Schmidt Ocean Institute Expedition Report
Interdisciplinary Investigation of the Pescadero Basin

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Co-Chief Scientist Leg 1: Ronald Spelz-Madero (Universidad Autónoma de Baja California)
Co-Chief Scientist Leg 2: Raquel Negrete-Aranda (Centro de Investigación Científica y de Educación Superior de Ensenada, Baja California)
Co-Chief Scientist Leg 3: Victoria Orphan (California Institute of Technology)

Cruise report compiled by Jennifer Paduan (Monterey Bay Aquarium Research Institute)

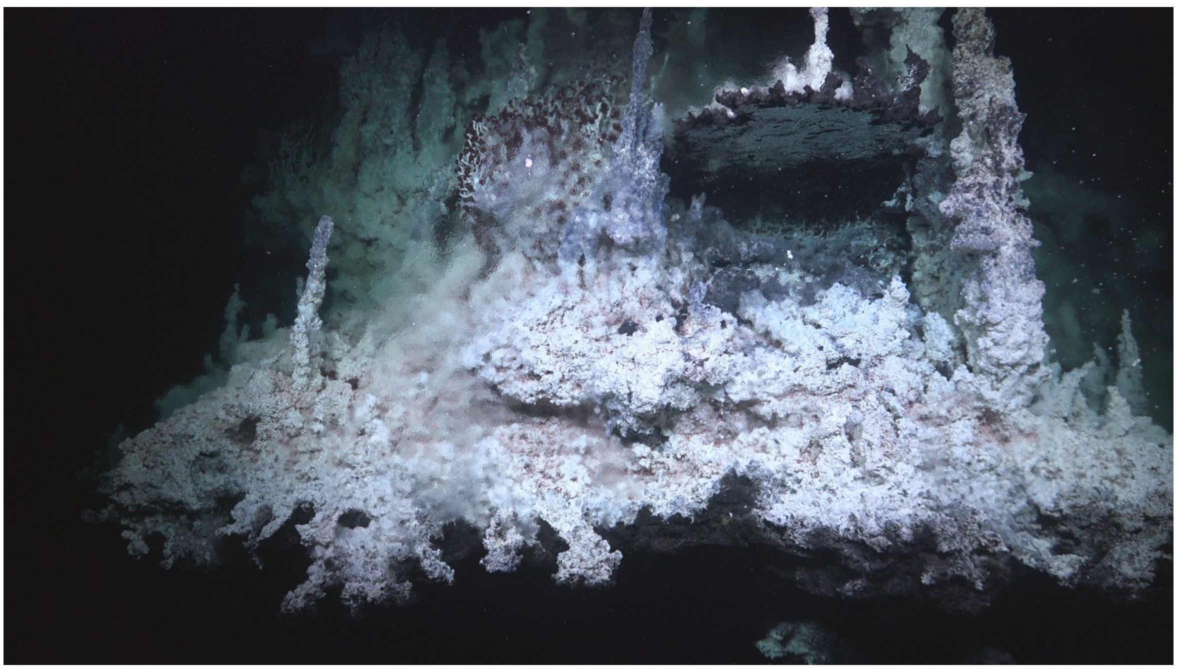

Figure 1. Hydrothermal flanges and mirror pools at the JaichaMaa ’ja’ag vent field observed on the R/V *Falkor* expedition FK210922.

Table of Contents

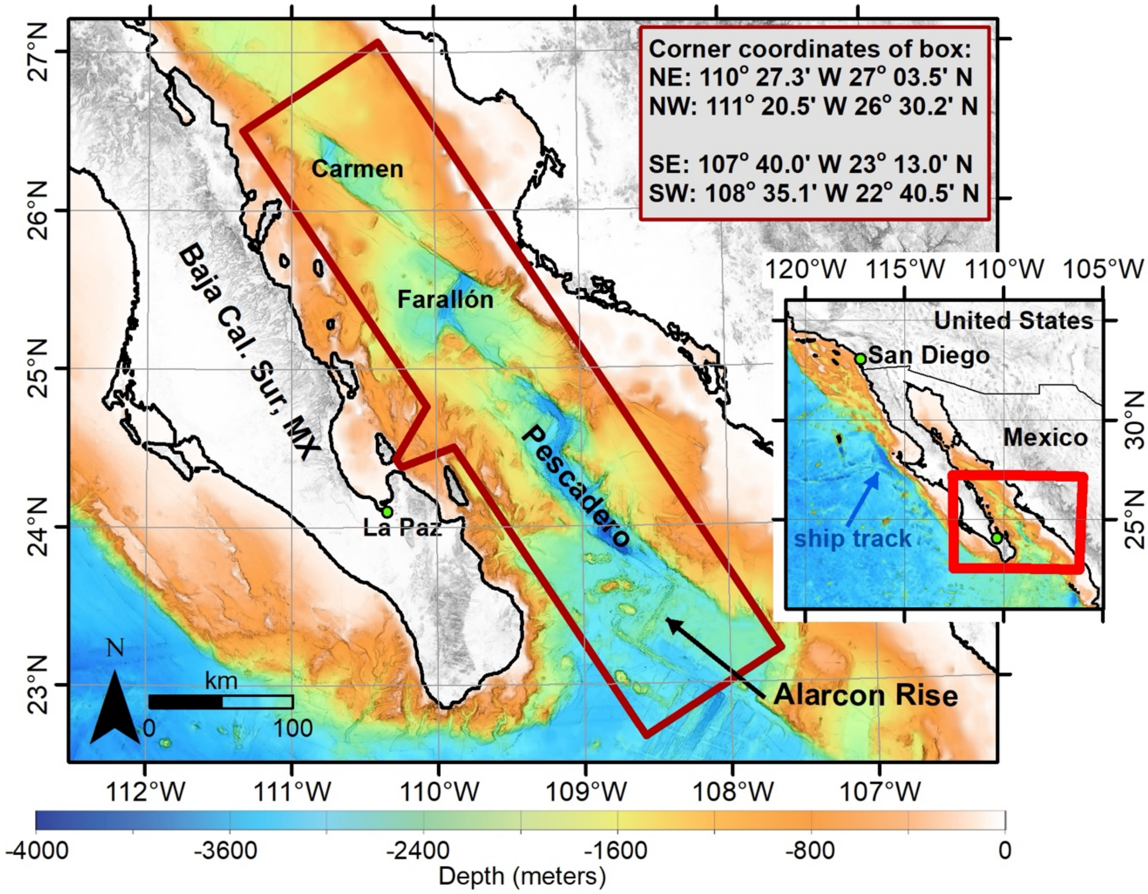

Figure 2. The study area in the southern Gulf of California, with the major rift basins labeled.

1. Expedition FK210922 Overview

1.1. Expedition Highlights

This final cruise of the R/V *Falkor*, expedition FK210922 to the southern Gulf of California (GoC), embarked on a multidisciplinary approach to understanding the tectonic, geochemical, microbiological, and biological interactions in hydrothermal fields in the sediment-covered pull-apart basins along a major transform fault system (**Figures 1 and 2**). The first leg was almost entirely devoted to shipboard multibeam mapping of the Carmen, Farallón, and Pescadero Basins. The second and third legs focused on using ROV *SuBastian* to sample and explore previously discovered hydrothermal vent fields in the South Pescadero Basin. The second leg combined ROV heat flow measurements in and around the southern Pescadero Basin vent fields with ROV fluid sampling at the vents. The third leg focused on ROV sampling of animals and microbes, but also of vent fluids and temperatures, sediments, and heat flow to establish the geochemical context that supports free-living and symbiotic microbial metabolisms, and to assess the densities, distribution patterns, and diversity of associated fauna.

The scientific party considers the cruise to have been highly successful, with all of the revised pre-cruise objectives met or exceeded. Highlights of the cruise include the following:

- Mapping with the R/V *Falkor's* modern and high-quality sonar systems was extended to cover all of the southern GOC tectonic basins and transform faults.
- Exploring the shallower (<1000 m) morphology and structural features associated with the highly extended continental crust located west of the tectonic basins, on the eastern margin of the Baja California microplate, south of 25ºN latitude.
- Dense array of heat flow measurements at the Auka and JaichMaa 'ja'ag vent fields in the southern Pescadero Basin, aligned with subbottom profiles collected by the MBARI Mapping AUV on FK181031.
- Vent fluids were collected at each of the three known vent fields (the two listed above and Maijia awi between them) which will allow us to assess differences and similarities in the chemical compositions and potential fluid source reservoir(s).Vent fluids were collected from the previously unsampled Matterhorn chimney in the Auka vent field, which will allow us to investigate the origin of the Ag-Au-Sb-rich barite mineralization that distinguishes this chimney from the carbonate base-metal mineralization that characterizes the other high temperature vents.
- Sediment samples (via pushcores) and samples of hydrothermal rocks including crusts, flanges, and orifices, as described above. Rock samples were split and processed for mineralogy/geochemistry and for biology. Biological samples were preserved for DNA sequencing and microbial community analysis, FISH microscopy, and live incubations. In total, 48 pushcores and 42 rocks were collected for analysis.

1.2. Background and Motivation

The Gulf of California is a transtensional tectonic plate boundary characterized by divergent right-lateral shear between the Pacific and North American plates. Continental extension began separating the Baja Peninsula from the mainland of Mexico ~12.3 Ma (Lizarralde et al., 2007, and references therein). Of the spreading segments accommodating that extension, the 50-km long Alarcón Rise is the longest. It lies at the mouth of the gulf between the southern tip of the Baja Peninsula and the mainland of Mexico (Figure 2). Seafloor spreading began there with the propagation of the East Pacific Rise (EPR) into the GoC ~3.5 Ma, and its full spreading rate is about 49 mm/year (DeMets et al., 2010). South from there almost to Antarctica, intermediate to ultra-fast-spreading, basaltic lava-covered ridge segments of the EPR offset by transform faults characterize the plate boundary between the Pacific Plate and the tectonic plates to its east. Alarcón Rise is the northernmost segment of the EPR that is not buried beneath continental sediment over its length. Its vigorous hydrothermal vent fields are typical of basalt-hosted systems, black smokers depositing metal-sulfide-rich chimneys (Paduan et al., 2018), and are populated with fauna typical of the EPR (Goffredi et al., 2017).

At the northeast end of the Alarcón Rise, the plate boundary enters the Gulf of California and becomes dominated by a system of long right-stepping, right-lateral transform faults, the northern-most being the San Andreas Fault, that connect a series of short spreading segments blanketed with increasingly thick terrigenous and biogenic sediment. The nearest of these spreading segments to the Alarcón Rise is 60 km NW along the Pescadero Transform Fault, the ~3,800-m-deep southern Pescadero Basin (Figure 2). It is one of a series of three grabens offset by transform faults collectively named the Pescadero Basin and located 150 km east of La Paz, Mexico.

Until the discoveries by the Monterey Bay Aquarium Research Institute (MBARI) of hydrothermal vents on the Alarcón Rise and in the southern Pescadero Basin in 2012 and 2015, respectively (Paduan et al., 2018), the only hydrothermal activity known in the GoC was in the Guaymas Basin, a gap of more than 750 km from the nearest site on the EPR at 21°N, and about 400 km NW of the Pescadero Basin (Figure 1a in Paduan et al., 2018). The Guaymas Basin is a sediment-filled spreading basin with more compositional and faunal diversity than EPR hydrothermal sites due to interaction of hot fluids with thick sediments (Goffredi et al., 2017, and references therein).

The MBARI expedition in 2015 used Autonomous Underwater Vehicle (AUV) seafloor mapping followed by ROV dives to discover and sample a distinctive hydrothermal field in the southern Pescadero Basin. This new vent field was named Auka (Goffredi et al., 2017; Paduan et al., 2018). During the 2017 EV *Nautilus* expedition NA091 (Michel et al., 2018), several ROV dives conducted additional biological sampling amongst the mapped mounds. Expedition FK181031 of the R/V *Falkor* to the Pescadero Basin followed in 2018, led by participants in the 2015 MBARI expedition. Mapping included shipboard multibeam and 1-m-scale AUV-based surveying to search for new hydrothermal vents in the southern and northern Pescadero Basins. Mapping also included the MBARI Low Altitude Survey System (LASS) mounted on the ROV *SuBastian* to survey the previously discovered Auka vent field with multibeam sonar, wide swath lidar, stereo cameras, and an inertial navigation system to achieve 1-cm-resolution bathymetry mapping and 2-mm color photomosaics. AUV mapping and ROV *SuBastian* dives discovered and explored a second vent field in the basin, named JaichMaa 'ja'ag.

These hydrothermal fields stretch over 2,750 m atop *en echelon* fault scarps at ~3670 m depth along the southwest margin of the southern Pescadero Basin. They are highly unusual in physical and chemical parameters and in faunal community structure (Paduan et al., 2015; Caress et al., 2015; Rouse et al., 2016; Goffredi et al., 2017; Paduan et al., 2018). In particular, the vents were found to be forming large white carbonate mounds deposited from clear fluids venting at up to 290 °C and to host chemosynthetic communities comprised of some animals associated with hot vents in Guaymas Basin, others associated with hot vents along the East Pacific Rise, and yet others previously associated with hydrocarbon-rich cold seeps.

The FK210922 expedition was proposed and led by participants of the 2015 MBARI and 2018 *Falkor* expeditions. Our return to the Pescadero Basin region in 2021 was a multidisciplinary, three leg expedition on the final cruise of the R/V *Falkor* to investigate the tectonics, biogeochemistry, microbiology and ecology of hydrothermal vent fields of the Pescadero Basin. The first leg had been planned to include AUV and LASS mapping and ROV dives focused on vent fluid sampling, but due to rescheduling was recast to be devoted to systematic shipboard multibeam mapping and magnetic data collection (the latter of which was not achieved). The second leg combined heat flow measurements in and around the Auka and JaichMaa 'ja'ag fields with fluid sampling at the vents from the ROV *SuBastian*. On the third leg, in order to establish the geochemical context that supports free-living and symbiotic microbial metabolisms, and to assess the densities, distribution patterns, and diversity of associated fauna, the ROV video observations were combined with sampling of animals, microbes, vent fluids, pore fluids, sediments and temperature and heat flow observations. Mounds between the Auka and JaichMaa ‘ja‘ag fields (Meijia awi) and to the south of JaichMaa ‘ja’ag (Melsuu) were also sampled for the first time. In the Auka field, the biological ROV dives were conducted in the context provided by the 2018 ROV-based LASS surveys, allowing targeted sampling of animals and bacterial mats.

1.3. Expedition plan, as executed

Three legs, all operated from and to La Paz, Baja California Sur, Mexico

Leg 1: Tectonics
October 2 to 17, 2021
Chief Scientists Ronald Spelz-Madero and David Caress (remotely)
Operations:
- Regional mapping using the hull mounted multibeam
- Ancillary exploration and rock sampling

Leg 2: Vent Field Heat Flow
October 17 to 25, 2021
Chief Scientists Raquel Negrete-Aranda and David Caress
Operations:
- ROV *SuBastian* dives at Jaichmaa ‘ja’ag vent field to conduct high-density heat flow measurements.
- Ancillary exploration, rock and fluid sampling

Leg 3: Vent Field Ecology, Biology, and Microbiology
October 28 to November 10, 2021
Chief Scientist Victoria Orphan
- ROV *SuBastian* dives at the Auka and JaichMaa ‘ja’ag vent fields to explore and collect biological/microbiological samples
- Ancillary exploration, rock and fluid sampling

1.4. Challenges

The R/V *Falkor’s* Summer and Fall 2021 schedule was cancelled in March 2021 when the purchase of the R/V *Falkor (too)* was announced by SOI. The schedule through October was then reinstated in June. However, the personnel required for MBARI seafloor mapping operations has been reassigned to other projects, so the originally planned AUV and LASS mapping could no longer be conducted.

Covid protocols forced the science party to be reduced to 8 on each leg so that cabins could be reserved in case of illness aboard. All crew and science party were required to be fully isolated for 96 hours then receive negative PCR test results before they could board the ship.

The Mexican research permit for the ship was not issued until after the expedition was scheduled to begin. US participants on the first and second legs could only then apply for their required

Permiso de Cooperante visas, travel once the visas were obtained, and then undergo the four day pre-boarding isolation in La Paz. This delay resulted in Dave Caress (Chief Scientist) and Rob Zierenberg being unable to join the *Falkor* for Leg 1 and consequently participating remotely. With Zierenberg not on board, the fluid sampling planned for leg 1 had to be postponed and was dove-tailed with the heat-flow and biological sampling during ROV dives on Legs 2 and 3. The same visa timing issues caused Robert Harris to be unable to be on board on Leg 2, and thus participating remotely during the heat flow operations.

The towed SeaSPY2 magnetometer was intended to be used during ship multibeam surveys of the southern GoC basins. Unfortunately, the magnetometer failed after the test dive of the ROV *SuBastian* at the beginning of the cruise (dive S0461). Despite considerable effort by the marine technicians, the magnetometer could not be repaired, and the planned systematic collection of magnetic data throughout Leg 1 had to be discontinued.

Vent fluid sampling using the ROV continued to provide challenges. Several on-site modifications of the hydraulic triggering mechanism allowed us to successfully collect at least one good quality vent fluid sample from each of the three known vent fields. However, the difficulty and amount of time spent for each fluid sample (and in some cases the quality of the sample) was notable compared to working with other crewed and uncrewed research platforms.

1.5. Participating institutions

California Institute of Technology (Caltech), Pasadena, California, USA
Centro de Investigación Científica y de Educación Superior de Ensenada, Baja California (CICESE), Ensenada, Mexico
Monterey Bay Aquarium Research Institute (MBARI), Moss Landing, California, USA
Occidental College, Los Angeles, California, USA
Oregon State University (OSU), Corvallis, Oregon, USA
Schmidt Ocean Institute (SOI)
Scripps Institution of Oceanography (Scripps), La Jolla, California, USA
Universidad Autónoma de Baja California (UABC), Ensenada, Mexico
University of California at Davis (UC Davis), Davis, California, USA

1.6. Science Party

Communications coordinator: Monika Naranjo – SOI
Artist at sea: Alejandra (Ale) de la Puente (Mexican artist based in Mexico City, https://schmidtocean.org/person/ale-de-la-puente/)

Leg 1 (Figure 3)

*David Caress – Chief Scientist – Geophysicist, seafloor mapping – MBARI
Ronald Spelz-Madero – Co-chief Scientist – Geologist, tectonics – UABC
*Rob Zierenberg – Geochemist – UC Davis
Nestor Ramirez-Zerpa – Ph.D student - Geology, tectonics - UABC
Usama Yarbuh Lugo – Geologist, tectonics - UABC
Luis Vega Ramirez – Ph.D student - Geology, tectonics – CICESE
Marc Juliá Miralles – Ph.D student - Geology, tectonics - UABC

Isabela Macías-Iñiguez – MSc. student – Geophysics, heat-flow - CICESE
*Participated remotely due to the delay in receipt of the ship's permit and Covid isolation requirement

Figure 3. Leg 1 science party on the bow of the R/V *Falkor* (photo credit: Monika Naranjo).

Leg 2 (Figure 4)

Raquel Negrete-Aranda – Co-chief Scientist – Geophysicist, heat flow – CICESE
David Caress – Chief Scientist – Geophysicist, seafloor mapping – MBARI
Rob Zierenberg - Geochemist – UC Davis
*Rob Harris – Geophysicist, heat flow – OSU
Florian Neumann – Geophysicist, heat flow – CICESE
Karina Fuentes-Bustillos – Ph.D student – Geophysics, heat-flow - CICESE
Isabela Macías-Iñiguez – MSc. student – Geophysics, heat-flow - CICESE
Manet Peña Salinas – Ph.D student – Oceanography, microbiology – UABC
*Participated remotely due to the delay in receipt of the ship's permit and Covid isolation requirement

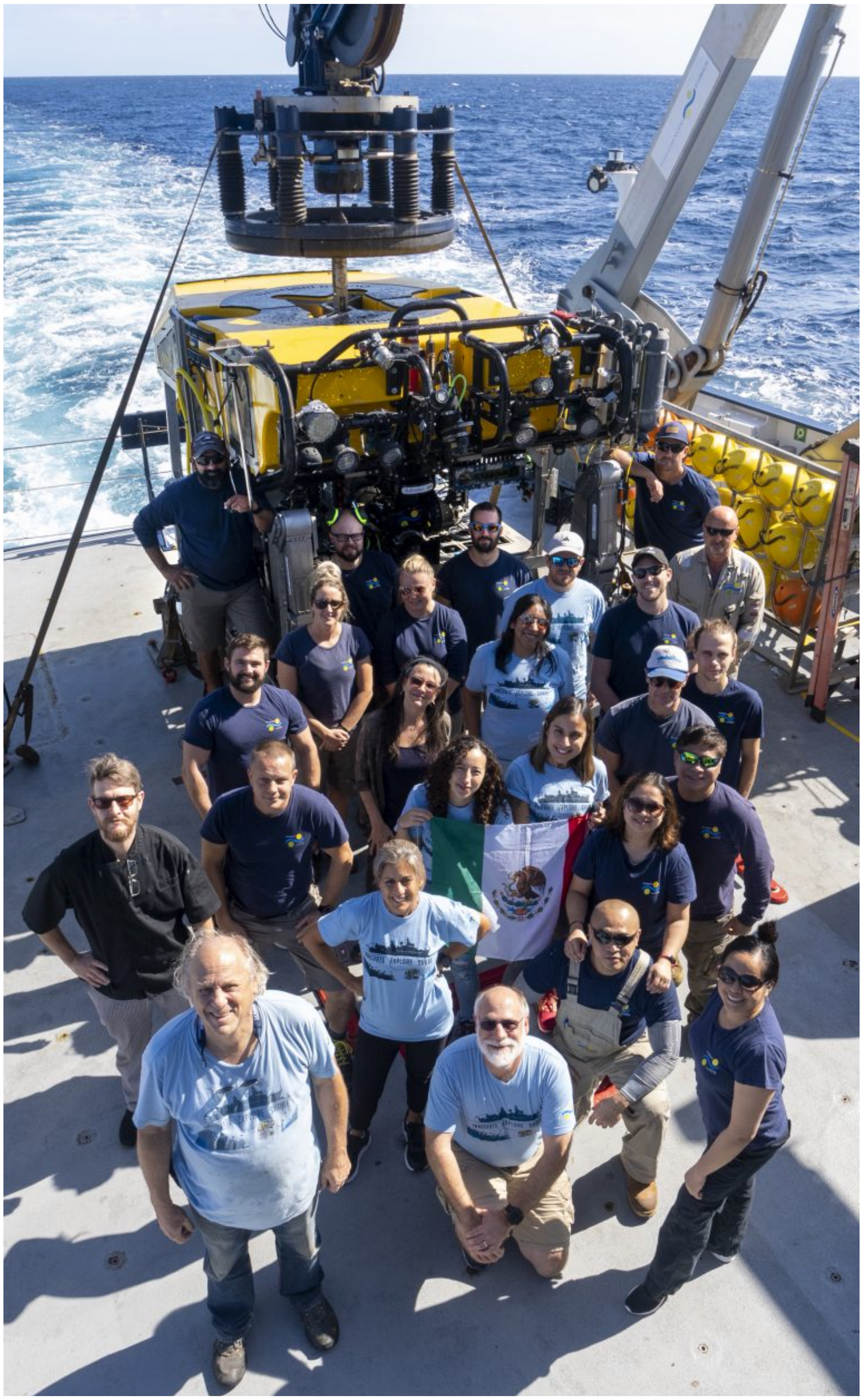

Figure 4. Leg 2 science party on the fantail of the R/V *Falkor* (photo credit: M. Naranjo).

Leg 3 (**Figure 5**)

Victoria Orphan – Co-Chief Scientist – Microbiologist –Caltech
Shana Goffredi – Biologist – Occidental College
Greg Rouse – Biologist – Scripps
Rob Zierenberg – Geochemist – UC Davis

John Magyar – Geobiologist – Caltech
Rebecca Wipfler – Ph.D student – Biologist – Caltech
Sergio Parra – Ph.D student – Biologist – Caltech
Manet Peña Salinas – Ph.D student – Oceanography, microbiology – UABC

Figure 5. Leg 3 science party taken by ROV *SuBastian* (photo credit: M. Naranjo).

Other remote participants:
David Clague - MBARI
Jennifer Paduan - MBARI

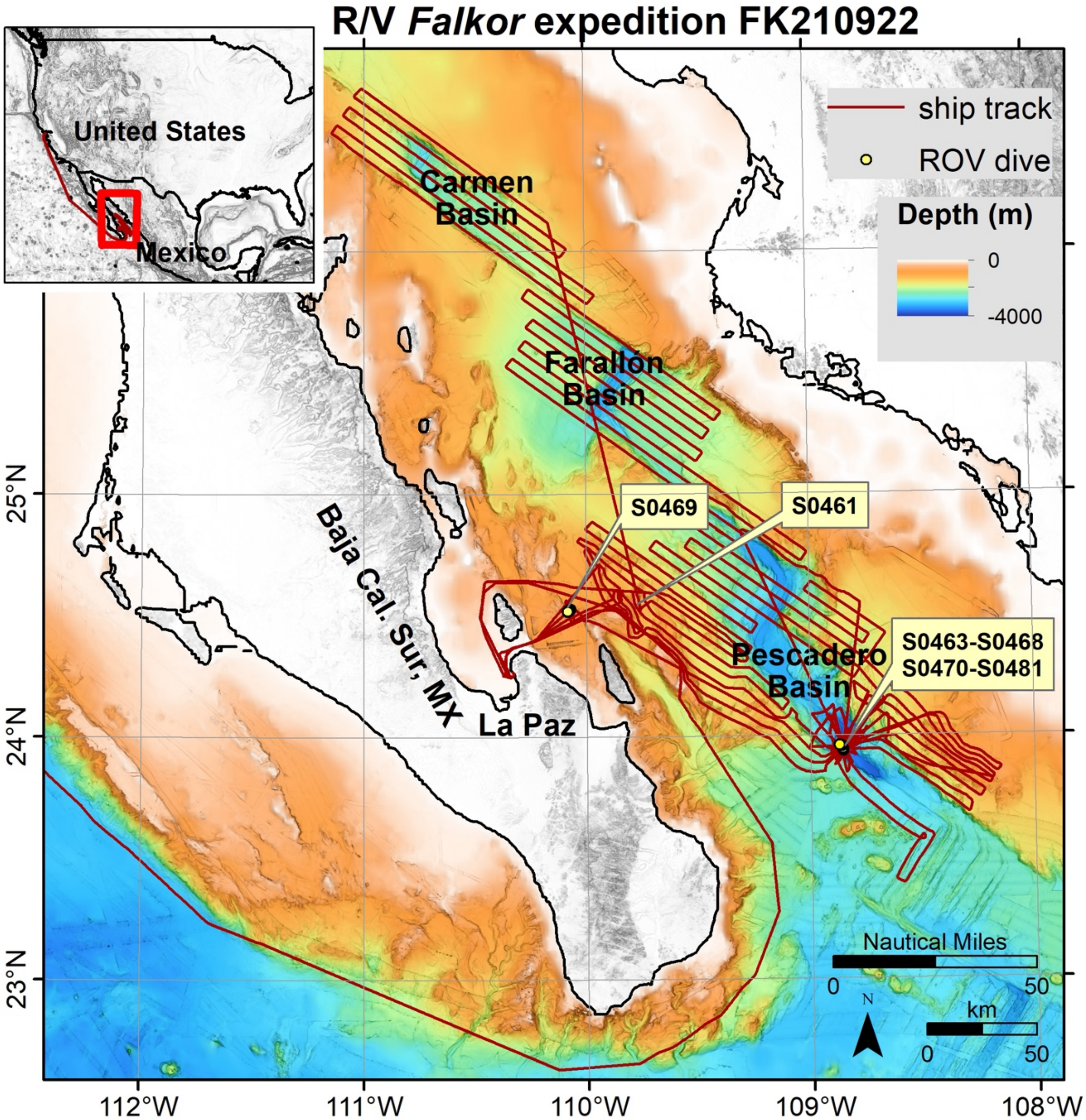

Figure 6. Map showing the navigation track of the R/V *Falkor* on the FK210922 expedition. Inset map: the transit from the San Francisco Bay to the southern Gulf of California. Main map: the end of the transit south to La Paz, and the three legs while the ship mapped and tended the ROV dives. ROV dive locations are indicated. Bathymetry shown is from a grid made with the Global Multi-Resolution Topography Data Synthesis (GMRT) mapping tool at https://www.gmrt.org.

2. FK210922 Shipboard Activities

2.1. FK210922 Event Synopsis

The ship track for the entire expedition FK210922 is shown in **Figure 6**. Daily events are listed below, together with links to the ROV dive videos.

24 September R/V *Falkor* departs Vallejo, CA
27 September Science party for Leg 1 into isolation in La Paz, Mexico
29 September Ship arrives Pichilingue, La Paz, Mexico

Leg 1: Tectonics
7 October Ship's permit granted and R/V *Falkor* departs Pichilingue.
8 October ROV test dive S0461 near La Paz.
https://www.youtube.com/watch?v=rG0SFojO83I&list=PLaSdYa-0SlqXOv7yuGMPnoN6msNK-XBqA&index=3&t=41s
Multibeam mapping of Carmen, Farallón and Pescadero Basins commences.
17 October Leg 1 science party set ashore with small boat transfer.

Leg 2: Vent Field Heat Flow
18 October Science party boards in Pichilingue and ship departs for Pescadero Basin.
19 October ROV dive S0462 (aborted after an hour)
ROV dive S0463 – JaichMaa 'ja'ag
https://youtu.be/QVhjazt2w-k
https://youtu.be/Woa7hdFxbmI
20 October ROV dive S0464 - JaichMaa 'ja'ag
https://www.youtube.com/watch?v=QVhjazt2w-k
https://www.youtube.com/watch?v=a89jnR_Ise0
https://www.youtube.com/watch?v=Woa7hdFxbmI
21 October ROV dive S0465 –JaichMaa 'ja'ag
https://www.youtube.com/watch?v=u4geLfBq8Gc
22 October ROV dive S0466 - JaichMaa 'ja'ag
https://www.youtube.com/watch?v=7_pcCaw0pmE
23 October ROV dive S0467 – Auka
https://www.youtube.com/watch?v=19Ka-qJKLQ8
24 October ROV dive S0468 – JaichMaa 'ja'ag
https://www.youtube.com/watch?v=84KkWMAajjk
https://www.youtube.com/watch?v=d1A5SLNuOD4
https://youtu.be/jmcpEWSWE2c
25 October ROV dive S0469 – Scarps offshore of Isla Espiritu Santo
https://www.youtube.com/watch?v=T6Q49CDUL_c
Leg 2 science party disembarks

Leg 3: Vent Field Ecology, Biology, and Microbiology
27 October Leg 3 science party boards in Pichilingue.
28 October Ship departs for Pescadero Basin. Multibeam mapping on transit.

29 October	ROV dive S0470 – Auka – sampling at Matterhorn https://www.youtube.com/watch?v=gtlOPY21jPU https://youtu.be/X1Y7U_Q158k
30 October	ROV dive S0471 - Auka – Z vent https://www.youtube.com/watch?v=ZCOd96ybvtU
31 October	ROV dive S0472 – Auka - Z vent https://youtu.be/GZmXsuT2AAI
1 November	ROV dive S0473 - Maijia awai mound https://youtu.be/SGxLb0YsZo0
2 November	ROV dive S0474 – Auka – Diane's vent https://youtu.be/gi4u9Ae9zPw https://youtu.be/7PSmU1tb99E
3 November	ROV dive S0475 - Auka – P vent https://youtu.be/1zn6NNU1Mck https://youtu.be/kz_j_LrLuOU
4 November	ROV dive S0476 – JaichMaa 'ja'ag – near Tay Ujaa https://www.youtube.com/watch?v=38g5yh_iRSQ https://www.youtube.com/watch?v=77FY5Y1CtPA
5 November	ROV dive S0477 – Auka https://www.youtube.com/watch?v=BK0kv8xtBvQ
6 November	ROV dive S0478 - JaichMaa 'ja'ag vent field Little Sister https://youtu.be/Zs7wVQGGyxI
7 November	ROV dive S0479 – south of JaichMaa 'ja'ag mounds and pockmark https://www.youtube.com/watch?v=VtrfuLAkPY8
8 November	ROV dive S0480 – Auka – Matterhorn https://youtu.be/qpQ3qG1RPRs https://youtu.be/w3s8A2WLqTg
9 November	ROV dive S0481 – JaichMaa 'ja'ag https://www.youtube.com/watch?v=gBGsrFa0uB4
10 November	Leg 3 participants disembark in Pichilingue. Ship sails to Spain, after a stop in Panama.

2.2. Note on Vent Field and Feature Names

Informal names or letters have been adopted for convenience for some vent field features, however, we continue the tradition started with the discovery of the Auka Vent Field in 2015 of using formal names derived from the languages of people indigenous to the adjacent area. Many of these ancient languages are poorly known and are dying out. It seems appropriate to use the local languages particularly since if our understanding of these vent fields is correct, they are also ancient and in a state of decline. It seems highly likely that vent fields have been active for at least as long as the ancient languages have been spoken. The name Auka was a greeting common to four distinct indigenous languages, which is appropriate as the Auka Vent Field is colonized by fauna derived from animals indigenous to the East Pacific Rise, Guaymas Basin, hydrothermal seeps, and pelagic environments.

The names for features described in this report derive from the language of the Kiliwa ethnic group that continues to live in northern Baja California. The names are approximate translations of descriptions of various features or informal names used during the cruise. The newly discovered vent field was named JaichMaa 'ja'ag, roughly Liquid Metal, in reference to the reflection of light off the interface of hydrothermal fluid ponded in the roof of a cavern and the reflections of coarsely crystalline calcite that covered the cavern walls. The southern-most of the four large mounds at the center of JaichMaa 'ja'ag is topped with lush colonies of *Oasisia* tube worms and was named Weey 'kual (Red Hill). The largest, central mound was the site of a cavern in 2018, which has since partially collapsed, that gives the vent field its name and is called Tay Ujaa (Big Cave). The pair of adjacent mounds at the north end of the vent field are named Muutp Mpáan (Little Sister) for the younger, more active hill to the NW and Tay Mpáan (Big Sister) or the larger and older of the mounds to the SE. Two small adjacent round holes that show up distinctly on sonar are called Juwak Yuum (Two Eyes). A hill to the northwest of the Auka vent field where the first basaltic rocks from Southern Pescadero Basin were collected has been named Uja' kunñjeeg Weey (Black rock Hill).

A feature observed for the first time during this expedition (dive S0473) is an actively venting mound that lies between the Auka and JaichMaa ‘ja’ag. It has been named Maijia awi, after the divine serpent of water in the creation myth of the Kumiai people, one of the Yuman indigenous groups of Baja California (**Figure 7**). Another is the southern-most mound of JaichMaa ‘ja’ag (dive S0479), which is to be named ‘Melsuu’, after the word for “blue” in the Kiliwa language, referring to the dense population of iridescent blue scale worms found in the JaichMaa ‘ja’ag vent field (**Figure 8**).

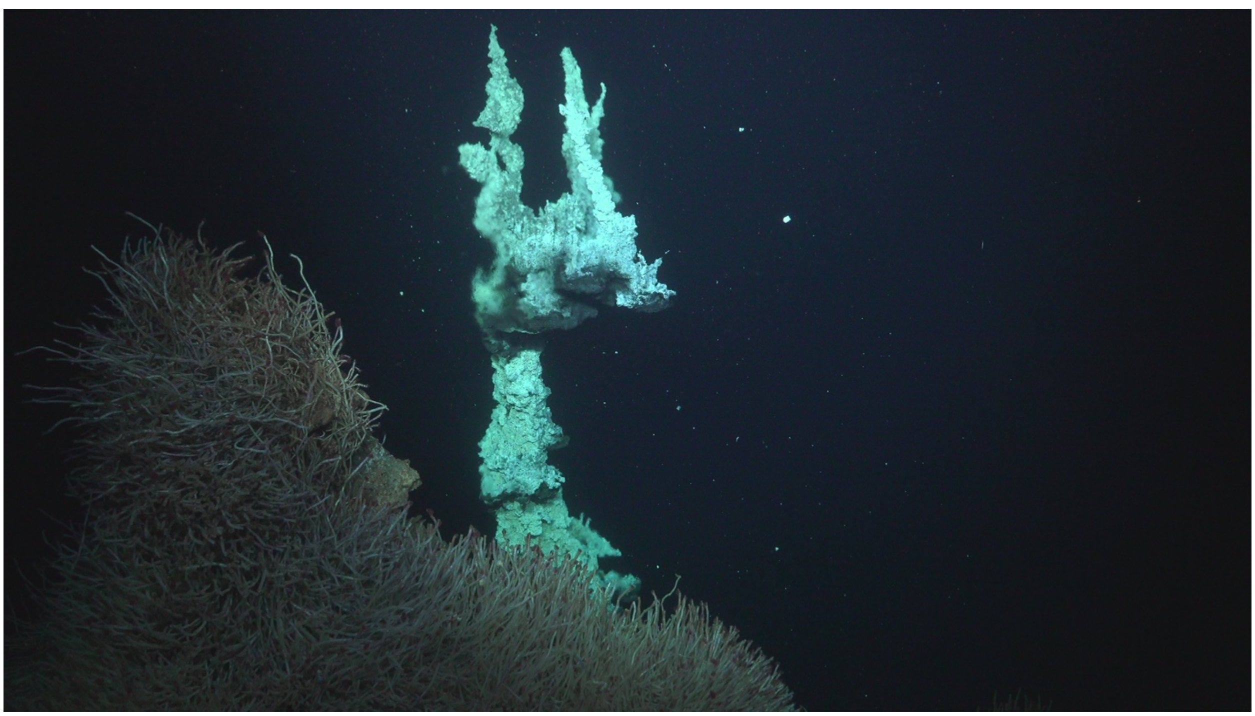

Figure 7. ROV framegrab of delicate active flange reminiscent of a serpent on Maijia awi, dive S0473.

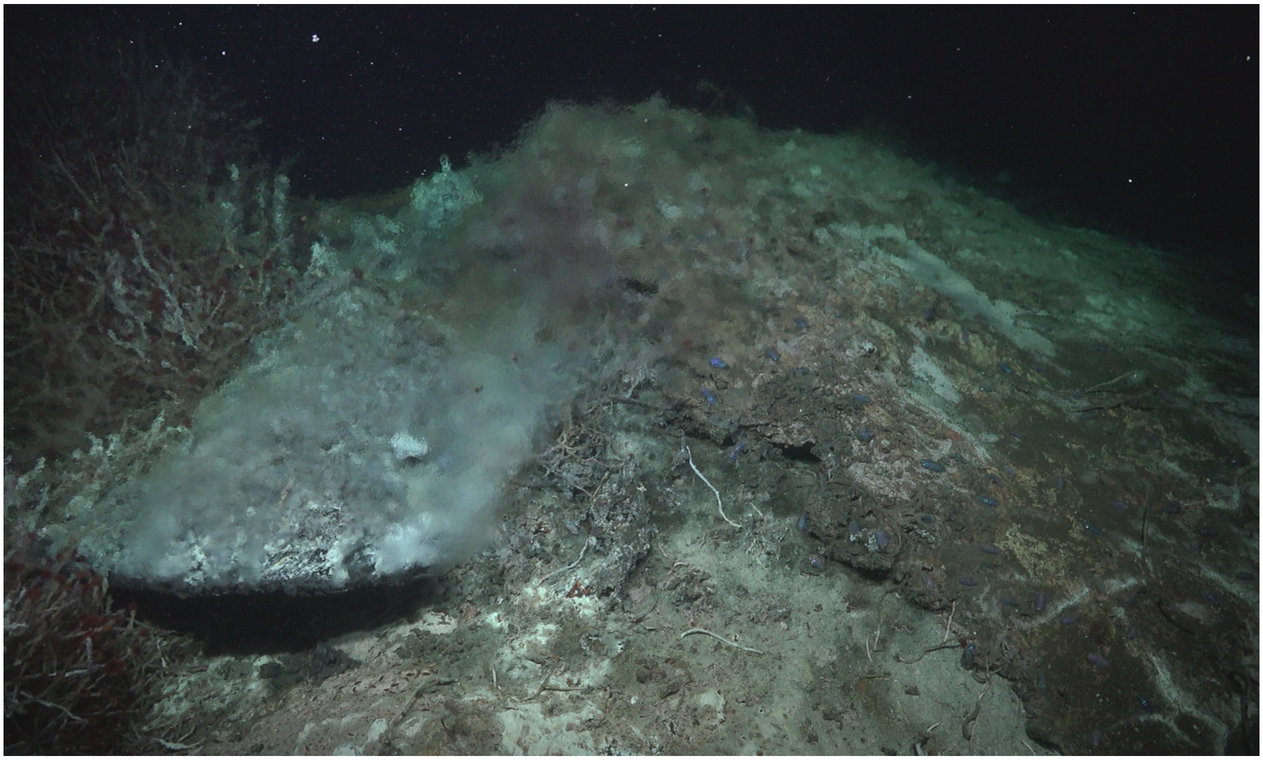

Figure 8. ROV framegrab of hydrothermal mound at Melsuu, explored on dive S0479, with some iridescent blue scale worms visible just right of center.

2.3. Shipboard Outreach and Education - Coordinated by Monika Naranjo and Hannah Nolan, SOI

All ROV dives were live streamed to YouTube and will be available in perpetuity to the public: https://www.youtube.com/playlist?list=PLJGVqQI3okzbYEirEgtUL7kcVEbv6l4mG (**Figure 9**).

Cruise blogs (13 posts) can be viewed here: https://schmidtocean.org/cruise/interdisciplinary-investigation-of-the-pescadero-basin/cruise-log/

Thirteen Ship-to-Shore connections took place during the expedition, engaging 1059 people.

