

**R/V Atlantis-Alvin AT15-9
Endeavour Segment
Juan de Fuca Ridge**

SENSORS 2006



August 25-September 12, 2006

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Cruise Summary and Acknowledgements: This cruise was highly successful with all 16 dives completed. All sulfide microbial incubators were recovered, and analyses of temperature data and fluid chemistry from Osmosamplers indicate that the experiments worked extremely well the entire year yielding definition of steep thermal and chemical gradients within the individual chambers. Onboard culturing and preservation of microbial material from the incubators will be analyzed over this next year, in concert with coregistered temperature, fluid chemistry, and mineralogical data to examine the extreme conditions under which life thrives, survives, and expires within the walls of active black smoker chimneys. A suite of poor-man incubators was recovered, and numerous instruments were deployed in the Main Endeavour and Mothra Hydrothermal Fields. Novel in situ Raman and Excitation-Emission Matrix spectrometers were successfully tested on six dives, with several spectra data sets obtained in black smoker and diffuse flow fluids. For the first time since 2000, all five hydrothermal fields were visited and sampled for fluid and volatile chemistry to continue a decade-long study of thermal and chemical changes in venting fluids along the Endeavour Segment. An intense CTD night program documented significant changes in hydrothermal plume characteristics along the Endeavour Segment since 2005, and a new hydrothermal site was discovered south of the Mothra Hydrothermal Field. During the final dive of the program a significant stockwork system with massive sulfide, reminiscent of mine deposits, was discovered near an area where plume anomalies were also detected. This stockwork may be the largest yet documented along mid-ocean ridge spreading centers in the Pacific Ocean. Five members of the science party dove to the seafloor in Alvin for the first time.

We are very grateful to the crew of the Atlantis and Alvin for their hard work and professionalism and to the Captain of the Atlantis, A.D Colburn, for making this cruise a success.

**AT15-9 ALVIN ATLANTIS PROGRAM TO THE ENDEAVOUR
SEGMENT OF THE JUAN DE FUCA RIDGE****

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****SAMPLE LOCATIONS, INSTRUMENT LOCATIONS AND RECOVERY AND DEPLOYMENTS, AND
TRANSPONDER AND CTD LOCATIONS ARE PROVIDED ON THE CD INCLUDED WITH THIS REPORT**

SENSORS 2006 Personnel

University of Washington

Deborah S. Kelley	Chief Scientist
Marvin D. Lilley	Co-Chief Scientist
Mitch Elend	Oceanographer
Deborah Glickson	Student
Jonathan Kellogg	Student
Mathew Lilley	Student
Min-Hui Lin	Student
Brian Marquardt	Scientist
Deirdre Meldrum	Scientist
Eric Olson	Oceanographer
Kevin Roe	Oceanographer (NOAA)
Wes Thompson	Student

Harvard University

Peter Girguis	Scientist
Spencer Nyhom	Scientist
Helen White	Scientist

Arizona State University

Jeff Cramer	Scientist
Yoon-Chang Kim	Scientist
Michelle Meighan	Student

University of Alaska

Geoff Wheat	Scientist
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University of Missouri

Mitch Schulte	Scientist
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University of Massachusetts

Jim Holden	Scientist
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China

Huaiyang Zhou	Scientist
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Captain Atlantis

A.D Colburn

Alvin Crew

Patrick Hickey	Expedition Leader
James Brennan	Tech
Sean Kelley	Tech
Michael McCarthy	Tech
Mark Sprear	Pilot
Bruce Strickrott	Pilot

1.0 SUMMARY OF CRUISE ACCOMPLISHMENTS:

This cruise was highly successful thanks to the hard work of the Atlantis and Alvin crew and the science party. All objectives of the program were accomplished and the success of the microbial incubator project exceeded expectations. Each instrument worked the entire year documenting steep thermal and chemical gradients within the four discrete chambers in the incubators. Minerals that precipitated in the individual chambers were sampled shipboard in concert with material for culturing of microbes and phylogenetic analyses. Culturing onboard yielded numerous positive cultures with some organisms precipitating magnetite. The Arizona State-UW instrumentation program was also very successful: the Raman and Excitation-Emission Matrix spectrometers were deployed on six dives and spectra were obtained in diffuse and high temperature fluids. Temperature-resistivity-hydrogen probes were recovered from two of the hydrothermal fields, each documenting changes in these environmental parameters over the year-long deployment. For the first time since 2005 all five vent fields were sampled for fluid and volatile chemistry. Preliminary results indicate continued changes in the Main Endeavour Field and High Rise Fields following the 1999-2000 diking-seismic events. An intense CTD program at night showed significant changes in hydrothermal plume characteristics since 2005. Near the end of the dive program an distinct plume anomaly was found south of the Mothra Hydrothermal Field, indicating another site of venting. The final dive of the program dove in this area, and although an active site of venting was not found, an area hosting extinct sulfides and a massive stockwork system along the faulted axial valley walls was discovered. The following discussion provides a more detailed overview of the work completed during this dive program, followed by descriptions of individual dives.

1.1 EXAMINING THE EXTREME CONDITIONS OF LIFE WITHIN THE WALLS OF BLACK SMOKER CHIMNEYS (KELLEY, LILLEY, GIRGUIS, WHEAT, UW-HARVARD-U ALASKA)

This project was a central component of this cruise, with 10 dives dedicated to recovery of microbial incubators deployed in 2005, cycling of the incubators and redeployment. The focus of this study is to examine 1) the extreme conditions under which microbial communities thrive, survive and expire within the walls of actively venting sulfide chimneys and 2) to characterize the microbes within these habitats in the context of the co-registered environmental measurements. This project is centered on the use of novel next-generation in situ microbial incubators that were designed, fabricated and deployed as part of this grant. This year marks the first full year field component of this NSF-funded RIDGE project: it was extremely successful. Because the incubators are the first instruments of their kind to be deployed in the worlds oceans, there were significant engineering and environmental challenges to surpass to obtain the difficult measurements outlined in the original proposal and so there was some risk that the instruments would fail. However, in every way possible this year has been a huge success.

During 2005, three next-generation incubators were built that included four discrete chambers each instrumented with nine thermocouples. Two chambers, typically the outer and inner third chamber were instrumented with OsmoSamplers for continuous, time-series sampling of hydrothermal fluid within the chambers, and the third inner chamber also contained a gold-palladium-based in situ hydrogen sensor. Two of these incubators were deployed for 1 year in black smokers in the Mothra and Main Endeavour hydrothermal fields. One instrument that was deployed in 2005 was recovered at the end of a 6-week expedition for short-term times series measurements.

During this 2006 cruise, we successfully completed all dives and recovered both in situ microbial incubators. Additional poor-man incubators (a single temperature probe and two Osmosamplers) were recovered, and new ones were deployed back into experimental holes in the structures Roane and Giraffe in the Mothra field, and Hulk in the Main Endeavour Field. This showed that 1) the instruments can be recovered after 1-year deployments into high temperature sulfide chimneys and 2) that the drill holes can be re-instrumented multiple times for time-series measurements of fluid and mineral chemistry, temperature and microbial community evolution.

In summary, the field, instrument, and sampling component of this program went exceedingly well and the initial results are extremely promising and exciting. We completed all of the initial goals set out in the field component of this project and over this next year we will be working to complete co-registered analyses of mineralogy, temperature, chemistry (rock and fluid) and sequencing and culturing of microbial material. This work forms the foundation for a master's student of Kelley and Baross (Minhui Lin) - it is expected that she will continue this work for her Ph.D. This project also is a component of postdoctoral work for Eric Cordes, a postdoc at Harvard under the mentorship of Peter Girguis.

Our ten-day Alvin program in August-September 2006 went extremely well with all major goals achieved. In addition to the successful recovery of both microbial incubators, several poor-man incubators equipped with OsmoSamplers and a temperature probe were deployed, recovered, and new ones deployed for another year-long period. Although these simpler instruments do not provide as detailed measurements as the fully instrumented ones, they are a relatively easy way to obtain time-series measurements of some fluid chemistry, mineral precipitation/chemistry, temperature and microbiological evolution. These instruments will be recovered in 2007 on a Girguis field program using Alvin. The poor man incubators are also used as an easy way to obtain a larger volume of sulfide-microbial material for testing and optimization of protocols, which can then be applied to the more valuable, but less abundant material recovered from the fully instrumented incubators. During the cruise we also recovered sulfide material from vigorously venting black smoker chimneys, and sampled vent fluids from all five fields on the Endeavour Segment. This was accomplished in collaboration with Marvin Lilley who brought 6 additional days of Alvin time through an NSF funded program to Booksh.

Material from the incubators was immediately recovered and subsampled in nitrogen-filled glove bags. Sulfide-anhydrite materials were used to inoculate five types of growth medium designed to enrich for hyperthermophilic sulfur and iron reducers. In addition to insert samples, five other sulfide samples were also used as inoculums in the same set of medium. During the cruise, all sulfide materials were subsampled and processed for use in future experiments. Materials were 1) flash-frozen in liquid nitrogen for later DNA extraction, 2) fixed in 4% paraformaldehyde overnight and preserved in 70% EtOH for microscopy study, and 3) inoculated with sulfide or sulfide slurry in 5 types of medium at three temperatures for isolation experiments. A total of 100 tubes were inoculated and incubated at 70°C, 90°C, or 100°C.

A critical component of this project concerns optimization of protocols for DNA extraction. Now that these protocols have been established, we will begin to work with the more valuable samples to characterize the microbial communities within each of the incubator chambers. Once all of the sequences are available, primers for quantitative PCR will be developed and certain phylotypes will be enumerated. We are also investigating different methods for verifying the results of the qPCR assays including cell counts using DAPI staining and FISH techniques as well as dot-blot hybridizations. The effort that has gone into the optimization of extraction, purification, amplification, and sequencing of the target genes from the incubator samples should allow us to generate data more efficiently in the coming year. The co-registered temperature data will also be more thoroughly processed using fourier-transform analyses to examine tidal variation in temperature (and fluid chemistry). Geoff Wheat will also be completing geochemical analyses of major and trace element fluid chemistry. Kelley and Lin will continue mineralogical and chemical analyses of mineral precipitates that crystallized during the year-long deployments.

2005-2006 Findings

- During the Alvin recovery cruise August-September 2006 we successfully completed all dives and recovered both instruments. Additional poor-man incubators (a single temperature probe and two osmo samplers) were deployed back into the holes in the structures Roane and Giraffe in Mothra, and into Hulk in the Main Endeavour Field. This showed that 1) the

instruments can be recovered after 1-year deployments into high temperature sulfide chimneys and 2) that the drill holes can be re-instrumented multiple times for time-series measurements of fluid and mineral chemistry, temperature and microbial community evolution.

- Both of the recovered incubators in Hulk and Giraffe worked the entire year, each measuring >750,000 temperatures. Preliminary processing of the temperature data show that the instruments measure well defined gradients both within individual chambers, as well as throughout the chimney wall. The ability to measure well defined gradients is central to the success of this experiment.
- The OsmoSamplers worked exceedingly well resulting in the first time, year-long measurement of co-registered fluid chemistry and temperature within the walls of active smokers. Chemistry of the fluids correlates well with implied environmental conditions from the temperature data. For example, the outer chambers exhibit lower temperatures consistent with significant mixing between hydrothermal fluid and seawater. The corresponding chemistry shows high Mg concentrations, reflecting influx of seawater. High-temperature (300°C) fluids in the inner chambers show near zero Mg concentrations, consistent with measurement of end-member hydrothermal fluids. Geoff Wheat has already processed a significant number of samples for chemistry.
- One of the in situ hydrogen probes functioned for most of the deployment. Laboratory calibration will be completed to backtrack in situ hydrogen concentrations.
- Newly precipitated sulfide and anhydrite material was successfully recovered from both instruments for follow-on petrographic, geochemical, and microbiological analyses. Preliminary results show distinct gradients in model mineralogy, consistent with the temperature data (i.e. the outer chambers are rich in anhydrite and sulfide, while the inner chambers are dominated with higher temperature sulfide phases). Sr and oxygen isotopic analyses of the anhydrite will yield important information on seawater-hydrothermal mixing ratios. These data will be important for evaluation of redox conditions and the presence of specific groups or species of archaea and bacteria.
- Synthetic and natural sterile materials placed immediately adjacent to thermocouples were successfully recovered from both instruments and processed onboard for culturing and phylogenetic analyses. Material was used to inoculate five types of growth medium designed to enrich for hyperthermophilic sulfur and iron reducers. Onboard culturing successfully yielded growth of organisms from some of the chambers. Work on these cultures, as well as cultures, obtained from newly precipitated material is ongoing.
- Preliminary recovery of DNA from some of the chambers for sequencing has been highly successful. Although it has only been two months since recovery of the instruments, this test phase has allowed optimization of DNA extraction procedures. These test runs yielded enough material for 16s rDNA clone library construction for both archaea and bacteria. Preliminary results show gradients in community makeup, consistent with the temperature and fluid data. These results also show that contamination from seawater-based organisms is likely minimal within the inner chambers.

