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Cordilleran or Butte-type Veins and Replacement Bodies as a Deposit Class in Porphyry Systems

Lluis Fontboté
Earth and Environmental Sciences, University of Geneva, rue des Maraîchers 13, CH-1205 Geneva, Switzerland

Ronner Bendezú
Bilbao 295, Lima, Peru

Abstract: Cordilleran or Butte type polymetallic mineralization in a porphyry-related setting is known in numerous districts. Most of it is largely epithermal, is found in the upper part of the systems, cuts earlier veins with potassic and phyllic alteration assemblages, and occurs as veins, massive replacement bodies, and sulfide-cemented breccias.

Keywords: porphyry, epithermal, polymetallic

1 Introduction

In magmato-hydrothermal porphyry systems one or more of the three following main deposit types may occur: 1) porphyry copper deposits, 2) intermediate and high sulfidation epithermal Au and Ag deposits, 3) Cu, Cu-Fe, Au, and Zn-Pb skarn deposits, 4) Cordilleran or Butte-type polymetallic veins and replacement bodies, 5) "distal" Au deposits.

Cordilleran or Butte type polymetallic mineralization in a porphyry-related setting is known in numerous districts. Most of it is largely epithermal, is found in the upper part of the systems, cuts earlier veins with potassic and phyllic alteration assemblages, and occurs as veins, massive replacement bodies, and as sulfide-cemented breccia bodies. This kind of mineralization is known among others in Butte ("Main Stage veins"), Magma, Superior, Bisbee and Tintic, USA; Yauricocha, Morococha, Julcani, Quiruvilca, Huarón, Hualgayoc, Colquijirca and Cerro de Pasco, Peru; Bor, Serbia; Erstberg, Indonesia. Specially in carbonate host rock, as it is the case of several Miocene Peruvian deposits, the mineralized volumes may be very important.

2 Main characteristics

The main characteristics of Cordilleran ore deposits can be summarized as follows (largely after Sawkins 1972 and Einaudi, 1982; Bendezú et al. 2008): (1) close association in time and space with calc-alkaline igneous activity, i.e., same geological environment as most porphyry Cu and high-sulfidation epithermal Au–Ag deposits. Several Cordilleran base metal deposits (e.g., Butte, Morococha) are superimposed on porphyry deposits, where others have no obvious link to a porphyry. (2) Deposition "late" in the evolution of the porphyry system (as seen from abundant cross-cutting relationships and sparse geochronological data; later than porphyry Cu, skarn, and high sulfidation Au (–Ag) deposits). Polymetallic mineralization frequently postdates an early quartz sericite stage that may deposit important pyrite volumes. (3) Deposition mostly under epithermal conditions at shallow levels beneath the paleo-surface. (4) Cu-Zn-Pb-W-Sn-(Ag-Au-Bi) metal suites, very rich in sulfides (up to more than 50 wt.% total sulfides). (5) Frequently, but not always, well-developed zoning of ore and alteration minerals (see below). (6) The main occurrence as open-space fillings (veins, breccia bodies) in silicate host rocks and as replacement in carbonate rocks. (7) Cordilleran ores display notably higher Ag/Au ratios than high-sulfidation epithermal Au-(Ag) mineralization. (8) Fluid inclusion data consistently point to moderate to aqueous fluids of (moderate) to low salinity and trapping temperatures below 375°C (e.g., Baumgartner et al., 2008, Bendezú et al., 2008, Beuchat et al., 2004, Catchpole et al. 2008, Deen et al. 1994; Friehauf, 1998; MacFarlane et al., 1994, Prendergast et al., 2005, Rusk et al., 2008).

3 "Late" character

As already pointed out by Einaudi (1982), those Cordilleran polymetallic deposits studied in detail appear to be systematically "late" in the life of the spatially associated magmato-hydrothermal systems. For instance, in Butte "the Main Stage veins always cut the porphyry Cu-Mo veins" and the pyrite-quartz-sericite veins (Rusk et al., 2008). In Morococha, similar observations are made (Kouzmanov et al., 2008). In Colquijirca, in addition to cross-cutting evidences (Bendezú and Fontboté, in press), absolute age determinations suggest that the Cordilleran polymetallic mineralization postdates by 0.3 My and as long as 0.8 My the high-sulfidation epithermal Au-(Ag) disseminated ores. Also in porphyry systems in which no economic polymetallic mineralization is known, late polymetallic veins are recognized (e.g., "third hydrothermal event" at La Escondida, Padilla et al., 2001).

