Regional Characterization of Western China

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ABSTRACT

Geological, geophysical, and seismic data are being assembled and organized into a knowledge base for Western China as part of the CTBT Research and Development regional characterization effort. We have begun our analysis using data from the station WMQ of the Chinese Digital Seismic Network (CDSN). Regional seismograms are being analyzed to construct travel time curves, velocity models, attenuation characteristics, and to quantify regional propagation effects such as phase blockages. Using locations from the USGS Preliminary Determination of Epicenters (PDE) we have identified Pn, Pg, Sn, and Lg phases, constructed travel time curves, and estimated apparent velocities using linear regression. Surface wave group velocities will be measured and inverted for regional structure. Preliminary noise spectra for WMQ have been obtained from the IRIS DMC. Chinese seismicity catalogs from the USGS and SSB are being used to identify and obtain seismic data (including mine seismicity) and information for lower magnitude events. We have identified the locations of nearly 500 mines in China for inclusion in the knowledge base. Future work will involve expanding the data collection and analysis efforts to a larger region using data from additional CDSN, IRIS and portable stations.

OBJECTIVE

We are characterizing regional excitation and propagation of seismic waves in Western China with sufficient accuracy to explain observed seismic data, and to detect, locate, and discriminate seismic events for the verification of a Comprehensive Test Ban Treaty (CTBT). Our primary source of seismic data for the initial effort has been the station WMQ of the Chinese Digital Seismic Network (CDSN) using events located by the USGS Preliminary Determination of Epicenters (PDE). Using seismic waveforms from WMQ and event locations from the PDE, we have identified Pn, Pg, Sn, Lg, Love and Rayleigh phases and picked arrival times for the body waves. The picks have been used with the PDE locations to compute preliminary travel time tables. We have also collected detailed Chinese seismicity catalogs that are complete to lower magnitudes than the PDE and will allow us to identify and study smaller events in the future. Noise spectra for WMQ have been obtained, and will allow a signal to noise detection threshold to be estimated based on the regional amplitude of various phases. We are compiling basic geologic and geophysical information for China including maps for surficial, basement, tectonic and structural geology which will prove useful for the interpretation of special events and forming estimates of seismic propagation characteristics in regions where we are unable to obtain observational data. Analysis of mining activity in China and an attempt to correlate the Chinese seismicity catalogs with mining operations are underway to provide information for geographic location and reference waveforms for discriminating mine explosions from earthquakes and nuclear explosions. We are working closely with the research efforts in discrimination at LANL to avoid redundant efforts and insure the effectiveness of the regional characterization results.

RESEARCH ACCOMPLISHED

Geologic and Geophysical Reference Data Compilation: As part of our effort to compile available geologic and geophysical reference information, Los Alamos is having the US Geological Survey (Flagstaff) construct digital geologic maps for basement, surficial, tectonic and structural geology for Southern Asia, beginning with China. These maps will be online reference material for natural and cultural seismic sources such as major faulting, mining and mineralized areas, and determination of bedrock under reservoirs, construction areas, mines, etc. The digital maps are scheduled for incremental completion, beginning with the basement geology of China in January 1996. We have recently received an additional geologic reference summary (Matzko, 1995) that will prove to be extremely useful in our compilation.

Seismicity Data (Natural, Explosion and Cultural combined): We have initially used the USGS Preliminary Determination of Epicenters for identifying the seismicity of Western China. For more detailed seismicity with a lower magnitude threshold we have obtained historical and contemporary seismicity catalogs for China to identify the characteristic regions and rates of observed seismicity. Historic catalogs are biased by population distributions (Lee et al. 1976, 1978) and the quality of the contemporary catalogs is unknown. The Chinese seismicity catalogs have no indication of the source type so we do not know if explosions from mining and construction operations have been included or deleted from the catalogs. Figure 1 shows the PDE seismicity for the study region for the years 1989 through 1994.

A preliminary analysis of mining and blasting in China is scheduled for completion in August 1995. In addition to identifying and describing the major mining areas of China, the paper will report on the state of blasting technology used in mining (and other fields such as civil engineering) in China. This report will be updated in about a year for final inclusion into the reference library for the China Regionalization results and inclusion into the knowledge base.

