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Proposal to Collaborate with the USGS Deep Continental Studies Group on the North Deployment of the Pacific Northwest Refraction Experiment

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Investigations

This research focuses on delineating the crustal structure of western Washington state and studying its implications for seismicity patterns in the Pacific Northwest. Key objectives addressed by this work are:

- Shallow crustal structure of the Pacific Northwest - What is the geometry of the sedimentary basins of the Puget Sound Basin? What is the nature and structure of terrane boundaries?

- Definition of the deep crustal structure - What is the along-strike geometry of the continental and oceanic Mohos? How is the crustal structure related to the subduction zone?

- Relationship of crustal structure to seismicity patterns - Are there north-south changes in crustal structure that correlate with seismicity patterns? Are there additional structural boundaries which have not yet been inferred from seismicity patterns?

Current investigations by our research group include determining seismic velocity structure by forward and inverse modeling of refraction/wide-angle reflection seismic data, constrained by analyses of gravity and magnetic data.

Seismic data were collected as part of the Pacific Northwest Seismic Experiment of 1991. The data set consists of two 300 km long north-south deployments in the Willamette Lowlands of Oregon and the Puget Basin of Washington. Seismic data were acquired in collaboration with the U.S. Geological Survey Deep Continental Studies Group, Canadian Geological Survey, Oregon State University and several other academic contributors. This report addresses the north deployment in the Puget Basin of Washington (Figure 1). Approximately 485 instruments were deployed at intervals of 600 meters. Nine borehole shots were successfully detonated as the sources (~30 km intervals) over the length of this transect.

Results

The field program was successfully completed in September, 1991. In spite of some noisy recording conditions due to the high population density in the area, first arrival energy was seen to distances exceeding 280 km. In general, the data contain clearly identifiable first arrivals. Later phases such as PmP and Pn have less energy and are more difficult to identify.

To enhance arrivals, deconvolution, bandpass filtering, and three different gain corrections have been applied to the data, using a conventional reflection seismic data processing package. This processing effort has significantly enhanced PmP and Pn arrivals as well as some later phases. True amplitude records, records with automatic gain control applied, and trace normalized records, have been generated for each shot. Figures 2 to 4 show examples of this processing for the northernmost shot. Each type of record has been used in the phase identification process.

To date, preliminary crustal velocity models have been produced using first-arrival, PmP, and Pn picks. The velocity field has been interpreted using the seismic velocity inversion outlined by Zelt and Smith (1992). This analysis has resulted in a multilayered velocity model for the crust (Figure 5). The model shows upper crustal velocities to range from 2.50 km/s to 6.30 km/s and middle crustal velocities to range from 6.10 km/s to 6.80 km/s. Upper crustal velocities in the model are comparable to upper crustal velocities found by Taber et al. (1986) in an area southwest of this study area. Middle crustal velocities are within a +/- 0.2 km/s range of velocities found by Crosson (1976). The middle crust shows a significant lateral velocity gradient. Velocities from north to south increase from 6.20 km/s to 6.30 km/s at ~10 km depth and 6.50

km/s to 6.80 km/s at ~20 km/s. Lower crustal velocities range from 7.15 km/s to 7.40 km/s. Lower crustal velocities show a lateral velocity change from 7.40 km/s to 7.25 km/s north to south, respectively. Significant topography on the Moho has also been detected. Depth to Moho varies from ~36 km to ~48 km along the transect.

The inversion results have been used as a basis for forward modeling more subtle features in the data. The method of forward ray trace modeling is from Luetgert (1992). This model (Figures 6 & 7) uses the generalized seismic velocity structure from the inversion results and adds the constraints from known geology, gravity and magnetic data. Figures 6 & 7 show an example of the ray trace model from the northernmost shot. These results (Figures 6 & 7) better define the velocity structure of the surface structure and particularly the Puget Basin. Velocities in the Puget Basin range from 2.00 km/s to 5.50 km/s. Along this transect, the basin has a maximum depth of 8 km. Velocities used to define the basin range from 2.00 km/s to ~4.80 km/s. Velocities of the upper crust beneath the Cascades ranges are significantly faster at 4.50 km/s at the surface to 6.00 km/s at ~10 km depth. The mid-crustal lateral velocity gradient remains unchanged from the inversion model. Forward modeling of the Moho results in a more smoothly varying interface than that produced by the inversion model.

Study of true amplitude records (e.g. Figure 2) indicate significantly lower amplitudes in the southern part of the profile. This pattern of lower amplitudes to the south is seen on every shot in the experiment. Reflectivity analysis is being used to study the origin of these diminished amplitudes.

At present, phases later than PmP are being interpreted. This includes a wide-angle reflection that may represent the top the subducted Juan de Fuca plate. 2 1/2 - D gravity modeling is being done in concert with the seismic velocity modeling. Reflectivity analysis has also begun in an effort to resolve the origin of amplitude changes along the profile.

