheries may not be intrinsically obvious because of their characteristic lack of prominent alteration features, unless defined on the basis of district-scale geochemistry (e.g., Babcock et al., 1995) or paleothermal anomalies (Cunningham et al., 2004).

Classic Carlin-type sedimentary rock-hosted Au deposits, if amagmatic, would be anticipated in any terrane where high paleothermal gradients induced deep meteoric water circulation or metamorphism, especially if throughgoing faults and receptive, thinly bedded, silty carbonate rocks—the preferred hosts—are available at epizonal (<5 km) depths. If all sedimentary rock-hosted Au deposits are intrusion related, however, such favorable structures and host rocks must be influenced by subduction-related intrusive activity, as in the Au trends of Nevada (e.g., Henry and Ressel, 2000). These considerations impose severe constraints on where to conduct grassroots exploration for sedimentary rock-hosted Au deposits. Although continental-margin settings provide most known sedimentary rock-hosted Au deposits, they also form in island arcs, as exemplified by the Mesel Carlin-type deposit in the late Tertiary porphyry Cu-Au and epithermal Au province of North Sulawesi, Indonesia (Turner et al., 1994).

Numerous discoveries of Carlin-type Au deposits in Nevada during the last 30 years have resulted from application of empirical models, but the worldwide search for additional sedimentary rock-hosted Au provinces has had little success and would surely benefit from clarification of the genetic model. Specifically, we need to ascertain if sedimentary rock-hosted Au deposits are all intrusion-related or if some, the classic Carlin type, are really amagmatic in origin. And if intrusions are critical, what compositions are particularly favorable? The formation of sedimentary rock-hosted Au deposits in island-arc terranes must be factored into the genetic modeling because of the obvious constraints that thin, primitive crust imposes on the nature of deep meteoric circulation and availability of sedimentary sequences for metamorphic dewatering. The multifaceted, district-scale approach adopted by Cunningham et al. (2004) at Bingham Canyon may offer the way forward.

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to page 30 · · ·

Commentary (Continued)

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COMMENTARY