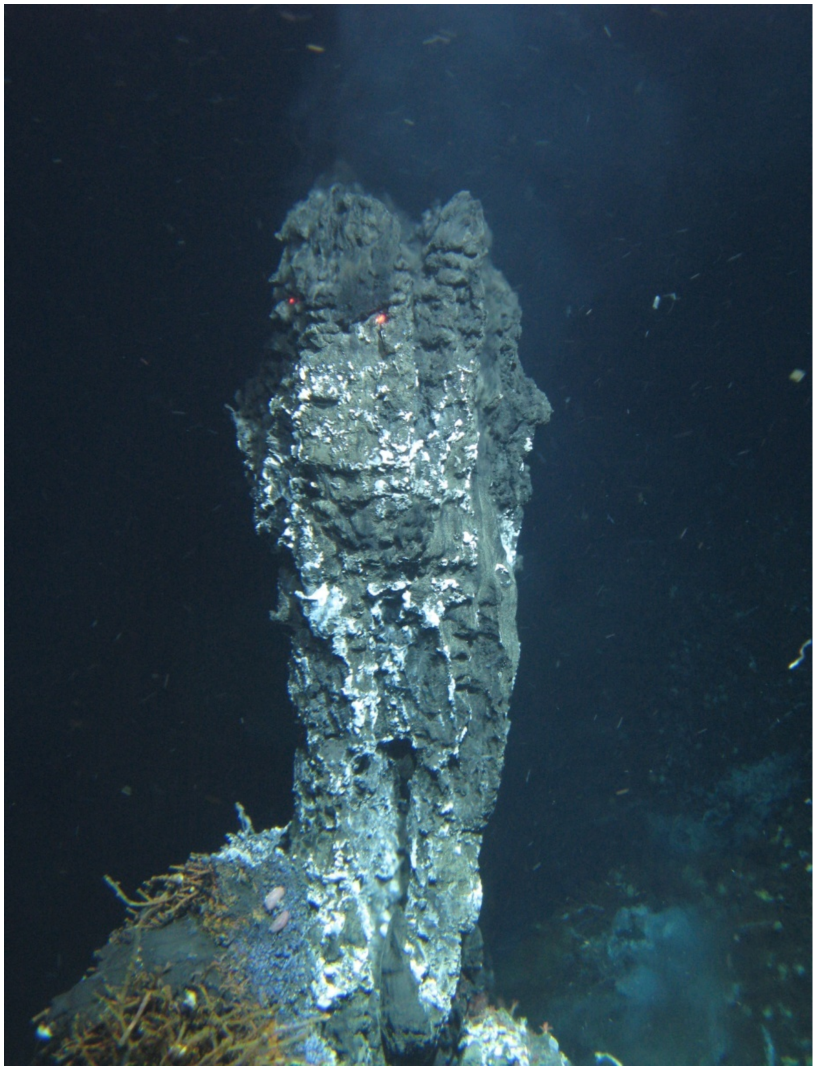
R/V *Atlantis* – DSV *Alvin* AT15-36
Endeavour Segment and Axial Volcano
Juan de Fuca Ridge, Northeast Pacific Ocean



August 18 – September 7, 2008

Chief Scientist
James F. Holden, University of Massachusetts Amherst, Geomicrobiology Project

Project Leaders
Daniela Di Iorio, University of Georgia, Heat and Fluid Fluxes
David A. Butterfield, University of Washington and NOAA/PMEL, Axial Volcano Research
David Clague, Monterey Bay Aquarium and Research Institute, Seafloor Mapping

Cruise summary and acknowledgments: This cruise involved 23 scientists from three countries and studied two deep-sea hydrothermal vent sites in the northeastern Pacific Ocean. It was a combination of two research programs funded by the National Science Foundation (NSF) to study the Endeavour Segment in Canadian territorial waters and one program funded by the National Oceanic and Atmospheric Administration (NOAA) to continue monitoring activity at Axial Volcano in U.S. waters. A middle-school science teacher from Athens, GA and an undergraduate honors student from the University of Massachusetts Amherst participated in the cruise as part of our educational and public outreach program. We successfully completed 16 of our 18 planned *Alvin* dives with two dives lost due to poor weather. With *Alvin*, we collected 220 hydrothermal fluid samples, 14 sulfide chimney samples of various ages, and three basalt rock samples. Two McLane fluid samplers that were deployed for a year were recovered and replaced with two new samplers that will remain in place until next summer. The *Alvin* and McLane fluid and sulfide chimney samples will be used for microbiological and geochemical analyses and the development of a quantitative biogeochemical model of fluid alteration at Endeavour and Axial Volcano. We also collected black smoker temperature and fluid flow rate measurements in high spatial resolution on and up to 20 m above three of the massive sulfide structures in the Main Endeavour Field for flux modeling. Nine people, including five graduate students and the science teacher, made their first dive in *Alvin*.

Other shipboard operations included seafloor mapping at Endeavour and Axial Volcano using an autonomous underwater vehicle (AUV) operated by the Monterey Bay Aquarium and Research Institute (MBARI). This was a no-cost addition to the three funded programs onboard. Four AUV surveys over Endeavour collected 35 km^2 of multibeam and sidescan bathymetry data with 1-m lateral resolution from 4.3 km south of the Mothra vent field to 0.5 km north of the Sasquatch vent field. Two surveys at Axial Volcano collected 22 km^2 of seafloor bathymetry over the southern portion of the caldera, completing a project that began in 2006 in collaboration with NOAA's Pacific Marine Environmental Laboratory (PMEL). We conducted three vertical CTD casts over Axial Volcano, two tow-yo CTD casts over the Main Endeavour field, and one background seawater vertical cast and collected 60 water column samples for chemical and microbiological analyses. We also collected SeaBeam seafloor bathymetry when weather conditions did not permit other operations, during AUV technical difficulties, and during transits between Endeavour and Axial Volcano.

We are very grateful to the crews of the *Atlantis* and *Alvin* for their hard work and professionalism, and specifically to the captain of the *Atlantis*, A.D. Colburn, and the *Alvin* Expedition Leader, Patrick Hickey, for making this cruise a success.

AT15-36 Alvin Atlantis Program to the Endeavour Segment and Axial Volcano on the Juan de Fuca Ridge, Northeast Pacific Ocean

Table of contents:

AT15-36 Personnel

University of Massachusetts Amherst	
James F. Holden	Chief Scientist
Helene Ver Eecke	Graduate Student
Dmitriy Tokar	Undergraduate Student
University of Washington	
David A. Butterfield	Scientist
Eric Olsen	Oceanographer
Kevin Roe	Oceanographer
My Christensen	Oceanographer
Rika Andersen	Graduate Student
Oregon State University	
Lee Evans	Oceanographer (Newport, OR)
Pacific Marine Environmental Laboratory, NOAA	
Noah Lawrence-Slavas	Oceanographer (Seattle, WA)
University of Georgia	
Daniela Di Iorio	Scientist
Guangyu Xu	Graduate Student
Rachael Parr	Teacher
Skidaway Institute of Oceanography	
Trent Moore	Oceanographer
Georgia State University	
Leonid Germanovich	Scientist
Marine Biological Laboratory	
Julie A. Huber	Scientist
University of Victoria	
Annie Bourbonnais	Graduate Student
University of Ottawa	
John Jamieson	Graduate Student
Monterey Bay Aquarium and Research Institute	
David Clague	Scientist
David Caress	Scientist
Hans Thomas	Engineer
Duane Thompson	Engineer
Marilena Calarco	Graduate Student
Captain *Atlantis*	A.D. Colburn
***Alvin* Crew**	
Patrick Hickey	Expedition Leader
Sean Kelley	Pilot
Robert Waters	Pilot
David Walters	Pilot-in-Training
Anton Zafereo	Pilot-in-Training
Korey Verhein	Pilot-in-Training
Mike Skowronski	Pilot-in-Training

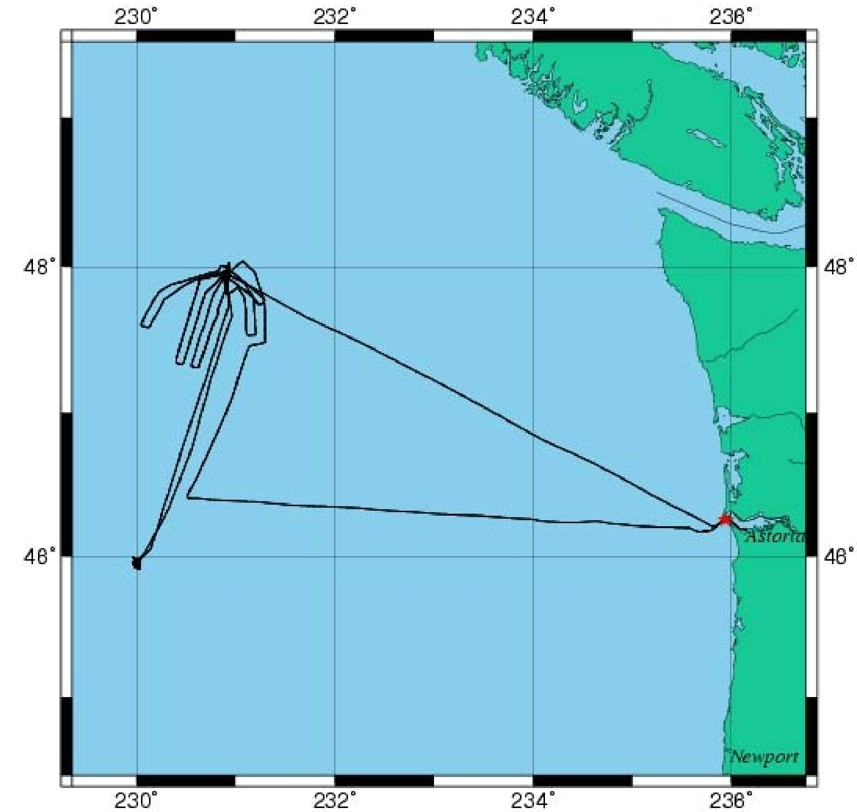


Figure 1. R/V *Atlantis* cruise track for AT15-36.

1.0 SUMMARY OF CRUISE OBJECTIVES AND ACCOMPLISHMENTS:

1.1 Geomicrobiology and Fluid Chemistry of Diffuse Hydrothermal Fluids (Holden (UMass), Butterfield (UW), Lilley (UW))

The goal of this study was to determine whether variations in environmental chemistry dictate which type of microorganisms will grow within a specific niche, and then quantitatively estimate the biogenic impact of these organisms on that environment. This will be done by determining the distribution and abundances of specific groups of organisms using culture-based and molecular approaches. Particular attention was given to methanogens and hyperthermophilic autotrophic iron reducers and sulfur-reducing heterotrophs. Low-temperature, diffuse hydrothermal fluid samples were collected and co-localized with high-temperature fluids to estimate the degree of chemical alteration within the subsurface between the high-temperature end-member fluid and the diffuse fluid. These co-localized fluids were collected at three sites at Axial Volcano (ASHES, Coquille, International District) and at ten sites along the Endeavour Segment (1 Mothra, 7 Main Endeavour Field, 2 High Rise). We also recovered two McLane fluid samplers from basalt-hosted diffuse venting at Easter Island in the Main Endeavour Field and Marker 33 at Axial Volcano that will provide information on fluid chemistry variability over time. All of these fluid chemistry data will constrain the types of microbial processes that may occur. At the Endeavour Segment and Axial Volcano, a total of 210 hydrothermal fluid samples were collected: 142 Hydrothermal Fluid Sampler samples (60 filtered, 50 unfiltered, 26 sterivex filters, 6 large-volume (4-liter) bags), 26 titanium major fluid samples, and 42 gas-tight fluid samples. These were used for gas, major ion, and pH analyses; culturing of microorganisms; and molecular analyses.

1.2 Microbe-Mineral-Fluid Interactions within Hydrothermal Sulfide Deposits (Holden (UMass), Kelley (UW), Hannington (UOttawa))

The goal of this project was similar to the previous project in that it sought to determine how the combination of fluid chemistry and sulfide chimney mineralogy shape microbial community composition within hydrothermal sulfide chimneys. This will be done by examining the types, distributions, and abundances of various groups of microorganisms within sulfide samples using culture-based, molecular, and microscopic methods with particular attention given to hyperthermophilic iron reducers, methanogens, and sulfur-reducing heterotrophs. Three actively venting and morphologically varied sulfide chimneys were collected, and hydrothermal fluid samples were collected from the vent orifice that produced the sulfide following sampling. The wurtzite-sphalerite rich region of these sulfides were removed and divided for quantitative hyperthermophile culturing; fluorescence in-situ hybridization microscopy; 16S rRNA nucleotide sequencing; petrology; and electron microprobe and trace metal analysis; and Mössbauer, TES, FTIR and synchrotron spectroscopies.

Sulfide samples recovered during the cruise have been sampled, archived, and documented through digital imagery and hand sample analyses. A subset of sulfide samples that were subsampled for co-registered detailed microbiological studies and vent fluid analyses have been processed for major and trace element geochemical analyses. A subset of samples was also provided to Dr. Mark Hannington, University of Ottawa, for incorporation into their on-going studies of sulfur isotopes and exploration of chimney dating. This work is the focus of a Ph.D. student at Ottawa. Sulfide samples have also been processes for petrographic analyses and delivery of sections is anticipated in 1-2 months. During this next year, representative samples will be analyzed petrographically under transmitted and reflected light for characterization of petrogenesis, interpretation of vent chimney formation, and mineralogical characterization of the mincroenvironments where biofilm formation takes place.

1.3 High-Temperature Fluid and Heat Fluxes from Massive Sulfide Deposits (Di Iorio (UGA), Germanovich (GaTech))

The objectives for this project were 1) recover the acoustic scintillation transmitter and receiver moorings that were deployed during cruise AT15-34 and redeploy them around Hulk vent for two weeks, 2) quantify the hydrothermal plume characteristics using high frequency multibeam sonar (the SM2000) imagery in both horizontal and vertical planes, 3) quantify heat fluxes from individual black smoker vents on Dante, Hulk, Grotto, and TP vents, and 4) quantify the particle concentration from specific black smokers on the top of these sulfide structures and 20 m above Dante and Hulk within the integrated plume for assessing how much of the forward scattered acoustic propagation is affected by particles rather than temperature fluctuations. Five *Alvin* dives to the Main Endeavour Field were used to complete each of these objectives.

1.4 Axial Volcano Hydrothermal Vent Monitoring (Butterfield (UW/NOAA))

NOAA's Pacific Marine Environmental Laboratory (PMEL) has been studying Axial Volcano under the New Millennium Observatory (NeMO) project since 1998, the year of a significant volcanic eruption in the southeast caldera and southern rift zone. The goals of this program (funded primarily by the NOAA/PMEL Vents program) are to follow the temporal evolution of the volcano and associated hydrothermal systems through an entire cycle from eruption to eruption, and to study in detail the links between microbial community structures and the chemical environment. In the ten years of the project, we have re-sampled many vent sites for chemistry and microbiology nearly every year. Dr. Julie Huber (MBL) and graduate student Andrew Opatkiewicz (UW) are both involved in detailed molecular studies of DNA collected from diffuse vet sites at Axial Volcano. Opatkiewicz is using the tRFLP technique to compare the most abundant phylotypes from a wide range of vent sites over time and comparing the microbial community structures with fluid chemistry using statistical techniques. For 2008, the primary goals of the project were to re-sample selected vent sites from ASHES, Coquille/Vixen, Bag City, Marker 113, International District, Marker 33, and Cloud. We accomplished all of these sampling goals, but there was insufficient time to sample north of Marker 33, specifically Marker N3 and the Forum.

As part of the time-series study, we have monitored several different vents (high- and low-temperature) using McLane Remote Access Samplers (RAS) and temperature recorders. In 2007, we deployed a RAS with a PVC cover to focus warm fluid venting from the tubeworm-filled crack at Marker 33. This sampler was recovered and replaced with a similar RS to be recovered in 2009. There were significant non-tidal variations in temperature and composition recorded by the 2007-2008 instrument that we recovered, but the causes of the variations is unclear.

1.5 Methanogen phylogeny in diffuse fluids based on *mcrA* gene analysis (Huber (MBL))

The objective of this project was to contribute to the Holden/Butterfield effort to model the biogenic flux of methane from diffuse flow vents at Axial Volcano and the Endeavour Segment. A molecular-based approach was used to determine the abundance, diversity, and activity of methanogens in the subseafloor. We collected low-temperature diffuse fluids for DNA- and RNA-based analyses of methanogens. The samples collected will be used to quantify methanogens using quantitative PCR of the *mcrA* gene, determine the diversity of methanogens using clone libraries and sequencing of the *mcrA* gene, and determine *in-situ* expression of the *mcrA* gene in select samples using RNA extractions and reverse transcriptase quantitative (RT-Q)-PCR. This level of analysis, which includes all thermal classes of methanogens, will allow for detailed integration with cultivation and chemical measurements to build models of methane flux at deep-sea hydrothermal vents. In addition to this effort, samples from Axial Volcano were collected for targeted culturing based on previous years' results. Organisms of interest include *epsilon*-proteobacteria, *Archaeoglobus* spp., *Deferribacter* spp., and *Aciduloprofundum* spp. This project was funded by L'Oreal and by the NASA Astrobiology Institute's Directors Discretionary Fund.

1.6 High-Resolution Seafloor Mapping using an Autonomous Underwater Vehicle (AUV) (Clague (MBARI))

The goal of this project was to collect four days of bathymetry data over the Axial Volcano caldera and rim to complete a high-resolution bathymetry map started in 2006 and to commence mapping the Endeavour Segment and its flanks. Twelve missions were attempted, and six of these collected bathymetry data. Two days of mapping were performed at Axial Volcano, which completed mapping of the caldera floor and the southern half of the caldera rim, and four days at the Endeavour Segment. The Endeavour mapping ran throughout the axial valley from 4.3 km south of the Mothra vent field to 0.5 km north of the Sasquatch vent field. Despite lost time due to weather and numerous technical issues, we succeeded in collecting 27 hours of survey data at Axial Volcano and almost 55 hours of data along the Endeavour Segment. These translate into 140 km and 239 km of track at Axial Volcano and the Endeavour Segment, respectively. Combined we mapped about 57 km^2 of seafloor at roughly 1-m resolution.

1.7 Age Dating of Extinct and Active Hydrothermal Sulfide Deposits (Jamieson/Hannington (UOttawa))

A sampling program was performed to collect active and extinct sulfides of various ages from the Main and Mothra vent fields of the Endeavour Segment. By dating the sulfides, a time series for vent field-scale growth can be established. Hydrothermal barite within the sulfides will be dated with a novel geochronological technique using uranium series disequilibrium to determine the growth history and accumulation rates of the Endeavour hydrothermal field. Age dates are calculated by measuring the ratio of ^{226}Ra-to-Ba in a barite sample. Over time, the ^{226}Ra/Ba ratio decreases, due to radioactive decay of ^{226}Ra (1,600 year half-life). If the initial ^{226}Ra/Ba ratio of a sample is known, then the decrease in activity of ^{226}Ra in a sample will correspond to the age of the sample. Initial ^{226}Ra/Ba ratios can be determined by measuring the ratios in barite from active chimneys. This technique is limited by the half-life of ^{226}Ra to samples ranging in age between 500 and 15,000 years. This time interval is ideal to evaluate the lifespan of vent fields, which are thought to exist over 1,000s to 10,000s of years. Fourteen sulfide samples were collected from Mothra, Main, and Sasquatch vent fields. These were cataloged, described and photographed (see section 4.0). Some of the samples will be archived at the University of Washington. The rest will be analyzed (mineralogy, whole-rock geochemistry, and ^{226}Ra activity) at the University of Ottawa.

1.8 Microbially-Mediated Nitrogen Cycling in Diffuse Hydrothermal Fluids (Bourbonnais/Juniper (UVic), Butterfield (UW/NOAA)

The goal of this project was to study microbially-mediated nitrogen cycling in hydrothermal vents using a combination of isotopic and microbial molecular ecology methods. The nitrogen cycle in hydrothermal vents is poorly understood, especially the reactions involving bioavailable (i.e., fixed) nitrogen. The isotopic composition of dissolved inorganic nitrogen will be analyzed, which will inform us about potential nitrogen cycle transformations, and denitrification rates will be measure in diffuse hydrothermal fluids using ^{15}N incubation techniques. The microbial communities mediating nitrogen cycle reactions will be determined using 16S rRNA sequencing functional gene analysis. Hydrothermal fluid samples were preserved from high and low temperature fluids for nutrient and nitrogen isotope analyses. DNA for the molecular analyses will come from the sterivex samples collected by Julie Huber at MBL.

1.9 Viruses in hydrothermal vent systems (Anderson/Baross (UW))

The objective of this project was to gather several large volume fluid samples for virus studies. This will provide preliminary data for a subsequent study of viruses in hydrothermal vent communities. Fluid samples (~ 4 liters) were collected from background seawater, two hydrothermal vent plumes and from diffuse hydrothermal output at six vent sites (Gollum, Marker 33, Marker 113, S&M, Hulk, and Godzilla). These samples were then concentrated and preserved for counting and imaging and stored for experimentation to determine whether a virus-host system could be established. The goal is to better understand the role of viruses in the Axial Volcano and Endeavour Segment microbial ecosystem. Ultimately, our goal is to determine whether viruses act as mediators of horizontal gene transfer in vent ecosystems via transduction.

1.10 Education and Public Outreach (Parr/Di Iorio (UGA))

Ms. Rachael Parr, a middle school teacher from East Jackson Middle School in Athens, Georgia, was invited to participate in this expedition as part of Daniela Di Iorio's educational outreach program. Our primary objectives for her participation and assistance in the science collection was to bring the research back to the middle school level and to develop a curriculum that will engage students in learning the science of hydrothermal vents. Classroom studies will include, but are not limited to:

a. Hydrothermal heat flux: flow and temperature measurements
b. Microbiology: microbial life found in and around the vents
c. Diversity: the diversity of life found in and around the vents
d. Geochemistry: the study of gases and volcanism

e. Plate tectonics: the types of plate boundaries and the movements within those boundaries
f. Mapping: Comparing SeaBeam Mapping to AUV Mapping
g. Technology: AUV, *Alvin*, acoustics, robotics, sonar, radar, and other technologies that are utilized on board
h. Outreach: To develop programs that will reach other students.

Since Georgia schools started on Aug 7, 2008, Ms. Parr had one week with her 7th grade students and took the opportunity to introduce the theory of plate tectonics to them. The Juan de Fuca Ridge was used as their primary example and she held discussions with the students as to why it is a heavily studied area by scientists. Other topics included 1) a discussion on buoyancy and *Alvin* with an inquiry activity where the students design and build a neutrally-buoyant submersible, 2) background information on the R/V *Atlantis* and the various types of research conducted on her, 3) lessons on the methods and tools used by scientists to study hydrothermal vent systems, again with focus on the Juan de Fuca Ridge, 4) lessons where students compare geysers on land with deep-sea hydrothermal vents, and 5) lessons on microbial life found around the vent systems and a comparison of these with those that live in your mouth.

While at sea, Ms. Parr developed an online blog site (http://rparr.edublogs.org/) to communicate with students and teachers at East Jackson Middle School. The blog served the following purposes:

a. The research activities taking place daily, along with pictures that helped in understanding the research, were posted. Much of the information was gathered through interviews with the scientists onboard *Atlantis*.
b. Each day all science teachers in the school, regardless of the discipline taught, held a class discussion on the blog content for the day. Students were given the opportunity to respond to the blog and ask questions. Questions that the students had were answered the following day.
c. The blog was also used to ask the students research questions, to which a log of answers was kept by the teacher for further discussion upon return to the classroom.

Each day, approximately 410 students read the blog and there were on average 15 comments by students and classes participating in the project. It will be continued as a teaching and communication method with other schools.

Ms. Parr also developed 6th-grade Earth Science curriculum materials on the ship that began use upon her return to the classroom. These materials include, but are not limited to 1) understanding the structure of the Earth, 2) understanding the theory of plate tectonics, and 3) modeling and demonstrating the types of plate boundaries with specific emphasis on the Juan de Fuca Ridge. Inquiry investigations on buoyancy, velocity, density, pressure, mass and volume are in development. Ms. Parr's 7th-grade Life Science curriculum will cover microorganisms with a comparison of archaea and bacteria and the conditions in which these grow. Class activities and discussions will also include symbiotic relationships found at the hydrothermal vents. There will be a research project on marine sanctuaries and protected areas, and the students will watch videos that feature deep-sea hydrothermal vents.

Finally, Ms. Parr will share her experiences with the K-12 teaching community through presentations on the benefits of connecting science teaching to the science community, her experience on her *Alvin* dive, and exploration beyond the classroom. She will also share a presentation with the science learning community or CLIMS (Community of Learners in Mathematics and Science) on connections to 'real world' science.

2.0 Dive Summaries

Atlantis left Astoria, Oregon at 0900 local time and steamed towards the Endeavour Segment hydrothermal vent field. We arrived early in the morning on the 19th. However, the winds rapidly increased to 30 sustained knots with gusts up to 35 knots. This delayed *Alvin* and AUV dive operations for two days until the gale subsided. After four dives at the Endeavour Segment, we transited to Axial Volcano for an additional four dives before returning to Endeavour to complete our dive program. A summary of *Alvin* dive operations is provided in Table 1 and Table A1. Summaries fluid and rock samples collected by *Alvin* are available in Tables A2 through A9. A summary of CTD water samples is available in Table A10.

Table 1. Dive participants and locations

Dive #	Date	Pilot	Port Observer	Stbd Observer	Location
4438	21 Aug 08	Pat Hickey	Dave Butterfield	Jim Holden	MEF
4439	22 Aug 08	Bob Waters	Trent Moore	Rachael Parr	MEF
4440	23 Aug 08	Sean Kelley	Trent Moore	Guangyu Xu	MEF
4441	24 Aug 08	Pat Hickey	Daniela Di Iorio	L. Germanovich	MEF
4442	25 Aug 08	Bob Waters	Kevin Roe	Dave Walters	ASHES
4443	26 Aug 08	Sean Kelley	Dave Butterfield	Noah Lawrence	Mk 33
4444	27 Aug 08	Pat Hickey	Dave Butterfield	Julie Huber	Vixen/Mk 113
4445	28 Aug 08	Bob Waters	Julie Huber	Rika Anderson	Int. District
4446	29 Aug 08	Sean Kelley	Dave Butterfield	Annie Bourbonnais	MEF
4447	30 Aug 08	Pat Hickey	Trent Moore	Korey Verhein	MEF
4448	31 Aug 08	Bob Waters	Dave Butterfield	Helene Ver Eecke	MEF
4449	1 Sept 08	Sean Kelley	Julie Huber	Jim Holden	MEF
4450	2 Sept 08	Pat Hickey	Eric Olson	John Jamieson	Mothra
4451	3 Sept 08	Bob Waters	Dave Butterfield	Hans Thomas	Sasquatch
4452	4 Sept 08	Sean Kelley	Trent Moore	L. Germanovich	MEF
4453	5 Sept 08	Anton Zafereo	Pat Hickey	Eric Olson	High Rise

2.1 Dive 4438: Main Endeavour Field **August 21, 2008**

Pilot: Pat Hickey
Port Observer: Dave Butterfield
Starboard Observer: Jim Holden

Primary objectives: 1) Release the RAS mooring at Easter Island, 2) extinct and active sulfide recovery, 3) major and gas-tight fluid sampling of high-temperature fluids, and 4) observations and temperature measurements of the southern half of MEF.

Sample summary: 6 major fluid samples, 6 gas-tight fluid samples, 3 sulfide chimney samples (1 active, 2 extinct), 2 vertical video surveys of Milli-Q, and recovered the RAS mooring.

Dive Summary:

The sub began its descent at 1511 UTC. We landed in the axial valley east of the Milli-Q vent at 1615 (x:5170, y:5932, z:2,208 m), which was the deepest point of our dive. We drove west over pillow basalts and lobate lavas dusted with light tan-colored sediment, crossing several fissures, climbing up roughly 15 m and encountered the ridge of extinct sulfide (x:5030, y:5954, z:2,205 m, h:194°). At 1635, we collected a roughly 20 cm-wide piece of old chimney here and stowed it in the rear port crate, toward the center. We proceeded west to the scarp that runs between the S&M and Milli-Q vents, then drove up and around to the RAS mooring in the Easter Island diffuse vent field using the Sonardyne beacon 16 to locate it (x:4860, y:6027, z:2,195 m). From 1657 to 1722, we photographed the mooring and measured temperatures at the RAS fluid inlet in the range of 21.8 to 22.2°C prior to pulling the mooring pin to release it to the surface. While at Easter Island (1731 UTC), we collected a black gas tight fluid sample ~3 m NW of the RAS site (x:4859, y:6027, z:2,195 m, h:229°) with a fluid temperature of 99°C.

