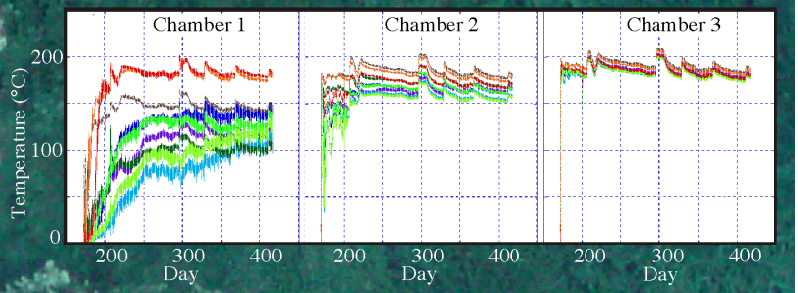
Sulfide-Microbial Incubator Cruise
R/V Atlantis-Alvin AT II-13
May 23-June 7, 2004



Chief Scientist: Debbie S. Kelley
Co-Chief: John R. Delaney

Acknowledgments: We express our deep appreciation to Captain George Silva and the crew of the R/V Atlantis and Alvin for their support, humor, and friendship. The cruise was very successful due to their hard work and help. We especially thank Pat Hickey for allowing a night dive and both Pat and Mitzi Crane for their exceptional help at the end of the cruise.

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Voyage 11 Leg 13
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1.0 INTRODUCTION AND CRUISE HIGHLIGHTS

This cruise included three main field components. The first study involved a 6-day leg using Alvin to recover two prototype sulfide-microbial incubators from sulfide structures within the Faulty Towers Complex of the Mothra Hydrothermal Field, Endeavour Segment, Juan de Fuca Ridge (Figures 1 & 2). This project focuses on the development of an *in-situ* sensor package designed to quantify the spatial and temporal variation of environmental parameters and associated microbial communities within submarine hydrothermal systems. The ultimate goals of this project are to determine under *in-situ* conditions the upper temperature limit to life, what environmental parameters may promote growth under these extreme conditions (e.g. Fe-reduction, biofilm development, elevated salt concentrations), and what consortia are present. We chose to work in the Mothra Hydrothermal Field on the Endeavour Segment of the Juan de Fuca Ridge because culturing of archaea from this field have extended the upper temperature limit of life to 121°C (Kashefi et al., 2003). This site was also chosen because 1) we have extensively studied the sulfide geochemistry, mineralogy and microbial populations within a few large intact sulfide edifices that were recovered from Mothra in 1998, 2) the energy-rich, porous interior chimney walls host dense and diverse microbial communities, and 3) because there is an extensive seismic array and coupled chemical sensors at the Endeavour Segment that allow us to examine changes in temperature and fluid chemistry as a function of well-characterized seismic events.

This field program builds on the successful field-testing of three prototype sulfide-microbial incubators within the Mothra and Main Endeavour (MEF) Fields in 2003, which NSF funded us to design, construct and test (Figure 2). The "proof of concept" prototype packages included titanium-sheathed, 53 cm long, 3-chambered probes that allow *in-situ* continuous recording of 27 temperatures within the interior of mature, active submarine hydrothermal sulfide chimneys. In 2003, three instruments were successfully deployed in the structures Roane, Hot Harold, and Milli-Q, two incubators were recovered, and one redeployed. This follow-on field program was designed to test 1) whether we could successfully recover the instruments from within the chimney walls after a one-year deployment, 2) the durability of the temperature sensors in the harsh environment present within the chimney walls, 3) if the design would allow delineation of gradients within the walls (this ability is critical to the hypotheses we are testing), and 4) whether microbes would colonize the chambers.

The second objective focused on cleaning up the Main Endeavour Hydrothermal Field, which included deploying new markers in sites routinely visited (Figure 3). The Endeavour system is a Canadian Marine Protected area and is one of three NSF-funded Integrated Studies Sites overseen by the RIDGE R2K program. It will also be a focus of the NEPTUNE regional cabled observatory and it is anticipated that numerous scientists will study this area over the coming decade. We requested 3 days submersible work to remove synthetic materials no longer in use from the field, to place new makers at the base of the structures to facilitate navigation, and to recover an array of transponders that have been in place since 1997 and 2000, respectively.

Finally, NSF and NURP provided 5 days to test prototype chemical-flow sensors designed for seep and diffuse flow environments. Two different types of instruments were to be tested. The first was a Chemical and Aqueous Transport (CAT) meter that uses the dilution of a chemical tracer to determine

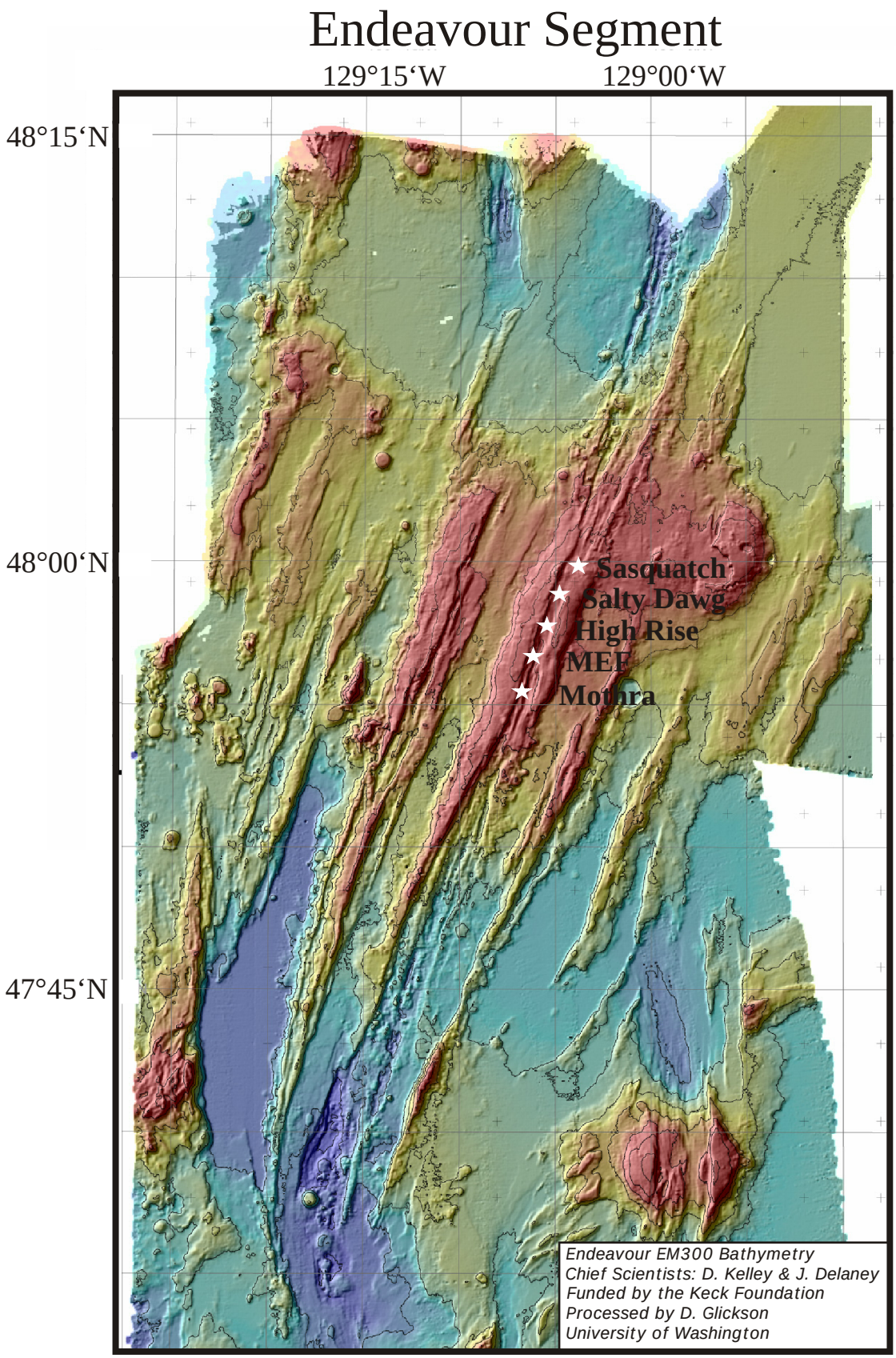
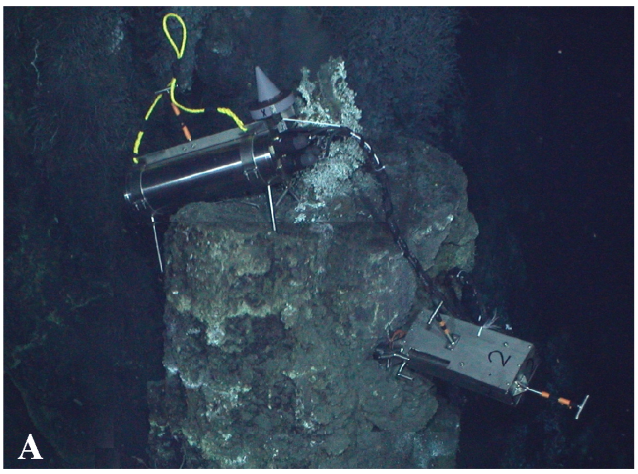

Endeavour Segment
129°15‘W
129°00‘W
48°15‘N
48°00‘N
47°45‘N
Sasquatch
Salty Dawg
High Rise
MEF
Mothra
Endeavour EM300 Bathymetry
Chief Scientists: D. Kelley & J. Delaney
Funded by the Keck Foundation
Processed by D. Glickson
University of Washington

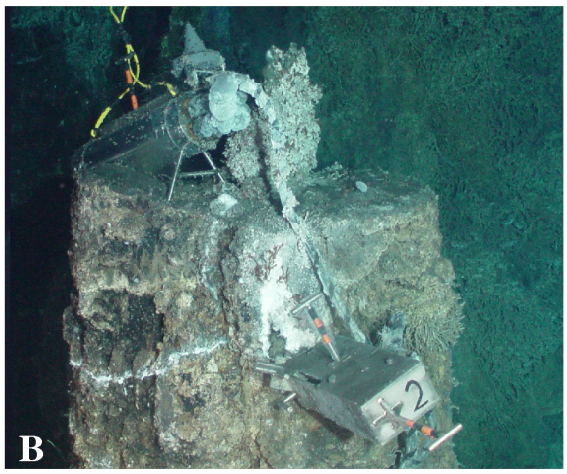
Figure 1.

June 2003



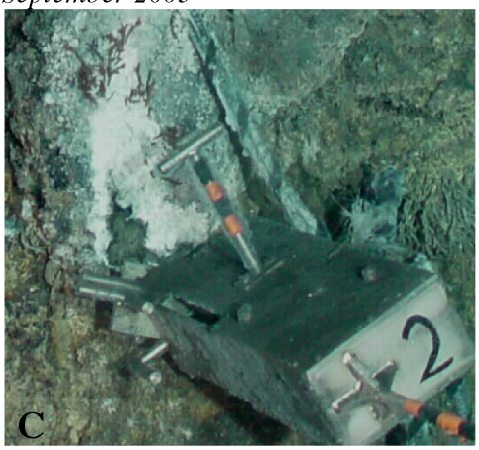
A) Sulfide microbial incubator in the diffusely venting chimney Roane, deployed in June 2003. Pressure housing, data logger, and ICL are at the top of the edifice. The upper ~2 m portion of this chimney was recovered in 1998, allowing detailed, coregistered mineralogical-microbiological studies (Schrenk et al., 2003). The corehole was drilled with the ROV Jason 2 hovering in doppler lock ~ 6 m above the seafloor.

September 2003

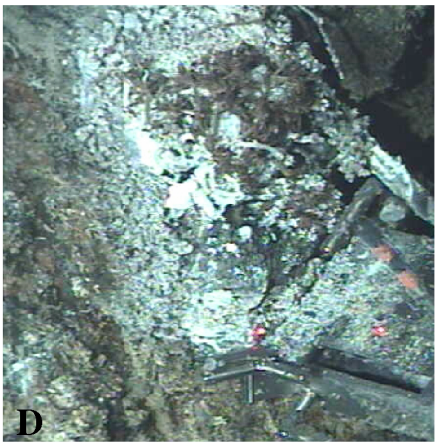


B) Incubator in September 2003 showing microbial mats, limpets, and worms that colonized the walls of the structure and instrument subsequent to deployment.

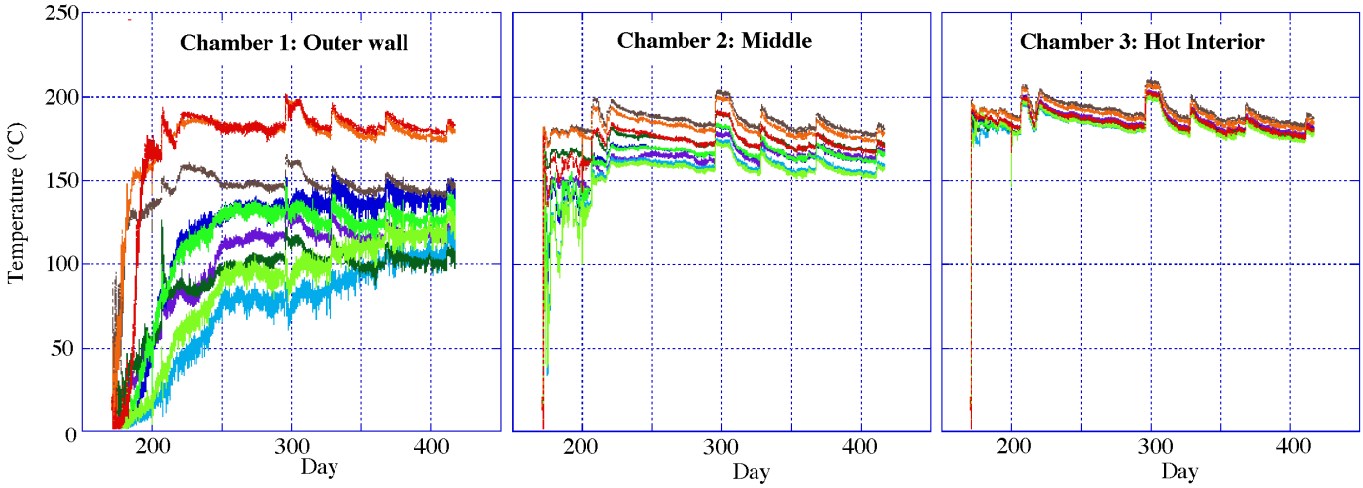
September 2003



June 2004



C) Sulfide microbial incubator in Roane after 3 months. D) Dense microbial mats and palm worm communities colonized the area during the 1-year deployment. The outer most chamber, which was completely embedded in the wall, was filled with anhydrite and lower temperature sulfide phases. Minor precipitation of higher temperature sulfide phases occurred within chambers 2 and 3.



