Lower Crustal and Upper-most Mantle Structure beneath Station WMQ, China by using teleseismic P-wave Polarization signals

Liping Gao and Paul G. Richards*
Lamont-Doherty Earth Observatory, Palisades, NY 10964
(*also, Dept. of Geological Sciences, Columbia University)
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Abstract

We have applied a polarization tomographic inversion to the single station WMQ to retrieve the velocity structure of the lower crust and upper-most mantle in the vicinity of Lop Nor. 828 teleseismic P-wave waveforms with event magnitude $M_b \geq 5.0$ around the world with excellent coverage of back azimuth were collected and are used to measure polarization anomalies. In addition, 39 PKP signals are used. Inversion results reveal a low velocity region or a depressed Moho to the northwest of the WMQ station.

Keywords: polarization tomography, crust and mantle velocity structure.

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Objective

The Chinese Digital Seismographic Network (CDSN) station WMQ (Urumqi) is the closest digital station to Lop Nor, known as the Chinese nuclear test site, in Xinjiang Province, China. It is also the only station for this area from which we can get data from the IRIS DMC. With limited resources of seismic signals, analysis of the crustal and upper mantle structure has been very difficult. Yet, understanding the velocity structure in the area is crucial in analyzing the seismic signals of both earthquakes and explosions. Also, the station WMQ is in a region of great interest geological and tectonically, being affected by the collision of India with Asia and the resulting continental deformation. In this paper, we have used the single station teleseismic polarization anomalies to study the lower crust and upper-most mantle structure, mainly in the vicinity of the Moho.

Research Accomplished

We have used the newly developed polarization tomography method [Hu and Menke, 1992] to study laterally varying velocity structure in the vicinity of the Chinese nuclear site in Xinjiang Province. Compared with teleseismic travel-time inversion, polarization tomography takes advantage of the facts that: (1) the measurement of polarization (i.e. ray arrival direction) does not depend upon the origin time of earthquakes; and (2) the polarization has little dependence on the structure near the source, the location error of the source, or the deep mantle structures, because the sensitivity of polarization to a velocity structure is, in a rough sense, inversely proportional to the distance between the structure and the station measured along the ray path. For instance, a 10 km location error, which may cause a 1 second delay in travel-time, only causes 0.1° anomaly on arriving azimuth at 60° distance. To get high quality polarization data at a station, requires high quality of the original waveform data. From 1988-mid 1994 (the data for WMQ starts from 1988 in IRIS), we obtained over 1500 broad band P-wave waveforms of events ($M_b \geq 5.0$) around the world with excellent back azimuth coverage (0°-360°). Among them, 828 teleseismic events with high signal to noise ratio and 39 high quality PKP signals are chosen to measure the polarization anomalies. Figure 1 shows the 867 event locations relative to the station, and Figure 2 shows two examples of the waveform data, one event from the Philippines with distance of 76° and azimuth 135° and the other from Greece with distance of 42° and azimuth 228°.

We adopted a very simple time domain least square fit [Hu, 1994] to measure the P-wave polarization — the azimuth and incident angles. For a signal (**z**, **n**, **e**), where data vectors have the components (z_i, n_i, e_i) with i=1, ..., N and N is the total number of points in the digital time series, we calculate azimuth angle by fitting **n** and **e** with a linear relationship, **e** = a + b**n**. The azimuth is $\phi = \tan^{-1}$ (b). The radial component is then **r** = **n**cos(ϕ) + **e**sin(ϕ). By fitting the linear relationship **r** = c + d**z**, we get the apparent incidence angle $\delta' = \tan^{-1}$ (d). Then, the true incidence angle, after correction for free surface reflections, is $\delta = \sin^{-1} [V_p^2(1-\cos\delta')/2V_s^2]^{1/2}$. Only the first few cycles of the P arrival are used to avoid noise introduced by later arrivals. The polarization residuals are with reference to the iasp91 global Earth model [Kennett and Engdahl, 1991] and locations are taken from the PDE catalog (Figure 3).

