NOAA Office of Ocean Exploration

Final Report Format

I. OVERVIEW

Grant Number (If applicable)

NA04OAR4600084

Amount of funding from Ocean Exploration

$122,885

Project Title

Exploring New Patterns of Biological Succession at the Rosebud Hydrothermal Vents - Galápagos Rift

Area of Operation (if applicable)

Galápagos Rift

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The Institute for Genomic Research (Naomi Ward, subcontract)
University of New Hampshire (Yuri Zhanov, participant)

Award Period: From _ 01/14/2005 To 01/31/2007

Period Covered by this Report: From 01/14/2005-01/31/2007 (ref: Semi-Annual Performance Report)

II. Summary

1. Abstract – 1-paragraph description of final report

In May-June, 2005, a multidisciplinary expedition was conducted on the Galápagos Rift between the Rosebud hydrothermal field at 86.5°W and the Inca Transform at 85ºW to investigate the role fluid chemistry and microbial assemblages play in the development of nascent hydrothermal communities, to conduct in-situ colonization experiments, to map the biology and geology of the Rosebud vent field through mosaic imaging, and to explore the eastern Rift for undiscovered low- and high-temperature hydrothermal systems. Through support from NOAA's Ocean Exploration Program, the National

Science Foundation, the Deep-Ocean Exploration Institute, and the Woods Hole Oceanographic Institution, a synergistic array of deep-ocean vehicles was used, including Alvin and TowCam, a digital towed camera system, to deploy experiments, collect samples, make seafloor observations, and acquire digital imagery. An Education and Outreach program that included Dive and Discover and NOAA Oceanexplorer web portals was successfully implemented. The Alvin-dive program began at the Rosebud hydrothermal vent site to assess the temporal changes that occurred in biological community structure and the nature of venting since visited in 2002. Every vent area active in 2002 was active during this 2005 program. Faunal communities were dominated by riftiid tubeworms and bathymodiolid mussels. Both *Riftia* and mussel communities had increased in both lateral and vertical extent. Hydrogen sulfide concentrations and temperature within these communities continued to be elevated to levels observed in 2002. Night operations during the cruise located the historic Musselbed community, which when subsequently visited by Alvin, was determined to be inactive. The historic Clambake II site (discovered in 1977) was found to be over 100m x a130m in extent and hydrothermally inactive. Two dives to the Garden of Eden vent field (also discovered in 1977) revealed an extremely large centrally-located *Riftia* community surrounded by mussel clumps, small tufts of *Riftia*, and dense surpulids. Additional exploration via multibeam mapping to the east and using TowCam did not reveal undiscovered hydrothermal activity to the east of these known vent fields. Integrated experiments, including the deployment of multiple autonomous time-series chemical loggers, co-located colonization panels, temperature loggers, and time-lapse imaging systems were successfully conducted within both a *Rifta*-dominated assemblage and a mussel-dominated assemblage at Rosebud over a ten-day period. To simultaneously correlate species-specific larval presence, two time-series larval collectors were deployed 10 meters from these experiments. Discrete water samples for fluids chemical analyses, and collections of faunal and microbial communities were made to assess the heterogeneity and diversity of environments hosting these communities. As evident in the advancing pages, we accomplished all of our pre-determined programmatic goals.

2. Purpose of Project:
   a. Describe issue that was addressed

In May 2002, exploration of the Galápagos Rift using DSV *Alvin* on a NOAA-Ocean Exploration Program cruise (R/V Atlantis, Cruise AT7-13) led to the discovery of a nascent low-temperature hydrothermal vent field (Rosebud) at 86° 13'W (Shank et al., 2003). The biological importance of this finding is two-fold. First, there was no previous evidence for low-temperature venting or robust faunal communities in the area near the Rose Garden vent (initially discovered in 1979; Hessler et al., 1988). We observed 24°C vent fluids (the highest recorded for Galápagos vents) supporting nascent communities of vent animals growing from cracks in what appeared to be a very recent lava flow with sheet and curtain-folded surface textures. The lava has a different geochemical signature from basalt previously sampled from the area around Rose Garden in 1985 (M. Perfit, pers. commun., 2002). The observational and geochemical data suggest a recent magmatic event resulting in a seafloor eruption of lava, probably within 2-3 years of May, 2002, had paved over the old Rose Garden vent community (as well as the abundant seafloor markers and *Alvin* weights previously observed in this area). The second remarkable characteristic of the new Rosebud vents is the nature of the faunal communities. The current distribution, size and type of fauna at Rosebud represent assemblages previously unseen at Pacific vents. Rosebud vents simultaneously host youthful assemblages of juvenile *Riftia*, mussels and clams (millimeters to a few centimeters in length). Previously observed community structures have never witnessed the temporal coexistence of these species at such juvenile stages. Also important is that our *in-situ* measurements of fluid chemistry (Ding et al., 2002) revealed that extensive suitable habitat space was available yet currently not colonized as of 2002.

The current expedition provided an important opportunity to study unique faunal assemblages at Rosebud vents within what is estimated to be <~6 years from the eruption event that led to Rosebud's formation, and to explore other nearby (<10 km) and well-known (historically significant) vent sites to determine the extent of the volcanic eruption that paved over Rose Garden (*e.g.*, Musselbed was a thriving low-T vent site when last visited in 1990). The Return to Galápagos Expedition took maximal advantage of the 2002 findings and explored the time and space domain via integrated co-located investigations of the temporal development of microbial and macrobiological community structure and the role which variations in diffuse fluid chemistry play in controlling community structure. Conducting these time-series studies was time critical because of the known short time span (following volcanic disturbance) over which many key ecological processes occur through species interaction and vent community colonization and development.

The Galápagos Rift hosts a biologically unique system in that its constituent vent fauna differs from East Pacific Rise (EPR) fauna by 58%. Several key ecological species (*e.g., Tevnia jerichonana* tubeworm) thought to facilitate and direct the sequential colonization of other fauna (*e.g., Riftia*) (Mullineaux et al. 2000) at EPR vents are notably absent at Rosebud. Thus, the ecological mechanisms (*e.g.,* larval input, species interaction, vent fluid chemistry, etc.) controlling the colonization and development of vent communities at the Galápagos Rift are expected to be markedly different from any previously documented at mid-ocean ridges (*e.g.,* Shank et al 1998; Van Dover 2000). Similarly, the presumed absence of long-lived high-temperature black smokers at 86°W places temporal constraints on the chemical composition of vent fluids. While the influence of high-temperature fluid chemistry is considered strong on EPR vent communities (Shank et al. 1998; Fornari et al. 1998), this component appears to be absent at the Galápagos Rift at 86°W where our recently collected near-bottom magnetic data show convincingly that no high-temperature venting has ever occurred here. Hence the impact of the lack of high-temperature chemical constituents on the development of faunal assemblages and their habitats on the Galápagos Rift is unknown.

b. Describe/list the project objectives

The specific goals of the project were to:

(1) biologically characterize and chemically "map" the Rosebud site and its microhabitats through the in-situ characterization of temperature, pH, and other physiochemical parameters that link with microbial biofilms and the colonization of different invertebrate species;

2) conduct comparative quantitative digital image surveys of the vent field to assess the changes in community structure that have occurred since May 2002. Image results extracted from the photomosaics and detailed imaging surveys of the Rosebud vent field in 2002 revealed that this site consists of 4 major venting areas containing vestimentiferan tubeworms, and linear rows of bathymodiolid mussels (average ~1cm in length) growing along cracks in the sheet lava surface, and adjacent carpets of amphianthid anemones;.

(3) install time-series instruments to assess correlations in the structure of the various vent communities with the presence of specific larval species (through time-series larval collectors), larval settlement (through basalt panel, time-lapse camera and temperature probe array deployments), and vent fluid temperature and chemistry (through autonomous in-situ measurements);

(4) obtain adults and juveniles (and larvae in traps) of vent species (e.g., tube worms and mussels) to examine their genetic composition. By sampling discrete populations, we can compare their genetic composition and infer how related each individual is to its community on the Galápagos Rift as well as to other communities inhabiting vent sites in the Eastern Pacific. By sampling the various life stages, we can use fine-scale genetic markers and analyses to infer the mechanisms the larvae use to get from one site to another and where they may have originated;

(5) conduct a night exploration program that employed a digital towed camera with a Conductivity/Temperature/Depth (CTD) system to explore for additional hydrothermal vents and conduct reconnaissance at the previously studied vents sites (e.g., Musselbed vent site 8km from Rosebud and last observed in 1990) to determine if and how these sites might have been affected by the volcanic activity that covered the Rose Garden site; to genetically assess inhabitants of these more eastern sites (as in #4 above; and to locate the first active high-temperature vents and the fauna they host on the Galápagos Rift, and;

(6) develop a well-documented and easy-to-use software package for PC-based computers that is tailored to convert video imagery acquired from Alvin, operated within both absolute (e.g. LBL) and relative (DVL) navigation networks, and quickly produce a set of geo-referenced photomosaics, which can then be directly layered within a Geographic Information System (GIS).

3. Approach:
    a. Describe the work that was performed
    b. Describe how the project was organized and managed
    c. Describe how data was organized, processed, and archived

The cruise departed Puntarenas, Costa Rica at 0630 hours (Local, -6) on May 19, 2005 and steamed directly to the primary dive site at 86° 13.5'W, 0° 48.5'N - the Rosebud vent site (see **Table 1** for full operations summary)(**Figure 1**). Early on May 21, we arrived on station and deployed two LBL transponders (see Figure 1 and Table 3 for locational information), surveyed them, and commenced diving with Alvin Dive 4114. Dive statistics are shown in **Table 2**. Eleven dives were successfully completed. Night operations during the cruise consisted of using the WHOI TowCam (Fornari, 2003) for digital camera surveys within the rift valley and along the axial volcanic ridge to search for additional sites of hydrothermal venting and conduct reconnaissance to better understand the geology of the rift valley and distribution of lava flows. Two larval traps and a digital time-lapse camera system were also deployed and recovered during this expedition. A single night Multibeam survey of the Galápagos spreading center was also completed on the 28^{th} of May.

