PMPR

DATA REPORT FOR THE PmP REFLECTIONS BENEATH THE SAN BERNARDINO MOUNTAINS, CALIFORNIA, FROM LANDERS AFTERSHOCKS

Submitted By

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PASSCAL Data Report 96-005

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Data Report for the PmP Reflections Beneath the San Bernardino Mountains, California, from Landers Aftershocks

(NSF Grant EAR-9316871)

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***** PASSCAL DATA REPORT *****

ABSTRACT

This report describes the distribution to the IRIS Data Management Center of data from Landers aftershocks collected by 35 PASSCAL 3-channel REFTEK instruments in the Mojave desert and the San Bernardino Mountains during January to March of 1993. The data formats and the list of files on the data tape are discussed. The final report of this research project to the NSF is included.

Scientific Targets:

Previous results from a 30-km long seismic reflection line of CALCRUST at the southern Mojave Desert/ northern San Bernardino Mountains showed: (1) a southward-dipping (12-15°) interface between the brittle and ductile parts of the crust, roughly coincides with the base of the southward-dipping seismogenic zone beneath the desert/mountains which reaches a maximum depth of ~20 km at the San Andreas fault along the southern flank of the range. (2) a prominent southward-dipping (6-8°) reflector at Moho depths. These southward dipping crustal elements were interpreted to be the result of elastic loading by the San Bernardino Mountains. During the spring of 1993, we deployed thirty-six REFTEKs in two arrays to further investigate the Moho beneath the San Bernardinos. Aftershocks of the 1992 Landers Earthquake, east of the range, were used to generate mid-points beneath the mountains. First, a 100-km long, east-west array with 3-km spacing was set up in the Mojave desert just north of the mountains to determine optimum distances for PmP recording. The data show clear coherent PmP arrivals at distances between 70 and 100 km. Next, a pair of 11-km long east-west three-component sub-arrays of sixteen stations with 0.75-km spacing were set up at the critical distance (90-100 km). One sub-array was in the Mojave desert along the first line and the other was about 20 km to the south, close to the San Andreas fault. Differential arrival times of the PmP phases relative to Pg recorded at these two sub-parallel seismic lines for a common aftershock were used to determine the apparent dip of the Moho beneath the San Bernardino Mountains. Forward ray-tracing synthetics of PmP, Pg and mid-crustal reflected phases show that the Moho dips southward about 10-12° beneath the San Bernardino Uplifts. This value is slightly larger than that from the reflection profiling because the mid points of two sub-arrays are located more south than the reflection line. It infers that the Moho has a greater deflection as it approaches the southern edge of the elastic plate at the San Andreas fault which is assumed to be a sliding boundary. During a 3-month experiment, we recorded ~100 aftershocks, each of which triggered more than 15 stations of seismic arrays.

The detailed results are given in the "Final Project Report for EAR-9316871" submitted to the National Science Foundation by Thomas L. Henyey and Yong-Gang Li. This report is attached here too.

Data Collection:

In Phase I of the experiment during January 24 (R24) to Febuary 3 (R34) of 1993, we deployed 36 PASSCAL REFTEK 72A-02 DAS units with 200 Mb hard disks along Line A (Figure 3a and 3b). The 36 stations were named by A1 to A36. Locations of stations measured by internal GPS are showed in the REFTEK log files included on the DATA TAPE submitted to the IRIS Data Management Center. The station space is 3 km. Each REFTEK unit has three channels; each channel was connected to a spread consisting of 6 L28 15 Hz vertical sensors. The spread space is 100 m.

In Phase II of experiment during Febuary 13 (R44) to March 5 (R64) of 1993, We deployed 32 REFTEK units along a compressive line in Line A (Figure 3a and 3b) from A09 to A30. The station space is 1.5 km. Each 3-channel REFTEK unit was connected to a L18 4.5 Hz three-component sensor. Three components were coordinated in the vertical, N-S and E-W directions. Locations of stations measured by internal GPS are showed in the REFTEK log files included on the DATA TAPE.

In Phase III of experiment during March 8 (R67) to March 29 (R88) of 1993, We deployed 32 REFTEK units along Line B and Line C (Figure 3a and 3b). The station space is 0.75 km. Each 3-channel REFTEK unit was connected to a L18 4.5 Hz three-component sensor. Three components were coordinated in the vertical, N-S and E-W directions. Locations of stations measured by internal GPS are showed in the REFTEK log files included on the DATA TAPE.