There have been some previous efforts by western scientists to study crustal structure in the area [for example, Mangino and Ebel, 1992; Roecker, et al., 1993; and Gao and Richards, 1994]. We chose a regional crust velocity model from our previous studies [Gao and Richards, 1994] as our reference, with which to develop the velocity variations. Our reference model was obtained by fitting regional seismic records (recorded at WMQ) from an explosion in Lop Nor. It has three layers in the crust, and Moho depth is at 46 km (Figure 4). This model represents an average structure along the path from the Lop Nor test site to the station WMQ (distance ~240km), which does not necessarily reflect the structure right underneath the station. In the inversion, we limited the three-dimensional velocity variation to be within a 15 km thick layer centered at Moho depth (46 km). The P-wave velocity at the top and bottom of this layer is fixed to join continuously with the one-dimensional background velocity (reference model). We represent the velocity in this layer with B splines and invert for the three-dimensional P-wave velocity variation in this layer by the method from Hu [1994] using only the polarization measurements (azimuth and incidence angles at WMQ). Our data distribution is not uniform in the back azimuth (Figure 3), because the data from 20° - 135° are much denser than those from the remaining directions (ratio is 3:1). We therefore gave the latter directions of the data a weight three times larger than the former. Our preliminary results (Figure 5) show that the general trend of the velocity isopaths is west-southwest for much of the region, which is also the trend of the Tian Shan mountain range in the same general location. There is a velocity depression (low velocity, more than 7% lower than the reference model) to the northwest of the station WMQ. This is consistent with the observation from Mangino and Ebel [1992] that there is a NW dipping structure underneath the station WMQ. Our studies indicate that this dipping structure could be the Moho.

Future Work and Recommendations

Our studies show that polarization tomography is effective although our data resources are limited (because there is only one station in Tian Shan - Lop Nor vicinity).

With help from the US Geological Survey and the State Seismological Bureau (SSB) of China, we have obtained a comprehensive catalog of local and regional earthquakes in the Lop Nor region (Xinjiang Province). This catalog provides additional information on seismicity. Some of the events have records available from IRIS. With the help of local and regional data, the understanding of the structure parameters, such as velocities and Q values of the region can be greatly improved. This effort is well underway here in Lamont.

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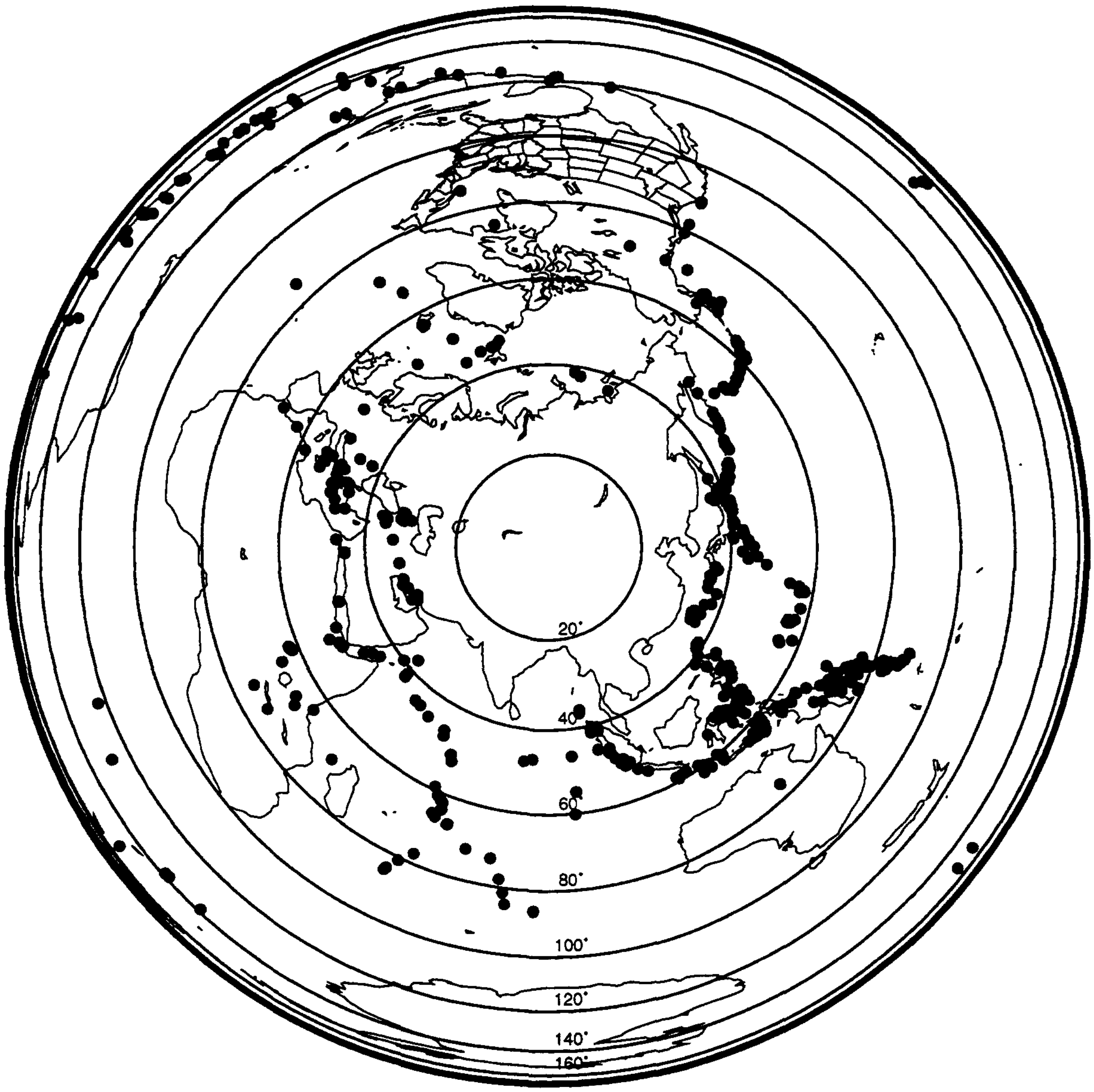


