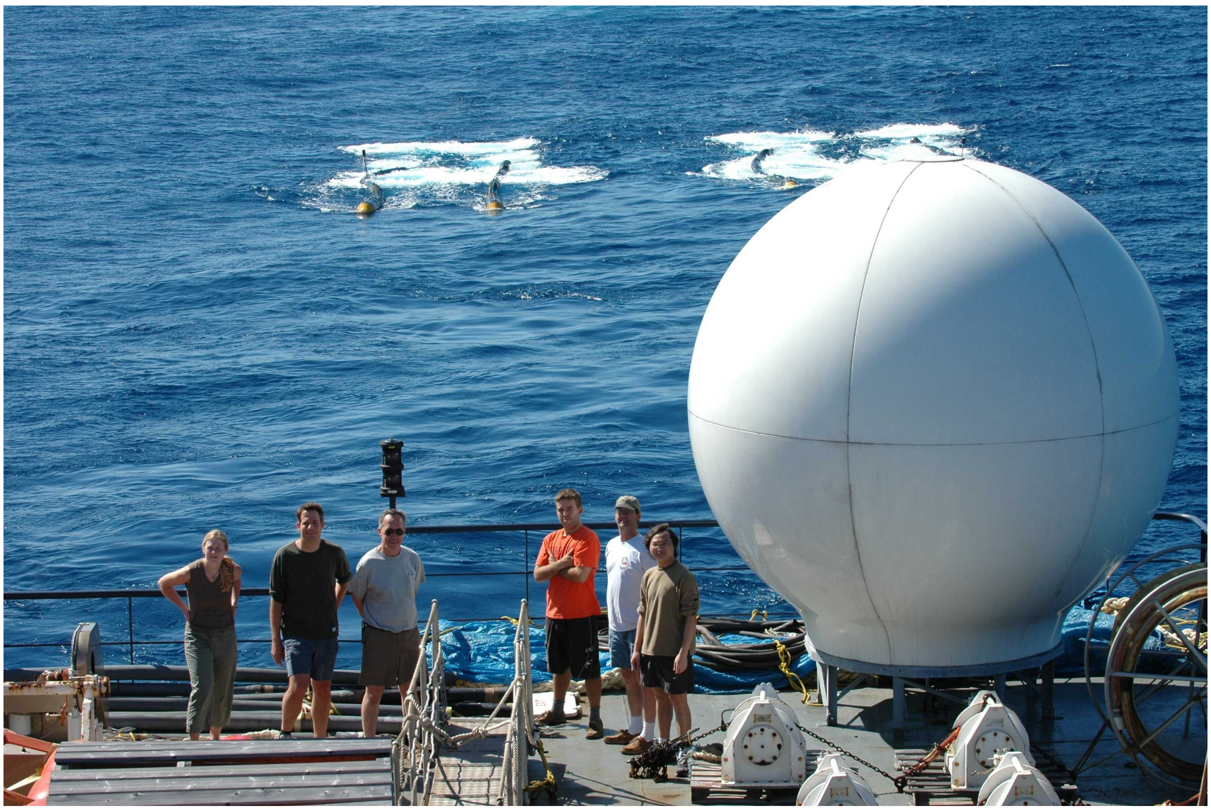
The Quebrada-Discovery-Gofar Transform Fault Experiment