The instrument parameters were down-loaded to the REFTEK units are shown in Table 1.

Table 1. Instrument Parameters Used in the Experiment

Parameter	Description
Trigger mode	event
Recording channels	1 - 3
Sample rate	250 samples/s
Preamplifier	32
Recording length	60 s
Pretrigger length	20 s
Short-term average length	0.1 s
Long-term average length	25 s
Trigger ratio (STA/LTA)	7.0

We used EXBYTE tape drive to dump the data from the REFTEK internal 200 Mb hard disks to the 8 mm tapes, and then transfer to the Sun station at USC. We sorted data from the field tapes based on the CIT/USGS southern California seismic network catalog during the time period from January 23 to March 29. The data are stored in ten sub-directories on the data tape A. Table 2 shows names of sub-directories and spaces.

Table 2. Contents in Data Tape A

Batch1	R023-R026	207 Mb	Batch2	R027-R031	134 Mb
Batch3	R030-R037	118 Mb	Batch4	R038-R044	83 Mb
Batch5	R044-R053	123 Mb	Batch6	R054-R062	138 Mb
Batch7	R062-R066	71 Mb	Batch8	R066-R070	15 Mb
Batch9	R073-R083	44 Mb	Batch10	R087-R088	23 Mb
Total space:		956 Mbytes			

For our current study, we are interested in the events which triggered more than 12 stations of our portable seismic arrays. Locations of these events are shown in Table 1 and Figure 3b of our Final Project Report For EAR-9316871 which is attached in this article. We sorted the data from these events. Table A shows the sub-directories, files and spaces. The sorted data are stored on the data tape B.

Table 2. Contents in Data Tape A

Bytes	Sub-Directories
2651	batch1/R026.01
5830	batch1
15218	batch10/R088.01
7604	batch10/R087.01
22823	batch10
2302	batch2/R027.01
4333	batch2/R028.01
11354	batch2/R029.01
5370	batch2/R030.01
1578	batch2/R024.01
5379	batch2/R025.01
12735	batch2/R026.01
1632	batch2/R031.01
391	batch2/R029.02
52095	batch2
6703	batch3/R032.01
3251	batch3/R033.01
7653	batch3/R034.01
20134	batch3
5850	batch5/R044.01
4952	batch5/R045.01
9239	batch5/R046.01
2296	batch5/R047.01
11511	batch5/R048.01
3545	batch5/R049.01
4035	batch5/R050.01
2374	batch5/R051.01
49376	batch5
4195	batch6/R053.01
6785	batch6/R054.01
5621	batch6/R055.01
2058	batch6/R056.01
2203	batch6/R057.01
21442	batch6/R058.01
9819	batch6/R059.01
9178	batch6/R060.01
61302	batch6
11535	batch7/R062.01
3056	batch7/R063.01
3992	batch7/R064.01
21119	batch7
4497	batch8/R067.01
3721	batch8/R070.01
10230	batch8
996	batch9/R073.01
1837	batch9/R075.01
3836	batch9/R076.01
916	batch9/R077.01
6314	batch9/R078.01

6954	batch9/R079.01
1283	batch9/R080.01
2800	batch9/R081.01
1893	batch9/R082.01
1533	batch9/R083.01
33380	batch9
Total:	276,289 bytes

The data format is SEGY created by the IRIS/PASSCAL software ref2segy. All data files are copied from Sun station to 8 mm tape as TAR format. The user can copy data files to their own Sun station hard disk using the command "tar xvf /dev/nrst0".

Acknowledgments:

This experiment was carried out by the Geophysics Group of University of Southern California through Thomas L. Henyey, Yong-Gang Li and David Okaya. The PASSCAL Instrument Center at Stanford provided considerable support. This project was supported by NSF Grant EAR-9316871. We also ask that any publications resulting from the use of this data set property acknowledge the source of the data and the extensive efforts of the scientist who collected it.

