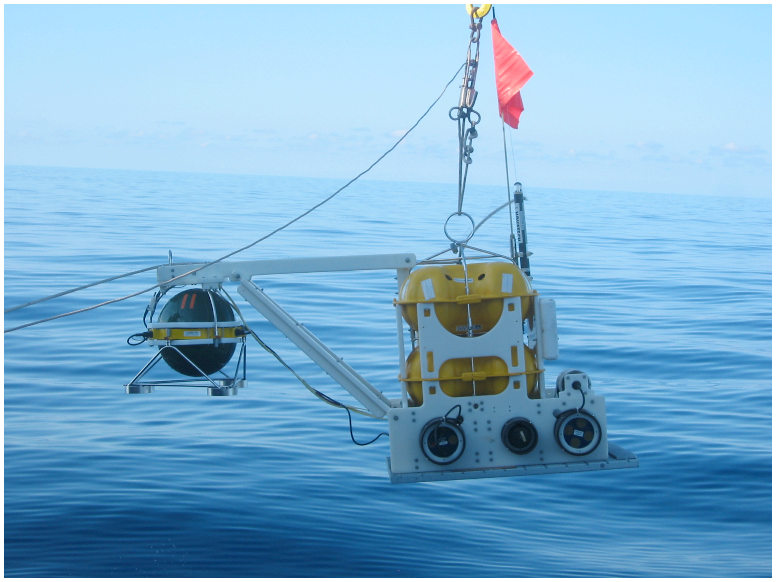
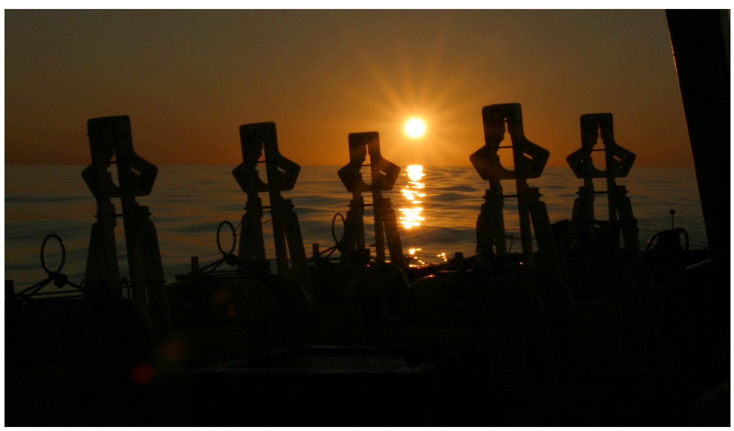
Sea of Cortez Ocean Bottom Array

Cruise Report: SCOOBA I -- Deployment

***R/V New Horizon*, October 12 – October 21, 2005.**





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JOHN COLLINS, Woods Hole Oceanographic Institution
CECILIO REBOLLAR, Centro de Investigacion Cientifica y de Eduacion Superior de Ensenada (CICESE)

1) Experiment Objectives

The overall goal of the SCOOBA passive seismic experiment is to evaluate the degree to which mantle processes control lithospheric rupture and the initiation of seafloor spreading in the Gulf of California (GoC). In October 2005, we deployed 15 broadband ocean bottom seismographs (OBS) in the GoC for a duration of 12 months (Figure 1). The data from these stations, in conjunction with observations from the MARGINS-funded NARS-Baja experiment, will be used to image mantle structure beneath the Gulf and the surrounding region. We will specifically address two questions that are important for achieving the goals of the Rifting Continental Lithosphere science plan:

- **Is the upper-mantle directly underlying GoC extension anomalously hot?** This question is critical to understanding the magmatic budget of GoC extension, and the role of this magmatism on strain localization and partitioning. The GoC lies on a broad region of very low seismic velocities, implying that temperatures in the upper mantle are elevated. Volcanism associated with rifting, however, appears to be quite modest in the region compared to many rifted margins. The OBS deployment will allow us to image structure directly beneath the gulf and its margins, better constraining thermal processes in the region.
- **To what extent do North-South variations in extensional style correlate with upper-mantle velocity variations?** Addressing this question will allow us to evaluate the importance of mantle state in controlling or modulating rift extension. Despite nearly constant total extension all along the rift axis over the past 5 Ma, the style of extension changes dramatically from continental extension in the north, to sea-floor spreading in the south. Mantle thermal and rheological properties probably modulate this process. The OBS deployment will allow us to image along-axis variations in mantle structure, placing better constraints on the impact of this structure on rifting.