Using sulfide material from the incubators and other materials collected a total of 100 tubes were inoculated and incubated at 70°C, 90°C, or 100°C. Twenty-six tubes showed signs of growth, 18 transfers were attempted at sea, of which 14 showed growth. Enrichment cultures are currently being analyzed and

maintained. DNA has been extracted from the two outermost chambers of the year-long deployment in Hulk. Archaeal and Bacterial 16s rDNA clone libraries have been constructed and are currently being analyzed.

In addition to this collaborative effort among Kelley, Girguis, and Wheat, the Girguis lab also completed several complementary studies on animals and sulfides. A summary of their studies includes:

- A microbial fuel cell deployed in 2005 was successfully recovered from Roane (Dive 4230). The data were downloaded and preliminary analyses indicate that energy was generated. Samples from the anode and cathode were taken for microbial analyses.
- Tube worms were collected by Alvin and maintained in pressure vessels aboard the *R/V Atlantis*. After a series of time points ranging from 24 to 96 hours, tube worms were preserved for further gene expression studies.
- Paralvinella sp.* worms and associated bacteria were collected and preserved for further genomic and gene expression studies.
- A short-term incubator tracer study was completed using a poor man incubator containing zirconium beads with a HOB0 (S/N 112) and Osmosampler. The experiment was deployed in Roane (Dive 4233) and recovered a week later (Dive 4240).
- High temperature sulfide incubation experiments were attempted on material recovered from sulfides recovered in the Main Endeavour, High Rise, and Sasquatch hydrothermal fields. The first two attempts at incubating sulfides from Sully and Boardwalk failed because the system did not hold pressure. Modifications were made and a successful incubation of a sulfide sample from Sasquatch (Dive 4236) was performed for 64 hrs.

1.2 TESTING OF FIELD-PORTABLE RAMAN AND EXCITATION-EMISSION MATRIX (EEM) SPECTROMETERS (LILLEY, MARQUARDT UW; BOOKSH, ASU)

The Booksh lab group focused on developing two instruments capable of in situ analysis of hydrothermal vents. Although these sites can be analyzed via sampling, the handling involved can corrupt results. Field-portable Raman and Excitation-Emission Matrix (EEM) spectrometers were developed. Raman spectra gathered from previous cruises did not yield quantifiable data; therefore, a means of signal enhancement via silver nanoparticles was developed for the current cruise. The goal of the Raman research was to study the sulfide emitted from both diffuse and smoker vents, whereas the goal of the EEM research was to study the organics emitted from diffuse vents.

During this program members of the Booksh lab group went on three dives: 4234, 4239, and 4244. The Raman was taken on all three dives, while the EEM was only taken on the last two. The first two dives were to Main Endeavor, and the last dive was to Salty Dawg. Vents studied include S&M, Easter Island, Peanut, Hulk, Lobo, Grotto, Grendel, and Salty Dawg with temperatures ranging from 6°C to 339°C. Data analysis of the spectra was required and involved Principal Component Analysis to reduce some of the spectral noise.

1.3 ABUNDANCES AND DISTRIBUTION OF MICROBES IN BLACK SMOKER CHIMNEYS (HOLDEN UMASS)

The purposes of the experiments conducted on this cruise were to determine the abundances and relative spatial distributions of three metabolic groups of well-known hyperthermophiles in sulfide deposits and to enrich for new strains. The three metabolic groups of hyperthermophiles are autotrophic iron reducers (e.g., Pyrodictiaceae, Archaeoglobaceae), methanogens (e.g., Methanococcales, Methanopyrales), and

sulfur-reducing heterotrophs (i.e., Thermococcales). More specifically, the purposes were to determine 1) whether autotrophic iron reducers are the predominant crenarchaeon found in the interior of sulfide deposits, 2) whether methanogens are very in low abundance in these samples relative to iron reducers, and 3) whether there is an inverse relationship between iron reducer and heterotroph abundances with heterotrophs more abundant near sulfide outer surfaces where macrofauna provide a rich source of organic compounds.

The nature abundances of these three groups of hyperthermophiles will be determined using three-tube Most-Probable Number (MPN) estimates of samples incubated at 90°C and fluorescent in situ hybridization (FISH) cell counts from samples preserved in 4% paraformaldehyde and stored at 4°C in 50% ethanol in phosphate-buffered saline. Eleven samples were analyzed during this cruise. Seven were hydrothermally-active sulfide deposits, three were sulfide deposit-hosted diffuse fluids (4.5°C to 140°C), and one was from *Paralvinella sulfincola* polychaete worms. Three of the sulfide samples came from the Main Field (Sully, Dudley, and Hulk), two were from Mothra (Giraffe and Faulty Towers), and two were from High Rise (Boardwalk). The diffuse fluid samples came from S&M (140°C), Phang (48°C), and Roane (4.5°C). The worm sample came from Faulty Towers. Preliminary analyses indicates that there was successfully enrichment for hyperthermophilic, autotrophic dissimilatory iron reducers and hyperthermophilic heterotrophs. The remaining analyses will be conducted in Holden's lab in the Department of Microbiology at the University of Massachusetts, Amherst.

1.4 TIME-SERIES INVESTIGATIONS OF HYDROTHERMAL PLUMES ON THE ENDEAVOUR SEGMENT (KELLOGG, UW)

As part of a time-series experiment to examine temporal and spatial variation in hydrothermal plumes along the Endeavour Segment, intense CTD operations were conducted at part of the night program onboard the R/V Atlantis (Appendix X). A total of 18 stations were sampled during CTD operations with the last four stations dedicated to finding a new hydrothermal field ~ 3 km south of the Mothra Hydrothermal Field. Significant differences exist between hydrographic transects made in the summers from 2004 to 2006. Along and across axis sections describe the hydrographic conditions above the segment in three dimensions. The resulting sections allow for rapid evaluation of the characteristics of the neutrally buoyant plume over each of the vent fields and its location relative to the ridge axis. Results indicate heat content over the northern vent fields, Salty Dawg and Sasquatch, significantly increased between the summers of 2004 and 2005. In 2004, the plumes over these vent fields were barely discernable while in 2005 prominent plumes existed with potential temperature anomalies over 0.1°C. At the time of a rapid response cruise in March 2005, no significant change in the heat content of the water column was detected. By July 2005, dramatic changes had occurred in the overlying water column structure. The potential temperature anomaly section from 2005 is indicative of a thicker (about 75 m) neutrally buoyant plume with and substantially more heat at the north end of the valley. In 2004, the shallowest plume depth was 1900 m contrasted with 1830 m in 2005. New data collected during this cruise indicate that the intense plume above Salty Dawg had diminished to pre 2005 values. This work forms the focus of Jonathan Kellogg's masters project.

1.5 STUDENT AND YONG RESEARCHER TRAINING AND DEVELOPMENT

Four graduate students, one undergraduate student, and three postdoct's participated on this cruise. The microbial incubator work is the focus on Minhui Lin's (a student of Kelley's) master's work. She helped prepare for the cruise and prepared all materials critical to her masters project that were required for onboard analyses and preservation. She also dove for the first time in Alvin and took the lead in writing up the dive summary for that dive. Matthew Lilley is completing his undergraduate double degree in Geology and Archeology at the University of Washington. Matt was a participant on this Alvin program, and also dove for the first time in Alvin. During the cruise, he received training in CTD operations, data

archiving, and navigation. He is working in Kelley's and Baross's labs where he is being trained in the use of GIS, culturing of microbial material, and sequencing.

Helen White also participated on the cruise as a postdoc of Peter Girguis's and also dove for the first time in Alvin. Helen received training in seagoing operations, and in sampling and processing of materials recovered from the sulfide microbial incubators.

2.0 DIVE SUMMARIES

August 25th Friday

The Atlantis left Astoria Oregon a bit delayed (1000) due to numerous fishing boats in the shipping lane and dense fog. Atlantis steamed towards the work site: during the day safety meetings, fire and boat drill, and Alvin briefings were held. We arrived on the worksite early in the morning on the 26th, in time for the launching of Alvin. A summary of dive operations is provided in Table 1 and CTD night operations in Appendix 1.

Table 1. Dive participants and location

Dive #	Date	Pilot	Co-Pilot/Stbd Observer	Port Observer	Location
4230	26-Aug-06	Patrick Hickey	Debbie Kelley	Min Lin	Mothra
4231	27-Aug-06	Mark Spear	Marv Lilley	Deborah Glickson	Main Endeavour
4232	28-Aug-06	Bruce Strickrott	Eric Olson	Geoff Wheat	Main Endeavour
4233	29-Aug-06	Patrick Hickey	Deborah Glickson	Mitch Schulte	Main Endeavour
4234	30-Aug-06	Mark Spear	Sean Kelley (PIT)	Michelle Meihgan	Main Endeavour
4235	31-Aug-06	Bruce Strickrott	Brian Marquardt	Deidre Meldrum	Main Endeavour
4236	1-Sep-06	Patrick Hickey	Marv Lilley	Deborah Glickson	Sasquatch - JdF
4237	2-Sep-06	Mark Spear	Brian Marquardt	Wes Thompson	Main Endeavour
4238	3-Sep-06	Bruce Strickrott	Marv Lilley	Matt Lilley	High Rise
4239	4-Sep-06	Patrick Hickey	Sean Kelley (PIT)	Michelle Meihgan	Main Endeavour
4240	5-Sep-06	Mark Spear	Deborah Glickson	Spencer Nyholm	Mothra
4241	6-Sep-06	Bruce Strickrott	Eric Olson	Huiyang Zhou	Main Endeavour
4242	7-Sep-06	Patrick Hickey	Marv Lilley	James Holden	Mothra
4243	8-Sep-06	Mark Spear	Brian Marquardt	Helen White	Main Endeavour
4244	9-Sep-06	Bruce Strickrott	James Brennan	Jeff Cramer	Salty Dog
4245	10-Sep-06	Patrick Hickey	Deb Kelley	Mitch Eland	New Vent Site

The first dive was un-navigated: transponders were deployed on the second dive. All transponders were recovered at the end of the program.