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Reports

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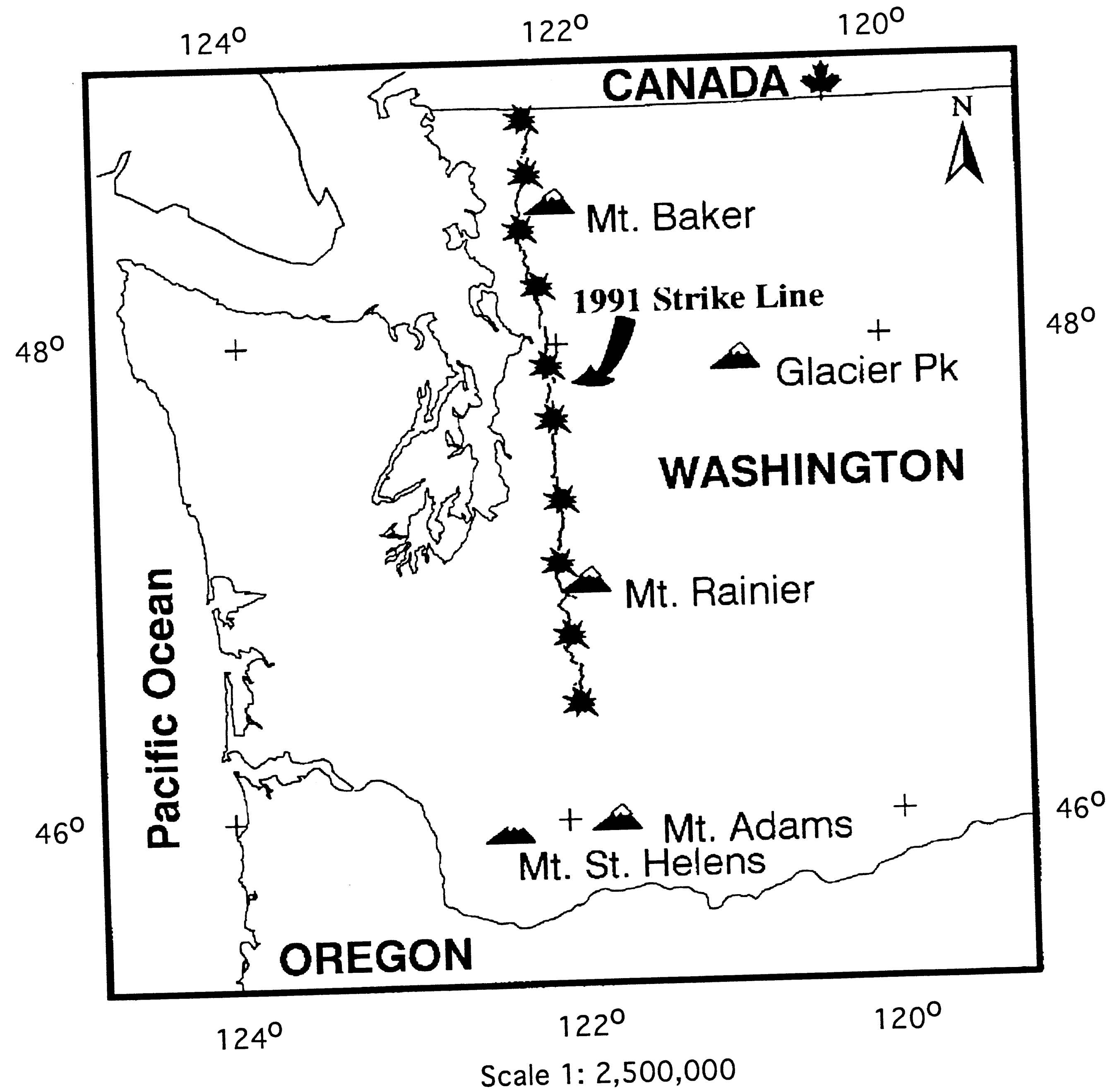


Figure 1. Location map of the profile recorded in 1991.

