Biogeochemical Exploration of the Pescadero Basin Vents

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Overview

In 2015, the deepest high-temperature hydrothermal vents in the Pacific Ocean (3,700 m) were discovered in a sediment-covered pull-apart basin along the Pescadero Transform Fault in the Gulf of California. Biological communities were observed thriving among the carbonate chimney structures (Figure 1; Goffredi et al., 2017). As a result of their striking contrast to other hydrothermal systems, the high-temperature, high-carbon Pescadero Basin vents provided the opportunity to examine the influence of tectonic setting on the nature of seafloor vent sites, the fundamental geochemical controls on biological colonization in the deep ocean, and the role of fluid venting on global-scale ocean chemistry and climate. In November 2017, with support from the Dalio Ocean Initiative, a multidisciplinary science team led by Woods Hole Oceanographic Institution scientists set out on E/V *Nautilus* to investigate this area of active venting.

Vent Exploration

We explored the primary known Pescadero Basin venting sites, including Z vent, C Vent, P Vent, Diane's Vent, and the Matterhorn. In addition to these prominent vertical mounds, numerous small areas of focused and diffuse venting were observed. Although located in close proximity (within ~500 m) and sharing many characteristics (microbial mats, fauna, structure, fluid chemistry), distinct features of each type of venting provided context for comparison. Diane's Vent is a short (~1 m high) carbonate chimney exhibiting exceptionally vigorous flow of hot fluids (~288°C) from an orifice ~30 cm across. The Matterhorn is a hydrothermal mound that rises ~12 m above the seafloor. Its central vent emits energy-rich fluids supporting dense *Oasisia* tubeworm colonies. Z vent is a large carbonate mound that rises ~20 m above the seafloor and exhibits a more variable structure, with large flange features along the outside of the mound and small chimneys venting fluids as hot as 299°C (Figure 2).

Biological Communities

Megafaunal epibenthic communities appeared to be distinctly zoned in relation to proximity of active fluid venting. On the outskirts of the larger carbonate mounds, more sparsely inhabited benthic communities included anemones, *Munidopsis* squat lobsters, and holothurians. Around the base of the mounds, clams and zoanthids were frequently quite dense on soft and hard substrata, respectively. Other types of fauna clustered more directly around venting fluid orifices in communities typically dominated by the tubeworm *Oasisia* (Figure 3), with occasional lone *Riftia*. Some areas near venting orifices exhibited a distinctly separate community structure, typified by microbial mats. An apparent zonation in microbial mat morphology and extent within these communities may indicate fluid venting governing both temperature and delivery of energy-rich fluids. Sediment push cores

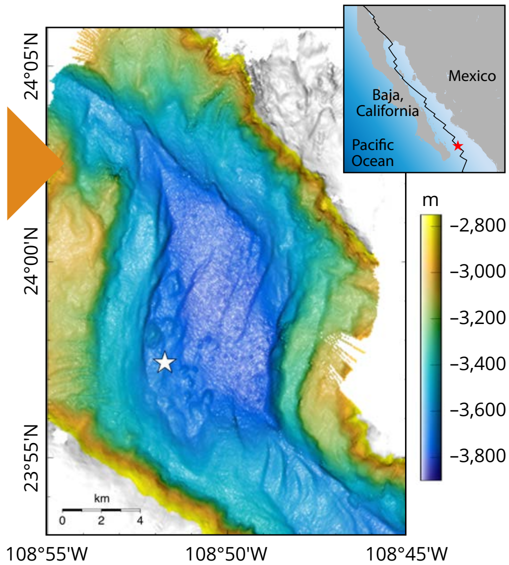


Figure 1. Location of Pescadero Basin (red star in inset) and vents (white star in bathymetric map) in the Gulf of California, which were discovered in 2015.

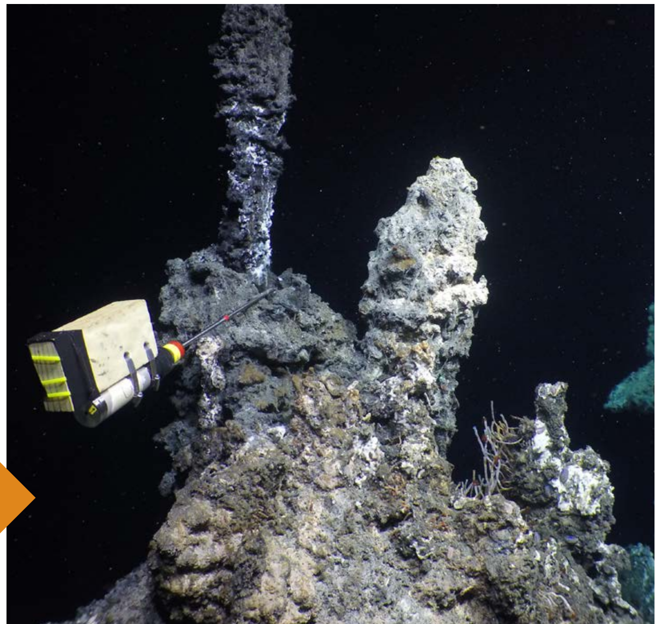


Figure 2. The Z vent was characterized by tall carbonate spires. An in situ temperature probe (left part of image) was installed to capture temperature variability of the fluids emanating from the chimneys.