Table 1. Operations summary for AT11-27

Date	Area	Alvin Dive	TowCam	Other Operations
19 May	Depart Puntarenas 0600			
20 May	Transit			
21 May	RoseBud	4114	1 - MusselBed	Deploy Xponders (2) Deploy larval traps (2)
22 May	RoseBud	4115	2 –MusselBed	Deploy TimeLapse Camera
23 May	RoseBud	4116	3 – MusselBed	
24 May	RoseBud	4117	4 – Garden of Eden	
25 May	MusselBed	4118	5 – East of Eden	
26 May	Rosebud	4119	6 – East of East of Eden	
27 May	Garden of Eden	4120	7 – West of Rosebud	
28 May	Garden of Eden	4121		Multibeam GSC
29 May	Rosebud	4122	8 – North of RoseBud	
30 May	Rosebud	4123	9 – Across axis	Recover TimeLapse camera
31 May	Rosebud RoseBowl	4124		Recover xponders Transit to Pt Caldera 1800

1 June	Transit			
2 June	Transit			
3 June	Arrive Pt Caldera 0800			

3.1 Alvin Operations

Table 2. Alvin Dive logistics for AT11-27 cruise.

					Time			
Date (May)	**Dive**	**Area**	**Pilot**	**Observers**	**Start**	**Stop**	**Total**	**Max Depth**
21	4114	00°48.350’N 86°13.659’W	Eppard	Shank Ding	15:39:00	23:06:00	7:27:00	2451
22	4115	00°48.350’N 86°13.659’W	Tarantino	Humphris Seyfried	14:10:00	23:00:00	8:50:00	2451
23	4116	00°48.350’N 86°13.659’W	Strickrott	Shank Khosla	14:00:00	21:26:00	7:26:00	2452
24	4117	00°48.350’N 86°13.659’W	Hickey	Fornari Dubno	13:59:00	22:55:00	8:56:00	2451
25	4118	00°47.894’N 86°09.210’W	Berry	Humphis Eppard	14:28:00	22:46:00	8:18:00	2493
26	4119	00°48.350’N 86°13.659’W	Tarantino	Fornari Nomikos	14:01:00	22:48:00	8:47:00	2453
27	4120	00°47.500’N 86°07.58’W	Strickrott	Beaulieu Soule	14:13:00	22:57:00	8:44:00	2489
28	4121	00°47.664’N 86°08.51’W	Hickey	Shank Govenar	14:01:00	22:32:00	8:31:00	2525
29	4122	00°48.350’N 86°13.659’W	Eppard	Knee Ward	13:58:00	21:57:00	7:59:00	2450
30	4123	00°48.375N 086°13.833W	Tarantino	Buckman Spear	14:23:00	23:05:00	8:42:00	2451
31	4124	00°48.350’N 86°13.659’W	Strickrott	Soule Ward	14:07:00	22:15:00	8:08:00	2452

3.2 Multibeam Mapping

A multibeam survey was conducted along the Galápagos Spreading Center (GSC) east to the Inca Transform at 85° 24’W, comprising two lines. The east heading line traversed within the axis of the rift valley while the west heading line traversed ~4 km north of the rift valley.

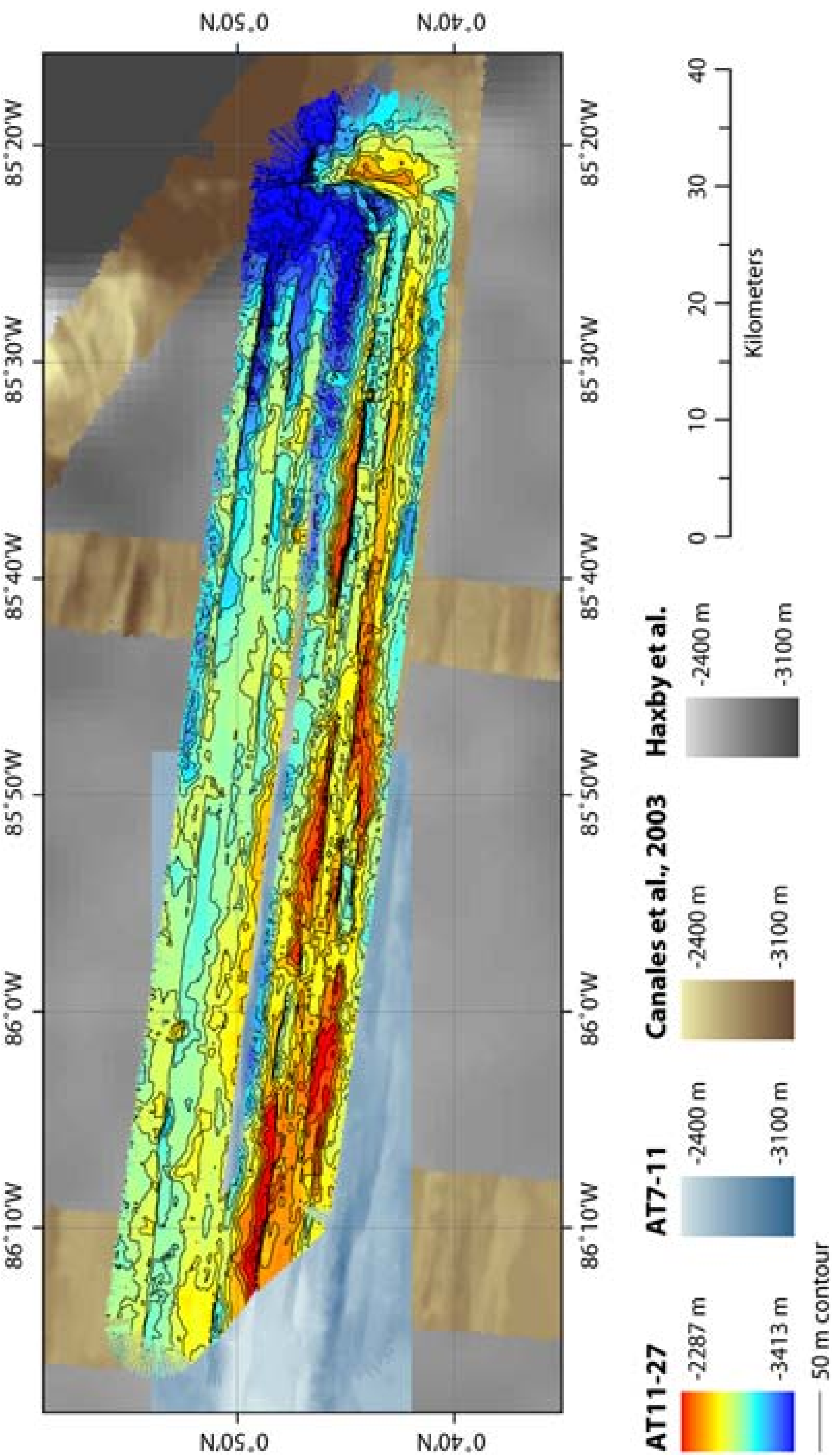


Fig. 1. Composite multibeam map.

Fig. 2, WHOI TowCam (left) and time-lapse camera system (right) as configured during AT11-27 cruise. Images are taken at ~ 2 m elevation with strobe illumination. Camera settings were 1/60 sec exposure at f-5.3.

3.3 Seafloor Imaging

Several types of digital still seafloor imaging were conducted during the cruise. A towed digital camera (TowCam) was used for night time surveying, a downlooking camera and strobes were mounted on Alvin for vertical incidence imaging, and a time-lapse system was deployed to take photographs of a colonization experiment that included macro- and microbiology and in situ chemical sensing. The digital camera is the same for all systems (DeepSea Power & Light DigiSeacam model) and consists of a Nikon 995 camera mounted in a pressure housing with water corrected optics. Strobe illumination for all systems was provided by a Benthos 383 strobe powering two 300 watt/sec flash heads.

3.3.1 TowCam, RatCam and Alvin DSPL

The WHOI TowCam is an internally recording digital deep-sea camera system that also permits acquisition of volcanic glass samples using up to eight (8) rock core winches, and triggering of four (4) 1.2 liter or 5.0 liter Niskin bottles, in conjunction with CTD water properties data (Fornari, 2003). The TowCam is towed on a standard UNOLS 0.322" coaxial CTD sea cable, thereby permitting real-time acquisition of digital depth and altitude data that can be used to help quantify objects in the digital images. The use of the conducting sea cable and CTD system permits real-time, manual triggering of any of eight rock core units and four Niskin bottles on the sled so that discrete samples of volcanic glass and seawater can be collected during a lowering from specific areas. By operating either at night in between Alvin dives, or during other seagoing programs, photographic information of the seafloor can be recorded for near real-time analysis and for planning subsequent Alvin dives or other sampling/surveying programs using other vehicle systems. The TowCam was used during AT11-27 to survey for additional hydrothermal vent sites and to conduct reconnaissance imaging to help compile the geologic map of the dive site. Details of the system are provided in a user manual posted on a web site at: http://www.whoi.edu/marops/support_services/list_equip_towed_camera.html

Surveys were done using layback navigation (difference between camera depth and wire out) assuming that the camera was directly behind the ship (found to be reasonable based on LBL navigated camera tows at other locations). Average layback position of the camera behind the ship was ~300-350 m while towing at ~1/3 knot. Nine camera tows were carried out. One tow was not successful due to problems with the CTD cable termination and altimeter settings. A pinger was used as a backup altimeter for all tows, but once the CTD cable termination issue was resolved, the altimeters worked very well. The system collects ~1800 digital images per lowering. They are 2048 x 1536 pixels, color, high-resolution JPEG format files, each ~900 kbytes in size. Each image is date/time stamped when acquired, but the image filenames are in standard Nikon format and must be converted in order for the files to be tagged with date and time as the file name. DOS and Apple Mac OSX Perl scripts are used for converting the raw Nikon formatted files to date/time named files having the format: "yyyy_mm_dd_hh_mm_ss.jpg". In addition, a Perl script has been written to correct image file name times based on correlation to photographs of GMT clock time at the beginning and end of each tow in order to correct for any clock drift over the course of a cruise. **Table 3** provides the calibrated field of view at normal towing altitudes.

Altitude above Bottom	3 meters	5 meters	7 meters
Field of View in Seawater	3.49mx2.62m	6.06x4.54m	8.03x6.02
Pixels/Meter	586	338	255

Table 3. Field of view in seawater for DSPL DigiSeaCam.