FINAL PROJECT REPORT FOR EAR-9316871

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PmP Reflections and Crustal Structures Beneath the Mojave Desert and San Bernardino Mountains, California, Using Landers Aftershocks

Introduction

A series of geophysical studies over the last two decades have explored aspects of the crustal and upper mantle structure beneath the Transverse Ranges of southern California (e.g., Hadley and Kanamori, 1977; Yeats, 1981; Bird and Rosenstock, 1984; Hearn, 1984a, b; Sheffels and McNutt, 1986). The ranges are characterized by a number of factors including: (1) the E-W structural trend of the province which is oblique to the predominantly northwesterly structural grain in California, (2) the spatial and age relationships between the province and the San Andreas fault system, and (3) the relative youthfulness and high relief of the ranges. Of particular interest has been the nature of the crust and Moho beneath the Transverse Ranges, and specifically the San Bernardino Mountains. Important questions concern their evolution and uplift mechanics. The San Bernardino Mountains -- the focus of this study -- are one of the most easterly blocks within the province, and are bounded on the south/southwest by the San Andreas fault. The high topographic relief and thrusting observed along both the northern and southern flanks of the San Bernardino Mountains are widely believed to be the result of convergence across the San Andreas fault, which strikes in a more east-westerly direction in this region than it does elsewhere in California (e.g., Weldon and Humphreys, 1986).

The pioneering work by Hadley and Kanamori (1977) stimulated a subsequent series of geophysical and geological studies of the eastern Transverse Ranges. Their suggestion, based on travel-time residuals, that the plate boundary in the crust, as represented by the San Andreas fault, may be offset from the plate boundary in the mantle, brought into focus the possibility that major low-angle detachments might exist beneath the eastern Transverse Ranges. This idea was reinforced by Yeats (1981), who proposed a "flake" tectonic model for the Transverse Ranges. Corbett (1984) in a particularly important observation, noted that the base of the seismogenic layer (nominally at a depth of between 10 and 15 km in southern California) dipped southward beneath the San Bernardino Mountains. Weldon (1989) and Meisling and Weldon (1989) used this observation in conjunction with geological mapping of the San Bernardino Mountains to suggest that the base of seismicity represented a decollement ramp, perhaps coinciding with a contrast in mechanical properties of the crust, into which the primary range front thrusts rooted, and that northward movement of the San Bernardino Mountains along this ramp may have been responsible for part of the uplift of the range. This contrast in mechanical properties may represent a change from brittle to ductile deformation has been discussed by Turcotte et al. (1980), Sibson (1982, 1983), Meisner and Strahlau (1982), Vetter and Ryall (1983), and Sanders (1990).

Several investigators have noted the apparent lack of correlation of Bouguer gravity with topography in the San Bernardino Mountains (McCulloh, 1960; Hadley and Kanamori, 1977; Oliver, 1980; Hearn, 1984; Sheffels and McNutt, 1986). Sheffels and McNutt (1986), for example, used this observation to infer the absence of a classical "Airy root" beneath the range. They suggest that the topography of the Transverse Ranges, with its relatively short N-S wavelength, may be supported by a rigid lithosphere. Compensation by elastic plate flexure would require considerably less relief on lower crustal and/or upper mantle density isopleths such as the Moho. Regional compensation models employing plate flexure have been applied in a number of other instances on continents (Walcott, 1970; Banks et al., 1977; McNutt, 1980; McNutt and Kogan, 1986). Although it is unlikely that the highly fractured upper crust in southern California has the requisite flexural strength to support appreciable loads, this may not, in fact, be true of the upper mantle.

A word of caution is in order, however, regarding the inference from Bouguer gravity of no root beneath the San Bernardino Mountains. Isostatic residual gravity maps (Jachens et al., 1989) show no obvious anomalies that correlate with the topography of the mountains. If there were no root or isostatic compensation beneath the mountains, an isostatic residual high might be expected. These data suggest that either the range is partially compensated at depth in some fashion, or that anomalous densities in the crust beneath the range and/or surrounding crustal blocks might be obscuring the effects of compensation occurring at greater depth (e.g., Carter et al., 1990). There is currently no evidence to either support or reject such density distributions. Thus, the existence or non-existence of an Airy root beneath the San Bernardino Mountains based on gravity alone remains equivocal.