E) Temperature record for 245-day deployment in Roane yielding 477,846 measurments. All 27 temperature probes functioned during the deploymentm, documenting well defined tidal signals and significant perturbations in temperarture that lasted for several days. Follow-on work will examine corresponding seismic records to examine if any of these events where responding to tectonic events. Culturing, microscopic, and sequencing analyses are being conducted on materials from each chamber.

Figure 2.

flux rates in areas of low flow. The tracers (Rb and Sr) are analyzed by optical emission spectrometry and allow a flux rate range of 0.01 to 1500 cm/yr to be measured. A second version of this instrument the CAT-II, includes two meters, each with its own remote collection chamber. Initial tests were completed within the Main Endeavour Field near the structure Milli-Q. Because these instruments need to be well coupled to the seafloor, optimal environments are those with sufficient sediment to partially bury the sensor heads. Because of limited dive time, the Endeavour area was not extensively surveyed prior to instrument deployment and the chosen sites were not optimal for instrument testing. We decided to recover the instruments and redeploy them at near Nootka area off of Vancouver Island near the toe of the accretionary prism. In 2003 small seeps were founded during a Keck-funded cruise, and this area was chosen as a test deployment site for a new state-of-the-art buoy designed by WHOI and funded through NSF. Real-time communication to shore is achieved through an Iridium communication system. The buoy currently hosts a seismometer, and in 2004 a hydrothermal package will be placed nearby at the seep sites. The assemblage of instruments will communicate to the satellite via an acoustic modem. Because of this, we believed it was important to test the instruments at this site, in addition to the Endeavour.

This field program was originally scheduled to include 14-15 dives. One dive was lost to weather. On the third to the last dive we received the tragic news that Captain George Silva's son had died and because of this information we came in early, loosing 2 additional dives. Even with the loss of dives, however, the cruise was highly successful. With help from the Alvin group and crew of the Atlantis all major goals were accomplished:

•**SULFIDE MICROBIAL INCUBATORS:** A sulfide-microbial incubator was recovered from the ~200°C structure Roane, complete with a 3/4-year temperature record that included results from 27 probes measuring discrete temperatures every 20 minutes. Data were collected on all probes for 245 days, with a total of 477,846 measurements completed (Figure 2). Well-developed gradients were delineated in each of the three discrete environmental chambers. Numerous perturbations were recorded simultaneously on all 27 probes showing temperature increases up to ~30°C. These data will be examined with co-registered tidal and seismic analyses to determine if they were induced by storms or seismic activity. A Hobo temperature probe deployed in a 300°C black smoker immediately adjacent to Roane, did not show corresponding perturbation events. A new incubator was redeployed in the experimental corehole at Roane, showing that the holes can be re-instrumented for time-series studies. The most outer chamber was completely filled with sulfate and sulfide minerals; sparse precipitation occurred in the two inner chambers. Microbiological analyses were completed shipboard on numerous samples collected from the insert in Roane (and on additional sulfide samples collected). Shore-based studies will include continued culturing, FISH, and genetic analyses of this material and analyses of biofilms on mineral wafers that were placed within the chambers prior to deployment last year.

A second data logger was recovered from the 280°C structure Hot Harold. Data were collected for 189 days on all probes yielding a total of 367,983 measurements. The temperature history for this high temperature structure was fundamentally different than that from Roane, showing no perturbations even though it is only ~ 25 m away. These results may indicate that porous flow and high flow-though chimneys are affected very differently by tidal and/or seismic activity. Unfortunately, the barrel assem-

bly could not be recovered from the chimney wall of Hot Harold, leading to a new design concept involving insertion of a third sheath into the boreholes. From this years and last years successes, however, we learned that the boreholes seal up after 10-20 days and that high temperatures are established immediately upon insertion of the instruments. We also learned that entire instrument assemblies can be easily recovered after 3 months in the higher temperature chimneys with significant biofilm development in some of the chambers.

In summary, this prototype-testing phase has been extremely successful. We have proven that the instruments and their sensors are robust, they do what they were designed to do, and that in 200°C vents they can be successfully deployed and recovered for 1-year experiments. Even after one year, the holes remain clean and instruments can be redeployed in the experimental boreholes. Well-defined gradients are measured in the chambers and the chambers are colonized by microbial populations. In higher temperature systems (i.e. 280°C), the instruments can be recovered if the experiments are shorter duration (3 months). For longer-term experiments the instruments will need to be redesigned -- we have already started down this path.

•**MEF AND TRANSPONDER CLEAN UP:** The Easter Island area within the Main Endeavour Field was cleaned extensively, with old markers, bucket lids, polyprope lines and cement instrument bases recovered. The appearance of the area is dramatically improved. Smaller items, not reachable with Alvin will be recovered on follow-on Tiburon and Ropos cruises. Fourteen large edifices within the MEF that are routinely visited were marked with a new set of markers. Other areas within the MEF will be cleaned on follow-on programs this summer. During clean up operations a MAV current meter owned by H.P Johnson was recovered that had been lost in 2003 with 1-year of data. An entire dive was dedicated to recovery of transponders that had been left at the Endeavour since 1997. We focused on recovery of five transponders located on the west and east sides of the axial valley. Transponder K (10.5/9.0) was recovered from the eastern wall. No evidence could be found for three transponders on the western wall, but it was clear that one transponder on the eastern wall had self-released. This is the second time that the western transponders have been looked for, so we believe that it is likely that they are no longer there and that they self-released.

•**IMAGENIX SURVEYS OF THE MEF AND MOTHRA FIELDS, CREATION OF BENCH MARKS:** High-resolution imagenix surveys completed during periods of opportunity resulted in a very high resolution map of the MEF documenting all major chimneys. Comparison of these new data with an older 1995 bathymetry documents significant growth of some chimneys (i.e. Milli-Q). Bathymetric results from this study will be overlain with data from a follow-on ABE survey using the SM2000 system in June-July, 2004, providing nested data sets for large parts of the field.

A very significant, but unanticipated outcome from this project was completion of a very high-resolution imagenix map of most of the the Mothra Hydrothermal Field, which shows the position of major chimneys within the 5-6 actively venting sulfide complexes, collapsed lava lakes, and a well developed fissure system (Figure 4). This

remarkable map will provide an extremely important base for follow-on geological, chemical and biological studies. It is the first map of its type completed within the Endeavour system. A benchmark was established at the structure Pinocchio within Mothra that provides an unequivocal x-y location for coregistration of navigational data on any follow-on dive program. New results show that Mothra extends for at least 600 m in length, making it the most extensive field within the Endeavour system. Because of Mothra's size and complexity, the map generated during this program is important to optimally plan follow-on studies. It also provides a wealth of information in terms of examining the tectonic evolution of this field, and structural controls that govern placement of hydrothermal complexes.

- **DISCOVERY OF A SIGNIFICANT SEEP SITE AT THE NOOTKA TRANSFORM-CASCADIA MARGIN JUNCTION**: As part of the flow sensor program, two exploration dives focused on finding adequate seep sites for testing of the prototype chemical flow sensors. This resulted in the discovery of a significant seep site near the southern intersection of the Nootka Transform Fault and the Cascadia subduction zone. Extending for many 10's of meters, the site contains discrete colonies of clams that are up to 20 cm in length, very large snails, bacterial mats, and sparse tube worm communities. Hundreds of articulated clamshells are also present, suggesting that this seep has been active for an extended period of time.

- **TESTING OF PROTOTYPE CHEMICAL-FLOW SENSORS:** As part of the Brown-Hilton program, two prototype chemical-flow sensors were deployed in a sedimented site near the base of the hydrothermal edifice Milli-Q in the Main Endeavour Hydrothermal Field. The site is on a bench that is capped by a several cm thick crust of highly oxidized hydrothermal sediment that is underlain by less altered sulfide sediment and talus. Diffuse flow occurs in and around surrounding sulfide talus. Because of lost dives this program, the instruments will be redeployed at the Nootka seep site on a follow-on Keck cruise in September 2004.

- **FIRST-TIME RECOVERY OF A COUPLED FLUID-PARTICULATE DNA LONG-TERM SAMPLER:** A Remote Access Sampler (RAS-48 samples) and Particulate DNA sampler (48 samples) was successfully recovered from a diffuse flow site near Hulk in the Main Endeavour Field. The coupled package is the first of it's kind to be deployed for a 1-year period. It will yield co-registered time-series measurements of temperature, fluid chemistry, and particulate DNA. The sampler successfully completed all 48 samples. A second stand alone RAS sampler was recovered from the Clam Bed site, ~ 1.5 km to the north. The sampler worked for 22 weeks, but then clogged due to a worm that had invaded the intake hose. Chemical and microbiological analyses are underway on these samples.

2.0 INSTRUMENTATION-SULFIDE-MICROBIAL INCUBATORS

Development and building of three prototype instruments (Figure 2) was funded by the National Science Foundation on this grant, by the University of Washington on a Royalty Research Grant to Kelley, and by the Keck Foundation. Modification of the original design to include additional thermocouples and an outside titanium sheath to prevent contamination resulted in a total cost of each instrument of $50,000.

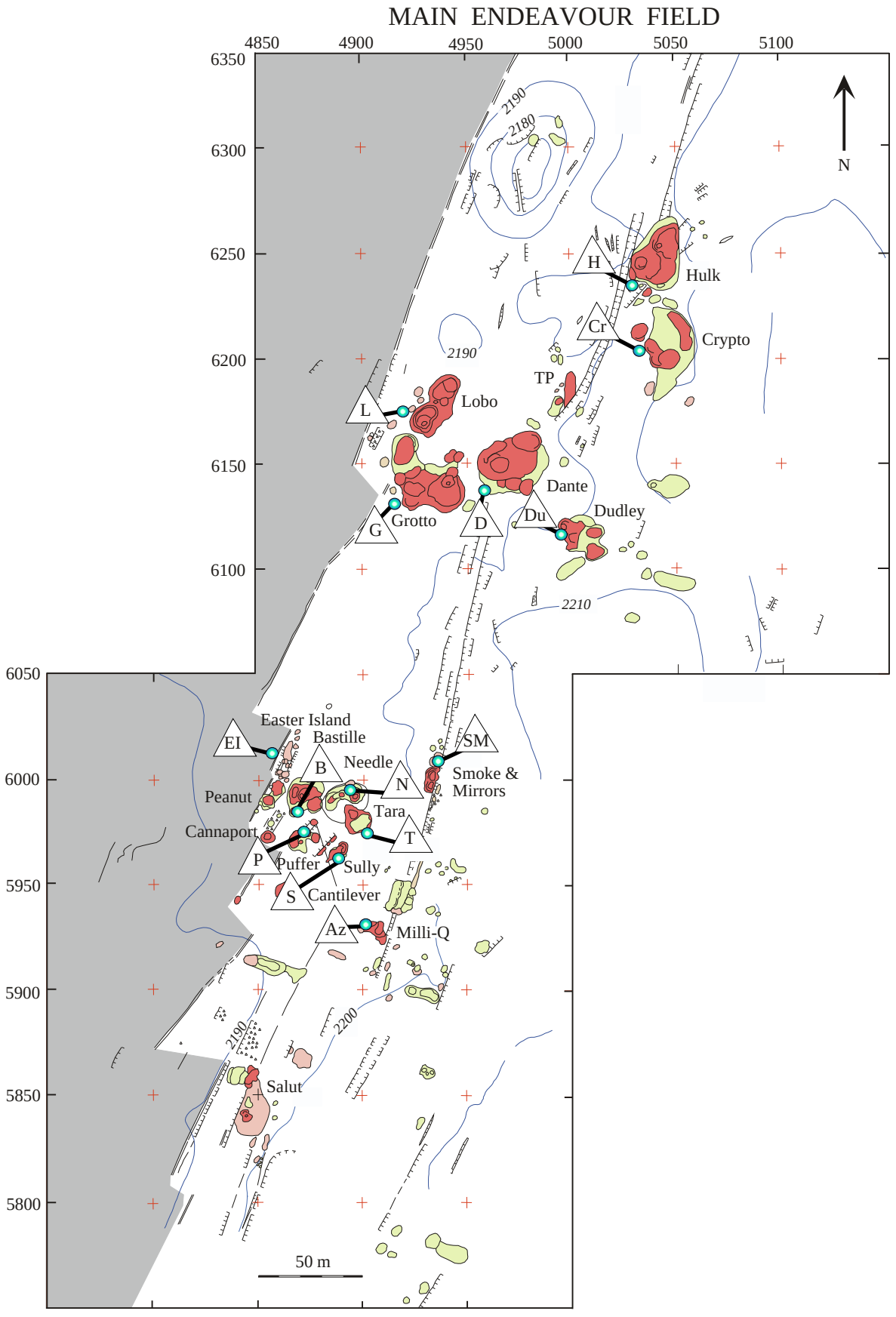

MAIN ENDEAVOUR FIELD
4850
4900
4950
5000
5050
5100
6350
6300
6250
6200
6150
6100
6050
6000
5950
5900
5850
5800
N
2190
2180
2210
2200
H
Hulk
Cr
Crypto
TP
L
Lobo
Dante
D
Du
Dudley
G
Grotto
Easter Island
EI
Bastille
B
Needle
N
SM
Smoke &
Mirrors
Peanut
Tara
T
Cannaport
P
Puffer
Sully
S
Cantilever
Az
Milli-Q
Salut
50 m

Figure 3.

