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The Spectrum of Ore Deposit Types, Volcanic Environments, Alteration Halos, and Related Exploration Vectors in Submarine Volcanic Successions: Some Examples from Australia

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Abstract

Variations in shape, metal content, alteration mineralogy, and volcanic host rocks of the ore deposits in the two major volcanic-hosted massive sulfide (VHMS) districts of eastern Australia, the Cambrian Mount Read Volcanics and the Cambro-Ordovician Mount Windsor subprovince, strongly reflect their volcanic environment, conditions of ore formation, and hydrothermal alteration processes.

Lens and sheet-style polymetallic zinc-rich deposits such as Rosebery, Hellyer, Que River, and Thalanga are considered to have formed in moderate to relatively deep water environments (500–1,000+m). These deposits probably formed either on the sea floor (e.g., Hellyer, Que River) or by replacement of porous volcaniclastic units directly below the sea floor (e.g., Rosebery). The footwall alteration associated with these polymetallic VHMS deposits was controlled by host-rock permeability and porosity, which are in turn related to volcanic facies type, degree of fracturing, and synvolcanic structural architecture. Focusing of hydrothermal fluids along synvolcanic structures has resulted in well-zoned chlorite-sericite footwall alteration pipes within footwall lavas at Hellyer. On the other hand, diffuse fluid flow through very thick pumice breccia at Rosebery and Hercules has resulted in strata-bound, sericite-dominated footwall alteration zones parallel to the paleosea floor and the ore lenses.

Massive and disseminated, pyritic Cu-Au deposits, such as those in the Mount Lyell field and at Highway-Reward, formed by subsea-floor replacement and are associated with only minor zinc-lead massive sulfide ore. These deposits formed from higher temperature fluids (>300°C), in which copper transport is enhanced, and are commonly located in felsic volcanic centers dominated by shallow porphyritic intrusions (e.g., Highway-Reward). The Cu-Au ore lenses may be strata-bound (e.g., Mount Lyell) or crosscutting pipes (e.g., Highway-Reward) depending on the structure and permeability characteristics of the felsic volcanic host rocks. The presence of high-sulfidation alteration minerals (e.g., pyrophyllite, zunyite) in some of the Cu-Au deposits (e.g., Mount Lyell field) indicates that fluids were relatively acidic and suggests the possibility of magmatic fluid input into the hydrothermal system. Alteration zonation associated with the Cu-Au VHMS deposits is more symmetrical than that of the Zn-rich deposits, with sericite-rich alteration extending into the hanging wall, in keeping with the subsurface replacement origin of these deposits.

Synvolcanic gold-rich deposits, with high gold/base metal ratios are less common than the Cu-Au and Zn-rich VHMS ore types. The gold-rich ores (e.g., Henty, South Hercules) are strata bound in nature, have low sulfide contents, and are associated with central zones of intense silicification, surrounded by envelopes of sericite-pyrite and carbonate alteration. Volcanological and geochemical studies at Henty indicate the gold-rich ore formed by the replacement of particular volcanic units deposited in a relatively shallow water environment dominated by volcaniclastic facies, lavas, and limestones.

This spectrum of Cu-Au, Zn-rich, and Au-only deposits in the Mount Read Volcanics and the Mount Windsor subprovince is interpreted to represent a continuum from classic sea-floor VHMS ores toward those with features more akin to porphyry Cu-Au and epithermal Au-Ag deposits. This spectrum relates to the interplay between factors in the submarine volcanic environment and the character of the hydrothermal fluid as follows: (1) proportions of volcaniclastic, lava, and subvolcanic intrusive facies; (2) depth of seawater; (3) permeability and porosity of volcanic host rocks; (4) balance between magmatic components and seawater components in the ore fluid; and (5) temperature and acidity of the ore fluid.

Mineralogical, lithogeochemical, and isotopic studies have revealed a range of alteration vectors useful in exploration for both the Zn-rich and Cu-Au VHMS deposits. Carbonate and white mica compositional variations are highlighted as important mineralogical vectors; thallium and antimony halos may be useful

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trace element vectors; and oxygen and sulfur provide important isotope vectors toward the center of the hydrothermal system.