T31B-0464

# Testing the Presence of Fluids/Crustal Melts in the India-Asia Collision Zone Using Rayleigh Wave Dispersion Analysis

Warren B. Caldwell[1], Simon L. Klemperer[1], Shyam S. Rai[2], Jesse F. Lawrence[1]

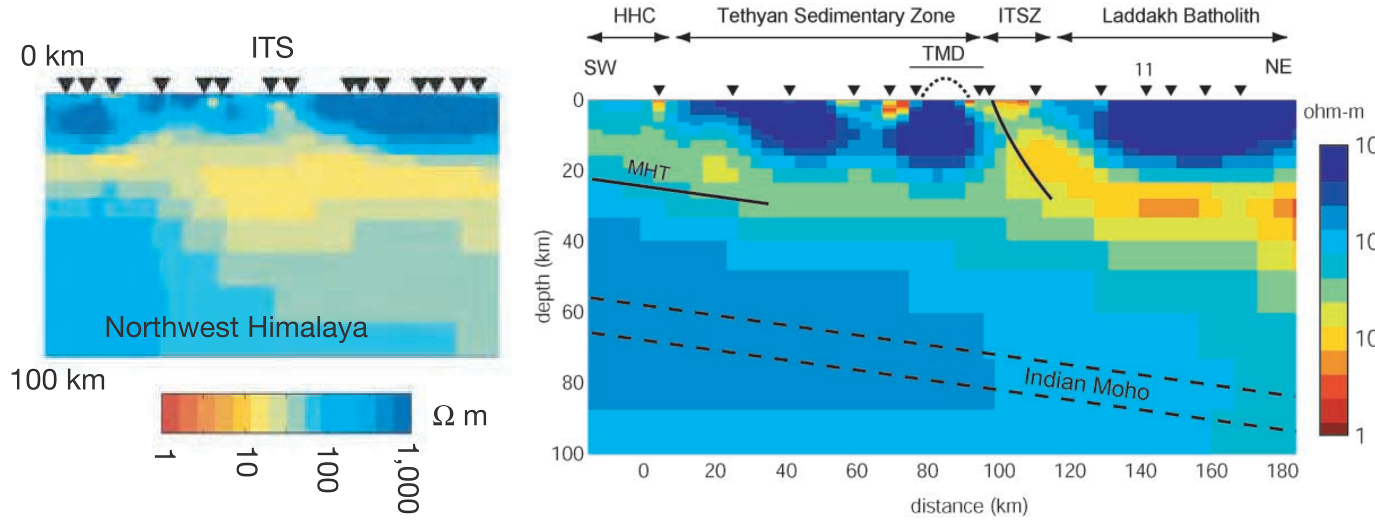
[1] Stanford University, Stanford, California [2] National Geophysical Research Laboratory, Hyderabad, India

## 1. Geologic setting and previous work

- The study area traverses the NW Himalaya, from the Indian plain, across the Indus-Tsangpo Suture (ITS) and the Tso Morari Dome, to the Karakoram Fault.

- The ITS is a fundamental discontinuity between rocks of Indian and Asian affinity. South of the ITS lies the Tethyan Himalaya, a fold and thrust belt of metasedimentary rocks which originated from deposits on the pre-collision continental margin of India. North of the ITS lies the Gangdese Batholith, the magmatic arc which formed above the subducting Neo-Tethys Ocean.

