

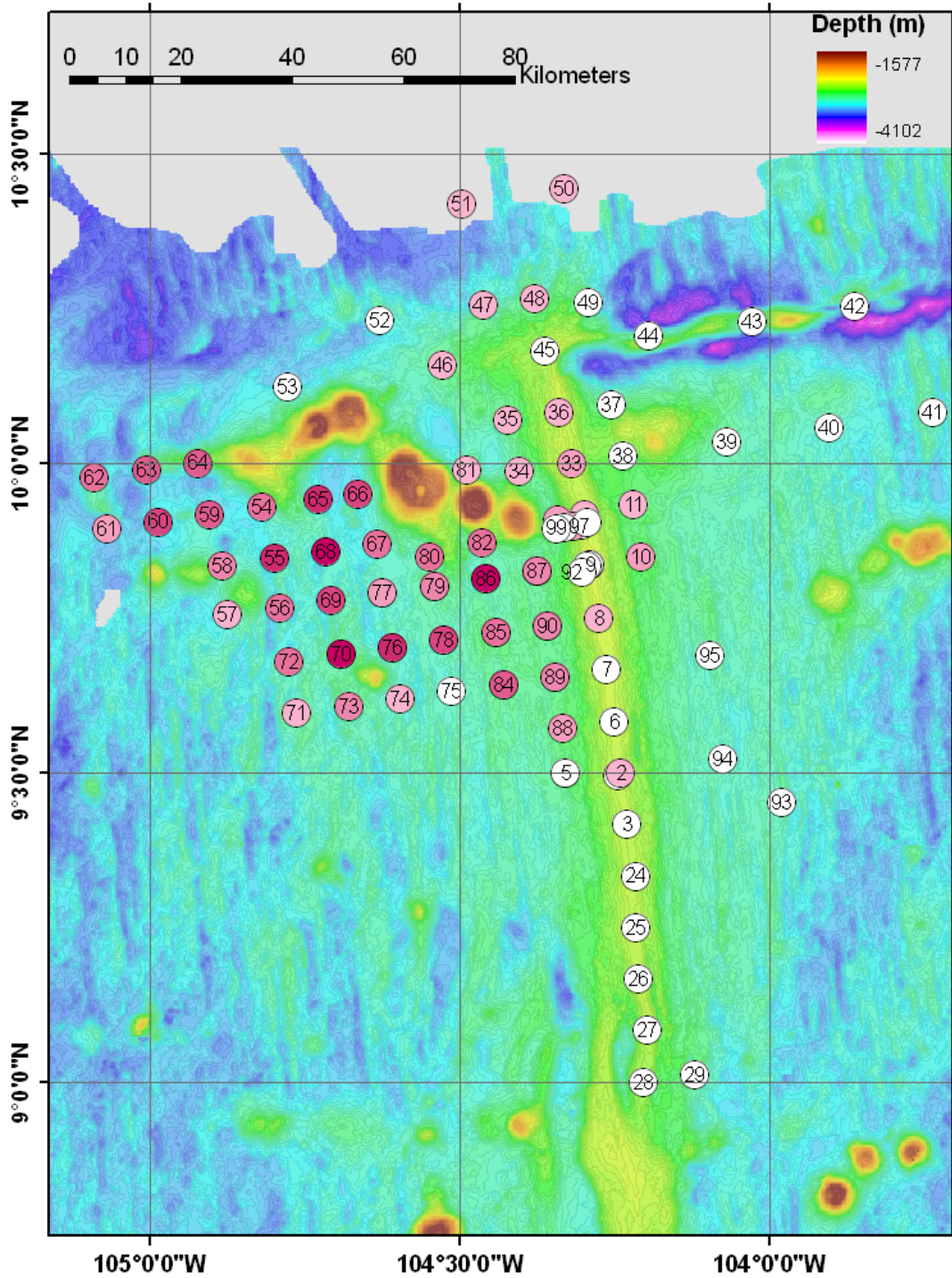
Cruise Report
R/V Atlantis, Cruise AT15-14
11 December 2006 - 5 January 2007
LADDER-2

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Acknowledgments

We thank Lauren Mullineaux, lead investigator of LADDER, for her guidance. Andreas Thurnherr led the LADDER-1 cruise and analyzed data from the bottom-mounted ADCP from on shore during LADDER-2 to help guide the tracer search. Guidance for tracer sampling was also provided by modeling by W. Lavelle, and D. McGillicuddy. The success of the LADDER-2 cruise would not have been possible without the excellent support of the crew and officers of *R/V Atlantis*, the team of Alvin pilots and engineers, and the SSSG technicians. Funding by NSF Grant OCE-0424953 is gratefully acknowledged.



LADDER-2 CTD/LADCP stations. The intensity of the red color increases with the column integral of SF₆ found during the tracer survey. Some of the later stations obfuscate earlier ones (see Figs. 3.1 and 3.2). Bathymetry is from the multi-beam survey of MacDonald et al. (1992).

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1. Overview

1.1 The LADDER Project

LADDER is a study of Larval Dispersal along the Deep East Pacific Rise, especially focused on hydrothermal vent species. LADDER-2 is the second of three cruises of the LADDER project. LADDER-1 took place in October and November, 2006, and LADDER-3 is scheduled for November and December 2007. The LADDER project aims to address the following questions¹:

Bio-1 - What are the influences of advection and eddy diffusion on the maximal dispersal distance of vent species with given larval life spans?

Bio-2 - What are the effects of ontogenetic changes in larval behavior (i.e., vertical positioning) on species' dispersal distances?

Bio-3 How are the probabilities that larvæ will be lost from the ridge system influenced by topography and flow? Might the axial summit trough² inhibit off-axis transport of larvæ, and serve as a conduit between habitable vent sites?

PO-1 What are the mean and temporally varying flows in the vicinity of a mid-ocean ridge crest, and what is their spatial structure and coherence?

PO-2 What is the magnitude of the diapycnal diffusivity near the ridge crest?

PO-3 How rapid is lateral dispersion, and how effective is lateral homogenization by eddy diffusion near the ridge crest?

In order to address these questions, the LADDER-2 cruise was carried out in the vicinity of the East Pacific Rise between 9°N and 10°N and between 103°W and 105°W. The cruise was concerned with the following components of LADDER:

Plankton Pumps (Section 2). The spatial and temporal distributions of larval invertebrates was determined by positioning plankton pumps near the seabed and at the height of the neutrally buoyant hydrothermal plumes to collect larvae and determine where species reside during different stages of their larval life spans.

Colonization Experiments (Section 2). Colonization experiments were deployed in order to quantify the influence of larval supply on recruitment, and monitor changes in recruitment as the new vent communities mature.

Tracer Survey (Section 3). A CTD/LADCP survey of the distribution of tracer that had been released in the axial trough during LADDER-1 was carried out.

¹See <http://www.ldeo.columbia.edu/eant/LADDER> for details

²The axial trough on the EPR crest is sometimes called the AST or ASCT. The PIs of the LADDER project prefer to call it the "trough" although the acronyms may also be used in this cruise report.

1.2 Ancillary Projects

The following activities carried out during the cruise are not part of the LADDER project, but are closely related:

Potential of hydrothermal plumes as a source of dissolved iron (Fe) to the deep ocean and a sink of dissolved organic carbon (DOC) (PI: Chris German/Sarah Bennett; Section 9). The aim of this project is a study of the role of inorganic colloidal Fe species in vent plumes and the role of hydrothermal plumes as potential scavengers of dissolved organic carbon (DOC). Water samples were collected using Niskin bottles attached to the CTD rosette and Alvin and were filtered using appropriate methods in preparation for analysis back in a land based laboratory.

Hydrothermal Vent Meiobenthos (PI: Monika Bright, Sabine Gollner, Sigrid Katz; Section 10). The aim of this project is to study the present status of the meiobenthic community shortly past eruption and to follow the succession of colonization and development of communities. Cruise activities included collection of meiofauna from different natural substrates, from the water column at various heights above the bottom, and from off-axis sediments. Additionally, meiofauna settlement devices were deployed and recovered.

Development of *Riftia Pachyptila* (PI: Monika Bright, Sabine Gollner, Sigrid Katz; Section 11). The aim of this project is to study the infection process, growth, and developmental processes in *Riftia Pachyptila* symbiosis as well as cell kinetics in symbiont-containing and symbiont-free host tissue. Cruise activities included recovery and re-deployment of tubeworm settlement devices, and recovery of basalt from warm vents to collect small tubeworms.

Early Life Stages of *Alvinella Pompejana* (PI: Florence Pradillon, Laure Corbari; Section 12). This project aims to understand how embryos of the polychaete annelid *Alvinella Pompejana* are able to disperse and colonize new vent sites. Two main activities were carried out during the cruise: 1) *In situ* experiments to analyze early development and larval colonization in relation to local environmental conditions. 2) *In vitro* development experiments were conducted on board to analyze sensitivity of early embryos at different pressure levels.

Chemical characterization of habitats (PI: Nadine le Bris; Section 13). Our objective for this cruise was to chemically characterize vent habitats at 9°N following the January 2006 eruption, in order to document initial environmental conditions of colonisation experiments (Lauren Mullineaux, Florence Pradillon and Monika Bright experiments) and to compare the actual conditions to those determined before the eruption. The relation of biologically relevant chemical factors, such as free sulphide or pH, with temperature is a potential driver of the species diversity in vent habitats.

Preliminary Deployment of Magnetic Collectors for Examination of Vent Particle Dispersal (PI: Chris Taggart, Barry Ruddick, Noreen Kelly; Section 14). Two sets of magnets were deployed near a black smoker chimney to test whether iron oxide particles from deep sea hydrothermal vents can be captured by passive magnetic collectors. If successful, iron oxide particles may be used as a proxy tracer for the potential dispersion of biological organisms from and to neighbouring vent communities.

2. Larval Studies

[Susan Mills, Travis Elsdon, Alexis Jackson and Kira Krumhansl, on behalf of Lauren Mullineaux, with help from Ryan Jackson.]

2.1 Overview

The main objectives of our group are to characterize the vertical and horizontal positions of larval invertebrates in the water column, to measure temporal changes in their supply to vent communities, and to examine the relationship between larval supply and recruitment into the benthos. These larval studies are coordinated with the LADDER tracer release and other physical oceanographic measurements, and will be integrated into a coupled biological-physical model. The timing of these studies is fortuitous because they are being conducted during the early stages of ecological succession after the Jan. 22, 2006 eruption at the 9°50'N area.

Our approach includes sampling with plankton pumps synoptically at locations near and above bottom, within and outside the axial trough. These pumps provide a snap-shot of larval distributions over a 24-hour period. We use sediment traps to monitor changes in larval supply over longer time scales of weeks to months. Colonization experiments are placed on the seafloor at the same sites and for the same durations as the larval supply measurements.

2.2 Larval Supply

We deployed and recovered three sets of paired moorings (PumpL9 through L14), each with a plankton pump at 3 m above bottom and another just below the level of the neutrally buoyant plume. At 9°50'N, the upper pump was located at 75 m above bottom; at 9°30'N the upper pump was at 140 m above bottom. For each pair of moorings, one was placed directly at a vent site within the axial trough ("on-site") and the other on axis, but away from known diffuse flow venting ("off-site"). Mooring sites were located near Ty/lo and Tica vents near 9°50'N and at K vent near 9°30'N. The moorings were lowered on the hydrographic wire and navigated in using a relay transponder, the Alvin LBL net, and DVLnav software in the computer lab. A wire-mounted Edgetech acoustic release was used to release the mooring from the wire and individual acoustic releases were used to release the mooring from the seafloor. The pumps were scheduled to run for 24 hrs, starting at 15:30 GMT (9:30 LT) for the off-site ones and 18:30 GMT (12:30 LT) for on-site pumps. This timing allowed for submersible relocation of the on-site mooring and recovery of both moorings during the Alvin dive. All pumps collected full, 24-hour samples, filtering more than 41,000 L during each deployment.

2.3 Colonization Studies

We recovered colonization surfaces (basalt blocks and sandwiches - six layers of roughed polycarbonate plates assembled into a cube 10 cm on a side), together with their associated Hobo temperature probes, from four sites where they were deployed on LADDER-1 (Tica, P vent, Sketchy (south of Ty/lo) and K vent). These had been deployed in three temperature regimes: 2-4°C (low temperature), 4-10° (intermediate temperature) and 10-30° (high temperature). These temperatures correspond roughly to the suspension-feeder zone, the bivalve zone and the vestimentiferan zone in the pre-eruption communities. At Sketchy there was only room for the high and low temperature treatments. At each temperature we had deployed five sandwiches and a Hobo; at Tica we also put out three basalt blocks with each set

of sandwiches. All surfaces that were deployed during LADDER-1 were recovered and replaced with new ones, in the same locations, matching temperatures where possible. In addition, sandwiches were deployed at a new site near V vent (9 47.27'N, 104 16.97'W) where pre-eruption communities of mussels, serpulids and tubeworms have survived. Three sets of five sandwiches each were deployed among *Tevnia*, mussels and serpulids, in temperatures matching the three temperature regimes listed above. A full description of these experimental sites is available on request from L. Mullineaux.

3. Tracer Release Experiment

[Jim Ledwell, Ryan Jackson, Leah Houghton and Cynthia Sellers, WHOI]

3.1. Tracer Injection during LADDER-1

Twenty moles of sulfur hexafluoride were released during LADDER-1 in a 1200-meter long line along the axial trough on 12 November 2006 near 9°30' N. Details of the release are in the LADDER-1 cruise report. In summary, the injection went smoothly in one continuous line at a constant injection rate. The mean height above the bottom was 4.8 meters, but the variability in the height above bottom was large due to collapse features along the track. *DSV Alvin* was moving at approximately 8 m/min, with the injection plume streaming back toward the vehicle and along and through its skin on the starboard side. The density of the water into which the tracer was released averaged $\sigma_2 = 36.9602$, but this density would have been decreased slightly by the thermal plume of the submarine and by mechanical mixing of shallower water within the wake of the submarine, and increased slightly by the density of the tracer itself. Estimation of the magnitude of these effects will be made on shore.

3.2. Tracer Survey

One of the main goals of the present cruise was to survey the tracer released during LADDER-1 after approximately 40 days of circulation and mixing. The survey was performed with conventional CTD/Rosette/LADCP casts and with a set of 1.2-L Niskin bottles mounted on *Alvin* and tripped in the axial trough during the various dives of the cruise. The survey began on 14 December 2006 and ended on 3 January 2007, and thus occupied the period between 32 and 51 days after release. The first phase of the survey was during the first five *Alvin* dives, with CTD operations at night only (Casts 2 through 12), and lasted from 14 to 18 December. The second phase comprised a continuous series of CTD casts over 10.5 days, from 18 to 28 December (Casts 13 through 82; 36 to 46 days after release). The final phase again involved casts at night, with *Alvin* dives during the day, from 28 December to 3 January (Casts 83 through 100).

The column integrals of tracer found at the first 53 stations are shown in Fig. 3.1 and at Stations 54 through 100 in Fig. 3.2. Two figures are required because several stations were reoccupied, with no tracer found the first time around and in some cases great quantities of tracer found the second time around, or visa versa. During the first phase of sampling, necessarily near the axial trough, tracer was found at the release site and along the trough near 9°50' N, 20 miles north of the release site. The tracer at the release site was confined to within the trough. Concentrations were as high as 90 fM (1 fM = 10^{-15} moles/l) in *Alvin* samples, taken very near the bottom, and were moderate up to the level of the rim of the trough. Above that level, and also 5 miles to the north, west and south, no tracer was found. The tracer found at this site is therefore surmised to be still emanating from the sediments or from deep pockets and caverns in the trough, i.e. left over from the release. Most of the tracer appeared to have been carried away from the release site by the time of this survey.

