IODP Proposal Cover Sheet

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Axial Seamount Observatory

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Title	Integrating subseafloor microbial, hydrological, geochemical, and geophysical 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 and heat budgets, and host novel ecosystems. Axial Seamount, located on the Juan de Fuca Ridge in the northeast Pacific Ocean, is one of the best studied and most active submarine volcanoes in the world. The dynamic nature of volcanism at Axial Seamount is well established, supported by real-time data flowing from the U.S. National Science Foundation's Ocean Observatories Initiative cabled observatory network, the Regional Cabled Array (RCA). Nearly three decades of geological, biological, geophysical, and geochemical studies provide a substantial baseline of information for ongoing research. Despite this expansive background, there remain many critical unanswered questions about subseafloor processes that require scientific ocean drilling to resolve.

We propose to establish reentry holes, case, drill, core and make measurements in five basement holes at Axial to examine linked microbial, hydrological, geochemical, and geophysical processes in zero-age oceanic crust, addressing multiple challenges listed in the IODP Science Plan. We will (1) investigate subseafloor microbial communities to determine microbe-mineral associations and microbial distribution and activity in subsurface zero-age crust (Challenge 5: What are the origin, composition, and global significance of subseafloor communities?); (2) evaluate subseafloor permeability, fluid flow processes, and fluid-rock interactions (Challenge 14: How do fluids link subseafloor tectonic, thermal, and biogeochemical processes?); and (3) examine the linkages between lava composition, volatile output, and mantle source dynamics, and the geologic significance of the seismic layer 2A/2B boundary in young oceanic crust (Challenge 9: How are seafloor spreading and mantle melting linked to oceanic crustal architecture?). The five drill sites (50–500 mbsf) will radiate outward from RCA nodes in the International District hydrothermal vent area of Axial Seamount. This plan is informed by community feedback from a 2017 USSSP workshop that focused on drilling at Axial Seamount. Hard-rock re-entry systems and cemented casing will enable sufficient hole stability to reach desired depths, recover samples, and complete borehole measurements.

The re-entry systems and casings deployed in the shallow basement holes will be leveraged by monitoring of nearby vent systems and post-drilling deployments of "CORK-Lite" observatories and a broadband seismometer, enabling augmentation of the RCA to include subseafloor monitoring. This will add significant value to the proposed drilling by enabling cross-hole and borehole manipulative experiments to examine the microbiology, geochemistry, and connectivity of the active hydrothermal system at Axial Seamount.

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Scientific Objectives

Our primary scientific goal is to understand the relationships between microbial, hydrological, geochemical, and geophysical processes in zero-age, hydrothermally active oceanic crust. Through a combination of drilling, casing, coring, and downhole measurements, we will pursue this goal at Axial Seamount by meeting the following three objectives:

(1) Determine the distribution and composition of crustal subseafloor microbial communities, their association with mineral surfaces, rates of activity, and role in biogeochemical cycling of carbon, iron, nitrogen, hydrogen, and sulfur;
(2) Determine the 4-D architecture of an active hydrothermal system and understand how the connectivity of the hydrological, chemical, and physical properties of the upper oceanic crust are linked to magmatic and tectonic deformation through a volcanic cycle; and
(3) Determine the temporal characteristics and nature (structure, composition, hydrostratigraphy) of the upper oceanic crust in an active mid-ocean ridge volcanic setting, including host rock petrology, geochemistry, alteration, and physical properties.

All of the proposed primary drill sites are situated in and around the International District vent field to allow for integration of datasets and close proximity to the Regional Cabled Array (RCA). These operations will create a network of drill holes in an area of active hydrothermal circulation, leveraging drilling activity many times over: facilitating interactive observatory-based subseafloor science, installing instrumentation and connecting it to the RCA post-drilling, and allowing for novel manipulative experiments, real-time long-term monitoring, and cross-hole studies.

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

Prior to standard logging, downhole temperature measurements will be made using the coreline Elevated Borehole Temperature Sensor tool. If the borehole temperatures do not permit deployment of the standard tools, a flasked high-temperature TC string will be assembled. We propose to test permeability in all the holes using a drill string packer. We will also carry out borehole fluid sampling using IODP or third-party tools. We also request a cementing engineer for creating cased, sealed boreholes. Synthetic PFT tracer will also be used for contamination tracing.