3.3.2 Mosaic Imaging

Imagery on this cruise was collected from three main sources: video cameras mounted on the top and manipulator arm of DSV Alvin (two single chip cameras and one 3-chip, respectively), DSL downlooking camera with 3.3 megapixel resolution, and TowCam. All the cameras were calibrated using checkerboard calibration target and Matlab Calibration toolbox from Caltech. The calibration data obtained is as follows:

Camera 1 (1-chip); Frame: 720*480; Horz FoV=70.5 degrees; Vert FoV=54 degrees

Focal Length: fc = [509.57783 464.21431] ± [3.85782 3.96879]
Principal point: cc = [348.57449 270.14089] ± [4.67584 3.54322]
Distortion: kc = [-0.24602 0.11213 0.00085 -0.00157 0.00000] ± [0.01252 0.01599 0.00123 0.00171 0.00000]
Pixel error: err = [0.24652 0.47076]

Camera 2 (1-chip); Frame: 720*480; Horz FoV=70.5 degrees; Vert FoV=54 degrees

Focal Length: fc = [509.84562 463.98912] ± [7.83021 7.35175]
Principal point: cc = [347.97465 274.59358] ± [5.61440 5.05080]
Distortion: kc = [-0.26799 0.17889 0.00221 0.00045 0.00000] ± [0.02048 0.04314 0.00272 0.00128 0.00000]
Pixel error: err = [0.52742 0.58354]

Camera 3 (3-chip); Frame: 720*480; Horz FoV=49.3 degrees; Vert FoV=37 degrees

Focal Length: fc = [784.21867 714.70979] ± [13.63366 12.74924]
Principal point: cc = [344.53577 224.02027] ± [11.24166 8.94783]

Distortion: kc = [-0.26093 0.08781 0.00040 0.00011 0.00000] ± [0.03393 0.15719 0.00242 0.00240 0.00000]
Pixel error: err = [0.21379 0.42367]

TowCam camera; Frame: 2048*1536; Horz Fov=48.88 degrees; Vert FoV=37.62 degrees

Focal Length: fc = [2253.16399 2254.87566] ± [89.02881 89.35861]
Principal point: cc = [1037.36487 811.15759] ± [9.03623 13.47364]
Distortion: kc = [-0.21183 0.19658 -0.00022 0.00210 0.00000] ± [0.02214 0.10705 0.00121 0.00094 0.00000]
Pixel error: err = [0.35527 0.32110]

Downlooking camera; Frame: 2048*1536; Horz Fov=49.31 degrees; Vert FoV=37.90 degrees

Focal Length: fc = [2230.90400 2236.51232] ± [31.27563 31.34162]
Principal point: cc = [1037.60103 751.93368] ± [15.56772 19.77844]
Distortion: kc = [-0.18069 0.40447 -0.01011 0.00372 0.00000] ± [0.02862 0.18486 0.00207 0.00145 0.00000]
Pixel error: err = [0.59522 0.84065]

Prior to dives observers and pilots were asked to:
1. Keep video cameras down (as normal with respect to the seafloor as possible) during the transects (relatively long, steady-motion runs of the vehicle), and
2. When the vehicle is not moving, pan one of the video cameras, trying to catch as wide as possible view of the interesting site.

The intention was to process video sequences of transects and panoramas, produce planar and panoramic mosaics, and eventually include mosaic images in GIS database associating them with linear paths or single locations. However this effort has been seriously hindered by lack of illumination, as this time Alvin did not have 1200 Watt DSL lights, which were present on the AT11-7 leg in February, 2004, when this processing was first attempted.
As part of the NSF-funded project, we have attempted the automatic processing of video imagery collected during a dive. Only the first stage of automatic processing has been achieved.

3.4 Navigation

3.4.1 Alvin Long Baseline (LBL) Acoustic Navigation

Long baseline (LBL) navigation was used primarily in the Rosebud area. We utilized the ABE 2002 microbathymetry to plan the dives. Details of the transponder network, including surveyed positions and local x/y origin used are shown in **Table 4**.

3.4.2 Alvin Navigation Processing

During all dives, *Alvin* navigation data were acquired using the bottom-lock Doppler navigation DVLNAV software (Whitcomb et al., 2003). When within the network of transponders deployed Rosebud, the Doppler navigation was supplemented with long baseline (LBL) acoustic navigation. When LBL was available, it was used to “renavigate” the Doppler navigation by matching the mean of the Doppler track to the mean of the LBL track. ‘Navplot’, a suite of MATLAB programs developed by D. Yoerger, L. Whitcomb, and J. Howland, allowed the user to manually remove bad LBL data points and apply the renav horizontal shift to the Doppler navigation data, which in turn was used in combination with software developed by V. Ferrini to ‘renavigate’ LBL and DVL navigation for our dives.

ALVIN Transponder Log			**Cruise**	AT11-27	**Chief Sci**	Shank	**Date**	May 05
Location	Galapagos Rift/ Rose Bud		**Origin**	00N15 86W15				
Purpose	Biology		**UTM Zone**	16	**Time Zone**	6	**Mag Var**	4°E

Xpdr Freq	**Owner**	**S/N**	**Net ID**	**Rel Code**	**Surveyed Pos**	**Surveyed Pos**	**Survey Dpth**	**Recovered**
11.0	ALVIN Burn Volts 13.7	48500	A	E	00N48.071 Y=60947	86W13.979 X=1894	2265M RMS 0.77 Pts=169	YES
10.5	ALVIN Burn Volts 12.0	35003	B	D	00N48.100 Y=61001	86W13.214 X=3314	2283M RMS 0.59 Pts=94	YES

Table 4. Copy of the Alvin LBL transponder positions based on surveys conducted using ship’s P-code GPS system. RMS error of position is < 1 m.

This shift, usually on the order of 10s of meters, improves navigational accuracy by including LBL navigation, and compensates for drift within the Doppler navigation that occurs over the course of the dive. If LBL was not used, the raw Doppler navigation data (‘*.csv’ files saved by DVLNAV) were used as *Alvin* navigation. These have less absolute accuracy than LBL or LBL-Doppler ‘renavigated’ navigation. However, it was found that if *Alvin* was surveyed in at the start of the dive, the navigation agreed very well with the expected terrain features imaged by the side scan sonar or previously run camera tows. All *Alvin* navigation data were binned at 1Hz to create text files and MATLAB (‘*.mat’) files containing time, position in local XY, UTM, Lat/Lon, water depth, altitude, pitch, heading, roll and altitude. Individual, time annotated maps for each *Alvin* dive are shown in section 5

3.4.3 Imagenex Scanning Altimeter Data Processing

Section 5 contains detailed navigation and bathymetry maps for each dive track. After processing navigation data, Imagenex (675 kHz scanning altimetry) data were processed using a set of MATLAB scripts to calculate the position and corrected depth soundings for each ping (‘go_vlf.m’). These soundings ignore the effects of tidal fluctuation. The depth data were filtered using offsets declared in a filter file called ‘imagenex filter.dat’. This file dictates the maximum allowable horizontal range (10 m) and the maximum depth range (25 m) as well as the number of standard deviations (7) about the mean outside of which data are considered unacceptable. Since this method does not remove all ‘bad’ depth data (i.e. when incorrect depth values are reported over time periods of many seconds), an additional step was included to allow the user to remove bad depth data. This was done by plotting depth as a time series of points that can be edited by drawing rectangles around bad depth points. The final xyz data were saved into two text files in the directory with the raw Imagenex data: one in Lat/Long (‘*.llz’) and the other in local XY (‘*.xyz’). These data provide substantial improvement over the ABE data acquired in 2002 where the AUV was flying at ~40 m altitude and with 60 m line spacing. A preliminary Imagenex composite map of Rosebud is shown in **Figure 3** and a comparison map showing differences between it and the Alvin Imagenex map made in 2002 is shown in **Figure 4**.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Fig. 3. Imagaenex composite map of the Rosebud area.

QuickTime™ and a
TIFF (Uncompressed) decom
are needed to see this pictu

Fig. 4 Comparison of Imagenex data between 2002 (top) and 2005 (bottom).

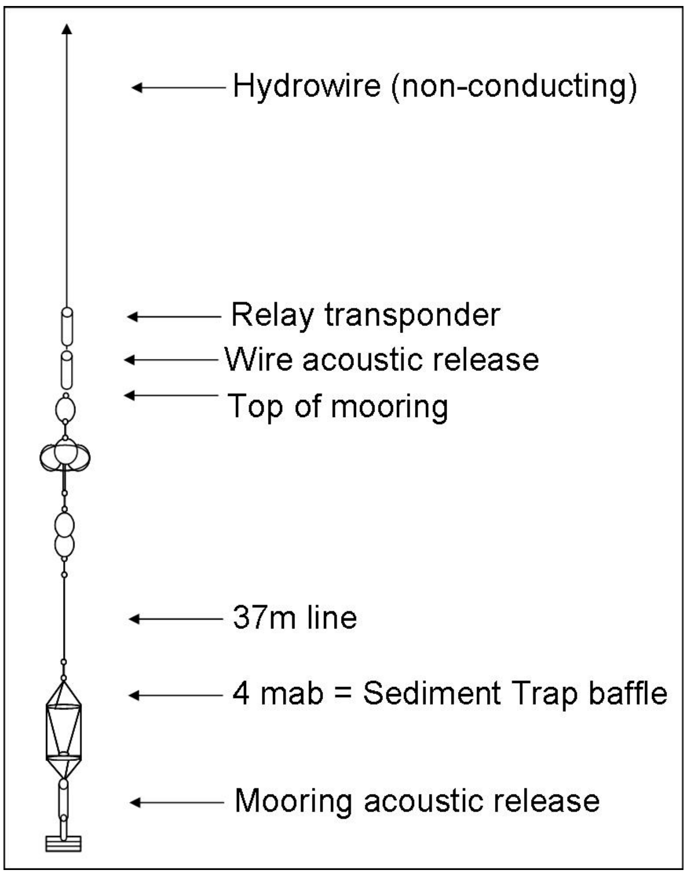
3.4.4 Layback Navigation for Camera Tows

Towed camera surveys were conducted with the ship using Dynamic Positioning (DP) at speeds ranging from 0.3 to 0.5 knots. Most of the survey lines ran from west to east across the rift valley axis. Figure 5 shows the locations of all the TowCam surveys. Detailed maps for each tow plotted over multibeam, ABE microbathymetry (when available) and side scan sonar are available upon request.

