Development of Automatic Processing Methods for Analysis of Local Network Datasets

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Non-technical Summary

Seismograph networks in southern California record a huge volume of data from local earthquakes. These records are currently used primarily to determine earthquake locations and magnitudes, but even such routine processing is a significant task considering the large number of stations and earthquakes that are involved. Most of the information in the seismograms is not used, except for selected events which make up only a small fraction of the total data available. This project involves the development of automatic techniques for analyzing local network seismic data which do not require any manual picking of the data. These methods will provide an efficient way to use more of the information in the seismograms and address a variety of research problems involving earthquakes and crustal structure.

Abstract

We apply automatic processing techniques to seismic records of local earthquakes in southern California. For 872 events with a roughly even spatial distribution, we identify the arrival times of seismic phases using an automatic picking algorithm. The results show that a much greater number of phases can be timed than is done in routine processing, and that this additional information could be used to measure lower crustal velocities and thicknesses with greater accuracy than is currently possible. In a related study we examine *PmP* arrivals for a variety of source-receiver geometries and identify regions of enhanced *PmP* amplitudes.

Investigations

Permanent and portable seismic networks in southern California record a huge volume of high-frequency waveform data from local earthquakes. These records are currently used primarily to pick *P*-waves for determining event locations and focal mechanisms, and to compute magnitudes based on amplitudes and coda decay rates. Even such routine processing is a significant task considering the large number of stations and earthquakes that are involved. Most of the information in the seismograms beyond the first break of the *P*-wave is not used, except for selected events which make up only a small fraction of the total data available. The occurrence of large earthquakes and their aftershocks further strains the capabilities of the system by increasing seismicity rates to many times the background rate.

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Our goal is examine these data through development of automatic techniques for processing and stacking local network seismic data which do not require any manual picking of the data. We have focused on two related problems: (1) stacking travel time and waveform data to image primary and secondary seismic phases, and (2) analysis of arrival time patterns in order to identify similar events, and to associate and locate events in the presence of multiple, nearly simultaneous earthquakes, such as typically occur early in aftershock sequences.

Results

We have selected 872 events from the ~250,000 events recorded by the Southern California Seismic Network (SCSN) and available through the Southern California Earthquake Center Data Center (SCECDC). Figure 1 shows the SCSN station distribution and the locations for the events that we chose to use. Our goal was to obtain a fairly uniform spatial distribution of earthquakes. This was achieved by dividing the region into 5 km by 5 km cells and searching for the "optimal" event within each cell (generally the largest event, but we excluded those with large location uncertainties and events above m_b = 4.0 where clipped waveforms are a problem).

Figure 2 is a plot of travel time versus range for 31,703 picks obtained from the SCECDC for these events. No corrections are applied for variations in source depth, causing some of the scatter in the *P* and *S* travel time curves. We process these data using software originally designed for analysis of the ~10 million pick database of global picks collected by the International Seismological Centre (ISC). The picks are saved in a compressed binary format (~16 bytes/pick); in this case all event information and picks are stored in a single ~600 kilobyte file and can be read and plotted in seconds.

Figure 3 is an analogous plot of 296,747 picks obtained by our automatic phase picker applied to waveforms from these events stored in the SCEC archives. Our autopicker is based on a simple STA/LTA algorithm and was first developed to study global short-period data (Earle and Shearer, BSSA 84, 366-376, 1994). For the SCEC data, we have modified the picking parameters for the higher-frequency waveforms. The threshold of the trigger was deliberately set very low so as to detect weak phases; this results in a background level of "noise" picks between the major phases.

A comparison between Figures 2 and 3 shows that the autopicker produces many more picks than are available in the hand-picked times. The operators appear most concerned with the first-arriving *P*-wave at ranges within about 250 km of the event. They do not routinely pick *S* or *Pg* beyond the *Pn* crossover point. In contrast, the autopick image reveals *Pn*, *Pg* and *S* out to beyond 500 km. A faint *Sn* phase can also be made out in the original of this plot. The agreement in the positions of the travel-time branches between Figures 2 and 3 suggests that the autopicker is producing reasonably accurate arrival times; in the future we plan more detailed comparisons between the picks.

The overall shape of the *P* and *S* travel time curves is determined by the average velocity versus depth profile for these ray paths. Presumably much of the scatter in the times reflects lateral velocity variations which can be explained with three-dimensional velocity inversions. There is clearly potential for using *Pn*, *Pg* and *S* arrival times at ranges beyond 200 km for regional studies of lower crustal and upper mantle velocities—much more information is contained in the archived waveforms than is currently available as travel-time picks.

