

The Carbonate Base Metal Association of Precious Metal Deposits

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Carbonate base metal (CBM) systems are distinctive among epithermal systems, exhibiting high base metal-sulfide contents, kilometric vertical extents, and other features distinguishing them from low-sulfidation epithermal systems. The CBM association hosts numerous large and commonly high grade gold-silver deposits, including Porgera (PNG), Buritica (Colombia), and Penasquito (Mexico). We clarify the key features of CBM systems, developing an exploration model for such potentially high value targets.

CBM mineralization is spatially and temporally associated with high-level intrusion complexes, typically of intermediate character but including mafic to felsic variants, exhibiting evidence of fractionation and hybridization in deeper magma chambers. The high temperature, relatively oxidized, hydrous parental magmas range from medium K calc-alkaline through to alkaline affinities. Intrusive complexes were emplaced largely below an unconformity with an overlying volcano-sedimentary succession or some other form of system cap (in the case of Porgera, a thick limestone package). Localized by regional arc-transverse and arc-subparallel structures, intrusions post-date a major regional shortening event. Significant CBM systems include carbonaceous (meta-) sedimentary country rocks. Mineralization takes the form of sheeted vein systems, stockworks, and breccias. Vertically extensive mineralized systems (more than 1600 m at Buritica) are localized in and around the margins of the intrusions and their altered country rock envelopes. CBM mineralization commonly overprints "porphyry-related" potassic, phyllic, propylitic, and skarn alteration. The mechanical contrast of the intrusions and their alteration envelopes with more ductile country rocks is a major factor in the localization of the mineralized fracture systems.

The earliest stages of auriferous CBM mineralization are sulfide-rich: pyrite and/or pyrrhotite followed by (iron-rich) sphalerite and galena (\pm arsenopyrite, chalcopyrite, and sulfosalts) and later quartz-carbonate infill (\pm sulfosalts, stibnite). Such veins commonly exhibit gold grades >10 g/t and are mantled by sericite-carbonate-chlorite-Kspars alteration, although deeper, apparently higher temperature mineralization at Buritica is associated with biotite-stable alteration. Fluid inclusion data for sulfide-rich mineralization (Buritica, Porgera) are consistent with depositional temperatures above 275°C, from moderate salinity fluids. Later stage vein mineralization may contribute significantly to precious metal inventories. Such bonanza styles are base metal sulfide-poor, telluride-bearing, with distinctive As/Sb/Bi/Te, a broad range of stable sulfur isotope compositions, are dominated by quartz and carbonate plus sulfates and may contain vanadiferous mica. These features indicate initially more oxidized transporting fluids otherwise similar to those involved in base metal-stage mineralization. Bonanza mineralization may be pene-concordant with and/or oriented differently from the latter having formed under different stress regimes, in the case of Porgera associated with normal faulting and extension.

We conclude that precious metal enrichment in the sulfide-rich stages of CBM systems is a product of sulfide precipitation from hydrothermal magmatic fluids in vertically extensive columns heated by intrusions to temperatures above those typical of low-sulfidation epithermal systems. Later stage bonanza mineralization involved the partial reduction of similar but more oxidized hydrothermal magmatic fluids by mixing with methane-bearing fluids that had resulted from interaction with nearby carbonaceous sediments. Such processes may also have contributed to base metal stage mineralization.