Cruise Report, Leg 2: Passive Deployment

R/V Marcus Langseth MGL0808 4/24/08-5/11/08



Project Background

This is the second cruise of the Quebrada/Discovery/Gofar (QDG) transform fault experiment located on the equatorial East Pacific Rise (EPR). The goals of the project are to understand the mechanical processes that control earthquake nucleation and the relative partitioning of seismic and aseismic fault slip. The QDG fault system is the most prolific known oceanic transform fault in terms of generating large earthquakes that are preceded by an immediate foreshock sequence. Approximately 50% of magnitude ⩾5.0 earthquakes on these faults are preceded by a foreshock in the hour before the mainshock. This spectacular behavior directly reflects the fundamental mechanics of faulting and detailed recordings of the sequences can be used to test competing hypothesis about earthquake nucleation. Additionally, the factors controlling whether a fault fails seismically or aseismically can be evaluated at QDG owing to the juxtaposition of three morphologically similar, high slip-rate transforms that exhibit nearly opposite styles of deformation. Earthquake catalogs indicate that all three transforms produce abundant micro-seismicity. However, the Discovery and Gofar transforms repeatedly rupture with $M_w > 5.5$ earthquakes while the Quebrada transform has had only one event of this size in the last 25 years. This difference is best quantified in terms of the seismic slip deficit, which is roughly 80-87% for Gofar, 69-81% for Discovery and 98-99% for Quebrada. The significantly higher level of seismic activity on the Discovery than on the Quebrada is quite surprising given that Discovery is shorter and warmer. A one year passive deployment of OBSs began in December of 2007, and this cruise shot two refraction lines across the Quebrada and Gofar transform faults to image any large scale differences in subsurface geology between the highly seismic and predominantly aseismic fault-zones.

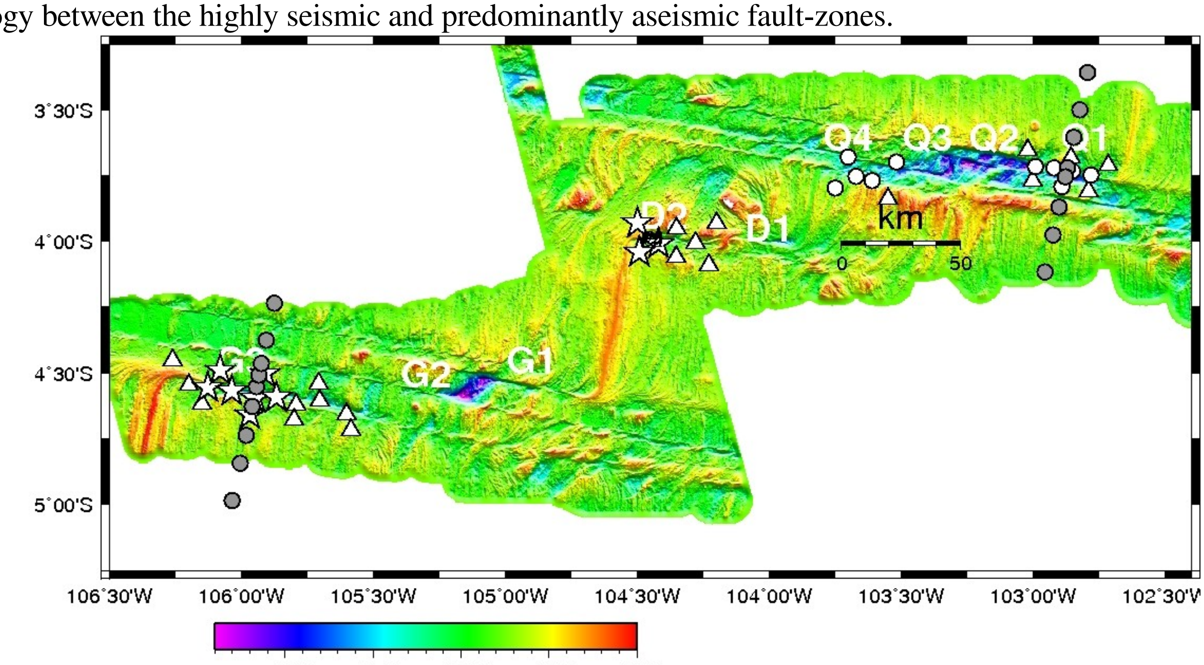


Figure 1. Map of the Quebrada, Discovery, and Gofar Transform Faults. White triangles, circles, and stars denote the locations of passive OBSs deployed in December 2007 on the R/V Thompson. The gray circles denote the OBS drop locations for the refraction lines shot on this leg. Bathymetry was collected on the R/V Knorr by D. Forsyth and R. Pickle of Brown Univ.