We have a contract with the University of Arizona to study regional seismicity catalogs for western China and correlate the mining sites to identify mining explosions and related seismicity in the catalogs. This will allow us to build a database of reference waveforms for Chinese mining operations and identify mining events for discrimination analysis.

Seismic Waveforms for Data Analysis and Reference Event Library: We have obtained broadband seismic recordings from CDSN station WMQ for events identified and located by the PDE for regionalization and discrimination analysis as well as for permanent archival as reference event waveforms. Station WMQ was chosen because it is close to source regions of interest and it has been operating since 1988 with data easily accessed from the IRIS DMC. In Figure 2 we present a 3 component recording of an earthquake 633 km from WMQ with the horizontals rotated from North and East to radial and tangential. The figure shows both the broadband velocity and the instrument corrected displacement seismogram showing the effective frequency range covering both body and surface waves. McNamara (1995) has shown in Tibet that Sn can have significant long period propagation even when the high frequency Sn phase is not observed, demonstrating the effectiveness of broadband data for complete regional characterization. Data analysis from seismograms recorded at WMQ will establish the excitation of specific seismic phases in the region of interest, and future analysis of longer paths using other CDSN and IRIS stations will allow us to study path specific effects at distances that may be closer to operational distances for regional monitoring of a CTBT.

Preliminary Phase Identification from Seismograms: Phase identification from 3 component broadband seismograms for regional events with known locations has been relatively easy for recordings from WMQ. Using approximate travel times and expected polarizations, seismologists can easily identify the phases Pn, Pg, Sn, and Lg on the majority of the well recorded events and pick arrival times. Figure 2 presents an example and shows the utility of using both velocity and displacement representation of broadband seismograms to emphasize various phases. We have established the excitation and propagation of these phases in the region around WMQ and need to examine longer paths and other stations to establish the attenuation or blockage or any of these phases. We have located some attenuation results (Jin, 1988) and are awaiting the completion of a manuscript by J. Xie (personal comm., 1995). As we collect data for longer paths and multiple stations we will assess the attenuation models.

Travel Time Tables (Pn, Pg, Sn, Lg, L, R): For events recorded at WMQ and locations from the USGS PDE, we have picked arrival times for Pn, Pg, Sn, and Lg when the signal is clear and estimated preliminary travel times for these phases with linear regression. Figure 3 shows the arrival times and the linear regression fits for Pn, Pg, Lg, and Sn. In Figure 4 we show the residuals after removing the regression estimate from the observed arrival times. There is significant scatter in the residuals, and we will need to examine the residuals to determine if there are any significant source region time corrections for WMQ. If depth estimates for the events can be refined by waveform modeling, we will correct the travel times for source depth. As we acquire data from more stations we will also need to determine station corrections. We will need to examine the arrival times for more distant events to expand the regional coverage of travel time tables, and carefully study the regional variations in travel times. We will measure the dispersion for Rayleigh and Love wave fundamental modes. Surface wave tomography results will be available after the completion of a contract with University California, Santa Cruz. We will study the correlation of the larger events that are located by the USGS and the Chinese seismicity catalogs to assess the location accuracy.

Noise Statistics for Seismic Station WMQ: Seismic noise level at the recording stations will be an critical item for establishing expected station detection performance based on signal to noise levels. We have obtained plots of the seismic noise at WMQ from the IRIS DMC for both annual average broad band noise level as well as the diurnal and seasonal variation for mid and long period noise. The noise power spectra are for acceleration ($m^2 / s^4 / Hz$) and were obtained with a Petersen high and low noise model for reference. These serve as a preliminary noise model and we can obtain similar noise studies for IRIS stations. We will need to form similar noise spectral estimates for other stations as they become available.

RECOMMENDATIONS AND FUTURE PLANS

We will continue the assembly of regional information, and begin the validation of models by comparing synthetics with real data. Waveform modeling for seismic source and event depth characterization will be attempted. We will continue the collaboration with the discrimination efforts to identify propagation issues and details relevant to discrimination, obtain smaller events identified from regional seismicity catalogs, and mining related events identified from correlation of catalogs with mining. Results we be organized in a form suitable for use by AFTAC in their routine processing and special event studies.