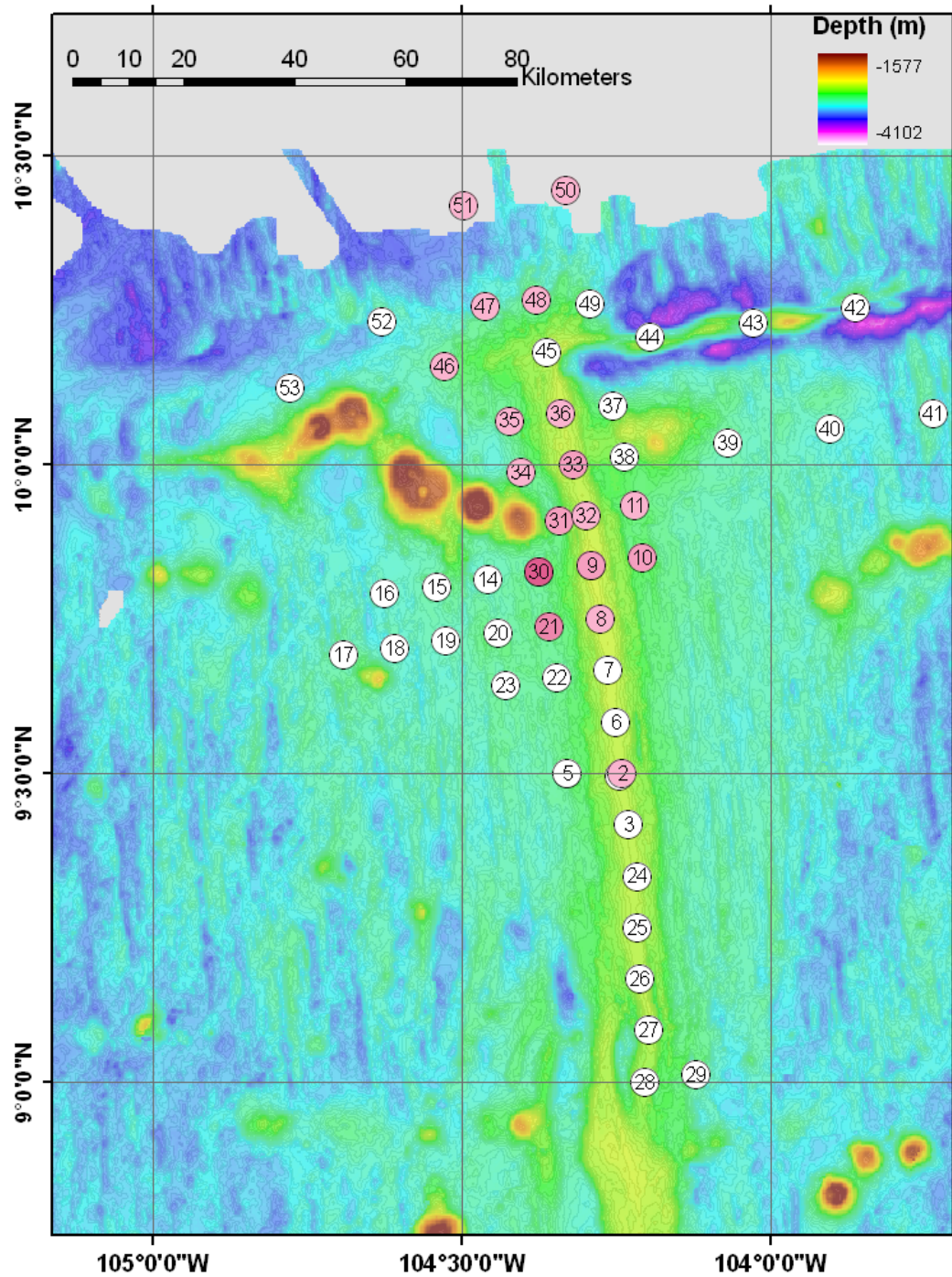


Figure 3.1. Stations 2 to 53 of the Tracer Survey. The intensity of the color indicates the column integral of tracer found. Bathymetry is from MacDonald et al., 1992.

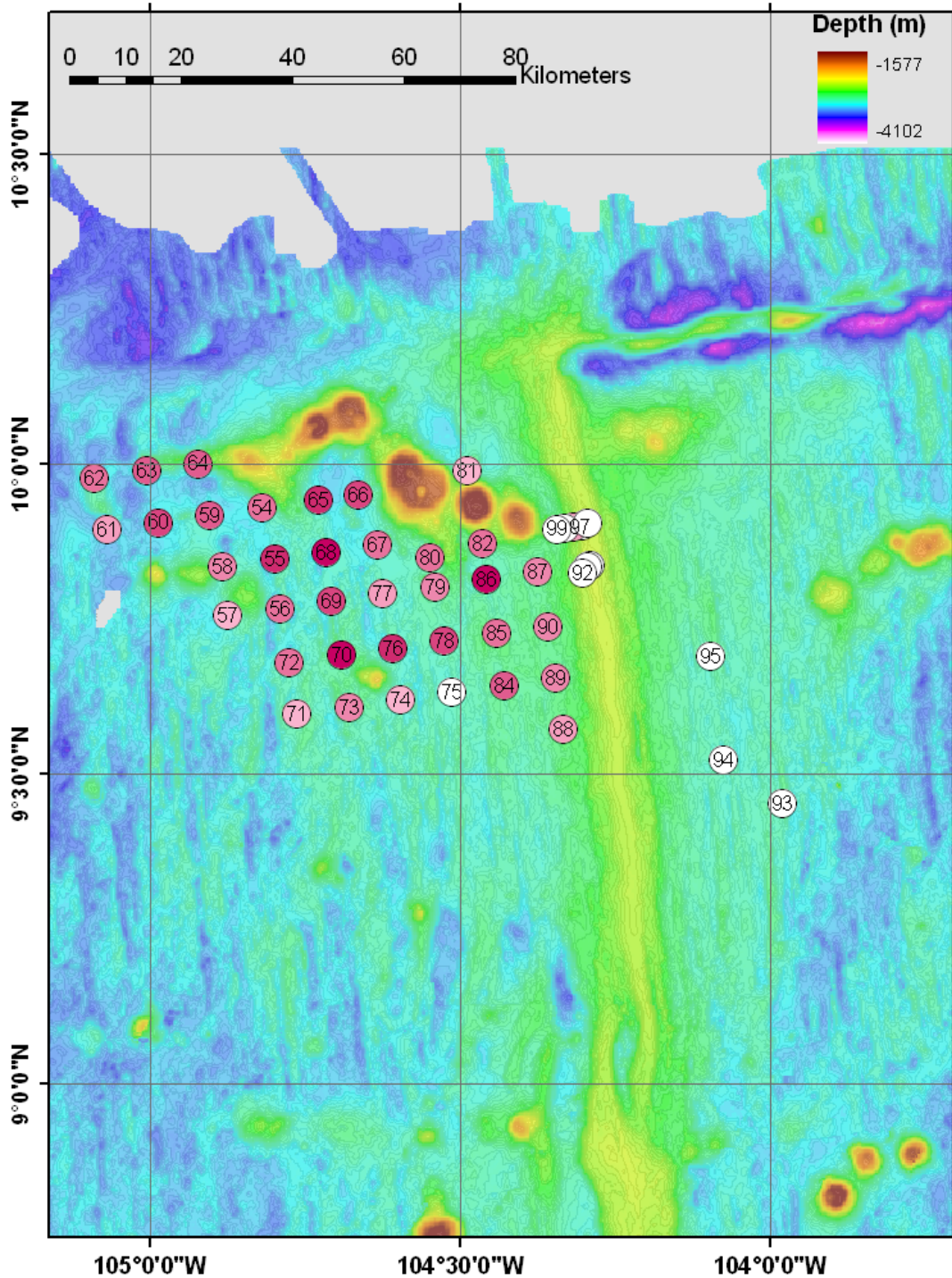


Figure 3.2. Stations 54 to 100 of the Tracer Survey. The intensity of the color indicates the column integral of tracer found. Bathymetry is from MacDonald et al., 1992. Stations west of the ridge and south of the seamounts now have tracer, while Fig. 3.1 shows that they did not earlier in the cruise. On the other hand there was at this time nearly no tracer on the ridge near 9-50 N, while there was tracer there before.

The tracer signal found near the 9-50 site during the first sampling phase was relatively weak. Later sampling to the north of 9-50 along the trough also found low levels of tracer, all the way to 15 miles north of the terminus of this segment of the East Pacific Rise.

Data from the bottom mounted ADCP from the period of 12 November to 15 December indicated that the flow over site of the release had been to the north and west for the first 25 days and then turned south and east for the remaining 8 days. These data suggested that we look west and north for the tracer. Hence, once the 10-day CTD series commenced, we set off to the west of the 9-50 site to try to intercept the tracer. We found no tracer in this direction except for the stations immediately to the west and southwest of the 9-50 site (Casts 13 and 21, respectively). Station spacing was approximately 5 miles.

We set aside this search direction after Cast 23 and decided to cover the trough to the south of the release. Stations 24 through 29 went as far as 9-0 N without finding any sign of the tracer. We then turned our attention to the 9-50 site and north of there, since this is where we had found tracer during the first phase. As mentioned earlier, there was tracer north of 9-50, but the signals were low. We checked to the east of the ridge, sampling as far as 35 miles east on a line 10 miles south of the Clipperton Fracture Zone, finding no tracer. Then we returned to the west, sampling along the Clipperton FZ starting 30 miles east of the northern terminus of the ASC, again finding no tracer until very low levels were found around the northern terminus. Very small quantities were also found at Station 46, north of the Lamont Seamounts and west of the ridge. We crudely estimated that at this point we had found only 2% of the tracer. However, it is an important 2% because it showed an example of a passive tracer traveling from one vent site to another 20 miles north in a larval lifetime of around 40 days. We speculate that currents confined to the ridge can carry significant fractions of larvae along the ridge in spite of general currents at and aloft of the ridge that would carry larvae away, in this case to the west.

Having found so little of the tracer after several days of sampling, we decided to increase the speed of covering area with our survey and headed southwest to and across the seamounts and again into the area west of the 9-50 site, but further west than before. We came across tracer at high concentration immediately south of the seamounts, in Cast 54, so we slowed down and restarted our 5-mile grid in that vicinity, for the remainder of the 10-day period, until Cast 82. Tracer was found in many of the stations during this period, in a swath about 10 miles wide, extending more than 50 miles to the WNW of the ridge, south of the seamounts. We did not delimit the western end of this patch – it seemed to extend further than we sampled. The eastern end was just west of the ridge at the time of sampling there. We seemed to delimit the southern edge, but one cannot be sure at 5-mile station spacing. The northern boundary was formed by the seamounts. A rough estimate is that about 50% of the tracer can be accounted for in this region. The tracer distribution in density space was centered at about the level of the injection, according to preliminary CTD calibrations.

After the 10-days of continuous CTD casts were finished, we were again confined to stations near the 9-50 dive site, with casts being done at night. We filled in some of the stations at and just west of the ridge to delimit the western patch with Casts 83-90. No tracer was now found in Cast 83 and Casts 91 and 92 at the 9-50 site along the trough. Apparently the southeastward flow that brought the western part of the tracer patch back toward the ridge carried the tracer that had been on the ridge to the east. An attempt was made in Casts 93-95 to find indications of tracer to the southeast with negative results.

With only one night of sampling remaining, we called an end to the search for missing parts of the tracer patch and occupied a CTD section across the gap between the ridge and the seamounts near 9-54 N, with Casts 95-99. Low levels of tracer, well correlated with density, were found in the bottom 50 meters of so of these casts. The deep density surfaces tended to rise to the east with the topography, suggesting that there is a negative vertical gradient in the northward flow in the deep water. This tendency was often observed for the entire cruise for pairs of stations, one to the west of the ridge and one on the ridge.

The CTD work was brought to a close with Cast 100, at 9-54 N atop the east wall of the axial summit. This station was an eastern continuation of the section just mentioned. There we found small amounts of tracer at levels above the bottom boundary layer, and at much lower densities than in the stations to the west. We also found in Cast 100 a buoyant plume from a vent that may be yet undiscovered.

4. Alvin Dive Summaries

The following dive summaries have been culled primarily from the dive reports submitted by the port observers. No attempt has been made to edit them e.g. to correct grammar, unify nomenclature, etc. A short list of dives is in Appendix C, while locations and other information on the hydrothermal vent sites mentioned can be found in Appendix D.

Dive 4285 13 December 2006

Pilot: Bruce Strickrott
Port Observer: Florence Pradillon
Starboard Observer: Noreen Kelly

Summary

During this dive, we deployed 2 magnetic collectors for Noreen at Bio9, one close to the smokers, one further in the south-east direction. We recovered 3 TRAC experiments for Florence, one at Bio9 (#2) and 2 at Tica (#1 and 3). We collected 4 sponge colonization experiments at Bio9 (#41) and Tica (#36, 40, 49), and 3 TASCs (#30, 31, 32) at Tica for Monika Bright's team. For each sponge and TASC recovered, we deployed a new one at the exact same location. At each sponge, TASC and TRAC recovered or deployed, we did temperature and chemistry measurements with Nadine Le Bris's sensors.

Dive 4286 14 December 2006

Pilot: Mark Spear
Port Observer: Susan Mills
Starboard Observer: Alexis Jackson

Summary

We began by locating pump mooring L9 about 300m west of K vent and moving it to a position north of the K vent sulfide mushroom. We then recovered Lauren's sandwiches at three sites at K vent (sulfide top, sulfide base and mussel patch), replacing them with new sandwiches to be deployed later. Two of the associated HOBO temperature probes were recovered; the third we couldn't locate. We put out three for careful deployment the following day by Nadine. We then drove south toward the site of PBR600, tripping Niskins along the way. We found a smoker, but are not sure it was the same one. We continued south to X10230, Y38750 where we triggered the last Niskin and then drove out of the ASC to drop weights.

Dive 4287 15 December 2006

Pilot: Pat Hickey
Port: Nadine Le Bris
Starboard: Tim Fischer

Summary: We started the dive by taking a first Niskin sample in the ASC about 1.3 km north of K-vent. Four other Niskin samples were taken on route to K-vents, at pre-defined locations of roughly equal distance from each others. Mid-way from K-vent we stopped to pick up the ADCP on the basket and waited there one hour in order to reach K-vent only after the pump has stopped pumping. About 40 meters south of the K-vent sulfide mushroom, we found Lauren's sandwiches that were left at the previous dive and positioned them on a mussel patch (some obviously dead, no visible sign of life in the patch but a slight temperature anomaly). Temperature was measured at the base of each sandwich and chemical probing was performed

on two points within the patch. Back on the sulfide mushroom chimney, we recovered the HOBO and sandwich that had fallen at the base and positioned the five sandwiches and the HOBO over a 'flange' on the upper part of the chimney that was colonized by anemonies and flowed with warm shimmering water. Temperature was measured at the base of each sandwich and chemical probing was performed on two points within the patch. The five remaining sandwiches and the last HOBO were positioned at the base of the chimney around a small venting source and temperature was measured at the base of each sandwich. Chemical measurement scans were taken at only 2 points close to the sandwiches (time out) before leaving the bottom.

Dive 4288

16 Dec 2006

Pilot: Bruce Strickrott
Port Observer: Ryan Jackson
Starboard Observer: Laure Corbari

Summary:

The main objectives for this dive were completed. The dive began at P vent where a Nisking sample was taken and 8 sandwiches were recovered and 8 deployed. In addition, 1 sponge and 3 TASCs were recovered and replaced with new surfaces. Work continued at Bio 9 where one sponge was collected, one sponge was deployed, and Alvinella was collected. On the transit to East Wall, four Niskins were tripped. The tasks at East Wall included recovery of 3 sponges and deployment of 3 new sponges. Chemical and temperature characterizations were completed at all the deployment sites. The dive ended with exploration to the north in the ASC where two sites with diffuse flow and Tevnia were found and may have possibilities for future deployments.

Dive 4289

17 Dec 2006

Pilot: Mark Spear
Port Observer: Florence Pradillon
Starboard Observer: James Brennan

Summary

We started the dive at P Vent where we recovered and deployed 7 sandwiches and 2 Hobo probes, at the high and at the intermediate temperature deployment site of Lauren Mullineaux's group experiments. Temperature was measured at each sandwich and each Hobo recovered and deployed. We chemically characterized 5 spots at the high temperature deployment site using Nadine Le Bris's chemistry wand. At each of the 2 deployment sites, we deployed a chemistry wand for Nadine. We moved to Tica to deploy 3 TRACs, one on an Alvinellid patch, one next to Tevnia, and one on the basalt. We measured temperature around each TRAC, and chemically characterized the surroundings of the 2 firsts TRACs. We recorded video with the mosaic configuration during transit between P Vent and Tica. We fired 2 Niskin bottles while driving in the ASC, one just before P Vent, one just before Tica.

Dive 4290

28 Dec 2006

Pilot: Pat Hickey,
Port Observer: Ryan Jackson,
Starboard Observer: Kira Krumhansl

Summary:

The main objectives for this dive were completed with time left for exploration. The dive began at Bio9 vent where an Alvinellid sample was collected and temperature and chemical characterizations were completed on a former TRAC site. Work continued at Tica where 4 sandwiches, 3 blocks, and a HOBO were recovered from the low Temperature deployment site and five fresh blocks and sandwiches were deployed in their place. Full temperature and chemical characterizations were completed for the recovered and deployed surfaces. The buried intermediate temperature deployment site at Tica was evaluated with respect to recovery of the deployment and the HOBO probe was recovered. The dive then moved to East Wall. The tasks at East Wall included moving one sponge from a live mussel patch to the periphery and taking samples of basalt and pelagic pump samples near the sponge deployments. No live mussels were collected since only about 8 live mussels were visible. With time left in the dive, we moved north in the ASC and scouted for diffuse flow and colonized sites. We reached the new diffuse vent site Perseverance near Bio9 discovered on dive 4288 and evaluated if it could be a possible deployment site for colonization experiments. The dive ended with a trek north to Hobbit Hole; however, this site was not found before we ran out of power and had to surface.

