SCOOBA

Sea of Cortez Ocean-Bottom Array Seismic Experiment

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Introduction

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:

1) 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 (Figure 2), 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.

2) 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.

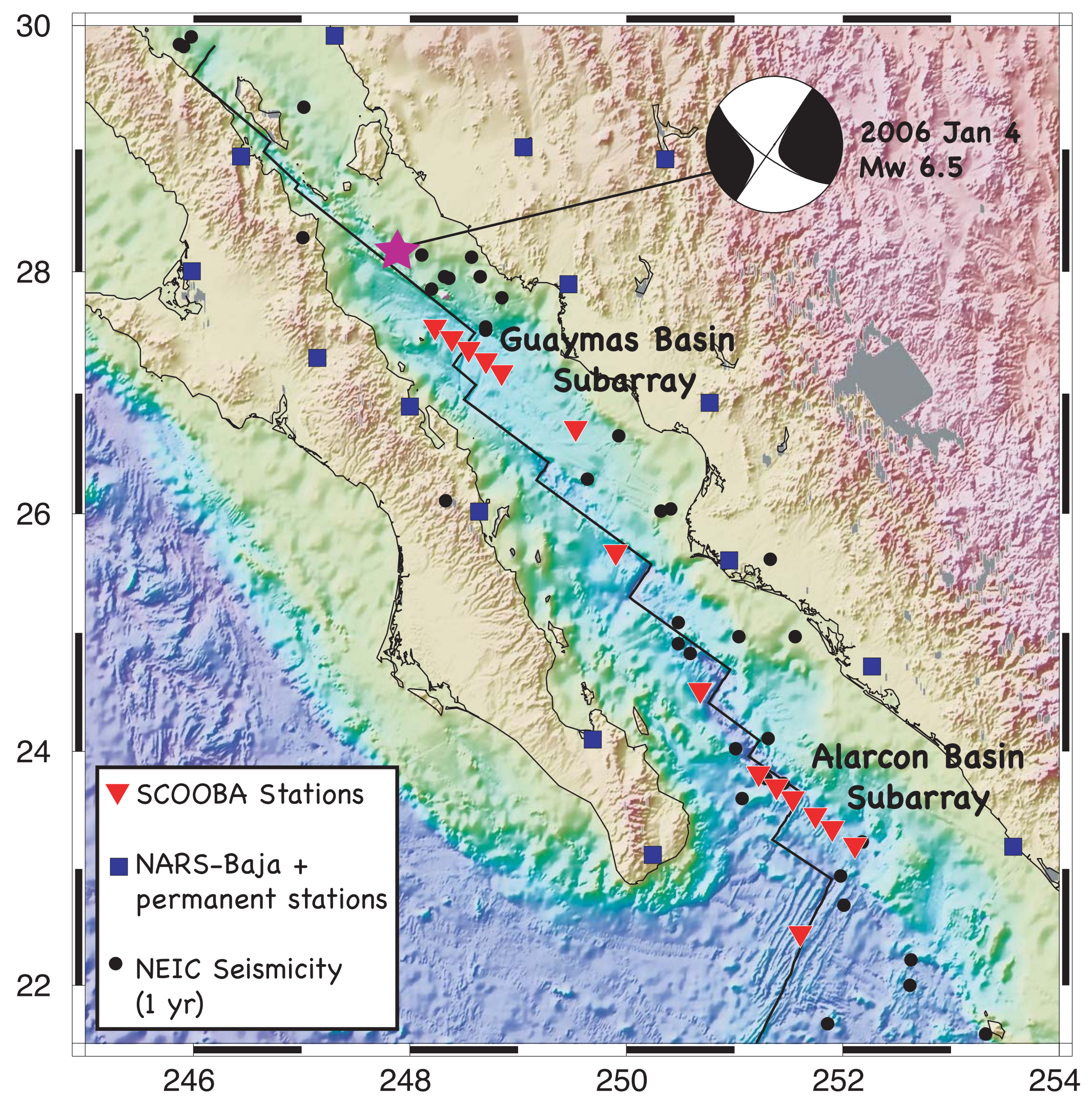

Figure 1. The locations of the SCOOBA stations (red triangles) on a bathymetric map of the southern Sea of Cortez. The experiment is designed to provide resolution of mantle structure with the Gulf proper, complementing the coverage provided by on-shore stations of the NARS-Baja experiment plus permanent broadband stations of the CICESE and UNAM regional networks (blue squares). The SCOOBA deployment consists of two dense subarrays in the Alarcon and Guaymas basins with station spacing of order 20 km, and a broader set of 4 stations that are located to give a nominal station spacing of 100-150 km, similar to NARS-Baja. In addition to the goals related to upper-mantle imaging, the stations will greatly improve earthquake locations (black circles) and thus fault behavior in the southern Gulf. The array should provide excellent recordings of the last week's large earthquake, shown with the purple star. Bathymetry is extracted from the LDEO MARGINS database via GeoMapApp. Solid line is the nominal Pacific-North America plate boundary.