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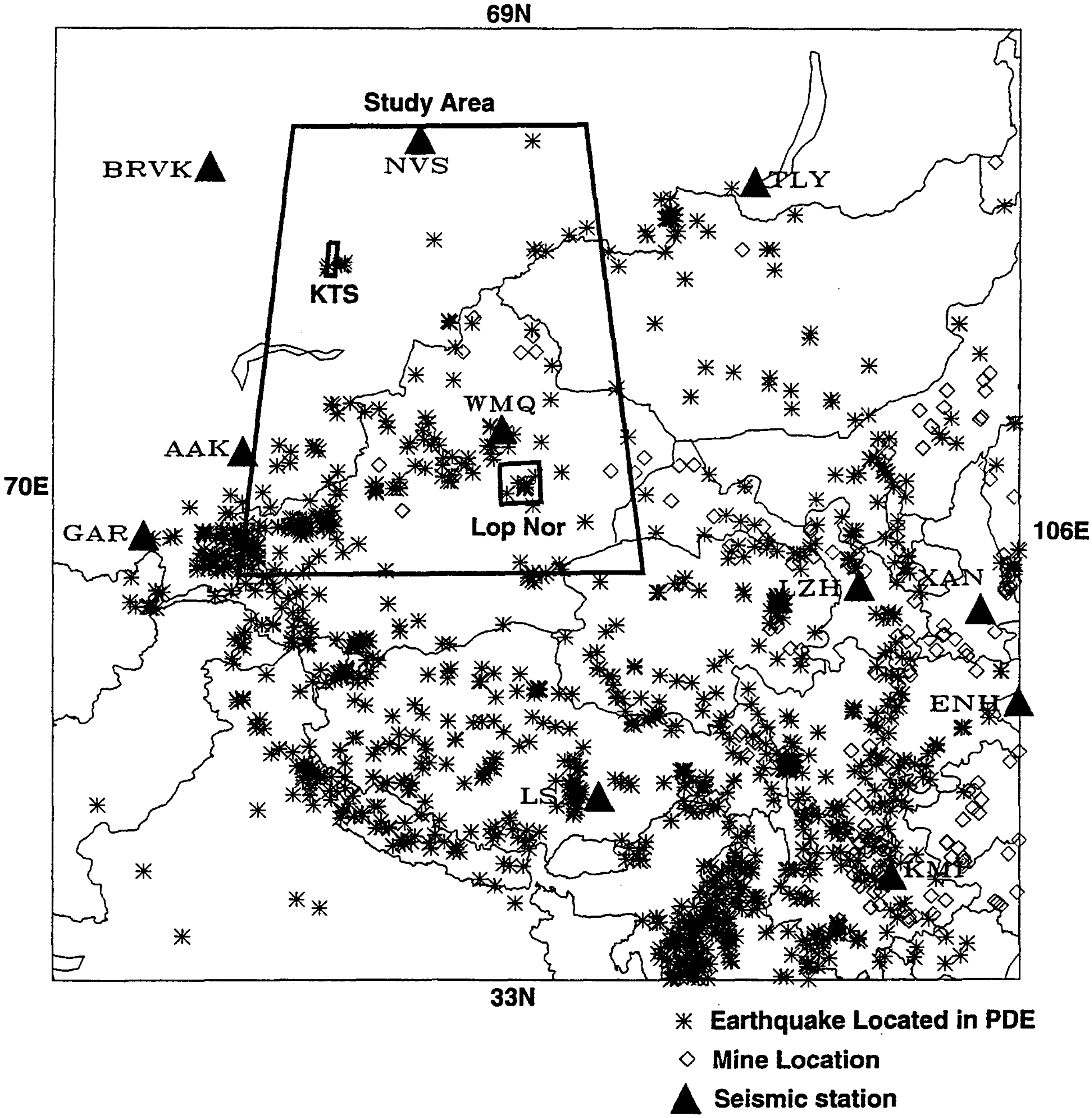

Figure 1. Map of Western China and surrounding areas. The study area, Lop Nor and the Kazakh Test site are outlined in bold borders. The map symbol key for earthquakes, mine locations, and seismic stations is shown at the lower right below the map. The seismicity is from the USGS PDE for the period 1989 through 1994.