The deployment builds upon the NARS-Baja backbone array deployed on land on both the western and eastern sides of the GoC, placing 4 OBS at ~100-150 km spacing down the southern gulf axis. In addition, 5- and 6-station sub-arrays span the Guaymas and Alarcon spreading centers, providing the means to image the mantle beneath two of the crustal transects shot by the Lizarralde et al. active-source experiment conducted in the fall of 2001. We will measure Rayleigh-wave velocities, *P* and *S* delay times, and attenuation structure in order to provide estimates of mantle temperature variations. We will map mantle flow patterns by measuring the magnitude and orientation of azimuthal anisotropy using *SKS* and *SKKS* phases and inter-station Rayleigh wave dispersion. Azimuthal anisotropy will be further constrained by *Pn* and *Sn* travel times from regional events. We will use receiver functions to map the depth to both mantle transition zone and shallow mantle discontinuities, thereby providing additional constraints on thermal, compositional and mechanical structure. If useable Love waves are recorded, we will constrain radial anisotropy, which could place important constraints on local mantle buoyancy.

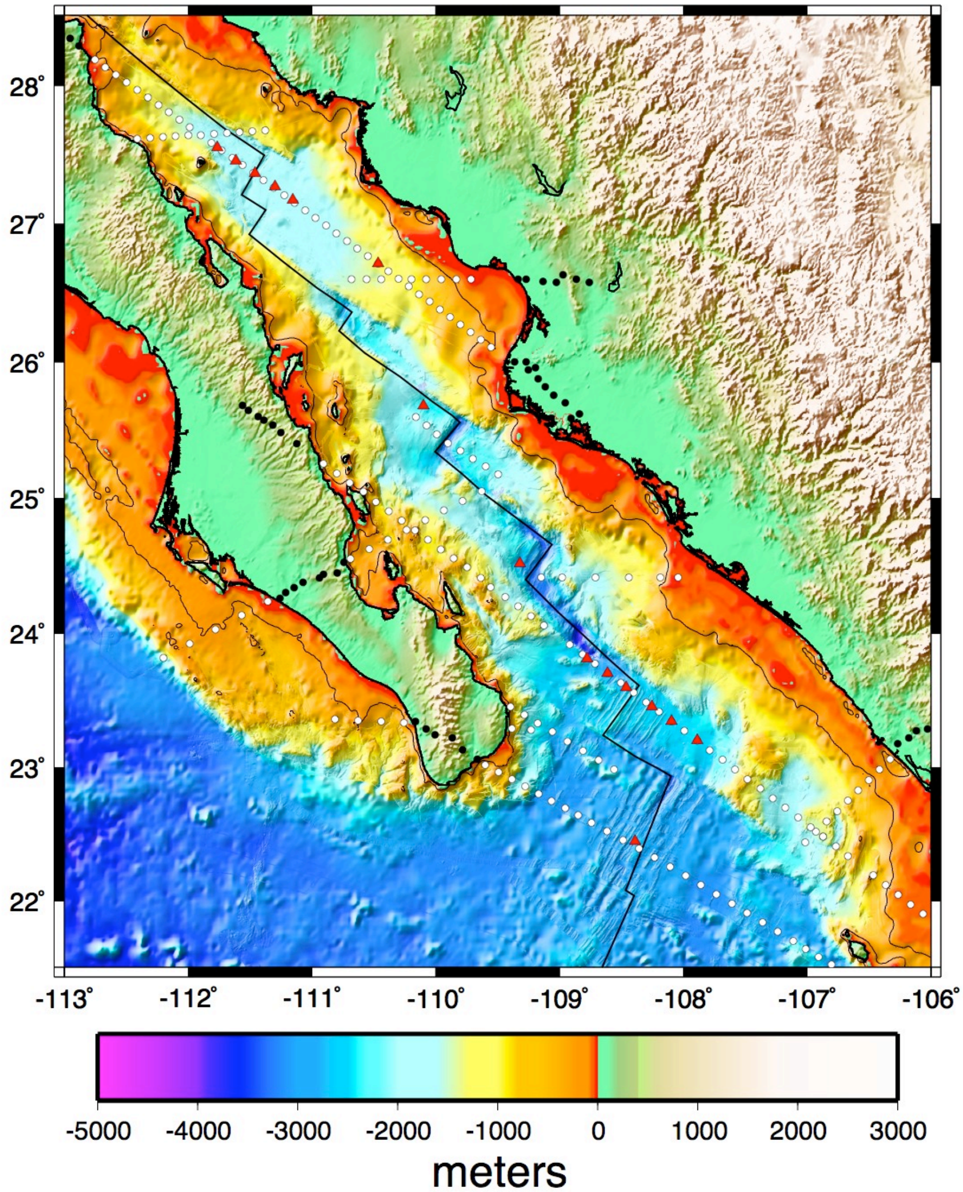

Figure 1. Locations of the SCOOBA stations (red triangles) plotted on a bathymetric map of the Gulf of California region. Bathymetry is extracted from high-resolution multibeam survey of Lonsdale and others, intermediate-resolution hydrosweep data of Lizarralde and others, and low-resolution model bathymetry from the global compilation of Smith and Sandwell. White (offshore) and black (onshore) dots show locations of seismometers deployed for the 2002 Lizarralde et al. active source experiment. The SCOOBA N and S subarrays are placed directly on the Guaymas and Alarcon active source lines, respectively.