A series of videos was created (find a complete list at https://schmidtocean.org/cruise/interdisciplinary-investigation-of-the-pescadero-basin/cruise-log/)

Microorganism Champions: https://schmidtocean.org/cruise-log-post/science-story-microorganism-champions-video-update/

Heat Flow and Vent Chemistry: https://schmidtocean.org/cruise-log-post/heat-flow-and-vent-chemistry-video-update/

Artist-at-Sea – Conversing With Rocks: https://schmidtocean.org/cruise-log-post/artist-at-sea-conversing-with-rocks-video-update/

Marine Geologist: https://schmidtocean.org/cruise-log-post/science-story-marine-geologist-video-update/

Tectonics and Mapping: https://schmidtocean.org/cruise-log-post/tectonics-and-mapping-video-update/

Understanding Mud: https://www.youtube.com/watch?v=oGwIolDmJeM

Press Release – SCIENTISTS DISCOVER NEW HYDROTHERMAL VENTS AND POSSIBLE NEW SPECIES IN THE GULF OF CALIFORNIA: https://schmidtocean.org/scientists-discover-new-hydrothermal-vents-and-possible-new-species-in-the-gulf-of-california/

Galleries of SOI press release visuals:

https://schmidtocean.photoshelter.com/galleries/C0000HRWFfu1r_rE/G0000TE.HVgK8150/PR-FK210922-Interdisciplinary-Investigation-of-the-Pescadero-Basin

https://schmidtocean.org/collection/interdisciplinary-investigation-of-the-pescadero-basin/

30-day Preliminary Cruise Report, used in the SOI Annual Report: https://schmidtocean.org/wp-content/uploads/PescaderoBasin-1.pdf

Links to ROV footage and a complete list of news coverage: https://schmidtocean.org/cruise/interdisciplinary-investigation-of-the-pescadero-basin/

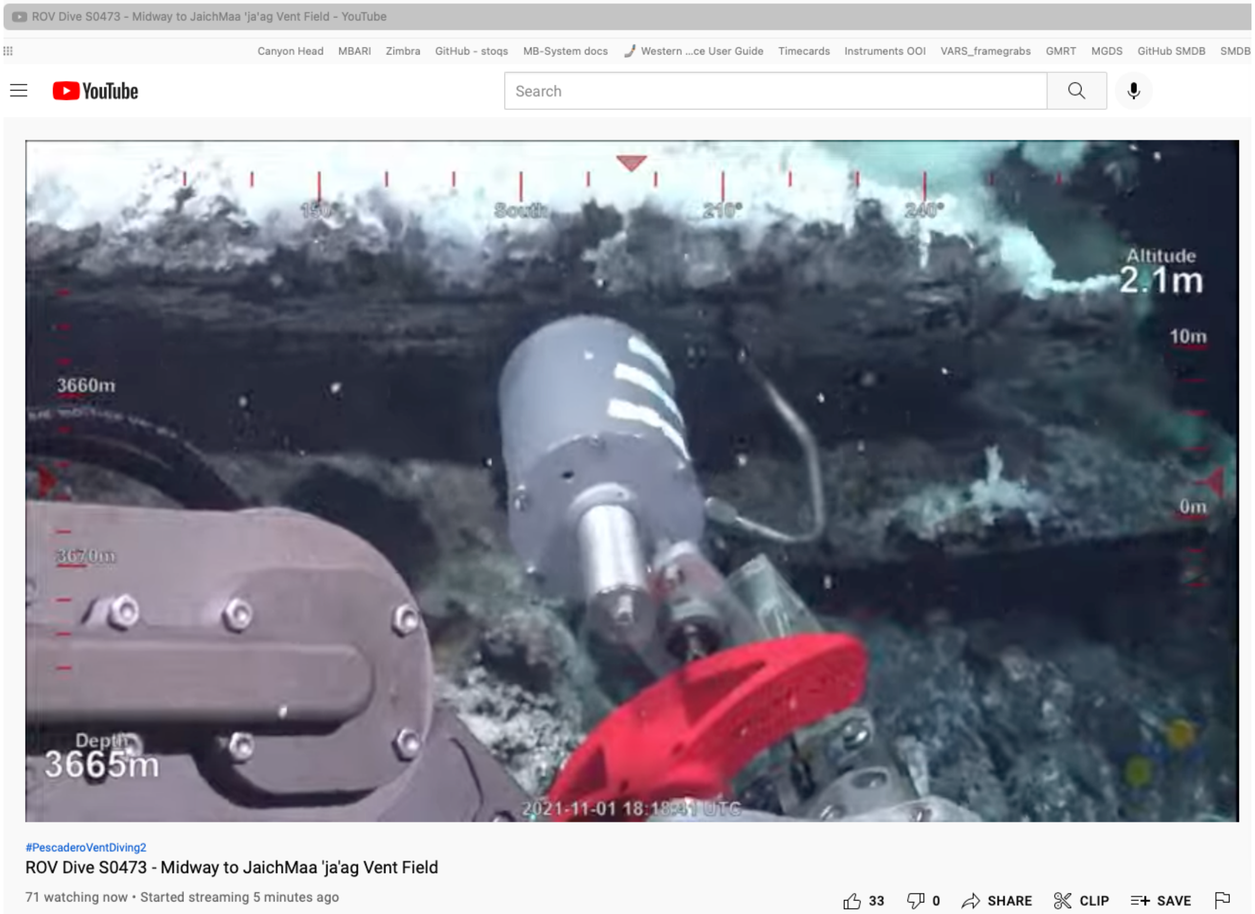

Figure 9. Screen grab taken November 1, 2021 from live video broadcast over YouTube of ROV *SuBastian* dive S0473, showing a fluid sample being taken at the Maijia awi mound (photo credit: J. Paduan).

2.4. Artist at Sea – Ale de la Puente

Ale de la Puente is an artist with a diverse background and continuum studies, including design, boatbuilding, navigation, astronomy, physics, and philosophy. She is known for her poetic and conceptual explorations of time and space across a wide field of mediums, ranging from installations and sculptures to drawings, photography, and video including art and science expeditions in the search of symbolic natural phenomena, how we signify them, and how we relate to the given meaning (**Figure 10**).

Figure 10. Artist at sea, Ale de la Puente, inspired by the variety of shapes, textures, and colors of the rock samples collected during Leg 1 (photo credit: M. Naranjo).

3. Data Archival

Raw and processed multibeam bathymetry data collected by R/V *Falkor* are archived at Rolling Deck to Repository and publicly available.

Raw and processed data collected by ROV *SuBastian* are publicly available at MGDS, including event documentation, navigation, imagery, CTD and heat flow data. The Heat Flow data base is https://www.marine-geo.org/tools/files/30947 and has DOI 10.26022/IEDA/330947.

ADCP data are curated and archived by University of Hawaii.

Benthic Invertebrate Specimens have been accessioned and are publicly available through the Scripps Institution of Oceangraphy's Benthic Invertebrate Collection. Data and metadata from animal specimen analysis is publicly available through the Scripps Institution of Oceanography's Benthic Invertebrate Collection.

Deep-sea anemone associated microbiome (describing a new chemosynthetic symbiosis between the sea anemone *Ostiactis pearseae* and intracellular bacteria) data is archived at NCBI.

You can search Nucleotide Accession Numbers here. Accession numbers are: MW148236, MS148237, MW148238, MW158740, MW165066, MW172213, MW172214 and MW172220, MW172221.

Processed sequence data, as well as representative sequences, of the newly discovered chemosynthetic anemone, *Ostiactis pearseae,* are available on the Dryad Digital Repository.

Complete genomes and Metagenome-assembled genomes of bacteria and archaea from Pescadero Basin can be found archived in NCBI.

Genome sequencing and assembly of the microbial community of sediments at Auka hydrothermal vent field in Pescadero Basin are also archived in NCBI.

Complete genomes and Metagenome-assembled genomes of bacteria and archaea from Pescadero Basin, including a new species of microbe are archived in NCBI.

4. Multibeam mapping (Legs 1, 2, and 3)

Mapping with the R/V *Falkor's* hull-mounted Kongberg EM302 and EM712 sonar systems was the focus of the first leg and continued on the second and third legs (**Figure 6**) to map the Carmen, Farallón, and Pescadero Basins, their margins, the Carmen, Atl, and Central Pescadero transform faults connecting these basins, as well as on a limited portion of the stretched continental margin of the Baja California microplate south of 25° N latitude (**Figure 11**). Bathymetry collected during FK210922 is shown in Figures 12 and 13, and the multibeam backscatter, also known as pseudosidescan, is shown in Figure 14. Unfortunately, the magnetometer was broken beyond repair at sea, so data that could have constrained the age and extent of creation of new seafloor in the extensional basins was not collected.

The seafloor mapping carried out during the combined R/V *Falkor's* 2018, 2019 and 2021 expeditions to the GoC covered an unprecedented area of nearly 20,000 km^2 across the largely unexplored Carmen, Farallón, Pescadero and Alarcón basins. The mapped area is equivalent to $1/8^{th}$ of the total surface area of the GoC, adding a significant contribution of mapping coverage to the GEBCO and Nippon Foundation collaborative project, which aims to facilitate the complete mapping of the global ocean floor by the year 2030. Bathymetric coverage collected on FK181031 contributed to the publications Vega-Ramirez et al. (2021) and Ramirez-Zerpa et al. (2022).

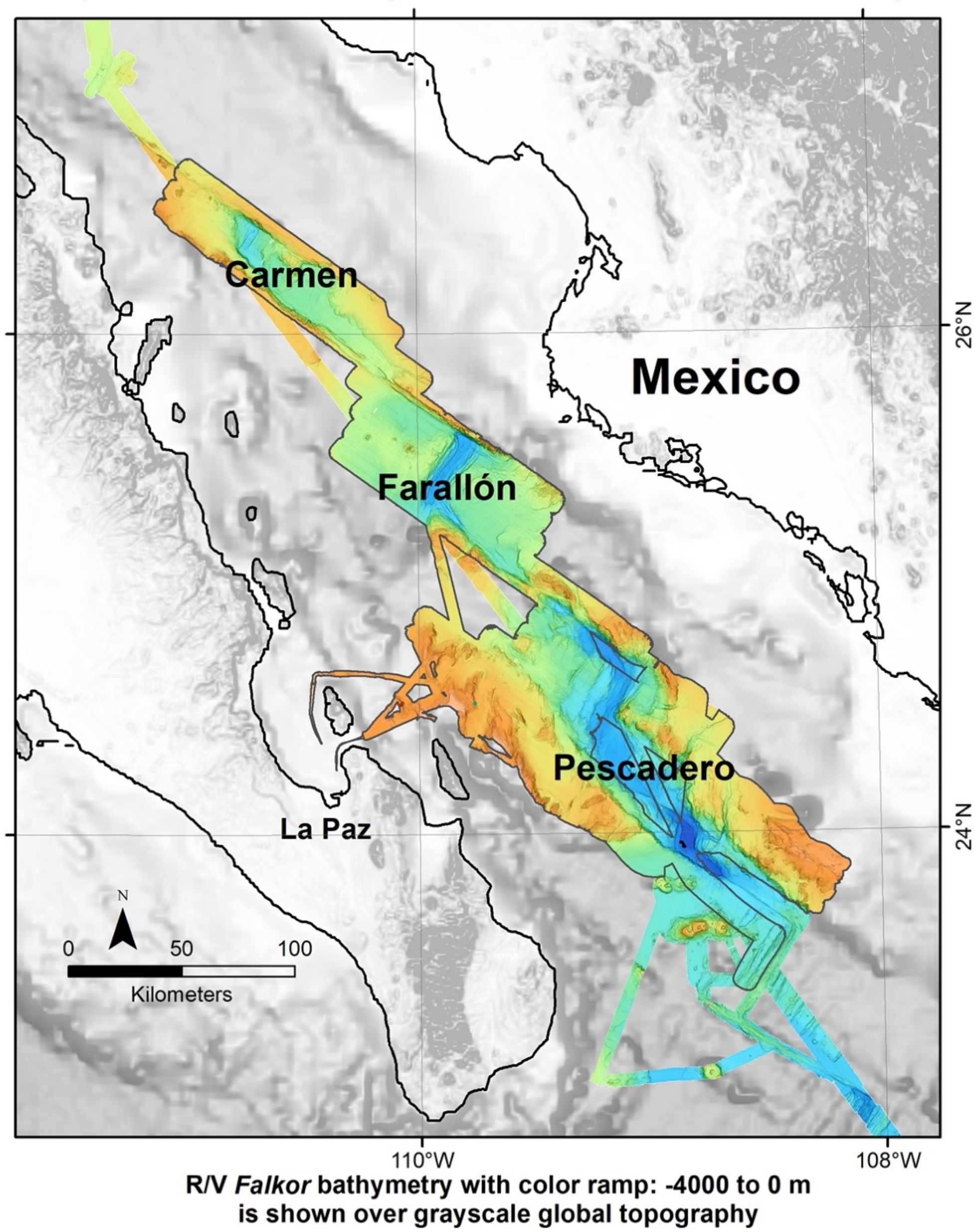

Figure 11. Map showing coverage collected by the multibeam sonars on the R/V *Falkor* in 2021 at 25 m resolution, outlined, over prior coverage collected by the *Falkor* (expeditions FK181031, FK190211 and FK190222) in the southern GoC, superimposed on global topography in grayscale. The color scheme for the *Falkor* data here and for the other maps in this report is the Haxby color scale from blue to orange, and here that color ramp is 4000 to 0 m depth. The Carmen, Farallón and Pescadero Basins are labeled.

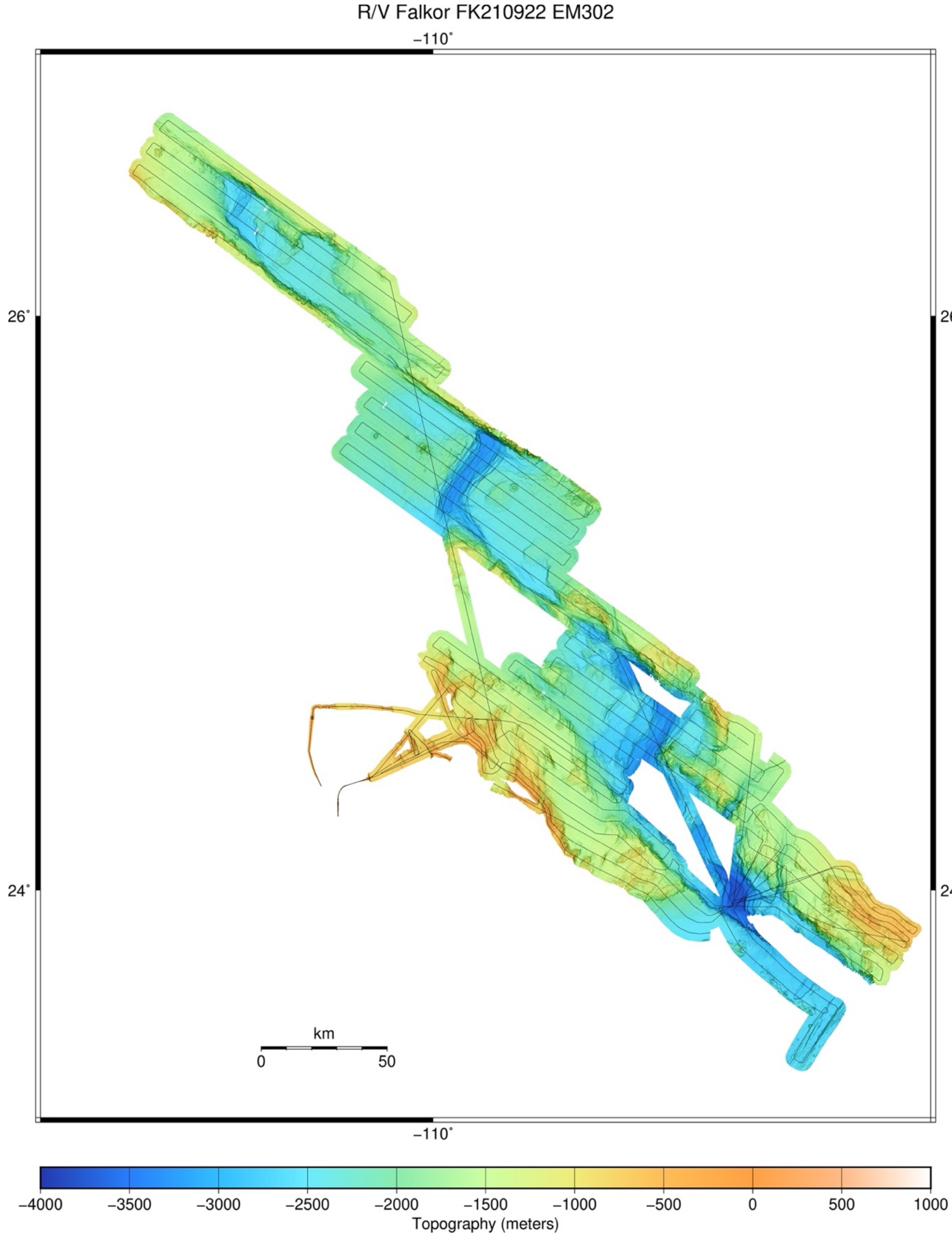

Figure 12. Map showing bathymetry collected on FK210922 with both of the EM302 and EM710 sonar systems. Grid resolution is 25 m and the image is shaded by slope. Track lines of the ship are superimposed.

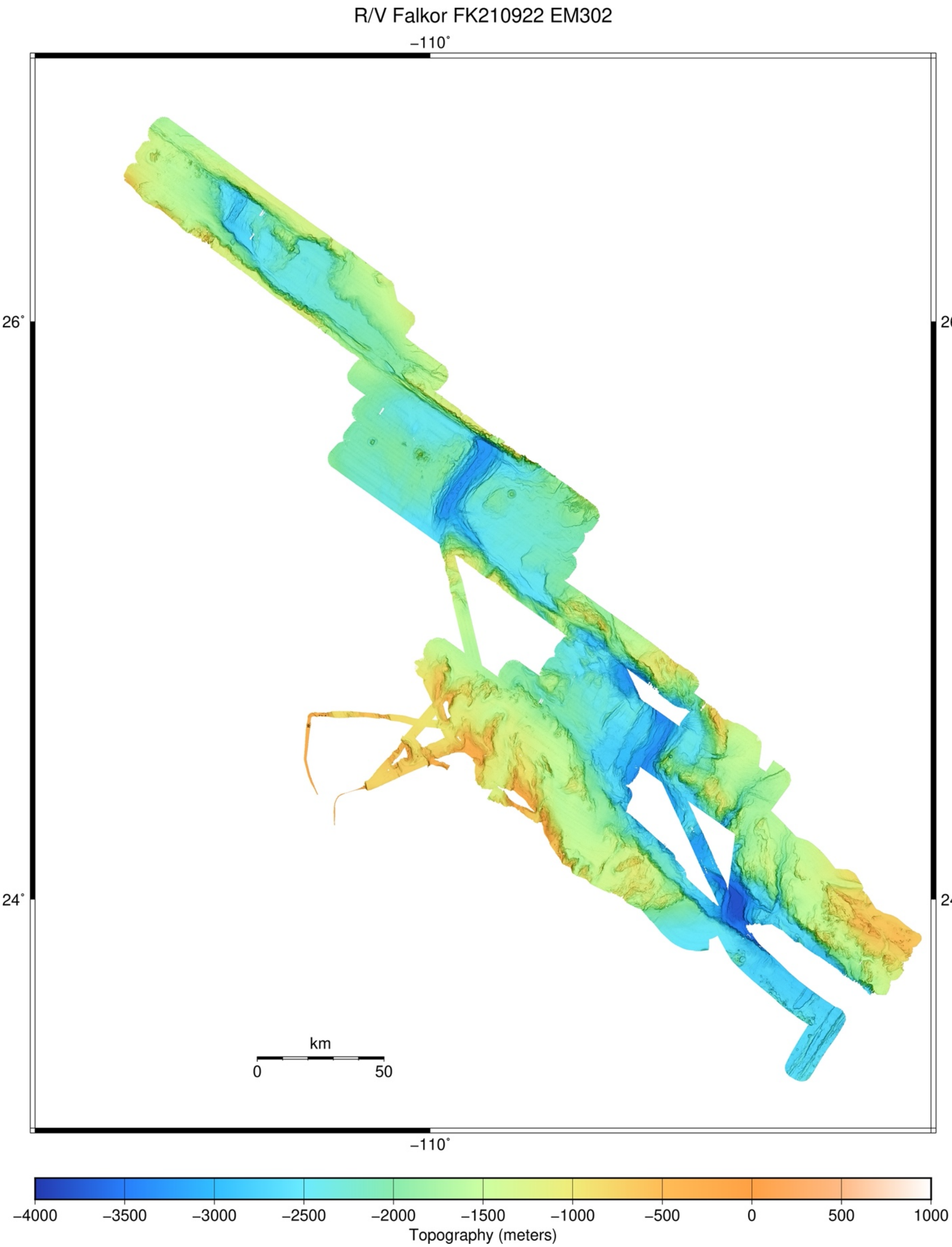

Figure 13. Map showing bathymetry collected on FK210922 with both of the EM302 and EM710 sonar systems. Grid resolution is 25 m and the image is shaded by slope.

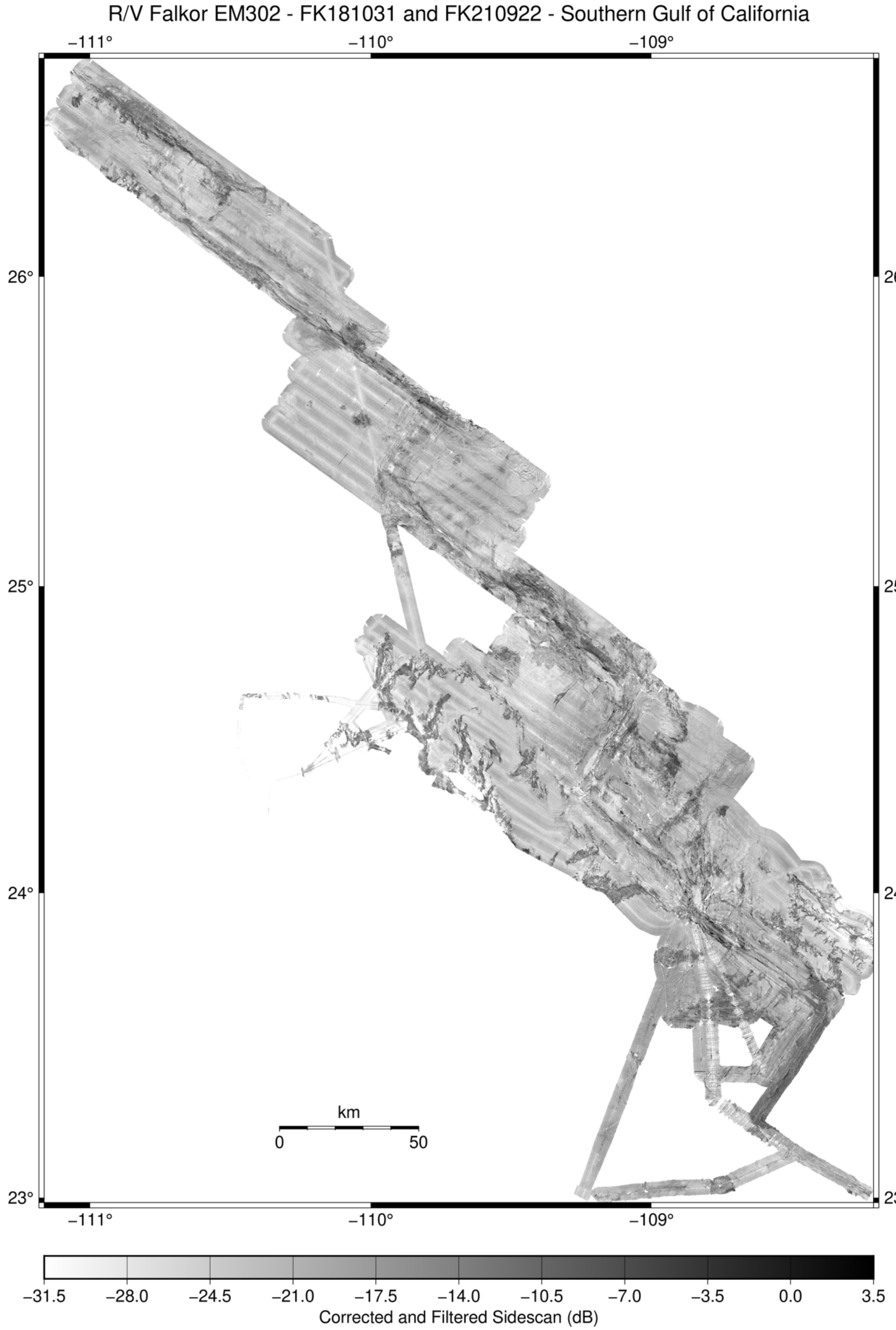

Figure 14. Multibeam backscatter from expedition FK210922 combined with that from FK181031. The backscatter has been corrected using an empirical amplitude-vs-grazing angle model and had a Gaussian smoothing filter applied. High amplitudes are shown dark.

Water column returns in the multibeam data revealed plumes of gas bubbles, inferred to be dominantly composed of methane similar to features elsewhere in the Gulf of California (e.g. Paull, et al., 2007; Berndt et al., 2016; Ondréas et al., 2018), emanating from the seafloor in 13 locations (**Table 1**).

Table 1. Locations of gas bubble plumes detected in the multibeam water column data.

Longitude	Latitude	Depth (m)	Comments
-110.099186	25.788063	-1592	CH4 plume: Farallon transform. The site is located on a fault-bounded ridge oriented subparallel to the Farallon transform.
-110.442057	26.195037	-2310	CH4 plume. On the footwall of a NW-dipping basin sidewall fault traversing the southernmost Carmen sub-basin.
-109.804462	25.547934		CH4 plume
-110.073089	25.614082	-2308	CH4 plume. Off-axis on the NW block of the Farallon spreading center
-110.173179	25.628843	-2102	CH4 plume. Off-axis on the NW block of the Farallon spreading center, SE of an uplifted hill, 3.4 km in diameter, probably formed by sill intrusion
-110.272616	25.579068	-2096	CH4 plume. Off-axis on the NW block of the Farallon spreading center, NW of an uplifted hill, 3.4 km in diameter, probably formed by sill intrusion
-109.761172	25.171095	-2404	CH4 plume: Atl transform, Site is located on the footwall of an east-dipping fault controlling the western margin of the plate boundary graben in the southern corner of the presently active Farallon spreading center
-109.664418	25.086574	-2431	CH4 plume: Atl transform, Site is located on the hanging wall of a secondary west-dipping fault controlling the eastern margin of the plate boundary graben in the southernmost corner of the Farallon sub basin
-109.636745	25.106115	-2536	CH4 plume: Atl transform, Site is located on the footwall of an east-dipping fault controlling the western margin of the plate boundary graben in the southernmost corner of the Farallon sub basin
-109.578466	25.011652	-1868	CH4 plume Atl transform. Suspicious mounds all around the plume site. Potential hydrothermal mounds?
-109.224889	24.675183	-2476	CH4 plume. Off-axis on the NW margin of the northern Pescadero basin. The site is located west of the basin's northern plate-boundary graben, and at the base of a basin sidewall fault traversing the northern Pescadero basin.
-109.007171	24.536723	-2398	CH4 plume. Off-axis on the SE margin of the northern Pescadero basin. The site is located on a fault bounded plateau in the SE corner of the basin.
-109.326734	24.527027	-2718	CH4 plume. Off-axis on the NW margin of the northern Pescadero basin, east of the Santa Cruz fault zone. The site is located at the base of a basin sidewall fault traversing the northern Pescadero basin.

5. ROV *SuBastian* dives (Legs 1, 2 and 3)

ROV *SuBastian* was configured for exploration and sampling (**Figure 15**). In addition to manipulators, bio-boxes and rock boxes, push cores, and a suction sampler, the ROV also carried a heat flow probe and, on some dives, Ti-major fluid samplers and/or gas-tight fluid samplers.

Figure 15. ROV *SuBastian* being recovered by the R/V *Falkor* (photo credit: R. Spelz).

5.1 ROV *SuBastian* Dive Locations

A test dive, S0461, was conducted on Leg one near Isla Cerralvo, just offshore as the ship sailed from La Paz to Pescadero Basin. On Leg 2, dives S0463 to S0468 were conducted at the hydrothermal vents in southern Pescadero Basin and S0469 on a series of fault blocks offshore of Isla Espiritu Santo as the ship sailed back to La Paz. On Leg 3, S0470 to S0480 were conducted in the southern Pescadero Basin. The dives near Isla Cerralvo and Isla Espiritu Santo are summarized in **Figure 16**. The dives at the vents in the southern Pescadero Basin are summarized in **Figure 17.** Dive tracks are shown on the AUV-derived bathymetric maps discussed the following sections of this report. Offsets between the ROV USBL navigation and the AUV bathymetry were on the order of 10 to 35 m.

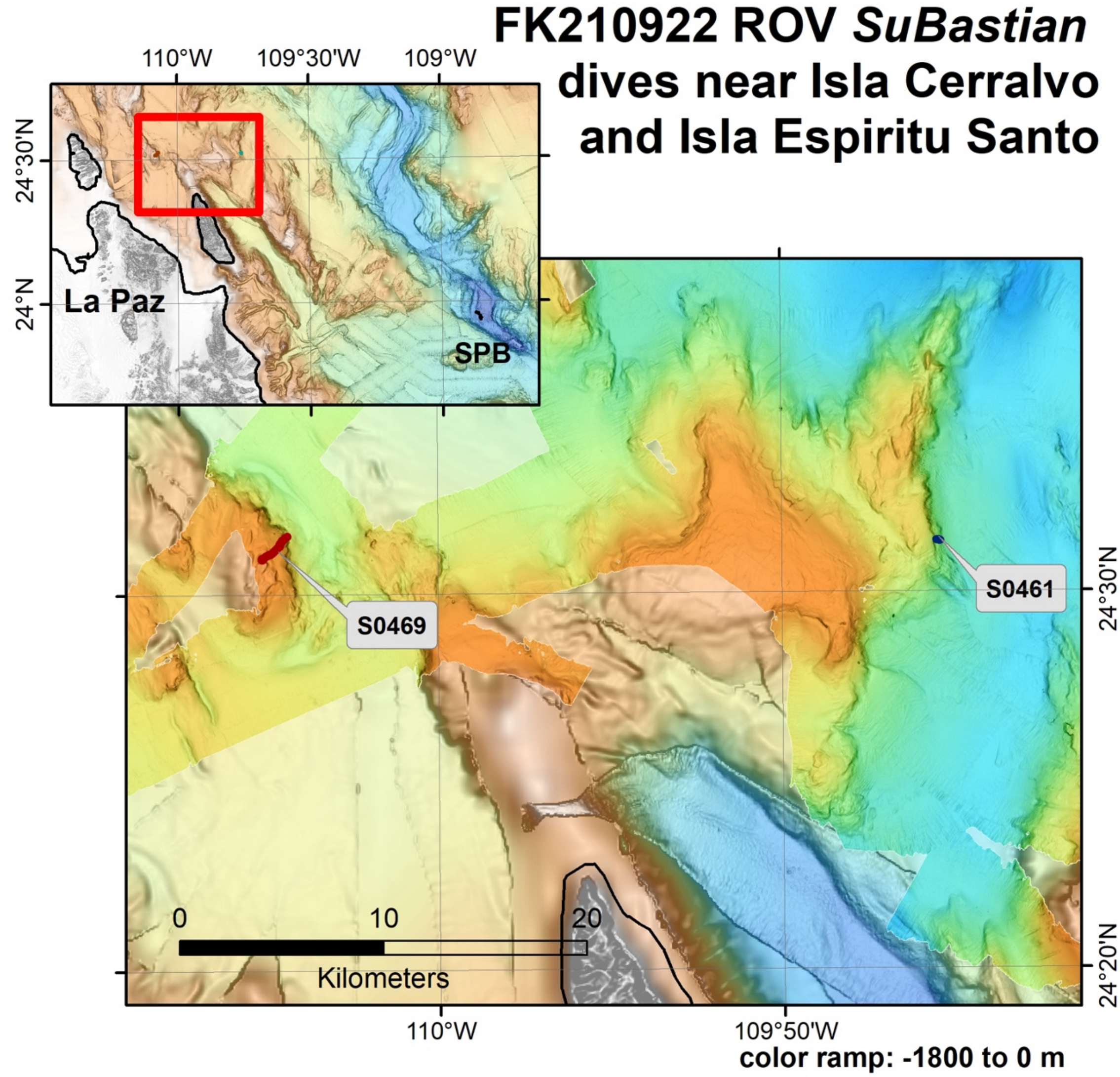

Figure 16. Dive tracks of the 2 ROV *SuBastian* dives conducted near Isla Cerralvo and Isla Espiritu Santo. Bathymetry is from FK210922 at 25 m resolution superimposed over a GMRT synthesis grid at 50 m resolution. The color ramp, blue to orange, is 1800 to 0 m depth.

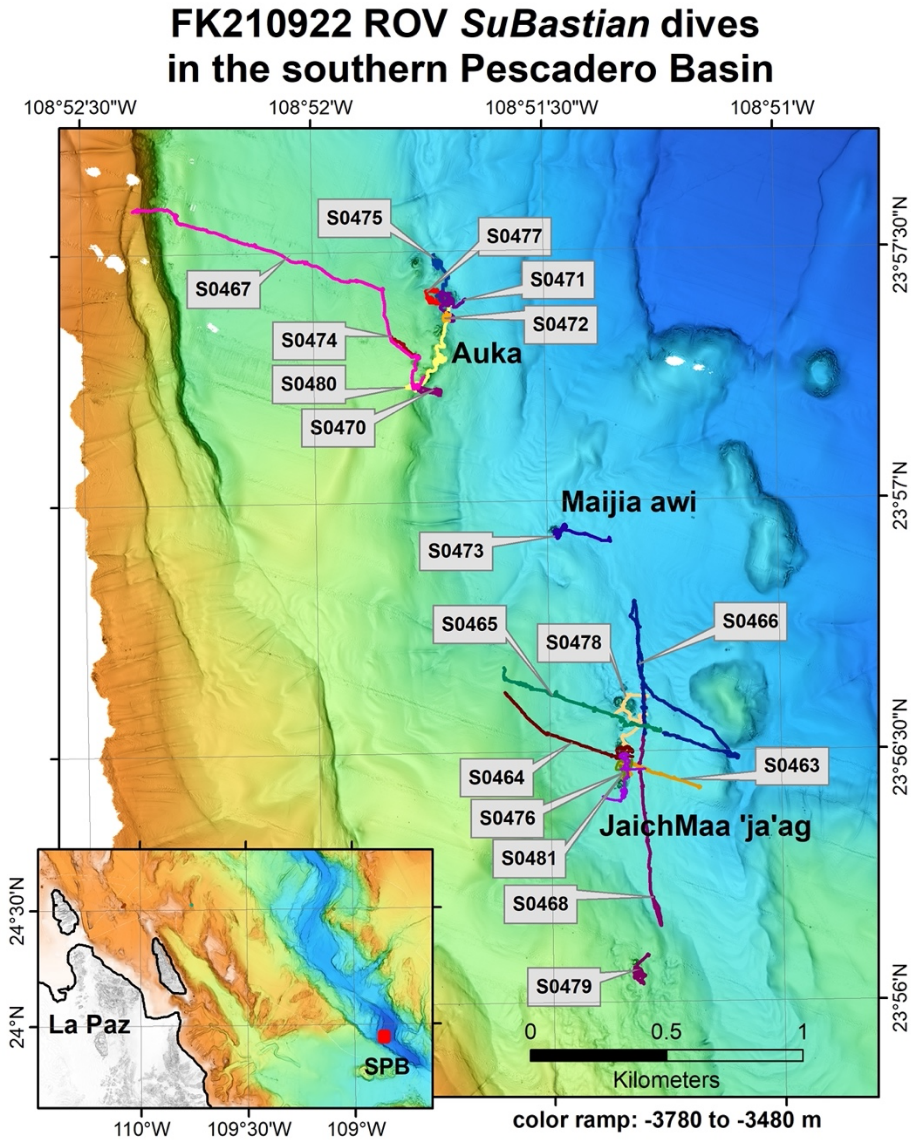

Figure 17. Dive tracks of the 18 ROV *SuBastian* dives conducted at the vent fields in the southern Pescadero Basin. The Auka and JaichMaa ‘ja’ag vent fields and the Maijia awi mound between them are labeled. Bathymetry is Mapping AUV data at 1-m resolution. The color ramp, blue to orange, is 3780 to 3480 m depth.

5.2. Dive by Dive Details for S0461 to S0481

ROV Dive S0461
Dive Location: Offshore of Isla Cerralvo
Dive Summary: Dive to 900 m near Isla Cerralvo to collect push cores and rock samples.

Start of dive: 2021-10-08 16:17:53
End of Dive: 2021-10-08 19:06:43
Max depth: 996.3 m

ROV video feeds: https://youtu.be/QVhjazt2w-k
https://youtu.be/Woa7hdFxbmI

Samples: 2 pushcores, 3 rocks **(Figure 18)**.

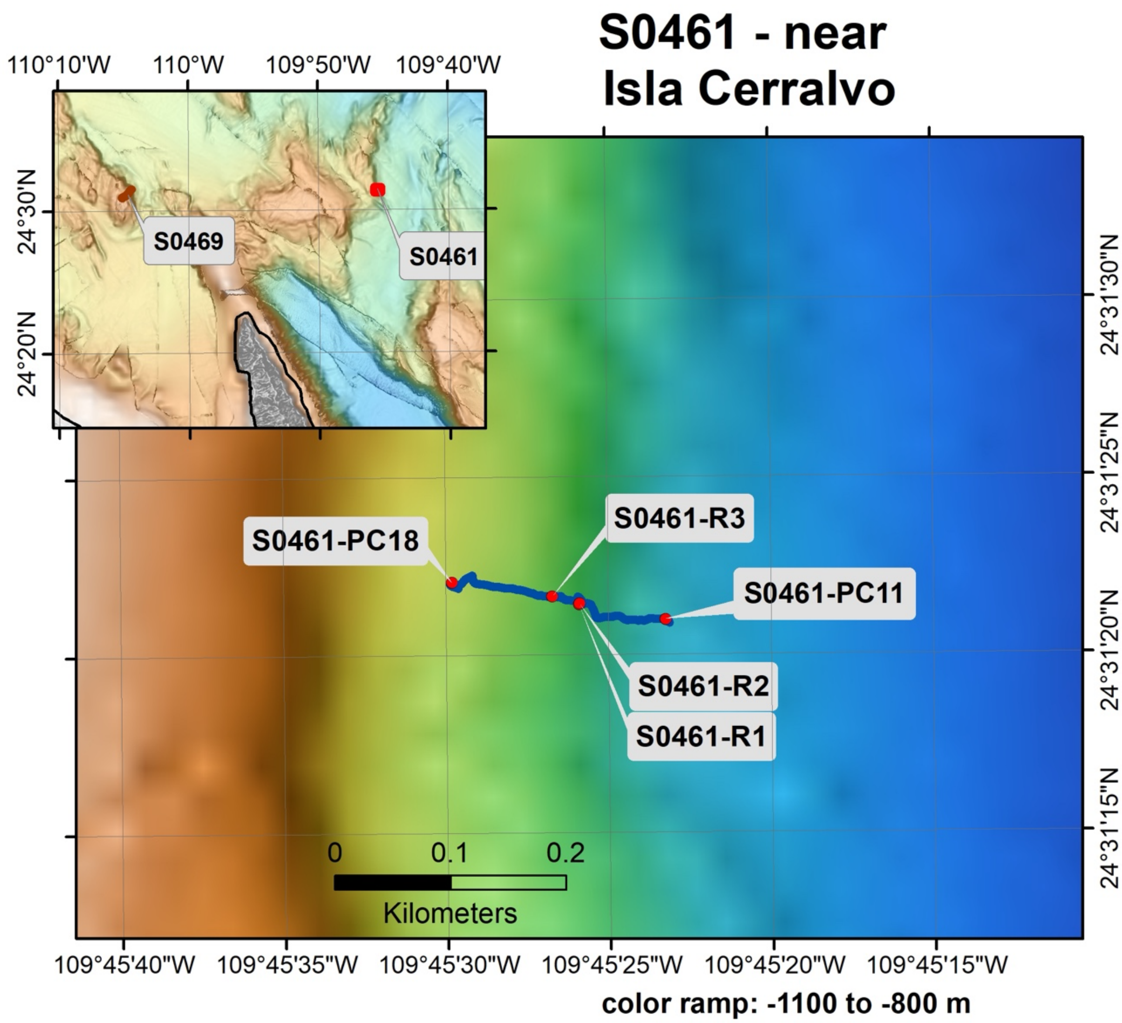

Figure 18. Map of ROV *SuBastian* dive S0461 on a ridge near Isla Cerralvo. Dive track is blue line; samples are red dots. Bathymetry was collected on FK210922 and is gridded at 25 m resolution. Color ramp is blue to orange, 1100 to 800 m depth.

ROV dive S0462
Aborted after about an hour in the water.

ROV Dive S0463
Dive Location: JaichMaa 'ja'ag Vent Field

Dive Summary: The JaichMaa 'ja'ag Vent Field consists of four large and several small hydrothermal edifices aligned roughly north-south and spanning a 400 m distance. The large edifices are up to 50 m across and 22 m high. The primary objective of this dive was to collect heat flow data using the heat flow probe on transects across the vent field. The lateral extent of the heat flow transects depended on how rapidly heat flow approached background levels away from the vents, typically less than 500 m. Secondary goals included collecting hydrothermal vent fluid samples at selected vents using both major and gas tight samplers, collecting push cores, collecting rocks, and collecting Niskin bottle samples of ambient water.

Start of dive: 2021-10-19 15:40:06
End of Dive: 2021-10-20 02:53:53
Max depth: 3673.3 m

ROV dive video feeds: https://www.youtube.com/watch?v=QVhjazt2w-k
https://www.youtube.com/watch?v=a89jnR_Ise0
https://www.youtube.com/watch?v=Woa7hdFxbmI

Samples: 6 heat-flow measurements, 1 pushcore, 1 Ti Major sample of bottom seawater for testing and background end member corrections (**Figure 19**).

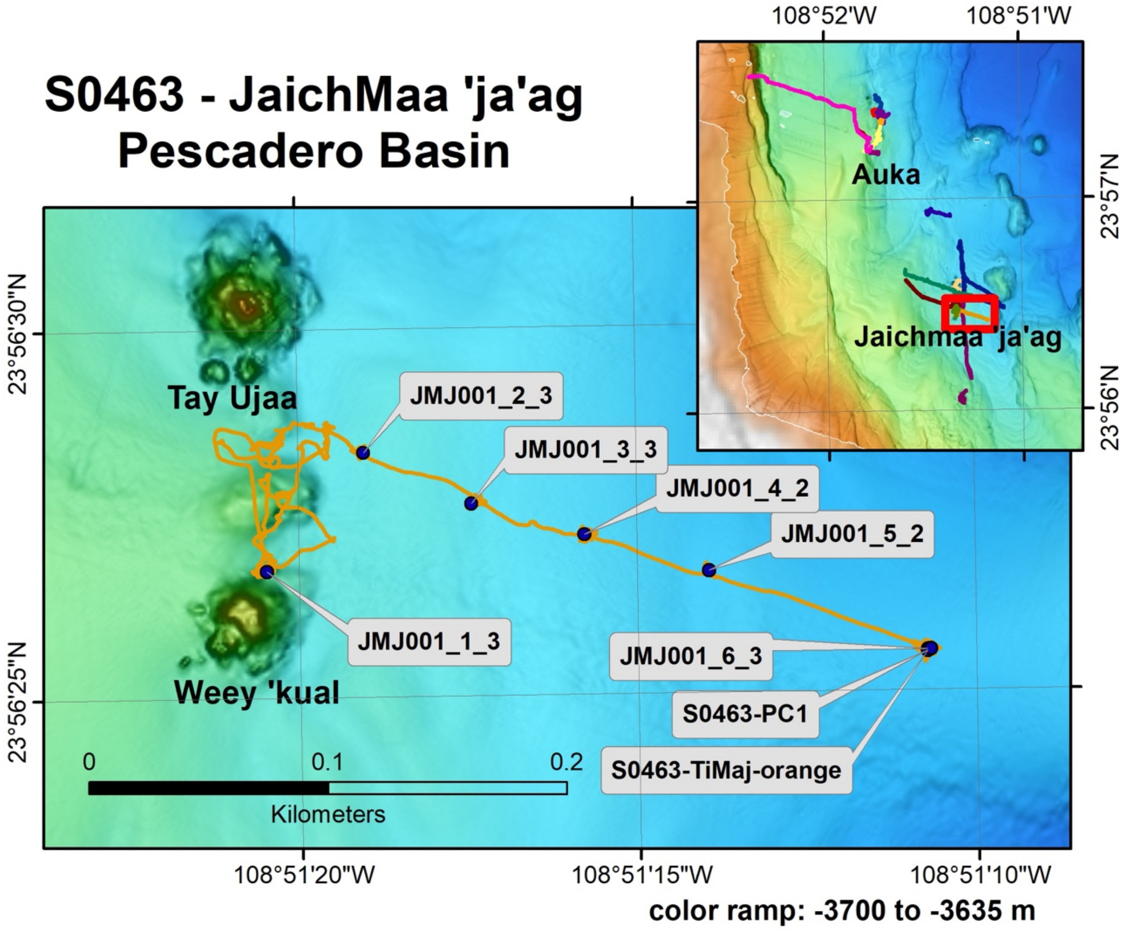

Figure 19. Map of ROV *SuBastian* dive S0462 at the JaichMaa ‘ja’ag vent field. Dive track is gold line; samples are blue dots. Heat flow measurements are numbered like “JMJ_001_*”. Bathymetry is Mapping AUV data at 1-m resolution. The color ramp, blue to orange, is 3700 to 3635 m depth.

ROV dive S0464
Dive Location: JaichMaa 'ja'ag Vent Field
Dive Summary: The JaichMaa 'ja'ag Vent Field consists of four large and several small hydrothermal edifices aligned roughly north-south and spanning a 400 m distance. The large edifices are up to 50 m across and 22 m high. The primary objectives of this dive were (1) to collect vent fluid samples at two sites ("cave with ponded fluid", "marker 5 vent") and (2) to continue collecting heat flow data using the heat flow probe on transects across the vent field. The lateral extent of the heat flow transects depends on how rapidly heat flow reduces toward background levels away from the vents - this distance is unlikely to exceed 500 m. A secondary goal was to collect push cores of sediment near and far from the vents.