We then drove a few meters south to Peanut vent where we found marker 1L. It was covered with worms and diffuse flow and had several flanges protruding from it, but there were very few smoker spires on it. Former smokers could be seen but were sealed off. We moved a few meters to the SE and found marker AM near smokers on Bastille. We did not see any other sites of smoker activity on Bastille. At 1754-1816 (x:4860, y:6002, z:2,193 m, h:100°), we collected green and red gas-tight fluid samples and a blue major pair fluid sample from 302.7°C fluid emitted from Bastille vent just below triangle marker B. We then sampled an active sulfide spire, which required that we move around to the other side of the structure in order to retrieve it (x:4860, y:6004, z:2,193 m, h:229°) and place it into the biobox. The sulfide piece broke into three large pieces as it was being placed into the box. The temperature of the fluid emitted from the orifice of this chimney following sampling was 282°C. We placed a Hobo temperature recorder in the orifice left behind. There were many rusty *Ridgeia* tubeworms in the area, but no visible worm plumes.

We moved next to Puffer vent where we saw only one smoker near Marker P with an exit fluid temperature of 261.5°C, which we did not sample. From Puffer, we moved slightly SE and found a large flange on a structure between Puffer vent and Sully vent (1846 UTC, x:4869, y:5984, z:2192 m, h:183°). The temperature of the fluid beneath the flange was 212.7°C. Pat thought that this would be an ideal flange for an *Alvin* recovery later in the dive program. From this flange, we drove ESE over inactive sulfide and basalt and arrived at the Milli-Q vent. We saw marker M on the north side, marker DK1 to the southeast, and marker AZ on WNW side of the structure. We found only a single active vent on the top of the structure with a fluid temperature of 71.8°C. At 1907, we took a white gas-tight fluid sample (x:4899, y:5949, z:2,179 m, alt:11.4 m, h:320°). We also did two vertical imaging transects of the northern and southern faces of the Milli-Q structure.

From Milli-Q vent, we drove north to S&M vent where we saw markers SM and MT3. At 1942, we collected a green major pair fluid sample and a blue gas-tight fluid sample from fluid near the top of the structure (x:4929, y:5999, z:2,181 m, alt. 20.4 m, h:254°) that was 328.7°C (highest temperature on this dive). The S&M vent was the most robustly venting structure that we saw and was still extensively covered with macrofauna. From S&M vent, we drove past Needle sulfide structure, seeing marker N on top and did not see any active chimneys. We continued onto Sully vent where we found both the star-shaped marker and triangle marker S. On top of Sully vent, there were two active smokers, one with a Hobo probe installed from a previous dive. At 2018, we measured the temperature of the fluid emitted from the second vent, which was 256.9°C. We collected an orange gas tight fluid sample and a red major pair fluid sample from this fluid (x:4886, y:5957, z:2,189 m, alt.:3.8 m, h:273°). The structure was covered with rusty *Ridgeia* with very few living tube worms or palm worms visible on the structure.

From Sully we drove west to the talus wall and then followed the wall south past Peanut vent. We eventually arrived at a worm-covered sulfide structure with very low activity and several barren chimney and flange structures. We believe that this is elongated structure on the MEF map near x:4850, y:5915 is Cathedral vent. There is still considerable worm coverage and shimmering water here with fluid temperatures up to 221°C on the north side and 118°C within diffuse flow. This is a good candidate for diffuse fluid sampling using the HFPS on a future dive. There were no visible markers at this vent site. At 2116, we drove 75 m south and found Salut vent with its arrow-shaped marker and marker G near the top (x:4852, y:5854, z:2,189 m, alt.:3.8 m, h:283°). All venting at Salut is diffuse with healthy palm worms and tube worms in the vicinity. Fluid temperatures were as high as 237°C with a lot of diffuse venting the temperature range of 25 to 36°C. Prior to departing the site, we sampled part of an inactive sulfide spire (x:4847, y:5865, z:2,189 m, h:356°) and stowed it in the forward crate on the basket. We were not quite out of power, but we were at the extreme south end of the field and had many samples to process back on the surface. Therefore, we drove up the western wall out of the axial valley and dropped weights at 2137. We were back at the surface at 2300.

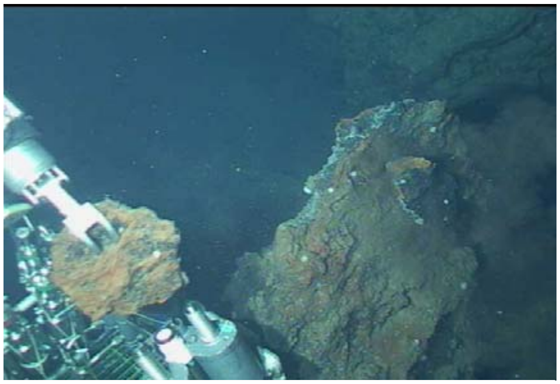


Figure 2.1.1. Extinct sulfide collected in the axial valley east of S&M vent.

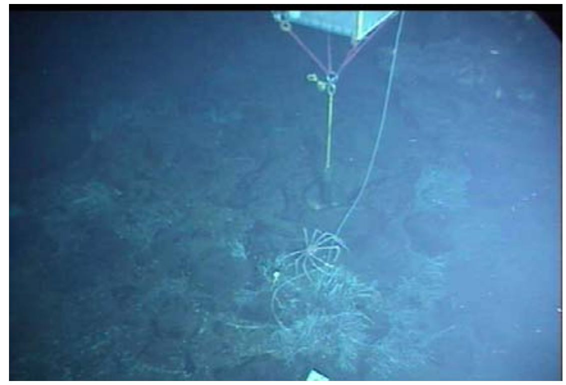


Figure 2.1.2. RAS mooring in Easter Island vent and its intake nozzle in diffuse fluids.

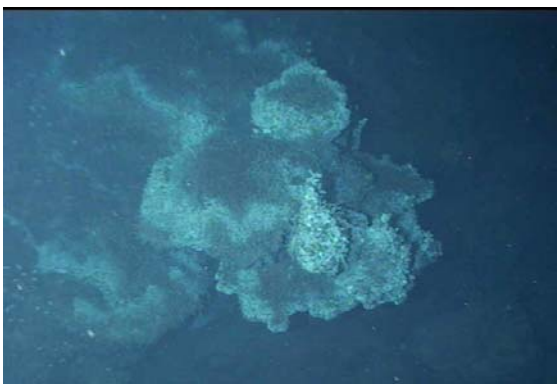


Figure 2.1.3. Flanges near the base of Peanut vent.

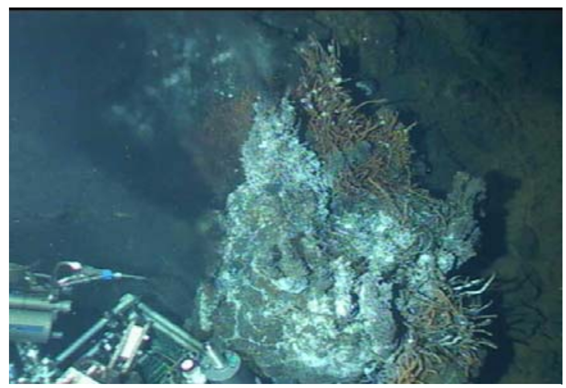


Figure 2.1.4. Sulfide spires and hydrothermal venting at Bastille vent. The spire on the left was retrieved for sampling.

Figure 2.1.5. Hydrothermal activity at Puffer vent.

Figure 2.1.6. A flange protruding from a small sulfide mound between Puffer vent and Sully vent.

Figure 2.1.7. Extinct sulfide spires on the top of Milli-Q vent.

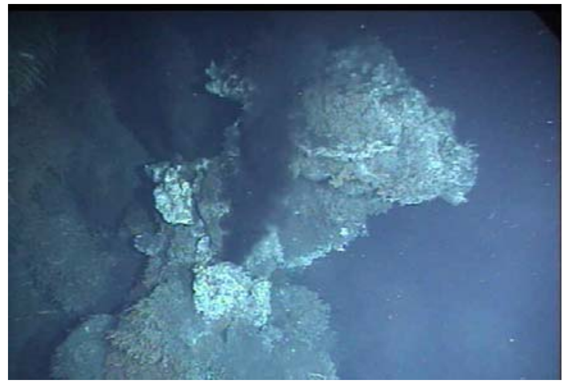


Figure 2.1.8. High-temperature venting at S&M vent, which had the highest temperatures in the southern MEF.

Figure 2.1.9. Sully vent with a hobo probe. The twin spire on the right was knocked over for the fluid sample.

Figure 2.1.10. Venting and macrofauna at the Cathedral vent site.

Figure 2.1.11. The G marker at Salut vent. There was considerable diffuse venting here and extensive coverage by macrofauna.

Figure 2.1.12. The extinct sulfide spire on the left at Salut vent was collected.

2.2 Dive 4439: Main Endeavour Field **August 22, 2008**

Pilot: Bob Waters
Port Observer: Trent Moore
Starboard Observer: Rachael Wilkinson-Parr

Primary objectives: The primary purpose of this dive was to recover the transmitter and receiver moorings that had been deployed by Di Iorio around Hulk vent in July 2008.

Sample summary: Released acoustic scintillation transmitter and receiver for surface recovery, flow measurements at smokers, a piece of a sulfide chimney near Lobo.

Dive Summary:

Alvin was launched at 1511 UTC. Once on the bottom at 1629, we transited to Marker G at Grotto vent marker and set the DVL navigation to this location. Many black, gray, and diffuse flow vents were observed and analyzed for temperature and flow. At first, the Schilling arm did not respond but then started to work. Temperatures in this area varied between 200 and 324°C. After two hours of work, we noticed that none of the tapes were recording. This was a real loss since our flow measurements rely on video imaging of the flow anemometer. Some of the measurements had to be redone; however, we could not resample all of them due to time constraints. Visual surveys to the north and south of Grotto were carried out to locate future mooring locations for the acoustic scintillation system if opportunities arise to redeploy the instruments.

We then went to Dante vent where a Hobo temperature probe was retrieved from the top most vigorous black smoker – 335 days of data were collected. Flow and temperature measurements were made from this smoker and the one next to it. Some mooring clean up was also performed at our previous TX mooring site to the southeast of Dante. From there we headed west to Lobo vent where flow and temperature analyses were made at various black smokers with temperatures near 333°C. Finally at 2204, a sulfide sample was taken at Lobo vent (x:4925, y:6163, d:2,183 m, h:265°) just prior to dropping weights.

The transmitter and receiver moorings were recovered during the dive. The receiver did not collect data on several channels and it was discovered later that a jumper cable connecting the CPU board with the timing board had dislodged itself. We fixed the problem by soldering the pins together. The batteries were changed and the moorings were rebuilt for another deployment around Hulk vent. The moorings were deployed the evening of Aug 22 so they could be positioned during dive 4440.

Figure 2.2.1. Hobo temperature probe retrieval from Dante vent.

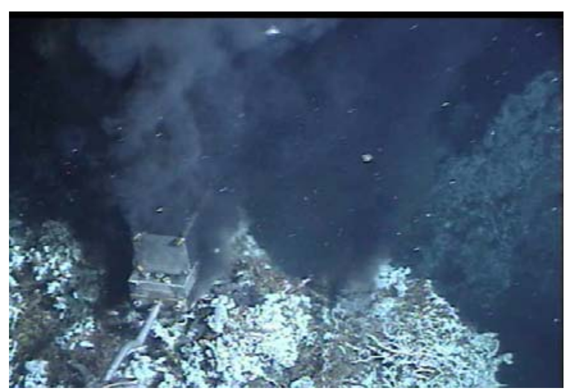


Figure 2.2.2. Flow meter measurement at Dante vent.

Table 2.2. Summary of activities on Dive 4439

Time	x-position	y-position	Depth (m)	Heading	Temp.	Remarks
1638	5070	6018	2,207	313°		No video recording until 1856
1702	4872	6000	2,186	077°		Bastille vent with grey smoker
1710	4924	6140	2,184	053°		Reset the DVL to Grooto marker
1715	4924	6146	2,184	038°		Attempted temp., no schilling arm
1732	4924	6145	2,185			Velocity wheel, grey smoker
1734	4924	6145	2,184	023°		Velocity wheel, white beehive
1736	4924	6145	2,185	023°		Velocity wheel, diffuse flow
1739	4924	6145	2,185	023°	323.7°C	Temp. measurement, grey smoker
1741	4924	6145	2,185	023°	289.0°C	Temp. measurement, white beehive
1743	4924	6145	2,185	023°	302.4°C	Temp. measurement, diffuse flow
1749	4924	6149	2,185	157°	207.0°C	Temp. measurement, diffuse flow
1754	4924	6149	2,185	158°	294.0°C	Temp. measurement, beehive smoker
1800	4924	6149	2,185	158°		Velocity wheel, diffuse flow
1805	4924	6149	2,185	158°		Velocity wheel, grey smoker
1811	4932	6150	2,185	139°		Velocity wheel, black smoker
1814	4931	6150	2,185	139°	322°C	Temp. measurement, black smoker
1825	4935	6152	2,188	180°	330°C	Temp. measurement, black smoker
1827	4934	6152	2,188	180°		Velocity wheel, black smoker
1846	4932	6143	2,187	269°		Velocity wheel, black smoker
1850	4932	6143	2,187	269°	334.5°C	Temp. measurement, black smoker
1856	4932	6143	2,187	269°		Video recorder turned on
1902	4923	6145	2,185	037°		Velocity wheel, 1732 smoker
1915	4935	6146	2,189	227°		Same smoker as 1825
1922	4932	6158	2,183	052°		Survey for mooring location, x:4968 y:6199, d:2,197 m; very flat bottom
1933	4939	6154	2,186	212°		Found 2 smokers, likely in Lobo
1948	4900	6105	2,194	199°		Good southern mooring site
2006	4974	6163	2,175	236°		Retrieve hobo on Dante
2012	4973	6162	2,176	236°	327.5°C	At Dante, velocity wheel at hobo site
2015	4973	6162	2,176	236°		Velocity wheel to right of hobo smoker
2017	4973	6162	2,176	236°	327.5°C	Temp. measurement, hobo smoker
2018	4973	6162	2,176	236°	325.1°C	Temp. meas., right of hobo vent
2043	4999	6131	2,197	178°		Clean old mooring gear S of Dante
2125	4953	6120	2,195	204°		At Lobo
2127	4940	6151	2,187	307°		Temp. & velocity at 3 smokers
2144	4943	6162	2,187	160°	333.0°C	Temp. & velocity at 3 smokers
2204	4925	6163	2,183	265°		Collected sulfide chimney from Lobo
2210						Dive ended

2.3 Dive 4440: Main Endeavour Field **August 23, 2008**

Pilot: Sean Kelley

Port Observer: Trent Moore

Starboard Observer: Guangyu Xu

Primary objectives: The objectives of this dive were 1) deploy the transmitter and receiver moorings for acoustic scintillation around Hulk vent, and 2) conduct acoustic profiling of the plumes.

Sample summary: A basalt rock sample was collected.

Dive Summary:

Alvin was launched at 1457 UTC and reached the bottom at 1606. At 1615, a basalt sample was collected near where *Alvin* touched down to the northeast of Hulk in the Main Endeavour vent field (x:5047, y:6363, d:2,195 m, h:306°). From there we made our way to where the scintillation transmitter was dropped during the previous nights operations. It landed near a fissure and was taken to the northeast side of Hulk where it was placed next to the anchor of our previous deployment. The mooring line from the old anchor was cut and removed. The scintillation receiver was then located and found inside a rocky hole. It was easily removed from the hole, moved to location, and deployed on the southwest side of Hulk. The receiver array was then rotated to the correct orientation.

The rest of the dive was taken up with horizontal imaging of the hydrothermal plume for cross sectional area measurements at various heights above Hulk to a maximum of 10 m. We were able to carry out 3 vertical transects and then the dive was terminated early because of increasing winds and waves on the surface.

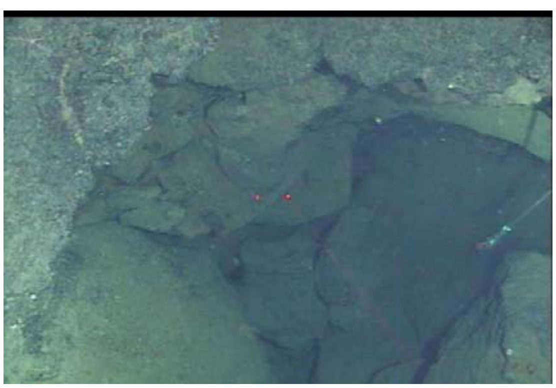


Figure 2.3.1. The receiver array found in a hole after deployment from the ship.

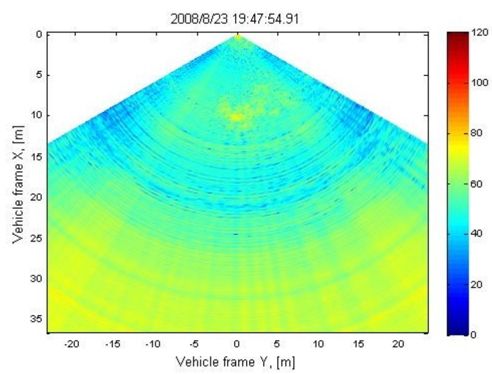


Figure 2.3.2. An acoustic image of the Hulk plume in the horizontal plane approximately 10 m above the structure. The plume is a yellow-orange circle at 10 m range.

Table 2.3. Summary of activities on Dive 4440

Time	x-position	y-position	Depth (m)	Heading	Temp.	Remarks
1612	5058	6353	2,193	002°		Dive begins
1615	5047	6363	2,195	306°		Collect basalt sample
1627	4957	6262	2,190	147°		At transmitter
1638	5063	6286	2,210	230°		Moved Tx next to old anchor
1656	5106	6162	2,205	143°		At Rx drop, in rocky hole, retrieved intact
1708	5002	6201	2,195	272°		Moved Rx mooring to x:4997 y:6200, z:2,195 m
1720	5007	6198	2,167	329°		Rotating Rx to NNE in line 138°
1750	5065	6244	2,209	318°		Setting up for SM2000 sonar
1814	5065	6243	2,193	318		Recording on 2,194 m
1825	5062	6244	2,177	295°		Something at 20 m range
1829	5062	6245	2,177	295°		No plume, stopping, moving to Hulk
1859	5036	6243	2,198	013°		At marker H at Hulk vent
1907	5033	6246	2,189	035°		Start recording sonar image, 2,184 m
1911	5030	6250	2,186	073°		Recording
1915	5028	6256	2,182	093°		Recording
1918	5029	6258	2,177	093°		Still see small plume
1926	5034	6257	2,177	093°		Plume image within 20 m
1928	5033	6255	2,179	092°		See top of Hulk
1930	5034	6257	2,181	092°		Rotating to east 109°, going up
1937	5034	6264	2,181	109°		Plume slightly to east
1939	5035	6266	2,178	108°		Plume blip barely visible to east
1943	5035	6266	2,172	107°		Go back down
1945	5037	6261	2,176	123°		Plume visible
1947	5039	6258	2,180	122°		Plume at 10 m
1950	5036	6258	2,182	113°		Big plume showing on sonar
1953						Dive over due to weather

2.4 Dive 4441: Main Endeavour Field **August 24, 2008**

Pilot: Pat Hickey
Port Observer: Daniela Di Iorio
Starboard Observer: Leonid Germanovich

Primary objectives: The objective of this dive was to collect heat flow measurements using direct temperature and flow rate analyses and acoustic plume imagery.

Sample summary: One basalt rock sample and one sulfide rock sample both near Dante vent.

Dive Summary:

Alvin was launched at 1455 UTC at reached the bottom at 1557. Shortly after we reached the bottom, Pat discovered that the DVL navigation was not working. The LBL navigation was also not getting a fix on our location. As a result, our whole dive was without navigation in the sub. We were able to get USBL fixes from the top lab but the errors in position may be high. The sub was particularly noisy, which consequently also made the SM2000 imagery rather noisy. We dropped the winch anchor at the Grotto marker and then rose to various heights above Grotto for horizontal imaging. We then moved to the south side of Dante, dropped the anchor, and rose up in the water column above Dante. We noticed two plumes in the imaging cross section which made us believe that there was another vigorous black smoker plume to the northeast of Dante. We thought that it might be TP vent. We then went to the north side of Dante and imaged toward the south and saw only one plume in the horizontal cross section. We carried out some heat flux measurements from one high temperature black smoker on the top of Dante. We then did some clearing of mooring lines left from previous scintillation deployments. At this location we took a basalt sample and then headed east to drop weights.

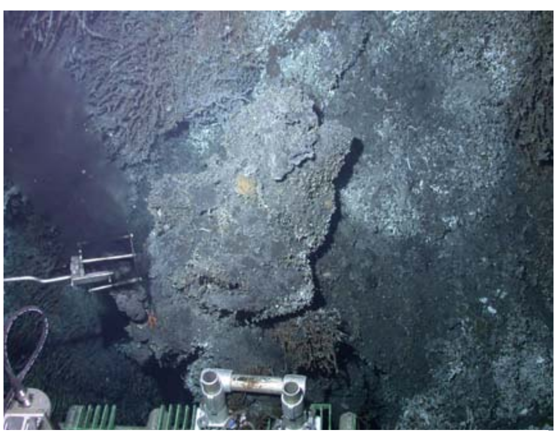


Figure 2.4.1. Flow meter measurement.

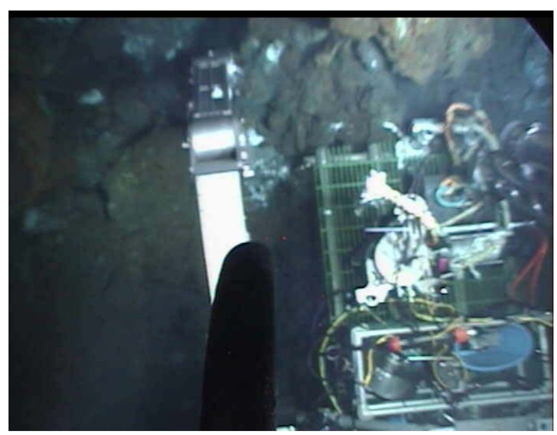


Figure 2.4.2. Basalt rock sample collection near Dante vent.

Table 2.4. Summary of activities on Dive 4441

Time	x-position	y-position	Depth (m)	Heading	Temp.	Remarks
1618						No DVL or LBL navigation
1648	4943	6131	2,189			At marker G at Grotto
1653						Dropped anchor
1707	4913	6747	2,186	023°		Start recording SM2000 imagery
1710	4913	6747	2,183	023°		Plume cross section
1714	4913	6747	2,181	002°		
1719	4913	6747	2,176	002°		
1724	4913	6747	2,173	002°		
1730	4913	6747	2,169	002°		
1733	4913	6747	2,169			Stopped recording, winching down
1811	4972	6147	2,196			Arrived SW side of Dante vent
1814	4972	6147	2,196			Start recording SM2000
1819	4972	6147	2,174	006°		Top of Dante vent
1821	4972	6147	2,170	005°		Tried unsuccessfully to fix the DVL
1828	4972	6147	2,167	005°		Changed heading to 37°, strong plume to NE
1835	4972	6147	2,163	032°		Hydraulic pump is noisy
1841	4972	6147	2,159	032°		No more plume
1845	4972	6147				Winching down
1907	4972	6147				Stopping recording
1912	4972	6147	2,196			Sulfide sample from the base of Dante
1925	4965	6170	2,192	200°		Base of northern part of Dante vent
1931	4965	6170	2,175	200°		Top of Dante, SM2000 horizontal profiling
1933	4965	6170	2,171	200°		
1940	4965	6170	2,163	170°		
1943	4965	6179	2,160	140°		
1949	4965	6179	2,159	140°		
1952	4965	6179	2,155	140°		No plume, winching down
2035	4954	6165	2,185	119°	328.0°C	3 chip recording black smoker flow
2049	4967	6175	2,172	145°		TP vent (?) is very vigorous
2115	4998	6205	2,192	352°		Dante Rx mooring clean up
2133	4998	6205	2,193	075°		Basalt rock sample collected

2.5 Dive 4442: ASHES Vent field, Axial Volcano **August 25, 2008**

Pilot: Bob Waters
Port Observer: Kevin Roe
Starboard Observer: Dave Walter (PIT)

Primary objectives: The goals of the dive were to 1) collect fluids from low temperature vents at Gollum and Marshmallow; 2) collect high temperature fluids from Virgin Mound, Inferno, and Hell vents; and 3) time permitting, move south to sample Vixen, Casper, and Mushroom vents.

Sample summary: 4 gas tight fluid samples and 15 HFS fluid samples (8 filtered, 3 unfiltered, 3 sterivex filters, and 1 large-volume bag).

Dive Summary:

The dive began at 1531 UTC and reached the bottom at 1611 and a depth of 1,540 m. We landed to the southwest of Gollum vent and began a heading of 337°. There was no in-sub navigation and got ranges and bearings from the ship.

Our first target for orientation purposes was Virgin Mound, which was sighted at 1634. We then headed for Gollum where we saw Marker 62. There was some metal frame work in the area with a square attached to the pipes with the numbers 32 and 33 on it. This may have been part of the larval array or the buried bac-traps. At 1713, the intake nozzle for the HFS was dropped and it was difficult to set up for sampling and required some repositioning since the vent site is in a depression. At 1751, we began HFS sampling and collected two unfiltered bags, one unfiltered piston, two sterivex filters with 2 L of fluid passed through each, and one large volume (4.5 L) bag sample. The pump had to be stopped and restarted on the large volume bag sample to keep the pump rate as high as possible. Still, the sampling time for the large volume bag sample was 35 minutes. The maximum temperature measured at Gollum was 23.3°C. At 1910, we transited to Marshmallow and found Marker I that identified the site. At 1932 and heading 344°, we arrived at three small white venting sites and measured a maximum temperature of 25°C in an area of white anhydrite and tube worms. At 1958, we moved to the left to a more actively flowing vent with focused flow through an anhydrite orifice and a temperature of 88.0°C. At 2008-2034, we collected a filtered piston, a filtered bag, and a sterivex filter using the HFS sampler.

At 2039, we arrived at Virgin Mound where there were four anhydrite chimneys in a line. The tallest was the second at a heading of 031°, but we sampled fluid from the first chimney in the line leaving the tallest one intact. Marker MISO 101 could be seen in the background behind the chimneys. We collected one filtered piston, one filtered bag, and the white gas tight sample. The temperature was 247.7°C. At 2121, we arrived at Inferno vent and removed a slender spire on top to sample the fluid. The sub's altitude and heading were 3.5 m and 298°. We collected two gas tights (black-white and red-white-blue), a filtered bag sample, and a filtered piston sample and measured a fluid temperature of 321.3°C. We did not hear the red-white-blue gas tight fire. Sampling concluded at 2151. At 2208, we arrived at Hell vent and began sampling on the top of the structure at 3 m altitude and a heading of 232°. We collected a filtered piston, a filtered bag, and the green gas tight and the fluid temperature was 285.9°C. Sampling ended at 2225.

2.6 Dive 4443: Marker 33/Cloud Vent, Axial Volcano **August 26, 2008**

Pilot: Sean Kelley
Port Observer: Dave Butterfield
Starboard Observer: Noah Lawrence-Slavas

Primary objectives: The objectives were to 1) release the RAS mooring at Marker 33, 2) deploy the new RAS at the same location, 3) collect fluid samples from the region, and 4) photograph the region around Marker 33.

Sample summary: 2 gas-tight fluid samples and 10 HFS fluid samples (2 filtered, 4 unfiltered, 3 sterivex filters, 1 large volume bag)

Dive Summary:

Alvin was launched at 1502 UTC and reached the bottom at 1549 near the RAS launch site. As we approached the bottom, the Sonardyne beacons on the new mooring (16) and the 2007 mooring (17) were both transmitting. We landed about 150 m north of Marker 33 and drove south to the vent. Upon arrival, we set up facing SE (heading 155), with the RAS mooring and intake line on our left. We measured temperatures of 6-11°C in front of the vent cover/collector (away from the crack) and 16-21°C on the back side over the crack. Sean removed MTR4001 from one of the holes in the cover, broke off the float and stowed it in the basket. We took fluid samples and filters inside the cover, with temperatures in the 20-21°C range (unfiltered piston 1, unfiltered bag 17, large volume bag #10, sterivex #11, filtered piston #9, gas tight fluid sample). We pulled off the MTR (labeled "Dave" in red marker, xx89 visible) and stowed it. At 1750, we moved away from the vent and released the RAS mooring to send it to the surface. We then headed east to find the RAS to be deployed. It landed in an extremely rough area of lava pillars and collapse. (The intended sheet flow area is about 40 meters north of where it landed.) It took a lot of work and maneuvering to free the anchor from the bottom and release the drop anchor. We arrived back at Marker 33 (55) at 1900, whereupon we set up the new RAS, putting the intake line with MTR attached under the vent cover. With the RAS set up, we were low on power and could only reach a nearby vent, so we drove east to Cloud, located the Pit vent (depth 1521 m at the vent). The flow was coming up the back vertical surface, where we sampled fluids of 6.9°C, very similar to last year. At Cloud/Pit we took sterivex filter 12, unfiltered piston 6, unfiltered bag 18, filtered bag 20, duplicate sterivex filter 13, and the blue gas tight. (Note that the laptop computer recording the HFS log had the time set to local PDT for this dive. I reset it back to UTC on the start of the next dive 4444.) At the end of the dive, we deployed the "happy face" marker on a high point above Cloud vent at 1517 m depth.

