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Changes in hydrothermal plume iron speciation in the 1-100 km distance from vent source

SARICK L MATZEN[1], ZVI STEINER[2], COLLEEN HOFFMAN[3], LAURA MOORE[3], RANDELLE BUNDY[3], JOSEPH A RESING[4], JESSICA N. FITZSIMMONS[5], ERIC P. ACHTERBERG[2], CHRISTOPHER R GERMAN[6] AND BRANDY M TONER[1]

[1]University of Minnesota-Twin Cities
[2]GEOMAR Helmholtz Centre for Ocean Research Kiel
[3]University of Washington
[4]NOAA/PMEL
[5]Texas A&M University
[6]Wood Hole Oceanographic Institution

Presenting Author: smatzen@umn.edu

Iron (Fe) limits phytoplankton productivity, and therefore carbon sequestration, in oceans globally. Formerly, dust deposition was considered the main source of iron to the oceans, but recent work suggests hydrothermal vents could also be an important source of iron to the surface ocean via upwelling at high latitudes. Dissolved iron concentrations in hydrothermal fluids are a million times those of surrounding ocean water. While considerable iron (>90%) precipitates close to vent sources, in a major scientific breakthrough, the international GEOTRACES program has revealed signatures of hydrothermally derived iron traced over long-distances through multiple deep ocean basins, worldwide. Models based on these results show that through isopycnal (density-controlled) upwelling, hydrothermally-sourced iron could support up to 10% of primary production in the North Pacific Ocean and up to 30% in the Southern Ocean. However, it remains unclear how some iron persists in dissolved form in the water column rather than being sequestered into sinking particles that are removed to underlying marine sediments both close to and distal from hydrothermal vent sources. The lifetime of iron species likely depends on speciation, with organic ligand-bound iron, pyrite nanoparticles, and iron oxyhydroxide nanoparticles all having different lifetimes in hydrothermal plumes. Critical processes constraining export of iron from vent sources to open ocean waters occur within the first ~100 km of plume evolution, and could vary with plume iron to sulfur ratios (Fe:S).

Here, we investigate how particulate iron speciation varies at vent source with Fe:S ratio, and within the first 70 km of dispersing plume evolution within one Fe:S ratio, working with samples from Rainbow vent system in the Mid Atlantic Ridge, and vent fields between 15-18S along the Southern East Pacific Rise. We use synchrotron-based methods (X-ray fluorescence spectromicroscopy and scanning transmission X-ray microscopy) and transmission electron microscopy to determine iron speciation and particle morphology. We interpret the results in the context of plume fluid chemistry, and propose mechanisms for particulate iron export from vent to open ocean.