The ship's navigation for the duration of the camera tows was extracted from the daily ship's '.dat' files. After shipboard analysis of wire out and TowCam depth during initial tows, the mean layback of the TowCam was determined to be ~350m and the position of the system behind the ship was calculated using a Matlab script, 'Layback.m', written by Adam Soule**.** The script utilizes the ship location to determine a course over ground. The layback is then applied to that position and course and sampled at the frequency of the CTD (~1 Hz) and flash data (~0.067 Hz) records collected by the camera system.

3.4.5 Near Bottom Magnetics - TowCam

A small, self-contained magnetometer system was built to record magnetic data during the deep-tow camera operations. The magnetic sensor is a Honeywell model HMR2300 digital 3-axis magnetoresistor that produces a digital RS232 output. This is the same type of sensor as used on ROV Jason. A separate pressure housing containing a datalogger and battery pack was built using a "Persistor" brand datalogger and compact flashcard memory storage (64 Mb). Data is collected at a 1 Hz rate and the hourly files log elapsed time, battery voltage and the three vector components of the magnetic field. A simple Perl script reads the ascii files and converts the elapsed time to GMT time and the raw millivolt readings to magnetic field units (6.667 nanoTesla per millivolt). The magnetic data were merged with ship navigation data as described earlier to produce a composite of camera tow depth, altitude, position and magnetic value. The three-component magnetic data can also be used to calculate a magnetic heading. A calibration circle of the magnetometer on the camera tow system was completed during work at the EPR in 2004. The result confirmed that the magnetic effect of the camera tow frame is negligible recording less than 82 nT for a magnetic effect, which is substantially less than the observed magnetic anomalies of several thousand nanoTesla.



3.5 Larval Trap Operations

Two time-series sediment traps (McLane PARFLUX Mark78G-21) were deployed "anchor-first" with an acoustic release on the hydrowire during night operations on 21 May 2005 (**Table 5**). Seafloor positions of the traps, just prior to dropping the moorings, were determined within the LBL net via a relay transponder clamped to the wire just above the wire acoustic release (Fig. 6). The two sediment traps were deployed within 200m from Marker B for 2.25days and moved by Alvin to within 20m of Marker B for 6 days over the same time period as the colonization experiments (Table 5). Sediment trap moorings were recovered individually via acoustic release on 30 May 2005.

Fig. 5. Mooring deployment configuration.

Sediment trap schedule (GMT = local + 6hr)

		LOCAL DATE/TIME			During	Dive Location	Chemical
Prior to positioning at Rosebud	CUP 1*:	22 May	04:00	6-hr			RNALater
	CUP 2*:		10:00	6-hr	D4115	Rosebud	RNALater
	CUP 3:		16:00	6-hr			DMSO
	CUP 4:		22:00	6-hr			DMSO
	CUP 5:	23 May	04:00	6-hr			DMSO
	CUP 6*:		10:00	6-hr	D4116	Rosebud	DMSO
	CUP 7:		16:00	6-hr			DMSO
	CUP 8:		22:00	6-hr			DMSO
	CUP 9:	24 May	04:00	6-hr			DMSO
	CUP 10*:		10:00	6-hr	D4117	Rosebud	DMSO
At Rosebud between Markers B and K	CUP 11:		16:00	1-day	D4118	MusselBed	DMSO
	CUP 12*:	25 May	16:00	1-day	D4119	Rosebud	DMSO
	CUP 13:	26 May	16:00	1-day	D4120	E of MusselBed	DMSO
	CUP 14:	27 May	16:00	1-day	D4121	E of MusselBed	DMSO
	CUP 15:	28 May	16:00	6-hr			DMSO
	CUP 16:		22:00	6-hr			DMSO
	CUP 17:	29 May	04:00	6-hr			DMSO
	CUP 18*:		10:00	6-hr	D4122	Rosebud	DMSO
	CUP 19:		16:00	6-hr			DMSO
	CUP 20:		22:00	6-hr			DMSO
	CUP 21:	30 May	04:00	6-hr			DMSO
	END	30 May	10:00				

* = corrupted due to resuspension by Alvin

Table 5. Temporal periods of collection by sediment trap cups, location, and preservative.

4. Findings:
   a. Describe actual accomplishments and findings
   b.. Inventory of activities (number of submersible dives, CTD, net tows, etc.)
   c.. Inventory of samples collected
   d.. Describe/list resulting publications, Web sites, presentations, etc.
   e. Location and status of data archive and/or sample storage

At Rosebud, three in-situ autonomous chemical loggers, ten temperature loggers, and twelve basaltic panels were deployed in *Riftia* and mussel assemblages to assess: 1) the relative differences in H_2, H_2S and pH in low temperature hydrothermal fluids issuing from vents characterized by different faunal assemblages; 2) the temporal variability of vent emissions and the delivery of nutrients to the constituent fauna; 3) identify the initial microbial colonizers at low temperature vents (on native and non-native basalt panels); 4) assess the role these colonizers play in influencing colonization by invertebrate species. A WHOI time-lapse digital camera system was successfully deployed for 6 days (acquiring an image every 6 minutes; total of 1650 images) with the colonization panels and data logger in the field of view.

4.1 Mulitbeam Mapping

Several discontinuities in the rift valley walls were observed at 86° 00'W and 86° 36'W. East of 86°W, the rift valley narrows to nearly 2 km in width, compared to the ~4 km width near Rosebud at 86° 14'W. The axial volcanic ridge that is prominent within the central portion of the rift valley from Rosebud east to the 86°W discontinuity, also appears to end at the discontinuity. The rift axis contains several small cones and lines of cones but their crests are 20-60 m deeper than those near Rosebud. There are several breaks in the rift valley walls and at times there is an inner rift wall usually along the southern margin of the rift valley. Abyssal hills are prominent on the Cocos plate north of the GSC rift and have a spacing of ~ 4-6 km between major scarps. The abyssal hills terminate about 2-6 km from the transform. The intersection area is marked by a prominent high with a 'cockscomb' plan-view appearance suggesting that there has been overshooting of dikes across the ridge-transform intersection (RTI) terrain over time. There is no prominent inside corner high at the RTI and the intersection deep has relief of only ~ 150 m.

4.2 Macrobiology

4.2.1 Area Summary

Comparative quantitative digital image surveys of the Rosebud field were conducted to assess the changes in community structure that have occurred since May 2002. Downlooking and panoramic video imagery from the 3-chip video camera and the DSPL downlooking camera with 3.3 megapixel resolution revealed the rapid colonization and expansive growth of the Rosebud tubeworm and mussel communities over the past 3 years. The clam population also increased in abundance within cracks in the sheet flow. Several *Riftia* communities in elevated flux (up to 20°C) within Rosebud were visually devoid of mussels, indicating that competitive interactions between tubeworms and mussels were not yet taking place. Sampling of these communities indicates that the number of species has more than tripled since 2002. Correlations of fluid chemistry in each community sampled and species composition will be undertaken. All sites that were active in 2002 were still active, and the extent of the communities has increased to the northeast and southeast.

Vents on the Galápagos Rift differ in faunal composition from all other hydrothermally active ridges by over 40%. This is largely due to the absence of black smoker habitats. While considered a key species in the development of vent communities on the EPR, *Tevnia jerichonana*, a vestimentiferan tubeworm that coexists with *Riftia*, has never been observered on the Galápagos Rift. We discovered and collected a *Tevnia*-like morph within the central Rosebud field (and at RoseBowl) that will be examined genetically to identify this species. This same approach will be utilized to investigate a (large) putative new species of teribellid polychaete.

To examine larval availability to the Rosebud site (as well as for genetic comparisons to adults), we deployed two larval/sediment traps inside and outside of the Rosebud vent field for 9 days (separated by 100m for three days and 20 meters for 6 days). Particulates and pelagic fauna in the upper water column suggested high rates of productivity above the vent field. Despite the short 6 hour duration in which each cup collected falling particulates, an eighth to a quarter inch of material was collected in each of the 21 sampling cups on each of the traps. Numerous bythrograeid crab megalopes were observed in both traps.

Little is known about the cellular adaptations of vent-endemic foraminiferal species for living in vent environments due to the cellular degradation during transport to the surface-warming and pressure changes upon ascent significantly affected their cellular structure, causing ultrastructural investigations to be equivocal. To investigate the cellular ultrastructure of benthic foraminifers such *as Abyssotherma pacifica*, we fixed (in sodium cacodylate and TEM-grade gluteraldehyde) colonization panels on the seafloor using the Enzymatic Sampler-1 constructed for this purpose. This first collection of over 30 forams will allow us to determine the presence/absence of (1) prokaryotic endobionts, (2) sequestered chloroplasts, (3) peroxisome-endoplasmic reticulum complexes, and (4) ectobionts,

4.2.2 Colonization blocks and time-lapse camera deployment

As shown in **Figures 6 and 7**, during Cruise AT11-27 we deployed two time-series experiments at Marker B at the Rosebud vent field on the Galápagos Rift (depth 2452m). Both experiments included a total of 6 colonization panels and blocks, consisting of 3 native EPR basalt panels and 3 non-native river basalt blocks. Both experiments also included a Seyfried chemical sensor and data logger (replaced once per site during each of the experiments) and 5 VEMCO temperature sensors. Experiment 1 (Expt1) was deployed within and right next to a thriving patch of *Riftia pachyptila* tubeworms, and Experiment 2 (Expt2) was deployed 1.5m away in a thriving patch of *Bathymodiolus thermophilus* mussels. As detailed in the Table 1, the deployment period for Expt2 (7days) was contained within the deployment period for Expt1 (9days for the panels/block collected in seawater and 10days for the blocks collected into glutaraldehyde and sodium cacodylate). Results for the basalt panels from Expt1 can be compared directly with an analogous experiment deployed in Feb. 2004 at Tica Vent at the EPR. A time-lapse camera system, nicknamed RatCam, was deployed to monitor Expt2 for 6days. In addition, two time-series sediment traps were deployed within 200m from Marker B for 2.25days and moved within 20m of Marker B for 6days over the same time period as the colonization experiments (see Sediment Trap Schedule elsewhere in the cruise report).

