LUSTRE '96
(LUcky STRike Exploration)

R/V Knorr Cruise 145-19

FINAL CRUISE REPORT

**Multidisciplinary Investigations of Hydrothermal Vents
on Lucky Strike Seamount
and the
Tectonic and Volcanic Structure of the Mid-Atlantic Ridge Rift
Valley Between 37°10'-25'N:**

**Near-Bottom Studies using the DSL-120kHz Sonar,
ARGO-II and ROV Jason**

**Funded by the National Science Foundation
Geology & Geophysics Program
(Grant #0CE - 9505579)**

August 15, 1996

Table of Contents

Contents of this Cruise Report, including many of the Figures, can be found on our Web page: http://drifor.whoi.edu

Cruise Participants and Affiliations

Shipboard Scientists

Dan Fornari - Co-Chief Scientist, Woods Hole Oceanographic Institution (WHOI)
Susan Humphris - Co-Chief Scientist, WHOI
Cindy Van Dover - U. Alaska
Karen Von Damm - U. New Hampshire
Philippe Blondel - Southampton Oceanography Centre, U.K.
Chris German - Southampton Oceanography Centre, U.K.
Lindsay Parson - Southampton Oceanography Centre, U.K.
Alison Bray - U. New Hampshire
Ken Feldman - WHOI
Elizabeth Gier - Lamont-Doherty Earth Observatory of Columbia University
Liane Hansen - U. Alaska
Steve Lerner - WHOI
Jose Monteiro - Geological Survey of Portugal
Tim Shank - Rutgers U.
Margaret Sulanowska - WHOI
Mike Thatcher - SSSG- Tech - WHOI
Fatima Teixeira - Geological Survey of Portugal
Jennifer Trask - U. Alaska
Cara Wilson - Oregon State U.
Karina Zavala - Slippery Rock State College

Shore-Based Scientific Collaborators

Charles Langmuir - Lamont-Doherty Earth Observatory of Columbia University
Marvin Lilley - U. Washington

WHOI-Deep Submergence Operations Group - Tethered Vehicles

Andy Bowen
Ralph Bachmayer
Tom Crook
Bob Elder
Skip Gleason
Jon Howland
James Knowles
Paul McCaffrey
Will Sellers
Bob Waters

Background

A long-term aim of studies of hydrothermal systems is to develop quantitative models of their distribution and characteristics in order to better evaluate the global scope of hydrothermal activity, and the role of hydrothermalism in mass and energy fluxes between the lithosphere and hydrosphere. Development of such predictive models requires a profound understanding of the range of geologic environments and tectono-magmatic settings in which hydrothermal activity is known to occur. The Lucky Strike hydrothermal site was discovered in 1992 during dredging operations at 37° 17'N on the Mid-Atlantic Ridge (MAR) (the FAZAR cruise - Langmuir, Klinkhammer et al., [1993]). Located on a seamount in the center of a segment just south of the Azores Platform, the Lucky Strike hydrothermal site provides an important opportunity to expand the range of settings in which hydrothermal activity has been investigated. The topography, crustal thickness, and basalt chemistry of this segment of the MAR rift valley have been strongly influenced by its proximity to a major hotspot. Submersible studies carried out in 1993 using Alvin [Langmuir, Klinkhammer et al., 1993; Langmuir et al., 1996] indicated that active vents are distributed over a wide area at shallow depths (1630-1730m), and that hydrothermal activity is episodic. Other unusual characteristics include the presence of barite in the mineral deposits, the first reported hydrothermal fluids from the Atlantic with chlorinities lower than seawater, and a biological community dominated by a new species of mussel that may constitute a previously unrecognized biogeographic province.

The LUSTRE '96 (**LU**cky **STR**ike **E**xploration) cruise was proposed as a detailed field investigation of the relation between volcanic and tectonic features, and the distribution of hydrothermal activity and composition of the associated biological communities at the Lucky Strike segment on the Mid-Atlantic Ridge. Our proposed program had the following aims:

[1] to thoroughly map the Lucky Strike hydrothermal vent fields and spatial distribution of individual vent sites present on the summit of the seamount in order to place them within their proper tectonic/volcanic context,

[2] to determine the geological, mineralogical, chemical and biological characteristics of vents on Lucky Strike seamount in order to compare them with other MAR hydrothermal vents occurring at sea floor depths which vary from >3000m (TAG, Snake Pit, Broken Spur) [e.g. Rona et al., 1986; 1993; Thompson et al., 1988; Murton et al., 1994, 1995; Humphris et al., 1995] to ~800 m (Menez Gwen) [Fouquet et al., 1994a,b].

[3] to obtain a detailed geological data set for a long-and-wide, magmatically robust slow-spreading ridge segment that exhibits end-member characteristics in terms of width, and depth variation per segment length.

The LUSTRE '96 field program was designed to utilize the suite of tethered, fiber-optic-based vehicles of the National Deep Submergence Facility based at the Woods Hole Oceanographic Institution's Deep Submergence Operations Group (WHOI-DSOG) (Plate A). We first used the high-resolution, near-bottom DSL-120 kHz side-looking sonar system to survey an ~16 km long section of the MAR rift valley, north and south of the Lucky Strike vent field. That work was followed by a focused study of selected areas on the summit of Lucky Strike seamount using the near-bottom ARGO-II optical and acoustical imaging system. Finally, sampling of vent fluids, sulfides, and endemic biology was carried out using the remotely operated vehicle (ROV) Jason. This investigative strategy was geared to provide a very high-resolution and spatially controlled dataset concerning the causal relationships between ridge segment morphology, the distribution of hydrothermal fields, volcanic features, tectonic activity, and the biological characteristics of individual vent sites. During the course of the next few years, shore-based analysis of the dataset collected during the LUSTRE '96 cruise will allow us to develop a model of the interrelationships among these processes within the Lucky Strike segment, and, by analogy, other magmatically robust slow-spreading mid-ocean ridge (MOR) segments.

Logistics

The R/V Knorr departed Barbados late on June 26, 1996 and arrived at the first field area on July 4. Tests of the DSL-120 sonar system were conducted at the Rainbow Ridge site (36° 16'N, 33° 52.5'W) for 2 days and then the ship transited north to the main field area in the Lucky Strike segment of the MAR rift valley (Figures 1 and 2). 120 kHz sonar, ARGO-II and Jason lowerings were carried out at Lucky Strike for 25 days, until July 31 (Figure 2). At the end of those surveys we transited south to Rainbow Ridge to carry out a Jason lowering to attempt to locate the sea floor source of the Rainbow hydrothermal plume. We departed Rainbow for Woods Hole on the morning of August 2, having spent a total of 29 days on station. The Knorr arrived in Woods Hole on August 8, 1996. Operational summaries for the vehicle lowerings are presented in Figures 3 and 4, and Tables 1 and 2. Specific breakdown of operational time for various science tasks carried out by Jason are provided on a lowering-by-lowering basis in Appendix I. A listing of digital event categories used in real-time during ARGO-II and Jason lowerings to characterize sea floor features and the distribution of biological organisms is presented in Appendix II.

Table 1 COMBINED VEHICLE SUMMARY (hours)

	In water	On Bottom
120 Sonar	207:56	184:48
ARGO-II	119:57	116:40
ROV Jason	150:32	113:49
Total	478:25	415:17

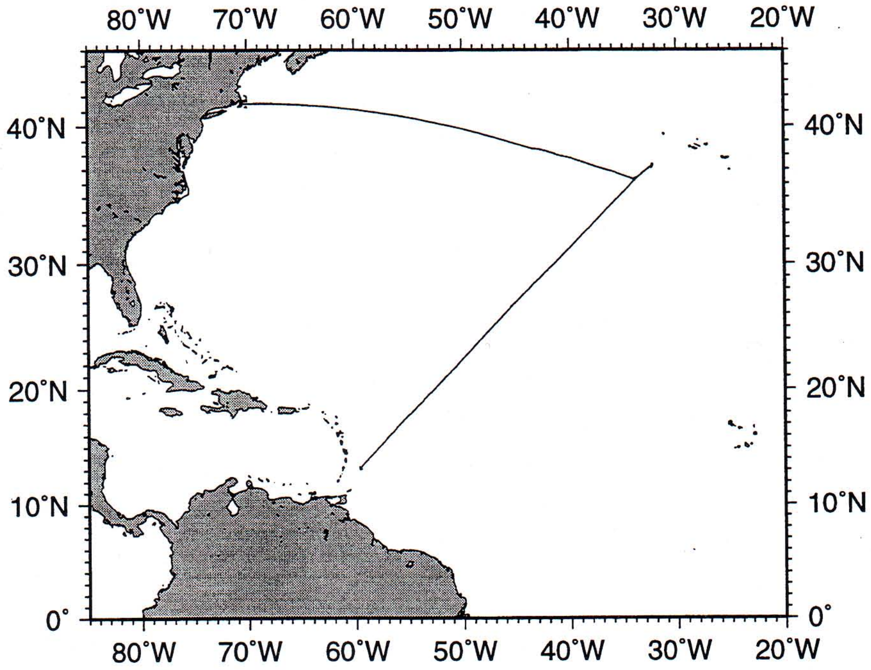

Figure 1 - General track chart for *R/V Knorr* 145-19, LUSTRE '96 cruise.

LUSTRE '96 - LUCKY STRIKE CRUISE

Sun	Mon	Tue	Wed	Thu	Fri	Sat
30 Departed Barbados 6/26 TRANSIT	1 TRANSIT	2 TRANSIT	3 TRANSIT	4 RAINBOW, 120, D#1	5 RAINBOW, 120, D#2	6 RAINBOW, 120 TRANSIT TO LUCKY STRIKE
7 LUCKY STRIKE, 3 XPONDERS NET #1, JASON	8 LUCKY STRIKE, JASON	9 LUCKY STRIKE, DEPLOY, NET #2 START 120 N. SURVEY	10 LUCKY STRIKE, 120 SURVEY-NORTH AREA	11 LUCKY STRIKE, 120 SURVEY, NORTH AREA	12 LUCKY STRIKE, 120 SURVEY, NORTH AREA	13 LUCKY STRIKE, 120 SURVEY, NORTH AREA
14 LS120 SURVEY, N. AREA SOL#19 0300L/14	15 LS120 SURVEY, EOL#24 1200L Recover 120 Xpond Rec. & Re-Launch	16 Start S. Area Survey Survey S. Net Launch 120 at 0800L	17 LS 120 SURVEY SOUTH AREA	18 End 120 Survey 1600L Rec. 120 Sonar & Xponder Rec. Rock Core	19 Deploy Jason - Lucky Strike 0400L Jason work at vent areas	20 Jason work at vent areas
21 1:59 Pull up Jason Ready ARGO - Launch 2300L Rock Coring	22 LUCKY STRIKE, ARGO WORK - N-S LINES	23 LUCKY STRIKE, ARGO WORK - E-W LINES	24 ARGO N-SADDLE AREA, DETAILED SURVEYS	25 200 KHZ SONAR ARGO - CONTD DETAILED SURVEYS &	26 Dredges 3-5 Recov. ARGO Xpon.A fish & Launch Jason 1600L	27 LUCKY STRIKE, JASON WORK #180 &181
28 LUCKY STRIKE, JASON WORK #181 - #182	29 LUCKY STRIKE, JASON WORK #182	30 LUCKY STRIKE, JASON WORK #183	31 Depart for Rainbow 0700L Transponders & Jason #184	1 RAINBOW Jason #184	2 End Survey, Rec. Xponders Start Transit - Woods Hole	3 TRANSIT
4 TRANSIT	5 TRANSIT	6 TRANSIT	7 TRANSIT	8 Arrive Woods Hole	9	10

Figure 2 - Calendar of Operations for LUSTRE '96 Cruise from June 30 to Aug 10. Note that from June 26-29 ship was in transit from Barbados to the MAR

Table 2 - Operational Summaries of Vehicle Lowerings during LUSTRE '96 Cruise.

120 kHz SONAR LOWERING SUMMARY

DSL120 Lowering	In Water	On Bottom	Left Bottom	Out of Water	In Water Time (hrs)	On Bottom Time (hrs)
32	7/5/96 08:40	7/5/96 11:50	7/5/96 22:10	7/6/96 01:03	16:23	10:20
33	7/6/96 07:47	7/6/96 10:11	7/6/96 13:20	7/6/96 15:28	7:41	3:09
34	7/9/96 19:15	7/9/96 21:34	7/10/96 10:00	7/10/96 11:30	16:15	12:26
35	7/10/96 14:20	7/10/96 16:15	7/15/96 14:30	7/15/96 17:00	122:40	118:15
36	7/16/96 10:17	7/16/96 12:09	7/18/96 04:47	7/18/96 07:14	44:57	40:38
				Total:	207:56	184:48

ARGO-II LOWERING SUMMARY

ARGO-II Lowering	In Water	On Bottom	Left Bottom	Out of Water	In Water Time (hours)	On Bottom Time (hours)
3	7/21/96 03:00	7/21/96 04:42	7/26/96 01:22	7/26/96 02:57	119:57	116:40

ROV JASON LOWERING SUMMARY

JASON Lowering	In Water	On Bottom	Left Bottom	Out of Water	In Water Time (hours)	On Bottom Time (hours)
176	7/7/96 15:21	7/7/96 16:53	7/8/96 13:00	7/8/96 14:23	23:02	20:07
177	7/19/96 00:13	7/19/96 02:13	7/19/96 20:16	7/19/96 22:15	22:02	18:03
178	7/20/96 02:54	7/20/96 05:03	7/20/96 15:15	7/20/96 17:45	14:51	10:12
179	7/21/96 03:20	7/21/96 04:56	7/21/96 08:05	7/21/96 10:45	7:25	3:09
180	7/26/96 22:11	7/27/96 02:06	7/27/96 17:30	7/27/96 20:55	22:44	15:24
181	7/28/96 04:23	7/28/96 06:09	7/28/96 17:22	7/28/96 20:02	15:39	11:13
182	7/29/96 01:53	ABORTED		7/29/96 07:17	5:24	0:00
183	7/29/96 16:00	7/29/96 17:49	7/31/96 5:30	7/31/96 7:25	39:25	35:41
184	8/1/96 1:22	8/1/96 4:43	8/2/96 4:03	8/2/96 8:22	31:00	23:20
				Total:	150:32	113:49

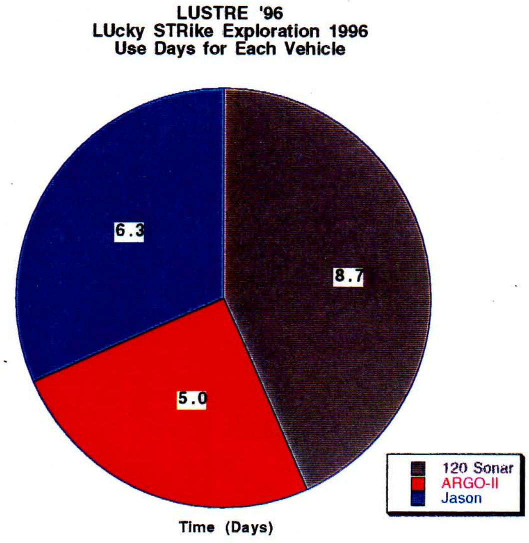

Figure 3a

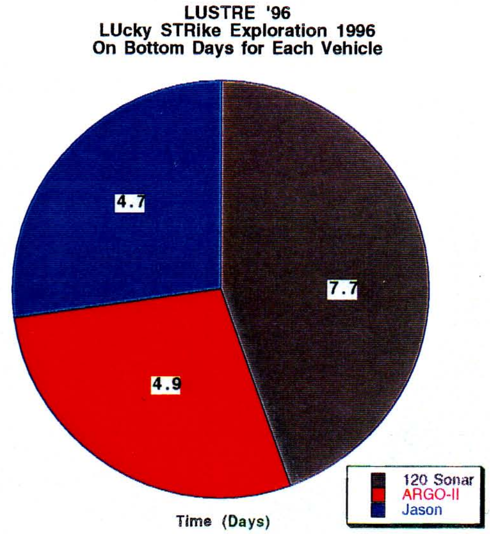

Figure 3b

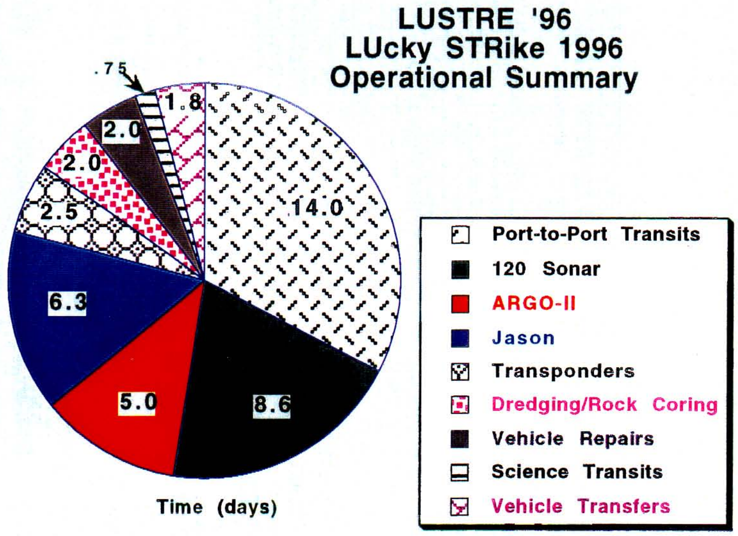

Figure 4

Transponder Navigation

All surveys except the first DSL-120 sonar lowering, which was the field test of the system, were navigated using long-baseline transponders. That first lowering was navigated using P-Code GPS positions and a relay transponder on the depressor weight, located ~30 m in front of the sonar vehicle, which provided a slant range to the vehicle. Lay-back positions of the vehicle behind the ship were computed every 10 minutes and used to compile the final navigation for the test lowering.

All other DSL-120 sonar, ARGO-II and Jason lowerings were navigated using an acoustic long-baseline transponder network with ~ 4 km baselines between each transponder and 150 m tethers between the anchors and the transponders. The only exception to this was the deployment of a short-baseline (0.8 km - 1.2 km between transponders) network of 3 transponders, each on 100 m tethers, which was used to navigate the Jason and ARGO-II lowerings on the seamount summit. All transponders were surveyed-in using P-Code GPS navigation from the ship. Two independent methods of acoustic positioning/calibration software were used to calculate the final locations and depths of each transponder. One method consisted of the standard Deep Submergence Operations Group (DSOG) navigation routines and GPSCAL2 surveying and calibration software. The second method employed the Pelagos WINFROG navigation and calibration software. Agreement between the two methods was between 1-14 m, with a mean of 6 m. A summary of transponder positions, based on the DSOG surveying algorithms which were selected as the final values, is presented in Table 3. Table 4 shows the differences between GPSCAL2 and WINFROG calculated positions for several of the transponders in the network. The precision of the navigation using the shorter baseline transponder network based on multiple fixes during times when Jason was sitting on the bottom sampling indicates that relative positioning resolution for Jason and ARGO-II tracks is <5 meters. Preliminary analysis of DSL-120 sonar navigation, based on crossing points between different lines, suggests that precision using the long-baseline transponder network was ~10-20m. Geodetic accuracy based on characteristics of P-Code GPS constellation of satellites is considered to be ~10 m.