2) Cruise Narrative

Monday, October 10. Gaherty, Collins, and Wilson arrive in San Diego.

Tuesday, October 11. Gaherty, Collins, and Wilson visit R/V New Horizon at the Scripps Institution of Oceanography (SIO) Nimitz Marine Facility at Point Loma. SIO engineers complete loading of 15 OBS plus supporting equipment. Gaherty and Collins discuss deployment operations with Jeff Babcock, manager SIO OBSIP. The two Mexican members of the science party (Cecillo Rebollar and Jose Gomez-Valdez) arrive in San Diego.

Wednesday, October 12. Science party moves aboard New Horizon at 0700 LT. Ship sails 0800 LT.

Thursday, October 13. Proceeding at 10 knots. Stop to carry out 2 lowerings of the SIO acoustic releases. All releases check out o.k. at 2,000 m+.

Friday, October 14. Gaherty and Collins decide station locations and which of the planned stations to eliminate. (We had planned on deploying 18 OBS, but only 15 were available.) To avoid confusion with the site names being used by the bridge for navigation, and to maintain consistency with the permits, we retained the original naming convention. Sites N01, I03, and I05 were eliminated and never deployed.

Saturday, October 15. Beginning at 2130 local time, deploy first station, I06, and conduct acoustic survey. Survey design is described in Appendix. Acoustics are excellent.

Sunday, October 16. Starting with the first launch around 4am local time, deploy and survey stations S06, S05, and S04 without difficulty. Deploy procedures and acoustic survey all run smoothly. Sink rate is about 55 m/min, total time on station averaged 2-2.25 hours.

Site S03 was problematic. The PI's attempted to locate the site on a rise in the axis of the Alarcon spreading center, which presumably was relatively young volcanics with little sedimentary cover. Water depth was about 2400 meters, or about 300 meters above the surrounding seafloor. In the first deployment using OBS SIO33, the OBS appeared to reach the seafloor (~2400 meters) and then immediately began rising again at ~28 m/min. Instrument was recovered. Subsequent analysis indicated that burn wire was present, but pin that connected to burn wire was missing. This had not previously been observed with these instruments, so the decision was made to reattempt deployment at the same site with another instrument. SIO82 was deployed, with exactly the same result – upon reaching depth of 2406, the OBS began rising at 28 m/min. Instrument was recovered, with same state of the release. At this point it was surmised that these broadband instruments had not previously been deployed in a hard-rock, unsedimented environment (site I06 not withstanding). The PI's chose to resite the station approximate 6 km to the NW, on seafloor that (based on MCS plots) clearly is sedimented. Instrument SIO02 was successfully deployed and surveyed. **During checkout, the instrument showed anomalously high drift rates, so timing must be carefully evaluated upon recovery.**

The station spacing (~26 km) between S03 and S04 (across the Alarcon SC) is slightly larger than the 18-20 km target spacing, but should be fine for most applications, and the impact on longer-period analyses such as surface-waves and shear-wave splitting should be negligible. Following deployment of S03, sites S02 and S01 were relocated to maintain a ~20km station spacing. New sites for stations I04 and I06 were chosen, moving them out of the deep extensional basins and onto higher-elevation sedimented seafloor to the west of those basins. Contrasting the character of upper mantle structure across four locations on the plate boundary may have proven very interesting. However it was decided that obtaining data from within these basins was not critical to the science plan (these sites were not presented in the proposal), and it was more important to ensure that the maximum number of sites delivered data. Given the clear failure of two consecutive hard-rock deployments, and the lack of spare anchors, the decision to move to sedimented sites seemed obvious.

Monday, October 17. Continued with the S subarray deployment. During checkout for site S02 and S01, instruments SIO75 and SIO81 showed high drift rates, and timing needs to be checked carefully upon recovery. S02 was deployed without incident. The S01 deployment does not appear to have been successful. OBS SIO81 was launched at 12:07 UTC (0707 local time), and depth was tracked until 1590 m, at which point all acoustic return from the instrument disappeared. This depth was well above the seafloor (~2700 m). Acoustic conditions were excellent, and acoustic return from the instrument had been regular and strong right up to the point where it disappeared. A number of tests were done to ensure that the failure was not within the acoustic system on the NH. It was confirmed that the deck box was receiving by using the Knudsen echosounder as a source. The transducer was swapped out, and it was confirmed that both transducers were sending using the Knudsen. The deck box was swapped out for the small portable unit. The over-the-side transducer was deployed. All attempts to contact the instrument through ranging and enable commands failed. Given the abrupt nature of the communications break, SIO personnel speculate that the pressure case leaked (although this acoustic device passed the Rosette test at much larger water depths), or that a glass sphere imploded.