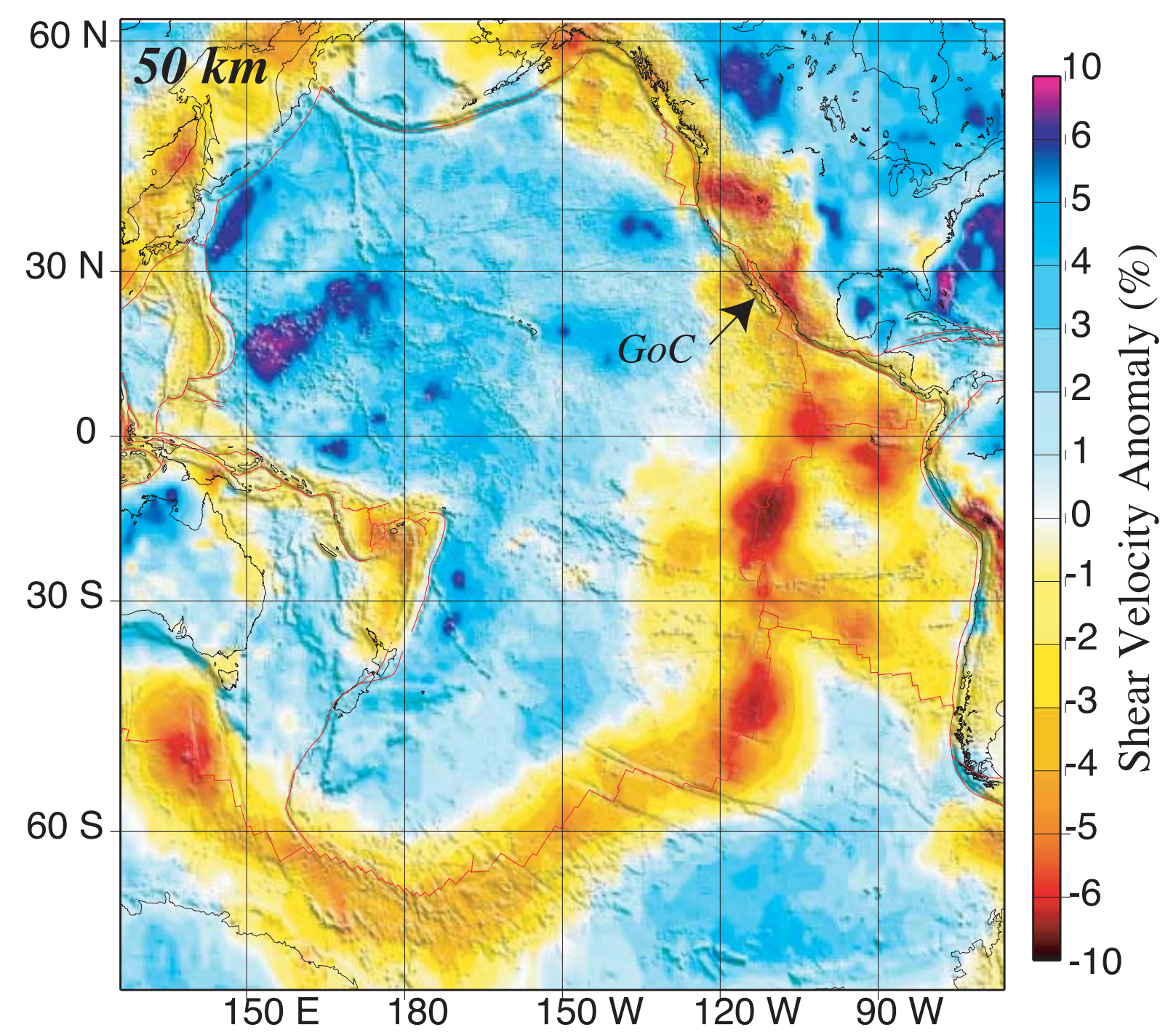

Figure 2. Shear velocity anomaly at 50-km depth relative to PREM, from a recent global model of Ritzwoller et al. (2002). At this depth, the Gulf of California (GoC) sits on a distinct velocity low that is matched or exceeded only in regions of hotspot volcanism (e.g. Yellowstone, Galapagos) and/or super-fast spreading on the EPR. This implies that GoC extension may be driven or facilitated by anomalously hot or wet underlying mantle, at odds with its non-volcanic nature. The spatial resolution of this model is of order 1000 km and greater, however, too large to discern whether the regional upper mantle anomoly is characteristic of the Gulf as well.

