Giant Carlin-type gold deposits: characteristics, origins and exploration methodology

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Although presently known to be common only in western North America, Carlin-type deposits (CTDs) are a significant source (~11%) of world gold production. These deposits are characterized by extremely fine-grained disseminated gold, hosted primarily by arsenian pyrite. Gold may be present dissolved in the lattice, or as atomic clusters in sizes below the limit of microscopic observation. The host rocks are dominantly silty carbonates, but ore is also present in siliceous and silicified rocks as well as intrusive rocks. Alteration consists of decarbonatization, silicification (jasperoid formation), and argillization, which are arranged both spatially and temporally in that order. Argillic alteration is zoned from kaolinite-dominated cores to sericite-dominated margins. The deposits commonly exhibit significant structural (faults) and stratigraphic (composition/permeability) controls.

Because of their fine-grained nature and the lack of macroscopic features such as veins, it has proven quite difficult to extract geochemical data that are clearly related to their genesis. However, fluid inclusion data indicate pressures corresponding to depths of 2-4 kilometres under lithostatic conditions. Temperatures are constrained by fluid inclusions and phase equilibria to near 225°C. Stable isotope data from alteration minerals and fluid inclusions indicate that the ore fluids were dominated by meteoric waters, some of which had clearly exchanged oxygen with wall rocks during their passage through the crust. In addition, some recent data are supportive of the presence of a magmatic fluid. Sulphur isotope values reported from CTDs span a wide range, from -30 to +45‰ (sulphides & sulphates), with ore-related sulphides (pyrite, realgar) falling between 0 and +20‰. The most likely ultimate source of sulphur was sedimentary; bedded barite is abundant in the Paleozoic section. It is equivocal whether that sulphur was scavenged by a meteoric fluid, or incorporated into an ascending magma that eventually spawned CTDs. The alteration and mineral assemblage indicate the ore fluids were probably near-neutral and gold was likely carried as a bisulphide complex. Multiple depositional mechanisms are required to explain the deposition of gold along with the observed alteration features (quartz precipitation, calcite dissolution and sericite-kaolinite coexistence). The primary mechanism causing deposition of gold was probably sulphidation, but mixing, cooling and oxidation all may have played a role. Virtually no evidence of phase separation ("boiling") has been documented in these deposits.

Until recently, the age of these deposits in the Great Basin was subject to much speculation, but the most recent data indicate that the deposits are restricted to 42–35 Ma. This corresponds to the timing of a transition from compressional to extensional tectonism in western North America, which was accompanied by magmatism. There are insufficient data to assess the timing and tectonic environment for other CTDs around the world.

The origin of this large gold province remains enigmatic, but the predominant theory at present is that these are distal, magmatic-related deposits. In the Great Basin, they are clearly related in time and space to magmatism, and to deep crustal features as elucidated by geochemical (isotopic) and geophysical (gravity, magnetics) features. On a very large scale, the deposits cluster near the Precambrian craton boundary on the western margin of North America, and at the boundary between Archean crust (to the N) and accreted Proterozoic (to the S) terranes. In addition, the deposits are arranged in linears that correspond with hypothesized deep structures in the craton margin.

Exploration for these deposits in the Great Basin focused on the presence of outcropping jasperoids and fundamental geologic mapping. Given the apparent link to magmatism in the Great Basin, the presence of igneous rocks is considered positive; however, CTDs in other areas of the world (particularly China) do not all have such a strong documented link to magmatic activity. Although Au is the most important trace element indicator, other metals such as As, Sb, Hg, Tl and Ba are utilized as exploration tools. Abundant geochemical sampling is critical, as all of these elements can have an erratic distribution. On a regional scale, deep crustal structures as indicated by geophysics or geochemistry are important.