Although not checked yet against the original hand-written sample grids, the following are totals for macrofauna sampled from the blocks/panels (including sample chamber "washings"). These totals do not include foraminifera saved for Joan Bernhard (see elsewhere in cruise report). Note the majority of these macrofauna are foraminifera (72 of total 136). Notably, we had on the order of 10 mussel recruits and several limpet recruits (based on size). Panel1: 3, Block2: 14, Block3: 6 (plus forams for J. Bernhard), Block4: 2 (plus forams for J. Bernhard), Panel5: 39, Panel6: 24, Block7: 9, Block8: 2, Block9: 5, Panel10: 15, Panel11: 7, Panel12: 10.

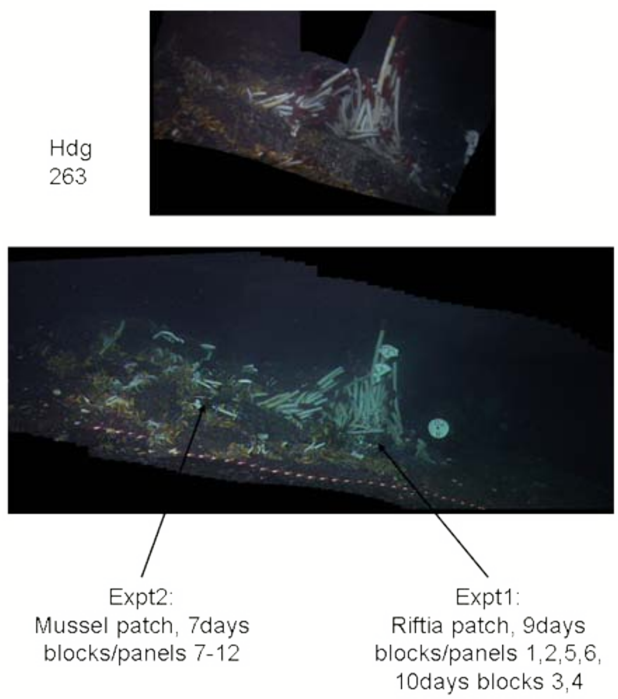


Fig. 6. Photomosaics of Marker B area and colonization block experiments.

In addition, the TIGR group (N. Ward and K. Penn) scraped the panels and blocks (and froze them for whole panel extractions) for microbial analysis (see TIGR group report elsewhere in cruise report). All panels and blocks were photographed whole in the cold room prior to sorting under the dissecting scope using sterile tools. Many of the recruits and microbial biofilms were digitally photographed under the dissecting scope.

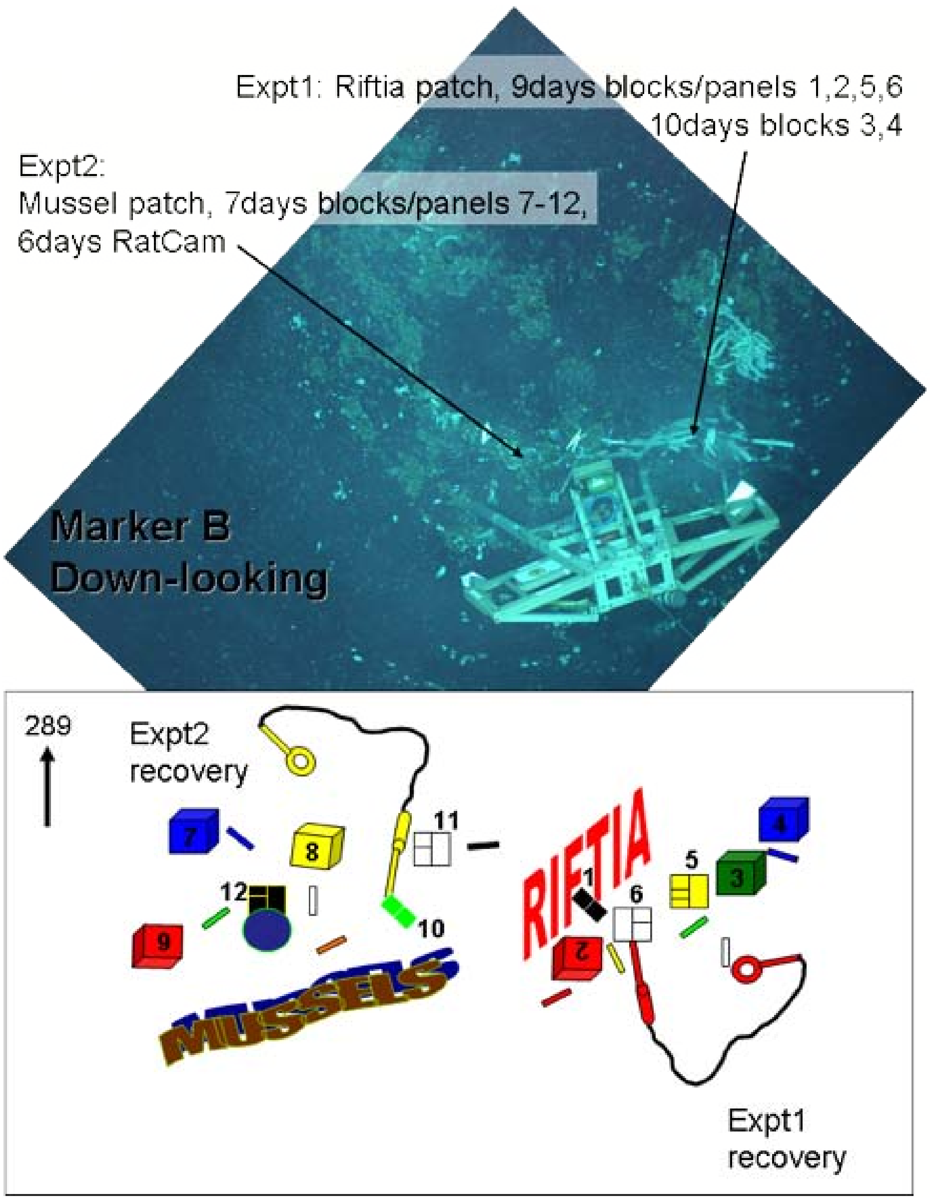


Fig 7. Upper - Downlooking photograph of experiment site. RatCam can be seen in lower. Lower, diagram of layout of blocks, and dataloggers for experiments 1 and 2.

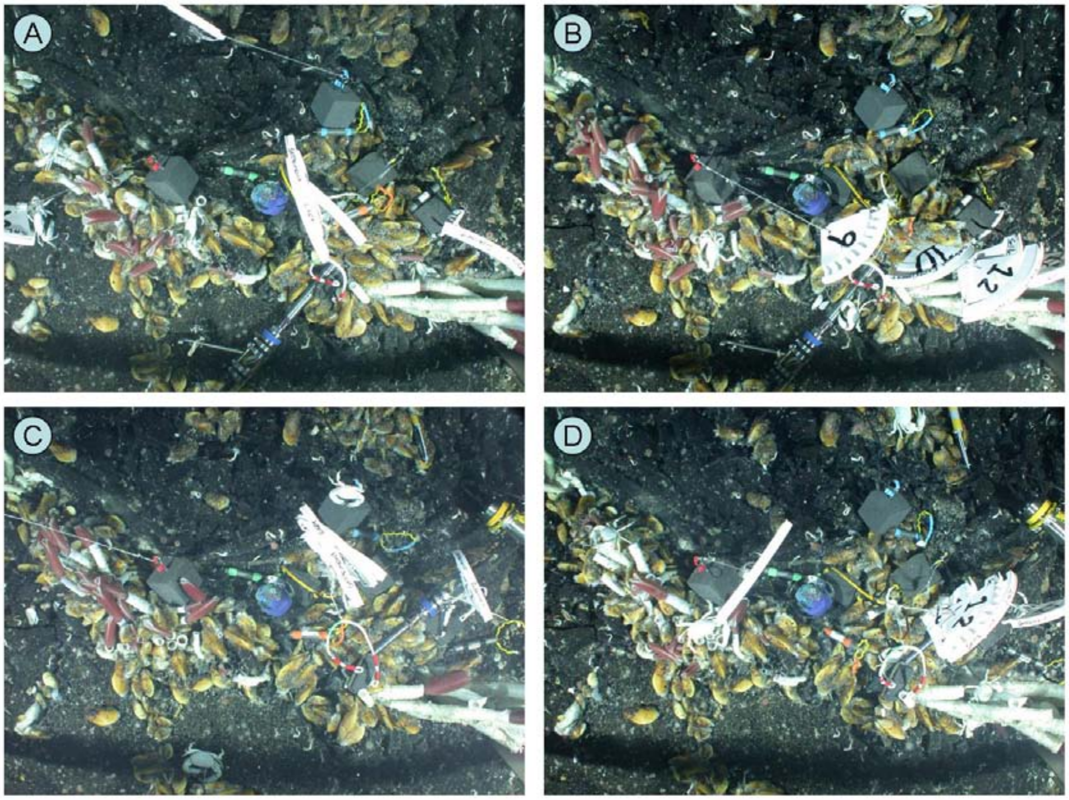


Fig. 8. Time-lapse camera images from RatCam. A. 2005_05_23_21_22_54 (first photo with globe in field of view); B. 2005_05-25_17_53_01 (2 days later); C. 2005_05_27_17_53_08 (4 days later); D. 2005_05_29_17_53_15 (6 days later, last photo prior to Ratcam recovery).

4.2.3 Larval Traps

Both sediment traps successfully completed the sampling schedule (Table 5) over the total of 8.25days. Despite the short 6-hour (or 1-day) duration in which each cup collected falling particulates, an eighth to a quarter inch of material was collected in each of the 21 sampling cups on each of the traps (Fig. 10). Particulates and pelagic fauna in the upper water column suggested high rates of productivity above the vent field. Several bythograeid crab megalopes were collected into the trap cups.

Fig. 10. Sediment trap cup samples from Mooring 1 (A) and Mooring 2 (B) deployed at Rosebud from 22-30 May 2005. Cups numbered 11-14 were open for 1-day while the rest were open for 6-hr intervals.

