Crustal velocity structure in NW India from surface wave dispersion tomography

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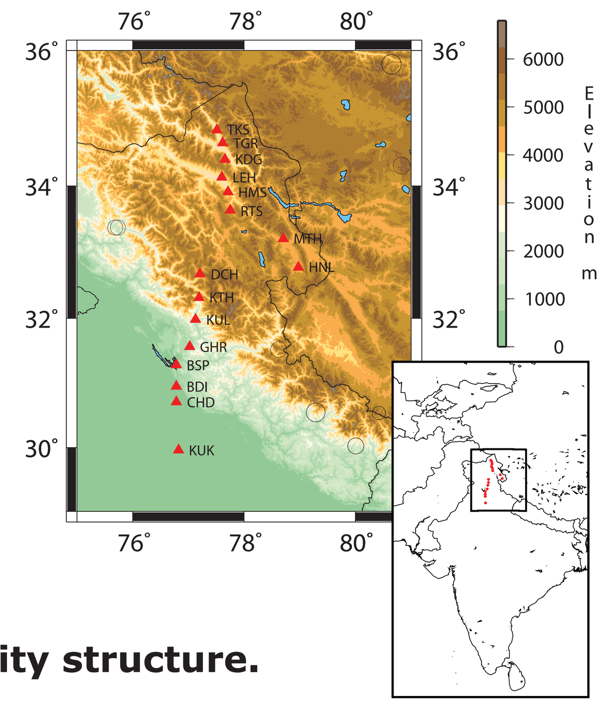
1. 1-D Velocity Modeling

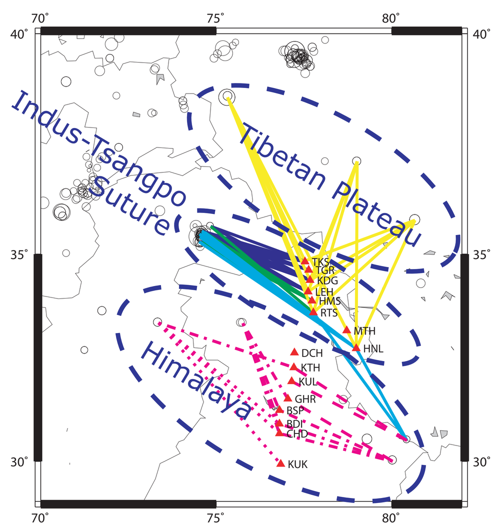
DATA: Under the HIMPROBE project, the Indian National Geophysical Research Institute (NGRI) operated a network of 15 broadband seismometers (with some stations operated by Cambridge University) for 18 months in 2002-2003 (Rai, et al., 2006). The array was approximately 500 km long and oriented roughly N-S. It traversed the NW Himalaya, from the Indian plain, across the Indus-Tsangpo Suture (ITS) and the Tso Morari Dome, to the Karakoram Fault.

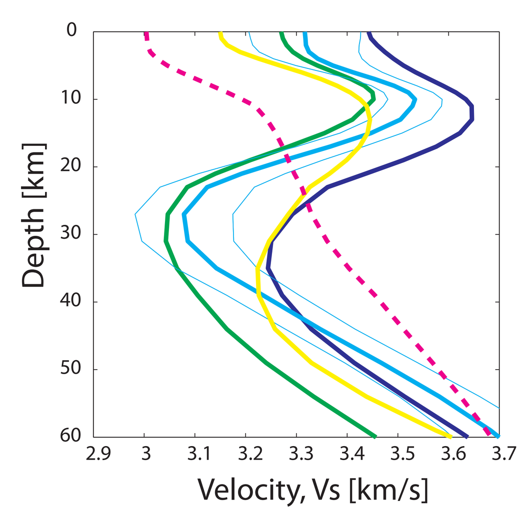


The first phase of our analysis of this data set was to invert dispersion records of surface waves to obtain 1-D models of velocity structure.