Start of dive: 2021-10-20 13:30:35
End of Dive: 2021-10-21 00:56:31
Max depth: 3676.2 m

ROV dive video feeds: https://www.youtube.com/watch?v=QVhjazt2w-k
https://www.youtube.com/watch?v=a89jnR_Ise0
https://www.youtube.com/watch?v=Woa7hdFxbmI

Samples: 7 heat-flow measurements, 1 pushcore, 3 fluid samples, 1 temperature (**Figure 20**).

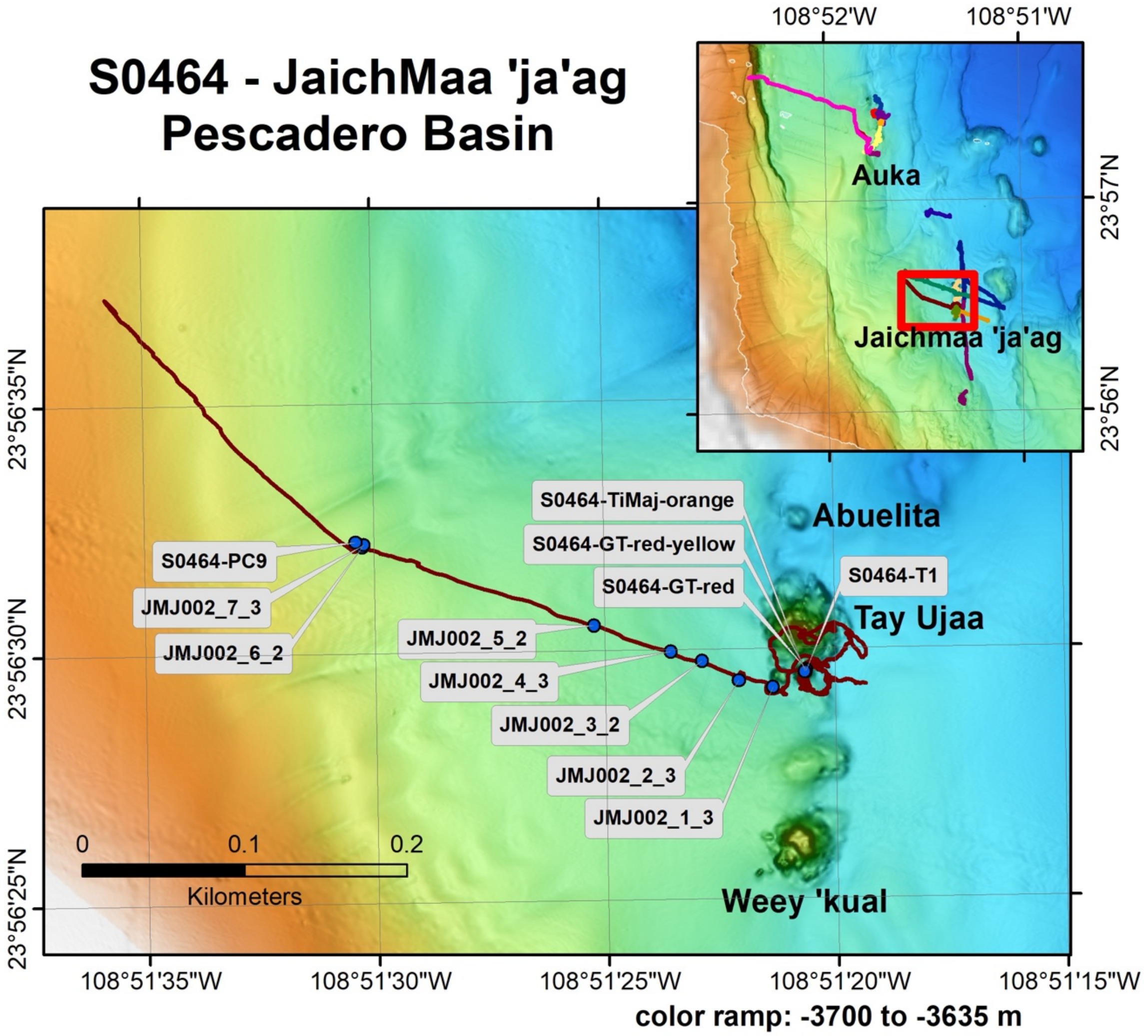

Figure 20. Map of ROV *SuBastian* dive S0464 at the JaichMaa 'ja'ag vent field. Dive track is brown line; samples are blue dots. Heat flow measurements are numbered like "JMJ_002_*". Bathymetry is Mapping AUV data at 1-m resolution. The color ramp, blue to orange, is 3700 to 3635 m depth.

ROV dive S0465
Dive Location: JaichMaa 'ja'ag Vent Field
Dive Summary: The JaichMaa 'ja'ag Vent Field consists of four large and several small hydrothermal edifices aligned roughly north-south and spanning a 400 m distance. The large edifices are up to 50 m across and 22 m high. The primary objective of this dive was to continue collecting heat flow data using the heat flow probe on transects across the vent field. A secondary goal was to collect push cores of sediment near and far from the vents. The on-bottom location is 550 m to the west of the northern pair of edifices. This location is on an AUV subbottom profile track, and the dive begins with a heat flow transect working towards the vents along the subbottom track.

Start of Dive: 2021-10-21 12:59:00
End of Dive: 2021-10-21 23:30:11
Max Depth: 3676.0 m

ROV dive video feed: https://www.youtube.com/watch?v=u4geLfBq8Gc

Samples: 15 heat-flow measurements, 2 pushcores (**Figure 21**).

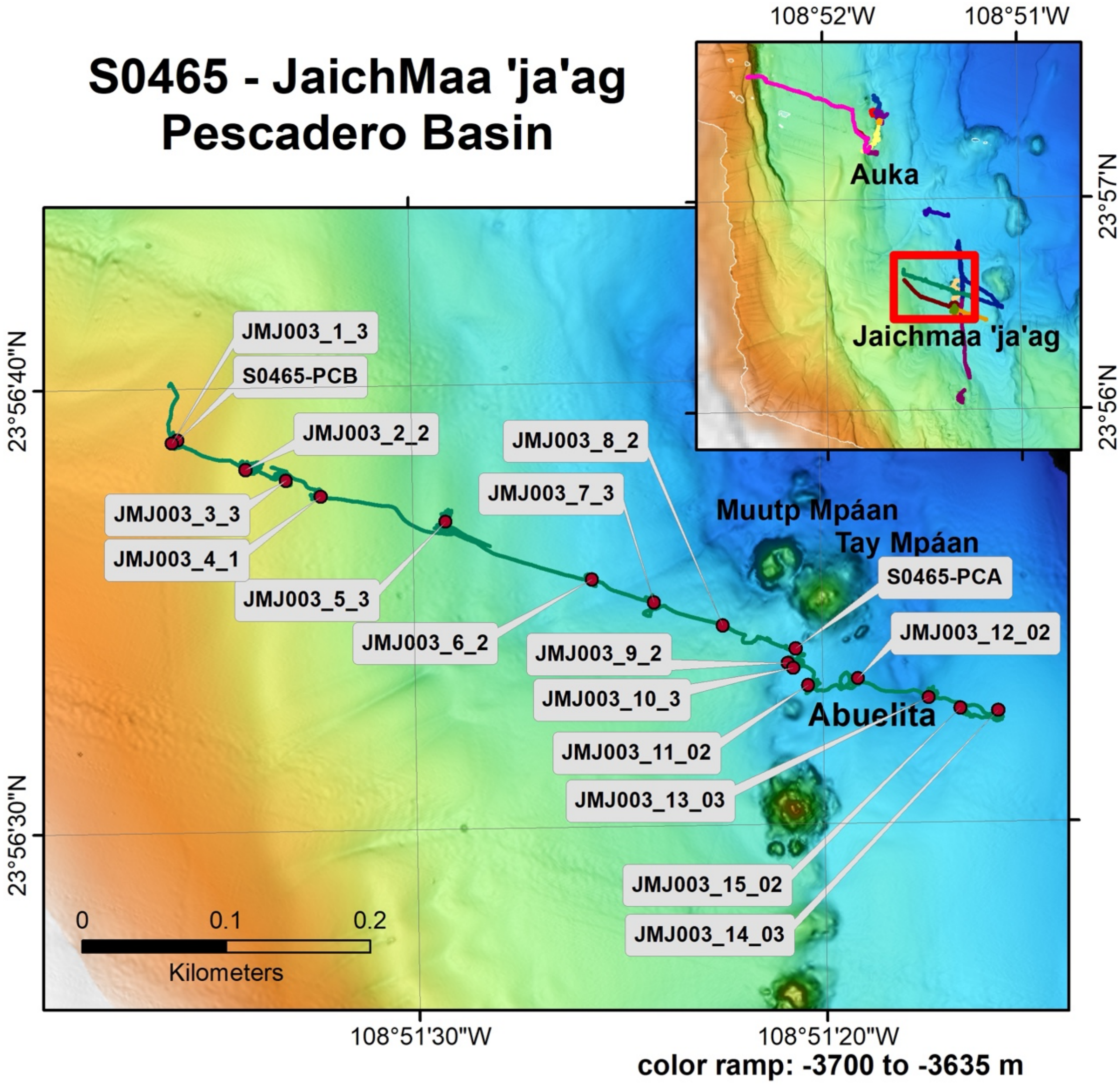

Figure 21. Map of ROV *SuBastian* dive S0465 at the JaichMaa 'ja'ag vent field. Dive track is green line; samples are red dots. Heat flow measurements are numbered like "JMJ_003_*". Bathymetry is Mapping AUV data at 1-m resolution. The color ramp, blue to orange, is 3700 to 3635 m depth.

ROV dive S0466
Dive Location: JaichMaa 'ja'ag Vent Field

Dive Summary: The JaichMaa 'ja'ag Vent Field consists of four large and several small hydrothermal edifices aligned roughly north-south and spanning a 400 m distance. The large edifices are up to 50 m across and 22 m high. The primary objective of this dive was to continue collecting heat flow data using the heat flow probe on transects across the vent field. A secondary goal was to collect push cores of sediment near and far from the vents. The on-bottom location is about 125 m east of the center of the northern pair of edifices, corresponding to the site of the last heat flow measurement during dive S0465. This location is on an AUV subbottom profile track, and the dive began by continuing the heat flow transect working eastward along the subbottom track away from the vents.

Start of Dive: 2021-10-22 14:00:16
End of Dive: 2021-10-23 00:55:46
Max Depth: 3691.6 m

ROV dive video feed: https://www.youtube.com/watch?v=7_pcCaw0pmE

Samples: 14 heat-flow (**Figure 22**).

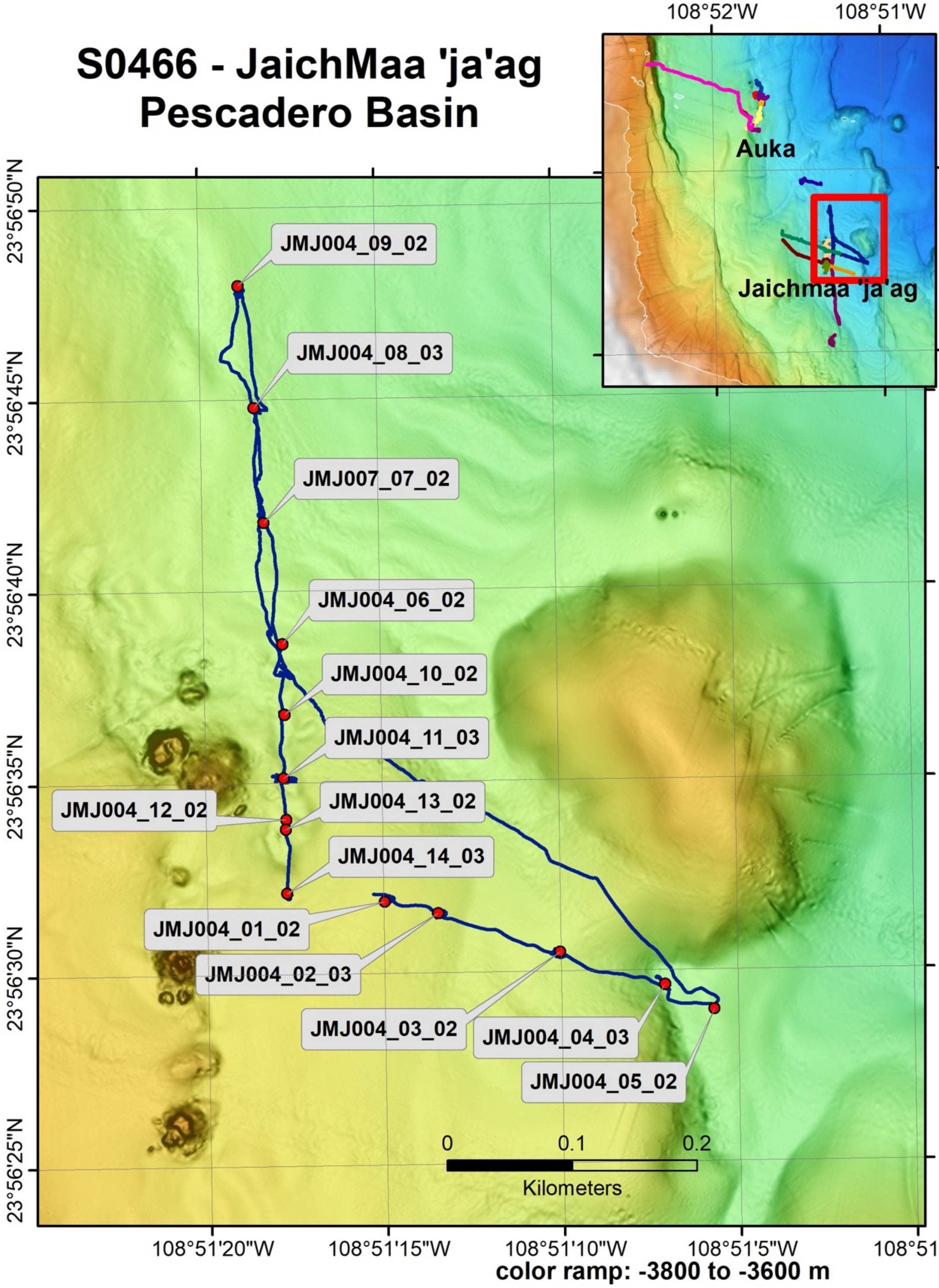

Figure 22. Map of ROV *SuBastian* dive S0466 at the JaichMaa ‘ja’ag vent field. Dive track is blue line; samples are red dots. Heat flow measurements are numbered like “JMJ_004_*”. Bathymetry is Mapping AUV data at 1-m resolution. The color ramp, blue to orange, is 3800 to 3600 m depth.

ROV dive S0467
Dive Location: Auka Vent Field
Dive Summary: The Auka Vent Field in the South Pescadero Basin consists of eight large and several small hydrothermal edifices in a roughly north-south oriented crescent spanning 600 m south to north. As at JaichMaa 'ja'ag, the largest carbonate edifices are up to 50 m across and 20 m high. Auka was discovered during a 2015 MBARI expedition when Mapping AUV surveys revealed apparent vent features and subsequent ROV dives confirmed active venting with carbonate dominated chimneys and edifices. This dive had two primary objectives: (1) obtain combined Ti-major and gas tight vent fluid samples from two vents, and (2) augment heat flow profiles begun during the 2018 expedition. One of the fluid sample sites is the vent known as Matterhorn, a tubeworm-covered chimney which has not previously been sampled. We then proceed north to Diane's vent, a vigorous high-temperature vent (289° C when last seen in 2018). Diane's Vent is on the western boundary of the Auka field, about 115 m north of the Matterhorn. At Diane's Vent we paid respects at a memorial plaque for Diane Adams, a well-known, well-respected, and well-loved marine biologist from Rutgers University and Woods Hole Oceanographic Institution. This plaque was placed at Diane's Vent in 2017 by her colleagues from WHOI using ROV Hercules operated from Ocean Exploration Trust's EV Nautilus. During the 2018 expedition FK181031, heat flow data were collected at Auka along three east-west profiles and one north-south profile, but the east west profiles extended much further to the east (basinward) than to the west. During this dive we extended the northernmost 2018 east-west profile to the west, away from the axis of the South Pescadero Basin. This follows an AUV subbottom profile track named 20181104m1-0008. As in previous dives, a secondary goal was to collect push cores of sediment near and far from the vents.

Start of Dive: 2021-10-23 14:00:00
End of Dive: 2021-10-24 01:10:05
Max Depth: 3647.3 m

ROV dive video feed: https://www.youtube.com/watch?v=19Ka-qJKLQ8

Samples: 8 heat-flow, 2 pushcores, 3 fluid, 1 temperature (**Figure 23**).

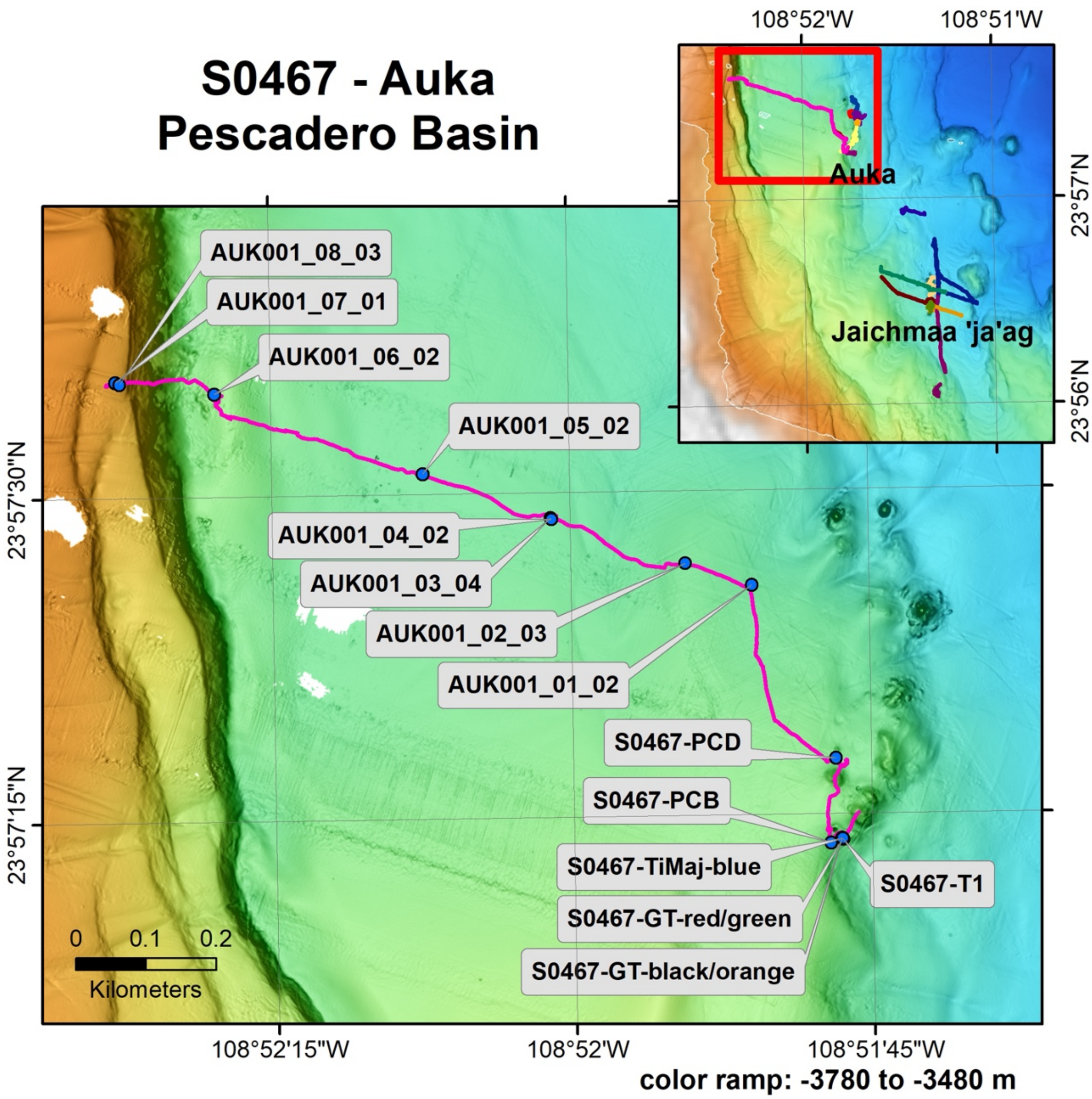

Figure 23. Map of ROV *SuBastian* dive S0467 at the Auka vent field. Dive track is pink line; samples are blue dots. Heat flow measurements are numbered like "AUK001_*". Bathymetry is Mapping AUV data at 1-m resolution. The color ramp, blue to orange, is 3780 to 3480 m depth.

ROV dive S0468

Dive Location: JaichMaa 'ja'ag Vent Field

Dive Summary: The JaichMaa 'ja'ag Vent Field consists of four large and several small hydrothermal edifices aligned north-south-ish and spanning a 400 m distance. The large edifices are up to 50 m across and 22 m high. The primary objective of this dive was to continue collecting heat flow data using the heat flow probe on transects across the vent field. A secondary goal was to collect push cores of sediment near and far from the vents. The on-bottom location is about 400 m south of the southernmost of the large edifices. This location is on an AUV subbottom profile track, and the dive began by continuing the heat flow transect working northward along the subbottom track, which passes east of the chain of edifices.

Start of Dive: 2021-10-24 14:00:00
End of Dive: 2021-10-25 00:46:34
Max Depth: 3683.05

ROV dive video feeds: https://www.youtube.com/watch?v=84KkWMAajjk
https://www.youtube.com/watch?v=d1A5SLNuOD4
https://youtu.be/jmcpEWSWE2c

Samples: 14 heat-flow, 1 pushcore (**Figure 24**).

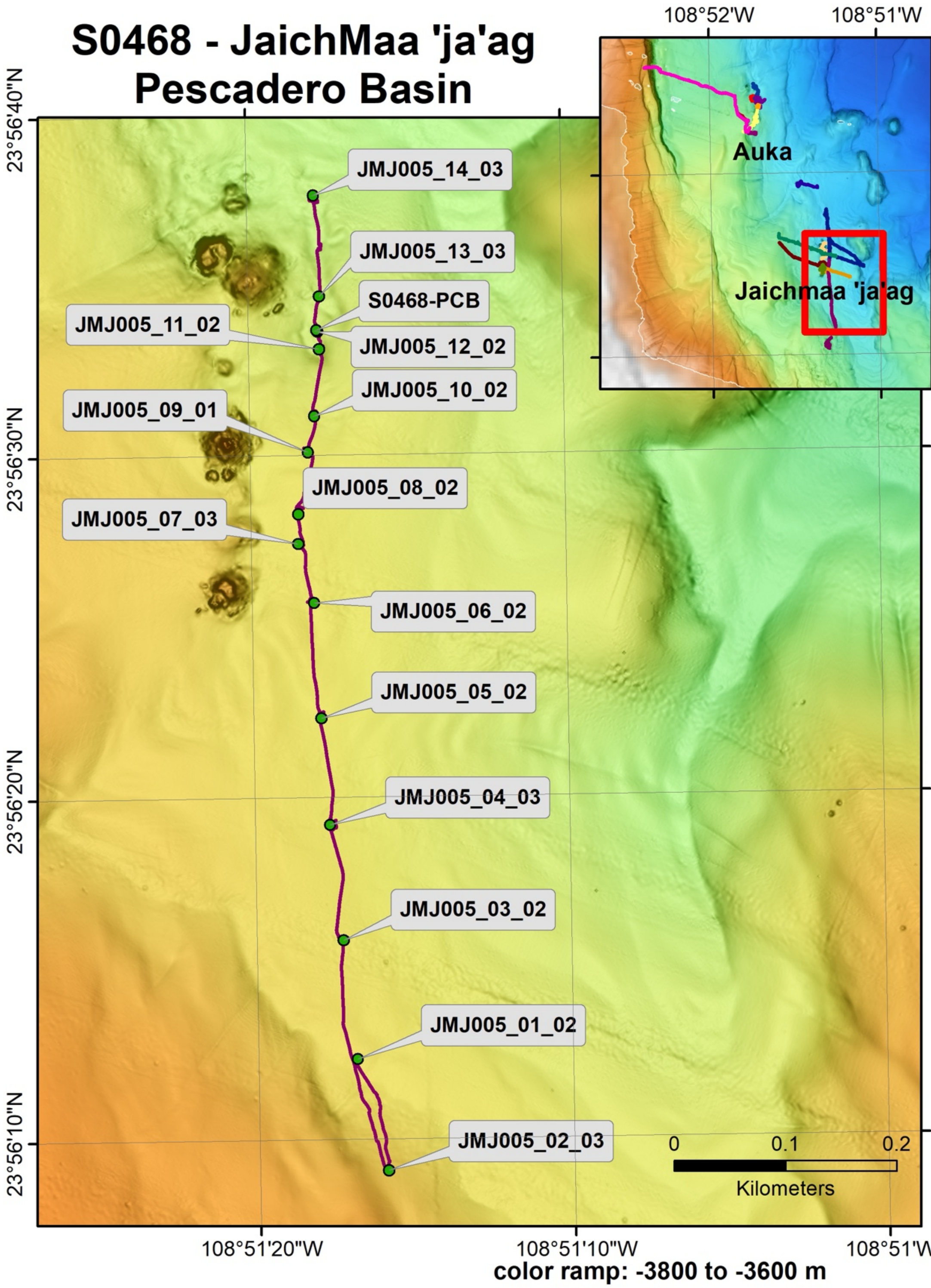

Figure 24. Map of ROV *SuBastian* dive S0468 at the JaichMaa 'ja'ag vent field. Dive track is red line; samples are green dots. Heat flow measurements are numbered like "JMJ005_*". Bathymetry is Mapping AUV data at 1-m resolution. The color ramp, blue to orange, is 3800 to 3600 m depth.

ROV dive S0469

Dive Location: Scarp offshore Isla Espiritu Santo

Dive Summary: The geology and morphology of the east margin of the Baja California Peninsula reflects the continental rifting that has created the Gulf of California, ultimately resulting in the development of several *en echelon* basins we have been studying. These rifting processes have included low angle normal faulting that has left behind many blocks of the pre-existing continental crust that have been broken up, tilted, and rotated. Ronald Spelz (Chief Scientist of Leg 1) and his students are studying these aspects of the rifting history, and they wish to test hypotheses about the formation of the many topographic highs between the Baja east coast and the deep basins. This dive aimed to sample rocks on the steep eastern scarp of a topographic high located about 24 km east of Isla Espiritu Santo. This short dive occurred early in the morning during the transit in to La Paz (Puerto Pichilingue) ending FK210922 Leg 2. The site does not have good multibeam coverage, and so a pass was made with the EM302 multibeam before setting up on the dive. The starting depth was about 700 m, halfway up the scarp, and the dive worked up toward the top of the ridge, sampling rocks as opportunities arose.

Start of Dive: 2021-10-25 10:31:55
End of Dive: 2021-10-25 16:10:37
Max Depth: 738 m

ROV dive video feed: https://www.youtube.com/watch?v=T6Q49CDUL_c

Samples: 10 rocks (**Figure 25**).

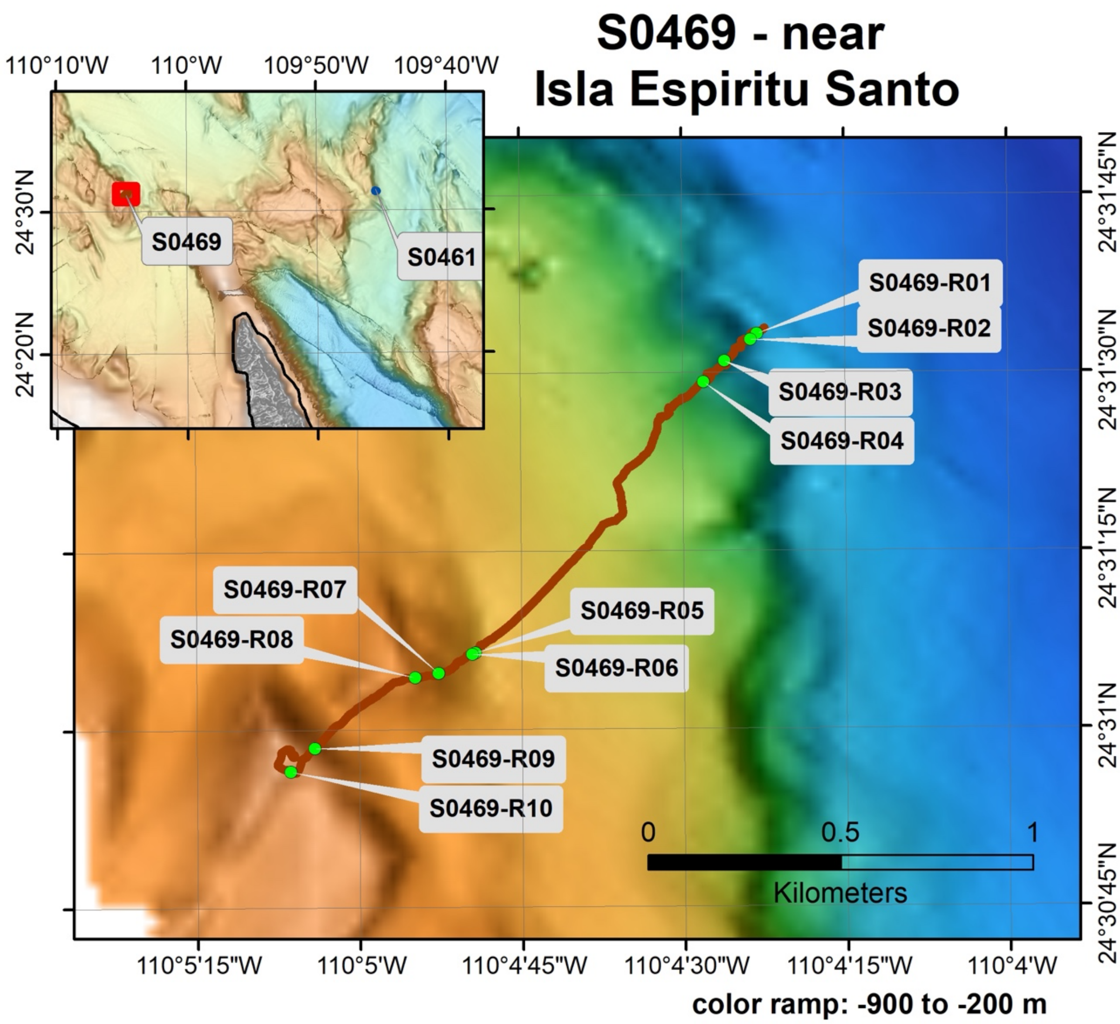

Figure 25. Map of ROV *SuBastian* dive S0469 offshore of Isla Espiritu Santo. Dive track is red line; samples are green dots. Bathymetry was collected on FK210922 and is at 25 m resolution. The color ramp, blue to orange, is 900 to 200 m depth.

ROV dive S0470

Dive Location: Auka Vent Field, Matterhorn

Dive Summary: The Auka Vent Field in the South Pescadero Basin consists of eight large edifices and several small hydrothermal features spanning 600 m in a south to north orientation. Auka was discovered during a 2015 MBARI expedition when Mapping AUV surveys revealed apparent vent features and subsequent ROV dives confirmed active venting with carbonate dominated chimneys and edifices. This dive had five primary objectives: (1) collect rock samples for microbial community and activity analyses from Matterhorn (2) sample animals at Matterhorn and in the surrounding area (3) obtain combined Ti-major and gas tight vent fluid samples from the Matterhorn vent, (4) deploy colonization rings at top of Matterhorn and (5) collect push cores and corresponding temperature profiles near Matterhorn and from the mounds in the surrounding area.

Start of Dive: 2021-10-29 12:00:21
End of Dive: 2021-10-29 22:59:51
Max Depth: 3650.1 m

ROV dive video feeds: https://www.youtube.com/watch?v=gtlOPY21jPU
https://youtu.be/X1Y7U_Q158k

Samples: 3 slurps and 2 animal grabs, 3 rocks, 2 push cores, 2 fluid samples, 6 Niskins, high temperature readings (**Figure** 26).

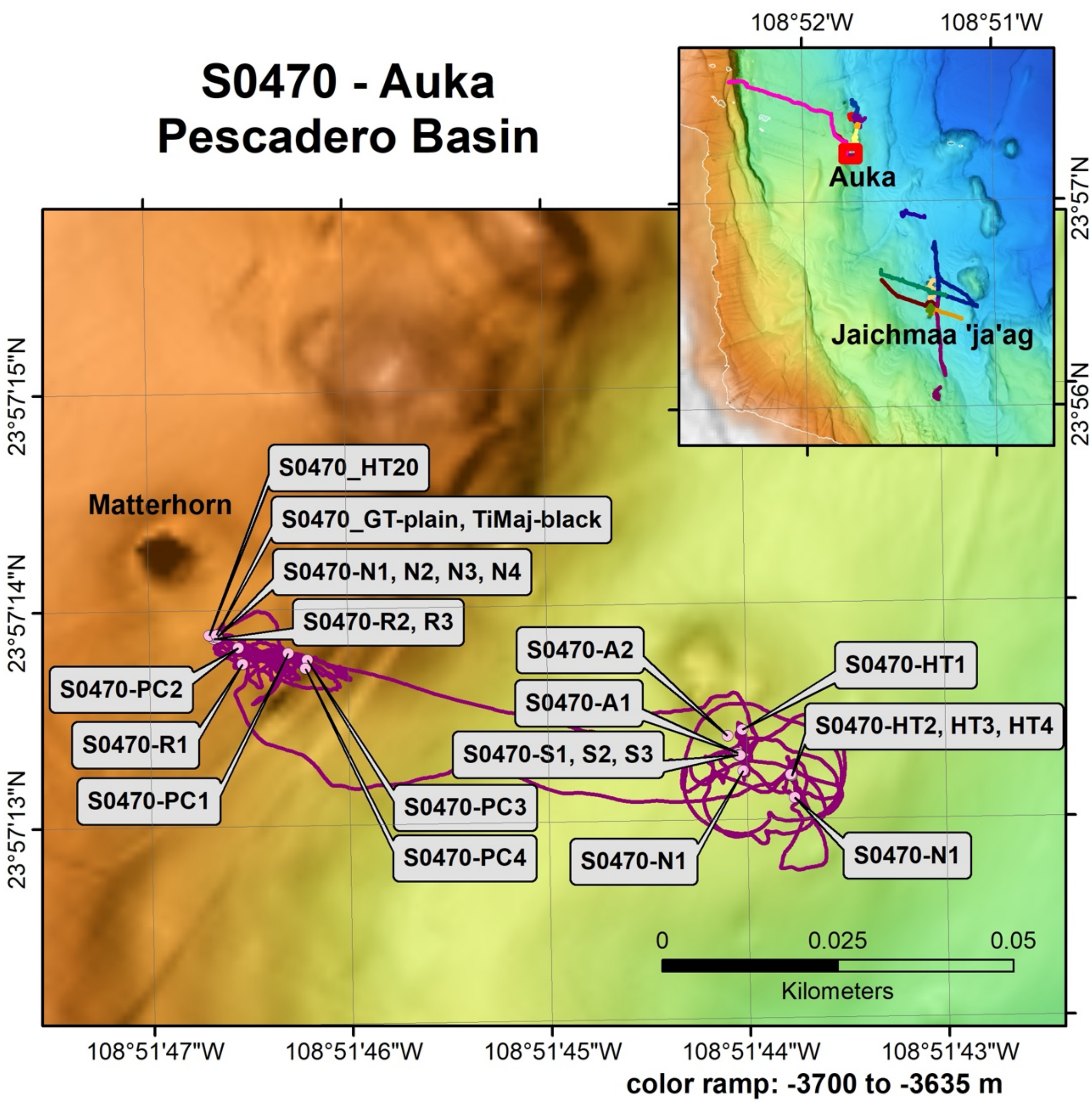

Figure 26. Map of ROV *SuBastian* dive S0470 at the Matterhorn in the Auka Vent Field. Dive track is purple line; samples are pink dots. Bathymetry is Mapping AUV data at 1-m resolution. The map is offset by about 15 m to the NW. The color ramp, blue to orange, is 3700 to 3635 m depth. The apparent offset of the map relative to the fluid sampling location at Matterhorn is 13 m to the NW.

Recap of S0470 – Matterhorn (October 29, 2021)

The launch target was Matterhorn, however we came in from the east and decided to check out the bacterial mat-covered mound obvious in the photomosaic from 2018. This turned out to be an amazing site, which we called 'Wonderland,' which contained numerous small mounds, covered in *Oasisia*, anemones, and bacterial mat, of numerous colors (white, yellow, and pinkish). Wonderland is ~70 m east of Matterhorn, and the 3 small inactive chimneys were another 10 m east of that. We collected animals (this site had paralvinellids and red copepods in shimmering water ponding over the mats) and thought we took a water sample over a snow blower (white bacterial mat floc that was coating the tubeworms in shimmering water)– that was activated when the ROV bumped up against the mound (but… the Niskin – N1- did not trigger so we went back at the end of the dive to get another). Hard substrate (3-5 cm sediment cover) prevented collection of push cores, and after several attempts poking with a high temp probe, we headed over to Matterhorn. Mats were grey and white colored with bright white patches around focused fluid flow. At Matterhorn, we collected a large rock covered in animals and partial microbial mat (S oxidizers) at the base (R1) next to a mat area and used the clam scoop to collect a friable rock (R2) in active HT flow just beneath the large tubeworm bush (~50 cm below the apex of Matterhorn). This rock had a reddish tinge to it and was coated in microbial mat (not just sulfur oxidizers in appearance) and had HT fluid oozing out of it when the clam scoop-sample was placed in biobox. R3 was collected part way down the chimney (smaller knob also red colored) and was placed in a bio quiver. Coring took place in a dusty grey small bacterial mat on the south side of Matterhorn (along with 2 temp gradients in 5 cm increments one at the edge of mat (rt side) prior to coring, and one outside the mat area in clam hash with few live clams. Temp gradient was not too hot, but warmer in mats relative to outside mat patch. This spot was chosen because of time constraints, but also because there aren't that many obvious targets in and around Matterhorn for push coring. 3 cores taken in the mat (1 short) and 1 outside of the mat. Z managed to get both a major and a gas tight water sample in the vigorous fluids of Matterhorn (measured to be 170°C). Matterhorn was as noted on leg 2 – changed in many ways – hotter with fewer *Oasisia* on top, but no real change in footprint.

ROV dive S0471

Dive Location: Auka Vent Field, Z mound

Dive Summary: The Auka Vent Field in the South Pescadero Basin consists of eight large edifices and several small hydrothermal features spanning 600 m in a south to north orientation. Auka was discovered during a 2015 MBARI expedition when Mapping AUV surveys revealed apparent vent features and subsequent ROV dives confirmed active venting with carbonate dominated chimneys and edifices. This dive had 5 primary objectives: (1) collect rock samples for microbial community and activity analyses from Z vent (2) sample animals at Z vent and from the surrounding area (3) deploy colonization arrays at top of Z vent and (4) collect push cores and corresponding temperature profiles at oily mat site. (5) fly over survey the areal extent of mats around Z vent. If time, collect major water and gas tight samples.

Start of Dive: 2021-10-30 12:00:53
End of Dive: 2021-10-30 23:09:02
Max Depth: 3673.41 m

ROV dive video feeds: https://www.youtube.com/watch?v=ZCOd96ybvtU

Samples: 5 slurps and 1 animal grab, 5 pushcores, 4 rocks, 4 Niskins (**Figure 27**).

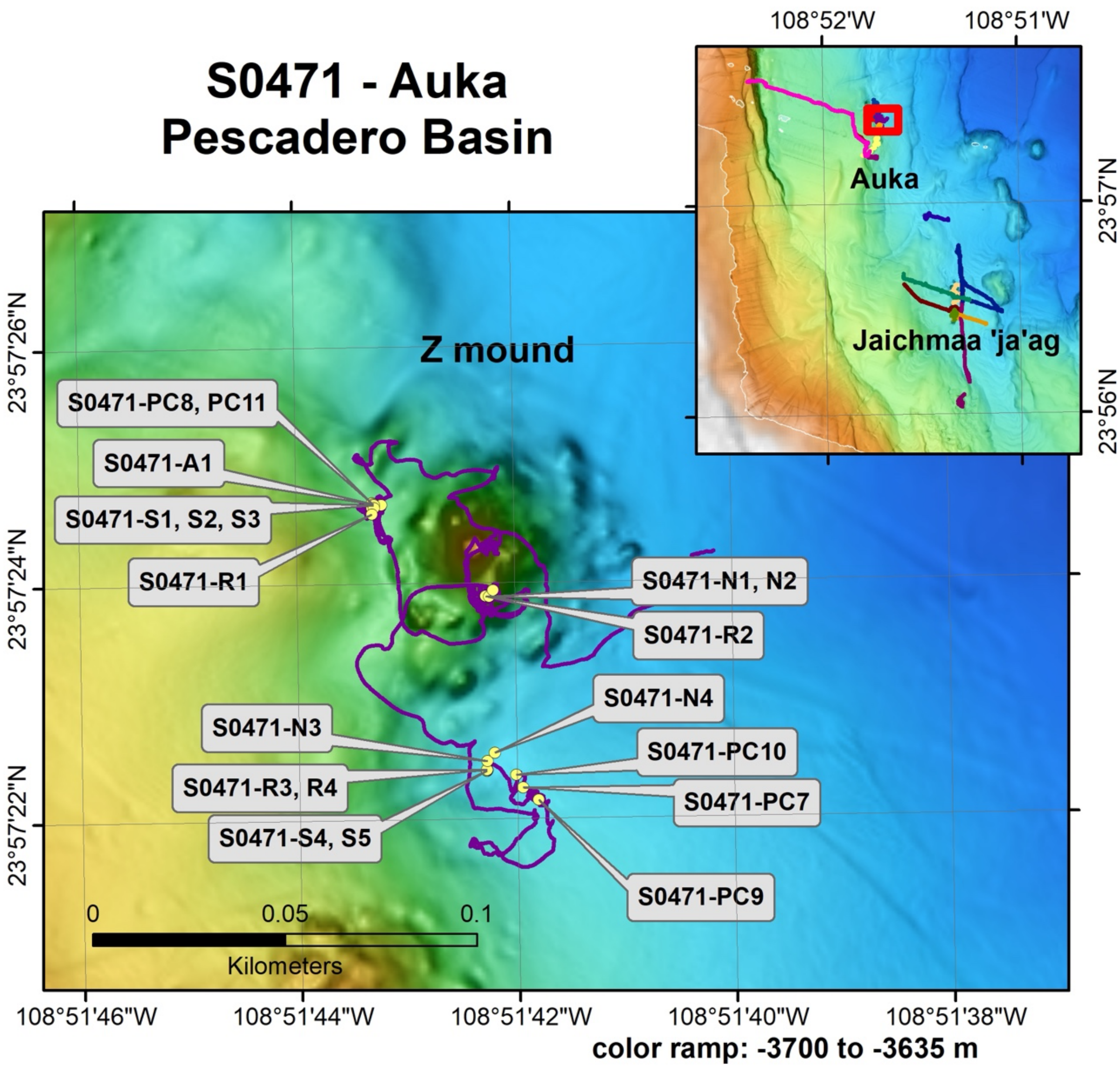

Figure 27. Map of ROV *SuBastian* dive S0471 near the Z mound in the Auka Vent Field. Dive track is purple line; samples are yellow dots. Bathymetry is Mapping AUV data at 1-m resolution. There is little map offset noted. The color ramp, blue to orange, is 3700 to 3635 m depth.

Recap of S0471 – Z Vent (October 30, 2021):

Today's launch target was Z Vent, which we approached from the east (heading 257°),), coming across sediment and zoanthid-covered talus blocks and then up to the base of the mound. We moved up the mound and around to the east to the giant flange and mirror pool, which looks much the same as in 2018, possibly a little larger. The top of the mound above and around the flange is covered in *Oasisia* tubeworms, one lone *Riftia*, and lots of microbial mat. We collected some nice closeup imagery of animals near the mirror pond. From the flange area, we headed north to find mats, using our DeepSee data visualization program and the 2018 high resolution photomosaic as a guide. We successfully found mats close to where Daan sampled in 2017 from the R/V *Nautilus*. These mats are at the west side of a small ridge (now called "Nautilus Mound") 30-40 m west of the main Z Vent. We collected a series of temperature measurements in the mat, reaching 155 °C within 10 cm and a max temp of 171 °C at 20 cm (S0471-HT1). We collected two push cores in the mat, one in a very hot area in the first use of one of our new aluminum core sleeves (S0471-PC11), and one nearby (also hot) using a standard polycarbonate core sleeve (S0471-PC8). There was a substantial crust at the surface, limiting where it was possible to core. We then measured additional temperatures: over copepods near hot fluid (6-10 °C) (S0471-HT2) and in the mat (30 cm deep) near the pushcore holes (115 °C) (S0471-HT3). We collected animals at the same spot (S0471-S1-3). Then we used the manipulator to collect a piece of the very friable crust material, which was placed in a quiver (S0471-R1).