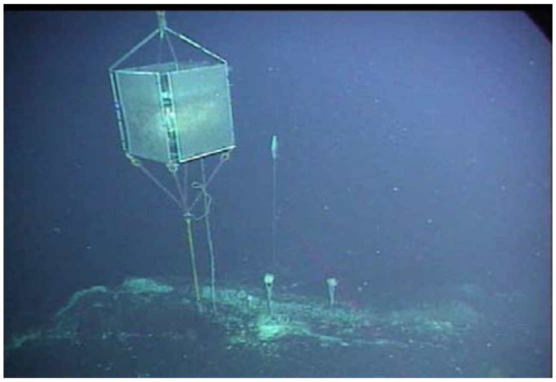


Figure 2.6.1. View of Marker 33/55 vent looking SSE at the beginning of the dive with the 2007 instrument in place. The RAS intake cover is midway along the crack.

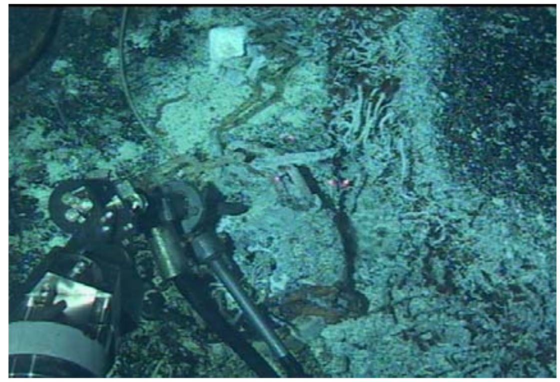


Figure 2.6.2. Sampling fluids from the RAS vent cover at Marker 33 with the 2007 intake still in place.

Figure 2.6.3. Trying to free the drop anchor on the RAS mooring in a rough pillar/collapse area.

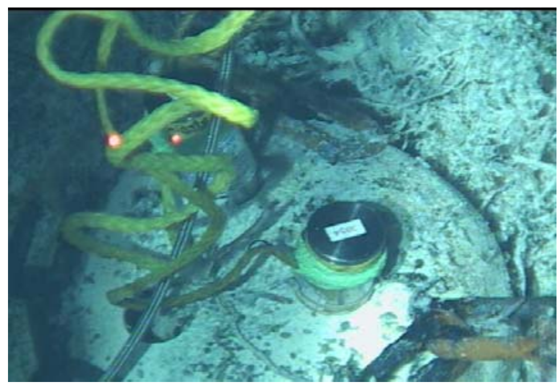


Figure 2.6.4. Vent cover for the newly deployed RAS at Marker 33. Temperature recorders 3054 and 3087 are placed in the cover and 3173 is attached to the intake line under the cover.

Figure 2.6.5. Final RAS setup for 2008-9, which is nearly identical to the 2007-8 setup. The intake is very near the edge of the crack under the vent cover. An MTR to be recovered next year is in the lower right of the photo, and an abandoned osmosampler is across the crack.

Figure 2.6.6. The Pit vent at Cloud (original Marker N6) still venting at nearly the same temperature as last year.

2.7 Dive 4444: Coquille vents field and north, Axial Volcano **August 27, 2008**

Pilot: Pat Hickey
Port Observer: Dave Butterfield
Starboard Observer: Julie Huber

Primary objectives: The objectives were to 1) sample high temperature fluids from Casper and Vixen, 2) sample diffuse flow in the Coquille vent field, 3) deploy the Germanovich flow meter and a Kadko Toaster in high temperature flow, and 4) sample diffuse flow at Bag City, and Marker 113.

Sample summary: 5 gas-tight fluid samples, 16 HFS fluid samples (7 filtered, 6 unfiltered, 2 sterivex filters, 1 large volume bag), and 1 toaster.

Dive Summary:

Alvin was launched at 1702 UTC after a two hour weather delay. We landed on the bottom at 1744 south of Vixen, the vent target area in Coquille field. We immediately saw white microbial mat, tube worms, limpets, clams, crabs, and rat tail fish. We drove 40 m at a 331° bearing and found Vixen and Casper vents, each with a HOBO temperature probe, at 1755. There was abundant diffuse venting and worms throughout the region. Marker 57 was visible near Vixen. Both Vixen and Casper have grown darker in color over the years. We began sampling at 1830 in a tube worm bush 2 m away from Vixen facing west (x:5709, y:1915, z:1,521 m). There was a lot of particulate material in the vent, as indicated by the large amount of white material coming out of the fluid sampler. While sampling at the 23°C diffuse vent, we noticed chunks of chimney blowing out of Vixen every once in awhile. At 1844, the sub moved and sampling was paused while we repositioned and removed an obstruction in the pump. At 1902, we collected an unfiltered piston, a filtered bag, and a sterivex filter from the same location. At 1915, we moved to Vixen for sampling (x:5709, y:1915, z:1,521 m). Vixen is a small mound with grey to clear venting from multiple orifices in the mound. At 1933, we measured a temperature of 334°C and collected a filtered piston and filtered bag from Vixen, followed by two gas tights. We then deployed the Germanovich flow meter (1936) at Vixen and filmed it with the high definition video camera inside the sub. At 1945, we collected a radium "toaster" sample for Dave Kadko and visually confirmed the fibers were intact after a few minutes in the vent. At 2000, we moved to the Casper high temperature vent (x:5704, y:1924, z: 1,538 m). Unlike Vixen, there are two small (~ 1 ft) grey structures at Casper, with focused fluid out of each structure. We measured a temperature of 304°C at Casper and collected two filtered pistons and 2 gas tight fluid samples.

At 2020, we began our transit to Bag City vent, approximately 330 m away on a heading of 112°. During the transit, we moved over areas of lobate flow with light sediment cover and then transitioned into more jumbled and fractured lava flows. At 2041, we arrived at Bag City with Marker 36 in view. There were abundant tubeworms, although they were not as healthy looking as those in the Coquille vent field. There were many crabs as well. The old camera frame from a previous NeMO deployment was also visible. We found a healthy looking tube worm bush right next to Marker 36 and started sampling the 11°C fluid at 2056 (x:5861, y:1761, z:1,532 m). We collected an unfiltered piston, a filtered bag, a sterivex, and one filtered piston from this site.

At 2128, we left Bag City and headed to Marker 113 (800 m, bearing 005°). About 350 m south of Marker 113, we noticed abundant iron rich coatings in the basalt cracks on lobate flows, and shortly thereafter there were only pillows without any iron staining. We arrived at Marker 113 (1998 marker is now gone) at 2156, finding the newer marker 62 at the vent sampled in previous years. Marker 113 time-series vent is located on top of a lava pillar with abundant tube worms, blue ciliates, and microbial mat. Once on site (x:6087, y:2549, z:1,521 m, h:308°), we began sampling the 26°C fluid near the ledge of the flat top at 2207 and collected the orange gas-tight, two unfiltered pistons, 1 unfiltered bag, and 1 large volume (4 L) sample. We left the bottom at 2251.

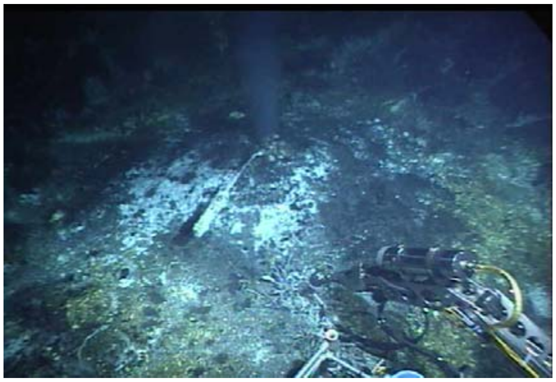


Figure 2.7.1. Diffuse fluid sampling near Vixen vent.

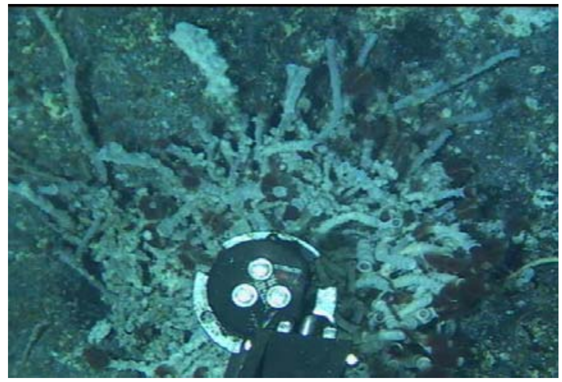


Figure 2.7.2. Diffuse fluid sampling near Vixen vent.

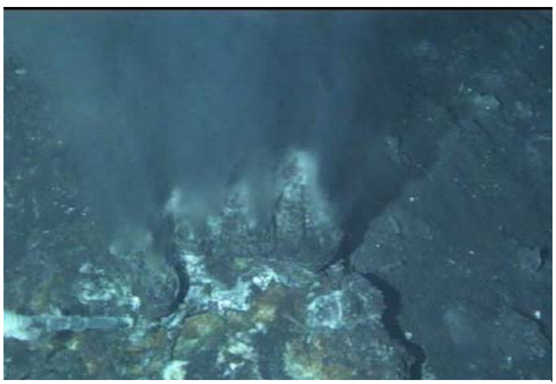


Figure 2.7.3. A close-up of high temperature venting at Vixen vent.

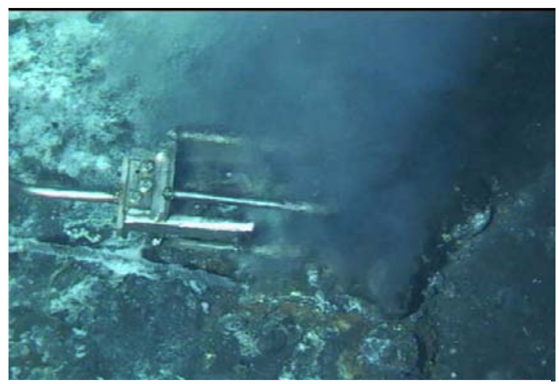


Figure 2.7.4. A flow meter measurement at Vixen vent using the Germanovich flow meter.

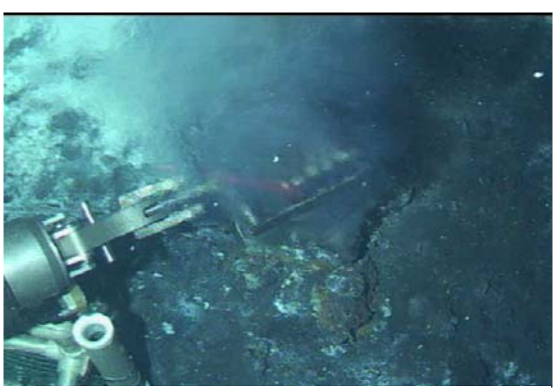


Figure 2.7.5. Collection of a toaster sample at Vixen vent.

Figure 2.7.6. High temperature venting at Casper vent.

Figure 2.7.7. A close up of venting at Casper vent.

Figure 2.7.8. Sampling at Bag City vent (Marker 36).

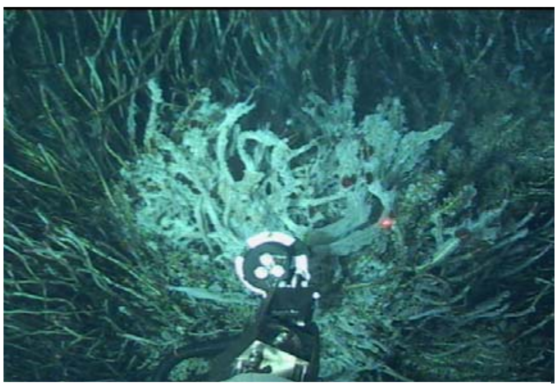


Figure 2.7.9. Sampling at Bag City (Marker 36).

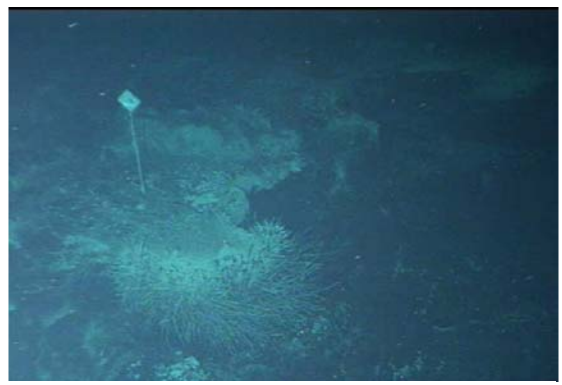


Figure 2.7.10. Venting at Marker 113 and Marker 62.

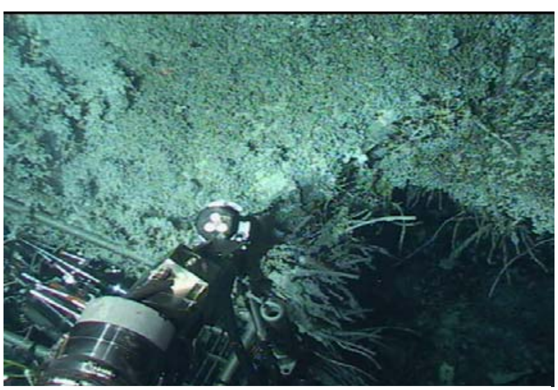


Figure 2.7.11. Fluid sampling at Marker 113.

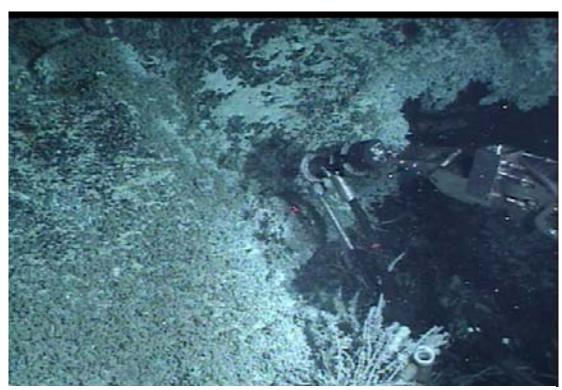


Figure 2.7.12. Fluid sampling at Marker 113.

2.8 Dive 4445: International District, Axial Volcano **August 28, 2008**

Pilot: Bob Waters

Port Observer: Julie Huber

Starboard Observer: Rika Anderson

Primary objectives: 1) Fluid sampling of high- and low-temperature fluids in the International District and 2) measurement of fluid flow with Germanovich flow meter.

Sample summary: 4 gas-tight fluid samples, 19 HFS fluid samples (7 filtered, 7 unfiltered, 4 sterivex filters, 1 large volume bag), and video of the Germanovich flow meter.

Dive Summary:

The dive began at 1500 UTC. The sub reached the bottom at 1549 at a depth of 1,502 m. We went east 100 m over ropy lavas. Hydrothermal staining began to be visible at 1609 and we arrived at a site close to Village at 1625. The navigation system on board the sub was not working properly, which prevented us from being able to obtain accurate x-y coordinates throughout the dive. We were given a USBL fix of x:6686, y:2881 for our first vent location, which placed us 10 m west of Village (this site is marked "Village" in most sampling spreadsheets). Marker '44 UW-Ocean' was nearby. This is an area of collapsed lava, and the vent we sampled was located on a flat top amidst the collapse within a tube worm bush with a temperature of ~ 19°C. We took 1 unfiltered piston sample, 1 unfiltered bag sample, and 1 Sterivex sample at Village with a heading of 353°. The HFS intake nozzle frequently became clogged with palm worms that had to be back-flushed and shaken off.

At 1713, we left Village and headed towards Castle vent, which is located about 40 m away at a heading of 090°. We arrived at Castle at 1723 (x:6721, y:2890, z:1,510 m). The only active venting at Castle was at the base of the structure, a small anhydrite chimney with a HOBO temperature probe in it. At 1729, we took a temperature reading with the high temperature probe and measured 245.8˚C. We then took a gas tight fluid sample at 1734.

We headed to El Guapo vent, which is the largest and hottest vent at Axial Volcano and is located 61 m away from Castle vent at a bearing of 041°. We arrived at El Guapo at 1740 (x:6779, y:2911, z:1,507 m). The sulfide structure was quite large and reached a height of at least 12 m. Tube worms were present on the sides of the structure. We attempted to take high definition digital video through the pilot's window but were unsuccessful. In lieu of this, we surveyed the structure using the pan-and-tilt cameras mounted on the submarine. The top portion of the venting chimney was removed by the sub exposing several new orifices. Through these, it appeared that phase separation and bubble formation could be seen as some of the fluids exited the structure. At 1814 and a heading of 210°, we began HFS fluid sampling and took one unfiltered piston sample and two filtered piston samples and two gas tight fluid samples.

At 1839, we finished sampling at El Guapo and moved to 9 Meter vent, which is a large sulfide structure covered with tube worms, palm worms, blue ciliates, and limpets. There was a fair amount of diffuse flow from the sides of the structure. At 1851, we parked the sub on a solid surface and began sampling ~35°C fluid and collected one unfiltered bag sample, one unfiltered piston sample, one filtered bag sample, and one Sterivex filter sample. We left the site at 1950. At 1952, we arrived at Diva vent (x:6795, y:2924, z:1,524 m). This is a very small anhydrite vent with very little life around the structure. There was a ring of thick iron sediment outside of the anhydrite area. At 1959 and a heading of 018°, we collected one filtered piston sample and a green gas tight fluid sample. At 2011, the Germanovich flow meter was used to measure flow rates of the fluids between 2013 and 2019.

At 2021, we left Diva we attempted to go to the Hermosa venting area but instead came to Escargot vent at 2023. This vent is a medium-sized sulfide vent with a snail shell-shaped structure perched at the top. There was abundant diffuse venting on the structure as well as some focused flow that was ~ 105°C. At 2031 and a heading of 265°, we collected a filtered piston and a filtered bag sample at this site. At 2047, we left in search of Hermosa.

After wandering the vent field with repeated visits to El Guapo to orient ourselves, we found a very large sulfide structure that resembled Hermosa vent at 2104. This vent had a large amount of diffuse venting and was covered in crabs, microbial mat (including filamentous white mat), tube worms, and blue ciliates. At the top of the structure there were about 10 small chimneys, none of which were venting. Our original fix at this site (x:6736, y:2910) placed us 40 m away from Castle vent, which did not match our maps. A later fix (x:6737, y:2930) came a bit closer to our original target. Dave Butterfield later confirmed that what we saw was Hermosa. We collected one unfiltered piston, one filtered bag sample, and two Sterivex filters from a small ledge area on the structure at a depth of 1,513 m. We lost communication with the fluid sampler at 2126 and had to halt sampling until communications were re-established at 2133 after cycling power to the sampler. We finished sampling at Hermosa at 2205.

We were then told to drive northwest for 15 minutes before dropping weights to return to the surface. During the transit, we passed over some lava flows in a collapse zone. We began to see diffuse fluid and tube worms at the top of some pillars. We don't know what vents these were or where exactly they are located on maps of the region. We dropped weights at 2224 at a depth of 1,513 m. While ascending, we had to slow our ascent rate so that the crew would have enough time to recover the AUV before our arrival. We arrived on deck at 2342.

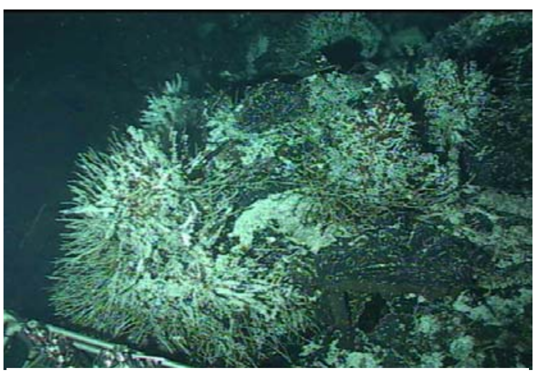


Figure 2.8.1. Diffuse venting at Village vent.

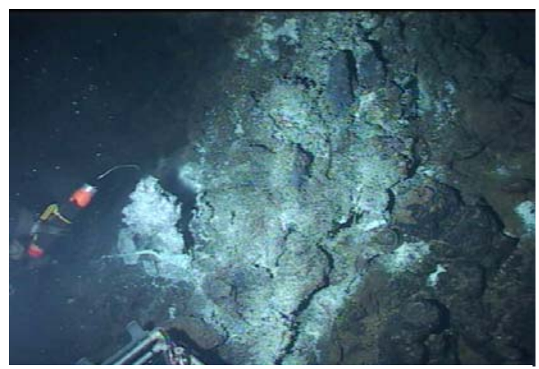


Figure 2.8.2. Temperature measurement at Castle vent.

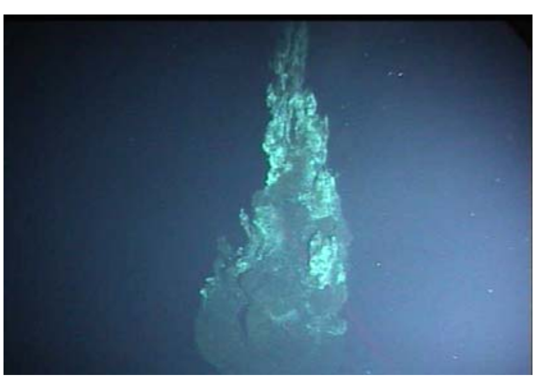


Figure 2.8.3. El Guapo vent structure from a distance.

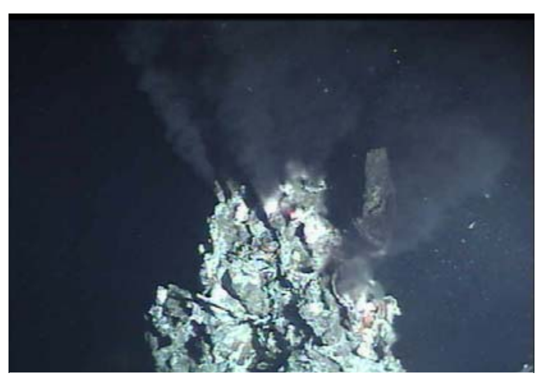


Figure 2.8.4. The top of El Guapo vent.

Figure 2.8.5. Fluid sampling at 9 m vent.

Figure 2.8.6. Venting at Diva vent.

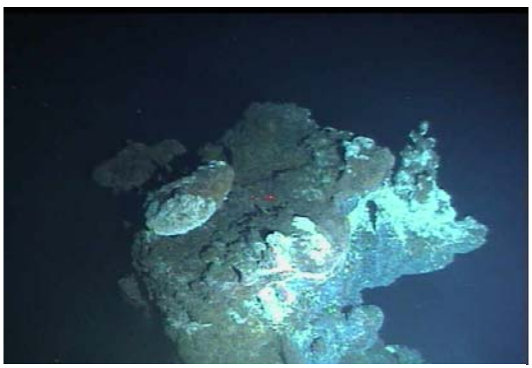


Figure 2.8.7. View of Escargot vent.

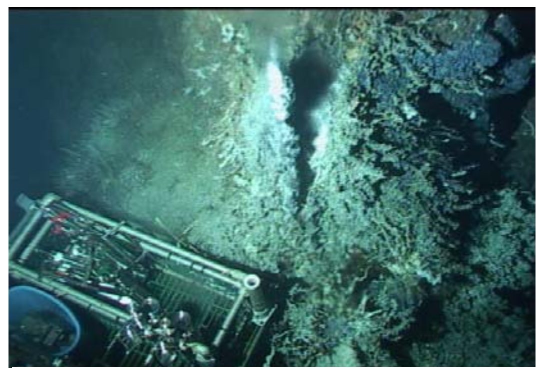


Figure 2.8.8. Venting at Escargot vent.

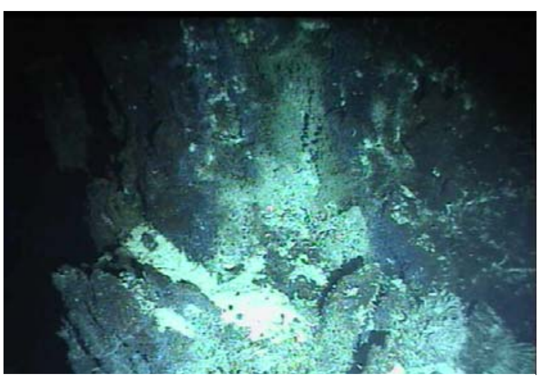


Figure 2.8.9. View of Hermosa vent.

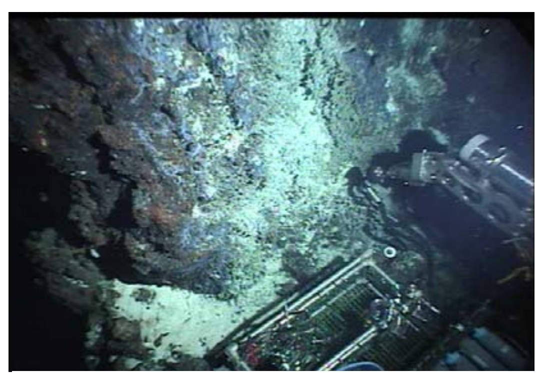


Figure 2.8.10. Fluid sampling at Hermosa vent.

2.9 Dive 4446: Main Endeavour Field **August 29, 2008**

Pilot: Sean Kelley
Port Observer: Dave Butterfield
Starboard Observer: Annie Bourbonnais

Primary objectives: The objectives were to 1) collect high and low temperature fluid samples from the southern region of the Main Endeavour Field, 2) collect a *Paralvinella sulfincola* worm sample from Salut vent, and 3) an extinct sulfide sample from near the landing site.

Sample summary: 3 gas-tight fluid samples, 21 HFS fluid samples (10 filtered, 6 unfiltered, 4 sterivex filters, 1 large volume bag), 2 sulfide samples (1 active, 1 extinct).

Dive Summary:

Alvin was launched at 1547 UTC and arrived at the seafloor at 1609 200 m east of Salut vent (x:5030, y:5840, z:2,207 m). At time 1629, we came up over a wall and collected an extinct sulfide sample on an extinct sulfide tower (x:5030, y:5840, z:2,195 m). At 1639, we arrived at Salut and collected unfiltered piston 1, filtered bag 24, and a sterivex filter sample (34°C) near triangle marker G (x:4870, y:5844, z:2,187 m). At 1735, we collected a sulfide chimney sample at the top of a white spire covered with palm worms (x:4878, y:5842, z:2,185 m) and a fluid sample (79°C). We tried to avoid tubeworms but they were everywhere; therefore, some tubeworms got mixed in the sample. At 1754, we collected unfiltered piston 3, filtered piston 2, unfiltered bag 17, and a red-white-blue gas tight fluid sample (x:4873, y:5845, z:2,187 m). At 1829, we headed towards Easter Island. We passed Cathedral, dead sulfide structures and some active tall spires covered with worms with no visible marker. After coming through the gap between Bastille/Peanut and the talus wall, we passed over Easter Island and then had to double back to it. At 1847, we arrived at Easter Island and took three low temperature fluid samples and two sterivex (14-19°C) at the diffuse vent where the RAS was deployed last year (x:4894, y:6011, z:2,197 m). While diffuse venting from sulfide structures is very common, this is one of the few sites within the MEF where warm water vents directly from basalt.

At 2004, we left Easter Island and passed Peanut vent with tall sulfide chimneys. At 2014, we arrived at triangle marker P at Puffer vent (x:4863, y:5979, z:2,193 m) and collected the black-orange gas tight fluid sample (252°C) and filtered piston 9. At 2031, we went to the northeastern side of Bastille vent (x:4877, y:6005, z:2,186 m) and collected a warm temperature fluid sample (maximum 145°C, average 74°C). At 2045, we arrived at the northeastern side of S&M vent (x:4938, y:6013, z:2,189 m) and collected unfiltered piston 4, filtered bag 16, sterivex filter 12, and a large volume bag sample (42-56°C) at a diffuse site with palm worms. We made a flow measurement using the Germanovich flow meter device where we sampled the diffuse flow at 42-56°C, which turned slowly and then stopped. At 2155, we went high up on the S&M smoker (x:4935, y:6002, z:2,181 m) and collected a blue gas tight fluid sample (326°C) and two fluid samples (192-228°C). Afterwards, we passed Grotto vent and went to Lobo vent at 2205 to look for diffuse flows on the east side of the site (triangle marker L; x:4924, y:6127, z:2,194 m). We noted that there was diffuse flow down low along the eastern margin of Lobo/Grotto, as well as strong diffuse venting on top of Lobo but did not have time to measure temperatures or investigate further. We plan to visit this site again to consider whether it would be a good place to deploy the new RAS mooring.

Figure 2.9.1. Collection of a piece of extinct sulfide near Salut vent.