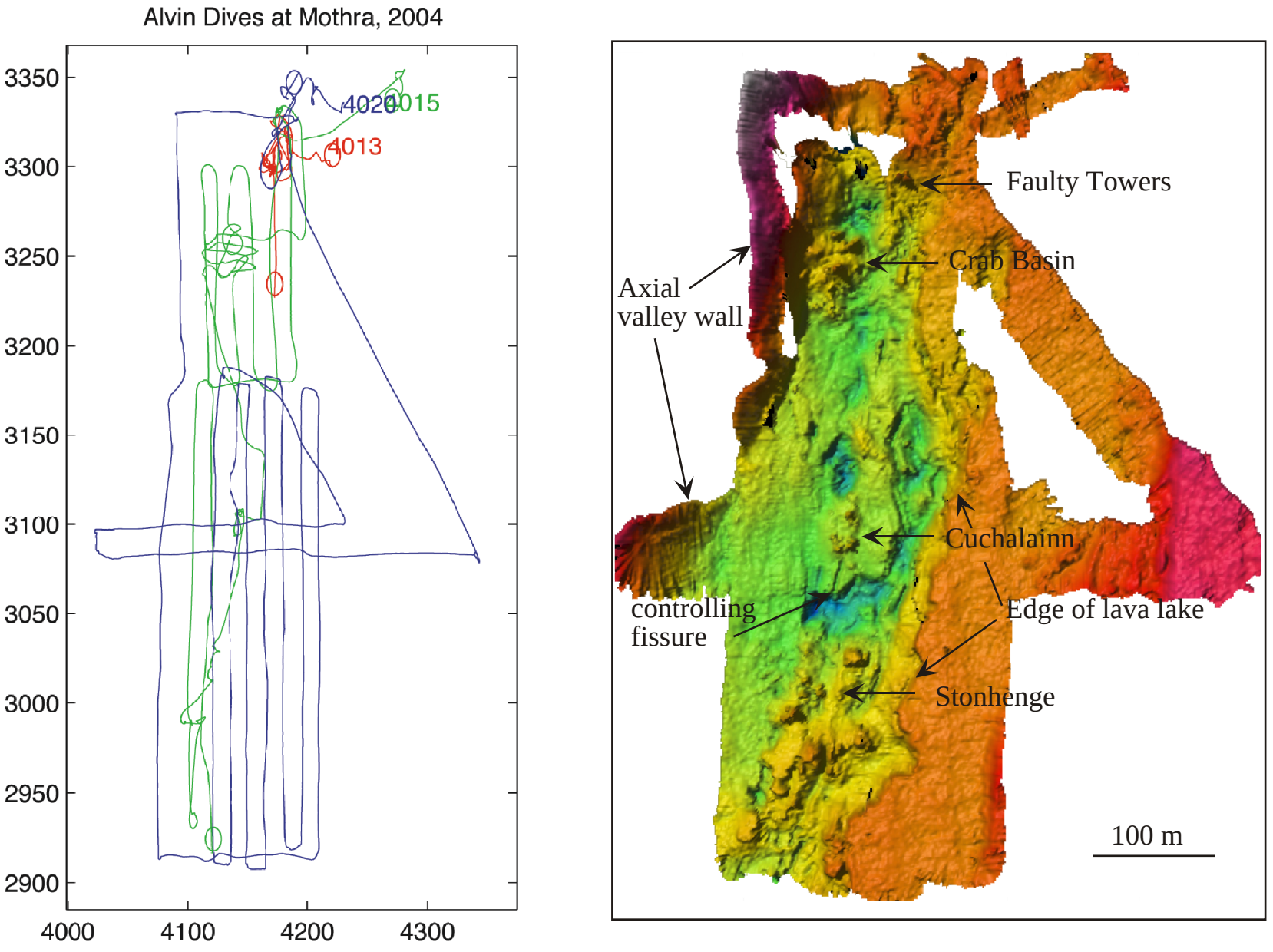

Alvin Dives at Mothra, 2004
3350
3300
3250
3200
3150
3100
3050
3000
2950
2900
4000
4100
4200
4300
4020
4015
4013
Faulty Towers
Crab Basin
Axial
valley wall
Cuchalainn
Edge of lava lake
controlling
fissure
Stonhenge
100 m

Figure 4.

The incubators were designed and built by Ocean Engineering Services at the UW in collaboration with Rex Johnson, the lead engineer, and with advice from John Frantz, Carnegie Institution of Washington. Except for an array of Teflon disks, the entire 46-53 cm long probes are made of titanium (Figure 2). Twenty-seven temperature probes housed within three discrete incubation chambers record temperatures from 0 to 500°C with a resolution of 2°C. The sulfide-microbial insert may be deployed for >500 days with use of a double Lithium battery pack, and a Lithium backup battery preserves data for up to three months after the main battery is expended.

The goal of this program was to recover two instruments that were deployed in the Mothra Hydrothermal Field in 2003. One instrument, in Roane was deployed in June, 2003 by the remotely operated vehicle (ROV) Jason, and a second instrument in the 280°C chimney Hot Harold in September, 2003 by the Candian ROV ROPOS. The instruments were set to collect data every 20 minutes for a period of one year. Temperature data were recorded and housed inside a separate titanium pressure housing. The heart of the data logger is an Onset Tattletale 4A Logger/Controller with 2 Megs of memory. The date, time, 27 temperature probes, and three reference temperatures were scanned and logged for later analyses. Each logger includes a standard hardwire RS232 serial port, and an inductive communications loop designed and provided by Al Bradley at Woods Hole Oceanographic Institution that allows the user to "listen" to the instrument by a robotic vehicle or submersible without having to recover the instrument from the seafloor.

Although not funded by this program, incubation materials of various compositions (pyrite, sphalerite, chalcopyrite, gold SEM microplates etc.) were included in a titanium mesh tube that was directly in contact with one of the thermocouple sheaths in each of the environmental chambers. These materials will allow preliminary examination of biofilm development, extraction of DNA for species characterization, and evaluation of the effect that microbes have on various mineral surfaces.

3.0 MICROBIOLOGICAL ANALYSES

During this cruise the University of Washington microbiological working group attempted to culture anaerobic mesophiles, thermophiles and hyperthermophiles from four hydrothermal fluid samples (two high temperature and two low temperature), two sulfide chimneys, and various materials from the sulfide incubator recovered from Roane. A "metabolic net" approach was used that involved inoculation into five different types of growth media incubated at three different temperatures. Sulfide samples with corresponding fluids were given a priority for microbiological and chemical analyses. Whenever possible subsamples were frozen for DNA extraction or preserved for Fluorescence In-Situ Hybridization (FISH) and total cell counts.

In addition to general heterotroph and autotroph media three new types of media to enrich for iron or sulfate reducers and hydrogen oxidizers were tested. Based on preliminary observations there seems to have been growth in these new media at varying temperatures from both the low temperature fluids and sulfides. Low temperature fluid samples taken at the two RAS locations (SE Hulk and Clam Bed) both yielded a high percentage of tubes initially positive for growth across a range of media and temperatures of incubation.

Sulfides were sectioned into inner and outer zones for culturing based on mineralogy when possible or simply on distance from the inner conduit. Both sulfide samples (Roane and Hulk) showed indications of growth in various media across the range of incubation temperatures with a few distinctions between

the two samples. While the outer zone of Roane yielded potential growth in all types of media, growth was more limited from Hulk with the absence of sulfate reducers in either zone. There also did not appear to be growth of any methanogens from the outer zone of Hulk. Growth of all cultures will be confirmed microscopically in the lab. The two high temperature fluid samples (Roane and Hot Harold) showed no preliminary signs of growth in any of the media used.

Microbial Incubator: Each of the three chambers in the sulfide incubator that was recovered from Roane contained a number of potential substrates for microbial attachment and growth that were evenly spaced along the length of the insert barrel. Thin mineral wafers (pyrite, chalcopyrite and sphalerite) and gold SEM grids were packed tightly and held in place using sterile glass wool. These materials were all wrapped in a titanium mesh and wire and threaded onto one of the thermocouples in the barrel of the insert.

After recovery, mineral wafers at each of the nine temperature record points were either frozen for DNA analysis or preserved for FISH. Pieces of the titanium mesh and wire, glass wool and minerals that had precipitated on all these surfaces were used as inoculum for "metabolic net" culturing from each of the three chambers. There appears to be limited indications of growth from the two outer chambers that will be confirmed microscopically in the lab.

Pressure Experiments: Materials from the middle chamber of the sulfide incubator were also used as inoculum for high pressure, high temperature culturing experiments. Titanium mesh and wire, glass wool and mineral precipitates were placed into autotroph media, iron reducer media and 0.2 μm filtered hydrothermal fluid and incubated at 100°C and 120°C and approximately 240 atm (3500 psi). At each temperature there was also an uninoculated control for the iron reducer media. These experiments were run for several days and time point subsamples were taken for cell counts and ferrozine assays (a measure of iron conversion to the reduced form, potentially indicating microbial growth). There appeared to have been some indication of growth in the autotroph media and filtered hydrothermal fluid at both temperatures. Ferrozine assays showed no indication of iron reduction at either temperature.

RAS and PPS Recoveries: Subsamples of fluids from the time series samplers at SE Hulk and Clam Bed were preserved for total cell counts with the exception of every fourth week in which the fluids were filtered through a 0.2 μm filter for other analyses. Filters on the particle sampler (PPS) at SE Hulk were treated in-situ with a NaCl-ethanol solution to preserve them for use in either DNA extractions or FISH microscopy. Filters were fast frozen in liquid nitrogen to minimize DNA degradation during freezing.

UMASS: In addition to the UW studies, Jim Holden from UMASS was invited as a guest investigator for microbial studies. His experiments were desgined to determine which kinds of hyperthermophiles in sulfide material grow at 95ºC in enrichment cultures under various chemical conditions. Novel hyperthermophilic autotrophs and heterotrophs will be cultured for subsequent characterization, which would expand understanding of their function and physiology. At a minimum, if culturing is not possible, the predominant organisms from each enrichment showing growth will be identified and partially characterized through the formation of a cDNA library created from the enrichment culture. Metabolites were analyzed during and after the incubations to show metabolic trends that will help define the activity of those organisms that grew and provide added information for culturing.

Nine samples were collected for culturing during the cruise. Three samples consisted of glass wool and titanium mesh collected from each of the three incubation chambers that comprised the sulfide insert recovered from Roane. The other six samples were small (< 20 cm diameter) actively-venting sulfides, three from the Mothra site at the Roane, Hot Harold and Stonehenge structures and three from the Main Field at the Sully, Clam Bed and Hulk structures. The soft, porous Zn-Fe-S region of the sulfides was used as the source material, as previous experience has shown that this region commonly contains hyperthermophiles. Each sample (~5 g) was mixed with 50 ml of sterile, anoxic artificial seawater in an N_2-CO_2 flushed serum bottle. Equal amounts of this slurry were used to inoculate 8 serum bottles and 8 Balch tubes, each containing a different medium. The samples were incubated at 95ºC for up to 72 h. The composition headspace gas in each serum bottle was monitored during incubation using a gas chromatograph to measure the consumption of H_2 and the production of H_2, N_2 and CH_4. Following the incubation, the concentration of Fe(II) in each bottle was determined spectrophotometrically, aliquots were filter sterilized and stored at 4ºC for sulfate and nitrate analyses using ion chromatography (to be performed by Dr. David Butterfield), aliquots were preserved in formaldehyde for cells counts and samples that showed growth were filtered through a Sterivex filter, frozen in liquid N_2 and stored at -80ºC for later genetic analyses. Preliminary analyses suggest that there was autotrophic growth in at least two bottles inoculated with material from the sulfide insert and heterotrophic growth in at least 9 bottles incubated with sulfide material.

4.0 Detailed Mapping of the Mothra and Main Endeavour Hydrothermal Fields with Imagenix

A major achievement during this program was the completion of very high-resolution bathymetric maps of the Mothra and Main Endeavour Hydrothermal fields (Figure 4). The rapid recovery, redeployment and success of the incubators freed up time for this mapping effort, which was not funded through any agency. These extremely detailed maps will provide critical base data for follow-on geological, chemical and biological studies within this Marine Protected Area and R2K Integrated Studies Site. We were extremely fortunate to have Vicki Ferrini, a new post-doc at Lamont, join our cruise. Vicki is funded through the Ridge R2K program to help facilitate processing of bathymetric data. The bathymetric maps, coupled with video and still imagery are providing unparalleled insights into the tectonic controls and geological setting of the hydrothermal vents, and the evolution of the hydrothermal systems.

With the exception of the Faulty Towers Complex, the Mothra field has not been well explored or mapped; the other 5 complexes have only been visited during a single ROPOS and Alvin dive. During this program, an area roughly 450 m x 150 m was imaged with the Imagenix sonar system during three dives, with most of the coverage occurring during a single dive ALV4020.

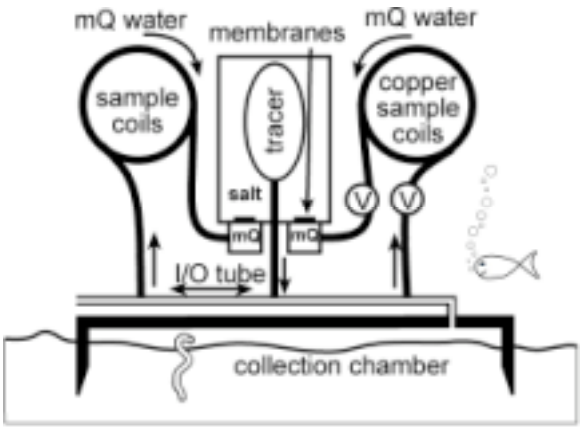
Navigation: During all dives, Alvin navigation data were acquired using the bottom-lock Doppler navigation DVLNAV software. When within the network of transponders deployed near Mothra and the Main Endeavour Field, the Doppler navigation was supplemented with long baseline (LBL) acoustic navigation. If LBL was available, it was used to "renavigate" the Doppler navigation by matching the mean of the Doppler track to the mean of the LBL track. Navplot, a suite of MATLAB programs that allow the user to manually remove bad LBL data points, was used to apply the renav horizontal shift to the Doppler navigation data. This shift, usually on the order of 10 meters, improves navigational accuracy by including LBL navigation, and compensates for drift within the Doppler navigation that occurs over the course of the dive. If LBL was not used, the raw Doppler navigation data (*.csv files saved by DVLNAV) were used as Alvin navigation. These have less absolute accuracy than LBL renav navigation, however it

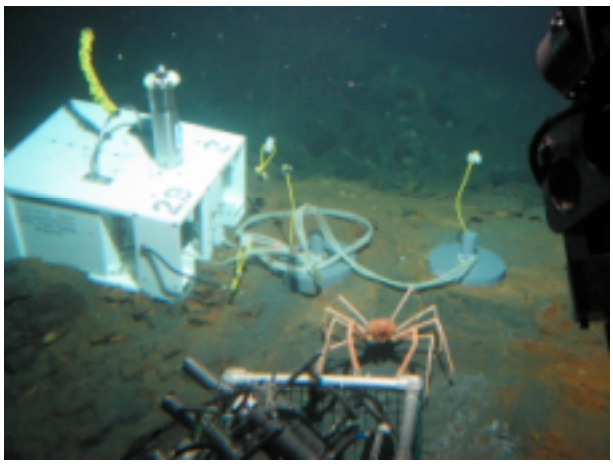
was found that if Alvin was surveyed in at the start of the dive, the navigation agreed very well with the expected terrain features imaged by the side scan sonar or previously run camera tows. All Alvin navigation data were binned at 1Hz to create text files and MATLAB ('.mat') files containing time, position in local XY, UTM, Lat/Lon, water depth, pitch, heading, roll and altitude.