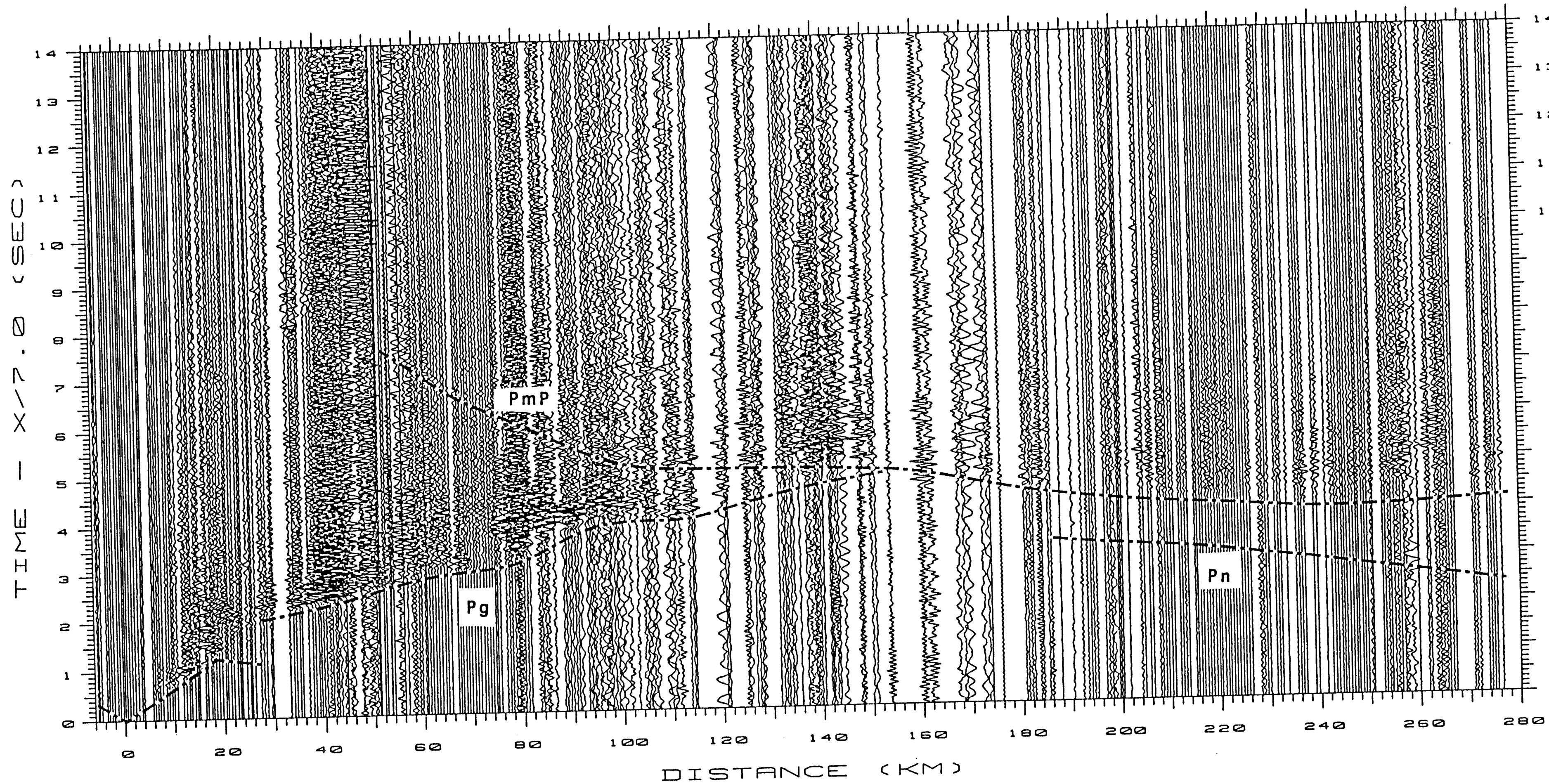


Figure 2. Seismic record of shot 1 with Pg, Pn and PmP arrivals denoted by the dashed line. This has been bandpass filtered, deconvolved and corrected for spherical spreading and plotted as true amplitude.