To image a system of thrusts, possible mid-crustal decollement, apparent base of the seismogenic zone and the Moho beneath the San Bernardino mountains, CALCRUST ran a 30 kilometer long N-S seismic reflection line across the southern Mojave Desert and onto the northern flank of the San Bernardino Mountains in southern California (Figure 1a, b). On the northern end of the seismic section (Figure 1c), the reflectivity increases markedly in the mid-crust at a depth of 12-15 km, suggesting a transition between non-reflecting brittle upper crust and reflecting ductile lower crust. The high reflectivity disappears at 24 km depth, and may be correlated with a change in seismic velocity in the lower crust from 6.3 km/sec to 6.8 km/sec. A band of reflectivity between 27 km and 30 km is believed to represent the Moho.

The mid-crustal reflectivity transition and Moho both deflect downward toward the San Bernardino Mountains uplift over the entire length of the profile. The deflection of the mid-crustal transition (12-15 degrees) appears greater than that of the Moho (6-8 degrees), resulting in a thinning of the lower crust to the south beneath the uplift (Figure 2). In addition, the mid-crustal transition coincides with the base of the seismogenic zone (brittle-ductile transition) which is also dipping southward beneath the San Bernardino Mountains, while the Moho deflection is consistent with elastic flexure resulting from edge loading by the San Bernardino Mountains which have been thrust over the Mojave block. It is suggested that the thinning of the lower crust beneath the San Bernardino Mountains is a result of north-directed ductile flow in response to loading by the over-thickened upper crust. Since a portion of the load is transmitted through the lower crust to the Moho, the time constant for flow equilibrium must be on the order of or greater than that for the time of uplift (≥2Ma). These results have been reported in our previous paper (Li et al., *JGR, 1992*).

The Present Work

During the spring of 1993, we deployed thirty-six REFTEK (Refraction Technology) instruments (borrowed from the IRIS) in the Mojave desert and San Bernardino Mountains to further investigate the Moho and the mid-crustal transition zone in the region. Aftershocks of the M7.4 Landers Earthquake of 1992, occurring east of the range, were used to generate mid-points beneath the desert and mountains.

Aftershocks of large earthquakes provide an opportunity to use natural seismic sources to study the depth and configuration of the Moho in the vicinity of the aftershock sequence. While this may not be of universal interest for all earthquakes, there are instances where such studies are useful, for example, where access by artificial sources is difficult, and where the Moho is not well known and may be regional complex. In such cases, aftershock readings may provide a relatively inexpensive alternative to other seismic methods although they have some limitations on the actual coverage which is expected.

However, the geometrical relationship of the Landers aftershock sequence to the Mojave block and San Bernardino Uplift (Figure 3a) provides a unique opportunity to use individual events in the sequence to illuminate the crust beneath the range. Since the aftershocks were on the east side of the range, seismic arrays could be deployed on the west side of the range to generate mid-points within the Mojave and San Bernardino blocks. Furthermore, because the aftershocks were distributed along a north-south line to the east of the range, a east-west array to the west of the range would produce mid-points along a north-south profile beneath the Mojave block and San Bernardino Mountains.

We deployed two sub-parallel linear arrays at the optimal distances for recording PmP (a critical reflected waves from the Moho discontinuity, which are usually with large amplitudes) from the Landers epicentral region. The variation of the Moho at the mid-points with respect to the two arrays can be estimated by comparing the traveltime difference between waves traveling through the crust and those reflected from the Moho for a common event. We assume that the PmP and Pg (a refracted wave due to the velocity gradients in the shallow part of the crust) from the event have the similar raypaths approaching the seismic array in the upper part of the crust. Thus, we can eliminate the effects of the surface complexity on the traveltimes by using the differential traveltime between the PmP and Pg rather than the direct traveltimes of them.

First, we need to know the critical distance for the PmP in the region. We deployed a 100-km long, east-west vertical-component array from the Soggy Lake to Pearblossom in the southern Mojave desert (Line A in Figure 3a,b) with 3-km spacing was set up in the

Mojave desert just north of the mountains to determine optimum offsets (or critical distances) for PmP recording. Line A was deployed for three weeks from late January to mid February of 1993. Most stations of the array (consisting of 36 stations) were triggered by aftershocks with M≥2.4. Figure 3b shows epicenters of aftershocks triggering more than fifteen stations of the arrays during the experiment from mid January to end March of 1993.