Two recovery options were considered. Option 1 was to attempt recovery immediately, hoping that the OBS was alive and capable of receiving commands; in this case, the decision of whether to redeploy another instrument would need to be made, since we had no spare acoustics or anchors. Option 2 was to leave the instrument, with hopes that it was operating and receiving commands; in this case it could be recovered in a year. In either case, it was recognized that recovery (if it is even possible) may be slow, in case the acoustic disconnect was caused by a sphere implosion or partial leakage that will reduce instrument buoyancy. It was decided that if the instrument is in a recoverable state, there was no obvious benefit to recovering it now versus a year from now. Therefore it was decided to go with option 2, and the instrument was left for possible recovery next year. Given the uncertainty of the length of this recovery effort, contingency ship time should be scheduled. In the confusion no "disable" command was sent to the instrument prior to departure.

At 1830 local time, site I04 was deployed. Instrument was followed closely to the bottom with strong acoustics. Survey was successful.

During checkout for I04, instrument **SIO60** showed flaky behavior, with bad signal on one channel. Datalogger and acoustics were swapped out for new ones, and SIO60 was put aside for analysis. Upon re-powering, the datalogger behaved fine, and was ultimately deployed at site N05**.**

Tuesday, October 18. Deployed site I02 at 0500. Checkout was clean, acoustics strong, survey was successful.

During transit to I01, options were considered for where to deploy the "problematic" equipment – DAS SIO60, and the two packages with MacGuyvered anchors. To increase the likelihood of having the maximum aperture across the N subarray, it was decided to deploy this equipment at sites N05 and N03 if possible. DAS SIO60 was assigned to N05.

Site I01 was deployed at 1331 UTC. During checkout, the **pin in the anchor release was found to be bent**. Not clear how this could happen – the unit was loaded on a pallet for transport to the ship, and was lifted via straps. This is the same type of pin that probably failed in the lost anchor deployments. Acoustics strong, survey was successful.

During transit to I02, the SIO team (with the assistance of 1^{st} engineer Laddie Rayala) finished the grinding and welding the sewer grates from the rosette tests, which were to be used as anchors for the two instruments that bounced off the bottom. The rosette anchors are smaller than those on the main packages, so they combined them in pairs for use on the OBS. There was some discussion (spurred by J. Babcock's suggestion) of using one grate per package, and welding on spare metal to increase the mass. This would have provided additional spares in case there were more anchor losses along the N leg. However, suitable spare metal was hard to find, and so ultimately the double anchors were constructed and installed.

Site N06 was deployed at about 8:00 pm local time. Due to shallower water in this region, the survey site was reduced to 0.75 km per arm. Acoustics were strong.

Site N05 was deployed about 10:30 pm local time. This site was chosen for deployment of two of the problematic components identified earlier: datalogger SIO60 was used, as was one of the MacGuyver anchors. Despite the extra anchor weights, the instrument lifted cleanly and looked reasonably well balanced, both when hanging from the crane, and when sitting in the water. Acoustics were strong and survey was successful.

Wednesday, October 19. Site N04 was deployed in the Guaymas rift valley at approximately 0130 local time. A MacGuyver anchor was used. Checkout was clean, acoustics strong.

It was decided to provide a break for the OBS crew. The ship skipped site N03 and slowly steamed to the end of the line, providing a 5 hour sleep window.

Site N02 was deployed at 0900 local time. A large pod of whales around the ship provided entertainment during the instrument's descent to the seafloor. Acoustics were strong and survey successful.

Site N03 was deployed at 1145 local time, hit the seafloor, and stuck. All cheered. Acoustic strong, survey successful, all deployments complete at 1322 local time.

Following deployment, there was a discussion about the viability of returning to S01, as well as a nearby instrument on which recovery failed during the 2002 experiment, in a final attempt to communicate with them. Rough estimate of extra ship time was nearly one day steaming, plus time on site. There seemed to be little substantial benefit to this activity. There were no new communication ideas that could be tried that hadn't been tried already. If the communication is successful, then the instrument could be surveyed, but that can also happen prior to recovery. If communication fails, then the status quo remains: wait until next year and then attempt recovery. Given that there was no clear benefit to this activity, it was decided to forgo it and head to La Paz for disembarking.

Table 1 lists the final deployment schedule. Table 2 gives the final instrument locations determined through the relocation procedure outlined in Appendix 1. Appendix 2 gives the complete list of SIO equipment deployed at each site, as well as notes from the instrument checkout process.