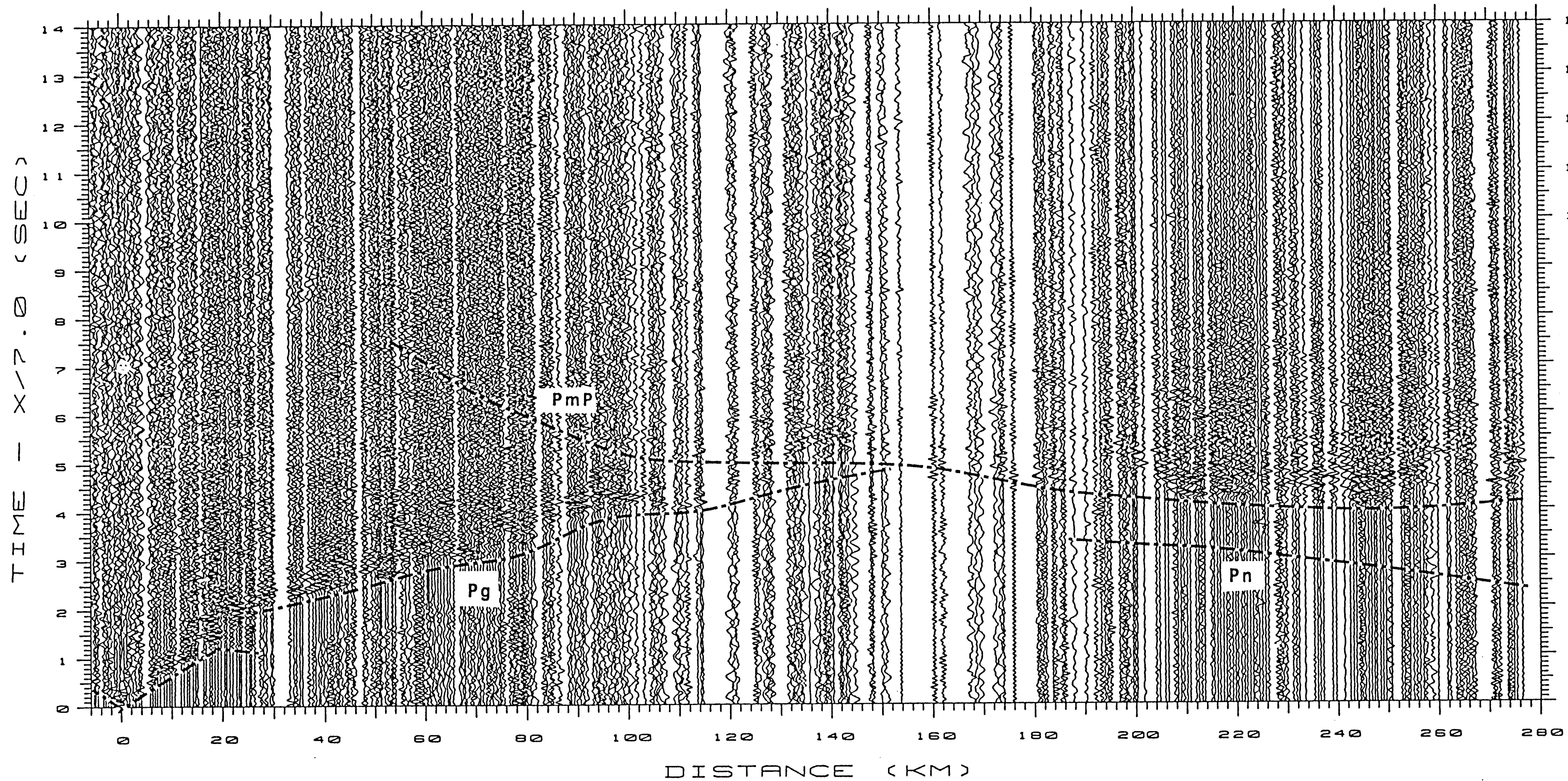


Figure 3. Seismic record of shot 1 with Pg, Pn and PmP arrivals denoted by the dashed line. This has been bandpass filtered, deconvolved and an automatic gain control has be applied.

