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Life's Ingredients: Nutrient Transition Metals in Hydrothermal Vent Fluids

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The enzymes that power Life require a suite of nutrient transition metals including V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Mo, Cd, and W. Throughout Earth's geologic and life-evolutionary history, seafloor hydrothermal vents represent a likely source of these elements to the deep ocean, with implications for nutrient transition metal availability and related biological evolution and productivity.

Here, we present a time series of nutrient transition metals in 281–304 °C vent fluids collected from Main Endeavour Field (Juan de Fuca Ridge) using a remotely triggered serial sampler connected to Ocean Network Canada's NEPTUNE cabled observatory, with special attention given to sampler precipitate (“dregs”) fractions. Samples exhibit little-to-no contamination by ambient seawater, providing unprecedented insight into subsurface processes. This time series approach provides insight into the effects of vent fluid temperature on transition metal concentrations. For example, a rapid ~20 °C temperature drop is accompanied by a >90% decrease in Cu, Zn, and Cd, demonstrating that minor changes in vent fluid temperature can dramatically affect vent fluid metal fluxes, with some changes attributable to near-surface mineral deposition.

Several vent fluid samples are enriched in Mo (29–220 nmol/kg) compared to modern seawater. This is surprising given the unremarkable temperature and major element chemistry of these vent fluids and previous reports indicating that high-temperature vent fluids are most often depleted in Mo. Analyses of sampler precipitates indicate preferential partitioning of Mo into metal-sulfide precipitates, suggesting that conventional sampling methods may undersample Mo. Furthermore, metal sulfide precipitates entrained in hydrothermal plumes may provide a mechanism for long-range Mo transport. Results obtained from natural fluids are compared with sample fluids from hydrothermal basalt alteration experiments, which likewise exhibit elevated Mo concentrations.

That Mo concentrations in high-temperature hydrothermal vent fluids may be greater than previously estimated has important implications for Mo availability in anoxic Archean oceans and related evolution of Mo-utilizing methanogenesis and denitrification pathways. Preferential partitioning of Mo into metal sulfide precipitates increases the potential for hydrothermal Mo delivery to the surface ocean as a component of hydrothermal plumes, despite predicted low levels of Mo solubility in anoxic Archean oceans.