Deployment Strategy

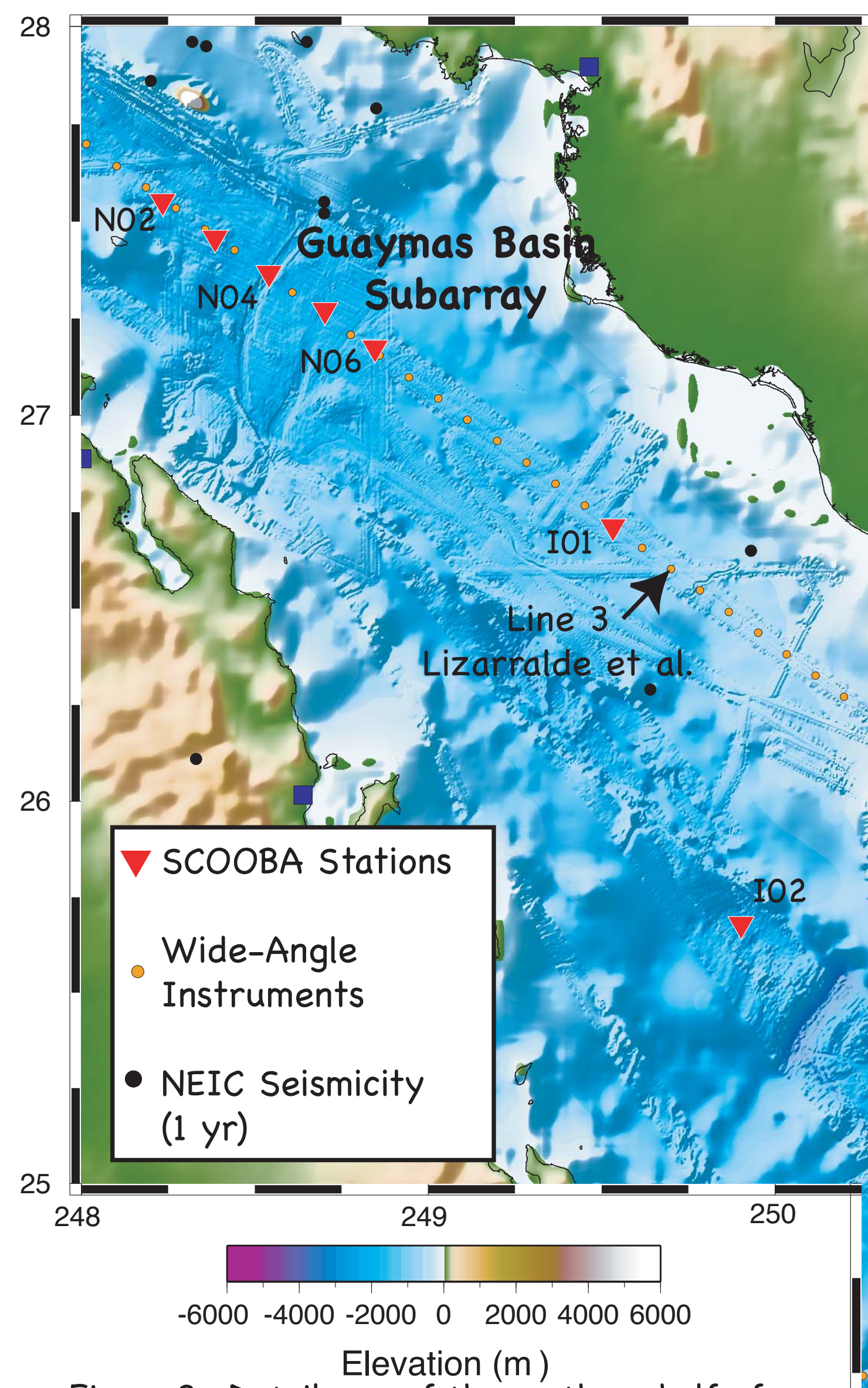

Figure 3. Detail map of the northern half of the SCOOBA array, including the Guaymas Basin subarray.

In addition to complementing the onshore broadband station coverage with offshore instruments, SCOOBA specifically builds on the MARGINS active-source and multi-beam activities in the region. In the Guaymas basin, the 5-station Guaymas sub-array is located directly on top of Line 3 wide-angle and MCS lines, presented at this workshop by Lizarralde et al. (Figure 3, at left). There are two benefits to this synergy: accurate knowledge of the overlying crustal structure will improve our resolution of the underlying mantle; and (2) covariations in crustal and mantle structure can be confidently interpreted. High resolution bathymetry is available from the Lizarralde et al. and Lonsdale experiments, and this data proved useful in instrument siting. Bathymetry in this figure is extracted from the MARGINS database at LDEO, via the GeoMapApp website.

Likewise, the Alarcon Basin subarray (Figure 4, at right) is located directly on top of Line 1 wide-angle and MCS lines, presented at this workshop by Sutherland et al. The 20 km spacing of each subarray will allow us to discern variations in across-axis structure in the shallow mantle just beneath the Moho. The structural variations (absolute and relative velocity, anisotropy, attenuation) observed in each subarray can be compared to that found beneath the EPR, allowing us to address question 1 (see Figure 8). The variation between the two subarrays should allow us to address question 2. During the deployment, we attempted to site the three of the four independent instruments on volcanic highs or within rift valleys associated with the nominal plate boundaries (I06 is so located). However, we experienced two anchor failures during deployment of S03 on the volcanic high in the center of Alarcon, and so we opted to site the remaining instruments on sedimented seafloor to avoid instrument loss.