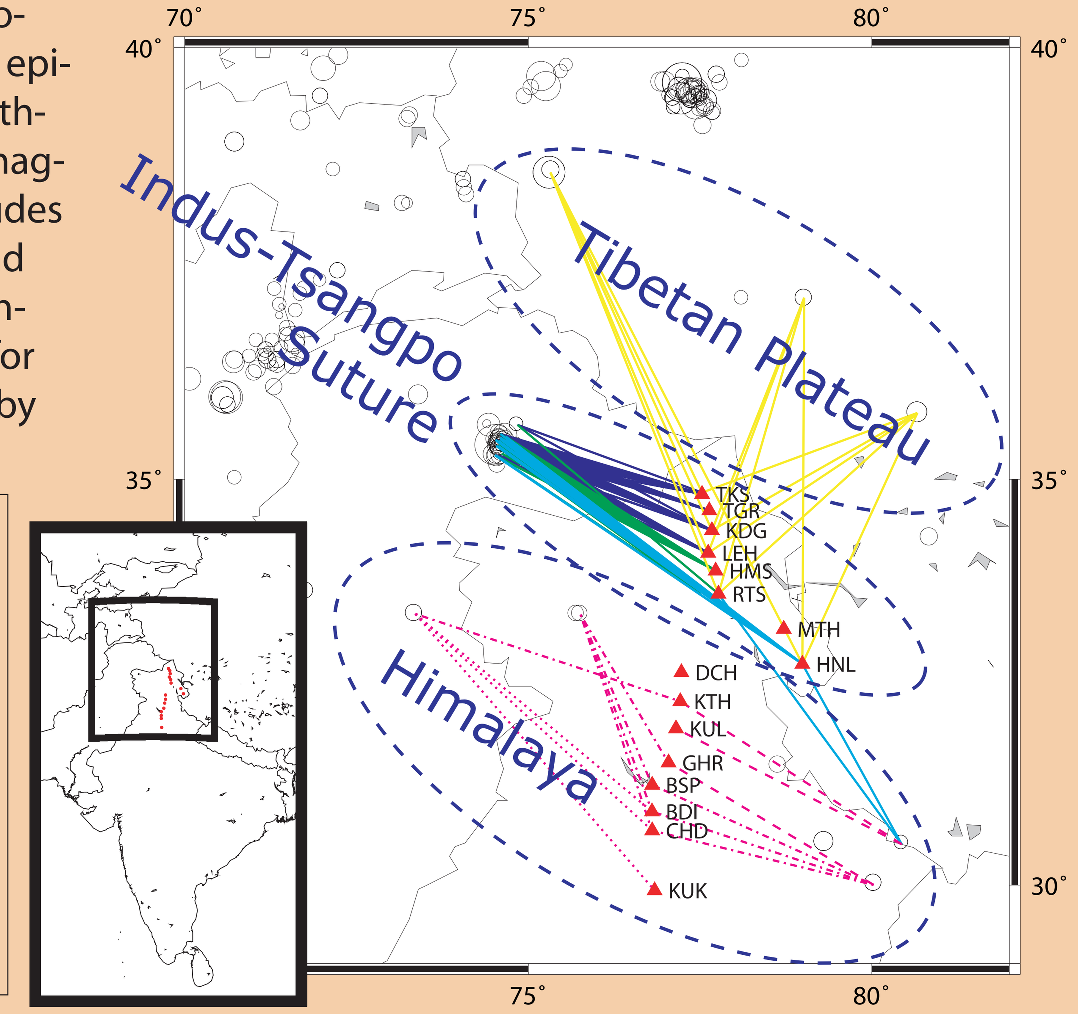
- Magnetotelluric (MT) studies in the vicinity of the ITS reveal low-resistivity zones which may be indicative of fluids, graphite, or partial melts in the mid-crust (Unsworth et al., 2005; Arora et al., 2007). This has been suggested as evidence for the crustal channel flow model of the deformation of the Tibetan Plateau.




Figures from Unsworth et al., 2005 and Arora et al., 2007

Locations of seismograph stations and epicenters of local earthquakes scaled by magnitude (all magnitudes are between 3.8 and 6.4). Lines are earthquake paths used for this study, colored by geologic region.

We designate 3 principal regions: 'Tibetan Plateau,' 'Indus-Tsangpo Suture' (ITS), and 'Himalaya.' We subdivide ITS into 'North,' 'West' and 'East,' and subdivide Himalaya into 'Higher' and 'Lesser' Himalaya and 'Foreland Basin.'




## 2. Data and methods

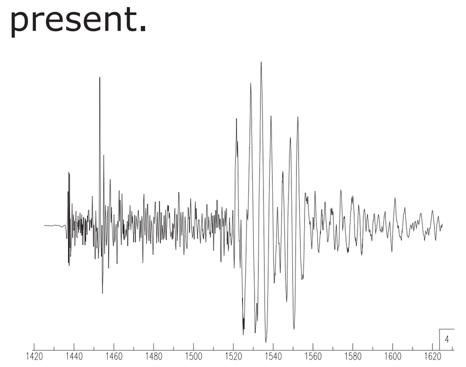
- A network of 15 broadband seismographs in an approximately 500 km long, N-S array recorded 12 months of data in 2002-2003 (Rai, et al., 2006).