Dive 4291

29 December 2006

Pilot: Bruce Strickrott

Port Observer: Susan Mills

Starboard Observer: Travis Elsdon

Summary: We began the dive by locating and moving pump mooring L11 from its drop position to a location about 35m south of Ty/Io. From there we moved south to the Sketchy deployment site and recovered and deployed 10 sandwiches and 2 HOBO's for Lauren Mullineaux and 3 TASC's and one sponge array for Monika Bright, taking temperatures and doing chemical characterizations at each device. After leaving the site we continued south in video mosaic mode, firing niskins at intervals. We came across several diffuse flow sites, most with *Tevnia* and some accessible for work with Alvin. In the area where pump mooring L12 was deployed (9° 49.290'N, 104° 17.325'W) the ASC disappeared and there were very few crabs. Further on, it reappeared and we began to see more diffuse flow sites, most with a few *Tevnia*. Around 2040 the dive was called back due to increasing winds. Total distance traveled was ~2km.

Dive 4292

30 Dec 2006

Pilot: Mark Spear

Port Observer: Nadine Le Bris

Starboard Observer: Sarah Bennett

Summary

First part of the dive was spent acquiring temperature and chemical measurements at Tica Lauren's high T experiment site, collecting 5 sandwiches and 3 blocks and deploying new ones. Then, 3 TRAC (Titanium Rings for Alvinella colonization) were recovered at another active site of Tica, with chemical measurements around and above the devices. On the transit to P-vent, 2 Niskins bottle were fired at Bio9 in a black smoke plume 2 meters above a chimney. At P-vent, 2 other Niskins plume samples were taken 3 meters above the large black smoker. Extra chemical measurements over Lauren's high T experiment site at P-vent were done. The last Niskin was triggered away from venting sources in the ASC

Dive 4293

31 Dec 2006

Pilot: Pat Hickey

Port Observer: Florence Pradillon

Starboard Observer: James Ledwell

Summary

All the objectives of the dive were completed. We deployed 3 sets of 5 sandwiches and 1 Hobo at V Vent, near marker AT15-13 #7 in 3 different habitats : on a *Tevnia* patch, among Mussels, and in the periphery of the site with Serpulids. We conducted thermal and chemical characterization at each deployment site. We collected 5 live *Riftia* near marker AT15-13 #11. Then, we drove south towards L Vent, where we collected *Alvinella* and one fish. We recorded video with the mosaic configuration during transit, and fired Niskin bottles while driving in the ASC.

Dive 4294

1 January 2007

Pilot: Bruce Strickrott

Port Observer: Susan Mills

PIT: James Brennan II

Summary:

We completed all the scheduled activities for this dive. We located and moved pump mooring L(for Lucky)13 to just north of Tica. At Tica we set out blocks and sandwiches at a new intermediate temperature site, measuring temperatures and chemistry, and retrieved the ones that were buried in the rock fall. We moved to Bio9 and recovered Noreen's Magnets and then to Sketchy site south of Ty/Jo, firing three niskins during the transits for Jim and noting the location of one diffuse flow site north of Ty/Jo. At Sketchy we repeated the chemistry measurements from AD4291, since the H₂S sensor had not worked. Then we returned to Ty/Jo, collecting two niskins in the hot fluids for Sarah.

Dive 4295

2 Jan 2006

Pilot: Mark Spear

Port Observer: Nadine Le Bris

Starboard Observer: Leah Houghton

Summary:

Beginning at East Wall we deployed sponges 63 on a dead mussel patch close to the two previously deployed sponges, and did a rapid chemical and thermal characterization. We collected 3 live mussels before leaving the site and firing a Niskin away from the dead mussel area. At Q-vent we collected two sponges (51 and 52) and replaced them by two new ones. Temperature combined with chemistry was checked at these two locations. A Niskin was fired after leaving Q-vent. The next site, Perseverance, is a newly found diffuse flow area south of Biovent. We looked for it for a while. The XY were slightly different from the one defined previously but it corresponds to the description of the area. *Tevnia* patches were found in the border of a large mat covered area, on the bottom of a collapse. Chemical and T measurements were done around one bush, before collecting a bunch of them. 3 TASKs were deployed close to this area on several small *Tevnia* patches among blocks covered with white mats. Chemical and T measurements were taken on the TASK and 2 min pumping 1 m above was done. Sponges were deployed in the periphery of the active area on black basalt with 2 min pumping above. A block of basalt was collected but erroneously put on the basket instead of a closed

box. We found Biovent soon after leaving this site and fired 2 Niskins in the plume of one of the black smokers. After leaving the area we fired the last Niskin for tracer analysis.

Dive 4296

3 Jan 2007

Pilot: Pat Hickey

Port Observer: Ryan Jackson

Starboard Observer: Sigrid Katz

Summary:

The main objective for this dive was exploration of the 9-54N to 9-55N area. Camera tows through this area as well as CTD records revealed hydrothermal activity. The dive objectives were to locate two sites identified in camera tows and evaluate their suitability for colonization experiments. Both sites revealed broad diffuse venting with many crabs and a significant amount of shimmering and smoky water. Both sites had small bushes of *Tevnia*, but they were small and scarce. Both sites also presented significant problems with accessibility as the ASC at these sites is a narrow, relatively deep fissure. Overall, both sites show promise for good colonization sites based on the amount of diffuse flow present, but the fauna are not as abundant as might be expected probably due to the recent eruption.

5. CTD Operations

[Jim Ledwell, Tim Fischer, Cynthia Sellers]

5.1 Overview

The main CTD was a SeaBird SBE 9-plus mounted horizontally at the base of a rosette frame. It had dual pumped C/T sensors and a pressure sensor for the primary variables. Auxiliary sensors were a SeaBird 43 Oxygen Sensor, a WETLabs Eco Combination Meter FLNTU fluorometer/turbidity sensor, a WETLabs Transmissometer, and a Datasonics Altimeter. A bottom pinger was also mounted on the frame. The rosette pylon was a SeaBird SBE 32 Water Sampler. For this cruise there were 21 10-liter Niskin bottles on the rosette frame, at positions 1 through 19 and 22 and 23. These Niskin bottles were used for tracer samples for almost every cast. Water samples for salinity calibration were taken from roughly 7 of the Niskin bottles approximately twice per day. Height above the bottom was recorded at the bottom of each cast on the written cast sheets, based on the altimeter if the reading was good, and on the pinger signal if not. The CTD casts collected with the main CTD/LADCP/rosette system were carried out at the stations shown in Figure 1 and are listed in Appendix C.

Notes:

1. Casts 30 and 34 are split into 2 parts with upcast in part 'a'
2. Cast 31 had some sensor clogging during the downcast which caused bad values of pressure near 211 m. The bad scans were removed during processing.
3. Casts 85 and 91 had unusable primary conductivity during the downcast. The secondary sensors are ok.
4. Casts 83, 86, 88, 89, and 90 had transmissometer trouble.
5. Potential density calculated by SeaBird software, and entered in some of the files listed below, differed from that calculated using the full equation of state, as described below.
6. The Turbidity Sensor voltage is converted to "Nephelometric Turbidity Units" (NTU) using a user polynomial, the constants of which are in the .CON files. The equation is:

$$\text{NTU} = \text{ScaleFactor} \times (\text{OutputVoltage} - \text{CleanWaterOffset})$$

The manufacturer's calibration gives CleanWaterOffset = 0.148V and ScaleFactor = 5 μ g/l/V. However, this gives slightly negative values for most of the water column on this cruise. A result that is always positive could be obtained by modifying the polynomial constants on line 76 of the .CON file.

7. Information on the constants used for all the sensors are in the .CON files. See the help pages in the SeaSoft Software package for a map of where these constants are. The help pages are also the best resource for explaining how to use the software, set up the processing modules and also for creating batch files for automated processing.

5.2 SBE 911plus

The SBE 911plus CTD system was used for vertical casts in conjunction with a 24-bottle rosette and a LADCP system.

Data Files

Original data files for the SBE 9 are in the directory ctd/ on the Science Data Disk 1 (Appendix B):

- * .DAT binary files with the raw data
- * .HDR header information for each file
- * .BL information on when the Niskin bottles were tripped
- * .CON configuration files for each cast

The following files were produced and saved for the SBE 9 data, and can be found on the Science

Data Disk 2 in the directory /science/PhysicalOceanography/CTD/911/:

- ./hf/*.cnv 24Hz data, aligned, filtered and cellTM applied. No derived variables, except for depth.
- ./hf/*.ros The records at 24Hz that are needed for the bottle summary data.
- ./avg1m/*.cnv 1-m averages of the data in ./hf/*.cnv after loopedit, with derived variables S0, S1, Θ , and σ_2 .
- ./avg1s/*.cnv 1-s averages (no loopedit), including S0, S1, Θ , and σ_2 .
- ./bottles/*.bt1 Average data from the CTD pertinent to the bottle trips. Note that the actual rosette position is not recorded in the first column of these files, but only the number in the sequence of bottle firing. For cases when the operator fired bottles at rosette positions that did not have bottles, there are extra records that must be sorted out according to the depth recorded in the cast sheets. The averaging time for the data during these trips is just 2 seconds. This is too short a time, especially for the secondary sensor pair, for which the C/T matching is poor. Another set of files has been prepared by J. Ledwell with 12-second averaging, in April 2007.
- ./mat/*.mat Matlab format files

The directories listed above also have the SeaBird .psa files with the set up parameters for processing and they have process*.txt files that are used in batch processing, with the batch command in the following directory:

- ./Batch/*.bat These are batch files that will re-process the CTD data. Paths will need to be modified when out of the Atlantis network environment.

Data Processing Decisions

The values suggested by SeaBird were used in Align, Filter, and CellTM. In LoopEdit all pressure reversals were excluded. The parameters actually used are always listed in the header of each file, along with the history of the processing steps applied to the file.

Inaccuracy in the SeaBird 911 Potential Density

Users of these data should beware that the potential densities derived by SeaSoft for the SBE 9 in the 1-meter and 1-second average files differ from those from the full equation of state provided by Phillip Morgan (which is consistent with routines used at the NOC in the UK). Figure 3 shows the difference for cast 24 as a function of depth. Care has been taken in this analysis to convert the temperature scale from ITS-90 to IPTS 68, i.e., multiplying by 1.00024, before applying the equation of state.

5.3 SBE 19

An SBE 19 CTD was used on every Alvin dive of the cruise. This instrument is an internally recording, battery-operated CTD with a strain gauge pressure sensor, temperature sensor and conductivity cell, but with no pump to aid matching between temperature and conductivity. When on Alvin the instrument is usually mounted athwart-ships just aft of the main basket. Flow through the cell is often not sufficient to attain good matching between temperature and conductivity since the cell tube is roughly perpendicular to the flow and Alvin is moving much slower than the ideal speed of 60 m/min. The SBE 19 was intercalibrated with the SBE 9 during cast 95. The intercalibration is described in section 5.4.

Data Files

Data files for the SBE 19 are found in directory

/science/PhysicalOceanography/CTD/SBE19/ on the Science Data Disk 2:

- ./Hex/*.hex Raw data in files with the header and the data stream in hex format. This directory also includes 8-2005-100-Hz.CON, the configuration file used for this instrument throughout the cruise.
- ./ASCII/*.cnv Files converted to ASCII, with no processing applied, with the header.
- ./Flat/*.flt The same as *.cnv, but with the header removed to make flat ASCII files for importing into Matlab.
- ./Plots/*.jpg Plots of pressure, temperature, salinity, and σ_2 for the part of the dive near the bottom, in the case of Alvin dives.

5.4 CTD Intercalibration

During cast 95 the SBE 19 was secured to the rosette frame with the sensors about 1 m higher than the SBE 911 sensors. The package was held 30 m off the bottom for 15 minutes to allow the package to thermally equilibrate with the surroundings and then to obtain a sufficiently long record for an accurate comparison. The results are shown in figure 3 and table 1.

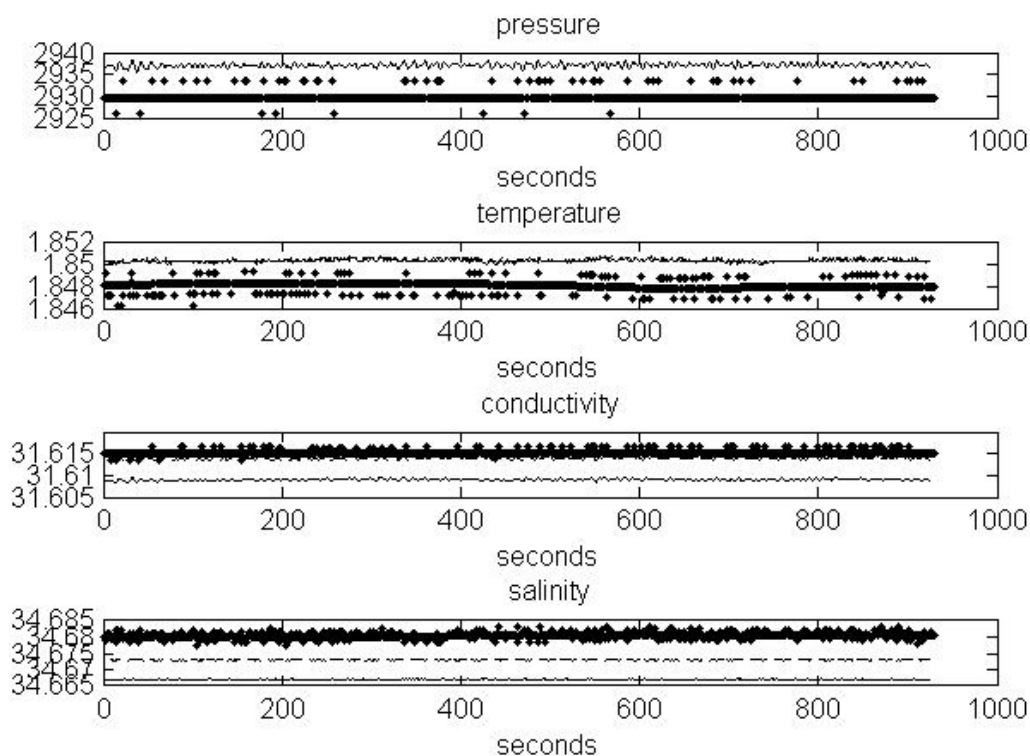


Figure 5.1: Comparison of pressure, temperature, conductivity and salinity of SBE 19 and the two sensors of SBE 911 during cast 95. Dots: SBE 19; straight line: SBE 911 primary sensor; dashed line: SBE 911 secondary sensor.

Table 5.1: Intercalibration of CTDs. Average values and standard deviations (in parentheses) of pressure, temperature, conductivity and salinity for the 15-minute intercalibration period of cast 95. The last column lists corrections to be added to the SBE 19 variables to bring them to agreement with the uncorrected SBE 911 variables.

| | SBE 19 | SBE 911 | SBE 911 – SBE 19 |
|------------|------------------|------------------|------------------|
| Pressure | 2929.8 (1.0) | 2937.1 (0.4) | 7.3 |
| Temp 1 | 1.8480 (0.0004) | 1.8503 (0.0001) | 0.0022 |
| Temp 2 | | 1.8504 (0.0001) | 0.0023 |
| Cond 1 | 31.6153 (0.0005) | 31.6090 (0.0002) | -0.0062 |
| Cond 2 | | 31.6139 (0.0002) | -0.0014 |
| Salinity 1 | 34.6804 (0.0008) | 34.6671 (0.0001) | -0.0133 |
| Salinity 2 | | 34.6729 (0.0001) | -0.0075 |

5.5 Cleaning of the Conductivity Cells

During the cruise, the conductivity cells in the SBE 9 and SBE 19 were cleaned by soaking with a 1% solution of Triton X 100 prior to the first cast on 13 December and prior to cast 78 and Alvin dive 4290 on 27 December.

6. CTD Salinity Calibration

[Jim Ledwell, Tim Fischer]

6.1 Salinometer Measurements

The Guildline Portasal 8410A salinometer from LADDER-1 was used to calibrate the CTD-derived salinities. About every fifth cast was sampled from usually seven of the 21 Niskin bottles on the rosette. Before use, at the start of the cruise, the salinometer conductivity cell was cleaned with 1%-Triton-solution and thoroughly rinsed with distilled water.

While measuring, there appeared to be many samples affected by saline/dirt particles. These samples characteristically show a sharp rise in conductivity followed by a gentle downslope during the multiple measurements of one sample. Presumably a saline particle from inside the sample bottle entered the conductivity cell and remained there until it finally dissolved after more than ten replacements of sample water. Even one or two of the replacements after that may be affected by a small amount.

