Deep Ocean Exploration Institute – Final Report

Using Iron Stable Isotopes as tracers of Subsurface Processes in Seafloor Hydrothermal Systems

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What were the primary questions you were trying to address with this research?

Past studies have highlighted the importance of subseafloor environments in controlling the diversity of seafloor hydrothermal vents. It is also well known that these environments harbor a diverse and unique biological community capable of using dissolved chemical species and minerals for energy metabolism. However, the mechanisms and extent of subseafloor metal precipitation, remobilization and bacterial cycling are still poorly constrained and new approaches are required. In this research, we proposed to undertake a combination of Fe isotope analysis of hydrothermal fluids and associated sulfides to develop a conceptual model for using Fe isotopes as new tracers of seafloor hydrothermal systems.

What have you discovered or learned that you didn't know before you started this work?

This study confirmed that seafloor hydrothermal fluids define a range in Fe isotopic composition that is shifted to low values compared to igneous rocks. However, we found significant variability suggesting that Fe-isotope composition of vent fluids is not unique and may depend on numerous parameters such as subsurface fluid mixing pathways, rock alteration processes and, possibly, phase separation processes. This study also provided the opportunity to explore natural variations of other stable isotopes, such as Zinc isotopes and rare Sulfur isotopes (^{33}S) that were not investigated previously in seafloor hydrothermal systems.

What is the significance of your findings for others working in this field of inquiry and for the broader scientific community?

Traditionally, the behavior of metals in seafloor hydrothermal systems have been investigated by integrating results from laboratory studies, theoretical models, mineralogy and fluid and mineral chemistry. Our new approach consists of using Fe isotopes as tracers of the interactions between hydrothermal fluid, altered rocks, sulfide deposits and biologic systems in subsurface environments. Through the characterization of this new isotopic tool, this study increased our understanding of the fate of Iron in modern and ancient seafloor hydrothermal systems. This approach also allowed us to contribute to the deep biosphere initiative as the identification of Fe stable isotope biosignatures requires a good understanding of the variability of Fe isotopes generated by abiotic processes solely from hydrothermal activity.

What is the significance of this research for society?

Variations in the isotopic ratios of light elements such as H, C, N, O and S have been widely studied over the last five decades and provided major advances in the knowledge of natural and anthropogenic processes directly affecting the society. For example, these stable isotope systems have been applied to a range of problems such as planetary geology, the origin and evolution of life, climate change, and water-rock interactions. However, much less attention has been paid to the stable isotope variations of heavier elements, such as Iron, mainly due to analytical

challenges. With the recent advent of multi-collector inductively-coupled plasma mass spectrometry (MC-ICPMS), the study of Fe stable isotopes is now accessible and should lead to unprecedented discoveries in biogeochemical cycles.

When and where was this investigation conducted?

The first work period (Nov. 2004) has involved the participation of the PI in a 21-days cruise using the submersible Alvin (Cruise AT11-20, R/V Atlantis, "Ridge integrated studies at 9ºN East Pacific Rise", M. Lilley, chief scientist). High-temperature vents (up to 383ºC) have been sampled on the East Pacific Rise at 9º50´N within an area sometimes referred to as the "Hole-to-Hell". Both hydrothermal fluids and sulfide chimney structures were recovered for subsequent on-shore work, including reflected light microscopy, chemical analysis and Fe-isotope determination.

What were the key tools or instruments you used to conduct this research?

An important aspect of the project has been the strong analytical commitment involving the use of the Multi-Collector ICPMS (inductively coupled plasma mass spectrometry) at WHOI. While the PI had prior experience in analyzing the isotopic composition of various metals and metalloids, this instrument has proved to be extremely valuable for high-precision analysis of Fe-isotopes in aqueous samples.

Is this research part of a larger project or program?

This research is part of a larger project currently funded by the NSF Ridge 2000 which is related to the impact of hydrothermal fluxes on the biogeochemistry of the overlying ocean. In particular, this project involves the analytical study of settling hydrothermal plume particles collected in sediment-traps deployed directly adjacent to two known vent-sites on the East Pacific Rise at 9°50'N.

What are your next steps?

This research served as a basis to investigate Fe-isotope composition in seafloor hydrothermal systems from various settings, including back-arc hydrothermal systems and volcanic seamounts as well as diffuse hydrothermal flow along mid-ocean ridges. We are also exploring the isotope composition of other metal and metalloid stable isotopes, such as Copper and Germanium isotopes, having distinct behaviors in seafloor hydrothermal systems. Ultimately, these larger projects should open the way for new approaches in the study of chemical and bacterial subsurface processes in seafloor hydrothermal systems.

Published findings and web pages related to this research

Rouxel O., Shanks W.C., Bach W. and Edwards K. Integrated Fe and S isotope study of seafloor hydrothermal vents at East Pacific Rise 9-10N. Submitted to Chemical Geology

S.G. John, O.J. Rouxel, P.R. Craddock, A.M. Engwall, and E.A. Boyle. Zinc isotope composition and fractionation in hydrothermal vent fluids and chimneys. Submitted to Earth Planet. Sci. Lett

S.A. Bennett, O.J. Rouxel, D. Garbe-Schönberg, C.R. German. Iron isotope fractionation in a seafloor hydrothermal system: Variations in end-member vent fluids and changes throughout

the buoyant plume (2007) InterRidge Theoretical Institute 'Biogeochemical interaction at deep-sea vents', Woods Hole, 10th-14th September.

A. Anbar & O. Rouxel. Metal Isotopes in Paleoceanography. (2007) Ann. Rev. Earth. Planet. Sci., 35: 717:746.

Ono S., Shanks III W.C., Rouxel O., and Rumble D. S-33 constraints on the seawater sulfate contribution in modern seafloor hydrothermal sulfides. (2007) Geochim. Cosmochim. Acta 71, 1170-1182.

Slack J.S., Grenne T., Bekker A., Rouxel O. and Lindberg P.A. Suboxic deep seawater in the late Palaeoproterozoic. (2007) Earth Planet. Sci. Lett. 255, 243-256.

Dauphas N. and Rouxel O. (2006) Mass spectrometry and natural variations of iron isotopes. Mass Spectrometry Reviews, 25, 515-550 (DOI 10.1002/mas.20078)

Relevant information on the PI can be found in the "postdoc spotlight" at:
http://www.whoi.edu/page.do?pid=7655
and web page: http://www.whoi.edu/hpb/viewPage.do?id=4656&cl=2