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Proposed Sites (Total proposed sites: 9; pri: 5; alt: 4; N/S: 0)

Site Name	Position (Lat, Lon)	Water Depth (m)	Penetration (m)			Brief Site-specific Objectives
			Sed	Bsm	Total	
AXIAL-01B (Primary)	45.925800 -129.978800	1520	0	150	150	Drilling at this site will provide the opportunity to sample an area of active hydrothermal circulation, including a likely upflow zone, for microbial, geological, and geochemical investigations, while also establishing a network of stable holes in close proximity to one another, thus enabling cross-hole experiments and measurements. We aim to drill ~150 mbsf to collect basalt core after casing and cementing is complete. Any producing holes will be sampled for fluids. Downhole logging will also provide insights into permeability and continuity between holes.
AXIAL-02B (Primary)	45.923931 -129.978170	1523	0	150	150	Drilling at this site will provide the opportunity to sample an area of active hydrothermal circulation, including a likely upflow zone, for microbial, geological, and geochemical investigations, while also establishing a network of stable holes in close proximity to one another, thus enabling cross-hole experiments and measurements. We aim to drill ~150 mbsf to collect basalt core after casing and cementing is complete. Any producing holes will be sampled for fluids. Downhole logging will also provide insights into permeability and continuity between holes.
AXIAL-03B (Primary)	45.924054 -129.973988	1530	0	150	150	Drilling at this site will provide the opportunity to sample an area of active hydrothermal circulation, including a likely upflow zone, for microbial, geological, and geochemical investigations, while also establishing a network of stable holes in close proximity to one another, thus enabling cross-hole experiments and measurements. We aim to drill ~150 mbsf to collect basalt core after casing and cementing is complete. Any producing holes will be sampled for fluids. Downhole logging will also provide insights into permeability and continuity between holes.
AXIAL-04B (Primary)	45.919632 -129.976725	1533	0	50	50	Drilling at this site will establish a stable, cased, and cemented hole for future installation of cabled broadband seismometer near an area of active hydrothermal circulation
AXIAL-05A (Primary)	45.920031 -129.962925	1559	0	500	500	Drilling at this site will provide the opportunity to examine the linkages between lava composition, microbial communities, volatile output, and mantle source dynamics, as well as the geologic significance of the seismic layer 2a/2b boundary in young oceanic crust. We aim to drill ~500 mbsf to collect basalt core after casing and cementing is complete. Any producing holes will be sampled for fluids. Downhole logging will also provide insights into permeability and continuity between holes.
AXIAL-06A (Alternate)	45.921980 -129.968270	1543	0	150	150	Drilling at this site will provide the opportunity to sample an area of active hydrothermal circulation, including a likely upflow zone, for microbial, geological, and geochemical investigations, while also establishing a network of stable holes in close proximity to one another, thus enabling cross-hole experiments and measurements. We aim to drill ~150 mbsf to collect basalt core after casing and cementing is complete. Any producing holes will be sampled for fluids. Downhole logging will also provide insights into permeability and continuity between holes.
AXIAL-07A (Alternate)	45.915250 -129.975270	50	0	50	50	Drilling at this site will establish a stable, cased, and cemented hole for future installation of cabled broadband seismometer near an area of active hydrothermal circulation
AXIAL-08A (Alternate)	45.925800 -129.972350	1533	0	150	150	Drilling at this site will provide the opportunity to sample an area of active hydrothermal circulation, including a likely upflow zone, for microbial, geological, and geochemical investigations, while also establishing a network of stable holes in close proximity to one another, thus enabling cross-hole experiments and measurements. We aim to drill ~150 mbsf to collect basalt core after casing and cementing is complete. Any producing holes will be sampled for fluids. Downhole logging will also provide insights into permeability and continuity between holes.
AXIAL-09A (Alternate)	45.917954 -129.957211	1579	0	500	500	Drilling at this site will provide the opportunity to examine the linkages between lava composition, microbial communities, volatile output, and mantle source dynamics, as well as the geologic significance of the seismic layer 2a/2b boundary in young oceanic crust. We aim to drill ~500 mbsf to collect basalt core after casing and cementing is complete. Any producing holes will be sampled for fluids. Downhole logging will also provide insights into permeability and continuity between holes.