1 Introduction

Volcanic-hosted massive sulfide deposits contain variable amounts of Au, both in terms of grade and total endowment. A large proportion of the total Au hosted in this deposit type is found in a small number of Au-rich deposits. These Au-rich deposits contain more than 30 metric tons of Au at grades exceeding 3.5 g/t (Mercier-Langevin et al., 2011). Comparison of the characteristics of these deposits and correlation with modern seafloor observations provide important constraints on the reasons for synvolcanic Au enrichment.

2 Ancient Massive Sulfide Deposits

Located in the Noranda South Camp of the Archean Abitibi greenstone belt, the Horne deposit represents the largest Au-rich massive sulfide deposit recognized so far. The mine has produced 53.7 Mt of ore grading 2.22% Cu and 6.1 g/t Au (Mercier-Langevin et al., 2011), which corresponds to an Au endowment of 10.53 Moz. The deposit comprises multiple ore lenses that are enveloped by extensive zones of quartz-sericite-pyrite alteration although localized discordant zones of chlorite alteration also occur (Gibson et al., 2000). The Horne deposit is hosted by a felsic volcanic succession dominated by a proximal facies association of coherent rhyolite domes and related breccia deposits. Mass-flow-derived felsic volcaniclastic deposits containing pyroclastic material are also present. The felsic host rock succession is cut by a mafic dike swarm that feeds into a thick package of mafic volcanic rocks in the hanging wall of the deposit.

The Quemont deposit, also located in the Noranda South Camp, contained 16.7 Mt of ore grading 1.8% Zn, 1.2% Cu, and 5.5 g/t Au (Mercier-Langevin et al., 2011). This corresponds to a Au endowment of 2.95 Moz. The nature of the alteration halo and the volcanic setting of massive sulfide formation are similar to the Horne deposit.

The LaRonde deposit in the Doyon-Bousquet-LaRonde Camp located further to the east in the Abitibi greenstone belt contains 71.3 Mt of ore grading 0.29% Cu, 1.94% Zn, 0.05% Pb, 3.91 g/t Au, and 40.7 g/t Ag (Mercier-Langevin et al., 2011). This corresponds to a total Au content of 8.96 Moz. The main ore lens of the deposit is associated with a large discordant metamorphosed alteration halo of quartz-biotite-muscovite-garnet. At depth, the metamorphosed alteration halo grades into an aluminous zone of quartz-kyanite-andalusite-muscovite-staurolite. The massive sulfides are hosted by a volcanic package dominated by dacitic to rhyodacitic flow breccias that are cut and overlain by rhyodacite and rhyolitic domes and/or partly extrusive cryptodomes and by intermediate to mafic sills and dikes (Mercier-Langevin et al., 2007).

The Boliden deposit in the Paleoproterozoic Skellefte district of Sweden contained 8.3 Mt of ore grading 1.5% Cu, 0.9% Zn, 0.3% Pb, and 15.5 g/t Au for a total of 4.14 Moz Au. The deposit was associated with metamorphosed aluminous alteration halo (Bergman Weihed et al., 1996; Mercier-Langevin et al., 2013).

The Jurassic Eskay Creek deposit in the Iskut River area of northwestern British Columbia, Canada, represents an unusual Au-rich sulfide and sulfosalt deposit. The deposit comprised 2.1 Mt of dominantly clastic ore grading 46.6 g/t Au and 2267 g/t Ag, for a total of 3.15 Moz Au. The footwall alteration halo is characterized by intense muscovite-K-feldspar alteration with local zones of chlorite enrichment (Roth et al., 1999). The immediate ore host is affected by intense carbonate alteration. The deposit formed on top of a submarine felsic volcanic center comprising extrusive and intrusive rhyolite units and breccia formed by phreatic-hydrothermal explosive...
eruptions. The mineralizing event coincided with a shift in volcanism towards mafic compositions as the hanging wall of the deposit is dominated by basaltic extrusive and intrusive rocks.

Comparison of the different Au-rich deposits demonstrates that both Cu-rich and Zn-rich massive sulfides can contain high Au grades. Acid-type alteration occurs in some deposits, but not all Au-rich deposits are characterized by this style of alteration. In terms of volcanic setting, Au-rich VHMS deposits appear to be primarily hosted by felsic volcanic rocks. However, the host rock successions as such are commonly bimodal in character. The deposits formed in geodynamic settings characterized by rapid crustal extension.

3 Modern Seafloor Hydrothermal Systems

On the modern seafloor, high Au grades (>3.5 g/t) can be encountered in seafloor sulfide accumulations forming on arc volcanoes. Enrichment of Au is also characteristic of seafloor sulfides located in arc-related rifts. In the rift zone of the eastern Manus basin, an indicated resource of 1.03 Mt grading 7.2% Cu, 0.4% Zn, 5 g/t Au, and 23 g/t Ag has been identified at the Suzette vent field (Nautilus press release). This corresponds to a gold endowment of 0.16 Moz. Sulfides from the nearby Pacmanus vent field contain an average Au content of 12.6 g/t (n=172). In contrast, seafloor sulfide occurrences located along the mature spreading center of the central Manus basin show distinctly lower average Au grades (Monecke et al., 2014).

Compilation of Au grades from modern seafloor sulfide occurrences suggests that there is no direct relationship between water depth of sulfide formation and Au content (Monecke et al., 2014).

4 Provinciality of Gold Enrichment

Currently available data suggests that there is a distinct provinciality of the distribution of Au-rich VHMS deposits. In some districts, only a single Au-rich VHMS deposit is recognized. In other districts, multiple Au-rich VHMS deposits occur. However, in these cases the Au-rich deposits are located in volcanic settings and stratigraphic positions that differ from Au-poor VHMS deposits in the district.

The apparent regional geological controls on the occurrence of Au-rich VHMS deposits suggest that the overall tectonic framework of the extensional setting in which the deposits form is key to synvolcanic Au enrichment. In the Manus basin, the highest Au grades in seafloor sulfides occur in a rift zone developing in older arc crust that is underlain by a sublithospheric mantle affected by extensive hydrous metasomatism (McInnes et al., 2001). Based on this observation, it is proposed here that Au enrichment in VHMS deposits occurs if spatially and temporally associated magmatism taps into an unusually fertile mantle region.

References