Next, we flew back around to the south side of Z mound, where we found our Marker 8. Marker 8 had been at the top of a chimney area and is now dropped down a couple of meters from where it was because of chimney collapse. The top part of the mound has changed from 2018, with more active venting now and more high T chimneys than before. We deployed a metal coil (marked with a monkey fist) in high flow venting as a mineral precipitation experiment, and we deployed a colonization array (VO1) in a cooler area of active flow above a flange structure. We collected a small flange rock from above the mineral precipitation experiment (S0471-R2), into Biobox-3A. We collected 2 Niskins over the venting fluid (S0471-N1, N2).

We then moved down the mound toward the oily mats southeast of Z Mound, which we sampled extensively in 2018. We observed the presence of *Xenoturbella*, at least 2 individuals.

We sat down at the edge of a peach colored mat and collected temperature measurements (4.5-25 °C over 30 cm depth) (S0471-HT4). We collected two (polycarbonate) push cores in the peach mat (S0471-PC7, S0471-PC9). We then moved a short distance to investigate a whiter mat, with some peach color. Temperatures were similar to those in the nearby peach mat (7-25.8 °C) (S0471-HT5). We collected a pushcore in the white-peach mat (S0471-PC10). We used the suction sampler to collect animals in the peachy mat (S0471-S4, S5). We then used the clam scoop to sample the snowman chimney into the bioboxes. It broke, and part one (S0471-R3/R4). We noted shimmering water coming out of the orifice where the snowman had been (pilots marked a "snowman chimney" waypoint). As the dive ended we fired the remaining 2 Niskins in the water column (S0471-N4, one fail).

ROV dive S0472

Dive Location: Auka Vent Field, Z mound

Dive Summary: The Auka Vent Field in the South Pescadero Basin consists of eight large edifices and several small hydrothermal features spanning 600 m in a south to north orientation. Auka was discovered during a 2015 MBARI expedition when Mapping AUV surveys revealed apparent vent features and subsequent ROV dives confirmed active venting with carbonate dominated chimneys and edifices. This dive had several primary objectives: (1) collect push cores and corresponding temperature profiles at oily mat site near Z vent (2) fly over survey the areal extent of mats south of Z vent (3) collect animals and gas tight sample in diffuse flow near oily mat site (4) collect rock samples in areas of active venting for microbial community and activity analyses, and (5) sample animals at P vent.

Start of Dive: 2021-10-31 13:00:28
End of Dive: 2021-10-31 23:57:52
Max Depth: 3666.82 m

ROV dive video feed: https://youtu.be/GZmXsuT2AAI

Samples: 7 slurps and 1 animal grab, 1 marine snow, 4 pushcores, 3 rocks, 4 Niskins, 2 fluid samples (**Figure** 28).

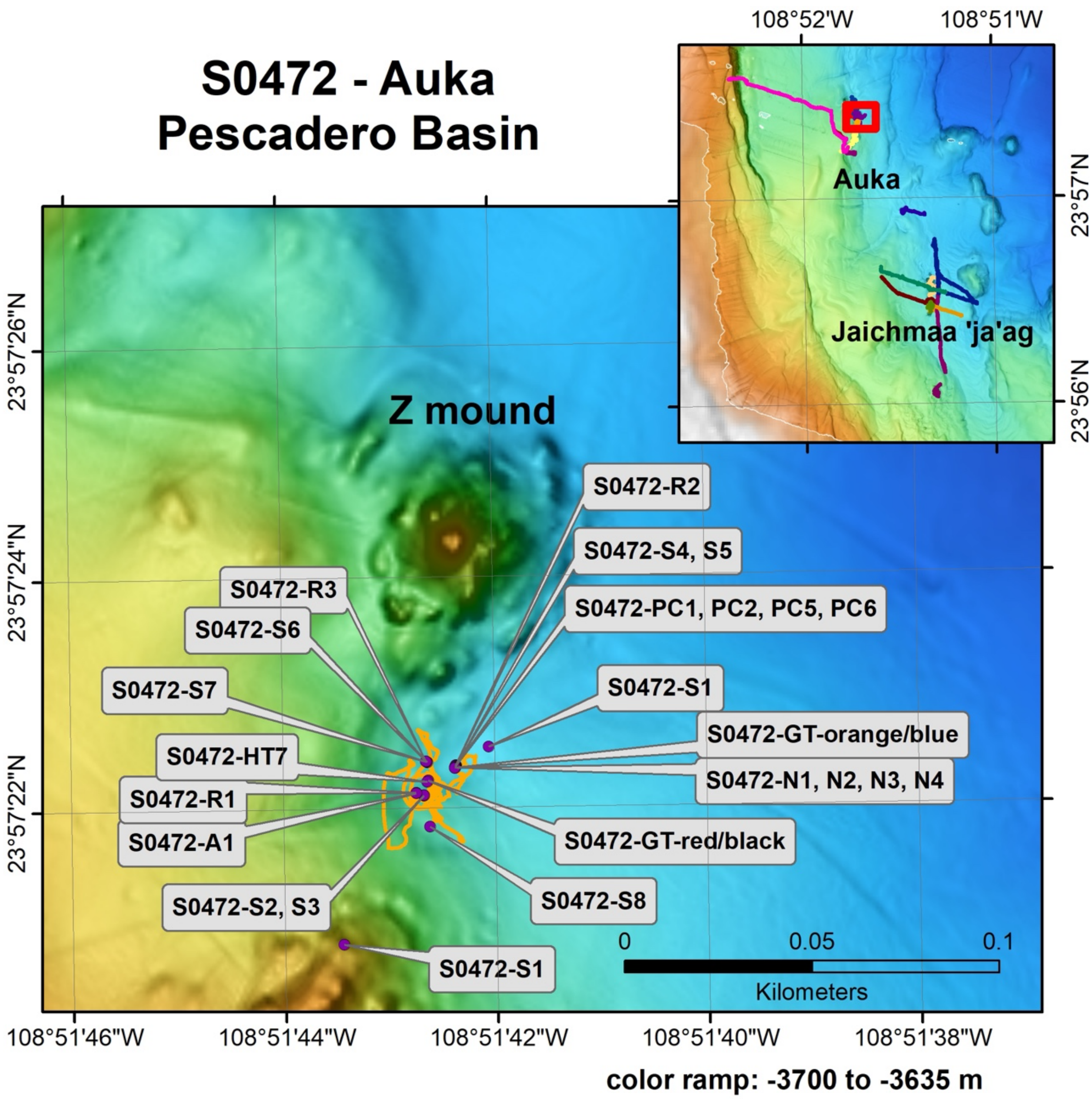

Figure 28. Map of ROV *SuBastian* dive S0472 near the Z mound in the Auka Vent Field. Dive track is peach line; samples are purple dots. Bathymetry is Mapping AUV data at 1-m resolution. There is little map offset noted. The color ramp, blue to orange, is 3700 to 3635 m depth.

Recap of S0472 – Oily mats at Z-Vent (October 31, 2021)

Today's launch target was the oily mats at Z-vent and a transect and exploration at P-vent, but the latter was dropped due to bottom time constraints, and the whole dive was at Z. Marine snow S0472-S1 and a *Flota* worm S0472-S2 were collected via slurp on the descent. 16:02, on bottom in a clam shell area - some small chimneys were visible. Headed to the 'Bunny Ears' chimney and tried a photomosaic (likely not great). Various mat colors observed in the vicinity. Did some further surveying in the vicinity of the Bunny Chimney before settling back there (heading 275°C). It was much less active than in 2018 and the *Oasisia* tubes seemed empty. Various mat colors were then targeted for heat flow. S0472-HT1 white mat, S0471-HT2 ash grey, S0471-HT3 brown. Couldn't penetrate very far so decided to move. Still in the area spotted hot sediment S0472-HT4/HT5 with only 5cm penetration. The water sampler (Halloween House) was deployed over venting sediment. S0472-HT6 at 5 cm near the Halloween House 24.5°C. Moved to the base of Bunny Ears and slurped jiggly white mat with lots of small shells S0472-S2-S3. Collected rock at the base of the Bunny Chimney. S0472-R1. Collected anemones on abandoned tubes S0472-A1 also at the base of Bunny Chimney. Returned to Halloween House and took a sample with GasTight S0472GT red-black. Temperature in Halloween House chimney S0472-HT7, and then in sediment near chimney S0472-HT8/HT9. Temperature in sediments near the Halloween House, all were 12°C or less. Retrieved Halloween House and moved to find another site with a small chimney that looked good for coring (T probe S0472-HT10 5cm at 26C). A full temperature series to 30 cm was taken to 106°C. Halloween House deployed on white mat, Series of pushcores taken by punching through the crust: S0472-PC1 paired with S0472-PC6, S0472-PC5 (aluminum). Oil on the tube was obvious. Another high temperature probe measurement S0472-HT11 series taken next to S0472-PC5, reached 116.9C. Reddish oil was observed coming out. Deployed pushcore with film S0472-PC2 paired with S0472-PC5, red oil drops observed. Scooped a piece of the crust with white mat S0472-R2. Then proceeded to slurp the mat adjacent to where cores were taken. S0472-S4 and S0472-S5. Prepared for gas tight sampling in the Halloween House chimney = S0472GT blue-orange. Four Niskin bottles were fired here (1 failed). High temperature probe was inserted into chimney of Halloween House and was 3°C. Collected Halloween House and went looking for a clam patch. Slurped 1 *Xenoturbella* S0472-S6 and the surface of crust/flange S0472-S7. Picked up a large piece of the flange S0472-R3. End of dive at 21:20.

ROV dive S0473

Dive Location: Maijia awi mound (between Auka and JaichMaa 'ja'ag)

Dive Summary: Exploratory dive to a suspected hydrothermal feature detected during seafloor mapping surveys found midway (~650 m) between Auka and the JaichMaa 'ja'ag Vent Fields. The objectives of this dive were to (1) explore and photo document the Midway vent feature and, if actively venting (2) measure temp of fluid flow and (3) collect representative animals, rock samples and push cores in the vicinity of the vent, followed by (4) heat flow measurements during a 650 m transit (heading 160°) to JaichMaa 'ja'ag and (5) collect Xenophyophores along the way. Time permitting, (6) take samples at the Big Sister of the 'The Sisters' site at JaichMaa 'ja'ag, the northernmost feature of a vent field that consists of four large and several small hydrothermal edifices aligned N-S over a 400 m distance. The Big Sister site has steep topography and is ~ 10 m high.

Start of Dive: 2021-11-01 12:30:43

End of Dive: 2021-11-02 00:15:37
Max Depth: 3686.97 m

ROV dive video feed: https://youtu.be/SGxLb0YsZo0

Samples: 4 slurp and 4 animal grabs, 1 pushcore, 4 heat flow measurements, 2 fluid samples, 1 Niskin, 4 rocks (**Figure 29**).

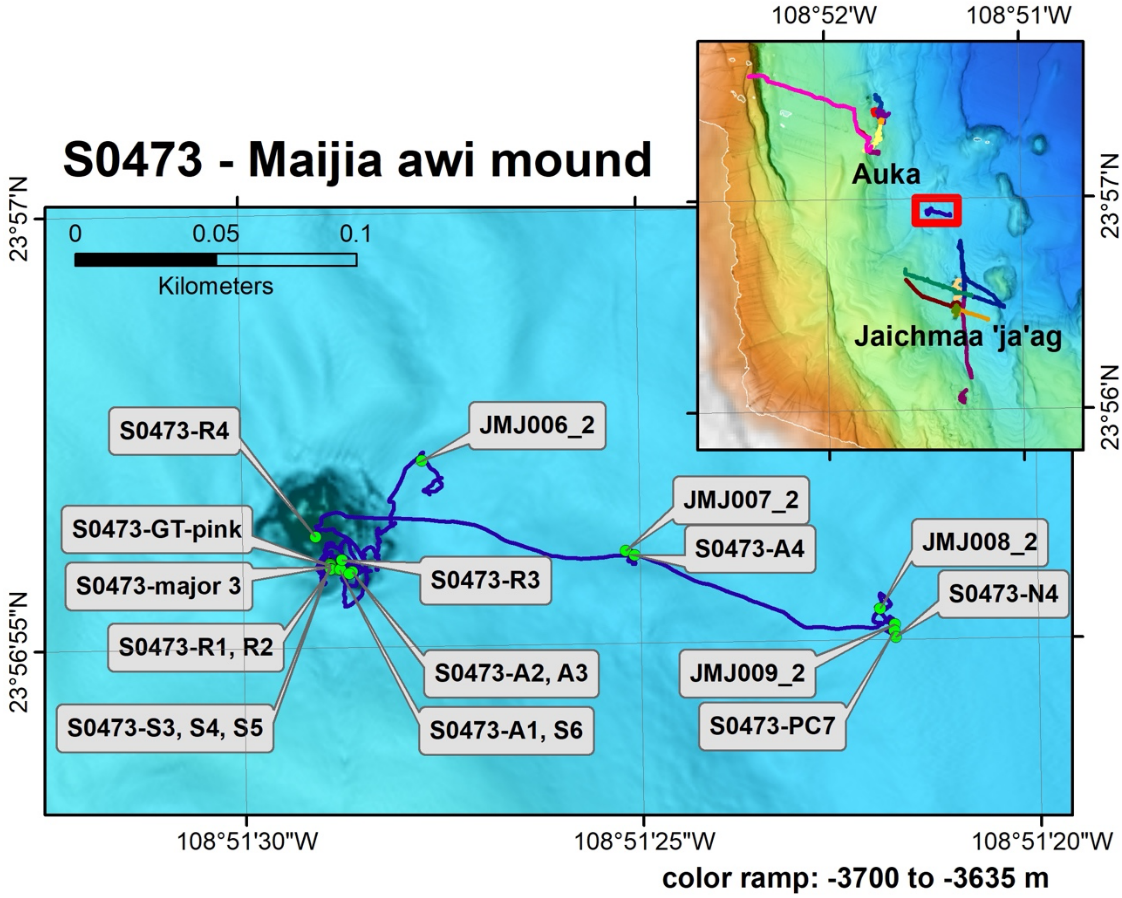

Figure 29. Map of ROV *SuBastian* dive S0473 at the Maijia awi mound between Auka and JaichMaa 'ja'ag. This actively venting mound has been named Maijia awi, after the divine serpent of water in the creation myth of the Kumiai people, one of the Yuman indigenous groups of Baja California. Dive track is blue line; samples are green dots. Heat flow samples are numbered like "JMJ00*". Bathymetry is Mapping AUV data at 1-m resolution. The color ramp, blue to orange, is 3700 to 3635 m depth.

Recap of S0473 - Mound midway between Auka and JaichMaa 'ja'ag November 1, 2021).

Today's launch target was a feature midway between south Auka and north JaichMaa 'ja'ag that was observed in the FK181031 mapping AUV survey from R/V *Falkor* with the MBARI AUVs. The feature in the AUV data appeared consistent with a hydrothermal mound, approximately 650 m from both Auka and JaichMaa 'ja'ag. Today's dive was the first exploration of this feature. On the way down, the pilots collected two samples of sea snot/marine snow using the suction sampler. S0473-S1 was at an unknown depth; S0473-S2 was at 3062 m. Upon reaching the seafloor, we observed a muddy area with sea pens, galatheid crabs, and vesicomyid clams with clam tracks. We saw hard targets ahead of us in the sonar consistent with a mound feature. Navigation/correspondence with the maps from the 2018 expedition (with offset by Dave Caress) was excellent. We landed NE of the mound, on one of the 2018 subbottom profile lines, 30 m NE of the mound. We made a heat flow measurement and continued to the mound (heading 207°). We soon came upon talus blocks covered in sediment and observed chaetognaths (arrow worms) and a giant isopod. Climbing up the NE side of the mound, we observed a large fissure filled with *Oasisia* tubeworm bushes, but they appeared pretty inactive-- very few plumes showing. There were also *P. orphanae* scaleworms (missing scales), *Provanna* gastropods, and amphipods. We followed the ridge in a NW direction. We came to a large flange with shimmering water and a mirror pool, surrounded by live *Oasisia*. Above the flange rose a large chimney, with bright white hydrothermal calcite precipitates in the shape of a dragon's head, with several small flanges/mirror pools on this head feature. The spires are delicate, and there is a lot of hydrothermal flow. We descended back to the main flange feature, where we observed copepods in shimmering water, with *Paralvinella* nearby. We used the suction sampler along a ledge below the flange feature (S0473-S3, S4) and in the soft material below the ledge (S0473-S5). We measured a temperature of 285 °C in the vent fluid below the flange. We collected vent fluid samples by gastight (S0473-GTpink) and Ti-Major (S0473-Major). We used the clam scoop to collect flange pieces (S0473-R1, R2); and we attempted to sample a small chimney, but the material was very delicate/friable and the collection was unsuccessful. We fired two Niskins above the flange area (S0473-N1, N1). We collected tubeworms with anemones on them from the base of the dragon-shaped spire (S0473-A1) and then slurped the tubeworm bush with the suction sampler (S0473-S6), collecting dorvilleids and scaleworms. We then descended, returning to the less active *Oasisia* in the fissure. We collected some of these less-active *Oasisia* (only one alive upon recovery), with anemones (S0473-A2). We slurped the tubeworm bushes (S0473-S7, S8). We sampled an inactive chimney using the clam scoop (S0473-R3). We returned to the summit and collected video of the dragon head, including with the lasers on it as eyes. We then intended to move east to an inactive area, but instead we came across an active area with folliculinids and white mat. We collected several small rock pieces with folliculinids on them and a piece of a rock ledge (S0473-R4). The original plan was to head southeast toward Tay Mpáan, but instead we continued east to intersect an AUV subbottom profile line. Along the way we observed living vesicomyids, *Acharax* shells, and a *Xenoturbella*. We set up in front of the *Xenoturbella* and filmed it while we collected a heat flow measurement, and then we collected the *Xenoturbella* (S0473-S8). We continued southeast along the 2018 AUV subbottom profile line. We observed a bacterial mat in a clam patch. We sat down outside the mat and did a heat flow measurement, and then we moved onto the mat to core (S0473-PC7) and did a heat flow measurement on the mat. The three heat flow measurements fill in a gap in a transect along this subbottom profile line. We fired two Niskin bottles (S0473-N3,N4) to end the dive.

ROV dive S0474

Dive Location: Auka Vent Field, Diane's Vent

Dive Summary: The Auka Vent Field in the South Pescadero Basin consists of eight large edifices and several small hydrothermal features spanning 600 m in a south to north orientation. One of the smallest is a high-temperature vent (~282 °C) named Diane's Vent with a 75-cm-wide orifice confined by 10-cm- wide chimney walls that only rise about 1.5 m above a small carbonate mound composed of chimney and flange talus. This dive had three primary objectives: (1) collect Xenophyophores en route to Diane's vent, (2) obtain combined Ti-major and gas tight vent fluid samples from Diane's vent, (3) take high temp measurements and collect push cores / suction samples in mats near Diane's vent, then travel to a site 65 m to the east called The Dolomites to collect rocks, animals, and push cores and corresponding temperature profiles.

Start of Dive: 2021-11-02 12:28:23
End of Dive: 2021-11-02 23:57:22
Max Depth: 3638.33 m

ROV dive video feed: https://youtu.be/gi4u9Ae9zPw
https://youtu.be/7PSmU1tb99E

Samples: 6 slurps in the midwater, 5 animal grabs on the seafloor, 2 fluid samples, 2 Niskins, 3 rocks, 6 pushcores, one heat flow measurement (**Figure 30**).

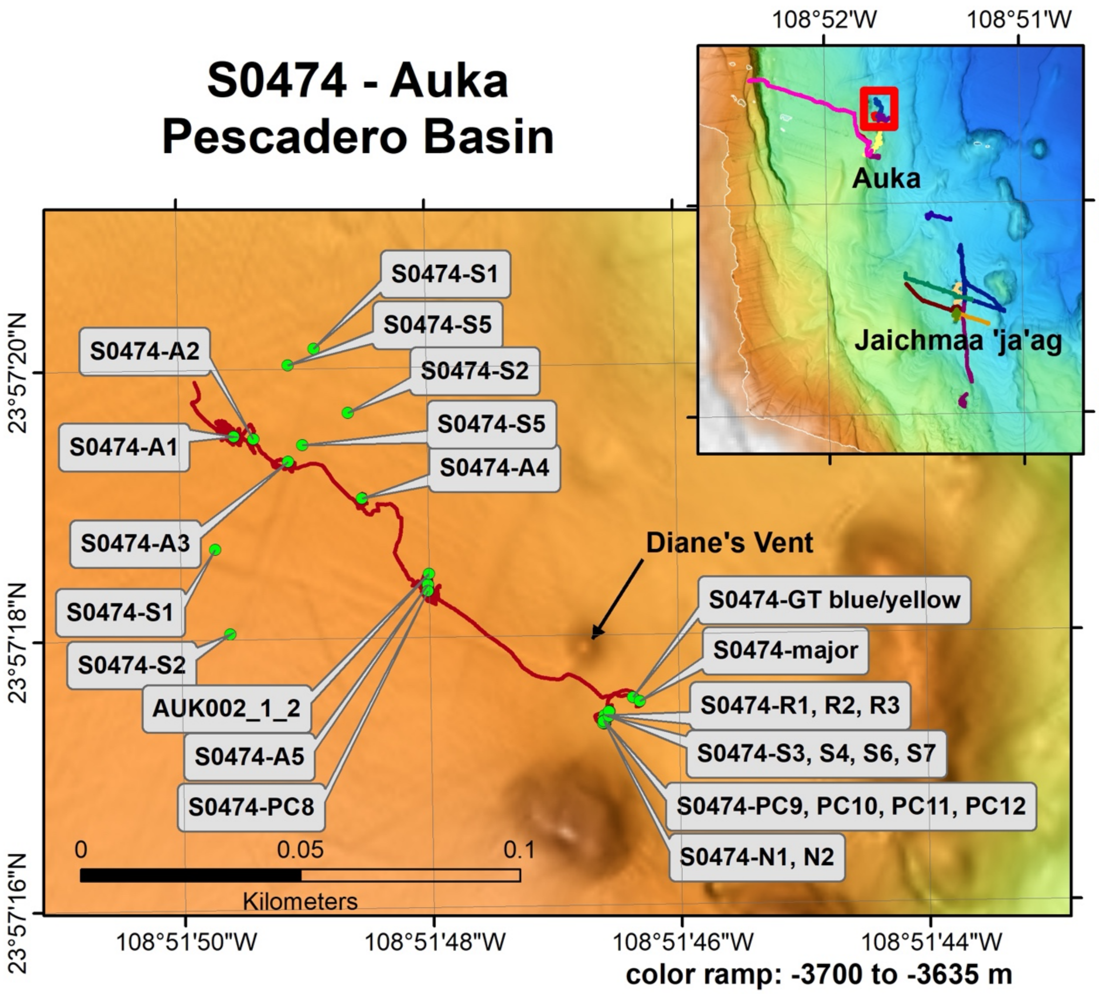

Figure 30. Map of ROV *SuBastian* dive S0474 at the Auka Vent Field. Dive track is red line; samples are green dots. Heat flow sample is numbered like “AUK00*”. Samples not along the dive track were collected in the midwater. Bathymetry is Mapping AUV data at 1-m resolution. The apparent offset of the map relative to the fluid samples collected at Diane’s Vent is 16 m to the NW. The color ramp, blue to orange, is 3700 to 3635 m depth.

Recap of S0474 – Diane’s Vent (November 2, 2021).

On the way to the seafloor, the pilots collected several samples in the water column: polychaetes (*Flota/Swima*) for Greg (S0474-S1, S5) and marine snow (2612 m) for Victoria (S0474-S2). Today’s launch target was a spot in the mud flats 75 m northwest of Diane’s Vent, with the goal of collecting xenophyophores on the way to the vent site. We observed xenophyophores shortly after landing, in an area of soft brown sediment. We successfully sampled a xenophyophore using the clam scoop (really it was half a xenophyophore) (S0474-A1). We moved along and immediately saw two more xenophyophores. We collected one with the clam scoop into a quiver, but it broke apart upon sampling (S0474-A2). We spotted another xenophyophore; it was sampled intact with the clam scoop (S0474-A3). A little more travel, and we encountered another xenophyophore, heavily colonized; we were able to collect part of it into the same quiver as A2 and A3. We continued along the transit to Diane’s Vent, stopping for a heat flow measurement about 40 m NW of the vent. Once the heat flow measurement was complete, we successfully collected a small xenophyophore atop a pushcore. We then transited to Diane's Vent and collected some imagery of the main orifice and surrounding mound. It is an area of very focused flow from a central chimney, with very little diffuse venting. We set up to the northeast of the mound and collected vent fluid using a gastight (S0474-GT-blueyellow) and a Ti-Major (S0474-Major) sampler. We then circled around to the south side of the mound to make temperature measurements and collect pushcores in a microbial mat area – fluffy orange and white mats. We collected 4 pushcores: two aluminum (S0474-PC11, PC12) and two polycarbonate (S0474-PC9, PC10). There were silver films for measuring sulfide on one aluminum and one polycarbonate pushcore. We took a series of temperature measurements (every 5 cm to 30 cm) at several locations in the mat area, in different mat environments (S0474-HT2, HT3, HT4). The highest high temperature observed was 144 °C at 30 cm in white mat. We also made temperature measurements (every 5 cm to 30 cm) in the brown sediment without mat (52 °C at 30 cm) (S0474-HT5). Following the temperature measurements, we used the suction sampler to collect *Paralvinella* worms, scaleworms, and mat from the area near where the pushcores were collected (S0474-S3, S4). We collected a piece of flange (S0474-R1). We deployed the colonization array (VO5) near the rock and mat sample site. We collected a rock (brownish, covered in fuzzy white mat) from an area with nearby diffuse flow (S0474-R2). This rock is likely a recently fallen piece of the main Diane's Vent chimney. We fired two Niskins (S0474-N1, N2). We discussed heading to another site 30 m south; but then we spotted Nereid worms at the top of the main vent, so we stayed to film and collect worms (Nereids, Hesionids). Various animals were collected S0474-S6, and the Nereid may have been successfully collected into S0474-S7 or it may have gotten hung up in the hose. We finished the dive by breaking off and collecting a rock from very close to the main Diane's Vent chimney (S0474-R3).

ROV dive S0475

Dive Location: Auka Vent Field, P mound

Dive Summary: The Auka Vent Field in the South Pescadero Basin consists of three large mounds - actively venting, steep-sided edifices 12–25 m high, with base diameters of 15–50 m. One of the largest is a high-temperature vent (~207 °C) named P Vent. This dive had four primary objectives: (1) survey P vent (last visited in 2015), (2) collect rocks, animals, and, if possible, push cores from P vent (3) obtain combined Ti-major and gas tight vent fluid samples from P vent, then (4) travel to a bacterial mat site NW of Z vent sampled on dive S0471 to collect additional push cores and corresponding temperature profiles.

Start of Dive: 2021-11-03 12:45:34
End of Dive: 2021-11-04 12:27:34
Max Depth: 3671.46 m

ROV dive video feed: https://youtu.be/1zn6NNU1Mck
https://youtu.be/kz_j_LrLuOU

Samples: 4 slurps, 4 push cores, 1 quiver, 2 Niskins, 2 fluid samples, 2 rocks, 1 heat flow (**Figure 31**).

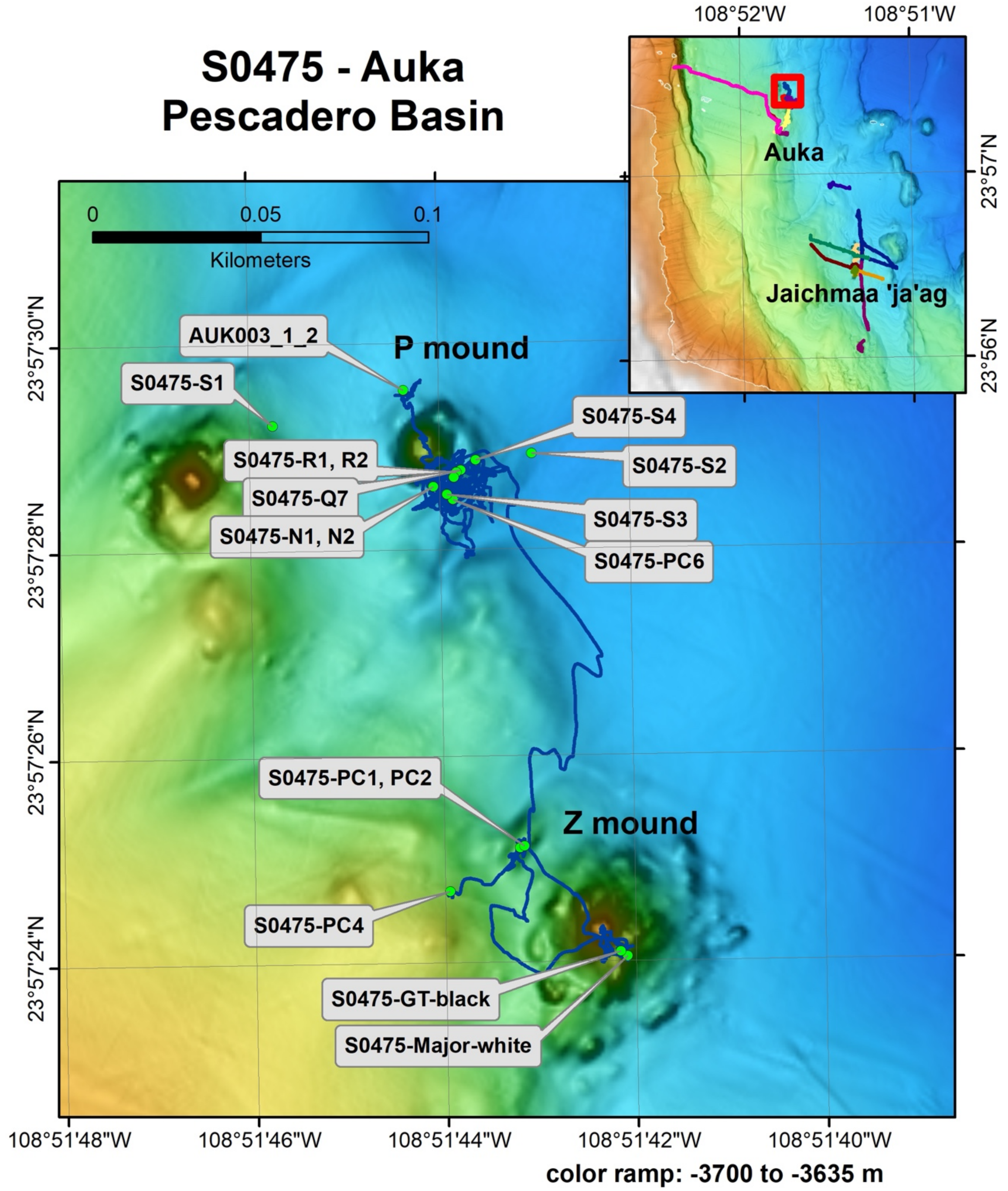

Figure 31. Map of ROV *SuBastian* dive S0475 at the Auka Vent Field. Dive track is blue line; samples are green dots. Heat flow sample is numbered like "AUK00*". Samples not along the dive track were collected in the midwater. Bathymetry is Mapping AUV data at 1-m resolution. Little map offset was noted. The color ramp, blue to orange, is 3700 to 3635 m depth.

Recap of S0475 – P Vent (November 3, 2021)
Upon arriving at the seafloor about 25-30 m northwest of P Vent, we made a heat flow measurement while observing animals (*Umbulella*, isopod, octocorals, sea cucumber,

ampharetids). We then moved toward P Vent while looking for xenophyophores. We came up on the P Vent scarp from the north and moved up the north side of the mound over numerous talus flanges. As we neared the top of the mound, we observed huge masses of *Oasisia* tubeworms, shimmering water, and some fairy castle-type chimney structures. At the top of the mound, we noted that the chimneys from the 2017 fluid sample were no longer active; and although there were numerous tubeworms, they appeared less happy than in 2015 or 2017. We did several passes around the mound for video photogrammetry. We moved around to the north side of the mound to a microbial mat area and measured temperatures at the base of a tubeworm bush. We collected one Al pushcore **(S0475-PC6).** After attempting another core and discovering that the sediment was extremely soft and fluffy, we used the pushcore as a scoop into a quiver **(S0475-Q7)**. We suction sampled the mat, collecting paralvinellids, dorvilleids, scaleworms, etc. **(S0475-S3)** and bacterial floc from the edge of the worm bush **(S0475-S4)**. We moved around the mound clockwise to the area with small chimney and collected a chimney **(S0475-R1)** and a flange piece **(S0475-R2)** with the manipulator. We fired two Niskins **(S0475-N1,N2)**. We then transited in the midwater to Z mound. We measured a temperature of 275 °C in the vent fluid at the flange **(S0475-HT4)** and then collected vent fluid samples using gastight and Major samplers **(S0475-Major-white; S0475-gastight-black)**. We then headed to the Nautilus site, looking for a place to sample. We observed large white and orange mats, mounds with tubeworms, and a *Xenoturbella*. We measured temperatures at a white mat **(S0475-HT5)** with live clams **(S0475-HT6)**. We collected two pushcores **(S0475-PC1; PC2)**, PC1 with silver film. We moved to a large dense clam bed with white/blue mats, measured temperature **(S0475-HT7)**, and collected two pushcores **(S0475-PC3, PC4)**. Off bottom, 21:33 UTC.

ROV dive S0476

Dive Location: JaichMaa 'ja'ag – near Tay Ujaa

Dive Summary: Tay Ujaa Big Cavern The JaichMaa 'ja'ag vent field in the South Pescadero Basin consists of four large and several small hydrothermal edifices. One of the largest is known as the Big Cavern (or Cave). This dive had three primary objectives: (1) travel to a bacterial mat and clam bed site SW of the Big Cavern to collect push cores and corresponding temperature profiles, including heat flow measurements, (2) travel to the Big Cavern to deploy mineral colonization experiments and collect rocks and animals, (3) If time, travel to the Big Sister site to collect animal and rock samples

Start of Dive: 2021-11-04 12:30:51
End of Dive: 2021-11-05 00:01:59
Max Depth: 3667.59 m

ROV dive video feed: https://www.youtube.com/watch?v=38g5yh_iRSQ
https://www.youtube.com/watch?v=77FY5Y1CtPA

Samples: 6 slurps, 1 animal grabs, 5 pushcores, 4 rocks, 2 Niskins (**Figure 32**).

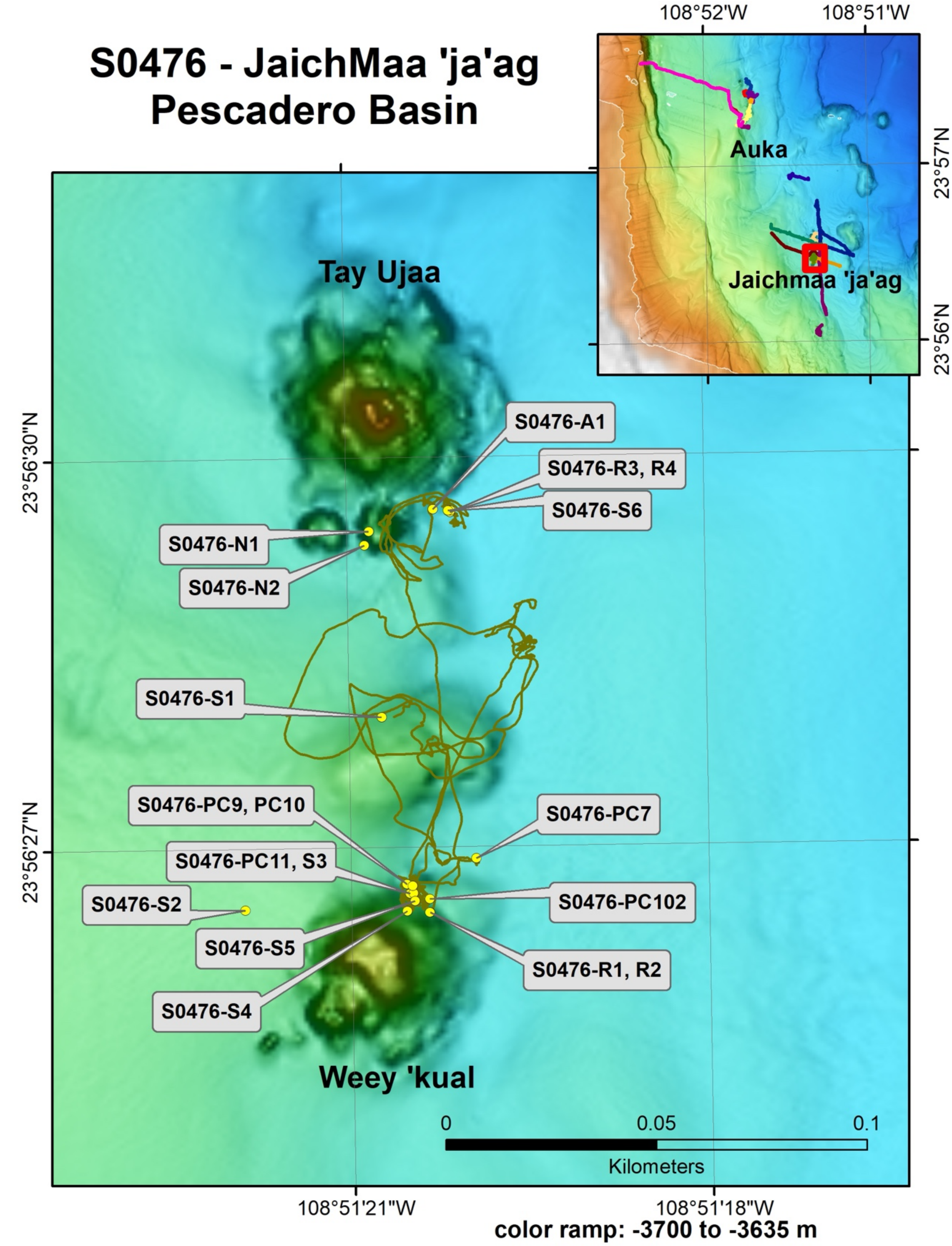

Figure 32. Map of ROV *SuBastian* dive S0476 at the JaichMaa ‘ja’ag Vent Field. Dive track is gold line; samples are yellow dots. Samples not along the dive track were collected in the midwater. Bathymetry is Mapping AUV data at 1-m resolution. The map was offset about 18m to the NW of the ROV navigation. The color ramp, blue to orange, is 3700 to 3635 m depth.

Recap of S0476 - Cavern and surroundings (November 4, 2021)
On the way to the seafloor, the pilots collected several samples in the water column: marine snow (1450 m) for Victoria (S0474-S1) and a polychaete (*Swima*) for Greg (S0474-S2). Today's launch target was the area of an upside-down flange SW of the Cavern (observed in 2018). From there, we transited to a bacterial mat / clam patch SW of the Cavern. On Bottom at 16:09 (9:09 am) at 3664m. We found a site off target that had shimmering water and bacterial mats – stopped to take temp measurements (S0476-HT1 over shimmering water / S0476-H2 grey sediment / S0476-HT3 white bacterial mat / S0476-HT4 to the right of shimmering water). Some complications with the temp probe tangling around the slurp – clouds of fine sediment over the top of the site. Attempted to push core but couldn't punch through, then tried to push core over paralvinellids and it did not seat on the stopper, then fell out when attempting to move it to the quiver. Had silver film though so S0476-PC7. Moved on to search for other mats. Spent quite a bit of time looking for the old site, observed old (2018) sled mark but no nearby mat. Saw broken up talus and finally the upside-down flange, where 2018 cores were taken ~9 m south. Old sled mark was spotted and originally thought to be from 2018, but Z said they landed here to take heat flow on Leg 2 2021. The clams were all dead. Heat flow measurement to S0476 ~11:30 (23.9412675/-108.85548). Dave Caress thinks it is 12 m NW of the closest location to Leg 2 heat flows. Headed back the way we came to the 1st bacterial mat site… but stopped at another mat with shimmering water. Took high temp measurements (S0476-HT5-HT8) and cores over shimmering white mat (S0476-PC11 Alum) and yellowish mat (S0476-PC9), plus S0476-HT9 in hole of PC9 (50 C). Slurped peachy mat (S0476-S3) and xenoturbellids (S0476-S4). Took high temp measurements (S0476-HT10) and cored over peachy mat (S0476-PC8,10,12,102). Another slurp over peachy mat (S0476-S5). Collected nearby modestly active rocks (S0476-R1/R2). Traversed north to Big Cave site. Deployed the house and VO6 on top of active flange near tubeworm bushes (high flow was noted – possibly area of old Marker 5). Collected clump of *Oasisia* S0476-A1. Note depths were off between sensors. Spectacular scene! Saw a beautiful broken off flange with crystals around the edge. Found the site of the Cavern – it had partially collapsed . Found and sampled "sulfur tubes" near cave site (S0476-Q7/R3). Slurped for worms in the sediment (S0476-S6). Fired Niskins (S0476-N1/N2).

ROV dive S0477

Dive Location: Auka – near Z mound
Dive Summary: The Auka Vent FIeld in the Pescadero Basin was discovered and characterized during 2012/2015 MBARI expeditions when Mapping AUV surveys revealed apparent vent features and subsequent ROV dives confirmed active venting with carbonate dominated chimneys and edifices. This dive had three primary objectives: 1) to collect push cores and corresponding temperature profiles at a site NW of Z vent. (2) to collect push cores and corresponding temperature profiles at the oily mat site SE of Z vent. (3) Then travel S to a site called The Dolomites to collect rocks, animals, and push cores and corresponding temperature profiles.

Start of Dive: 2021-11-05 13:00:09
End of Dive: 2021-11-06 00:06:51
Max Depth: 3662.16 m

ROV dive video feed: https://www.youtube.com/watch?v=BK0kv8xtBvQ

Samples: 7 slurps, 2 animals, 6 pushcores, 2 rocks, 2 heat flow (**Figure 33**).