4.2.3 Mosaic Imaging

All path of the submarine on the seabottom (with good Doppler bottom lock) was divided into 15 meter segments. Depending on the speed of the submarine, single segment may have taken from approximately one minute up to 10 minutes. Obviously, all 30 frames per second in video are not required for successful creation of the mosaic. For efficiency, frames have to be decimated, and the rate of decimation should depend on the speed and camera altitude, because the altitude determines size of the camera footprint. We have assumed that robust co-registration of video frames by the featureless frequency domain-based automatic technique requires 90 percent overlap between sequential frames. As an input we have used the data obtained from the process of re-navigation – blending measurements from Doppler velocimeter with LBL fixes from the transponders with known position. This data also contains measurements of vehicle altitude (from the Doppler altimeter), vehicle heading and attitude. Given the starting frame (and its footprint) at the beginning of a segment, the algorithm was searching for the next frame, with the footprint overlapping with the starting one by 90 percent. Number of skipped frames was recorded for the next processing stage. Typical record for a segments looks like the following:

```
  18   34     35.0000    2450.0600     5.2825    259.6470    -8.8886     0.8217 586027.2660  89086.3681
  18   36      4.0000    2449.1700     6.0600    258.8220    -8.6046     0.6221 586012.2151  89085.5318
25,122,102,88,83,86,121,102,113,139,148,163,138,146,159,77,98,106,63,72,107,97,95,113,107,23
```

First two lines show the navigation and attitude data for the beginning and end of segment respectively (hour/minute/second/depth/altitude/heading/pitch/roll/UTM X/UTM Y). Third line starts with the number of frames required for the mosaic of this segment, 25, followed by numbers of skipped frames between the frames that are going to be used for mosaicing. The sum of these numbers, 2668, corresponds to the number of frames in a period of time from the beginning to the end of the segment, 1 min 29 sec.

The following stages of processing will consist of automatic acquisition of frames, specified in segment descriptions, their pre-processing (correction for lens distortion, cropping, contrast enhancement), pairwise co-registration, and combination in mosaics that can be geo-referenced by using results of re-navigation.

On three dives (4115, 4117 and 4124) imagery from the downlooking still digital camera was collected for the purpose of creation of a map of the Rosebud site, to be compared to the analogous map of this site created from the data collected in 2002 during the dive 3790. On the first two dives data from the LBL transponders were available, and so the data collected by DVLNAV underwent the process of re-navigation. Positioning and attitude information associated with the moments when the images were taken (images have creation timestamp encoded in EXIF information and after downloading from the camera are renamed accordingly to this timestamp) are used by the program PatchMap to display georeferenced locations of image footprints. Color on the produced map indicate density of coverage.

The least robust measurement in this processing is the camera altitude that defines size of the image footprint. DSV Alvin usually has two altimeters, but one of them was flooded in the beginning of the cruise, so only the data from the Doppler altimeter have been used. It is mounted 6.553 meters aft of the bow, which is the furthest point forward on the hull (just behind the pilot's viewport). The altimeter is measured to be -1.124 meters from the metal bottom skids. The raw data reported by the altimeter is corrected for this vertical offset before logging.

Nevertheless horizontal offset between the altimeter and the camera makes an assumption that size of the image footprint is known unreliable. This was confirmed by comparison of overlap between two consecutive images based on navigational data and from imagery. Often images that have to have significant overlap according to the navigational data, do not have it in reality at all. Although this may be explained by inaccuracies in positioning, the most likely reason is the altitude errors.

Figure 11 shows the output of PatchMap – combined coverage from three dives. The density of coverage and absence of significant gaps suggest that the post-processing would allow for construction of the map for comparison with the Rosebud map from 2002.

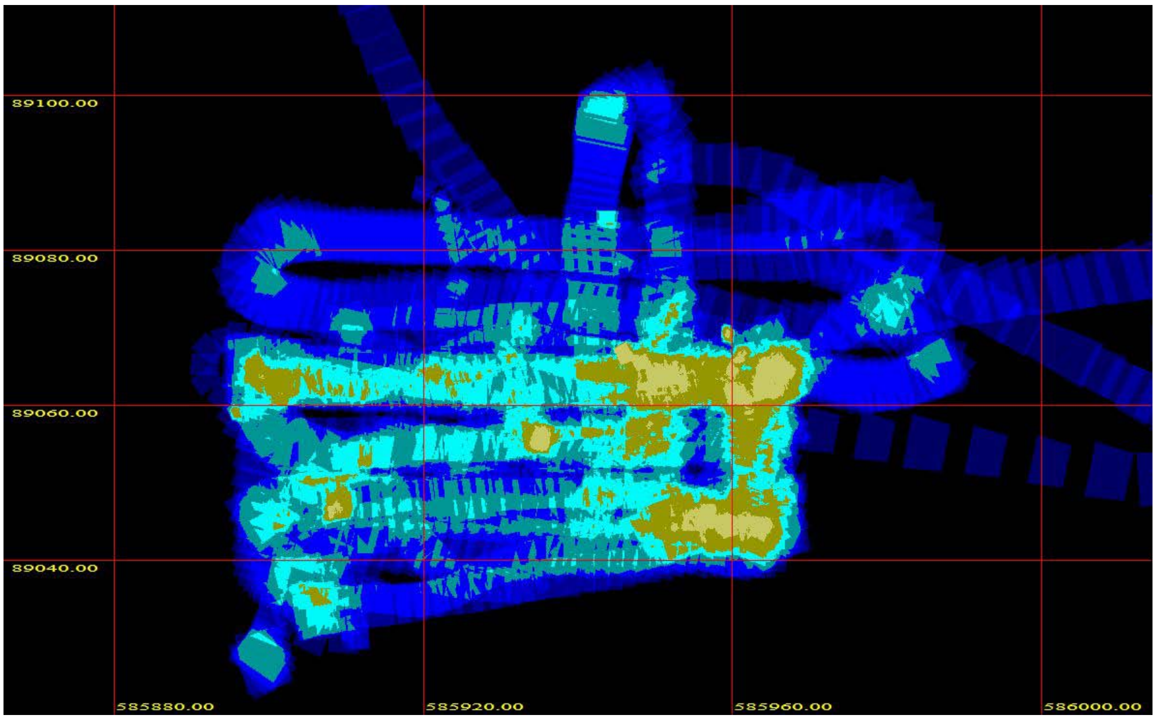


Fig. 11. Coverage of downlooking Alvin digital images over the Rosebud vent field. Dark blue is light blue is %, brown is % and tan is & overlap.

4.3 Microbiology

Filaments of sulfur bacteria attached to the colonization blocks consisted of extremely large cells (estimated diameter 50 μm) packed inside a rigid sheath and containing phase-bright globules that we assume to be sulfur. Filamentous sulfur bacteria from deep hydrothermal vents have been previously reported, but the large size of these cells is unusual and to our knowledge there are no published accounts of similar morphologies from deep vents.

More than 200 microbiological samples were collected, from multiple individuals of *Riftia pachyptila*, *Bathymodiolus thermophilus*, and *Calyptogena magnifica,* as well as a smaller number of other vent fauna. To our knowledge this is the most comprehensive collection of surface biofilms from deep hydrothermal vents yet performed, and will allow us to gain a better understanding of the role of these biofilms, together with diffuse fluid chemistry, as settlement cues for vent fauna.

The primary objective of the microbiological work conducted on this cruise was to determine the structure of prokaryotic communities that form biofilms on the surfaces of vent fauna and other solid substrates. This information will be used to gain a better understanding of the role of these biofilms, together with diffuse fluid chemistry, as settlement cues for vent fauna. Preliminary data collected from a limited number of *Riftia pachyptila* individuals from the East Pacific Rise suggested the presence on the tube exterior of a diverse bacterial population that differed in composition from that found in the water column and on inanimate (rock) surfaces. In returning to the Rosebud and Mussel Bed vent sites, we intended to sample multiple *R. pachyptila* individuals, to determine (a) whether the apparently characteristic tube biofilm population was supported by more intensive sampling, (b) whether different parts of the tube were inhabited by different bacterial species, and (c) whether bacterial populations found at Rosebud would resemble those found at EPR. Collection of biofilms associated with other vent fauna, and with inanimate surfaces, was planned. We also aimed to perform colonization experiments in which the settlement and colonization of both microbes and macrofauna would be investigated after a short (approximately 10 day) deployment. We expected these experiments to help us identify the primary microbial colonizers, which provide the foundation for development of a complex biofilm.

During 11 Alvin dives between May 21 and May 31 2005, we collected biofilm samples from 38 *R. pachyptila* individuals, of which 17 were sampled in triplicate and the remainder once only, giving a total of 72 biofilm samples. Three *R. pachyptila* trophosome samples were preserved for investigation of microbial symbionts. A total of 33 *Bathymodiolus thermophilus* individuals were sampled (11 in triplicate), resulting in 55 separate biofilm samples. Biofilms were also harvested from 5 dead mussel shells (total 7 biofilm samples) collected at Mussel Bed, and three *B. thermophilus* gill samples were preserved for future symbiont studies. Seven *Calyptogena magnifica* individuals were sampled (total 9 biofilm samples), and three gill samples also retained for analysis of symbionts. Other animal biofilms sampled included those from 5 *Tevnia*-like tube worms (total 11 samples), one shrimp, and one galatheid crab. Fourteen biofilm samples were obtained from the surfaces of ten different rocks, and background water column samples were taken once using major pairs, and twice with Niskin bottles (10 liter volume) mounted on the TowCam. Biofilms were also harvested from multiple surfaces of colonization panels, with sampling being guided by the location of macrofauna. Where possible, biofilm samples were taken from areas colonized by fauna and control areas lacking faunal settlement. A total of 43 samples were harvested from the colonization experiments. The final number of samples taken during the cruise exceeded 200, providing us with an excellent opportunity to examine the composition of microbial communities associated with vent surfaces, in the context of the chemical data.

Phase-contrast microscopy of the samples suggested the presence of active bacterial communities on nearly all surfaces examined. The *R. pachyptila* tube surface was particularly heavily colonized, and similar cell morphologies were observed in multiple individuals, from Rosebud, Garden of Eden, and the new vent site discovered on Dive 4124. Dominant members of the flora included phase-bright rods, probably indicating intracellular deposition of sulfur, and filamentous cells of several different morphologies. As the bulk of sample processing (DNA extraction, PCR, cloning and sequencing) and analysis will be conducted at TIGR post-cruise, information regarding the exact composition of the bacterial communities is not yet available. We recovered several pieces of rock and a galatheid crab that were heavily colonized by extremely large filamentous bacteria, visible to the naked eye. These filaments also dominated the biofilm formed on the colonization panels. Phase-contrast microscopy showed these filaments to consist of very large cells (estimated diameter 50 μm) packed inside a rigid sheath and containing phase-bright globules that we assume to be sulfur. Filamentous sulfur bacteria from deep hydrothermal vents have been previously reported, but the large size of these cells is unusual and to our knowledge there are no published accounts of similar morphologies from deep vents. Samples were preserved for future light and electron microscopy, and for the phylogenetic analysis that will allow us to place these bacteria in relationship to other large sulfur bacteria.