Imagenex Scanning Altimeter Data Processing: After processing navigation data, Imagenex data were processed using a set of MATLAB scripts to calculate the position and corrected depth soundings for each ping. These soundings ignore the effects of tidal fluctuation. The depth data were filtered using offsets declared in a filter file called 'imagenex_filter.dat', which dictates the maximum allowable horizontal range, the maximum depth range, and the number of standard deviations about the mean outside of which data are considered unacceptable. Since many of the Imagenex survey lines were flown at an altitude of 10 m or more (especially at Mothra), the filter was modified to allow a maximum range of 20 m and a maximum depth of 25 m. Since this method does not remove all depth fliers (i.e. when incorrect depth values are reported over time periods of many seconds), an additional step was included to allow the user to remove bad depth data. The user can remove fliers in either profile or XY mode. The final xyz data were saved into 2 text files in the directory with the raw imagenex data: one in Lat/Long ('*.llz') and the other in local XY ('*.xyz'). These files were then used to create 1-m grids for each dive, each of which was automatically saved as a Lat/Long ArcView grid.

5.0 CAT Flux Meter and Discovery of the Nootka Seeps

The Endeavor-Nootka cruise (AT 11-13) was divided into two distinct segments. The first segment occurred in the main Endeavor field where we deployed a new version of the Chemical and Aqueous Transport meter (CAT-II) on a sediment covered bench near the Milli-Q hydrothermal vent in the southern Endeavor main field. The second segment was dedicated to exploring a portion of the intersection of the Nootka transform fault with the accretionary front offshore central Vancouver Island, Canada, with the main purpose of finding suitable seep sites for deployment of instrumentation (CATs and Optical Flux Meters) to monitor seep activity.





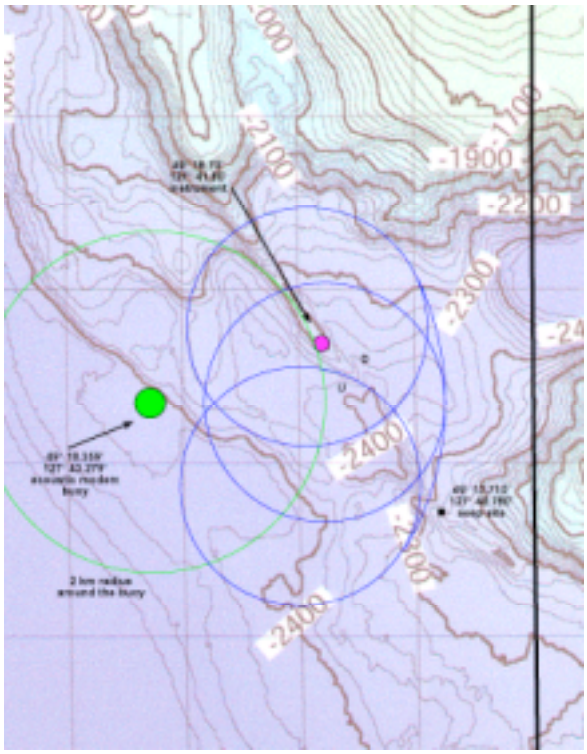
The Chemical and Aqueous Transport (CAT) meter [*Tryon et al.*, 2001] uses the dilution of a chemical tracer to determine flux rates. An osmotic pump injects a tracer at a constant rate into the water stream as it moves through the outlet tubing. A portion of the fluids moving out of the top of the chamber is col-

lected in sample coils, giving a unique pattern of chemical tracer distribution. The two sample coils allow both positive and negative flow to be measured and give a serial record of the flow rates. The Rb and Sc tracers are analyzed by optical emission spectrometry and allows a flux rate range of 0.01 to 1500 cm/yr. At high outflow, seawater is flushed from the meter's dead volume allowing a serial record of the outflow fluid chemistry to also be obtained. The temporal resolution of the measurements can be as high as 0.5% of the deployment time. The new version of this instrument, the CAT-II, includes two meters, each with its own remote collection chamber. All fluid pathways are chemically inert and clean so that trace element analyses may be done on the collected samples. The instrument also contains copper collection coils on the seep side of the outlet tube and can maintain samples at in situ pressures for later gas sampling. A timing mechanism inserts a small "tic" of dye tracer at regular intervals into each collection coil so that temporal events in the data can be resolved to a much greater accuracy than in previous version of the CAT. The instrument used for this program also included an Argonaut MD current meter, an Antares temperature sensor (resolution 0.001°C) in the main instrument frame and Tidbit temperature sensors (resolution 0.16°C) in each remote collection chamber.

During Alvin dive 4016 on May 28 the instrument was deployed on a sediment covered bench near the Milli-Q hydrothermal vent in the southern MEF and a temperature probe survey was undertaken in the immediate area to determine the general pattern of temperature distribution and hopefully heatflow. Subsequent analysis of the temperature data indicated that there was very likely lateral transport of hydrothermal fluids through the sediment with very little vertical flow. Temperatures typically reached their maximum of about 28°C at 15-20 cm depth just above the sediment to sulfide platform interface and then decreased at the interface itself. Fluid flux data from the CAT meter will be analyzed upon our return to shore.

6.0 Discovery of the Nootka Seeps

Alvin dive 4023 and 4024, June 4 and 6, were dedicated to surveying a small faulted ridge near to and paralleling the front of the Vancouver Island accretionary complex near where it intersects the Nootka fault zone. Dive 4023 began at an instrument site from the prior year's campaign and proceeded SE along the fault scarp into the turbidite channel. The scarp became increasingly subdued and eventually disappeared beneath the turbidite channel. While indicators of prior seep activity (carbonate filled fractures, clam shells) and minor current seepage (small tubeworm patches) were seen, no significant currently active seeps were found. Dive 4024 began at the southern end of the faulted ridge and proceeded NW in a zigzag search pattern covering the top and a portion of the sides of the ridge. As the ridge began a relatively steep descent toward the turbidite channel, the area became increasingly broken with fractures striking both parallel to the accretionary front and to the Nootka fault. A significant area of current seepage was found in this region that included small patches of microbial mats, dense patches of chemosynthetic clams, and a type of snail commonly associated with sulfide seeps (Fig. 3, 4). The area was surveyed both visually and with the Imagenix system over an area of approximately 3500 m^2. The patterns of seepage seemed to follow a series of linear trends striking approximately 310°. There were many orders of magnitude more clam shells in the area than live clams, possibly indicating that the patterns of seepage may have changed significantly in the recent past, either diminishing or moving its focus to some other area. While this seep site appears to be quite good and certainly adequate for our long term goals for monitoring fluid flow in the area, we are confident that we will find much more seepage in the highly faulted region to the NW as the fault trend intersects a strand of the Nootka fault at the SE edge of the turbidite channel.



The image to left shows the location of the WHOI Buoy and its watch circle. Also shown is the location of a long-lived seep site that hosts abundant clams (which reach up to 20 cm in length), large snails and minor bacterial mats.

7.0 Evolution of Hydrothermal Fluids in the Endeavour ISS

Hydrothermal Fluid Sampling

During this Alvin cruise, we used the titanium major samplers to sample vent fluids from the Mothra, Main Endeavour, and Clambed hydrothermal fields. We also took a major sample pair at a cold seep in the Nootka fault zone. A total of 27 titanium major samples was recovered and processed on board. For details of water samples, see the Excel spreadsheet file.

In the Mothra field, we sampled Roane and Hot Harold, where the two sulfide insert – microbial incubators were deployed since August, 2003. We also sampled vents at the Cuchalain and Stonehenge structures. Fluid salinities from refractive index measurements were slightly above seawater levels. Temperatures were similar to previous years. Shipboard measurements indicate that the strong gradients that existed in the MEF prior to 1999 have not returned. We did not make extensive temperature measurements in hot vents during this cruise, but the measurements we did make are lower than in previous years at Grotto, MQ, and Hulk structures and nearly identical to previous years at Sully vent. Salinities from refractive index measurements are 25 to 28 per mil in the hot fluid samples. At Clambed, we sampled diffuse fluids at or near the point of the RAS intake and also hot fluids from a chimney that had a maximum temperature of 305C, hotter than any previous measurement at this site.

On board the ship, we measured pH, alkalinity, hydrogen sulfide, ammonia, and dissolved silica. Samples were frozen for additional nutrient analysis on shore. Various samples cuts were preserved for analysis of major, minor, trace elements and stable isotope ratios. Gretchen Fruh-Green will analyze vent

fluid samples for hydrogen and oxygen isotopes of water and sulfur isotopes in dissolved sulfide and sulfate.

Time series chemical and microbial sampling instruments

Part of our work during this cruise is to investigate the link between seismic activity, microbial communities and hydrothermal flow. In August of 2003 during the ROPOS cruise, we deployed 3 instruments to sample hydrothermal fluids and particles. These instruments are intended to monitor the chemical and microbial composition of the vents and provide samples that will allow us to determine any changes that might occur over the year, and how the changes relate in time to seismic activity detected by the seismometer array. There have been very few collections of vent fluid samples on this time scale, and none in association with an array of seismometers. We recovered all of the time series samplers during this Alvin cruise.

The instruments involved are two Remote Access Samplers (RAS) and one Phyto-Plankton Sampler (PPS) manufactured by McLane Research Laboratories. The RAS collects 48 water samples (up to 500 ml per sample), and each sample is filtered to remove particulate material entrained with the sample. Filters and fluids will be analyzed for chemical composition when the samplers are recovered. Filters are either pre-combusted, pre-weighed glass fiber filters (0.45 micron effective pore size) or 0.2 micron pore size polycarbonate (GTTP, Millipore).

The PPS collects 24 particle samples that are preserved for microbiological analysis (e.g. DNA extraction, FISH). The preservative is 2 wt% NaCl in 50% (by volume) ethanol. Filters are 47mm diameter, 0.2 micron pore size polycarbonate type GTTP filters (Millipore). The PPS and one RAS were combined on a single mooring with one intake line to assure that we get chemistry and microbiology from the same vent. This sampler mooring was dropped from the ship and landed approximately 50 meters east of the south end of Hulk. The final deployment site for this combination sampler was a diffuse vent at the south end of Hulk, approximately 1 m east of the main fissure that runs from Hulk to Dante, in an area of strong diffuse flow. Coordinates are (x,y) (5049, 6242) or 47 deg 57.00246' N, 129 deg 5.81838' W, at 2200m depth. This is one of the most vigorous diffuse flow sites seen in the MEF. It is at the base of Hulk, and is associated with a very thin layer of sulfide in some areas. The intake was placed directly over a crevice lined by palm worms and limpets and surrounded by tube worms. This mooring had a Homer Pro (ID #15) attached to it. The PPS sampled every two weeks starting at 11:20 GMT on 8/19/2003. The RAS was intended to sample every week at 12:00 GMT starting 8/19/2003, but based on the date and time upon recovery, the RAS was set to Pacific Time (GMT-7) by mistake. The sampler was on the seafloor for 3 days and not installed until 8/21/03 05:00, so the first RAS and PPS samples are ambient bottom seawater at a depth of 2200 m.

The second RAS mooring was dropped at 47° 57.7850 N, 129° 05.4367, approximately 100 m east of the Clam Bed site. The final deployment site for this sampler was directly on the "Kiss" mound, immediately adjacent to the 3 settling arrays deployed by Noreen Kelly. Extreme care was taken not to disturb the area during installation. There are clear hot fluids venting from this mound, and strong diffuse flow. One water sample was taken at the site. The temperature measured by the fluid sampler in the location of the RAS intake was 20-45°C. No sample of the hot fluids was taken prior to installation of the RAS, as we were trying to minimize the time spent around the settling plate experiments. This RAS takes a sample every week starting at 12:00 GMT on 8/20/2003. It was installed on 8/18/2003.

Recovery and processing of RAS-9 and PPS at SE Hulk. RAS sampler deployments are numbered according to the sequence in which they are taken out of the water. The RAS at SE Hulk (serial # 11605-02) is number 9 since the first deployment in 2000. The time series water and particle samplers at SE Hulk were visited on dive 4014 (5/26/04) and a major sampler pair was taken. The intake for the sampler was picked up to verify that the temperature recorder was attached and the intake was placed back down in a slightly different position. Two days later the sampler was released (using a pull-pin) on dive 4016. It was recovered on deck within approximately one hour of being released, the PPS was disconnected from the RAS, both were thoroughly rinsed and wiped off on deck, and then both were moved into the walk-in cold room. The mini-temperature recorder #3053 was recovered from the top of the sampler where it was placed before releasing from the seafloor. The RAS clock was 17 minutes and 11 seconds behind local time. The intake line was pulled out during recovery, but did not suffer any damage. All plumbing was leak-free upon recovery. Samples were kept cold and unexposed to air in their original laminated bags during all sample processing. Each sample label was verified, the volume measured by the level of water remaining in the cylinder (none of the cylinders leaked through the deployments and recovery). Water was analyzed on board for pH, alkalinity, hydrogen sulfide, ammonia, and dissolved silica. Two of the samples from RAS 9 had puncture holes in the bags (#4 and #38) and were therefore compromised. Every water sample was filtered through either a glass fiber filter or a polycarbonate membrane. The filters were rinsed in the holders with a small volume of milliQ water to remove saltwater and were suctioned partially dry and stored in labeled Petri slides. Selected filters were frozen at -70 for organic carbon analysis. Remaining filters will be dried, weighed and analyzed for chemical composition.

The PPS filters were preserved in-situ with ethanol/NaCl buffer. They were suctioned to partial dryness, folded, placed in small centrifuge vials, flash frozen in liquid nitrogen, and stored in the -70C freezer. The first sample of the PPS took the full 1500 ml programmed. All remaining samples filtered near 350ml and then stopped due to low pump limit. The PPS clock was 22 minutes and 24 seconds behind GMT. Andrew Opatkiewicz will be working on the PPS samples for DNA analysis and studying microbial communities in the context of a variable chemical environment. Ben Larson and Brooke Love analyzed methane and hydrogen concentration in the time series samples from both RAS instruments.