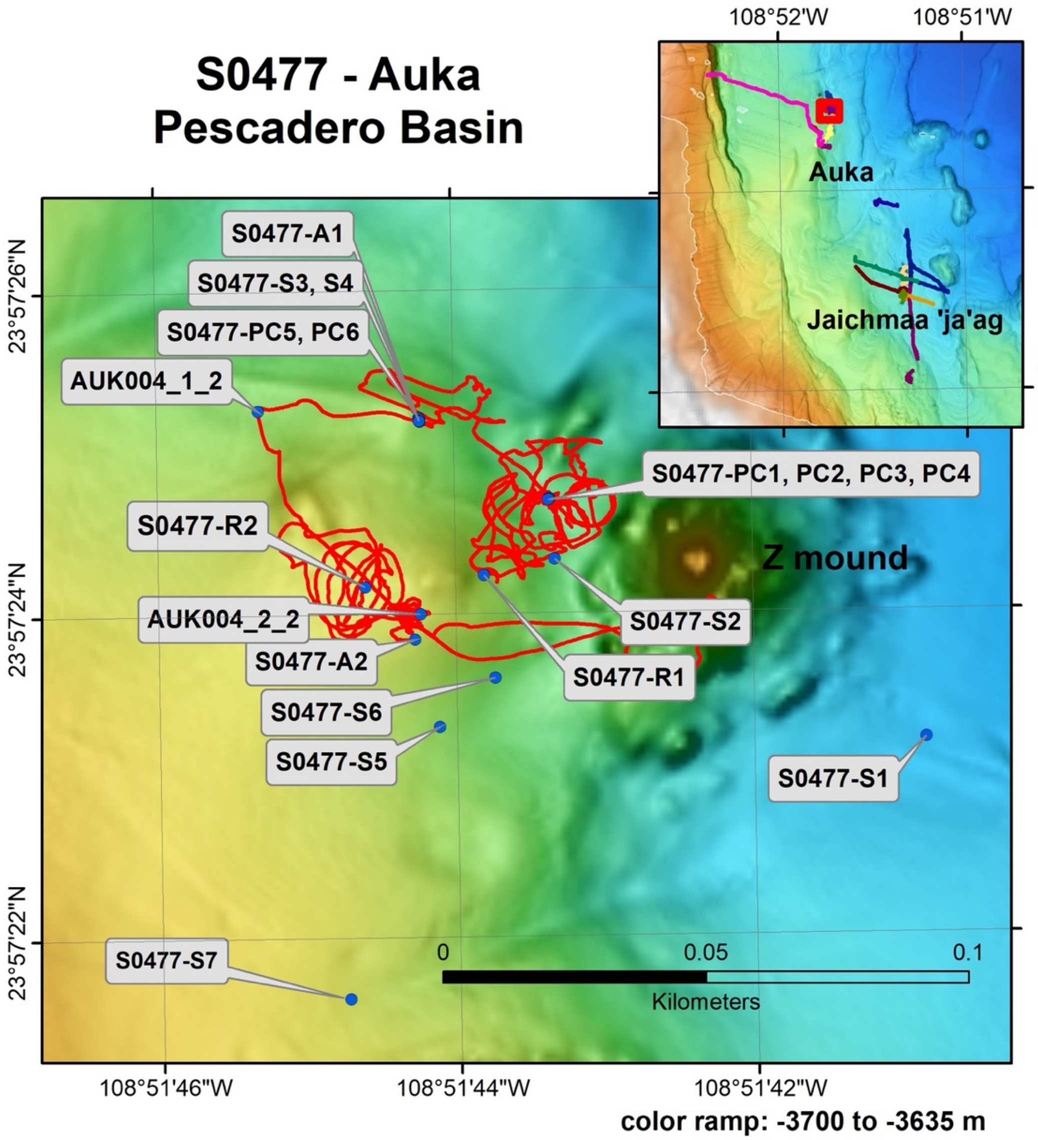

Figure 33. Map of ROV *SuBastian* dive S0477 at the Auka Vent Field. Dive track is red line; samples are blue dots. Heat flow samples are numbered like "AUK00*". Samples not along the dive track were collected in the midwater. Bathymetry is Mapping AUV data at 1-m resolution. Map offset may be about 15 m to the NW. The color ramp, blue to orange, is 3700 to 3635 m depth.

Recap of S0477 – Northern mats of Z vent and Western mounds, Auka (November 5, 2021)
On the descent and ascent, the pilots collected samples in the water column: marine snow for Victoria **(S0477-S6),** a polychaete (*Swima*) for Greg (possibly from 2048 m from dive photos); **(S0477-S1),** and a *Poeobius* annelid **(S0477-S7).** Marine snow sample was collected on ascent

and later found to be partially contaminated with debris from seafloor slurps. Slurp 2 of marine snow was unsuccessful. Slurp 5 was filled with debris and sediment.

Today's launch target was the area North of Z vent that was sampled during Dive S0471 (2017 Nautilus mat sample site) where coreable high temperature sediments were found. We traversed this area looking for localized fluid venting in the sediments. Navigation was a little off and ended up further west from our target. Collected photogrammetry images of the 'amphitheater' tubeworm bush on rock and surrounding mats and clams (possibly SE edge of Nautilus mound). Observed rocky area to west with dense white anemones and stalked *Clavularia* anemones coated with white microbial mat. Sampled a rock with many *Clavularia* and associated bacteria (R1 in biobox 3) Traversed back to waypoint and collected sampes in a localized linear white mat feature with 3 distinct areas of hydrothermal fluid discharge located at the bottom of a depression. Took temp probe measurement in shimmering water HT1 surrounded by bright white mat (temp at 5 cm 115ºC). Collected **PC2** (aluminum core with sulfide film) just to the right of the flow. **PC4** (polycarb) inserted adjacent to PC2. **HT3** taken to left of HT2 and PC2 closer to shimmering water. Temps reached 125ºC. **HT5** directly in active flow in 2nd vent to the left reached 140ºC at <15cm. Push cores collected around vent PC3 just behind **HT5** measurements in white mat, **PC1** taken in front of PC3, white mat on top well preserved. **HT6** depth profile to right of **PC3** (113ºC highest). Transit back to area with mats (trying to find 2018 sample spot). **HT7** gray white mat patch by anemone - high flow here. Measured temp in water adjacent to white anemone on clam shell (3.4ºC) in shimmering water (**collected A1 in Q7**), near paralvinellids (20ºC) and above copepods (9ºC). HT11 in vent fluid orifice (81ºC). Collected additional temp measurements in gray mat (highest 57ºC) and 2 push cores **(PC5)** and **PC6**. Oil droplets released when collected. Slurp in venting fluids with bright white mats (**S3 and S4**). Headed west to do a heat flow measurement (**AUK004-1**). Collected frenulate (**A2** in biobox4), and 2 additional heat flow measurements near west to larger mound (clamwow). Smaller mound to the west appeared less active. Collected rock pieces with anemones from 'clamwow' site (R2 in biobox 3A) and 2nd photogrammetry. All 4 niskins fired above site. Off bottom.

ROV dive S0478

Dive Location: JaichMaa 'ja'ag Vent Field, The Sisters

Dive Summary: The JaichMaa 'ja'ag vent field in the South Pescadero Basin consists of four large and several small hydrothermal edifices. This dive had three primary objectives: (1) land at The Little Sister (Muutp Mpáan), the younger and more active of two adjacent mounds, at the north end of the vent field, to possibly collect rocks and animals, then transit to the Big Sister (Tay Mpáan) to the SE, to survey visually any changes from 2018, (2) travel south past the Big Cavern on the eastern side (look for the ctenophore outcrop), and (3) transit south to Red Hill (Weey 'kual), the southernmost mound in this vent field topped with lush colonies of *Oasisia* tubeworms, to collect animal and rock samples.

Start of Dive: 2021-11-06 12:00:24
End of Dive: 2021-11-07 00:15:35
Max Depth: 3682.68 m

ROV dive video feed: https://youtu.be/Zs7wVQGGyxI

Samples: 5 animals, 7 slurps, 3 pushcores, 5 rocks, 2 temperatures, 2 Niskins (**Figure 34**).

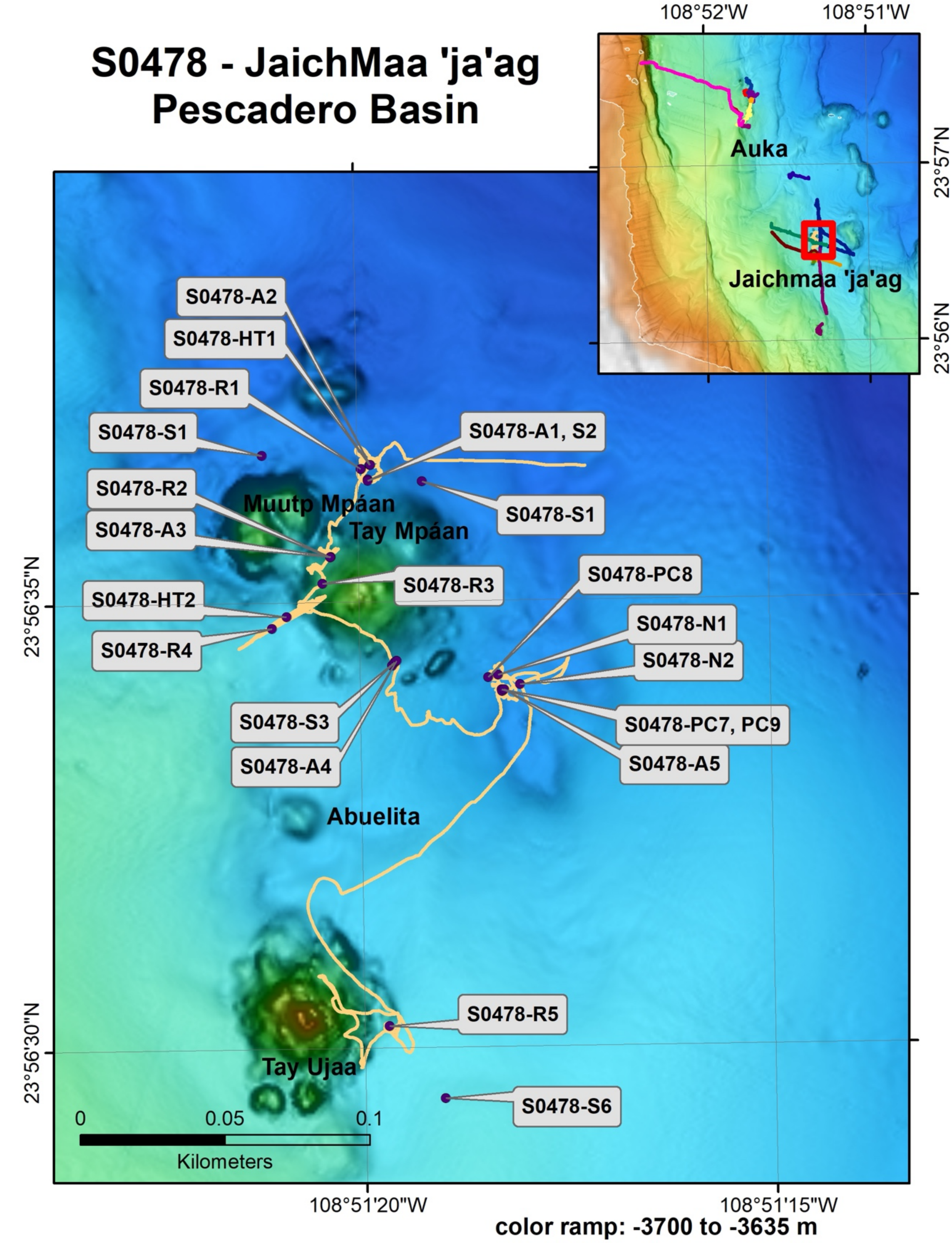

Figure 34. Map of ROV *SuBastian* dive S0478 at the JaichMaa 'ja'ag Vent Field. Dive track is tan line; samples are purple dots. S3 material was also slurped into S1. Samples not along the dive track were collected in the midwater. Bathymetry is Mapping AUV data at 1-m resolution.

The map was offset ~20 m NW; HT1 and R1 were from on the top of the small mound and R5 was at the base of the steepest slope on the NE side of Tay Ujaa (ctenophore wall). The color ramp, blue to orange, is 3700 to 3635 m depth.

Recap of S0478 – The Sisters (November 6, 2021):

On descent - slurped Marine snow (S1 – but then slurped over it – this is a pervasive issue of not knowing what slurp canister we are on). Landed NE of The Sisters. Headed due W to a small mound N of the Sisters. This mound turned out to have some significant activity at the top with a moderately sized *Oasisia* clump. Temps only measured 40 °C in shimmering water (S0478-HT1), but couldn't get a good orifice. Slurped inactive tubes (S0478-S2), sampled inactive anemones (S0478-A1), + an inactive rock (S0478-R1), plus active *Oasisia* (S0478-A2). Traveled on to the Little Sister. Moving up the N side we collected a patch of tubeworms that looks more like *Lamellibrachia* (S0478-A3). We also collected blue mat on a rock S0478-R2. The top of Little Sister turned out to be spectacular with numerous thin, fast-growing chimney spires. We first collected a fuzzy, less active chimney (S0478-R3) and then knocked one over and sampled 286.2 °C water (S0478-HT2). Collected gelatinous bacterial floc on chimneys (S0478-R4). Traveled over the top of the Big Sister (from NW) and slurped in brown sediments (S0478-S1) and white mat (S0478-S3) in the inactive / active transition. Collected an unusual looking tubeworm (S0478-A4) – might just be *Oasisia*. Traveled down the SE side of the Big Sister, we observed "*Riftia* condos" with 1-5 *Riftia* surrounded by *Oasisia* in very small clumps. At the SE base there were dense clam fields, where we took temp measurements (S0478-HT3) and push cores (S0478-PC7,8,9). Also collected 2 clams (S0478-A5), which do not qualitatively appear to be A. gigas, the clam we know is in Pescadero Basin. Collected water samples a little off bottom near the clam patch (S0478-N1/N2). Headed SW passed Abuelita mound enroute to the North side of the Big Cave to look for the ctenophore wall on the north side. Found it!! Sampled the ctenophores and rocks at this site (S0478-R5). Off bottom. On ascent - slurped Marine snow (S0478-S6) and a *Swima* worm (S0478-S7).

ROV dive S0479

Dive Location: Mounds south of JaichMaa 'ja'ag Vent Field and pockmark

Dive Summary: Exploratory dive to suspected hydrothermal features detected during seafloor mapping surveys located South of the JaichMaa 'ja'ag Vent Field. The objectives of this dive are to (1) explore and photo document the South Mound vents and, if actively venting, (2) measure temp of fluid flow and (3) collect representative animals, rock samples and push cores in the vicinity of the vent. (4) If time, heat flow measurements and Xenophyophores will be collected during the 780 m transit (heading 357°) to JaichMaa 'ja'ag upside-down flange site (5) collect push cores near the big Cavern and if time sample at Red Hill to the South. Study site coordinates: Southern-most mound to the south: -108.8553594 23.9340751 Depth: -3652.530 m 108 51.321565 W 23 56.044507 N Big Cavern (Tay Ujaa) -108.855782; 23.941602; 3669 m (coordinates for the cavern) Upside-down flange (dive S0476 waypoint) -108.855744; 23.941126 depth: 3663 m

Start of Dive: 2021-11-07 12:34:45
End of Dive: 2021-11-08 00:01:08
Max Depth: 3645.95 m

ROV dive video feed: https://www.youtube.com/watch?v=VtrfuLAkPY8

Samples: 7 slurps and 1 animal, 5 push cores, 3 rocks, 2 Niskins, 2 heat flow (**Figure 35**).

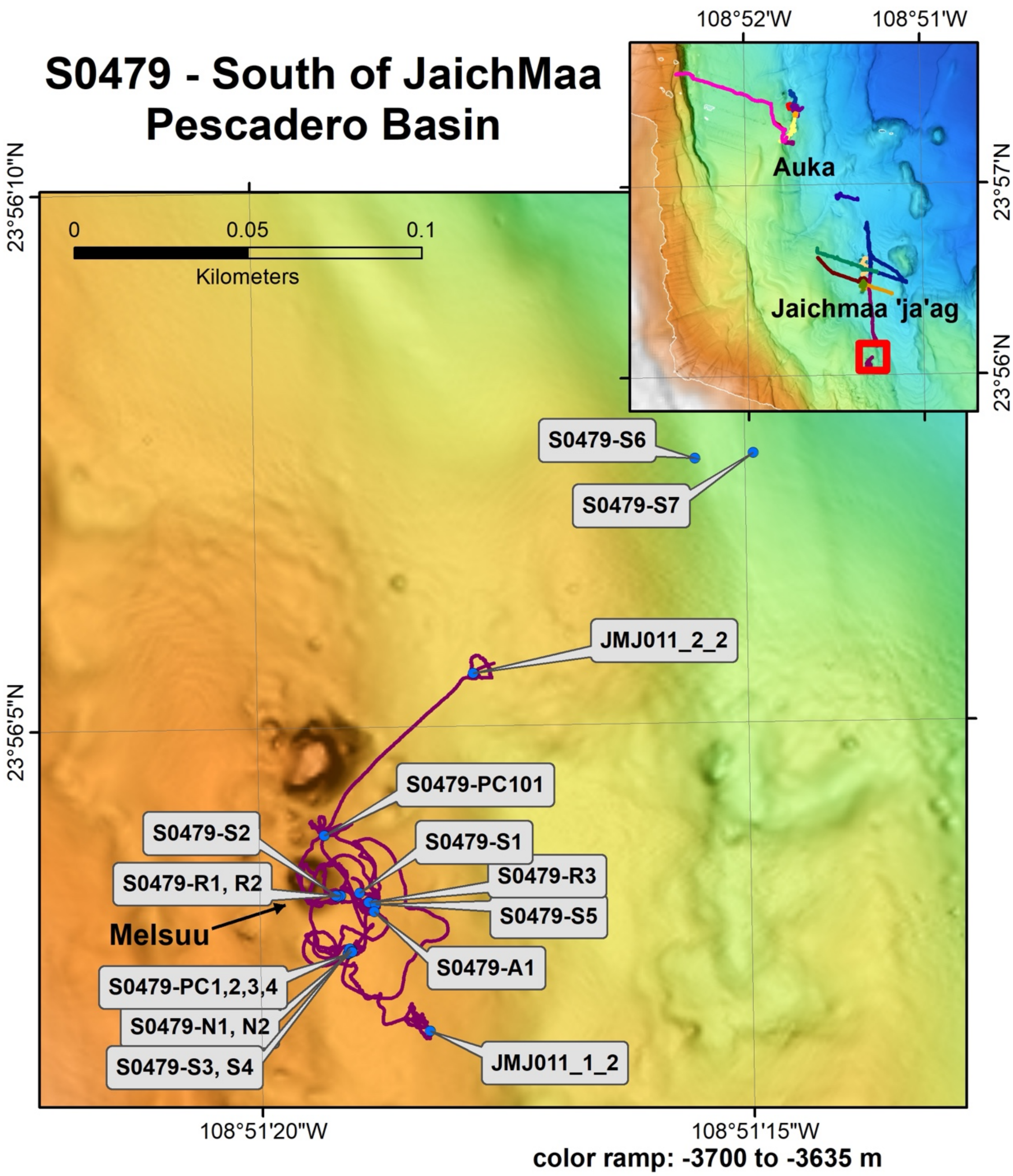

Figure 35. Map of ROV *SuBastian* dive S0479 south of the JaichMaa 'ja'ag Vent Field. This southern-most mound of the field is named Melsuu, after the word for "blue" in the Kiliwa language, referring to the dense population of iridescent blue scale worms found in the vent field. Dive track is purple line; samples are blue dots. Samples not along the dive track were collected in the midwater. Heat flow samples are numbered like "JMJ00*". Bathymetry is Mapping AUV

data at 1-m resolution. The map offset was 12 m NNW; the loop in the track (near PC1,2,3,4) should be centered on southern hill. The color ramp, blue to orange, is 3700 to 3635 m depth.

Recap of S0479 – The South Mounds (November 7, 2021):

The dive target was a pair of 20-40 diameter low hills located ~700 m south of the Weey ‘kual mound, just south of the southern-most heat flow station at JaichMaa ‘ja’ag. We landed on a flat muddy bottom with fairly abundant clam shell hash about 20 m south of the southern mound. A heat flow measurement revealed rather hot sediment (gradient=21.88C/m; HF=17.50 W/m2). We next flew over and then circled the smaller, southern mound. The mound is mostly inactive, with abundant anemones covering hard rocks. Near the top of the mound was a 15 m patch of grey, white, and peach bacterial mat, with one distinctive area of shimmering water. A few meters away was a 1-m diameter, 3-m high chimney with a crown of bright red *Oasisia*, and at the very top, orange plumed *Oasisia*. While the navigation was quite good when we landed on bottom, there was a shift ~12m NW while we were circling the mound. This was likely the result of getting USBL hits that traveled through the hot hydrothermal fluid while we were on bottom taking heat flow. The INS seemed to drift back during the dive. We also noticed that the high temperature probe was drifting between -0.4 and 0.7 when the CTD temperature was reading the expected 2.0 C.

We did a quick fly over of the larger northern hill to get a picture of the setting before returning to the southern mound to collect push cores in the mat. The base of the larger mound is surrounded by 1-6 meter scale talus blocks, mostly inactive. Approaching the upper terrace of the mound we saw areas of patchy mat and old, less vigorous *Oasisia* clumps. Near the crest we passed an active 2-m wide hot flange and at the top there are patchy mats and tube worm bushes. The main venting area at the top is a 15-m long fracture-controlled line of high temperature flow with a cluster of small thin chimneys at the NW end rising out of a small collapsed fissure. The tallest chimney was about 2-3 m high and the fracture trend 130°. We stopped along the flowing fracture and collected fragments of a small bacterial covered chimney (S0479-R1), followed by a scoop sample of a small chimney with gelatinous bacterial material (S0479-R2). We attempted to measure fluid temperature, but there was no good orifice, so we could only confirm that the fluids were hotter than 140 °C. We slurped bacterial mat in the area (S0479-S2).

We then transited back to the smaller mound for push coring in mat (S0479-PC1-4) in various areas of different colored mat, accompanied by temperature-depth profiles using the High T probe. We slurped orange mat (S0479-S3) followed by white mat (S0479-S4) in the area where we collected the cores. Water samples were taken (S0479-N1/N2 – but N1 leaked on the way up).

We next transited back to the larger, more active northern mound to find a place to measure high T flow, passing by the small, 3-m high chimney visible in the bathymetry 20 m east of the southern edge of the northern mound. This isolated chimney is topped by a cap of healthy tube worms, like a smaller version of the Matterhorn. After surveying the top of the mound for a suitable place to measure fluids, we chose to do so at the 2-m vigorously venting flange projecting from near to top of the slope leading to the upper terrace of the mound. A stable temperature of 270° C was recorded, which should be closer to 272° C given the offset in bottom water temperature. We collected a couple of pieces broken from the active flange

(S0479-R3). Next, we suctioned paralvinellids next to the flange (S0479-S5), followed by a tube worm grab, with attached anemone (S0479-A1).

We left the mound flying to the east and dropped down to the base to investigate an extensive area of bacterial mat that wraps around the base of the mound trending off the north in a shallow moat-like depression. We decided to land on some peach-colored mat in order to collect a quick push core (S0479-PC101) in an extensive area of granular, ashy, grey colored mat. We next transited approximately 50 m at heading ~025 and landed near a small, non-distinct pockmark shown on the bathymetry for a final heat flow measurement (gradient = 8.45C/m; HF=6.76 W/m2). S0479-S6 and S0479-S7 collected concentrated marine snow on ascent, but these failed and were instead full of sediment.

ROV dive S0480

Dive Location: Auka Vent Field – Matterhorn and Z mound

Dive Summary: The Auka Vent Field in the South Pescadero Basin was discovered and characterized during expeditions in 2012-2015 with mapping AUV surveys and ROV dives in 2015-2018. The largest southernmost vent edifices in this region are Matterhorn and Z vent, where we explored and sampled earlier on this expedition. This dive had 4 primary objectives: 1) to land ~ 50 W of the Matterhorn to deploy a colonization array (intended to be picked up in April 2022), 2) travel to Matterhorn to recover a short-term mineral colonization experiment deployed on dive S0470, 3) transit to the Dolomites site to collect push cores and corresponding temperature profiles, and then 4) transit to Z vent to recover a short-term colonization array deployed on dive S0471. If time allows, we will do a temp survey in the sediments around the oily bacterial mats SE of Z vent. Study site coordinates (in order): Matterhorn Vent: -108.8630482° 23.9538143° Depth: -3641 m The Dolomites: -108.862350° 23.954747° Depth: -3636 m Z Vent: -108.86183° 23.956665° Depth: -3663 m Oily Mats (Way point from S0471): -108.861697° 23.956168° Depth: -3668 m.

Start of Dive: 2021-11-08 13:00:22
End of Dive: 2021-11-09 00:03:10
Max Depth: 3664.08 m

ROV dive video feed: https://youtu.be/qpQ3qG1RPRs
https://youtu.be/w3s8A2WLqTg

Samples: 7 slurps, 3 push cores, 4 rocks, 4 colonization arrays, 2 Niskins (**Figure 36**).

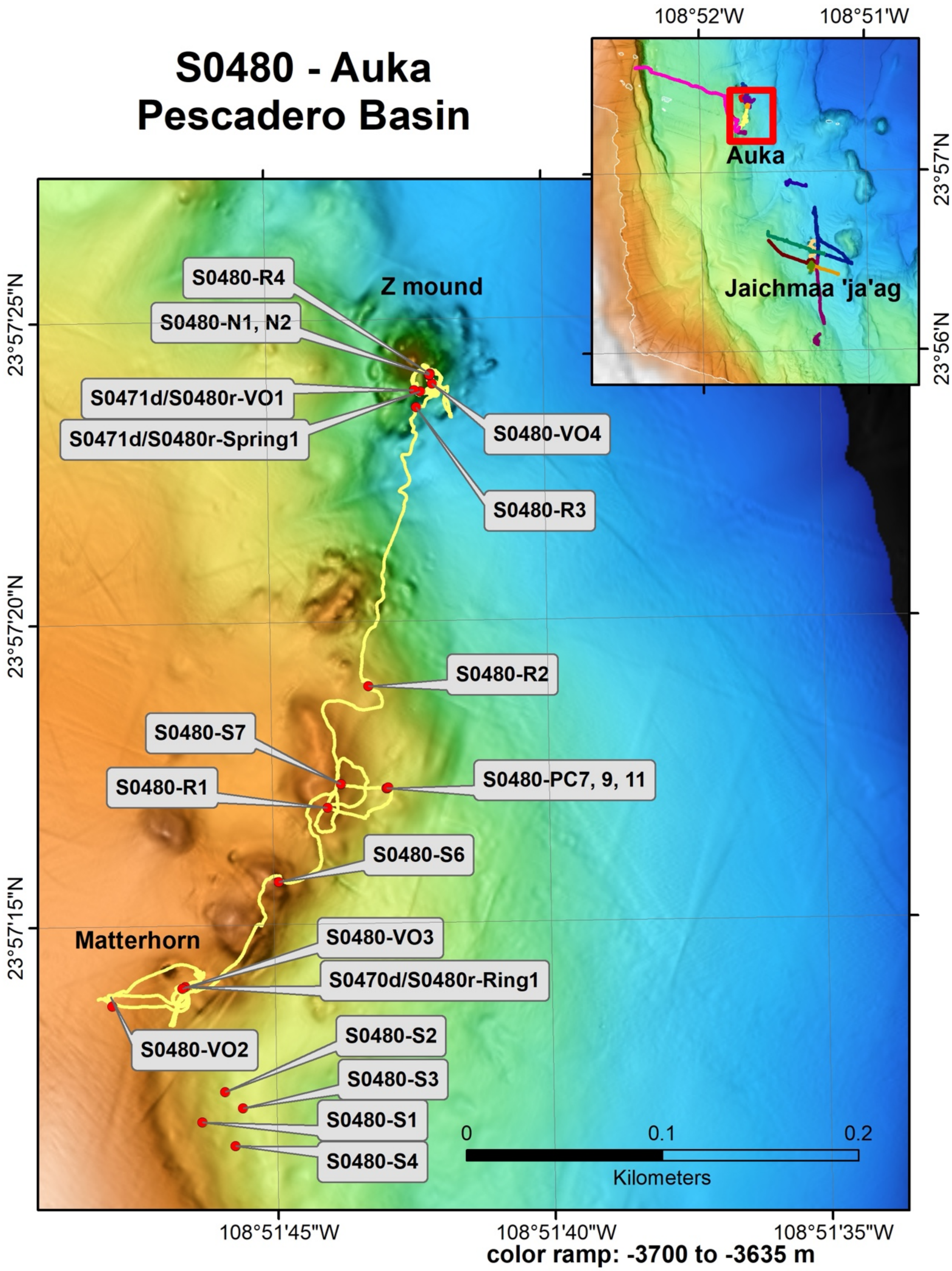

Figure 36. Map of ROV *SuBastian* dive S0480 in the Auka Vent Field. Dive track is yellow line; samples are red dots. Samples not along the dive track were collected in the midwater. Bathymetry is Mapping AUV data at 1-m resolution. The map is offset about 30m to the NE of the ROV track; VO2 was placed on top of Matterhorn. The color ramp, blue to orange, is 3700 to 3635 m depth.

Recap of S0480 – Z Vent (November 8, 2021):

On descent, we slurped 4 marine snow samples (S0480-S1 thru 4). Landed 37 m West of the Matterhorn to deploy an inactive colonization array [Originally deployed VO-3, but then swapped it for VO-2 when we realized there was bone on some of them – see below]. Travelled to Matterhorn, did fly arounds for 3D reconstruction, and then recovered S0470d/S0480r-Ring1 mineralization expt. Then returned to the inactive launch point to switch the arrays (Deployed S0480-VO2 in inactive area). Returned to Matterhorn and deployed S0480-VO3 in an active area at the top.

Enroute to the Dolomite area we noticed numerous Riftia in a clump with *Paralvinella* (turned out to be *P. grasslei*), which we slurped (S0480-S6). There was shimmering fluid and clam beds sporadically. Collected S0480-R1 near tube anemones, brown sediments. Travelled E and took pushcores (S0480-PC7,9,11 in peachy mat and brown sediment) along with high temp measurements (S0480-HT1/2/3). We also slurped peachy mat (S0480-S7).

Transit to Z vent – along the way we collected S0480-R2 from a reddish rock outcrop S of Z vent, which had numerous zoanthids and a large barnacle on it. At the base of Z vent, we collected S0480-R3, which was an upside-down flange with dramatic tubular dendritic structures. Up the mound, spotted 2018 'Marker 8' and then located and recovered S0471d/S0480r-Spring1. Also observed and collected what remained of the sad charred remains of colonization array S0471d/S0480r-VO1 (note polypro melted, along with some of the bags – not our finest moment, but flow became much more vigorous after deployment). Deployed S0480-VO4 in an active area in a saddle between tubeworm clumps at the top. Departed Z vent summit and collected one last rock S0480-R4. Niskins were tripped (S0480-N1/N2).

ROV dive S0481

Dive Location: JaichMaa 'ja'ag

Dive Summary: The JaichMaa 'ja'ag vent field in the South Pescadero Basin consists of four large and several small hydrothermal edifices. One of the largest, is known as the Big Cave (or Cavern). Our final dive had three primary objectives: (1) travel to a site slightly S of the Big Cavern mound to collect push cores and corresponding temperature profiles, (2) travel to the Big Cavern to deploy and observe/ recover colonization experiment from S0476 and collect rocks and animals, (3) travel to the Red Hill (Weey 'kual) site to collect animal and rock samples. Upside-down flange (S of Big Cave): -108.855744° 23.941126° Depth: -3663 m Study site coordinates: Upside-down flange (S of Big Cave): -108.855744° 23.941126° Depth: -3663 m Big Cave: -108.855827° 23.941493° Depth: -3647 m Weey 'kual (Red Hill): -108.855866° 23.940522° Depth: -3646 m

Start of Dive: 2021-11-09 11:41:09
End of Dive: 2021-11-10 00:04:21
Max Depth: 3666.93 m

ROV dive video feed: https://www.youtube.com/watch?v=gBGsrFa0uB4

Samples: 8 slurps and 2 animal grabs, 4 Niskins, 2 push cores, 5 rocks, 2 heat flow, 2 colonization arrays (**Figure 37**).

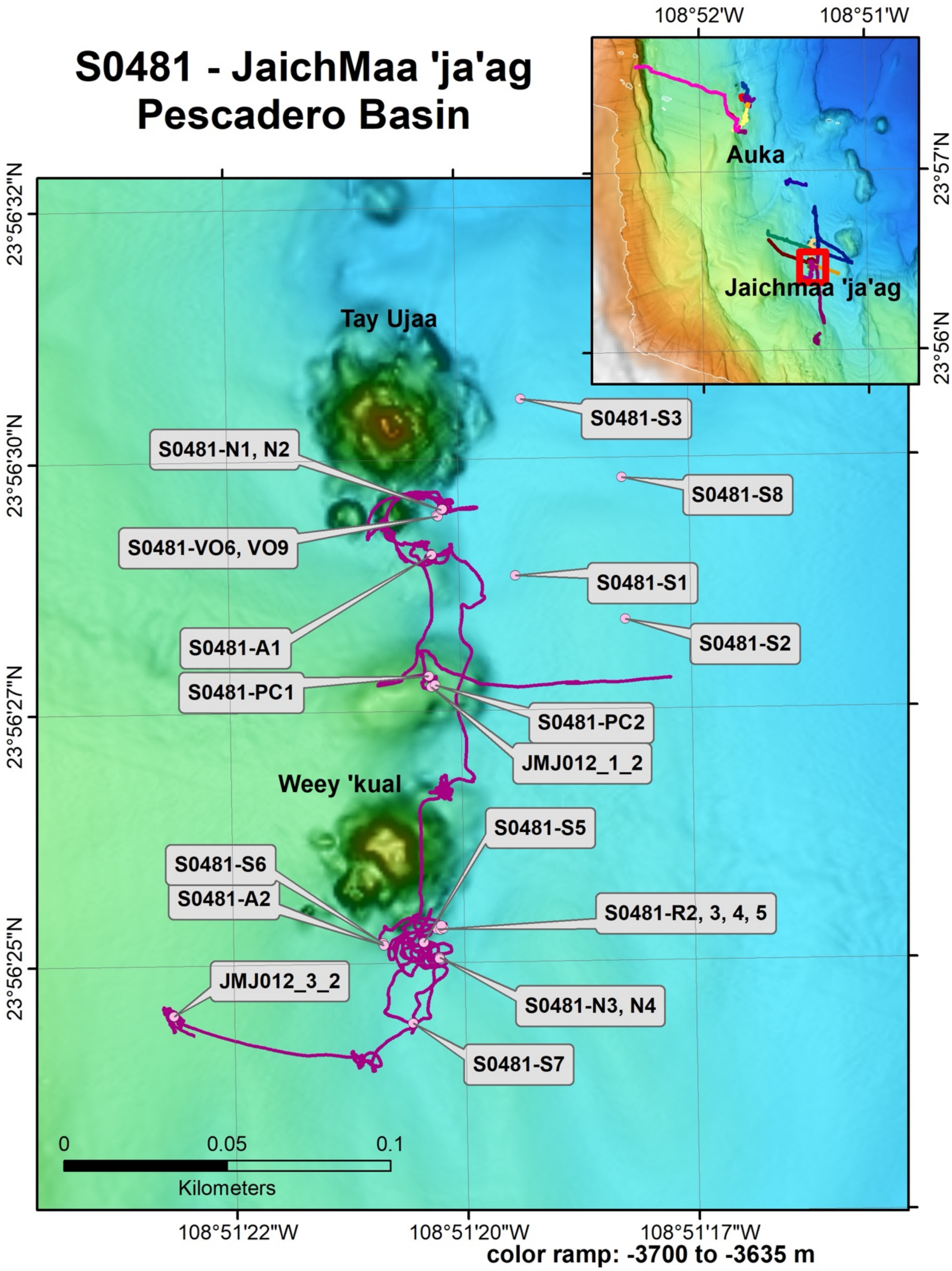

Figure 37. Map of ROV *SuBastian* dive S0481 in the JaichMaa 'ja'ag Vent Field. Dive track is purple line; samples are pink dots. Samples not along the dive track were collected in the midwater. Heat flow samples are numbered like "JMJ00*". Bathymetry is Mapping AUV data at

1-m resolution. Map is offset ~30 m NNW; R2-5 were collected on the northern edge of the high spot on Weey ‘kual. The color ramp, blue to orange, is 3700 to 3635 m depth.

Recap of S0481 - Big Cave to Red Hill (November 9, 2021)

On descent, collected a polychaete, and marine snow from 3 different depths. Landed on bottom very near the upside-down flange area – did heat flow measurement (JMJ012; HF = 5.5 W/m^2 – which has changed a lot since 2018, which at the time measured 120 W/m^2). Took 2 pushcores, S0481-PC1 and S0481-PC2, both in inactive sediment (in an area that was formerly active in 2018).

During the transit to the Big Cave active area, we saw what we called the ‘lazy pool’ with water barely flowing out – very interesting feature, some dark yellow and tan mineral structures. Made our way to the top, and recovered S0476d/S0481r-VO5 and deployed new / improved S0481-VO9 array. Spectacular spires, including some beehive looking structures. Observed the nearby House (deployed on S0476) – it had turned black and precipitated some metals on the house chimney. Collected water samples S0481-N1/N2 near active high point near *Oasisia*.

After attempting unsuccessfully to sample sulfur tubes up under the collapsed cave walls, we spotted a solitary flange that had fallen off. Giant piece collected into the milkcrate (S0481-R1) – it had the finger-like projections on the formerly fluid facing side. Marker 5 spotted – picked up foam, but also the bottom anchor, both of which had fallen downhill since 2018. Collected anemones on dead tubes (S0481-A1). Moved on to observe mats – took temperature measurement in white shimmering surface (S0481-HT1; 85 °C at 5 cm), as well as S0481-HT2 and S0481-HT3 in peach mat and gray sediment, resp. S0481-HT4 taken in clams. Headed to Red Hill, and took the opportunity for a photo op with the R/V *Falkor* replica. Slurped active *Oasisia* clump (S0481-S5), Slurped fully inactive clump (S0481-S6), Collected inactive anemones (S0481-A2) and then slurped a transitional zone real (S0481-S7). Searched and found an active chimney to sample (S0481-R2 = very friable so now in bits) and S0481-R3 (chimney stub structure). Gnawing off inactive flange covered with bacteria (S0481-R4 is the inside of the structure and S0481-R5 is the top of the flange. Did a final fly around for 3D reconstruction. Fired S0481-N3/N4 near Red Hill. Commencing Heat Flow – did 2 stations. Off Bottom. What a dive!

6. ROV *SuBastian* Sample Collections

The list of samples below (Table 2) was derived from the R/V *Falkor* marine techs’ output of CSV, XYZ, KML, and Sample Summary PDF files. Excel spreadsheets and GIS shapefiles can be obtained from the Chief Scientist.

Table 2. ROV-collected samples.

SampleName	Timestamp	Latitude	Longitude	Depth (m)	Comment*	Type
S0461						
S0461-PC11	2021-10-08T17:31:56Z	24.522491	-109.756482	1001.8	Sediment sample 1; The escarpment is fully sedimented. No rock observation	Push core
S0461-R1	2021-10-08T17:46:58Z	24.522613	-109.757218	968.2		Rock
S0461-R2	2021-10-08T17:52:57Z	24.522621	-109.757214	968.4		Rock
S0461-R3	2021-10-08T18:02:11Z	24.522675	-109.757449	956.9	It looks different than the two other ones. Perhaps weathering	Rock
S0461-PC18	2021-10-08Z18:13:01Z	24.522791	-109.758303	931.0		Push core
S0463						
JMJ001_02	2021-10-19T21:23:12.706Z	23.940749	-108.855787	3677.7	probe in mud	Heat flow probe
JMJ001_1_3	2021-10-19T21:36:34.876Z	23.940757	-108.855767	3677.5	heat pulse	Heat flow probe
JMJ001_2_3	2021-10-19T22:34:26.594Z	23.941199	-108.855365	3686.3	heat pulse	Heat flow probe
JMJ001_3_3	2021-10-19T22:58:19.316Z	23.941003	-108.854923	3686.1	heat pulse	Heat flow probe
JMJ001_4_2	2021-10-19T23:16:35.964Z	23.940880	-108.854462	3688.4	probe in mud	Heat flow probe
JMJ001_5_2	2021-10-19T23:32:04.666Z	23.940738	-108.853951	3690.8	probe in mud	Heat flow probe
JMJ001_6_3	2021-10-20T00:00:22.426Z	23.940431	-108.853056	3692.5	heat pulse	Heat flow probe
S0463-PC1	2021-10-20T00:09:58.149Z	23.940424	-108.853057	3692.6	Background push core; full insertion	Push core
S0463-TiMaj_orange	2021-10-20T00:24:44.017Z	23.940431	-108.853042	3692.6	Background bottom water sample	TiMajor fluid
S0464						
S0464-T1	2021-10-20T19:02:17.853Z	23.941534	-108.855810	3668.1	286oC under flange	High temp
S0464-GT-red-yellow	2021-10-20T19:15:14.770Z	23.941540	-108.855810	3668.0	under flange	Gas-tight fluid
S0464-GT-red	2021-10-20T19:26:09.307Z	23.941545	-108.855807	3668.0	under flange	Gas-tight fluid
S0464-TiMaj-orange	2021-10-20T19:41:58.857Z	23.941536	-108.855816	3667.9	under flange	TiMajor fluid
JMJ002_1_3	2021-10-20T20:08:24.183Z	23.941450	-108.856012	3683.1	heat pulse	Heat flow probe
JMJ002_2_3	2021-10-20T20:28:36.352Z	23.941488	-108.856217	3682.8	heat pulse	Heat flow probe
JMJ002_3_2	2021-10-20T20:41:31.101Z	23.941601	-108.856438	3682.0	probe in mud	Heat flow probe
JMJ002_4_3	2021-10-20T21:01:48.676Z	23.941655	-108.856626	3680.9	heat pulse	Heat flow probe
JMJ002_5_2	2021-10-20T21:15:12.943Z	23.941805	-108.857089	3678.9	probe in mud	Heat flow probe
JMJ002_6_2	2021-10-20T21:39:19.599Z	23.942260	-108.858484	3675.8	probe in mud	Heat flow probe
JMJ002_7_3	2021-10-20T21:54:02.117Z	23.942272	-108.858475	3675.9	heat pulse	Heat flow probe
S0464-PC9	2021-10-20T22:11:24.681Z	23.942286	-108.858524	3675.6		Push core
S0465						
S0465-PCB	2021-10-21T16:24:20.401Z	23.944121	-108.860007	3664.8	Pushcore B	Push core
JMJ003_1_3	2021-10-21T16:36:18.290Z	23.944105	-108.860046	3664.8	heat pulse	Heat flow probe
JMJ003_2_2	2021-10-21T16:50:53.619Z	23.943933	-108.859546	3669.2	probe in mud	Heat flow probe
JMJ003_3_3	2021-10-21T17:11:09.943Z	23.943863	-108.859272	3670.6	heat pulse	Heat flow probe
JMJ003_4_1	2021-10-21T17:22:16.951Z	23.943757	-108.859035	3672.4	probe in mud	Heat flow probe
JMJ003_5_3	2021-10-21T17:49:16.844Z	23.943591	-108.858189	3680.7	heat pulse	Heat flow probe
JMJ003_6_2	2021-10-21T18:07:19.613Z	23.943214	-108.857197	3687.1	probe in mud	Heat flow probe
JMJ003_7_3	2021-10-21T18:29:08.743Z	23.943065	-108.856775	3689.8	heat pulse	Heat flow probe
JMJ003_8_2	2021-10-21T18:43:47.116Z	23.942915	-108.856311	3689.9	probe in mud	Heat flow probe
S0465-PCA	2021-10-21T19:02:43.587Z	23.942764	-108.855817	3681.5	about 1-2 m away from inactive hydrothermal chimney	Push core
JMJ003_9_2	2021-10-21T19:16:56.072Z	23.942674	-108.855872	3687.2	probe in mud; measurement stopped	Heat flow probe
JMJ003_10_3	2021-10-21T19:29:00.029Z	23.942644	-108.855836	3687.2	heat pulse	Heat flow probe
JMJ003_11_02	2021-10-21T19:46:45.739Z	23.942535	-108.855733	3688.9	probe in mud	Heat flow probe
JMJ003_12_02	2021-10-21T20:03:06.928Z	23.942572	-108.855392	3691.3	probe in mud	Heat flow probe
JMJ003_13_03	2021-10-21T20:24:44.932Z	23.942446	-108.854911	3695.4	heat pulse	Heat flow probe
JMJ003_14_03	2021-10-21T20:45:20.432Z	23.942359	-108.854441	3691.8	heat pulse	Heat flow probe
JMJ003_15_02	2021-10-21T21:02:45.894Z	23.942379	-108.854698	3693.1	probe in mud	Heat flow probe

* Comments and other data drawn from sample lists provided by the R/V *Falkor* techs.

Table 2 (continued).

