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Numerical Heat and Fluid-Flow Modeling of the Panorama Volcanic-Hosted Massive Sulfide District, Western Australia

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Abstract

Exceptional exposure of the Archean Pilbara block in Western Australia reveals a cross section through an Archean massive sulfide-hosting volcanic succession with underlying subvolcanic intrusion in the Panorama district. A numerical model based on available detailed geologic information has been constructed to simulate heat and fluid flow in the Panorama district. The modeling provides insight into the evolution of the hydrothermal system and evaluates key geologic parameters and their influence on fluid-flow, hydrothermal circulation, and the genesis of massive sulfide orebodies. The model simulates important aspects of the Panorama massive sulfide district, such as temperature distribution, relative alteration zonation, and the size and distribution of orebodies. Predicted temperatures ranging from 150ºC at the top of the volcanic pile to ~400ºC at the andesite-diorite interface are comparable to temperature estimates based on previously published oxygen isotope mapping. Modeled fluid discharge temperatures are highest for the Sulphur Springs deposit (300º–400ºC) and lower for the Kangaroo Caves and other deposits (250º–350ºC). The most favorable conditions to reproduce the orebodies and their related alteration zonation occur at anisotropic rock permeabilities comparable to the upper oceanic crust (10^{-15}–10^{-14} m^2) and higher fault permeabilities (10^{-14}–10^{-13} m^2) with a specific fault arrangement similar to that mapped in the field. The 4.6 million metric tons (Mt) Sulphur Springs orebody is predicted to form in less than 5,000 yr, assuming a hydrothermal fluid with seawater salinity, 10 ppm base metal concentration, and a low deposition efficiency (≤10%); other deposits form above the faults under similar conditions. A large range of base metal concentrations in the fluids can account for the known orebodies, but high temperatures (≥250ºC) and high-flow velocities (>10^{-7} m/s) are necessary to produce the observed alteration patterns and distribution of ore deposits. Results indicate that the establishment of a significant hydrothermal system capable of forming economic massive sulfide deposits is favored in fresh volcanic rock packages that have not been affected by earlier compaction or alteration. Under these conditions, economic massive sulfide orebodies (>5 Mt of 10% Zn + Cu) may form in a few thousand years, although the overall lifespan of the hydrothermal system may be between 30,000 and ~200,000 yr, depending on the variations in rock and fault permeability with time.

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