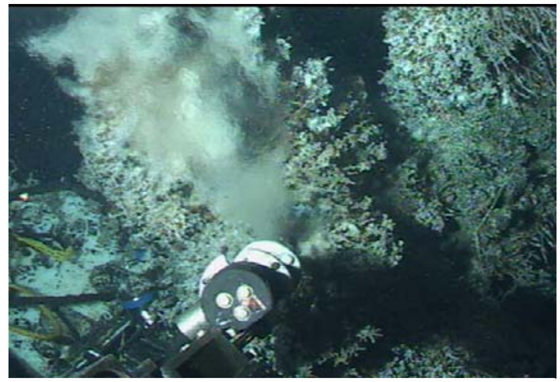


Figure 2.9.2. Sampling high temperature fluids at Salut vent.

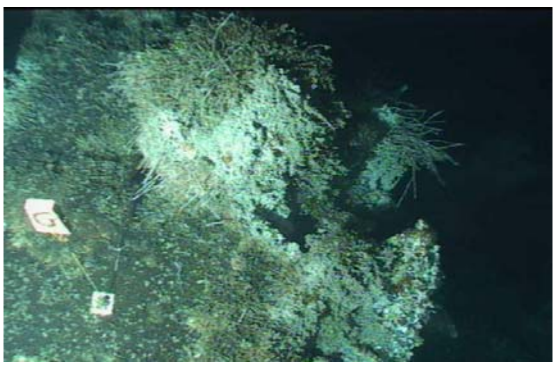


Figure 2.9.3. Location of the palm worm sample collected from a mound on Salut vent near marker G.

Figure 2.9.4. Fluid sampling at a diffuse vent at Easter Island where the RAS sampler was deployed in 2007-8.

Figure 2.9.5. High temperature fluid sampling at Puffer vent.

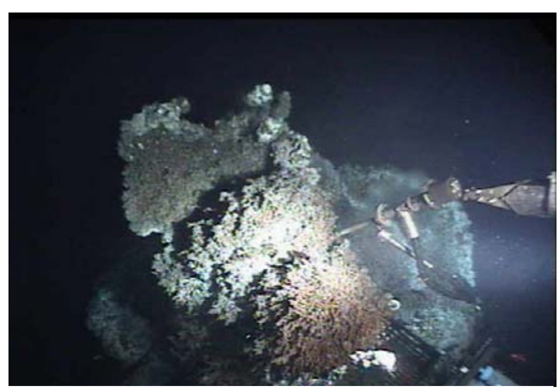


Figure 2.9.6. High temperature fluid sampling at Bastille vent.

2.10 Dive 4447: Main Endeavour Field **August 30, 2008**

Pilot: Pat Hickey
Port Observer: Trent Moore
Starboard Observer: Korey Verhein (PIT)

Primary objectives: The objectives of this dive were to 1) conduct acoustic imaging of the hydrothermal plume, 2) collect temperature and flow rate measurements at specific black smokers, and 3) collect black smoker fluid samples at the point of discharge using major fluid samplers and plume fluids using Niskin water bottles.

Sample summary: 5 Niskin bottle plume water samples, 6 major fluid samples, 1 active sulfide.

Dive Summary:

High temperature fluid samples were taken at two vigorously venting smokers on the top of Dante vent. One of these had a HOBO deployed in it for the previous year; the other was adjacent to this vent. Velocity sampling devices were also used, and a major fluid sample was collected from each orifice. A downward looking sonar image was taken with the *Alvin* rising above the structure in the plume and 3 Niskin water samples were taken at 20 m over the top of Dante vent.

At a structure identified as TP, a major fluid sample was collected at a hot active vent along with temperature and velocity measurements. Additional velocity samples were taken at the top of the structure, and temperature and velocity were taken at a smaller diffuse type vent lower on the structure. We now believe that this structure is in fact the northeast side of Dante. DVL navigation was not available, and might have been useful in determining this.

Similar methods were used to take two Niskin water samples at 20 m above the structure at Hulk vent, along with two major fluid samples, velocities, and temperature at active smokers. Towards the end of the dive, the Rx mooring line from a previous deployment was retrieved. We also attempted to collect a rock sample but could not get it loose from the seafloor.

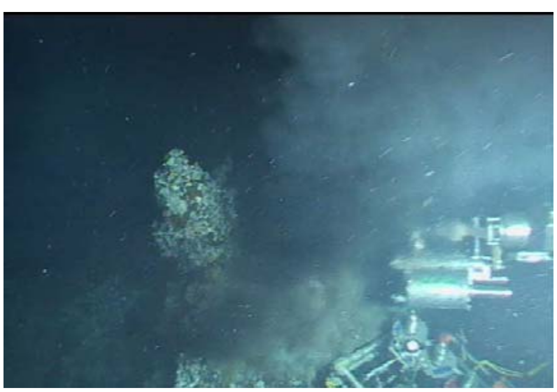


Figure 2.10.1. Major fluid sample collected from a black smoker on top of Dante vent.

Figure 2.10.2. Major fluid sample collected from a black smoker on top of Dante vent.

Table 2.10. Summary of activities on Dive 4447

Time	x-position	y-position	Depth (m)	Heading	Temp.	Remarks
1635	4977	6157	2,175	247°		Top of Dante vent, hobo smoker
1639	4977	6157	2,175	247°		Velocity wheel, hobo smoker
1641	4977	6157	2,175	247°		Velocity wheel, right of hobo smoker
1644	4977	6157	2,175	247°		Toilet seat velocity, hobo smoker
1652	4977	6157	2,175	247°		Toilet seat velocity, right of hobo
1654	4977	6157	2,175	247°	325.0°C	Temp. measurement, hobo vent
1655	4977	6157	2,175	247°	322.9°C	Temp. measurement, right of hobo vent
1656	4977	6157	2,175	247°		#10 green left major fluid from hobo vent
1658	4977	6157	2,175	247°		#16 green right major fluid, right of hobo
1713	4977	6157	2,175	260°		Starting sonar over Dante, camera pointing down
1714	4977	6157	2,172	261°		5 m over top of Dante vent
1717			2,150	283°		Niskin bottles 1,2,3 at 2,154-2,150 m
1722			2,145	114°		Sonar noisy, lost plume, high in column
1725			2,161	139°		Plume image, thruster noise on descent
1734			2,171	260		Plume image, just over top of Dante
1738			2,156	296°		Image at 20 m over Dante
1750	4986	6166	2,174	282°		At Dante, clean off orifice on east side
1754	4986	6166	2,174	282°	337.2°C	Temp. measurement, E chimney Dante
1756	4986	6166	2,174	282°		#20, #22 red major fluid at E Dante vent
1809	4986	6166	2,174	282°		Velocity wheel, E smoker at Dante vent
1819			2,173	263°		Velocity wheel, Dante tall chimney
1827			2,172	308°		Starting sonar imaging of Dante
1830			2,161	326°		10 m above Dante, see two plume images
1834			2,152	223°		20 m above Dante, image on sonar
1852	4980	6163	2,179	026°		Sulfide sample at Dante
1902	4980	6163	2,179	049°		Velocity wheel, grey smoker at Dante
1927	5042	6256	2,187	157°	320.0°C	Temp. measurement, Hulk smoker
1929	5042	6256	2,187	157°		#23 blue left major fluid, Hulk smoker
1943	5047	6246	2,188	357°	308.0°C	Temp. measurement, Hulk smoker
1945	5047	6246	2,188	357°		#24 blue right major, Hulk smoker
1950	5047	6246	2,188	357°		Velocity wheel, Hulk smoker
2000			2,181	011°		Sonar imaging, Hulk 5 m over top
2003			2,166	330°		Niskin bottles 4,5 at 20 m over Hulk
2005			2,170	330°		15 m over top with image
2006			2,175	330°		10 m over top with image
2030	4997	6200	2,197	125°		Retrieved old Rx mooring at Hulk vent
2109			2,216	310°		Unsuccessful rock sampling, dive ended

2.11 Dive 4448: Main Endeavour Field **August 31, 2008**
Pilot: Bob Waters
Port Observer: Dave Butterfield
Starboard Observer: Helene Ver Eecke

Primary objectives: The objectives were to 1) deploy the RAS fluid sampler at diffuse venting near Lobo, and 2) collect low and high temperature fluids in the northern portion of the Main Endeavour Field.

Sample summary: 3 gas-tight fluid samples, 8 HFS fluid samples (5 filtered, 2 unfiltered, 1 sterivex), and 1 extinct sulfide.

Dive Summary:

Alvin was launched at 1510 UTC and landed east of S&M vent at 1622 before going west to the RAS drop target. The RAS mooring was dropped from the surface prior to the dive and landed very near to the east (lower) side of the scarp ~20 m NE of S&M at 2,206 m depth. One of the RAS bags ended up on the seafloor suggesting that at least one of the cylinders broke on the way down, allowing the bag to be dislodged and fall out. One side panel was loose, but there was no clear damage to the instrument. It did appear that one row of bottles may be loose (i.e., hold-downs not secured). If so, that side could have floated up and then crashed down at the bottom. There is no way to know until after recovery. We then drove to Lobo vent, spotting triangle marker G on Grotto first and then driving around the east end of Grotto. We saw significant diffuse flow on top of Lobo with a flat surface. We looked along the base of Lobo and Grotto for any diffuse venting on basalt, but could not find any. We decided to go back up to the flat area on top of Lobo (depth 2,188 m) to take fluid samples and further evaluate the site for a RAS deployment. It appeared that this would be a good site for the RAS, with temperatures of diffuse venting from 25 to 60°C. At 1825, we began sampling the diffuse fluid on top of Lobo and collected unfiltered piston 1, filtered bag 24, filtered bag 23, and sterivex filter 15 (x:4952, y:6160, z:2,188 m, h:208°). During HFS pumping, there was cloudy fluid coming out of the manifold and the pump needed to be slowed during filtering. We deployed the RAS-shape marker with its anchor directly on the spot that we sampled to make it easy to identify when we returned with the RAS. At 1915, we moved about 4 m west to several smokers on the same flat area on Lobo (x:4936, y:6172, z:2,188 m, h:166°). We first sampled a smoker using the HFS, collecting filtered piston 2 and filtered bag 22 with a temperature of 315°C. At 1938, we collected an orange gas-tight fluid sample and a red major pair, but from an orifice about 25 cm away from the first one. Using the high-T probe, the temperature of both of the sampled chimneys was 330.8°C.

At 2010, we went back to the new RAS mooring (x:4966, y:6043, z:2,208 m), pulled the pin to release the drop anchor, picked up the RAS by the shackle holding one corner, and drove directly to the Lobo vent. At 2045, we placed the anchor at Lobo just a few inches from the venting but out of the flow. The intake tube/temperature probe placement was difficult. After getting a near-perfect looking setup, the intake fell over. We ended with the 3 MTR's tilted into the slope of the terrain, but looking pretty stable. The temperature around the intake is higher than what we sampled, in the 30-60°C range. This should be a hotter time series than last year.

By the time we finished deploying the RAS, we had only 20 minutes left so we drove to nearby TP vent. The maximum temperature was 334.6°C. At 2204, we collected the black and the green gas tight fluid samples (x:4998, y:6187, z:2,191 m, h:311°). The lower portion of the structure was dead, orange and red, with a vertical sheared face from mass wasting. We collected a piece of extinct sulfide just below the active smoker used for fluid sampling. This was stowed in the forward basket with the gas-tight bottles. We then drove east 100 m to drop weights and ascend to the surface.

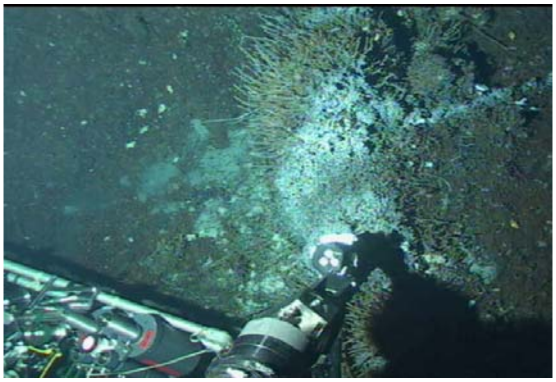


Figure 2.11.1. Sampling diffuse fluids on Lobo vent prior to the RAS deployment.

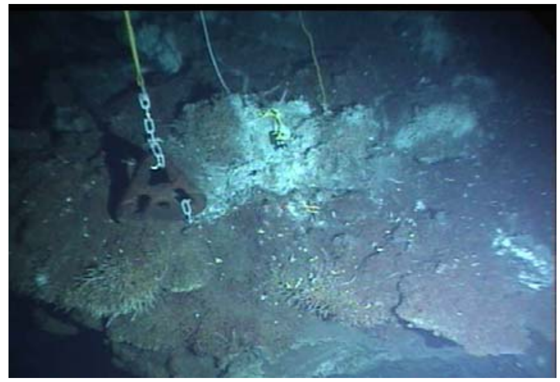


Figure 2.11.2. RAS mooring deployed at Lobo vent with the mooring anchor, a bundle of three temperature recorders, and the intake line in the white mat area. The RAS marker is on the right.

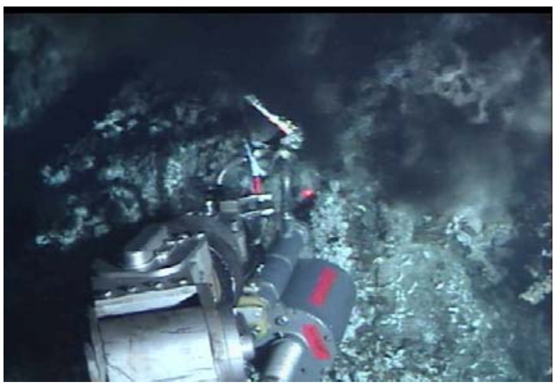


Figure 2.11.3. Red major fluid sample collected in 331°C fluid a few meters from the RAS site.

Figure 2.11.4. Collection of a gas tight fluid sample at Lobo vent from 331°C fluid.

Figure 2.11.5. High temperature (334°C) venting at TP vent where fluids were collected.

2.12 Dive 4449: Main Endeavour Field **September 1, 2008**

Pilot: Sean Kelley
Port Observer: Julie Huber
Starboard Observer: Jim Holden

Primary objectives: The goals of the dive are to 1) collect co-localized low and high temperature fluids from Hulk, Grotto, and Cathedral vents; 2) collect an active sulfide from Dante with high temperature fluids from the same orifice; 3) collect high temperature fluids from Milli-Q vent; and 4) collect a piece of extinct sulfide.

Sample summary: 3 gas-tight fluid samples, 23 HFS fluid samples (9 filtered, 9 unfiltered, 4 sterivex filter, 1 large-volume bag), 2 sulfide samples (1 active, 1 extinct), 1 toaster, and 1 flow meter measurement.

Dive Summary:

The sub entered the water at 1459 UTC and landed approximately 100 m east of Hulk vent at 1607. At 1630, a piece of extinct sulfide was collected at the bottom of the scarp below Hulk (x:5057, y:6243, z:2,198 m). Triange marker M was visible from the starboard window. We then went to the diffuse vent site at the southern base of Hulk just east of triangle marker H (x:5043, y:6243, z:2,197 m h:324°). At 1642-1722, fluid samples were collected using the HFS (14.5°C-34.8°C). These were unfiltered bag 18 (14.5°C) for culturing, unfiltered bag 19 for Annie (17.1°C), filtered bag 20 (17.7°C), four liters of large-volume sample for Rika's virus work (24.8°C) and a sterivex filter (#11) for Annie (34.8°C). At 1723, we took flow meter measurements using the Germanovich device. We measured flow over a small spire next to diffuse venting, but the wheel did not spin for the measurements over the shimmering diffuse fluids. We then moved to the NE corner of Hulk (x:5046, y:6262, z:2,191 m, h:143°) 7.4 m above the bottom to collect high temperature fluids. At 1748, we used filtered piston 2 (301°C) but had temperature stability problems. We repositioned, measured 328°C with the *Alvin* temperature probe, collected a white gas tight fluid sample at 1801, a toaster sample at 1802 for 3 minutes, and then a stable temperature unfiltered piston 3 (321°C).

We drove south to the south side of Grotto to collect low temperature fluids on the edge of a flange (x:4935, y:6140, z:2,188 m, h:000°, alt.:4.8 m). The triangle G marker was visible outside the port window. At 1841-1904, HFS fluids were collected using unfiltered bag 17 (16.4°C), filtered bag 22 (17.7°C), and sterivex filter 12 (18.1°C). At 1913, we moved to collect high temperature fluids from Grotto (x:4939, y:6142, z:2,188 m, h:000°, alt.:4.3 m). The high temperature probe measured 332°C. A red gas tight sample was collected along with HFS filtered piston 5 (319.7°C) and unfiltered piston 6 (319.7°C). As we left Grotto, we stopped to photograph a beautiful black smoker spire over 1 m tall (x:4941, y:6147, z:2,189 m, h:343°) at the eastern base of Grotto. At 1938, we collected a piece of active sulfide at Dante (x:4970, y:6148, z:2,186 m, h:356°). Its fluid temperature was 300°C using the *Alvin* temperature probe. HFS fluids were collected using filtered piston 7 (296.6°C) and unfiltered piston 8 (297.2°C).

We drove south to Cathedral vent (x:4848, y:5923, z:2,183 m, h:315°). At 2039, we collected an orange-black gas tight sample (212°C) and then HFS unfiltered piston 4 (107.7°C) and filtered piston 9 (137.8°C). We then deployed marker JFH on the top flat part of the site. We repositioned to collect low temperature fluids at Cathedral (x:4846, y:5928, z:2,185 m, h:204°). At 2117-2147, the following HFS samples were collected: unfiltered piston 1 (24.0°C), filtered bag 24 (22.9°C), and sterivex filters 13 (22.0°C) and 14 (22.9°C). We ended the dive at Milli-Q (x:4910, y:5940, z:2,181 m, h:005°) above triangle marker M. At 2159, HFS filtered bag 16 (70.3°C) and unfiltered bag 21 (70.8°C) were collected from the single white crack orifice at the top of the structure. We dropped weights at 2220 and surface at 2345.

Figure 2.12.1. Extinct sulfide collected near the base of Hulk vent.

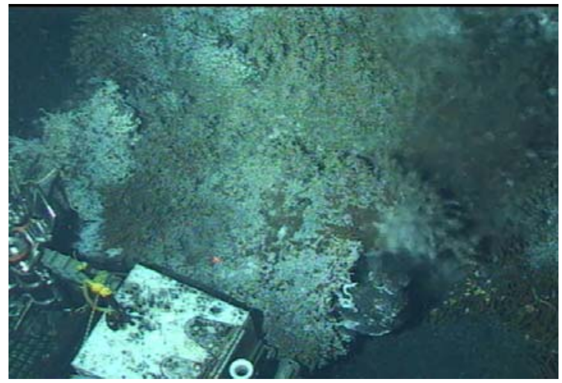


Figure 2.12.2. Low-temperature venting sample site at Hulk vent.

Figure 2.12.3. High-temperature fluid sampling at Hulk vent.

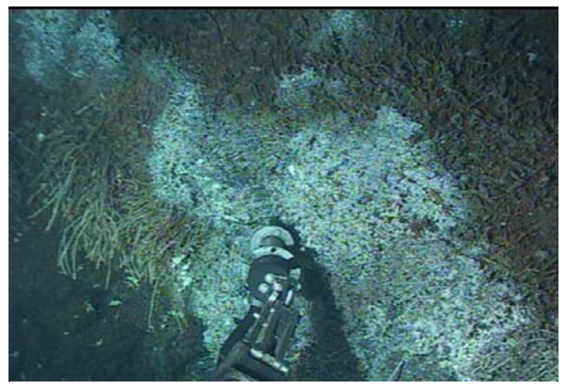


Figure 2.12.4. Low-temperature fluid sampling at Grotto vent.

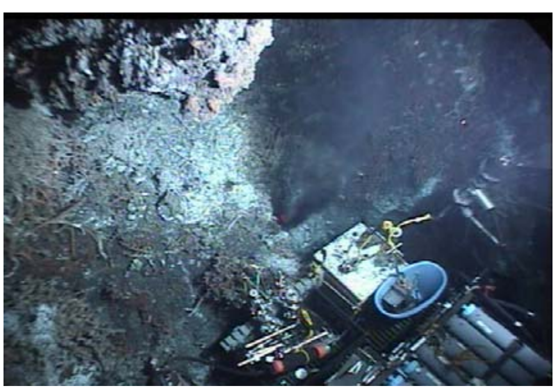


Figure 2.12.5. High-temperature fluid sampling at Grotto vent.

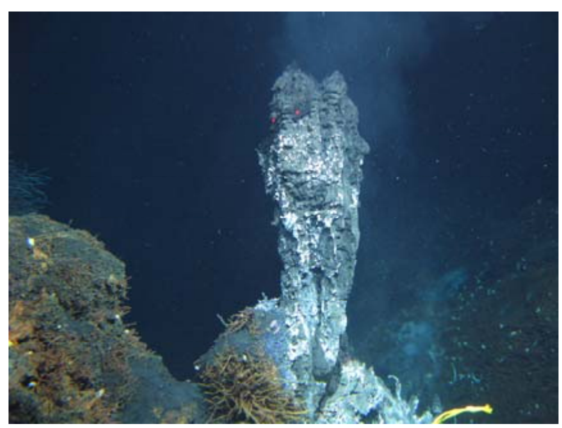


Figure 2.12.6. Unsampled black smoker at the southern base of Grotto and Dante vents.

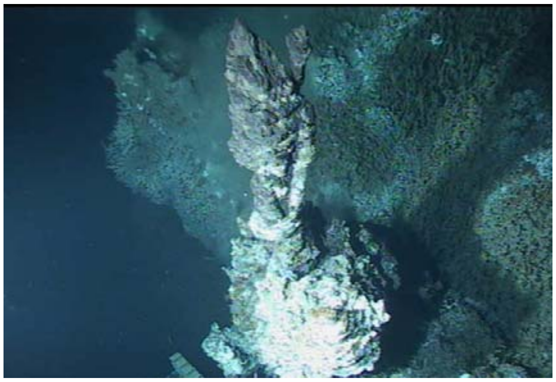


Figure 2.12.7. Sampled sulfide chimney from Dante vent.

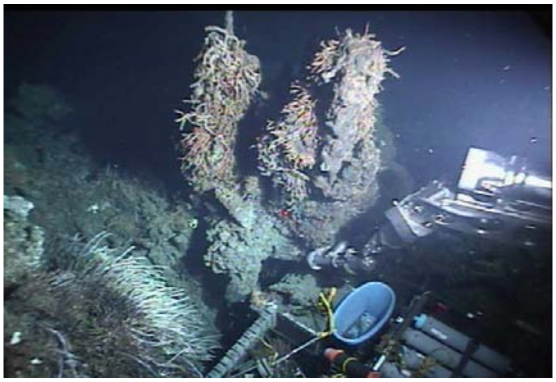


Figure 2.12.8. Fluid sampling at Cathedral vent.

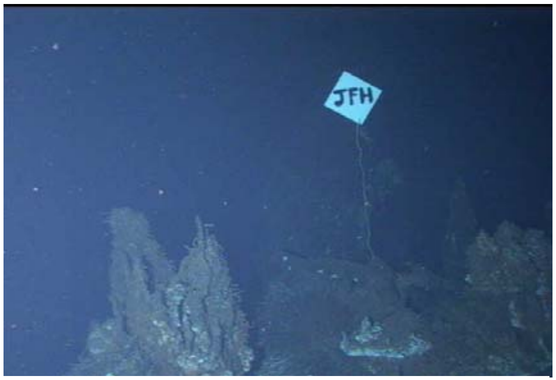


Figure 2.12.9. View of the Cathedral venting region.

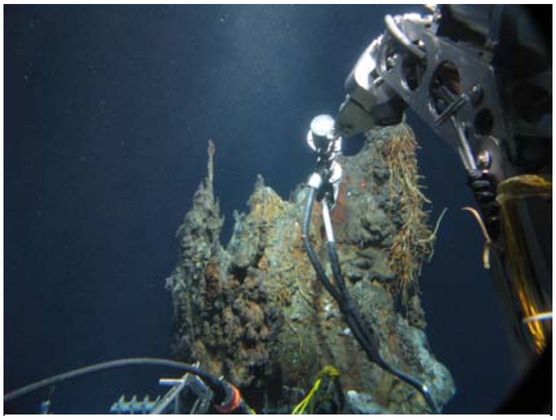


Figure 2.12.10. Fluid sampling atop of Milli-Q vent.

2.13 Dive 4450: Mothra Vent Field **September 2, 2008**

Pilot: Pat Hickey
Port Observer: Eric Olson
Starboard Observer: John Jamieson

Primary objectives: The goals for this dive were to 1) collect co-localized low and high temperature fluids from a vent structure, 2) collect high temperature fluids from all of the vent sites at Mothra, 3) collect an active sulfide spire from Hot Harold vent on Faulty Towers, 4) collect an extinct sulfide also from Faulty Towers, and 5) conduct a top-to-bottom image survey of Finn and Roane along their western face.

Sample summary: 3 gas tight fluid samples, 15 HFS fluid samples (6 filtered, 7 unfiltered, 2 sterivex filters, 1 large volume sample), 2 sulfides (1 active, 1 extinct), a video survey of Finn and Roane, and x flow rate measurements.

Dive Summary:

Note: There was no Doppler navigation available. All XY data is from the LBL.

Alvin was launched at 1459 UTC. At 1603, the sub landed approximately 130 m east of the Cauldron vent structure in the Mothra vent field (x:4441, y:3471). A transit was made over sediment covered pillows and the Cauldron structures were quickly located. At 1618, we moved into position at Cauldron (x:4268, y:3544, z:2,249 m, h:090°) to collect samples. The high temperature fluid was 299°C. At 1627-1643, a green gas tight sample, a filtered piston sample, and an unfiltered piston sample were collected. At 1648-1710, low temperature fluids (29°C-40°C) were collected using a filtered sample, two unfiltered samples, and a sterivex filter.

At 1715, we transited south past the Twin Peaks vent field to the benchmark adjacent to the Faulty Towers vent structure (x:4171, y:3343, z:2,269 m). At 1737, we moved to Hot Harold vent on Faulty Towers (x:4162, y:3335, z:2,271 m) where pieces of an active sulfide chimney were placed into the small biobox on the basket. The fluid temperature from the orifice left by the sulfide was 321.3°C. HFS samples (1 filtered, 1 unfiltered) were collected (x:4162, y:3333, T:318°C) followed by deployment of a "toaster" experiment for one minute. A rotary flow-meter measurement was made for several minutes using many cameras. At 1809, we arrived at the base of the complex near Roane (x:4157, y:3313) where fluid temperatures of 323°C were measured. At 1829 and heading 047°, a piece of extinct sulfide was collected from the 'fallen tree' along the western side of the Faulty Towers complex (x:4171, y:3333, z:2,280 m). At 1838, we began the first video survey on the western face of Roane and Finn using a handheld video camera, but this proved too difficult due to bottom currents. At 1844, we ran two video mosaics of these vents using pan-and-tilt cameras and external stills from the southwest corner of the complex. At 1853 and heading 295°, a diffuse fluid vent site near Roane was used for another rotary flow-meter measurement. The temperature of the fluid was 105°C-107°C with considerable fluctuations. We left the site at 1900.

At 1910, we arrived at Crab Basin (x:4127, y:3268, z:2,279 m, h:138°). Fluids here were 225°C and a filtered sample and an unfiltered fluid sample were collected with the HFS. We then transited south and stopped to collect an old battery box left behind from previous work. At 1947, we arrived at the Cuchalainn structures near marker G (x:4126, y:3128, z:2,291 m, h:230°). Fluid temperatures were 302.9°C, and the blue gas tight sample, a filtered sample, and an unfiltered sample (293°C) were collected. A sterivex filter sample was collected by mistake with about 90 ml of high temperature fluid pumped through it before moving the nozzle to a nearby patch of tube worms. Here the fluid temperature was 30°C and 1.4 liters were passed through the filter. At 2042, we arrived at Stonehenge vent and possibly passed over marker M1. We began sampling fluids at 2044 (x:4103, y:3023, z:2,290 m, h:206°). Fluid temperatures were 309.5°C and an orange gas tight sample was collected. The HFS sampler was used to collect a filtered sample and an unfiltered sample. The rotary flow-meter was deployed in the vent for a few minutes of video work.

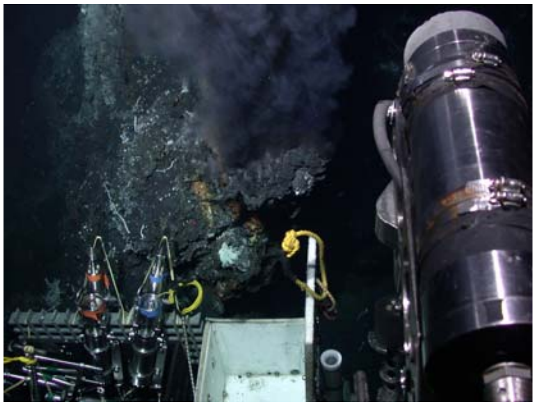


Figure 2.13.1. Sampling the Hot Harold sulfide chimney on the Faulty Towers complex.

Figure 2.13.2. Sampling of an extinct sulfide from the 'log' on the west side of the Faulty Towers complex.