To fix the problem, sample bottles of series L and N were thoroughly wiped out during a sunny Christmas afternoon, revealing a brown flaky substance on the inside walls and bottom of many bottles. After that, care was taken during measurements to only use cleaned bottles, not to homogenize the samples and not to touch the inside of the bottles with the tip of the salinometer's small sample hose. This procedure dramatically increased the number of trustworthy measurements (Figs. 6.1 and 6.2).

6.2 Comparison with CTD-salinities

The main results from comparing the Portasal salinities to the CTD-derived salinities taken from the bottle-files are:

The difference between the CTD primary salinity and the CTD secondary salinity drifted considerably from cast to cast.

The difference between the Portasal salinity and the CTD secondary salinity is pretty constant over time, especially when excluding the samples rated as 'dirty' (Fig. 6.2).

The difference between the Portasal salinity and the CTD primary salinity (Fig. 6.1) shows a similar drift over time to the difference between secondary and primary salinity, and a higher variation of values than Portasal-secondary salinity. So it seems reasonable to use the secondary salinity as a base for further calculations.

The best estimates for salinity corrections (as mean values, with standard deviations in parentheses) are:

Table 6.1 Salinity Calibrations
(Standard Errors are in parentheses)

Portasal salinity – primary salinity:

0.0070 (0.00029) for all samples

0.0067 (0.00034) excluding samples rated ‘dirty’

0.0063 (0.00043) excluding samples rated ‘dirty’ and undecided ones

0.0069 (0.00046) for all samples after exclusive use of clean bottles

0.0055 as before, but without differences exceeding 0.01

Portasal salinity – secondary salinity:

0.0012 (0.00023) for all samples

0.0005 (0.00020) excluding samples rated ‘dirty’

0.0001 (0.00023) excluding samples rated ‘dirty’ and undecided ones

0.0002 (0.00019) for all samples after exclusive use of clean bottles

The range of values in the above table, depending on which set of bottles is used, indicates the overall variability of the Portasal operation, and so it is most conservative to claim that the uncertainty in any value chosen from those reported above is 0.001. The Portasal operation was checked for the previous LADDER cruise, LADDER-1, by shipping samples back to Woods Hole for analysis in the lab using the more stable Autosal. This exercise confirmed the Portasal accuracy, within 0.001.

The secondary sensor salinity is more stable according to the above table, and it is also more stable when evaluated by looking at salinity at fixed potential temperature at a deep level for the casts from LADDER-1 and from LADDER-2. However, the secondary sensor salinity is much noisier than the primary on time scales of a few seconds because of poorer matching between temperature and conductivity, perhaps due to a faulty pump on the secondary sensor pair. Thus for work requiring long-term stability, the secondary pair is to be preferred. For work looking at fine structure in the CTD casts, it is better to use the primary sensor pair.

CTD calibration plays an important role in determining how the tracer injected during LADDER-1 moved in density space by the time of LADDER-2. A detailed investigation of the calibration of the two sensor pairs is underway and will be reported separately.

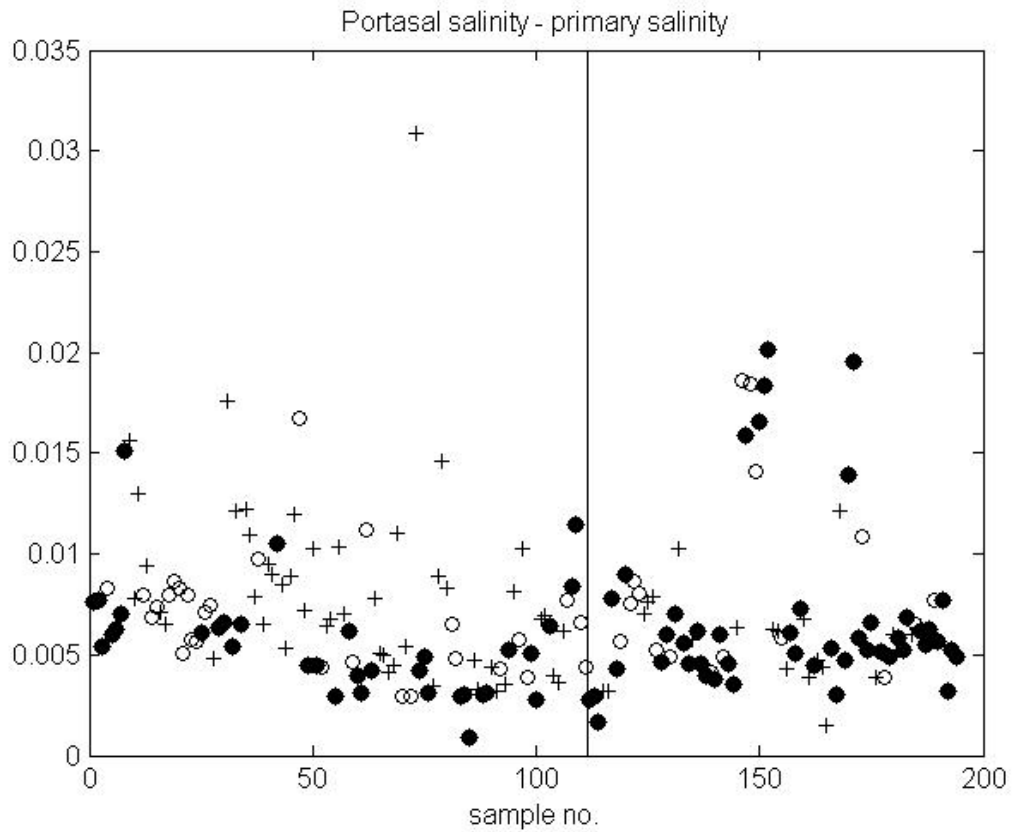


Figure 6.1. Salinity calibration; Primary sensor pair. Difference between salinity derived from the salinometer and the CTD-primary salinity. Filled circles: samples rated as clean; crosses: samples rated as dirty; open circles: samples undecided. Samples to the right of the perpendicular line were obtained from clean sample bottles.

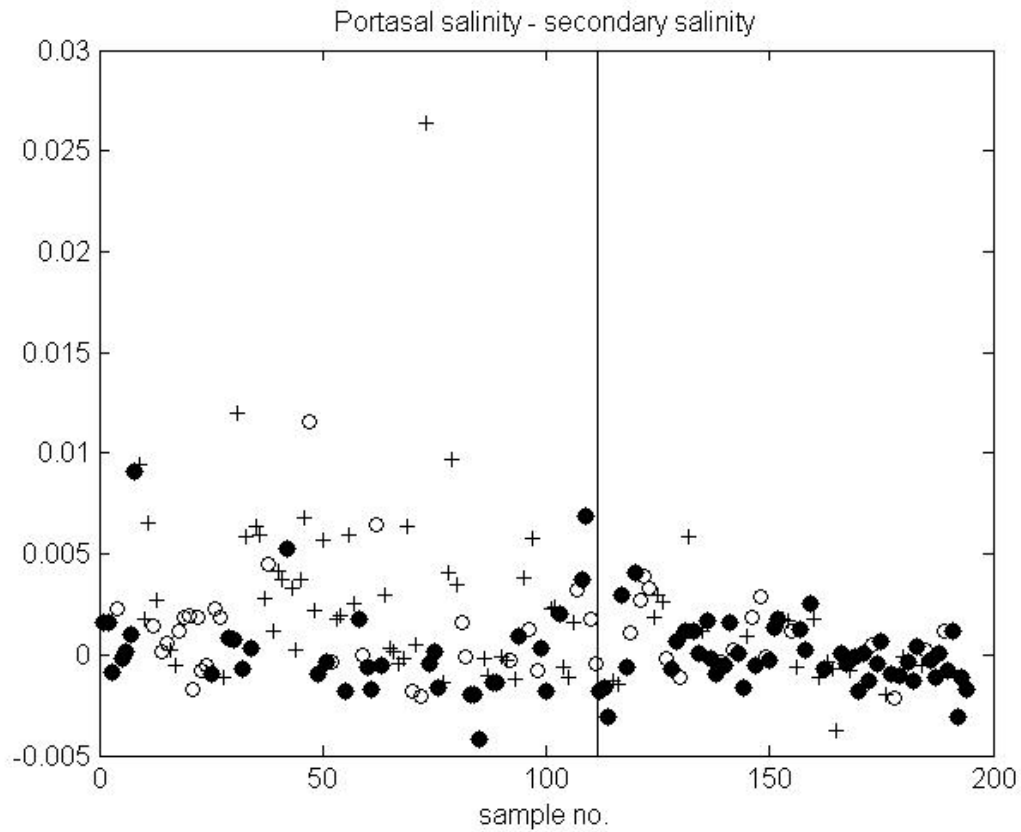


Figure 6.2. Salinity calibration; Secondary sensor pair. Difference between salinity derived from the salinometer and the CTD-secondary salinity. Filled circles: samples rated as clean; crosses: samples rated as dirty; open circles: samples undecided. Samples to the right of the perpendicular line were obtained from clean sample bottles.

7. LADCP Operations

[P. Ryan Jackson, Tim Fischer, Cynthia Sellers, Andreas Thurnherr]

7.1 Data Acquisition

Velocity profiles were obtained during all casts using a WHOI LADCP system mounted on the CTD rosette sampler with the following instrument setup:

Table 7.1. LADCP Configuration

| | |
|-----------------------|-----------------------------------|
| Number of depth cells | 28 |
| Length of depth cells | 8m |
| Blanking distance | 0m |
| Coordinate system | radial beam |
| Pinging setup | staggered pings every 1.5/2.0 s |
| Ambiguity velocity | $2.5 \text{ m}\cdot\text{s}^{-1}$ |

The initial ADCP configuration used two identical RDI 300 kHz instruments; one as a down-looker, and one as an up-looker. Two separate ADCPs (serial numbers 4953 (up), 7877 (down)) were used during the cruise.

7.2 Processing

All LADCP data were processed with version IX 3 of the LDEO software package, using bottom-tracking, GPS data and minimally processed on-station shipboard ADCP data to constrain the barotropic flow. All casts were done while the ship was in DP mode so there are at most a few meters difference between the cast deployment and recovery positions. Based on the self-consistent picture of the circulation that emerges from the LADCP-derived velocities at different stations, the LADCP data quality is considered to be very high; however, only shipboard preprocessing has been completed at this stage. The quality of the data and the post-processing will be completed by Andreas Thurnherr at LDEO following the LADDER II cruise and the results will be reported in the final version of this cruise report.

8. Bottom-Mounted ADCP

[P.R. Jackson (WHOI), A. Thurnherr (LDEO)]

In order to investigate the temporal variability and the vertical shear of the flow field in and above the axial trough in the center of the long-term mooring array during the tracer-release experiment, an RDI Workhorse 300kHz ADCP (the same model that was used as the LADCP) was deployed during Alvin dive 4259 in the axial trough near 9-30N. On the basis of LADCP observations and a similar deployment carried out on the MAR earlier this year, the estimated range of good velocity observation is somewhat below 100m. Instrument setup:

Table 8.1. Bottom ADCP Configuration

beginning of record 2006/10/31, 15:00 GMT
ambiguity velocity $1\text{m}\cdot\text{s}^{-1}$
number of depth cells 32
length of depth cells 4m
hab of first valid velocity 6m (zero blanking distance, discard 1st bin)
coordinate system radial beam coordinates
sampling scheme 1 ensemble every 20 minutes; 180 pings per ensemble; max.
pinging rate

This instrument was recovered on Alvin dive AD4287 on Dec. 15, 2006 during the LADDER II cruise (AT15-14). The instrument was found in good condition and easily recovered by the submersible Alvin. Once on deck, the data were downloaded and pre-processed on shore by Andreas Thurnherr. The processed data, a progressive vector diagram (PVD, Figure 1) and a velocity profile above the ASC (Figure 2) were sent back to the ship and used to help guide the search for the tracer. The ADCP velocity record was very useful because it was positioned in the approximate center of the section of ASC in which the tracer was injected.

The PVD (Figure 5) shows a relatively strong (10 to 20 cm/s) northwestward flow at the time of the injection at the injection site. With the exception of small tidal influences, this flow pattern continued for approximately 25 days until the flow reversed. The southeastward flow continued for approximately 9 days before the ADCP was recovered. LADCP records indicate that the SE flow continued for at least 7 more days following the recovery of the bottom mounted ADCP. It is important to note that the PVD represents a hypothetical trajectory assuming that the flow is the same on and off the ridge. Therefore, the displacement represented in the PVD is likely an overestimate of the actual displacement because of the flow acceleration above the ridge and subsequent deceleration to the west of the ridge. Nevertheless, the ADCP record proved to be very useful in finding the tracer and a majority of the tracer was located to the northwest of the injection site—a result that is consistent with the ADCP records.

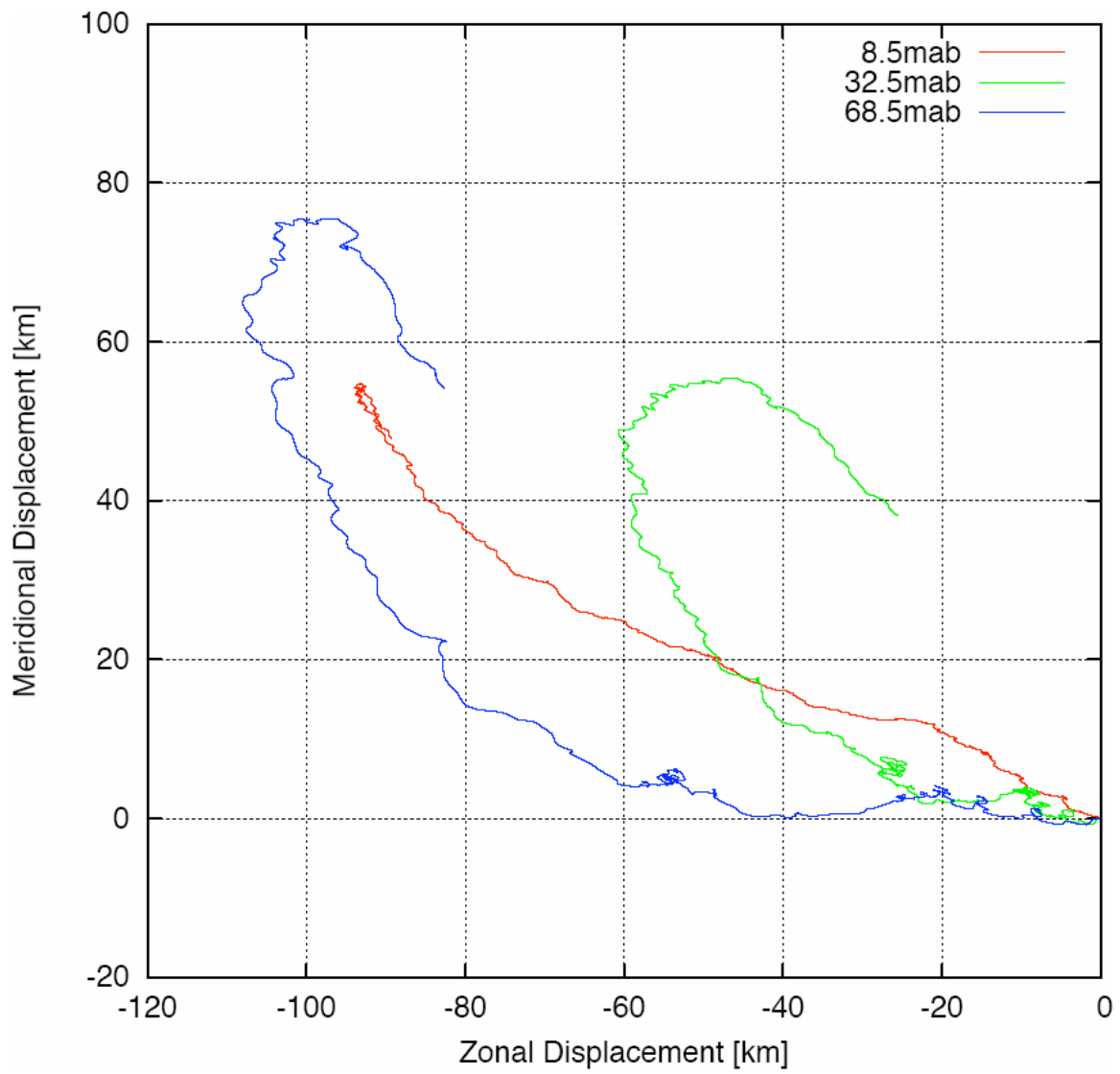


Fig. 8.1. Progressive vector diagrams for three bins from the bottom mounted ADCP at 9-30N in the ASC. The deployment period was 10/31/2006 to 12/15/2006, yet the record above starts at the tracer injection on 11/12/2006.