Recovery and processing of RAS-10 from Clambed We documented and released RAS-10 (serial # 11605-01) from the mound vent at Clambed during dive 4018. It appeared that there had been significant growth of tube worms on the mound and the intake line and temperature recorder were completely hidden. The intake line appeared to lead from the RAS into new sulfide material, and the stainless steel jacket around the Teflon was totally dissolved from this portion of the intake line. We could not find the temperature recorder and recovered the RAS without it. If possible, we will look for the recorder with ROPOS in September of this year. RAS-10 was recovered at the surface and processed in the same way as RAS-9. Samples 1 through 23 were filled. The remaining samples were empty. The intake line was blocked by organic debris and the pump was not functional at all after recovery. The clock was 25 minutes and 46 seconds behind GMT after recovery (measured on 6/7/04). Several samples have extremely low pH (2.0) and almost certainly have been contaminated with HCl that was used to partly flush the intake line between samples. The remaining samples provide a useful time series of highly variable conditions on a growing sulfide mound at Clambed.

8.0 MATERIALS AND PUMP TEST

An apparatus to test direct siphoning and pumping of vent fluid through a cooling coil was deployed on Dive 4017 at Sully. The main purpose of this test was to see if this siphon/pump system could be used

as a way to cool fluids before they entered a mass spectrometer and gas chromatograph. Attached to the intake of the system were titanium wire cages containing samples of several materials. The experiment was recovered on Dive 2021. The siphon began to work right away but appeared to stop up at least in the first couple as days as a flyby on 4019 did not show obvious flow. The pump intake was blocked during deployment and that test was inconclusive. A second test included in this assemblage included a variety of materials that were put in flow to determine their durability in high temperature venting environments. Of the materials that were tested, alumina and graphite seemed to fare well. Boron nitrate disintegrated completely, ruby was inconclusive, and cubic zirconia shattered, most likely from thermal shock.

9.0 CTD Operations

CTD operations during this cruise succeeded in exploring several of the CH_4 hits identified by Marv Lilley in July and September, 2000. Two areas north of Sasquatch were explored for signs of vent activity. Casts 2-3 were tow-yos conducted along valley between 48° 4.0' N and 48° 6.0'N. No signs of venting were identified in this region and we were not able to find the CH_4 hits that Marv found four years ago. Casts 4-12 concentrated on the region ~0.5 mile north of Sasquatch vent field. This series of tow yos (casts 4-6) and pogos (casts 7-12) completed in lines along- and across- valley positively identified a vent plume during all eight casts, with a maximum T anomaly of ~0.140 and a maximum CH_4 concentration of 296nM. We believe that casts 11 and 12 were closest to the source of the plume (highest T anomalies and CH_4 concentrations). Traces in cast 12 show signs of a bimodal plume where the highest CH_4 and greatest T anomalies were found in the sharp, thin peaks in both T anomaly and transmissivity. The combined data from these casts suggests that there may be a field on the eastern wall of the axial valley, northeast of the Sasquatch field.

10.0 Education and Outreach

The Education-Outreach program on this cruise included three main components; the participation of an anthropologist from MIT, hosting of the Dive and Discover program and Web site, and the Bosun's poetry night (BPN). Although one might wonder why we consider the BPN, as it is now known, as part of Education and Outreach, it is clear from the outcome of this event that it touches many scientists and shps crew in very nonlinear ways, and it is our way of honoring the crew. If there is any doubt that we did not all come away much richer from this experience, a poem written by Kevin Threadgold, an OS on the Atlantis, is included at the end of this section for consideration.

Stefan Helmreich, an anthropologist from MIT, joined the cruise to learn more about contemporary vent science, toward a book he is writing about the cultural implications of changing scientific knowledge about the sea in the age of deep exploration, DNA sequencing, and digital imaging. As a social scientist, he was interested in following, in practice, how marine scientists apprehend such locales as hydrothermal vents, ecologies that stretch our closest conceptions of the very limits of life itself. Extreme Marine Biology, the tentative title of his book, will draw from his experiences and conversations on the Atlantis and Alvin (among other ships and sites) to deliver a portrait of how marine scientists are newly imagining the ocean as a network of microbial life hyperlinked to global biogeochemical process, as a site in which recently discovered geological processes reposition our understanding of vitality, and as an analog to extraterrestrial environments that may support life.

The cruise hosted the Dive and Discover program overseen by the Woods Hole Oceanographic Institution (see http://www.atlantis.whoi.edu/webpages/DiveDiscover). Amy Nevela sailed as a writer and photographer for the web site, producing daily descriptions of cruise operations and science, daily slide

shows, and interviews with scientists, students, and crewmembers. Woods Hole provided posters and postcards previous to the cruise to advertise this program. By all accounts the program was extremely successful, with numerous questions sent to us at sea by students, classrooms and the public. From May 24 to May 31 (mid-way through the cruise) there were approximately 13,643 visits to Dive and Discover. This equals an average of 1,700 visits per day. The average visit length is12 minutes and 14% of the visits are international. Amy was a delight to sail with and we thank Woods Hole for their participation.

Top Countries by # of visits	Top States by # of visits	Top Domains
1) US (86%)	1) California (21%)	1) Commercial (67%)
2) UK (3%)	2) Massachusetts (15%)	2) Network (22%)
3) Canada (2%)	3) Virginia (10%)	3) Education (9%)
4) Australia (1%)	4) Ohio (7%)	4) Organization (1.5%)
5) Germany (1%)	5) Washington (7%)	5) Government (0.5%)

BOSUN'S POETRY NIGHT:

There has been a tradition established on the Atlantis to honor the Bosun, Wayne Bailey, in the form of a poetry-reading night. It has turned into a very special occasion, much look forwarded to by the science party and the crew. The poem below was a product of that evening.

BOSUN'S POETRY NIGHT: A POEM BY Kevin Threadgold

A sailor moves uneasily between two worlds. There is the sea upon which he works - an unambiguous, liquid prison filled with garrulous, chain smoking PeterPans- and there is the world always just beyond his reach, redolent of cold beer and women and music on the radio: aluminous crystal cathedral built on an active fault and furnished throughout with lovingly doctored memories of all the things that might have been. It would be less than accurate to call it a dreamworld; the fountainhead is always a place fixed firmly in both time and space -a locker room in Beaumont, a fishing camp in Hot Springs, three acres in Maine- but it is less the place itself than the spirit invoked by such a place that rides the sailor's shoulder like John Silver's parrot, editing, colorizing, revitalizing the tiny piece of sacred ground from which a man draws his strength. It is to this psychic carnival of florid, desultory apocrypha, emotional memory and genetic predisposition that a sailor barters his allegiance, and with which he will be forever bound up as tightly as the foot of an imperial geisha. Moses called it the PROMISED LAND. Sailors call it THE BEACH.

A job on the beach is a rare and precious thing. There is, forever deck sailor, just as there is for every convict, a point at which he can no longer function as a free man. The ship feeds him, washes his plate, makes his coffee, gives him a warm bed, a hot shower, pays his doctor, his dentist, his concubine and, inevitably, his counsel in matters pertaining to divorce, alimony and child support. The ship is the devil he knows, and though his may be a talent of folkloric dimension, his skills are vestigal and increasingly anachronistic, his fate ultimately sealed by time and stubborn dedication.

Sailors walk a thankless wire. Alternately envied our freedom and scorned as a delinquent cabal of tattooed, fornicating rum sponges, we have been miscast, although perhaps not sorely, in the role of hopeless prodigal. Yes, it has been my experience that

even the most grotesque caricature distills to a shot glass of truth, and yes, there is hardly a man amoung us who has not paid for a woman or staggered drunk up a gang-way. But do we not all, one way or another, pay for our women? And is the world really such a paradise that the mystery of the drunkard's fugitive, headlong rush to the circular ruins of unconscious bliss should confound even the most insipid Pollyanna? Before doctors, before lawyers, before there was a high priest in Bethleham, there was a sailor, and while there is spice to sell and a ship to move it, there will be sailor's still.

Table 1. Atlantis-Alvin AII-13 2004 Personnel

University of Washington

Debbie Kelley	Chief Scientist
John Delaney	Co-Chief Scientist
David Butterfield	Scientist
Mitch Elend	Oceanographer
Sheryl Bolton	Oceanographer
Deborah Glickson	Student
Ben Larson	Student
Kris Ludwig	Student
Andrew Opatkiewicz	Student
Brooke Love	Student

Scrippts Institution of Oceanography

Kevin Brown	Scientist
David Hilton	Scientist
Michael Tryon	Post Doc
Allison LaBonte	Student

ETH-Zurich

Gretchen Früh-Green	Scientist

Massachusetts Institute of Techonology

Stefan Hemreich	Scientist

University of Massachusetts

Jim Holden	Scientist

Woods Hole Oceanographic Institution

Amy Nevela	Writer

Lamount Observatory

Vicki Ferrini	Post Doc

Shipboard Support

Dave Sims	SSSG
Kazumi Baba	SSSG

Atlantis Personnel

George Silva	Master
Mitzi Crane	1st Mate
Craig Dickson	2nd Mate
Adam Seamans	3rd Mate
Jeffrey Perkins	Com/ET
Wayne Bailey	Bosun
Jerry Graham	AB
Raul Martinez	AB
Edward Popowitz	AB
Kevin Threadgold	OS
Jose Andrade	OS
Jacob Greenberg	OS
Jeff Little	Chief Eng
Gary McGrath	1st Engr
Monica Hill	2nd Engr
Michael Sprull	3rd Engr
Philip Treadwell	Oiler
Stuart Meacham	Oiler
Carl Wood	Steward
Mark Nossiter	Cook
Linda Bartholomee	MA

Alvin Crew

Patrick Hickey	Expedition Leader
Bruce Strickrott	Pilot
Gavin Eppard	Tech
Mark Spear	Tech
Anthony Berry	Tech
Sean McPeak	Tech
George Meier	Tech

TABLE 2: ATLANTIS 11-13 OPERATIONS SUMMARY

Date	Operations	Comments
5/23/04	0930 Transit from Seattle to Endeavour Segment	Good weather
5/24/04	Arrived on site at 14:30 and deployed XX recoverable transponders from Alvin Group. Spent part of the evening surveying in the net.	High winds and poor sea state precluded dive operations
5/25/04	**Alvin Dive 4013** Faulty Towers Complex. Pilot: Hickey, Port: Kelley, Stbd Delaney. Successfully recovered data loggers from Hot Harold and Roane, and complete incubator assemblage from Roane. Barrel assembly could not be recovered from Hot Harold. Got gas tight and major samples from both structures, started 65 m Imagenix line to south	No night operations.
5/26/04	**Alvin Dive 4014** Main Endeavour Field. Pilot: Bruce Strickrott. Port: Butterfield, Stbd: Brown Labonte flow sensor was deployed east of Milli-Q in an area rich in hydrothermal sediments. A temperature survey was completed in the sediments with temperatures reaching 27°C, and water samples were taken of diffuse flow in the area. Butterfields remote access sampler and particulate DNA sampler was examined at Hulk and water samplers (gas tight and majors) were taken in diffuse flow near the instrument. An imagenix survey was completed within the MEF.	**Cast 1&2** Night operations included CTD operations. A background cast was completed at 47°59.998N, -129°20.01W Depth: ~2200m. Follow-on tow-yo work was done starting at 48°04.2051, -129°02.8291 running south about one mile to find new field. Towards the end of the Tow, may have found a ground fog at ~2400m – with a noticeable change in transmissivity and potential T- one bottle was tripped at this site
5/27/04	**Alvin Dive 4015** Mothra Hydrothermal Field. Pilot: Hickey, Port: Delaney, Stbd: Glickson. Crab Basin was mapped using the Imagenix system (~ 60x100 m box), and Cuchalainn and Stonehendge were sampled and partially mapped.	Very high resolution map produced **Cast 3** Night operations defined new hydrothermal plume north of Sasquatch with methane concentrations 10 x's background values Plume has a complex structure that reaches ~ 240 m above the seafloor.
5/28/04	**Alvin Dive 4016** Main Endeavour Field. Pilot: Strickrott, Port: Kelley, Stbd: Tryon LaBonte flow sensor recovered, Tryon chemical-flow sensor deployed at base of Milli-Q near LaBonte site. Continued temperatue survey at instrument site, recovery of RAS and PPS from near south face of Hulk. One-year deployments successful.	**Cast 4: Tow-yo N of Sasquatch 1** Evening operations focused on defining plume north of Sasquatch. The plume is characterized by an average potential T anomaly of 0.09 and a spike in transmissivity. Five of these bottles contained above background levels of methane (10 - 34 nM).
5/29/04	**Alvin Dive 4017** Main Endeavour Field Pilot: Berry, Stbd:Hickey, Port: Larson. Pressure sensor recovered, temperature-resistivity probe in Sully listened to with ICL-probe is still working, siphon and materials tests put in other orifice at Sully, gas tight and major water samples taken, a few Imagenix lines completed on north side of Grotto.	**Cast 5: Tow-yo N of Sasquatch 2** This line ran from N to S on the E side of the axial valley. The T anomaly was only ~0.04 and the small plume was mostly between 1900 and 2000m.