Table 1: Deployment Schedule (Final version 2.8)

	SN		lat	long	depth	Start Time	End Time	Transit (hr)
1)	I06	OB	22.4486	-108.3932	2591	10/15/05 21:35	10/15/05 23:54	5.3
2)	S06	OB	23.2020	-107.8883	2456	10/16/05 4:55	10/16/05 6:55	1.4
3)	S05	OB	23.3469	-108.0940	2560	10/16/05 8:21	10/16/05 10:36	1.1
4)	S04	OB	23.4556	-108.2504	2505	10/16/05 11:41	10/16/05 13:41	1.1
5)	abort		23.5608	-108.4131	2421	10/16/05 14:46	10/16/05 17:16	0.0
5)	abort		23.5608	-108.4131	2421	10/16/05 18:25	10/16/05 20:55	0.0
5)	S03	OB	23.5981	-108.4585	2709	10/16/05 22:15	10/17/05 0:30	1.1
6)	S02	OB	23.7044	-108.6122	2790	10/17/05 1:34	10/17/05 3:49	1.1
7)	S01	OB	23.8154	-108.7768	2745	10/17/05 4:58	10/17/05 7:58	10.5
8)	I04	OB	24.5187	-109.3206	2722	10/17/05 18:28	10/17/05 20:43	8.2
9)	I02	OB	25.6844	-110.0997	2371	10/18/05 4:52	10/18/05 6:52	6.4
10)	I01	OB	26.7142	-110.4670	1327	10/18/05 13:18	10/18/05 15:03	4.9
11)	N06	OB	27.1746	-111.1537	1784	10/18/05 19:55	10/18/05 21:40	1.0
12)	N05	OB	27.2692	-111.2974	1886	10/18/05 22:37	10/19/05 0:22	1.0
13)	N04	OB	27.3658	-111.4584	2042	10/19/05 1:24	10/19/05 3:03	6.0
15)	N02	OB	27.5546	-111.7663	1636	10/19/05 9:03	10/19/05 10:33	1.3
14)	N03	OB	27.4581	-111.6129	1775	10/19/05 11:48	10/19/05 13:24	20.0
	La Paz		23.8154	-108.7768	0	**10/20/05 9:24**		

Notes:
1) Locations are target drop points. Actual drop coordinates and surveyed seafloor locations are given in Table 2.
2) All times local (GMT - 0700)

Table 2. Instrument Drop Points and Final Surveyed Station Locations

Station	SIO OBS #	Drop Latitude	Drop Longitude	Water Depth at Drop Site (uncorr. meters)	Sounding Velocity (m/s)	Station Latitude	Station Longitude	Station Depth (m)	Distance Shift (m)	Azimuth Shift (degrees)	Initial Misfit (ms)	Final Misfit (ms)
I06	SIO28	22 26.907 N	108 23.576 W	2565	1491	22 26.921 N	108 23.544 W	2537	61	64	9	2
S06	SIO03	23 12.130 N	107 53.294 W	2462	1491	23 12.195 N	107 53.348 W	2437	151	323	23	2
S05	SIO32	23 20.820 N	108 05.659 W	2572	1491	23 20.922 N	108 05.759 W	2539	255	318	35	2
S04	SIO71	23 27.356 N	108 15.051 W	2497	1491	23 27.402 N	108 15.187 W	2477	247	290	33	2
S03	SIO02	23 35.885 N	108 27.518 W	2703	1492	23 35.984 N	108 27.697 W	2680	356	301	48	2
S02	SIO75	23 42.267 N	108 36.748 W	2785	1492	23 42.274 N	108 36.763 W	2762	28	299	4	2
S01*	SIO81	23 48.905 N	108 46.609 W	2723								
I04	SIO82	24 31.116 N	109 19.228 W	2723	1492	24 31.143 N	109 19.143 W	2706	152	70	21	2
I02	SIO72	25 41.056 N	110 05.978 W	2376	1491	25 40.787 N	110 05.924 W	2352	507	170	74	2
I01**	SIO11	26 42.831 N	110 28.033 W	1331	1492	26 42.818 N	110 28.024 W	1300	28	147	5	2
N06	SIO43	27 10.460 N	111 09.219 W	1785	1491	27 10.492 N	111 09.211 W	1761	60	13	9	2
N05	SIO60	27 16.158 N	111 17.850 W	1888	1491	27 16.271 N	111 17.926 W	1861	244	329	29	2
N04	SIO33	27 21.947 N	111 27.502 W	2049	1491	27 22.008 N	111 27.569 W	2016	158	316	19	2
N02	SIO67	27 33.276 N	111 45.967 W	1640	1491	27 33.128 N	111 46.015 W	1594	285	196	45	2
N03	SIO74	27 27.476 N	111 36.775 W	1791	1491	27 27.474 N	111 36.896 W	1747	199	269	29	2

* Acoustic contact with OBS lost during deployment at 1590 m slant range.