9. Hydrothermal plumes as a source of dissolved iron (Fe) and a sink of dissolved organic carbon (DOC) in the deep ocean

[Sarah Bennett, NOC; PI: Chris German, WHOI,]

On board, 2 separate experiments were carried out for the analysis of colloidal Fe species and for DOC. For the first half of the cruise, 2 seawater samples were collected for a time series experiment to look at the stability of colloidal Fe species in hydrothermal plumes. A Teflon lined externally sprung OTE bottle (acid cleaned) was used to collect a background sample away from any hydrothermal inputs and a sample at the top of a buoyant hydrothermal plume at 9°50 (CTD005 and CTD012). Each Niskin bottle was sampled into three 1-L acid cleaned Teflon bottles and stored in a cold room (4°C) covered with a black bag. The samples were then filtered over the next 4 days through 0.2 and 0.02 µm Anotop syringe filters into acid cleaned LDPE bottles at regular intervals (6 times in total for each sample) and the filtrate was acidified using nitric acid (OPTIMA grade, 0.1%). These samples will be analysed in a clean laboratory back at The National Oceanography Centre, Southampton, UK, using flow injection analysis with DPD catalytic spectrophotometric detection.

For the second half of the cruise samples were collected for the analysis of DOC and particulate organic carbon (POC). Seawater samples were collected using internally sprung (silicone springs) OTE bottles from a buoyant plume at Bio9 (CTD083) and 2 neutrally buoyant hydrothermal plumes 500 m and 2 km SW of Bio9 (CTD091 and CTD092, respectively). LADCP was used to confirm the current direction. Three background samples were also selected from previous casts (CTD048 and CTD076). Niskin bottles (1.2-L) attached to Alvin were fired a few meters above 4 of the vent sites at 9°50, (Bio9, P Vent, Ty/Io and Biovent).

All the samples were filtered immediately after collection using combusted GF/F (450°C, 5hr) filters into certified DOC clean EPA vials. The filtrate was acidified using hydrochloric acid (trace metal grade, glass bottle, 0.1%) and the filters were frozen. DOC samples will be analysed back at The National Oceanography Centre, Southampton, UK, using a DOC analyzer and the POC samples will be sent to Plymouth Marine Labs, UK.

10. Hydrothermal Vent Meiobenthos

[Sabine Gollner and Sigrid Katz; PI: Monika Bright, University of Vienna]

The aim of this project is to study the present status of the meiobenthic community (small animals between 32 microns and 1 mm) shortly past eruption and to follow the succession of colonization and development of communities. In order to get an overview of the present meiobenthic communities, we followed two approaches: natural substrate collections (see list of collections) and deployments and recoveries of artificial substrates (see list of deployments/recoveries). The natural substrate collections will be used to estimate the occurrence of meiobenthic species at specific sites and temperatures. These will be compared with the artificial substrate collections for which abundance, biomass, species richness, and several diversity indices will be calculated. The artificial substrates deployed during the LADDER-1 cruise in October/November 2006 were recovered.

Upon assessment of the present vent and off-axis communities, we chose to concentrate on the following habitats: *Alvinella pompejana* community on a black smoker from Bio9, *Tevnia jerichonana* communities from Tica, P-vent, Sketchy, *Tevnia/Alvinella pompejana* mixed community from Tica, empty tubes of *Riftia pachyptila* and empty shells of *Bathymodiolus thermophilus* communities from East Wall, empty tubes of *Alvinella pompejana* from inactive black smoker Q vent, and peripheral basalt communities from Bio9, Tica, Sketchy, P-vent, East Wall, and Q vent. Artificial substrates were recovered and redeployed at each of the sites in order to study the short term colonization. All these artificial substrates will remain until the end of 2007 for long term studies. Additionally we deployed artificial substrates within a live mussel patch at East Wall and chose a new *Tevnia* site at Perseverance for new deployments of artificial substrates, and also collected natural substrates from this site.

In addition, samples for studying the microbial community were also collected. All natural substrate collections were done in collaboration for Stephan Sievert (Woods Hole Oceanographic Institution, USA). All artificial substrate collections were done in collaboration for Markus Weinbauer (CNRS-UPMC, Villefranche-sur-mer, France) in order to estimate the microbial abundance on the artificial substrates.

11. Development, growth and cell kinetic studies in *Riftia Pachyptila*

[Sabine Gollner and Sigrid Katz; PI: Monika Bright, University of Vienna]

The aim of this project is to study the infection process, growth, and developmental processes in *Riftia pachyptila* symbiosis (giant tubeworms) as well as cell kinetics in symbiont-containing and symbiont-free host tissue. For studying developmental processes, we recovered and redeployed tubeworm artificial settlement devices (TASCs) from *Tevnia jerichona* aggregations at Tica, Sketchy, and P-vent. We additionally deployed 3 TASCs at the site Perseverance. They are planned to stay at the sites until the end of 2007. Upon collection of a basalt colonized by *Riftia pachyptila* from the area V-Vent (9°47'), we conducted window labeling incubations using the thymidine analogues Bromodeoxyuridine for cell kinetic studies in 5 specimens of *Riftia*.

12. Development and colonization processes in *Alvinella pompejana*

[Florence Pradillon, U. Pierre e Marie Curie, and Laure Corbari, U. Liege, in collaboration with Nadine Le Bris, IFREMER]

12.1 Objectives

Alvinella pompejana is one of the first metazoa which colonizes newly formed surfaces at hydrothermal vents. By building tubes on the mineral walls of chimneys, this species modifies fluid flows, and allows the arrival of other species later on. Migration of adults and juveniles on a newly formed surface from adjacent areas has been observed. Yet, larval recruitment processes are still unknown. Early embryos can not develop at temperatures higher than 14°C, which would restrict their potential location to places with moderate hydrothermal influence. Outside the vent environment, embryonic development is arrested by low abyssal temperature (1.8°C), and low pressure prevailing near the surface does not allow normal development. Development would then be restricted to the deep-sea, in areas with moderate hydrothermal influence. Alternatively, embryos could disperse between vents, in an arrested state. Other factors than temperature might actually limit development of embryos, like sulfide levels at vent sites, or pressure variations during dispersal through the water column.

During this cruise, our objectives were to:

- determine pressure thresholds for early embryonic development, in order to estimate whether early embryos would be able to develop higher in the water column.
- determine sulfur effects on early embryos, and see whether this could be even more limiting than temperature for embryonic development at vents.
- conduct colonization experiments with chemical characterization, focusing on larval or post-larval stages.

12.2 Dive operations and on board experiments

Two main strategies were used during the cruise:

- 1) *In situ* experiments using TRAC devices (*Titanium Ring for Alvinellid Colonization*, Fig.1) equipped with sensors (temperature, sulfur, and pH monitoring) were deployed at vent sites to analyze early development and larval colonization in relation to local environmental conditions. These devices served as support for colonization surfaces (made of aquarium filter wool) and incubators containing embryos obtained by *in vitro* fertilization.
- 2) *In vitro* development experiments were conducted on board, in controlled conditions, in pressure vessels (PICCEL & PIRISM: *Pressure Incubators for the Culture of Cells, Embryos and Larvae*, & PICCEL Related Imaging System) to analyze sensitivity of early embryos to different pressure levels, and to sulfur.

Alvinella colonies were sampled at Bio9 (new post-eruption chimneys) and L Vent (old chimney not touched by the eruption) using a water tight insulated collection box (Table 12.1). Size and sex of each *A. pompejana* individual were noted. Collections from Bio 9 and L Vent were notably different, with a significantly higher proportion of large individuals at V Vent

(average size =5.5 mm width of the 4th setigerous segment (S4), average S4 width at Bio9 = 3.7mm), perhaps reflecting the recent re-colonization of Bio9. Large individuals collected in these samples were used to harvest gametes for *in vitro* fertilization and development studies. Other individuals were frozen or formalin fixed for on land analyses.

TRAC deployments were conducted as series of 3 devices, each one deployed in a different environment: (1) on *Alvinella* colonies with temperature preferably below 20°C (Fig. 12.1), (2) on *Tevnia* diffuse flow communities, (3) on basalt at the periphery of vent sites, at ambient temperature.

A series of 3 TRACs, deployed during the LADDER-1 cruise, was recovered during this cruise, after a 30-day deployment (Table 1). A second series of 3 TRACs was deployed and recovered after a 15-day deployment (Table 1). These 2 series will be analyzed with a first series deployed for 4 days during the LADDER-1 cruise. All TRAC deployments conducted during the LADDER-2 cruise were combined with thermal and chemical characterization.

The day before the deployment dive, *in vitro* fertilization was performed and the embryos obtained were maintained at low temperature before being loaded into the incubation vials and deployed during the next dive. At recovery, colonization surfaces were preserved for search and identification of settling larvae or juveniles (using molecular probes), and embryos in incubation vials were preserved for morphological and molecular analyses.

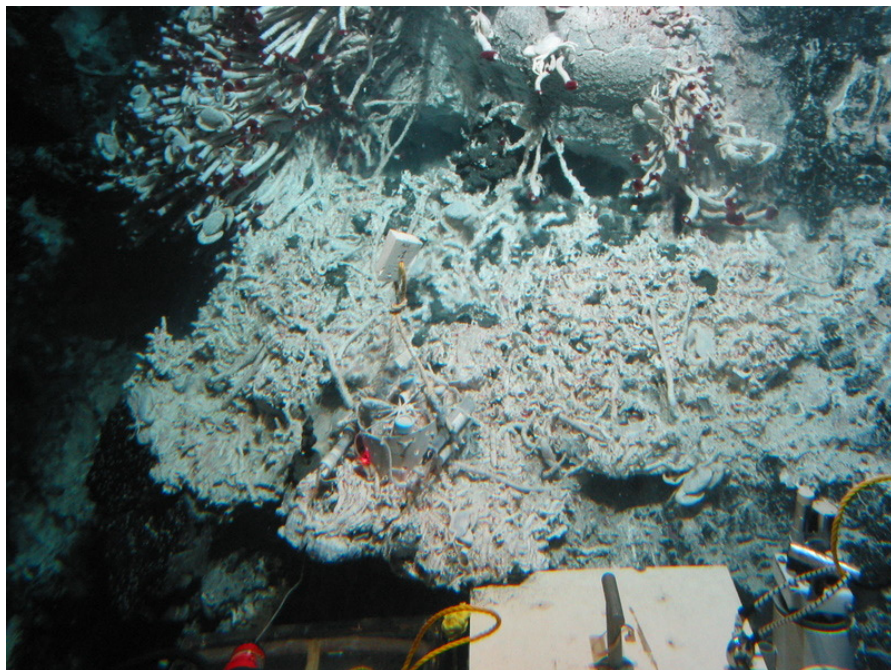


Figure 12.1. TRAC deployed at Tica on *Alvinella* AD#4292

In vitro development experiments were carried out on board, in pressure vessels with controlled temperature and pressure conditions. Embryos obtained by *in vitro* fertilization were exposed to a range of different pressures (150 atm up to 300 atm) at temperature previously found to be suitable for early development (10°C). In addition, one incubation experiment was conducted at vent pressure, in the presence of sulfur. Incubations were conducted over 48 h, allowing the

embryos to go through their first developmental cleavages (4-cell to 8-cell embryos). After incubations, embryos were preserved for morphological and molecular analyses.

Table 12.1. *Alvinella pompejana* collections and TRAC experiments conducted *in situ* during Alvin dives.

| Date | Time (GMT) | Site | Y | Lat. | Long. | Depth | Action |
|----------|-------------|--------|-------|------------|--------------|-------|--|
| 13/12/06 | 17:04 | Bio9 | 77985 | 9°50.31 N | 104°17.48 W | 2508m | Recovery TRAC 2 (serie 2) + chemistry |
| 13/12/06 | 17:50 | Tica | 78164 | 9°50.40 N | 104°17.49 W | 2511m | Recovery TRAC 3 (serie 2) + chemistry |
| 13/12/06 | 18:30 | Tica | 78168 | 9°50.41 N | 104°17.49 W | 2510m | Recovery TRAC 1 (serie 2) + chemistry |
| 16/12/06 | 18:17-18:28 | Bio9 | 77998 | 9°50.31 N | 104°17.48 W | 2505m | Alvinella collection |
| 17/12/06 | 19:27 | Tica | 78168 | 9°50.41 N | 104°17.49 W | 2507m | Deployment TRAC 1 (serie 3) + chemistry |
| 17/12/06 | 19:54 | Tica | 78171 | 9°50.41 N | 104°17.49 W | 2509m | Deployment TRAC 2 (serie 3) + chemistry |
| 17/12/06 | 20:18 | Tica | 78166 | 9°50.41 N | 104°17.49 W | 2509m | Deployment TRAC 3 (serie 3) chemistry at former TRAC 2 (serie 2) depl. site |
| 28/12/06 | 15:54-16:15 | Bio9 | 77986 | 9°50.31 N | 104°17.48 W | 2508m | Alvinella collection |
| 28/12/06 | 16:26 | Bio9 | 77992 | 9°50.31 N | 104°17.48 W | 2505m | video survey TRAC 1 (serie 3) |
| 28/12/06 | 16:48 | Tica | 78166 | 9°50.41 N | 104°17.49 W | 2510m | video survey TRAC 2 (serie 3) |
| 28/12/06 | 16:46 | Tica | 78164 | 9°50.41 N | 104°17.49 W | 2507m | video survey TRAC 3 (serie 3) |
| 28/12/06 | 16:44 | Tica | 78161 | 9°50.41 N | 104°17.49 W | 2509m | Recovery TRAC 1 (serie 3) + chemistry |
| 30/12/06 | 18:59 | Tica | 78168 | 9°50.41 N | 104°17.49 W | 2507m | Recovery TRAC 3 (serie 3) + chemistry |
| 30/12/06 | 19:15 | Tica | 78166 | 9°50.41 N | 104°17.49 W | 2509m | Recovery TRAC 2 (serie 3) + chemistry |
| 30/12/06 | 19:34 | Tica | 78171 | 9°50.41 N | 104°17.49 W | 2509m | Alvinella collection |
| 31/12/06 | 19:34 | L Vent | 70546 | 9°46.272 N | 104°16.740 W | 2520m | |

13. Chemical characterization of habitats

(N. le Bris, IFREMER)

13.1 Objectives

Our objective for this cruise was to chemically characterize vent habitats at 9°N following the January 2006 eruption, in order to document initial environmental conditions of colonisation experiments (Lauren Mullineaux, Florence Pradillon and Monika Bright experiments) and to compare the actual conditions to those determined before the eruption. The relation of biologically relevant chemical factors, such as free sulphide or pH, with temperature is a potential driver of the species diversity in vent habitats. To establish these correlations short-term measurements were performed during Alvin dives, on various points over the deployment areas of colonisation devices. A newly designed chemical probe was repeatedly used with *DSV Alvin* (Table 13.1). This probe combines two temperature sensors (Pt100 and thermocouple), a glass pH electrode, a sulphide potentiometric electrode and a fifth sensor, which was either an Eh electrode or a second sulfide electrode for security (Fig. 13.1). The sensing tip is about 5 mm overall diameter. From these measurements, free sulfide and pH will be calculated in the habitat studied and combined with temperature.

Our knowledge of temporal chemical variability in vent habitats is generally limited to these repeated short term characterisations, but there is a great interest to better characterise the evolution of environmental conditions in combination with temperature over time, especially during colonisation. This cruise offered us the opportunity to test the possibility to monitor chemistry continuously over days to weeks using autonomous sensors required for this to be optimized.

13.2 Operations

The probe has been used for all except 2 dives. The measurements have been mostly successful with only a few sensor failures. Data are available for various habitats where experiments were deployed (both in diffuse flow areas for Lauren Mullineaux and Monika Bright and for focused flow as part of a collaboration on *Alvinella* colonization with Florence Pradillon) for 7 active sites (Tica, Bio9, P-vent, V-vent, K-vent, Sketchy, Perseverance). Punctual chemical characterizations were also done at inactive sites (East wall, Q-vent).

A set of sensors was also deployed for two weeks of autonomous measurements, either on TRACs or independently (Table 13.1). This part was not as successful as the real time data acquisition, but some good records for periods of days to almost two weeks were obtained (see detail below).