2.1 August 26, 2006 Dive 4230 Mothra Hydrothermal Field, Faulty Towers Complex

Pilot Pat Hickey

Port: Debbie Kelley

Stbd: Min Lin

Summary:

Alvin arrived on bottom at 16:50 (x=4345, y=3277, alt=253, depth=2256, hdg=250)-the dive was a bit delayed due to weather. Alvin arrived almost on top of the Faulty Towers Complex and then traversed to the T-R-H₂ sensor in Hot Harold (x=4345, y=3278, alt=5.1, depth=2269, hdg=226). The probe was not no longer inserted in the orifice. Pat noted that the surface of the probe was clean and commented that perhaps it had only fallen out of the orifice recently. After inspecting the resistivity probe briefly, Alvin transited to Giraffe, where the sulfide microbial incubator #2 had been deployed on September 8, 2005. At 17:02 (x=4179, y=3301, alt=178, depth=2268, hdg=300), Alvin arrived at Giraffe. The exterior part of the incubator was completely covered with white microbial mat. After positioning the sub closer, Pat pulled on the side T-handle of the incubator to attempt to retrieve the incubator from the chimney (17:08, x = 4178, y=3303, alt=178, depth=2266, hdg=315). The incubator was well cemented into the chimney. Pat moved the manipulator to grab and pull on the rear T-handle. The insert stayed in place. He then grabbed the Titanium case itself and rotated the incubator. At 17:18, the stop plate had come loose from the Titanium case. An attempt was made to pull on the stop plate, however, this was not successful. We discussed redesigning the incubator for easier retrieval after long-term deployment in the future. At 17:33, the decision was made to leave the incubator in place for now so we could accomplish other goals planned for this dive.



Sulfide microbial incubator at Giraffe.

At 17:36, we arrived back at Hot Harold where the resistivity probe was deployed (x=4170, y=3312, alt=179, depth=2271, hdg=123). There was a new growth chimney that had formed since res probe deployment last year. The maximum temperature recorded from the vent fluid at the new growth was 320.4°C. A piece of the new growth was collected and placed in the biobox (time = 17:40:28, x=4171, y=3311, alt=4.1, depth=2271, hdg=106). Two vent fluid samples were collected from the center of the orifice with a black gas tight and a blue gas tight at 17:45:25 and 17:46:50, respectively. Then a blue major sample was taken at 17:51:46. At 17:56:07, Marv's T-R-H₂ probe was recovered from Hot Harold.

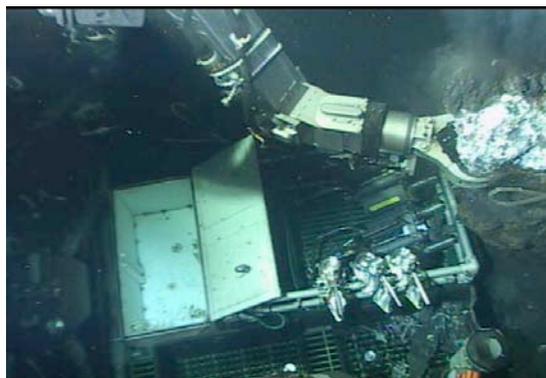
After recovering the resistivity probe Alvin transited towards Roane and Girguis' bug battery instrument was observed at the base of Roane (time=18:11:00, x=4164, y=3293, alt=, depth=2276, hdg=217). We looked around the base of Roane to find a smoker to sample vent fluid. At 18:14:27, we spotted a small black smoker east of Roane base, which was named "Shishi" on this dive (x=4164, y=3293, alt=1.6, depth=2276, hdg=18). The maximum temperature reading form Shishi was 322.7°C. The short chimney

was very crumbly. Pat broke the chimney to open up the conduit before taking a yellow major water sample (time=18:32:01, x=4164, y=3294, alt=2, depth=2276, hde=50). The major sampler was drawing fluid very slowly at first, but fluid flow into the sampler eventually picked up. Pat noted there seemed to be hot fluid through the sampler. An orange gas tight sample were taken from the same orifice at 18:34:25.

After the fluid samples were collected, we headed towards the top of Roane and saw the poor man's incubator with osmo samplers still in place after one-year deployment (time=18:44:32, x=4161, y=3294, alt=193, depth =2272, hdg=8). The sulfide directly above the poor man's insert was covered with white microbial mats. Before recovering the poor man's incubator, we conducted an imaginary survey of **Finn**. After the survey, a piece of Finn was collected from the top of the structure (time=18:58:00, x=4159, y=3290, alt=135, depth=2269, hdg=183). A small tubeworm bush was collected from the same location shortly after that (time = 19:00:00).



New growth of Finn colonized with tube worms.



Sampling of sulfide collected at Hot Harold.

At 19:09:55, Alvin arrived back near the top of Roane. At 19:15:15, the poor man's incubator along with the Osmosampler was recovered (x=4160, y=3294, alt=4.9, depth=2273, hdg=11). A dummy plug was then inserted into the same borehole to keep the hole open for future deployment at the site. At 19:21:00, the poor man's incubator was secured in the basket. We then descended to the base of Roane to recover Girguis' microbial battery (time = 19:26:03, x = 4160, y= 3291, alt=1.3, depth=2276, hdg=16). At this point all dive goals except for the microbial incubator recovery had been accomplished. It was decided that the microbial incubator would be recovered on a subsequent dive. Before ending the dive, we went hunting for homer#45 that could not be pinned earlier. At 19:32, we had visual sighting of the homer at the right location above a seismometer (x=4191, y=3343, alt=217, depth=2272, hdg=45). However, it was discovered this homer was #10 and not #45 as noted in the dive plan, which was why we could not pin it before. At 19:36:04, we dropped weight and left the bottom.



Poor man's incubator at the top of Roane.



Microbial battery at the base of Roane.

2.2 August 27, 2006 Dive 4231 Main Endeavour Field

Pilot: Mark Spear

Port Observer: Marv Lilley

Stbd Observer: Deb Glickson;

Summary:

Our dive target was ~150 m east of the clearing in MEF. We landed over 300 m east of the clearing in a collapse feature (pillars, heavy sed, small extinct chimneys), and traversed toward Grotto (1616). We traversed over pillows and talus, then went upslope over a large wall with chopped up-looking basalts (1635). In an area of heavy sedimentation, we crossed over a fissure that was probably the main fissure of the field (1642). A few minutes later, we saw the seismometer's data logger and pressure sensor (1644). We identified the homer on the seismometer logger as Homer #97, then reset the doppler to X=4913, Y=6115, the coordinates of the homer from last year (1646). We placed Tim's hydrophone about 30 m south of the data logger and 5 m south of Marker MD (X=4897, Y=6072) for a day of ambient noise collection (1708). This area had pillow mounds with breadcrust texture, and some were younger-looking with less sediment.

We turned back to the east to pick up the fissure and drive south to S&M (X=4986, Y=6068), passed over sheet/lobate covered in sediment. We passed Marker CU, extinct chimneys, and more markers we couldn't read on the stbd side (1730-1734). Somehow we missed the fissure and drove over talus and pillows before reacquiring the fissure (1739). We then passed S&M on its east side, then another structure (1743). We got lost and decided to drive west to the wall. We soon found a chimney we thought was Peanut, with Marker 1L(?) at X=4814, Y=6030, before turning to the south. We then drove to the east and passed over a large depression filled with sediment and a toppled basalt pillar (1800). We arrived at Puffer (Marker U), surrounded by pillows and old sulfide (1812). After continuing to the east, we went over a drop off and realized we were lost and that the Doppler did not seem accurate. We headed back west to reacquire the wall and passed many old sulfides (1822).

We arrived at Marker DK1 north of Milli-Q and found the Doppler was off by X=40 m, Y=15 m (1832). After reaching Marker Az (also at Milli-Q), we headed 330° to Sully and traversed over lobate, pillows, and sediments. We got a visual on Tara (Marker T) at X=4836, Y=6009 (1845), then arrived at Sully (1850; X=4827, Y=5993, Z=2189). We reset the Doppler to X=4890, Y=5960 for Sully (1856). We began a video survey of the structure, with both pan&tilts facing the same direction with a bit of basket in view (1900-1915). We took a high temperature probe of the orifice above the resistivity probe (max 347.6°C; hdg=267; 1925), then took a yellow major pair (1936), a yellow gas tight (1941), and a red gas tight (1942). We then recovered the pig and res probe (1950), and deployed the materials tester in the orifice (X=4886, Y=5957, Z=2190; 2009). Our last task was an Imagenex survey of Sully at a constant depth of 2187 m (2020-2024).

Alvin headed north along the fissure, heading to Hulk (2047; X=4912, Y=5941, hdg=73). There were 4-5 extinct sulfide chimneys in the fissure from the starboard side. We passed Dante on the left, but decided to skip imaging the top of Dudley due to time constraints (2058). Somehow we went north rather than 020° and ended up wandering around the ridge NW of Hulk (X=4854, Y=6125, Z=2173; 2105-2122). We used Homer #15 at Gremlin to correct our approach and arrived at Gremlin.

The high temperature probe measured 318.5°C at the resistivity probe orifice. We recovered the res probe and fired the blue major pair (2201; ICL 313.4°C), the red&black gas tight (2204; ICL 318.5°C), and the blue gas tight (2205; ICL 318.5°C) in the orifice. We then attempted to recover DeeDee's materials test but could not reach it. We recovered the resistivity probe pig and looked for Wheat's Osmosampler. By the time we found it, covered in macrofauna, we had to leave the bottom.



Hydrophone measuring ambient noise.



Resistivity probe at Sully encased in sulfide.



Taking toaster sample at Sully.



Homer, and resistivity probe at Gremlin.

2.3 August 28, 2006 Dive 4232 Main Endeavour Field

Pilot: Bruce Strickrott

Port Observer: Eric Olson

Starboard Observer: Geoff Wheat

Summary:

Alvin landed east of the open expanse between the north and south vent clusters in the Main Endeavour Field. Upon transiting towards the seismometer and attached Homer an old PVC piece of equipment was discovered at the base of the fault scarp (16:14 X 5112, Y 6027). It was left in place. Upon arrival at the Homer/seismometer/pressure sensor the Doppler navigation was re-set to the coordinates provided (X 5055 Y 6067, re-set Doppler X Y to 4913 6115). A search for the hydrophone was begun looking 10 m on a heading of 190. The hydrophone was found at 37 m on a heading of 190. From there Alvin transited up the Easter Island gap into the Bastille complex. Several loops were made in search of the U and P markers (to signify Puffer). Marker B was seen and an attempt was made to position the sub at Puffer on the basis of this marker.

Following observation of Marker B (actually at Bastille) a structure with visible vents and a bench was selected for work. The hydrophone was deployed as detailed in the instructions after some excavation with sulfide put on starboard side of the basket (17:53 X 4863, Y 5977, re-set Doppler as Doppler reads quite different. Surface navigation provided a fix that was in good agreement with the map but poor agreement with the Doppler- the Doppler was re-set again. Port side overlays went out. Subsequent to leaving the hydrophone site to the southeast, Markers P and U were located, indicating the vent Puffer. Upon review, it seems likely that hydrophone was at the southernmost of the two Peanut spires. Sully marker and vents were observed on the starboard side as Alvin left the complex. The sub transited

northeast to Dudley and quickly observed Marker B9. A worksite was discovered for vent cap deployment. Alvin hi-temperature measurements gave 327°C and water samples were taken (major pair and two gas-tights: blue gt-audible, orange gt-audible 18:33 X 5002, Y 6096). The vent cap was successfully deployed, making a good seal after excavation and recovery of sulfide to the port side of the basket. The microbial pagoda was placed to the right of the vent cap in nearby tubeworm patch.



Hydrophone deployed at Peanut.



Vent cap & colonization experiment on Dudley.

A transit to Hulk (homer 15 on RAS) followed deployment of the vent cap. At Hulk the sulfide incubator was located on the east face (19:30 X 5029 Y 6033). The incubator was imaged after the sub was set up for removal. The incubator was removed and the poorman's insert emplaced. Following the instrument swap a search was commenced for the Osmospike. The nearby RAS and attached floatation made a search of the likely area too hazardous to approach for detailed search. A search for the objects left on Gremlin was undertaken but the location of Gremlin was again proximal to the RAS sampler and not well enough identified to allow a search in the appropriate site. The remaining power was consumed without success. A game of basket chess ensued in getting the incubator's data logger aboard and the Osmosampler package deployed.



Microbial incubator in Hulk.



Over view of the poor man incubator.