Science Party: WHOI Group

Jeff McGuire	Chief Scientist
Peter Lemmond	Scientist
Dave Dubois	Scientist
Nathan Miller	Grad Student
Min Xu	Grad Student
Emily Roland	Grad Student

Langseth Technical+IT Group

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Megan Meyer	
Elliot Aguilar	
Zhiqiang Zhang	

Gunners:

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Luis Villalobos	

Marine Mammal Officers:

Heather Patterson
John Nicholas
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Nicholas Engelmann
Claudio Fossati

Line 1: The Quebrada Fault

Line 1 OBS Deployments

The OBS deployments were lead by Dave Dubois and Peter Lemmond with one watch stander to assist on a tag line. The OBSs for line 1 were deployed between 3:30 a.m. and 11:00 a.m. ship time on 4/30. All 8 deployments went smoothly with an average on station time of 10-15 minutes. Acoustics were generally good in the first 300 m of fall time before being disabled. EM120 was turned off after each drop and restarted after each disable command.

OBS #	Name	Drop Lat	Drop Lon	Drop Depth
D32	L1-1	3 21.33	102 47.62	3292
D34	L1-2	03 29.992	102 49.40	3255
D51	L1-3	03 36.3470	102 50.747	3091
D40	L1-4	03 43.23	102 52.225	3405
D25	L1-5	03 45.335	102 52.678	4191
D47	L1-6	03 52.205	102 54.13	2864
D11	L1-7	03 58.53	102 55.50	3203
D50	L1-8	04 07.007	102 57.268	3442

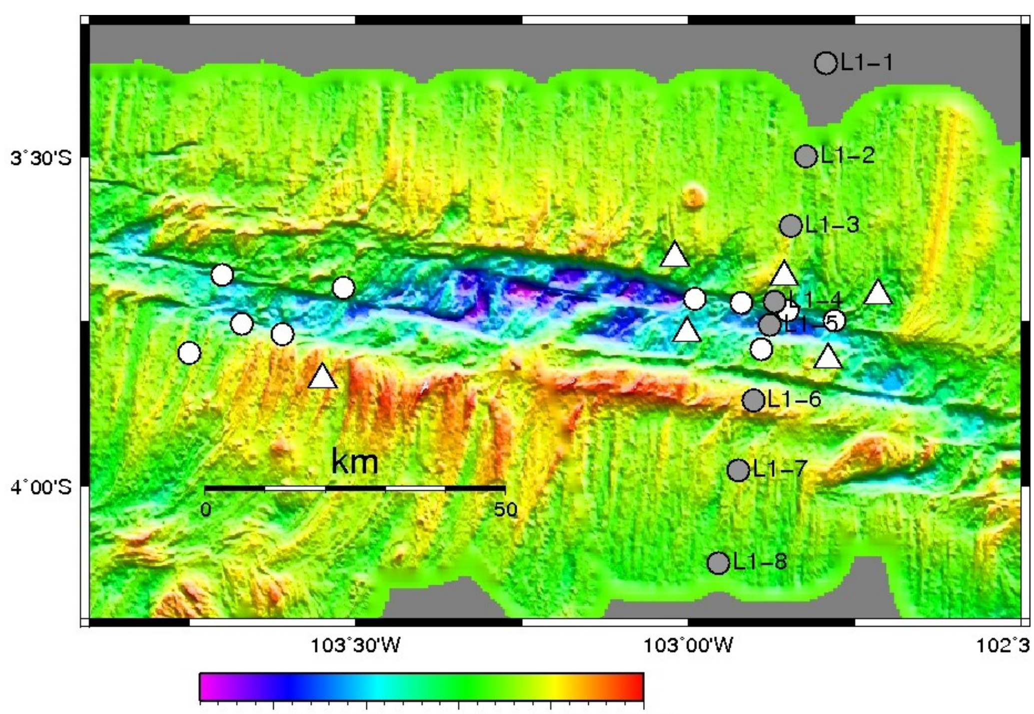

Figure 2. The OBSs deployed for Line 1 (gray circles) along with the Passive OBSs deployed on the Quebrada fault (white triangles and circles).