Table 3 - Transponder Summary: R/V Knorr Cruise 145 Leg 19 LUSTRE '96

SUMMIT NET

Origin: N37 15' W32 19' UTM-zone: 25 Antenna.dat: -3.55m -33.17m

ID	X	Y	Z	LAT	LONG	UTM-X	UTM-Y	slot	reply	rel.
A	2988.9	3950.1	1482.3	N37 17.1356	W32 16.9787	563558.83	4126795.82	9.5	9.25	A
B	3781.4	4023.6	1603.2	N37 17.1753	W32 16.4427	564350.07	4126875.34	10.0	10.8	H
C	3044.9	5444.2	1471.4	N37 17.9433	W32 16.9408	563603.45	4128289.82	10.5	11.0	B

NEW SUMMIT NET

(NB- Transponder S was deployed and this net installed because Transponder A failed to respond or release)

Origin: N37 15' W32 19' UTM-zone: 25 Antenna.dat: -3.55m -33.17

ID	X	Y	Z	LAT	LONG	UTM-X	UTM-Y	slot	reply	rel.
S	3272.7	4096.3	1516.3	N37 17.2146	W32 16.7868	563841.27	4126944.13	9.50	10.00	C
B	3781.4	4023.6	1603.2	N37 17.1753	W32 16.4427	564350.07	4126875.34	10.50	10.75	H
C	3044.9	5444.2	1471.4	N37 17.9433	W32 16.9408	563603.45	4128289.82	10.00	11.00	B

Table 3 (continued)- Transponder Summary: R/V Knorr Cruise 145 Leg 19 LUSTRE '96

NORTH NET

Origin: N37 14' W32 23 UTM-zone: 25 Antenna.dat: -3.55m -33.17m

ID	X	Y	Z	LAT	LONG	UTM-X	UTM-Y	slot	reply	rel.
A	8905.6	5799.8	1482.3	N37 17.1356	W32 16.9787	563558.80	4126795.82	13.5	9.25	A
B	9689.4	5873.2	1603.2	N37 17.1753	W32 16.4488	564341.18	4126875.24	14.5	10.75	F
C	8961.7	7293.8	1471.4	N37 17.9433	W32 16.9408	563603.50	4128289.78	14.0	11.00	D
D	2678.6	-1310.7	2206.6	N37 13.2914	W32 21.1889	557387.20	4119643.06	7.5	10.25	D
E	4713.8	406.5	1988.8	N37 14.2198	W32 19.8129	559409.75	4121373.78	8.0	10.00	C
F	5859.3	4704.4	1836.5	N37 16.5434	W32 19.0384	560523.74	4125678.34	7.0	13.00	F
G	6825.8	8474.6	1515.8	N37 18.5817	W32 18.3849	561461.66	4129454.25	10.0	11.25	E
H	7398.1	12416.2	1601.0	N37 20.7127	W32 17.9980	562003.96	4133398.72	7.5	9.50	G
I	10777.9	14107.3	2109.1	N37 21.6270	W32 15.7128	565364.18	4135114.94	9.5	10.50	G
J	11719.3	10789.2	2045.5	N37 19.8331	W32 15.0763	566329.92	4131805.35	8.0	10.00	C
K	10743.7	6809.6	1556.9	N37 17.6815	W32 15.7359	565387.01	4127819.45	8.5	9.75	E
L	9682.6	2847.6	1705.4	N37 17.6815	W32 15.7359	564357.59	4123850.63	10.5	11.50	F
M	7722.4	-1202.0	2053.9	N37 13.3501	W32 17.7787	562428.93	4119787.67	9.5	10.50	D

SOUTH NET

Origin: N37 4' W32 27' UTM-zone: 25 Antenna.dat: -3.55m -33.17m

ID	X	Y	Z	LAT	LONG	UTM-X	UTM-Y	slot	reply	rel.
N	15673.0	13052.8	2179.9	N37 11.0571	W32 16.4263	564461.08	4115562.89	8.5	9.75	E
O	12325.9	9866.8	2506.6	N37 9.3345	W32 18.6844	561143.63	4112353.04	8.0	10.00	C
P	10594.7	5879.3	2751.5	N37 7.1787	W32 19.8524	559443.26	4108354.55	10.0	9.50	G
Q	6884.6	7057.4	2643.7	N37 7.8156	W32 22.3554	555729.46	4109506.93	9.5	10.50	G
R	8014.3	11458.6	2415.3	N37 10.1952	W32 21.5932	556828.08	4113914.14	10.5	11.50	F
D	8613.6	17185.4	2206.6	N37 13.2914	W32 21.1889	557387.24	4119643.07	7.5	10.25	D
M	13668.4	17294.1	2053.9	N37 13.3502	W32 17.7787	562428.90	4119787.68	9.5	10.50	D

Table 4 - The differences (in meters) in the absolute positions of transponders used during the LUSTRE '96 cruise as calculated by GPSCAL2 and WinFROG software (gps = GPSCAL2 program, wnf = WinFROG program).

Transponder	Xgps-Xwnf	Ygps-Ywnf	Dgps-Dwnf
A	0.00	-1.71	1.02
B	0.59	-6.59	0.02
C	6.00	4.27	-0.21
D	-0.2	-2.5	0.02
E	-1.68	-0.37	4.65
F	0.93	2.13	0.35
G	5.48	0.16	12.48
H	-2.8	-1.67	1.42
I	0.52	-5.5	-1.81
J	1.27	0.87	0.64
K	-0.8	-2.1	5.54
L	-2.1	-0.9	0.4
M	NA	NA	NA

120 kHz Sonar Surveys

Field Testing

The area around 36° 16'N, 33° 52.5'W was chosen as the site to conduct tests of the DSL-120 kHz sonar system. In preparation for the trials we carried out a 5 hour SeaBeam survey using P-code GPS navigation over the Rainbow Ridge hydrothermal plume site discovered by German, Klinkhammer et al. in 1994 [German et al., 1995; 1996]. The multibeam survey covered the area between 36°10'-24'N and 33° 44'-58'W with overlapping swaths of sonar data. The Sea Beam 2100 data show that Rainbow Ridge is an elongate feature, ~8km long and trending N010°E, extending from the east margin of the MAR rift valley in the South AMAR segment. The contours on the west side of the ridge are scalloped suggesting that mass-wasting has occurred along the slope. In addition, there are several linear, N-S trending embayments on the west flank between 2000-2300 m depth which suggest that the morphology is partially controlled by a tectonic fabric. The east slope of the ridge is broader as it descends into the non-transform discontinuity (NTD) basin which has a maximum depth of ~3200 m. The NTD basin also contains several 4-8 km long, N to NNE-trending ridges which may be either relict constructional features, or faults associated with the development of the rift valley at the adjacent spreading center.

The basic contour style of the sea floor in this area, as first resolved by the Simrad multibeam data collected in 1993 using standard GPS navigation, remains relatively unchanged by our survey, and the navigation offset between the old multibeam data and the new Sea Beam 2100 bathymetry is small (clockwise rotation around the center of the survey area resulting in ~150 m offset). Shifting of the TOBI imagery and Simrad data to the new Sea Beam bathymetry was done manually on the real-time Sea Beam map in order to place various features seen on TOBI in their correct geodetic position.

The P-Code navigated Sea Beam map provided the accurate geodetic framework required to carry out an 18 hour lowering of the 120 kHz sonar at Rainbow Ridge in order to conduct trials of the system prior to the large area surveys planned for the Lucky Strike segment. The test lowering afforded an opportunity to: 1] carry out a field check of the DSL-120 sonar towfish, vehicle ballasting, and topside acquisition hardware and software, 2] compare the backscatter data collected by the DSL-120 sonar with 30 kHz TOBI imagery of the area provided by Dr. L. Parson (Southampton Oceanography Centre, UK), 3] collect acoustic backscatter and high resolution phase bathymetry of the western and northern flanks of the large ridge that protrudes into the NTD that offsets the MAR rift valley at this location, and 3] verify whether the previously identified hydrothermal plume was still present in the water column by using the CTD, transmissometer and light backscattering devices mounted on the DSL-120 sonar vehicle.

The DSL-120 sonar was deployed at Rainbow on July 4; however, during the lowering, a cable to the doppler flooded and the vehicle was recovered. The doppler was removed (cable dummied), and the instrument was redeployed. On the second test lowering, after passing 1900m depth, telemetry problems occurred, which affected both high speed sonar and low speed vehicle attitude information. The high speed problem was due to difficulties in the topside fiber optic interface which were easily corrected. The vehicle attitude problems persisted through the next lowering; however, data processing was able to remove the effects. The problem was finally diagnosed as a bad capacitor in the topside AMS sonar telemetry interface panel and repaired. Data were acquired on 3 test lines (including one orthogonally crossing line). Although some noise and bottom detect problems continued, they decreased when the vehicle was towed at a depth of ~75 m above the sea floor rather than at the planned depth of ~100 m. Using the test data, DSOG technicians modified the sonar processing parameters to improve the quality of the slant- and speed-corrected data. The phase-bathymetric data were also analyzed and determined to be reliable and of very good quality. We believe this small decrease in the fish to bottom distance helped boost the signal to noise ratio which characterizes this mixed terrain of sediment, scarps and relatively fresh, and variably sedimented volcanic flows.

DSL-120 kHz Sonar Surveys in the Lucky Strike Segment

On July 6 we transited north to our principal field areas- Lucky Strike seamount (located at 37° 17'N, 32° 17'W) and the MAR rift valley segment between 37° 10'-30'N (Figure 5). Four 120 kHz sonar lowerings were carried out between July 5-July 18 resulting in 325 km of survey lines. The main survey centered on Lucky Strike seamount encompassed an area of 160 km^2 (10 km E-W x 16 km N-S) (Figure 6) in the central and eastern Lucky Strike segment from 37°22'N to 37°13'N. Eleven tracks spaced at a nominal 800 m interval were aligned along an 014° azimuth, parallel to the strike of the rift valley, and at an orientation most favorable for the imaging and quantification of neotectonic fabric associated with this slow-spreading ridge system. These lines provided 100% insonification of the axial floor, except for short sections where technical difficulties in data acquisition were experienced. Additional cross lines along an azimuth of 105° were also run, as well as two short lines across the summit of the seamount in order to ensure high quality data, and full coverage of the area of focus for ARGO-II and Jason studies.

A second survey consisting of 6 lines, each approximately 10 km long, was conducted south of the main survey area to provide swaths of backscatter imagery and phase bathymetry over portions of the rift valley which contain volcanic and tectonic structures that reflect transitions in crustal accretion processes towards the segment end. These lines also provided further cross-reference and calibration of previously collected TOBI 30 kHz sonar [Parson et al., 1996] and multibeam bathymetric compilations [Needham et al., 1994 and unpublished data; Detrick et al., 1995].

Sonar data were processed by DSOG personnel in real time for slant-range and preliminary speed correction, and provided to the science party as processed hourly files of backscatter and 32-bit floating-point phase bathymetry. A hand-compiled mosaic of both survey areas was completed on board and used to pick sonar targets and acoustic facies boundaries in order to accurately locate the regions to be studied using ARGO-II and Jason. A geographically referenced, gridded digital mosaic of the backscatter data from the main survey area was also completed on board, and selected portions of the phase bathymetric data were further processed and gridded, including the area over the seamount summit (see Appendix III).

Data quality throughout the survey was excellent, with only localized and non-systematic "drop out" problems experienced. One of the possible explanations for these "dropout" lines may be local changes in the platform's attitude, for example when flying higher to avoid large, vertical-relief features on the sea floor (e.g. scarps and seamounts). Following pre-processing, radiometric correction and routine histogram equalization, the data were printed on paper and hand-mosaicked into a working shipboard copy. Digital processing of the entire dataset as a mosaic was handled by the SOC team. As a first approximation, hourly files were printed assuming a constant ship speed of 1.3 knots. This speed did vary during the survey, leading to along-track inaccuracies of a few to several tens of meters. Using software developed onboard, and ERDAS-Imagine- a commercial map making and image processing software program running on a Unix workstation, the swath lines were corrected for the average speed variations, geo-rectified and geo-referenced. Resulting positioning inaccuracies are generally less than 1 meter (i.e. ~1 pixel). The 25 survey lines were mosaicked together (Figure 7) using a linear feathering technique to account for the overlaps between adjacent swaths and to enhance the signal-to-noise ratio at far range. The processing also smoothed out local artifacts in the data. The final mosaics of the Northern and Southern Lucky Strike survey areas were made available to the science party as grids at 1-m resolution, as well as ~1:13000 scale paper maps.

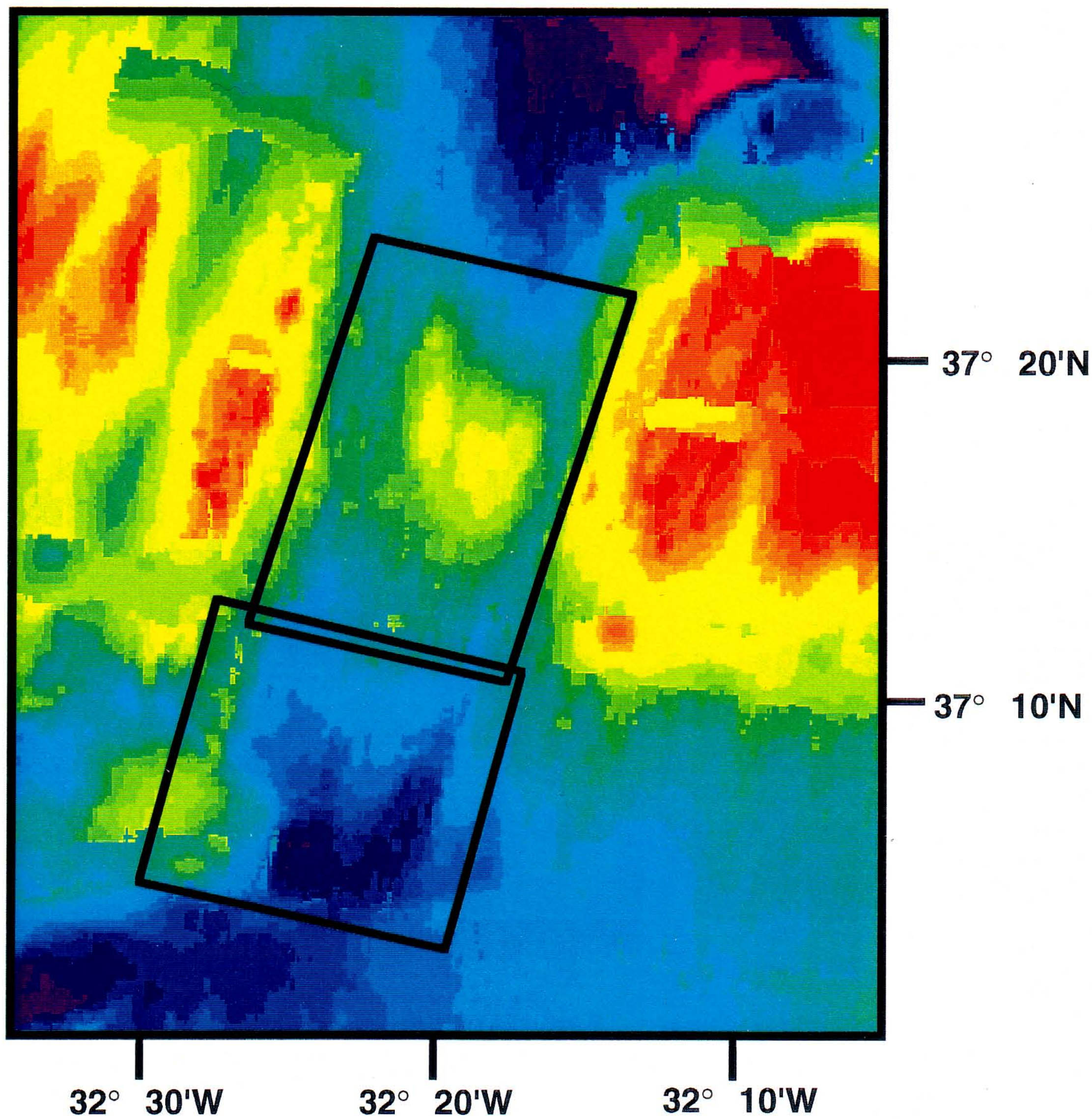

Figure 5 - Simrad 100 m gridded bathymetry (from Detrick et al., 1994, and D. Needham, unpublished data) for Lucky Strike segment showing general areas surveyed using the DSL-120 Sonar. Figure 7 corresponds to portion of the northern box within the rift valley.

Our preliminary interpretations of the acoustic backscatter data are as follows. Lucky Strike seamount is a highly tectonized feature in the center of the segment. Each of the three cones present on the summit are cut by prominent faults which splay and continue north and, to a lesser extent, south of the summit. The rift valley floor north of the seamount has a structural fabric that is ~20° oblique to the trend of the rift valley, while the rift floor south of the seamount is much less faulted. The center of this ridge segment appears to be dominated by amagmatic extension, with an increase in volcanic constructional terrain towards the segment ends, especially at the inside corners of the non-transform discontinuities where bright acoustic reflectors suggest less sediment cover, and outcrops of younger volcanics. The backscatter and phase-bathymetry data provide clear images of morphological and structural associations between volcanic constructs and faults in the rift valley floor and the spatial distribution of these features along the segment. The ~0.6 m pixel resolution of the 120 sonar data has allowed us to image small hydrothermal vent structures and determine their relationships to the surrounding volcanic and tectonic features of the summit area.

The 160 km^2 area within the Lucky Strike segment we mapped contains some well-defined morphotectonic domains. To the east, extensive areas of sea floor characterized by uniformly weak backscatter suggest sedimented sea floor, which is locally interrupted by clusters of partially buried conical and dome-like seamounts. Very few linear features were imaged in this area, apart from major scarps at the extreme eastern margin of the survey. Those features are located at the base of the rift valley wall, and are manifested as a series of continuous bright targets. These are interpreted as the lower faces of the axial valley walls that are partially obscured by their weathering and erosional products. Parts of this eastern area, along with significant sections of the rest of the central floor, are characterized by a finely-mottled acoustic texture, which was later ground-truthed during a rock dredge station (KN145/19-05) as relatively fresh basalt flow surfaces, apparently with little or no sediment cover.

Throughout the center of the axial valley floor, a more tectonically active swath of terrain is clearly marked on each side by a conjugate set of inward-facing faults. These tectonic boundaries are ~6 km apart at the northern extent of the survey area, but converge southwards, narrowing to less than ~3.5 km separation at the mid-point of the axis. Their spacing diverges southwards to more than 4 km at the southern limit of our data. Between the bounding faults, a pervasive fabric of closely-spaced lineations were found to cut brightly backscattering sea floor, suggesting a focusing of extensional deformation within this zone.