The Moho reflected phases *PmP* and *SmS* are valuable for constraining Moho depths and lower crustal structure in tomographic inversions. A preliminary analysis of the autopicks from the 872 selected events suggests that clear *PmP* arrivals are fairly rare, but can be seen for certain source-receiver geometries. To further examine *PmP*, we extracted seismograms from over 4000 earthquakes with well-constrained locations. By mapping reflections to their Moho bouncepoints we have identified large-scale systematic variations in *PmP/P* amplitude ratios (Figure 4). *PmP/P* amplitudes appear to be largest in regions of generally flat topography, and reduced in areas of significant topography, a result that we preliminarily attribute to increased scattering of reflections off a rougher Moho surface beneath the mountainous regions.

Reports

Dinger, K.B. and P.M. Shearer, Results of applying an autopicker to archived waveforms from southern California earthquakes, *EOS Trans. AGU (Fall meeting supplement)*, **75**, 483, 1994.

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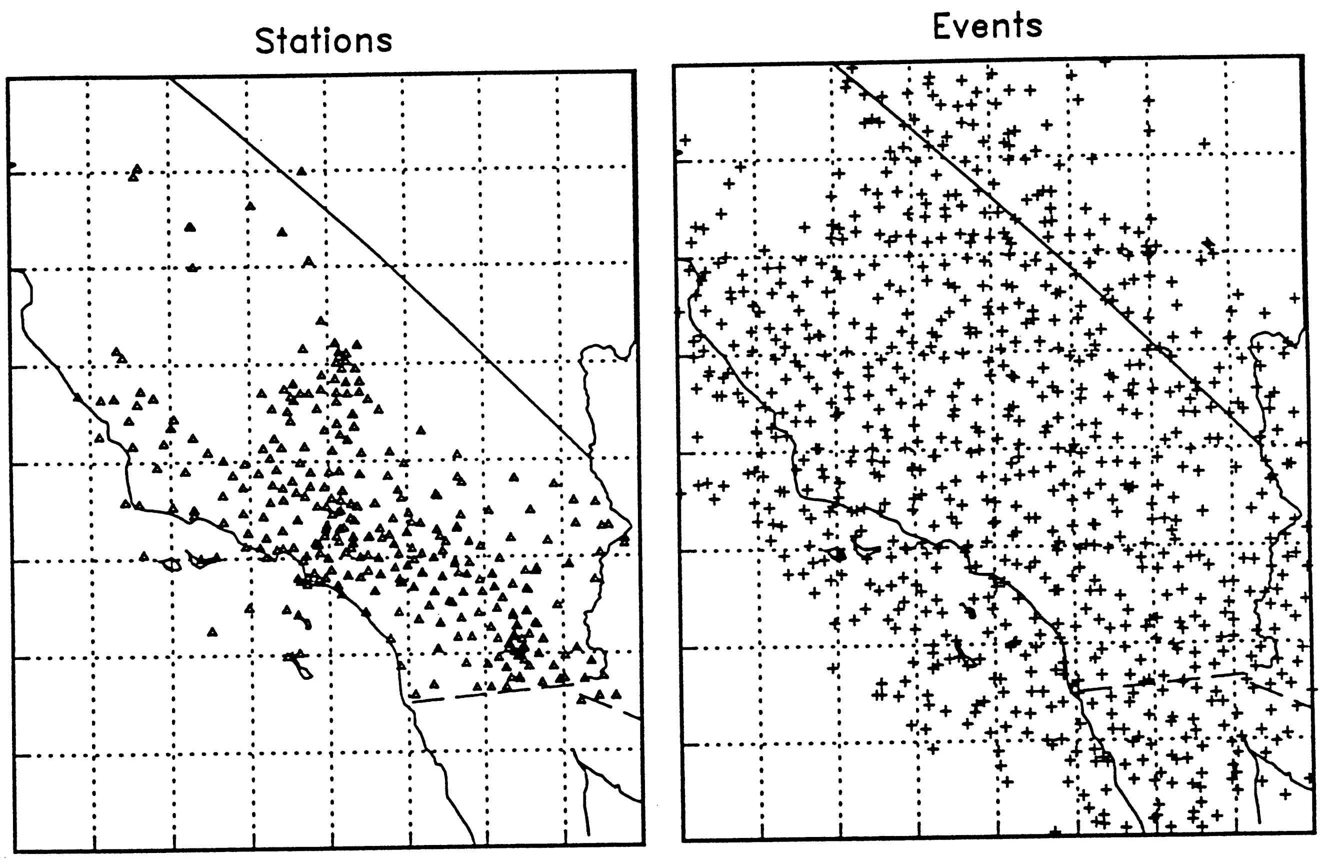


Figure 1. Locations of Southern California Seismic Network (SCSN) stations and 872 selected events from the ~250,000 events in the SCEC database. A reasonably even spatial distribution of events was achieved by searching for the best event within 5 km by 5 km cells.