Line 1 Shooting

It took us approximately 7 hours to deploy the airguns+PAM system, and get the spectra/digishot system running satisfactorily. We had one 8 minute power down to 1 gun for a turtle immediately after starting rampup, but otherwise animal sightings were not an issue. There were also some short ramp downs due to compressor problems, but this only occurred while we were getting the spectra system running not during the line. The primary delay in starting the line was due to difficulty in getting spectra to properly log shot points. Initially when we started shooting on distance, spectra was calling every shot point shot "0000" instead of sequentially numbering them. As we approached the start of the line we were uncertain as to whether this would effect our ability to extract the shot locations+times afterward so we asked the bridge to do a circle. While circling, Mike figured out the magic trick in spectra and we were ready to begin the line once the ship completed the circle.

The shooting of the line progressed without incident. The outer 26 km on each side were shot at 150 m distance at about 4.8 knots (about 60 s). There was some uncertainty about the exact limits on the speed at which the airguns can be towed in particular whether we should be worried about the STW readout in the mainlab exceeding 5 knots for short periods of time. This appears to have been a misunderstanding as the proper limit is 5.5 knots. The middle portion of the line (between OBSs L1-2 and L1-7) was shot at 100 m spacing at 4.0 knots (about 48 seconds).

XBTs deployed during shooting were generally unsuccessful due to the wire grounding on the ship/streamer after ~500 m in depth. This was likely due to high currents. XBTs had tobe launched during recoveries.

Line 1 OBS Recoveries

Dave Dubois and Peter Lemmond lead the recovery of the OBSs with one watchstander on deck to help out. The recoveries took about 15 hours. All instruments needed only one burn to start rising and all were sighted on the surface within a few minutes of their expected arrival time. The MMO staff helped out from the tower making daylight recoveries straightforward. The recovery radios were only moderately useful in being picked up by the bridge. The night time recoveries were straightforward as well.

Line 1 Data:

All 8 instruments recorded 4 channels of seismic data. Of the 32 channels only one appears to have returned bad data (component 2 on D40, L1-4). In general, the portion of record sections from outside the transform valley have very clean first arrivals (Pg, Pn) out to 30+ km, while those portions that cross the fracture zone valley have very limited energy beyond ~15-20 km. Figure 3 presents record sections from stations L1-4 and L1-6. Both sections show much clearer signals from ray paths through the Pacific Plate north/south of the Quebrada TTZ than those through the transform valley.