Lucky Strike seamount consists of a ~5 km wide (E-W) edifice with N-S trending volcanic ridges that extend from the northwestern and southeastern corners of the complex, and three prominent summit cones that form the northwest, northeast and south limits of the summit. On the seamount summit, the area containing the hydrothermal vents was imaged as a locally highly tectonized zone of mixed acoustic facies, varying from brightly backscattering mottled surfaces to uniform, sediment mantled areas. Undeformed and fresh-looking hummocky volcanic constructs, and a more uniformly bright backscatter pattern are recognized in the floor of the central depression bounded by the three summit cones. The bright backscatter area correlates to the observed limits of the lava lake as mapped by ARGO-II and Jason.

In the central part of the segment, the survey did not extend far enough to the west to image the western axial valley walls. The westernmost recorded data, however, suggest very similar sedimented topography to that recognized in the extreme east, i.e. weakly backscattering uniform surfaces punctuated by numerous rounded seamounts. Further along strike, juxtaposed complexes of variably deformed mounded, volcanic topography and flat-lying flow-like features dominate the southwestern and northeastern sections of the segment.

ARGO-II Lowerings

ARGO-II surveys of the summit of Lucky Strike seamount were carried out in order to map the geology of the summit area and hydrothermal sites in detail, ground-truth the 120 kHz sonar data, and provide additional targets for the detailed mapping and sampling work carried out using Jason. Data were collected in three phases, on a total of 75 ARGO-II lines throughout the summit area of Lucky Strike seamount (Figure 8). A series of N-S lines spaced at ~25m intervals was run over the known vent areas located on the eastern margin of the summit area based on the locations determined from the Alvin diving in 1993 [Langmuir et al., 1996]. Data were also acquired in a regional E-W grid of ARGO lines, at 50m spacing, over the entire summit area, including the lower flanks of the three cones which delimit the summit depression. Finally, a N-S grid of lines, spaced variably at 10-30 m intervals, was run over specific areas to fill in gaps between previously run ARGO lines where active vents, areas of fresh volcanics, specific biological communities, and other hydrothermal, volcanic, and tectonic features needed to be mapped in greater detail. Figure 9 shows a generalized map of the summit area with the locations of the principal high temperature vents that were sampled.

Previous observations, based on data from the Alvin dives indicated the presence of a N-S trending swath of terrain in which the active vent sites are located. The northern part of this area is dominated by sulfide rubble, while the southern part is composed of hydrothermally cemented breccia ("slab-like" material). This spatial distribution of features and hydrothermal facies was found to be somewhat inaccurate in that nearly the entire southeastern corner of the summit, and the saddle area between the southern and eastern cones, comprises a broad area containing hydrothermally cemented breccia, and sulfide rubble which are variably distributed around the active vent sites in this region (Figure 10). In fact, the whole area may be underlain by the hydrothermally cemented material, although the pelagic sediment cover and sulfide rubble present throughout this area make this prediction difficult to confirm. The dominant tectonic fabric on the eastern side of the summit area is generally N-S with a variation in strike of features that ranges from ~340° to 020°. Fracturing of the slab facies, which dominates around the Eiffel Tower and Marker #4 vents in the southeastern part of the summit, appears to follow both a N-S and roughly orthogonal pattern.

A ponded lava flow which has formed a shallow (~<5 m deep) lava lake is present over a ~250 m (N-S) x ~350 m (E-W), roughly triangular-shaped area of the summit depression on Lucky Strike seamount (Figures 9 and 11). In places the lava flow exhibits extensive collapse structure (including lava pillars ~2-3 m high, with diameters generally <0.5-1m), and other volcanic forms indicative of rapid eruption rates and relatively low-viscosity lava. The flow surfaces have glassy, sediment dusted surfaces and have morphologies which range between lobate, sheet, ropy, and jumbled forms (Figure 11 and Plate B). This area is considered to have been subjected to a relatively recent emplacement of lava based on the freshness of the glass and relatively light dusting of sediment. In places, older collapse margins located outside the present boundary of the lava lake suggest that the summit depression has been subjected to multiple eruptions. Contact relationships between the lobate, sheet, ropy and jumbled flows and surrounding collapse talus could indicate that the most recent eruptive phase was characterized by multiple events. Shore-based analysis of the video and electronic still camera (ESC) data will provide additional constraints on the interpretation of the volcanic history of the lava lake and its relationship to the recent history of Lucky Strike seamount.

Apart from the vents in the hydrothermal field previously described, active hydrothermal vents are located near the eastern and southwestern margin of the lava lake (Figure 9). 2608 vent, located on the east rim of the lake, and Crystal vent, located at the southwest margin of the lake, are sites of high temperature hydrothermal flow which may owe their present activity, in part, to the most recent eruptive phase on Lucky Strike. The two vents do, however, exhibit different fluid chemistries and a significant difference in temperature (2608 is a black smoker with the highest measured temperature of 328°C, while Crystal vent produces clear fluid with a temperature of 281°C). A large area of sulfide deposits was also found NW of the lava lake (Figure 10). The sulfide rubble terrain covers an area of ~600 m^2

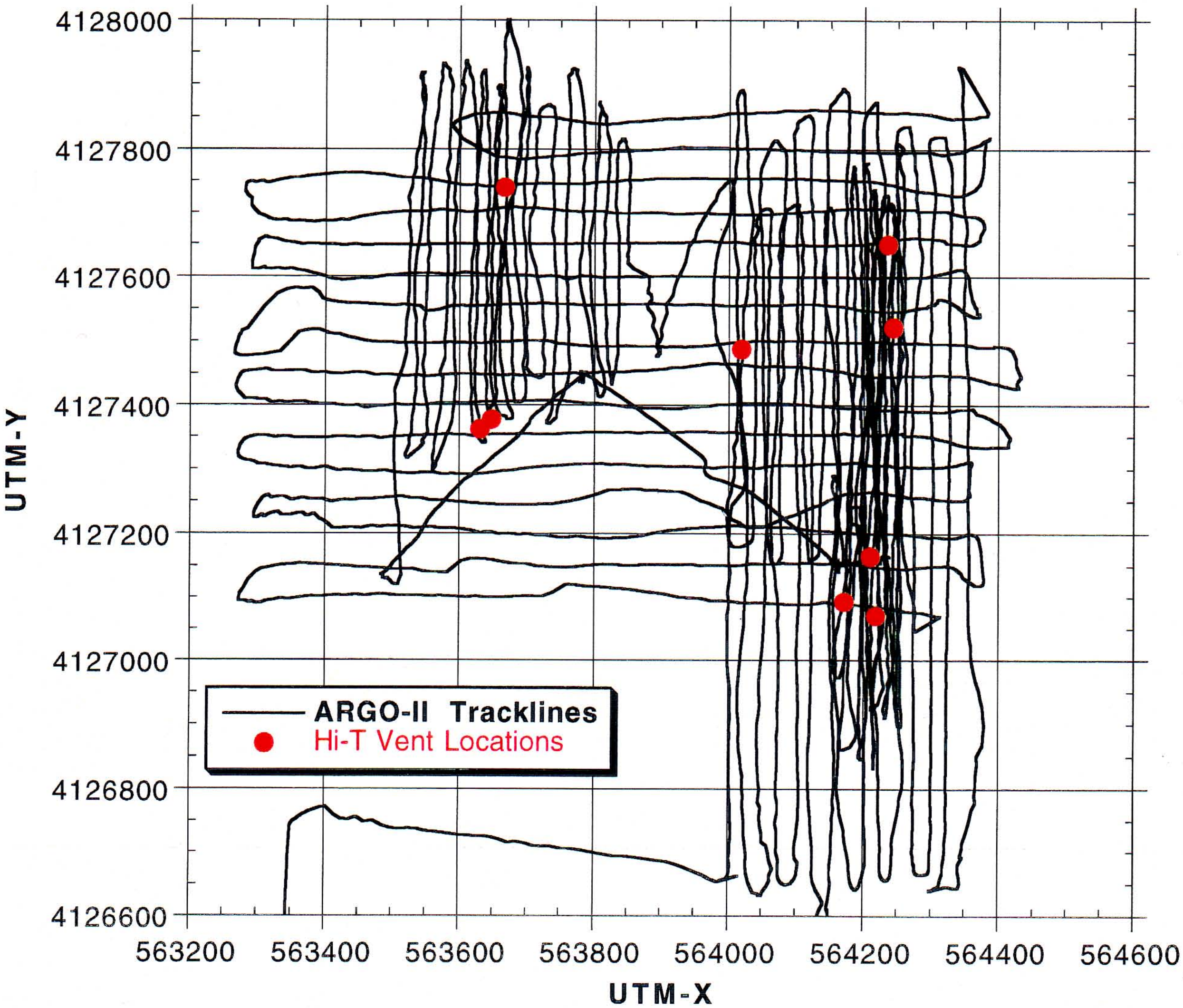

Figure 8 - Tracks of ARGO-II survey lines collected during the LUSTRE '96 cruise.

and consists of a series of sulfide mounds with numerous inactive chimneys. Near the northern edge of the deposit is an ~11 m high active chimney vigorously discharging 308°C fluids. This structure has been named Jason Vent.

Large areas of the summit of Lucky Strike seamount are carpeted by sulfide rubble (Figure 10). The spatial distribution and inferred volume of this material suggests that hydrothermal activity has occurred over a long period of time, and that active tectonism, which has clearly influenced the structural development of the seamount as it grew, has resulted in a relatively continuous disaggregation of sulfide structures and mass-wasting of the hydrothermal debris. Exposures into the slope at the northwestern and eastern regions of the summit area suggest that a large percentage of the exposed rock surfaces at the inside base of each summit cone consists of sulfide rubble and/or hydrothermally cemented slab facies.

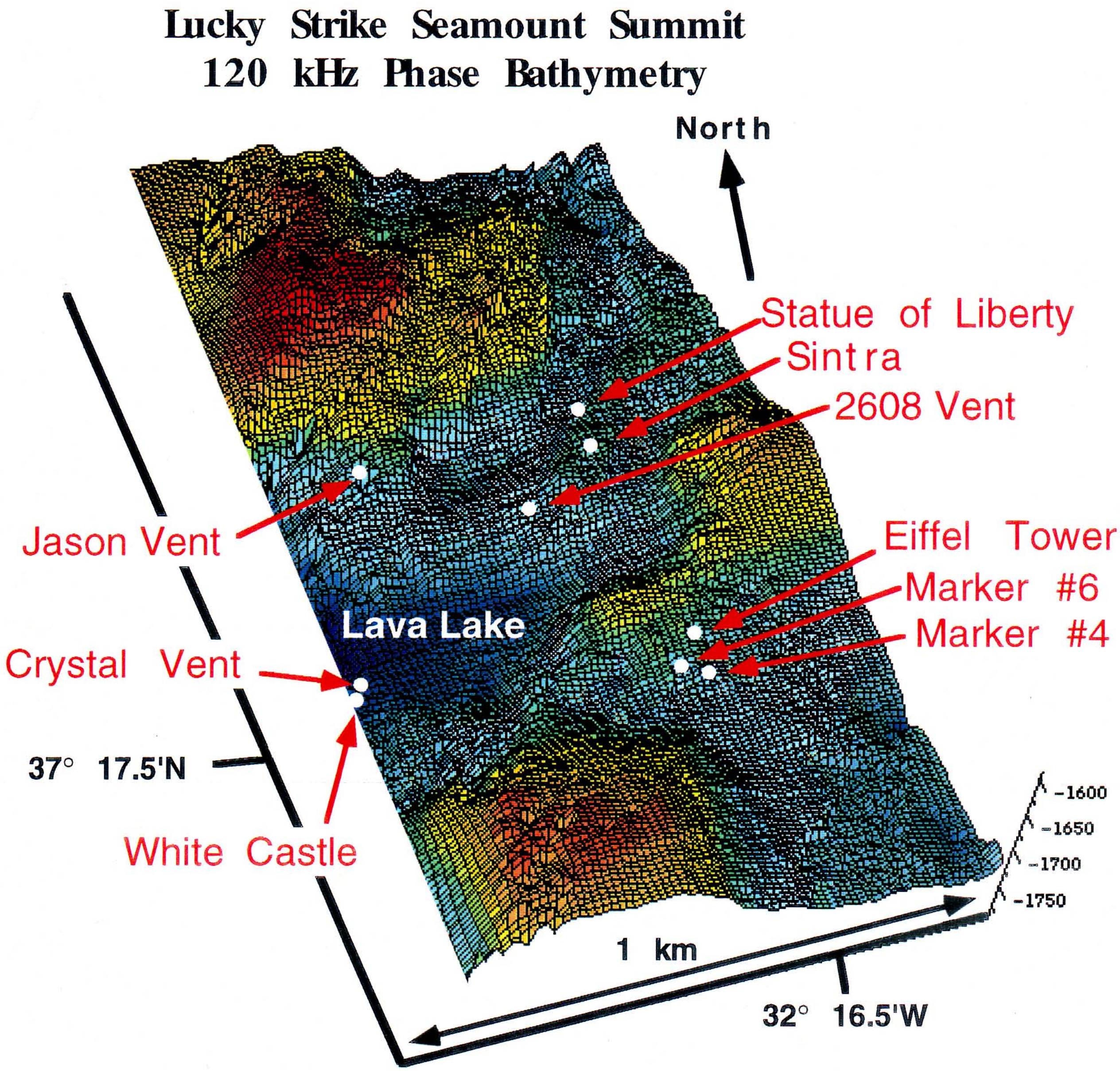

Figure 9 - Perspective surface model using 120 kHz phase-bathymetry data from Line 15 of the DSL-120 sonar survey on the summit of Lucky Strike seamount. View is to the north-northwest. Locations of principal high temperature hydrothermal vents are shown.

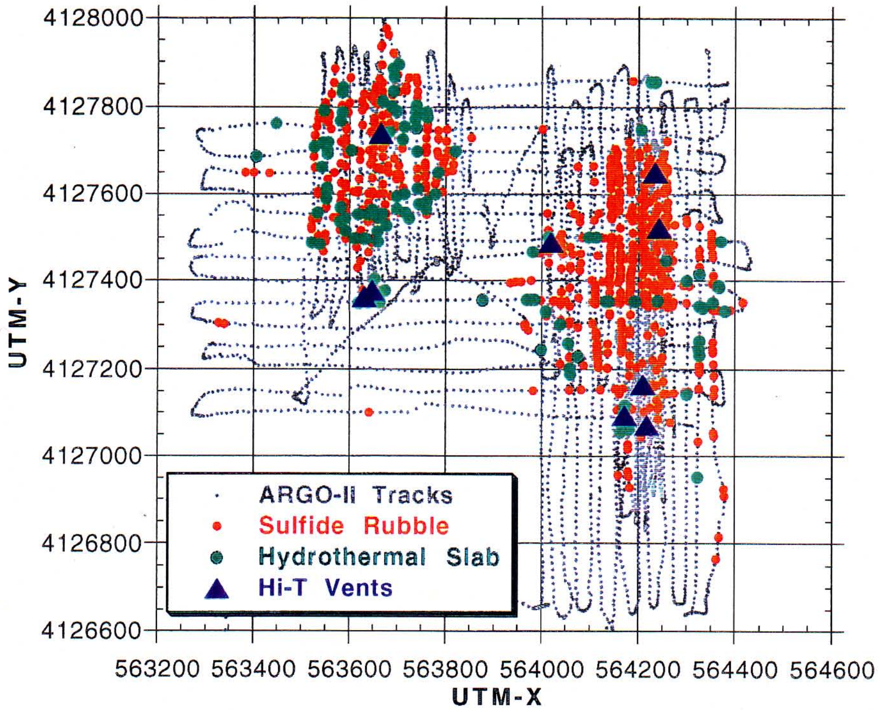

Figure 10 - Hydrothermal sediment, rubble and slab facies mapped using digital event data from the ARGO-II survey on the summit of Lucky Strike seamount.

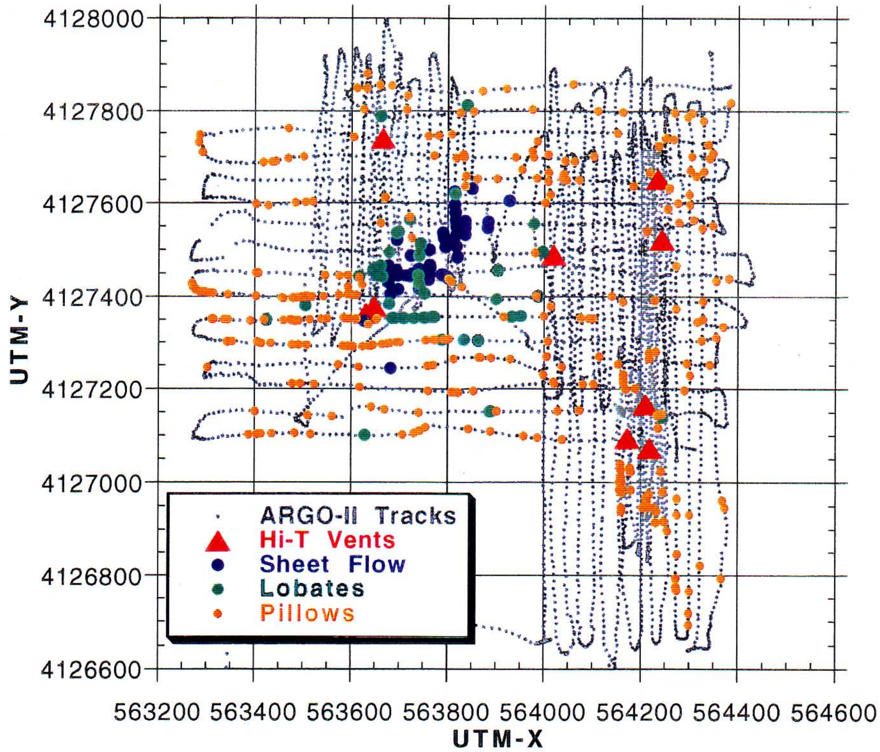

Figure 11 - Volcanic flow types mapped using digital event data from the ARGO-II survey on the summit of Lucky Strike seamount.

ROV Jason Lowerings

Observations and Sampling

Nine Jason lowerings were conducted during the cruise: eight at Lucky Strike and one at Rainbow Ridge. One lowering at Lucky Strike (#182) had to be abandoned prior to reaching the sea floor because of problems with the claw on the manipulator. However, the other seven lowerings successfully carried out various elements of the sampling program. Tracks for each lowering at Lucky strike are compiled in Figure 12. Figure 13 summarizes the time expended on various science operations. Table 5 gives the positions of principal high temperature vents sampled during the LUSTRE '96 cruise. A complete listing of all samples collected on each lowering is given in Table 6.

Jason Lowering #176 - Lucky Strike: 7-8 July

The location of the Lucky Strike Seamount was confirmed by a 45-minute, one-swath SeaBeam survey using P-code GPS which corroborate the data acquired in 1993 using the Sea Beam system on the *R/V Atlantis II* [Langmuir et al., 1996]. Three transponders were then deployed and surveyed in around the summit of the seamount for use during ARGO II and Jason operations throughout the program.

Lowering 176 of Jason/Medea commenced at 1522Z on 7 July with the objectives of 1) carrying out reconnaissance of the southern portion of the known hydrothermally active area along the southeastern side of the depression, and 2) imaging and sampling of selected hydrothermal sites (Marker 4 and Eiffel Tower). The substrate in the southern area consists of broken slabs of hydrothermally cemented breccia with shell chaff on its surface that increases in abundance with proximity to an active vent site. Mussels are concentrated along those fissures where diffuse flow of hydrothermal fluids was observed.