Figure 4 shows vertical components of seismograms recorded by the seismic array along Line A for three aftershocks having various hypocentral distances to the array. The origin time, locations and magnitudes of aftershocks are plotted in the figure and listed in Table 1. We observed the probable PmP energy at stations located about 80-100 km from events A and B (Figure 4, top and bottom). The coherency of the PmP is not clear enough because the large station spacing of 3 km might be too large. On the other hand, however, we did not observe the probable PmP energy at stations located at distances from the events shorter than 50-60 km. These features are further confirmed by results from other six aftershocks shown in Figure 5. Eventually, we estimate the critical distance for PmP in the range of about 80-100 km. This distance is shorter than the value of about 120 km commonly seen in active seismic wide-angle reflection/refraction profiles in the continents. It is because that we used the earthquakes which occurred at depth closer to the Moho than the surface seismic sources. The relatively short critical distance may also suggests that the Moho in the Mojave block is shallower than elsewhere in California.

Second, we compressed the seismic array from Line A to Line A' with the station spacing of 1.75 km at the critical distance range of about 80-100 km from the Landers epicentral region. Figure 6 shows seismograms recorded at the compressed array along Line A' for a M4 Landers aftershock occurring almost in line of the array. We observed the coherent PmP waves clearly at stations located about 75-100 km from the epicenter of the event. The PmP waves are characterized by relatively large amplitudes as shown in the true amplitude plot (Figure 6, bottom). On the other hand, the PmP waves are not seen at stations having the distances from the event shorter than 50-60 km. Seismograms from eight other aftershocks with various hypocentral distances from the array show the same features (Figure 7). To further confirm the observations of the PmP waves at the critical distances of about 80-100 km, we synthesize the PmP, Pg and mid-crustal phases using 2-D ray tracing in terms of a velocity model given by Li et al (1992). Results from ray tracing are shown in Figure 8a. The relatively large amplitude PmP waves appear at distances between 70 km and 110 km, corresponding to the Moho depth of 28 km and the focal depth of 6 km. Figure 8b shows that the synthetic PmP waves are agreeable with seismograms recorded at the array along Line A' for the aftershock in Figure 6.

Third, we deployed a pair of 11-km long east-west three-component sub-parallel arrays, each array consisting of sixteen stations with 0.75-km spacing, at the critical distances (between 90 and 100 km). One sub-array along Line C was in the Mojave desert, same as the first line (Line A), and the other along Line B was about 20 km to the south (Figure 3). Figure 9 shows vertical components of seismograms recorded at two arrays for two aftershocks occurring at depths of about 2.5 km and similar distances between the events and the arrays. The PmP phases are clearly recorded at both arrays. The PmP phases are most clearly recorded in the vertical components because they have near-vertical ray paths (Figure 10). Importantly, we observed that the traveltime difference (1.0 s) between the PmP and Pg recorded at Line C in the Mojave desert is smaller than the traveltime difference (1.8 s) recorded at Line B in the mountains near the San Andreas fault. This suggests that the Moho in the Mojave block is shallower than the Moho beneath the San Bernardino Mountains, provided that the velocity of the lower crust is the same but the crustal thickness is different at the two places. The increased traveltime difference of 0.8 s between the PmP and Pg registered at

Line B indicates that the Moho depth increases 2.5 km at the mid point between Line B and the event, corresponding to the average lower crustal velocity of 6.4 km/s. Figure 11 shows the ray-tracing synthetics of PmP, Pg and mid-crustal reflected phases in terms of two velocity models with the Moho at depths of 28 km and 31 km, corresponding to the Moho at Mojave block and the San Bernardino Mountains, respectively. The shallower Moho produces the smaller traveltime difference between the PmP and Pg. Figure 12 shows a comparison of synthetics with observations. The synthetics confirms that the Moho depth beneath the San Bernardino Mountains is greater than the Moho in the Mojave block. The results from both observations and synthetics infer the lower crust thickening in the San Bernardino Uplifts with a southward-dipping Moho. The dipping angle is estimated to be about 10 to 12 degrees, corresponding to the geometry of the arrays and event. This value is greater than 6 to 8 degrees resulted from the CALCRUST reflection profiling. It infers that the Moho dips steeper as it approaches the San Andreas fault, the tectonic plate boundary.