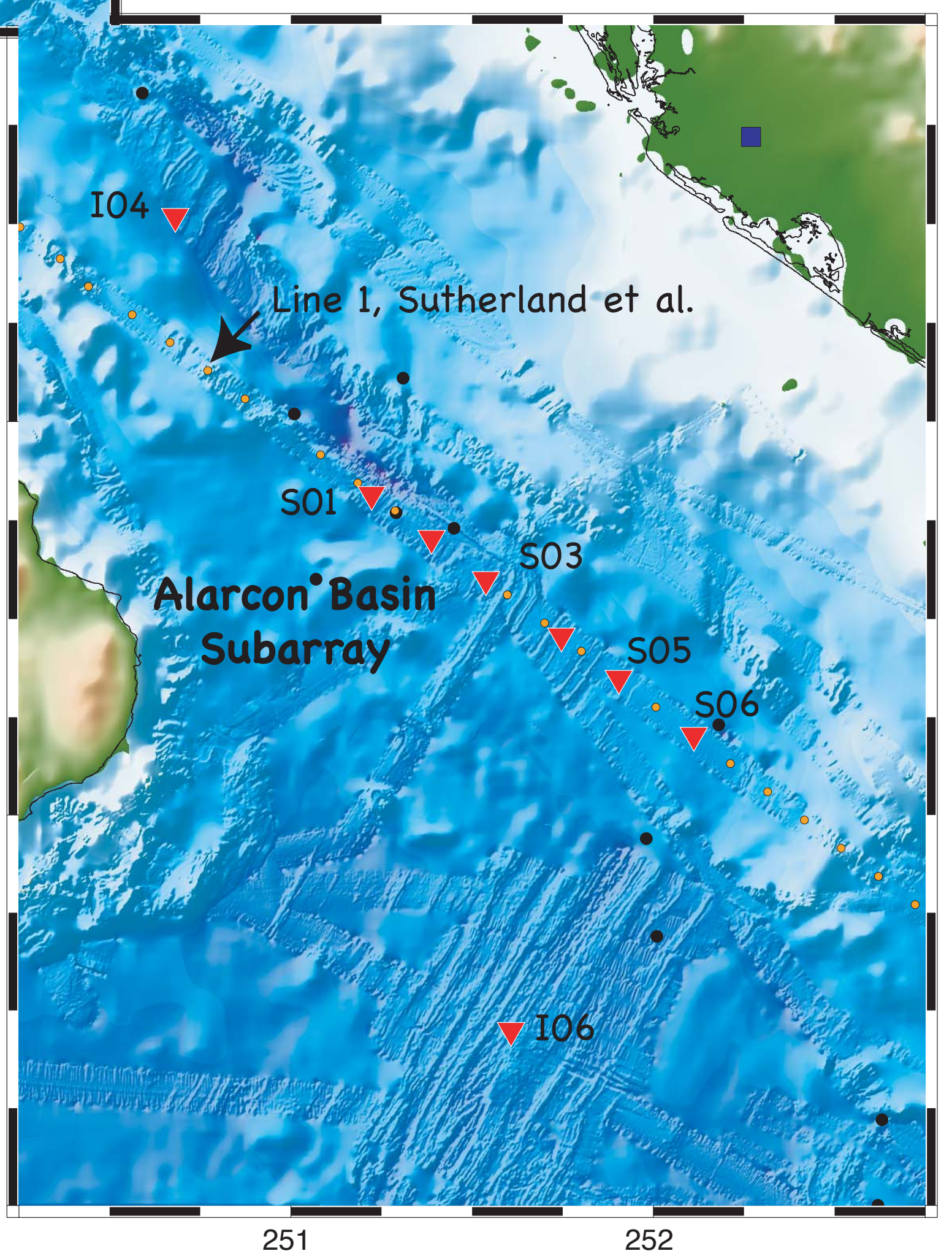

Figure 4. Detail map of the southern half of the SCOOBA array, including the Alarcon Basin subarray. Symbols are the same as in Figure 3.