The first hydrothermal site encountered was considerably different from the previously reported small mounds in this area, and was located about 70-80 m east of Marker 4 and Marker 6 vents (Figure 9). It consisted of an elongate deposit trending ~345° and about 5 m long and 5.3 m high with diffuse flow emanating from most of its surface. Several small chimneys (<0.5 m high) with more vigorous flow of clear fluids were also present. Small mussels covered much of its surface.

The hydrothermal mound marked by Marker #6 was identified to the west of the newly found site. Comparison of its position within the new transponder net compared with that from the 1993 Alvin net suggests that there is an ~80 m offset to the west between navigation data of the 1996 network compared to the 1993 transponder net. The general morphology of the deposit was similar to that observed in 1993, consisting of a mound <1 m high built on a substrate of hydrothermally cemented breccia. A few small patches of mussels were observed in areas of diffuse flow on the mound. A push core (Sample 176-1-1) was attempted in this area and appeared to have been successful when withdrawn from the sediment. However, during its return to its quiver, sediment was seen to be falling out of the core tube and on recovery it was found to be empty.

During a series of E-W transects that were run to find the Marker #4 mound, mussels were observed along many cracks within the slabby, hydrothermally cemented breccia from which diffuse flow was discharging. This substrate does not extend far to the east (probably <50 m) where it is replaced by sediment with basaltic outcrops. A mound with no marker about 3.5 m high with a small, active black smoker chimney on its summit was found to the south of Marker #6. No vent fauna were present on this mound.

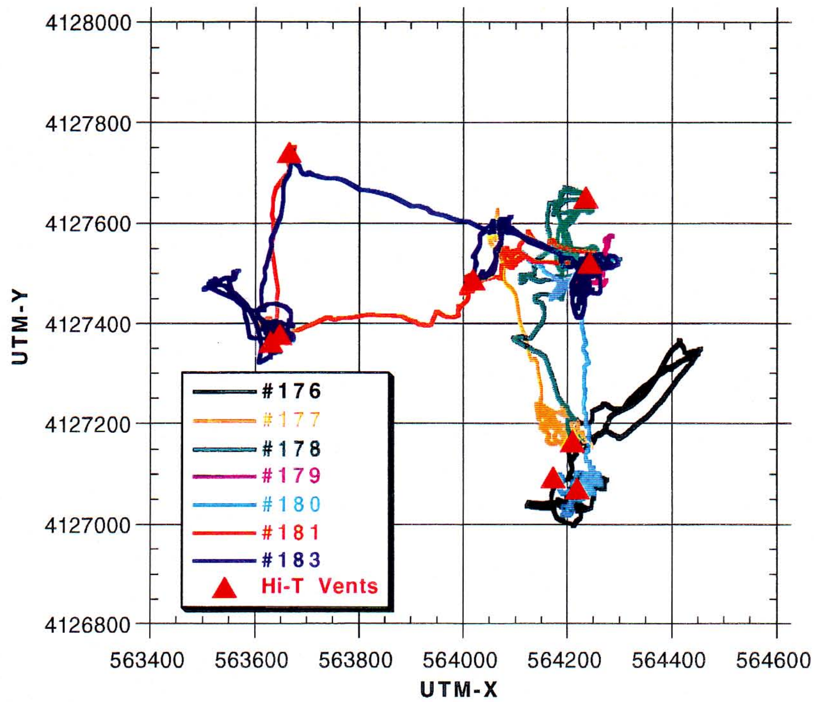

Figure 12 - Tracks of Jason lowerings conducted during the LUSTRE '96 cruise.

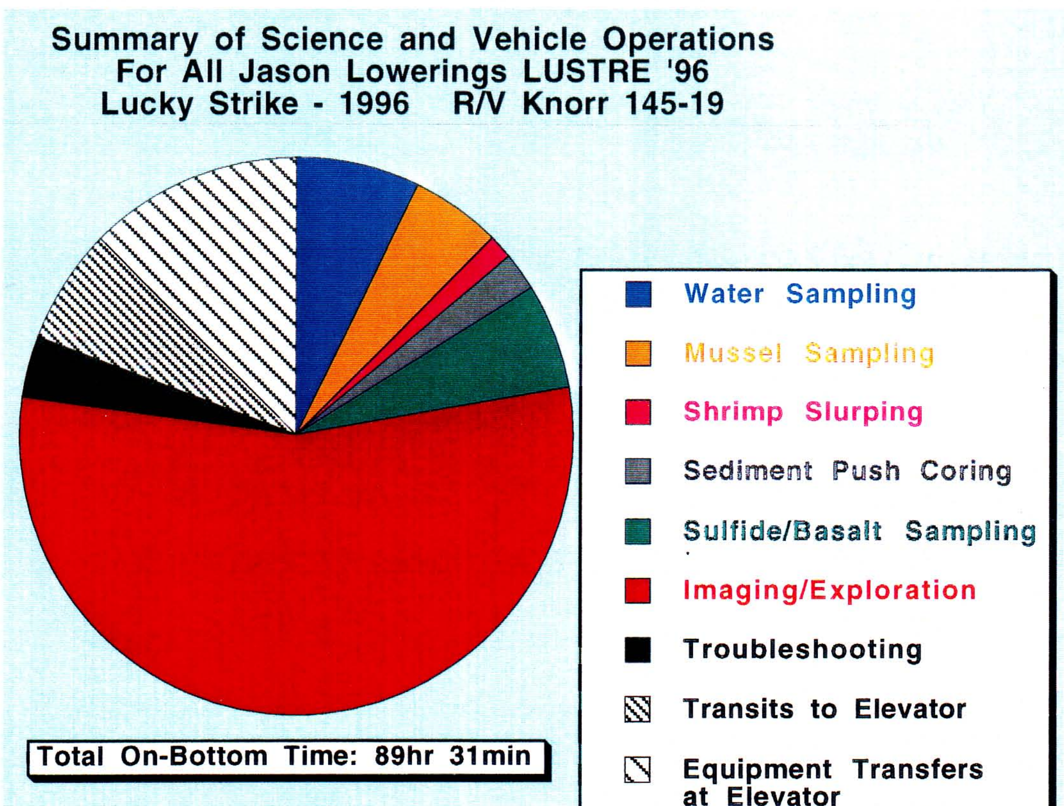

Figure 13

The Marker #4 mound was found 25-30 m southeast of the Marker #6 mound. Since the 1993 observations, the mound has been colonized in areas of diffuse flow by numerous small mussels with mats of filamentous bacteria growing on both the mussels and on the surface of the mound. Other organisms identified included polynoid polychaetes, limpets, brachyuran crabs and shrimp. A small black smoker chimney was present at the base of the 5 m high structure. A clump of mussels was collected from the surface before beginning the transit to Eiffel Tower.

Although the marker set out in 1993 was not observed (Marker #5), Eiffel Tower was found about 50 m north of the Marker #4 mound and was identified based on its distinct morphology. The central spire, which is about 10 m tall and covered with mussels, rises from a wider base of hydrothermal material from which both diffuse flow emanates. Vigorous flow of clear hydrothermal fluids was also observed from a few small chimneys. A series of fluid samples was taken at this site. A 35 mm photomosaic of an area selected for mussel collection was made prior to disturbance by sampling. Temperature measurements both on the surface of the mussel shells and in between them ranged from close to ambient (~4.5°C) up to 10.8°C (Figure 14). One sample (four clumps - Sample 176-2-1) of mussels was then collected from one small portion of the mussel sampling area, and the area marked (Marker "L") for future sampling from the same area.

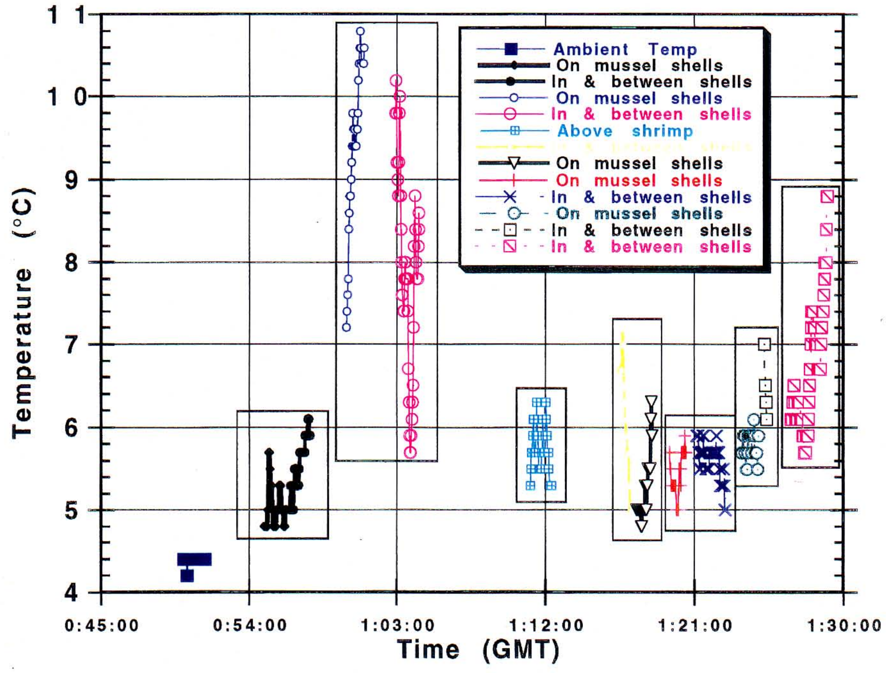

Figure 14 - Discrete temperature measurements among mussels and shrimp at Eiffel Tower vent, made using Vemco Minilogger™ self-recording temperature probes (2 sec. sampling interval).

The ship was then maneuvered ~350 m to the northeast in order to reach the elevator launch position. This transit up the side of the eastern cone crossed over a series of ridges trending ~N-S consisting of sediment with outcrops of broken pillows. Several pieces of black coral were also collected (Sample 176-3-1), as well as a fragment of weathered basalt (Sample 176-3-2) that was not recovered.

The elevator was launched at 0424Z on 8 July, and Jason/Medea returned to the Eiffel Tower site. Stalked hydroids barnacles were observed in the talus at the base of the hydrothermal deposit. A small orifice was selected for sampling fluid, and water with a temperature of 289°C (Sample 176-4-1) was collected. The slurp gun was then used to sample shrimp from the same area (Sample 176-4-2). Jason/Medea returned to the elevator to off load all of the samples. The elevator was recovered at 1400Z, and Jason/Medea was brought on deck at 1430Z on 8 July.

Jason Lowering #177 - Lucky Strike: 18-19 July

The mission for Jason Lowering 177 was to complete the sampling program at Eiffel Tower and then to move on to the Statue of Liberty and Sintra vent sites located about 400-500 m to the north (Figure 9). An elevator was deployed at 1648Z on 18 July and landed 50-60 m NW of Eiffel Tower. During this deployment, one of the transponders ceased responding, and so an additional transponder had to be deployed and surveyed in to provide sufficient coverage for operations at the summit of Lucky Strike seamount.

Jason was launched at 0013Z on 19 July. During the transit to Eiffel Tower, two pieces of hydrothermally cemented hyaloclastite (Sample 177-1-1 and 2-1) were collected. Once on site, the mussel sampling program continued with the collection of two buckets of mussels (Samples 177-3-1 and 177-3-2) from the area of the "L" marker positioned on the previous dive. Jason then returned to the elevator to pick up the final two mussel buckets,

Table 5 - Locations of all high temperature hydrothermal vents on the summit of Lucky Strike seamount sampled during the LUSTRE '96 cruise.

	UTM Coordinates		Latitude	Longitude	
Vent	X	Y	N	W	Depth (m)
Eiffel Tower	564210	4127166	37° 17.33'	32° 16.54'	1687
Marker 4	564218	4127072	37° 17.28'	32° 16.53'	1700
Marker 6	564172	4127094	37° 17.29'	32° 16.56'	1703
Statue of Liberty	564235	4127651	37° 17.60'	32° 16.52'	1630
Sintra	564243	4127522	37° 17.53'	32° 16.51'	1618
2608 Vent	564019	4127489	37° 17.51'	32° 16.66'	1719
Jason Vent	563666	4127740	37° 17.65'	32° 16.90'	1644
Crystal Vent	563648	4127378	37° 17.45'	32° 16.92'	1726
White Castle	563631	4127363	37° 17.44'	32° 16.93'	1724

Table 6 - Listing of samples collected on each Jason lowering during the LUSTRE '96 cruise.

JASON LOWERING # 176 July 7/ 8 1996

Sta#	Time (Z)	UTM -X Longitude	UTM-Y Latitude	Depth (m)	Data & Samples Collected
1	19:09	564172	4127100	1703	Sediment push core sample #1 at Marker 6 - No Rec.
2	01:40	564207	4127171	1687	Mussel sample #1, box No. 1, at Eiffel Tower
3	03:37	564441	4127343	1639	Black coral, sample #1
3	03:55	564444	4127346	1639	Weathered basalt from outcrop, sample #2; Not Rec.
4	08:14	564214	4127172	1690	Water sample #1(green pair),t=296°C, -Eiffel Tower
4	08:22	564216	4127171	1689	Shrimp slurp sample #2, at Eiffel Tower

JASON LOWERING # 177 July 19 1996

Sta#	Time (Z)	UTM -X Longitude	UTM-Y Latitude	Depth (m)	Data & Samples Collected
1	04:19	564157	4127186	1689	Hydrothermal slab, sample #1
2	04:41	564212	4127156	1700	Hydrothermal slab, sample #1
3	05:20	564218	4127168	1688	Mussel sample #1, box No.1, at Marker L
3	05:39	564218	4127168	1688	Mussel sample #2, box No. 3, at Marker L
4	06:28	564162	4127208	1685	Basalt, sample #1
5	09:05	564204	4127167	1687	Mussel sample #1, box No.4, at Marker L
5	09:33	564204	4127167	1687	Mussel sample #2, box No.5, at Marker L
6	17:50	564225	4127166	1689	Water sample #1 (yellow pair), t=323°C, -Eiffel Tower
6	18:27	564225	4127166	1689	Water sample #2 (red pair), t=323°C,- Eiffel Tower

JASON LOWERING # 178 July 20 1996

Sta#	Time (Z)	UTM -X Longitude	UTM-Y Latitude	Depth (m)	Data & Samples Collected
1	05:53	564226	4127174	1689	Gas tight sample # 1, (blue), serial No.4, - Eiffel Tower
2	07:11	564157	4127459	1662	Fe- oxyhydroxide, sample # 1
3					Chimney sample #1, Eiffel Tower (volunteer)

JASON LOWERING # 179 July 21 1996

Sta#	Time (Z)	UTM -X Longitude	UTM-Y Latitude	Depth (m)	Data & Samples Collected
1	05:48	564258	4127535	1619	Crab trap sample # 1, at Sintra (Marker 3)
1	06:18	564249	4127528	1618	Vemco probes sample # 2
2	06:29	564246	4127528	1619	Sulfide chimney sample #1, clear water vent, Sintra
2	06:47	564247	4127524	1618	Water sample # 2, (yellow pair), t=222°C, at Sintra
2	06:55	564249	4127528	1618	Shrimp slurp sample # 3, at Sintra
2	06:55	564249	4127528	1618	Part of chimney, sample #4 (volunteer)

Table 6 (continued) - Listing of samples collected on each Jason lowering during the LUSTRE '96 cruise.

JASON LOWERING # 180 July 27 1996

Sta#	Time (Z)	UTM -X Longitude	UTM-Y Latitude	Depth (m)	Data & Samples Collected
1	03:22	564218	4127072	1700	Sulfide sample # 1, at Marker 4
1	04:05	564218	4127071	1700	Water sample # 2, (green pair), t=318°C, at Marker 4
1	04:19	564219	4127072	1700	Shrimp slurp sample # 3, at Marker 4
1	06:27	564219	4127069	1700	Water sample # 4, (yellow pair), t=318°C, at Marker 4
1	06:34	564219	4127071	1700	Gas tight sample # 5, (blue), at Marker 4
1	06:45	564219	4127069	1700	Shrimp slurp sample # 6, at Marker 4
2	08:22	564195	4127034	1702	Sediment push core sample # 1, (yellow clay), SW Marker 4
3	09:07	564226	4127050	1705	Sediment push core sample # 1, NW of Marker 4
4	12:11	564236	4127072	1705	Hydrothermally cemented slab sample # 1, NW of Marker 4
5	15:09	564259	4127530	1618	Water sample # 1, (white pair), t=222°C, at Marker 3 Sintra
5	15:29	564258	4127531	1618	Gas tight sample # 2, (green), t=222°C, at Marker 3 Sintra
6	16:10	564186	4127482	1655	Coral sample # 1, mound off from Sintra

JASON LOWERING # 181 July 28 1996

Sta#	Time (Z)	UTM -X Longitude	UTM-Y Latitude	Depth (m)	Data & Samples Collected
1	09:37	564259	4127533	1621	Mussel sample #1, box No.4, at Sintra
1	10:23	564259	4127533	1621	Mussel sample #2, box No.3, at Sintra
2	14:16	564018	4127488	1727	Shrimp slurp sample #1, at 2608 vent

JASON LOWERING # 183 July 29/ 30/ 31 1996

Sta#	Time (Z)	UTM -X Longitude	UTM-Y Latitude	Depth (m)	Data & Samples Collected
1	18:45	564019	4127489	1719	Water sample #1, (green pair), t=328°C, at 2608 vent
1	19:05	564019	4127489	1719	Gas tight sample #2, (blue), t=328°C, at 2608 vent
1	19:43	564015	4127487	1731	Sulfide sample #3, at 2608 vent - lost
1	21:55	564017	4127489	1719	Water sample #4, (yellow pair), t=328°C, at 2608 vent
1	22:02	564017	4127489	1719	Sulfide sample #5, top of chimney at 2608 vent
1	22:08	564020	4127488	1720	Shrimp slurp sample #6, at 2608 vent
1					Sulfide chimney sample #7 (fvolunteer), 2608 vent
2	05:08	564261	4127533	1618	Mussel sample #1, box No.5, at Sintra
2	05:08	564261	4127533	1617	Sulfide sample #2, (red brown), at Sintra
2	05:23	564261	4127533	1618	Mussel sample #3, box No.1, at Marker 3 Sintra
2	08:15	564259	4127530	1618	Mussel sample #4, box No.3, at Marker 3 Sintra
2	08:29	564258	4127529	1618	Mussel sample #5, box No.2, at Marker 3 Sintra
2	11:59	564284	4127510	1629	Sediment push core sample # 6, at base of Sintra
3	13:02	564213	4127466	1645	Niskin sample #1, at Sintra

Table 6 (continued) - Listing of samples collected on each Jason lowering during the LUSTRE '96 cruise.