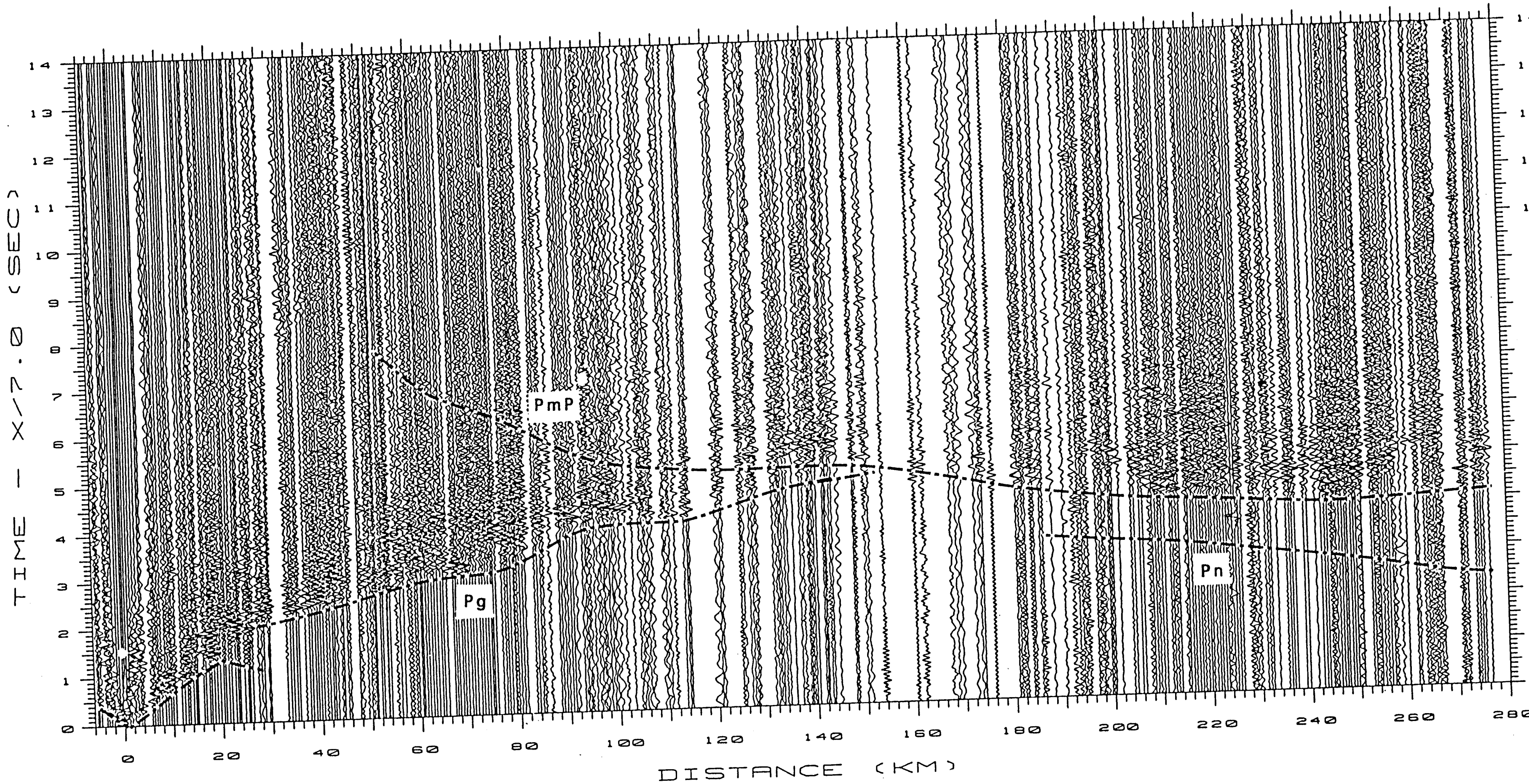


Figure 4. Seismic record of shot 1 with Pg, Pn and PmP arrivals denoted by the dashed line. This has been bandpass filtered, deconvolved and plotted with trace normallization.