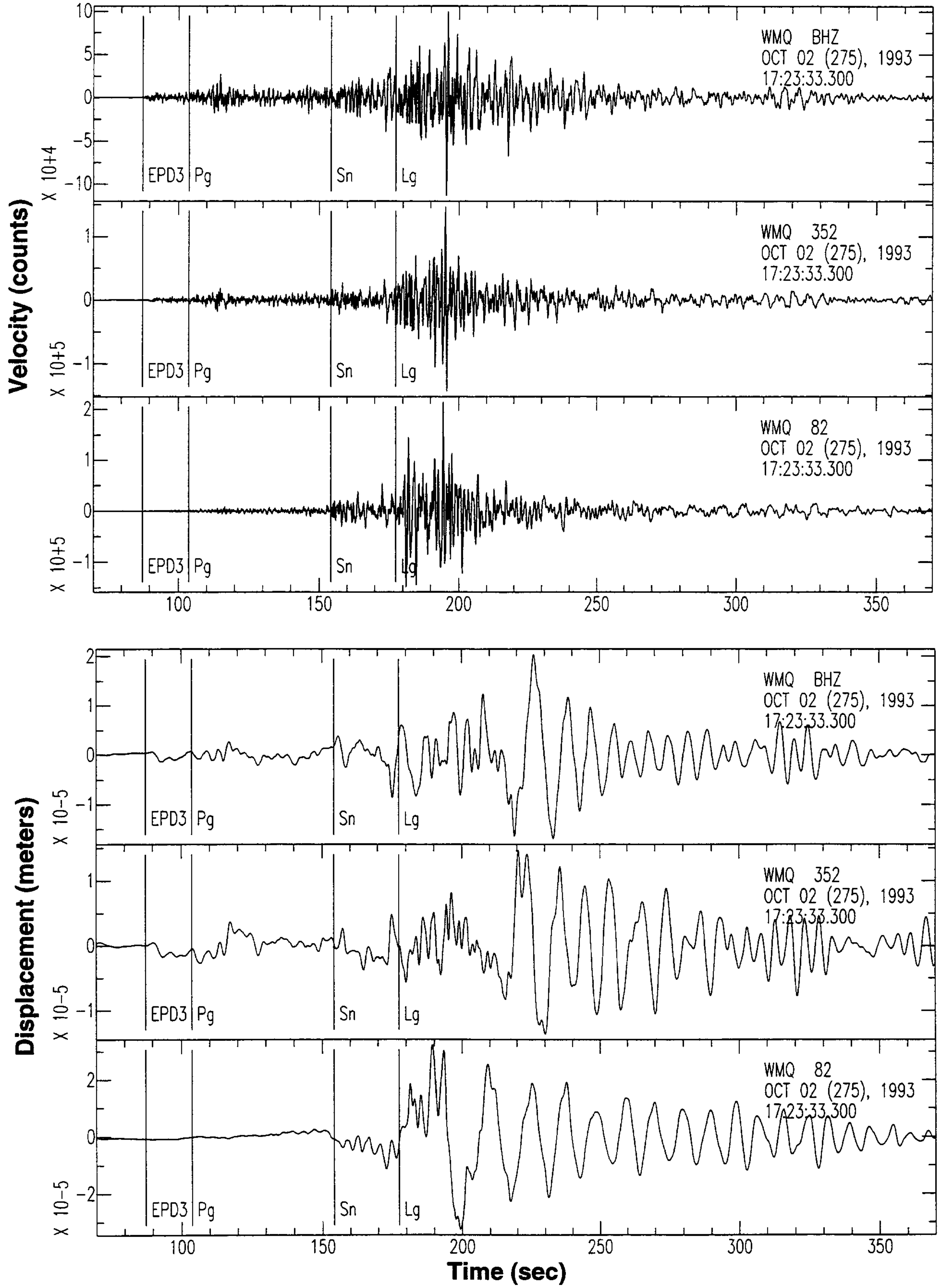

Figure 2. Seismograms for and earthquake 633 km from WMQ. The top traces are raw broadband velocity and the bottom traces are instrument corrected displacement low pass filtered at 0.2 Hz. In both plots the horizontal components are rotated to radial and tangential directions. The displacement shows the dispersed surface wave energy, not visible in the velocity version.

