Los Angeles Region Seismic Experiment (LARSE)

Cruise Report

Summary

Nine Ocean Bottom Seismometers (OBSs) were deployed in the Inner California Borderland as part of the Los Angeles Region Seismic Experiment (LARSE) to delineate the offshore continuation of crustal structure under the Los Angeles Basin. The experiment which was conducted in October 1994, was a cooperative study involving scientists from the US Geological Survey, Caltech, the University of Southern California, the University of California Los Angeles, and the Southern California Earthquake Center (SCEC). The offshore wide-angle seismic experiment was the first such experiment in the area since 1958. The data quality recorded on the OBSs was very good with high signal-to-noise ratio on PmP arrivals in the majority of the OBSs. The total OBS data recovery rate for both deployments was about 80%. Preliminary analysis and modeling of the data indicates that the crustal structure between shore and San Clemente Ridge may differ from that under and southwest of San Clemente Ridge. Crustal thickness appear to be ~20-km-thick in both areas.

Experimental design

Two offshore-onshore lines, oriented north-south and centered on the Los Angeles basin and the epicenters of the 1933 Long Beach, the 1987 Whittier-Narrows, and the 1994 Northridge earthquakes, were recorded during the experiment. The onshore-offshore lines were each 200-250 km long, with the offshore lines being between 90 and 150 km long. The offshore section of Line 1 extended from Seal Beach to San Clemente Island crossing the Catalina Ridge near the SE tip of Catalina Island. The offshore section of Line 2 extended from Santa Monica to 40 km south of San Clemente Ridge passing near the NW tips of Catalina and San Clemente Islands. The onshore parts of the lines were recorded by 170 PASSCAL Reftek recorders and the offshore parts were recorded by the OBSs and by 4 PASSCAL Reftek stations on San Clemente and Catalina Islands.

The R/V Maurice Ewing's 20-element air gun array, totaling 137.7 liters (8470 cu. in.), was used as a seismic source for the wide-angle seismic recordings. The array,

composed of Bolt air guns, was generally towed at depths between 8 and 10 meters. The ship-to-gun distance was staggered to minimize fouling the air guns and to optimally separate the air bubbles created by the air gun array: the center of the air gun array was towed approximately 87.4 meters behind the Magnavox Global Positioning Satellite (GPS) receiver of the ship. The width of the air gun array across the beam of the ship was roughly 33.8 meters. The sizes of the air gun chambers varied from 145 cu. in. (2.4 liters) to 875 cu. in. (14.2 liters) to provide a tuned outgoing source wavelet. Air gun shot times recorded in the navigation files were from the air gun fire command time determined from a Magnavox GPS clock. Given the less than a millisecond jitters in the air gun firing times, these shot times are considered accurate to within a millisecond. The Ewing's fired at a slow rate (every 60 and 90 seconds along Lines 1 and 2, respectively) to minimize acoustic-wave interference from previous shots in the OBS data. These rates correspond to shot intervals of ~150 meters and ~225 meters, respectively. The Ewing repeated portions of these lines up to 5 additional times with a repetition rate of 20 seconds (which corresponds to ~50 meters shot interval) to enhance the fold of the wide-angle data recorded onshore. Multichannel seismic reflection data were also recorded during these additional passes by the Ewing's 4.2-kilometers, 160-channel, digital streamer.

The OBSs were deployed and recovered by the R/V Yellowfin, a 76-foot vessel operated by the Southern California Marine Institute, a consortium of universities in Southern California, and based in San Pedro, California. Seven of the OBSs were operated by the USGS Branch of Atlantic Marine Geology and the two others were loaned for the LARSE experiment by Dalhousie University, Halifax, Nova Scotia. Separate OBS deployments were made along Lines 1 and 2 to provide control on the crustal velocities along these lines (Table 1). Each OBS deployment recorded air gun signals only along the line on which it was deployed. All shots from all the lines were recorded on four channels (vertical, two horizontals, and a hydrophone) for 60 seconds each at a sampling interval of 10 milliseconds. For the most part, the OBSs were concentrated on the northern ends of these lines, to help resolve the velocity structure nearest the Los Angeles Basin. One OBS on the Line 2 deployment was deployed to the southwest of San Clemente Island in an attempt to record reversed upper mantle refractions (Pn).

Results

Preliminary analysis and modeling of the data indicates that the crustal structure between shore and San Clemente Ridge may differ from that under and southwest of San Clemente Ridge. Pg arrivals on Line 1 extend out to 60 km from the receivers and are followed 1.5 seconds later by PmP (Moho reflections) on almost all the OBSs. These arrivals indicate a non reflective crust with a constant velocity. Preliminary 1-D ray tracing suggests a 20±2 kilometers thick crust of 6.2±0.3 kilometers/second velocity, which can be interpreted as a uniform crust composed of Catalina Schist. The crustal velocity structure on Line 2 north of San Clemente Ridge appears similar to that of line 1. Pg arrivals in the part of Line 2 south of Catalina Island extend, however at least 80 km from the receivers, where they are crossed by PmP. These arrivals indicate an increasing crustal velocity with depth. Preliminary 1-D ray tracing suggests that in the vicinity of San Clemente Ridge the crust is 18±2 kilometers thick with velocities increasing from 6.2±0.3 to 6.9±0.3 kilometers/second. Shots fired northward across the Catalina Ridge on both Lines 1 and 2 are highly