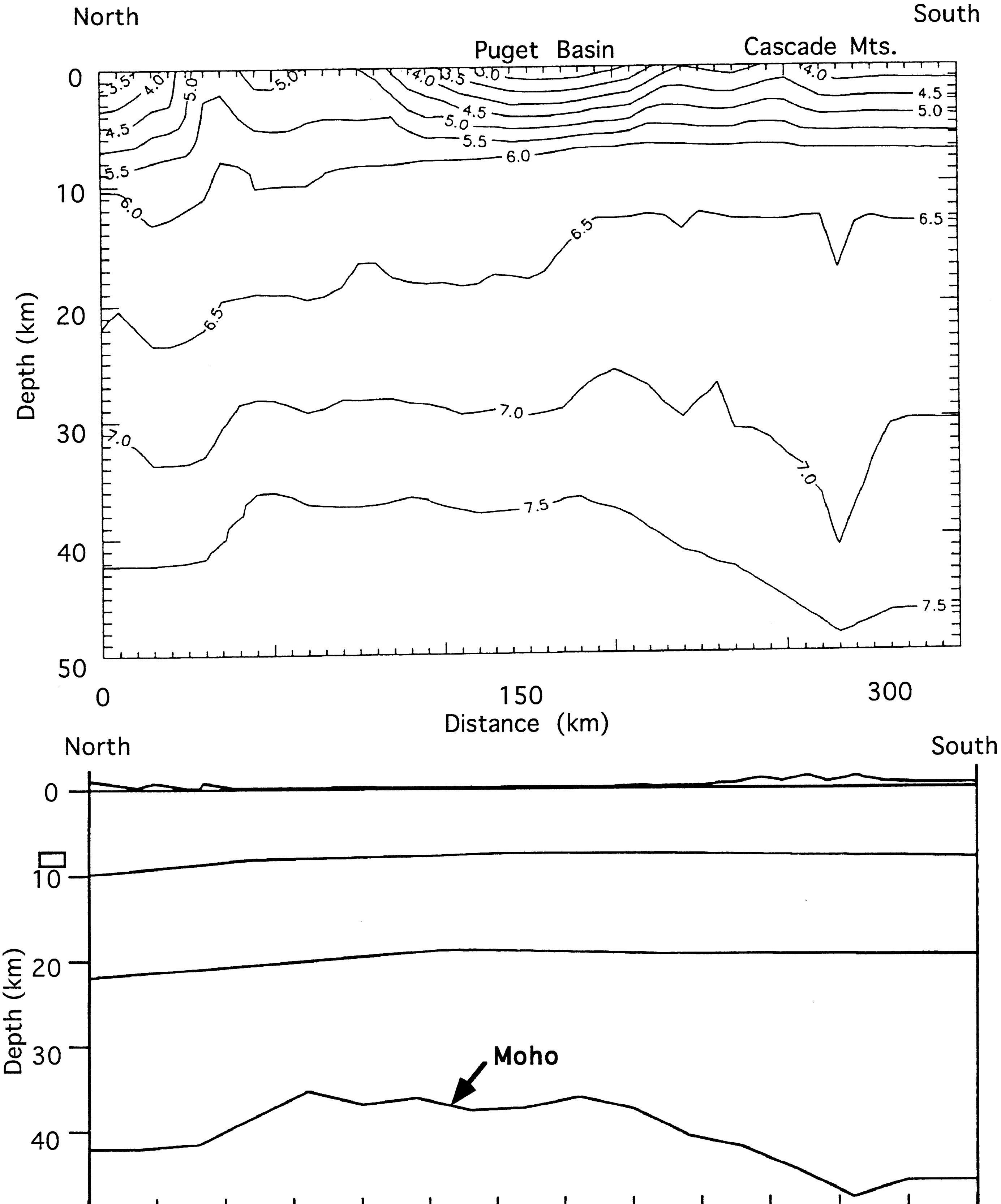
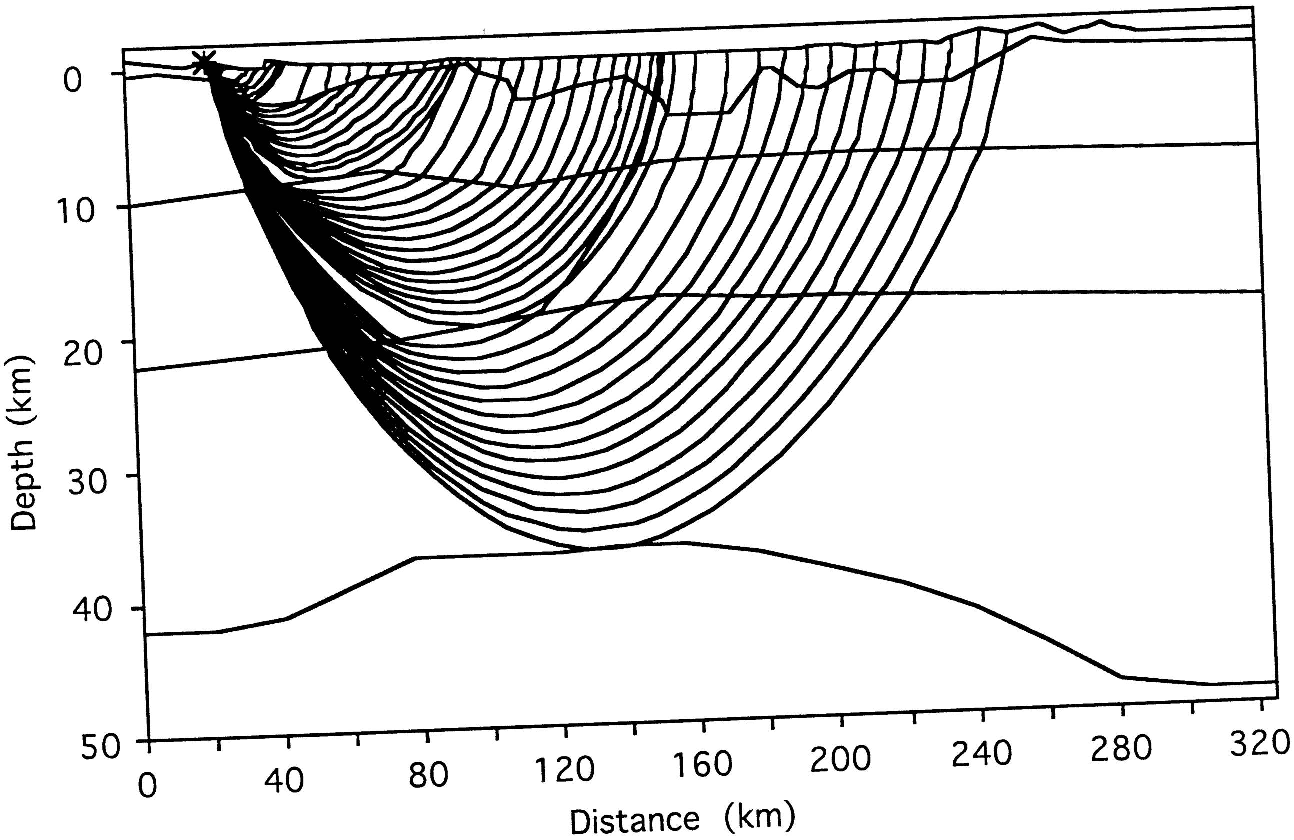


Figure 5. Seismic velocity model produced from inversion results of Pg, PmP and Pn arrivals. Upper figure shows the velocity field and the lower figure shows structure. Velocities are in km/s.