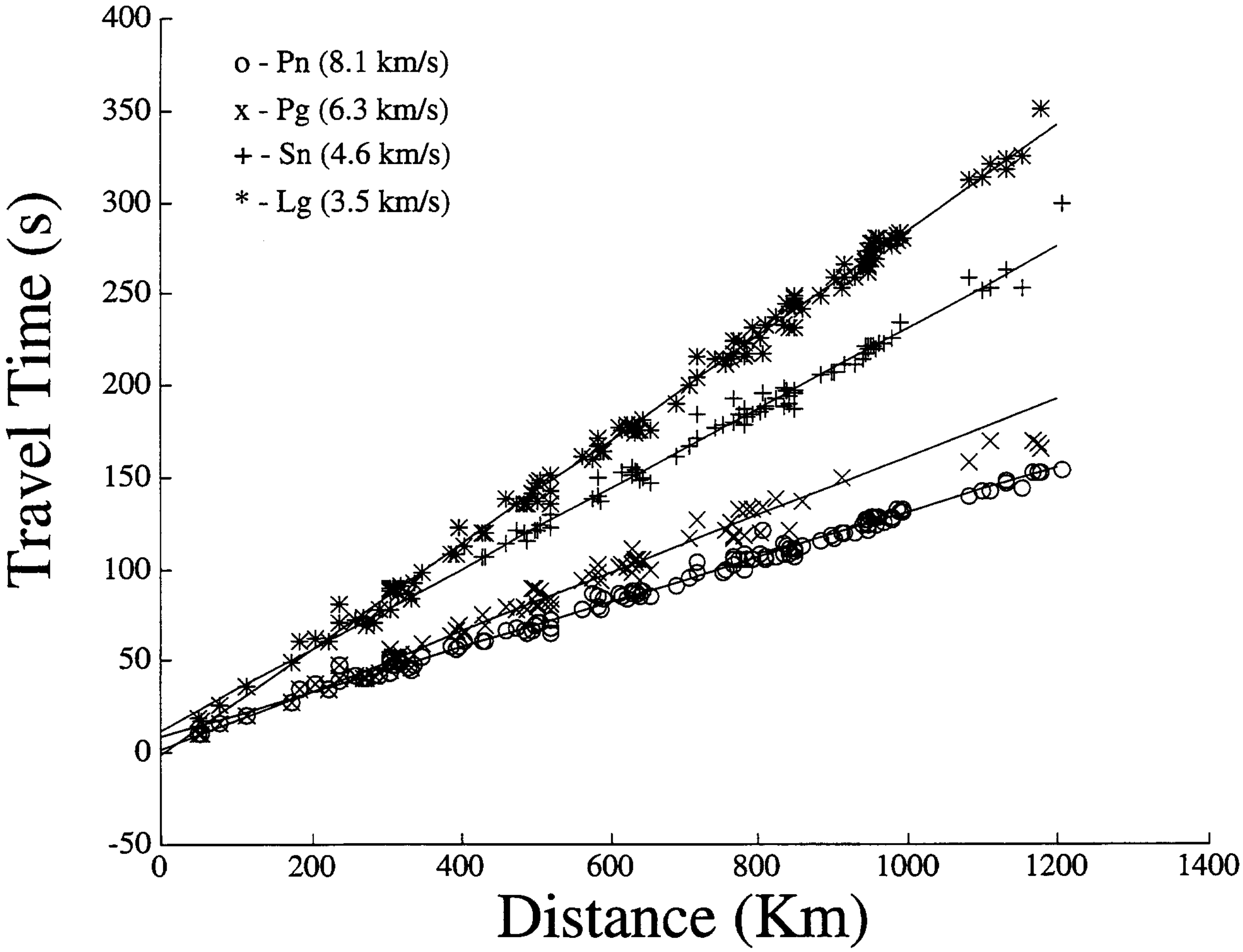

Figure 3. Travel times for Pn, Pg, Sn, and Lg for earthquakes recorded at WMQ. Lines show the linear regression results and estimated velocities for each phase are shown in the symbol key in the upper left hand corner.

