# Reply

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Krishna and Ramesh (1996) present a new P-wave velocity model to fit the seismic profile shown in Vidale et. al. (1995). The changes in the model include a far lower velocity gradient from 200 to 400 km depth as well as a far larger jump in velocity at the 410 km discontinuity. If their model were appropriate for the upper mantle then it would have significant implications for the chemical composition of the Earth, as discussed in their comment.

The model that Krishna and Ramesh (1996) propose does indeed do a better job fitting the data in our study than our model. However, this does not necessarily mean that it is a better representation of the actual Earth. The seismic profile shown in Vidale et. al. (1995) only extends over the distance range from $11.5^o$ to $14^o$. Data over a longer distance range are necessary to constrain velocity in the upper 400 km's of Earth. The model changes proposed by Krishna and Ramesh (1996) would have significant effects on P waves recorded at distances from 18 to 24 degrees. Specifically, the low gradient from 200 to 400 km depth would produce an extended arrival from that depth range that could be seen beyond 22 degrees distance. The higher gradient in our model does not produce such an arrival. Although our profile does not extend that far, Walck (1984a) showed data from the Gulf of California and Walck (1984b) showed data for paths from Vancouver to California that did not show the extended arrival that a very low gradient from 200 to 400 km depth would produce.

Similarly, the large 9.2% jump in velocity at 390 km depth proposed by Krishna and Ramesh (1996) would have drastic effects on seismograms from 19 to 21 degrees distance. Specifically, the P wave arrival from below the "410" discontinuity would arrive earlier than the arrival from above the discontinuity at a closer distance than predicted by our model and the models discussed in Walck (1984a,b). Again, Walck's data prohibit this. We focus on Walck's data because they sample a region close to the region our data sampled, but it should also be noted that most other high-quality P-wave studies have found 410 km discontinuity jumps similar or smaller in size than the model presented in our paper. We therefore feel it is unlikely that the model proposed by Krishna and Ramesh (1996) is appropriate.

If the new model has serious difficulties then why does it fit the data in the profile shown in Vidale et. el. (1995) better than other models? We suspect two factors may be responsible. First, Q probably varies with depth in the region sampled by our data and it is not clear whether Krishna and Ramesh (1996) or we have used the correct Q structure in the synthetics. The P velocity in the upper 150 to 200 km's in our model is very low and this may also correspond to a very low Q region (see Solomon (1972) for example). Very low Q in the upper 200 km's of the mantle would reduce the amplitude of the first arrival shown in our profile relative to the "410" reflection. The second problem with synthetic modeling is that lateral variations in velocity are not included. In our profile this may be a serious problem because some of the data pass through the subducted Juan de Fuca slab. Amplitudes of short period P-waves are very sensitive to such heterogeneity. Lateral heterogeneity may then be responsible for the very low amplitude first arrivals near 12 degrees distance in our profile.

In summary, we agree with Krishna and Ramesh (1996) that their model fits our data better than the model we presented. We are skeptical, however, whether it is actually a better model since it would predict waveforms inconsistent with observations made at larger distances than are shown in our profile.

## References

Krishna, V. G. and D. S. Ramesh, A discussion on "The 410-km depth discontinuity: A sharpness estimate from near-critical reflections" by Vidale et. al., *Geophys. Res. Lett. this issue*

Solomon, S. C., Seismic-wave attenuation and partial melting in the upper mantle of North America, *J. Geophys. Res., 77,* 1483-1502., 1972.

Vidale, J. E., X. Y. Ding, and S. P. Grand, The 410-km-depth discontinuity: A sharpness estimate from near-critical reflections, *Geophys. Res. Lett., 22,* 2557-2560, 1995.

Walck, M. C., The P-wave upper mantle structure beneath an active spreading center: the Gulf of California, *Geophys. J. R. astr. Soc., 76,* 697-723, 1984a.

Walck, M. C., Teleseismic array analysis of upper mantle compressional velocity structure, *PhD Thesis, Caltech,* 1984b.

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