The refined shapes of the Moho and the mid-crustal transition zone beneath the southern Mojave desert and the San Bernardino Mountains will be produced from the inversion of traveltimes from all available events. This work is on-going.

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Figure Captions

Fig. 1 (a) Location of the CALCRUST seismic reflection profile which crosses Line A in Figure 3. (b) Expanded map of the area of the CALCRUST line (from VP170 to VP945). (c) Seismic depth section along the CALCRUST line. A-A' represents the transition from non-reflective upper crust to reflective lower crust. B-B' shows the location of the Moho.

Fig. 2 Top: Proposed model for development of the crust beneath the Mojave desert and San Bernardino Mountains from Li et al. (1992). Bottom: Relationship of the transition in reflectivity (stars and crosses) and the Moho (squares) to the base of the seismogenic layer (hypocenters shown in circles). Note that the southward dip of the base of the seismogenic zone.

Fig. 3 (a) The map shows locations of Line A, Line B and Line C, along which 36 REFTEK instruments were deployed, and epicenters of the Landers aftershocks. (b) The map shows station locations along line A, Line B and Line C, and epicenters of the Landers aftershocks which were recorded by at least 15 stations during the experiment.

Fig. 4 Vertical components of seismograms recorded at Line A for three aftershocks located with different hypocentral distances. The trace spaces in the plot are uneven because not all thirty-six stations of the array were triggered by the event. The origin time of events are labeled at the top of each panel. The location parameters of events are listed in Table 1. Event A (top panel) was located at latitude $34^{o}23'$, longitude $116^{o}27'$, depth 6 km, almost in plane of Line A. The PmP coherency intersects the Pg at the distance between 80 and 100 km from the epicenter.

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Fig. 5 Vertical components of seismograms recorded at Line A for six aftershocks located with various hypocentral distances. The origin time of events are labeled at the top of each panel. The location parameters of events are listed in Table 1. There is no PmP coherency was recorded for the events having the hypocentral distance shorter than the critical distance (80-100 km). Other notations as in Figure 4.

Fig.6 Vertical components of seismograms recorded at the compressed line (Line A') for a M4 aftershock located at latitude 34°24', longitude 116°28', depth 5.5 km, almost in plane of the receiver line. The PmP energy clearly appears at the distance between 75 and 100 km following Pg in the sections. The top section is plotted with the maximum peak-to-peak for each trace while the bottom section is plotted with true amplitudes for traces.

Fig. 7 Vertical components of seismograms recorded at Line A' for eight aftershocks located with various hypocentral distances. The origin time of events are labeled at the top of each panel. The location parameters of events are listed in Table 1. There is no PmP coherency was recorded for the events having the hypocentral distance shorter than the critical distance (80-100 km). Other notations as in Figure 6.

Fig. 8 (a) Ray tracing synthetics from the crustal velocity model of Li et al. (1992). PmP, PcP and PccP are phases from the Moho, and mid-crustal reflectors. (b) A comparison of the synthetics in (a) with the seismograms in Figure 6.

Fig. 9 Vertical components of seismograms recorded at Line B and Line C for two aftershocks located at latitude 34°23', longitude 116°28', depth 2.5 km. The origin time of events are labeled at the top of each panel. The location parameters of events are listed in Table 1. The differential time between the PmP and Pg for Line C is shorter than that for Line B.

Fig. 10 (a) Three-components of seismograms recorded at Line B and (b) from Line C for the event in Figure 9, top. Sg and SmS are seen in the transverse and radial components.

Fig. 11 (a) Ray tracing synthetics from the presumed crustal velocity model along Line C in the Mojave desert note the Moho depth of 28 km), and (b) along Line B in the Transverse Range near the San Andreas fault (note the Moho depth of 31 km. PmP, PcP and PccP are phases from the Moho, and mid-crustal reflectors. The synthetic differential time between the PmP and Pg for Line C is shorter than that for Line B due to the shallower Moho depth beneath the Mojave desert than the mountains.

Fig. 12 Comparison of synthetics derived in figure 11 with vertical component seismograms from Line B (right) and Line C (left). Note the increased differential time between the PmP and Pg for Line B results from the deeper Moho beneath the mountains.