- We calculated the group velocity dispersion of surface waves along the ray paths of nearby (<900 km distant) earthquakes, which ranged in magnitude from 4.0 to 6.4.

- We found the dispersion curves by analyzing the Z-component of fundamental mode Rayleigh waves using Robert Herrmann's Computer Programs in Seismology (CPS) (Herrmann and Ammon, 2002). Most of the dispersion curves were picked in the period range 4 - 50 s, though some extended to 1 s and to 100 s.

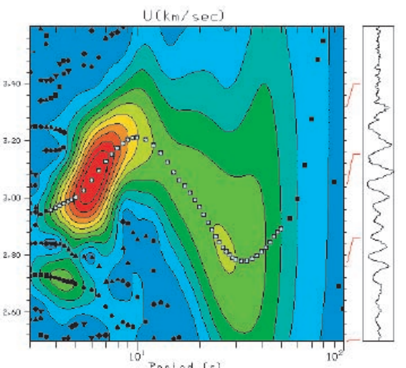
- We inverted the dispersion curves using CPS to create 1-D models of crustal shear wave velocity structure. The inversion goes to 150 km depth, but we consider only the upper 60 km of the models.

- The models should contain low-velocity zones if partial melts or fluids are present.

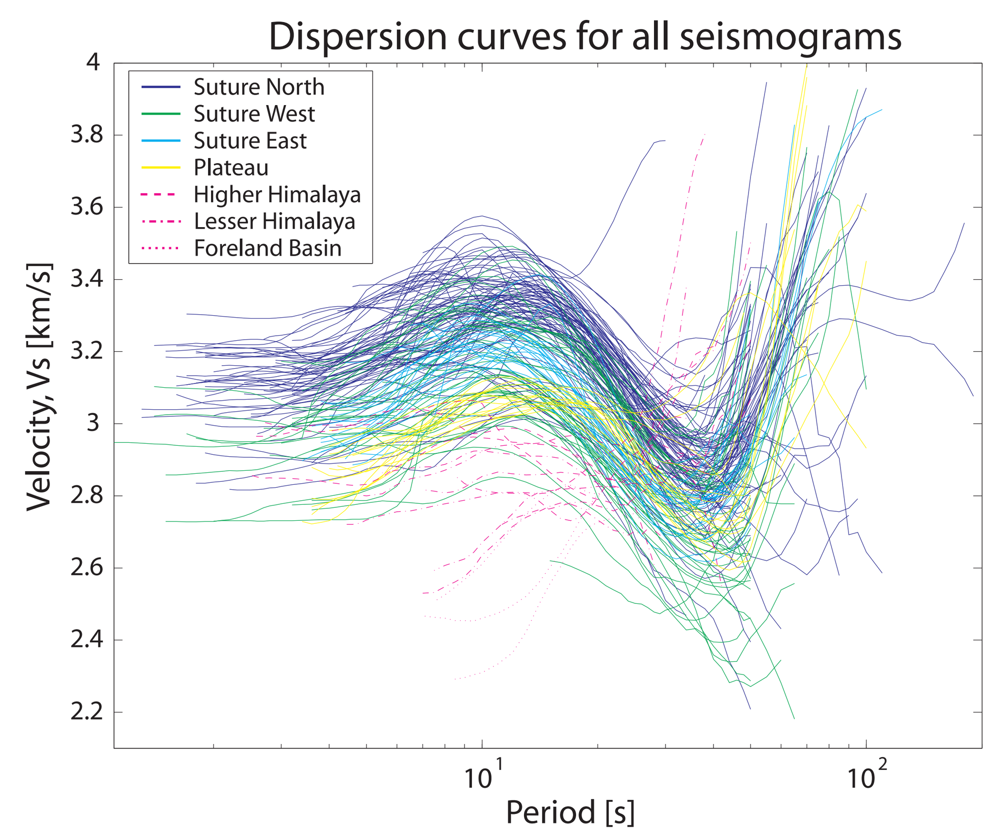


< A sample seismogram from our data set (M 5.0, 500 km distant)