2.4 August 29, 2006 Dive 4233 Mothra Hydrothermal Field

Pilot: Pat Hickey

Port: Deb Glickson

Starboard: Mitch Schulte

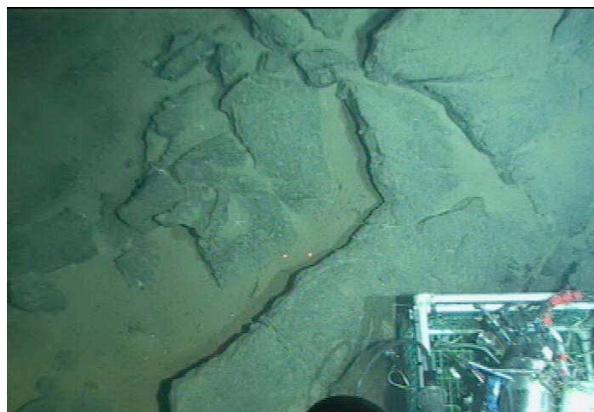
Summary:

Alvin reached the sea floor approximately 74 m east of Homer 10 at 1615 GMT. After driving, we arrived at the homer at 1620, and proceeded to Faulty Towers. We passed the benchmark at X=4182, Y=3332 at Pinocchio at 1623 and reset the Doppler. Imaging of Hot Harold took place for several minutes beginning at 1625. At 1635 we arrived at Roane, where we recovered the dummy plug and the osmo sampler deployed there. The poor man's incubator was inserted into Roane at 1642, and the plug was stuck into the quiver. After working feverishly for a number of minutes and a great deal of swearing, Pat successfully loosened the sulfide insert from Giraffe at 1704. Because the dummy plug had to be extracted from the quiver, there was more swearing, but it was successfully extracted and placed into the biobox. The sulfide insert, logger and osmo sampler were placed into the basket at 1719.

At 1728, we began our traverse up the western wall, on a heading of 300°. On that transect we went over a bench and fell into a 4m deep depression which had sheet flows, lobate flows and some bathtub rings. We went over another ridge at 1751 and into another collapse with similar features to the previous one. We started to head back down into the valley on a heading of 51°. A massive sheet flow was observed on the starboard side on the way down, and a sample of basalt was collected at 1804. Alvin then transitted into an area of brecciated basalt with extinct sulfide structures at X=4083, Y=3648, depth=2203 meters. The sheet flow was sampled at 1820; we continued to go down slope over a brecciated basalt ridge and went over a 9 m wall of mostly intact pillow basalts. We arrived back in the valley at 1838 and turned to the north.



Massive flows



Moderately sedimented sheet flows.

While traversing northward there were numerous collapse features and another extinct sulfide field (smaller than the previous one, and like Mothra with no flanges) at X=4325, Y=4053, depth=2258 m. Two more samples, a basalt pillar and a ropy flow, were taken at 1856 and 1909, respectively. Heading at 315° from X=4400, Y=4340, depth=2225 meters at 1925, we observed lots of talus, pillows and moderate to heavy sediment. At 1940, we turned due east to cross the valley (from X=4311, Y=4456, depth=2205 m). As Alvin drove east through the valley, lots of collapse features, coherent sheet flows and bathtub rings were evident. One basalt pillar was approximately 15 m tall. Our final sample, of a highly altered basalt, was taken at 2004 (X=4502, Y=4483, depth=2229 m). We reached the top of a sheet flow at 2007 and climbed ropy sheet flows. There were pillows down a meter or two, and then we went into a collapse basin. We climbed the pillows and talus onto a ridge and ended the dive at 2015.



Pillar marked by bathtub rings.



Hydrothermal sediment and highly altered basalt.

2.5 August 30, 2006 Dive 4234 Main Endeavour Field

Pilot: Sean Kelley

Port: Mark Spear

STBD: Michelle Meighan

Summary:

Alvin landed near Homer 97 (4871, 6110) and set the doppler to those coordinates. We then got slightly lost trying to find S&M. We passed marker 117 and CV. We ended up in the valley so we headed slightly further south, climbed the crevice on our right and were S&M. While at S&M we took a blue major (time 1800) water sample, and two gas tights (yellow @ 1808, red @ 1818), and deployed Zhou's vent cap (1830) and his basket (time 1839). The temperature of the smoker was 273°C. We then collected a Raman spectrum (1845). Our coordinates for the S&M activities were 4882, 6054, 2192.



Taking gas-tight sample at S&M.



Raman collection at S&M.

From S&M, Alvin transited to Easter Island, passing markers CG+CH (1937), and CB (1944). We collected Raman spectra from a diffuse vent at Easter Island (1955 4862, 6003, Z = 2194) with a temperature of 21°C. We then left Easter Island and transited south to Peanut at 2034 (4863, 6012, Z = 2196). The hydrophone and pig were moved farther away from the vent by approximately 1.5 meters. A toaster sample was taken at 2053 at this location as well. After working Peanut, Alvin traveled north to Gremlin by following the talus wall. At 2140, we recovered the Osmosampler. Skinny tube worms were gathered at 2148, while looking for DeeDee's materials test experiment. At 2157, we located DeeDee's experiment, attached to the Y marker, removed it, as well as the closest Homer (97). Alvin departed Gremlin at 2212 and left bottom.

2.6 August 31, 2006 Dive 4235 Main Endeavour Field

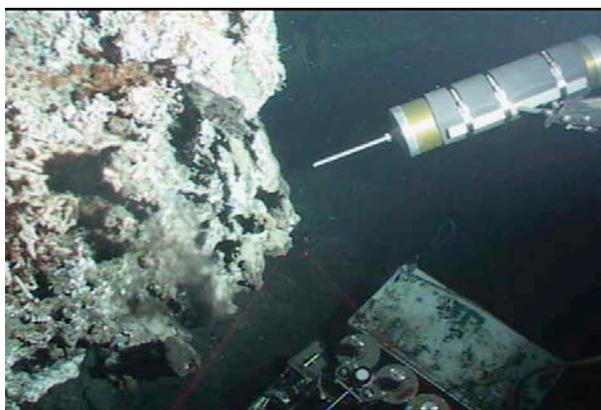
Pilot: Bruce Strickrott

Port Observer: Brian Marquardt

Starboard Observer: DeeDee Meldrum

Summary:

Alvin landed between the north and south clusters within the Main Endeavour Field. From our landing area Alvin drove east to the fissure and followed it south until reaching S&M. At S&M we set up to perform Raman measurements at a flange on the NE side of the structure at a depth of 2193 m ($x=4935$, $y=6000$). The water temperature coming from under the flange with the high temperature probe was 140-150°C. Five Raman spectra were collected in this flow. Another high temperature was collected closer to the flange lip at 305°C. A Raman spectrum was collected in this flow. The red major pair was also collected at S&M in the initial diffuse flow area (18:03). The bottle temperature reading during collection was 130°C. The left side of the bottle worked properly but the right side failed on triggering and could not be retriggered.



Raman analysis at S&M flange (140-150°C).



Collecting tube worms at S&M.

From S&M Alvin drove to Easter Island and arrived at the site at 18:27. We setup at Easter Island at a hdg of 296 ($x=4935$, $y=6001$). Using the high temperature probe a temperature of 22°C was measured in diffuse flow at a slow flowing site with some tube worms. At 18:41 we deployed the Raman instrument for collection at Easter Island. Two Raman data sets were collected at the site. At approximately 18:50 the navigation computer froze and it had to be restarted. Because of this there are two sonar files for the dive (d4235 and d4235a). At 19:12 we left Easter Island to return to S&M.

Alvin arrived at S&M at 19:24 to survey the structure for healthy tube worms. We collected worms at S&M on hdg 093 about 2/3 of the way up the structure. Two large clumps of worms and attached sulfide were sampled and they were placed in the bio box. The tube worms sampled were mostly red and alive at the time of collection. Alvin left S&M for Hulk at 19:35.

Arrived at Hulk at 20:02 after passing Dudley to the East en route at 19:51. After arriving at Hulk we landed at a small smoker at a heading 184 approximately 1/3 up the structures on the North side (20:08). Took a high temperature of the smoker (315.8°C) and the proceeded to deploy the toaster approximately 8" above the orifice. Toasted for 8 minutes (20:16 – 20:24). After replacing the toaster in the basket the yellow major pair was fired in the smoker with a temperature of 315.5°C. The Raman instrument was deployed in the same smoker and three data sets were collected at the site (2 Hulk sets and one background set off to the side of the sub in 4°C water). Alvin left Hulk for Gremlin at 21:06.

At 21:15 we reached what we thought was Gremlin near marker “H” close to the base of the RAS probe. A temperature of 23°C was measured at a diffuse flow site. We deployed the Raman instrument into diffuse flow and worms at this site and collected three sets of Raman data. Alvin left the site at approximately 21:50 to survey for sulfide near Crypto. At the north side of Crypto, sulfide was collected at 22:10. A small black smoker was found on Crypto at a hdg of 077. A temperature of 77°C was measured near the bottom of the structure and 300°C was measured at the top. An attempt was made to collect the chimney but was not easily reached. With time was running out, Alvin dropped weights at 22:30 for the surface.



Raman measurement at a 315.5°C smoker at Hulk

2.7 September 1, 2006 Dive 4236 Sasquatch Hydrothermal Field

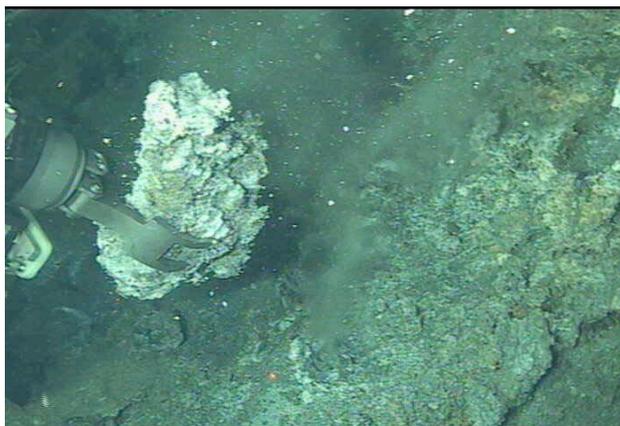
Pilot: Pat Hickey

Port Observer: Marv Lilley

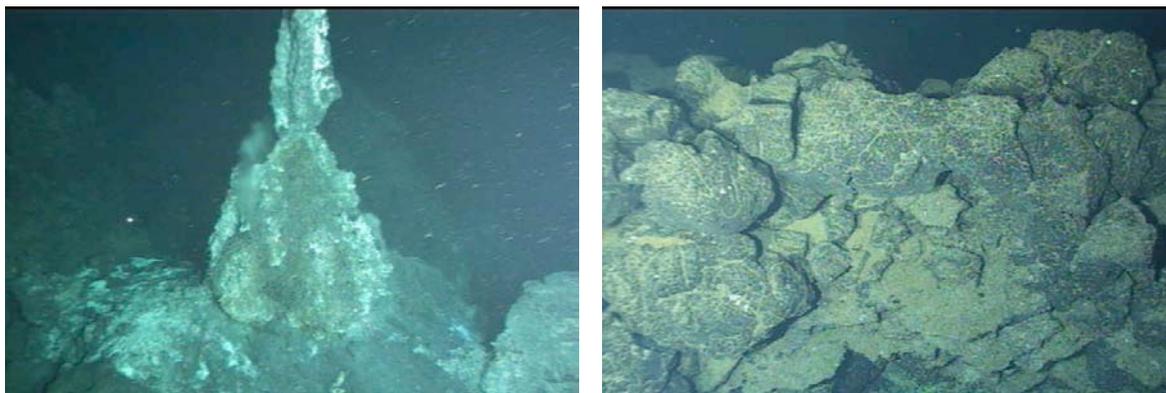
Starboard Observer: Deborah Glickson

Summary:

Alvin landed southeast of the field in an area of pillow talus, old sulfide, and heavy hydrothermal sediment. Alvin transited ~30 m to the Pico vent site (Marker DK3), which had not grown at all since the last visit in 2005, but the upper chimney was 3-4 m high. Facing 91°, another small active chimney was visible from the starboard window that was growing out of talus and surrounded by a small ring of diffuse flow. A pillow wall was also to stbd. We broke the chimney off Pico vent to sample, but no good vent orifice was found (1628, X=7313, Y=11508). Homer 22 was deployed and the upper part of the chimney was sampled. The high temperature probe measured 283.7°C (ICL 285°C); we collected fluid samples with the blue major pair, and the red and black, and blue gas tights (ended at 1649, X7312, Y=11507).