Instrumentation and Instrument Location

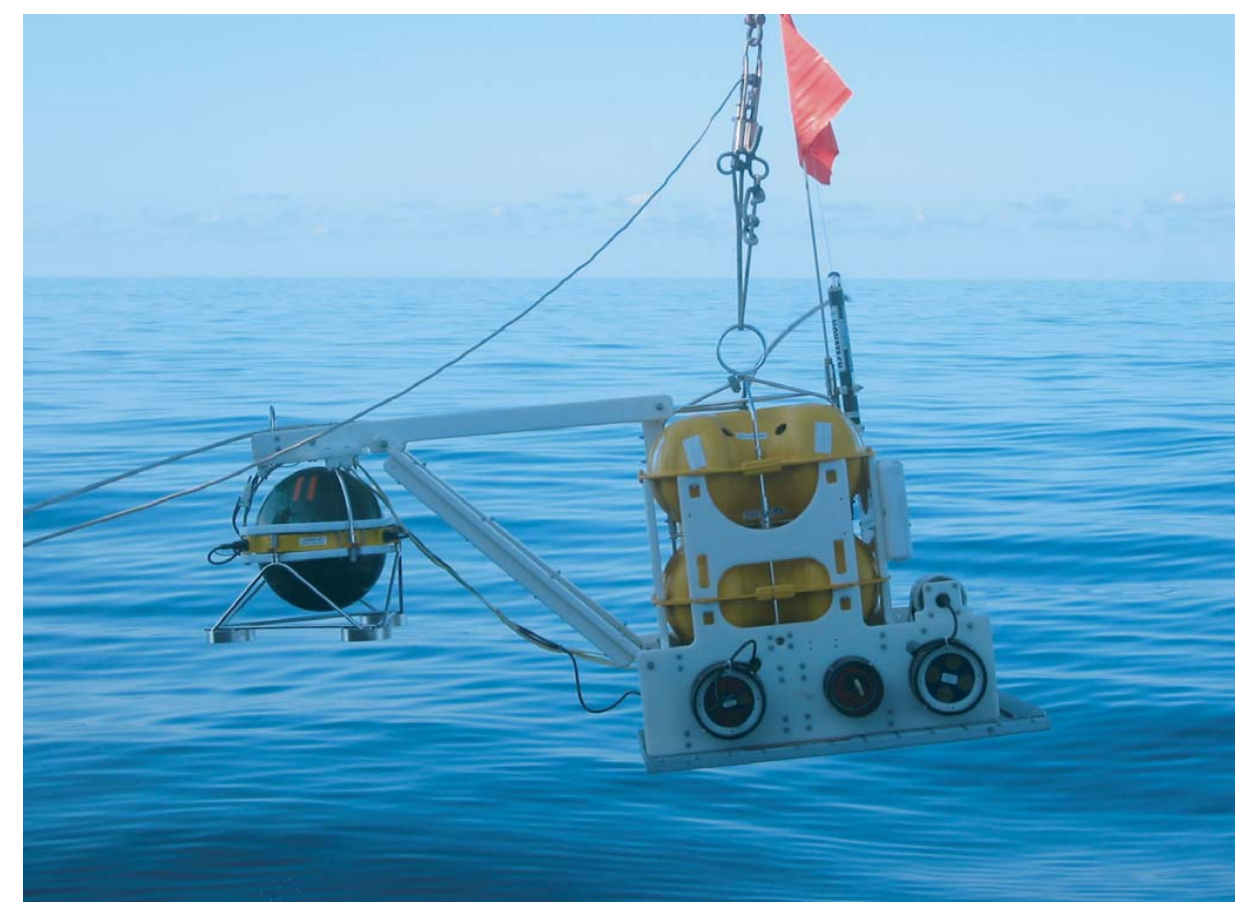

Figure 5. Deployment of station S05. Seismometer is located in green sphere; remaining instrumentation, power, and communication are located in pressure tubes just beneath yellow flotation spheres. Metal grate on bottom is the anchor.

The SCOOBA instruments were provided by the Scripps OBSIP facility. Each instrument is equipped with a three-component broadband (Trillium 240) seismometer and a Differential Pressure Guage,with recording on a high-resolution seismograph at a 32 Hz sample rate. Instruments are dropped over the side (Figure 5); upon arrival at the seafloor, the seismometer ball is released from the arm, mechanically decoupling it from the higher-profile instrument package. In general, the deployment was quite successful; one instrument lost acoustic contact, and in one cae we found that the instrument anchors were not strong enough to survive impact with hard-rock seafloor. Spare anchors were constructed on board, and the instrument was redeployed on sediment a few kilometers away.