JASON LOWERING # 183 (continued) July 29/ 30/ 31 1996

Sta#	Time (Z)	UTM -X Longitude	UTM-Y Latitude	Depth (m)	Data & Samples Collected
4	16:30	563653	4127739	1644	Water sample #1, (red pair), t=308°C, at Jason vent
4	17:08	563666	4127740	1644	Sulfide chimney sample # 2, at Jason vent
4	17:17	563666	4127741	1644	Water sample #3, (white pair), t=308°C, at Jason vent
5	19:18	563626	4127331	1713	Basalt outcrop sample #1, SW of lava lake
6	19:29	563654	4127327	1714	Sulfide sample #1, at Crystal
7	23:55	563631	4127363	1724	Sediment push core sample #1, at White Castle
7	00:30	563634	4127366	1724	Sediment slurped sample #2, at White Castle
8	02:11	563648	4127378	1726	Water sample #1, (green pair), t=281°C, at Crystal site
8	03:19	563650	4127380	1729	Water sample #2, (yellow pair), t=281°C, Crystal site
8	03:42	563650	4127380	1729	Sulfide sample #3, at Crystal site
9	05:24	563520	4127476	1689	Niskin sample #1

collecting a sample of weathered basalt (Station 177-4-1) on the transit. The mussel sampling program at Eiffel Tower was completed with the collection of Samples 177-5-1 and 177-5-2, and the buckets placed in the elevator. Two major pair water samplers and a sulfide sampler were then picked up and Jason returned to Eiffel Tower. Several attempts to collect a piece of the chimney that was to be sampled for fluid were unsuccessful because of the friable nature of the chimney walls. A small orifice was then excavated and two fluid samples were collected with temperatures of 323°C (Samples 177-6-1 and 177-6-2). These were placed in the elevator and a gas-tight sampler picked up before the elevator was released. However, while attempting to collect a gas-tight water sample, the tube that contains the thermocouple for the inductively-coupled temperature probe became tangled, and Jason had to be recovered. This also provided the opportunity to repair one of the lateral thrusters on Jason and the slurp gun which had failed to work.

Jason Lowering #178 - Lucky Strike: 20 July

Jason Lowering 178 returned to Eiffel Tower and successfully collected a gas-tight water sample (Sample 178-1-1), although the slurp gun still did not function. Jason then headed north to find a suitable site for multidisciplinary sampling of the vents that had lower temperatures in 1993 [Langmuir et al., 1996]. During the transit, a piece of weathered basalt was collected (Sample 178-2-1). The first site located was the Statue of Liberty (Figure 11); however, this structure appeared to be less active and with fewer mussels than in 1993, and not a good sampling target.

Sintra was found and confirmed by the presence of Marker #3 that was deployed in 1993 (Figure 9). It exhibited a very similar morphology to that described in 1993, consisting of two main structures, the taller of which was about 6 m high. On one side of the structure, abundant mussels (and a few sea urchins of two different species), and small chimneys with focused flow as well as diffuse flow, were present, while the other side of the main chimney was concave and inactive, suggesting that it might have collapsed away from the main structure. Given the abundance of mussels (of multiple size classes) and the presence of focused flow through small chimneys, this site was selected as the sampling site for the northern area. However, when preparing to collect samples, the elbow of the manipulator malfunctioned requiring that Jason be recovered for repairs. A volunteer piece of sulfide found on the basket was ascribed to other sampling operations at Eiffel Tower.

Jason Lowering #179 - Lucky Strike: 21 July

At 0210Z on 21 July, an elevator was launched to land in the vicinity of Sintra so that a complete sampling program could be carried out. Jason Lowering 179 commenced at 0320Z and during transit across the sea floor to Sintra, Marker #2 from the 1993 Alvin dives was found in an area of pillow lavas.

Once at Sintra, a baited crab trap was deployed (Sample site 179-1-1) at the base of the structure. In addition, Vemco self-recording low-temperature probes (Sample site 179-1-2) were placed in an area of diffuse flow on the shoulder between the two chimney structures to make time-series measurements. It was planned that these two pieces of equipment would be left and picked up during a subsequent Jason lowering. A small chimney on the western end of the structure was selected as the sampling site for sulfides and fluids, and a small chimney was collected (Sample 179-2-1). The orifice was then excavated, and a fluid with a temperature of 221°C (Sample 179-2-2) was sampled. The slurp gun was then used to successfully capture shrimp (Sample 179-2-3) by slurping through the mussel beds. A large piece of sulfide that fell into the basket during slurp operations was kept as Sample 179-2-4. Jason then returned to the elevator, but while transferring the sulfide sample, the problem with the elbow on the manipulator arm recurred and the lowering had to be abandoned. Both Jason and the elevator were returned to the surface and preparations were made to launch ARGO-II. During the ARGO-II surveys, repairs were made to Jason in preparation for additional work later in the cruise.

Jason Lowering #180 - Lucky Strike: 26-27 July

The goal of Jason Lowering 180 was to attempt to complete all of the sampling from the vent sites at the eastern margin of the summit depression that were previously studied in 1993. Fluid sampling at the Marker #4 vent (Figure 9) was selected as the highest priority, since it exhibited the highest H_2 concentrations in 1993. The elevator was launched at 2118Z on 26 July, followed by Jason at 2232Z. After some initial power supply problems, Jason reached the bottom and traversed sediment-covered slab material to the Marker #4 site.

A small chimney was selected just south of the marker as the sampling site for sulfides and fluids, and a few small pieces of the chimney were collected (Sample 180-1-1). The orifice was then excavated, and a fluid with a temperature of 318°C (Sample 180-1-2) was sampled. While Jason was in position against the chimney, the slurp gun was used to collect shrimp from around the mussels (Sample 180-1-3). Jason then transited to the elevator, transferred the samples already collected, and picked up a second major pair and gas-tight water samplers before returning to the Marker #4 vent. The major pair water sample (temperature 318°C) was taken (Sample 180-1-4) from the same orifice, followed by the gas-tight sample (Sample 180-1-5). A second slurp sample was also taken in an attempt to increase the number of shrimp collected (Sample 180-1-6). This completed the sampling from the Marker #4 vent, and Jason returned to the elevator to off load the samples. The box of push cores was then picked up with the objective of collecting two types of sediment. Some patches of bright yellow material (hydrothermal clay?) that were deposited along a crack in the hydrothermally cemented slab substrate were sampled (Sample 180-2-1) about 40 m SW of the Marker #4 vent. In addition, a sample of the iron oxyhydroxide sediment was collected from a few meters to the NW of the Marker #4 vent (Sample 180-3-1). The push core box was returned to the elevator and the HOBO temperature probe and a major pair were picked up. A 5 minute temperature recording was made at the Marker #4 vent with the HOBO to provide a calibration of the inductively-coupled temperature probes. The probe was then returned to the elevator prior to its release. While waiting for the recovery of the elevator, a piece of hydrothermally cemented slab was collected (Sample 180-4-1) about 15 m north of Marker #4.

Jason then departed for Sintra traversing over sediment-covered hydrothermal slab with occasional inactive sulfide mounds and chimneys. Once on site, the second fluid sample from this site was collected with a temperature of 220°C (Sample 180-5-1). A gas tight sample with a temperature of 221°C (Sample 180-5-2) was also collected. While waiting for the elevator to be deployed, an unusual black, rosette-shaped structure a few cm. in diameter was observed on the side of an inactive chimney. This was sampled and proved to be a coral (Sample 180-6-1). While transiting to the elevator, Jason lost all telemetry, so this lowering had to be terminated and Jason was recovered, with the samples being removed from the basket at the surface by a swimmer.

Jason Lowering #181 - Lucky Strike: 28 July

Jason Lowering 181 commenced at 0423Z on 28 July and went straight to the elevator dropped at the end of the previous lowering to pick up two mussel boxes. These were both filled to complete the mussel sampling at Sintra and Jason returned to the elevator (Samples 181-1-1 and 1-2). However, the claw on the manipulator arm failed and the basket of Jason could not be unloaded. Since sampling was now complete at this vent, the elevator was released and Jason was then used in a reconnaissance mapping mode to locate the other vents at which sampling was planned for future lowerings.

Based on the ARGO-II survey, a range and bearing was established for the 2608 vent about 80 m to the west of Sintra. Vent 2608 was located near the edge of the lava lake (Figure 9). It is a spire, ~13 m high, with a narrow base that widens into a bulbous, mussel covered white structure a few meters above the base, from which clear, diffuse flow emanates. Above this, two thin chimneys extend several meters high with only a few shrimp on their surface. Vigorous black smoke discharges from these chimneys and also from smaller orifices on their surfaces. A video and 35 mm survey of the entire structure was completed. A slurp sample (Sample 181-2-1) was taken in an attempt to collect shrimp and bacteria from around the mussels covering the bulbous white structure about half way up the spire.

The survey continued to the southwest with the objective of defining the edge of the lava lake and describing some of the flow textures and surface morphology of the lava, as well as investigating two active vents on the west side of the lava lake identified during the ARGO-II survey. Along the edge of the lava lake, collapse pits and lava pillars were observed, and lava morphologies ranged from lobate pillows to sheet flows with ropy to hackly textures (Figure 11 and Plate B). On the SW edge of the lava lake, a field of small diffusers was observed. In general, these structures were located on the tops of small sulfide mounds up to 1 m high, and consisted of small (<1 m) white bulbous chimneys with clear fluids discharging vigorously from their surfaces. Although bacteria was present on some of the structures, no other vent fauna was observed.

Jason then transited north to a large area of relict sulfides on the NW side of the lava lake, where a large active chimney had been identified in the ARGO-II survey. This area consisted of a series of sulfide mounds several meters high, on the top of which were many inactive chimneys. The active vent (named Jason vent) consisted of a tall chimney about 11 m high, with mussels on parts of its outer surface. Video and 35 mm imagery were taken of the structure before Jason was recovered for repairs to the manipulator.

Jason Lowering #182 - Lucky Strike: 29 July

The objective of this lowering was to collect samples from the 2608 vent and then to move to the W side of the lava lake for further sampling at the other two areas of hydrothermal activity.

The elevator for Jason Lowering 182 was launched at 2334Z on 28 July, followed by the launch of Jason at 0153Z on 29 July. Tests were run on the claw of the manipulator at 100 m and 600 m to ensure that it was working. However, at 1500 m, the claw became intermittent and unreliable, and so the lowering was terminated and Jason was recovered at 0717Z.

Jason Lowering #183 - Lucky Strike: 29-30 July

The lowering commenced at 1600Z on 29 July after repairs had been made to the manipulator and transited directly to the 2608 vent. The goal of this lowering was to conduct the sampling at 2608 vent and then complete the mussel sampling at Sintra before moving to the vents on the west side of the lava lake (Figure 9).

Attempts to collect a sulfide sample *in situ* at the 2608 vent failed due to the friable nature of the chimney wall material, so an orifice was excavated in preparation for fluid sampling. The first major pair and a gas tight sample were taken (Samples 183-1-1 and 1-2 respectively) when the fluid temperature was 328°C. A sample of sulfide (Sample 183-1-3) was then collected at the base of the structure from a piece of the chimney that had been knocked off during the excavation process for water sampling, but this sample was later lost when it crumbled during transfer to the elevator. After picking up another major pair, as well as a marker labeled "2608" for deployment at the site, Jason returned to the 2608 vent and deployed the marker on the SE side of the vent. The second major pair sample was taken from the same orifice (Sample 183-1-4), and a sample of sulfide from the mouth of the orifice was broken off (Sample 183-1-5). The slurp gun was then used to collect shrimp (Sample 183-1-6) from the same station.

All of the samples were then placed in the elevator, and two bio-boxes and a scoop designed to collect mussels were picked up so that the mussel sampling program at Sintra could begin once the elevator was recovered. Once the elevator was recovered at 0230Z on 30 July, Jason transited to the area of Sintra to a position for redeployment of the elevator. Mussel sampling was completed at Sintra (Samples 183-2-1, 2-3, 2-4 and 2-5) and a small sample of oxidized sulfides was recovered (Sample 183-2-2). The Vemco low-temperature probes were recovered, but the crab trap was left in place as no crabs had been collected. After depositing all of the samples and equipment in the elevator, the push core box was picked up and a sample taken of the iron oxyhydroxide sediment at the base of Sintra (Sample 183-2-6). Finally, a Niskin bottle was tripped to collect a sample of ambient bottom seawater (Sample 183-3-1) and two major pairs were placed on Jason's basket before the elevator was returned to the surface.

Jason then transited in the water column to the Jason vent on the NW side of the lava lake and excavated a small orifice for sampling. Two major pair fluid samples were collected (Samples 183-4-1 and 4-3) at a temperature of 308°C, as well as a small sulfide chimney fragment from the same site (Sample 183-4-2). This completed the sampling program at the Jason vent on the NW side of the lava lake. Jason then transited south to the clear diffuser vents on the SW side of the lava lake in the water column. While waiting for the elevator to be readied for deployment, two sites were selected from among the many small vents in the area; one for collection of a water/sulfide sample pair (at a vent named Crystal), and the other for a push core (at a vent named White Castle) (Figure 9).

The elevator was launched at 1903Z on 30 July and, while waiting for it to descend, a basalt sample (Sample 183-5-1) and a relict sulfide sample (Sample 183-6-1) were collected from two different areas. Once the sample and equipment transfer at the elevator had taken place, Jason maneuvered to the White Castle vent and attempted a push core (Sample 183-7-1) at the base of the slope of a mound leading up to a small (<1 m) white diffuser. Since the sediment proved to be extremely light and fluffy, this was only partially successful, so the slurp gun was used to collect additional sediment (Sample 183-7-2). The push core box was then left at the site, while Jason headed over to the Crystal vent to collect fluids and a sulfide sample. Two fluid samples were taken with temperatures of 281°C (Samples 183-8-1 and 8-2) from a wide orifice that was vigorously discharging very clear fluids. Finally, a sulfide sample (Sample 183-8-3) was collected adjacent to the water sampling orifice.

Jason returned to the elevator with the fluid and sediment samples to off load. The Niskin bottle on the elevator was tripped to provide an ambient bottom water sample (Sample 183-9-1), since the valve on the Niskin bottle, which was tripped on the previous dive, had leaked. This completed the planned sampling program for the vents at Lucky Strike, and the elevator and Jason were recovered.

Jason Lowering #184- Rainbow Ridge: 1-2 August

Prior to the final Jason lowering, three transponders were deployed on the west side of Rainbow Ridge and surveyed.

Jason Lowering 184 commenced at 0129Z on 1 August. The objective of the lowering was to survey features on the western side of Rainbow Ridge identified on the TOBI records as potential source sites for the large hydrothermal plume that had been observed in the water column at about 2000 m depth. Jason was lowered at the point where the maximum transmissometer signal had been detected earlier in the cruise, and a small anomaly was detected. No evidence for hydrothermal activity was observed on the sea floor. The terrain was heavily sedimented with variable accumulations of talus that ranged in size from cobbles to large rectangular blocks 3-5 m in size. Much of the western slope of Rainbow Ridge was sediment-covered, with numerous ripple marks suggestive of very strong currents in the area. A steep fault, a few meters high just to the east of the plume site exposed massive weathered rock on the exposed face.

Further to the north of the plume site, a circular, low backscatter feature was investigated that proved to not be significantly different from the rest of the sediment-covered terrain. Jason then continued north to the site of Dredge #1 in which clam shell fragments and a few relatively fresh-looking mussel shells had been recovered. The dredge track was located, and was followed upslope; however, no additional evidence of hydrothermal deposits was found. Jason then traversed back to the south along the contour interval at which the hydrothermal activity was expected to be present (based on plume height calculations); however, no evidence for sea floor hydrothermal venting was detected. Recovery of Jason commenced at 0401Z on 2 August with the transmissometer profile again being recorded on the ascent. Following its recovery, the transponders were recovered before departing for Woods Hole.

Sample/Data Descriptions

Fluid Chemistry

High temperature hydrothermal fluids (pairs of titanium, major syringe samplers as well as four (4) gas tight fluid samples for M. Lilley - UW) were collected from vent sites at Lucky Strike vents as part of a time series data set begun in 1993 [Langmuir et al., 1996]. The samplers were fitted with inductively-linked temperature probes, developed by A. Bradley, B. Walden and R. Catanach (WHOI), and modified for use on Jason by E. Snow (WHOI), to provide real-time temperature monitoring during the fluid sampling (see Appendix IV). Total alkalinity, pH, H_2S, silica and salinity based on refractive index were determined shipboard. The remaining fluid analyses for major elements will be done on shore at U. New Hampshire and U. Washington.

A total of 26 vent fluid samples were collected as well as a sample of bottom seawater using a Niskin bottle to serve as a reference for the local bottom seawater chemistry. Fluids were collected from the following vents: Eiffel Tower, Sintra, Marker #4, Dive 2608 Vent, Jason Vent, and Crystal Vent (Table 5). The first 3 of these vents had been sampled during the 1993 Alvin program in this area, and these new data provide time series data for these vents. Jason and Crystal represent newly discovered vents, and thus these are the first fluid samples collected from them. The 2608 vent had been discovered during an Alvin dive but no fluids had been collected, although a temperature was measured. We also attempted to sample the

Statue of Liberty vent, but it was found to be largely inactive. Temperatures measured in 1996 were slightly greater than those in 1993 for Sintra and Marker 4, slightly lower for 2608, and the same within the error for Eiffel Tower (Table 7).

Preliminary shipboard analyses suggest that each vent is slightly different from the others in composition. 2608 vent has higher sulfide and silica concentrations than were measured in any of the samples collected in 1993. This is consistent with it still being the highest temperature vent fluid sampled in this area. Measured pH is also slightly lower than those noted in 1993, although in general Lucky Strike vent fluids have higher pH's than most other sea floor vent fluids [Von Damm, 1990]. All vents have chlorinities either equal to or slightly less than the seawater value, although at their measured temperatures they are all below the local boiling curve for seawater. The most southerly vent, Marker #4, continues to have the lowest chlorinity. Observations and preliminary analyses of fluids from Crystal Vent suggest this vent is somewhat atypical. At its measured temperature of 280°C, most metals (e.g., Fe, Zn) should be retained in solution, yet these fluids were clear. While it is possible that Crystal vent has deposited metal sulfides subseafloor, its relatively high pH argues against this, and the measured H_2S in the fluids suggests that the lack of "smoke" is not due to the lack of this species. Resolution of this will require further shore-based analyses.

Biology

Mussel Sampling

Mussel communities are widely distributed both in shallow water and at deep-sea hydrothermal vents. In shallow water, mussel beds have high species richness but are typically dominated by a few very abundant species. We conducted replicate sampling of vent mussel beds at Lucky Strike (Table 8) to measure species diversity and its structural complexity (interstitial volume, mussel size-frequency). Five replicate samples of mussels and associated biota were sampled and curated from the Eiffel Tower vent site. An additional 6 samples were processed from Sintra vent. Sample volumes ranged from 1.5 to 3.0 liters and the time required to collect each mussel bucket sample (once JASON was in position) averaged 27 minutes. The mussel interstitial community is dominated by shrimp (*Chorocaris fortunata*), amphipods, ostracods, copepods, free-living polynoid polychaetes and polynoid polychaetes commensal with the mussel (*Branchipolynoe seepensis*). All of the macro-invertebrates collected have been counted and identified. A total of 17,242 individual organisms associated with the mussel collections were recovered and 1,400 mussels were sampled. Large samples of individuals of several taxa have been preserved for ancillary studies of reproductive biology, taking advantage of the spatially discrete and replicated sampling technique used. Studies of mussel communities from Lucky Strike and other vent biogeographic provinces will eventually allow us to investigate correlations between spreading rate (and its hydrothermal and biological correlates) and diversity. We expect that local vent biodiversity will reflect a strong regional and historical (phylogenetic) influence underlain by the spatial and temporal constraints on hydrothermal activity imposed by fast- vs slow-spreading rates and by tectonic history.