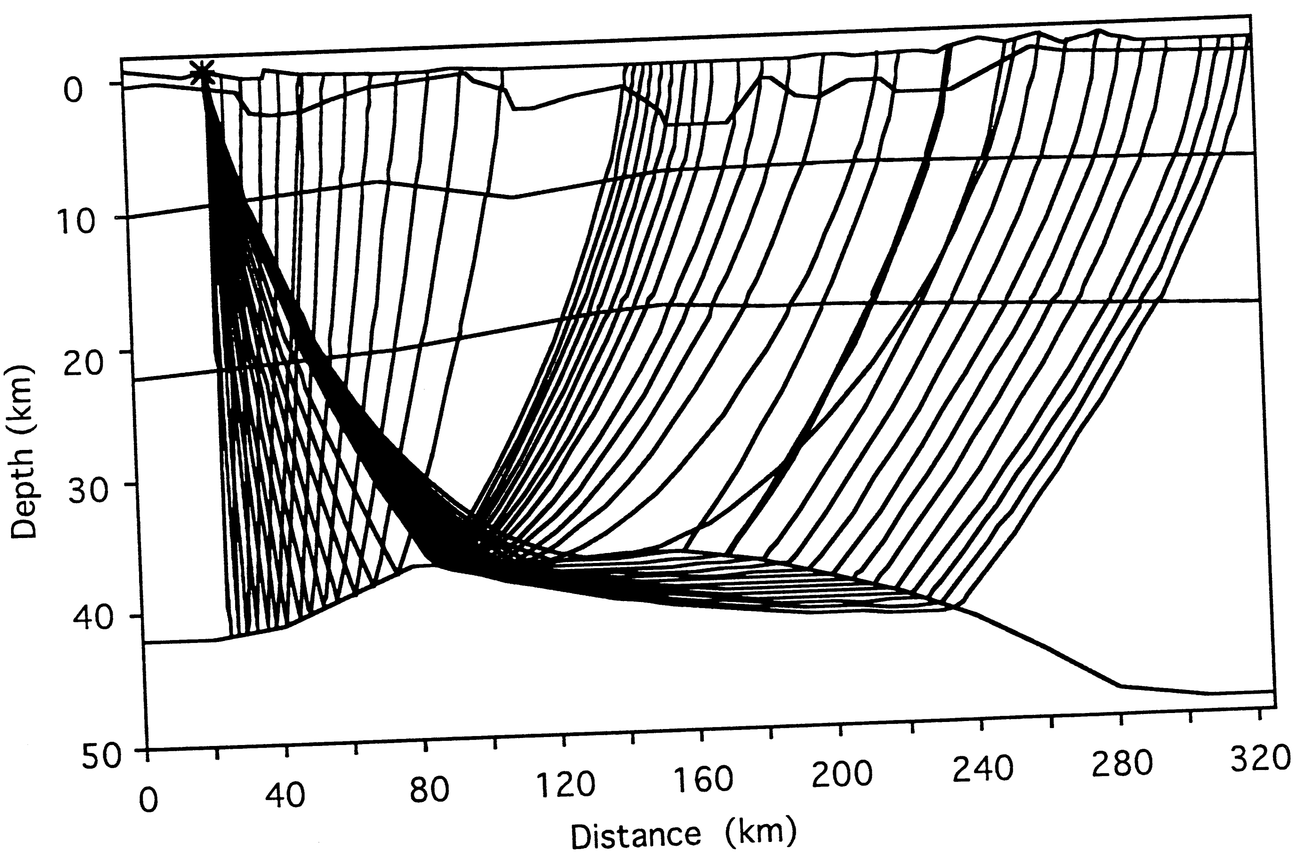


Figure 6. Forward ray trace model of the northern most shot. Upper figure is Pg arrivals and the lower figure is PmP and Pn arrivals.