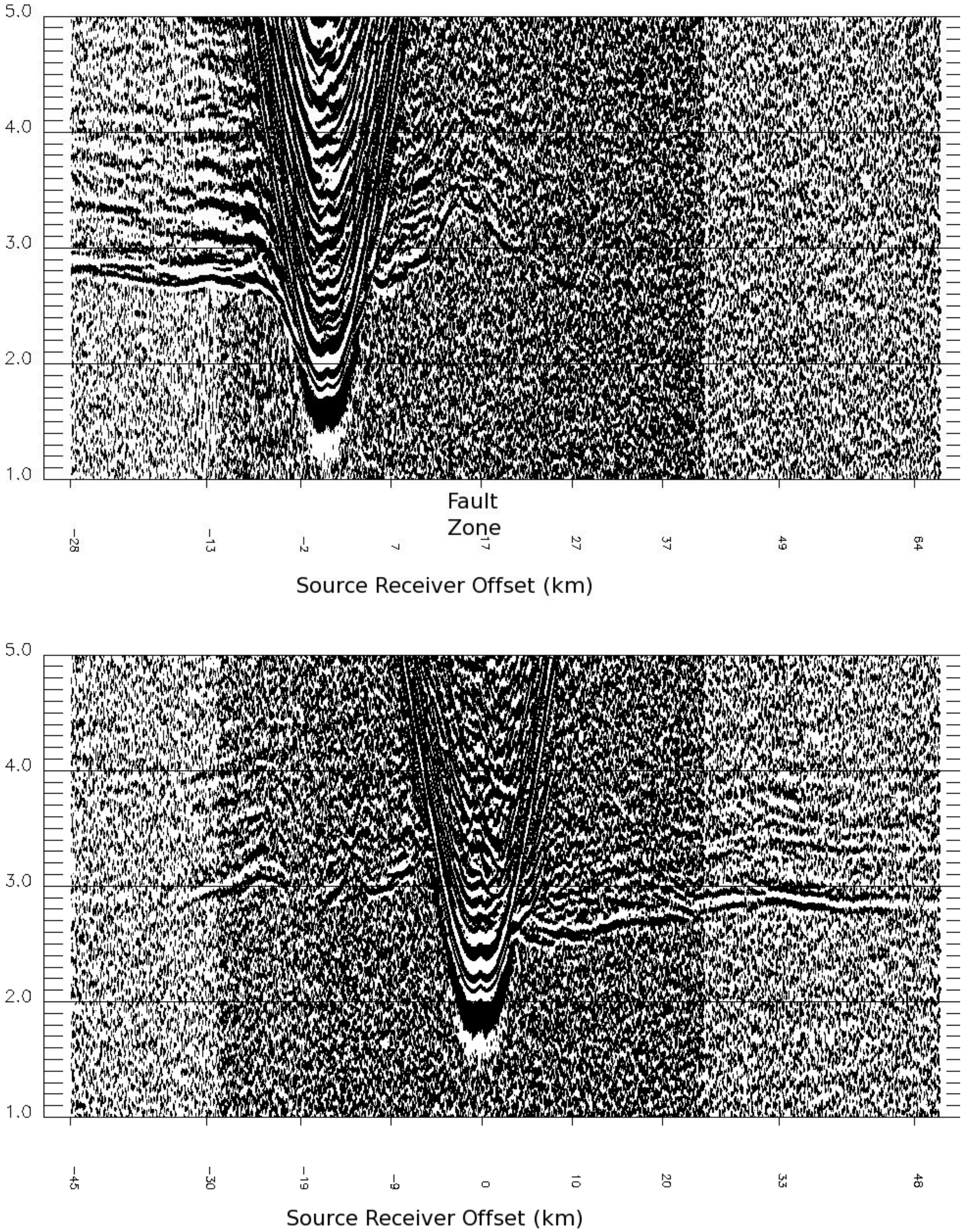

Figure 3. Reduced travel time (7 km/s) record section for the hydrophone component of stations L1-6 (top) and L1-4 (bottom). The shots on the lefthand side are from the south of the instrument and those on the righthand side are from the north. The higher level of darkness in the center of the image results from the 100m shot spacing in the middle of the line relative to the 150 m spacing on the outer edges. These figures demonstrate the difficulty in getting energy through the crust of the transform fault domain. While there is a very clear Pg/Pn arrival from shots outside the domain (south of L1-6 and north of L1-4), shots that have to cross the transform domain (from the north of L1-6 and the south of L1-4) have very little energy in Pg/Pn..

Line 2: The Gofar Fault

Line 2 OBS Deployments

The Line 2 OBS deployments were lead by Dave Dubois and Peter Lemmond with one watch stander to assist on a tag line. The OBSs for line 1 were deployed between 8:30 p.m. on 5/2 and 4:30 a.m. ship time on 5/3. Due to a fast transit speed between lines (11.5 knots) we had time to deploy an extra D2 on the north side of the fault. All 9 deployments went smoothly with an average on station time of 10-15 minutes. Acoustics were generally good in the first 300 m of fall time before being disabled. EM120 was turned off after each drop and restarted after each disable command.