Alvin drove at 240° to another 2-3 m high chimney (1652, X=7296, Y=11500, Z=2153) that was on top of a ridge of basalt or sulfide. When parked in front of it, another 6 m high chimney was to starboard. At 1655, we deployed Marker C at the 2-3 m high chimney and knocked over an orifice for sampling. The high temperature probe measured 289.1°C. We fired a yellow gas-tight, black gas-tight, and green major pair (X=7297, Y=11500, Z=2151, 1659-1702). We then deployed the HOBO high temperature probe, which is set to sample for 542 days. There was a small vent below the area we were sampling. At the 233° angle we were facing, we could see a wall of pillows, tubeworms, and ciliates.



The overlay on the video died while we were turning around to look for Marker DK2 (which we never found). We traversed over pillows and sulfide, and further south 100% basalt with no sulfides. We drove up to the site of the 6 m tall chimney, which was next to another 3-4 m chimney and a 1 m tall Xmas tree beehive structure. We called the taller structure Late Bloomer, and decided this vent site may have been the one sampled for microbiology last year. At 1735, we set up in front of the smaller chimney (X=7289, Y=11505, Z=2154) and measured fluids of 252°C with the high temperature probe. Fluid samples were collected using the yellow major, an orange gas-tight, and a red gas-tight (1740-1744). We then collected the top of the chimney for sulfide and tubeworms (1745). These chimneys are sitting on top of sulfide, and Marker C is above and to starboard. Alvin set up on the other side of the Xmas tree vents (71°C, X=7285, Y=11503, Z=2155) and collected another clump of sulfide with short, fat tubeworms (1805).

We drove 74° back to Pico vent, where we deployed the toaster for 10 minutes (X=7309, Y=11507, Z=2153, 1810-1820). The overlays were lost on the port side at 1810, and the starboard side was lost at 1815: the computers were shut down and restarted. At 1908, we moved Homer #22 to the top of the ridge above Pico vent and sat around to reset the Doppler at DK3.

We started running the Imagenex survey at 1913 by making the Homer the center of a 100 m grid. At 1919, we headed for the first corner, but lost bottom lock and had to reset the Doppler to LBL. At 1922, we lost bottom lock again. At 1927, we reset the Doppler to LBL at X=7279, Y=11465. As we started on the survey, on the starboard side there was a >10 m tall extinct sulfide, Marker C was then passed to starboard and Late Bloomer was directly beneath Alvin.

We surveyed until 2020, as which point Alvin left bottom. The LBL and Doppler were offset from one another in the X direction, but very good in Y. While the LBL would normally be trusted, Pat indicated that the turns he made during the survey look closer to the Doppler track.

2.8 September 2, 2006 Dive 4237 Main Endeavour Field

Pilot: Mark Spear

Port Observer: Brian Marquardt

Stbd Observer: Wes Thompson

Summary:

Alvin touched down at 1620 hours at X=5016 Y=6310 and a depth of 2209 m. We landed just above a large fissure; unclear if this was the main fissure in MEF. Alvin drove south-east to Hulk and a search was initiated for the RAS sampler and Osmo sampler. The RAS sampler was quickly found, but the Osmo sampler was more difficult. There was no depth given for the location of the Osmo sampler so we circled Hulk at different depths for about an hour. Finally, a small instrument was observed a couple feet from the RAS sampler.

We assumed that the small instrument was the Osmo Sampler, however it was too close to the RAS sampler to be safely retrieved. Alvin drove to what was thought to be Gremlin and proceeded to collect Raman data at 1757 hours. We collected 3 exposures in a patch of tubeworms with the Alvin external lights off; these were finished at 1802 hours. The Raman probe had moved out of the diffuse flow area we had chosen, and was repositioned deeper into the tubeworm patch and 3 new exposures were collected, this time with slightly different accumulation parameters (3 exposures, 3 accumulations at 20 seconds). It was noticed that there was a possible fluorescence spectra in the data from the tubeworms waving in front of the probe. This sampling experiment was finished at 1815 hours and a temperature measurement was attempted. While the temperature was being established, a background Raman spectra were collected from the basket with the Alvin lights on and video of the RAS probe and Osmo sampler was collected (1822 hours). The temperature of this diffuse flow was too low for the high temperature probe to measure so a new location was found on Gremlin: a temperature of 9.8°C was measured at this site. After the temperature was determined, the Raman probe was grabbed by the starboard manipulator. Mark had some trouble getting a good grip on the T-handle, but using both manipulators he managed to finally get it and Raman spectra was collected from this location at 1846 hours.



Collecting Raman spectra in tube worm patch.



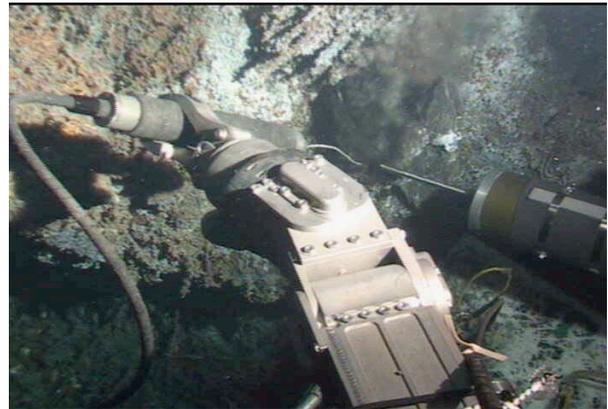
Vent cap at Dudley hosting a small chimney.

Subsequent to collection of the raman spectra, Alvin drove to Dudley at 1902 hours. The vent cap was found at 1909 and significant time was spent collecting video and still imagery of the vent cap and the colonization experiment. There was a small chimney growing on the Vent cap that was ~6–8 inches tall. It was not clear if there was flow coming from the bottom of the cap, but it appeared that the majority of flow was through the top. The bio experiment was well positioned and was covered in limpets and well within diffuse flow.

At 1919 hours temperature data were collected from diffuse flow near the top of Dudley with a temperature of $\sim 28^{\circ}\text{C}$. Raman spectra were collected in this diffuse flow site at 1921 hours. During this period, an XY fix from the ship was obtained and the navigation was reset to $X=4993$ $Y=6139$. Our position was only about 15 meters off. Some fluorescence was noticed in the data, probably again from the worms. A second collection at this location started at 1928 hours. Seven minutes into the spectra collection it was noticed that the worms were causing a large disturbance in the spectra collection so the external lights were turned on briefly to move the probe slightly out of the worms. Just below this diffuse site there was a small group of smokers that looked promising for Raman, so Mark repositioned the sub to sample this area. The temperature of the smokers was 310°C . Mark put the Raman and high temperature probes two inches above the orifice of the smoker at the same time and found water that was 75°C . Raman spectra were collected here, starting at 1955 hours.



Microbial colonization experiment at Dudley



Collection of spectra a temperature data at Dudley

At 2008 hours we finished collecting spectra and moved the probe slowly out of the plume to allow it to slowly equilibrate to a lower temperature, hopefully not cracking the sapphire sphere. The Yellow Major was fired at this smoker with a temperature of 303.5°C at 2013 hours. Following sampling at Dudley, Alvin drove to Milli-Q, arriving at 2050. The computer inside the Raman instrument was not communicating with the laptop, so the power was cycled to the instrument. While it was rebooting, the temperature on a flange was measured as 128°C . On the edge of the flange, temperatures were less, $\sim 50-70^{\circ}\text{C}$. Raman spectra were collected here at 2112 hours. Two minutes later the external lights were turned back on to reposition the probe after we drifted out of the higher temperature water. Collection of Raman spectra finished at 2131 hours and before we flew off to Cathedral, we collected tubeworms from near the top of Milli-Q at a depth of 2182 meters.



Collecting a fluid sample.



Making a tube worm collection at Milli-Q.

Alvin arrived at Cathedral at 2154 and rapidly found a small white smoker venting fluids at 267°C. The green major was fired in this fluid at 2203 with a temperature of ~260°C. Raman spectra were collected at 2208 and 2220 from two slightly different locations in smokers.

An attempt was made to grab sulfide samples from Cathedral, but they were crushed when trying to put them into the bio box. At 2232 the weights were released; we were not able to recover the Hydrophone or deploy toasters on this dive.



Collection of Raman spectra at Cathedral

2.9 September 3, 2006 Dive 4238 High Rise Hydrothermal Field

Pilot: Bruce Strickrott

Port Observer: Marvin Lilley

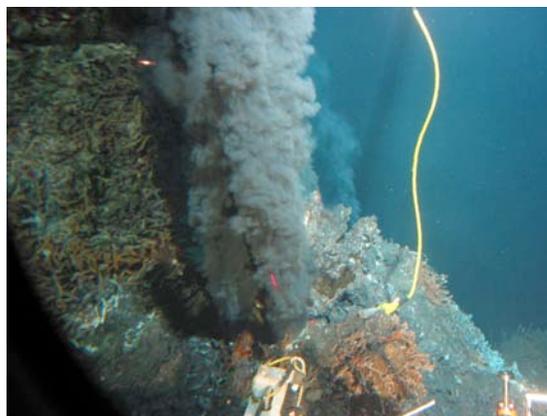
Starboard Observer: Matthew Lilley

Summary:

Alvin reached bottom at 1617 (x=5606, y=8445, z=2172) and began looking for Godzilla. The first smoker edifice found, however, was Boardwalk first. At 1645, a yellow major pair (1655) and yellow and blue gas tights (1702, 1705) were sampled with a temperature of 356°C. The 'Y' triangle marker was deployed 1.5 meters left of the sample site. At 1728, Alvin arrived at a structure tentatively believed to be Godzilla (lbl x=5790, y=8314). However, Marv believed the structure was too small to be Godzilla, but there was a smaller structure to the east that may have been Bambi (putting Alvin at the correct chimney). A red major pair (1735) and red and red-black gas tights (1743, 1740) were sampled, as was a toaster (1749-1754). Marker 'T' was placed adjacent to the sample site, closest to the sampled orifice.



Sampling at Boardwalk.



Sample site at Godzilla. Base of marker is at right.

At 1759, Alvin headed south towards Fairy Castle. Alvin ($x=5775$, $y=8129$) followed talus slope (1812) leading to a basalt wall with visible layered flows, and began ascending; the wall extends up to 2160 m. At 1847, Alvin arrived Fairy Castle ($x=5697$, $y=8122$, $z=2147$) and a blue major pair (1900) and 2 (black, orange) gas tights (1907, 1909) were sampled with a corresponding fluid temperature of 350.8°C. At 1911, the Doppler was reset to Alvin LBL, giving a location 77 m west of known XY for Fairy Castle.

At 1921, Alvin began a transit to Clam Bed to look for Huaiyang's baskets that had been previously deployed in 2005. At 1927, Alvin transited across a heavily sedimented lobate flow ($x=5545$, $y=7899$, $z=2183$). An extinct smoker ($x=5530$, $y=7862$) with patches of dead tubeworms nearby was found at 1930. Further south ($x=5521$, $y=7850$) there was diffuse flow with live tubeworms and crabs. At 1937 the navigation computer froze again, and the navigation was reset to $x=5500$, $y=7843$. At 1948 a black smoker with flanges was observed. After nearly 15 minutes of looking for Huaiyang's baskets, they could not be found and Alvin moved south missing Lion's Head, possibly passing Clam Bed on way. At 2006, two buckets of unknown origin were found, located in the middle of a tubeworm field ($x=5460$, $y=7703$, $z=2184$). These were recovered and put in the biobox. At 2041 the DVLNAV navigation was reset to $x=5385$, $y=7272$.

