

Geochemical Anatomy of Silica Iron Exhalites: Evidence for Hydrothermal Oxyanion Cycling in Response to Vent Fluid Redox and Thermal Evolution (Mt. Windsor Subprovince, Australia)

G. J. DAVIDSON,† A. J. STOLZ*

Centre for Ore Deposit Research, University of Tasmania, GPO Box 252-79, Hobart, Tasmania 7001, Australia

AND S. M. EGGINS

Geology Department, Australian National University, Canberra, Australian Capital Territory 2601, Australia

Abstract

In the Cambro-Ordovician Mount Windsor subprovince, well known for its massive sulfide deposits, silica iron oxide exhalites possess complex textural and geochemical features that provide an insight into the very early stages of typical massive sulfide deposit development. In exploration they are also useful for identifying hotter systems most likely to host massive sulfide deposits. Three examples were mapped and sampled from outcrop and analyzed for magnetic susceptibility, major and trace elements, REE, and Nd and Sr radiogenic isotopes. They share a common evolutionary history. Early microbially mediated silica iron oxyhydroxides (stage 1), which grew with very little clastic sediment incorporation, probably developed an Fe, U, V, Mo, As, Ag, Cd, P, Y, Be, Mg, and REE element association that has also been documented from metalliferous sediments on the modern sea floor. This stage is commonly overprinted by siliceous veins (stage 2), indicating that the exhalites directly overlay diffuse hydrothermal upflow zones. Less commonly, the silicification assemblage includes pyrite. Y, U, Be, V, and Mg positive correlations with Fe survived the subsurface silicification. Ag, As, Mo, Sb, REE, and Ba were leached from stage 1 zones during stage 2, presumably liberated during recrystallization of iron oxyhydroxide and were reprecipitated in narrow crosscutting zones within stage 2 silicification. The depositional mechanism is not well understood, but radiogenic isotope trends indicate that interaction between hydrothermal fluid and detrital silicates preferentially precipitated some of these metals. The hydrothermal transition from low-temperature (<100°C) oxidized to higher temperature (>150°C), H₂S-bearing volcanic-hosted massive sulfide (VHMS)-style fluids in some systems is evidenced by the addition of Cu, Pb, Zn, Tl, Mn, Se, and possibly Eu, mainly as trace elements in pyrite.

The Sr and Nd isotope systematics of the jaspers can be explained for stage 1 by mixing of seawater, clastic, and hydrothermal end members, giving rise to complex isotopic populations. The stage 1 signatures are supplanted by relatively simple isotopic compositions with increasing stage 2 alteration intensity. This replacement is best expressed in plots of resistant detrital elements and metals such as As, Se, Zn, and Pb versus ϵ_{Nd} and $^{87}\text{Sr}/^{86}\text{Sr}_i$. The hydrothermal component has $\epsilon_{\text{Nd}(480 \text{ Ma})} \sim -2$, best explained by leaching of the underlying Trooper Creek Formation ($\epsilon_{\text{Nd}(480 \text{ Ma})} = +3.8$ to -7.3) rather than leaching of deeper Mount Windsor Formation rhyolitic volcanics ($\epsilon_{\text{Nd}(480 \text{ Ma})} = -4.7$ to -12.8). There is no support for a magmatic fluid, because no match exists with the known Trooper Creek Formation $\epsilon_{\text{Nd}(480 \text{ Ma})}$ magmatic populations ($\epsilon_{\text{Nd}(480 \text{ Ma})} = -4.1$ to -7.3 and $+3.8$ to -0.9). The radiogenic isotopes support a shallow convecting model with jasper deposition from rock-buffered seawater. The evolution of fluids from cooler, oxidized to hotter, reduced conditions, either records heating induced by arrival of a subsurface thermal plume or the propagation of extensional faults deeper into a layered convective system.