Figure 1. Location map showing the events used in the study.

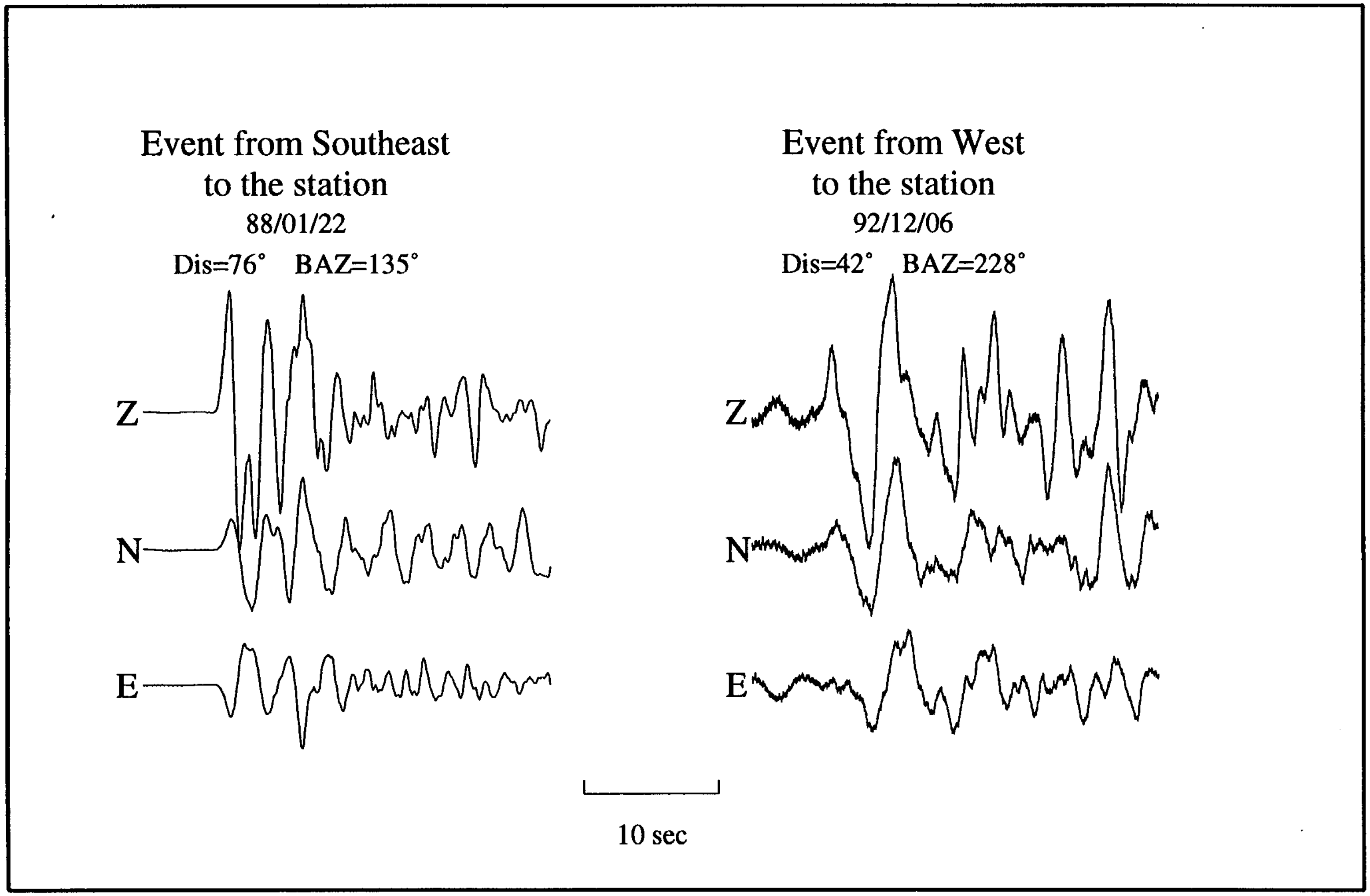


Figure 2. Two examples of the teleseismic records recorded at WMQ station. One event is from the southeast to the station (88/01/22) and the other is from the west to the station (92/12/06).