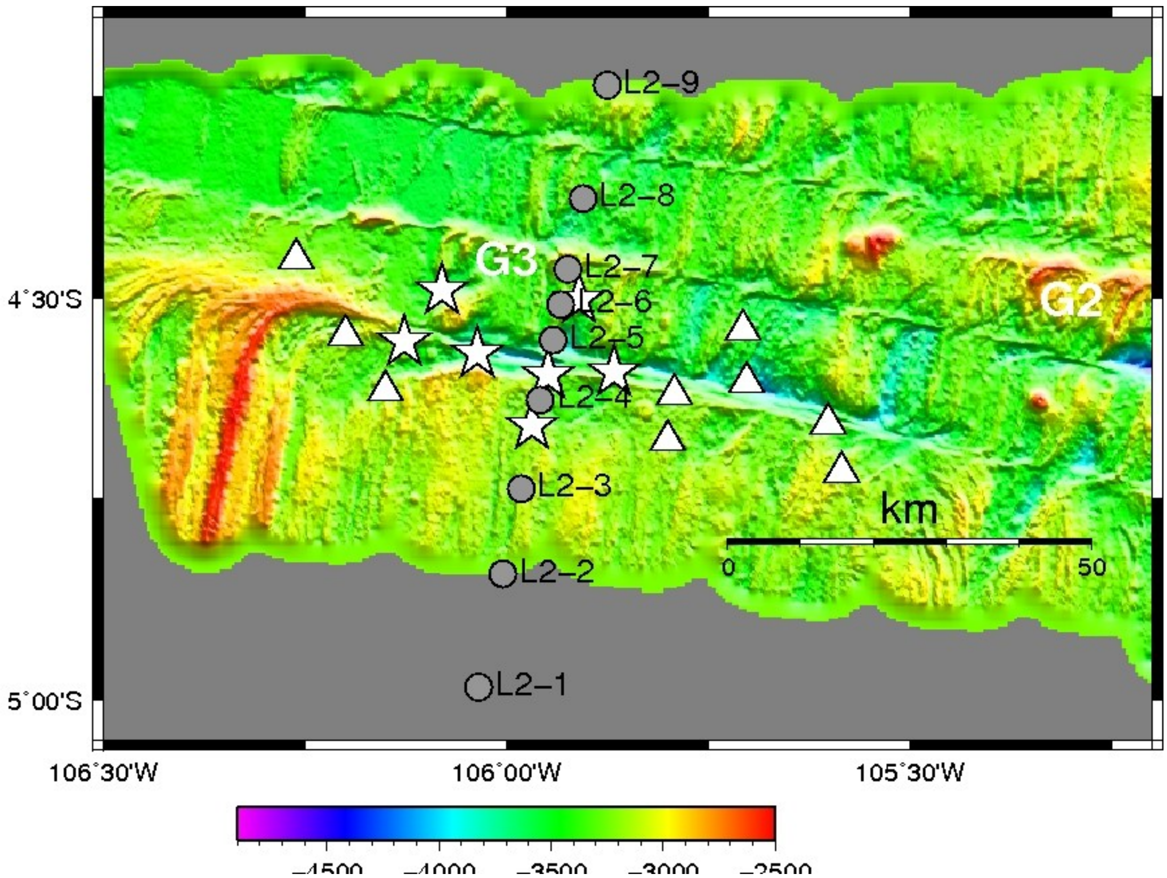

Figure 4. The OBSs deployed for Line 2 (gray circles) along with the Passive OBSs deployed on the Gofar fault (white triangles and circles).

Line 4 Shooting

Deployment of the airguns and PAM system began around 6 am on 5/3 and we reached the nominal start of line 2 at about 10 a.m. to allow the OBSs time for their seismometers to detach from the hardhat. The line extend 20 km beyond the northern and southernmost OBSs. We had no MM sightings of any kind on this line and the line proceeded without incident.

Line 2 Recoveries

The second instrument we tried to recover (L2-2) did not rise from the bottom. The burn command was sent 10 times, most of which resulted in very clear confirmations after 15 minutes. After the tenth command did not free the instrument from the bottom we disabled it and moved on. All other recoveries went very smoothly.

Line 2 Data

In general the data quality on line 2 is even higher than that of line 1. This presumably results from more efficient wave propagation through the Gofar fracture zone than the Qeubrada fracture zone.