4.4. Chemistry

We have obtained the first simultaneous *in-situ* chemical and temperature data for the Galápagos Rift hydrothermal system. Real-time ("Ghostbuster") and time-series (data-logger) data reveal close correspondence between chemical species concentrations and temperature- the higher the temperature the greater the dissolved concentration of H_2S and H_2, while pH lowers. Preliminary data suggest that at the highest temperatures encountered at Rosebud (Marker B) (approximately 17-18C), pH (*in-situ*) is nearly two log units lower than ambient seawater.

The relatively high temperatures observed for mussels at Rosebud (Marker B) suggest dissolved redox chemistry and pH similar to that of the nearby *Riftia*-sourced fluids, although this point needs to be confirmed by more complete examination of the data from this and other sites.

The maximum dissolved H_2S measured and/or monitored (*in-situ*) or directly sampled from vent fluids during the cruise is more than a factor of 20 lower than reported in 2002. It is likely that this will have a very significant effect on the bio-geochemical evolution of the system with concomitant effects on faunal communities at Galápagos.

The primary objective of the geochemistry group from the University of Minnesota was to acquire time series data on the chemistry of diffuse flow vent fluids issuing from bio-geochemical environments on the Galápagos Rift. Three different approaches were used to accomplish cruise objectives. The first and second entailed the use of in-situ chemical sensors, while the third made use of conventional "majors" samplers that were used to obtain discrete samples from approximately 25 vents (Table 1). These samples revealed a vent fluid chemistry dominated by mixing with seawater as indicated by the moderately low temperatures and moderate values of pH and alkalinity. In general, the highest temperatures (~17C) and lowest pH values were observed for fluids issuing from the base of Riftia at Marker B, Rosebud vent complex. Full fluid chemistry for major and minor dissolved species will be determined in the geochemistry labs at the University of Minnesota.

In addition to the discrete samples, a major activity of the group involved deployment of real-time and time series in-situ chemical sensors throughout the Galápagos vent field. Real-time measurements of temperature, pH and redox species was provided using the chemical sensor array- or "Ghostbuster", as it is more endearingly referred to by the Alvin group.

4.4.1 Real-time in-situ temperature and chemistry

This Ghostbuster array of temperature and electrochemical sensors is used an ICL/RS232 communication package to provide continuous information on vent fluid temperature and chemistry (**Figure 12**). As with all devices of this sort, however, steady state temperature is an essential prerequisite for acquisition of quantitatively meaningful chemical data.

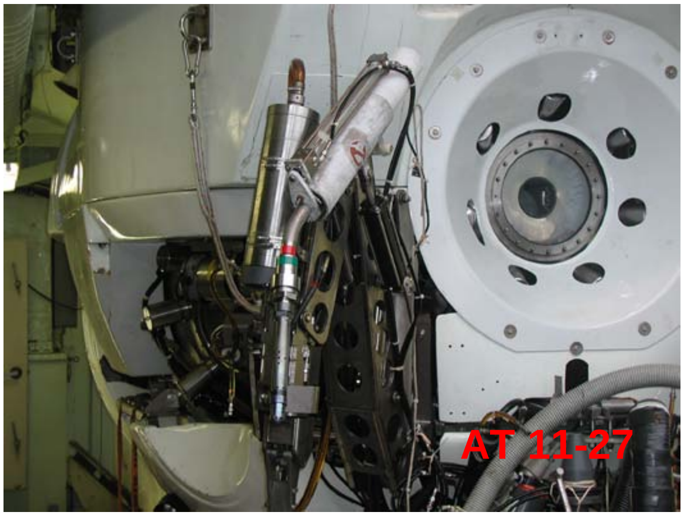


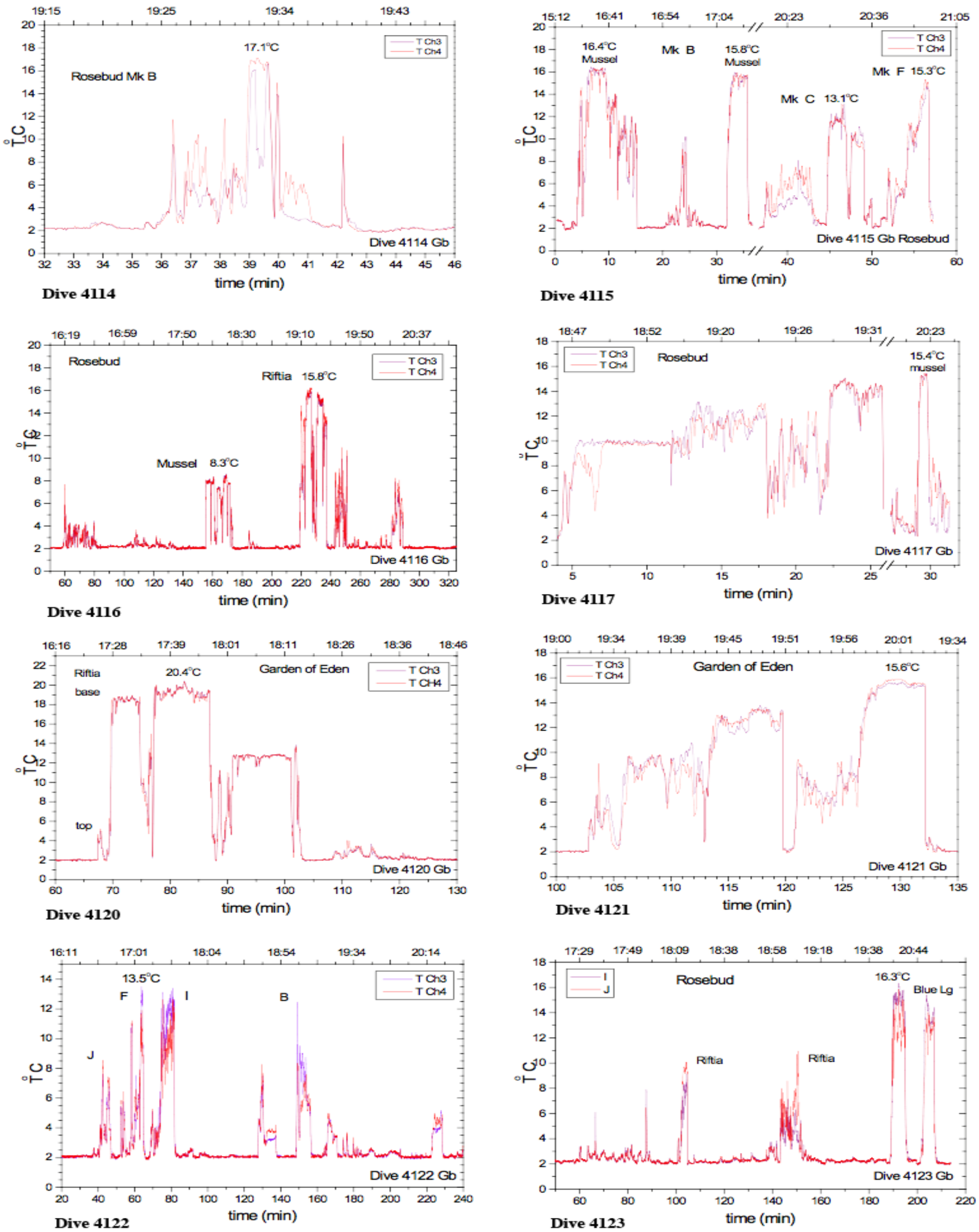
Figure 12. "Ghostbuster" chemical and thermal sensor on the DSV Alvin prior to a dive.

Preliminary assessment of real-time sensor measurements by the UM group and other cruise participants indicates moderate success in fulfilling this requirement (Figure 13). For example, data indicate that approximately 50% of the real-time measurements failed to satisfy the steady state condition. One reason for this likely involves the relatively low vent temperatures, which is an indication of dynamic mixing processes near vents, shrinking the region of maximum temperature stability. Even so, the data that were obtained indicate relatively low H_2S concentrations for the 2005 Galápagos vent fluids, perhaps less than approximately 50um/kg. These preliminary estimates contrast greatly with H_2S data obtained from similar vents in 2002 where values as greater than 550 um/kg were reported.

In-situ pH and H_2 data have not yet been assessed. Thus, Ghostbuster measurements indicate the following:

- The highest measured in-situ temperature is 20.4C during dive 4120, Garden of Eden
- The highest measured temperature in the Rosebud field is 17.1C, obtained during dive 4114 at Site, Marker B.
- The Ghostbuster sensor package was used effectively on 10 dives. The lone exception (dives 4119) was caused by ALVIN communication difficulties.

Following unambiguous interpretation of temperature measurements during all dives, chemical variability of redox species and pH will be assessed with good accuracy in order to constrain better the feedback between geochemical and biological processes.



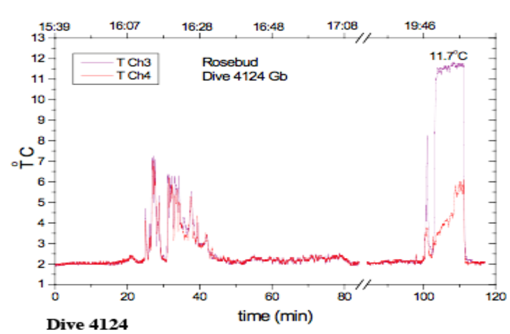


Fig 13. Time-series temperature data for the Ghostbuster chemical and temperature sensor.