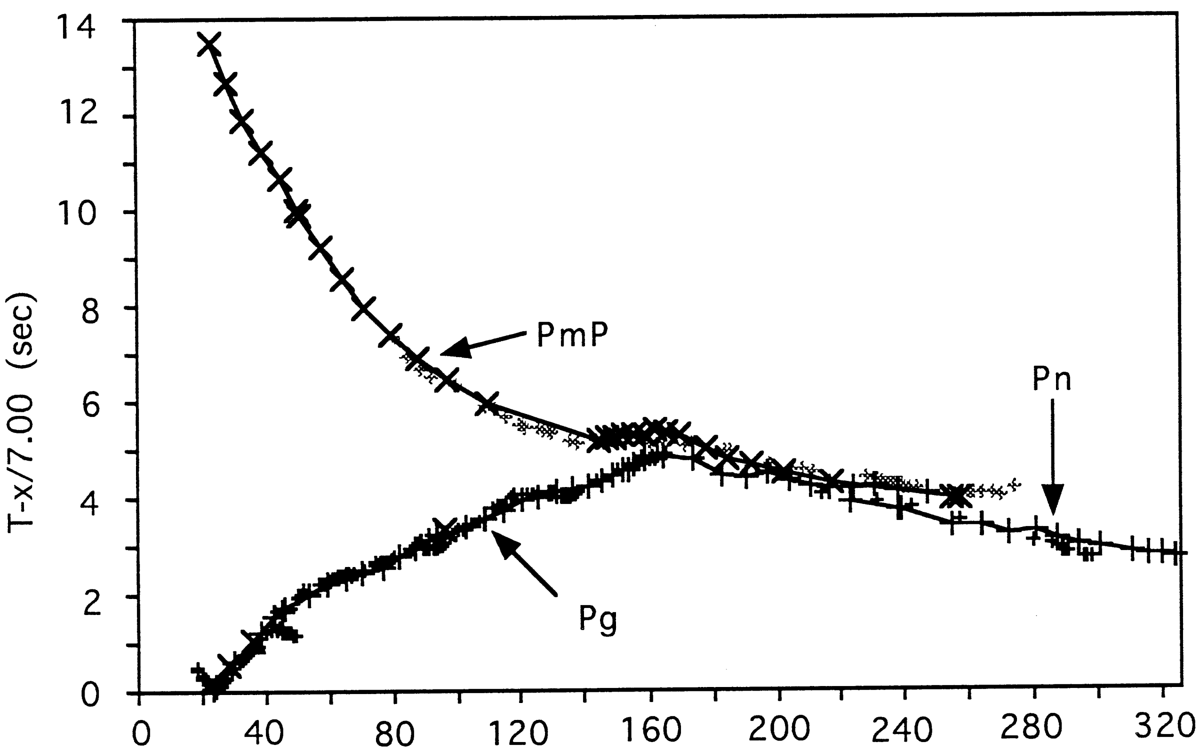


Figure 7. Forward ray trace model arrival fit for arrivals in Figure 6.

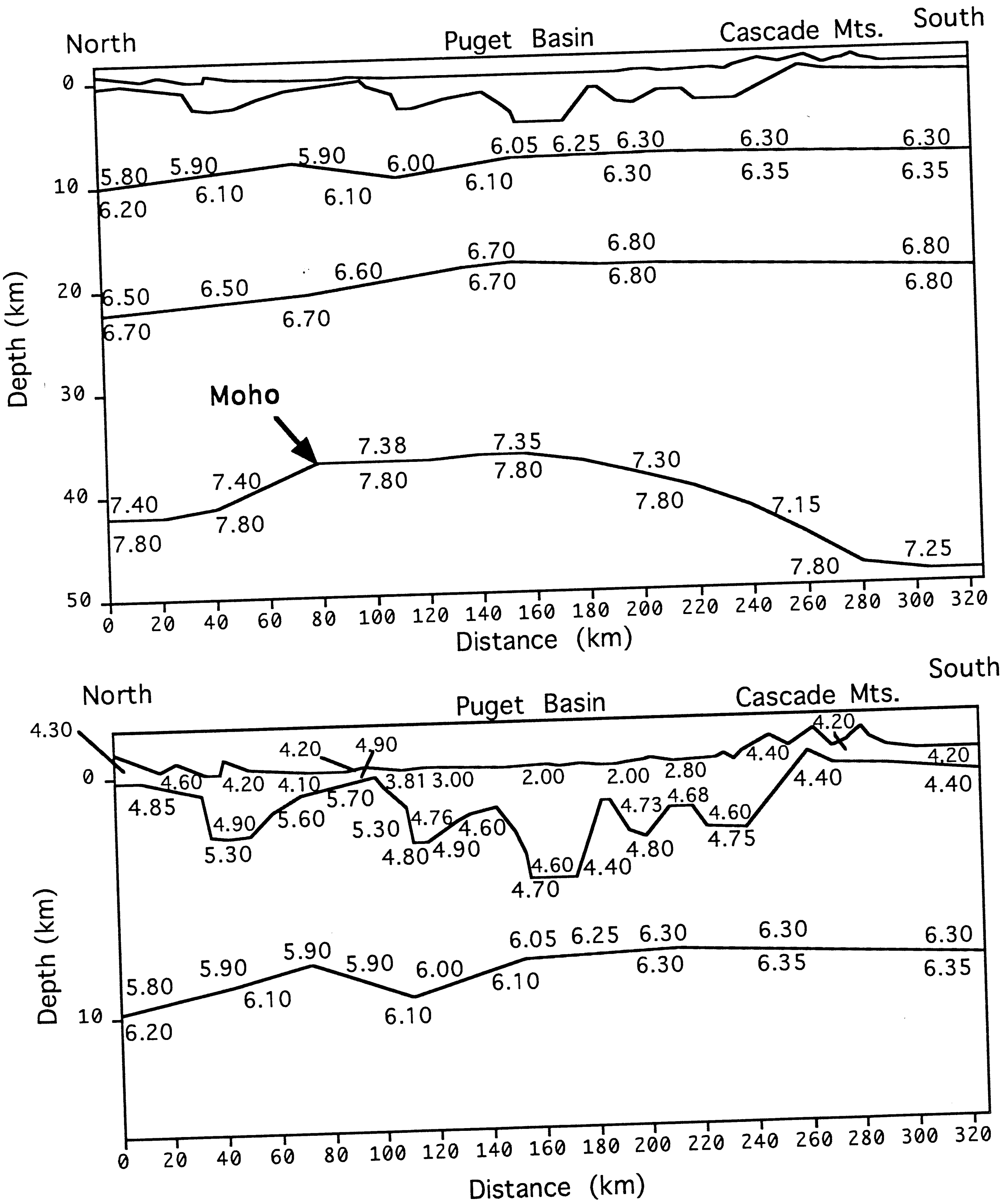


Figure 8. Top portion of the figure is the middle and lower crustal velocity structure from the forward ray trace model in Figures 6 & 7. Lower portion of the figure an is an elargement of the upper crustal velocity structure. Velocities are in km/s.