Inversion of Newberry Volcano High-Resolution Traveltime Residuals

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Inversion of the 1984 traveltime data from the array at Newberry Crater was accomplished using a variant of the method presented by Aki and others [1973]. The program was written by Ellsworth and Zandt, and has been modified and used extensively for teleseismic-P studies by us and others at the USGS. The volume beneath the seismic array is subdivided into rectangular bins and a linear inversion of the observed traveltime residuals is performed to obtain an estimate of the average velocity perturbation for each bin (Figures 1-4).

Five-hundred-sixty-five traveltime observations for Pg and a deeper reflection, weighted by their variance estimates, were included in the inversion. Azimuths from receiver-to-source range from 800 to 2800. The three shots to the north yielded few traveltime measurements. Residuals were calculated by computing and removing a weighted least-square linear fit of observed times versus distance from the source. Separate fits were made for the Pg and the deeper reflection phases.

The initial-velocity model for the inversion has four layers (Figure 5). The top layer, starting at the surface and extending to an elevation of 1300 meters above sea level, had a P-velocity of 2.5 km/s. There are three layers below this one, each 1500-m thick, with P-velocities of 4.0, 4.6, and 5.2 km/s. Lateral dimension of the bins is 1500 m in the three lower layers; a separate bin in the top layer is assigned to each receiver location.

The predominant feature in the inversion result in the upper two layers (surface to 200-m below sea level), is the ring of high velocities coincident with the caldera ring-fracture system. This high-velocity ring is up to 11% faster than the average for these two layers. In these layers velocities are a few percent slower than average in the center of the caldera and range from 5 to 10% slower outside the caldera to the south, east, and north. High velocities continue westward outside the caldera to the edge of the seismic array. In the third layer (-200 to 1700 m elevation), the magnitude of the high-velocity anomaly around the ring-fracture system is reduced, but the bin in the center of the caldera is nearly 9% slower than the layer average. Velocity perturbation estimates in the bottom layer are not as reliable and should not be interpreted.

A relatively simple geologic model can explain the P-velocity model just described. The ring-fracture system serves as a conduit for magma and is the locus for intrusion in the shallow crust. If most of the intrusions have cooled to below solidus temperatures and are crystalline, they are expected to have higher seismic velocity and higher density than surrounding extrusive-igneous and sedimentary rocks, which have higher porosity and glass content. The ring fractures from opposite sides of the caldera intersect in the center of the caldera 1- to 3-km below sea level if projected with 600 dips. This intersection is within or just below the low-velocity body in the center of the caldera in layer three. It is possible that magmas present in this region account for the low observed P-velocities. An alternate possibility is that the low-velocity anomaly in the caldera center in layer three is caused by downfaulting of lower velocity volcanics into a higher velocity crystalline basement. Further analysis of the magnitudes of the anomaly may help distinguish these hypotheses.

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FIGURE CAPTIONS

Fig. 1. Velocity perturbations in the first layer of the ACH inversion model. "Vav" is initial velocity used in model; number next to each station is velocity perturbation in percent. Station symbol is color coded according to the velocity scale at the bottom. Heavy lines are mapped ring fractures. The northwest well symbol shows the location of the USGS hole; the southeast symbol represents the Sandia hole. The two lines show the positions of the cross sections in Figure 5. Diagonals of the resolution matrix range from 0.05 to 0.49 in this layer and are greater than 0.20 at most stations.

Fig. 2. Layer two of the ACH inversion. In each bin the upper number is the velocity perturbation and the lower number is the diagonal element of the resolution matrix. Plus sign marks center of model.

Fig. 3. Layer three of the ACH inversion. The central bin (-8.73%/0.53) has one off diagonal resolution element of 0.14; all others are less than or equal to 0.09.

Fig. 4. Layer four of the ACH inversion.

Fig. 5. Vertical cross sections through the ACH inversion model; no vertical exaggeration. Heavy lines are hypothetical ring fractures, assuming 60° dip from mapped surface fractures. Cones in upper layer are "bins" assigned to each station and represent cone of rays arriving at each.

Layer 1 Surface to 1300 m $V_{av} = 2.5$ km/s

Layer 2 1300 m to -200 m $V_{av}=4.0$ km/s

5 km

Layer 3 -200 m to -1700 m $V_{av}=4.6$ km/s

5 km

Layer 4 -1700 m to -3200 m $V_{av}=5.2$ km/s

5 km

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