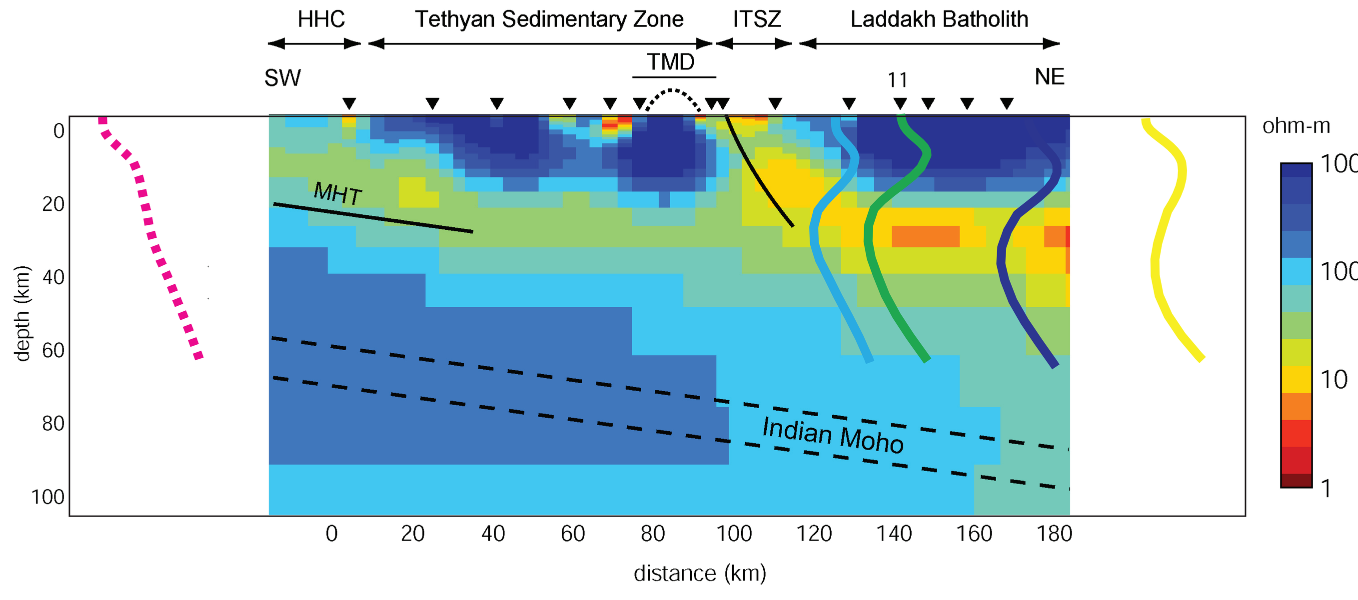
METHODS: We calculated the group velocity dispersion of fundamental mode Rayleigh waves from earthquakes less than 900 km from the array. using Robert Herrmann's Computer Programs in Seismology (CPS, Herrmann and Ammon, 2002). Most of the dispersion curves could be reliably picked in the period range 8 - 50 s, corresponding roughly to sensitivity in the 12 - 75 km range.

RESULTS: We inverted the curves for 1-D velocity structure using CPS, grouped the models based on geologic region (right), discarded outliers, and averaged the remaining models (far right). The models show a strong low-velocity layer that shallows to the south and does not extend south of the ITS.





SIGNIFICANCE: Magnetotelluric (MT) studies in the vicinity of the ITS reveal low-resistivity zones which may be indicative of fluids, partial melts, or graphite in the mid-crust (Unsworth et al., 2005; Arora et al., 2007). If fluids or partial melts are the cause, this would serve as evidence of crustal channel flow model beneath the Tibetan Plateau. Below, our velocity models are overlain in their approximate locations on the MT model obtained by Arora et al. (2007).