SampleName	Timestamp	Latitude	Longitude	Depth (m)	Comment*	Type
S0466						
JMJ004_01_02	2021-10-22T17:09:47.129Z	23.942183	-108.854238	3692.0	probe in mud	Heat flow probe
JMJ004_02_03	2021-10-22T17:32:26.106Z	23.942095	-108.853822	3693.7	heat pulse	Heat flow probe
JMJ004_03_02	2021-10-22T17:46:21.662Z	23.941805	-108.852864	3697.8	probe in mud	Heat flow probe
JMJ004_04_03	2021-10-22T18:19:19.843Z	23.941561	-108.852041	3705.7	heat pulse	Heat flow probe
JMJ004_05_02	2021-10-22T18:35:39.036Z	23.941378	-108.851656	3711.0	probe in mud	Heat flow probe
JMJ004_06_02	2021-10-22T19:24:58.541Z	23.944060	-108.855014	3704.5	probe in mud	Heat flow probe
JMJ007_07_02	2021-10-22T19:41:31.874Z	23.944940	-108.855148	3705.8	probe in mud	Heat flow probe
JMJ004_08_03	2021-10-22T20:03:37.688Z	23.945771	-108.855214	3707.1	heat pulse	Heat flow probe
JMJ004_09_02	2021-10-22T20:18:56.180Z	23.946657	-108.855326	3706.8	probe in mud	Heat flow probe
JMJ004_10_02	2021-10-22T20:53:55.628Z	23.943549	-108.855008	3701.5	probe in mud	Heat flow probe
JMJ004_11_03	2021-10-22T21:15:59.483Z	23.943088	-108.855020	3697.8	heat pulse	Heat flow probe
JMJ004_12_02	2021-10-22T21:28:58.333Z	23.942787	-108.855003	3695.8	probe in mud	Heat flow probe
JMJ004_13_02	2021-10-22T21:41:24.418Z	23.942718	-108.855008	3696.1	probe in mud	Heat flow probe
JMJ004_14_03	2021-10-22T22:07:44.861Z	23.942255	-108.855004	3694.2	heat pulse	Heat flow probe
S0467						
S0467-T1	2021-10-23T17:24:06.273Z	23.953835	-108.862997	3649.9	in orifice on side of chimney	High temp
S0467-GT-red-green	2021-10-23T17:48:04.891Z	23.953843	-108.863001	3650.0		Gas-tight fluid
S0467-GT-black-orange	2021-10-23T18:08:25.896Z	23.953851	-108.863007	3649.9		Gas-tight fluid
S0467-TiMaj-blue	2021-10-23T18:19:16.061Z	23.953845	-108.863001	3649.8	trigger ram broke off; collected ambient sample	TiMajor fluid
S0467-PCB	2021-10-23T18:47:16.953Z	23.953791	-108.863163	3653.7		Push core
S0467-PCD	2021-10-23T19:26:45.634Z	23.954877	-108.863075	3655.9		Push core
AUK001_01_02	2021-10-23T20:03:14.325Z	23.957112	-108.864215	3666.3	probe in mud	Heat flow probe
AUK001_02_03	2021-10-23T20:31:30.090Z	23.957402	-108.865142	3663.0	heat pulse	Heat flow probe
AUK001_03_04	2021-10-23T20:53:39.666Z	23.958008	-108.867020	3665.6	probe out of mud	Heat flow probe
AUK001_04_02	2021-10-23T20:56:48.300Z	23.957992	-108.867002	3665.6	probe in mud	Heat flow probe
AUK001_05_02	2021-10-23T21:18:44.331Z	23.958597	-108.868797	3664.7	probe in mud	Heat flow probe
AUK001_06_02	2021-10-23T21:52:10.931Z	23.959655	-108.871694	3648.5	probe in mud	Heat flow probe
AUK001_07_01	2021-10-23T22:12:11.342Z	23.959822	-108.873076	3577.9	heat flow measurement?	Heat flow probe
AUK001_08_03	2021-10-23T22:26:31.376Z	23.959796	-108.873015	3578.2	heat pulse	Heat flow probe
S0468						
JMJ005_01_02	2021-10-24T17:09:18.123Z	23.936763	-108.854760	3684.1	probe in mud	Heat flow probe
JMJ005_02_03	2021-10-24T17:38:23.398Z	23.935857	-108.854501	3681.4	heat pulse	Heat flow probe
JMJ005_03_02	2021-10-24T18:12:39.853Z	23.937728	-108.854872	3685.5	probe in mud	Heat flow probe
JMJ005_04_03	2021-10-24T18:38:10.293Z	23.938665	-108.854975	3686.4	heat pulse	Heat flow probe
JMJ005_05_02	2021-10-24T18:55:08.042Z	23.939531	-108.855040	3685.7	probe in mud	Heat flow probe
JMJ005_06_02	2021-10-24T19:11:57.563Z	23.940468	-108.855085	3685.9	probe in mud	Heat flow probe
JMJ005_07_03	2021-10-24T19:33:47.924Z	23.940948	-108.855218	3685.8	heat pulse	Heat flow probe
JMJ005_08_02	2021-10-24T19:44:34.565Z	23.941190	-108.855217	3686.1	probe in mud	Heat flow probe
JMJ005_09_01	2021-10-24T20:14:37.417Z	23.941692	-108.855124	3688.6	probe in mud; real time: 20:17:43	Heat flow probe
JMJ005_10_02	2021-10-24T20:31:10.816Z	23.941982	-108.855060	3690.7	probe in mud	Heat flow probe
JMJ005_11_02	2021-10-24T20:51:23.900Z	23.942526	-108.855011	3696.2	probe in mud	Heat flow probe
JMJ005_12_02	2021-10-24T21:04:12.471Z	23.942665	-108.855020	3696.1	probe in mud	Heat flow probe
S0468-PCB	2021-10-24T21:13:29.661Z	23.942680	-108.855030	3696.1	core tube 1; fully inserted near a clam field	Push core
JMJ005_13_03	2021-10-24T21:30:09.116Z	23.942953	-108.855006	3697.4	heat pulse	Heat flow probe
JMJ005_14_03	2021-10-24T21:55:59.205Z	23.943772	-108.855042	3702.2	heat pulse	Heat flow probe

* Comments and other data drawn from sample lists provided by the R/V *Falkor* techs.

Table 2 (continued).

SampleName	Timestamp	Latitude	Longitude	Depth (m)	Comment*	Type
S0469						
S0469-R01	2021-10-25T12:00:55.313Z	24.525901	-110.073101	730.0		Rock
S0469-R02	2021-10-25T12:12:46.612Z	24.525769	-110.073267	703.1		Rock
S0469-R03	2021-10-25T12:33:46.762Z	24.525267	-110.073941	634.3	Triangle shape.	Rock
S0469-R04	2021-10-25T12:44:42.426Z	24.524780	-110.074484	612.0	Its a more flat rock.	Rock
S0469-R05	2021-10-25T14:07:34.797Z	24.518456	-110.080369	410.1	TENNIS BALL SIZE	Rock
S0469-R06	2021-10-25T14:13:21.599Z	24.518426	-110.080448	405.5		Rock
S0469-R07	2021-10-25T14:30:29.665Z	24.517976	-110.081313	347.9	A LOT OF ORGANISMS IN IT	Rock
S0469-R08	2021-10-25T14:44:59.055Z	24.517879	-110.081923	317.9	KIND OF TRIANGLE SHAPE	Rock
S0469-R09	2021-10-25T15:22:32.257Z	24.516235	-110.084507	273.7	REDDISH OXYGENIZED ROCK SPONGES	Rock
S0469-R10	2021-10-25T15:44:37.846Z	24.515689	-110.085116	247.4	REDDISH	Rock
S0470						
S0470-A1	2021-10-29T15:34:32.036Z	23.953697	-108.862312	3668.0	anemones and Oasisia	Manipulator
S0470-S1	2021-10-29T15:47:06.250Z	23.953694	-108.862312	3668.0	tubeworms	Suction sampler
S0470-S2	2021-10-29T15:49:41.496Z	23.953693	-108.862311	3668.0	tubeworms	Suction sampler
S0470-S2	2021-10-29T15:53:00.658Z	23.953693	-108.862309	3668.0	snail	Suction sampler
S0470-S3	2021-10-29T15:55:47.401Z	23.953693	-108.862310	3668.0	tubeworms	Suction sampler
S0470-HT1	2021-10-29T16:07:47.067Z	23.953726	-108.862306	3668.5		High temp
S0470-N1	2021-10-29T16:16:29.741Z	23.953674	-108.862305	3667.1	in snowblower bacterial floc	Niskin
S0470-HT2	2021-10-29T16:22:45.218Z	23.953666	-108.862238	3669.1	3 cm 62.3 C	High temp
S0470-HT3	2021-10-29T16:24:12.882Z	23.953666	-108.862239	3669.1	3 cm	High temp
S0470-HT4	2021-10-29T16:26:19.169Z	23.953668	-108.862239	3669.1	3 cm 37.5 C	High temp
S0470-R1	2021-10-29T17:00:59.473Z	23.953819	-108.863003	3655.9		Rock
S0470-R2	2021-10-29T17:18:00.434Z	23.953853	-108.863043	3651.0	top of Matterhorn	Rock
S0470-R3	2021-10-29T17:27:13.139Z	23.953856	-108.863043	3651.1	mid Matterhorn	Rock
S0470-PC1	2021-10-29T18:14:48.289Z	23.953833	-108.862939	3657.2	in white-gray mat; paired with core and temp outside of mat nearby	Push core
S0470-PC2	2021-10-29T18:16:31.456Z	23.953840	-108.863009	3657.2	in white mat	Push core
S0470-PC3	2021-10-29T18:24:15.917Z	23.953824	-108.862913	3657.2	in white mat	Push core
S0470-PC4	2021-10-29T18:34:33.000Z	23.953813	-108.862915	3657.2	position info from 18:37:10; in brown sediment on other side of mat	Push core
S0470-HT20	2021-10-29T18:54:46.975Z	23.953857	-108.863049	3649.8		High temp
S0470-TiMaj-black	2021-10-29T19:21:52.012Z	23.953854	-108.863038	3649.9	associated with Matterhorn 170oC	TiMajor fluid
S0470-GT-plain	2021-10-29T19:38:32.361Z	23.953858	-108.863039	3649.9		Gas-tight fluid
S0470-N2	2021-10-29T19:45:29.771Z	23.953856	-108.863037	3649.9	near top of Matterhorn	Niskin
S0470-N4	2021-10-29T19:46:30.555Z	23.953856	-108.863038	3649.9	near top of Matterhorn	Niskin
S0470-N3	2021-10-29T19:47:58.299Z	23.953856	-108.863038	3649.9	near top of Matterhorn	Niskin
S0470-N1	2021-10-29T20:11:56.169Z	23.953638	-108.862234	3666.7	near top of Matterhorn	Niskin
S0470-A2	2021-10-29T20:23:42.743Z	23.953719	-108.862327	3655.2	from Wonderland; most were lost during sampling	Manipulator

* Comments and other data drawn from sample lists provided by the R/V *Falkor* techs.

Table 2 (continued).

SampleName	Timestamp	Latitude	Longitude	Depth (m)	Comment*	Type
S0471						
S0471-PC11	2021-10-30T16:54:00.982Z	23.956845	-108.862105	3679.7	annotated as PC12	Push core
S0471-PC8	2021-10-30T16:57:24.694Z	23.956856	-108.862105	3679.7		Push core
S0471-A1	2021-10-30T17:27:19.453Z	23.956853	-108.862102	3679.7	clam shell with anemone	Manipulator
S0471-S1	2021-10-30T17:33:02.074Z	23.956852	-108.862083	3679.7	snails, scaleworms	Suction sample
S0471-S2	2021-10-30T17:37:13.103Z	23.956851	-108.862101	3679.6	pink worms	Suction sample
S0471-S3	2021-10-30T17:38:06.628Z	23.956845	-108.862101	3679.7	copepods and crust	Suction sample
S0471-R1	2021-10-30T17:45:18.576Z	23.956830	-108.862106	3679.7	crust	Rock
S0471-R2	2021-10-30T18:26:42.674Z	23.956634	-108.861818	3665.0	small piece of flange near Serg deployment	Rock
S0471-N1	2021-10-30T18:34:25.482Z	23.956633	-108.861809	3656.2	above Z vent	Niskin
S0471-N2	2021-10-30T18:34:55.154Z	23.956648	-108.861799	3653.7	above Z vent	Niskin
S0471-PC9	2021-10-30T19:26:31.204Z	23.956155	-108.861690	3687.7	paired with PC7 in peachy mat	Push core
S0471-PC7	2021-10-30T19:30:00.473Z	23.956183	-108.861730	3687.7	paired with PC9 in ornage mat	Push core
S0471-PC10	2021-10-30T19:54:36.508Z	23.956214	-108.861747	3686.7	same mat as HT5	Push core
S0471-S4	2021-10-30T20:10:01.253Z	23.956223	-108.861821	3684.1	in peach mat near short white chimney	Suction sample
S0471-S5	2021-10-30T20:11:05.703Z	23.956224	-108.861822	3684.1	anemone in peach mat	Suction sample
S0471-R3	2021-10-30T20:21:38.467Z	23.956226	-108.861821	3684.1	small white chimney	Rock
S0471-R4	2021-10-30T20:25:46.545Z	23.956226	-108.861821	3684.1	base part of R3 "snowman" small white chimney	Rock
S0471-N3	2021-10-30T20:30:59.118Z	23.956247	-108.861821	3679.5	Above Z vent	Niskin
S0471-N4	2021-10-30T20:31:22.584Z	23.956266	-108.861800	3677.2	Over Z vent as ascending	Niskin
S0472						
S0472-S1	2021-10-31T13:50:07.388Z	23.955784	-108.862146	445.4	Marine Snow	Suction sample
S0472-S8	2021-10-31T14:57:09.980Z	23.956066	-108.861917	2116.6	Swima or Flota S0472-001	Suction sample
S0472-S1	2021-10-31T15:39:46.076Z	23.956256	-108.861759	3193.5	Marine Snow	Suction sample
S0472-S2	2021-10-31T17:44:03.548Z	23.956140	-108.861931	3683.8	midwater worm	Suction sample
S0472-S3	2021-10-31T17:48:17.311Z	23.956142	-108.861932	3683.7	white mat	Rock
S0472-R1	2021-10-31T18:01:39.628Z	23.956147	-108.861952	3683.0	chimney with anemones	Rock
S0472-A1	2021-10-31T18:05:40.464Z	23.956147	-108.861952	3683.0	anemones and tubeworms	Manipulator
S0472-GT-red/black	2021-10-31T18:24:45.599Z	23.956177	-108.861919	3683.1	in chimney of little house	Gas-tight fluid
S0472-HT7	2021-10-31T18:46:28.483Z	23.956173	-108.861922	3682.9	Halloween house chimney 12C	High temp
S0472-PC1	2021-10-31T19:34:17.271Z	23.956211	-108.861847	3685.2	grey mat next to white fluffy r	Push core
S0472-PC2	2021-10-31T20:05:16.081Z	23.956212	-108.861847	3685.2	in white mat	Push core
S0472-PC6	2021-10-31T20:09:21.135Z	23.956211	-108.861846	3685.2	aluminum core	Push core
S0472-PC5	2021-10-31T20:11:43.809Z	23.956211	-108.861846	3685.2		Push core
S0472-R2	2021-10-31T20:18:07.456Z	23.956210	-108.861847	3685.3	crust from white mat; lots of c	Rock
S0472-S4	2021-10-31T20:25:29.934Z	23.956208	-108.861848	3685.3	on white mat	Suction sample
S0472-S5	2021-10-31T20:27:24.690Z	23.956208	-108.861848	3685.3	in white mat area	Suction sample
S0472-GT-orange/blue	2021-10-31T20:36:31.049Z	23.956206	-108.861849	3685.3	in house at white fluffy mat	Gas-tight fluid
S0472-N1	2021-10-31T20:40:42.221Z	23.956207	-108.861849	3685.3		Niskin
S0472-N2	2021-10-31T20:41:12.653Z	23.956207	-108.861849	3685.3		Niskin
S0472-N3	2021-10-31T20:41:24.282Z	23.956206	-108.861849	3685.3		Niskin
S0472-N4	2021-10-31T20:42:58.684Z	23.956206	-108.861849	3685.3		Niskin
S0472-S6	2021-10-31T21:12:00.558Z	23.956221	-108.861921	3683.2	Xenoturbella	Suction sample
S0472-S7	2021-10-31T21:13:47.438Z	23.956222	-108.861923	3683.1		Suction sample
S0472-R3	2021-10-31T21:16:30.986Z	23.956222	-108.861924	3683.1	slab over which S7 was collect	Rock

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Table 2 (continued).

SampleName	Timestamp	Latitude	Longitude	Depth (m)	Comment*	Type
S0473						
JMJ006_2	2021-11-01T16:18:30.261Z	23.949206	-108.857780	3699.7		Heat flow probe
S0473-S3	2021-11-01T17:33:00.155Z	23.948880	-108.858100	3684.1	brown material and little animals in active fluid	Suction sample
S0473-S4	2021-11-01T17:38:12.851Z	23.948878	-108.858100	3684.1	limpets	Suction sample
S0473-S5	2021-11-01T17:40:28.729Z	23.948877	-108.858100	3684.1	worms in soft sediment	Suction sample
S0473-GasTight-pink	2021-11-01T18:07:22.371Z	23.948875	-108.858100	3684.2		Gas-tight fluid
S0473-major 3	2021-11-01T18:19:14.383Z	23.948871	-108.858100	3684.2	in deep flange mirror pool	TiMajor fluid
S0473-R1	2021-11-01T18:37:13.619Z	23.948864	-108.858100	3684.1	at the edge of the flange paired with fluid samples	Rock
S0473-R2	2021-11-01T18:47:03.952Z	23.948863	-108.858100	3684.1		Rock
S0473-A1	2021-11-01T19:16:24.817Z	23.948860	-108.858070	3681.5		Manipulator
S0473-S6	2021-11-01T19:23:25.532Z	23.948861	-108.858070	3681.6		Suction sample
S0473-A2	2021-11-01T19:47:44.507Z	23.948854	-108.858030	3686.6	slurp of dead/dying worm push; same as A1	Manipulator
S0473-A3	2021-11-01T19:49:38.578Z	23.948848	-108.858040	3686.5	red anemones from dead/dying tube worm push (same as A1 and A2)	Manipulator
S0473-R3	2021-11-01T19:56:13.553Z	23.948892	-108.858060	3685.0	chimney; less active area; two pieces	Rock
S0473-R4	2021-11-01T20:24:28.496Z	23.948967	-108.858150	3694.7	scoop of follics (sic) from edge of flange and below	Rock
JMJ007_2	2021-11-01T20:47:19.530Z	23.948907	-108.857070	3701.7		Heat flow probe
S0473-A4	2021-11-01T20:57:55.261Z	23.948894	-108.857040	3701.7	xenot	Manipulator
JMJ008_2	2021-11-01T21:10:36.984Z	23.948710	-108.856190	3706.0		Heat flow probe
JMJ009_2	2021-11-01T21:25:35.040Z	23.948659	-108.856140	3706.1		Heat flow probe
S0473-PC7	2021-11-01T21:35:00.012Z	23.948638	-108.856140	3706.1	white/grey microbial mat ring shaped in soft sediment; associated with heat flow data	Push core
S0473-N4	2021-11-01T21:36:51.913Z	23.948618	-108.856130	3700.6		Niskin
S0474						
S0474-S2	2021-11-02T14:45:21.073Z	23.955012	-108.863857	1720.8	Midwater slurp	Suction sample
S0474-S1	2021-11-02T14:51:36.198Z	23.955186	-108.863889	1882.1	Flota	Suction sample
S0474-S5	2021-11-02T15:13:47.975Z	23.955399	-108.863690	2452.0	Flota 2	Suction sample
S0474-S2	2021-11-02T15:20:42.216Z	23.955464	-108.863588	2623.4	Marine snow	Suction sample
S0474-S1	2021-11-02T15:26:54.638Z	23.955597	-108.863663	2736.1	Flota	Suction sample
S0474-S5	2021-11-02T15:37:46.697Z	23.955563	-108.863720	2945.2	Swima	Suction sample
S0474-A1	2021-11-02T16:35:42.289Z	23.955418	-108.863843	3657.0	Xenophyophore	Manipulator
S0474-A2	2021-11-02T16:49:52.513Z	23.955412	-108.863799	3656.8	Xenophyophore	Manipulator
S0474-A3	2021-11-02T17:04:28.980Z	23.955365	-108.863723	3656.4	Xenophyophore	Manipulator
S0474-A4	2021-11-02T17:12:38.984Z	23.955287	-108.863559	3656.0	Xenophyophore, partial	Manipulator
S0474-A5	2021-11-02T17:21:36.590Z	23.955108	-108.863414	3655.3	Xenophyophore	Manipulator
AUK002_1_2	2021-11-02T17:26:00.493Z	23.955131	-108.863411	3655.3		Heat flow probe
S0474-PC8	2021-11-02T17:38:57.371Z	23.955095	-108.863414	3655.2		Push core
S0474-Gas tight blue/ye	2021-11-02T18:12:25.720Z	23.954870	-108.862959	3654.8		Gas-tight fluid
S0474-major	2021-11-02T18:41:00.342Z	23.954862	-108.862944	3654.3		TiMajor fluid
S0474-PC9	2021-11-02T19:22:24.170Z	23.954822	-108.863022	3655.1		Push core
S0474-PC10	2021-11-02T19:27:10.086Z	23.954821	-108.863022	3655.1		Push core
S0474-PC12	2021-11-02T19:54:01.116Z	23.954818	-108.863022	3655.1		Push core
S0474-PC11	2021-11-02T19:54:51.044Z	23.954818	-108.863022	3655.1		Push core
S0474-S3	2021-11-02T20:17:19.769Z	23.954817	-108.863024	3655.1		Suction sample
S0474-S4	2021-11-02T20:21:20.342Z	23.954818	-108.863026	3655.1		Suction sample
S0474-R1	2021-11-02T20:36:17.380Z	23.954834	-108.863023	3654.4		Rock
S0474-VO5	2021-11-02T20:42:25.468Z	23.954800	-108.863000	3654.3	near Diane's vent at edge of white mat, close to where pushcore samples were taken and rocks	Colonization arra
S0474-R2	2021-11-02T20:47:07.358Z	23.954823	-108.863025	3654.7		Rock
S0474-N1	2021-11-02T20:48:53.398Z	23.954823	-108.863025	3654.8		Niskin
S0474-N2	2021-11-02T20:49:18.425Z	23.954822	-108.863025	3654.8		Niskin
S0474-S6	2021-11-02T21:05:09.869Z	23.954831	-108.863013	3653.2		Suction sample
S0474-S7	2021-11-02T21:15:30.648Z	23.954842	-108.863012	3654.4		Suction sample
S0474-R3	2021-11-02T21:16:22.390Z	23.954841	-108.863013	3654.4		Rock

* Comments and other data drawn from sample lists provided by the R/V *Falkor* techs.

Table 2 (continued).

SampleName	Timestamp	Latitude	Longitude	Depth (m)	Comment*	Type
S0475						
S0475-S1	2021-11-03T13:46:22.676Z	23.958115	-108.862786	440.8	marine snow	Suction sample
S0475-S2	2021-11-03T15:30:35.783Z	23.958033	-108.862030	3004.3	Swima	Suction sample
AUK003_1_2	2021-11-03T16:03:04.878Z	23.958207	-108.862402	3690.7		Heat flow probe
S0475-PC6	2021-11-03T17:15:32.779Z	23.957912	-108.862261	3674.2	aluminum core tube	Push core
S0475-Q7	2021-11-03T17:41:10.428Z	23.957991	-108.862237	3674.1	fine sediment scooped with PC3	Push core
S0475-S3	2021-11-03T18:11:07.490Z	23.957926	-108.862279	3674.6	mat, scaleworms, tubeworm, Paralvinella	Suction sample
S0475-S4	2021-11-03T18:12:56.298Z	23.958017	-108.862194	3674.6	tubeworms, bacterial floc	Suction sample
S0475-R1	2021-11-03T18:34:43.299Z	23.957985	-108.862250	3674.1	3B-inactive chimney	Rock
S0475-R2	2021-11-03T18:52:24.165Z	23.957971	-108.862258	3675.1	P-vent flange chunk from under R1	Rock
S0475-N1, N2	2021-11-03T18:55:31.236Z	23.957947	-108.862317	3670.6	above P-vent	Niskin
S0475-Major-white	2021-11-03T19:42:02.250Z	23.956680	-108.861770	3667.5	at large flange at Z vent; temp 275 oC.	TiMajor fluid
S0475-GT-black	2021-11-03T19:50:34.100Z	23.956692	-108.861789	3667.4	at Z-vent flange	Gas-tight fluid
S0475-PC2	2021-11-03T20:57:33.991Z	23.956974	-108.862079	3681.9	brown live clam sediment	Push core
S0475-PC1	2021-11-03T21:01:25.867Z	23.956978	-108.862067	3681.9	short core; film tarnished only at bottom 5cm	Push core
S0475-PC4	2021-11-03T21:27:34.319Z	23.956858	-108.862286	3673.6	in dense clam bed at white patch; lost most	Push core
S0476						
S0476-S1	2021-11-04T14:37:31.483Z	23.941112	-108.855835	1494.6	S0476_001 Marine snow	Suction sample
S0476-S2	2021-11-04T15:26:48.265Z	23.940703	-108.856160	2656.1	S0476_002 Swima	Suction sample
S0476-PC7	2021-11-04T17:36:47.889Z	23.940808	-108.855620	3679.7	over paralvinalla worms close to active venting	Push core
S0476-PC11	2021-11-04T19:09:47.185Z	23.940734	-108.855776	3677.5	white mat	Push core
S0476-PC9	2021-11-04T19:15:37.823Z	23.940754	-108.855783	3677.4	other small white mat	Push core
S0476-S3	2021-11-04T19:28:44.289Z	23.940735	-108.855768	3677.4	orange mat	Suction sample
S0476-S4	2021-11-04T19:31:11.726Z	23.940696	-108.855783	3677.4	Xenoturbella	Suction sample
S0476-PC102	2021-11-04T20:07:43.048Z	23.940722	-108.855730	3677.2	aluminum core tube	Push core
S0476-PC10	2021-11-04T20:10:49.131Z	23.940751	-108.855769	3677.2	peachy mat	Push core
S0476-S5	2021-11-04T20:15:07.817Z	23.940718	-108.855765	3677.2	peachy mat and worms	Suction sample
S0476-R1	2021-11-04T20:30:12.022Z	23.940693	-108.855729	3677.5		Rock
S0476-R2	2021-11-04T20:31:12.351Z	23.940693	-108.855730	3677.5		Rock
S0476-HOUSE	2021-11-04T20:46:12.302Z	23.941600	-108.855700	3664.3	next to tubeworms and active fluid	Colonization arra
S0476-A1	2021-11-04T20:49:20.199Z	23.941555	-108.855710	3661.9	tubeworms next to house	Manipulator
S0476-R3	2021-11-04T21:09:52.809Z	23.941548	-108.855670	3671.4	white orange staining	Rock
S0476-R4	2021-11-04T21:14:42.621Z	23.941552	-108.855669	3671.3	from bottom Big Cave (R3 in summary table)	Rock
S0476-S6	2021-11-04T21:20:08.244Z	23.941552	-108.855674	3671.4	tubeworms and scaleworms	Suction sample
S0476-N1	2021-11-04T21:29:30.520Z	23.941509	-108.855859	3632.7		Niskin
S0476-N2	2021-11-04T21:30:12.675Z	23.941479	-108.855870	3615.0		Niskin

* Comments and other data drawn from sample lists provided by the R/V *Falkor* techs.

Table 2 (continued).

SampleName	Timestamp	Latitude	Longitude	Depth (m)	Comment*	Type
S0477						
S0477-S1	2021-11-05T15:15:48.000Z	23.956446	-108.861424	2596.6	Swima	Suction sample
S0477-S2	2021-11-05T15:50:13.290Z	23.956758	-108.862113	3393.9	Marine Snow 3380m?	Suction sample
S0477-R1	2021-11-05T17:13:38.942Z	23.956732	-108.862247	3672.8	Fuzzy rock, covered in white mats, anemones in 3B	Rock
S0477-PC2	2021-11-05T17:39:29.813Z	23.956863	-108.862123	3680.2	In little white mat patch, targetted at center of direct flow. Paired with HT1 measurement. Has film	Push core
S0477-PC4	2021-11-05T17:42:21.103Z	23.956863	-108.862122	3680.2	Inserted into same small patchy white mat area, direclty to right of PC2. Paired with HT1. ERROR - This is S0477-PC4. Mud popped up through the stopper when racked. Might be over penetrated.	Push core
S0477-PC3	2021-11-05T18:09:53.796Z	23.956862	-108.862124	3680.0	White small mat area #2. Associated with HT5 and PC 1; PC3 inserted at this time	Push core
S0477-PC1	2021-11-05T18:13:07.220Z	23.956860	-108.862124	3680.0		Push core
S0477-PC5	2021-11-05T19:24:59.903Z	23.957003	-108.862364	3676.8	Placed in grey sediment next to active venting	Push core
S0477-PC6	2021-11-05T19:28:19.379Z	23.957001	-108.862363	3676.8	Inserted into ground. hit something hard with 5-8cm left to push down. Oil came up	Push core
S0477-S3	2021-11-05T19:37:03.024Z	23.956998	-108.862364	3676.7	Worms, mat	Suction sample
S0477-S4	2021-11-05T19:39:34.182Z	23.956997	-108.862363	3676.7	going after anemone, in same hot white mat as S3; some tube worms	Suction sample
S0477-A1	2021-11-05T19:42:51.616Z	23.956997	-108.862363	3676.7	Grab of anemone on clam shell, anemone from hot white mat fluid active area, originally in S3 and S4 location	Manipulator
AUK004_1_2	2021-11-05T19:57:09.452Z	23.957017	-108.862665	3676.8	Probe in mud; Only 3 termistors are inside de sediment	Heat flow probe
AUK004_2_2	2021-11-05T20:24:05.378Z	23.956666	-108.862365	3668.6	Probe in mud. All thermistors inside sediment	Heat flow probe
S0477-A2	2021-11-05T20:33:04.846Z	23.956623	-108.862377	3668.5	Long frenulate observed at heat flow site en route to "the dolomites"	Manipulator
S0477-R2	2021-11-05T21:10:56.132Z	23.956713	-108.862469	3667.7	Piece of larger crumbly rock covered in biology/tube anemones. Orange. Biobox 3A; no nav in sealogExport	Rock
S0477-S5	2021-11-05T22:14:04.569Z	23.956472	-108.862332	2619.9	Something from the water column...	Suction sample
S0477-S6	2021-11-05T23:04:51.952Z	23.956555	-108.862228	1357.8	Yellow marine snow in slurp 6	Suction sample
S0477-S7	2021-11-05T23:32:56.348Z	23.956007	-108.862506	628.4	Poeobius, collected during ascent. Check Biology Observation for photo.	Suction sample

* Comments and other data drawn from sample lists provided by the R/V *Falkor* techs.

Table 2 (continued).

SampleName	Timestamp	Latitude	Longitude	Depth (m)	Comment*	Type
S0478						
S0478-S1	2021-11-06T14:47:33.153Z	23.943514	-108.855955	1915.2	S0478_001; Small amount of marine snow; slurped over it	Suction sample
S0478-S1	2021-11-06T15:05:31.641Z	23.943428	-108.855416	2384.7	Marine Snow 1	Suction sample
S0478-S2	2021-11-06T16:18:12.432Z	23.943436	-108.855598	3695.1	Tubeworms, anemones, scaleworms	Suction sample
S0478-A1	2021-11-06T16:26:37.389Z	23.943431	-108.855598	3695.1	Tubeworms with anemones in Bio-Box 3A	Manipulator
S0478-R1	2021-11-06T16:38:34.762Z	23.943469	-108.855622	3695.4	Big piece of rock in Bio Box 3A paired with anemones.	Rock
S0478-R1	2021-11-06T16:39:12.474Z	23.943469	-108.855621	3695.4	rock on top of tubeworms in 3B looks like low/ inactive site	Rock
S0478-HT1	2021-11-06T16:46:18.740Z	23.943481	-108.855591	3695.1	S0478-HT1	High temp
S0478-A2	2021-11-06T16:55:29.190Z	23.943481	-108.855589	3695.0	Active tubeworms in Bio-Box 3A	Manipulator
S0478-A3	2021-11-06T17:20:22.334Z	23.943196	-108.855728	3692.9	Different Tubeworms collected in little sister	Manipulator
S0478-R2	2021-11-06T17:28:05.786Z	23.943195	-108.855729	3692.3	Rock covered with blue material	Rock
S0478-R3	2021-11-06T17:59:39.310Z	23.943113	-108.855757	3681.2	Fuzzy, low active chimney covered with mat in top Little Sister, North side	Rock
S0478-HT2	2021-11-06T18:26:16.173Z	23.943011	-108.855880	3679.3	286.2 oC, directly in the chimney	High temp
S0478-R4	2021-11-06T18:37:32.527Z	23.942975	-108.855930	3679.3	Skinny and fragile chimney covered with mat, at the top of Little sister in Q6. Paired to HT2	Rock
S0478-S3	2021-11-06T19:01:23.157Z	23.942856	-108.855525	3675.4	slurp in brown material at base of white covered rock on larger sister mound.	Suction sample
S0478-S3	2021-11-06T19:08:04.645Z	23.942865	-108.855517	3675.3	White mat near top of big sister (brown sediment was suppose to go in S3, but was pulled into S1 by mistake. New S3 was taken of white sediment)	Suction sample
S0478-A4	2021-11-06T19:15:25.409Z	23.942870	-108.855510	3675.2	grab of red plumed tube worm, solitary, from top of big sister. near site of Slurp 3. oisisia	Manipulator
S0478-PC7	2021-11-06T20:08:04.839Z	23.942776	-108.855156	3694.3	Inserted into edge of live clam bed, associated with HT3.	Push core
S0478-PC9	2021-11-06T20:12:26.891Z	23.942772	-108.855155	3694.3	inserted next to PC7, but hit temp probe about hafl way inserted. removed, short core	Push core
S0478-A5	2021-11-06T20:19:13.488Z	23.942776	-108.855147	3694.2	live clam with attached white sea anemone from live clam bed.	Manipulator
S0478-PC8	2021-11-06T20:42:52.842Z	23.942816	-108.855200	3694.0	PC8 inserted into soft brown sediment, a few m away from live clam patch. inserted in sparse clam area, associated with HT4	Push core
S0478-N1	2021-11-06T20:51:03.521Z	23.942823	-108.855167	3692.0	Firing over live and dead clam sample areas, east of large mound	Niskin
S0478-N2	2021-11-06T20:52:09.412Z	23.942792	-108.855094	3686.0	same as N1 east of large mound, over clam sample area live and dead	Niskin
S0478-R5	2021-11-06T21:33:29.441Z	23.941735	-108.855553	3685.4	Scoops of ctinophore wall of grey and red rock sections. Placing entire scoop in biobox 4.	Rock
S0478-S6	2021-11-06T21:58:29.610Z	23.941508	-108.855365	3134.2	Marine Snow Ascent	Suction sample

* Comments and other data drawn from sample lists provided by the R/V *Falkor* techs.

Table 2 (continued).

SampleName	Timestamp	Latitude	Longitude	Depth (m)	Comment*	Type
S0479						
S0479-S1	2021-11-07T15:06:57.635Z	23.934293	-108.855352	2214.0	Swima	Suction sample
JMJ011_1_2	2021-11-07T16:14:53.876Z	23.933932	-108.855159	3661.4		Heat flow probe
S0479-R1	2021-11-07T17:15:36.867Z	23.934287	-108.855409	3653.3	little chimney chunk by gelatinous biofilm on ridge by mat mound	Rock
S0479-R2	2021-11-07T17:23:08.084Z	23.934286	-108.855406	3653.3	rock scoop with more white mineral and gelatinous biofilm	Rock
S0479-S2	2021-11-07T17:52:08.269Z	23.934284	-108.855415	3653.2	fireworm; chimney bits; dorvilleids; copepods; maybe limpets; mat	Suction sample
S0479-R1	2021-11-07T18:13:01.741Z	23.934286	-108.855420	3653.2	broken/fallen chimney chunks	Rock
S0479-PC3	2021-11-07T18:31:15.256Z	23.934134	-108.855388	3659.1		Push core
S0479-PC2	2021-11-07T18:37:06.966Z	23.934135	-108.855386	3659.2	blue mat	Push core
S0479-PC1	2021-11-07T19:05:28.686Z	23.934138	-108.855381	3659.0	peachy mat	Push core
S0479-PC4	2021-11-07T19:29:51.651Z	23.934146	-108.855379	3659.1	brown sediment; broke through crust twice	Push core
S0479-S3	2021-11-07T19:36:58.439Z	23.934147	-108.855384	3658.8	orange mat and worms	Suction sample
S0479-S4	2021-11-07T19:41:05.897Z	23.934148	-108.855382	3658.8	white mat with copepods and worms	Suction sample
S0479-N1	2021-11-07T19:55:15.610Z	23.934141	-108.855377	3657.3	in pushcore area with orange and white mats	Niskin
S0479-N2	2021-11-07T19:55:38.480Z	23.934140	-108.855376	3657.2		Niskin
S0479-R3	2021-11-07T20:25:06.055Z	23.934267	-108.855326	3653.8	large flange on south side of top of large mound; 270oC	Rock
S0479-S5	2021-11-07T20:39:05.402Z	23.934263	-108.855308	3653.6	paralvinella worms near large flange	Suction sample
S0479-A1	2021-11-07T20:42:01.184Z	23.934243	-108.855312	3653.7	tube worms with anemones near large flange; covered in white microbial mat	Manipulator
S0479-PC101	2021-11-07T20:53:44.964Z	23.934443	-108.855450	3658.0	grey mat - two punches - half way; hit hard substrate	Push core
JMJ011_2_2	2021-11-07T21:06:20.174Z	23.934858	-108.855022	3664.8		Heat flow probe
S0479-S6	2021-11-07T21:34:31.711Z	23.935408	-108.854387	3259.2	small yellow marine snow	Suction sample
S0479-S7	2021-11-07T21:46:42.561Z	23.935420	-108.854222	3173.3	marine snow	Suction sample
S0480						
S0480-S1	2021-11-08T14:08:57.660Z	23.953260	-108.862953	-922.5	S0480_001 marine snow	Suction sample
S0480-S2	2021-11-08T14:21:37.081Z	23.953398	-108.862836	-1213.6	Marine snow 1	Suction sample
S0480-S3	2021-11-08T15:11:00.091Z	23.953323	-108.862747	-2466.9	Marine snow	Suction sample
S0480-S4	2021-11-08T15:17:12.354Z	23.953149	-108.862787	-2623.3	Marine snow/larvation	Suction sample
S0480-VO2	2021-11-08T16:09:01.297Z	23.953800	-108.863395	-3645.2	colonization array; float is broken so hanging in mud; switched from V03	Colonization array
S0480-Ring1	2021-11-08T16:31:00.660Z	23.953884	-108.863028	-3643.3	colonization array; S0470d/S0480r-Ring1	Colonization array
S0480-VO3	2021-11-08T17:08:12.172Z	23.953877	-108.863043	-3643.7	colonization array	Colonization array
S0480-S6	2021-11-08T17:40:42.372Z	23.954361	-108.862552	-3648.7		Suction sample
S0480-R1	2021-11-08T18:24:28.128Z	23.954699	-108.862301	-3647.0		Rock
S0480-PC7	2021-11-08T18:49:30.254Z	23.954785	-108.862003	-3659.6	Al core with film inserted into peachy mat	Push core
S0480-PC9	2021-11-08T18:51:33.534Z	23.954785	-108.862002	-3659.6	polycarbonate core into peachy mat	Push core
S0480-PC11	2021-11-08T19:13:07.391Z	23.954789	-108.861995	-3659.6		Push core
S0480-S7	2021-11-08T19:31:19.086Z	23.954807	-108.862232	-3648.3	peachy mat (not captured on time)	Suction sample
S0480-R2	2021-11-08T19:45:00.778Z	23.955256	-108.862087	-3656.7		Rock
S0480-R3	2021-11-08T20:19:29.815Z	23.956537	-108.861827	-3669.9	underside of flange with dendritic crystal growth	Rock
S0480-Spring1	2021-11-08T20:34:39.581Z	23.956609	-108.861806	-3658.0	colonization array; S0471d/S0480r-Spring1	Colonization array
S0480-VO1	2021-11-08T20:49:27.564Z	23.956615	-108.861836	-3655.7	recovered (annotated as S0478-VO1); S0471d/S0480r-VO1	Colonization array
S0480-VO4	2021-11-08T21:00:47.021Z	23.956644	-108.861748	-3656.9	deployed near Marker 8 at Z vent near shimmering flow	Colonization array
S0480-R4	2021-11-08T21:19:43.318Z	23.956691	-108.861756	-3657.3	10x10cm piece from weather rock chunk near marker 8	Rock
S0480-N2	2021-11-08T21:22:10.621Z	23.956684	-108.861760	-3657.4	near Marker 8 at top of Z-vent	Niskin
S0480-N1	2021-11-08T21:23:55.243Z	23.956686	-108.861758	-3657.3	near Marker 8 at top of Z-vent	Niskin

* Comments and other data drawn from sample lists provided by the R/V *Falkor* techs.

Table 2 (continued).

SampleName	Timestamp	Latitude	Longitude	Depth (m)	Comment*	Type
S0481						
S0481-S1	2021-11-09T13:04:59.364Z	23.941343	-108.855465	638.6	Marine Snow	Suction sample
S0481-S2	2021-11-09T13:26:00.964Z	23.941220	-108.855137	905.2	Marine Snow	Suction sample
S0481-S3	2021-11-09T13:59:25.435Z	23.941830	-108.855443	1726.5	Marine snow sampled on the descent	Suction sample
S0481-S8	2021-11-09T14:23:46.633Z	23.941611	-108.855142	2319		Suction sample
JMJ012_1_2	2021-11-09T15:40:14.477Z	23.941038	-108.855722	3683.8	Probe in mud	Heat flow probe
S0481-PC1	2021-11-09T15:50:31.809Z	23.941068	-108.855729	3683.8		Push core
S0481-PC2	2021-11-09T15:52:42.925Z	23.941044	-108.855711	3683.8		Push core
S0481-VO6	2021-11-09T16:51:20.962Z	23.941512	-108.855700	3665.8	Colonization array VO6 in Biobox4	Colonization array
S0481-VO9	2021-11-09T16:57:26.805Z	23.941509	-108.855696	3665.7	Colonization array VO9	Colonization array
S0481-N1	2021-11-09T17:02:32.131Z	23.941526	-108.855684	3665.2	Niskin 1	Niskin
S0481-N2	2021-11-09T17:03:22.854Z	23.941529	-108.855682	3663.1		Niskin
S0481-A1	2021-11-09T17:47:01.125Z	23.941403	-108.855716	3668.3	Clump of inactive tubeworms and many white anemones - in Bio Box 3B	Manipulator
S0481-S5	2021-11-09T18:50:17.286Z	23.940334	-108.855757	3670.6	animal slurp in tube worm push in active oissisia bushes	Suction sample
S0481-S6	2021-11-09T19:01:07.477Z	23.940333	-108.855879	3676	slurp of animals in inactive oissisia tube worm bush with white anemones	Suction sample
S0481-A2	2021-11-09T19:05:03.193Z	23.940327	-108.855876	3675.5	Grab of white anemones from inactive tube worm push. BioBox 3b (already has anemones and that is ok)	Manipulator
S0481-S7	2021-11-09T19:23:03.747Z	23.940112	-108.855793	3681.9	transition tube worm bush area, very short tube worms with scale and fire worms, baby riftia, aimed for brown material in small bush area	Suction sample
S0481-R2	2021-11-09T19:43:13.604Z	23.940370	-108.855715	3671.6	grab of inactive chimney from top of red hill, covered in filamentous material and anemones	Rock
S0481-R3	2021-11-09T19:48:35.175Z	23.940369	-108.855706	3671.6	Grab from same area as R2, on top of red hill. brittle, crumbly tower pieces covered in white filamentous material and sea anemones. Placing in Biobox 3A.	Rock
S0481-R4	2021-11-09T20:00:43.160Z	23.940372	-108.855697	3671.7	grab from rock ledge / flange near top of red hill. same location as R2 and R3, placing into quiver 8 (same quiver as R2)	Rock
S0481-R5	2021-11-09T20:12:12.387Z	23.940380	-108.855703	3671.7	slab from flange top that fell down and we grabbed.	Rock
S0481-N3	2021-11-09T20:33:44.260Z	23.940292	-108.855710	3667.7		Niskin
S0481-N4	2021-11-09T20:34:06.012Z	23.940288	-108.855710	3668.8		Niskin
JMJ012_3_2	2021-11-09T21:16:48.316Z	23.940139	-108.856511	3679.3	Probe in mud	Heat flow probe

* Comments and other data drawn from sample lists provided by the R/V *Falkor* techs.