Evolutionary and Populations Genetics of Hydrothermal Fauna

The question of how hydrothermal vent species disperse and maintain their populations in patchy, ephemeral vent habitats scattered along mid-ocean ridges is one of the most intriguing problems in vent evolutionary ecology. The location of active sites containing vent-endemic shrimp in relation to the regional geomorphologic setting on the slow-spreading MAR provides opportunities to test hypotheses addressing potential barriers to dispersal of vent-endemic organisms. Depth differences, large ridge offsets, and fracture zones can act as an isolating mechanisms, while potential modes of dispersal such as vent plumes may serve to homogenize diversity along a ridge segment. The specific age of formation of each of the fracture zones provides a time-frame over which phylogeographic implications and speciation events can be inferred. Long wavelength cycles of venting (TAG and Snake Pit) and

Table 7 - Shipboard fluid chemistry for high temperature hydrothermal vent fluids sampled during the LUSTRE '96 cruise to Lucky Strike seamount.

Dive #	Date	Bot. #	Type	Vent	Temp °C	pH	Alk meq/l	Silica mmol/l	H_2S mmol/l	Wt. % NaCl
176	7/8/96	13	PR-GR	Eiffel	296	n.m.	1.73	3	0.1385	3.6
		14	PR-GR	Eiffel	296	5.22	0.79	5.96	1.02	3.2
177	7/19/96	5	PR-YL	Eiffel	323	4.53	-0.17	14.1	2.23	3.3
		9	PR-YL	Eiffel	323	4.48	-0.1	14.1	1.62	3.1
		10	PR-RD	Eiffel	323	4.06	-0.14	14.5	1.23	3.0
		16	PR-RD	Eiffel	323	4.22	-0.15	14.4	1.53	3.0
178	7/20/96	GT4	GT	Eiffel	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.
179	7/21/96	5	PR-YL	Sintra	222	4.3	-0.13	11.8	2.01	3.5
		9	PR-YL	Sintra	222	4.6	-0.12	11.8	2.07	3.2
180	7/26/96	5	PR-YL	Mkr4	318	3.77	-0.1	14.6	3.09	2.9
		9	PR-YL	Mrk4	318	4.26	0.4	10.6	2.06	3.2
		11	PR-WH	Sintra	222	4.83	-0.65	6.84	0.526	3.5
		13	PR-GR	Mkr4	318	4.02	-0.01	13.6	2.93	2.9
		14	PR-GR	Mkr4	318	3.87	-0.15	14.1	2.85	2.8
		15	PR-WH	Sintra	222	3.95	-0.02	11.6	1.12	3.4
		GT3	GT	Sintra	222	n.m.	n.m.	n.m.	n.m.	n.m.
		GT5	GT	Mkr4	318	n.m.	n.m.	n.m.	n.m.	n.m.
183	7/29/96	5	PR-YL	2608	328	3.69	-0.18	15.7	4.26	3.3
		9	PR-YL	2608	328	4.65	0.63	9.69	2	3.4
		10	PR-RD	Jason	308	3.93	-0.09	12.4	2.21	3.5
		11	PR-WH	Jason	308	3.96	-0.1	12.9	2.64	3.5
		13	PR-GR	2608	328	3.89	-0.01	15	3.55	3.4
		14	PR-GR	2608	328	3.75	-0.15	15.6	4.46	3.4
		15	PR-WH	NW	308	4.45	0.19	8.84	1.56	3.5
		16	PR-RD	NW	308	4.37	0.15	9.82	2	3.5
		GT7	GT	2608	328	n.m.	n.m.	n.m.	n.m.	n.m.
183-2	7/30-31/96	5	PR-YL	Crystal	281	4.18	-0.06	13.5	1.75	3.4
		9	PR-YL	Crystal	281	4.21	-0.03	13.1	1.65	3.4
		13	PR-GR	Crystal	281	4.66	0.6	8.44	1.25	3.5
		14	PR-GR	Crystal	281	4.12	-0.07	13.8	1.95	3.4
		Niskin		Seawater	4.5	7.11	2.41	0.014	0	n.m.

observations of recent re-activations (Broken Spur and Lucky Strike) observed on the MAR may account for relatively high rates of species turnover as well as our subsequent finding that the bresiliid shrimp inhabiting hydrothermal vents and hydrocarbon seeps represent a recently diverged group (Shank et al. in prep.) .

Recent evidence based on phylogenetic analyses of mitochondrial DNA has revealed that a genetically divergent shrimp inhabits the Lucky Strike vent area. In terms of gross morphology, this species appears most similar to the chorocarids (i.e. in terms of its reduced rostrum and eyes, and anterior cephalothorax morphology), but DNA sequence divergence does not support a close relationship with any of the present genera (Shank et al. in prep.). A total of seventy-three "chorocarid-like" shrimp were collected from Eiffel Tower, Sintra, Marker 4, and the 2608 vent. Molecular approaches will be utilized to reconcile taxonomic groupings with genetic divergence and morphological grades.

The distribution of mitochondrial DNA signatures or haplotypes within species of shrimp discretely sampled at individual chimneys on Lucky Strike seamount will be examined to elucidate levels of mitochondrial diversity within these populations. Lineage diversity among species will also be compared by examining the relationship between number of haplotypes detected and number of individuals sampled. Diverse fauna collected from the Eiffel Tower, Sintra, 2608, and Marker #4 vent site by slurp sampling using Jason included

Table 8 - Listing of mussel samples collected during the LUSTRE '96 cruise to Lucky Strike seamount.

JASON Mussel Samples, LUSTRE '96 - Lucky Strike, July 1996									
LOCATION	Date	JASON #	Box #	Rep #	Start Time	End Time	Elapsed Time (min)	Mussel Volume (L)	Number of Individuals*
Eiffel Tower	07/08/96	176	1	1	01:38	02:05	27	2.2	2,427
	07/19/96	177	1	2	05:05	05:30	25	2.6	687
	07/19/96	177	3	3	05:34	06:02	28	3	1,076
	07/19/96	177	4	4	08:58	09:30	32	2.1	1,680
	07/19/96	177	5	5	09:30	10:11	41	3	1,120
Sintra	07/28/96	181	3	1	09:56	10:23	27	1.5	2,192
	07/28/96	181	4	2	08:46	09:37	51		
	07/30/96	183	5	3	05:06	05:21	15	2	623
	07/30/96	183	1	4	05:21	05:38	17	2.4	660
	07/30/96	183	3	5	08:14	08:29	15	2.1	4,165
	07/30/96	183	2	6	08:29	08:45	16	3	2,612
							mean = 26.7	mean = 2.4	total =17,242

*exclusive of mussels (except mussel post-larvae)

Table 9 - Listing of miscellaneous biological samples collected during the LUSTRE '96 cruise to Lucky Strike seamount.

Miscellaneous Biological Samples, LUSTRE '96 - Lucky Strike, July 1996					
Type	Date	Vehicle	Location	Sample #	Disposition
RAINBOW					
vesicomyid and bathymodiolid shell, solitary coral, gastropod, small deep-sea bivalves	07/05/96	Dredge 1	36° 13.3'N, 33° 53.9'W	164	Van Dover
gastropods, solitary coral, sponges, small deep-sea bivalves	07/06/96	Dredge 2	36°16.0'N, 33°53.24'W	165	Van Dover
LUCKY STRIKE					
juvenile urchin	07/26/96	Dredge 5	37°16.0'N, 32°16.6'W	226	Van Dover for M. Sibuet
sponge, scaphopods, gastropod	07/26/96	Dredge 5	37°16.0'N, 32°16.6'W	228	Van Dover
dried limpets from sulfide sample 179-2-1	07/21/96	JASON 179	Sintra	227	Van Dover
black coral (dead)	07/08/96	JASON 176	37°17.43'N, 32°16.38'W	174	Fornari for S. Hart
Amathys lutzi	07/08/96	JASON 176	Mkr 4 "practice mussels"	175	Shank for R. Lutz
limpets from sulfide sample 183-2-2	07/30/96	JASON 183	Sintra	239	Van Dover
rosette coral from extinct chimney	07/27/96	JASON 180	37°17.5'N, 32°16.5'W	229	Fornari for S. Hart

shrimp, amphipods, pycnogonids, copepods, limpets, mussels, and polynoid polychaetes. These, together with samples collected during the Lucky Strike 1993 expedition will be utilized in ongoing molecular systematic and population genetic studies to elucidate: (1) the evolutionary relationships among these predominant deep-sea hydrothermal vent-endemic taxa; (2) the historical patterns of dispersal via indirect estimate rates of gene flow among disjunct populations along the MAR; (3) patterns of genetic diversity among and within species along a slow-spreading mid-ocean ridge. Congruence of phylogeographic patterns among different species groups can provide strong insights into the processes that have shaped species diversification.

Other Samples

Miscellaneous biological samples were recovered from several Jason lowerings and also from dredges and rock surfaces. These are listed in Table 9 and have been preserved for further studies on shore.

Sediment Coring

Geochemical analysis of hydrothermal sediments provides an empirical approach towards understanding the impact of hydrothermal venting upon oceanic sediment geochemical budgets. During the LUSTRE 96 cruise, a suite of push-core sediment samples were collected for both conventional transition metal analysis and also for novel measurement of a suite of "toxic" metals - Hg, As, Se, Sb and Te.

Push-cores, each 30 cm long and ~7.5 cm diameter, equipped with aluminum (soda-can) core-catchers proved capable of penetrating and recovering sediment in the terrain encountered. Cores were deployed either four at-a-time or two at-a-time in a specially made corer-box mounted in the Jason elevator. Typically, the core box was lifted from the elevator and carried in Jason's manipulator arm to the core site. The weighted box was then placed on a relatively flat spot on the sea floor in the designated coring area, and individual cores removed for coring operations before being returned to their individual quivers.

After coring it became routine practice to leave the core-box in position on the sea floor while other Jason operations continued, the core-box being recovered by Jason only immediately prior to transit back to the elevator for transfer back to the surface.

Three sediment cores were collected during the course of the sampling program, one each in three of the major provinces visited:

1) During Jason lowering #180 a push core was collected from an area of apparent extinct diffuse flow following a fissure through the hydrothermal slab. The material sampled apparently represents weathered sulfides deposited during a time of earlier activity.

2) During Jason lowering #183 a push core was collected from the base of a steep scarp immediately to the south (inactive side) of Sintra. This material clearly represented mass-wasting of weathered sulfide material derived from the main Sintra complex, uphill from the coring site. Active shimmering water and intact and broken extinct chimneys characterized the adjacent area.

3) During Jason lowering #183 an additional push core was collected from the base of the White Castle diffuser vent-site. At this station, push-coring was augmented by further sampling of the thin veneer of surficial oxides (underlain by indurated slab) using the basket-mounted slurp-gun.

Upon recovery, bulk samples from all 3 cores were transferred to polyethylene zip-lock bags and stored in a refrigerator at 4°C to await transport to the laboratory. Sub-samples from each core (approx. 5g wet sediment) were also stored airtight (SaranWrap around screw threads) in glass vials for Hg analysis. These Hg samples were also refrigerated at 4°C to await transport to the home laboratory at SOC-UK.

The sediment coring approach adopted during the LUSTRE 96 Jason operations can be considered to be generally proven and to be recommended for future sediment sampling operations using Jason. The principal recommendation regarding push coring would be for the science party to work with the DSOG in different core catcher designs for difficult, coarse-grained sediment sampling, or in developing other grab sampling techniques for surface sediment sampling. Lastly, the adaptation of box corers used with Alvin should be considered for Jason use where appropriate.

Water Column Studies

Three different types of water column sensors were deployed on the DSOG vehicles: a CTD (conductivity, temperature and depth), a transmissometer, which measures particle abundance inversely related to the light transmission through a 25 cm pathlength, and a backscatter sensor, which measures particle abundance directly related to the amount of backscatter received 180° from the light source. A summary of the sensors used for each of the 15 deployments is shown in Table 10.

Table 10 Water Column sensor summary for LUSTRE '96 Cruise

Deployment	Region	CTD	LSS	LT	Comments
AMS032	Rainbow		X	X	LT plume
AMS033	Rainbow		X	X	LT plume
JAS176	Lucky Strike				
AMS034	Lucky Strike	X	X	X	CTD data bad
AMS035	Lucky Strike	X	X	X	CTD data bad
AMS036	Lucky Strike		X	X	
JAS177	Lucky Strike				
JAS178	Lucky Strike				
JAS179	Lucky Strike				
ARG003	Lucky Strike	X			LT data stream died- no data
JAS180	Lucky Strike				
JAS181	Lucky Strike				
JAS182	Lucky Strike			X	Deployment aborted
JAS183	Lucky Strike			X	
JAS184	Rainbow	X		X	LT plume

CTD Data

Initially the WHOI-DSOG Sea Bird Seacat SBE 19-02 CTD was on the first sonar lowering (032), but was removed when it appeared to cause power problems with the system. Once the power problems were resolved it was put back on for lowerings 034 and 035. However, all of the CTD data from these two deployments were bad. Upon recovery of the vehicle after lowering 035 it was discovered that the connector on the CTD had flooded, and one pin was ~80% corroded. A spare CTD (FSI Micro CTD supplied by Chris German of SOC) had been brought aboard and was placed in service. This CTD was used on the ARG003 deployment and it acquired good data. Only the last Jason deployment at Rainbow was equipped with a CTD. The absolute accuracy of the temperature values are questionable as there was an offset of >0.1°C between different deep (> 2000 db) profiles. However, ignoring the offset problem, individual temperature profiles delineate the structure of the water column. During the time when Jason went through a buoyant plume, warm temperature anomalies were evident in the temperature profile shown in Figure 15, Also shown in the same figure is the light transmission and vehicle depth record for the same period.

Light Scattering Sensor (LSS)

Two Seatech Light Scattering sensors were used, one brought by Chris German (SOC) and one brought by Cara Wilson (OSU). These small, inexpensive devices have proven to be more sensitive detectors of hydrothermal plumes than more traditional light transmissometers. Initially the SOC sensor was on the sonar vehicle for the first deployment. However when power problems were experienced it was removed, thinking that the "at-sea" molding done during a previous cruise was leaking. The OSU sensor was put on the sonar vehicle for lowering 032 and 033. However, it appears that it was incorrectly wired to the vehicle, as it gave large negative voltages in the surface particle layer, as opposed to the expected large positive values. More problematic was that the signal, which was very quiet throughout the surface layer, became very noisy at depth. This was probably because the sensor was hooked up at low sensitivity range, rather than at the higher sensitivity range that is optimal for hydrothermal plumes. A plume that was detected with the light transmissometer during both lowerings 032 and 033 was not visible in the LSS record. Between the end of lowering 033 and the start of lowering 034 the OSU LSS stopped drawing current. Attempts to troubleshoot the problem resulted in three of its five connector pins being broken off. At this point the molding on the SOC LSS was redone by the DSOG and subsequently used on the rest of the sonar lowerings (034-036). At the beginning of lowering 035 the LSS data behaved well, but it continually became more noisy as the five day deployment progressed. The noise problem was severe enough that any plume signals would probably not have been seen. The LSS was quiet during lowering 036 in the southern area of the segment, but we did not detect any plumes.

Light Transmissometer (LT)

The light transmissometer was deployed successfully on every sonar lowering and the last two Jason lowerings. Both sonar lowerings at Rainbow appear to have gone through a non-buoyant hydrothermal plume, shown in Figure 16. The plume is not well-defined by the data from lowering 032, partially due to the fact that during this first deployment the LT data channel kept cutting out, so that there are large gaps in the record, as is evident in Figure 16. However, an anomalously low light transmission (meaning more particles) is visible, centered around 2100m depth. A larger, better defined plume was observed during lowering 033, centered slightly shallower at 2000m depth. The magnitude of this signal, 200 mVolts, was about four times larger than the signal recorded during lowering 032. These two signals occurred relatively close to one another, at approximately 36° 14'N and 33° 54' W. It was partially on the basis of these plumes that the Jason lowering #184 at Rainbow searched in this area. While these are the only plumes observed during these two deployments, it should be noted that the times when these events were noted were the only times that the sonar vehicle was in the 2000m depth range in the water column in this area of Rainbow Ridge. During the downcast of lowering 032 the light transmission channel was not alive at this depth range. The observed plume occurred when the vehicle was pulled up for technical tests. The plume observed during lowering 033 was during the downcast. The upcast of both deployments were in different areas of Rainbow Ridge and did not observe any plume signals. No plume signals were observed in the Lucky Strike area.

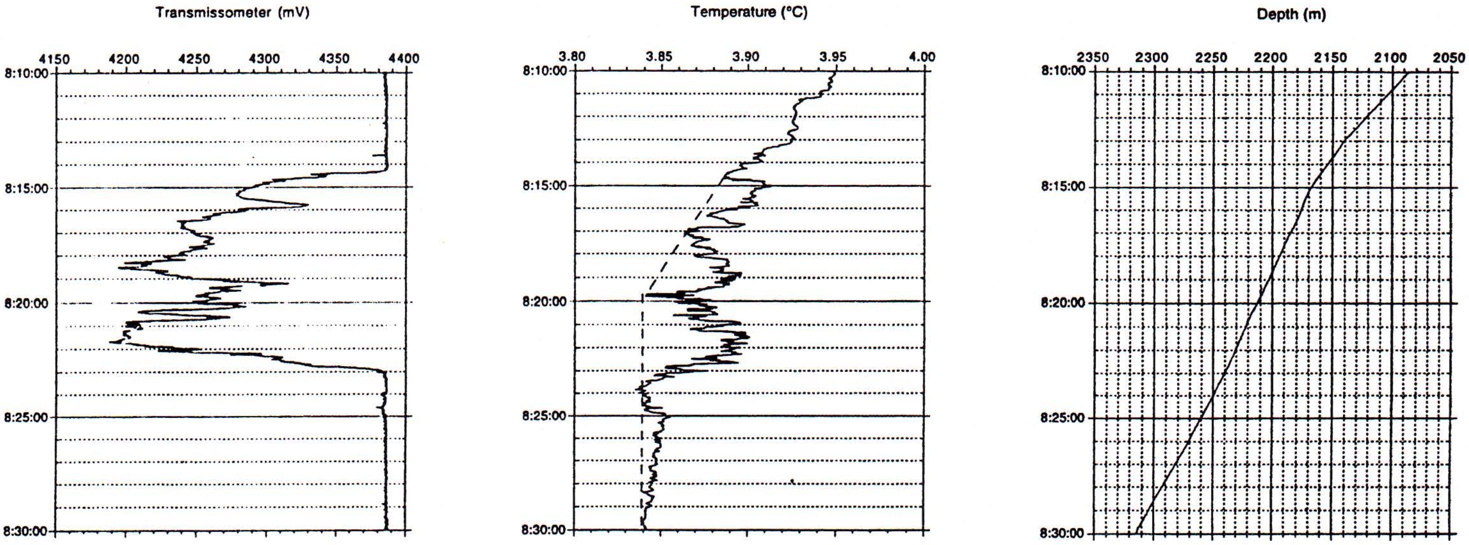

Figure 15 - Profiles of transmissometer, temperature and depth versus time during Jason Lowering #184 through the buoyant plume at 36° 14'N - Rainbow Site, Mid-Atlantic Ridge. Note pronounced transmissometer anomalies and positive temperature anomalies at the time window 08:14 to 08:23Z which equates to the depth interval from 2150-2240m depth.