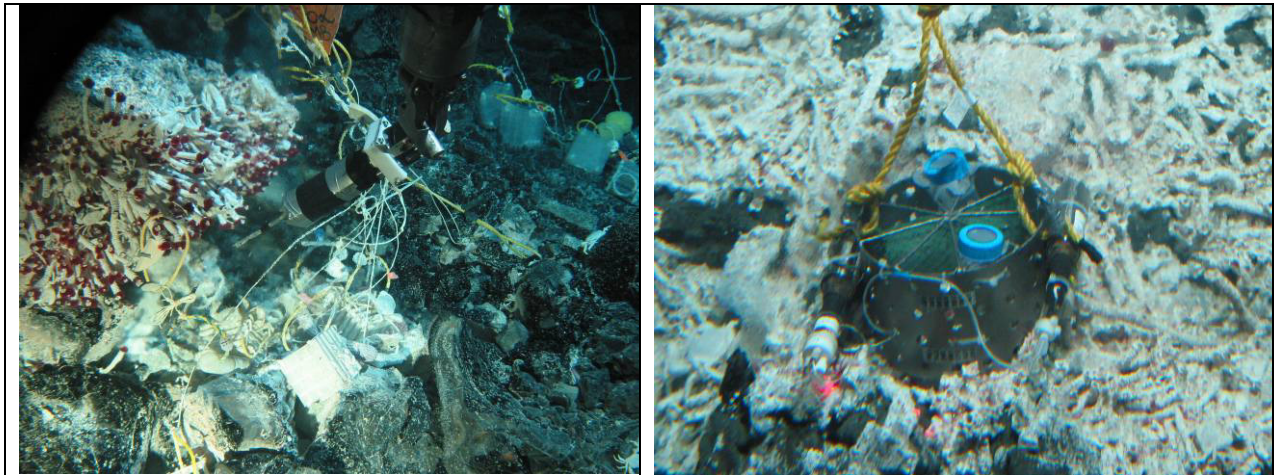


Figure 13.1: Chemical sensing. Left: Measurements with the chemical probe above Lauren Mullineaux's colonisation devices at a high T diffuse flow site. Right: Sensors on a TRAC (Titanium Ring for Alvinella Colonisation).

13.3 Summary of autonomous deployments

- Probe # 1 S+pH Electrodes failed (electrical problem)
- Probe # 2 S+pH White mats covered the electrodes at recovery. This likely degraded measurement accuracy. Data are out of expected ranges.
- TRAC2 (Tevnia) S 13 days of sulfide measurement; apparently OK.
- TRAC1 (Alvinella) S+pH
T increased from 15 °C to above 150 °C in one week resulting in destruction of the pH and S electrode destruction as well as the temperature sensor. Hopefully this high T was very local inside the TRAC, preserving the electronics. pH and S data should be OK in the first days but difficult to validate beyond this.

Table 13.1 : Real time measurements summary, Dives 4285-4289

| Dive | Port Obs. | Area | Site | Exp. | pH | sulfide | Eh | Comments |
|------|-----------|-------|---|--|--------|---------|--------|--|
| 4285 | Florence | 9°50' | Bio9 Tica | TRAC LM&MB | nd | ✓ | ✓ | pH electrode failure |
| 4287 | Nadine | 9°30' | K-vent | LM | ✓ | ✓ | ✓ | Mussels (mostly dead) and top and base of a chimney with anemonies and mats |
| 4288 | Laure | 9°50' | P-vent Bio9 | LM MB / AP sample | ✓ ✓ | ✓ nd | ✓ ✓ | At Bio9, probe exposed to high T (up to 120°C). Subsequent sulfide data incorrect |
| 4289 | Florence | 9°50' | P-vent Tica | LM&MB TRAC1 TRAC2 | ✓ | nd | ✓ | S electrode failure Alvinella Tevnia |
| 4290 | Ryan | 9°50' | Bio9 Tica East wall | former TRAC1 site LM_HT MB | ✓ | ✓ | nd | Eh sensor removed to duplicate S probe (live?) mussel |
| 4291 | Suzan | 9°50' | Sketchy (close Ty/Io) | LM | ✓ | nd | nd | Sulfide electrode failure Tungsten electrode added |
| 4292 | Nadine | 9°50' | Tica P-vent P-vent | LM & MB TRAC1 TRAC2 TRAC3 LM | ✓ | ✓ | nd | Tevnia/mats Alvinella basalt Tevnia Tevnia /mats |
| 4293 | Florence | 9°50' | V-vent | L_exp HT L_exp IT Alvinella sample | | | | Tevnia Mussels Fluid flowing from the chimney while basket was against the wall for collection |
| 4294 | Suzan | 9°50' | Sketchy | LSB | ✓ | ✓ | nd | Tevnia/mats |
| 4295 | Nadine | 9°50' | East Wall Q-vent Perseverance | Sponges Sponges Tevnias + TASKs | ✓ | ✓ | nd | Dead mussels and riftia tubes, a few mussels alive Extinct chimney New diffuse flow area close to BioVent with large white mats and tevnia patches |

LM: Lauren's Sandwiches and Blocks. MB Monika's sponges and TASKs.

14. Preliminary Deployment of Magnetic Collectors for Examination of Vent Particle Dispersal

[Noreen Kelly; PIs: Chris Taggart and Barry Ruddick, Dalhousie University]

The primary goal of this experiment was to test if iron oxide particles from black smoker chimneys at deep sea hydrothermal vents can be captured by passive magnetic collectors. If successful, iron oxide particles may be used as a proxy tracer for the potential dispersion of biological organisms from and to neighbouring vent communities.

Two magnetic collectors (MCs) were deployed at Bio9 vent. Each magnetic collector contained 4 magnets elevated on stainless steel posts, which were positioned equidistant within the collector (Fig. 14.1), such that the magnetic field would capture any iron particulates sinking through the collector area. One MC (“near”) was deployed 1 chimney height away (3 m) from a black smoker chimney (Fig. 14.1), while the second MC (“far”) was deployed 4.3 chimney heights away in a SE direction from the same black smoker (13 m). Both MCs were recovered after 19 days of deployment.

Preliminary examination showed black films of particulates covering the surfaces of all magnets, with the “near” magnets containing ~ 3 times more material on their surfaces than the “far” ones. Sediment had also collected in the bottom of both MCs. Colonization of bacterial mats occurred on the magnet surfaces, particularly at the “far” deployment. Several tubes of *Alvinella pompejana* were found in the bottom of the “near” collector, presumably having fallen from the surface of the Bio9 chimney.

Upon returning to the lab, the material collected on the surface of the magnets will be analysed for its iron content. Based on the results of this trial, a larger scale experiment will be designed to assess how the particles evolve with distance from the plume, and to estimate the rate at which they precipitate.

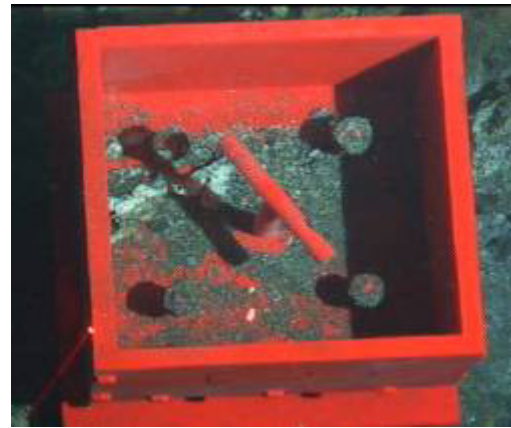


Fig. 14.1. Magnetic collector, “near” deployment. *Left* “Near” collector deployed 3 m away from a black smoker chimney at Bio9 vent. *Right* Four magnets within the “near” collector, covered with particulates after 19 days of deployment. (Alvin Dive #4294).

References

Macdonald, K. C., P. J. Fox, S. Miller, S. Carbotte, M. H. Edwards, M. Elsen, D. J. Fornari, L. Perram, R. Pockalny, D. Scheirer, S. Tighe, C. Welland, and D. Wilson. The East Pacific Rise and its flanks, 8-18 N: History of segmentation, propagation and spreading direction based on Sea-MARC II and Sea Beam studies. *Marine Geophysical Researches*, **14**, 299-344, 1992.

Appendix A. Cruise Participants

A.1 Ship's Crew

| | |
|-------------------|--------------------------------|
| George Silva | Captain |
| Mitzi Crane | Chief Mate |
| Peter Leonard | Second Mate |
| Rick Bean | Third Mate |
| John Porter | Communication Electronics tech |
| Wayne Bailey | Bosun |
| Ken Rand | Able-Bodied Seaman |
| Jerry Graham | Able-Bodied Seaman |
| Ed Popowitz | Able-Bodied Seaman |
| Kevin Threadgood | Ordinary Seaman |
| Patrick Neumann | Ordinary Seaman |
| Lance Wills | Ordinary Seaman |
| Jeff Little | Chief Engineer |
| Jim Schubert | First Assistant Engineer |
| Monica Hill | Second Assistant Engineer |
| Mike Spruill | Third Assistant Engineer |
| Sacha Wichers | Electrician |
| Andy Gillen | Oiler |
| Paul Ruh | Oiler |
| Carl Wood | Steward |
| Larry Jackson | Cook |
| Linda Bartholomee | Mess Attendant |
| Dave Sims | SSSG Tech |
| Ken Feldman | SSSG Tech |

A.2 Alvin Group

| | |
|-----------------|-------------------|
| Pat Hickey | Expedition Leader |
| Bruce Stickrott | Chief Pilot |
| Mark Spear | Pilot |
| Mike McCarthy | Pilot in Training |
| James Brennan | Pilot in Training |
| Chris Griner | Technician |

A.3 Science Personnel

| | | |
|----------------------|-----------------|--|
| James R. Ledwell | Chief Scientist | jledwell@whoi.edu |
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| Travis Eldson | Scientist | travis.elsdon@adelaide.edu.au |
| Nadine Le Bris | Scientist | Nadine.Le.Bris@ifremer.fr |
| Florence Pradillon | Scientist | florence.pradillon@snv.jussieu.fr |
| Laure Corbari | Post Doc | |
| Patrick Ryan Jackson | Post Doc | pjackson@whoi.edu |
| Cynthia Sellers | Res. Associate | csellers@whoi.edu |
| Leah Houghton | Res. Associate | lhoughton@whoi.edu |
| Tim Fischer | Grad Student | tfischer@ifm-geomar.de |
| Sigrid Katz | Grad Student | sigrid.katz@gmx.at |
| Sabine Gollner | Grad Student | sabine.gollner@gmx.at |
| Sarah Bennett | Grad Student | saroban@noc.soton.ac.uk |
| Noreen Kelly | Grad Student | kellyn@dal.ca |
| Alexis Jackson | Student | alexis.jackson@yale.edu |
| Kira Krumhansl | Student | kakrum02@stlawu.edu |

Appendix B. Science Data DVDs

The LADDER-2 science data are stored on DVDs, each of which has a file Diskinfo.txt, which contains additional information:

Alvin Data: One directory per dive with Alvin underway data (navigation, etc.), frame-grabber images, and top-lab data. Handheld still-camera images are found in a separate directory tree under pictures. Data directories of instruments that were not used are empty (e.g. magnetometer). The CTD subdirectories on this DVD are empty — Alvin CTD data (as well as Alvin renavigation) can be found on Science Data Disk 2.

Science Data Disk 1: Shipboard ADCP (OS75); Atlantis underway data (date, time, depth, heading, speed, GPS, meteorology, SST/SSS, fluorometer); cruise-participant photographs; SBE 911 (main CTD) raw data; documentation & scripts.

Science Data Disk 2: All data residing in the science subdirectory during the cruise: Alvin dive plans, dive reports & sampling procedures; tracer data; GIS maps; Alvin DVL navigation of mooring deployments; mooring slant-range surveys; SBE 911plus CTD processed data; Alvin SBE19 CTD; LADCP; CTD & LADCP logsheets; tidal prediction; Imagenex renavigation processing, pump mooring information, metadata and this report as of the time the DVD was generated.

Additionally, there are external-camera video DVDs (usually 6 per Alvin dive), DVDs containing the images taken with the external still camera (3 dives per DVD), one DVD containing the videos taken with the handheld camera, and a CD containing the raw navigation data.

Appendix C. Operations

C.1 Event Log

| Date | Time | N Lat | Lat | Lon | Lon | Event | Dive # | Cast # |
|-----------|-------|----------|--------|-------|--------|-----------------------------------|-----------|-----------|
| | (GMT) | (deg) | (min) | (deg) | (min) | | | |
| 13-Dec-06 | 0 | | | | | Cleaned cond cell on SBE 19 | | |
| 13-Dec-06 | 1345 | 9 | 50.3 | 104 | 17.48 | Alvin Dive at BIO-9 | 4285 | |
| 13-Dec-06 | 1900 | | | | | Cleaned cond cell on SBE 9plus | | |
| 14-Dec-06 | 544 | 9 | 29.73 | 104 | 14.641 | Pump Mooring #9 Deployed | | |
| 14-Dec-06 | 1044 | 9 | 30.09 | 104 | 14.531 | Pump Mooring #10 Deployed | | |
| 14-Dec-06 | 1200 | 9 | 29.73 | 104 | 14.64 | Station H7 | | 1 |
| 14-Dec-06 | 1345 | 9 | 29.68 | 104 | 14.584 | Alvin Dive | 4286 | |
| 15-Dec-06 | 32 | 9 | 29.98 | 104 | 14.51 | Station H7 | | 2 |
| 15-Dec-06 | 353 | 9 | 25.05 | 104 | 13.85 | Station I7 | | 3 |
| 15-Dec-06 | 635 | 9 | 30 | 104 | 19.8 | Station H8 | | 4 |
| 15-Dec-06 | 1020 | 9 | 30 | 104 | 19.8 | Station H8 | | 5 |
| 15-Dec-06 | 1345 | 9 | 30.43 | 104 | 14.58 | Alvin Dive southbound to K vent | 4287 | |
| 15-Dec-06 | 1645 | | | | | Pump Mooring #10 Recovered | | |
| 15-Dec-06 | 2000 | | | | | Pump Mooring #9 Recovered | | |
| 15-Dec-06 | 2102 | 9 | 30.438 | 104 | 14.342 | Transponder (9.0/10.5) on Deck | | |
| 16-Dec-06 | 2 | 9 | 29.72 | 104 | 14.343 | Transponder(9.0/11/0) on Deck | | |
| 16-Dec-06 | 124 | 9 | 34.99 | 104 | 15.04 | Station G7 | | 6 |
| 16-Dec-06 | 300 | | | | | SBE19 batteries replaced by James | | |
| 16-Dec-06 | 400 | 9 | 40.08 | 104 | 15.72 | Station F7 | | 7 |
| 16-Dec-06 | 630 | 9 | 44.96 | 104 | 16.51 | Station E7 | | 8 |
| 16-Dec-06 | 1000 | 9 | 50.27 | 104 | 17.48 | Station D7 | | 9 |
| 16-Dec-06 | 1345 | 9 | 50.27 | 104 | 17.289 | Alvin Dive at P vent | 4288 | |
| 17-Dec-06 | 30 | 9 | 51 | 104 | 12.5 | Station D6 | | 10 |
| 17-Dec-06 | 400 | 9 | 56.02 | 104 | 13.2 | Station C6 | | 11 |
| 17-Dec-06 | 1000 | 9 | 50.27 | 104 | 17.48 | Station D7 | | 12 |
| 17-Dec-06 | 1345 | 9 | 50.35 | 104 | 17.289 | Alvin Dive | 4289 | |
| 18-Dec-06 | 200 | 9 | 49.57 | 104 | 22.49 | Station D8 | | 13 |
| 18-Dec-06 | 500 | 9 | 48.86 | 104 | 27.48 | Station D9 | | 14 |
| 18-Dec-06 | 840 | 9 | 48.15 | 104 | 32.52 | Station D10 | | 15 |
| 18-Dec-06 | 1240 | 9 | 47.46 | 104 | 37.5 | Station D11 | | 16 |
| 18-Dec-06 | 1700 | 9 | 41.48 | 104 | 41.55 | Station E12 | | 17 |
| 18-Dec-06 | 2040 | 9 | 42.19 | 104 | 36.54 | Station E11 | | 18 |
| 19-Dec-06 | 0 | 9 | 42.88 | 104 | 31.53 | Station E10 | | 19 |
| 19-Dec-06 | 400 | 9 | 43.59 | 104 | 26.54 | Station E9 | | 20 |
| 19-Dec-06 | 715 | 9 | 44.31 | 104 | 21.51 | Station E8 | | 21 |
| 19-Dec-06 | 1040 | 9 | 39.29 | 104 | 20.78 | Station F8 | | 22 |
| 19-Dec-06 | 1410 | 9 | 38.59 | 104 | 25.78 | Station F9 | | 23 |
| 19-Dec-06 | 2020 | 9 | 20 | 104 | 12.99 | Station J7 | | 24 |
| 19-Dec-06 | 2350 | 9 | 15 | 104 | 12.97 | Station K7 | | 25 |
| 20-Dec-06 | 330 | 9 | 10.05 | 104 | 12.81 | Station L7 | | 26 |