3) Data

The primary data to be collected during the experiment is the passive-source seismic data from the OBS; these will be recovered in approximately 12 months on the recovery cruise. In addition, two underway data sets were collected during the cruise. Data from the 12.5 kHz Knudsen echosounder is available for most of the cruise, with the exception of the periods when instruments were being deployed. For information on and access to this data, contact J. Gaherty. In addition, the Acoustic Doppler Current Profiler (ADCP) system was utilized on and off during the duration of the cruise. Contact Jose Gomez-Valdez at CICESE regarding availability of this data. All underway data is in the process of being transferred to the LDEO MARGINS Database.

4) Feedback for Future Operations

Crew, *R/V New Horizon*. Overall performance of the New Horizon crew was excellent. The New Horizon is a very good platform for OBS deployments, at least in locales where high-resolution (multibeam) bathymetry is previously available. The only significant criticism is that the computer support is barely adequate. The Unix mail server was flaky and insufficient resources are on-board to deal with problems with it. The news service subscription is completely useless. Given the improved inter- and intra-net and email resources available on other UNOLS vessels, it is clear that this system sorely needs an upgrade.

SIO OBSIP Team. Overall performance of the OBS technicians was excellent. The team was very responsive to all requests and needs of the science party. There is some concern about the timing on two instruments (stations S02 and S01), the timing on these need to be evaluated closely upon recovery. The only significant criticism is that the OBS team went to sea with no spare equipment. This possibly impacted the experiment, in that the spare anchors that were constructed and deployed to replace those lost are not ideal: they contain unnecessary welds, were not galvanized, and the grate required grinding to accommodate the release. It will not be known if these modifications worked until the instruments are successfully recovered. These uncertainties (as well as the extra work required on board) could have been avoided if SIO OBSIP had shipped extra anchors. Likewise, failure of any of the equipment (seismometers, DAS, acoustics) during checkout would have resulted in sites not being deployed. Given the cost of seagoing deployments, it seems that all of the OBS facilities should make an effort to have at least one spare of each major component available on board.

5) Personnel

Science Party
James Gaherty, Chief Scientist
John Collins, Co-chief Scientist
Cecilio Rebollar, Co-chief Scientist
Jose Gomez-Valdez, watchstander
Charles Wilson, watchstander
Mark Gibaud, SIO OBS Technician
Martin Rapa, SIO OBS Technician
David Willoughby, SIO OBS Technician
Lucian Parry, NH Science Tech

New Horizon Crew
John Manion, Captain
Roger Price, 1st Mate
Melissa Turner, 2nd Mate
Gary Curry, A/B
Ed Keenan, A/B
Donel Johnson, A/B
Ron Wheatley, Chief Engineer
Laddie Rayala, 1st Engineer
Eddie Bautista, Oiler
Eddie Lograsso, Cook
Mark Smith, Cook

Additional onshore support for logistics and permitting were provided by Rose Dufour and Elizabeth Brenner of the SIO Ship Scheduling Office, and Dana Weant and Angelica Narvaez of the US State Department in Mexico City.

Appendix 1. Determining OBS Seafloor Locations

Accurate knowledge of each OBS location on the seafloor is a requirement for most of the seismic techniques that will be applied to the SCOOBA data. Knowledge of the OBS drop or launch positions is insufficient, as these locations can differ from the final seafloor positions by hundreds of meters due to the effects of ocean currents and/or non-vertical OBS descent due to asymmetries in the instrument's buoyancy distribution. We determined seafloor positions in the usual manner: by ranging acoustically to the OBS from many known ship locations distributed over a broad range of ship-OBS azimuths.

We carried out acoustic surveys for each of the 14 successful OBS drops on SCOOBA1. We followed near-identical procedures for each OBS drop. The OBS drop location and the water depth beneath the ship at the time the OBS was dropped was noted in a log sheet (Table X-1). The OBS was then tracked acoustically as it sank to the seafloor, and the range of the OBS from the ship at the time the OBS reached the seafloor was noted. Once we were confident that the OBS had not prematurely released (as happened on two drops), the bridge was asked to drive the ship through a pre-agreed series of waypoints at a speed-over the-ground of 4 knots. For the majority of the OBS drops, the way-points were as follows: (1) the OBS drop position; (ii) 1 km south of the drop position; (iii) 1 km west of the drop position; (iv) 1 km north of the drop location; (v) 1 km east of the drop location; and (vi) the drop position again. At the final waypoint we disabled the Edgetech transducer on the OBS. For some shallow deployments in the Guaymas basin, the waypoints were positioned 0.75 km from the drop location. The shorter distance was chosen to avoid complex acoustic paths between the ship and the OBS. We did not carry out XBT (expendable bathythermograph) measurements, as we did not have XBTs on board.