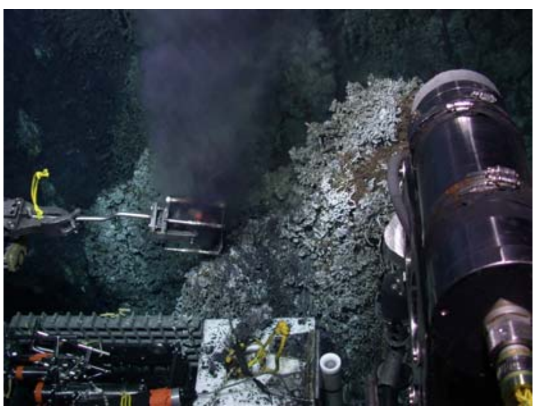


Figure 2.13.3. Rotary flow meter measurement at Stonehenge vent.

2.14 Dive 4451: Sasquatch vent field and AUV Recovery **September 3, 2008**

Pilot: Bob Waters
Port Observer: Dave Butterfield
Starboard Observer: Hans Thomas

Primary objectives: The objectives of this dive were to 1) collect hydrothermal fluids from the Sasquatch vent field, 2) collect two pieces of basalt between Sasquatch and Summit Seamount, and 3) recover the AUV from the seafloor near Summit Seamount.

Sample summary: 2 gas-tight fluid samples, 4 major fluid samples, 1 active sulfide, and 1 basalt.

Dive Summary:

Note: There was no Doppler navigation or LBL navigation. Fixes are from the USBL.

Alvin was launched at 1453 UTC and reached the bottom at 1552 at a depth of 2,140 m. After 45 minutes of searching, the Sasquatch vents were found by looking in regions with the correct bottom depth. The terrain was very rough. At 1637, we found an extinct sulfide tower that was 20-25 m tall. At 1706, we found venting at Marker C with a HOBO/MISO SN116 in it (z:2,150 m, h:344°). We recovered the HOBO temperature probe that had been installed in 2006 and measured 285.3°C in the venting fluids. From this vent we collected a blue major pair and a red-white-blue gas tight fluid sample. We moved a short distance to a 10 m tall, very slender chimney with venting at the top and the base. Discussion with Deb Kelley after the cruise indicated that this chimney was previously called 'Christmas Tree' and was sampled and knocked over in 2006. We collected a small active spire at the base of this structure (z:2,153 m, h:229°) and measured a fluid temperature of 275°C. We also collected a left-side green major fluid sample and a white gas tight sample from this fluid. We rose up the spire to get a photomosaic transect of the structure and then moved a short distance to the vent with the flamingo and marker DK3. We sampled fluid with the right side of the green major fluid sampler and the orange gas tight sampler and measured a fluid temperature of 275°C.

At 1810, we had finished sampling and began our transit to the AUV. Upon leaving the flamingo vent at a heading of 270°, we saw the tall chimney on the port side, DK3/flamingo on the eastern side of the field, Christmas Tree vent in the middle, and marker C on the western edge of the field. The terrain was dominated by NE-trending ridges with extreme slopes. We steadily climbed along the transit stopping once on top of a ridge to collect a piece of basalt (x:6700, y:11,315, z:2,155 m). We proceeded southwesterly and began climbing up a steep hill toward the AUV site. The terrain became progressively steeper until we were climbing up a slope that had several rock overhangs. We picked up the Sonardyne beacon on the AUV ~150 m away from the vehicle. We found the AUV at a depth of 1,984 m wedged in a crevice at a heading of 230° and at a downward angle of 45°. It appeared to be intact. We attached the recovery line onto the AUV and with only a slight tug the AUV began rising out of the crevice towards *Alvin*. The pilot throttled backwards and the AUV quickly floated up and away. We immediately dropped weights and began our ascent to the surface while attached by the line to the AUV. At the surface, the AUV was secured by the small surface boat and released from the submarine by the swimmers. *Alvin* and the AUV were recovered around 2120.

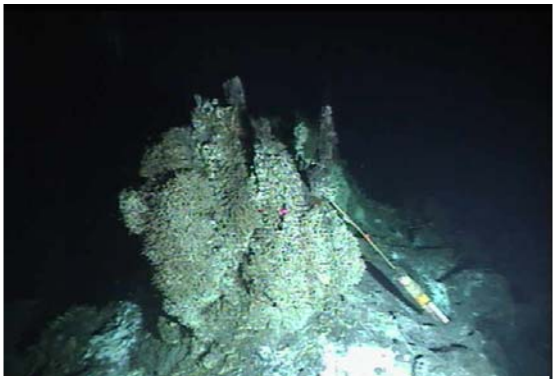


Figure 2.14.1. Venting at Marker C with the hobo temperature probe recovered on this dive.

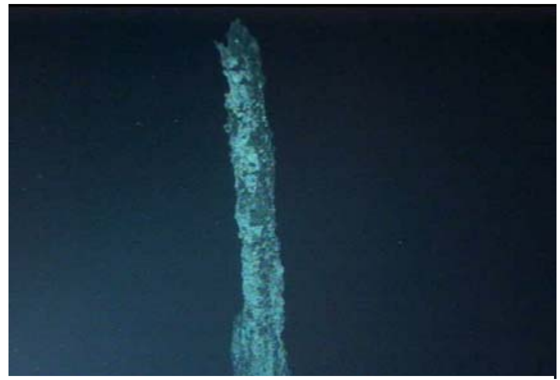


Figure 2.14.2. The upper portion of Christmas Tree vent, which was 8 m tall.

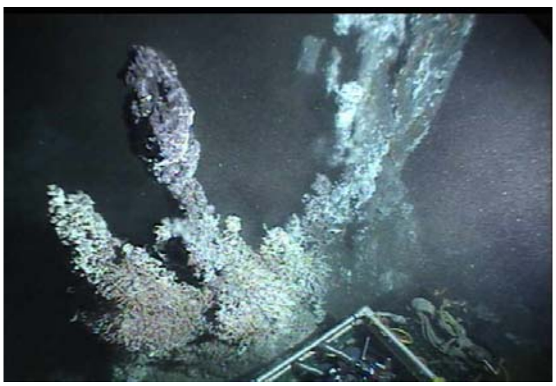


Figure 2.14.3. Small chimneys at the base of Christmas Tree. The black bulbous chimney second from the left was recovered and fluids were collected here.

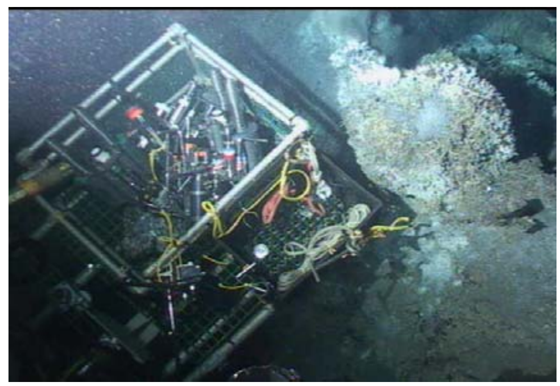


Figure 2.14.4. Fluids at Flamingo/DK3 vent that were sample.

Figure 2.14.5. The site where the basalt sample was collected. One of the broken pieces in the foreground was sampled.

Figure 2.14.6. The AUV lodged in a crevice in a near vertical scarp along the side of Summit Seamount.

2.15 Dive 4452: Main Endeavour Field **September 4, 2008**

Pilot: Sean Kelley
Port Observer: Trent Moore
Starboard Observer: Leonid Germanovich

Primary objectives: The objectives of this dive were to 1) collect acoustic data for the plumes over Hulk and Dante vents, 2) collect plume water using Niskin bottles over Hulk, 3) determine whether previously analyzed vents are at TP or Dante, 4) collect high-temperature fluids from Crypto and Dudley vents, and 5) retrieve the hobo temperature probe from Bastille.

Sample summary: 2 gas-tight fluid samples, 8 major fluid samples, and 5 Niskin plume water samples.

Dive Summary:

The dive began with imaging the plume at Hulk vent in a downward-looking mode with the SM2000 multibeam sonar. At 20 m above Hulk, 5 Niskin water samples were collected within the plume having temperatures of 2.3°C. Then a second sonar image of the plume was taken until no plume could be seen.

A major fluid sample was taken at two black smokers on Hulk vent, along with the flow speed and temperatures at approximately three depths (0, 6, and 12 inches above the orifice) in order to get an estimate of the temperature gradient. This was also carried out at a black smoker on Crypto vent along with a gas tight fluid sample. In this dive, we were also able to clearly identify sulfide features that are TP vent compared to those that are from the northeastern part of Dante vent, which we thought were TP vent on earlier dives (noted as TP?). Fluid flow and temperature gradient measurements were made on a black smoker orifice. From TP vent, the dive went to survey both peaks of Dante vent to confirm that previous dive measurements were actually from the northeastern structure.

The sonar imagery of the plume was specifically carried out along a 139° heading so that we could see the two peaks of Dante vent. In fact two plumes were visible and the imagery showed the plumes coalescing further up into the water column forming one plume at 20 m. This is important information since the acoustic scintillation measurements is based on integrated plume. Diffuse flow measurements were made at a site where we deployed a CTD on the northwestern side of Dante (which was recovered during the AT15-34 cruise). Vertical speeds will be calculated using flow visualization along a ruler. From there we were interested in obtaining the perimeter of Dante at the base so we can confine our localized measurements of heat flux. Two rotations around Dante were obtained.

Black smoker fluid measurements with majors, velocity wheel, and temperature sensors were carried out at the top of Dante on four different black smoker chimneys. From here we went to Dudley for a fluid sample with majors and gas tights. The dive ended with the retrieval of a HOBO on Bastille and a basalt sample west of Bastille just before weights were dropped.

Figure 2.15.1. Major fluid sample from Crypto vent.

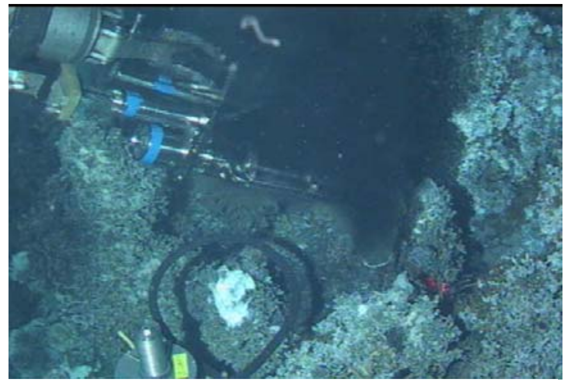


Figure 2.15.2. Gas tight fluid sample from Crypto vent.

Figure 2.15.3. Black smokers atop of TP vent.

Figure 2.15.4. Black smokers atop of Dante vent.

Table 2.15. Summary of activities on Dive 4452

Time	x-position	y-position	Depth (m)	Heading	Temp.	Remarks
1625			2,197	038°		Arrived at marker H at Hulk vent
1629	5041	6251	2,175	060°		Plume imaging 10 m over Hulk
1630			2,170	060°		Plume imaging 15 m over Hulk
1631	5040	6254	2,165	060°		5 Niskins fired 20 m above Hulk
1636			2,171	000°		Repeat sonar imaging going up
1637	5051	6247	2,159	007°		Hulk imaging, 20+ m altitude, no plume
1650	5068	6262	2,191	185°		#10 green left major fluid at Hulk smoker
1656	5068	6262	2,191	185°	327.7°C	0,6,12″ temp. - 327°, 220°, 140°C
1658	5068	6262	2,191	185°		Velocity wheel, Hulk smoker
1701	5068	6262	2,191	157°	85.1°C	0,6,12″ temp. at beehive - 85°, 25°, 2°C
1703	5068	6262	2,191	157°		Velocity wheel, beehive
1717	5047	6247	2,188	356°	320.1°C	0,6,12″ temp., Hulk - 320°, 111°, 42°C
1719	5047	6247	2,188	356°		#16 green right major fluid at smoker
1721	5047	6247	2,188	356°		Velocity wheel in smoker
1730	5050	6220	2,201	095°	328.0°C	0,6,12″ temp., Crypto smoker - 328°, 205°, 136°C
1731	5051	6219	2,201	095°		Blue majors (23,24), blue gas tight at Crypto
1736	5051	6219	2,201	095°		Velocity wheel, Crypto smoker
1746	4998	6188	2,191	007°	333.5°C	0,6,12,18,24″ temp., TP smoker, 333°, 250°, 192°, 130°, 101°C
1754	4998	6188	2,191	003°		Velocity wheel at TP smoker
1815	4977	6169	2,166	139°		Sonar imaging, Dante, 2 plumes visible
1816	4974	6169	2,156	139°		No plume image, video overlay broken
1819			2,171	139°		2 plume images
1823			2,155	140°		2 plume images
1824			2,137	139°		Sonar recording off
1835	4960	6156	2,197	187°		CTD mooring site, velocity wheel
1838	4960	6156	2,197	187°		Stick measure at CTD site
1843	4960	6156	2,197	187°	6°C	Temp. measurement, CTD site
1852	4985	6155	2,187	357°		At Dante marker, CCW navigation around structure
1854	4948	6245	2,188	228°		Nav. circle – 4993, 6168; 4990, 6173
1855	4986	6180	2,191	171°		Circumnavigation
1856	4992	6171	2,191	129°		Circumnavigation
1858	4976	6146	2,189	045°		Circumnavigation
1859	4981	6150	2,187	060°		At marker D at Dante
1901	4994	6170	2,186	175°		Starting CW circumnavigation of Dante
1902	4995	6161	2,187	232°		Circumnavigation
1903	4990	6156	2,188	206°		Circumnavigation
1904	4983	6152	2,188	238°		Circumnavigation
1907	4953	6188	2,192	082°		LBL slow to update
1908	4977	6172	2,192	067°		Circumnavigation
1909	4988	6176	2,192	160°		Circumnavigation
1911	4993	6165	2,190	195°		Circumnavigation
1911	4995	6162	2,188	246°		At Dante marker, end circumnavigation
1928	4974	6153	2,175	032°	249°C	0,6,12″ temp., Dante - 249°, 91°, 35°C
1930	4974	6153	2,175	032°	163°C	0,6,12″, beehive - 163°, 16°, 2°C
1932	4974	6153	2,175	032°		Velocity wheel, beehive
1935	4974	6153	2,175	032°		Velocity wheel, grey smoker

1941	4986	6173	2,173	180°		At northern side of Dante
1951	4989	6171	2,175	280°		Video survey of northern Dante
1956	4990	6167	2,174	263°		Video survey of 2 large chimneys on northern Dante, 4-5' apart
2012	4983	6164	2,179	058°	337.0°C	Temp. measurement, Dante smoker
2013	4983	6164	2,179	057°		#20 left red major fluid, Dante smoker
2015	4983	6164	2,179	057°		Velocity wheel, Dante smoker
2025	4982	6166	2,179	104°	321.0°C	0,6,12" temp., Dante - 321°, 55°, 2°C
2027	4982	6166	2,179	104°		#22 right red major fluid, Dante smoker
2045	4988	6173	2,173	163°		Attempt temp. meas., but cannot maintain position
2054	5011	6132	2,194	247°	314.0°C	Temp. measurement at Dudley, not hot enough for sampling with major
2059	5008	6124	2,191	157°	319.0°C	Temp. measurement, Dudley smoker
2100	5008	6124	2,191	157°		Black gas tight fluid sample, Dudley
2102	5008	6124	2,191	157°		Yellow major fluids at Dudley
2109	4999	6123	2,192	139°		Have smoker sample from AT15-34 at this Dudley location
2136	4870	5994	2,194	092°		Recover hobo probe from Bastille
2209						Basalt rock sample, W of Bastille

2.16 Dive 4453: High Rise Field **September 5, 2008**

Pilot: Anton Zafereo (PIT)
Port Observer: Pat Hickey
Starboard Observer: Eric Olson

Primary objectives: The goals for this dive were to 1) collect high-temperature fluids from as many structures within the High Rise vent field as possible, and 2) collect high/low temperature pairs of fluids for comparison from at least two of the vent structures.

Sample summary: 4 gas tight fluid samples, 14 HFS fluid samples (6 filtered, 6 unfiltered, 1 sterivex filter, 1 large-volume bag).

Dive Summary:

Note: There was no Doppler navigation available. All XY data is from the LBL.

Alvin was launched at 1500 UTC. At 1604, we reach the seafloor east of the High Rise vent field (x:5886, y:8121). At 1627, we drove at heading 335° and steadily climbed a slope until we reached a vertical face at 1632 (depth 2,169 m) that we assumed was the eastern face of the horst upon which High Rise sits. Atop the rise, the visibility diminished due to particles in the water and scattered patches of sulfide staining could be found. At 1641, a number of tall structures were quickly located and navigation showed that we were within the vent field. Considerable time was spent surveying the structures in relation to one another and looking for markers. At 1721, a bucket lid with a turtle shape cut out of the center was found, but was not on the marker list provided.

At 1755, we set up to sample high temperature fluids at Godzilla (x:5784, y:8331, z:2,137 m, h:179°). The highest temperature measured with the high-temperature probe was 358.1°C. At 1810, a black-and-white gas tight fluid sample was collected. At 1821, we began sampling fluid using the HFS using unfiltered piston 1 (1823, 345°C) and filtered piston 2 (1826, 345°C). We then repositioned the submarine 4 m to port for low-temperature fluid sampling amongst some tube worms (x:5802, y:8335, d:2,135 m, h:268°). At 1846, we began collecting fluids into unfiltered bags 19 (1846) and 18 (1852) and filtered bag 16 (1857, 30°C). At 1902, the 4 liter bag was filled (30-35°C). Sampling at Godzilla was completed at 1922.

At 1952, we began low-temperature fluid sampling at Boardwalk from a tube worm clump high on the structure (x:5790, y:8289, d:2,136 m, h:359°). Using the HFS, filtered bag 20 (1958) and unfiltered bag 17 (2002) were filled and fluid was pumped through Sterivex filter 11 between 2007 and 2018 (~ 20°C). At 2050, we were repositioned at Boardwalk to collect high-temperature fluid samples (x:5784, y:8292, d:2,136 m, h:281°). The high temperature probe measured fluid temperatures up to 351.8°C. At 2053, filtered piston 5 and unfiltered piston 3 were filled (343.7°C), and at 2108 and 2110 the white and the blue, respectively, gas tight samplers were used to collect fluids.

At 2117, we arrived at what we think is Park Place, although with the navigation we cannot rule out the possibility that we were at the Baltic structure (x:5769, y:8239, d:2,138 m, h:130°). The high temperature probe was unable to achieve a steady temperature measurement. At 2138, a black gas tight fluid sample was collected. At 2140, HFS unfiltered piston 6 and filtered piston 7 were used to collect fluids (334°C). At 2200, we returned to Godzilla to make vertical video transects. The relocation effort resulted in too little time and video tape to accomplish this. It was necessary to leave the bottom before we could get any clear transects on the digital still camera.

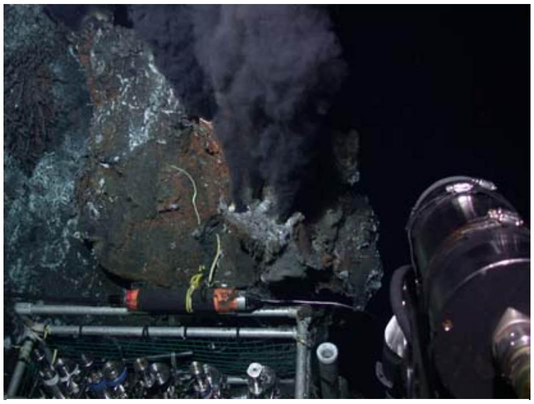


Figure 2.16.1. High-temperature fluid sampling at Godzilla vent.

Figure 2.16.2. High-temperature fluid sampling at Boardwalk vent.

3.0 Summary of non-dive operations

3.1 MBARI Seafloor Mapping AUV Missions

The AUV *D. Allen B.* was constructed by MBARI, is torpedo shaped (Fig. 3.1) and is rated to depths of 6,000 m. It is equipped with a 200 kHz multibeam sonar, 110 kHz and 410 kHz chirp sidescan sonar, and a 2-16 kHz sweep chirp sub-bottom profiler. However, on this cruise the sub-bottom profiler was turned off to save power since there was little to no sediment in the mapped areas. The multibeam provides a 120° swath with 0.94° by 0.94° beam resolution. The AUV can travel at three knots for up to 18 hours on battery power. Missions were typically run 50 m above the bottom with 170 line spacing between the track lines. Navigation is derived from an internal navigation system (INS) that incorporates a ring-gyro aided by GPS at the surface and by velocity-over-ground observations from a Doppler velocity log (DVL) when within 130 m of the seafloor. It can achieve a navigational precision of 0.05% of distance travelled with continuous DVL bottom lock. The AUV was tracked on board the R/V *Atlantis* using the ship's Nautronix ultrashort baseline (USBL) system and the AUV's Sonardyne beacon. Navigation updates were sent to the AUV during its descents using the hull-mounted transducer used for voice communications to DSV *Alvin*.

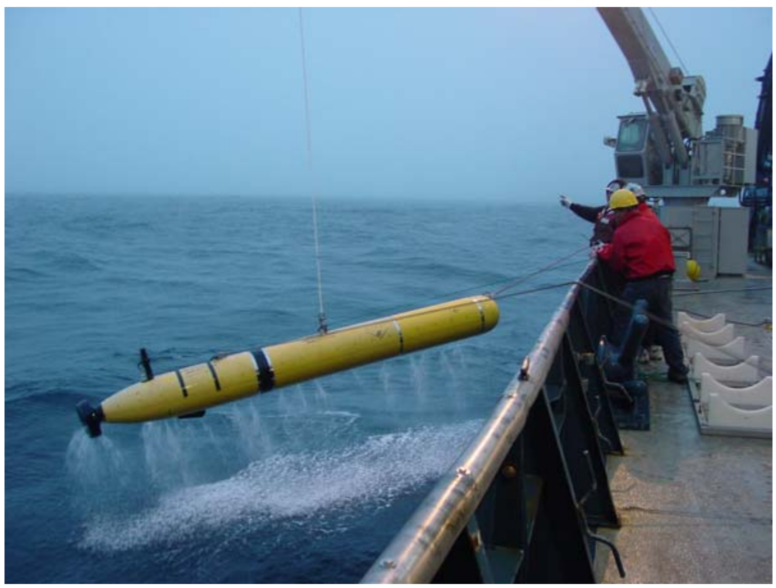


Figure 3.1. The MBARI seafloor mapping AUV *D. Allen B.* being recovered on the R/V *Atlantis* following a deployment.

During the cruise, the MBARI AUV was launched twelve times to complete high-resolution mapping over the Axial Seamount caldera and to initiate mapping over the Endeavour Segment axial valley. The AUV successfully collected data on six missions: two at Axial Seamount and four at the Endeavour Segment. The original plan was to launch the AUV at night at the Endeavour Segment for the first three nights on station so that the region closest to the Main Endeavour Field, the primary *Alvin* dive site for the cruise, could be mapped without interfering with Alvin dive operations. We were unable to launch the AUV the first two nights that we were on station (August 19 and 20) due to poor weather conditions. However, our plan was to remain at Endeavour until our first four *Alvin* dives were completed before transiting to Axial Seamount. This still left three opportunities to complete the seafloor mapping around the Main Endeavour Field. These three missions at Endeavour and the first dive at Axial Seamount each failed for different technical reasons. They included malfunction of the tailcone, malfunction of the Reson 7100 multibeam sonar that resulted in collection of sidescan sonar data only, mission abortion caused by an acoustic modem failure, and a second mission abortion caused by an errant reset of the INS, respectively.

The second mission at Axial Seamount on August 26 successfully mapped the southwestern floor of the caldera (Fig. 3.2), which was the only portion of the caldera floor left unmapped during NOAA NeMO cruises in 2006 and 2007. This mission also completed several mapping lines around the western rim of the caldera. We were unable to launch the AUV on the following day due to poor weather, but on August 28 were completed mapping of the southeastern rim of the caldera (Fig. 3.2).

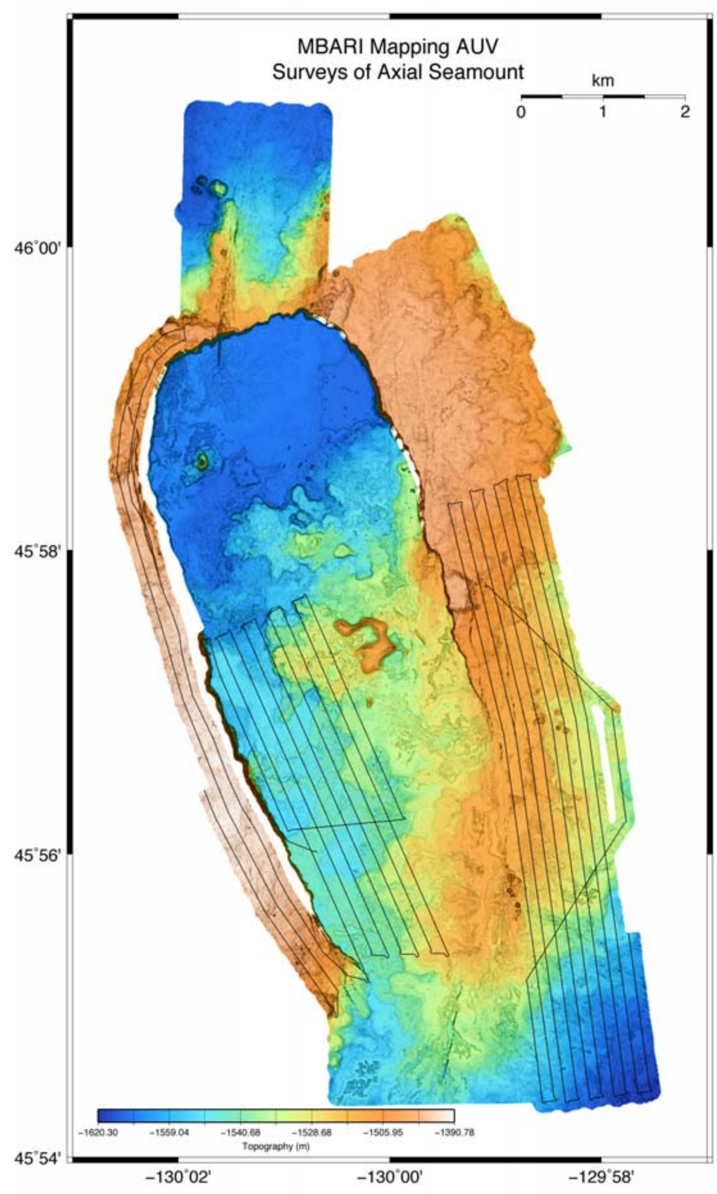


Figure 3.2. High resolution bathymetric coverage of Axial Seamount combined with previous MBARI AUV mapping from 2006 and 2007. The survey tracks from AT15-36 are shown. The multibeam bathymetry achieves a lateral resolution of 1 m and a vertical precision of 10 cm.

After four days at Axial Seamount, we returned to the Endeavour Segment and continued our mapping efforts. Our first mission successfully mapped the Mothra vent field and the 3 km zone to the south of Mothra, although the mission was shortened by several hours due to a failure of the internal CTD prior to launch that required setting a constant sound speed. This mission was followed by two more aborted missions that were caused by INS resets due to a failed cable. On September 1, another mission succeeded in mapping the Main Endeavour Field. This mission was also shortened by several hours due to a vehicle computer malfunction.

