OS33A-1462 Three-Dimensional Slowness Images of the Upper Crust Beneath the Lucky Strike Hydrothermal Vent Sites

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MARIE CURIE ACTIONS

Introduction

In June/July 2005 we carried out the SISMOMAR experiment, as a part of the MOMAR project (Monitoring the Mid-Atlantic Ridge). The main objectives of this experiment were to determine the crustal structure beneath the hydrothermal vent fields on the "Lucky Strike" volcano and to place this volcano in the magmatic context of the segment. The cruise was split into two legs. During the first leg we conducted a 3D seismic reflection survey covering both the Lucky Strike volcano and hydrothermal vents field (yellow box, Figure 1). To obtain full coverage inside the 18 km x 3.8 km box, shots continued for 2.25 km on either side of the box and extended out to the median valley bounding faults.

To complement the streamer data, 25 Ocean Bottom Seismometers (OBS) were deployed to record wide-angle reflections and refractions. These wide-angle-measurements can be used to constrain the velocity structure beneath the Lucky Strike segment of the Mid-Atlantic Ridge. During the first leg the instruments were placed in an 18 km x 18 km area centered on the volcano. Nine of the OBS positions lie inside the 3D reflection box (Figure 1). These OBS recorded turning ray arrivals at a very fine sampling interval (37.5 m x 100 m) and can be used to construct an image of the 3D velocity structure beneath the Lucky Strike volcano and hydrothermal vent field.

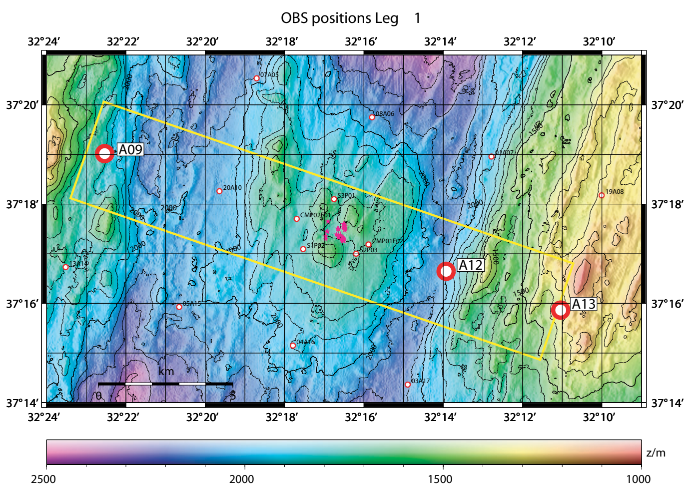

Figure 1: Overview of the first part of the Lucky Strike experiment. The distribution of shots during the 3D reflection experiment is marked by the yellow rectangle. The red circles represent the OBS positions, while the purple stars denote the location of hydrothermal vents (Charlou et al., 2000, and Langmuir et al., 1997). Bathymetric information from the Sismomar, Flores and SudAcores cruises. (Cannat et al, 1999; Y. Fouquet - unpublished, 1997).

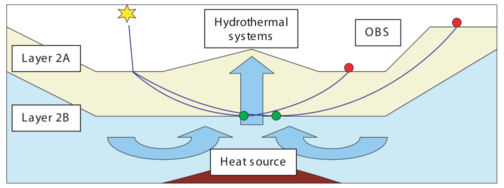

Figure 2: Hydrothermal system and penetrating rays. Every shot (yellow star) is picked up by multiple receivers (red circles). Green points mark the turning points of the rays.

Concept

The aim of this work is to develop a fast way for mapping changes of the slowness distribution in the upper crust. The slowness is equal to the inverse of the velocity at turning depths. The presence of fluid due to hydrothermal circulation should for example appear as a low velocity anomaly beneath the hydrothermal vents. To accomplish this we pick the refracted arrival from the interface of seismic layers 2A and 2B. Next we map small-scale variations (approximately 100 m) in the gradient of the travel times. After accounting for variations in the 3D topography these changes should be related to deviations from an homogeneous velocity structure.

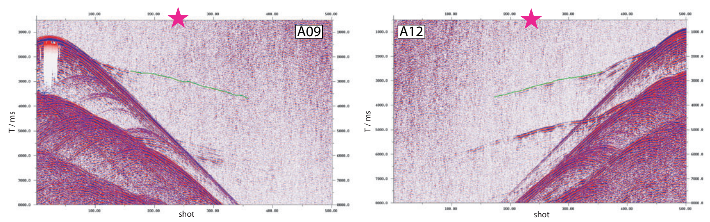

Figure 3: Receiver gathers for lines passing directly over the volcano summit: OBS A09 (left) and OBS A12 (right). The green line marks the refracted arrival from the interface between layer 2A and 2B. The purple stars mark the center of the volcano.