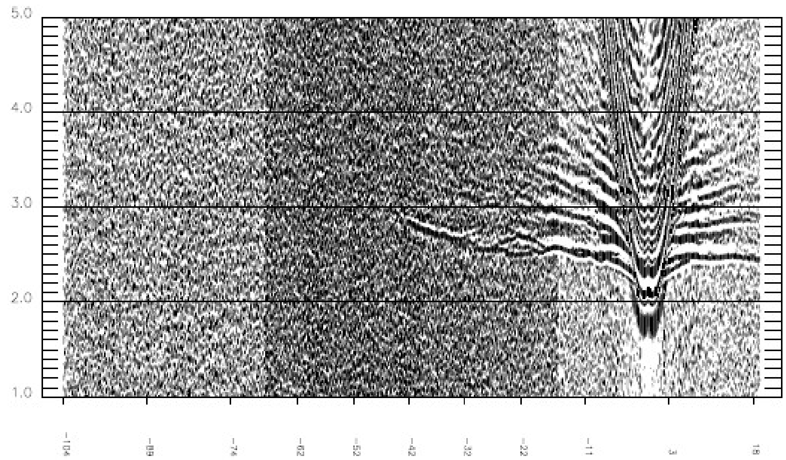

Figure 5. Seismic Section (reduced at 7 km/s) for instrument L2-1.

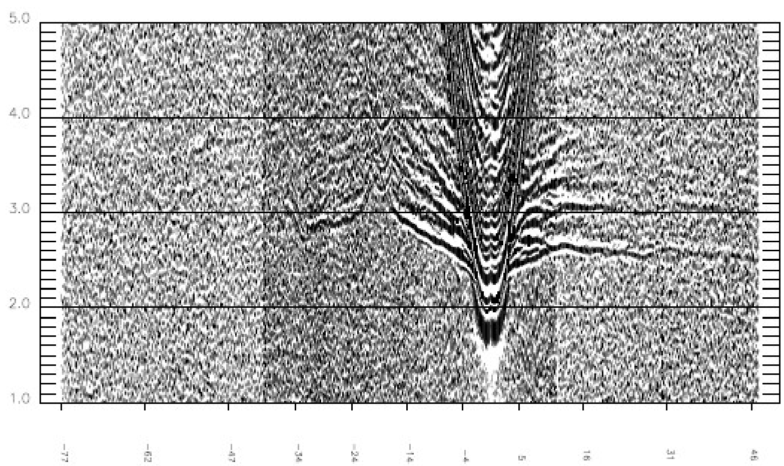

Figure 6. Seismic Section for instrument L2-3 (reduced at 7 km/s).

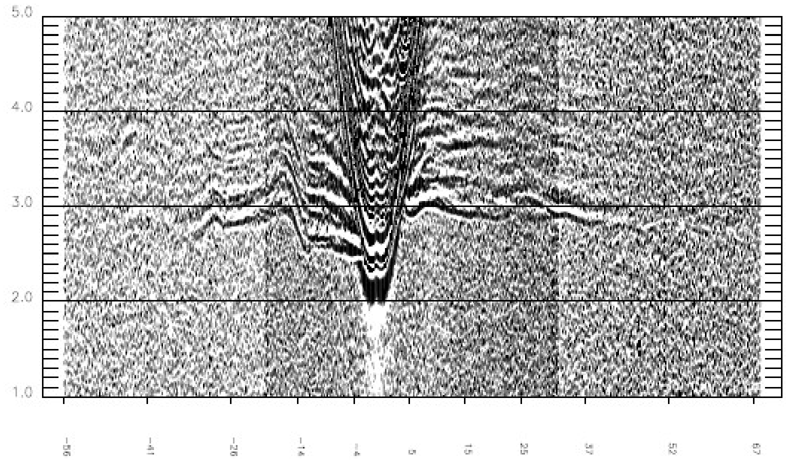

Figure 7. Seismic Section for instrument L2-5.

