Investigations of Iron and Manganese Fluxes from Hydrothermal Sources in the South Atlantic Ocean

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All life on Earth requires trace metals for growth and survival, and hydrothermal vents have long been hypothesized to be major sources based on the thick plumes that are rich in metals. Yet their overall contribution to the inventory of dissolved metal micronutrients in the global ocean has been difficult to measure given the difficulties associated with observing these vent sites. With support from the Ocean Ridge Initiative, my laboratory team and I analyzed samples collected from two expeditions in the Atlantic Ocean to characterize the influence of hydrothermal vent activity on trace metal biogeochemistry.

The cruises were conducted in two areas: a transect across the South Atlantic from Brazil to Namibia and a transect along the large region of the Mid-Atlantic Ridge (Ports of South Africa and Cape Verde). The first expedition discovered a large >1,000-kilometer (620 mile)-wide plume of iron in the deep ocean (Figure 1). This was a great surprise because previous studies had only observed the extent of dissolved metals to be 10's of kilometers, primarily because a large scale ocean "section" sampling approach of taking samples from the surface to the sea floor at regular intervals had not been employed. While we knew we were over the Mid-Atlantic Ridge, we had only expected to see a single station show evidence of manganese and iron inputs, but instead observed their imprint in several adjacent stations resulting in the "bullseye" pattern of iron and manganese. We further worked with a WHOI helium geochemist, Bill Jenkins, to characterize the potential influence of these metal fluxes. (Previous studies had estimated insignificant fluxes of iron from hydrothermal vents in the South Atlantic based on the ratio of iron to helium, a gas that spews in abundance from active hydrothermal vents. Since the Mid-Atlantic Ridge is slow moving and produces less helium than faster moving ridges, such as those in the Pacific Ocean, the concentration of

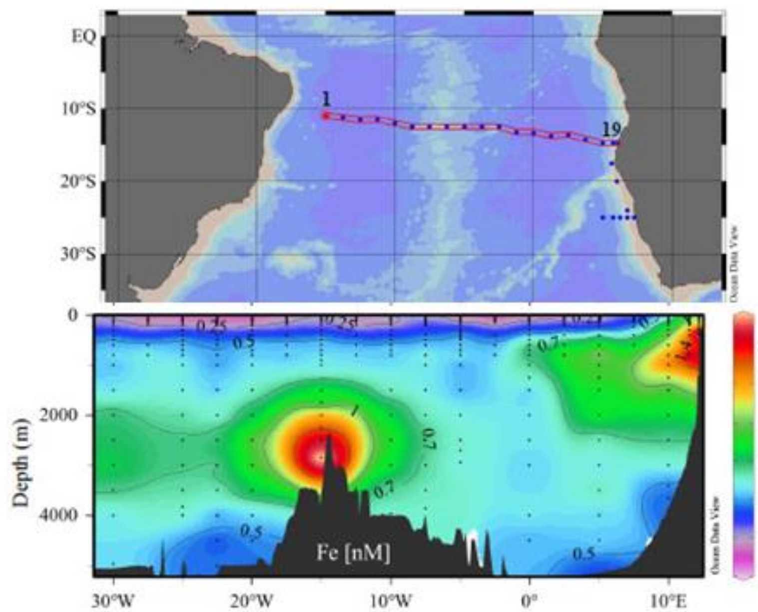

Figure 1: (Top): Expedition transect from Brazil to Namibia, each dot represents a station where dissolved metals were sampled. **(Bottom)**: Distributions of dissolved iron (Fe) in nanomoles per liter (nM) with a color scale on the right. Note the bullseye in red indicating high concentrations of iron of the Mid-Atlantic Ridge.

iron at these ridges was thought to be low.) However, our results showed that the helium-iron ratio was not uniform throughout the world ocean, but instead was 80-fold larger at the Mid-Atlantic Ridge than in the Pacific, demonstrating that the previous models underestimated the global hydrothermal iron fluxes by about a factor of two. This discovery of a massive hydrothermal iron plume was published in the journal, *Nature Geosciences*, and garnered significant press interest (e.g. *New York Times*, *Christian Science Monitor*, *LiveScience*, *Die Welt*). Moreover, these plumes have also been identified in other ocean regions through the International Study of Marine Biogeochemical Cycles of Trace Elements and their Isotopes (GEOTRACES) – our work has been added to a recent compilation of iron for the Atlantic as part of their Intermediate Data Product (Figure 2).