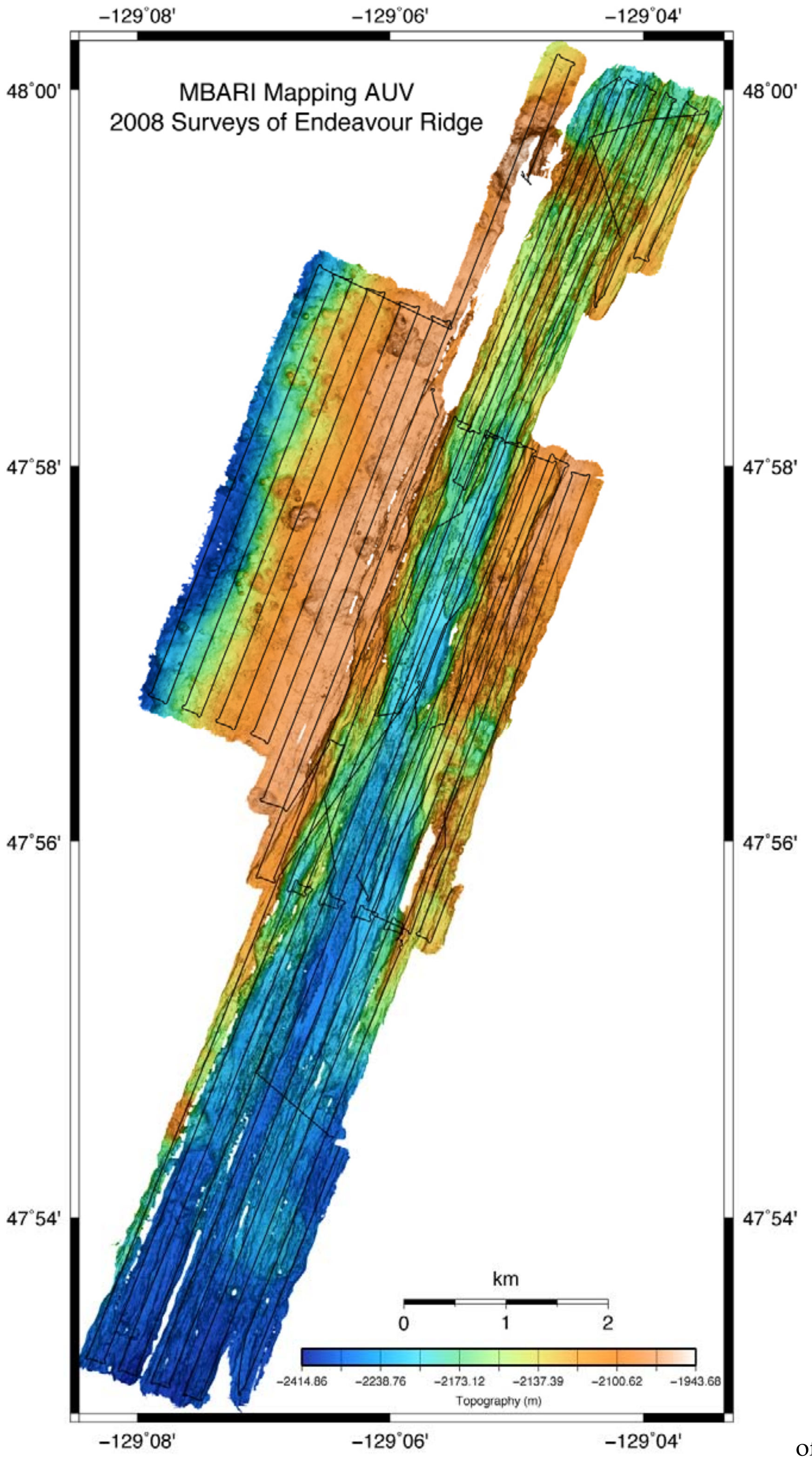
On September 2, we succeeded in mapping the western flank of the ridge near the Main Endeavour Field. However, the AUV failed to surface at the end of its mission. We located the AUV on the seafloor at a depth of 1,996 m using the USBL system near a southbound survey line adjacent to Summit Seamount, a split volcano on the western rim of the axial ridge and the shallowest point along the Endeavour Segment. *Alvin* was required the next day to retrieve the AUV. It was found pointed nose-down in a crevice in a nearly vertical wall of talus and jumbled lava flows facing the axial valley. The AUV was loosely wedged between the rocks and was easily retrieved. We attached a rescue line to the AUV, and only a slight nudge was required to cause the AUV to become buoyant and rise in tandem with *Alvin* to the surface. A post-recovery examination showed that all of its systems were intact and that only the nosecone suffered a crack in the faring.

On September 4, the AUV successfully mapped the region between High Rise vent field and Sasquatch vent field as well as certain gaps that remained in the area around the Main Endeavour Field. This mission ran without any technical problems and the full duration of the mission.

Despite three missions lost due to weather and the numerous technical issues that impacted all but one mission, we succeeded in collecting 27 hours and 55 hours of survey data at Axial Seamount and the Endeavour Segment, respectively. These translate into 140 km and 239 km of survey track at Axial Seamount and the Endeavour Segment, respectively. In total, we mapped about 57 km^2 of seafloor at roughly 1-m resolution. For comparison, the two previous mapping efforts at Axial Seamount in 2006 and 2007, each also with technical difficulties, ran 229 km of survey track in 44 hours of bottom survey time covering roughly 34 km^2. Therefore, there was a significant improvement in the amount of seafloor mapped on this cruise.

The survey at Axial Seamount will be used to complete a flow-by-flow geologic map of the caldera flow and much of the rim (Fig. 3.2). The western rim of the caldera has numerous fissures and faults and in this respect resembles the eastern rim of the caldera, although no young flows are evident. The entire rim appears to be blanketed by low-backscatter, 1-2 m thick pyroclastic deposits that have been sampled previously. Despite this drape of fine clastic debris, the flow boundaries and channels are clearly imaged. The southeast rim shows more of the young flows that cover a large portion of the northeastern rim as well as numerous fissures and faults. A small cluster of volcanic pillow mounds or perhaps hydrothermal mounds occur about 600 m east of Magnesia vent. Otherwise, the rim is characterized by large flows with collapsed ponds in their centers and pillowed margins, much the same as is seen on the northeast rim. The caldera floor survey shows clear flow boundaries with most flows having the characteristic pillowed margins and interior collapsed lava lakes. In several of these flows, the lava lakes are several hundreds of meters in diameter.

The seafloor mapping results and survey track lines are shown in Fig. 3.3. They show an enormous variation in tectonic and magmatic style along and across the ridge. The western flank is cut by only a few fissures, mostly seen cutting across only the oldest pillow mounds. Most of the flows that cover the majority of the flank are essentially unfaulted. In contrast, the axial valley is highly tectonized with numerous faults and fissures. The tectonic fabric, particularly south of Mothra vent field and north of High Rise vent field, is so pervasive that evidence for the volcanic origin of the rocks is difficult to discern. Small sheet flows comprise many of the fault slices separated by axial



faults. Most of these sheet

Figure 3.3. High resolution bathymetric coverage of the Endeavour Segment collected using the MBARI AUV during cruise AT15-36. Vehicle tracks from the four successful missions are shown. The multibeam bathymetry achieves a lateral resolution of 1 m and a vertical precision of 10 cm.

faults. Most of these sheet flows, especially those in the deepest portions of the ridge axis, have central collapse structures but lava pillars are rare around their margins.

Between Salty Dawg and Sasquatch vent fields, the axis is elevated and severely tectonized. This region lies east of the half volcano known as Summit Seamount, where the AUV ran aground. A tiny remnant of the seamount occurs on the east side of the axial valley, but half of the volcano has been sliced into numerous ridges during spreading across the axis. This spreading did not occur in a narrow zone, splitting the volcano neatly in half, but rather at many parallel loci of spreading distributed across the entire axial valley.

The AUV mapped all five major hydrothermal vent field along the Endeavour Segment and revealed the distribution of sulfide deposits at each site. Oblique views of Mothra, Main Endeavour, and High Rise vent field are shown in figures 3.4 through 3.6. In addition, a quick examination of the maps indicate that there are many additional chimney structures scattered and clustered along the axial valley and on the uplifted fault blocks that bound the axis. The region between High Rise and Salty Dawg vent field has particularly abundant chimney structures that are previously undescribed. In addition to the chimneys imaged at the known vent sites, perhaps an additional hundred are seen in the high resolution data. Many of the vents occur either near the edges of collapsed lava lakes, as at Mothra vent field, or along the crests of horst-like fault slices, as at High Rise and Sasquatch vent fields. Many also occur within sheet flows or along faults with vertical offsets. A very preliminary distribution of more than 700 previously known and newly discovered chimney structures is shown in figure 3.7.

The AUV is also equipped with a CTD sensor. A preliminary analysis of the temperature and salinity data collected during all fo the Endeavour Segment surveys reveal that several vents produce temperature and salinity anomalies measureable at 50 m altitude (Fig. 3.8). The maximum temperature anomaly of 1.0°C was observed over Godzilla vent in the High Rise vent field.

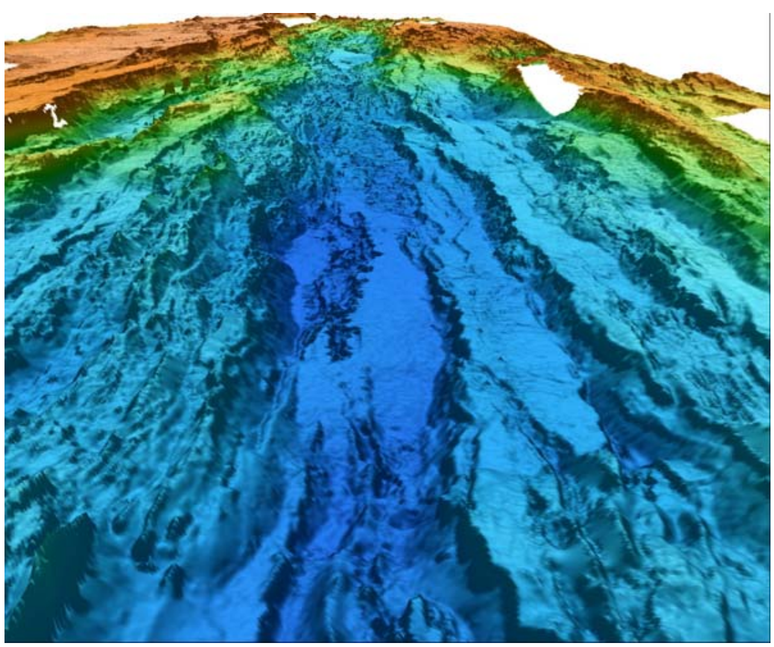


Figure 3.4. Perspective view of the Mothra vent field looking northward through the axial valley.

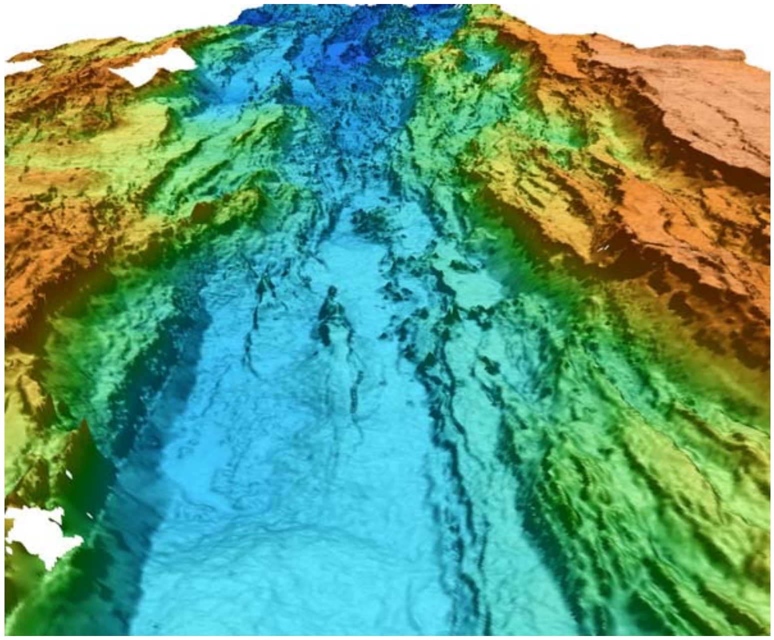


Figure 3.5. Perspective view of the Main Endeavour vent field looking southward through the axial valley.

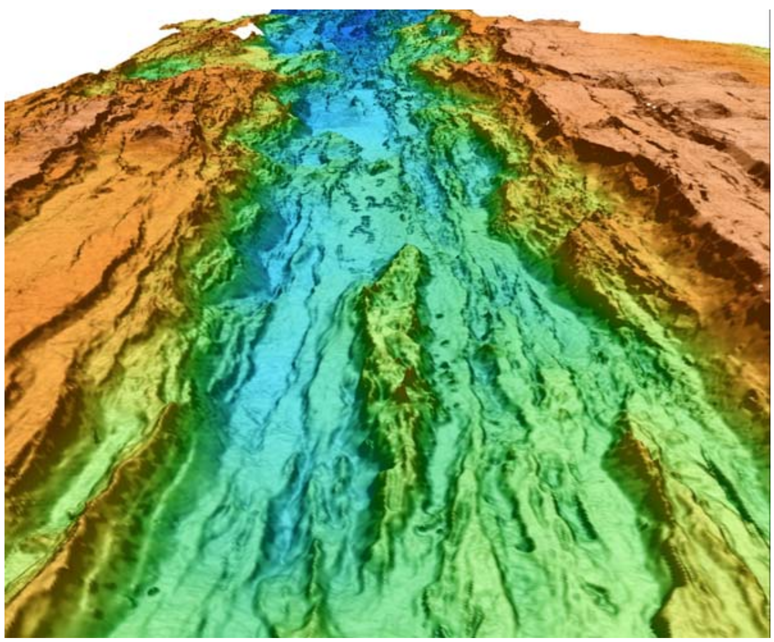


Figure 3.6. Perspective view of the High Rise vent field looking southward through the axial valley.

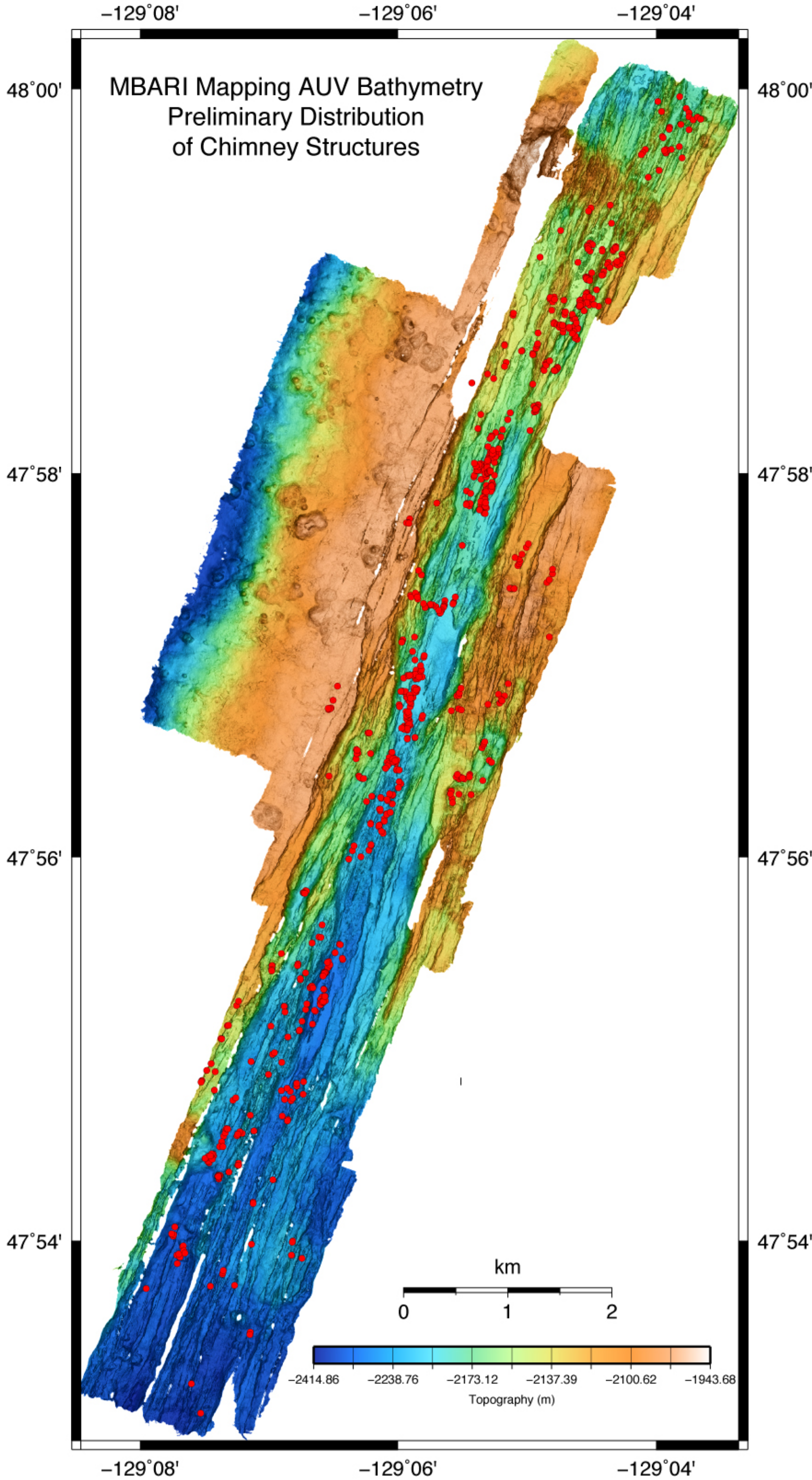


Figure 3.7. Our initial inspection of the high resolution bathymetry of the Endeavour Segment has revealed not only the morphology of known vent structures but also the existence of hundreds of similarly shaped mounds both on and off axis.

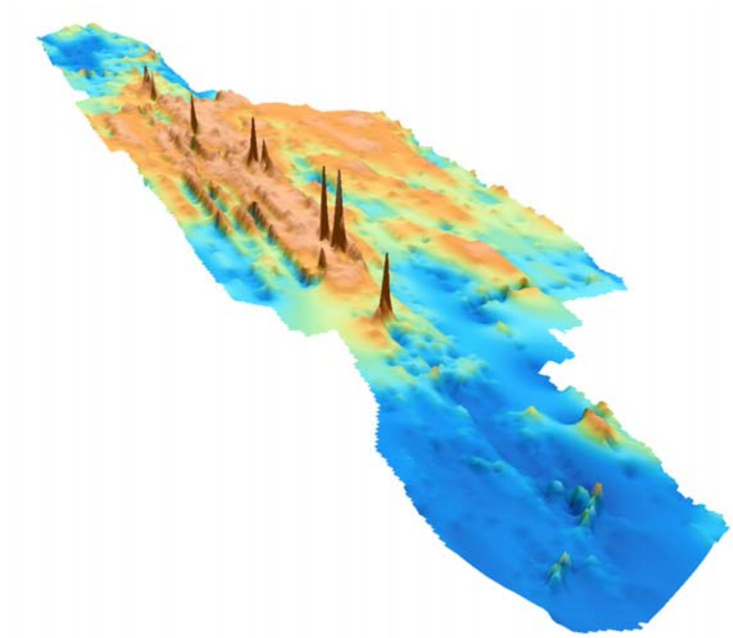


Figure 3.8. Temperature anomaly map derived from AUV CTD measurements during the mapping missions at 50 m altitude above the seafloor. The view is from the north, and hydrothermal plumes were detected over Salty Dawg, High Rise, Main, and Mothra vent fields.

3.2 SeaBeam bathymetry surveys

We collected SeaBeam seafloor bathymetry when either the weather did not permit other operations, such as AUV deployments, when an AUV mission was ended due to technical difficulties, or when transiting between the Endeavour Segment and Axial Volcano. The SeaBeam 2100 system hull-mounted on the R/V *Atlantis* was used to collect the data. The track lines were in locations west of the Cobb Segment and west of the southern terminus of the Endeavour Segment (Fig. 3.9) where the only data available at NGDC predates GPS navigation and are low-resolution SeaBeam Classic data.

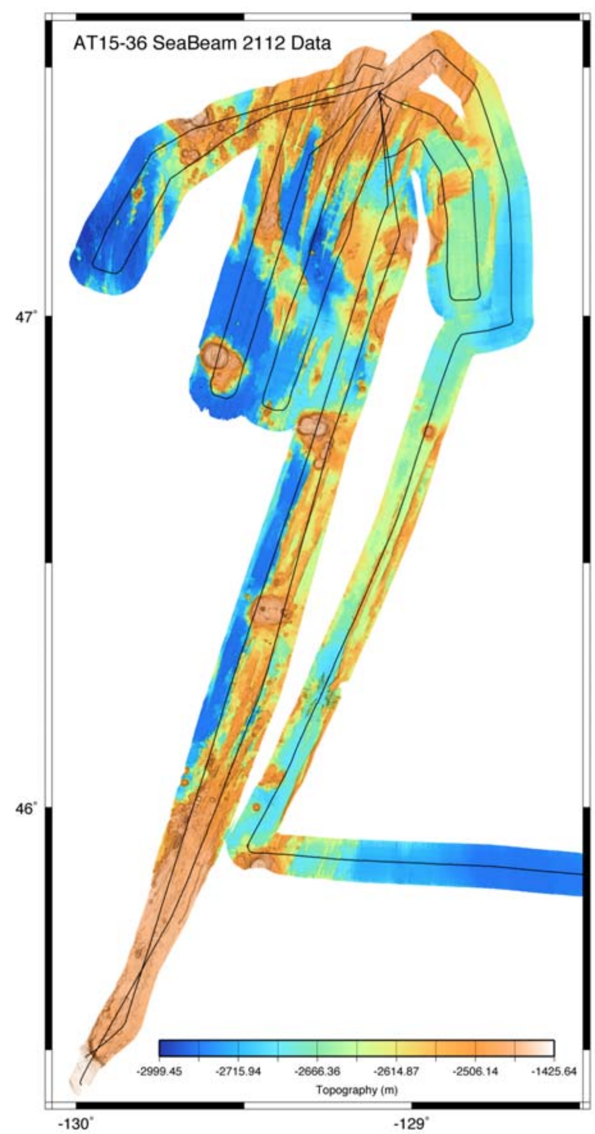


Figure 3.9. SeaBeam 2112 multibeam bathymetry collected during AT15-36.

3.3. CTD water column analysis and sampling

Six CTD casts were performed during night operations or when the weather did not permit other research operations. Two of these were drifting tow-yo's from west to east over Dante vent in the northern Main Endeavour Field and over Bastille vent in the southern Main Endeavour Field. An LBL transponder on the CTD package provided precise Alvin XY navigation throughout the casts. Larger temperature anomalies were observed over the northern portion of the field and only small anomalies were observed over the southern portion, which is generally in keeping with the observed waning of hydrothermal activity in the southern field. A third vertical CTD cast was performed away from the hydrothermal venting to collect background seawater from 1,525 m and 2,200 m depth for experiments and background measurements. Fluids were analyzed for H_2 and CH_4 and will be analyzed for ^3He, total dissolvable metals, and virus particles. On the first tow-yo, we also took samples for shipboard pH and dissolved silica analysis.

The remaining three CTD casts were vertical casts over venting at Axial Volcano. These were performed as part of NOAA's NEMO monitoring program. The casts occurred over ASHES, CASM, and the International District vent clusters. Water was collected at various depths using Niskin bottles within the hydrothermal plume and was used for shipboard H_2 and CH_4, and preserved for shore-based ^3He and total dissolvable metal analyses.

3.4 Hydrothermal fluid sampling and shipboard analysis

3.4.1. *Sampling equipment*. Our tools for collecting hydrothermal fluids and particles included the PMEL Hydrothermal Fluid and Particle Sampler (HFPS), WHOI/DSOG's titanium major samplers, and titanium gas-tight samplers from the Lilley and Lupton labs. The HFPS was mechanically and electronically redesigned in 2007 and 2008 such that it now is configured to take a combination of 18 water samples in PVC piston or acrylic cylinders with collapsible plastic bags of Tedlar, an inert and impermeable polymer. Each water sampler has an in-line filter holder and check valve built into the lid. Approximately half of the water samples were set up with filters while the other half were unfiltered in order to allow culturing of microorganisms. During this cruise, we used either Millipore 47 mm diameter polycarbonate type HTTP 0.4 micron pore size membrane filters, or Millipore quartz fiber filters (Fisher catalog AGFA04700) combusted at 500°C for 10 hours. All filters were pre-weighed and stored in individual filter holders. Upon recovery, filters were suctioned to remove excess fluid, rinsed with a small volume of deionized water, suction dried, and air dried in petri slides.

During this expedition, we also used a large volume acrylic cylinder originally designed by Susan Lang to collect samples of approximately three liters volume for virus analysis by Rika Anderson. This cylinder was mounted next to the HFPS on *Alvin* and plumbed into the main manifold near the point where fluids enter from the intake hose. The large-volume sampler worked well and had no failures. PVC piston samplers have viton o-rings with Teflon guides and were lubricated with a small amount of inert Fluorolube high-temperature grease, the same compound used in titanium major samplers. Samplers were cleaned with hot water and laboratory detergent, hot water rinse, ethanol rinse, wiping with Kimwipes, deionized water rinse, and filtered deep seawater rinse (2,200 m for Endeavour, 1,525 m for Axial Volcano). Dead volumes were filled with filtered deep seawater collected during this cruise and kept in acid-cleaned containers. The manifold redesign was intended to minimize dead volumes and also to keep particles from accumulating near the inlets to sample containers. We collected a total of nine background seawater samples, mainly at the end of dives to test potential cross-contamination of diffuse fluid samples by previously collected high-temperature samples. Based on shipboard Si, H_2S, NH_3, and alkalinity measurements, the degree of cross-contamination is insignificant. In one case, a failed check valve from a high gas sample appears to have leaked gas into the manifold and into the background sample collected during ascent/decompression. Based on visual inspection of filter blanks from multiple dives, particle cross-contamination is also minimal. Titanium major and gas-tight samplers were used only in the discrete mode and were not attached to the HFPS manifold.

3.4.2. *Shipboard processing and analysis*. Gas-tight samples were stored in the lab until extracted by Leigh Evans. All other fluid samples were immediately put into the cold room or in an ice-bath until they could be processed. The primary sample processor was usually Kevin Roe, who would split the samples into their sub-containers and distribute them for analysis. At times, Dave Butterfield either shared or took over this role. Eric Olson analyzed all HFPS samples and RAS samples for H_2 and CH_4 by shipboard chromatography (detection limits for H_2 increased over the course of the cruise due to an increasingly noisy baseline). When a gas phase was present, both gas and liquid were analyzed. Gases were not analyzed on titanium major samples because they do not have effective seals to prevent fluid and gas exchange. Kevin Roe analyzed total H_2S using methylene blue method after Cline (1969). My Christensen measured pH with a Ross Sure-Flow electrode standardized daily with commercial pH buffers (3, 4, 7, 8), titrated samples for alkalinity with the Brinkmann Titrino automated titrator, and analyzed silica content on samples diluted in 0.02 N HCl (diluted by Kevin Roe during sample processing). Annie Bourbonnais analyzed all samples (excluding gas-tights) for NH_3 by spectrophotometry. We saved aliquots of all samples for nutrients (filtered, purged, frozen), major ions (filtered), and trace metals (acidified with SeaStar conc. HCl, 2% by volume) analysis on shore. Selected samples were saved for S, C, H, O, N, and Sr isotope analysis. Noah Lawrence-Slavas maintained the HFPS throughout the cruise.

3.4.3. *RAS setup and processing*. RAS time-series samplers were recovered during *Alvin* dives and brought on deck. After external cleaning, the sample bags were removed, valves closed, and stored on ice. Samples were weighed in the bags to determine volume of liquid. All samples were analyzed for gases, H_2S, pH, alkalinity, silica, and NH_3 on board. Aliquots for major ions, trace metals, and nutrients (frozen) were saved. The RAS instruments deployed in 2008 were all deployed with 47 mm diameter, 0.4 micron pore size HTTP polycarbonate membrane filters. RAS serial number 11072 (stainless steel frame) with Sonardyne beacon 16 was deployed at Marker 33 vent to start sampling noon UTC 9/1/2008 and then every 7 days, 5 hours, and 50 minutes until 8/7/2009, and has 1% HCl with 10 mg/liter Er tracer as a backflush. RAS serial number 11431.01 (titanium frame) was deployed on top of Lobo vent, also with HTTP filters. This RAS is not using backflush acid, and starts sampling at noon UTC on 9/7/2008 every 7 days, 5 hours, and 50 minutes thereafter. Sonardyne beacon 15 is attached to this RAS.

4.0 Preliminary description of sulfide samples

<table>
<tr><td>ALV4438-1816

X: 1859
Y: 4859
Z: 2,193 m
Alt: 3.2 m
F.G.: 0269-0318
Date: Aug. 21, 2008</td><td></td></tr>
<tr><td colspan="2">Sample was an active chimney venting black smoke at 282.1°C, from the Bastille vent complex, southern Main Endeavour Field. Sample was covered in tubeworms, polychaete worms, and scale worms. Original sample height was 40 cm. Sample contains numerous interior fluid conduits with various diameters (max. 5 cm). Main, central conduit contained loosely, consolidated (mushy) porous sphalerite.
Composition: sample consists of > 90% grey, fine to medium porous matrix of marcasite/pyrite, sphalerite and silica. Most conduits are lined with ~1 mm thick rind of euhedral chalcopyrite. Some conduits also lined with very thin (< 0.2mm) rind of sphalerite/wurtzite (< 0.1mm crystal size). Outer surfaces coated in avg. 5 mm biogenic marcasite crust with minor white, bacterial coating and minor red, oxidized coating.</td></tr>
</table>

<table>
<tr><td>ALV4438-1635

X: 5030
Y: 5954
Z: 2,205 m
Alt: 3.3 m
F.G.: 0078-0089
Date: Aug. 21, 2008</td><td></td></tr>
<tr><td colspan="2">Sample was collected from an old, extinct sulfide field, east of the Milli-Q vent complex, southern Main Endeavour Field. Sample dimensions are 27 × 25 × 9 cm. The shape and textures suggest the sample was broken off of an extinct flange. Fossilized tubes are preserved on the “top”. Compositional (mineralogical) zoning along flat plane of sample. Sample porosity is ~20%.
Composition: The sulfide surface has a rusty red oxidized iron and black manganese coating. A fresh surface is green/grey and consists of massive pyrite/marcasite and sphalerite/wurtzite. Max crystal size of 0.2 mm pyrite. Minor white precipitate on surface (possible barite).</td></tr>
</table>

ALV4438-2132

X: 4847
Y: 5865
Z: 2,189 m
Alt: 2.4 m
F.G.: 0671-0676
Date: Aug. 21, 2008

Inactive sulfide spire at Salut, southern MEF. Spire is attached to mound with live tubeworms (F.G. 0674). No megafauna on sample. Sample consists of two parts: an upper chimney (30 cm) and a lower hybrid chimney/flange with a large cavity (base: 22 × 13 cm, depth: 14 cm). The chimney has a concentric interior with many small (~1cm), irregular shaped. The interior walls of the cavity are irregular and partly oxidized. A 15 mm fluid conduit runs along the supported end of the cavity.