attenuated, whereas those fired southward across the ridge are not. Shots fired across the San Clemente Ridge in both directions are, on the other hand, unaffected by the ridge. Schist, granite, and mafic and ultramafic rocks are uplifted and exposed on Catalina Island, whereas San Clemente Island has only Miocene sedimentary outcrops. If the attenuation across the Catalina Ridge is due to a (dipping?) propagation barrier, then the barrier probably extends at least 8 km deep and may be composed of rocks similar to those exhumed on Catalina Island .

Cruise Participants

R/V Yellowfin

- **Dr. Uri tenBrink** - USGS - Atlantic Marine Geology, Chief Scientist
- Greg Miller - USGS - Atlantic Marine Geology - technician
- Dave Foster - USGS - Atlantic Marine Geology - technician
- Robert Illucci - Dalhousie - technician

Cruise Data

There were two deployments of OBS's in this experiment. Four lines were shot on the first deployment: one for OBS (shooting once every 60 seconds) and three more shooting at a faster rate (every 20 seconds) with the multichannel streamer deployed. The second deployment had three lines recorded: one for OBS (shooting every 90

seconds) and the others with the multichannel streamer. The following graphics show the deployment locations for the OBS's for both deployments. The line drawn on each graphic is the navigation track of the shooting ship for the line shot specifically for OBS recording. These are interactive displays. Click the mouse button on an OBS location, and a sample data section will be displayed with the details of each deployment site. The data displayed are raw record sections of the vertical geophone from each instrument.

Log of the experiment

Nine OBSs along Line 1 were deployed on 12 October 1994 after being programmed to begin recording at 1600 UTC on JD 286 (0900 L on 13 October 1994). These OBSs recorded during both OBS and MCS passes of Line 1 (Lines LA01 and LA01R) made by the Ewing, and were recovered in the night and morning of 14-15 October 1994. Eight OBSs were immediately recovered from this deployment and all 8 provided useful data for Lines LA01 and LA01R (as well as for part of Line 1X). OBS C1 was found floating at the surface after being lost for about 4 days. This OBS apparently did not stay attached to its anchor and released shortly after impacting the sea floor, recording only 10 shots of Line LA01. 653 shots were recorded during Line LA01 and 2310 shots during LA01R.

The remaining eight OBSs were deployed along Line 2 between 0900 and 1800 UTC on JD 290 (0200 and 1100 L on 17 October 1994), and were programmed to begin recording at 0200 UTC on JD 291 (1900 L on 18 October 1994). The OBSs were recovered between 0215 and 1420 UTC on JD 292 (night and morning of 19-20 October) and thus recorded both OBS and MCS passes of Line 2 (Lines LA02R and LA02X); four OBSs recorded at least part of MCS Line LA02Y (Table 2). Two OBSs, C9 and A2, were not immediately recovered from this deployment (Table 1). Both were found floating at the sea surface after the LARSE MCS experiment ended. OBS A2 recorded 100 shots (12%) of Line LA02R before it released prematurely. OBS C9 stayed on the sea floor for nearly a day, and recorded 550 shots of Line LA02R (representing 66% of the line). The Canadian OBS C failed to record any useful data during this deployment (Table 1). 721 shots were recorded during Line LA02R and 1296 shots during LA02X.

Line 1

OBS Name	Latitude (N) Deg. Min.	Longitude (W) Deg. Min.	Depth (m)
A3	33 34.0844	118 08.7095	97
A1	33 31.1492	118 09.8185	321
A2	33 26.5097	118 11.5804	723

A_	33 21.0082	118 13.4897	711
C_	33 16.8277	118 15.1957	177
C1*	33 12.8067	118 16.5421	1134
C9	33 06.7002	118 20.1462	1158
C4	33 01.0848	118 23.2386	798
C3	32 56.3934	118 25.2850	1191-1196

Line 2

OBS Name	Latitude (N) Deg. Min.	Longitude (W) Deg. Min.	Depth (m)
C4	33 58.6342	118 34.9445	77
C3	33 53.0789	118 36.0271	79
C9*	33 47.8420	118 37.0280	833
A1	33 42.9050	118 37.8090	705
A2*	33 35.2470	118 39.3110	618
A3	33 21.9648	118 40.6503	1200
C_#	33 12.4439	118 41.3244	1330-1340
D_	32 55.2289	118 42.5562	1210-1215

*OBS was not immediately recovered but was found drifting a few days after the others were retrieved. C9 recorded useful data on line 2 before drifting off, but Line 1 C1 and Line 2 A2 did not. #OBS failed to record data. -When a range of depths is given, the depth-sounder on the Yellowfin could not provide more accurate readings at these depths.

Line 1

Line 2R