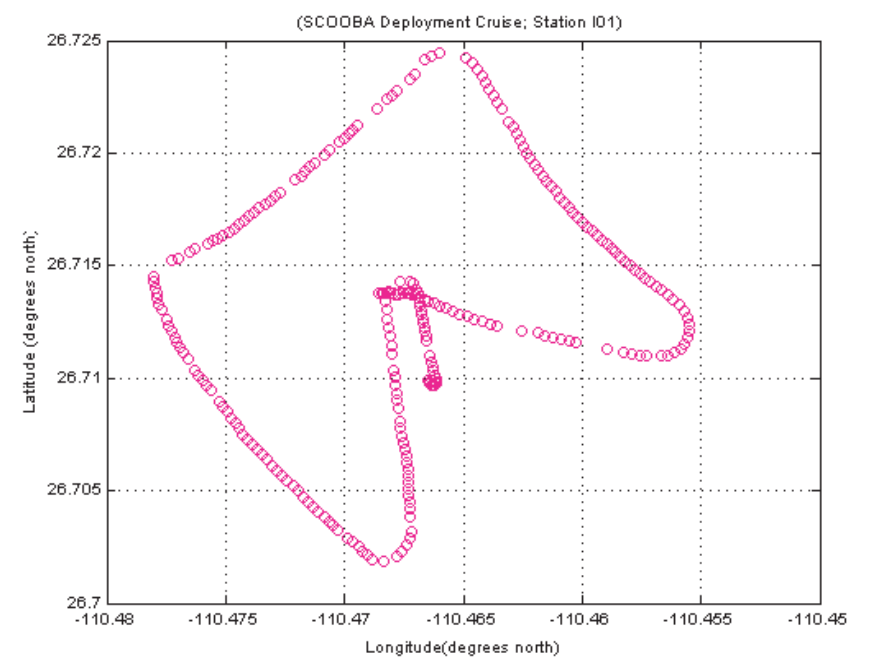

Figure 6. Sounding locations used to relocate instrument I01. At each of these locations we acquired an acoustic travel time from the instrument to the ship.

Table 1. 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.

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 by ranging acoustically to the OBS from many known ship locations distributed over a broad range of ship-OBS azimuths. Knowing the ship location, we invert for instrument location using a least-squares procedure. 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"). Table 1 provides the initial and final locations for all stations.

Science to come...

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 (Figure 7), 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 8).

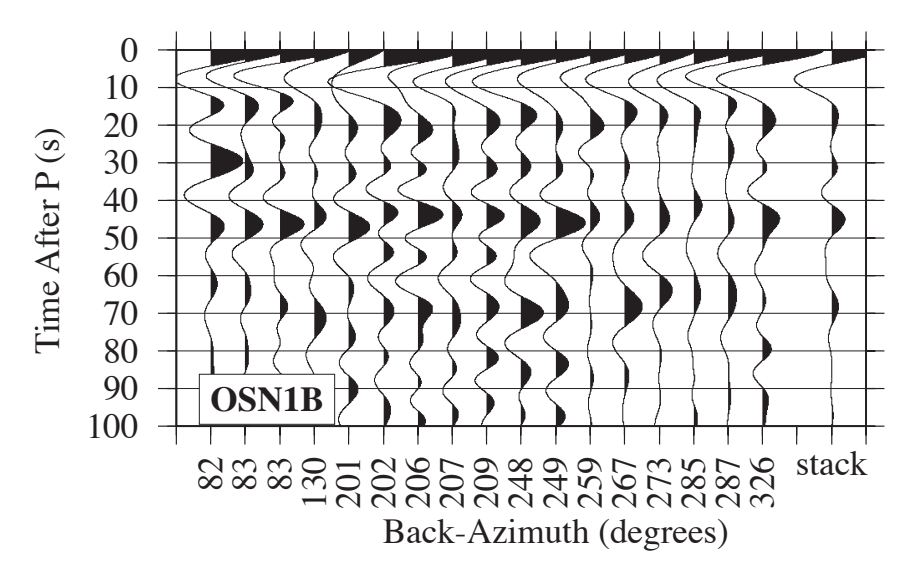

Fig. 7. Receiver functions for an OSNPE broadband OBS station, plotted versus back-azimuth. Body wave magnitudes for these events ranged from 5.3 to 6.6. The right hand trace is the sum of the individual receiver functions. P-to-S conversions from the 410- and 660-km discontinuities are seen in the individual receiver functions as positive phases at ~45 s and 60-70 s. The P660s and P410s times vary with event back-azimuth. [From Collins et al., 2002].