| Date | Time | N Lat | Lat | Lon | Lon | Event | Dive # | Cast # |
|-----------|-------|----------|-------|-------|-------|--------------|-----------|-----------|
| | (GMT) | (deg) | (min) | (deg) | (min) | | | |
| 20-Dec-06 | 630 | 9 | 5.04 | 104 | 11.9 | Station M7 | | 27 |
| 20-Dec-06 | 940 | 9 | 0.03 | 104 | 12.21 | Station N7 | | 28 |
| 20-Dec-06 | 1310 | 9 | 0.7 | 104 | 7.2 | Station N6 | | 29 |
| 20-Dec-06 | 1950 | 9 | 49.7 | 104 | 22.48 | Station D8 | | 30 |
| 20-Dec-06 | 2320 | 9 | 54.56 | 104 | 20.51 | Station C8a | | 31 |
| 21-Dec-06 | 240 | 9 | 55.07 | 104 | 18.2 | Station C7 | | 32 |
| 21-Dec-06 | 600 | 10 | 0.05 | 104 | 19.18 | Station B7 | | 33 |
| 21-Dec-06 | 900 | 9 | 59.3 | 104 | 24.18 | Station B8 | | 34 |
| 21-Dec-06 | 1245 | 10 | 4.3 | 104 | 25.37 | Station A8 | | 35 |
| 21-Dec-06 | 1610 | 10 | 4.99 | 104 | 20.35 | Station A7 | | 36 |
| 21-Dec-06 | 1900 | 10 | 5.7 | 104 | 15.35 | Station A6 | | 37 |
| 21-Dec-06 | 2240 | 10 | 0.7 | 104 | 14.21 | Station B6 | | 38 |
| 22-Dec-06 | 250 | 10 | 2.1 | 104 | 4.2 | Station B4 | | 39 |
| 22-Dec-06 | 700 | 10 | 3.48 | 103 | 54.19 | Station B2 | | 40 |
| 22-Dec-06 | 1050 | 10 | 4.92 | 103 | 44.18 | Station B0 | | 41 |
| 22-Dec-06 | 1510 | 10 | 15.22 | 103 | 51.7 | Station AA1 | | 42 |
| 22-Dec-06 | 1900 | 10 | 13.81 | 104 | 1.71 | Station AA3 | | 43 |
| 22-Dec-06 | 2230 | 10 | 12.41 | 104 | 11.72 | Station AA5 | | 44 |
| 23-Dec-06 | 210 | 10 | 11 | 104 | 21.73 | Station AA7 | | 45 |
| 23-Dec-06 | 540 | 10 | 9.59 | 104 | 31.7 | Station AA9 | | 46 |
| 23-Dec-06 | 850 | 10 | 15.36 | 104 | 27.74 | Station AB8 | | 47 |
| 23-Dec-06 | 1220 | 10 | 16.07 | 104 | 22.74 | Station AB7 | | 48 |
| 23-Dec-06 | 1530 | 10 | 15.73 | 104 | 17.55 | Station AB6 | | 49 |
| 23-Dec-06 | 1900 | 10 | 26.66 | 104 | 19.86 | Station AD6 | | 50 |
| 23-Dec-06 | 2250 | 10 | 25.26 | 104 | 29.83 | Station AD8 | | 51 |
| 24-Dec-06 | 230 | 10 | 18.9 | 104 | 38.6 | Station AB10 | | 52 |
| 24-Dec-06 | 620 | 10 | 7.48 | 104 | 46.78 | Station AA12 | | 53 |
| 24-Dec-06 | 930 | 9 | 55.78 | 104 | 49.24 | Station B13 | | 54 |
| 24-Dec-06 | 1240 | 9 | 50.78 | 104 | 48.01 | Station C13 | | 55 |
| 24-Dec-06 | 1600 | 9 | 46.09 | 104 | 47.1 | Station D13 | | 56 |
| 24-Dec-06 | 1910 | 9 | 45.27 | 104 | 52.39 | Station D14 | | 57 |
| 24-Dec-06 | 2220 | 9 | 50.09 | 104 | 53 | Station C14 | | 58 |
| 25-Dec-06 | 140 | 9 | 53 | 104 | 54.2 | Station B14 | | 59 |
| 25-Dec-06 | 530 | 9 | 53.39 | 104 | 59.23 | Station B15 | | 60 |
| 25-Dec-06 | 920 | 9 | 53.7 | 104 | 4.25 | Station B16 | | 61 |
| 25-Dec-06 | 1250 | 9 | 58.67 | 105 | 5.38 | Station A16 | | 62 |
| 25-Dec-06 | 1620 | 9 | 59.37 | 105 | 0.4 | Station A15 | | 63 |
| 25-Dec-06 | 1920 | 9 | 59.01 | 104 | 55.4 | Station A14 | | 64 |
| 25-Dec-06 | 2310 | 9 | 56.59 | 104 | 43.68 | Station B12 | | 65 |
| 26-Dec-06 | 230 | 9 | 57.03 | 104 | 39.94 | Station B11a | | 66 |
| 26-Dec-06 | 620 | 9 | 52.15 | 104 | 38.08 | Station C11 | | 67 |
| 26-Dec-06 | 950 | 9 | 51.48 | 104 | 43.01 | Station C12 | | 68 |

| Date | Time | N Lat | Lat | Lon | Lon | Event | Dive # | Cast # |
|-----------|-------|----------|-------|-------|--------|--|-----------|-----------|
| | (GMT) | (deg) | (min) | (deg) | (min) | | | |
| 26-Dec-06 | 1250 | 9 | 46.81 | 104 | 42.55 | Sation D12 | | 69 |
| 26-Dec-06 | 1620 | 9 | 41.46 | 104 | 41.65 | Station E12 | | 70 |
| 26-Dec-06 | 1920 | 9 | 35.78 | 104 | 45.8 | Station F13 | | 71 |
| 26-Dec-06 | 2230 | 9 | 40.75 | 104 | 46.57 | Station E13 | | 72 |
| 27-Dec-06 | 220 | 9 | 36.51 | 104 | 40.88 | Station F12 | | 73 |
| 27-Dec-06 | 600 | 9 | 37.19 | 104 | 35.79 | Station F11 | | 74 |
| 27-Dec-06 | 920 | 9 | 37.88 | 104 | 30.81 | Station F10 | | 75 |
| 27-Dec-06 | 1220 | 9 | 42.19 | 104 | 36.54 | Station E11 | | 76 |
| 27-Dec-06 | 1600 | 9 | 47.47 | 104 | 37.54 | Station D11 | | 77 |
| 27-Dec-06 | 1830 | | | | | Cleaned cond cell of SBE19 | | |
| 27-Dec-06 | 1900 | 9 | 42.89 | 104 | 31.54 | Station E10 | | 78 |
| 27-Dec-06 | 2200 | | | | | Cleaned cond cell of SBE 9 plus | | |
| 27-Dec-06 | 2210 | 9 | 48.16 | 104 | 32.49 | Station D10 | | 79 |
| 28-Dec-06 | 120 | 9 | 50.96 | 104 | 32.9 | Station C10a | | 80 |
| 28-Dec-06 | 520 | 9 | 59.45 | 104 | 29.41 | Station B9a | | 81 |
| 28-Dec-06 | 910 | 9 | 52.35 | 104 | 27.9 | Station C9a | | 82 |
| 28-Dec-06 | 1345 | 9 | 50.21 | 104 | 17.465 | Alvin Dive | 4290 | |
| 29-Dec-06 | 540 | 9 | 50.09 | 104 | 17.545 | Pump Mooring #11 Deployed | | |
| 29-Dec-06 | 749 | 9 | 49.2 | 104 | 17.325 | Pump Mooring #12 Deployed | | |
| 29-Dec-06 | 920 | 9 | 50.3 | 104 | 17.49 | Station D7 | | 83 |
| 29-Dec-06 | 1345 | 9 | 50.1 | 104 | 17.521 | Alvin Dive | 4291 | |
| 30-Dec-06 | 30 | 9 | 38.61 | 104 | 25.7 | Station F9 | | 84 |
| 30-Dec-06 | 340 | 9 | 43.56 | 104 | 26.6 | Station E9 | | 85 |
| 30-Dec-06 | 650 | 9 | 48.87 | 104 | 27.49 | Station D9 | | 86 |
| 30-Dec-06 | 950 | 9 | 49.57 | 104 | 22.48 | Station D8 | | 87 |
| 30-Dec-06 | 1345 | | | | | Alvin Dive | 4292 | |
| 30-Dec-06 | 1700 | | | | | Pump Mooring #11 Recovered | | |
| 31-Dec-06 | 100 | | | | | Pump Mooring #12 Recovered | | |
| 31-Dec-06 | 230 | 9 | 34.3 | 104 | 20.05 | Station G8 | | 88 |
| 31-Dec-06 | 620 | 9 | 39.3 | 104 | 20.76 | Station F8 | | 89 |
| 31-Dec-06 | 930 | 9 | 44.29 | 104 | 21.53 | Station E8 | | 90 |
| 31-Dec-06 | 1345 | 9 | 50.4 | 104 | 17.334 | Alvin Dive | 4293 | |
| 1-Jan-07 | 253 | 9 | 50.42 | 104 | 17.544 | Pump Mooring #13 Deployed | | |
| 1-Jan-07 | 552 | 9 | 50.62 | 104 | 17.561 | Pump Mooring #14 Deployed | | |
| 1-Jan-07 | 710 | 9 | | 104 | | Station for plume water (500m SW Bio9) | | 91 |
| 1-Jan-07 | 950 | 9 | 49.49 | 104 | 18.18 | Station for plume water (2km SW Bio9) | | 92 |
| 1-Jan-07 | 1345 | 9 | 50.4 | 104 | 17.502 | Alvin Dive | 4294 | |
| 2-Jan-07 | 210 | 9 | 27.11 | 103 | 58.79 | Station I4 | | 93 |
| 2-Jan-07 | 540 | 9 | 31.41 | 104 | 4.5 | Station H5 | | 94 |
| 2-Jan-07 | 910 | 9 | 41.41 | 104 | 5.76 | Station F5 with SBE19 for intercalibration | | 95 |
| 2-Jan-07 | 1345 | 9 | 50.51 | 104 | 17.398 | Alvin Dive | 4295 | |

| Date | Time | N Lat | Lat | Lon | Lon | Event | Dive # | Cast # |
|----------|-------|----------|-------|-------|--------|----------------------------|-----------|-----------|
| | (GMT) | (deg) | (min) | (deg) | (min) | | | |
| 2-Jan-07 | 1630 | | | | | Pump Mooring #14 Recovered | | |
| 2-Jan-07 | 1930 | | | | | Pump Mooring #13 Recovered | | |
| 2-Jan-07 | 2340 | 9 | 54.05 | 104 | 18.23 | Station GAP-1 | | 96 |
| 3-Jan-07 | 220 | 9 | 53.9 | 104 | 19 | Station GAP-2 | | 97 |
| 3-Jan-07 | 500 | 9 | 53.8 | 104 | 19.9 | Station GAP-3 | | 98 |
| 3-Jan-07 | 730 | 9 | 53.75 | 104 | 20.67 | Station GAP-4 | | 99 |
| 3-Jan-07 | 1030 | 9 | 54.29 | 104 | 17.7 | Station GAP-5 | | 100 |
| 3-Jan-07 | 1345 | 9 | 54.28 | 104 | 17.664 | Alvin Dive | 4296 | |

C.2 Alvin Dives

| Date | Dive No. | Location Name | Pilot | Observer 1 | Observer 2 |
|-------------|-----------------|----------------------|------------------|--------------------|-------------------|
| 13-Dec-06 | 4285 | 9N50 BioTran | Bruce Strickrott | Florence Pradillon | Noreen Kelley |
| 14-Dec-06 | 4286 | 9N30 BioTran | Mark Speak | Susan Mills | Alexis Jackson |
| 15-Dec-06 | 4287 | 9N30 BioTran | Pat Hickey | Nadine LeBris | Tim Fisher |
| 16-Dec-06 | 4288 | 9N50 BioTran | Bruce Strickrott | Ryan Jackson | Laure Corbari |
| 17-Dec-06 | 4289 | 9N50 BioTran | Mark Speak | James Brennan | Florence Padillon |
| 28-Dec-06 | 4290 | 9N50 BioTran | Pat Hickey | Ryan Jackson | Kira Krumhansl |
| 29-Dec-06 | 4291 | 9N50 BioTran | Bruce Strickrott | Susan Mills | Travis Elsdon |
| 30-Dec-06 | 4292 | 9N50 BioTran | Mark Speak | Nadine LeBris | Sarah Bennentt |
| 31-Dec-06 | 4293 | 9N47 BioTran | Pat Hickey | Florence Pradillon | Jim Ledwell |
| 1-Jan-07 | 4294 | 9N50 BioTran | Bruce Strickrott | James Brennan | Susan Mills |
| 2-Jan-07 | 4295 | 9N50 BioTran | Mark Speak | Nadine LeBris | Leah Houghton |
| 3-Jan-07 | 4296 | 9N55 BioTran | Pat Hickey | Ryan Jackson | Sigrid Katz |

Appendix D. Hydrothermal Sites

2in1 (new site). $x = 4381\text{m}$, $y = 79852\text{m}$, $z = 2508\text{m}$; 9 ± 51.32 0N, 104 ± 17.61 0W. Two areas, one with patches of white bacterial mats, the other one on the eastern wall of steep, narrow ASCT with lots of diffuse flow and *Tevnia*, not accessible for Alvin. (Note: This site is possibly called Hobbit Hole by the Alvin team.)

BioVent. 19:29–19:34 GMT Dive 4268 (position from renav: $x = 4368\text{m}$, $y = 79199\text{m}$) 2 smokers with *Alvinella*, surrounded by pillow lava, white bacterial mats in cracks; Diffuse flow in vicinity with bacterial mats and limpets observed on Dive 4261 at 21:28 GMT (position from renav: $x = 4386\text{m}$, $y = 79151\text{m}$).

M-Vent. $x = 4420\text{m}$, $y = 78877\text{m}$, $z = 2500\text{m}$; 9 ± 50.79 0N, 104 ± 17.59 0W. Inactive smoker. RESET Marker 13, note lava pooled at base.

Q-Vent. $x = 4428\text{m}$, $y = 78783\text{m}$, $z = 2502\text{m}$; 9 ± 50.74 0N, 104 ± 17.58 0W. Inactive smoker with dead *Alvinella* tubes; swarms of amphipods around it and also in some of the basalt areas there are these amphipods. HOBO 20 and RESET Marker 1.

Mussel Bed. No diffuse flow, appears to be filled in with new basalt.

East Wall. $x = 4557\text{m}$, $y = 78425\text{m}$, $z = 2500\text{m}$; 9 ± 50.55 0N, 104 ± 17.51 0W. No vigorous diffuse flow; large accumulations of mussel shells and tubes of *Riftia*; also on higher parts of East Wall some patches of mussel shell and tubes of *Riftia* that appear to be in original place and have not been covered with lava; also some patches with live mussels *Bathymodioulus thermophilus*.

StaBB (new site). $\frac{1}{4}$ 150m North of Tica. New diffuse vent in ASC near East Wall 18:19 – 18:22 GMT Dive 4273 (renav. not available). Estimate $\frac{1}{4}$ 2.5–3m² with abundant *Tevnia* and vigorous diffuse flow. *Bythograeids* abundant.

Tica. $x = 4580\text{m}$, $y = 78174\text{m}$, $z = 2510\text{m}$; 9 ± 50.41 0N, 104 ± 17.5 0W. Still very active area of diffuse flow, although no black smoker, several patches of *Tevnia* on the false eastern wall of ASCT and also in ASCT, back side towards the east has also a patch of *Tevnia*; a few live *Riftia* and mussels (survivors); one patch found with *Alvinella/Tevnia*.

Bio 9 area. $x = 4615\text{m}$, $y = 77968\text{m}$, $z = 2508\text{m}$; 9 ± 50.30 0N, 104 ± 17.48 0W. A series of small chimneys. *Alvinellid* Stump is now a smoker complex (multiple chimneys). Large table (southern) structure now a smoker complex with multiple spires (>20 spires). Rusty *Riftia* field (10m off complex) is gone. Shape of Bio9 same as pre-eruption. Bio 9 prime and Bio9 proper are still recognizable according to Pat Hickey. Nearby, in depression, is “Fish Hole” area (renav. position: $x = 4612\text{m}$, $y = 77958\text{m}$). This area had diffuse flow with *Tevnia* and bacterial mats.

Hole-to-Hell (part of the Bio9 complex). $x = 4609\text{m}$, $y = 78005\text{m}$; 9 ± 50.32 0N, 104 ± 17.48 0W. Series of multiple smokers/smoker field (where the old marker should be), *Riftias* are extinct, *Alvinella* present.

P Vent. $x = 4627\text{m}$, $y = 77910\text{m}$, $z = 2508\text{m}$; 9 ± 50.27 0N, 104 ± 17.47 0W. Still active, first higher spire is clear, second lower one is gushing; with *Alvinella* on sulfide walls, with patches of *Tevnia*, one large, old *Riftia*. RESET Marker 10 and HOBO 21. RESET Marker 5, new marker L-O.

Alvinella Pillar. Not found during LADDER-1 dives.