Alvin began at transit south and at 2053, a small field was found that was believed to be Raven ($x=5270$, $y=7076$). At 2100 the navigation completely failed. At 2112, with batteries funning out an attempt was made to sample what was believed to be basalt, however, on the surface, it was clear that this was a large, extinct sulfide sample. Subsequent to sampling, Alvin dropped weights to return to the surface. ascent.



Unknown buckets at Clam Bed ($x=5460$, $y=7703$, $z=2184$)

2.10 September 4, 2006 Dive 4239 Main Endeavour Field (Pit Dive)

Pilot: Sean Kelly

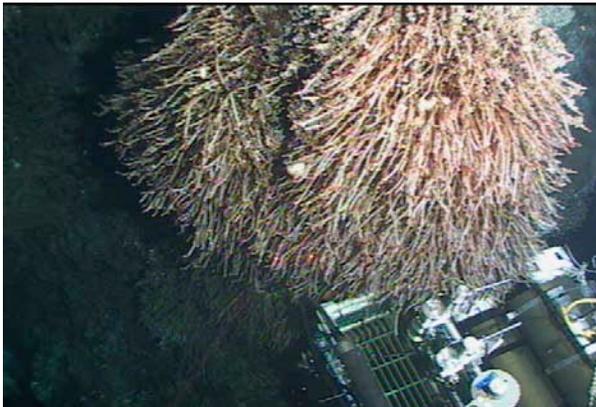
Port Observer: Pat Hickey

Starboard Observer: Michelle Meighan

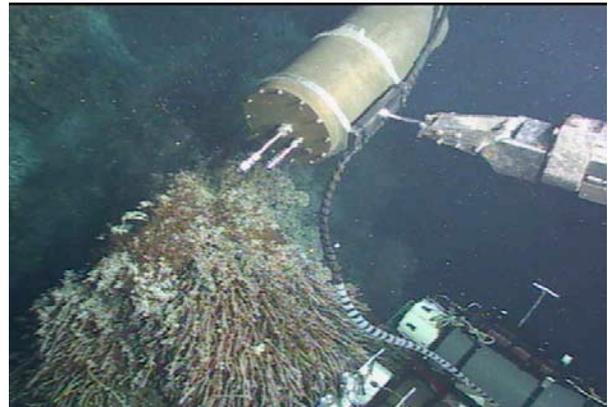
Summary:

Alvin began the descent at 1455 and landed at 1621 ($x=5160$, $y=6240$, and $Z=2207$) in an area that was mostly large pillow basalts. From there, Alvin headed toward Hulk to look for the osmosampler. After radioing up, we were informed that we were on the wrong side of the structure, and that we needed to move to the west side. We recovered the osmosampler at time 1647 (5057, 6264, 2188). While on the northwest side of Hulk, we collected Raman and EEM (Excitation Emission Matrix Spectroscopy) measurements. We also sampled two areas with this field, which were covered with thin, yellow-orange

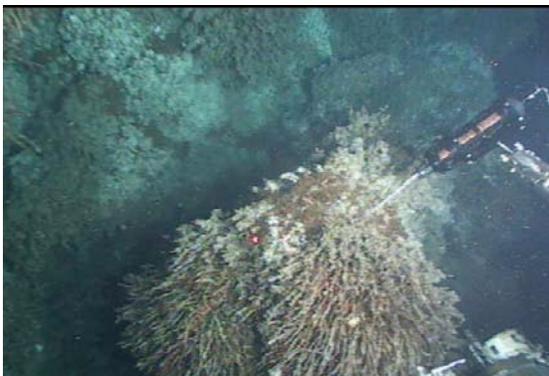
tube worms. Temperatures at the sampling sites were 6°C and 17°C. Following work at Hulk, Alvin drove to a good diffuse site on Lobo by following the talus wall south and west from Hulk (4956, 6210, 2191). The site was a large structure with a large “field” of tube worms (figure 5). Both Raman and EEM spectra were gathered at times 1808 and 1835, respectively at a temperature of 10°C. At 1849, we departed Lobo and headed towards Grotto (4945, 6154, 2188). The diffuse vent had a temperature of 15°C and EEM spectra were taken. Alvin moved to a smoker on a nearby structure (4930, 6139, 2188), with a fluid temperature of 339°C (figure 9). A blue major was taken at 1932, a red and black gas tight at 1937, and a blue gas tight at 1940 (figures 10 and 11). Two Vemco probes were also recovered from this site at time 1916. A Raman spectrum was also collected. We departed for the surface at 2012. We failed to reach Cathedral or Milli-Q due to lack of power.



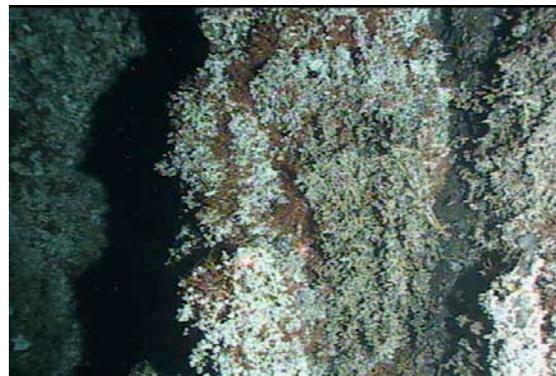
Site sampled at Hulk.



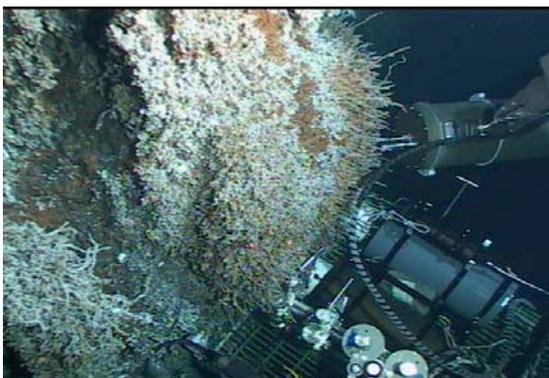
EEM measurements at Hulk.



Site sampled at Lobo



Site of EEM measurements at Lobo



Raman at Lobo



Diffuse Structure at Grotto



Black smoker at Grotto.



Taking double major (blue) at Grotto.



Taking gas-tight sample at Grotto.

2.11 September 5, 2006 Dive 4240 Mothra

Pilot: Mark Spear

Port Observer: Deborah Glickson

Starboard Observer: Spencer Nyholm

Summary:

Our dive target was ~70 m east of Faulty Towers in the Mothra Hydrothermal Field. Alvin landed at 1610, about ~100 away from Homer 10 near the short-period seismometer in a terrain of jumbled, ropy flows. We could not get a good Homer hit. Alvin drove at 290° until it reached lobate flows intermixed with sheet flows: good hits with from the homer started coming in. In response, we took a new heading of 215°. At 1626, we reached the Homer and seismometer and went west until we reached Marker M-1 at Twin Peaks (1640). Alvin turned south and reached Faulty Towers, passing the benchmark at Pinocchio on the way.

Alvin traveled along the west face of Faulty Towers to Roane, but we couldn't set up due to a strong current (1659). Alvin circled around again, got set up (1708, X=4157, Y=3298, Z=2273), and tried to brush away the clump of tubeworms at the top of Roane (1725). They refused to budge, so we sampled water around them, firing the yellow (1727) and black (1730) gas tight samplers and a green major (1735) bottle just above the tubeworms. This sample was very diffuse with an ICL temperature of 4.5°C (note, we found out at the surface that the yellow gas tight fired in the basket and sucked up a rubberband). With sampling completed, we prepared to recover the short-term osmosampler from the hole at Roane, but the HOBO snapped off the milk-crate osmo/bug battery instrument we were to deploy (1743). We removed the poor man's insert from Roane and placed it in the basket, to be moved into the biobox (1745). The rest of the package went into the basket (1749). The milk crate was deployed on top of

Roane first (1753, X=4157, Y=3299, Z=2273), then deployed the poor man's insert (1805). At 1810, we pulled out the second intake – the osmosampler spike – and tried to deploy it. We traveled a meter or so down the side of the chimney looking for a good place before realizing that the red Tygon tubing going to the insert was caught on the basket. While trying to untangle it, we pulled the milk crate off the top of Roane.



OsmoSampler-poor man incubator on top of Roane.



Small orifice on structure north of Giraffe.

While recovering from that, the spike got wrapped around the basket as well. At 1840, with lots of equipment and cable tangled up, we talked to Deb Kelley topside and decided to not deploy the milk crate at all. We gathered everything aboard at 1844 and went on to Giraffe.

We looked for Giraffe, and found a newer looking chimney that we thought might be the chimney. This chimney turned out to be the one north of Giraffe, but it had a nice beehive that we tried to knock off (1911). When we did that, a whole chunk of the chimney, including many nice tubeworms, disintegrated. We relocated to the real Giraffe, found a beehive about 4-5 m down and proceeded to knock it away and look for the hole (1928, X=4165, Y=3309, Z=2268). At 1936 we probed the hole with the high T probe and decided to try the insert. We began to deploy the insert, but could not get it to seat horizontally. We looked for other holes, but at 2007 went back to our first hole. The insert repeatedly went in partway at a high angle, and since the osmosampler was supposed to dangle below it, we decided not to deploy it. Running out of power, we went to the Tower to find some tubeworms for Spence Nyholm. A few worms sampled, along with some palm worms (2047), before we left bottom.



Poor man incubator part way in Giraffe.



Sampling tube worms and palm worms.

2.12 September 6, 2006 Dive 4241 Main Endeavour Field

Pilot: Bruce Strickrott

Port Observer: Eric Olson

Starboard Observer: Huaiyang Zhou

Summary:

Alvin landed east of the open expanse between north and south vent clusters. The vehicle transited up the scarp face towards the seismometer and Homer 97. Upon arrival at the homer, seismometer, and pressure sensor, the Doppler navigation was re-set to the coordinates provided (X=4904 Y=6118). The nearby pressure sensor was quickly recovered. From here the sub transited up the Easter Island gap into the Bastille complex (16:23).



Pressure sensor in MEF prior to recovery.



Hydrophone at Peanut.

Several loops were made in search of the U and P markers (to signify Puffer). Puffer was located and water samples (major blue pair, and orange gas-tight) were taken after using the high temperature probe to measure a temperature of 356°C. The sampling complete, Alvin turned and set up on Peanut (X= 4829 Y = 6020 17:06). Here, water samples (red/black and blue gas-tights, yellow major) were collected after measuring 327.6°C with the high temperature probe and the hydrophone array was recovered.



Vent cap at S&M hosting large chimney.



Diffuse flow area in the Raven field

The next transit was to Dudley with a stop at S&M for visual inspection of the vent cap deployed there. It was noted that a very large chimney had grown in that vent cap. Following the fissure north towards Dudley, Alvin came to Dante. A new bearing brought the sub to Dudley (4974, 6126 18:17). The small plastic microbial incubator (pagoda in notes) was recovered and a temperature of 3°C measured in it's immediate location. The large titanium vent cap was freed from the vent with a largely intact sulfide chimney. Some chimney was knocked into the open biobox but the cap was quickly secured into a milk crate with minimal disturbance of the attached sulfide. A yellow gas-tight was taken (19:03).



Extinct sulfide chimneys in the Raven field.

The long-term vent cap was deployed on the same orifice (X = 5005 Y=6114 19:12). A new pagoda was deployed nearby and tube worms collected (to the biobox) from that location. After completing the work on Dudley approximately 1 hour was taken to trace electrical ground issues and restart computers. The next transit was ~500 m to the north following roughly 020 to look for the Raven field. Upon arrival at the Raven area, a search was made for active and inactive sulfide structures. A number of inactive sulfides were found with what appeared to be hydrothermal “smoke” in the water in many places. Eventually an area of tube worm patches was located with one distinct patch of diffuse flow (the high temperature probe was broken at this point so no temperature data was collected). Two pieces of basalt were broken from this patch of flow and collected to the basket. A nearby extinct sulfide was sampled to the basket as well (X = 4976 Y=6744, 2127) before dropping weights and ascending.