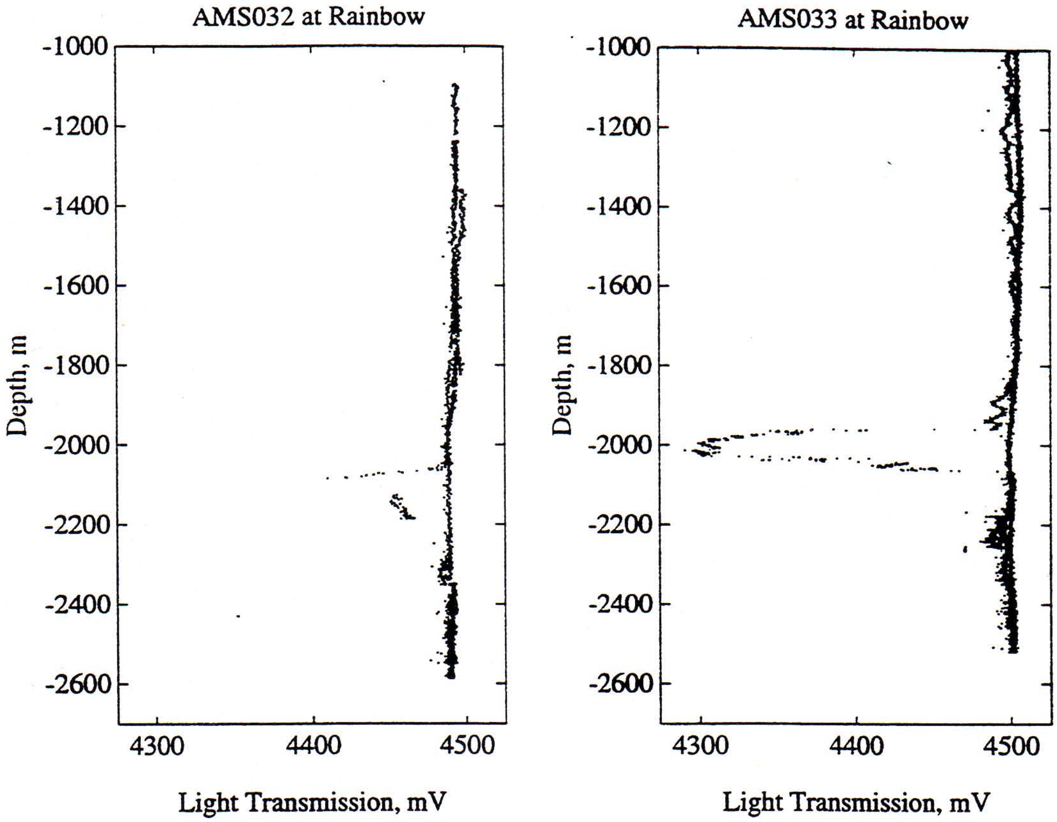

Figure 16 - Transmissometer data collected during DSL-120 lowerings at Rainbow Site.

Ancillary Studies

Dredging

Five dredging stations were conducted during the cruise and are listed in Table 10. During the down time when the sonar system was being repaired at Rainbow Ridge, we conducted two dredges over TOBI targets that were considered candidate locales for the sea floor vent site(s). Dredge Knorr 145-19-1 sampled the west slope of Rainbow Ridge between 2438-2113 m depth, and recovered an assemblage of weathered basalts, serpentinites, peridotites, and brown pelagic/hydrothermal? mud, together with clam and mussel fragments. The recovered shell fragments represented two bivalve taxa -- a vesicomyid clam and a mytilid mussel -- characteristic of chemosynthetic communities. The clam fragments, when reconstructed, represented two weathered but intact valves. The mussel shell fragments came from more than one individual and were fresh-looking in appearance with an outer yellow shell layer and inner irridescent nacreous layer. The occurrence of both bivalves and the freshness of the mussel shell argues for an active hydrothermal vent within a short distance (<100 m) from the dredge track. While mussels are characteristic of Mid-Atlantic Ridge vents, especially in the nearby Lucky Strike and Menez Gwen areas, there is only one other record of a vesicomyid on the Mid-Atlantic Ridge (cited by French colleagues from a site near 15°N). Other biological material collected included the exoskeletons of solitary corals and of small bivalves, both of which are typical deep-sea fauna living on and in sediment.

Dredge Knorr 145-19-2 was collected from the northern end of Rainbow Ridge between 2518-2403 m depth. About 150 kg of serpentinites, basalt fragments (some with fresh glass), and pelagic sediment were recovered. All animals recovered, which included coral, gastropods and sponges, are considered typical deep-sea fauna.

Three dredges were conducted in the Lucky Strike segment during the time taken to transfer equipment from ARGO-II to Jason. Dredges Knorr 145-19-3 and 145-19-4 sampled the large area of sulfide mounds identified from the ARGO-II survey on the NW side of the lava lake. Massive sulfides (dominated by pyrite) comprised the bulk of the rocks recovered, although weathered, highly porphyritic and vesicular basalts were also collected.

Dredge Knorr 145-19-5 was conducted in an area about 3.5 km south of the Lucky Strike seamount. The DSL-120 sonar survey had indicated that the backscatter data for 30-40% of the central platform within the segment was characterized by an isotropic, finely mottled pattern with no appreciable texture or topography. Hence, it was considered important to determine the nature of the sea floor in these areas. About 125 kg of relatively fresh basalts, many of which had glassy surfaces, were recovered, suggesting that the mottled backscatter texture in this area results from basaltic flows with the interstices between rocks filled with pelagic sediments.

Table 10

Dredging Stations during LUSTRE '96

Dredge	Location	Start	End	Depth (m)	General Description
145-19-1	W. side of Rainbow Ridge	36°14.56'N 33° 53.80'W	36°14.18'N 33°53.01'W	2438-2113	About 145 kg. weathered basalts, serpentinites, brown pelagic mud, clam and mussel fragments
145-19-2	N. end of Rainbow Ridge	36°16.00'N 33°53.24'W	36°16.50'N 33°52.26'W	2403-2518	150 kg. serpentinites, basalt fragments (some with fresh glass), pelagic sediment. Coral, gastropods, sponges
145-19-3	NW side of lava lake, Lucky Strike	36°17.57'N 32°16.98'W	36°17.65'N 32°16.83'W	1706-1692	About 1 kg. fragments of sulfides, Fe-hydroxides and basalts
145-19-4	NW side of lava lake, Lucky Strike	36°17.57'N 32°16.98'W	36°17.76'N 32°16.73'W	1702-1675	About 63 kg. massive sulfides, scoria, porphyritic basalts
145-19-5	S of Lucky Strike seamount	36°15.75'N 32°17.00'W	36°16.44'N 32°16.56'W	1893-1710	About 125 kg. relatively fresh basalts, many with glass

Rock/Sediment Coring

Periods when the mapping and imaging vehicles were being repaired or readied for deployment were dedicated to rock and sediment coring along the rift valley in the Lucky Strike segment using a modified gravity core with core tips filled with wax.

Nineteen cores were collected and recovered both basaltic glass and sediment (Table 11). The sediment samples will be analyzed on shore for major, trace, and REE elements in order to investigate the hydrothermal input to the sediment as a function of distance from a known high temperature venting site, as well as variations in hydrothermal activity over time. Basaltic glass analyses will augment the data collected from previous rock coring cruise (by C. Langmuir during cruises AII-127 and 129) to examine the geochemical variations in basalt chemistry within and between segments of the northern Mid-Atlantic Ridge.

Table 11 Knorr 145-19 Rock Coring Stations
(All weights are approximate)

RC#	Latitude (°N)	Longitude(°W)	Depth (m)	comments
RC-1	37° 22.70'	32° 13.40'	2539	10g sediment
RC-2	37° 06.90'	32° 21.50'	2917	10g sediment
RC-3	37° 09.59'	32° 19.70'	2506	0.2g sediment 0.1g rock
RC-4	37° 17.50'	32° 16.85'	1767	0.5g glass
RC-5	37° 16.15'	32° 16.05'	1778	0.5g sediment 0.5g glass
RC-6	37° 16.02'	32° 17.80'	1836	0.25g sediment 0.5g glass
RC-7	37° 12.30'	32° 17.80'	2044	1g glass, rocks and plagioclase with a very light coating of sediment
RC-8	37° 10.91'	32° 18.33'	2452	0.4g of sediment
RC-9	37° 21.60'	32° 12.00	1879	3g sediment
RC-10	37° 04.95'	32° 23.05'	2707	6g sediment
RC-11	37° 03.51'	32° 22.45'	2801	5g sediment
RC-12	37° 03.45'	32° 25.00'	2844	7g sediment
RC-13	37° 18.40'	32° 17.80'	1736	a little bit of glass
RC-14	37° 16.35'	32° 16.47'	1714	0.1g sediment
RC-15	37° 17.55'	32° 15.33'	1714	0.2g sediment a few flecks of glass
RC-16	37° 15.05'	32 17.20'	1965	0.5g glass, rock, and plagioclase
RC-17	37° 20.44'	32 15.59'	2220	8g of sediment a few flecks of glass
RC-18	37° 17.21'	32 17.86'	1778	6g of sediment a few glass chips
RC-19	37° 15.27'	32° 19.00'	2075	5g of sediment some glass chips

Appendix II
Science - Digital Event Datalogging

Level (1) Entries - Major Categories of Observations

VOL - Volcanic
HYD - Hydrothermal
BIO - Biological
TEC - Tectonic
SED - Sedimentary
ERR - Error
COM - Comments

For each Level (1) category there is the option of specifying a "HIT", to identify key areas of interest

Level (2) Entries - Subcategories of Level 1 "Event Type"
Level (3) Entries - 5 allowed for each Level 2 Entry
Level (4) Entries - Scrolling List

Source:

ESC - Electronic Still Camera
VID - Video Camera
SON - Sonar image
IMA - Imagenex
35M - 35 mm camera

Text Entry Line - is for details like size, shape, orientation that may be able to be observed depending on data source

VOL - Volcanic (1)

- ***HIT (2)***
- ***Pillows (2)***
  - Shape(3)
    - Rounded (4)
    - Elongate (4)
    - W/Tubes (4)
  - Diameter (3)
    - 0-1m (4)
    - 1-2m (4)
    - 3-5m (4)
  - Weathering (3)
    - Fresh_Glass (4)
    - Weathered (4)
    - Pelagic_Dusting (4)
    - Hydrothermal_Dusting (4)
    - Unknown (4)
- ***Lobates (2)***
  - Shape (3)
    - Plain (4)
    - W/Tubes (4)
  - Diameter (3)
    - 0-1m (4)
    - 1-2m (4)
    - 3-5m (4)

VOL - Volcanic (1)

Lobates (2) **[continued]**
- Weathering (3)
  - Fresh_Glass (4)
  - Weathered (4)
  - Pelagic_Dusting (4)
  - Hydrothermal_Dusting (4)
  - Unknown (4)

Sheet_Flow (2)
- Type (3)
  - Smooth (4)
  - Folded (4)
  - Hackly (4)
- Weathering (3)
  - Fresh_Glass (4)
  - Weathered (4)
  - Pelagic_Dusting (4)
  - Hydrothermal_Dusting (4)
  - Unknown (4)

For Above in text line note rough flow direction from lineations in lava surface in degrees XXX°, or other textural information about flow surface

Ridge (2)
- Lithology (3)
  - Whole_Pillows (4)
  - Pillow_fragments (4)
  - Breccia (4)
  - Sulfide (4)
  - Unknown (4)

Haystack (2)
Flow_Front (2)
Construct_Escarpme(2)
Eruptive_Fissure (2)
Lava_Lake (2)
Collapse_Pit (2)
Lava_Pillars (2)
Lava_Remnant (2)
Talus (2)
- Shape (3)
  - Angular (4)
  - Rounded (4)
  - Mixed (4)
- Size (3)
  - Gravel (4)
  - Cobbles (4)
  - Boulders (4)
  - Mixed (4)
- Weathering (3)
  - Fresh_Glass (4)
  - Weathered (4)
  - Sed._Dusting (4)

Appendix II
Science - Digital Event Datalogging

VOL - Volcanic (1) [continued]

- ***Talus (2)***
  - Weathering (3)
    - Hydro._dusting (4)
    - Unknown (4)

HYD - Hydrothermal (1)

- ***HIT (2)***
- ***Act_Chmn (2)***
  - Type (3)
    - Black_Smoker(4)
    - White_Smoker(4)
    - Shim_Water(4)
  - Height (3)
    - 0-1m (4)
    - 1-3m (4)
    - 3-5m (4)
    - >5m (4)
    - Unknown (4)
  - Shape (3)
    - Round (4)
    - Elongate (4)
    - Branched (4)
    - Complex (4)
  - Animals (3)
    - Present (4)
    - Not_Present (4)
- ***Act_Chmn_Fln (2)***
  - Type (3)
    - Black_Smoker (4)
    - White_Smoker (4)
    - Shim_Water(4)
  - Height (3)
    - 0-1m (4)
    - 1-3m (4)
    - 3-5m (4)
    - >5m (4)
    - Unknown (4)
  - Shape (3)
    - Round (4)
    - Elongate (4)
    - Branched (4)
    - Complex (4)
  - Animals (3)
    - No_Animals(4)
    - Animals (4)

- ***Act_Mnd (2)***
  - Type (3)
    - Black_Smoker (4)
    - White_Smoker (4)
    - Shim_Water(4)

HYD - Hydrothermal (1) [continued]

- ***Act_Mnd (2)***
  - Height (3)
    - 0-1m (4)
    - 1-3m (4)
    - 3-5m (4)
    - >5m (4)
    - Unknown (4)
  - Shape (3)
    - Round (4)
    - Elongate (4)
    - Branched (4)
    - Complex (4)
  - Animals (3)
    - No_Animals(4)
    - Animals (4)

- ***Act_Chmn_Mnd (2)***
  - Type (3)
    - Black_Smoker (4)
    - White Smoker (4)
    - Shim_Water(4)
  - Structure_Height (3)
    - 0-1m (4)
    - 1-3m (4)
    - 3-5m (4)
    - >5m (4)
    - Unknown (4)
  - Shape (3)
    - Round (4)
    - Elongate (4)
    - Branched (4)
    - Complex (4)
  - Animals (3)
    - No_Animals(4)
    - Animals (4)

- ***Act_Chmn_Fln__Mnd (2)***
  - Type (3)
    - Black_Smoker (4)
    - White_Smoker (4)
    - Shim_Water(4)
  - Height (3)
    - 0-1m (4)
    - 1-3m (4)
    - 3-5m (4)
    - >5m (4)
    - Unknown (4)
  - Shape (3)
    - Round (4)
    - Elongate (4)
    - Branched (4)
    - Complex (4)

HYD - Hydrothermal (1) [continued]

- ***Act_Chmn_Fln__Mnd (2)***
  - Animals (3)
    - No_Animals(4)
    - Animals (4)

- ***Inact_Chmn (2)***
  - Height (3)
    - 0-1m (4)
    - 1-3m (4)
    - 3-5m (4)
    - >5m (4)
    - Unknown (4)
  - Shape (3)
    - Round (4)
    - Elongate (4)
    - Branched (4)
    - Complex (4)
  - Animals (3)
    - No_Animals(4)
    - Animals (4)

- ***Inact_Chmn_Fln (2)***
  - Height (3)
    - 0-1m (4)
    - 1-3m (4)
    - 3-5m (4)
    - >5m (4)
    - Unknown (4)
  - Shape (3)
    - Round (4)
    - Elongate (4)
    - Branched (4)
    - Complex (4)
  - Animals (3)
    - No_Animals (4)
    - Animals (4)

- ***Inact_Mnd (2)***
  - Height (3)
    - 0-1m (4)
    - 1-3m (4)
    - 3-5m (4)
    - >5m (4)
    - Unknown (4)
  - Shape (3)
    - Round (4)
    - Elongate (4)
    - Branched (4)
    - Complex (4)
  - Animals (3)
    - No_Animals(4)
    - Animals (4)

HYD - Hydrothermal (1) [continued]

Inact_Chmn_Mnd (2)

- Structure_Height (3)
  - 0-1m (4)
  - 1-3m (4)
  - 3-5m (4)
  - >5m (4)
  - Unknown (4)
- Shape (3)
  - Round (4)
  - Elongate (4)
  - Branched (4)
  - Complex (4)
- Animals (3)
  - No_Animals(4)
  - Animals (4)

Inact_Chmn_Fln_Mnd (2)

- Structure_Height (3)
  - 0-1m (4)
  - 1-3m (4)
  - 3-5m (4)
  - >5m (4)
  - Unknown (4)
- Shape (3)
  - Round (4)
  - Elongate (4)
  - Branched (4)
  - Complex (4)
- Animals (3)
  - No_Animals(4)
  - Animals (4)

Diff_Flow_Mnd (2)

- Mound_Height (3)
  - 0-1m (4)
  - 1-3m (4)
  - 3-5m (4)
  - >5m (4)
  - Unknown (4)
- Mound_Shape (3)
  - Round (4)
  - Elongate (4)
  - Branched (4)
  - Complex (4)
- Animals (3)
  - No_Animals(4)
  - Animals (4)

Diff_Flow_alng_Fis (2)

- Animals (3)
  - No_Animals(4)
  - Animals (4)

Appendix II
Science - Digital Event Datalogging

HYD - Hydrothermal (1) [continued]

Diff_Flow_Coll_Pit (2)

- Size (3)
  - 0-1m (4)
  - 1-3m (4)
  - 3-5m (4)
  - >5m (4)
  - Unknown (4)
- Shape (3)
  - Round (4)
  - Elongate (4)
  - Branched (4)
  - Complex (4)
- Animals (3)
  - No_Animals(4)
  - Animals (4)

BIO - Biological

MAR_Sess_Vnt_F (2)

- MAR_SVF (3)
  - Anemones (4)
  - Bacteria_Flocs (4)
  - Bacterial_Mats (4)
  - Candelabrum (4)
  - Clams (4)
  - Mussels (4)
  - Serpulids (4)
  - Barnacles (4)
  - Other (4)

MAR_Mobl_Vnt_F (2)

- MAR_MVF (3)
  - Amphipods (4)
  - Brittle_Stars (4)
  - Crab_Indeterminate (4)
  - Crab_Brach. (4)
  - Crab_Galeth. (4)
  - Fish_Bythitid (4)
  - Fish_ Chimeraeid (4)
  - Fish_Other (4)
  - Fish_Zoarcid (4)
  - Gastropods_Coiled (4)
  - Polynoid_Polychaete (4)
  - Limpets (4)
  - Octopus (4)
  - Shrimp (4)
  - Urchins (4)
  - Other (4)