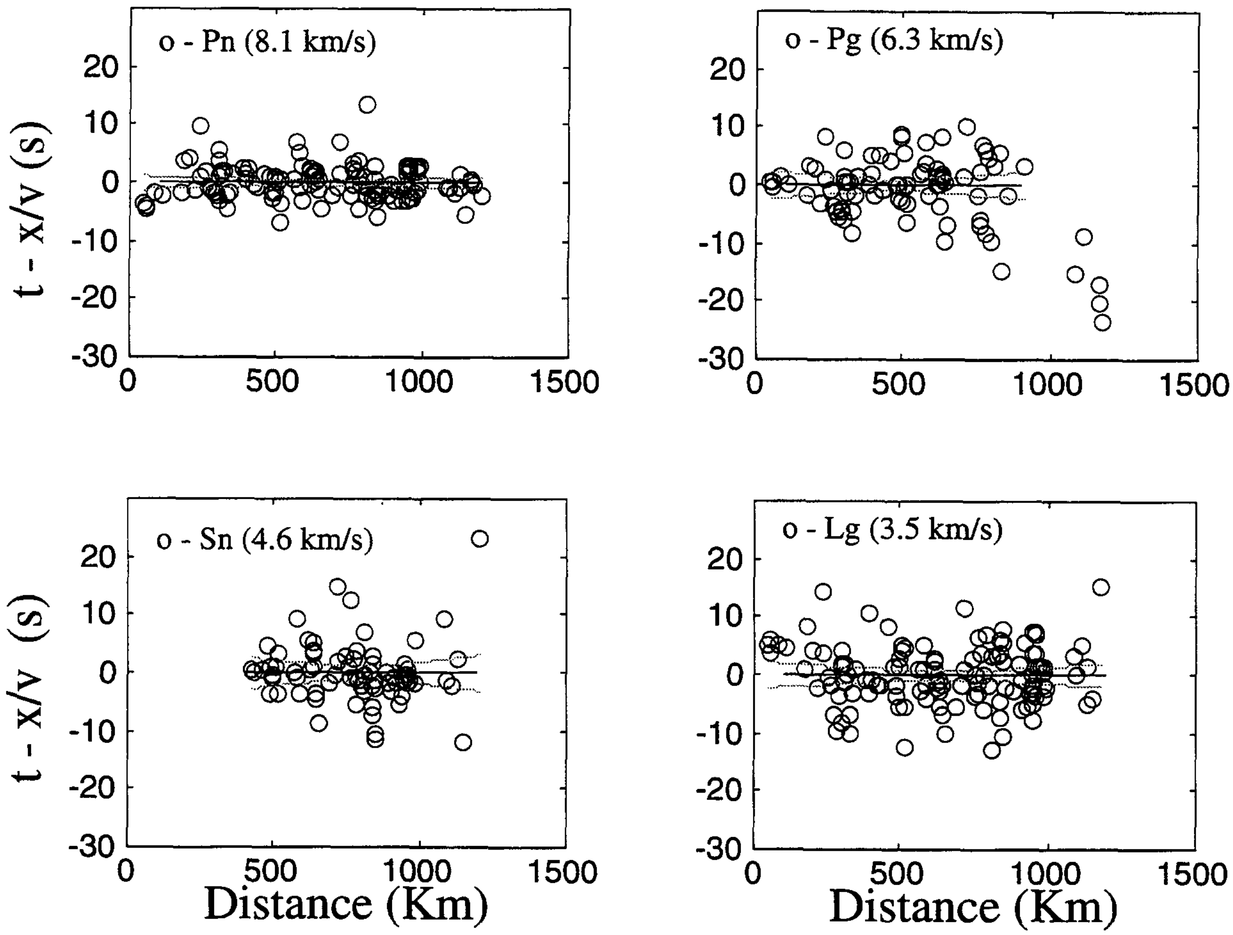

Figure 4. Reduced travel times and linear regression results from the earthquake travel times for events recorded at WMQ shown in Figure 3. The results for Pn, Pg, Sn, and Lg are shown on a common scale for comparison. The residuals for the later phases show more scatter about the regression line and the 95% confidence region (dashed lines) is broader. The velocity estimated from the regression is shown in the upper left hand corner for each phase. For Pg the regression only used arrivals out to 1000 km in order to avoid the more distant arrivals that appear to be from another phase.