Date	Operations	Comments
5/30/04	**Alvin Dive 4018** Clam Bed and Main Endeavour Field Pilot: Stricrott, Stbd: Butterfield, Port: Früh-Green Ras sampler recovered from High Rise and major and gas-tight samples taken, transited down to MEF with Imagenix on and imagenixed northern part of the field.	**Cast 6: Tow yo N of Sasquatch 3** This line was planned to bisect the axial valley floor, from N to S. The highest methane concentrations were found towards the end of the tow line
5/31/04	**Alvin Dive 4019** MEF Clean up and Marker Deployment Pilot: Hickey, Stbd: Kelley, Port: Love Dive focused on clean up of Easter Island because this was the most littered place in the field. Significant progress was made in recoverying old markers, lines, pieces of gear. Johnson's MAV was recovered that was lost in 2003, new makers were placed at almost all of the structures in MEF.	**Cast 7: Along valley pogo line near hot spot found in Cast 6** A pogo track line was run along valley with pogos every 100 m.
6/01/04	**Alvin Dive 4020** Imagenix survey of Mothra Pilote: Strickrott; Port: Delaney, Stbd Helmreich Dive focused on imagenix mapping of Mothra 5 southern complexes completed and significant area east and west. Very high resolution map produced.	**Cast 8: Pogo line across valley, intersecting Cast 7 line** An across-valley pogo line perpendicular to Cast 7. The plume was consistently ~150-200 m above the seafloor. CH_4 con-cen-trations ranged from 3-28 nM.
6/02/04	**Alvin Dive 4021** MEF Instrument retrieval and water sampling dive. Pilot: Hickey, Port: Butterfield, Stbd: Opatkiewicz. The flow meter at M-Q was released, photomosaic completed of MQ and water samples taken. Resistivity wand and siphon test recovered from Sully, Grotto was sampled 330°C, water sample taken at Hulk 297°C, and a few Imagenix survey lines completed.	**Cast 9: Pogo line across valley, south of cast 8** CH_4 concentration was 175nM. The plume was an average 150 – 200 m above the seafloor.
6/03/04	**Alvin Dive 4022** Transponder Recovery north of Mothra on west and east axial valley walls. Pilot: Strickrott, Port: Ferrini, Stbd: Eppard Transponders were searched for on west side, but not found. Alvin transited to east and recovered Transponder K (10.5/9). A second weight was found with a short piece of line, but no transponder. It must have self released.	**Cast 10: Zig-Zag pogo line across valley, south of cast 9** At ~1000 m, we realized that the trans-mis-someter was not detecting any changes **Cast 11: Pogo line across valley, south of cast 9 (cast 10 resumed)** This cast began at the second station of the proposed track for cast 10. This cast marks some of the highest T anomalies (up to 0.140) and CH_4 con-centrations (296 nM)
6/04/04	Weather Day with high winds, so after pulling trans-ponders we left station and transited to Nootka to test Brown et al. Flow sensors and search for appropriate seep sites.	**Cast 12: Pogo line SE of cast 10 & 11** T anomaly gradually increased as did the CH_4 concentration in the plume (from 20 to 283nM). Cast marks some of the highest T anoma-lies (up to 0.140) and CH_4 concentra-tions (296 nM). Weather deteriorated and cast was terminated

Date	Operations	Comments
6/05/04	**Alvin Dive 4023** Nootka transform and relsease of Tyon CAT sampler. Pilot: Hickey, Port: Brown, Stbd: LaBonte, CAT sampler was released from small seep site after a 1-year deployment. Survey was completed along small ridge at front of margin to look for new seep sites. Marker K was placed at a site of dead tube worms	No night program
6/06/04	**Alvin Dive 4024** Nootka transform and discovery of new seep site. Pilot: Strickrott, Port: Delaney, Stbd: Tryon. Southern portion of accretionary margin was explored and a new seep was found near the plunge pool. Extensive areas of dead clams, a few well developed clusters of large live clams and isolated pods of large snails were found. Sparse bacterial mats were also observed (X = 18499 Y = 14290, Z =2275 m). Clams reached up to 20 cm in length. **Alvin Dive 4025** Bounce dive to recover Alison LaBontes instrument. Pilot: Hickey, Port: Brown, Stbd: Hilton. Night dive to recover instrument, completed within a couple hours. Transit begun to Port Angeles.	No night program
6/07/04	Transited to Port Angeles, transferred Captain Silva to shore and steamed to Seattle. Arrived in port ~ 2200.	

11.0 SUMMARY OF CRUISE OPERATIONS

MAY 23, SUNDAY TRANSIT

The R/V Atlantis departed from the University of Washington, School of Oceanography dock at 0930 and transited through the Ballard locks to the Straits of Juan de Fuca and on to the Endeavour Segment of the Juan de Fuca Ridge. The transit was smooth and we arrived on site at 1430 on May 24th. (47°55.44'N 129°06.522'W).

MAY 24, MONDAY ARRIVE ON SITE AND DEPLOY TRANSPONDERS

Transiting continued under good weather conditions and the Thompson arrived on station at ~1430. Three transponders were deployed to cover the Main Endeavour and Mothra Hydrothermal Fields and surveyed.

TABLE 3. TRANSPONDER LOCATIONS AT11-13 / KELLEY ET AL, MAY/JUNE 2004

Endeavour Ridge - Origin 47N53.634 129W09.870 Mag Var 21.5 East UTM Zone 9 Time Zone +7

Xpdr Freq	Owner	S/N	Net ID	Rel Code	Proposed Lat.	Proposed Lon	Surveyed Lat	Surveyed Lon	Survey Dpth	Recovered
Transponders A and B Mothra Field, 24 May 04.										
9.0/10.5	ALVIN	35003	A	D	47N55.40	129W06.00	47N55.342	129W05.829		6/4/04
					RMS=0.90	Pts=155	Y=3166	X=5037	1963 m	
9.0/13.0	ALVIN	54374	B	G	47N56.00	129W05.75	47N55.995	129W05.739		6/4/04
					RMS=0.58	Pts=126	Y=4376	X=5148	1940 m	
ACNAV .NIT file 11 13A.NIT										
Transponders A and B Main Endeavor Field, 24 May, 04										
9.0/8.0	ALVIN	68268	C	H	47N56.75	129W05.50	47N56.644	129W05.537		6/4/04
					RMS=0.90	Pts=138	Y=5400	X=5578	1966 m	
9.0/10.0	Perm	65213	D	N/A	47N57.350	129W04.967	47N57.364	129W05.005		
					RMS=0.06	Pts=206	Y=6913	X=6064	1881 m	

MAY 25, TUESDAY ALVIN DIVE 4013 RECOVER SULFIDE-MICROBIAL INCUBATORS FAULTY TOWERS COMPLEX, MOTHRA HYDROTHERMAL FIELD

Pilot: Pat Hickey
Port: Debbie Kelley
Stbd: John Delaney

The goals of this dive was to recover two sulfide microbial incubators from the structures Roane and Hot Harold at Faulty Towers in the Mothra Hydrothermal Field and to redploy one incubator back into Roane. The instruments were deployed in June and September of 2003, respectively. Water samples were to be taken at these to sites (major pairs and gas tights), in addition to imaging of the structures. The final goal of the dive was to begin imagenix surveys of the field.

The dive started on time with a dive target of 47°55.381 and 129°06.465 (x = 4244, y = 3237), about 100 m SE of Faulty Towers. Following an ~ 1.5 hour transit to the bottom, we arrived on site at 16:08 about 40 m east of the complex in an area of lobate flows enclosed by well developed ponds of hydrothermal sediment. Transiting to the west over lobate and rubbly basaltic flows, we reached the pinnacles within about 5 minutes and found the incubator in Hot Harold near the northernmost corner of the pinnacles on the eastern face of the complex. We imaged the structure, noting a 2.5 m chimney growing from the orifice where the incubator was emplaced. The base of the chimney colonized with animals and worms, as was the upper 2/3 of the chimney. In contrast the lower portion of the chimney lacked macrofaunal development and was highly oxidized. A small piece of chimney had toppled onto the cable between the data logger housing and the incubator and so we removed this.

At 16:18 we transited south along the east face of the Faulty Towers Complex to recover the incubator from near the top of Roane. We arrived at Roane (X= 4165 Y = 3297) within a few minutes and began an intense video survey of the structure prior to beginning the recovery operations. At 16:48 we began our attempt at recovering the insert, which started with closing the outer barrel of the instrument. We then tried to pull, twist, and leverage the incubator out of the hole. Unfortunately during this process (17:05), the screws holding the face plate to the incubator barrel assembly sheared off and the assembly pulled free of the plate, ripping the thermocouple arrays out of their titanium sheaths and breaking the wires. The barrel assembly remained in the hole, but the thermocouple-termination housing fell down the side of Roane, but was held by the cable still attached to the data logger housing. The barrel assembly was then pulled free at 17:16 and placed in the holster at the front of the submersible basket.

At 17:20 we used the high-temperature probe to measure the temperature inside the hole, with an upper temperature of xxx. This temperature was believed to be much lower than the actual temperature within the hole due to entrainment of seawater into the corehole. Because of this, the top portion of the small pinnacle on Roane was sampled (17:25, x = 4169 y = 3297, depth = 2271, alt = 5.9, hdg = 24) to provide a site for good water sampling. A temperature of 207.4 was measured, and at ~17:29 water samples were taken using the double yellow major pair and the orange gas tight bottles. We then imaged the corehole, which showed that it was still very clean and actively venting clear, relatively particle free fluid. At 17:42 we started a video mosaic traverse from the base of Roane to the top. Following this, at 17:53 we began to deploy the new insert into the hole. This operation went very smoothly, with the first 2 barrels going into easily. The decision was made to leave the remaining barrel out of the hole, and to finish the deployment by placing the data logger on top of the stump of Roane. We left this area at 18:10 to head back to Hot Harold, leaving the original data logger and faceplate assembly at Roane for later pick up.

Alvin arrived back at Hot Harold at 18:18, and began an imaging survey of the site to prepare for removal of the insert. A 2.5 m tall chimney had sprouted from the corehole orifice at the top of the sulfide insert. At 18:28 we used the high-temperature probe to take a temperature at the top of the 1-year old chimney, yielding a temperature of 286°C. The top portion of the chimney broke off and we recovered this sample at 18:32 (x = 4178 y = 3313, hdg = 243, alt 2.6, z = 2270). We then took double major blue and gas tight blue fluid samples from the newly established orifice. After taking the water samples the sub repositioned to attempt to get the incubator out of Hot Harold. After trying unsuccessfully for several minutes to pry, pull, tug the insert, the decision was made to shear off the barrel assembly to at least recover the data. At 18:55 the data logger and face plate holder was recovered, leaving the barrel insert inside the chimney wall. We then transited south to Roane to recover the data logger from Roane.

We arrived easily back at Roane and recovered the data logger at 19:12. After recovering the data logger we imaged the area around Roane, doing a mosaic transect of Finn and Phang, and recovering Hobo TG that was deployed in 2003 in a black smoker near the base of Roane to the east (x = 4170, y = 3295, hdg 68, alt 2.1, depth 2276 m). At 19:37 we started an imagenix survey centered over the Tower and running south. We traveled ~ 65 m to the south, and then ran out of power, ending the dive at ~ 20:00 (x = 4154, y = 3208). We dropped weights and slowly rose to the surface.

MAY 26, WEDNESDAY ALVIN DIVE 4014 DEPLOY FLOW SENSOR
Main Endeavour Field

Pilot: Bruce Strickrott
Port: David Butterfield
Stbd: Kevin Brown

Alvin dropped east-northeast of Dudley, drove west over extinct sulfide chimneys and faults and found the structure Dudley. It was quickly determined that there was no suitable site for a flow meter deployment, and Alvin started driving south along the fissure toward S&M. The area around the north end of S&M was investigated where new smokers have been growing since 2000. There is diffuse flow here, but not through sediment. After a brief look around, we drove down around the N end of S&M on the east side, checked out another diffuse site at the base of the wall by S&M and continued toward Milli-Q vent along the wall.

Alvin drove directly to the DK1 marker site and found flat sedimented areas on top of weathered sulfide. This looked like a promising site for the flow meter deployment. We performed a temperature survey using the low-temperature probe and found uniformly high temperatures in the sediments, typically near 4-5°C at the surface, 10-12°C at 5cm depth, and up to 25-27°C at 10 to 15 cm depth. At the bottom of the sediment that we could penetrate with the temperature probe, the temperature dropped again, indicating that this was not simple upward flow of warm water through sediments, but required some kind of lateral transport.

The optical flow meter ("Allison") was deployed at this site (18:24:34 gmt; X= 4945 Y = 5953; hdg 301, alt 2.4, depth 2192 m). After the deployment, we moved 2 meters away and surveyed another patch of sediment. This had similar profiles, but the bottom layer drop in temperature was not as pronounced. We took a gas-tight sample at the edge of the patch where the flow meter was deployed. A small amount of loose sediment was entrained into the gas-tight bottle when it fired. Temperature maximum measured in the shimmering fluid at this spot was 18°C prior to sampling. Although there were some concerns about the choice of site, we nonetheless left the instrument where it was and went on with the rest of the dive objectives.

Alvin drove north toward the RAS/PPS time series samplers at a diffuse vent SE of Hulk vent. Using the Homer transponder, we easily found this site and took some video documentation. Alvin moved the intake nozzle slightly to make sure the temperature recorder was attached, then took a major sample pair at the intake location. Temperature at this site was also about 18°C. After taking the major sample pair, we drove south to the pressure sensor at Homer #91 and recovered the pressure sensor. We then started a series of N-S lines for Imagenix mapping in a box that contained S&M and MQ vents. During the mapping we drove over Sully and part of the Bastille complex as well as over and around S&M and MQ.

LBL navigation was unreliable. Frame grabber was accidentally turned off on the touch-screen computer shortly after leaving the flow meter site near MQ, probably while adjusting sonar. It remained off for the rest of the dive because it was not noticed.

CTD Night Operations

Cast 1: Background SW Vertical Cast

We steamed approximately 10 miles to the west of the ridge axis for background seawater collection. Bottles 2 and 3 were fired at 2088 m and collected for Dave Butterfield for background seawater. No one else requested background seawater. Potential temperature and salinity data from this cast were used to determine variables for calculating the potential temperature anomaly for upcoming vent plume casts.

Cast 2: Tow-yo near July, 2000 "far north" CH_4 hits 1

Tow-yo conducted from N to S along line located "far north" of Sasquatch. The purpose of this line was to pass near two CH_4 hits located by Marv in July, 2000. This was more or less a "shake down" run for those of us learning the process of tow-yos. The line was planned 1 mile north and 1 mile south of the target sites and ~200 m to the west of the targets. Wind was coming from the west and the ship's bow was into the wind and crabbed along the southbound trend line, towing the CTD off the starboard side. Tow-yos began at ~2400 and continued until ~0500. We did not have values set correctly for potential temperature anomaly- these were post-corrected on 27 May 2004 and new print outs for the casts replaced the old ones in the binder. Ship speed was 0.3kt and CTD wire was changed from 30m/min to 50m/min to speed up the process. The METS sensor was not working and is likely flooded. Bottle 2 was fired at the end of the tow in something that appeared to be "ground fog," but no CH_4 was found in the sample.

MAY 27, THURSDAY ALVIN DIVE 4015 IMAGENIX MAPPING AND SAMPLING

Mothra Hydrothermal Field

Pilot: Pat Hickey
Port: John Delaney
Stbd: Deborah Glickson

The dive began by flying to Pinocchio, an extinct sulfide between Twin Peaks and Faulty Towers. This site was used as a benchmark for Doppler and LBL (X=4180, Y=3331). A survey was then begun of the area around Crab Basin. We completed a box (~80 x 110m) around Crab Basin consisting of 6 N-S lines and 5 E-W lines (focused on the structures) flying dominantly at xx m above the bottom. But a few higher lines were flown at an altitude of xx to image the tops of the structures. A final line was surveyed back to Pinocchio to check for offsets.

After completing our survey, we began traversing to the S to locate structures at Cuchalainn and Stonehenge. We took water and gas tight samples at Brigid (Cuchalainn; Marker G) and at one of the structures at Stonehenge (near Marker E). After exploration to the S, we began N-S lines from Stonehenge to the edge of the Crab Basin box (~200-250m line). We completed 2 lines before the power ran out.