Ty-Io. $x = 4672\text{m}$, $y = 77616\text{m}$, $z = 2504\text{m}$; 9 ± 50.11 0N, 104 ± 17.45 0W. It is not clear whether this is Ty or Io smokers. A series of several small to a few meters high black smokers with extensive *Alvinella* populations is present. Diffuse flow area (including Marker 8/11 and L-M Deployment site) extends towards the south with many patches of diffuse flow, white bacterial mats, fish, limpets and both bythograeid and galatheid crabs and patches of *Tevnia* up to 30 cm length, most *Tevnia* patches are probably not accessible for Alvin.

Sketchy (new site). $x = 4684\text{m}$, $y = 77524\text{m}$, $z = 2506\text{m}$; 9 ± 50.06 0N, 104 ± 17.44 0W. L-M Deployment site, new marker S. Relatively narrow fissure with submersible access at $180 \pm$, then turning to $150 \pm$ to manipulate experiments.

Finn (new site; old Marker 119?). $x = 4706\text{m}$, $y = 77331\text{m}$, $z = 2504\text{m}$; 9 ± 49.95 0N, 104 ± 17.43 0W. Thriving *Tevnia*, extensive bacterial mat along crack. Along the steep, eastern wall of ASCT, but not accessible, on top of ASCT may be some place where deployments or collections are possible.

L-41 Marker (old Marker 141?). $x = 4743\text{m}$, $y = 77137\text{m}$; 9 ± 49.85 0N, 104 ± 17.41 0W. Several collapse pits, two of which had extensive *Tevnia* clumps.

Tubeworm Pillar. Not found during LADDER-1 dives.

Choo-choo (new location). Old location: $x = 4807\text{m}$, $y = 76714\text{m}$; 9 ± 49.62 0N, 104 ± 17.38 0W. Paved with new basalt, patches of diffuse flow.. New Location: $x = 4841\text{m}$, $y = 76547\text{m}$; 9 ± 49.53 0N, 104 ± 17.36 0W. Found Choo-choo marker (flag is partially paved, says marker 371) and dead mussel community 170m south of original location.

PBR600 (new site). $z = 2567\text{m}$; 9 ± 29.27 0N, 104 ± 14.39 0W. High-temperature vents discovered by Pat, Brian & Ryan during Pat's dive#600. Looks like a castle on top of a 14–16m-high pillar with many spires and some curved spires (like a crown; Figure 22). One distinct black smoker on top, others probable behind the pillar.

9-35 (new site). 2 CTD profiles carried out at 9 ± 35.0 0N, 104 ± 15.1 0W intersected a near-field (buoyant) plume.

9-40 (new site). 2 CTD profiles carried out at 9 ± 40.0 0N, 104 ± 15.7 0W intersected a near-field plume.

Appendix E. CTD Stations

E.1 CTD Stations

| Cast # | Station ID | Date | Time (UTC) | Lat (deg) | Lat (min) | Lon (deg) | Lon (min) | Max Depth (m) |
|---------|------------|------------|------------|-----------|-----------|-----------|-----------|---------------|
| CTD-001 | H7 | 12/14/2006 | 12:20 | 9 | 29.726 | -104 | 14.64 | 1002 |
| CTD-002 | H7 | 12/15/2006 | 0:32 | 9 | 29.9786 | -104 | 14.5091 | 2567 |
| CTD-003 | I7 | 12/15/2006 | 3:52 | 9 | 24.99 | -104 | 13.7991 | 2570 |
| CTD-004 | H8 | 12/15/2006 | 7:06 | 9 | 29.984 | -104 | 19.7735 | 2783 |
| CTD-005 | H8 | 12/15/2006 | 10:20 | 9 | 29.9991 | -104 | 19.7989 | 2607 |
| CTD-006 | G7 | 12/16/2006 | 1:05 | 9 | 34.998 | -104 | 15.042 | 2543 |
| CTD-007 | F7 | 12/16/2006 | 4:11 | 9 | 40.0464 | -104 | 15.7404 | 2528 |
| CTD-008 | E7 | 12/16/2006 | 7:00 | 9 | 44.9754 | -104 | 16.53 | 2520 |
| CTD-009 | D7 | 12/16/2006 | 9:58 | 9 | 50.2716 | -104 | 17.4828 | 2494 |
| CTD-010 | D6 | 12/17/2006 | 0:43 | 9 | 50.9982 | -104 | 12.4992 | 2783 |
| CTD-011 | C6 | 12/17/2006 | 4:02 | 9 | 56.0002 | -104 | 13.206 | 2741 |
| CTD-012 | D7 | 12/17/2006 | 10:06 | 9 | 50.2728 | -104 | 17.4816 | 2494 |
| CTD-013 | D8 | 12/18/2006 | 1:59 | 9 | 49.5672 | -104 | 22.4856 | 2861 |
| CTD-014 | D9 | 12/18/2006 | 5:22 | 9 | 48.652 | -104 | 27.4885 | 2946 |
| CTD-015 | D10 | 12/18/2006 | 8:38 | 9 | 48.1608 | -104 | 32.4984 | 2938 |
| CTD-016 | D11 | 12/18/2006 | 12:39 | 9 | 47.4588 | -104 | 37.4988 | 2959 |
| CTD-017 | E12 | 12/18/2006 | 17:01 | 9 | 41.4828 | -104 | 41.5488 | 2912 |
| CTD-018 | E11 | 12/18/2006 | 20:34 | 9 | 42.1848 | -104 | 36.546 | 2978 |
| CTD-019 | E10 | 12/19/2006 | 0:14 | 9 | 42.888 | -104 | 31.542 | 2964 |
| CTD-020 | E9 | 12/19/2006 | 3:50 | 9 | 43.5912 | -104 | 26.538 | 2845 |
| CTD-021 | E8 | 12/19/2006 | 7:11 | 9 | 44.3004 | -104 | 21.5328 | 2810 |
| CTD-022 | F8 | 12/19/2006 | 20:34 | 9 | 39.2952 | -104 | 20.7744 | 2872 |
| CTD-023 | F9 | 12/19/2006 | 14:08 | 9 | 38.592 | -104 | 25.7784 | 2895 |
| CTD-024 | J7 | 12/19/2006 | 20:15 | 9 | 19.9776 | -104 | 12.9984 | 2571 |
| CTD-025 | K7 | 12/20/2006 | 0:10 | 9 | 14.9976 | -104 | 12.972 | 2562 |
| CTD-026 | L7 | 12/20/2006 | 3:38 | 9 | 10.014 | -104 | 12.7488 | 2571 |
| CTD-027 | M7 | 12/20/2006 | 6:36 | 9 | 4.9992 | -104 | 11.8848 | 2601 |
| CTD-028 | N7 | 12/20/2006 | 9:37 | 9 | 0.0036 | -104 | 12.2052 | 2634 |
| CTD-029 | N6 | 12/20/2006 | 13:05 | 9 | 0.6984 | -104 | 7.2012 | 2852 |
| CTD-030 | D8 | 12/20/2006 | 19:59 | 9 | 49.6812 | -104 | 22.4844 | 2859 |
| CTD-031 | C8a | 12/20/2006 | 23:28 | 9 | 54.5604 | -104 | 20.5068 | 2862 |
| CTD-032 | C7 | 12/21/2006 | 2:48 | 9 | 54.9984 | -104 | 17.9868 | 2541 |
| CTD-033 | B7 | 12/21/2006 | 5:51 | 10 | 0.0306 | -104 | 19.1928 | 2544 |
| CTD-034 | B8 | 12/21/2006 | 8:55 | 9 | 59.3028 | -104 | 24.1944 | 2920 |
| CTD-035 | A8 | 12/21/2006 | 12:43 | 10 | 4.2948 | -104 | 25.3644 | 2857 |
| CTD-036 | A7 | 12/21/2006 | 16:05 | 10 | 4.998 | -104 | 20.3604 | 2532 |
| CTD-037 | A6 | 12/21/2006 | 19:02 | 10 | 5.7 | -104 | 15.348 | 2898 |
| CTD-038 | B6 | 12/21/2006 | 22:52 | 10 | 0.6864 | -104 | 14.1816 | 2680 |
| CTD-039 | B4 | 12/22/2006 | 2:46 | 10 | 2.109 | -104 | 4.1988 | 2894 |
| CTD-040 | B2 | 12/22/2006 | 6:45 | 10 | 3.4752 | -103 | 54.186 | 2960 |
| CTD-041 | B0 | 12/22/2006 | 10:53 | 10 | 4.9212 | -103 | 44.1828 | 2974 |
| CTD-042 | AA1 | 12/22/2006 | 15:04 | 10 | 15.2184 | -103 | 51.7026 | 2925 |
| CTD-043 | AA3 | 12/22/2006 | 19:07 | 10 | 13.8072 | -104 | 1.7076 | 2963 |
| CTD-044 | AA5 | 12/22/2006 | 22:42 | 10 | 12.4056 | -104 | 11.7156 | 2491 |
| CTD-045 | AA7 | 12/23/2006 | 2:13 | 10 | 10.998 | -104 | 21.726 | 2590 |

| Cast # | Station ID | Date | Time (UTC) | Lat (deg) | Lat (min) | Lon (deg) | Lon (min) | Max Depth (m) |
|---------|------------|------------|------------|-----------|-----------|-----------|-----------|---------------|
| CTD-046 | AA9 | 12/23/2006 | 5:30 | 10 | 9.5904 | -104 | 31.734 | 2882 |
| CTD-047 | AB8 | 12/23/2006 | 8:43 | 10 | 15.3732 | -104 | 27.7446 | 3040 |
| CTD-048 | AB7 | 12/23/2006 | 12:14 | 10 | 16.0656 | -104 | 22.74 | 2870 |
| CTD-049 | AB6 | 12/23/2006 | 15:28 | 10 | 15.7236 | -104 | 17.5488 | 2856 |
| CTD-050 | AD6 | 12/23/2006 | 19:07 | 10 | 26.6652 | -104 | 19.8528 | 3240 |
| CTD-051 | AD8 | 12/23/2006 | 22:58 | 10 | 25.2552 | -104 | 29.8368 | 2836 |
| CTD-052 | AB10 | 12/24/2006 | 2:22 | 10 | 18.8916 | -104 | 38.616 | 2792 |
| CTD-053 | AA12 | 12/24/2006 | 6:06 | 10 | 7.4124 | -104 | 46.7868 | 2812 |
| CTD-054 | B13 | 12/24/2006 | 9:35 | 9 | 55.8264 | -104 | 49.1916 | 2772 |
| CTD-055 | C13 | 12/24/2006 | 12:37 | 9 | 50.772 | -104 | 48.03 | 3022 |
| CTD-056 | D13 | 12/24/2006 | 15:58 | 9 | 46.0932 | -104 | 47.1 | 2944 |
| CTD-057 | D14 | 12/24/2006 | 19:11 | 9 | 45.2856 | -104 | 52.3836 | 2874 |
| CTD-058 | C14 | 12/24/2006 | 22:24 | 9 | 50.0916 | -104 | 53.0052 | 2993 |
| CTD-059 | B14 | 12/25/2006 | 1:46 | 9 | 55.0548 | -104 | 54.2412 | 993 |
| CTD-060 | B15 | 12/25/2006 | 5:27 | 9 | 54.3936 | -104 | 59.232 | 3119 |
| CTD-061 | B16 | 12/25/2006 | 9:09 | 9 | 53.7252 | -105 | 4.2264 | 3133 |
| CTD-062 | A16 | 12/25/2006 | 12:47 | 9 | 58.6668 | -105 | 5.3856 | 3207 |
| CTD-063 | A15 | 12/25/2006 | 16:12 | 9 | 59.3688 | -105 | 0.3984 | 2974 |
| CTD-064 | A14 | 12/25/2006 | 19:36 | 9 | 59.0052 | -104 | 55.3932 | 2808 |
| CTD-065 | B12 | 12/25/2006 | 23:22 | 9 | 56.5836 | -104 | 43.6812 | 3074 |
| CTD-066 | B11a | 12/26/2006 | 2:36 | 9 | 57.024 | -104 | 39.942 | 3097 |
| CTD-067 | C11 | 12/26/2006 | 6:15 | 9 | 52.1502 | -104 | 38.0052 | 3040 |
| CTD-068 | C12 | 12/26/2006 | 9:43 | 9 | 51.4608 | -104 | 43.0668 | 3040 |
| CTD-069 | D12 | 12/26/2006 | 12:50 | 9 | 46.7808 | -104 | 42.5436 | 2933 |
| CTD-070 | E12 | 12/26/2006 | 16:15 | 9 | 41.4588 | -104 | 41.6466 | 2982 |
| CTD-071 | F13 | 12/26/2006 | 19:35 | 9 | 35.7696 | -104 | 45.8442 | 2952 |
| CTD-072 | E13 | 12/26/2006 | 22:46 | 9 | 40.7616 | -104 | 46.5588 | 3030 |
| CTD-073 | F12 | 12/27/2006 | 2:17 | 9 | 36.4992 | -104 | 40.8588 | 2903 |
| CTD-074 | F11 | 12/27/2006 | 5:47 | 9 | 37.188 | -104 | 35.8332 | 2998 |
| CTD-075 | F10 | 12/27/2006 | 9:10 | 9 | 37.8888 | -104 | 30.804 | 3018 |
| CTD-076 | E11 | 12/27/2006 | 12:38 | 9 | 42.1992 | -104 | 36.5634 | 2975 |
| CTD-077 | D11 | 12/27/2006 | 15:52 | 9 | 47.4708 | -104 | 37.5396 | 2941 |
| CTD-078 | E10 | 12/27/2006 | 19:06 | 9 | 42.918 | -104 | 31.602 | 2958 |
| CTD-079 | D10 | 12/27/2006 | 22:16 | 9 | 48.126 | -104 | 32.4648 | 2931 |
| CTD-080 | C10a | 12/28/2006 | 1:29 | 9 | 50.9592 | -104 | 32.9004 | 2894 |
| CTD-081 | B9a | 12/28/2006 | 5:21 | 9 | 59.4492 | -104 | 29.3904 | 2961 |
| CTD-082 | C9a | 12/28/2006 | 9:06 | 9 | 52.356 | -104 | 27.906 | 2899 |
| CTD-083 | D7 | 12/29/2006 | 9:07 | 9 | 50.298 | -104 | 17.49 | 2489 |
| CTD-084 | F9 | 12/30/2006 | 0:34 | 9 | 38.6064 | -104 | 25.7892 | 2886 |
| CTD-085 | E9 | 12/30/2006 | 3:44 | 9 | 43.6008 | -104 | 26.6112 | 2909 |
| CTD-086 | D9 | 12/30/2006 | 6:45 | 9 | 48.876 | -104 | 27.5112 | 2951 |
| CTD-087 | D8 | 12/30/2006 | 9:42 | 9 | 49.566 | -104 | 22.4952 | 2864 |
| CTD-088 | G8 | 12/31/2006 | 2:41 | 9 | 20.0388 | -104 | 34.3008 | 2803 |
| CTD-089 | F8 | 12/31/2006 | 6:16 | 9 | 20.7708 | -104 | 39.2976 | 2869 |
| CTD-090 | E8 | 12/31/2006 | 9:29 | 9 | 21.5304 | -104 | 44.298 | 2812 |
| CTD-091 | n/a | 1/1/2007 | 7:07 | 9 | 50.1084 | -104 | 17.6604 | 2497 |
| CTD-092 | n/a | 1/1/2007 | 9:50 | 9 | 49.4904 | -104 | 18.186 | 2587 |
| CTD-093 | I4 | 1/2/2007 | 2:23 | 9 | 27.1344 | -103 | 58.8378 | 2947 |
| CTD-094 | H5 | 1/2/2007 | 5:41 | 9 | 31.3968 | -104 | 4.5168 | 3073 |

| Cast # | Station ID | Date | Time (UTC) | Lat (deg) | Lat (min) | Lon (deg) | Lon (min) | Max Depth (m) |
|---------|------------|----------|------------|-----------|-----------|-----------|-----------|---------------|
| CTD-095 | F5 | 1/2/2007 | 9:11 | 9 | 5.7876 | -104 | 41.3916 | 2935 |
| CTD-096 | GAP-1 | 1/2/2007 | 23:48 | 9 | 18.2328 | -104 | 54.048 | 2558 |
| CTD-097 | GAP-2 | 1/3/2007 | 2:19 | 9 | 19.0092 | -104 | 53.9022 | 2623 |
| CTD-098 | GAP-3 | 1/3/2007 | 4:54 | 9 | 19.9056 | -104 | 53.8044 | 2715 |
| CTD-099 | GAP-4 | 1/3/2007 | 7:37 | 9 | 20.6712 | -104 | 53.748 | 2775 |
| CTD-100 | GAP-5 | 1/3/2007 | 10:31 | 9 | 54.29 | -104 | 17.74 | 2551 |