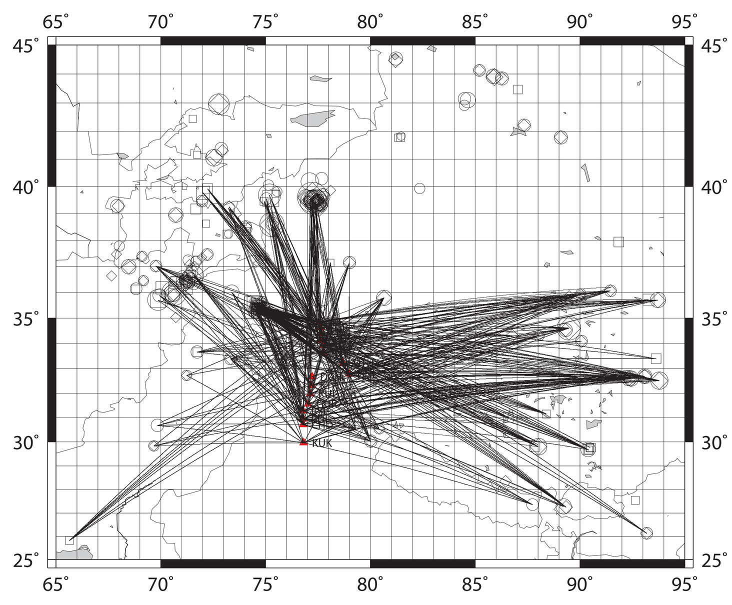


INTERPRETATION: Our observed low-velocity layer shows a good spatial correspondence with the low-resistivity layer seen in the MT data. Of the proposed explanations for low-resistivity in the mid-crust, only fluids or partial melts explain both the low-resistivity and low-velocity. These results are consistent with the postulation of Unsworth et al. (2005) that a low-viscosity channel exists in the mid-crust of Tibet, and suggests that a partially-molten channel may exist in NW India.

2. Tomographic Inversion

The second phase of our analysis (currently ongoing) is to obtain tomographic models of shear wave velocity perturbations, also using surface wave dispersion.

DATA: We have extended our catalog of dispersion curves to ~500 event-station pairs from ~120 earthquakes that are within 1500 km of the array (see right).