CTD Night Operations

Cast 3: Tow-yo near July, 2000 "far north" CH_4 hits 2

Tow-yo conducted near same line as Cast 2, only this line was designed to pass directly over the two CH_4 targets (Marv, 2000). Watches were established and from now on, a team of 6 people will complete CTD ops. Ship speed was increased to 0.5kt, CTD wire controlled at 50m/min. During the beginning of the cast, we had a few computer and software glitches- first the printer wasn't able to print casts (fixed), then the read-out of the winch wire went mysteriously to zero (it was accidentally switched off), and then there was a lack of communication between the Seabird software and the depth readings. We re-booted the computer and started again- the new data file that was created and used for the rest of the night has an "a" at the end of the file name.

The tow was conducted from N to S. Coordinates were plotted on the "Northern Endeavor Segment" map in the lab at the beginning of every other "up" cast (see map) and marked with GMT time on the map. During the 0000-0300 watch, there was a spike in the potential T anomaly. This was apparent throughout the rest of the tow at a depth of ~2000-2200m. This does not appear to have any correlated changes in transmissivity. The CTD was slowed to 30m/min while going through the "plume." We fired a total of 15 bottles (Niskins 2-16) in this plume during the tow. These were sampled for CH_4 to be analyzed later in the day. No CH_4 was found in these samples.

MAY 28, FRIDAY ALVIN DIVE 4016 RECOVERY OF FLOW METER, RAS, PPS

Main Endeavour Field

Pilot: Bruce Strickrott
Port: Debbie Kelley
Stbd: Mike Tryon

Alvin reached bottom at 0929 on a easterly dipping talus slope. Navigation errors at the beginning of the dive precluded good fixes and a lot of time was spent trying to determine proper headings to the dive target. It is very likely that the sub landed high up (2152 m) on the western wall of the axial valley significantly north of Hulk. We ranged in on the homer on the south face of Hulk to determine our location and transited to this site. Once there, navigation was recalibrated so that we could keep bottom Doppler lock, and the x-y's were checked. Alvin transited along the fissure system south past S&M to near DK1. At 17:18 we arrived at Allison Labonte's Optical Flow meter on the sedimented bench just north of MQ, we attached floats to the instrument and it was elevatored to the surface. A series of temperature measurements were completed around the position of the Optical Flow Meter, and the double major blue bottle was fired at a very weak, diffusely venting flow site that was seeping from a crack in the crust of oxidized hydrothermal sediment.

At 1855 Alvin moved a few meters to the north, staying on the bench and began an extensive gridded temperature survey of the bench. Eight new survey points, with multiple readings at each location were completed, adding to the previous survey. At 19:30 the CAT flow meter was deployed on the bench (X = 4943 Y = 5960, depth = 2299, hdg 238, alt 1.3). At 1950 we attempted to take another major sample using the double yellow bottles, but the bottles could not be rotated into position. After storing the bottles we left site and began transiting to the Remote Access Sampler (RAS) near the base of Hulk.

Alvin arrived at the RAS at 20:11, imaged the instrument with digital stills and video imagery, and then pulled the pull pin to release the instrument (X = 5048, Y = 6241, Z = 2200, hdg = 333, alt = 1.0). With battery power running low, we completed one westerly line immediately west of Hulk that ran to the western axial valley wall, just to the talus line. We circled once to start a new line but were out of power and the dive was terminated at 2058.

CTD Night Operations

Cast 4: Tow-yo N of Sasquatch 1

We planned a track line to the N of Sasquatch vent field using the rationale that the other fields at Endeavor seem to be approximately the same distance apart from one another, so that there may be another field that distance just N of Sasquatch. The track line was planned slightly to the W of the axial valley and we dropped into a well-defined plume. We tracked this plume to an area near Sasquatch. The plume is characterized by an average potential T anomaly of 0.09 and a spike in transmissivity. The plume was at ~1900 – 2100m, which is ~250m above the seafloor in this region. The structure of the plume changed from single – to bi-modal signatures and seemed to go back and forth between these forms as the tow continued from N to S. A total of 13 Niskins were fired throughout the tow in the plume and later analyzed for CH_4. Five of these bottles contained above background levels of methane (10 - 34 nM). These were Niskins 5, 7, 9, 13, and 14.

MAY 29, 2004 SATURDAY ALVIN DIVE 4017 INSTRUMENT TESTS AT SULLY, IMAGENIX MAPPING MAIN ENDEAVOUR FIELD

Pilot: Anthony Berry - PIT
Port: Pat Hickey
Stbd: Ben Larson

The drop target for this dive was just Northeast of S&M at X = 5050, Y = 6050. After landing just north of the target, the Pat and Berry determined the cause of a ground fault to be the Dan-cam, so it was shut off for the remainder of the dive. The Doppler was set to the Top Lab's coordinates (X = 5113, Y = 6087), and the sub transited to S&M and then southwest to Sully. Alvin transited to Sully to listen to the resistivity probe, deploy the materials test, and to test the siphon. Once at Sully, we set up with the ICL loops to listen to the resistivity probe deployed there in August of 2003. After photographing the deployment set-up, communications were established, and the resistivity and temperature readings appeared to be valid, so the probe was left intact at the vent which had a temperature of 363.6 ºC according to the res probe (GMT: 17:42 – 18:35, X = 4900, Y = 5972, Depth = 2190 m, Hdg = 301)

After listening to the res probe, we set up just to the right of the orifice that the instrument was in for fluid and rock sampling GMT: 1901 – 19:17, X = 4896, Y = 5973, Depth = 2190 m, Hdg = 148). The vent effluent was measured with the Alvin high temperature probe, and we observed a temperature of 363ºC. The blue gas tight was taken at 19:01. The yellow major pair was taken between 19:06 – 19:09. Pictures were taken of the sample site prior to rock sampling at 19:12. A sulfide rock sample was collected between 19:12 – 19:17. File 2004_05_29_19_12_20.jpg shows the orifice from which fluids were sampled just prior to the sulfide sample, and file 2004_05_29_19_22_56.jpg shows the same orifice after the rock sample was taken. The notch right in front is the location of the rock sample.

After the fluid and rock sampling, we prepared to deploy a materials test at this same orifice. So, without moving the sub, the resistivity test wand (containing a non-functioning prototype of the next generation resistivity sensor) was deployed into the orifice from which the fluids were sampled (with a fluid temperature of 363 ºC)(GMT: 19:17 – 19:22, X = 4895, Y = 5973, Depth = 2189 m, Hdg = 148).

After deploying the resistivity wand, we repositioned ourselves to an orifice just to the left of us and attempted to deploy the siphon test. This apparatus consists of two titanium tubes one with a pump on the back end, the other open at the back end. Lashed to the front end of the two conjoined tubes is a collection of materials that may be used for in-situ sensor construction. The attempted deployment failed because the orifice was not big enough to accommodate the chunk of materials secured to the end of the tubes. So, we returned to the previous orifice, which had been widened by the rock sampling and were able to forcibly deploy the siphon/materials test in the same orifice as the resistivity test wand (GMT: 19:26 – 19:49, X = 4896, Y = 5974, Depth = 2189 m, Hdg = 101). After deploying the siphon materials test, we deployed an 'S' marker at the top of the Sully structure (GMT: 19:50 – 19:52, X = 4895, Y = 5974, Depth = 2190 m, Hdg = 156). We then moved away from the Sully structure slightly, dropped weights at 19:57 and began our ascent.

CTD Night Operations
Cast 5: Tow-yo N of Sasquatch 2
Another track line was planned to hone in on the plume found last night. This line ran from N to S on the E side of the axial valley. The cast began near a site where Marv found a CH_4 hit in September, 2000. A faint plume was evident throughout the tow, but was not as well defined as Cast 4. The T anomaly was only ~0.04 and the small plume was mostly between 1900 and 2000m. Later in the tow (~D17) it seemed to expand in depth from 1900-2100m. We tripped Niskin bottles 2-9, which were later analyzed for CH_4, and most of them had levels of CH_4 not much above background (0 - 7 nM). These methane concentrations, like the temperature anomalies, were significantly lower than those measured in Cast 4.

30 MAY 2004 SUNDAY ALVIN DIVE 4018 RECOVERY OF REMOTE ACCESS SAMPLER FROM CLAM BED, IMAGENIX MEF

Pilot: Bruce Strickrott
Port Observer: Dave Butterfield
Stbd Observer: Gretchen Früh-Green

Alvin landed close to Clam Bed and drove to the site and located the RAS within about 5 minutes. The mound was overgrown with abundant tubeworms, which had buried the temperature recorder. The stainless steel braiding on the outside of the teflon intake line was also corroded away near the end, and it appeared that the end of the tube disappeared into sulfide. We spent an hour searching for the temperature recorder, but could not find it. It was placed on a flat part of the mound in clear shimmering flow with palm worms in August, 2003, but now most of the mound is covered with long tube worms and there is new sulfide growth. We were not able to look from different angles because there were two settling plate arrays around the mound that we did not want to disturb. We took two major samples (green and black) and 1 gas tight (with no tape) sample at the intake site (X = 5467, Y = 7683, hdg = 346, alt = 1.8, depth = 2187). The left green major didn't fire. ICL-Temperatures at the intake site were 38-59°C. We released the RAS, then tried again to find the temperature recorder. We sampled a small chimney, ~30 cm tall, that had grown on the mound at Clam Bed (X=5464, Y = 7683, Z = 2189, alt = 1.7, hdg = 24.3). Temperature

maximum at this chimney measured with the high-T probe was 305°C. We took the white gas tight water sample and the blue major pair.

We then transited south to the MEF. The remainder of the dive was dedicated to flying Imagenix lines north of what we thought was Hulk, but we missed Hulk by going around it to the west. As it turns out, we were probably in the vicinity of Lobo or Grotto instead. The RAS arrived safely and was onboard as we returned from the dive. Only 22 of 41 scheduled samples were collected because the intake was blocked by a worm that had gotten into the Teflon line.

CTD Night Operations
Cast 6: Tow yo N of Sasquatch 3
This line was planned to bisect the axial valley floor, from N to S. Because of some ship steering problems and currents, we were off course for U1-D3 (see lat/lons) at the beginning of the tow. From north to south, we tracked a small plume with a T anomaly that increased from ~0.050 in D2 to 0.120 in D15 and decreased to 0.105 at the very end of the line at D20. The highest methane concentrations were found towards the end of the tow line in the plume observed in U15, where CH_4 reached 17nM (Niskin 14). A total of 13 bottles were collected during this cast.

31 MAY 2004 MONDAY ALVIN DIVE 4019 MEF CLEAN UP AND MARKER DEPLOYMENT

Pilot: Pat Hickey
Port Observer: Deb Kelley
Stbd Observer: Brooke Love

This dive was dedicated to cleaning up the MEF and to deploying navigational markers at as many chimneys as possible routinely visited by investigators. Alvin landed close to Hulk and proceeded to place markers at Hulk, Crypto, Dante, Grotto, Lobo, Dudley, Smoke and Mirrors, Easter Island, Bastille, Puffer, Tara, and Needle. All markers are white triangles with letter cutouts on ~ 1 m long yellow polypope lines. During work around Grotto, we located a MAV current meter of Johnson at the UW, which was lost year. Alvin successfully recovered the instrument, which is believed to have a years worth of current meter data logged. Significant changes were noted with in the MEF field. An area immediately west of Lobo, which had been a tube worm-rich diffuse flow site, now hosts a well developed black smoker chimney. There was a new small smoker at the base of Bastille near the new marker and the top several meters of Puffer had fallen over, creating a large area of sulfide talus. The structure is now a small mound and hosts a small chimney, which has developed immediately east to where we used to take many of our samples. A hobo that was cemented in the structure was recovered from the old work site. Significant progress was made in cleaning up Easter Island, picking up a variety of old markers, weights, blocks, a Medusa guide base, and other junk.

CTD Night Operations
Cast 7: Along valley pogo line through hot spot found in cast 6
A pogo track line was run along valley with pogos every 100m. The intention was to go through and investigate the hotspot found the previous night. During the night, the temperature anomaly increased from ~0.060 to 0.110 from west to east. The plume became better defined towards the end of the line and appears to be a neutrally buoyant plume ~150 - 200 m above the seafloor. Niskin bottles 2-12 were fired at various points of the pogo line and later analyzed for CH_4 concentrations, which ranged from 2-13nM.

1 JUNE 2004 TUESDAY ALVIN DIVE 4020 IMAGENIX MOTHRA

Pilot: Bruce Strickrott
Port: John Delaney
Stbd: Stefan Helmreich

This dive focused on Imagenix mapping of the Mothra hydrothermal field. A total of 13 N-S lines were completed during the survey, which started just north of Faulty Towers and finished south of the Stonehenge complex. During this dive a bench mark was established at a small extinct structure called Pinocchio (X = 4180, Y = 3331), which is located in between Faulty Towers and Twin Peaks. During the survey, the lines were conducted at a spacing of 15 m, and generally 10 to 15 m off bottom. This survey resulted in a very high resolution map of the field and delineated a major collapse basin, individual chimneys within the complexes, and very well defined fissures.

CTD Night Operations
Cast 8: Pogo line across valley, intersecting cast 7 line
An across-valley pogo line that is perpendicular to cast 7 was planned. We dropped into the plume on the first downcast and similar to cast 7, the T anomaly of the plume increased as we continued from west to east. The peak T anomaly during this line was 0.125. The plume was consistently ~150-200 m above the seafloor. Niskin bottles 2-18 were fired throughout the pogo line and later analyzed for CH_4. Concentrations ranged from 3-28 nM, with higher concentrations in bottles 14-18 at the end of the pogo line.

2 JUNE 2004 WEDNESDAY ALVIN DIVE 4021 MEF INSTRUMENT RETRIEVAL AND WATER DIVE

Pilot: Pat Hickey
Port: Dave Butterfield
Stbd: Andrew Opatkiewicz

On the way to the bottom, we attempted to establish contact with the pressure recorder on the basket with the ICL onto a laptop in the sub. The serial connector to the computer came off once, but we reconnected, secured it and waited for 30 minutes with no data coming in. After a call to the surface and discussion with Ben Larson, we decided not to leave the pressure sensor on the bottom and stowed it in the back of the basket.