> A sample dispersion curve from the CPS program

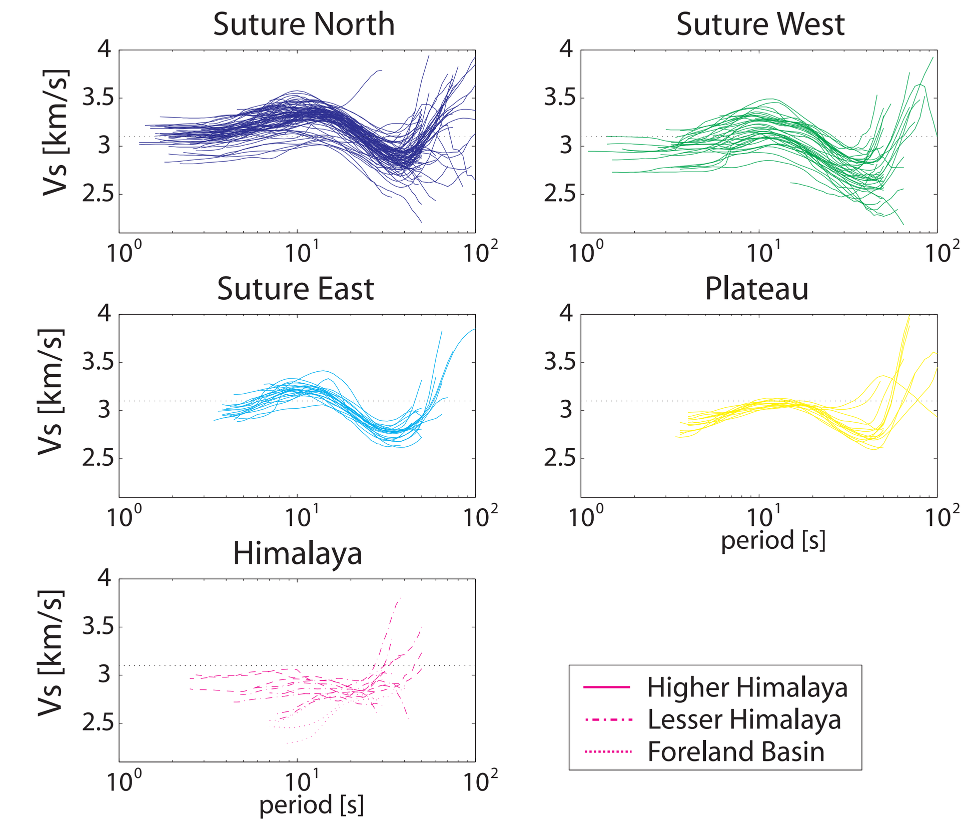


## 3. Group velocity analysis

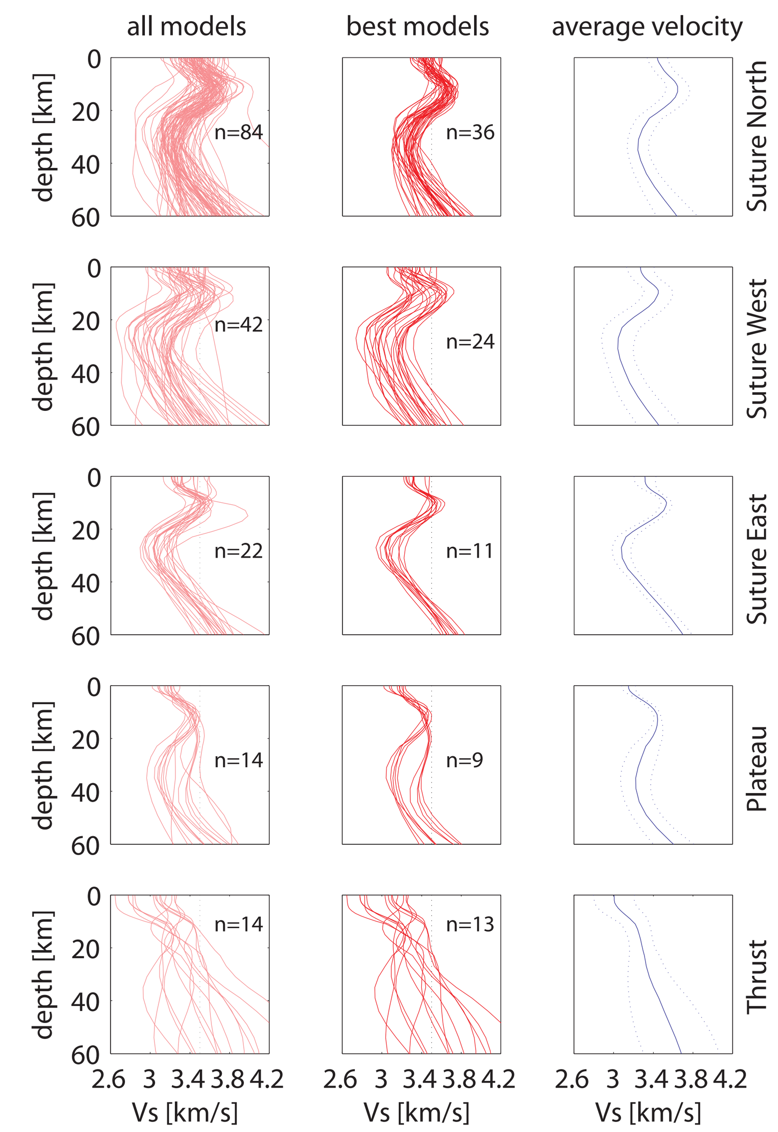



< Dispersion curves for all event-station pairs, colored by geologic region, as shown in the map at left. All curves from the ITS and Tibetan Plateau show a characteristic decrease in velocity in the 30 - 50 s range.

> Dispersion curves sorted by region. The highest velocities occur north of the ITS, in the Gangdese Batholith. 'Himalaya' paths are any paths south of the ITS, and are further broken down, from north to south, into 'Higher Himalaya,' 'Lesser Himalaya' and 'Foreland Basin.' The range of geology