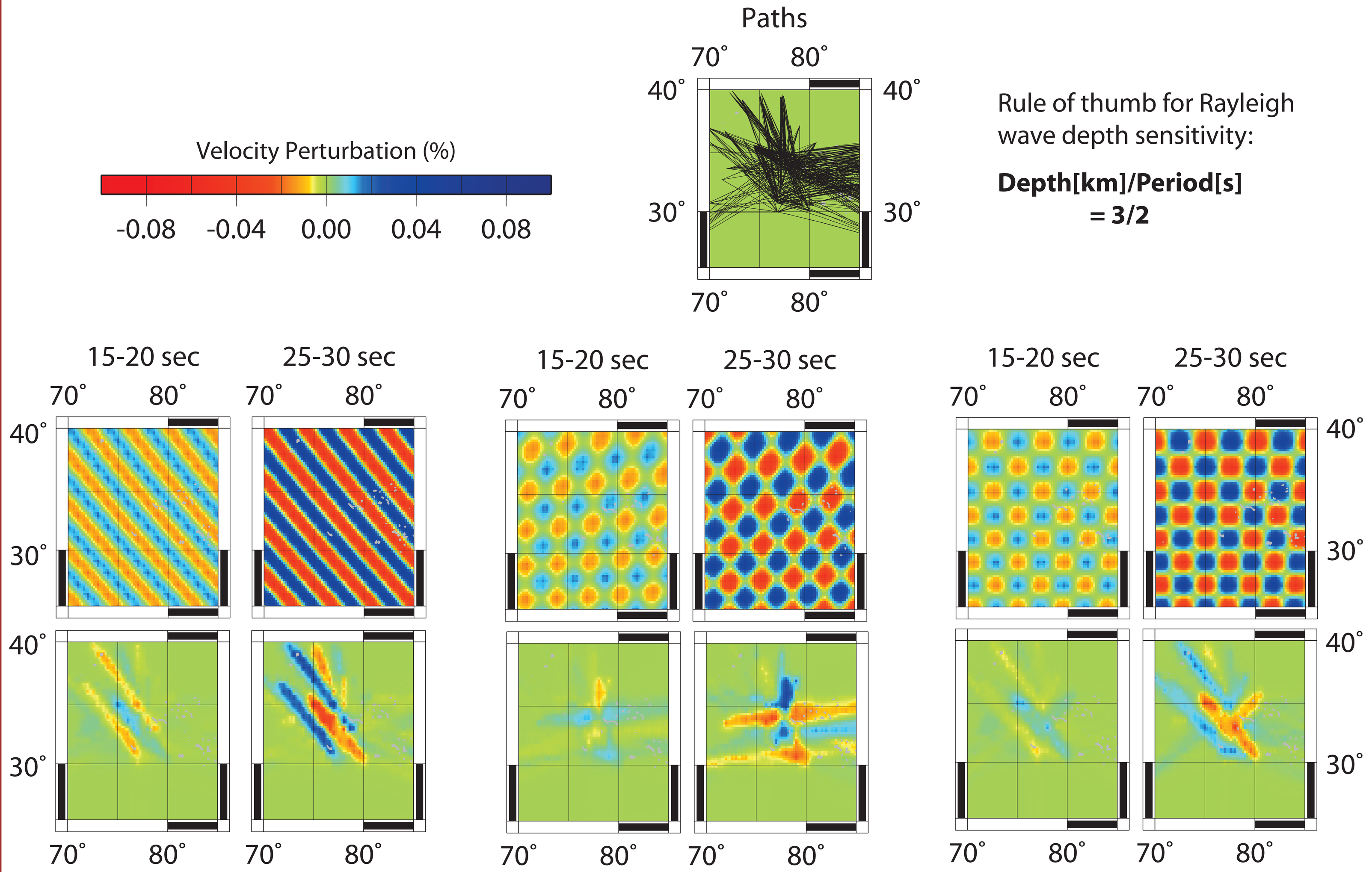


METHODS: The earth model for the inversion is a cubic region under the array whose depth axis is period (in seconds). The model parameters are the slownesses of each block. The data are the travel times for each period for each event-station pair, calculated from the dispersion records. The resulting models are regularized with three-dimensional smoothing.

