

# Geology, Genesis, and Exploration Implications of the Footwall and Hanging-Wall Alteration Associated with the Hellyer Volcanic-Hosted Massive Sulfide Deposit, Tasmania, Australia

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## Abstract

Hellyer is a large (16.2 million metric tons), high-grade (13.9% Zn, 7.1% Pb, 0.4% Cu, 168 g/t Ag, 2.5 g/t Au), sea-floor, mound-style, polymetallic volcanic-hosted massive sulfide (VHMS) deposit located in the Mount Read Volcanics of western Tasmania. The deposit is hosted by the Que-Hellyer Volcanics, a sequence of late Middle Cambrian mafic to felsic coherent volcanics and polymict volcanoclastics.

Hydrothermal alteration occurs in the regional footwall, immediate footwall, and hanging wall. Alteration in the regional footwall is confined to patchy quartz, albite, and chlorite, with minor sericite, epidote, and hematite. Underlying Hellyer is a zoned alteration pipe with a central siliceous core (quartz-sericite), which passes into zones of chlorite, chlorite-carbonate, sericite-chlorite, and finally sericite-quartz (stringer envelope zone) on the margin. Overlying the central part of the deposit, within the hanging-wall basalt, is a distinctive and zoned alteration plume. Five alteration zones have been identified: fuchsite, chlorite, carbonate, quartz-albite, and sericite. Fuchsite-dominated alteration occupies the central portion of the hanging-wall alteration plume. Chlorite and carbonate alteration surrounds the fuchsite zone with carbonate zones forming near to the ore deposit and chlorite zones extending above and lateral to the carbonate. Outward is quartz-albite alteration, which extends laterally into distal sericite alteration.

Mass-change calculations for the footwall and hanging wall indicate that, in general, the footwall alteration zones are depleted in CaO, Na<sub>2</sub>O, La, Sr, Ni, Cr, and V but have enrichments of Fe<sub>2</sub>O<sub>3</sub>, MnO, MgO, K<sub>2</sub>O, S, and most metals. Compared to the host basalt, the hanging-wall alteration has gained CaO, K<sub>2</sub>O, Na<sub>2</sub>O, CO<sub>2</sub>, S, in Rb, Ba, Ag, As, Mo, Sb, Cs, and Tl, while Fe<sub>2</sub>O<sub>3</sub>, MnO, MgO, P<sub>2</sub>O<sub>5</sub>, La, Sr, Pb, Zn, Th, U, Cd, and Nd are depleted. CaO, Na<sub>2</sub>O, Cr, V, and Ni are depleted in the footwall andesite but enriched in the hanging-wall alteration plume. This relationship suggests that these elements were sourced from the breakdown of feldspars, pyroxenes, and andesitic groundmass of the footwall lithologies and transported in the hydrothermal fluid into the overlying basalt and precipitated as albite, calcite, and white micas in the hanging-wall alteration.

The development of alteration associated with the Hellyer VHMS deposit occurred in three stages. Stage 1 regional footwall alteration was formed by unfocused hydrothermal convection of seawater down into the recently deposited volcanic pile at temperatures between approximately 250° and 200°C and at low to moderate water/rock ratios. Stage 2 alteration formed by structurally controlled fluid flow from a deep intensifying hydrothermal convection system and created the footwall alteration pipe. Decreasing water/rock ratios and temperatures, over a range of 350° to less than 200°C, led to the development of the concentric alteration pipe mineral zones. Based on modeling of whole-rock  $\delta^{18}\text{O}_R^f$  values, geochemical modeling, and mineral assemblages, the siliceous core is interpreted to have formed at temperatures near 350°C, the chlorite-rich alteration zone at 300° to 250°C, and the outer sericite-rich alteration at temperatures of 250° to 150°C. The final, synmineralization fluid-flow event, stage 3, created the hanging-wall alteration plume. After rapid burial of the deposit by basalt, continuation of upward hydrothermal fluid flow created the zoned hanging-wall alteration. Distribution of hanging-wall alteration assemblages suggests a temperature gradient from approximately 250°C for the fuchsite zone to lower temperatures (150°C) for the distal quartz-albite and sericite alteration zones.

Alteration mineralogy, mineral chemistry, litho-geochemistry, and stable isotope characteristics of the footwall and hanging-wall alteration have been combined into a comprehensive set of vectors, which can be used in exploration for VHMS deposits in similar geologic settings.