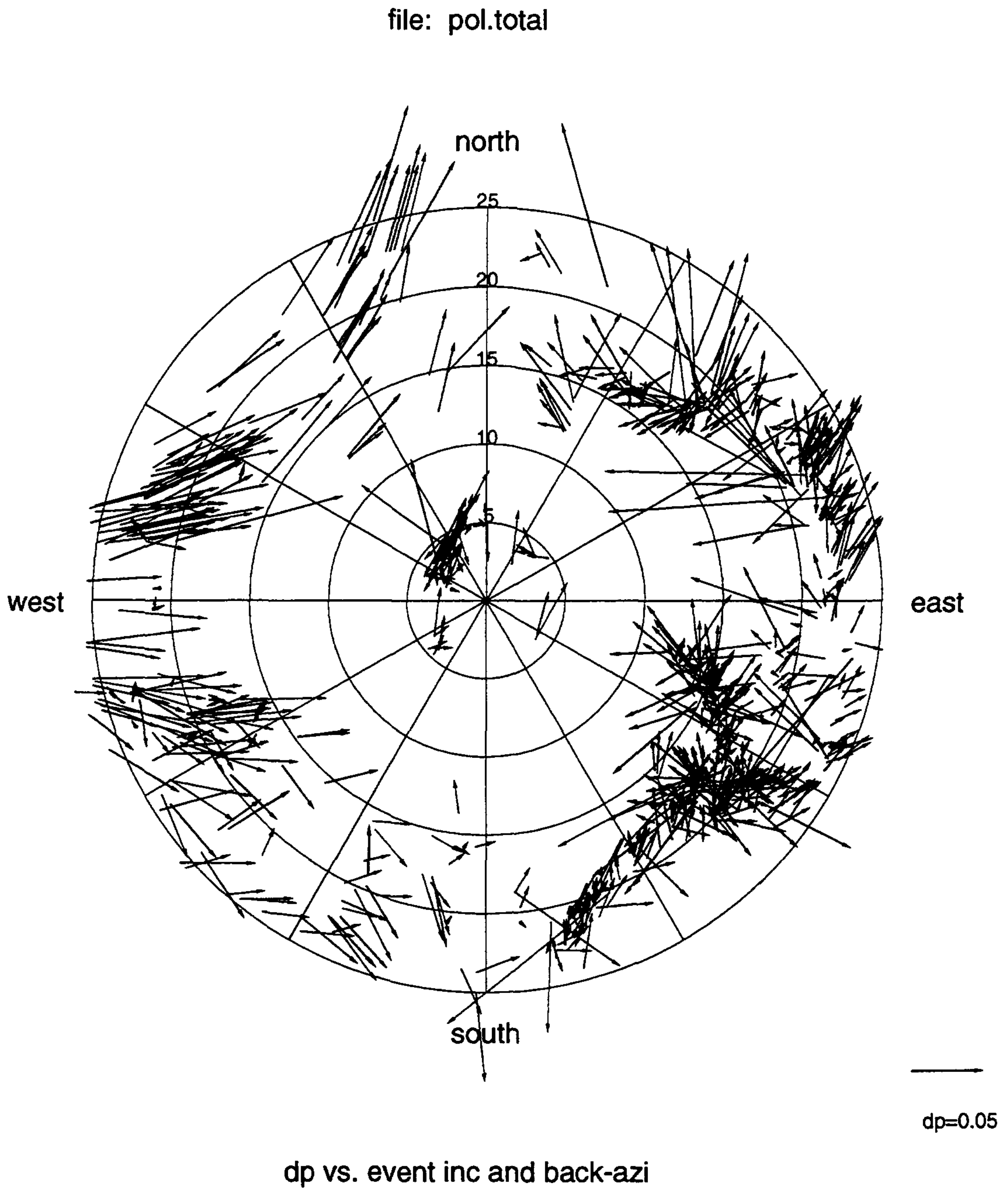


Figure 3. Polar plot of the polarization residuals. The radial axis shows the incident angle of the polarization vector and the position of each vector is plotted according the back-azimuth.