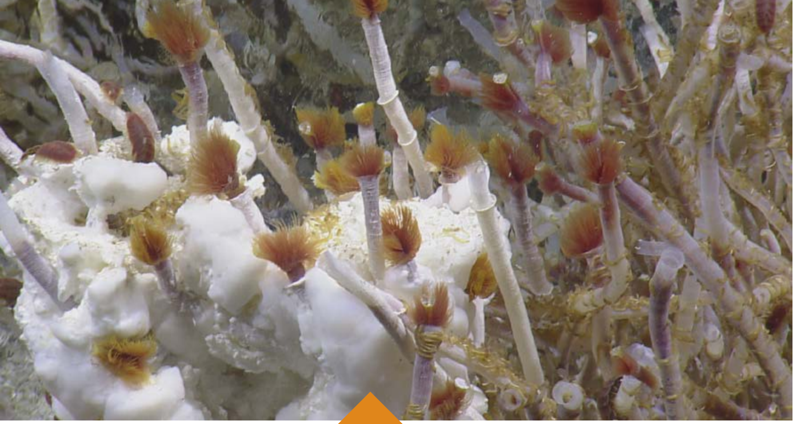
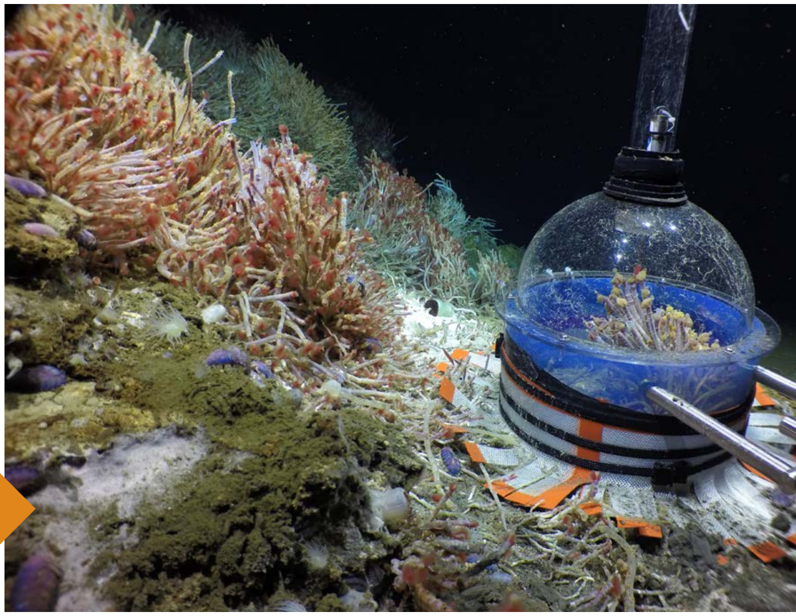


Figure 3. *Oasisia* tubeworms were a prominent species observed near sites of active fluid venting. Some of these areas also contained microbial mats enshrouding tubeworms as shown above.

Figure 4. A flux integrator coupled to both an in situ laser spectrometer and a mass spectrometer allowed chemical fluxes and temperature fluxes to be measured.



were collected to study infaunal and microbial community structures, pore water chemistry, and chemical and mineralogical composition of sedimentary particles. Representative rock specimens were also collected for analysis of rock-hosted megafaunal and microbial communities.

To understand vent biological community compositional differences and zonation, we collected fauna from distinct positions within the communities and from the water column at seven locations. Water column samples will be examined to compare the taxonomic composition of larvae with that of the benthic communities. We collected megafauna and sediment push cores for the Universidad Nacional Autónoma de México. To complement the biological sampling, we made in situ chemical measurements at these same locations.

In Situ Chemical Analyses Using Advanced Technologies

A range of novel deep-sea tools and advanced technologies were employed for chemical analyses. An in situ mass spectrometer was used for real-time measurement of dissolved volatiles, including hydrogen, methane, carbon dioxide, hydrogen sulfide, and higher-order hydrocarbons. A deep-sea laser spectrometer facilitated in situ measurement of the stable carbon isotopic composition of methane. To enable chemical and temperature measurements of diffuse flows in and around tubeworm clusters, a flux integrator (Figure 4) was coupled to these instruments. The combined instrument deployment for chemical concentration and isotope measurements was a scientific first for deep-sea vent exploration, and will prove essential for quantifying the origins and fluxes of carbon and other chemical species from these types of hydrothermal vent systems. Preliminary analyses indicated an abundance of hydrogen, methane, carbon dioxide, and higher-order hydrocarbons in the vent fluids, likely influenced by the organic-rich sediment overburden.

Isobaric gas-tight samplers were used to collect high-temperature fluid samples for determining their inorganic, organic, and volatile chemistry. In combination with in situ chemical data, these discrete measurements will constrain sources of dissolved carbon dioxide, hydrocarbons, organic acids, lipids, and other organic species to the seafloor at the Pescadero Basin vent field. The nitrogen and sulfur systems and fluid metal contents will be examined to comprehensively describe the Pescadero Basin geochemical framework.

Geological Studies

Geological sampling and analyses focused on the mineralogical and geochemical characterization of rock samples, particularly hydrothermal precipitates, to constrain past and ongoing hydrothermal conditions. Collection of representative rock samples, including carbonates, from the vents will permit detailed mineralogical studies. A few geologic samples contained obvious hydrothermal/petroleum-like hydrocarbon, which had not been observed previously at Pescadero Basin. Rock slabs and chimneys associated with lower temperature biological communities contained more abundant barite relative to previously collected material. Further examination of these samples promises to shed light on the unique nature of this hydrothermal system. To measure vent fluid temperature changes, a temperature logger was deployed in the Z vent (Figure 2). Upon returning three days later, we discovered a new chimney had grown ~1 m high above the logger and samples were collected to examine this growth.

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