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Table 1 Times, Locations and Magnitudes of the Landers Aftershocks Recorded at Lines A, B and C with More Than 15 Stations Triggered by the Events

Year	M	D	H	M	Sec	Latitude		Longitude		Mag	Deoth			Event ID	
1993	1	24	8	32	21.96	34	55.32	116	52.14	2.6	4.22	26	0.15	3089080	15
1993	1	25	3	15	36.84	34	16.95	116	41.29	2.0	5.18	15	0.10	3089148	20
1993	1	25	3	37	28.61	34	55.60	116	52.04	2.1	3.23	19	0.14	3089150	15
1993	1	25	19	03	1.62	34	13.20	116	28.80	1.9	13.10	36	0.15	3089208	16
1993	1	26	0	14	54.50	34	1.75	117	14.11	2.1	14.76	52	0.17	3089234	15
1993	1	26	1	27	13.98	33	57.90	116	20.22	3.2	5.47	43	0.13	3089241	22
1993	1	26	5	1	9.77	34	54.68	116	57.02	2.4	0.68	48	0.18	3089255	19
1993	1	26	9	34	2.48	34	55.54	116	51.43	2.2	0.50	39	0.14	3089289	15
1993	1	26	10	6	28.64	34	7.74	116	23.81	2.3	2.54	39	0.16	3089291	19
1993	1	27	5	54	16.99	34	21.50	116	53.61	2.3	3.75	51	0.17	3089362	22
1993	1	28	10	23	02.8	34	18.60	116	51.00	1.6	0.9	6	6	6	16
1993	1	28	23	56	52.64	34	58.41	116	56.01	3.0	0.00	82	0.22	3089592	23
1993	1	29	1	40	20.31	34	58.15	116	56.55	2.1	4.37	14	0.13	3089596	18
1993	1	29	2	56	09.3	34	34.80	116	37.80	1.9	4.6	6	6	6	16
1993	1	29	3	55	9.85	34	58.86	116	56.92	2.1	5.34	21	0.12	3089610	16
1993	1	29	7	29	43.25	34	22.29	116	27.29	2.3	0.92	47	0.13	3089700	15
1993	1	29	12	17	43.32	35	1.07	116	58.09	2.3	4.66	45	0.18	3089649	23
1993	1	29	13	22	44.4	34	19.80	116	52.80	1.9	0.8	6	6	6	16
1993	1	30	9	46	43.16	35	4.07	116	59.81	2.0	4.26	21	0.18	3089765	17
1993	1	30	10	59	48.4	34	55.80	116	55.80	1.6	4.5	6	6	6	18
1993	1	30	19	41	56.74	34	22.50	116	52.80	2.0	4.08	23	0.10	3089811	16
1993	1	31	11	56	32.25	33	45.26	116	8.03	3.5	2.21	65	0.13	3089876	15
1993	2	1	1	16	05.6	34	18.00	116	58.20	1.8	10.0	6	6	6	16
1993	2	1	6	1	39.73	34	14.24	116	48.23	3.2	2.13	28	0.12	3089961	16
1993	2	1	7	17	39.70	34	59.27	116	56.88	3.0	4.80	39	0.16	3089964	16
1993	2	1	11	22	56.0	34	22.20	116	52.80	1.3	3.5	6	6	6	15
1993	2	2	2	12	32.42	34	14.10	116	48.05	2.3	0.54	55	0.19	3091308	15
1993	2	2	11	20	38.20	35	0.66	116	58.08	2.1	4.83	21	0.18	3090143	15
1993	2	3	4	47	49.16	35	2.54	116	58.48	2.6	3.66	30	0.18	3091178	16
1993	2	3	8	51	23.51	34	20.76	116	27.66	2.3	0.93	24	0.17	3091022	23
1993	2	3	8	52	12.18	34	26.28	116	31.15	2.3	0.98	36	0.10	2082055	16
1993	2	3	14	37	56.03	34	6.19	116	23.51	2.3	5.23	43	0.16	3091115	14
1993	2	13	6	40	4.94	34	1.60	117	35.00	2.4	3.37	85	0.20	3092188	15
1993	2	13	9	44	22.10	34	57.50	116	56.50	2.0	0.00	30	0.16	3092199	18
1993	2	13	13	45	16.01	34	18.00	116	53.31	2.7	5.40	78	0.16	3092215	19
1993	2	14	7	4	27.32	34	16.00	117	23.82	2.3	8.14	48	0.13	3092295	29
1993	2	14	21	15	52.48	34	38.23	116	30.62	2.2	8.31	35	0.14	3092353	18
1993	2	15	4	12	09.5	34	19.80	116	55.20	2.0	2.5	6	6	6	25
1993	2	15	7	59	33.2	34	24.00	116	27.60	4.2	6.0	6	6	6	29
1993	2	15	8	02	01.3	34	24.60	116	27.60	2.7	6.0	6	6	6	28
1993	2	16	23	15	56.21	34	36.88	116	39.33	2.4	9.08	27	0.10	3092575	20
1993	2	17	2	36	14.93	34	12.60	117	34.92	2.9	7.82	66	0.19	3092587	29
1993	2	17	4	36	16.19	34	21.34	116	52.49	2.4	1.12	46	0.18	3092609	20
1993	2	17	19	10	47.21	34	56.65	116	46.68	2.8	2.94	43	0.18	3092692	25
1993	2	17	19	17	30.38	34	56.44	116	46.77	2.2	2.94	24	0.15	3092694	
1993	2	17	22	5	11.64	34	28.41	116	30.70	2.1	2.87	28	0.11	3092746	14
1993	2	17	23	58	52.00	35	3.30	116	58.75	2.4	0.43	36	0.25	3092781	19
1993	2	18	4	22	37.09	34	35.64	116	18.36	2.2	6.00	35	0.26	3092812	12
1993	2	18	7	11	11.71	34	23.54	116	27.23	2.3	3.81	34	0.10	3092822	22
1993	2	19	17	36	27.40	34	18.38	116	51.50	3.1	2.78	46	0.14	3093087	21
1993	2	19	23	57	28.52	34	35.91	116	38.04	2.6	4.16	52	0.19	3093118	16
1993	2	20	8	20	28.50	34	58.59	116	55.96	2.4	3.45	44	0.16	3093154	22
1993	2	22	10	44	8.06	34	15.50	116	26.62	2.4	3.23	40	0.13	3093377	20
1993	2	22	10	54	42.28	34	15.51	116	26.63	2.5	3.42	41	0.12	3093378	19