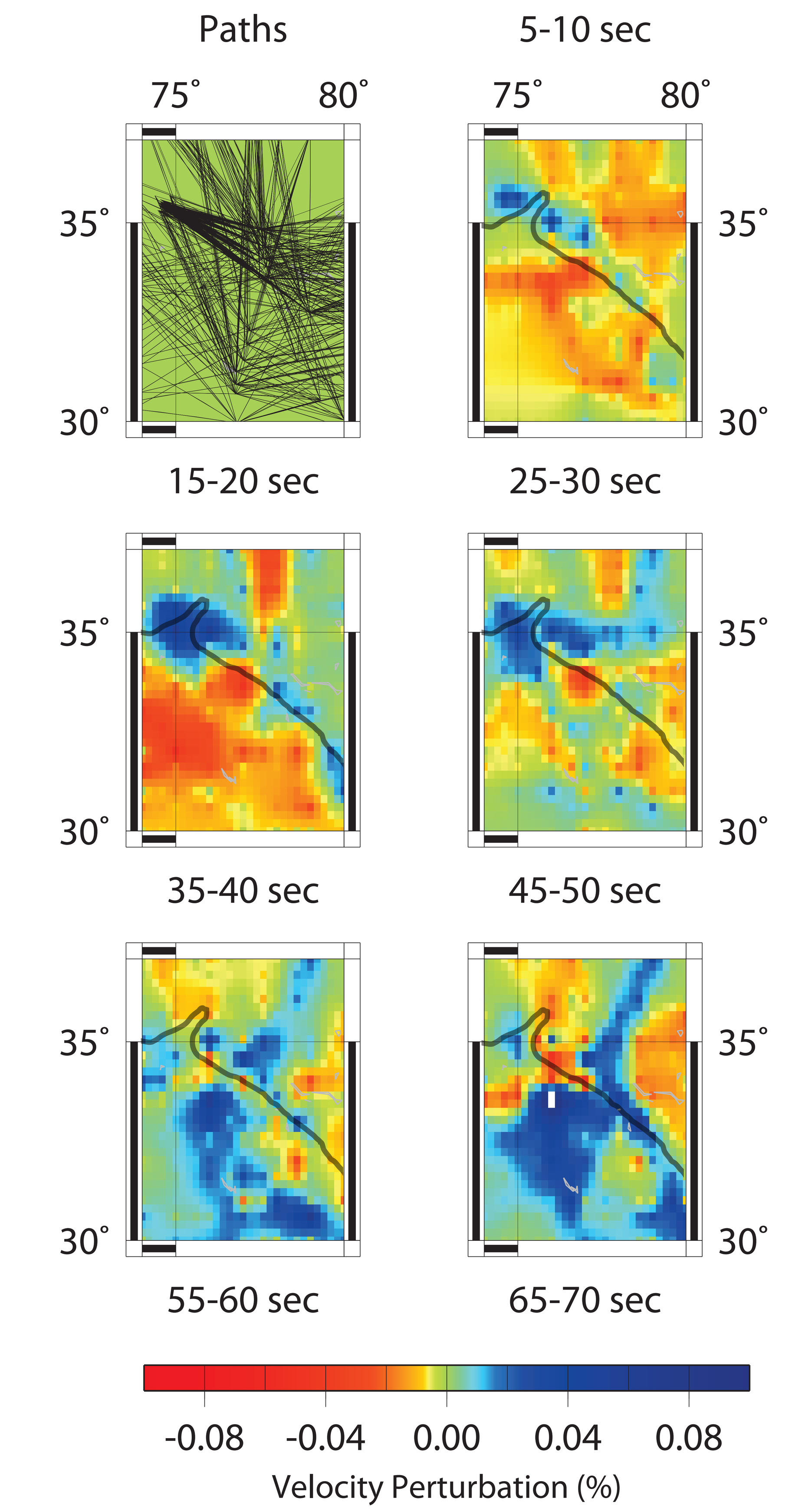
RESOLUTION: Linear arrays are not ideally suited to tomography, because the number of crossing raypaths is limited. This leads to smearing along the raypaths at the edges of the model (see below). However, the checkerboard tests are encouraging in that no false structures are identified.

The Himalaya strike approximately NW-SE in this region, and the leftmost panels below represent idealized geology that is continuous along strike. The inversion successfully recovers portions of this model. The center panels feature along-strike variability, and the inversion correctly does not show along-strike smearing. This indicates that any features which are consistent along strike are genuine.

Our tests show that we can image geologic belts ~50 km wide and identify discontinuities, though we have yet to determine the upper limits of our resolution.



The above figure shows the results of resolution tests for three different starting models: idealized along-strike structures (left), along-strike variability (center), and a standard checkerboard (right). Two period slices are shown for each test.



RESULTS: We observe broadly similar features in the 1-D and tomographic inversions:

- at shallow depths (panels 1 and 2), velocities are slower south of the ITS (marked in grey) than north.

- at greater depths (panels 4 and 5), velocities are faster south of the ITS than north.

The high velocity of the Ladakh Batholith at ~10 km depth seen in the 1-D inversion can be seen here in panels 1 and 2.

These results are preliminary, but encouraging.

3. Future Work

We will soon have access to data from an adjacent array that will create many additional crossing raypaths and will therefore likely improve resolution. Incorporating interstation phase velocity will also improve resolution in the vicinity of the array.

References

Arora, B.R., Unsworth, M.J. & Rawat, G. Deep resistivity structure of the northwest Indian Himalaya and its tectonic implications. Geophysical Research Letters 34, L04307 (2007).

Herrmann, R.B. & Ammon, C.J. Computer Programs in Seismology: Surface Waves, Receiver Functions and Crustal Structure. St. Louis University, St. Louis, MO (2002).

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