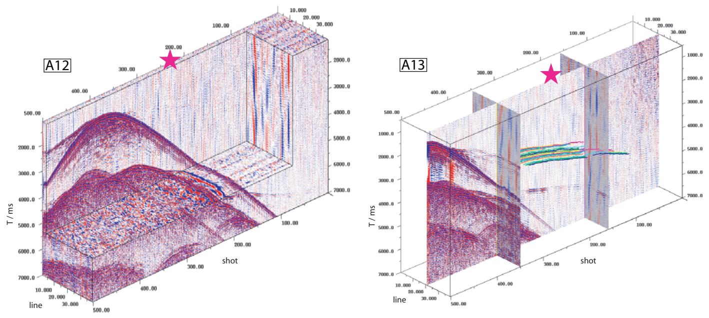

Figure 4: 3D receiver gathers viewed as voxels: OBS A12 (left) and OBS A13 (right). The colored lines mark the refracted arrivals from the interface between layer 2A and 2B. The purple stars mark the center of the volcano.

Estimating the horizontal slowness

With high-resolution 3D OBS data it is desirable to visualize and pick the data both inline and across-line to ensure consistency of the picks between adjacent shotlines. We used the commercial program *VoxelGeo* which maps the seismic traces to color coded voxels (volumetric pixel) assigning a color to each amplitude. The program also provides advanced routines to recognize horizons.

As a first step towards a joint 3D travel time and slowness tomography, we present the slowness function versus latitude and longitude for different OBSs (Figure 5 & 6) - a brute stack velocity image of the subsurface (c.f. Barton and Edwards, 1999). To get an estimate of the distribution of the subsurface slowness we picked the first arrivals for each instrument and selected those picks corresponding to the boundary between seismic layers 2A and 2B (Figure 4). To determine the slowness we take the inline gradient, normalize by the shotpoint spacing, smooth with a seven-point-moving average and plot the resulting slowness in the common midpoint position (Figure 5). The traveltime (Figure 5A) shows an increase of travel times as we move away from the OBS. Calculating the horizontal slowness (Figure 5B) acts like a high-pass filter, amplifying small variations.

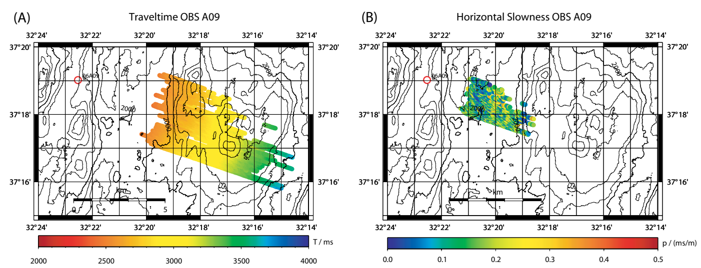

Figure 5: Refracted arrivals OBS A09: Traveltime (A) and horizontal slowness (B). The red circle marks the location of the OBS and the map shows the bathymetry of the Lucky Strike segment.

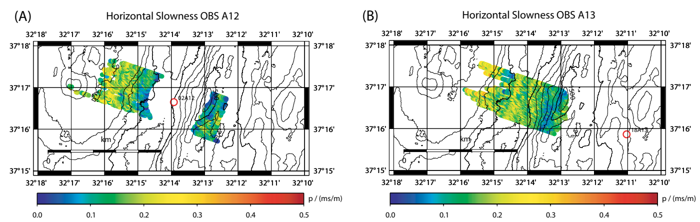

Figure 6: Horizontal slowness maps: OBS A12 (A) and OBS A13 (B). The red circle marks the OBS positions.

Discussion

Although our analysis is very preliminary we can draw some conclusions. All the shown instruments (A09, A12, and A13 - Figures 5 & 6) show a decrease of slowness near the receiver, which is possibly a processing effect. However, the mean slowness of 0.184 for all three instruments, corresponds to a velocity of approximately 5.4 km/s consistent with results from other experiments. Although receivers A12 and A13 are more than 4.5 km apart the two instruments give similar slowness images. One can denote zones of increased and decreased slowness. The large scale variations at long offsets should be related to changes of the subsurface slowness. We also see a decrease in the amplitude of the refracted arrival to the west of a volcano (OBS A12 & A13 - Figure 3) , which could be related to hydrothermal circulation.

There are some important problems we still have to address. First we have to find a way to map the shotpoints to the seafloor. Second in order to assess the reliability of our results a careful analysis of the confidence intervals of our picks and the derived slowness estimates is needed.

After these questions have been resolved we plan to invert the traveltime picks. The fine sampling interval within the 3D box provides the unique opportunity to jointly invert travel time and slowness. The slowness data contain information on local gradients and should provide a very detailed velocity of the subsurface, including information on hydrothermal systems and possible anisotropy (e.g. Cherret and Singh, 1999).

References

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