IODP Proposal Cover Sheet

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Axial Seamount Observatory

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Title	Integrating subseafloor geophysical, hydrological, geochemical, and microbial processes in zero-age, hydrothermally active oceanic crust at Axial Seamount, Juan de Fuca Ridge
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Area	Juan de Fuca Ridge

Proponent Information

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Abstract

Deep-sea volcanoes and associated hydrothermal vents impact global ocean chemistry, heat budgets, and host novel ecosystems. Axial Seamount, located on the Juan de Fuca Ridge in the northeast Pacific, is one of the best studied submarine volcanoes in the world. The dynamic nature of volcanism at Axial Seamount is well established, as exemplified by data flowing from a long-term interactive observatory, the U.S. NSF-supported Regional Cabled Array (RCA). Nearly three decades of geological, biological, geophysical, geochemical, and water column studies provide a substantial baseline of information for ongoing research. We propose drilling, coring, downhole measurements, and creation of cabled borehole observatories that take advantage of the RCA to expand our understanding of microbial, geophysical, hydrological, and geochemical processes in zero-age, hydrothermally-active oceanic crust. Three of the four IODP research themes, including Biosphere Frontiers, Earth Connections, and Earth in Motion, will be addressed through this effort involving a multidisciplinary group of scientists across a broad spectrum of ocean sciences.

At Axial, the linkages between lava composition, volatile output, and mantle source dynamics, as well as the geologic significance of the seismic layer 2A/2B boundary in very young oceanic crust will be examined using borehole logging and rock cores. Seismic studies focused on low-frequency signals and their relationship to magma replenishment and hydrothermal processes in the subseafloor will be determined with a cabled borehole broadband seismometer. Subseafloor permeability, fluid flow processes, and fluid-rock interactions and resulting geochemistry of crustal fluids will be studied through both downhole logging and establishment of additional cabled borehole observatories, enabling cross-hole experiments to examine the connectivity of an active hydrothermal system. Subseafloor microbial communities will also be investigated in rock cores and crustal fluids to determine the nature of microbe-mineral associations and their distribution and activity at Axial Seamount. To enable these diverse lines of scientific inquiry, we propose drilling a set of four cased boreholes, a plan informed by community feedback from a 2017 USSSP workshop that focused on drilling at Axial Seamount. The proposed borehole locations will leverage the RCA to establish two cabled and instrumented holes allowing novel in situ experiments, cross-hole studies, and real-time data flow, providing new insights into the dynamics of hydrothermal processes at an active submarine volcano.

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Scientific Objectives

To integrate our understanding of relationships among geophysical, hydrological, geochemical, and microbial processes in zero-age, hydrothermally-active oceanic crust, we seek to drill Axial Seamount. We propose a combination of drilling, coring, downhole measurements, and the installation of cabled borehole observatories to establish a network of drill sites in an area of active hydrothermal circulation, facilitating long-term, interactive observatory-based subseafloor science, including instrumented holes connected to the OOI cabled observatory for novel in situ experiments and cross-hole studies. Three of the proposed primary drill sites are situated in and around the International District vent field to help resolve the 3-D dynamics of hydrothermal processes, as well as obtain a long section of neovolcanic crust through the layer 2A/2B boundary. Operations at a fourth proposed site will include drilling to 100 mbsf followed by installation of a cabled downhole broadband seismometer.

Specific objectives include (1) determining the structure and composition of the upper oceanic crust at depth in an active mid-ocean ridge volcanic setting, including the nature of the host rock in terms of petrology, geochemistry, alteration, and physical properties; (2) determining the 3-D architecture of an active hydrothermal system, with a focus on the connectivity and temporal dynamics of the hydrological, geochemical, geophysical, and seismic properties of the upper oceanic crust and crustal fluids; and (3) determining the distribution and composition of crustal subseafloor microbial communities, their association with mineral surfaces, rates of activity, and impact on cycling of elements such as carbon, iron, nitrogen, hydrogen, and sulfur.

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

We will prioritize installing two CORK, cabled borehole observatories in holes drilled to ~100-200 mbsf. CORKs will be some combination of CORK-II designs as deployed on the Juan de Fuca Ridge and North Pond flanks, and CORK-Lite designs that can be deployed post-drilling using an oceanographic vessel with an ROV. In addition, we intend to deploy the standard Triple Combo and Formation Microscanner (FMS)-Sonic downhole wireline logging suites. Prior to logging, downhole temperature measurements will be made. If the borehole temperatures do not permit deployment of the standard tools, a flasked high-temperature TC string will be assembled.

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Proposed Sites (Total proposed sites: 8; pri: 4; alt: 4; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
AXIAL-01A (Primary)	45.925414 -129.977862	1525	0	200	200	Location of a CORK borehole observatory in the International District vent field to measure temperature, geochemistry, permeability, sample crustal fluids, and carry out microbial incubation and cross-hole experiments. Log basement after casing and cementing
AXIAL-02A (Primary)	45.926026 -129.971828	1534	0	200	200	Location of a CORK borehole observatory in the International District vent field to measure temperature, geochemistry, permeability, sample crustal fluids, and carry out microbial incubation and cross-hole experiments. Log basement after casing and cementing.
AXIAL-03A (Primary)	45.916465 -129.976786	1536	0	400	400	Location of a deep hole near 2A/2B boundary to determine the structure and composition of the upper oceanic crust, including petrology, geochemistry, alteration, and physical properties of young crust; core recovery after casing set; Log basement after coring
AXIAL-04A (Primary)	45.943507 -129.970176	1525	0	100	100	Location of broadband seismometer installation to detect low-frequency signals that may accompany deep magma resupply and the movement of magma and hydrothermal fluids in the upper crust.
ASHES-01A (Alternate)	45.933473 -130.013867	1540	0	200	200	Alternative to AXIAL-01A in the ASHES vent field; Location of a CORK borehole observatory in the ASHES vent field to measure temperature, geochemistry, permeability, sample crustal fluids, and carry out microbial incubation and cross-hole experiments. Log basement after casing and cementing
ASHES-02A (Alternate)	45.933886 -130.007486	1532	0	200	200	Alternative to AXIAL-02A in the ASHES vent field; Location of a CORK borehole observatory in the ASHES vent field to measure temperature, geochemistry, permeability, sample crustal fluids, and carry out microbial incubation and cross-hole experiments. Log basement after casing and cementing
ASHES-03A (Alternate)	45.926376 -130.005483	1539	0	400	400	Alternative to AXIAL-03A south of the ASHES vent field; Location of a deep hole near 2A/2B boundary to determine the structure and composition of the upper oceanic crust, including petrology, geochemistry, alteration, and physical properties of young crust; core recovery after casing set; Log basement after coring
ASHES-04A (Alternate)	45.933059 -130.020229	1411	0	100	100	Alternative to AXIAL-04A west of the ASHES vent field; Location of broadband seismometer installation to detect low-frequency signals that may accompany deep magma resupply and the movement of magma and hydrothermal fluids in the upper crust.