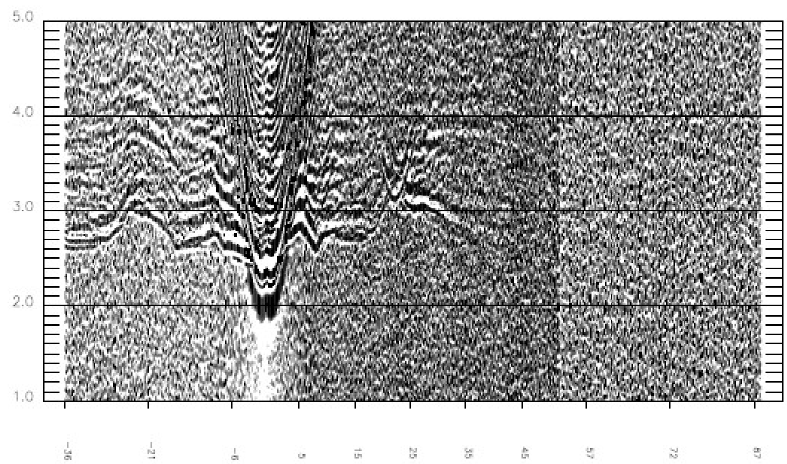

Figure 8. Seismic Section for instrument L2-8.

Triggered Earthquakes

A swarm of at least 100 microearthquakes appears to have been triggered by our refraction line across the Quebrada fault. Figure 9 shows the seismograms from station L1-3 from the time period immediately after the end of shooting. Several small earthquakes are seen in the first 30 minutes following the end of shooting. Initially microearthquakes in the swarm, microearthquakes were occurring every few minutes but by the time the most sensitive OBSs were recovered a 4-8 hours later, the rate of earthquakes had died down considerably, similar to an aftershock sequence. Dynamic earthquake triggering by high frequency waves is often a difficult phenomenon to constrain because high-frequency waves attenuate very quickly similar to static stress changes from earthquakes that generate them. Thus, our dataset will be a unique dataset for studying this phenomenon on a plate boundary fault.

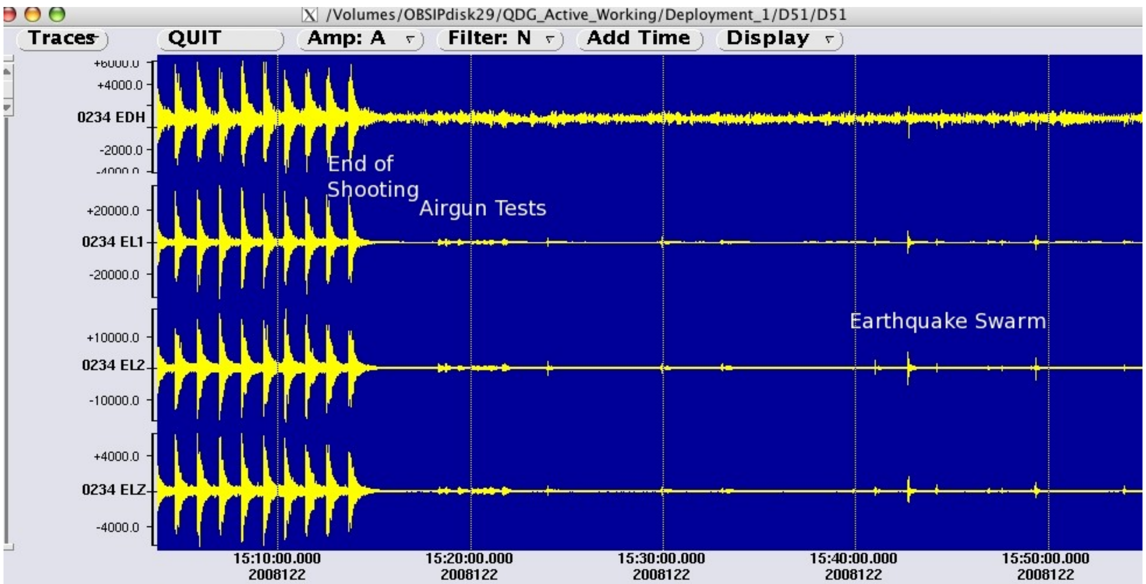

Figure 9. One hour of seismogram (4 channels) from station L1-3, just north of the Quebrada fault covering the end of our shooting of line L1. Shooting ends at ~15:15, then we tested a series of individual airguns until ~15:25, theremaining half hour of seimograms show numerous microearthquakes with P-S times of about 2.5 seconds indicating they came from the portion of the Quebrada fault that our line intersected..