Hydrothermal Estuaries Noble Gases

Website: https://www.bco-dmo.org/dataset/986923
Version: 1
Version Date: 2025-10-14

Project
» Collaborative Research: Hydrothermal Estuaries: What Sets the Hydrothermal Flux of Fe and Mn to the Oceans? (Hydrothermal Estuaries)

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Coverage

Spatial Extent: **Lat**:0 **Lon**:0

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Parameters

Parameters for this dataset have not yet been identified

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Project Information

Collaborative Research: Hydrothermal Estuaries: What Sets the Hydrothermal Flux of Fe and Mn to the Oceans? (Hydrothermal Estuaries)

Coverage: Juan de Fuca Ridge

NSF Award Abstract:
Like volcanoes on land, the mid-ocean ridges that cross the ocean floor are not continuously erupting; however, the magmatic heat present just beneath the surface can continue to drive hot springs, just like the ones found within the crater of the "super volcano" at Yellowstone. In our recent work, we have shown that the chemicals released into the oceans from seafloor hot-springs can be dispersed all across the oceans. Now our interest has focused in on one element in particular, iron. This is one of the most abundant elements in every planetary body in the Universe yet it is vanishingly rare in Earth's oceans today. Set against that, it is essential to just about every form of life on Earth from the simplest and most ancient strains of microbes to the most complex animals including humans. In Earth's oceans, the lack of this "essential micro-nutrient" has been found to limit how much life can flourish near both the south and north poles in the Pacific Ocean in the sunlit surface ocean even though the supply of sunlight and other major nutrients (phosphorous, nitrogen) should be more than adequate. Our newest research suggests that iron released from hydrothermal plumes (where the concentrations coming from vents are more than 1 million times higher than normal ocean water) could play a major role. Despite undergoing massive dilution as hydrothermal solutions leave the vents and

traverse thousands of kilometers through the oceans, we believe that at least some of the iron released from deep sea hot springs can survive this journey and make a significant impact on how much live exists in Earth's polar oceans and how much CO2 it draws down from the atmosphere. To investigate that idea, this project will study the fate of iron released from a hydrothermal vent over a length scale that hasn't been studied before - from the first 1km through the ocean out to 100km away from the vent-site. This will fill a gap in our knowledge between what happens right at a vent-site (as studied by research submarines) and what happens to ocean chemistry all across Earth's entire ocean basins (as studied by a huge international research project called GEOTRACES). Our work will use a 3D computational model to predict where the plume of material from a vent in the Northeast Pacific Ocean should escape to after it is erupted from some vents at a volcanic system called the Juan de Fuca Ridge. We will then use an advanced autonomous free-swimming robot to search out in the predicted plume area, first to test the accuracy of our predicted model and, second, to collect samples from the hydrothermal plume from where it first forms to as far out as we can follow it. The samples we collect will include both filtered seawater and the particulate material (whether mineralogical or microbiological) that we can extract from the filters. Together, this will allow us to track the fate of the iron and other key physical and geochemical tracers down-plume away from the vents, to work out where it ends up (in the water and in the sediments) and also how fast those processes happen. The work we do will also help plan how to conduct similar robotics-based exploration on future space missions beyond Earth where it has been hypothesized that seafloor events also exist (e.g. Saturn's moon Enceladus) and where, if we are really lucky, we may find that life is hosted based on the energy from seafloor volcanoes, just as happens here on Earth. We have a resident artist embedded in our program who has already begun experimenting with the use of air-flow and sound in her sculptures to help communicate the complex nature of these plumes. She will join our cruise, and work with our team post-cruise to design and hopefully build a sculpture that that could potentially result in a large and long-term outdoor installation.

The international GEOTRACES program has revealed that iron (Fe) is released ubiquitously from submarine ridges to the deep ocean. Results from US GEOTRACES section GP16 showed that both dissolved and particulate (colloidal) Fe may persist so far as to be able to influence primary productivity in High-Nutrient/Low-Chlorophyll (HNLC) regions of the Southern Ocean. As a complement to these sectional studies, we propose a detailed process study to elucidate the mechanisms by which hydrothermally sourced Fe can persist across the oceans at the scale that GEOTRACES has revealed. Specifically, while the "persistent" Fe in a hydrothermal plume appears to behave quasi-conservatively from 100km to 4000km across the SE Pacific Ocean, it is also known that the majority of the Fe present at the Southern EPR on that US GEOTRACES GP16 cruise did not persist over the 100km separation between that station and the next deep ocean station beyond the ridge crest. To fill that gap, this project will conduct a coupled modelling and field study to investigate the fate of hydrothermally sourced Fe at ranges of 0-1, 1-10 and 10-100km down-plume away from a well established vent-source. To begin, we will use the detailed micro-bathymetry and the long-term current meter data available from the Main Endeavour Segment of the Juan de Fuca Ridge to implement a recently developed 3D theoretical plume dispersion model that can predict both the detailed 3D dispersion trajectory and the rate of flow within the hydrothermal plume away from two long-studied and well characterized Main Endeavour Field (MEF) vents. At sea, we will use that predictive model to guide Sentry autonomous underwater vehicle (AUV) surveys that will follow the plume "down-wind" and "across-plume" to compile a 3D survey using in-situ sensors [optical, redox, conductivity, temperature, depth (CTD)] that will allow us to (1) confirm (and better constrain) the predictive model, and to (2) map out the shape and trajectory of the plume to provide context for discrete water column samples that we will collect - both from the AUV and from a trace metal clean CTD-rosette. Sampling from the AUV will use the latest generation of SUPR samplers designed for the CLIO trace-metal-clean water sampler. This will suffice for samples of dissolved, colloidal and particulate trace metals and collection of filtered material for grain-by-grain mineralogical and biogeochemical analyses. That sampling program will be backed up by larger volume sampling down-plume using a CTD-rosette to augment our AUV-based program with helium isotope analyses (to track extents of physical plume dilution at increasing distances downwind and across plume) and for complementary ligand and organic compound analyses to investigate the role that organic complexation might play in protecting reduced species of Fe [and manganese (Mn), too] against oxidative precipitation and removal from the oceanic water column. Post cruise, our combination of biogeochemical measurements and improved 3D physical modelling will not only be able to provide new insights into the processes that control the fluxes of Fe and Mn to the oceans from hydrothermal venting but also the length scales over which those processes take effect. Finally, because our 3D theoretical model includes velocities, we also anticipate being able to deduce the rates at which these processes occur.

This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1851007

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