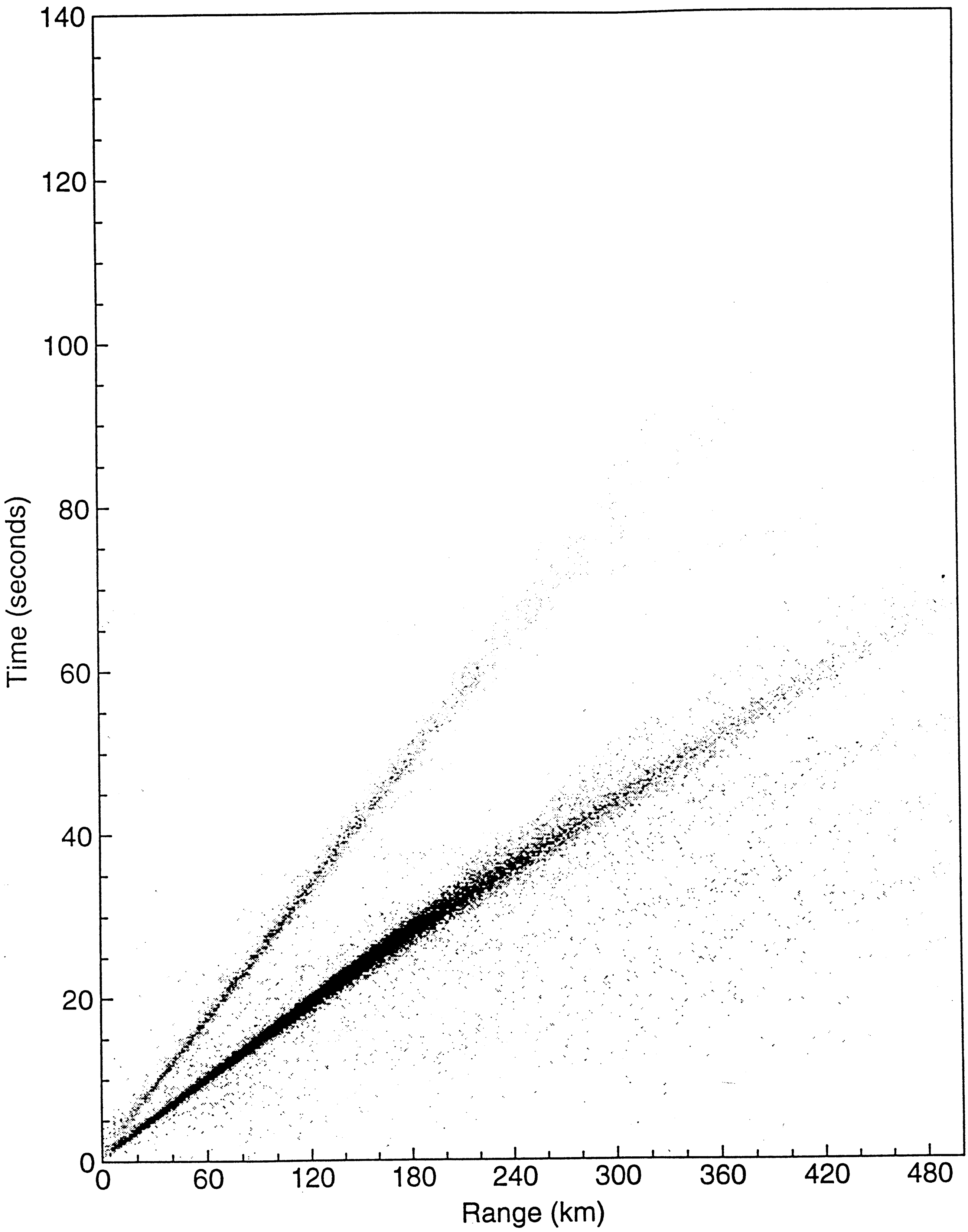


Figure 2. A time versus range plot of 31,703 picks stored at the SCSNDC for the 872 events shown in Figure 1. All source depths are included.