Composition: The chimney is composed of grey, porous (30%) pyrite-sphalerite-silica. Conduits contain bladed orange-purple covellite crystals (up to 1 mm), associated with a chalcopyrite rind. Some conduits are filled with black fine to medium sphalerite/wurtzite crystals, and minor white crystalline anhydrite. The walls of the large cavity are composed of grey pyrite-sphalerite-silica. The main conduit along the side of the cavity has an outer 1mm chalcopyrite layer, with an inner 2 mm sphalerite/wurtzite layer. Covellite is present at the top of the conduit (corresponds to covellite at the bottom of the chimney.

ALV4441-2135

X: 4998
Y: 6205
Z: 2,195 m
Alt: 2.4 m
F.G.: 0694-0698
Date: Aug. 24, 2008

Old massive sulfide taken from south end of Dante, Main Endeavour field. Sample is a porous (10%) massive sulfide measuring 20 × 15 × 10 cm. Weathered surface is oxidized (red/yellow). Fresh surface is metallic yellow/green/grey. Minor green atacamite(?) on surface. Vuggy texture with euhedral pyrite (1 mm) coating inside of vugs. Max vug size is 4 cm. Bands (up to 1 cm thick) of coarse (~1mm) euhedral pyrite with low porosity and associated barite/anhydrite. Sample is composed of 95% pyrite, with minor barite or anhydrite (bladed and acicular euhedral clear crystals up to 2 mm long). Possible sphalerite intergrown with finer porous pyrite.

ALV4441-1912

X: 4972
Y: 6147
Z: 2,196 m
Alt: 0.8 m
F.G.: 0412-0413
Date : Aug. 24, 2008

Sample consists of small pieces collected from south of Dante, Main Endeavour Field. The primary mineralogy consists of fine pyrite/marcasite and sphalerite/wurtzite. The sample also contains ~5% anhydrite. An outer marcasite crust contains ~20% anhydrite. A 1 cm central conduit is lined with fine sphalerite/wurtzite. Outer surface is brown/orange and is slightly oxidized. There is evidence of past biological activity suck as tubeworm scars. However, no live fauna was living on the sample at the time of collection. The inner, pyrite/sphalerite material has up to 50% porosity.

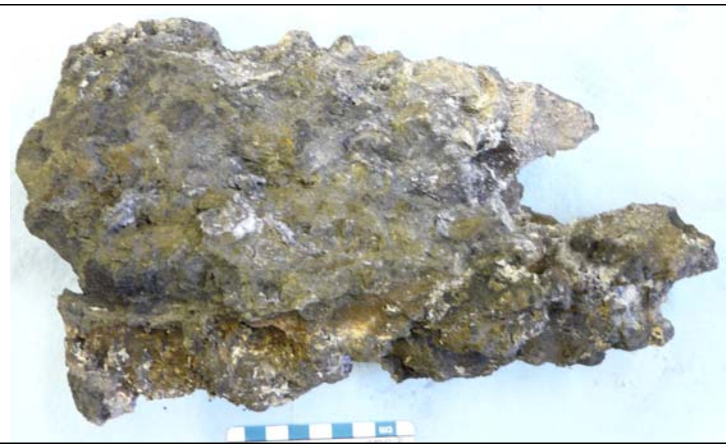
ALV4446-1628

X: 5030
Y: 5840
Z: 2,195 m
Alt: 4.6 m
F.G.: 0022-0027
Date: Aug. 29, 2008

Sample consists of 6 pieces of old, extinct sulfide, from east of Salut, Main Endeavour Field. The striking characteristic of this sample is the high porosity (up to 70%). The high-porosity regions consist of sulfide-replaced tubeworms (up to 2 mm diameter). Fresh surfaces are grey and weathered surfaces have an orange-brown oxidized iron coating. The overall mineralogy consists of fine sphalerite/wurtzite and pyrite/marcasite. The tubeworm linings are more pyrite-rich. There are traces of blue/purple covellite which suggests the occurrence of minor chalcopyrite. Some exposed surfaces covered in macrofauna and a brown, 5 mm marcasite crust. One partial 3 cm diameter fluid conduit with a sphalerite/wurtzite 2 mm inner crust.

ALV4446-1735

X: 4870
Y: 5844
Z: 2,185 m
Alt: 2.0 m
F.G.: 0160-0160
Date: Aug. 29, 2008



This active chimney was collected from Salut, Main Endeavour Field with clear, diffuse venting at 79.2°C. Sample is 24 × 17 × 10 cm and is composed of fine sphalerite/wurtzite, pyrite/marcasite ± silica, with minor (5%) anhydrite. Multiple, irregular-shaped open conduits (max 2 cm) lined with 0.5 mm euhedral reddish-brown/black sphalerite/wurtzite. Porosity is ~10%. Outer surface is covered in fossil tubeworms, white/cream bacterial mats and a 0.5 to 1 cm marcasite crust. A number of small, fist-sized pieces were also collected from the same site, but not necessarily from the same chimney structure. These pieces are distinguished from the main chimney piece by their high porosity (up to 40%) and high anhydrite content (up to 50%). The white anhydrite has large (up to 1 cm long) bladed crystals.

ALV4448-2211

X: 4911
Y: 6124
Z: 2,194 m
Alt: 0.9 m
F.G.: 0672-0677
Date: Aug. 31, 2008

This extinct sulfide sample was collected from the TP vent structure, which had a recorded venting temperature of 334°C. The sample measures 30 × 20 × 15 cm. The weathered surfaces are oxidized red/orange. Fossil tube worms are incorporated into the surface on one side (interpreted as a former chimney wall or mound surface). The interior is composed of irregular concentric mineralogical banding, indicating a complex growth history. Bands are either pyrite/marcasite- or sphalerite/wurtzite-rich. Pyrite/marcasite bands are fine grained. Black sphalerite/wurtzite bands have a coarser crystal size (up to 0.5mm). No clear distinct fluid conduits or high-T chalcopyrite rinds. Sample has vugs (most < 1cm, one large 'crack' 1 cm wide with oxidized inner surfaces). Sample contains 10% porosity. Yellow bacterial mats cover part of oxidized surface. Oxidized 1 cm marcasite crust on outer surface.

<table>
<tr><td>ALV4449-1630

X: 5057
Y: 6243
Z: 2,199 m
Alt: 7.5 m
F.G.: 0036-0046
Date: Sept. 1, 2008</td><td></td></tr>
<tr><td colspan="2">This extinct sulfide was collected at the base of Hulk, Main Endeavour Field. The sample contains multiple small (max 5 mm) fluid conduits, suggesting the sample was a chimney (diameter of 15 cm). Interior has a porosity of ~20%, which decreases towards exterior. Weathered surface is highly oxidized red/brown, with white/cream bacterial mat staining. Abundant fossil tubeworms are incorporated into exterior. Interior is grey and is composed of fine sphalerite/wurtzite and pyrite/marcasite. Black sphalerite-rich rinds (up to 2mm) line fluid conduits.</td></tr>
</table>

<table>
<tr><td>ALV4449-1938

X: 4970
Y: 6148
Z: 2,186 m
Alt: 9.7 m
F.G.: 0413-0443
Date: Sept. 1, 2008</td><td></td></tr>
<tr><td colspan="2">This active chimney was collected from Dante, which was venting clear fluid at 300°C. The interior is mushy, black/brown, and highly porous, and was likely a sphalerite/wurtzite-rich porous fluid conduit fill. The black crystals are bladed (up to 3mm long) and have a preferential alignment that may be related to fluid flow direction. The crystals show a clear concentric layering and are mixed with fine pyrite- and possible chalcopyrite-rich layers. This material was scooped out of the largest piece for microbiological culturing. The outer surfaces are grey with white bacterial mat staining and some tubeworms (removed). Minor white anhydrite also present on outer surfaces. A 7 mm marcasite crust is the outermost layer.</td></tr>
</table>

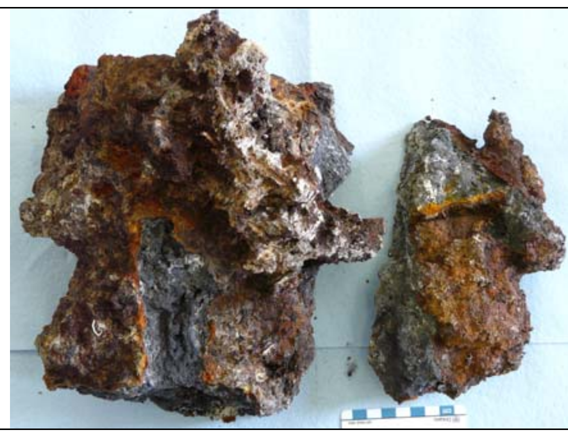
ALV4450-1538

X: 4162
Y: 3335
Z: 2,271 m
Alt: 4.3 m
F.G.: 0210-0269
Date: Sept. 2, 2008

This small sample was collected from Hot Harold vent, at the Faulty Towers complex of the Mothra vent field. This chimney was venting black smoker fluid at 320.8°C. The sample has a number of small (max 14 mm) fluid conduits. The composition of the sample is dominated by dark grey/black sphalerite/wurtzite with very fine disseminated pyrite/marcasite. The sample also contains ~10% white, bladed (up to 2mm) anhydrite. Porosity of ~15%.

ALV4450-1829

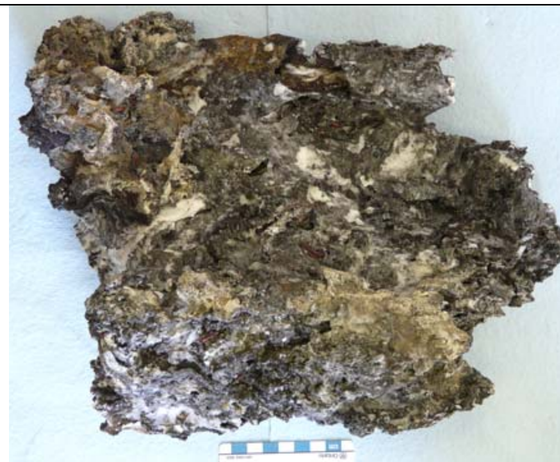
X: 4147
Y: 3333
Z: 2,280 m
Alt: 0.9 m
F.G.: 0310-0318
Date: Sept. 2, 2008



This extinct sulfide was collected from a collapsed chimney at the base of the Faulty Towers complex, in the Mothra vent field (the chimney 'log' in the lower left corner of the M. Elland photomosaic of the Faulty Towers complex). The sample has a red/brown oxidized surface that is partially covered by white bacterial mats. Fresh surfaces are grey and white. The sample is composed of porous (~20%) grey, fine-grained pyrite/marcasite and sphalerite/wurtzite with 10% anhydrite or barite. Replaced fossil tube worms occur throughout sample. Degree of porosity is highly variable and cm-scale conduits occur randomly throughout.

ALV4451-1725

X: 7316
Y: 11426
Z: 2,153 m
Alt: 1.7 m
F.G.: 0185-0203
Date: Sept. 3, 2008



This sample was taken from Christmas Tree, an active chimney, venting black smoker fluid at 275°C in the Sasquatch vent field. The sample is distinctly rich in fibrous, bladed and massive anhydrite (60% of sample). Variable anhydrite content in the sample gives it a mottled texture. The remainder of the sample is composed of fine pyrite/marcasite and sphalerite/wurtzite. A number of ~circular, open conduits run along the length of the sample. The conduits are lined with black, euhedral (up to 0.5mm) sphalerite/wurtzite crystals. The sample contained some palm worms and bacterial mats on the outer surfaces. Minor orange oxidation occurs on outer surface.

ALV4452-1706

X: 5040
Y: 6262
Z: 2,191 m
Alt: 4.7 m
F.G.: 0123-0133
Date: Sept. 4, 2008

This active sample was collected from a beehive chimney, venting clear fluid at 85°C from the base Hulk, in the Main Endeavour Field. The sample consists of small fragments, but clearly shows an exterior surface and an interior fluid conduit. The conduit walls are 1-2 cm thick and are composed of fine pyrite/marcasite and sphalerite/wurtzite, with 10% acicular to bladed white anhydrite (1-2 mm crystals). The interior conduits are lined with euhedral black sphalerite/wurtzite and maybe minor chalcopyrite.

Table A1. *Alvin* Dive Statistics for AT15-36

Dive no.	Date	Location	Max. depth	Launch time	Time at bottom	Time off bottom	Surface time	Total bottom time	Total dive time	Dive completed because
4438	21 Aug 2008	MEF	2,208 m	1511	1615	2137	2300	5:22	7:49	Finished objectives
4439	22 Aug 2008	MEF	2,198 m	1500	1629	2211	2322	5:42	8:22	Power
4440	23 Aug 2008	MEF	2,210 m	1457	1606	2011	2140	4:05	6:43	Weather
4441	24 Aug 2008	MEF	2,222 m	1455	1557	2141	2308	5:44	8:13	Power
4442	25 Aug 2008	Axial	1,542 m	1531	1611	2250	2352	6:39	8:21	Time
4443	26 Aug 2008	Axial	1,521 m	1502	1549	2057	2155	5:08	6:53	Time
4444	27 Aug 2008	Axial	1,531 m	1702	1744	2251	2347	5:07	6:45	Time
4445	28 Aug 2008	Axial	1,522 m	1500	1549	2224	2320	6:35	8:20	Power
4446	29 Aug 2008	MEF	2,210 m	1547	1609	2225	2345	6:16	7:58	Time
4447	30 Aug 2008	MEF	2,219 m	1504	1608	2108	2241	5:00	7:37	Power
4448	31 Aug 2008	MEF	2,181 m	1510	1622	2220	2349	5:58	8:39	Power
4449	1 Sept 2008	MEF	2,202 m	1459	1607	2220	2346	6:13	8:47	Power
4450	2 Sept 2008	Mothra	2,283 m	1459	1603	2115	2248	5:12	7:49	Finished objectives
4451	3 Sept 2008	Sasquatch	2,146 m	1453	1552	1953	2120	4:01	6:27	Finished objectives
4452	4 Sept 2008	MEF	2,210 m	1500	1602	2152	2324	5:50	8:24	Finished objectives
4453	5 Sept 2008	High Rise	2,203 m	1500	1604	2222	2345	6:18	8:45	Time

Total dives funded: 18
Total dives completed: 16
Dives lost: 2 (weather)

Table A2. Summary of filtered samples collected using the Hydrothermal Fluid Sampler for chemical analysis

Sample ID	Date	Time (UTC)	Fluid Temp.	Location	Local X	Local Y	Depth	Heading
4442-fluid-HFS-FP8	25 Aug 2008	2008	82.1°C	Axial – Marshmallow	No nav.	No nav.	1,546 m	079°
4442-fluid-HFS-FB24	25 Aug 2008	2015	85.7°C	Axial – Marshmallow	No nav.	No nav.	1,546 m	079°
4442-fluid-HFS-FP7	25 Aug 2008	2048	232.4°C	Axial – Virgin Mound	No nav.	No nav.	1,546 m	030°
4442-fluid-HFS-FB23	25 Aug 2008	2056	246.8°C	Axial – Virgin Mound	No nav.	No nav.	1,546 m	030°
4442-fluid-HFS-FB21	25 Aug 2008	2132	315.9°C	Axial – Inferno	No nav.	No nav.	1,547 m	297°
4442-fluid-HFS-FP5	25 Aug 2008	2138	320.9°C	Axial – Inferno	No nav.	No nav.	1,547 m	297°
4442-fluid-HFS-FP8	25 Aug 2008	2208	278.0°C	Axial – Hell	No nav.	No nav.	1,546 m	230°
4442-fluid-HFS-FB16	25 Aug 2008	2215	285.8°C	Axial – Hell	No nav.	No nav.	1,546 m	230°
4443-fluid-HFS-FP9	26 Aug 2008	1739	20.4°C	Axial – Marker 33	6546	3685	1,520 m	140°
4443-fluid-HFS-FB20	26 Aug 2008	2033	6.8°C	Axial – Cloud	6560	3693	1,522 m	237°
4444-fluid-HFS-FB24	27 Aug 2008	1911	17.9°C	Axial – Vixen Diffuse	5709	1915	1,521 m	236°
4444-fluid-HFS-FP7	27 Aug 2008	1924	334.0°C	Axial – Vixen	5709	1915	1,521 m	236°
4444-fluid-HFS-FB23	27 Aug 2008	1927	334.2°C	Axial – Vixen	5709	1915	1,521 m	236°
4444-fluid-HFS-FP2	27 Aug 2008	2013	302.8°C	Axial – Casper	5704	1924	1,538 m	158°
4444-fluid-HFS-FP5	27 Aug 2008	2016	302.9°C	Axial – Casper	5704	1924	1,538 m	158°
4444-fluid-HFS-FB21	27 Aug 2008	2102	11.2°C	Axial – Bag City/Mk 36	5861	1761	1,532 m	049°
4444-fluid-HFS-FP9	27 Aug 2008	2122	11.2°C	Axial – Bag City/Mk 36	5861	1761	1,532 m	049°
4445-fluid-HFS-FP5	28 Aug 2008	1824	310.2°C	Axial – El Guapo	6779	2991	1,507 m	210°
4445-fluid-HFS-FP7	28 Aug 2008	1831	314.4°C	Axial – El Guapo	6779	2991	1,507 m	210°
4445-fluid-HFS-FB21	28 Aug 2008	1917	36.4°C	Axial – 9 m	No nav.	No nav.	1,517 m	148°
4445-fluid-HFS-FP2	28 Aug 2008	2004	212°C	Axial – Diva	6795	2924	1,524 m	018°
4445-fluid-HFS-FP9	28 Aug 2008	2031	75.4°C	Axial – Escargot	No nav.	No nav.	1,520 m	265°
4445-fluid-HFS-FB23	28 Aug 2008	2039	98.0°C	Axial – Escargot	No nav.	No nav.	1,520 m	265°
4445-fluid-HFS-FB20	28 Aug 2008	2201	34.0°C	Axial – Hermosa	6737	2930	1,519 m	146°
4446-fluid-HFS-FB24	29 Aug 2008	1706	44.3°C	MEF – Salut	4870	5844	2,187 m	334°
4446-fluid-HFS-FP2	29 Aug 2008	1807	266.1°C	MEF – Salut	4873	5845	2,187 m	304°
4446-fluid-HFS-FB17	29 Aug 2008	1813	268.1°C	MEF – Salut	4873	5845	2,187 m	304°
4446-fluid-HFS-FP5	29 Aug 2008	1934	18.5°C	MEF – Easter Island	4894	6011	2,197 m	092°
4446-fluid-HFS-FP9	29 Aug 2008	2019	247.6°C	MEF – Puffer	4863	5979	2,193 m	112°
4446-fluid-HFS-FB23	29 Aug 2008	2036	74.4°C	MEF – Bastille	4877	6005	2,186 m	184°
4446-fluid-HFS-FB16	29 Aug 2008	2124	56.2°C	MEF – S&M	4938	6013	2,189 m	249°

Sample ID	Date	Time (UTC)	Fluid Temp.	Location	Local X	Local Y	Depth	Heading
4446-fluid-HFS-FB22	29 Aug 2008	2157	228.8°C	MEF – S&M	4935	6002	2,181 m	249°
4446-fluid-HFS-FB21	29 Aug 2008	2202	191.5°C	MEF – S&M	4935	6002	2,181 m	249°
4446-fluid-HFS-FP7	29 Aug 2008	2240	2.3°C	MEF – background SW	-	-	1,750 m	-
4448-fluid-HFS-FB24	31 Aug 2008	1832	23.7°C	MEF – Lobo	4952	6160	2,188 m	208°
4448-fluid-HFS-FB23	31 Aug 2008	1901	24.3°C	MEF – Lobo	4952	6160	2,188 m	208°
4448-fluid-HFS-FP2	31 Aug 2008	1917	306.2°C	MEF – Lobo	4936	6172	2,188 m	155°
4448-fluid-HFS-FB22	31 Aug 2008	1923	313.4°C	MEF – Lobo	4936	6172	2,188 m	155°
4448-fluid-HFS-FB21	31 Aug 2008	2231	2.1°C	MEF – background SW	-	-	1,900 m	-
4449-fluid-HFS-FB20	1 Sept 2008	1650	17.7°C	MEF – Hulk	5043	6243	2,197 m	324°
4449-fluid-HFS-FP2	1 Sept 2008	1748	301.0°C	MEF – Hulk	5046	6262	2,191 m	179°
4449-fluid-HFS-FB22	1 Sept 2008	1846	17.7°C	MEF – Grotto	4935	6140	2,188 m	000°
4449-fluid-HFS-FP5	1 Sept 2008	1917	319.7°C	MEF – Grotto	4939	6142	2,188 m	000°
4449-fluid-HFS-FP7	1 Sept 2008	1958	296.6°C	MEF – Dante	4970	6148	2,186 m	356°
4449-fluid-HFS-FP9	1 Sept 2008	2105	137.8°C	MEF – Cathedral	4848	5923	2,183 m	315°
4449-fluid-HFS-FB24	1 Sept 2008	2122	23.7°C	MEF – Cathedral	4846	5928	2,185 m	204°
4449-fluid-HFS-FB16	1 Sept 2008	2200	70.3°C	MEF – Milli-Q	4910	5940	2,181 m	005°
4449-fluid-HFS-FB23	1 Sept 2008	2214	2.0°C	MEF – background SW	4943	5943	2,201 m	097°
4450-fluid-HFS-FP2	2 Sept 2008	1639	291.1°C	Mothra – Cauldron	4268	3544	2,249 m	090°
4450-fluid-HFS-FB16	2 Sept 2008	1653	36.6°C	Mothra – Cauldron	4268	3544	2,249 m	090°
4450-fluid-HFS-FP5	2 Sept 2008	1758	291.4°C	Mothra – Hot Harold	4162	3333	2,271 m	-
4450-fluid-HFS-FP7	2 Sept 2008	1924	248.2 °C	Mothra – Crab Basin	4127	3268	2,279 m	138°
4450-fluid-HFS-FP9	2 Sept 2008	2012	293.2°C	Mothra – Cuchalainn	4126	3128	2,291 m	230°
4450-fluid-HFS-FB20	2 Sept 2008	2058	306.5°C	Mothra – Stonehenge	4103	3023	2,290 m	206°
4453-fluid-HFS-FP2	5 Sept 2008	1827	345.5°C	High Rise – Godzilla	5784	8331	2,137 m	179°
4453-fluid-HFS-FB16	5 Sept 2008	1857	30.9°C	High Rise – Godzilla	5802	8335	2,135 m	268°
4453-fluid-HFS-FB20	5 Sept 2008	1958	19.6°C	High Rise – Boardwalk	5790	8289	2,136 m	359°
4453-fluid-HFS-FP5	5 Sept 2008	2053	336.7°C	High Rise – Boardwalk	5784	8292	2,136 m	281°
4453-fluid-HFS-FP7	5 Sept 2008	2146	330.6°C	High Rise – Park Place	5769	8239	2,138 m	130°
4453-fluid-HFS-FB24	5 Sept 2008	2230	2.2°C	High Rise – seawater	-	-	-	-

Sample summary:

60 filtered HFS fluid samples

Table A3. Summary of unfiltered samples collected using the Hydrothermal Fluid Sampler for chemical and microbiological analyses

Sample ID	Date	Time (UTC)	Fluid Temp.	Location	Local X	Local Y	Depth	Heading
4442-fluid-HFS-UP1	25 Aug 2008	1751	20.6°C	Axial – Gollum	No nav.	No nav.	1,547 m	107°
4442-fluid-HFS-UB18	25 Aug 2008	1907	20.1°C	Axial – Gollum	No nav.	No nav.	1,547 m	107°
4442-fluid-HFS-UB19	25 Aug 2008	1912	21.2°C	Axial – Gollum	No nav.	No nav.	1,547 m	107°
4443-fluid-HFS-UP1	26 Aug 2008	1649	16.2°C	Axial – Marker 33	6546	3685	1,520 m	140°
4443-fluid-HFS-UB17	26 Aug 2008	1656	19.0°C	Axial – Marker 33	6546	3685	1,520 m	140°
4443-fluid-HFS-UP6	26 Aug 2008	2022	6.8°C	Axial – Cloud	6560	3693	1,522 m	237°
4443-fluid-HFS-UB18	26 Aug 2008	2028	6.8°C	Axial – Cloud	6560	3693	1,522 m	237°
4444-fluid-HFS-UP8	27 Aug 2008	1902	20.7°C	Axial – Vixen Diffuse	5709	1915	1,521 m	236°
4444-fluid-HFS-UP1	27 Aug 2008	2056	11.2°C	Axial – Bag City/Mk 36	5861	1761	1,532 m	049°
4444-fluid-HFS-UP3	27 Aug 2008	2207	26.2°C	Axial – Marker 113/62	6087	2549	1,521 m	308°
4444-fluid-HFS-UP4	27 Aug 2008	2212	19.5°C	Axial – Marker 113/62	6087	2549	1,521 m	308°
4444-fluid-HFS-UB19	27 Aug 2008	2222	24.7°C	Axial – Marker 113/62	6087	2549	1,521 m	308°
4444-fluid-HFS-UP6	27 Aug 2008	2255	2.7°C	Axial – background SW	-	-	-	-
4445-fluid-HFS-UP8	28 Aug 2008	1641	18.0°C	Axial – Village/Mk 44	6686	2881	1,520 m	353°
4445-fluid-HFS-UB19	28 Aug 2008	1646	17.5°C	Axial – Village/Mk 44	6686	2881	1,520 m	353°
4445-fluid-HFS-UP6	28 Aug 2008	1827	317.9°C	Axial – El Guapo	6779	2991	1,507 m	210°
4445-fluid-HFS-UP3	28 Aug 2008	1851	30.0°C	Axial – 9 m	No nav.	No nav.	1,517 m	148°
4445-fluid-HFS-UB17	28 Aug 2008	1912	27.5°C	Axial – 9 m	No nav.	No nav.	1,517 m	148°
4445-fluid-HFS-UP1	28 Aug 2008	2155	22.1°C	Axial – Hermosa	6737	2930	1,519 m	146°
4445-fluid-HFS-UB18	28 Aug 2008	2215	2.5°C	Axial – background SW	-	-	-	-
4446-fluid-HFS-UP1	29 Aug 2008	1700	42.6°C	MEF – Salut	4870	5844	2,187 m	334°
4446-fluid-HFS-UP3	29 Aug 2008	1755	79.2°C	MEF – Salut	4870	5842	2,187 m	334°
4446-fluid-HFS-UB19	29 Aug 2008	1901	18.8°C	MEF – Easter Island	4894	6011	2,197 m	092°
4446-fluid-HFS-UB18	29 Aug 2008	1909	12.5°C	MEF – Easter Island	4894	6011	2,197 m	092°
4446-fluid-HFS-UP4	29 Aug 2008	2055	42.0°C	MEF – S&M	4938	6013	2,189 m	249°
4446-fluid-HFS-UP8	29 Aug 2008	2246	2.5°C	MEF – background SW	-	-	1,595 m	-
4448-fluid-HFS-UP1	31 Aug 2008	1826	30.7°C	MEF – Lobo	4952	6160	2,188 m	208°
4448-fluid-HFS-UP3	31 Aug 2008	2236	2.3°C	MEF – background SW	-	-	1,750 m	-
4449-fluid-HFS-UB18	1 Sept 2008	1642	14.5°C	MEF – Hulk	5043	6243	2,197 m	324°
4449-fluid-HFS-UB19	1 Sept 2008	1646	17.1°C	MEF – Hulk	5043	6243	2,197 m	324°
4449-fluid-HFS-UP3	1 Sept 2008	1811	321.0°C	MEF – Hulk	5046	6262	2,191 m	179°