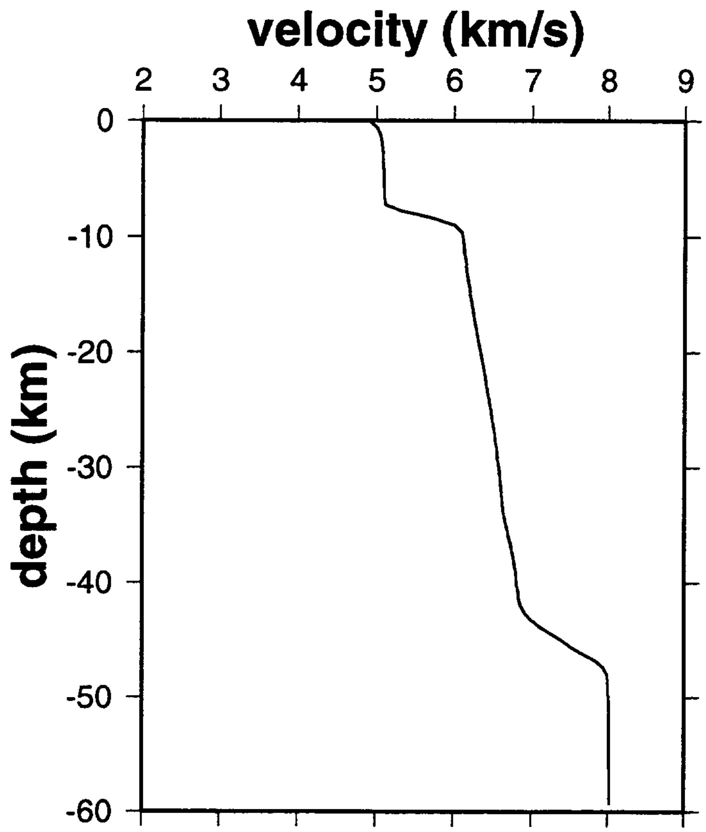
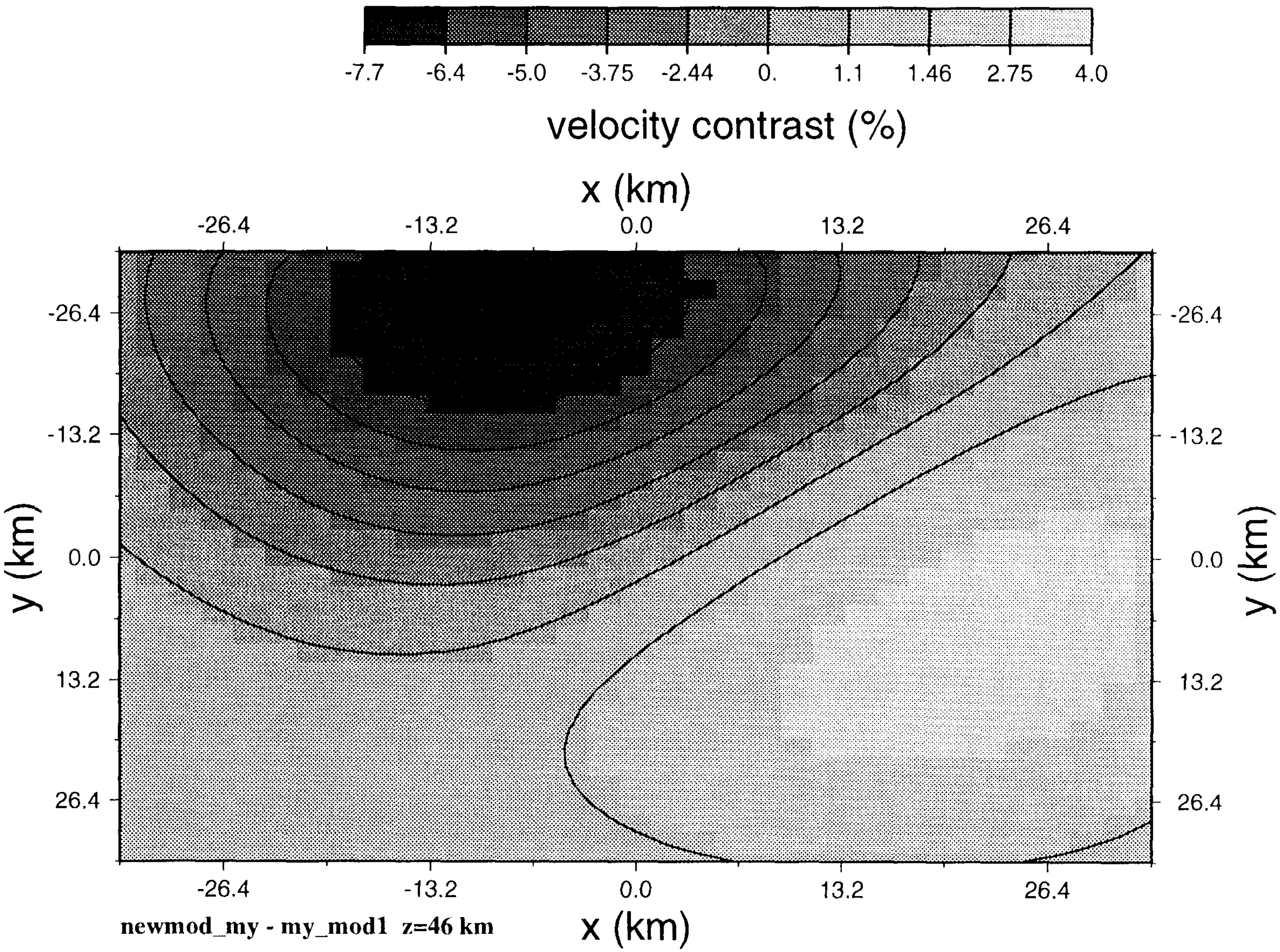


Figure 4. Reference (starting) 1-Dimensional model from Gao and Richards [1994].



newmod_my - my_mod1 z=46 km

Figure 5. A horizontal slice at depth 46 km of the model resulting from the inversion showing a low velocity depression to the NW of station WMQ (centered at (0,0)).