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1993  2 23  12 27 24.85  34  2.00 117 11.09  2.6      14.95 59    0.16 3093499 25
1993  2 23  21 56 43.01  34  0.03 116 17.05  2.7       3.14 61    0.18 3093595 17
1993  2 24   4 44 06.70  34 19.80 116 54.00  1.9       1.4   6     6    6      17
1993  2 24   6 47 03.4   34 17.40 117 08.40  1.5       0.5   6     6    6      21
1993  2 24  14 30 51.29  34 32.08 116 32.10  2.1       0.00 26    0.18 3093688 16
1993  2 25   8 35  7.62  34 54.97 116 45.41  2.2       6.00 23    0.16 3093773 19
1993  2 26   9 52 33.1   34 02.40 117 14.40  1.8      15.0   6    6     6      21
1993  2 27   2 12 38.60  34 39.16 116 28.73  2.6       2.83 46    0.17 3094024 18
1993  2 27   5 26 14.42  34 34.73 116 31.70  2.6       4.53 49    0.15 3094046 19
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1993  2 27  21 58 40.25  34  6.89 116 50.41  2.6       4.36 74    0.19 3094120 20
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1993  3  3  17 37 24.43  33 58.29 117 50.98  2.9       4.42 83    0.19 3094574 24
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1993  3 16   7 50 13.54  34 13.44 116 45.40  3.5       1.79138    0.15 3096210 20
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1993  3 19  23 16 35.31  33 59.94 116 18.44  2.7       5.43 56    0.17 3096791 15
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1993  3 21   8 44 37.91  34 28.43 116 29.80  2.3       1.46 54    0.15 3097010 14
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1993  3 29   8 51 35.19  34 23.02 116 27.59  2.6       2.60 55    0.17 3098180 30
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* The right column includes the number of stations triggered by the event.
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