Sample ID	Date	Time (UTC)	Fluid Temp.	Location	Local X	Local Y	Depth	Heading
4449-fluid-HFS-UB17	1 Sept 2008	1841	16.4°C	MEF – Grotto	4935	6140	2,188 m	000°
4449-fluid-HFS-UP6	1 Sept 2008	1922	319.7°C	MEF – Grotto	4939	6142	2,188 m	000°
4449-fluid-HFS-UP8	1 Sept 2008	2003	297.2°C	MEF – Dante	4970	6148	2,186 m	356°
4449-fluid-HFS-UP4	1 Sept 2008	2059	107.7°C	MEF – Cathedral	4848	5923	2,183 m	315°
4449-fluid-HFS-UP1	1 Sept 2008	2117	24.0°C	MEF – Cathedral	4846	5928	2,185 m	204°
4449-fluid-HFS-UB21	1 Sept 2008	2205	70.8°C	MEF – Milli-Q	4910	5940	2,181 m	005°
4450-fluid-HFS-UP1	2 Sept 2008	1634	291.1°C	Mothra – Cauldron	4268	3544	2,249 m	090°
4450-fluid-HFS-UP4	2 Sept 2008	1648	31.5°C	Mothra – Cauldron	4268	3544	2,249 m	090°
4450-fluid-HFS-UB19	2 Sept 2008	1710	40.8°C	Mothra – Cauldron	4268	3544	2,249 m	090°
4450-fluid-HFS-UP3	2 Sept 2008	1753	318.3°C	Mothra – Hot Harold	4162	3333	2,271 m	-
4450-fluid-HFS-UP6	2 Sept 2008	1920	239.3°C	Mothra – Crab Basin	4127	3268	2,279 m	138°
4450-fluid-HFS-UP8	2 Sept 2008	2008	292.5°C	Mothra – Cuchalainn	4126	3128	2,291 m	230°
4450-fluid-HFS-UB21	2 Sept 2008	2054	305.9°C	Mothra – Stonehenge	4103	3023	2,290 m	206°
4453-fluid-HFS-UP1	5 Sept 2008	1823	345.0°C	High Rise – Godzilla	5784	8331	2,137 m	179°
4453-fluid-HFS-UB19	5 Sept 2008	1846	20.1°C	High Rise – Godzilla	5802	8335	2,135 m	268°
4453-fluid-HFS-UB18	5 Sept 2008	1852	14.0°C	High Rise – Godzilla	5802	8335	2,135 m	268°
4453-fluid-HFS-UB17	5 Sept 2008	2003	21.3°C	High Rise – Boardwalk	5790	8289	2,136 m	359°
4453-fluid-HFS-UP3	5 Sept 2008	2057	328.4°C	High Rise – Boardwalk	5784	8292	2,136 m	281°
4453-fluid-HFS-UP6	5 Sept 2008	2150	332.3°C	High Rise – Park Place	5769	8239	2,138 m	130°

Sample summary:

50 unfiltered HFS fluid samples

Table A4. Summary of Sterivex filter samples collected using the Hydrothermal Fluid Sampler for microbiological analyses

Sample ID	Date	Time (UTC)	Fluid Temp.	Location	Local X	Local Y	Depth	Heading
4442-fluid-HFS-St11	25 Aug 2008	1758	20.3°C	Axial – Gollum	No nav.	No nav.	1,547 m	107°
4442-fluid-HFS-St12	25 Aug 2008	1819	18.7°C	Axial – Gollum	No nav.	No nav.	1,547 m	107°
4442-fluid-HFS-St13	25 Aug 2008	2022	84.9°C	Axial – Marshmallow	No nav.	No nav.	1,546 m	079°
4443-fluid-HFS-St11	26 Aug 2008	1724	20.8°C	Axial – Marker 33	6546	3685	1,520 m	140°
4443-fluid-HFS-St12	26 Aug 2008	1958	6.7°C	Axial – Cloud	6560	3693	1,522 m	237°
4443-fluid-HFS-St13	26 Aug 2008	2038	6.8°C	Axial – Cloud	6560	3693	1,522 m	237°
4444-fluid-HFS-St14	27 Aug 2008	1830	23.5°C	Axial – Vixen Diffuse	5709	1915	1,521 m	236°
4444-fluid-HFS-St15	27 Aug 2008	2107	11.2°C	Axial – Bag City/Mk 36	5861	1761	1,532 m	049°
4445-fluid-HFS-St13	28 Aug 2008	1651	15.4°C	Axial – Village/Mk 44	6686	2881	1,520 m	353°
4445-fluid-HFS-St10	28 Aug 2008	1857	29.7°C	Axial – 9 m	No nav.	No nav.	1,517 m	148°
4445-fluid-HFS-St11	28 Aug 2008	1924	29.7°C	Axial – 9 m	No nav.	No nav.	1,517 m	148°
4445-fluid-HFS-St14	28 Aug 2008	2121	32.2°C	Axial – Hermosa	6737	2930	1,519 m	146°
4445-fluid-HFS-St15	28 Aug 2008	2144	33.4°C	Axial – Hermosa	6737	2930	1,519 m	148°
4446-fluid-HFS-St15	29 Aug 2008	1711	33.7°C	MEF – Salut	4870	5844	2,187 m	334°
4446-fluid-HFS-St14	29 Aug 2008	1915	17.8°C	MEF – Easter Island	4894	6011	2,197 m	092°
4446-fluid-HFS-St13	29 Aug 2008	1943	19.3°C	MEF – Easter Island	4894	6011	2,197 m	092°
4446-fluid-HFS-St12	29 Aug 2008	2130	47.4°C	MEF – S&M	4938	6013	2,189 m	249°
4448-fluid-HFS-St15	31 Aug 2008	1839	22.7°C	MEF – Lobo	4952	6160	2,188 m	208°
4449-fluid-HFS-St11	1 Sept 2008	1716	34.8°C	MEF – Hulk	5043	6243	2,197 m	324°
4449-fluid-HFS-St12	1 Sept 2008	1850	18.1°C	MEF – Grotto	4935	6140	2,188 m	000°
4449-fluid-HFS-St13	1 Sept 2008	2127	22.0°C	MEF – Cathedral	4846	5928	2,185 m	204°
4449-fluid-HFS-St14	1 Sept 2008	2137	22.9°C	MEF – Cathedral	4846	5928	2,185 m	204°
4450-fluid-HFS-St10	2 Sept 2008	1658	38.8°C	Mothra – Cauldron	4268	3544	2,249 m	090°
4450-fluid-HFS-St11	2 Sept 2008	2017	293.4°C	Mothra – Cuchalainn	4126	3128	2,291 m	230°
4453-fluid-HFS-St11	5 Sept 2008	2008	21.1°C	High Rise – Boardwalk	5790	8289	2,136 m	359°
4453-fluid-HFS-St12	5 Sept 2008	2235	2.4°C	High Rise – seawater	-	-	-	-

Sample summary:

26 sterivex filter samples

Table A5. Summary of large volume bag samples collected using the Hydrothermal Fluid Sampler for microbiological analyses

Sample ID	Date	Time (UTC)	Fluid Temp.	Location	Local X	Local Y	Depth	Heading
4442-fluid-HFS-LVB10	25 Aug 2008	1830	20.5°C	Axial – Gollum	No nav.	No nav.	1,547 m	107°
4443-fluid-HFS-LVB10	26 Aug 2008	1702	19.7°C	Axial – Marker 33	6546	3685	1,520 m	140°
4444-fluid-HFS-LVB10	27 Aug 2008	2227	23.0°C	Axial – Marker 113/62	6087	2549	1,521 m	308°
4446-fluid-HFS-LVB10	29 Aug 2008	2101	43.4°C	MEF – S&M	4938	6013	2,189 m	249°
4449-fluid-HFS-LVB10	1 Sept 2008	1656	24.8°C	MEF – Hulk	5043	6243	2,197 m	324°
4453-fluid-HFS-LVB10	5 Sept 2008	1902	29.0°C	High Rise – Godzilla	5802	8335	2,135 m	268°

Sample summary:

6 large-volume bag samples

Table A6. Summary of major fluid samples for chemical analyses

Sample ID	Date	Time (UTC)	Fluid Temp.	Location	Local X	Local Y	Depth	Heading
4438-fluid-M23	21 Aug 2008	1806	303°C	MEF – Bastille	4859	6002	2,193 m	100°
4438-fluid-M24	21Aug 2008	1806	303°C	MEF – Bastille	4859	6002	2,193 m	100°
4438-fluid-M16	21 Aug 2008	1942	322°C	MEF – S&M	4929	5999	2,181 m	254°
4438-fluid-M10	21 Aug 2008	1942	322°C	MEF – S&M	4929	5999	2,181 m	254°
4438-fluid-M20	21 Aug 2008	2018	257°C	MEF – Sully	4886	5957	2,189 m	273°
4438-fluid-M22	21 Aug 2008	2018	257°C	MEF – Sully	4886	5957	2,189 m	273°
4447-fluid-M10	30 Aug 2008	1656	323°C	MEF – Dante	4977	6157	2,175 m	247°
4447-fluid-M16	30 Aug 2008	1656	323°C	MEF – Dante	4977	6157	2,175 m	247°
4447-fluid-M20	30 Aug 2008	1756	337°C	MEF – Dante	4986	6166	2,174 m	282°
4447-fluid-M22	30 Aug 2008	1756	337°C	MEF – Dante	4986	6166	2,174 m	282°
4447-fluid-M23	30 Aug 2008	1929	320°C	MEF – Hulk	5042	6256	2,187 m	157°
4447-fluid-M24	30 Aug 2008	1945	308°C	MEF – Hulk	5042	6246	2,188 m	357°
4448-fluid-M20	31 Aug 2008	1942	331°C	MEF – Lobo	4936	6172	2,188 m	166°
4448-fluid-M22	31 Aug 2008	1942	331°C	MEF – Lobo	4936	6172	2,188 m	166°
4451-fluid-M?	3 Sept 2008	1706	285°C	Sasquatch – Marker C	No nav.	No nav.	2,150 m	344°
4451-fluid-M?	3 Sept 2008	1706	285°C	Sasquatch – Marker C	No nav.	No nav.	2,150 m	344°
4451-fluid-M?	3 Sept 2008	1732	275°C	Sasquatch – X-mas Tree	No nav.	No nav.	2,153 m	229°
4451-fluid-M?	3 Sept 2008	1758	277°C	Sasquatch – Pico	No nav.	No nav.	2,152 m	305°
4452-fluid-M10	4 Sept 2008	1650	328°C	MEF – Hulk	5068	6262	2,191 m	185°
4452-fluid-M16	4 Sept 2008	1719	320°C	MEF – Hulk	5047	6247	2,188 m	356°
4452-fluid-M23	4 Sept 2008	1731	328°C	MEF – Crypto	5051	6219	2,201 m	095°
4452-fluid-M24	4 Sept 2008	1731	328°C	MEF – Crypto	5051	6219	2,201 m	095°
4452-fluid-M20	4 Sept 2008	2013	337°C	MEF – Dante	4983	6164	2,179 m	057°
4452-fluid-M22	4 Sept 2008	2027	321°C	MEF – Dante	4982	6166	2,179 m	104°
4452-fluid-M5	4 Sept 2008	2102	319°C	MEF – Dudley	5008	6124	2,191 m	157°
4452-fluid-M26	4 Sept 2008	2102	319°C	MEF – Dudley	5008	6124	2,191 m	157°

Sample summary:

26 major fluid samples

Table A7. Summary of gas-tight fluid samples for gas chemistry analyses

Sample ID	Date	Time (UTC)	Fluid Temp.	Location	Local X	Local Y	Depth	Heading
4438-fluid-GT18	21 Aug 2008	1731	99°C	MEF – Easter Island	4859	6027	2,195 m	229°
4438-fluid-GT2	21 Aug 2008	1756	303°C	MEF – Bastille	4859	6002	2,193 m	100°
4438-fluid-GT9	21 Aug 2008	1802	303°C	MEF – Bastille	4859	6002	2,193 m	100°
4438-fluid-GT17	21 Aug 2008	1907	72°C	MEF – Milli-Q	4899	5949	2,179 m	320°
4438-fluid-GT12	21 Aug 2008	1942	329°C	MEF – S&M	4929	5999	2,181 m	254°
4438-fluid-GT16	21 Aug 2008	2018	257°C	MEF – Sully	4886	5957	2,189 m	273°
4442-fluid-GT17	25 Aug 2008	2039	248°C	Axial – Virgin Mound	No nav.	No nav.	1,546 m	030°
4442-fluid-GT5	25 Aug 2008	2121	321°C	Axial – Inferno	No nav.	No nav.	1,547 m	297°
4442-fluid-GT15	25 Aug 2008	2121	321°C	Axial – Inferno	No nav.	No nav.	1,547 m	297°
4442-fluid-GT2	25 Aug 2008	2208	286°C	Axial – Hell	No nav.	No nav.	1,546 m	230°
4443-fluid-GT9	26 Aug 2008	1912	18°C	Axial – Marker 33	6546	3685	1,520 m	140°
4443-fluid-GT12	26 Aug 2008	2049	7°C	Axial - Cloud	6560	3693	1,522 m	237°
4444-fluid-GT15	27 Aug 2008	1933	334°C	Axial – Vixen	5709	1915	1,521 m	236°
4444-fluid-GT5	27 Aug 2008	1934	334°C	Axial – Vixen	5709	1915	1,521 m	236°
4444-fluid-GT7	27 Aug 2008	2005	304°C	Axial – Casper	5704	1924	1,538 m	158°
4444-fluid-GT17	27 Aug 2008	2007	304°C	Axial – Casper	5704	1924	1,538 m	158°
4444-fluid-GT16	27 Aug 2008	2211	26°C	Axial – Marker 113/62	6087	2549	1,521 m	308°
4445-fluid-GT16	28 Aug 2008	1734	246°C	Axial – Castle	6721	2890	1,510 m	-
4445-fluid-GT9	28 Aug 2008	1836	319°C	Axial – El Guapo	6779	2911	1,507 m	210°
4445-fluid-GT17	28 Aug 2008	1838	319°C	Axial – El Guapo	6779	2911	1,507 m	210°
4445-fluid-GT2	28 Aug 2008	2011	225°C	Axial – Diva	6795	2924	1,524 m	018°
4446-fluid-GT15	29 Aug 2008	1754	268°C	MEF – Salut	4873	5845	2,187 m	304°
4446-fluid-GT7	29 Aug 2008	2012	252°C	MEF – Puffer	4863	5979	2,193 m	112°
4446-fluid-GT12	29 Aug 2008	2155	326°C	MEF – S&M	4935	6002	2,181 m	249°
4448-fluid-GT16	31 Aug 2008	1938	331°C	MEF – Lobo	4936	6172	2,188 m	166°
4448-fluid-GT18	31 Aug 2008	2206	335°C	MEF – TP	4998	6187	2,191 m	311°
4448-fluid-GT2	31 Aug 2008	2207	335°C	MEF – TP	4998	6187	2,191 m	311°
4449-fluid-GT17	1 Sept 2008	1801	328°C	MEF – Hulk	5046	6262	2,191 m	179°
4449-fluid-GT9	1 Sept 2008	1913	332°C	MEF – Grotto	4939	6142	2,188 m	000°
4449-fluid-GT7	1 Sept 2008	2039	212°C	MEF – Cathedral	4848	5923	2,183 m	315°
4450-fluid-GT2	2 Sept 2008	1627	299°C	Mothra – Cauldron	4268	3544	2,249 m	090°

Sample ID	Date	Time (UTC)	Fluid Temp.	Location	Local X	Local Y	Depth	Heading
4450-fluid-GT12	2 Sept 2008	1947	303°C	Mothra – Cuchalainn	4126	3128	2,291 m	230°
4450-fluid-GT16	2 Sept 2008	2044	310°C	Mothra – Stonehenge	4103	3023	2,290 m	206°
4451-fluid-GT15	3 Sept 2008	1711	285°C	Sasquatch – Marker C	No nav.	No nav.	2,150 m	344°
4451-fluid-GT17	3 Sept 2008	1737	275°C	Sasquatch – X-mas Tree	No nav.	No nav.	2,153 m	229°
4451-fluid-GT7	3 Sept 2008	1800	277°C	Sasquatch – Pico/DK3	No nav.	No nav.	2,152 m	305°
4452-fluid-GT12	4 Sept 2008	1731	328°C	MEF – Crypto	5051	6219	2,201 m	095°
4452-fluid-GT18	4 Sept 2008	2100	319°C	MEF – Dudley	5008	6124	2,191 m	157°
4453-fluid-GT5	5 Sept 2008	1810	358°C	High Rise – Godzilla	5784	8331	2,137 m	179°
4453-fluid-GT12	5 Sept 2008	2108	352°C	High Rise – Boardwalk	5784	8292	2,136 m	281°
4453-fluid-GT17	5 Sept 2008	2110	352°C	High Rise – Boardwalk	5784	8292	2,136 m	281°
4453-fluid-GT18	5 Sept 2008	2138	332°C	High Rise – Park Place	5769	8239	2,138 m	130°

Sample summary:

42 gas tight fluid samples

Table A8. Summary of *Alvin* Niskin bottle samples for particle analyses

Sample ID	Date	Time (UTC)	Location	Local X	Local Y	Depth	Altitude	Heading
4447-fluid-Niskin-1	30 Aug 2008	1717	MEF – Dante	4977	6157	2,150 m	20 m	283°
4447-fluid-Niskin-2	30 Aug 2008	1717	MEF – Dante	4977	6157	2,150 m	20 m	283°
4447-fluid-Niskin-3	30 Aug 2008	1717	MEF – Dante	4977	6157	2,150 m	20 m	283°
4447-fluid-Niskin-4	30 Aug 2008	2003	MEF – Hulk	5047	6246	2,166 m	20 m	330°
4447-fluid-Niskin-5	30 Aug 2008	2003	MEF – Hulk	5047	6246	2,166 m	20 m	330°
4452-fluid-Niskin-1	4 Sept 2008	1631	MEF – Hulk	5040	6254	2,165 m	20 m	060°
4452-fluid-Niskin-2	4 Sept 2008	1631	MEF – Hulk	5040	6254	2,165 m	20 m	060°
4452-fluid-Niskin-3	4 Sept 2008	1631	MEF – Hulk	5040	6254	2,165 m	20 m	060°
4452-fluid-Niskin-4	4 Sept 2008	1631	MEF – Hulk	5040	6254	2,165 m	20 m	060°
4452-fluid-Niskin-5	4 Sept 2008	1631	MEF – Hulk	5040	6254	2,165 m	20 m	060°

Sample summary:

10 *Alvin* Niskin samples

Table A9. Summary of sulfide and basalt rock samples collected using *Alvin*

Sample ID	Date	Time (UTC)	Fluid Temp.	Location	Local X	Local Y	Depth	Heading
4438-extinct sulfide	21 Aug 2008	1635	-	MEF – E of S&M	5030	5954	2,205 m	194°
4438-active sulfide	21 Aug 2008	1816	282°C	MEF – Bastille	4860	6003	2,193 m	229°
4438-extinct sulfide	21 Aug 2008	2132	-	MEF – Salut	4847	5865	2,189 m	356°
4439-active sulfide	22 Aug 2008	2204	ND	MEF – Lobo	4925	6163	2,183 m	265°
4440-basalt	23 Aug 2008	1615	-	MEF – NE of Hulk	5047	6363	2,195 m	306°
4441-active sulfide	24 Aug 2008	1912	ND	MEF – Dante	4972	6147	2,196 m	-
4441-basalt	24 Aug 2008	2133	-	MEF – Dante	5047	6363	2,195 m	075°
4446-extinct sulfide	29 Aug 2008	1628	-	MEF – E of Salut	5030	5840	2,195 m	-
4446-active sulfide	29 Aug 2008	1735	79°C	MEF – Salut	4878	5842	2,185 m	334°
4447-active sulfide	30 Aug 2008	1852	ND	MEF – Dante	4980	6163	2,179 m	026°
4448-extinct sulfide	31 Aug 2008	2211	-	MEF – TP	4998	6187	2,194 m	311°
4449-extinct sulfide	1 Sept 2008	1630	-	MEF – E of Hulk	5057	6243	2,198 m	-
4449-active sulfide	1 Sept 2008	1938	300°C	MEF – Dante	4970	6148	2,186 m	356°
4450-active sulfide	2 Sept 2008	1737	321°	Mothra – Hot Harold	4162	3335	2,271 m	-
4450-extinct sulfide	2 Sept 2008	1829	-	Mothra – Faulty Tower	4171	3333	2,280 m	047°
4451-active sulfide	4 Sept 2008	1725	275°C	Sasquatch – X-mas Tree	No nav.	No nav.	2,153 m	229°
4451-basalt	4 Sept 2008	1836	-	W of Sasquatch	6700	11,315	2,155 m	-

Sample summary:

8 active sulfides, 6 extinct sulfides, 3 basalts

Table A10. Summary of CTD water column samples using 10-liter Niskin bottles

Sample ID	Date	Time (UTC)	Location	Latitude	Longitude	Depth	Temp.	Trans. %
AT1536001-3	19 Aug 2008	2100	Off-axis – Endeavour	47° 55.290	-129° 4.070	2,200 m	-	-
AT1536001-5	19 Aug 2008	2100	Off-axis – Endeavour	47° 55.290	-129° 4.070	2,200 m	-	-
AT1536001-11	19 Aug 2008	2100	Off-axis – Endeavour	47° 55.290	-129° 4.070	2,200 m	-	-
AT1536001-12	19 Aug 2008	2100	Off-axis – Endeavour	47° 55.290	-129° 4.070	2,200 m	-	-
AT1536001-17	19 Aug 2008	2100	Off-axis – Endeavour	47° 55.290	-129° 4.070	1,525 m	-	-
AT1536002-1	20 Aug 2008	2140	S. Main Endeavour	47° 56.990	-129° 6.119	1,923 m	1.960°C	88.00
AT1536002-2	20 Aug 2008	2144	S. Main Endeavour	47° 56.984	-129° 6.105	1,963 m	1.976°C	87.30
AT1536002-3	20 Aug 2008	2201	S. Main Endeavour	47° 56.934	-129° 6.025	1,917 m	1.961°C	88.54
AT1536002-4	20 Aug 2008	2203	S. Main Endeavour	47° 56.930	-129° 6.020	1,925 m	1.950°C	88.67
AT1536002-5	20 Aug 2008	2206	S. Main Endeavour	47° 56.918	-129° 6.012	1,982 m	1.960°C	87.60
AT1536002-6	20 Aug 2008	2220	S. Main Endeavour	47° 56.862	-129° 5.959	1,986 m	1.960°C	88.00
AT1536002-7	20 Aug 2008	2222	S. Main Endeavour	47° 56.856	-129° 5.955	2,023 m	1.921°C	88.69
AT1536002-8	20 Aug 2008	2227	S. Main Endeavour	47° 56.840	-129° 5.936	2,146 m	1.890°C	88.30
AT1536002-9	20 Aug 2008	2231	S. Main Endeavour	47° 56.830	-129° 5.923	2,104 m	1.905°C	88.10
AT1536002-10	20 Aug 2008	2243	S. Main Endeavour	47° 56.778	-129° 5.872	1,850 m	2.000°C	88.80
AT1536002-11	20 Aug 2008	2256	S. Main Endeavour	47° 56.724	-129° 5.830	2,159 m	1,876°C	88.30
AT1536002-12	20 Aug 2008	2258	S. Main Endeavour	47° 56.733	-129° 5.817	2,123 m	1.900°C	87.80
AT1536002-13	20 Aug 2008	2259	S. Main Endeavour	47° 56.726	-129° 5.805	2,100 m	1.907°C	87.90
AT1536002-14	20 Aug 2008	2301	S. Main Endeavour	47° 56.719	-129° 5.800	2,059 m	1.900°C	88.80
AT1536002-15	20 Aug 2008	2304	S. Main Endeavour	47° 56.713	-129° 5.800	2,000 m	1.923°C	88.80
AT1536002-16	20 Aug 2008	2306	S. Main Endeavour	47° 56.711	-129° 5.803	1,948 m	1.940°C	88.82
AT1536003-1	24 Aug 2008	0330	N. Main Endeavour	47° 56.949	-129° 6.221	1,958 m	1.958°C	87.48
AT1536003-2	24 Aug 2008	0334	N. Main Endeavour	47° 56.956	-129° 6.180	1,952 m	1.957°C	87.64
AT1536003-3	24 Aug 2008	0348	N. Main Endeavour	47° 56.955	-129° 6.154	2,045 m	1.937°C	87.87
AT1536003-4	24 Aug 2008	0353	N. Main Endeavour	47° 56.958	-129° 6.122	1,954 m	1.956°C	87.87
AT1536003-5	24 Aug 2008	0359	N. Main Endeavour	47° 56.967	-129° 6.071	1,810 m	2.061°C	88.62
AT1536003-6	24 Aug 2008	0405	N. Main Endeavour	47° 56.968	-129° 6.024	1,946 m	1.970°C	87.48
AT1536003-7	24 Aug 2008	0412	N. Main Endeavour	47° 56.969	-129° 5.965	2,108 m	1.927°C	88.08
AT1536003-8	24 Aug 2008	0423	N. Main Endeavour	47° 56.978	-129° 5.860	1,991 m	1,961°C	87.35
AT1536003-9	24 Aug 2008	0428	N. Main Endeavour	47° 56.978	-129° 5.869	1,981 m	1.961°C	87.35
AT1536003-10	24 Aug 2008	0436	N. Main Endeavour	47° 56.988	-129° 5.731	1,971 m	1.959°C	87.43

Sample ID	Date	Time (UTC)	Location	Latitude	Longitude	Depth	Temp.	Trans. %
AT1536003-11	24 Aug 2008	0443	N. Main Endeavour	47° 56.989	-129° 5.675	2,147 m	1.882°C	88.52
AT1536003-12	24 Aug 2008	0449	N. Main Endeavour	47° 56.997	-129° 5.631	1,998 m	1.948°C	87.72
AT1536004-1	26 Aug 2008	0422	Axial – S. Caldera	45° 55.573	-129° 58.814	1,506 m	2.368°C	87.56
AT1536004-2	26 Aug 2008	0424	Axial – S. Caldera	45° 55.573	-129° 58.814	1,495 m	2.344°C	87.69
AT1536004-3	26 Aug 2008	0427	Axial – S. Caldera	45° 55.573	-129° 58.814	1,468 m	2.398°C	87.72
AT1536004-4	26 Aug 2008	0432	Axial – S. Caldera	45° 55.573	-129° 58.814	1,420 m	2.440°C	87.82
AT1536004-5	26 Aug 2008	0436	Axial – S. Caldera	45° 55.573	-129° 58.814	1,369 m	2.504°C	87.90
AT1536004-6	26 Aug 2008	0439	Axial – S. Caldera	45° 55.573	-129° 58.814	1,320 m	2.567°C	87.97
AT1536004-7	26 Aug 2008	0444	Axial – S. Caldera	45° 55.573	-129° 58.814	1,220 m	2.819°C	88.08
AT1536005-1	27 Aug 2008	0356	Axial – ASHES	45° 55.972	-130° 0.809	1,527 m	2.440°C	-
AT1536005-2	27 Aug 2008	0400	Axial – ASHES	45° 55.972	-130° 0.809	1,518 m	2.399°C	-
AT1536005-3	27 Aug 2008	0401	Axial – ASHES	45° 55.972	-130° 0.809	1,506 m	2.400°C	-
AT1536005-4	27 Aug 2008	0403	Axial – ASHES	45° 55.972	-130° 0.809	1,490 m	2.414°C	-
AT1536005-5	27 Aug 2008	0404	Axial – ASHES	45° 55.972	-130° 0.809	1,481 m	2.414°C	-
AT1536005-6	27 Aug 2008	0405	Axial – ASHES	45° 55.972	-130° 0.809	1,470 m	2,414°C	-
AT1536005-7	27 Aug 2008	0407	Axial – ASHES	45° 55.972	-130° 0.809	1,460 m	2.416°C	-
AT1536005-8	27 Aug 2008	0408	Axial – ASHES	45° 55.972	-130° 0.809	1,450 m	2.422°C	-
AT1536005-9	27 Aug 2008	0410	Axial – ASHES	45° 55.972	-130° 0.809	1,430 m	2.461°C	-
AT1536005-10	27 Aug 2008	0412	Axial – ASHES	45° 55.972	-130° 0.809	1,400 m	2,492°C	-
AT1536005-11	27 Aug 2008	0417	Axial – ASHES	45° 55.972	-130° 0.809	1,299 m	2.650°C	-
AT1536006-1	28 Aug 2008	0804	Axial – CASM	45° 59.330	-130° 1.636	1,560 m	2.339°C	87.99
AT1536006-2	28 Aug 2008	0806	Axial – CASM	45° 59.330	-130° 1.636	1,545 m	2.357°C	88.05
AT1536006-3	28 Aug 2008	0808	Axial – CASM	45° 59.330	-130° 1.636	1,520 m	2.355°C	88.10
AT1536006-4	28 Aug 2008	0810	Axial – CASM	45° 59.330	-130° 1.636	1,495 m	2.363°C	88.12
AT1536006-5	28 Aug 2008	0812	Axial – CASM	45° 59.330	-130° 1.636	1,470 m	2.386°C	88.08
AT1536006-6	28 Aug 2008	0814	Axial – CASM	45° 59.330	-130° 1.636	1,445 m	2.383°C	88.23
AT1536006-7	28 Aug 2008	0816	Axial – CASM	45° 59.330	-130° 1.636	1,420 m	2.488°C	88.23
AT1536006-8	28 Aug 2008	0818	Axial – CASM	45° 59.330	-130° 1.636	1,395 m	2.509°C	88.36
AT1536006-9	28 Aug 2008	0820	Axial – CASM	45° 59.330	-130° 1.636	1,370 m	2.538°C	88.36

Sample summary:

60 Niskin water column samples