<u>*Equipment Used:*</u>

- Edgetech 8011A deck box;
- Macintosh iBook laptop running Mac OS X 10.3;
- Logging software, "*gpsranging*" (written by SIO-OBSIP engineer Paul Georgief);
- USB-to-two-serial-port connector (Keyspan®)
- RS-232 cables with appropriate connectors to connect the Edgetech and the laptop;
- "Zyfer® GPStarplus 565-210 Rev A" time and frequency system GPS receiver;
- RS-232 cable with appropriate connectors to connect the GPS receiver and the laptop;
- Matlab® inversion software, "find_obs_position.m".

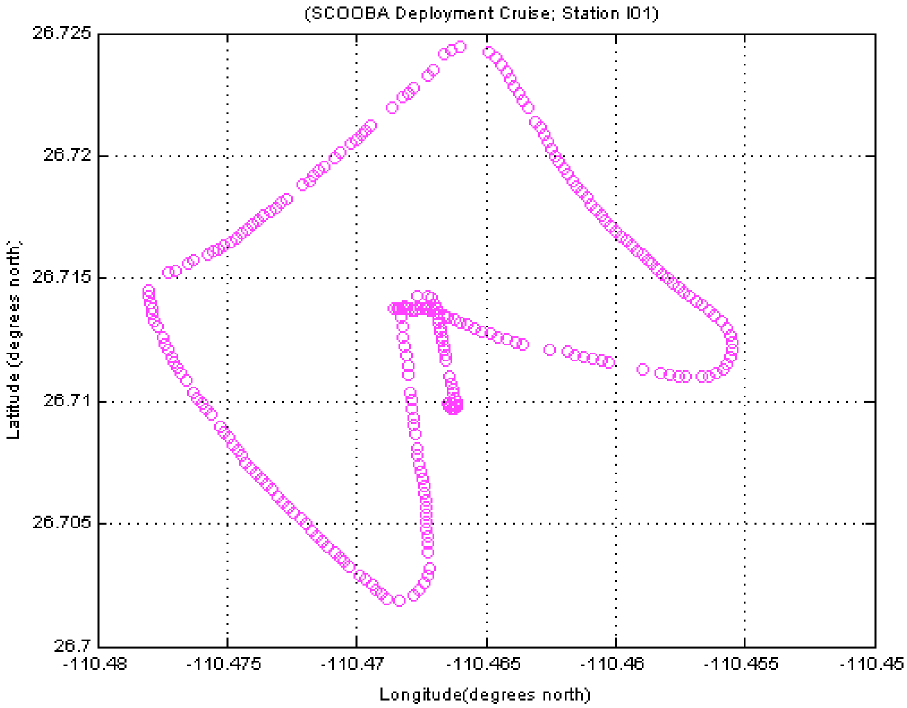

Figure 1 Survey pattern followed for station I01

```
Ranging data taken on:   2005-10-18 13:50:40.873574
Cruise:                  SCOOBA1
Site:                    I01
Instrument:              SIO11
Drop Point (Latitude):   26 42.831 N
Drop Point (Longitude):  110 28.033 W
Depth (meters):          1331
Comment:                 Fwd xducer
===================================================


 910 msec.  Lat: 26 42.5944 N  Lon: 110 27.9882 W  Alt: -22.78 Time(UTC): 2005:291:20:50:28
 910 msec. Lat: 26 42.5944 N  Lon: 110 27.9882 W  Alt: -22.78 Time(UTC): 2005:291:20:50:28
 910 msec. Lat: 26 42.5944 N  Lon: 110 27.9882 W  Alt: -22.78 Time(UTC): 2005:291:20:50:28
 910 msec. Lat: 26 42.5944 N  Lon: 110 27.9882 W  Alt: -22.78 Time(UTC): 2005:291:20:50:28
 911 msec. Lat: 26 42.5944 N  Lon: 110 27.9882 W  Alt: -22.78 Time(UTC): 2005:291:20:50:28
 911 msec. Lat: 26 42.5944 N  Lon: 110 27.9882 W  Alt: -22.78 Time(UTC): 2005:291:20:50:29
 911 msec. Lat: 26 42.5941 N  Lon: 110 27.9882 W  Alt: -22.85 Time(UTC): 2005:291:20:50:29
 911 msec. Lat: 26 42.5941 N  Lon: 110 27.9882 W  Alt: -22.85 Time(UTC): 2005:291:20:50:29
 913 msec. Lat: 26 42.5941 N  Lon: 110 27.9882 W  Alt: -22.85 Time(UTC): 2005:291:20:50:29
 913 msec. Lat: 26 42.5941 N  Lon: 110 27.9882 W  Alt: -22.85 Time(UTC): 2005:291:20:50:29
 914 msec. Lat: 26 42.5939 N  Lon: 110 27.9882 W  Alt: -22.83 Time(UTC): 2005:291:20:50:30
 914 msec. Lat: 26 42.5914 N  Lon: 110 27.9869 W  Alt: -22.29 Time(UTC): 2005:291:20:50:40
 916 msec. Lat: 26 42.5886 N  Lon: 110 27.9855 W  Alt: -21.76 Time(UTC): 2005:291:20:50:50
```

Figure 2. Example of a portion of the output file written by “gpsranging”.