We reached the bottom at 16:21 GMT at a location east of MilliQ vent, drove west over small ridges of sulfide rubble to the DK1/flow meter site. Our recorded x,y at the site was 4931,5952, which is about 15-20 meters SE of Milli-Q vent. We attached the recovery buoy and released the flow meter, which ascended rapidly and without problem. Next, we drove the short distance to Milli-Q vent, deployed marker M on the NE side of MQ, Doppler x,y of 4918,5944, 2186 m depth and heading 160. We ran two up-down photo-mosaic runs with and without strobes at MQ. The first run was on the NE side, heading 182. The second run was on the south end, heading approximately 330. We chose the top of the spire to sample fluids, and took the black major pair and red gas-tight at the top vent, with measured temperature of 310 to 311 using both the high-T probe and the ICL temperature sensor on the major pair. Some pieces of the chimney that we sampled for fluids were put in the forward port corner of the basket.

We left MQ and drove to Sully, where we recovered the resistivity wand test and the siphon and pump materials test and data recorder. We then drove to the S&M marker and at 18:22 reset the Doppler to 4955, 6016, which moved our position 15 meters to the east. The LBL navigation was erratic all day, so we relied on the Doppler. We continued past the seismometer at homer beacon #91 up to Grotto. Pat saw marker G and we drove east along the south edge of Grotto to an embayment in the structure where we found a cluster of smokers at 2190 meters depth, on the lower half of the structure. When we toppled a weak portion of the forward chimney with the high-T probe, a few seconds later a small chimney about .5m behind the one we touched "exploded" up into the water. We took the yellow major pair and gas-tight with no tape at this vent at location 4954, 6139, z=2190, heading 340. Temperature was 330°C on the high-T probe and 333-334 on the ICL.

We left Grotto at 18:51 and drove NE towards Hulk, finding the large fissure and driving a few meters on the west side, then noticed Hulk directly across from us. Pat saw the H marker near the south end and we proceeded to find a hot vent to sample on the west side, northern half of the structure, with an old triangle marker, not very legible but probably "8", a few meters away to the south. We recovered a small piece of sulfide chimney to the forward starboard corner of the basket. We took the white gas-tight and the blue major pair here, measuring a maximum of 297C with the high-T probe. Following the water sampling we recovered a large piece of this chimney with hot fluids still venting and numerous sulfide worms in the forward basket. We proceeded to run 6 Imagenix mapping lines in a box with sides at x= 5025 and x=5075, y=6150 and y=6300. These lines took us around both sides of Hulk and Crypto and over the top of these structures as well. We lost bottom lock once when we crested the top of a steep sulfide dropping away to the north. We finished this mapping box at the SE corner and headed for the next box between Hulk and the western talus slope, but only completed one line before we were out of power. We turned and dropped weights over the talus and headed for the surface.

CTD Night Operations

Cast 9: Pogo line across valley, south of cast 8

To attempt to put a southern constraint on the plume found in cast 8, we planned a second across-valley pogo line that is parallel to the line in cast 8. For this cast, the ship traveled from NW to SE across the valley with pogos every 100 m. The first downcast hit the plume where there was 0.090 potential temperature anomaly with a methane concentration of 17nM. Both of these parameters increased as we steamed towards the SE along the track line. The maximum potential T anomaly observed during this cast was 0.115 (D12, D13) where the CH_4 concentration was 175nM. The plume was an average 150 – 200 m above the seafloor.

3 JUNE 2004 THURSDAY ALVIN DIVE 4022 TRANSPONDER RECOVERY NORTH OF MOTHRA

Pilot: Bruce Strickrott
Port: Vicki Ferrini
Stbd: Gavin Eppard

The focus of this dive was to recover transponders from the western and eastern flanks of the Endeavour Segment. Numerous targets were visited based on best known estimates of transponder locations, however the sonar was not working well and only one transponder was recovered. This transponder was recovered from the edge of the vertical wall at the top of a steep talus slope at X=5158, Y=4374. A second

set of weights was located at X=5270 Y=4375, but the line had been severed and no transponder was found. The dive was terminated at 13:00 because Alvin ran out of power.

CTD Night Operations

Cast 10: Zig-Zag pogo line across valley, south of cast 9

The line planned for this cast was a "zig zag" shape, designed to continue the NW/SE line begun in cast 9 as well as cover area further to the south to better constrain the plume. At ~1000m, we realized that the transmissometer was not detecting any changes and reading at a flat number. The CTD was lowered to plume depth (~2000 m) to determine if this would change, but it appeared that the transmissometer was not working and possibly flooded. The CTD was brought back on deck with 3 Niskin bottles (8, 9, 10) imploded (one was not cocked). The transmissometer was also not working, independent of the implosion. Bottles and transmissometer were removed, we steamed to the next station (100 m NW along the track line), and the CTD was launched again. A new data file was started as cast 11 (see below).

Cast 11: Pogo line across valley, south of cast 9 (cast 10 resumed)

This cast began at the second station of the proposed track for cast 10. This cast marks some of the highest T anomalies (up to 0.140) and CH_4 concentrations (296 nM) observed during any of the CTD night ops. As we steamed NW with pogo stations every 100 m, the T anomaly and CH_4 concentrations decreased to 0.120 and 126nM, respectively. We suspect that we were closer to the source of the plume at the beginning of this cast (47° 59.9757, 129° 02.9233) given this trend in T and CH_4.

4 JUNE 2004 FRIDAY WEATHER DAY – TRANSIT TO NOOTKA

Cast 12: Pogo line SE of cast 10 and 11

In an attempt to put a southern and eastern limit on the plume tracked during cast 11, we planned a line that began SE of the starting point of Cast 11 (where we found the highest signal). The goal of this track was to complete pogos every 100m towards the NW and drive into the plume observed during last night's cast. The pinger was not working for this cast (pin not removed) but the altimeter was working well and was used to lower the CTD to ~10m above bottom. The first downcast hit the plume (peak ~150 m above bottom) and as we moved along the track line towards the NW, the potential T anomaly gradually increased as did the CH_4 concentration in the plume (from 20 to 283nM). Unfortunately, weather conditions continued to deteriorate – the ship was having increasing difficulties holding position and moving along the proposed track line. Near 0900 GMT (~0300 PST), with 30kt winds and 8-10' swell, we decided to end CTD operations. Station 10 is not on the track line since the ship could not stay on station or on line. We decided to do one last cast where the ship was at the end of the night (see lat/lon in log). A total of 12 bottles were taken for CH_4 analyses. Methane concentrations appear to be increasing in the NW-bound direction of this line.

5 JUNE 2004 SATURDAY ALVIN DIVE 4023 NOOTKA TRANSFROM AND WHOI BUOY

Pilot: Pat Hickey
Port: Kevin Brown
Stbd: Alison LaBonte

Alvin dropped into the Nootka site a few hundred meters east of the target site. This first target, a small seep site at 49º 18.70N 127º 41.80W and 2282m depth, was the location of Mike Tryon's CAT meter de-

ployed by ROPOS, August 2003. After failing to communicate with homer #93 believed to be located at the site, we stopped to survey the sub in. Keeping ground lock, we used Alvin's navigation to find our way up and over the 40-50m incline to the seep site where homer #93 was no more. This incline appears to be the scarp showing interspersed bedding planes. We also noted bits of carbonate and scattered dead clams.

After releasing Mike's CAT meter from the site by clipping glass balls to float the instrument up, we observed the black sediments that were turned over. This, the neighboring tube worms, and an old exposed carbonate structure were the only indicators of flow. The Optical Flow Meter (OFM) was deployed in the same location. We confirmed that the external chamber was sealed to the sediment, checked that homer #15 attached was functioning, grabbed a sample rock (most likely country rock from the brecciated zone that didn't survive the ascent and recovery) and headed off to survey seep sites.

We followed the lineage of the scarp at a 142º heading and unfortunately were not able to scan for the high backscatter seep sites with the forward looking sonar as it wasn't functioning properly. We did keep the imagenix on throughout the dive. During the survey, we noticed a handful of clumps of tubeworms at various locations, but predominately located between rocky scarp terrain and sediment, areas not particularly akin to flow meter coupling.

Losing the scarp lineage off and on as we followed the ridge down into the turbidite channel we noticed blocks of uneroded carbonates exposed some trending more perpendicular to general scarp strike. Crossing by dead tube worms, and more dead clams we came to a clear looking fault scarp, ie. a smooth black vertical exposure at 17956,15475 and 2367m depth. The ridge even seemed graben like. This being the only significant feature so far, we placed marker K. Continuing our tour to try to pick up the scarp on the opposite bank of the turbidite channel, we ran out of battery power and ascended.

6 JUNE 2004 SUNDAY ALVIN DIVE 4024 NOOTKA TRANSFORM: DISCOVERY OF NEW SEEP SITE

Pilot: Bruce Strickrott
Port: John Delaney
Stbd: Mike Tryon

The purpose of this dive was to explore the southern portion of the accretionary margin for seep sites that could be instrumented for testing of the Brown et al., flow sensor package and for the hydrothermal packaged to be deployed on a follow-on Keck program. The focus of the beginning of the dive was to locate the frontal fault at the southern end of Nootka/frontal thrust site area. Alvin landed on bottom and began a zig-zag patterned survey heading NW over faulted ridge. After about an hour into the dive, extensive evidence for deformation was found with multiple scarps and outcrops seeming to trend N, NW, and W. Abundant clam shells, mostly disarticulated, were observed and all clams were dead. In this same area, numerous small patches of microbial mat about 20 cm across were found, in concert with Neptunia (?) snails (X= 18496-Y= 14350). Marker I was left at this site, and a gas tight and major water sample was taken. Following sampling the submersible moved north and found two Two dense patches of Calyptogena clams and Marker K was deployed (X = 18499 Y = 14290, Z =2275 m). The clams were about 20 cm long and all are live: a few of them were sampled for shorebased analyses. The end of the dive was focused on completing a small Imagenix survey of the area.

This general area, the northern part of our overall survey, is broken by ridges and fault scarps that have strikes that vary from N to NW to W. Our feeling is that there are more seep sites here and that there may

be more broken up grounds to the NW, approaching a strand of the Nootka fault. The seep area itself was approximately 60 x 60 meters and may be larger. We visually surveyed this area and found seep indicators in roughly linear patches in shallow valleys between ridges. The topography in this area is relatively rough with up to 20 meters of relief. This site appears to be a good site to instrument as part of the program to look at how earthquakes may effect the subsurface hydrogeology and rates and chemistry of fluid flow at seeps.

7 JUNE 2004 SUNDAY ALVIN DIVE 4025 NIGHT BOUNCE DIVE

Pilot: Pat Hickey
Port: Kevin Brown
Stbd: David Hilton

Because of the tragic death of Captain Silva's son and need to immediately steam to shore, Pat Hickey graciously agreed to conduct a rare night dive. The goal of the dive was to recover a flow meter that was the focus of a Ph.D. project. The dive started at 2001, was on bottom by 2116, and left bottom by 2126, with a surface time of 2235. The instrument was successfully recovered. Subsequent to securing the instrument, we immediately steamed to Port Angeles.

8 JUNE 2004 MONDAY TRANSIT TO PORT ANGELES AND SEATTLE

Under calm seas the Atlantis made extremely good progress to Port Angeles and the Captain was shuttled to shore early in the morning. The Atlantis steamed to Seattle, arriving in port at ~1400.

Appendix 1.

Marker Deployment May 31, 2004

Structure	Mkr	Time	X	Y	Z	alt	Hdg	Comments
S&M	SM		4955	6016	2194		226	N. end near fault ledge
Dudley	Du	1757	5011	6120	2200	1.8	122	SW corner
Dante	D	1643	5002	6150	2190		284	SW corner
Crypto	Cr		5059	6216	2203	1.5	118	Western side
Hulk	H	1627	5044	6242		2.1	26	S end near fissure
Lobo	L		4948	6172	2192		67	S. end
Grotto	G		4943	6131	2189	9.7?	211	SW corner
Tara	T		4919	5978	2184		12	On extinct sulfide SE of Tara high on eastern side
Needle	N	1905	4917	6000	2177		205	On top
Puffer	P	1841	4891	5979	2194	2.9	145	Inside ring, N side base by old U
Sully	S	1950	4895	5974	2190	1.4	156	N side of Sully near summit
Bastille	B	1837	4894	5992	2193	1.3	11.9	S face middle, by old P
Easter Island	EI		4882	6018	1296	1.2	244	Edge of wall

Appendix 2. Microbiology Sample List

Date	Dive #	Description	Culture	DNA	FISH	Cell Counts
25-May	ALV4013	Double major #25/26 at Roane, Mothra (T=187 deg C)	*	*		*
25-May	ALV4013	Double major #23/24 at Hot Harold, Mothra (T=286 deg C)	*	*		*
25-May	ALV4013	Piece of sulfide from the top of Roane, above the insert	*	*	*	
25-May	ALV4013	Piece of sulfide from Hot Harold, growing out of insert hole		*		
25-May	ALV4013	Roane Sulfide Insert deployed 2003	*	*	*	
26-May	ALV4014	Major #23 at RAS-9 - SE Hulk, Main Endeavour (T=18 deg C)	*	*		*
27-May	ALV4015	Double major #10/16 at Cuchalainn, Mothra (T=307 deg C)		*		*
27-May	ALV4015	Double major #22/25 at Stone Henge, Mothra (T=302 deg C)		*		*
28-May	ALV4016	RAS-9 at SE Hulk, Main Endeavour, year-long deployment, sampled once/week				*
28-May	ALV4016	Particle sampler (PPS) at SE Hulk with RAS-9, filters were in-situ preserved		*	*	
29-May	ALV4017	Sterile sulfide insert burrito exposed to seawater on ascent (control)	*			
30-May	ALV4018	RAS-10 at Clam Bed, year-long deployment, sampled once/week				*
30-May	ALV4018	Major #11 at Clam Bed near RAS-10 intake (T=14-57)	*	*		*
30-May	ALV1018	Major #15 at Clam Bed near RAS-10 intake (T=14-57)	*	*		*
30-May	ALV4018	Major #16 at Clam Bed near RAS-10 intake (T=6-27)				*
30-May	ALV4018	Major #23 at Clam Bed near sampled sulfide chimney (T=150-168 deg C)				*
30-May	ALV4018	Major #24 at Clam Bed near sampled sulfide chimney (T=150-168 deg C)				*
2-Jun	ALV4021	Sulfide chimney from West side of Hulk, Main Endeavour	*	*	*	
2-Jun	ALV4021	Double major #23/24 at Hulk from sampled chimney orifice (T=238 deg C)		*		*
2-Jun	ALV4021	Major #11 from South side of Milli-Q, Main Endeavour (T=309 deg C)				*
2-Jun	ALV4021	Double major #25/26 from South side of Grotto, Main Endeavour (T=334 deg C)				*