7. Discussions of Each Discipline Aboard FK210922

7.1. Tectonics and Rocks (Leg 1 and 2)

The southern portion of the Gulf of California (GoC) formed as a result of the tectonic separation (rifting) of the Baja California peninsula from mainland Mexico. The GoC is one of the best examples worldwide of a young (~12.3 Ma) continental-rift margin. It is characterized by an increasingly high-angle component of oblique-divergence resulting from the northwestward motion of the Pacific plate relative to North America. Studying how the GoC is forming expands our knowledge of the formation of continental margins, the places where most people live today.

The southern GoC represents a unique domain of the rift system where we can study the evolution of continental breakup and the onset of seafloor spreading, including the effects of a high-obliquity angle on strain localization, fault organization, basin architecture, and rift evolution during the last few million years. This largely unexplored domain is characterized by small, deep spreading centers with young sediment cover connected by relatively long transforms with considerable overlapping that conform with classic plate tectonic models. This is one of very few young rifts globally where three-dimensional oblique rifting processes can be documented from surface geology.

Systematic mapping operations during Leg 1 of the expedition across the Carmen, Farallón, and Pescadero Basins resulted in bathymetric maps with a spatial resolution of about 25-meters. These have revealed the structure and geomorphology of the Gulf's oceanic floor with unparalleled detail. Analysis of the surface geology derived from these maps will allow study of the three-dimensional processes of oblique-divergence and the opening of the Gulf of California (Figure 38).

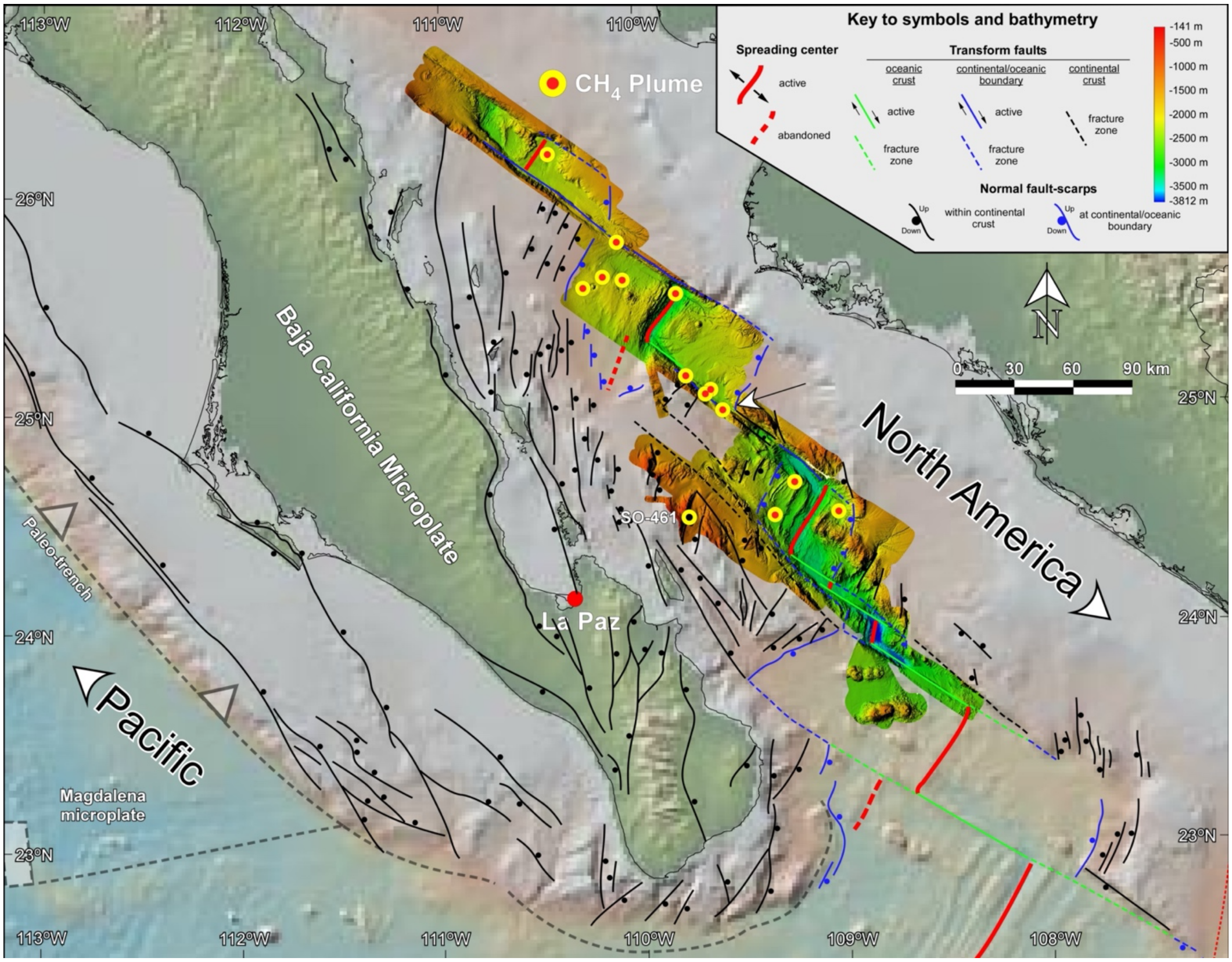


Figure 38. Tectonic map of the southern Gulf of California showing the relative motion between the Pacific and North American plates, and the major fault systems accommodating shear along the margins of the Baja California microplate. Faults are color coded on the basis of activity, kinematics, and composition of the crust involved during faulting (after Ramirez-Zerpa et al., 2022). Black dashed lines west of Baja peninsula denote the paleo-trench and the partially subducted Farallon-derived Magdalena microplate captured by the Pacific plate ca. 12 Ma. Abbreviations: SPB = South Pescadero Basin, CPB = Central Pescadero Basin, NPB = North Pescadero Basin, CPT = Central Pescadero transform. Bathymetry shown over the background map is from R/V *Falkor* mapping in 2018, 2019, and 2021, combined. The location of ROV *SuBastian* dives S0461 and S0469 and 13 methane gas plumes that were detected in the water-column data (**Table 1**) are shown.

Water column returns in the multibeam data revealed the occurrence of 13 gas-bubble plumes rising from the seafloor up to 1600 m into the water column (**Table 1**; **Figures 38 and 39**). Methane can be produced biologically by methanogens (microbes) and/or by the thermochemical decomposition of organic matter (thermal methane); the source of these plumes is yet to be determined. These locations offer the opportunity to investigate new potential seep or vent sites, where fluid flow and its associated biodiversity of extremophile organisms could be occurring in response to the geologic and tectonic processes operating in the Gulf of California.

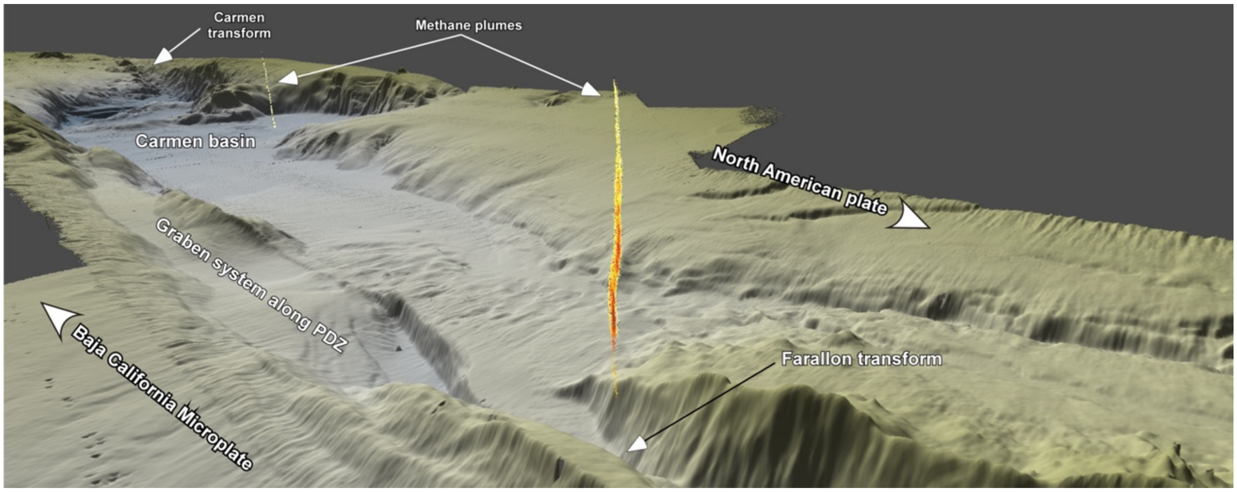


Figure 39. Oblique view of the Carmen Basin showing the two methane plumes detected in the basin and adjacent transform. The foreground plume emanates directly along the Farallón transform fault trace, while the distant plume can be seen emerging from the center of the basin's sedimentary cover. View is looking roughly northwest at the northern-most plumes indicated in **Figure 38**. Abbreviations: PDZ = Principal Deformation Zone.

Thirteen rock samples were collected during ROV *SuBastian* dives S0461 near Isla Cerralvo and S0469 near Isla Espíritu Santo, along the eastern slopes of two (out of several) structural footwall blocks of continental crust. Thin sections (**Tables 3 and 4**) of the collected rocks indicate that some of these samples have been altered due to the effect of dynamic metamorphism. XRF and ICP-MS analyses of two lavas collected on S0469 indicate they are andesitic in composition (**Table 5**).

The current model of the opening of the southern GoC is that it is the result of symmetric shear, where our observations and other recent studies in the area suggest that the opening of the southern Gulf could be attributed to an asymmetric detachment-style rift system, similar to the model inferred for the northern Gulf. We interpret that the footwall blocks examined (**Figure 40**) are associated with an east-directed detachment system of low-angle normal faults along the eastern margin of the Baja California microplate that continue to accommodate an important component of crustal thinning along the continental margin.

Table 3. Descriptions of rock samples collected on dive S0461 near Isla Cerralvo.

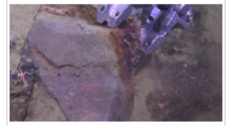
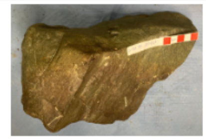
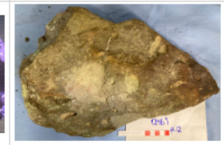
Sample	Depth (m)	Description (Zierenberg)	Thin section description (Zierenberg)	Framegrabs	Lab Photos
S0461-R1	963.1	Talus block about 15 cm on a side. Holocrystalline grey basalt/andesite with a homogeneous texture. No vesicles. About 10 % euhedral, generally clear plagioclase phenocrysts 1-3 mm. Matrix is generally 1 mm or less intergrown plagioclase (Plag) and clinopyroxene (Cpx). Less that 1% visible titanomagnetite (TiMt). Minor greenish matrix alteration, preferentially in plagioclase, with rare, diffuse, non-continuous replacement 'veins' 1-2 mm wide of greenish alteration. One fracture surface shows poorly developed linear striation, but no penetrative fabric in the rock.	Pervasively altered/metamorphosed Plag-Cpx igneous rock. Probably an andesite flow, but maybe a shallow intrusive. Alteration includes chlorite, epidote, and actinolite replacing cpx.		
S0461-R2	963.4	Irregular angular talus ~16x16x12 cm. Holocrystalline with no vesicles. 10-20% angular breccia fragments up to 1 cm, that are similar to the host rock, but differ in the crystallinity, particularly of the matrix, and phenocryst abundance. Compared to R1, more coarsely crystalline, more porphyritic, more feldspar-rich and more pervasively altered. Plag phenos 2-4 mm, maybe 20-25%, some clear, mostly cloudy. Blocky, subhedral 2-4 mm pyroxene, generally altered to dark greenish color. Minor amount of mm size titanomagnetite. Matrix shows cloudy alteration to orange-reddish color. All the inclusions/fragments on the cut surface of the rock are finer-grained, more volcanic-looking, breccia fragments that are otherwise similar to the holocrystalline host rock. No cumulate or exotic fragments observed on the cut surface.	Andesite flow with fresh plag-cpx phenocrysts and low T, clay alteration of matrix. Small quartz/calcedony veins.		
S0461-R3	963.4	Knobby textured 8x8x7 cm interpreted as a hyaloclastite breccia with volcanic rock fragments, but actually a pelloidal mudstone. The bulk of the rock is smooth spherical pelloids uniformly 0.5-1 mm in diameter. The matrix is yellow green in color as opposed to red brown color of subaerial/subglacial palagonite. Volcanic rock fragments include both sharp-edged breccia, and at least on smooth, well-rounded pebble.	Pelloidal mudstone with mud plus minor silt matrix. Abundant oblate to spherical (fecal?) pellets that are mud with some very fine silt. There are also very poorly preserved fossils, mostly forams, that are filled with mud. No calcite remains. There is some coarse silt in the mud matrix which is angular, relatively fresh igneous looking plagioclase, and less common volcanic hornblende and angular igneous(?) magnetite. There is less abundant and more rounded quartz silt, including some polygonal quartz. There are a few volcanic fragments, including spherical ones, that have fine grained quench plagioclase microlites. There well could be some altered glass spheres as well, but no typical shard-like glass fragments as would be found in typical hyaloclastite. Some of the glass(?) spherules have poorly developed fibropalagonite like textures with some subhedral replacive pyrite.		

Table 4. Descriptions of rock samples collected on dive S0469 near Isla Espiritu Santo.

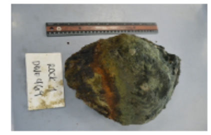
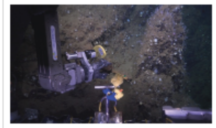
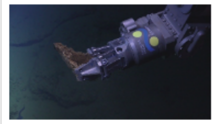
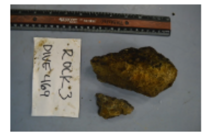
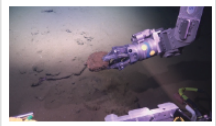
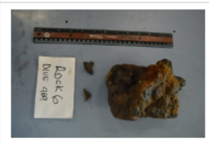
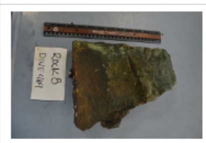
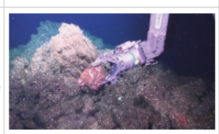
Sample	Depth (m)	Description (Zierenberg)	Thin section description (Zierenberg)	Framegrabs	Lab Photos
S0469-R1	727.0	30x22x15 cm. Rounded boulder of basaltic breccia. Fragments range from coarse sand to multi cm and are mostly slightly rounded. Many fragments with 3-5 mm plag, which is more abundant than pyroxene. Plag is generally euhedral, elongated prisms 2-3 mm long, and in some places there are equant to blocky prx crystals to 6 mm. Euhedral, 2 mm titanomagnetite is abundant. There are some fragments of hyaloclastite, and parts of the rock seem to be a breccia with an igneous matrix, where as others look like basaltic breccia in a hyaloclastite matrix.	Volcanic breccia where most fragments are similar textured plag-pyroxene porphyry. Strongly zoned plagioclase. Most phenocrysts are unaltered and only low-T clay alteration is present in the matrix.		
S0469-R2	700.4	Rounded 10x10x8 cm (with several smaller fragments) orange weathered volcaniclastic sandstone with mm thick manganese coating on exposed surface. The sample is highly weather with a palagonitic orange-brown color. Most of the grains and matrix are altered past the point of recognition. Poorly cemented and still somewhat friable. Mostly silt sized to fine sand matrix with coarse sand and rare near pebble size rock fragments. Of the larger fragments, most look to be fine grained mafic volcanic, a few looked like totally devitrified pumice. 2-3 mm rounded glass spherules, one of which had mm scale clear, greenish, glassy plagioclase phenocrysts, another was dark black obsidian. Some glass and volcanic fragments picked out and stuck between two layers of clear tape and taped on to an index card for microprobe analysis. There are a few mm scale orange jasperoid veins.	Fine volcanic breccia or coarse volcanoclastic. Not dissimilar to R-1, but greater variation in grain size and texture. Lots of "sieve textured" plag phonocrysts. Some "scoriatious" fragments that are finer grained with abundant irregular shaped vesicles.		
S0469-R3	631.7	17x8x6 cm wedge shaped angular fragment. Poorly sorted orange weathering angular siltstone/sandstone. Volcanoclastic matrix? Most of the larger sand-sized fragments are broken calcareous shells in various stages of dissolution. Some mollusk shell fragments. Probably relatively shallow water sediment.	Volcanic siltstone. Dominantly angular igneous plagioclase with lesser cpx and minor igneous hornblende in a muddy clay altered matrix. A few poorly preserved fossil fragments. Mostly forams(?).		
S0469-R4	609.6	20X25X5 cm flat rounded siliceous rock with abundant forams. What looks like a non-crystalline basalt with a glassy margin is in fact silicic sediment. Some zones are fine grained and glassy looking. Other zones look like finely vesiculate non-crystalline basalt is in fact a siliceous sediment with abundant forams. The forams are somewhat recrystallized, but maintain their geometry and chambers. There are sparse 1 mm euhedral crystals of marcasite in the matrix.	Layered foram and fossil rich "turbidites" that grade upward from foram-rich bases to clay rich tops. Forams and fossil fragment all replaced/dissolved with no remaining carbonate. Abundant fecal pellets. Very minor amount of angular silicate silt.		
S0469-R5	408.2	Irregular, rounded, 3 cm fragment of volcanic breccia. Abundant 1-4 mm clear euhedral plagioclase laths and less abundant 2-4 mm blocky pyroxene and rare 1 mm euhedral titanomagnetite in a holocrystalline to cryptocrystalline matrix. The dominant (only) fragments are irregular to rounded, cm sized pieces red weathering 'basaltic' scoria, indicating a subaerial origin.	Volcanic breccia with heterogeneous textured clasts. Largest clasts are scoriatious with irregular elongate vesicles and plagioclase phenocrysts. Mostly andesitic looking volcanic fragments in a muddy-silty matrix.		
S0469-R6	403.4	15X9x5 cm rectangular block of what appears to be plagioclase -rich crystal-lithic tuff with a poorly developed rheomorphic texture. Abundant 2-3 mm plag laths and less abundant but coarser green pyroxene phenos to 4-5 mm. Non vesicular matirix, but some fragments that may have been pumice.	Plagioclase porphyry with abundant coarse plag and less abundant coarse cpx phenos, in a plag microlite-rich matrix. Slight flow alignment of the plag micorlites in the matrix. There is a contact between the edge of the large volcanic fragment that makes up most of the thin section and foram-rich sediment. Forams replace/dissolved.		
S0469-R7	346.1	18x11x7 cm rounded slab of plagioclase porphyry with a poorly developed rheomorphic texture. Abundant 2-3 mm plag laths and less abundant but coarser green pyroxene phenos to 4-5 mm. Non vesicular matirix.	Plag-cpx porphyry. Sieve textured plag and partly resorbed to rounded cpx in an opaque crystalline matrix. Some glomeroporphyritic crystals and one inclusion of microgabbro with the same mineralogy.		
S0469-R8	315.9	23x15x5 cm wedge shaped slab of plag-cpx porphyry. Approximately 25% 4-6 mm clear plagioclase phenocrysts in a fine- to med-grain matrix. 3% euhedral, often elongate prismatic, pyroxene phenocrysts, 2-3 mm wide and up to 7mm long, glassy brown in the cores and black on the rims. Compared to R-6 and R-7, finer-grained with less abundant plagioclase and better defined rheomorphic texture defined by a series of subparallel mm scale "veins" that are parallel to the large flat surfaces that bound the slab. These some what irregular, often discontinuous "veins" do not appear to be either tectonic or hydrothermal but rather suggest flow banding. One surface has a couple of attached "pebbles" of what may be agglutinated spatter. Non-vesicular.	Plag-cpx porphyry similar to above with common glomerocrysts. Matrix is coarser gained with felted plagioclase microlites.		
S0469-R9	271.7	24x11x9 cm irregular shaped volcanic breccia or possibly a crystal lithic lapilli tuff. Lithified, but not welded. Dominant fragments are up to 1.5 cm in diameter with 15% plag phenos, and very minor fine-grained biotite. Lithics appear to include crystalline rhyolite with crowded plagioclase phenos and sparse beta quart. Mafic crystals are sparse but seem to be dark brown to black cpx > light brown opx (?), biotite and titanomagnetite. Large, rounded fragments of plagioclase-rich slightly vesicular, relatively unaltered andesite volcanic clasts.	Volcanic breccia with most fragments similar to the plag-cpx porphyries described above. The largest fragment has coarse plag-cpx phenocrysts/glomerocrysts in a matrix with finer-grained, but anomalously large, blocky to equant plag "microlites". Other fragments show more normal porphyry texture in a volcanoclasitic, sandy matrix. Does not look like a pyroclastic rock in thin section.		
S0469-R10	245.4	13x9x8 rounded fragment with two flat fracture surfaces. Fine grained porphyritic andesite. Subequal (~10% each) amounts of plag and prx. Unusual in that the pyroxene tends to be more euhedral that the plag. Pyroxene occurs both as 4 mm euhedral crystals and as 1-2 glomerocrysts of euhedral crystals, both clear glassy green. Potential exists for dating the feldspars.	Plag-rich porphyry with well zoned to sieve texture plag phenos and slightly finer grained plag-cpx glomerocrysts in a felted plag microlite matrix.		

Table 5. Major and trace element analyses of volcanic rocks.

XRF	S0469-R6	S0469-R10	ICP-MS	S0469-R6	S0469-R10
SiO_2 (wt %)	55.90	59.65	La (ppm)	22.34	20.92
TiO_2	1.02	0.90	Ce	47.82	44.31
Al_2O_3	20.46	18.19	Pr	5.96	5.52
FeO*	5.82	5.97	Nd	23.83	21.89
MnO	0.06	0.10	Sm	5.05	4.64
MgO	2.40	3.18	Eu	1.38	1.23
CaO	7.84	7.10	Gd	4.76	4.35
Na_2O	3.61	3.17	Tb	0.73	0.68
K_2O	2.16	1.52	Dy	4.29	3.98
P_2O_5	0.72	0.21	Ho	0.85	0.79
Total	97.46	99.52	Er	2.32	2.16
Ni (ppm)	14	20	Tm	0.35	0.32
Cr	46	48	Yb	2.12	2.03
Sc	22	20	Lu	0.33	0.32
V	188	162	Ba	692	631
Ba	691	641	Th	5.95	5.48
Rb	62	40	Nb	8.21	7.27
Sr	499	455	Y	23.24	22.07
Zr	163	148	Hf	4.19	3.82
Y	23	22	Ta	0.52	0.47
Nb	8.7	7.5	U	2.21	1.21
Ga	22	20	Pb	10.18	9.52
Cu	12	14	Rb	62.4	40.1
Zn	71	77	Cs	1.82	1.16
Pb	9	8	Sr	482	443
La	23	23	Sc	19.9	18.2
Ce	48	44	Zr	161	145
Th	5	5			
Nd	25	23			
U	2	1			

[a]Major elements normalized to 100% on a volatile-free basis.
FeO* is total iron expressed as FeO.
Analyses performed at the Peter Hooper GeoAnalytical Lab at Washington State University.
Internal standards included 76KOL-1, L1382-22, and USGS standards AGV-2, BCR-2, and BVHO-2.
Underlined elements have more precise analyses by ICP-MS.

Figure 40. The scientific team had speculated they would find a rock outcrop in the area of ROV *SuBastian* dive S0461, a fault scarp, but could not be certain until the ROV explored further. Marc Julia, Isabela Macias-Iniguez, and Ismael Yarbuh celebrate as their expectations are confirmed (photo credit: M. Naranjo).

7.2. Heat Flow (Leg 2 and 3)

The second leg combined heat flow measurements in and around the Pescadero Basin vent fields with fluid sampling at the vents. The main goal was to carry out systematic heat flow measurements in the JaichMaa' ja'ag hydrothermal vent field. We measured 79 stations covering much of the vent field during 12 dives, producing 4 main heat flow transects with additional heat flow measurements in key places (**Figures 41 and 42**). Part of this survey was accomplished during leg 3 where scattered heat flow measurements were taken during the microbiology dives.

In this cruise heat flow data were collected using a 60 cm heat probe lance mounted on the forward starboard frame of the ROV *SuBastian*. The probe was inserted with a hydraulic actuator and the insertion was monitored using a dedicated video camera. Heat flow measurements generally consisted of an in-situ thermal gradient measured with the 5 thermistors in the probe followed by a thermal conductivity measurement made by observing the decay of a quantified thermal pulse input to the sediment through a resistance heater in the probe (Negrete-Aranda et al., 2021). Each deployment of the heat flow probe lasted approximately 15 minutes.

The new heat flow data set consists of thermal gradients and thermal conductivity to compute the heat flow in Pescadero Basin, Gulf of California. The data have been processed to convert from resistance to temperature using calibrations for each thermistor. Heat flow was estimated by combining the thermal gradient and thermal conductivity using the Bullard method (Negrete-Aranda et al., 2021)

Preliminary interpretations of the new data set include: i) The differences in the heat flow decay between the Auka and JaichMaa ‘ja’ag vent fields suggesting very different cooling conditions and charge/discharge scenarios between them (**Figure 43**). ii) A clear relationship between high heat flow values and high densities of clam fields were observed along JaichMaa ‘ja’ag N-S axis (**Figure 44**). More analysis will be needed to determine a pattern but at this point, it seems promising (**Figure 45**).

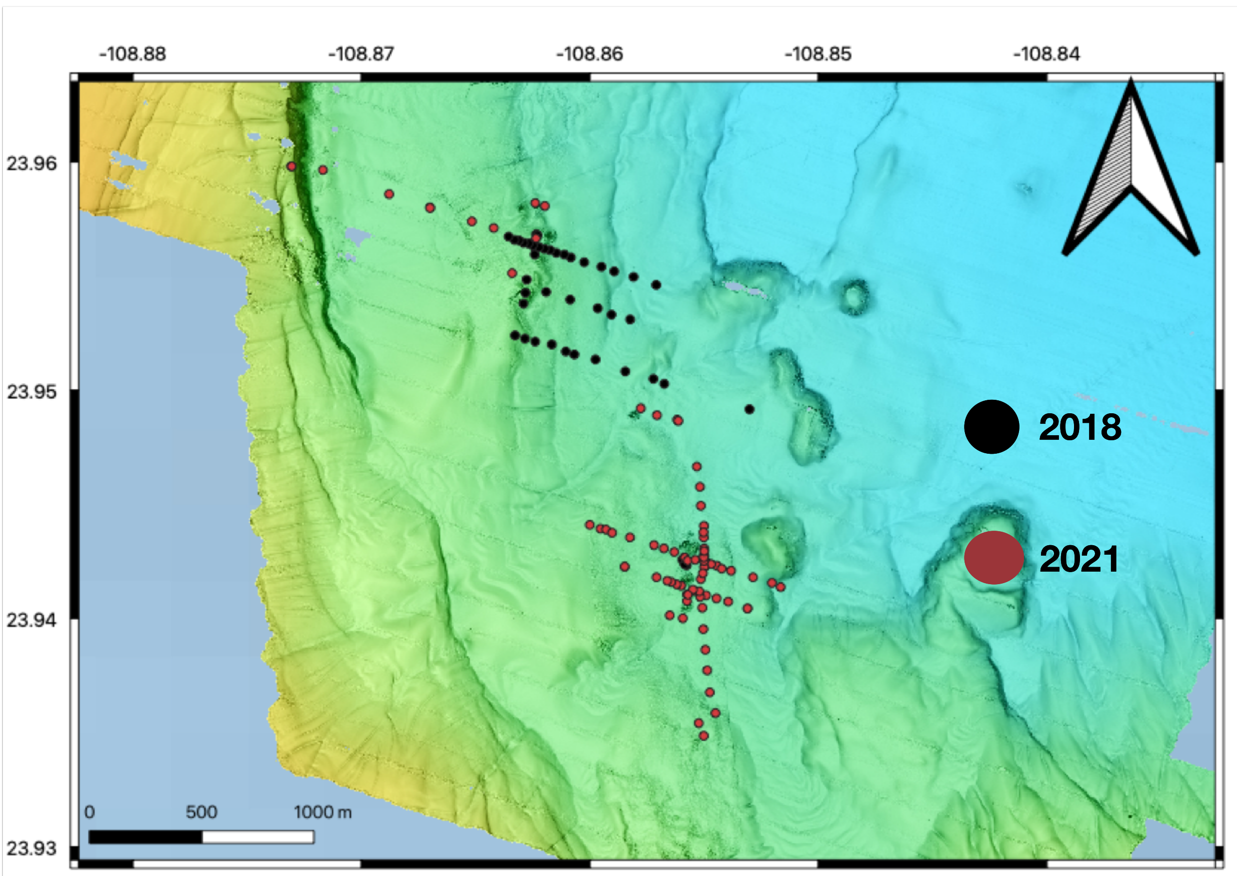


Figure 41. Heat flow measurement array for Auka and JaichMaa ’ja’ag vent fields. Red circles mark the location of heat flow stations carried out on the 2021 cruise; black dots correspond to the 2018 cruise.

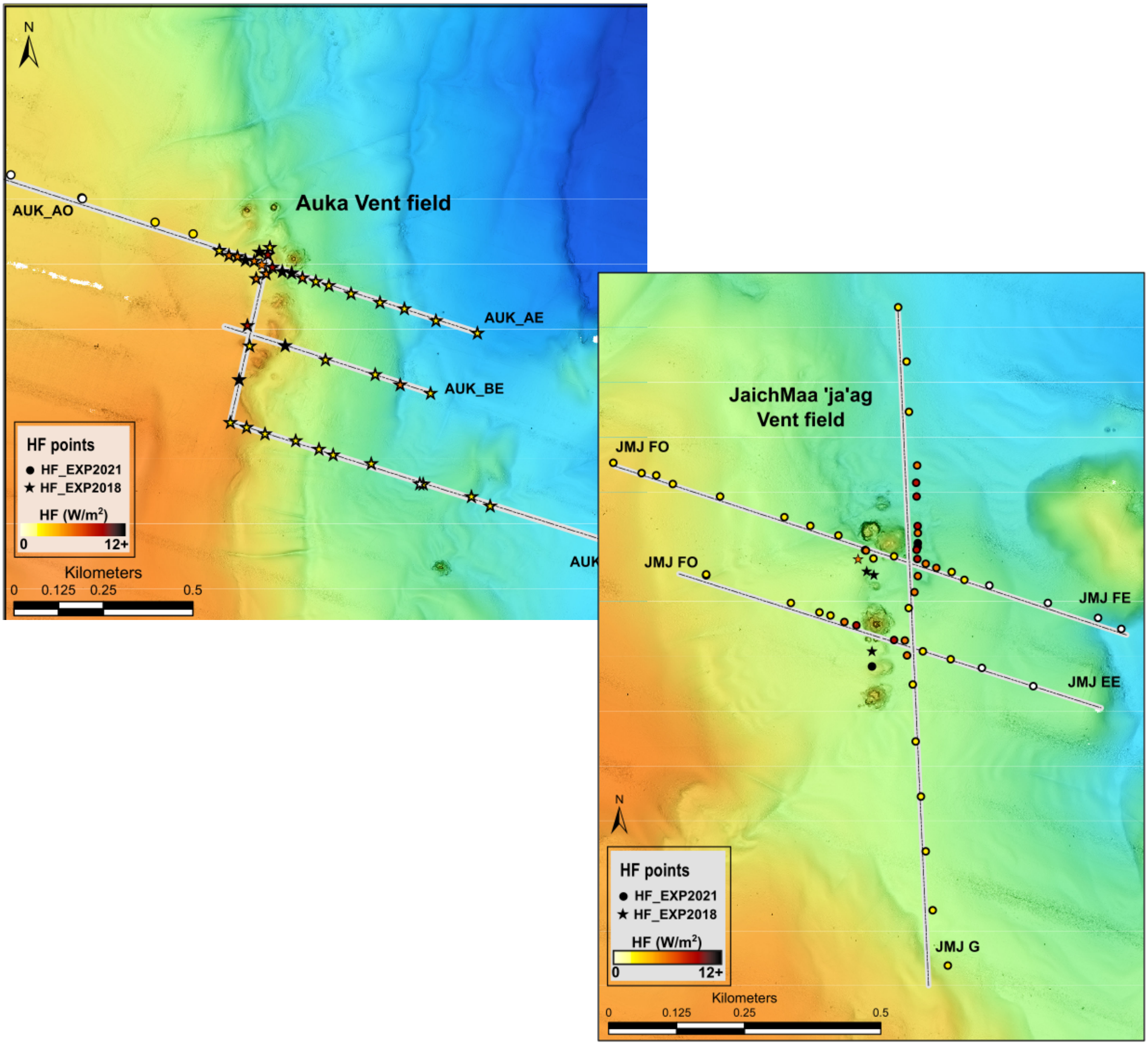


Figure 42. Color coded heat flow values for both Auka and JaichMaa 'ja'ag vent fields from 2018 and 2021 expeditions. The heat flow survey carried out during the 2021 expedition accounted for a total of 79 measurements, which extended beyond the limits of both vent fields and with a main focus on the JaichMaa 'ja'ag vent field.

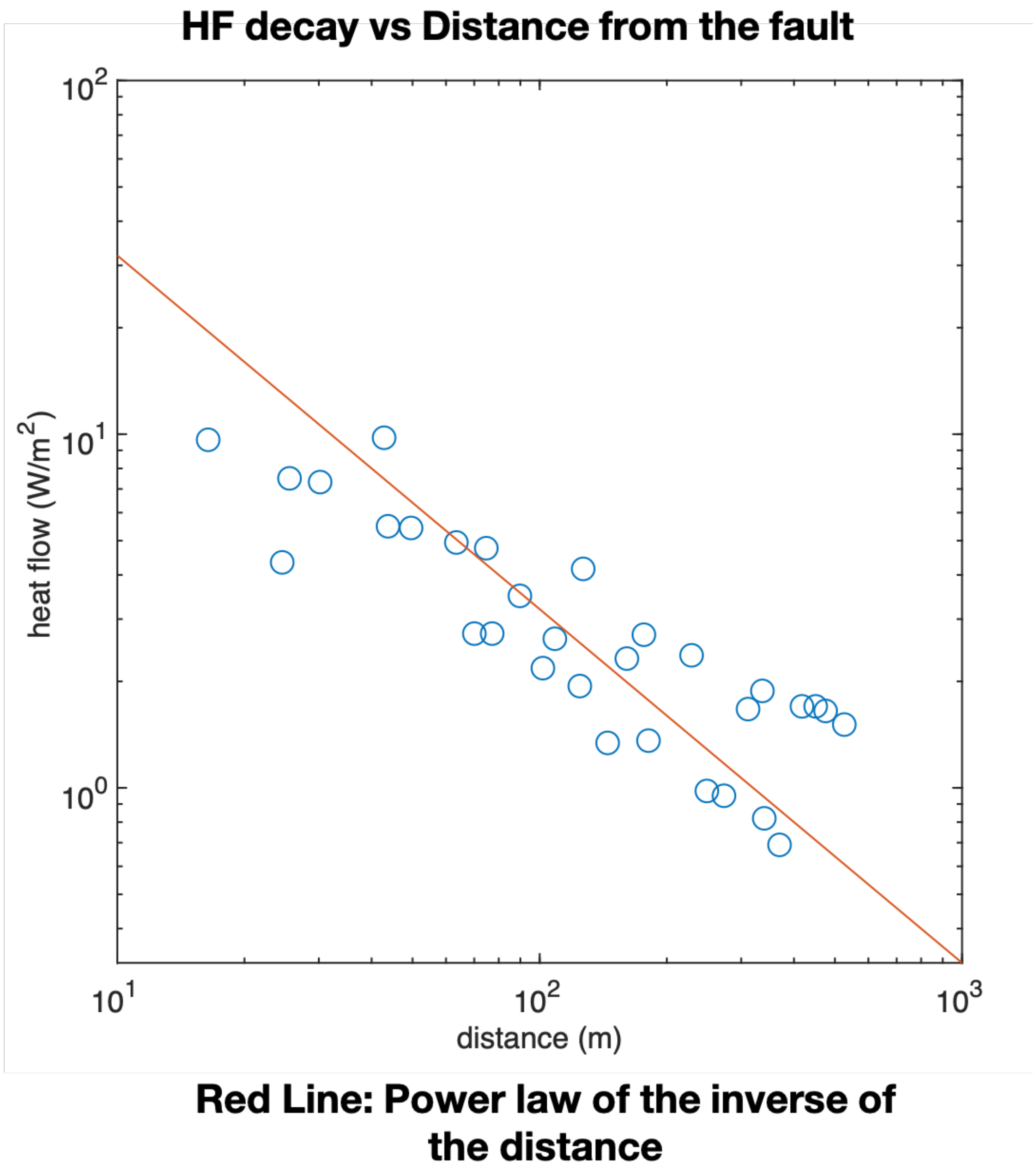


Figure 43. Heat flow values plotted with the distance from JaichMaa 'ja'ag vent field. Blue circles represent the actual heat flow measurements whereas the red line represents the power law of the inverse of the distance in good fit with the overall data trend**.** In contrast in the Auka vent field heat flow decayed much faster following the inverse of the distance trend (Negrete-Aranda et al., 2021)

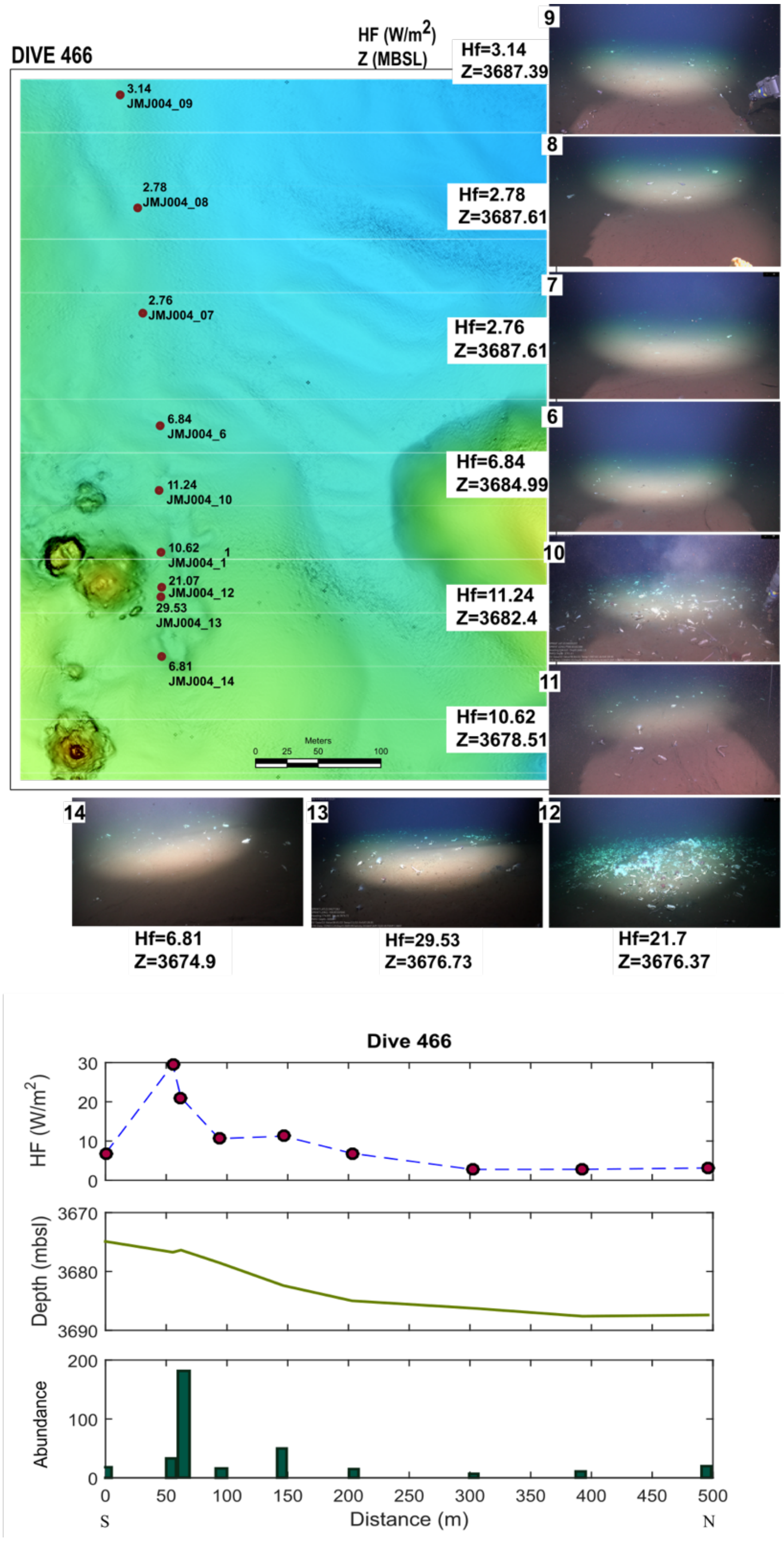


Figure 44.
Preliminary observations on board led to the hypothesis of a possible relation between heat flow values and the abundance of certain organisms, in particular with clams. Higher heat flow values are consistent with a higher abundance of biology on the seafloor.

Figure 45. Florian Neumann and Raquel Negrete-Aranda react to findings during ROV dive S0468 at the JaichMaa 'ja'ag Vent Field (photo credit: M. Naranjo).

7.3. Vent Fluid and Deposit Sampling (Leg 2 and 3)

Eleven Ti-Major vent fluid samples and 15 Gas-tight fluid samples (**Figure 46**) were collected during the cruise, but some samples were dominantly seawater and a few of the gas-tight bottles were not triggered. (**Table 6**).

Based on the data available when this report was prepared, the major conclusion to be drawn from the vent fluid sampled in each of the three separate vent fields (Auka, Maijia awi, and JaichMaa 'ja'ag) is that they appear to be identical, at the level of resolution of the data, supporting the unlikely hypothesis that they are all being derived from a single large and geographically extensive hydrothermal reservoir.

Table 6. Fluid samples collected on FK210922.