4 Zoning

The zoned character of these deposits is a frequent, but not compulsory characteristic of the class. Two
end members can be distinguished. Strongly zoned deposits have cores dominated by enargite, pyrite, quartz±(tennantite, wolframite, chalcopyrite, covellite, chalcocite, alunite, dickite, kaolinite) and external parts by Fe-poor sphalerite, galena±(sericite, kaolinite, dickite, hematite, siderite). Weakly zoned deposits consisting of internal parts bearing pyrrhotite, pyrite, quartz±(chalcopyrite, arsenopyrite, tetrahedrite, carbonates, sericite, chloride, quartz) and external parts of Fe-rich sphalerite, galena, pyrrhotite±(rhodocrosite, siderite, and other carbonates, sericite, chloride, quartz). Both end-member styles are present in the same deposit, indicating that mineralizing fluids strongly fluctuated in terms of pH and sulfidation states from highly acidic and very high sulfidation states, to mildly acidic and low sulfidation states. It appears that the sulfidation state in Cordilleran ore deposits depends on several factors, including the temperature and spatial path followed by the ore forming fluids and their interaction with the host rock (e.g., Baumgartner et al., 2008). Therefore, the same type of fluids originated by similar magmatohydrothermal systems may develop or not metal zoning.

![Figure 1. Schematic position of Cordilleran polymetallic deposits and other porphyry-related ore deposit types.](image)

Similarly, the existence of very acidic host rock alteration zoning depends to an important degree of the proportion of vapors which are degassed coeustaneously with the aqueous low saline fluids thought to be responsible of the polymetallic mineralization. If the proportion of acidic oxidized vapor-derived fluids is high, up to advanced argillic alteration can develop and hence a zoned alteration pattern may occur. However, if the low saline, less acidic aqueous fluids dominate, i.e., the fluids thout to be responsible for the Cordilleran mineralization (e.g., Baumgartner et al., 2008; Bendezú and Fontboté, in press; Catchpole et al., 2009), no acidic alteration is developed. This may explain that several deposits that share the main characteristics of Cordilleran ore deposits, including their "late character" in the life of a magmato-hydrothermal system, show only weak zoning (e.g., San Cristobal vein in Central Peru, Campbell 1984, Beuchat et al., 2004, large parts of the Morococha veins, Catchpole et al., 2008). If carbonate-hosted high-temperature, carbonate-hosted Ag-Pb-Zn(Cu) deposits in Northern Mexico (Megaw et al., 1988) also to weakly or non-zoned Cordilleran polymetallic deposits remains to be evaluated.

5 Nomenclature issues and conclusion

This class of ore deposits have been traditionally named Cordilleran or Butte-type base metal veins or lodes (e.g., Meyer et al. 1968; Sawkins, 1972; Einaudi, 1982; Guilbert and Park, 1985; Bartos, 1987; Macfarlane and Petersen, 1990; Hemley and Hunt, 1992; Bendezú et al., 2003 and 2008; Dilles et al., 2004, and Baumgartner et al., 2008).

"Epithermal polymetallic veins", "intermediate" or "high sulfidation polymetallic veins" (e.g. Hedenquist et al., 1998) are other terms that have been used recently. We prefer to keep the classical terms of "Cordilleran" or "Butte-type" for these polymetallic veins and replacement bodies. In our view, the main distinctive features of the class are the "late" character within the evolution of a porphyry system, specifically post-dating quartz-sericite-pyrite veins, a well as the sulfide rich polymetallic, i.e., Zn-Pb-Cu-W-Sn-(Au-Ag-Bi), mineral assemblages. As discussed above, the terms
"epithermal" and "intermediate" or "high sulfidation" can be applied to many Cordilleran deposits. However they are not sufficiently precise and, in the porphyry context, these terms bear the danger of favoring an abusive assimilation with the acid-sulfate or high-sulfidation epithermal Au-(Ag) disseminated ores, that in several deposits appear to form coe growth with the quartz-sericite-vein stage (e.g. Muntane and Einaudi, 2001). These veins when present, are systematically cut by Cordilleran base metals veins. The term "zoned base metal veins" (Einaudi et al., 2003), again, can be applied to a number of Cordilleran polymetallic deposits, including to some of the most representative, but a well-developed zoning is not an intrinsic feature of the class.

It is important, also for exploration purposes, to recognize Cordilleran or Butte-type polymetallic mineralization as an specific class, which may produce very large deposits (e.g., Cerro de Pasco, Colquijirca, Butte) in the late stages of the life of porphyry systems. Ongoing research (e.g., Catchpole et. al. submitted) examines the question if the low saline aqueous fluids responsible for the Cordilleran polymetallic mineralization represent single phase magmatic fluids in the sense of Heinrich (2007) or are magmatic brines diluted with meteoric water and, by acquiring a lower density, are able to ascend to upper parts of the hydrothermal system.

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