2.13 September 7, 2006 Dive 4242 Mothra Hydrothermal Field

Pilot: Pat Hickey

Port Observer: Marv Lilley

Starboard Observer: Jim Holden

Alvin reached bottom at 1617 in an area of jumbled basalt with light sediment cover (Depth is 2,275 m). To starboard there was a collapse basin approximately 10 m wide, 20 m long, and 2-3 m deep. After setting the buoyancy Alvin headed toward the Faulty Towers complex. At 1622 Alvin stopped at the Pinocchio extinct sulfide structure (X=4280, Y=3401, Z=2274 m) to reset our navigation. The Doppler was set to the Nautronics, (X=4280, Y=3298). At 1631 Alvin left Pinocchio and drove to Faulty Towers. The sub reached Faulty Towers near Giraffe, then turned south and drove around the structure in a clockwise direction, then moved into position next to Roane (X=4163, Y=3299) to deploy the incubator assembly. The milk carton portion was rested on top of the flat Roane stump and the titanium cylinder fit nicely into the hole. At 1652, the deployment of the incubator was complete and the sub pulled away to head for Giraffe.

At 1704 Alvin reached Giraffe (X = 4172, Y=3309, Z=2,267 m, hdg=311°) and began deployment of the second insert into a hole in the side of Giraffe. The hole is halfway to two-thirds up the side of the structure on the eastern face. There were problems with getting the incubator inserted into the hole properly, most likely because the hole had partially collapsed due to the rough recovery of the previous insert. There was quite a bit of side current, which pushed the sub away from the structure. The insert was left just barely hanging into the hole and a photomosaic of Giraffe was completed. Following this, a search was made at the base of Giraffe for a good diffuse flow site for sampling.

At the base of Giraffe there were a number of empty tube worm husks, and most of the tube worms appeared dead, but there did not appear to be much diffuse venting. The highest temperature of venting measured was less than a degree above the ambient temperature. At 1741, Alvin was pointed towards Phang, where there was considerable diffuse venting coming out of the lower portion of the structure. Poking around at the base of Roane and Phang, the temperature probe again only measured about a degree above ambient temperature.

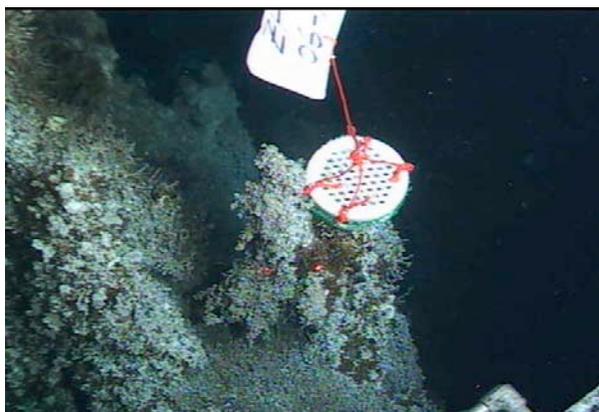


Poor man's incubator deployed in Roane.



Poor man's incubator partially deployed in Giraffe.

At the very southern end of Faulty Towers (17:56 X=4158, Y=3297, Z=2,277 m, hdg=021°), there was considerable shimmering water with many palm worms and white bacterial mat on the rocks. The temperature of the fluid exiting a small white smoker at the site was 48°C. At a diffuse vent site on the south end of Phang black and red gas-tight samples were taken with an ICL temperature of 48°C. The blue major pair water sampler was used to collect more diffuse fluid from the same site as the other two samples. Fluid was seen being drawn into the nozzle. Huaiyang Zhou's biology basket (#06-1, Zhou) was deployed at 1814 on top of the diffuse fluid flow. A small white smoker sulfide that was emitting the diffuse fluid where the fluid samples were collected was knocked over and the basket was put in its place. The sulfide was only a few 10's of centimeters tall. At 1815 work was completed at Phang and a photomosaic transect was completed for Finn. At 1826 (X= 4163, Y=3301, Hdg=012°), a large clump of healthy-looking tubeworms and a small, fragile chimney that were both growing out of the side of Finn right next to each other were collected and placed into the BioBox. Upon completion of sampling, Alvin headed towards Hot Harold to conduct the Toaster incubation.



Huaiyang Zhou's colonization experiment deployed.



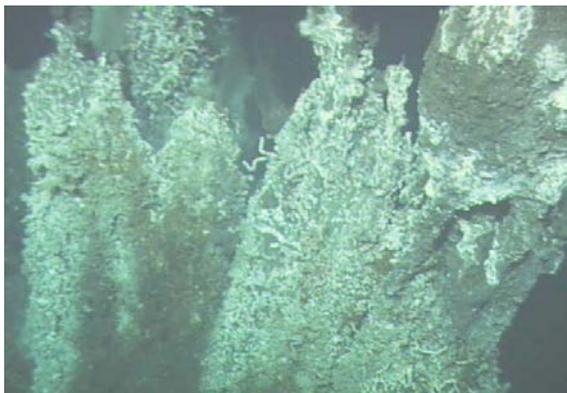
Sampling tube worms and sulfide from Finn.

At 1832 Alvin arrived at the base of Hot Harold (X=4171, Y=3317, Z=2273 m, Hdg=119°) to begin a toaster sampling for Dave Kadko, which lasted about 5 minutes. Following this Alvin went back to

Pinocchio again to check for drift in the Doppler navigation prior to the geological transect. The navigation checked out with only minimal drift. At 1851, Alvin left Pinocchio and moved into position to begin the geology survey along a heading of 030°. The bottom consists of broken pieces of basalt and is ~75% sedimented with a thin layer of sediment. At 1853, the sub is (X=4201, Y=3327, Z=2,274 m, 031°) ~ 3 m above the bottom in an area of jumbled basalt and a collapse zone. The terrain rises and falls about 4-5 m. The basalt asalt appears somewhat ropey. At 1858, the sub is still in an area of collapse with (X=4240, Y=3460 Z=2,269 m, Hdg=030°) some bathtub rings visible on the basalt. At 1900, Alvin (X=4253, Y=3483, Z=2,265 m) Alvin arrived at a Marker 'Y' made out of a bucket lid. Cauldron was reached at 1901 (X=4266, Y=3507, Hdg=031°). To starboard there is a white structure covered with tubeworms with vigorous venting from the top. There are several black smokers and beehives on the top of the structure, which rises 15 m above the seafloor. At 1907, Alvin completed the circle around Cauldron and the survey to the north was begun.



Chimneys within the Cauldron complex.



Highly colonized edifice within Cauldron.

At 1911 a basalt sample was collected (X=4298, Y=3528, Z=2,266 m) from an area that is very broken and jumbled. But looking somewhat ropey in texture. The piece was put in the front of the basket to the right. We have a good video image of the rock in the claw of the arm prior to placing it in the basket. At 1915 Alvin passed over the edge of a large collapse zone that appears to drop down as much as 10 m. Some bathtub rings are apparent and the basalt texture is slightly ropey. Alvin continued to traverse over (X=4337, Y=3600, Z=2,261 m, Hdg=030°) a large collapse zone with jumbled basalt that hosted 2-3 m tall columns of basalt (somewhat lobate looking). A second basalt sample was collected at 1925 (X=4397, Y=3717, Z=2,262 m). At 1929 (X=4412, Y=3751, Z=2,261 m, Hdg=031°) 1.5 m above bottom) Alvin was in drain back region of jumbled somewhat ropey basalt.



Area from which the first basalt was sampled.



Area from which the second basalt was sampled.

At 1932 (X=4439, Y=3799, Z=2,259 m) Alvin came into a region with quite a bit of hydrothermal sediment and hydrothermally altered basalt, but no evidence of even extinct sulfides. Hydrothermally altered basalt. At 1935, (X=4456, Y=3815, Z=2,257 m, Hdg=031°) 2.7 m above bottom Alvin is still over an area covered with hydrothermally-derived sediment and altered basalt. At 1945 (X=4540, Y=3881, Z=2,239 m) Pat indicated that there was only have about 30 min of battery power left. Therefore, the transect was changed to the east to cover as much of the wall as possible. At this point, the third basalt sample was collected in a region that slopes upwards rapidly. After imaging the sample, it was placed on top of the snorkel of the major sampler. This portion of the slope appears to be mostly talus with numerous bits of broken basalt around. The fourth basalt was collected at 1953 (X=4559, Y=3904, Z=2,219 m) from the top of intact pillow lavas. At 2000, the dive weights are dropped and Alvin begin the ascent to the surface.



Area from which the third basalt was recovered.



Area from which the fourth basalt was recovered.

2.14 September 8, 2006 Dive 4243 Main Endeavour Hydrothermal Field

Pilot: Mark Spear

Port Observer: Brian Marquardt

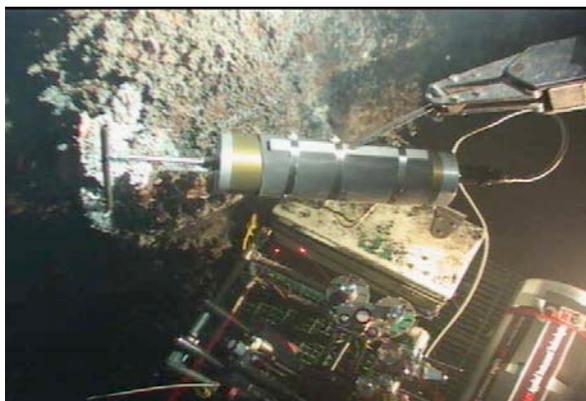
Starboard Observer: Helen White

Summary:

Alvin landed to the east of the MEF fissure at 16:05 at a top lab fix of $x=4967$, $y=5987$ and a depth of 2210 m. Upon arrival the attitude and ballast of Alvin was adjusted before proceeding to the main north south trending fissure wall, and then on to our first objective at Milli-Q. We had difficulty finding Milli-Q initially and we found a small “M” (upside down triangle) and “U” marker (Puffer) on the northwest side of the structure. We arrived at the “AZ” marker on Milli-Q at 17:25 and began to setup at a black smoker ($x=4943$, $y=5919$, $hdg=190$ and depth 2183 m). At 17:29 the set up was complete and a high temperature measurement was obtained of 330.8°C. Two gas tights (orange and red) were fired, and a red major pair with an ICL temperature of 272°C obtained during the sample collection. The Raman instrument with new Ti flume flow tee at the probe end was deployed in an area of good diffuse flow (89°C). Five Raman data sets were collected at this site at varying experimental parameters. The Milli-Q sampling site was left at 18:46 for Cathedral.

Alvin arrived at Cathedral at 18:59 ($x=4830$, $y=5911$, $hdg=125$ and depth of 2181 m). At 19:05 we began to video survey the site while flying above the structures. Numerous stills were also collected at the site to further enhance the survey. Short fat tube worms were present in various places around the site. Using the high temperature probe, a temperature of 105°C was measured in diffuse flow near a white smoker ($x=4837$, $y=5909$, $hdg=144$ and depth 2183 m). Four sets of Raman data were collected in diffuse flow. A temperature of 297°C was measured in a white smoker near the diffuse flow site (20:15, depth=2184 m).

Alvin left Cathedral at 20:17 and flew South to Salut, arriving at 20:31 ($x=4858$, $y=5853$, $hdg=264$ and depth of 2189 m). Alvin setup at a diffuse site up on the northeast side of the structure and fired the green major pair in diffuse flow ($T=130^{\circ}\text{C}$). A short video survey was completed of the site and digital stills collected to supplement the video survey. One set of Raman data were collected at the site before leaving for S&M at 20:47.

