IODP Proposal Cover Sheet

900 - Pre

Rainbow Massif Hydrothermalism

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Title	Mantle, water, and life at end-member hydrothermal systems on the Rainbow massif		
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Abstract

Fluid-rock interactions associated with hydrothermal circulation in young oceanic lithosphere impact seawater chemistry and the subseafloor biosphere. When mantle rocks are involved, the consequences include lithospheric weakening due to serpentinization and production of H2 and abiogenic organic compounds that can promote the development of a deep biosphere. These processes play a vital role in the redox cycling of carbon and other elements as well as the storage and stability of CO2 in the seabed. Ultramafic-hosted hydrothermal systems are thus key to understand the interactions between mantle, fluids and (sub)surface microbial ecosystems, one of the main decadal goals of the new IODP science plan.

We propose to study these interactions at the Rainbow massif (36°14N on a non-transform offset of the Mid-Atlantic Ridge, MAR), which hosts the active Rainbow hydrothermal field (RHF), one of the most spectacular expressions of high-temperature hydrothermalism hosted in an ultramafic substrate. It shares the main characteristics of other ultramafic fields that vent fluids at T>300°C and give rise to the development of Cu-Zn-(Co-Au) massive sulfide mineralizations. Of these sites, the geological context, structure, and hydrothermal activity are best studied at Rainbow after >20 years of research since its discovery. The most recent studies revealed two additional fossil fields (Clamstone and Ghost City) associated with alkaline low-temperature hydrothermal discharge, similar to the Lost City hydrothermal field (Atlantis Massif, MAR). This ephemeral hydrothermal activity likely overlapped with that of RHF, without any apparent spatial-temporal progression.

Recent geophysical data and models suggest that the underlying seismic structure represents variable extents of alteration, which may be directly link to the different types of hydrothermal activity. They reveal a complex three-dimensional structure, with a high-velocity, cone-shaped lithospheric volume at the core of the Massif that shoals near the seafloor in the vicinity of the active and fossil sites. This high-velocity core is capped by a lower-velocity layer dipping and thickening away from the hydrothermal area.

Rainbow Massif features a variety of vents in a well-established geological context, which provides a unique opportunity for studying and comparing reactions between fluids, mantle rocks and ecosystems in the hydrothermal upflow zones of both an active, high-temperature and a fossil lower-temperature vent system. We propose sampling the sub-surface to a few hundreds of meters drilling both types of hydrothermal systems, as well as the variably altered host rock. This will provide new insights into how these processes dynamically interplay in MOR environments.

900 - Pre

Scientific Objectives

We propose drilling three sites to 200-500 m below seafloor (mbsf) at the Rainbow massif (1) near the high-temperature, acidic, active Rainbow field, (2) near the low-temperature, alkaline, fossil Clamstone field, and (3) into a lithospheric body with high seismic velocities (less altered and fractured). Cores from these holes will sample fluid-rock-ecosystem reactions (alteration, mineralizations, biosphere, fluids) from different styles of hydrothermal activity within a variably altered lithospheric mantle. Geological and petrophysical core data and logging results will constrain links and feedbacks between deep structure, fluid circulation, hydrothermal styles, and vent locations. Main questions are: 1) Are hydrothermal fluid pathways controlled by the heterogeneous underlying structure? Or is the structure a result from fluid circulation patterns controlled by late-stage tectonics? 2) Are the different hydrothermal sites linked to each other or are they independent systems with distinct histories of fluid-rock-microbe interactions? The scientific objectives that will allow us addressing those questions are:
1)Compare the nature/conditions of fluid-rock reactions and associated bio-geochemical processes at end-member ultramafic-hosted hydrothermal sites, and explore their evolution with depth.
2)Establish the nature of the seismically distinct basement units and their relation to magmatism, alteration, deformation, and fluid flow.
3)Study the temporal evolution of hydrothermal activity from rocks sampling and measurement of associated biodiversity.
4)Constrain the present-day fluids and deep biosphere by characterizing active processes with in-situ sensors, notably measuring and monitoring dissolved H2 and pH.

Non-standard measurements technology needed to achieve the proposed scientific objectives

900 - Pre

Proposed Sites (Total proposed sites: 7; pri: 3; alt: 4; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
RAINM-1A (Primary)	36.22947 -33.90433	2230	0	500	500	High-T hydrothermalism. Up flow zone close to the active Rainbow field. Fluid-rock reactions and subseafloor ecosystems. Nature of the low seismic velocity upper layer.
RAINM-2A (Primary)	36.23396 -33.88396	2150	0	300	300	Characterization of background alteration of mantle rocks (serpentinization/alteration). Constraints on alteration/fracturing yielding high seismic velocity in upper lithosphere at center of massif. Geomicrobiology and ecosystems associated with pervasive serpentinization/alteration.
RAINM-3A (Primary)	36.230472 -33.879667	1950	0	200	200	Low-temperature, alcaline fossil hydrothermalism (Clamstone). Fluid-rock reactions and subseafloor ecosystems. Interactions between low-T fluid flow, alteration, and possible high-T flow recorded in subseafloor. Transition zone between high to low seismic velocity domains.
RAINM-4A (Alternate)	36.229837 -33.904480	2220	0	500	500	Alternate site - High-T hydrothermalism. Up flow zone close to the active Rainbow field. Fluid-rock reactions and subseafloor ecosystems. Nature of the low seismic velocity upper layer.
RAINM-5A (Alternate)	36.229517 -33.904167	2230	0	500	500	Alternate site - High-T hydrothermalism. Up flow zone close to the active Rainbow field. Fluid-rock reactions and subseafloor ecosystems. Nature of the low seismic velocity upper layer.
RAINM-6A (Alternate)	36.234228 -33.88724	2150	0	300	300	Alternate site - Characterization of background alteration of mantle rocks (serpentinization/alteration). Constraints on alteration/fracturing yielding high seismic velocity in upper lithosphere at center of massif. Geomicrobiology and ecosystems associated with pervasive serpentinization/alteration.
RAINM-7A (Alternate)	36.230667 -33.879667	1930	0	200	200	Alternate site - Low-temperature, alcaline fossil hydrothermalism (Clamstone). Fluid-rock reactions and subseafloor ecosystems. Interactions between low-T fluid flow, alteration, and possible high-T flow recorded in subseafloor. Transition zone between high to low seismic velocity domains.