Inversion of the acoustic data to yield estimates of the OBS position was done using Matlab®. Bad data points due to the Edgetech deck box triggering on ambient noise or reverberations were identified by visually scanning the raw data and by plotting the travel time residuals for the OBS drop position. For each OBS, the inversion was carried out using least-squares and grid-search techniques. The estimated OBS positions (latitude, longitude, and depth) returned by the two techniques agreed to within a couple of meters. The final misfits are 2 ms, implying that the errors in the estimated locations are a few meters, and arise from the limited precision of the travel time measurements (1 ms ~ 1.5 m), and a variety of errors arising from approximating the true oceanic sound-speed profile with a single value ("sounding velocity"). We used sounding velocities calculated from mean annual sound-speed profiles provided in the 2001 World Ocean Atlas database (http://www.nodc.noaa.gov/OC5/indprod.html). Sounding velocities were calculated for each station, and ranged in value from 1491-1492 m/s. Given our "straight ray-path" approximation to what are in reality more complex acoustic paths, the quoted location errors are a lower bound. The inadequacy of this approximation was evident in the inversion for the location of station I01, which was deployed in 1300 m of water, our shallowest station. That the survey lines were clearly too long for this station was evident in the magnitude of the travel time residuals. For this station, we threw away all data values for which the horizontal distance between the ship and the OBS drop location exceeded 750 m.

Appendix 2: OBSIP Instrument Checkout Summary

SCRIPPS INSTITUION OF OCENOGRAPHY
Institute for Geophysics and Planetary Physics.
Ocean Bottom Seismograph Instrument Pool

INSTRUMENT CHECKOUTS AND DEPLOYMENTS
Sea of Cortez Ocean Bottom Array (SCOOBA)
October 16-19, 2005

Between October 15 and October 19, 2005, 15 L-CHEAPO LC-2000L Ocean Bottom Seismographs were deployed in the Gulf of California from the R/V New Horizon for Principal Investigators James Gaherty and John Collins. Table 1 shows the serial numbers for the key instrument components used for each deployment.

Site	Transponder and Data Logger No.	Sensor Ball No.	Trillium No.	Leveling Software Version	Differential Pressure Gauge No.	Comments
I06	0028	2	240-120	2.0.17	05007	
S06	0003	31	240-118	2.0.17	2003-0017	
S05	0032	11	240-121	2.0.17	2003-0024	
S04	0071	29	240-106	2.0.14	05019	
S03	0002	9	240-106	2.0.14	05014	
S02	0075	8	240-109	2.0.18	2003-0025	Note 1
S01	0081	5	240-107	2.0.14	2003-0001	Note 1
I04	0082	27	240-110	2.0.18	05015	2nd deployment
I02	0072	26	240-108	2.0.18	2003-0007	
I01	0011	1	240-119	2.0.17	2003-0022	
N06	0043	30	240-101	2.0.18	2003-010	
N05	0060	32	240-114	2.0.18	05029	Note 2
N04	0033	13	240-104	2.0.14	05041	2nd deployment
N02	0067	10	240-103	2.0.17	2003-0011	
N03	0074	28	240-111	2.0.18	2003-0021	

Two of the instruments were deployed twice; each of them apparently broke apart from its anchor upon impact with very rocky seafloor topography at Site S03. The first deployment of each of these instruments is not shown in the table. Replacement anchors were fabricated from ballast anchors used in the Acoustics Test Rosette assembly and the instruments were re-deployed at other locations.

Excessive clock frequency error was noted in the instruments shown in the table with comment “Note 1.” In Data Logger No. 0075, the second mark shifted by 0.5 mS in 10 minutes (at room temperature), which is equivalent to 72 ms/day, or 37 S over a one-year deployment. Data Logger No.00 81 displayed similar behavior, thought the error was somewhat less. Other significant clock errors may have been missed during the brief span over which the position of the second mark is checked in the lab during preparation for deployment.

“Note 2” refers to Data Logger 0060, which displayed anomalous analog-to-digital converter behavior at the beginning of the checkout. This was one of the few instruments in which the instrument power-up sequence briefly caused a problem with all four A-to-Ds. After that, the output of the channel 2 A-to-D appeared to display anomalous values that repeated in groups, such as 2065, 2065, 2065, 8, 8, 0, 8, 2065…etc. The instrument was set aside and the problem was not seen again when it was powered up several hours later.

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