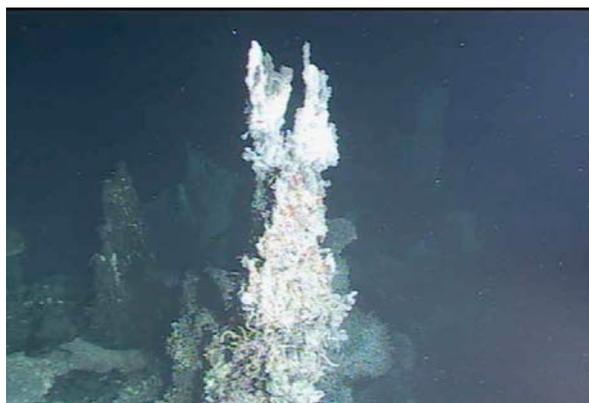


Raman Probe deployed at Milli-Q.

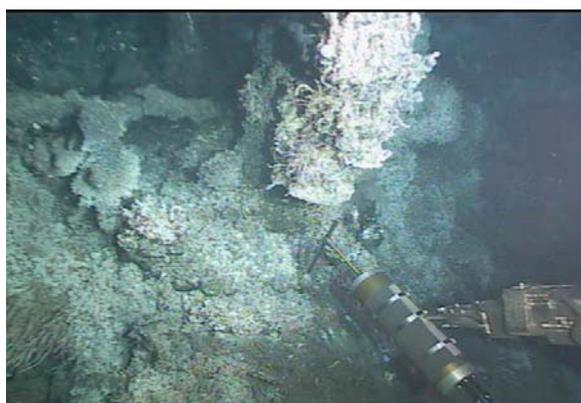


Close-up of flow through probe flume-T

Alvin arrived at S&M at 20:59 and landed at a site to recover Zhou's vent cap experiment ($x=4943$, $y=6023$, $hdg=206$ and depth 2196). The vent cap experiment was recovered with the port arm, but during manipulating of the experiment into the bio-box an approximately 1 m tall sulfide chimney that had grown on the vent cap crumbled and fell to the seafloor. An attempt was made to recover as much of the sulfide as possible, but very little was recovered due to the highly fragile nature of the material. After loading the vent cap experiment into the bio-box a high temperature measurement was made in the same vent as the vent cap to be (320.6°C). A fluid sample was collected with the blue gas-tight from the black smoker. Loading of the basket and collection of the remaining crumbled sulfide was completed at 21:55. Alvin transited to the east side of S&M structure to deploy the Raman instrument at a flange sampled during Dive 4235 ($x=4943$, $y=6016$, $hdg=130$ and depth 2193 m). Two sets of Raman data were collected at a flange in diffuse flow that measured 92°C . After stowing the Raman probe Alvin dropped weights for the surface at 22:18.



Chimney in Cathedral (Raman and video survey).



Raman analysis at Cathedral.



Salut area of video survey and Raman analyses



Zhou vent cap recovery at S&M.

2.15 September 9, 2006 Dive 4244 Salty Dawg Hydrothermal Field (Pit Dive)

Pilot: Bruce Strickrott

Port Observer: Jeff Cramer

Starboard Observer: James P. Brennan II

Summary:

The magnetometer was initiated at 15:15. During the initial descent, background spectra were taken with both ASU instruments. It was also determined that the high temperature probe had a positive offset of 77°C, which had been taken into account into other reported temperatures. The sea floor was reached at 16:10 at X=6624 Y=9673. Shortly after landing, a tube worm patch was discovered (X=6658 Y= 9713). Additional tube worm and diffuse flow activity were found in other nearby areas south of Salty Dawg (X=6621 Y=9799), and Target 22 was deployed in the area (X=6593,Y=9774). Biological activity in this area seemed to be on the wane, with the surrounding area containing large amounts of extinct sulfides.

The hydrothermal complex Grendel was found at X=6634 Y=9812 at 16:28. Between 16:37 and 16:46, sampling of fluids was completed at a vent with a temperature of ~ 297°C (Hi T) or 284°C (ICL) using one major pair (blue) and two gas tights (yellow and black). The ASU Raman and EEM instruments were deployed in diffuse flow until 17:25 GMT at the same location. Extinct sulfides were found in the nearby area (X=6660 Y=9832, X=6670 Y=9844, and X=6644 Y=9808) as the chimney Salty Dawg was approached.

Alvin arrived at the hydrothermal chimney Salty Dawg area at 17:48 (X=6587 Y=9823). This location contained a large amount of diffuse flow hosting a significant community of tube worms. Eventually, the primary spire of Salty Dawg was found (X=6591/Y=9829) and Alvin climbed to its peak. At 17:59, Alvin descended the spire to an area conducive to hot water sampling (X=6585 Y=9828). It should be noted that this is also where the high temperature probe offset was updated from 77°C to 72°C, which is taken into account into the temperatures given in the remainder of the report. At 18:08, a temperature of 312°C was measured with both the high temperature probe and ICL and a yellow major pair was used for sampling. After an unsuccessful attempt at flow sampling using the red/black gas tight, the blue gas tight was used in this same hot water flow at 18:23. Subsequently the ASU instruments were used in a nearby diffuse flow to obtain spectra.

At 19:13 GMT, a 303°C location was found at X=6564 Y=9806. The second gas tight was reattempted, but, upon firing, there was a release of oil, which indicated an instrument failure. The toaster was deployed at this site at 19:29 (duration: 5 minutes). At 19:44, a recovery was attempted of a piece of sulfide that had broken off of this area of Salty Dawg during operations. At 19:49, the recovery operation was abandoned, although an apparently extinct piece of sulfide was inadvertently obtained during the

procedure. The Salty Dawg structure was revisited at X=6579 Y=9809, for reorientation. Diffuse flow was found at 20:11 at X=6591 Y=9826, and spectra were obtained with the ASU instruments. At 20:41, spectra were obtained with the ASU instruments in flanges nearby to the preceding diffuse flow (X=6587 Y=9827) site. Several on-board and hand-held cameras were focused on the underside of a few large flanges both during the sampling operation and afterwards during the final surveying of the area (from 21:04 to 21:09), with weights away at 21:13.

Appendix 1 CTD Operations Summary

Station 1

Purpose: Background Cast 22 km East of Axial Valley

Date(mjd) / Time (UTC): start 53974 / 0245 , end 53974 / 0429

Location(s): start [47° 56.8027, -128° 49.6707], end [47° 56.754, -128° 9.183]

Files: at15090101.xxx

Station 2

Purpose: Background Cast 17 km East of Axial Valley

Date(mjd) / Time (UTC): start 53974 / 0507, end 53974 / 0659

Location(s) (UTM): start [47° 56.982, -128° 51.149], end [47° 56.984, -128° 51.146]

Files: at15090201.xxx

Station 3

Purpose: Background Cast 12 km East of Axial Valley

Date(mjd) / Time (UTC): start 53974 / 0750 , end 53974 / 0932

Location(s) (UTM): start [47° 56.983, -128° 56.117], end [47° 56.984, -128° 56.118]

Files: at15090301.xxx

Station 4

Purpose: PVOC Down Axial Valley: Stations 0 - 6

Date(mjd) / Time (UTC): start 53975 / 0158 , end 53975 / 1119

Location(s) (UTM): start [47° 54.814, -129° 06.746], end [47° 56.376, -129° 06.095]

Files: at15090401.xxx to at15090414.xxx

Station 5

Purpose: PVOC Down Axial Valley: Stations 7 - 14

Date(mjd) / Time (UTC): start 53976 / 0143 , end 53976 / 1122

Location(s) (UTM): start [47° 56.643, -129° 06.022], end [47° 58.360, -129° 05.028]

Files: at15090501.xxx to at15091601.xxx

Station 6

Purpose: PVOC Down Axial Valley: Stations 15 - 19

Date(mjd) / Time (UTC): start 53977 / 0457 , end 53977 / 1109

Location(s) (UTM): start [47° 58.660, -129° 04.868], end [47° 59.638, -129° 04.181]

Files: at15090601.xxx to at15090610.xxx

Station 7

Purpose: PVOC Down Axial Valley: Stations 22 – 20 and VOT Curtain around Salty Dawg

Date(mjd) / Time (UTC): start 53978 / 0151 , end 53978 / 1055

Location(s) (UTM): start [48° 00.341, -129° 03.577], end [47° 59.005, -129° 04.549]

Files: at15090701.xxx to at15090722.xxx

Station 8

Purpose: Plume Hunt VOT North of Sasquatch in East Valley

Date(mjd) / Time (UTC): start 53979 / 0205 , end 53979 / 1055

Location(s) (UTM): start [48° 09.229, -128° 58.414], end [48° 03.534, -128° 00.976]

Files: at15090801.xxx to at15090825.xxx

Station 9

Purpose: VOT Curtain Around High Rise

Date(mjd) / Time (UTC): start 53980 / 0158 , end 53980 / 1051

Location(s) (UTM): start [47° 58.187, -129° 05.049], end [47° 57.594, -129° 05.166]

Files: at15090901.xxx to at15090927.xxx

Station 10

Purpose: Plume Hunt VOT on Half Ridge to the West of Axial Valley

Date(mjd) / Time (UTC): start 53981 / 0152 , end 53981 / 1053

Location(s) (UTM): start [48° 02.404, -129° 08.155], end [47° 56.932, -129° 10.673]

Files: at15091001.xxx to at15091038.xxx

Station 11

Purpose: VOT Curtain Around MEF

Date(mjd) / Time (UTC): start 53982 / 0145 , end 53982 / 1057

Location(s) (UTM): start [47° 57.086, -129° 05.665], end [47° 56.803, -129° 05.293]

Files: at15091101.xxx to at15091129.xxx

Station 12

Purpose: Plume Hunt VOT Through Central Split Seamount

Date(mjd) / Time (UTC): start 53983 / 0149 , end 53983 / 1057

Location(s) (UTM): start [47° 40.149, -128° 59.678], end [47° 38.591, -128° 56.729]

Files: at15091201.xxx to at15091225.xxx

Station 13

Purpose: VOT Curtain Around Mothra

Date(mjd) / Time (UTC): start 53984 / 0150 , end 53984 / 1038

Location(s) (UTM): start [47° 55.232, -129° 06.685], end [47° 54.659, -129° 06.167]

Files: at150901.xxx to at150923.xxx

Station 14

Purpose: Plume Hunt VOT South of Mothra

Date(mjd) / Time (UTC): start 53985 / 0349 , end 53985 / 1102

Location(s) (UTM): start [47° 51.401, -129° 10.089], end [47° 52.496, -129° 07.758]

Files: at15091401.xxx to at15091424.xxx

Station 15

Purpose: VOT to Zero in on New Vent Field South of Mothra

Date(mjd) / Time (UTC): start 53987 / 0153 , end 53987 / 1203

Location(s) (UTM): start [47° 53.744, -129° 07.975], end [47° 53.156, -129° 08.322]

Files: at15091501.xxx to at15091548.xxx

Station 16

Purpose: VOT Along Western Wall to Zero in on Kumungwe

Date(mjd) / Time (UTC): start 53988 / 0205 , end 53988 / 0618

Location(s) (UTM): start [47° 53.830, -129° 07.954], end [47° 52.594, -129° 08.999]
Files: at15091601.xxx to at15091614.xxx

Station 17

Purpose: VOT Zig Zag to Locate Kumungwe

Date(mjd) / Time (UTC): start 53988 / 0720 , end 53988 / 1159

Location(s) (UTM): start [47° 53.602, -129° 08.150], end [47° 53.385, -129° 08.287]

Files: at15091701.xxx to at15091718.xxx

Station 18

Purpose: VOT to Locate Kumungwe

Date(mjd) / Time (UTC): start 53989 / 0235 , end 53989 / 1221

Location(s) (UTM): start [47° 53.591, -129° 08.161], end [47° 53.760, -129° 07.884]

Files: at15091801.xxx to at15091840.xxx