4.4.2 Data-logger deployment/results

During the first series of dives to the Galápagos vents in 2005, chemical and temperature data-loggers were deployed at Rosebud in direct association with faunal colonization panels (basalt slabs). In-situ communication data for the deployed loggers revealed inconsistencies attributable to unusual power consumption. Accordingly, the deployment periods were shortened to three-four days, rather than the initially anticipated 8-10 day deployments. Results from one data-logger indicate small scale and recurrent temperature variability- on the order of 10-20%, together with moderately low H_2S (analogous to data obtained from real-time measurements), which fluctuate too, but precisely in phase with temperature variability. Preliminary pH data suggest acidification relative to seawater by as much as 2 orders of magnitude, with the lower pH corresponding to the higher temperature fluids. Similar results exist for dissolved H2, although these data may be close to our analytical limits of detection. Additional efforts will be needed to quantitatively establish the monitored geochemical signals in terms of the high-resolution time series trends. This will be accomplished during subsequent analysis at the University of Minnesota.

Table 6. Fluid samples ("majors") obtained from vents in 2005 during Galápagos Rift Expedition 9: May 20-June 3, 2005.

Water Samples – U. of Minnesota				
Dive	**Sample**	**Location**	**T (°C)**	**pH**
4114	M-4114-23	Rosebud / Marker B	17	7.6
	M-4114-24	Rosebud / Marker B	17	7.8
	M-4114-25	Rosebud / Marker B	17	6.9
	M-4114-26	Rosebud / Marker B	17	7.4
4115	M-4115-23	Rosebud / Marker B	15	7.0
	M-4115-24	Rosebud / Marker B	15	7.6
	M-4115-25	Rosebud / Marker B	15	7.1
	M-4115-26	Rosebud / Marker B	15	7.2
4116	M-4116-23	Rosebud / Marker N	17	7.0
	M-4116-24	Rosebud / Marker N	17	7.1
	M-4116-25	Rosebud / Marker N	16	7.1
	M-4116-26	Rosebud / Marker N	16	7.0
4117	M-4117-23	Rosebud / Marker I	14	6.8
	M-4117-24	Rosebud / Marker I	14	6.6
	M-4117-25	Rosebud / Marker I	15	6.6
	M-4117-26	Rosebud / Marker I	15	7.0
4120	M-4120-23	Garden of Eden	seawater	
	M-4120-24	Garden of Eden	seawater	
	M-4120-25	Garden of Eden /Marker Q/Riftia	18	7.2
	M-4120-26	Garden of Eden /Marker Q/Riftia	18	7.3
4121	M-4121-23	Garden of Eden /Marker Q/Riftia	16	7.0
	M-4121-24	Garden of Eden /Marker Q/Riftia	16	7.2

	M-4121-25	Garden of Eden /Marker Q/Riftia	16	7.0
	M-4121-26	Garden of Eden /Marker Q/Riftia	16	7.3
4122	M-4122-23	Rosebud / Marker I	12	7.3
	M-4122-24	Rosebud / Marker I	12	7.2
4124	M-4124-23	New Site / XY: 2342_61532	8	7.6
	M-4124-24	New Site / XY: 2342_61533	8	7.5
	M-4124-25	Rosebud / Marker B	17	6.9
	M-4124-26	Rosebud / Marker B	17	7.6

4.5. Geology

Based on multibeam sonar and detailed ABE near-bottom altimetric mapping, the 4 km wide rift valley of the GSC in the Rosebud area is characterized by steep north and south walls with 100-150 m of relief. The rift floor slopes gently to the north and south from the apex of the axial volcanic ridge (AVR) at ~2420 m to the base of the rift-bounding walls at ~2460 m depth. The AVR is composed of several volcanic cones spaced ~200-400 m apart with ~20-50 m total relief and basal diameters of ~100-300 m. The AVR trends ~280° and lies ~200 m north of a small fissure system mapped by ABE in 2002 that cuts the Rosebud vent field and is the presumed location of the dike heat source driving the hydrothermal system at the site.

Over ~25 km of the AVR was investigated using the TowCam, from 86° 15'W to 86° 0'W. The dominant flow morphologies include variably sedimented pillow lava found mainly on the volcanic cones, interspersed areas of lobate flows, some exhibiting collapse features, and zones of channelized sheet flows having a range of surface textures that suggest high effusion rates. Fissures, 1-20 m wide are nearly continuous on the crest of the AVR and are, in places, the sites of active hydrothermal diffuse flow.

TowCam #9 traversed the rift valley at the longitude of Rosebud and provides a good characterization of the relative ages of lava flows within the rift based on sediment cover and extent of faulting and fissuring across the rift floor. Small faults are observed on either side of the main rift walls within a few hundred meters of the principal scarp. Extensive talus is present at the base of the wall and overlies sedimented pillow and lobate flows. Most of the rift floor is variably sedimented pillow flows at times tending to lobate morphology. The sediment cover decreases markedly within the rift valley, compared to flows north and south of the rift walls; flows within the rift show glassy reflections in the photographs despite the sediment cover.

A glassy, curtain-folded sheet flow is present ~300-500 m south of Rosebud and has similar morphology to the flow that hosts the hydrothermal communities. Detailed mapping using Alvin and TowCam data from 2002 and 2005 cruises will be carried out in the next few months, but based on the dive and photographic observations it is clear that an eruptive fissure that sourced the flow at Rosebud is present ~100-150 m north of the hydrothermal vent field. The eruptive fissure was identified on dive 4124 and followed for ~400 m to the west. The fissure is ~1-5 m wide and 2->8 m deep, occasionally forming 5-10 m wide collapse areas along the fissure strike. The inner walls of the fissure are lined with bathtub rings indicating it was filled with lava that drained back down into the fissure within the recent past. Divers observed fresh sheet flows emanating from the fissure and flowing south. There are areas where the sheet flows shows clear channels with lineated-sheet morphologies indicating the direction of flow. The small volcanic cone north of Rosebud was also investigated and found to consist of older, sedimented pillow flows. The Rose Bowl vent community was found in one of the collapse features along the fissure ~200-300 m WNW of Rosebud.

One of the key results of the geological mapping conducted during this cruise was to unequivocally identify the source of the Rosebud flow and to confirm that it is a recent eruption sourced from an E-W trending fissure along the southern margin of the AVR in this area of the rift valley.

4.6 Geographic Information Systems

We constructed a GIS database for Rosebud and the surrounding area using ESRI's ArcMap software. We began from a base of gridded multibeam bathymetry data for the Galápagos Spreading Center. Data collected during 2002 was added to the database including vent locations, sample locations, Alvin tracks, high-resolution near bottom bathymetry, and towed-camera tracks. We added data from the 2005 cruise as it was collected including multibeam bathymetry, near-bottom Imagenex bathymetry from Alvin, sample locations, and transponder locations. Alvin tracks have metadata including vehicle attitude and downlooking photographs. TowCam tracks have metadata including CTD data and images. A total of 33,000 images of the seafloor are contained in the database.

4.7 Education and Outreach

Dive and Discover, Expedition 9: Return to the Galápagos Rift

Dive and Discover was designed in 2000 by Susan Humphris and Dan Fornari (WHOI Geology and Geophysics Department) with the goal of immersing students in the excitement of exploring the oceans. The ninth expedition took place May 20 to June 3, 2005. The expedition returned to the Galápagos Rift, located on a mid-ocean ridge about 250 miles from the Galápagos Islands where hydrothermal vents and exotic organisms were first found in 1977. Before the expedition Katherine Joyce (WHOI Graphic Services) redesigned the site; she also posted all materials to the site from shore throughout the cruise. It was the first redesign in five years. During Expedition 9, science writer Amy Nevala (WHOI Communications Department) wrote 16 daily stories, which were edited by Dan and Susan; took 7 to 12 photos daily, each with captions and photo credits; produced 9 videos, and wrote 5 interviews with scientists and crew. Also provided were the daily meals and weather. On shore, Jim Kent (WHOI Communications Department) provided daily editing for all text produced. Susan responded to more than 100 emails sent to the ship from students and the public, with the input of scientists, *Atlantis* crew and *Alvin* pilots. Danielle Fino (WHOI Web Group) provided the following statistics for the expedition:

Dive and Discover stats From May 20 to June 1

Visits

Total: 20,592
Avg per day: 1,584
Visit duration: ~14 minutes
International visits: ~11%
WHOI visits: 2.5%
Search Engine Bots - 21%

- *Note: This is much higher than usual. May be because it is a new site.

% Visits by Domain
..com - 53%
..net - 19%
..edu - 5%
..org - 1%

% Visits by Top Countries
United States - 89%
United Kingdom - 2%
Canada - 1%
Netherlands - 1%
Australia - 1%

% Visits by Top States
California - 43%
Mass - 10%
Virginia - 8%
Penn - 3%
New York - 3%

Images and text were also sent for use on the Noaa Oceanexplorer web portal, which also featured this expedition. A summary of the cruise can be seen on this web site: www.oceanexplorer.noaa.gov.

III. Evaluation:

1. Accomplishments – Explain special problems, differences between scheduled and accomplished work.

Our accomplishments are outlined above, and we accomplished everything we proposed to do, and more, including additional multibeam surveys and exploratory dives and camera surveys.   There were no special problems.

2. Expenditures:
   a. Describe original planned expenditures
   b. Describe actual expenditures
   c. Explain special problems, differences between planned and actual expenditures

Again, there were no special problems.   All expenditures were in line with our budget. Actually, I was able to leverage the OE effort to obtain additional funding from NSF and WHOI for additional education and outreach.

3. Next Steps:
   a. Planned or expected reports (professional papers, presentations, etc.)
   b. Brief description of need for additional work, if any (next project phase, new research questions, unaccomplished work, etc.)

This work has resulted in a special session at the Fall 2005 AGU meeting, numerous presentations in geological, chemical, microbiological and macrobiological meetings, as well as over thirty published abstracts and five journal publications. This work led to the development of a joint geological and biological survey of the western rift region (the most inflated part of the ridge), (Haymon et al., program) and the subsequent discovery of the first black smokers on the Galapagos Rift. This discovery now provides an opportunity to discover biological communities associated with these black smoker s and a biogeographical and genetic comparison of Galapagos Rift faunal communities to those on the neighboring East Pacific Rise. Sampling these newly-discovered communities would provide a first order fundamental insights into if and/or why despite the strong similarities in habitat and geographic proximity, the Galapagos Rift fauna only share 46% of its species with the East Pacific Rise.

Prepared By: ________________ 4/14/07__________
Signature of Principal Investigator   Date