Appendix II
Science - Digital Event Datalogging

BIO - Biological [continued]

MAR_ Mobl_Non-Vnt_F (2)

- MAR_MNVF (3)
  - Fish (4)
  - Urchins (4)
  - Brittle_Stars (4)

MAR_ Mobl_Non-Vnt_F (2)

- Holothurians (4)
- Shrimp (4)
- Other (4)

MAR_ Sess_Non-Vnt_F (2)

- MAR_SNVF (3)
  - Corals (4)
  - Sponges (4)
  - Crinoids_ stalked (4)
  - Crinoids_not_ stalked (4)
  - Other (4)

TEC - Tectonic

Fault (2)

- Azimuth (3)
  - 0-45 (4)
  - 45-90 (4)
  - 90-135 (4)
  - 135-180 (4)
  - 180-225 (4)
  - 225-270 (4)
  - 270-315 (4)
  - 315-360 (4)
  - Unknown (4)
- Up_Side (3)
  - north (4)
  - south (4)
  - east (4)
  - west(4)
  - Unknown (4)
- Throw (3)
  - 1-5m (4)
  - 5-10m (4)
  - 10+m (4)
  - Unknown (4)
- Fault-Face (3)
  - Fresh (4)
  - Weathered (4)
  - Unknown (4)
- Rock_Type (3)
  - Pillows (4)
  - Sulfide (4)
  - Massive (4)
  - Massive_layered (4)
  - Dike (4)
  - Unknown (4)

Appendix II
Science - Digital Event Datalogging

TEC - Tectonic [continued]

Fissure (2)
- Width (3)
  - 1-3m (4)
  - 3-6m (4)
  - >6m (4)

Fissure (2)
- Azimuth (3)
  - 0-45 (4)
  - 45-90 (4)
  - 90-135 (4)
  - 135-180 (4)
  - 180-225 (4)
  - 225-270 (4)
  - 270-315 (4)
  - 315-360 (4)
  - Unknown (4)
- Spacing (3)
  - none (4)
  - 1-3m (4)
  - 3-6m (4)
  - >6m (4)

Ridge (2)
- Azimuth (3)
  - 0-45 (4)
  - 45-90 (4)
  - 90-135 (4)
  - 135-180 (4)
  - 180-225 (4)
  - 225-270 (4)
  - 270-315 (4)
  - 315-360 (4)
  - Unknown (4)
- Relief from base (3)
  - 1-3m (4)
  - 3-6m (4)
  - >6m (4)
  - Unknown (4)

SED - Sedimentary

Pelagic (2)
- Color (3)
  - White (4)
  - Tan (4)
  - Brown (4)
  - Gray (4)
  - Mottled 4)
- Cover (3)
  - <10%_cover (4)
  - 10-50%_cover (4)
  - 50-100%_cover (4)

SED - Sedimentary [continued]

Pelagic (2)

Staining (2)

No_Hyd_Stain
Hyd_Stain (4)

Hydrothermal_Sed (2)

Type (3)

Sulfide_Rubble (4)
Red_Oxide_Mud (4)
Brown_Oxide_Mud (4)

Cover (3)

<10%_cover (4)
10-50%_cover (4)
50-100%_cover (4)

Hyaloclastites (2)

Type (3)

Glassy
Fragments
Hydro_Cemented

Cover (3)

<10%_cover (4)
10-50%_cover (4)
50-100%_cover (4)

Sed_Shell_Chaff (2)

SSC (3)

<10%_cover (4)
10-50%_cover (4)
50-100%_cover (4)

ERR - Error

Error (2)

Error Entry (3)

last_entry_erroneous (4)
many_errors_here (4)

COM - Comment only

Appendix III

DSL120 Bathymetric Data Processing Using Some GMT Routines

Portions of the bathymetric data collected by the DSL-120 sonar were mapped and printed out on board. Two hours worth of data that were collected directly over the lava lake (Line 15) were given a preliminary analysis. The along-track swath files were filtered and surfaced by the DSL group using a combination of in-house and GMT routines. These files were then geodetically referenced by Cara Wilson (OSU) using the navigation positions of the start and end times and assuming a constant speed. The resulting files were printed out using GMT (Wessel and Smith, 1991).

Ken Feldman and Steve Lerner (both at WHOI) wrote a series of programs and scripts to create a pipeline to grid, surface and rotate individual hourly along-track bathymetry files. Cara's GMT routines were added to the pipeline so that an individual hourly bathymetry file could be processed and printed. Five lines comprising sixteen different hourly bathymetry files were run through this processing pipeline and printed out. Areas which were shadowed result in areas that were artificially smoothed over by the surfacing process. A masking routine (the GMT routine psmask) was used to mask out these areas, and maps with the areas of no data were also printed out.

During the Lucky Strike 96 cruise a pipeline was developed to produce plots of sonar bathymetry data gridded on an hour by hour basis. Each hourly file is assumed to have been generated at a constant speed and direction from the beginning along-track navigation point to the ending along-track navigation point. Navigation positions should be given in x-y (UTM) coordinates. These plots will not be as accurate as proper gridding of all data on a ping by ping basis - especially if there were changes in heading or velocity, or if navigation was not very good during the hour.

Requirements

- All programs and scripts should be in the directory $SONARUTIL/atrack_scripts
- The output of all scripts will be written in the current directory.
- Most scripts are written in csh. make_mask_grd is written in perl.
- GMT version 3.0 or higher is required to produce the postscript plots.
- The following are C programs which will need to be recompiled if running under something other than Solaris:
  - grd2xyz_simple
  - xyz2grd
  - bound_xyz
  - ddgsurface
  - blockmedian (DSL modified version of the GMT v2 routine)

Instructions for Producing Plots of Hourly Bathymetry Files

For each hourly file (DSL120.YYMMDD_hhmm.bat.ras and .bat.grd) enter the following command to produce a "gridded" postscript plot of the data. Start XY is the along-track position at the start of the file, end XY is the along-track position at the end of the file.

```
make_atrack_grid -v -e -p /source/DSL120.YYMMDD_hhmm startx starty endx endy
```

To produce plots which have areas without data masked out, run the following. It can be used on multiple hourly files sequentially (must be run after make_atrack_grid has processed each file):

```
mask_it DSL120.YYMMDD_hhmm [DSL120.YYMMDD_hhmm ...]
```

Once all hourly files in a given line have been processed the following 3 commands will produce a postscript file containing the entire line on a single plot. The hp650 option to the gmt_script_mask command will produce a postscript file suitable for printing on 36"-wide paper.

```
cat *.srf.xyz > all.xyz
cat *.srf.mask > all.mask
gmt_script_mask all.xyz "title of plot" [hp650]
```

If a non-masked plot of all files is desired, type:

```
cat *.srf.xyz > all.nomask.xyz
gmt_script all.nomask.xyz "title of plot" hp650
```

Appendix IV

Inductively Coupled Temperature Probes for Hot Hydrothermal Fluid Sampling

Background

Hydrothermal fluids at Lucky Strike were sampled by Jason using pairs of titanium major syringe samplers (Von Damm et al., 1985) and the Lilley/Lupton gas-tight samplers (M. Lilley, pers. commun., 1996). Accurate placement of the orifice of the bottle nozzles into the highest temperature, most representative fluid is essential to collecting good fluid samples. In the past, and when sampling from Alvin, fluid samples have been taken by positioning the bottles into a vent orifice after it had been excavated and probed with a temperature sensor that was linked by cable to the vehicle datalogging system. However, water samples taken in this manner, while usually of reasonable quality, had the potential to not be from the hottest fluid, because of turbulence at the orifice, and because the boundary layer between the hot venting fluid and the ambient (~2-4°C) seawater is often only millimeters thick and therefore difficult to determine without simultaneous temperature information. This problem was solved by the development of the NOAA manifold sampler in 1987 (Massoth et al., 1988) which permits the active sampling of fluids (the sampler has inlet and outlet pumps which permit fine-tuning of the fluid entry into the manifold system) and concurrent measurement of temperature via a calibrated thermocouple array at the tip of the sampling wand. However, for many experiments which require sampling of hot hydrothermal vent fluids, scientists have relied on manipulator-deployed titanium bottles. Hence a simple system for monitoring temperature in real-time at the nozzle tips of the bottles, without the requirement for individual cables that link the bottles to the vehicle, is desirable.

In 1994, WHOI scientists and engineers received internal funding from a Keck grant to evaluate methodologies for implementing the following engineering/science objectives:

1] efficiently sensing temperature while using manipulator-deployed water sampling bottles, without the requirement of a hard-wired cable between the bottle and the vehicle,
2] to develop a prototype of the system, and
3] to review the design of the existing titanium syringe samplers to see whether improvements could be made.

This effort, led by A. Bradley, B. Walden, R. Catanach, E. Snow, D. Fornari, and J. Seewald, has resulted in working prototypes of inductively coupled temperature probes that can be used with major syringe samplers and gas-tight samplers during hot hydrothermal fluid sampling. These devices have now been used successfully on two cruises: one using Alvin in April, 1996 at the East Pacific Rise at 9° 50'N, and the other on the LUSTRE '96 cruise using Jason at the Lucky Strike vent areas on the Mid-Atlantic Ridge in July-Aug. 1996. The following description is excerpted from a summary of the inductive coupled link (ICL) development effort written by A. Bradley of WHOI. Further information on this subject was presented in an AGU poster abstract presented at the Fall, 1995 Annual Meeting (Bradley et al., 1995).

Technical Description of the Inductively Coupled Link (ICL) (from A. Bradley)

Brief Description of ICL

The ICL Interface allows non-contact serial communication with an instrument via the pulsed AC magnetic field of a simple coil of wire. It was designed to be used by an ROV or submersible to "talk" or "listen" to an instrument deployed on the sea floor without making a direct electrical contact. An ICL can support half-duplex bidirectional communication at up to 9600 baud. It uses only about a microwatt while waiting for a signal. It works in air as well as in water.

Appendix IV

Brief Description of Remote Temperature Probes

The remote temperature logging devices are small, cylindrical titanium pressure vessels approximately 1.5" x 5" which were fabricated to house the ICL electronics. The thermocouples are housed in 1/8" titanium tubing which is welded at the sensor end and connected to the housing via a pressure resistant swadge fitting. They are corrected for the cold junction and have a ~1°C resolution for the range between 0°-420°C. Additional development and calibration will permit increased resolution at lower temperatures. The tubing containing the thermocouples is sufficiently malleable to permit the sensor to be contoured to the water bottle nozzles so that it can be positioned at the nozzle opening. The pressure housing is small enough to permit it to fit between a pair of major syringe samplers or banded to a gas-tight sampler.

The ICL loop attached to the remote temperature logger is embedded in a small epoxy cylinder that is fitted to the T or X handle of the water bottle. This loop makes contact with an equivalent coil embedded in the grip (for the ROV) or bottle actuator (for Alvin) of the manipulator. The coil on the manipulator is wired into the ROV or Alvin. Data is read out and stored on an Apple Macintosh Powerbook, running a BASIC program, either in Alvin or in the ROV control van.

ICL Loop Configuration

In the current temperature probe design one wire loop is connected via a potted deep sea cable to the probe housing and an identical one is carried by the ROV or sub. We have used loops from 1 to 4 inches in diameter. The magnetic field generated by one loop must couple into the other. They therefore need to be within about 1/4 of a loop diameter of each other for adequate communication. The bigger the loop, the larger this becomes. Maximum lateral offset is also about 1/4 diameter. The current loop design is approximately 2" in diameter.

Communication Method

Data is passed by keying pulses of a 225 kHz carrier from one loop to the other. Only this single frequency is used and to minimize drive power the coils are adjusted to be self resonant in sea water at this frequency. With this single frequency, only half duplex data is possible. (Only one coil can transmit at a time.) When a coil transmits, its receiving circuitry echos back the data being sent. The carrier is keyed on by the start bit of a serial character, then follows the state of the subsequent bits. The stop bit(s) turn the carrier off.

Interface Circuits

Two interface circuits are available. One is designed for the deployed instrument and the other for the sub or ROV.

Subsea Interface

This is a small circuit card about 1 x 3 inches which may be operated at ambient pressure (6000 db) in oil (it is currently installed inside the ROV Jason manipulator arm assembly) or inside a pressure housing (as used on Alvin). It has a four wire interface to the sub or ROV. These are ground, +12 volts, RS-232 data in and RS-232 data out. These are true RS-232 levels and typically connect directly to a computer serial port. Two additional wires go to the coil which may be up to about 10 feet from the circuit. (Longer cables are possible, but require readjusting the coil for proper resonance at 225 kHz with the added capacity by removing turns). The circuit takes several milliamperes (for the Maxim RS-232 interface chip) when listening and several 10's of ma when transmitting. It will echo back all data sent to it whether or not its coil is near an instrument.

Instrument Interface

There are several options for this component. It is built as a 24 pin module about 0.7S x 1.3S x 0.4S. It is usually built up in two different versions and it is important to understand the trade-offs involved.

Appendix IV

Since the instrument is usually battery powered, every effort has been made to reduce the power drain of the interface. Most applications include long periods when the instrument is not communicating, therefore the interface is designed to be able to listen for a "wake up call" on minimal power. With 12 volts driving the transmitting coil, the open circuit voltage on the adjacent receiving coil is over 2vpp. This is enough to turn on a base-emitter junction of a transistor in the receiver which can set a cmos flip flop to "on". Until a signal is received, the flip flop is completely static and uses well below a microwatt. The output from the flip flop goes typically to the gate of a p-channel power FET which turns on power to the rest of the circuitry. Without further data transfers, the power drain is all in a 5v regulator which requires about 50 micro amperes. The user's system should eventually turn off the flip-flop by a pulse to its "reset" input.

There are currently two configurations. In both, the interface requires 9-12v and only draws power when active. (The cmos flip-flop is powered by this voltage). In the simpler version, both the p-channel power switching FET and the 5v regulator are included with the interface. The serial data signals (sdi and sdo) are 5v cmos levels and idle at 5v. (This allows direct connection to a UART.) The interface can supply 5v to the instrument limited by the heat sinking on the LT1121-5 regulator. The circuit draws a few ma when receiving data and a few 10's of ma when transmitting and about 50 microamps when on, but waiting for data. A positive pulse of one volt or more on the "kill" input shuts down the regulator until the signal from the coil turns it on again. When the flip-flop is in the off state, the 5v supply drops and brings down the sdo (data out) line. This may confuse some UARTS which may report continuous framing errors. The sdi (data in) line is not clamped to the 5v and may remain either high or low.

In the more invasive version (which is simpler in many systems but requires more effort at integration) the p-channel power switch and 5v regulator are removed. The flip-flop output is still available to tell the instrument that the interface has been turned on and may be used to turn on the gate of an external p-channel FET with heat sinking for high power needs. The 5v for the level shifters must be supplied by the instrument. The sdi and sdo signals remain the same. All the circuitry is now static and draws essentially no power unless data is being sent or received. The state of the flip-flop has no effect on the rest of the circuit. This would be the preferred configuration for an instrument that blurts out occasional data frames whether someone is there or not.

Future Development

WHOI-DSOG is currently writing a proposal to: 1] improve and refine the ICL remote temperature logging device so that all hand-held hydrothermal fluid samples can be drawn from a vent while monitoring the fluid temperature, and 2] to permit a standard RS232 ICL for other types of sea floor monitoring and recording instruments. The latter development will result in avoiding the need for costly subsea connectors and potential problems involved in connector corrosion or malfunction. ICL connections have the potential to simplify and standardize sea floor instrumentation data downloading, reprogramming, continued recording, and power resupply without the need to physically move the instrument on the sea floor or return it to the surface. Further development and streamlining of the electronics design, standardization and documentation of the electrical connection requirements and power requirements, and documentation of software protocols will permit a wide range of researchers to incorporate ICL technology into sea floor instrument design. We intend to make the design specifications available to other deep submergence vehicle operators so that they can also incorporate this capability into their vehicle systems.

Appendix IV

References

Bradley, A.M., Tivey, M.K., Liberatore, S.P., Duester, A.R., Development and testing of thermocouple/thermistor array packages for monitoring temperature at hydrothermal vent sites, EOS, Trans. American Geophy. Union, 411, 1995.

Massoth, G.J., H.B. Milburn, S.R. Hammond, D.A. Butterfield, R.E. McDuff and J.E. Lupton, The geochemistry of submarine venting fluids at Axial Volcano, Juan de Fuca Ridge: New sampling methods and a VENTS program rationale, in Global Venting, Midwater, and Benthic Ecological Processes, ed. M.P. DeLuca & I. Babb, NURP Research Report 88-4, 29-59, 1988.

Von Damm, K. L., J. M. Edmond, B. Grant, C. I. Measures, B. Walden & R. F. Weiss, Chemistry of submarine hydrothermal solutions at 21°N, East Pacific Rise, Geochim. Cosmochim. Acta, 49, 2197-2220, 1985.

Appendix V

SeaNet

SeaNet Communciations Node

The SeaNet Communcations Node (SCN) provides an infrastructure for transparent inter-connectivity between remote sites and land-based sites over different communication interfaces such as high-speed digital satellite, cellular, rf lan, etc. Designed as a collaborative effort, SeaNet encourages the use of standard off-the-shelf products as well as application "plug-in" modules. At the user level, the SCN can provide an easy to use interface to promote accessing, sharing, and processing of scientific data. The SCN operator uses this page as a jumping off point for normal SCN operations functions, and users will be interested in the SCN Applications.

SeaNet for Lucky Strike96

SeaNet provided the infrastructure to build a data access module to provide instant access to data collected from the DSOG vehicles - DSL120, ARGO-II,and Jason used during the LUSTRE'96 cruise. This system allowed scientists to view, search, and access data on a variety of computer platforms (PCs, MACs, Unix) from data collected from multiple vehicles and sensors. Data accessible on-line included over 24,000 electronic still images, 32 lines of processed DSL120 kHz sonar amplitude and bathymetric data, navigation and attitude data, and peripheral sensor data such as magnetometer, transmissometer, and CTD. Some of the features implemented included the following:

Electronic Image Access - search by tape, time, location, generate coverage plot
- **Sonar Amplitude/Bathymetry Access** - display images by line number and hour
- **Navigation** - interactive gmt navigation plot by vehicle
- **Galleries** - repository for interesting ESC images, sonar images, nav plots, & mosaics

SCN Operator's Interface

The Operator's interface provides the tools to install and manage SeaNet operations.

Operator Log
- **Configuration Manager** - includes site configurations
- **Accounting Manager**
- **Link Manager** - communication link interface
- **Logging Facility** - serial ports and network
- **Batch Job Management**
- **IP System Test/Verification**

SCN Applications

SCN Applications are user "plug-in" modules. They are built on top of the core SeaNet architecture and can take advantage of such things as the Netscape user interface, cgi programs, configuration files, batch queues, etc. The available applications are user-definable via an ASCII index file per site configuration. Example SCN applications include Batch FTP, Data Access, etc.