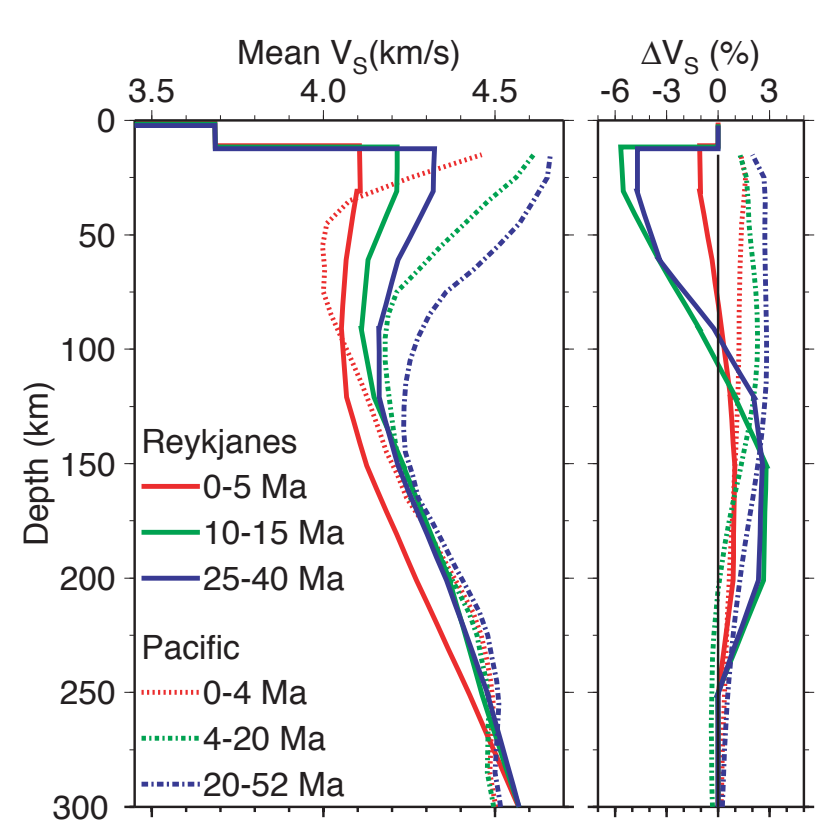

Fig. 8. Shear-velocity models of the Reykjanes region south of Iceland displaying evidence for buoyancy-driven upwelling beneath this hotspot-influenced spreading center. Left panel displays mean shear speed (VS = (VSH+VSV)/2), while right panel displays radial shear anisotropy (ΔVS = (VSH-VSV)/VS) in percent). Three age regions are shown: 0-5 Ma (red), 10-15 Ma (green), and 25-40 Ma (blue). These models are contrasted with models for Pacific upper-mantle of comparable ages (dashed). Reykjanes region is systematically slower than the Pacific, and the negative anisotropy at shallow depths suggests that olivine fabric within the lithosphere has been quasi-vertically aligned by buoyancy-driven flow within the melting zone near the ridge. [From Gaherty, 2001].

Acknowledgments

John Manion, Captain, and the crew of the R/V New Horizon
Jose Gomez-Valdez, CICESE, watchstander
Charles Wilson, LDEO, watchstander
Mark Gibaud, SIO OBS Technician
Martin Rapa, SIO OBS Technician
David Willoughby, SIO OBS Technician
Lucian Parry, NH Science Tech

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.