IODP Proposal Cover Sheet

955 - Full 2

Axial Seamount Observatory

Received for: 2020-10-01

Title	Integrating subseafloor microbial, hydrological, geochemical, and geophysical processes in zero-age, hydrothermally active oceanic crust at Axial Seamount, Juan de Fuca Ridge
Proponents	Julie Huber, Tim Crone, Adrien Arnulf, Thibaut Barreyre, Suzanne Carbotte, Cornel de Ronde, Aida Farough, Andrew Fisher, Lisa Gilbert, Tobias Hoefig, Jim Holden, Susan Humphris, Deborah Kelley, Susan Lang, Beth Orcutt, Dax Soule, Jason Sylvan, Dorsey Wanless, Geoff Wheat, William Wilcock
Keywords	lithosphere, hydrothermal, biogeochemistry, volcanism, microbiology
Area	Juan de Fuca Ridge

Proponent Information

Proponent	Julie Huber
Affiliation	Woods Hole Oceanographic Institution
Country	United States

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Abstract

Deep-sea volcanoes and associated hydrothermal vents impact global ocean chemistry and heat budgets, are driven by conditions common to seafloor magmatic systems more broadly, and host highly productive chemosynthetic ecosystems. Axial Seamount, on the northern Juan de Fuca Ridge, is one of the best studied and most active submarine volcanoes on Earth. 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 make Axial Seamount unique in the opportunities it presents for discovery and hypothesis testing. There are many fundamental questions to be answered about subseafloor properties and processes at Axial that can only be addressed with scientific ocean drilling, measurements, and experiments.

We propose to drill and sample at four basement sites at Axial, leaving cased boreholes to enable future testing and experiments to explore linked microbial, hydrological, geochemical, and geophysical processes in zero-age oceanic crust, addressing multiple challenges listed in the IODP Science Plan. We will (1) resolve 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) quantify subseafloor permeability, fluid flow processes, and fluid-rock interactions (Challenge 14: How do fluids link subseafloor tectonic, thermal, and biogeochemical processes?); and (3) elucidate the linkages between lava composition, volatile output, and mantle source dynamics in young oceanic crust (Challenge 9: How are seafloor spreading and mantle melting linked to oceanic crustal architecture?). The drill sites (target depth of 50-325 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. Hard-rock re-entry systems and cemented casing will enable sufficient hole stability to reach desired depths, recover samples, and complete borehole measurements.

Instrumentation of the RCA will enable monitoring of nearby vent systems during drilling and during rebound of environmental conditions in the boreholes, which will be a major value-added benefit of work at this site to inform objectives 1 and 2. Furthermore, the cased boreholes will be leveraged in the future for installation of "CORK-Lite" observatories for cross-hole and borehole experiments to extend all objectives.

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 assemblages, 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 PMD tracer will also be used for contamination tracing.

Proposal History

Submission Type: Resubmission from previously submitted proposal

Review Response

We appreciate the positive comments from the SEP regarding the strong scientific objectives, diverse science plan, and considerable leveraging of the observatory infrastructure at Axial Seamount.

In response to the SEP's major concern, we have removed primary site AXIAL-05A and alternate site AXIAL-09A. While we remain convinced that Axial is an excellent target for drilling through the 2A/2B boundary, we agree with the SEP that this objective may be overly ambitious in the context of our other goals for the expedition. Once successful drilling at Axial is achieved, future proposals could make this scientific objective a top priority. Therefore, we have removed the deepest hole in this revision. Instead, we propose to drill deeper (~325 mbsf) at three of the originally proposed sites in an effort to address other SEP concerns related to core recovery and downhole logging.

We have also added more specific details about experiments to be conducted and hypotheses to be addressed, particularly for the microbiology objectives. We clearly delineate which objectives can be addressed with drilling, and which will require additional cruises or instrumentation. We believe that the three activities (pre-drilling instrumentation to monitor subsequent drilling perturbations, rock/fluid recovery during the drilling expedition, and post-drilling infrastructure for borehole experimentation) are all interrelated and important to include to achieve the holistic program that is unique to Axial's observatory network. We highlight what will be achieved specifically during the drilling expedition, with a focus on core recovered, downhole logging, and fluid sampling. The SEP had some concerns about packer experiments; hence, we have expanded our discussion of these measurements, which are critical to our objectives. The approach proposed has proven successful in other crustal settings. Another comment from SEP included concerns about the predicted geothermal gradient at our sites, which we elaborate on in this revision, acknowledging significant uncertainties. Given that we are going to drill in an area of active hydrothermal circulation, we are planning for the possibility of high downhole temperatures at the site closest to the International District, and we include flasked tools in the operations plan.

Finally, the SEP remains concerned about the overall drilling success in zero-aged basaltic rocks. We acknowledge these challenges, but (a) ocean drilling has demonstrated success in bare rock settings, and (b) we have worked closely with IODP engineers throughout this process to ensure that the operational design will meet this challenge. In consultation with multiple members of the IODP Science Operations team, we have proposed a drilling plan that uses the latest technological advances in hard rock drilling and allows considerable flexibility in operations on the basis of actual conditions in the field. Flexibility and having options is the key, and will increase the probability for overall program success by permitting sites to be shifted as needed, providing multiple attempts and options to achieve critical objectives. In combination with eliminating the deepest site and focusing on getting stable, deeper holes in multiple locations, we have optimized the plan for successful operations.

Proposed Sites (Total proposed sites: 7; pri: 4; alt: 3; 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	325	325	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 ~325 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	325	325	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 ~325 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	325	325	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 ~325 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-06A (Alternate)	45.921980 -129.968270	1543	0	325	325	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 ~325 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	1545	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	325	325	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 ~325 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.