and Moho depths in this region accounts for the range of velocities observed in this set of curves: the further south (through the Himalaya and into the foreland basin), the lower the velocity.



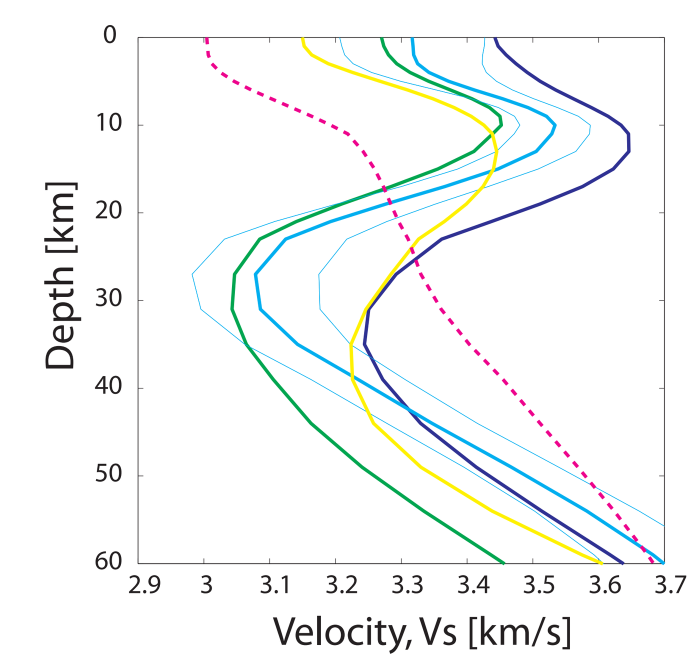

## 4. Results




- All plausible dispersion curves were inverted to generate the velocity profiles shown in the left column.

- Within each family of curves, any models which deviated from the mean by more than two standard deviations were discarded. This process was repeated a second time, and the remaining curves are shown in the center column.

- The mean of the remaining models are shown in the third column, with one standard deviation.