Sample	Bottle #	Time	Latitude	Longitude	Depth INS	Depth Parosci	Temp	pH 25°C	Notes	Notes +
Dive S0463										
S463 N1	N-1	10/19/21 20:48	23.941773	-108.857050	3642.5		1.8	7.68	Bottom water	
S463 Ti Orange	MB 2	10/20/21 0:24	23.940431	-108.853042	3673.28		2	7.65	Bottom water	
Dive S0464										
S464 GT Yellow/Red	#12	10/20/12 19:15	23.941540	-108.855810	3649.13	3668.04	286.5		Flange sample	
S464 GT Red	#9	10/20/21 19:26:09	23.941545	-108.855807	3649.06	3668	286.5		Flange sample	
S464 Ti Orange	MB 2	10/20/21 19:41:58	23.941536	-108.855816	3660.95	3667.87	286.5	6.0 to 7.4 and climbing.	Flange sample	Extremely gassy, 375 ml total
Dive S0467										
S467 GT Orange/white/Black	#18	10/23/21 17:48:04	23.953843	-108.863001	3631.11	3649.97	187		Top of Matterhorn	Snorkel likely not in vent
S467 GT Green/Red	#16	10/23/21 18:08:25	23.953843	-108.863007	3631.01	3649.86	187		Top of Matterhorn	Snorkel may be in vent
Dive S0470										
S470 Ti Black	WCPR-02	10/29/21 19:21:52	23.953854	-108.863038	3631.18	3649.93	187 Max measured 170	5.6 to 6.3 and climbing	Top of Matterhorn	Some venting, gasys, mod. H_2S
S470 GT White	#17	10/29/21 19:38:32	23.953858	-108.863039	3631.22	3649.93	187 Max measured 170		Top of Matterhorn	
Dive S0472										
S472 GT Red/black	#6	10/31/21 18:24:45	23.956177	-108.861919	3664	3683.07	12		2018 Oily mat site, no oil seen	
S472 GT Blue/Orange	#10	10/31/21 18:46:28	23.956173	-108.861922	3663.9	3682.89	3		2021 oily mat	funnel flushed with lot T fluid, but no flow when sampled
Dive S0473										
S473 Ti White	WCPR-01	11/1/21 18:19:14	23.948871	-108.858102	3665.07	3684.2	285	6.0 to 6.7 and climbing	Flange at Falkor mound	Gassy, moderate H_2S
S473 GT Purple	#11	11/1/21 18:07:22	23.948875	-108.858104	3665.1	3684.24	285		Flange at Falkor mound	
Dive S0474										
S474 Ti White	WCPR-01	11/2/21 18:41:00	23.954862	-108.862944	3635.52	3654.29	Not measured	6.1 to 6.9 and climbing	Diane's Vent	
S474 GT Blue/Yellow	#2	11/2/21 18:12:25	23.954870	-108.862959	3635.91	3654.82	Assumed 289° C		Diane's Vent	
Dive S0475										
S475 Ti Black	WCPR-02	11/3/21 19:42:02	23.956680	-108.861770	3648.5	3667.54	279° C	6.5 to 6.9 and climbing	Big flange on Z vent	
S475 GT Black	#5	11/3/21 19:50:34	23.956692	-108.861789	3648.38	3667.38	279° C		Big flange on Z vent	

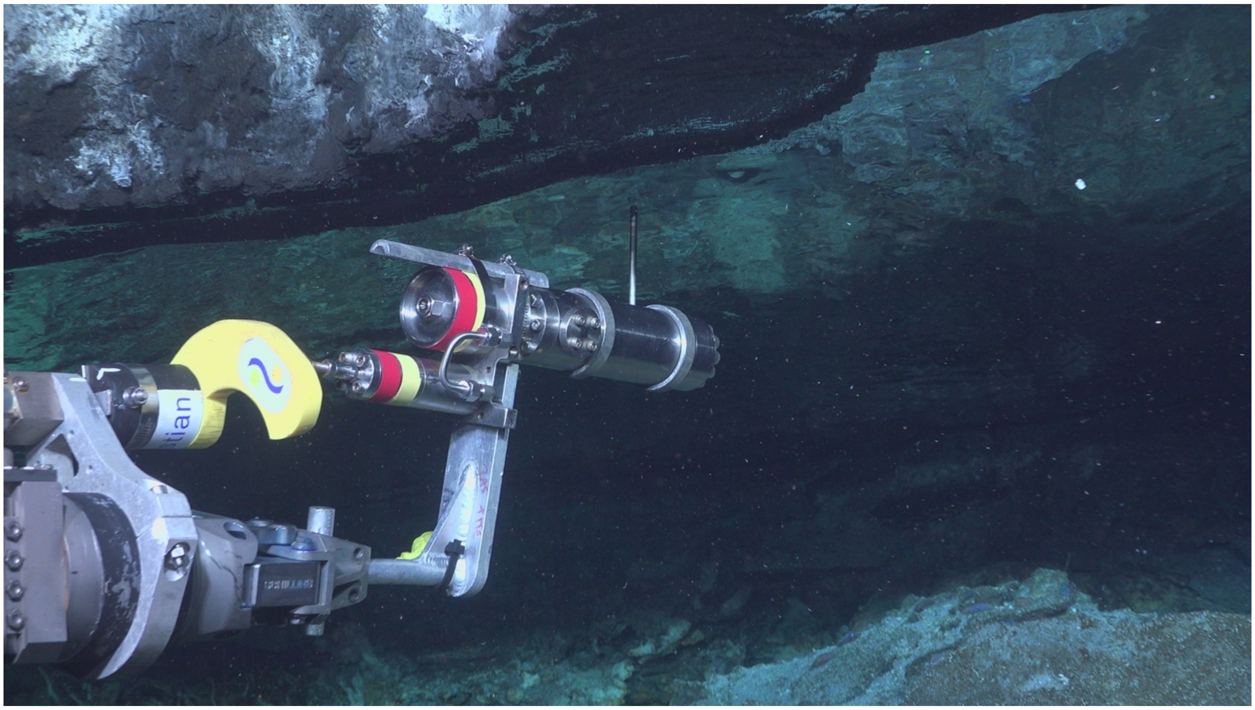


Figure 46. Gas-tight sample S0464-GT-red-yellow being collected from underneath a flange in the Tay Ujaa mound in the JaichMaa 'ja'ag Vent Field (framegrab from the ROV video).

Analysis of hydrothermal vent fluid from the Auka vent field suggests that the fluid was originally phase-separated at >450 ^{o}C by interaction with volcanic rock and had significant interaction with carbonate-bearing sediment before venting to the seafloor (Paduan et al., 2018). Vent fluids collected on FK210922 and FK181031 include samples from each of the three vent fields, spanning a distance of 2.75 km, and found to be homogeneous. This requires a large reservoir of hot fluid circulating below that is tapped by the fault zone of the southwestern margin of the basin. The sources of heat and carbonate producing this unusual scenario are not fully understood.

Although an igneous heat source is indicated, the relationship to new oceanic crust formation in the southern Pescadero rift basin is not well constrained. A hard acoustic reflector can be seen beneath 20–50 m of sediment cover on most of the AUV subbottom profiles, however, it remains to be confirmed that this is recently formed oceanic crust. AUV sidescan sonar does not image any surface lava flows, but there is at least one outcrop of MORB-related basalt, a hill uplifted by a sill north of the Auka vent field (Paduan et al., 2018). However, there is no known hydrothermal venting that is spatially related to this intrusion. Surficial basaltic lava flows indicate recent rift-related volcanism in the northern Pescadero Basin, 45 km to the NW, and the Alarcon Rise, 70 km to the SE of the southern Pescadero Basin, is magmatically robust (Clague et al., 2018).

The thickness and composition of the sediment and nature of the fluid reservoir in the southern Pescadero Basin also have not been determined. As stated, there is at least 20–50 m of sediment cover in the basin (Paduan et al., 2018), in contrast to the Alarcón Rise, where sediment was too thin to detect seismically (from a dusting observed with the ROV to ~3 m thick in areas observed from submersible) until a distance of some 2.5 to 4.5 km from the neovolcanic axis (Clague et al., 2018). While basins of the northern GoC are deeply buried with sediment derived from the Colorado River, the Pescadero Basin has thinner cover (10s of meters), as it is not connected to that source of hemipelagic sediment. There are, however, sediment channels leading into the Pescadero Basin from the east that could supply terrigenous input, but the graben is presently deeper than the CCD so accumulating hemipelagic sediment should not contain carbonate , although carbonate-bearing turbidites may be periodically deposited in the deep basins. This implies that the carbonate acquired by the circulating fluid emanating from the vents along the southwestern margin of the basin is derived in part from pre-rift carbonate-bearing sediment, such as the >2 km thick sediment imaged in other transform basins by the existing multichannel seismic lines (Ramírez-Zerpa et al., 2022). Better constraints are needed on 1) the extent of oceanic crust and the transition to thinned continental crust, 2) the thickness and composition of the sediment, and 3) the tectonic history and structural controls on fluid flow. Further studies, including multichannel seismic surveys, regional scale heat flow measurements, and drilling are needed to answer outstanding questions.

Rocks were sampled from several of the hydrothermal sites with the goal of characterizing the interactions and interrelationship between microbial processes and mineral deposition. A small subset of these samples were prepared for thin-section petrography and chemical analysis at U.C. Davis. Based on information available at the time of this report, the samples examined are similar to those described by Paduan et al. (2018). Most of the high temperature vents structures are composed of calcite, accompanied by anhydrite in the actively venting areas, with only minor amounts accompanying metal sulfide minerals. Sampling at the Matterhorn confirmed that this chimney structure is composed of barite, not carbonate. These samples lack base-metal sulfides, but are significantly enriched in gold, silver, and antimony. Hydrothermal fluids from the Matterhorn vent at lower temperature, but appear to be identical in terms of major element and volatile element composition. This suggests that the barite-Au-Ag-Sb mineralization is not related to difference in fluid source, but rather is related to mineral fractionation or zone-refining processes associated with subsurface cooling of the Matterhorn fluids.

Examination of a sample collected on the FK181031 cruse (S0199-R1) is noteworthy as it potentially addresses the influence of microbes on mineral deposition. This sample contains the rare mineral getchellite ($AsSbS_3$), a phase not previously reported from seafloor hydrothermal deposits. The getchellite selectively replaces fossilized bacteria occurring as linear chains of ~1 µm spheres, very similar in appearance to the sulfur-oxidizing bacteria *Thiomargarita*. The sample has been shared with the microbiology team in an attempt to understand the relationship between minerals and microbes, including bioavailability of potentially toxic trace metals.

7.4. Microbiology: Sediments, Minerals, Macrofauna, and Water (Leg 3)

The chemosynthetic communities at hydrothermal vents are built on a foundation of microbial life, and interpretation of all life at these vent sites requires an understanding of these microbes. Vent fluids contain high concentrations of reduced compounds such as hydrogen, hydrogen sulfide, and methane, which vent communities oxidize as a source of energy. Oxygen and sulfate used in this oxidation are present in seawater, and the microbial communities are therefore found at the interfaces where vent fluids and seawater mix.

We collected sediment samples (via pushcores) and samples of hydrothermal rocks including crusts, flanges, and orifices, as described above. Rock samples were split and processed for mineralogy/geochemistry and for biology. Biological samples were preserved for DNA sequencing and microbial community analysis, FISH microscopy, and live incubations. In total, 48 pushcores and 42 rocks were collected for microbial analysis. Laboratory and bioinformatics investigations of these samples are underway.

Figure 47 shows some of the flange pieces collected, both under white light and under ultraviolet light. The fluorescence derives both from the minerals that make up the rock as well as the hydrocarbons that permeate some of these samples. In **Figure 48**, we see one of the spectacular microbial observations of leg 3, a thick microbial mat from an area rich in hydrothermal fluid. A highlight of Leg 3 was the discovery of two new active mounds, including Melsuu, named for the proliferation of iridescent blue *P. orphanae* scaleworms observed here (**Figure 49**). We also were able in these dives to observe and collect a variety of rare deep sea invertebrates, including xenoturbellids (**Figure 50**) and xenophyophores (**Figure 51**).

Several colonization arrays made of a variety of materials (e.g., rock chips, sponges, metal rings; **Figure 52**) were deployed with the intention of their being retrieved on a future expedition (**Table 7**). A steel house constructed by the R/V *Falkor's* engineers was deployed at Tay Ujaa as a mineral precipitation experiment, also to be collected on a future expedition (**Figure 53**).

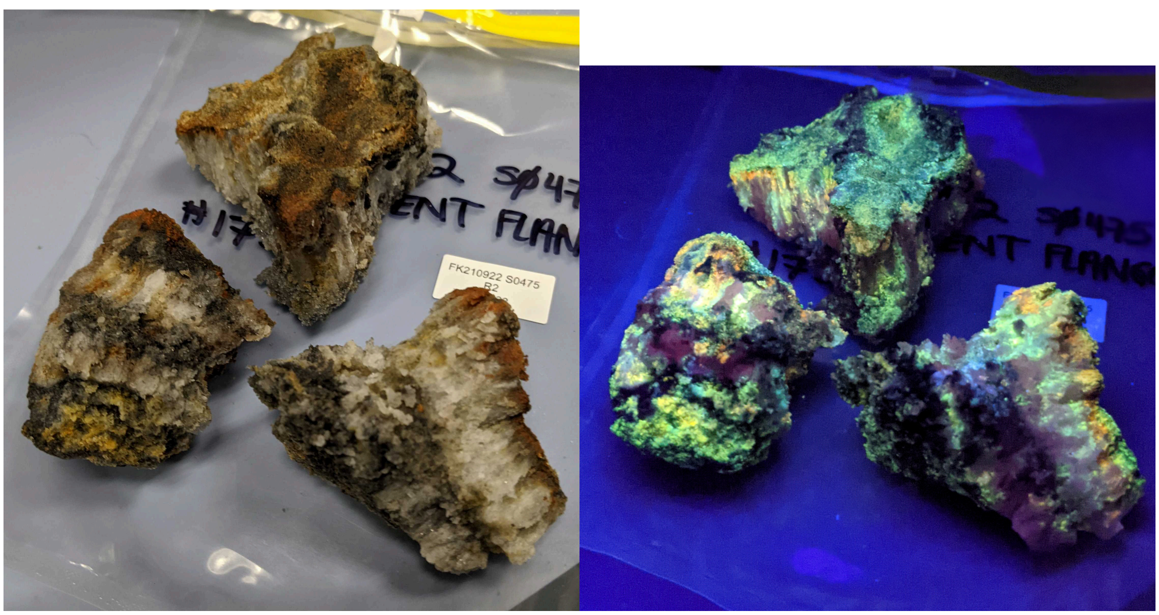


Figure 47. Flange pieces from dive S0475 viewed under ambient light (left) and ultraviolet light (right), showing the dramatic fluorescence of the samples. This fluorescence comes from the minerals that make up the rock (e.g., calcite) as well as from hydrocarbons that permeate these samples (Photos: Orphan Lab).

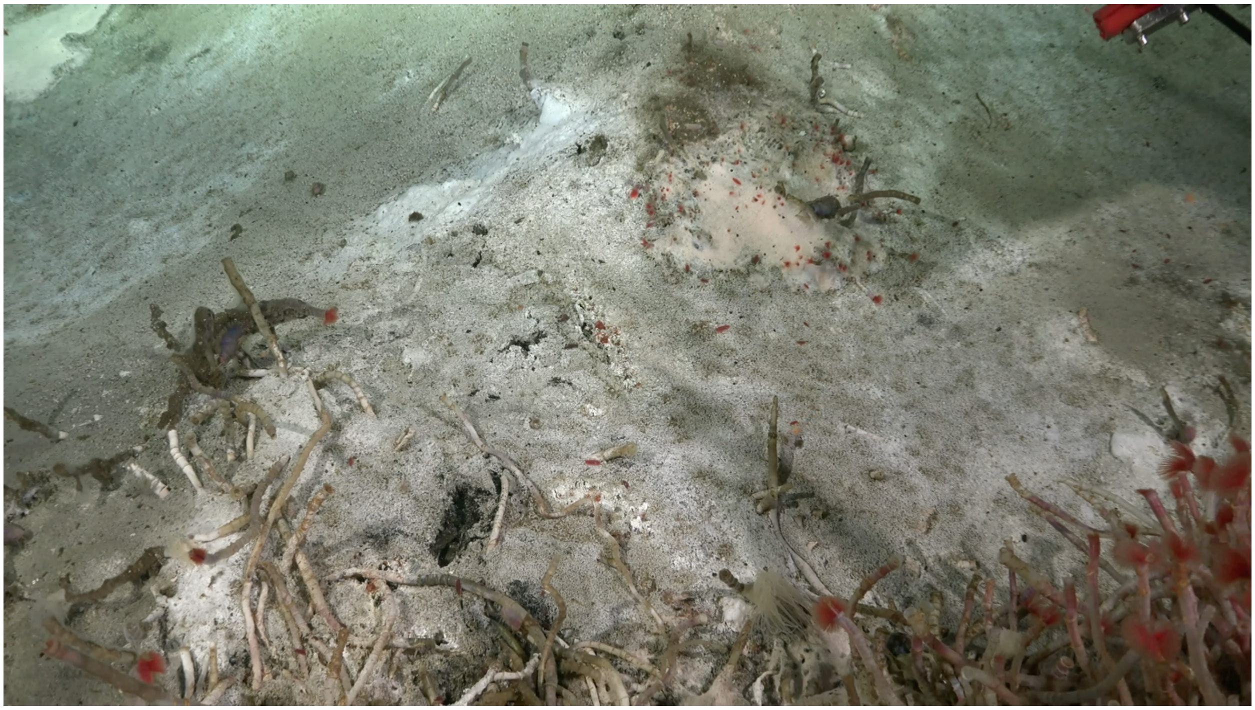


Figure 48. Extensive microbial mat with an area of concentrated hydrothermal flow at center, dive S0470 in the Auka Vent Field. Mats such as these were examined with the temperature probe and then sampled for microbial community analysis, geochemistry, and incubations. Also visible are anemones, tubeworms, and scaleworms (framegrab from ROV video).

Figure 49. Mineral crusts, microbial mats, *P. orphanae* scaleworms, and hydrothermal flow at the Melsuu mound discovered on Leg 3 (framegrab from ROV video).

Figure 50. Xenoturbella observed along a heat flow transect line near Maijia awi on dive S0473. (framegrab from ROV video).

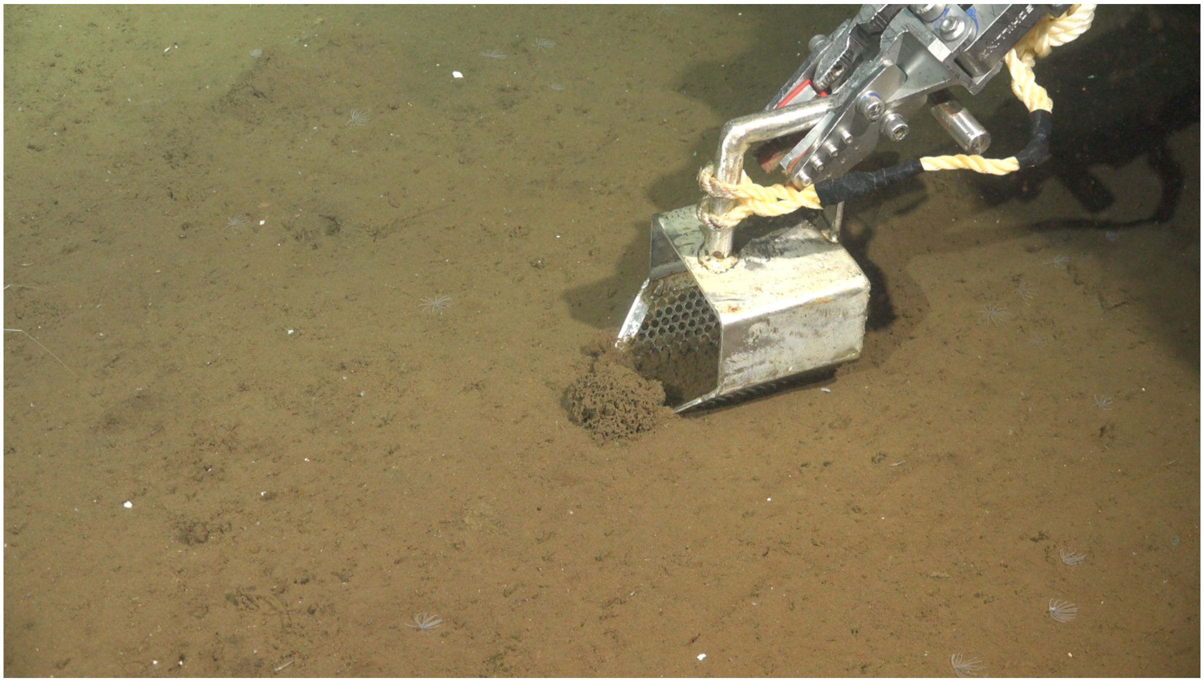


Figure 51. Collection of a xenophyophore from muddy sediment in the Auka Vent Field on dive S0474 (framegrab from ROV video).

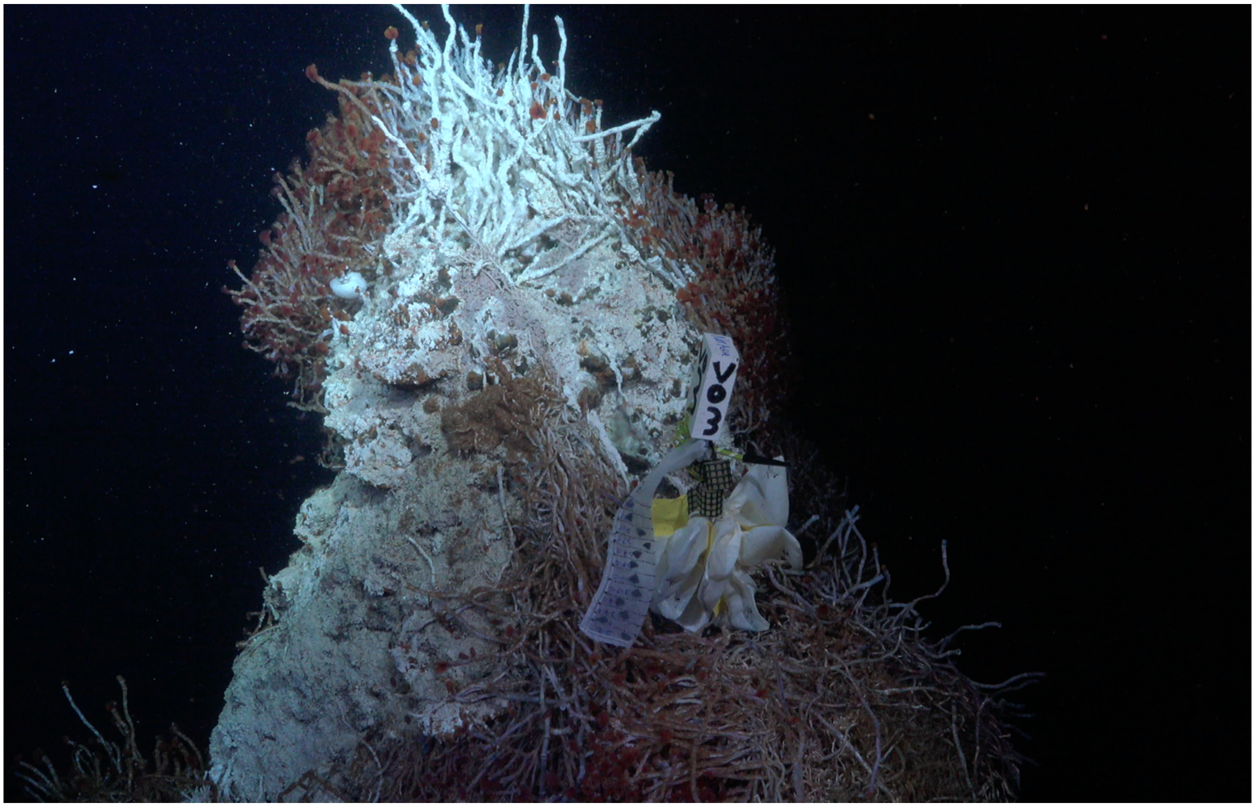


Figure 52. One of the typical colonization arrays at the top of Matterhorn in the Auka Vent Field (framegrab from ROV video).

The house on the Hill at Big Cave

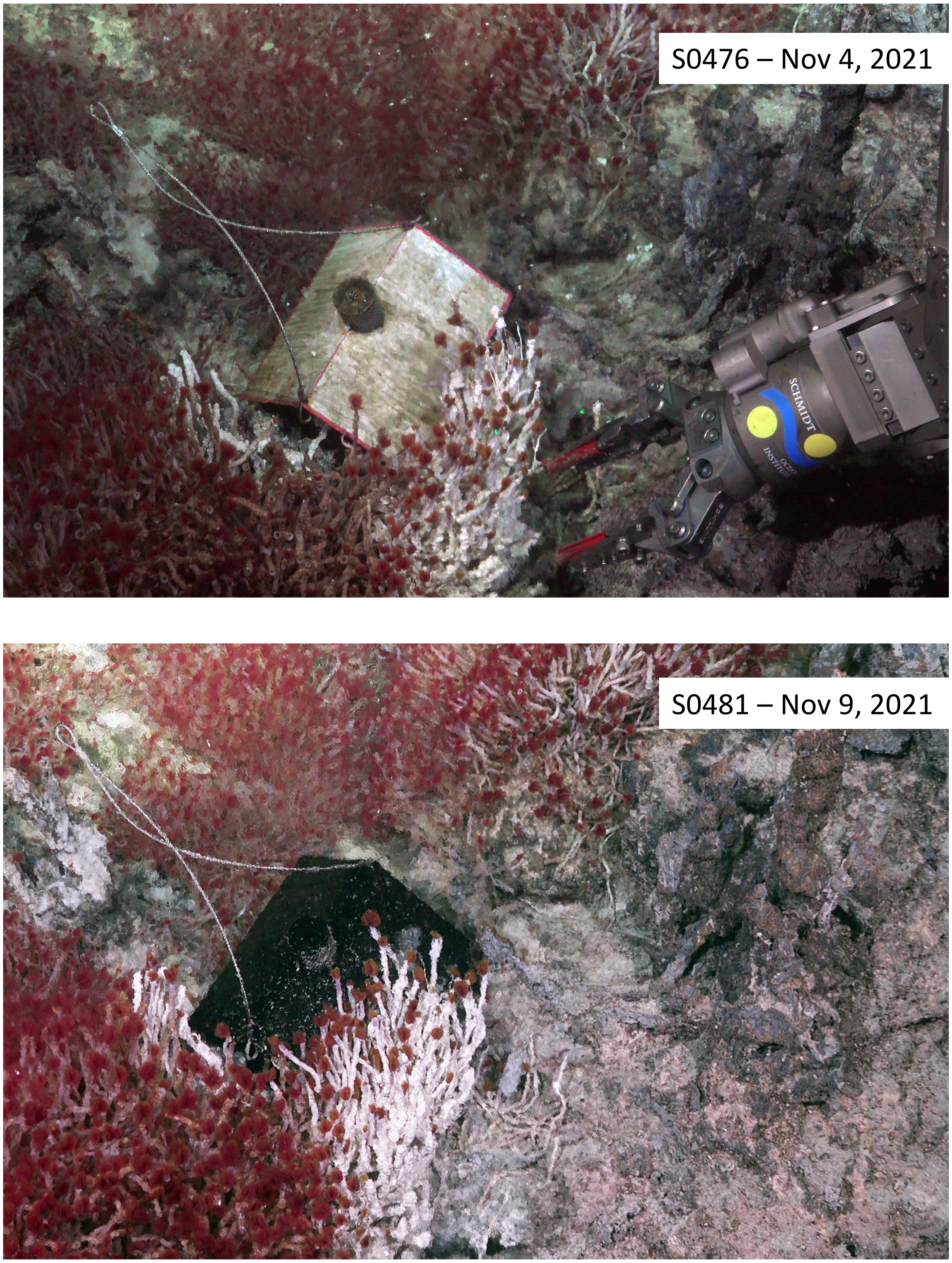


Figure 53. The steel house S0476-HOUSE constructed by engineers on the R/V *Falkor* was deployed as a mineral precipitation experiment, also to be collected on a future expedition. Top: the house upon deployment at Tay Ujaa. Bottom: the house five days later.

Table 7. Colonization arrays deployed for future recovery.

Sample Number	Description	Depth (m)	Latitude	Longitude
S0480-VO2	colonization array, in muddy area	3652.1	23.9538	-108.8634
S0480-VO3	colonization array, next to tubeworms and active flow	3650.2	23.9539	-108.8630
S0480-VO4	colonization array, at saddle point between two tubeworm bushes, near active venting site, across tubeworms from marker 8	3650.2	23.9539	-108.8630
S0474-VO5	colonization array, near marker 8 at Z vent, near low shimmering flow	3663.0	23.9566	-108.8618
S0481-VO9	colonization array, near House	3665.7	23.9415	-108.8557
S0476-HOUSE	steel house colonization experiment	3664.3	23.9416	-108.8557

In collaboration with researchers at NASA/JPL, ArtCenter College of Design, and Caltech, through the "Data to Discovery" program, we developed and field-tested a program for integrating high resolution deep sea bathymetry and photomosaics with sample locations, geochemical data, and microbial community sequence data. This data visualization tool aids in the selection of sampling sites and can be used both for dive planning and during dives in the ROV control room. More information about the project is available here: https://datavis.caltech.edu/projects/deepsee/. Manuscripts describing the tool and its use are currently in preparation, and the tool will be made freely available upon publication, distributed through the Orphan Lab GitHub repository.

A new chemosynthetic symbiosis between the anemone *Ostiactis pearseae* and bacteria within the SUP05 (Gammaproteobacteria) thrives at the deep hydrothermal vents in the Pescadero Basin. At these newly discovered vents, *O. pearseae* is exceptionally abundant, rivalling the obligate chemosynthetic tubeworm *Oasisia alvinae*. Unlike other cnidarians, the sulfur-oxidizing symbionts of *Ostiactis* are intracellular and housed in the tentacle epidermis. In 2021, *Ostiactis* was collected from areas where venting had significantly diminished or appeared inactive, compared to previous expeditions, and where the obligate vent tubeworm *Oasisia* had perished. *Ostiactis* from inactive areas showed a shift away from their characteristically more negative tissue stable isotope values (implicating nitrogen as a potential commodity from the symbiont), with an increase in δ15N. A possible return to conventional feeding by the anemone was suggested by the observation of food in the gastrovascular cavity of 'inactive' individuals. The facultative nature of this dynamic relationship appears to be a successful strategy for survival in these similarly dynamic deep-sea vents.

The Rouse lab will have one new species appearing soon, *Ophryotrocha marinae* from the Pescadero Basin (Zhang et al., in press), and also a new species of *Nereis* and a range extension for *Nereis sandersi* from the Galapagos/EPR vents (the crazy worms out and about near the jetting hot water; Rangani and Rouse, in prep). There are more range extensions from shallower vents and new species of *Chrysopetalidae*, *Dorvilleaide* and *Hesionidae* are in process.

8. Commemoration to the R/V *Falkor*

On the final ROV dive on this final expedition of the R/V *Falkor*, a commemorative piece of art was brought down to 3651 m and displayed in the JaichMaa 'ja'ag vent field for appreciation by the team onboard and the broad audience watching the live video feed (**Figure 54**). The piece was a faithful depiction of the profile of the ship, fabricated by the ship's engineers from a plate of steel to which a brass-plated propellor was welded, onto which the lettering of the *Falkor's* impressive stats was applied by the ROV pilots (**Figure 55**).

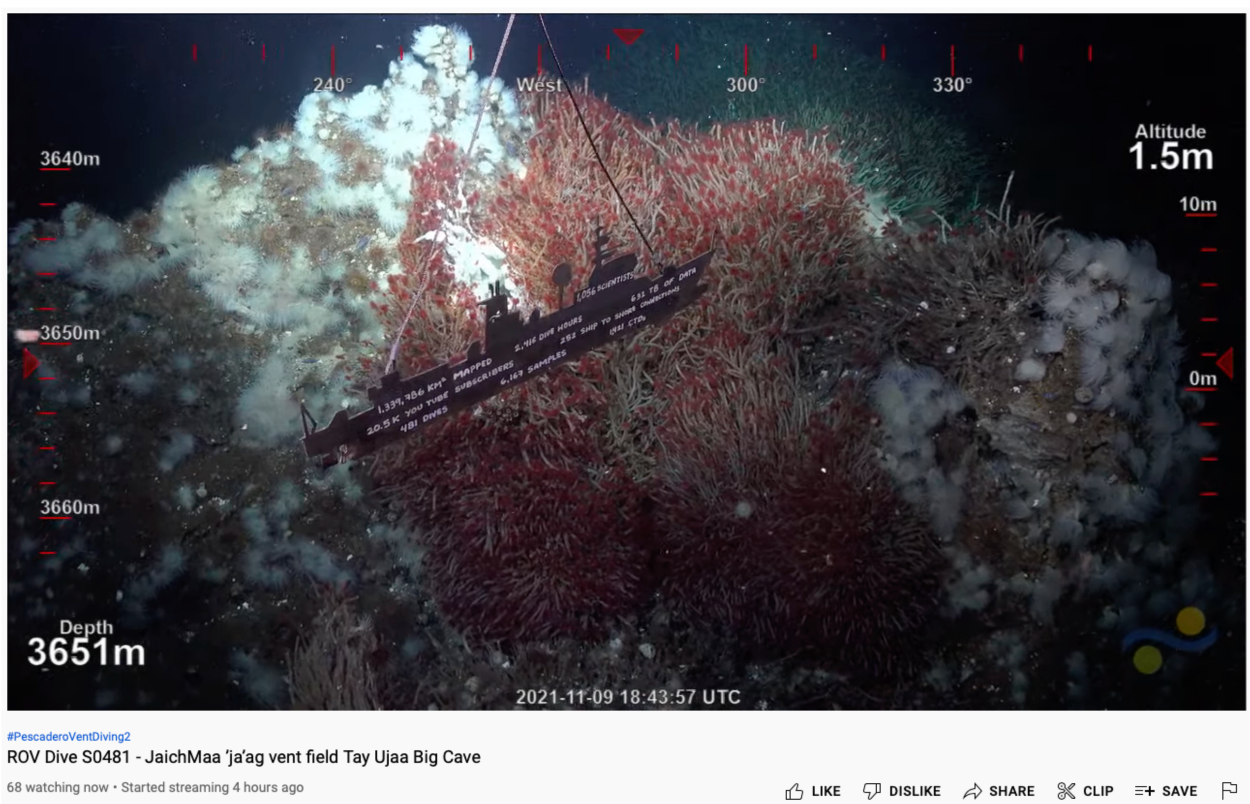


Figure 54. Artwork commemorating the final cruise of the R/V *Falkor* is displayed on ROV dive S0481 in the JaichMaa 'ja'ag vent field (screen grab by J. Paduan).

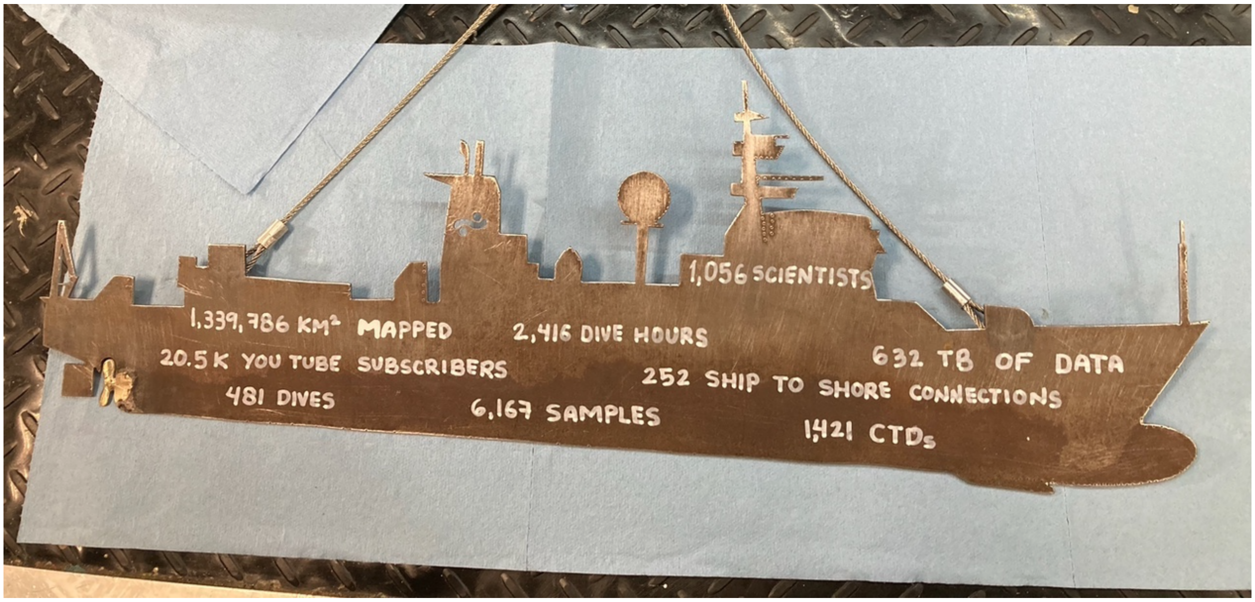


Figure 55. The commemorative steel and brass artwork in the ROV hangar prior to deployment (photo credit: J. Magyar).

9. Acknowledgements

We gratefully acknowledge the Schmidt Ocean Institute (SOI) for supporting this work by providing the ship time, access to the state-of-the-art shipboard facilities, and all of the associated logistical and planning support. We thank all of the SOI personnel for their skilled and dedicated collaboration with us prior to and during FK210922. In addition, SOI provided funds to cover the lodging and food expenses of Mexican participants during the quarantine period in La Paz, BCS, prior to the departure of the ship. The participation of Raquel Negrete-Aranda was facilitated by the award of CICESE's internal project No. 644165. The participation of Monterey Bay Aquarium Research Institution (MBARI) personnel was supported by the David and Lucile Packard Foundation.

10. References

10.1. Related Publications of Our Science Party

Caress, D.W., G. Troni, D.A. Clague, J.B. Paduan, J.F. Martin, H. Thomas, D. Thompson, D. Conlin, E. Martin, E. Meneses-Quiroz, C. Nieves-Cardoso, M.A. Santo Rosa del Rio (2015) Detection of active hydrothermal vent fields in the Pescadero Basin and on the Alarcon Rise using AUV multibeam and CTD data. Abstract OS23C-2027 presented at 2015 Fall Meeting, AGU, San Francisco, Calif., 14-18 Dec.

Caress, D.W., Zierenberg, R.A., Paduan, J.B., Negrete-Aranda, R., Orphan, V.J., Goffredi, S., Spelz, R.M., Clague, D.A., Harris, R.N., Neumann, F., Rouse, G.W., Magyar, J.S., Martin, E.J., Troni, G., Ramirez-Zerpa, N.A., Lilley, M.D., & Wheat, C.G. (2022) Multidisciplinary study of South Pescadero Basin hydrothermal venting reveals a single source for vent fields along the southwest basin margin. Abstract OS45D-1227 presented at 2022 Fall Meeting, AGU, Chicago, IL, 12-16 Dec.

Goffredi S.K., Johnson, S., Tunnicliffe, V., Caress, D., Clague, D., Escobar, E., Lundsten, L., Paduan, J.B., Rouse, G., Salcedo, D.L, Soto, L.A., Spelz-Madero, R., Zierenberg, R., & Vrijenhoek, R. (2017). Hydrothermal vent fields discovered in the southern Gulf of California clarify role of habitat in augmenting regional diversity. *Proc. R. Soc. B,* 284: 20170817. 10.1098/rspb.2017.0817.

Goffredi, S., Motooka, C., Fike, D., Gusmao, L., Tilic, E., Rouse, G., and Rodriguez, E. (2021). Mixotrophic chemosynthesis in a deep-sea anemone from hydrothermal vents in the Pescadero Basin, Gulf of California. *BMC Biology,* 19(8), doi: 10.1186/s12915-020-00921-1. [This article has been published as OPEN ACCESS].

Hatch, A., Liew, H., Hourdez, S., and G. Rouse. (2020). Hungry scale worms: Phylogenics of Peinaleopolynoe (Polynoidae, Annelida), with four new species. *Zookeys 932:27-74,* doi: 10.3897/zookeys.932.48532.

Michel, A., S. Wankel, S. Beaulieu, S. A. Soule, L. Mullineaux, D. Coleman, E. Escobar Briones, A. Gaytán- Caballero, J. McDermott, S. Mills, D. Speth, R. Zierenberg (2018). Biogeochemical Exploration of the Pescadero Basin Vents, *Oceanography*, 31 supplement 1: 42-43.
https://doi.org/10.5670/oceanog.2018.supplement.01

Negrete-Aranda, R., Neumann, F., Contreras, J., Harris, R. N., Spelz, R. M., Zierenberg, R., & Caress, D. W. (2021). Transport of heat by hydrothermal circulation in a young rift setting: Observations from the Auka and JaichMaa Ja'ag' vent field in the Pescadero Basin, southern Gulf of California. *Journal of Geophysical Research: Solid Earth*, 126, e2021JB022300. 10.1029/2021JB022300

Paduan, J.B., Clague, D.A., Caress, D.W., Lundsten, L., Troni, G., Zierenberg, R., Wheat, G., Spelz-Madero, R. (2015) Seafloor Hydrothermal Activity in the Southern Gulf of California. Abstract OS22C-03 presented at 2015 Fall Meeting, AGU, San Francisco, Calif., 14-18 Dec.

Paduan, J.B., Zierenberg, R.A., Clague, D.A., Spelz, R.M., Caress, D.W., Troni, G., Thomas, H., Glessner, J., Lilley, M.D., Lorenson, T., Lupton, J., Neumann, F., Santa Rosa del-Rio, M., & Wheat., C.G. (2018). Discovery of hydrothermal vent fields on Alarcón Rise and in Southern Pescadero Basin, Gulf of California. *Geochemistry, Geophysics, Geosystems,* 19(12), 4788-4819. 10.1029/2018GC007771.

Ramirez-Zerpa, N., Spelz, R.M., Yarbuh, I., Negrete-Aranda, R., Contreras, J., Clague, D.A., Caress, D.W., Zierenberg, R., Gonzalez-Fernandez A. (2022) Architecture and tectonostratigraphic evolution of the Pescadero Basin Complex, southern Gulf of California: Analysis of high-resolution bathymetry data and seismic reflection profiles. *Journal of South American Earth Sciences*, 114, 103678, 10.1016/j.jsames.2021.103678

Rouse, G. W., N. G. Wilson, J. I. Carvajal, R. C. Vrijenhoek (2016). New deep-sea Xenoturbella and the placement of Xenacoelomorpha, *Nature* 530: 94-97. 10.1038/nature/16545

Speth, D., Yu, F., Connon, S., Lim, S., Magyar, J., Pena, M. et al. (2021). Microbial community of recently discovered Auka vent field sheds light on vent biogeography and evolutionary history of thermophily. *BioRxiv.* doi: 10.1101/2021.08.02.454472. [This article has been published as OPEN ACCESS].

Vega-Ramírez, L.A., R.M. Spelz, R. Negrete-Aranda, F. Neumann, Caress, D.W., Clague, D.A., Paduan, J.B., Contreras, J., & Pena-Dominguez, G. (2021) A new method for fault-scarp detection using linear discriminant analysis in high-resolution bathymetry data from the Alarcón Rise and Pescadero Basin. *Tectonics*, 40, 10.1029/2021TC006925

10.2. Related Publications in Preparation

Miralles, M.J., Yarbuh, I., Spelz, R.M., Negrete-Aranda, R., Contreras, J., González-Fernández, A., Zierenberg, R., & Caress, D.W. (in prep.) Crustal structure and tectonic history of the Carmen Basin, southern Gulf of California: insights from high-resolution bathymetry and 2D seismic reflection profiles.

Rangani, E.R. and Greg W. Rouse, G.W. (in prep.) Systematics of deep-sea Nereididae (Annelida) from vents, seeps and whalefalls (SICB 2023 poster and then a paper).

Zhang, D., Zhou, Y., Yen, N., Hiley, A., and Rouse, G.W. (2023) *Ophryotrocha* (Dorvilleidae, Polychaeta, Annelida) from deep-sea hydrothermal vents, with the description of five new species. *European Journal of Taxonomy*, in press.

10.3. Other References Cited

Berndt, C., Hensen, C., Mortera-Gutierrez, C., Sarkar, S., Geilert, S., Schmidt, M., Liebetrau, V., Kipfer, R, Scholz, F., Doll, M., Muff, S., Karstens, J., Planke, S., Petersen, S., Böttner, C., Chi, W,-C., Moser, M., Behrendt, R., Fiskal, A., Lever, M.A., Su, C.-C., Brennwald, M.S., and Lizarralde, D. (2016) Rifting under steam – How rift magmatism triggers methane venting from sedimentary basins. Geology, 44, 767-770. doi:10.1130/G38049.1.

Clague, D.A., Caress, D.W., Dreyer, B.M., Lundsten, L., Paduan, J.B., Portner, R.A., Spelz-Madero, R., Bowles, J.A., Castillo, P.R., Guardado-France, R., Le Saout, M., Martin, J.F., Santa Rosa-del Rio, M.A., & Zierenberg, R.A. (2018). Geology of the Alarcon Rise, Southern Gulf of

California. *Geochemistry, Geophysics, Geosystems*, 19(3), 807-837. doi: 10.1002/2017GC007348.

DeMets, C., Gordon, R. G., & Argus, D. F. (2010). Geologically current plate motions. Geophysical Journal International, 181(1), 1–80. https://doi.org/10.1111/j.1365-246X.2009.04491.x

Lizarralde, D., Axen, G. J., Brown, H. E., Fletcher, J. M., Gonzales-Fernandez, A., Harding, A. J., et al. (2007). Variations in styles of rifting in the Gulf of California. Nature, 448(7152), 466–469. https://doi.org/10.1038/nature06035

Ondréas, O., Scalabrin, C., Fouquet, Y., and Godfroy, A. (2018) Recent high-resolution mapping of Guaymas hydrothermal fields (Southern Trough). BSGF – Earth Sciences Bulletin, 189, 6, https://dio.org/10.1051/bgfs/2018005.

Paull, C.K., Ussler, W. III, Peltzer, E.T., Brewer, P.G., Keaten, R., Mitts, P.J. Nealon, J.W., Greinert, J., Herguera, J-C, and Perez, M.E. (2007) Authigenic carbon entombed in methane-soaked sediment from the northeastern transform margin of the Guaymas Basin, Gulf of California. Deep-Sea Research Part II, 54 1240-1267.