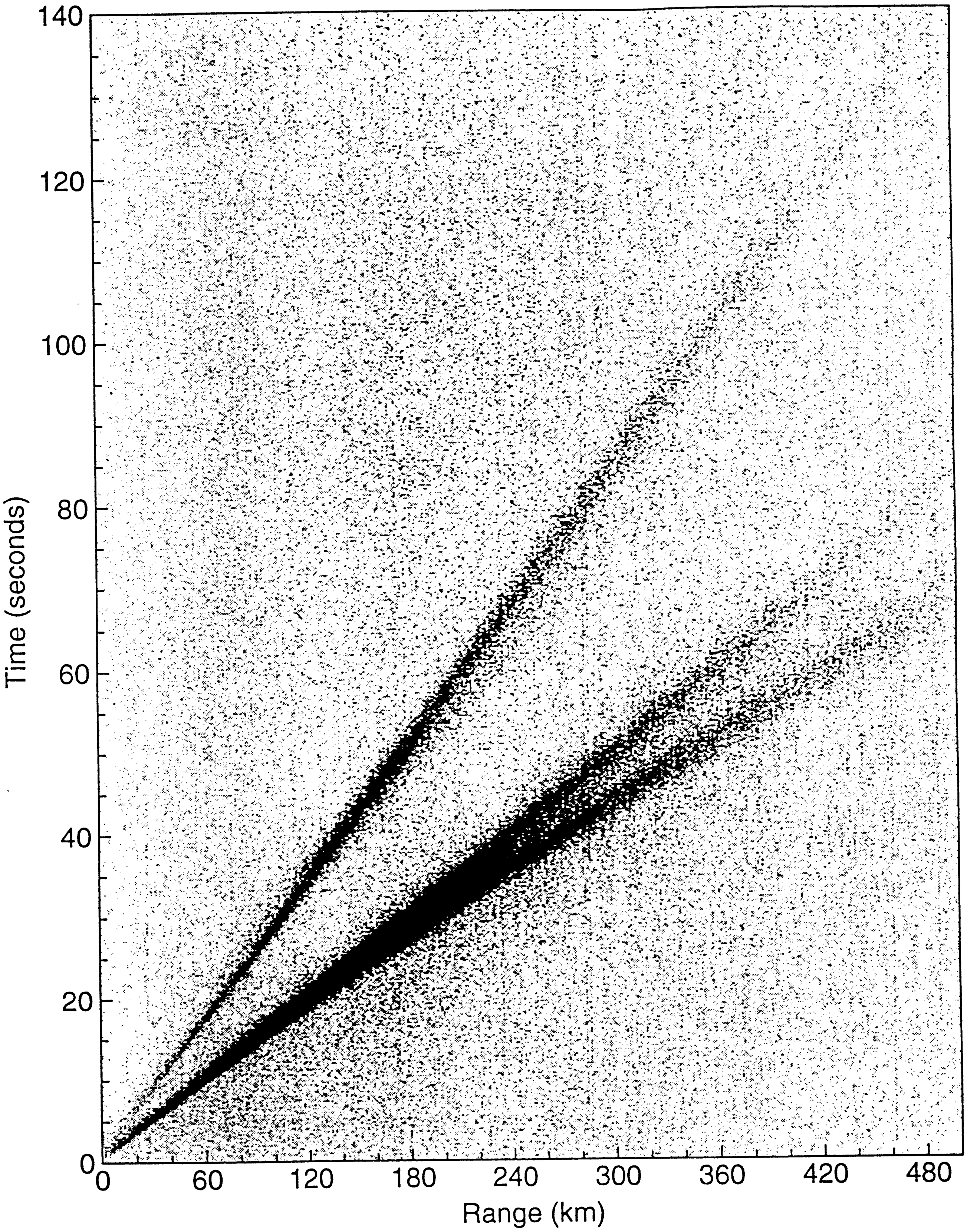
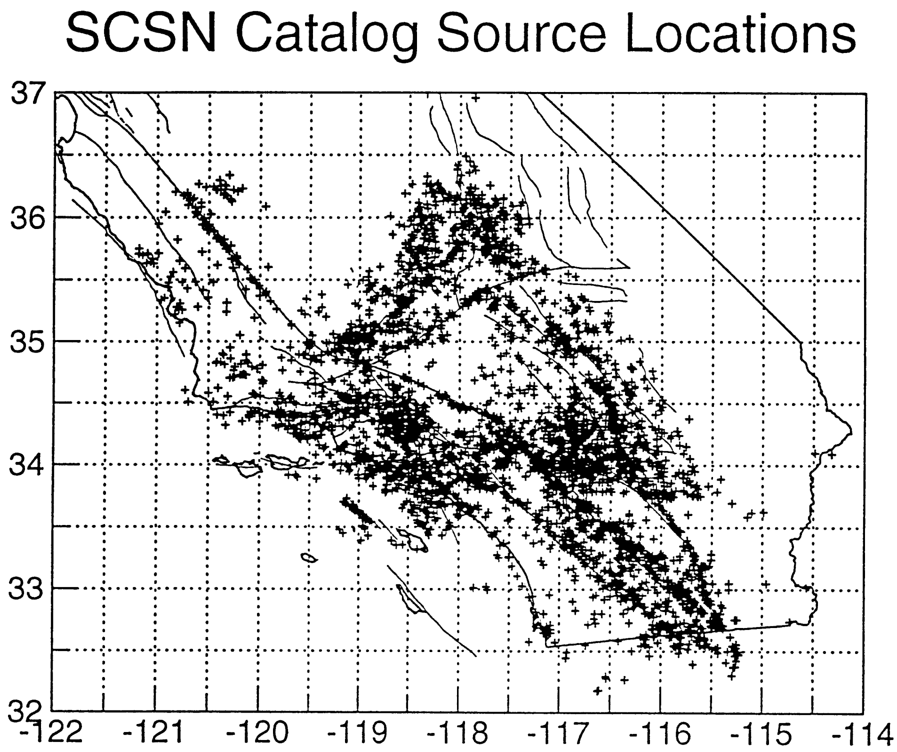
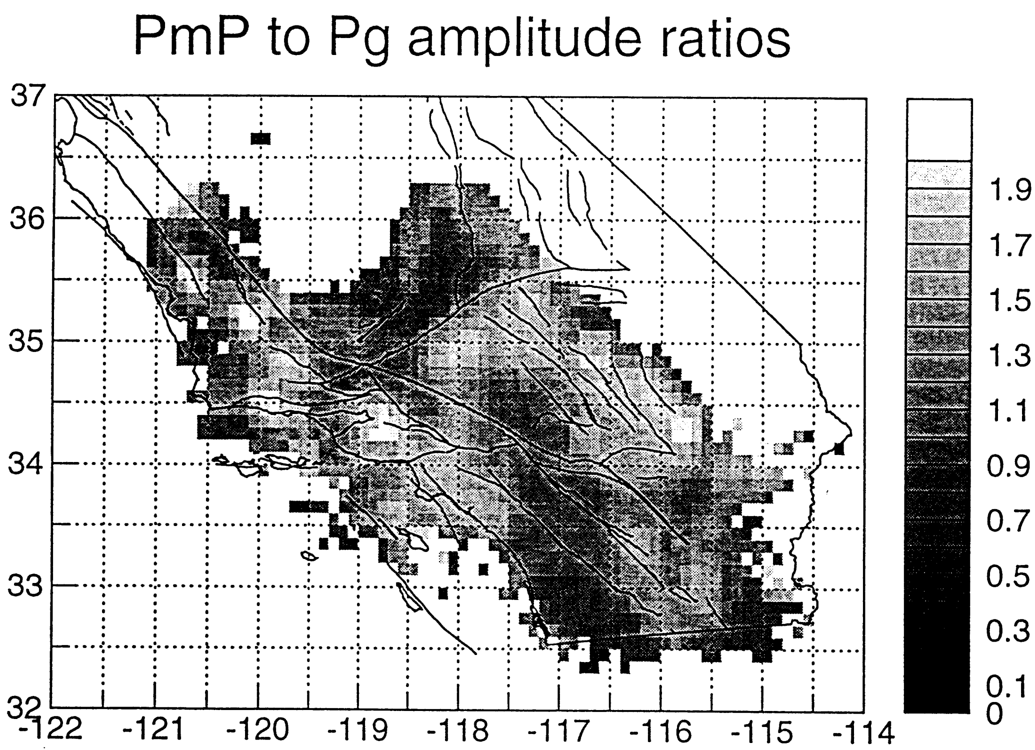


Figure 3. A time versus range plot of 296,747 picks obtained by an automatic picking algorithm applied to records from the 872 events shown in Figure 1. All source depths are included. Note the clearly resolved Pg and Pn branches, and the greater number of picks at ranges beyond about 250 km, compared to the picks in Figure 2.



(a)



(b)

Figure 4. (a) Locations of earthquakes used in the PmP analysis, (b) PmP/Pg amplitude ratios plotted at the Moho bouncepoints.