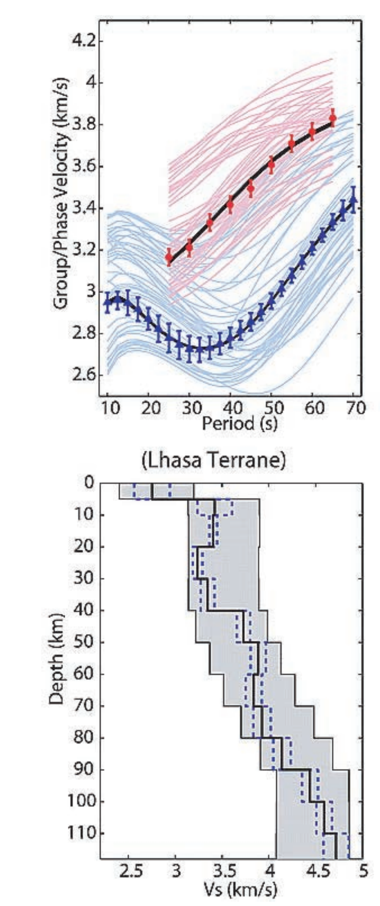



Mean of the models in each group, with 1 standard deviation shown for the 'Suture East' profile (light blue). Color scheme follows the map.

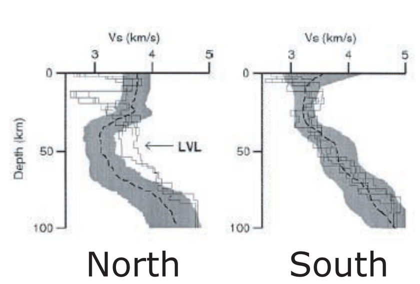
Note that the ITS profiles have a pronounced low-velocity zone at ~28 km.

The velocity models south of the ITS show no low-velocity zone (LVZ). **The models from the Tibetan Plateau show an LVZ at ~35 km depth, and those located on or near the ITS show a shallower (~28 km depth) and more pronounced LVZ.**
It is tempting to speculate that this southward shallowing of the LVZ is a manifestation of crustal channel flow (Klemperer, 2006); however, at this stage the observed trends are on the order of the uncertainty in the models.

### Comparison with published results:




< Dispersion curves from the Lhasa Terrane in Southern Tibet found by Rapine et al. (2003) show a similar decrease in velocity in the 30 - 40 s range, as well as a similar range of velocities, as our results. (Blue curves are group velocity.)




- Velocity models from Rapine et al. (2003) (above left) for the Lhasa Terrane are similar to our 'Plateau' models (yellow), also for the Lhasa Terrane.

- Cotte et al. (1999) found models (above right) south and north of the ITS. As in our models, there is no LVZ south of the ITS, but there is one to the north, although it is ~15 km deeper than our LVZ.

It should be noted that the stations of Rapine et al. and Cotte et al. were ~1300 km east of the stations in this study.

## 5. Future Work

- Complete a similar study using phase velocity (inter-station method).

- Carry out regional group and phase velocity tomography, incorporating more earthquakes (and hence more backazimuths)

- Use our velocity model for teleseismic migration of existing receiver functions.

## References

1. 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).
2. Cotte, N. et al. Determination of the crustal structure in southern Tibet by dispersion and amplitude analysis of Rayleigh waves. Geophysical Journal International 138, 809-819 (1999).
3. Herrmann, R.B. & Ammon, C.J. Computer Programs in Seismology: Surface Waves, Receiver Functions and Crustal Structure. St. Louis University, St. Louis, MO (2002).
4. Klemperer, S.L. Crustal flow in Tibet: A review of geophysical evidence for the physical state of Tibetan lithosphere. Channel flow, ductile extrusion and exhumation of lower mid-crust in continental collision zones Special Publication, Geological Society of London, London 632, (2006).
5. Rai, S.S. et al. Configuration of the Indian Moho beneath the NW Himalaya and Ladakh. Geophysical Research Letters 33, L15308 (2006).
6. Rapine, R. et al. Crustal structure of northern and southern Tibet from surface wave dispersion analysis. Journal of Geophysical Research 108, 2120 (2003).
7. Unsworth, M.J. et al. Crustal rheology of the Himalaya and Southern Tibet inferred from magnetotelluric data. Nature 438, 78-81 (2005).

## Acknowledgements

Seismic data were acquired and generously provided by NGRI, Hyderabad, India and University of Cambridge, England.