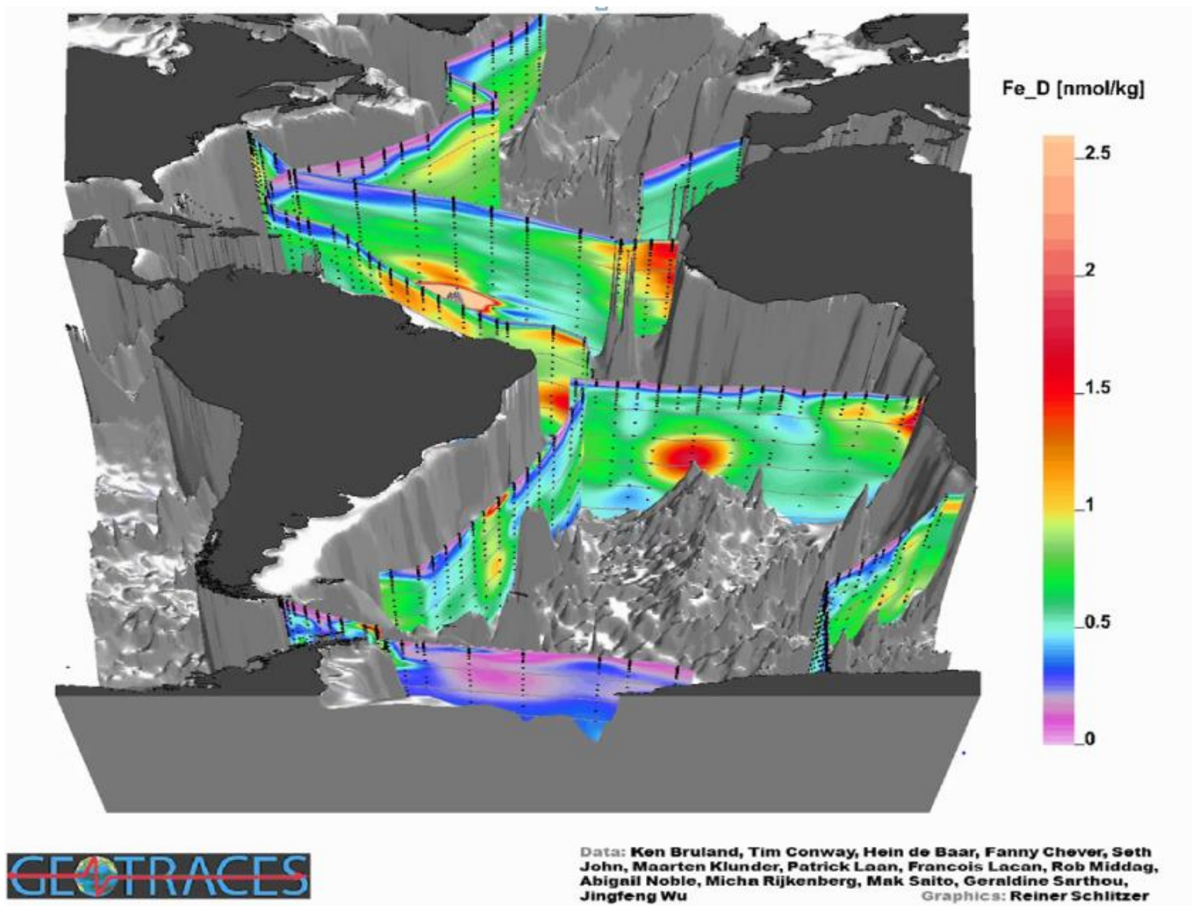

Figure 2: The 3-D image of dissolved iron in the Atlantic Ocean. Our work was featured in this compilation, which was part of the International GEOTRACES program that was released in 2014.

A key question that remained from the South Atlantic study was whether our observation was a relatively isolated source along the South Atlantic Ridge or if this was a continuous feature all along this slow spreading ridge. To address this issue, we participated in a 40 day cruise with a group of German researchers that departed from Cape Town, South Africa and arrived at the island country of Cape Verde. The cruise deployed autonomous vehicles and collected geochemical observations. While the results are not yet finalized, we did observe significant dissolved manganese, a metal indicative of hydrothermal sources, at multiple locations and depths along the transect. Interestingly, the dynamic range of concentrations was very large, implying that at high concentrations we were in quite close proximity to sources, and at the lower range we were often observing the extended plume as we did in the *Nature Geosciences* study. We are continuing to finalize these results and will be comparing results with the German geologists and geochemists to revise and improve the data on the influences of hydrothermal vents on the inventory of iron and other metals in the South Atlantic.

Research from these two expeditions has contributed to the global study of dissolved iron fluxes from hydrothermal vents, which has important implications for the influence of iron nutrition on photosynthesis and carbon fixation in the ocean. Moreover, this study contributed to the education of an undergraduate visiting student, Noelle Held, who is now a first year doctorate graduate student in our laboratory through the MIT/WHOI Joint Program. We are very appreciative of the support provided by the Ocean Ridge Initiative which has enabled this research.