Crustal Velocity Structure from Surface Wave Dispersion Tomography in the Indian Himalaya

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Partial Melt in the Mid-Crust of the Northwest Indian Himalaya Revealed by Rayleigh Wave Dispersion

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In review in *Tectonophysics*

Data Source

Thank you to Dr. S.S. Rai and the Seismic Tomography Group at NGRI (and Cambridge University) for collecting and sharing these data.

- 16 station, 3C, broadband seismic array:
  - Mix of Guralp 3T and Guralp 3ESP sensors
  - Active in 2002-2003
  - ~500 km array length
  - 35 km average station spacing

Outline

- Geologic setting & motivation
- Background on surface wave dispersion
- Study area and data
- Methods
- Results
- Conclusions

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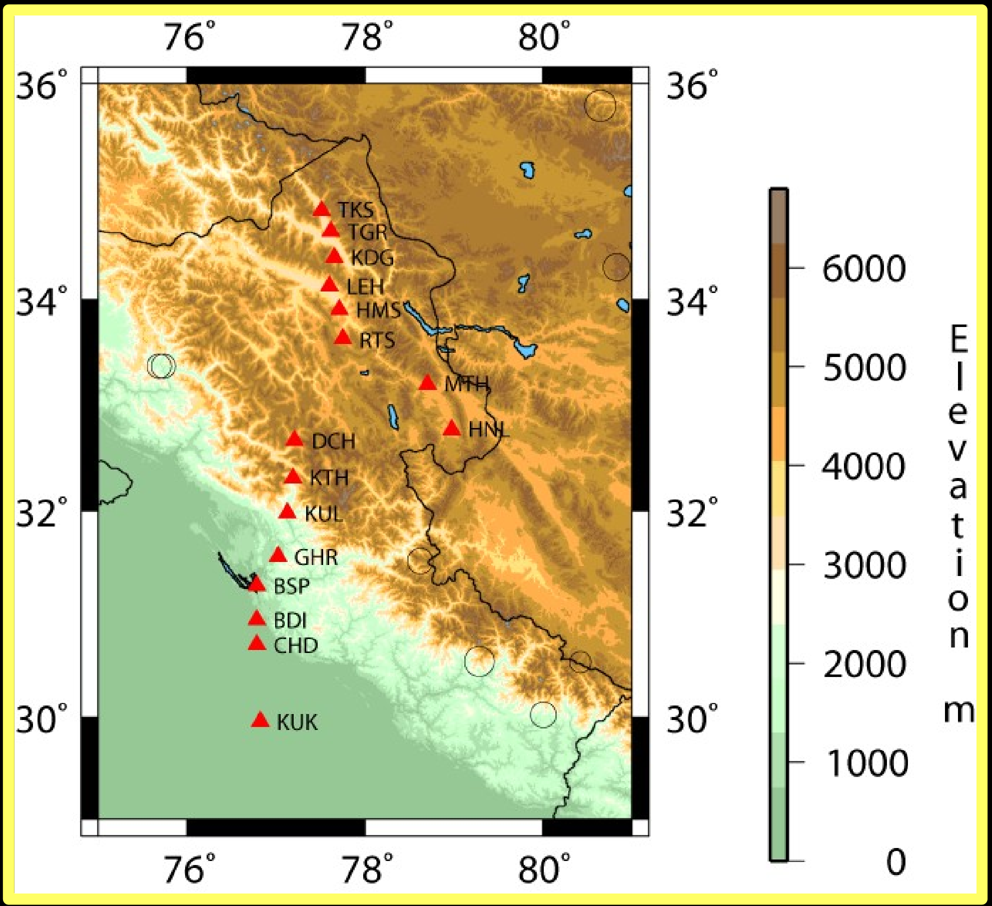
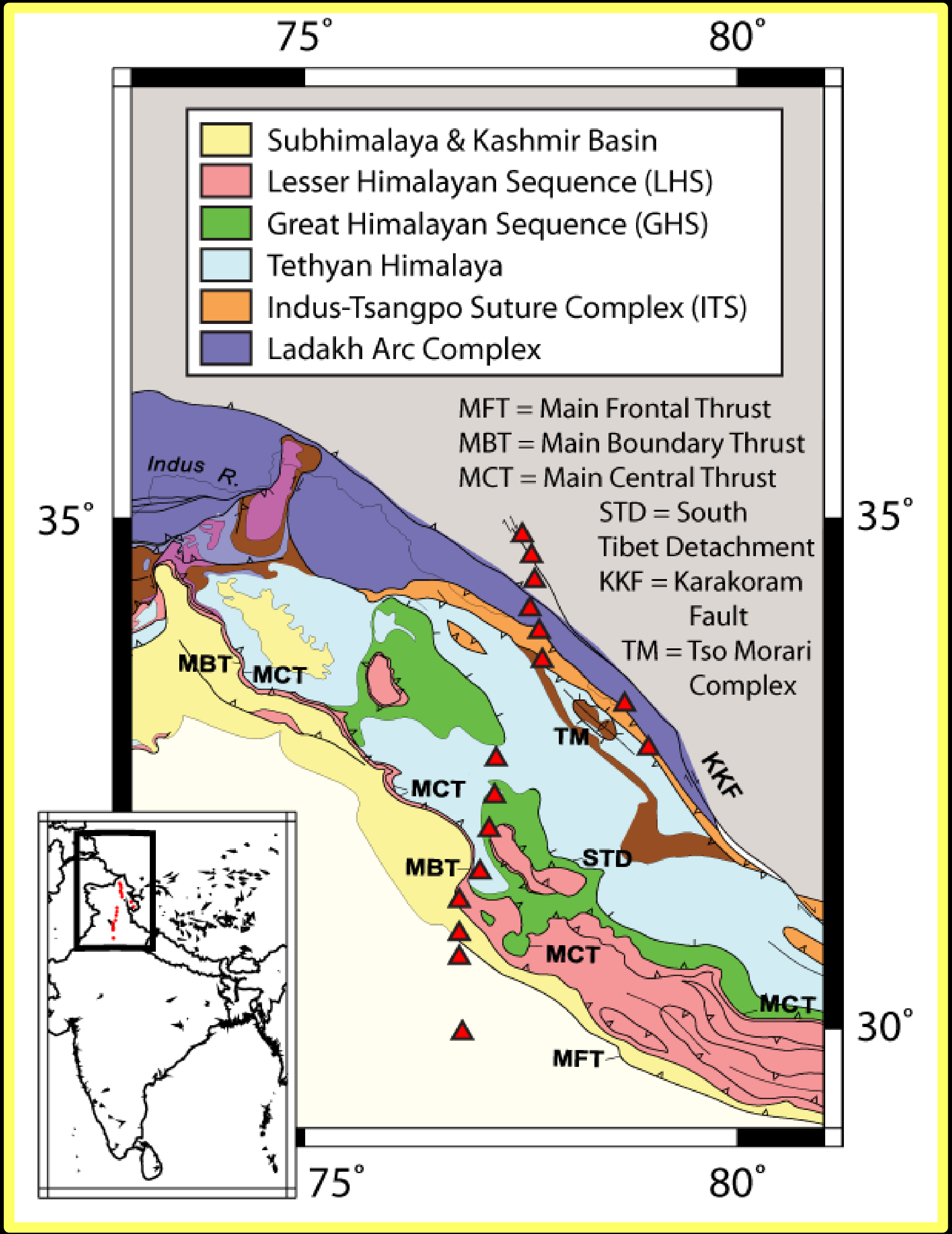
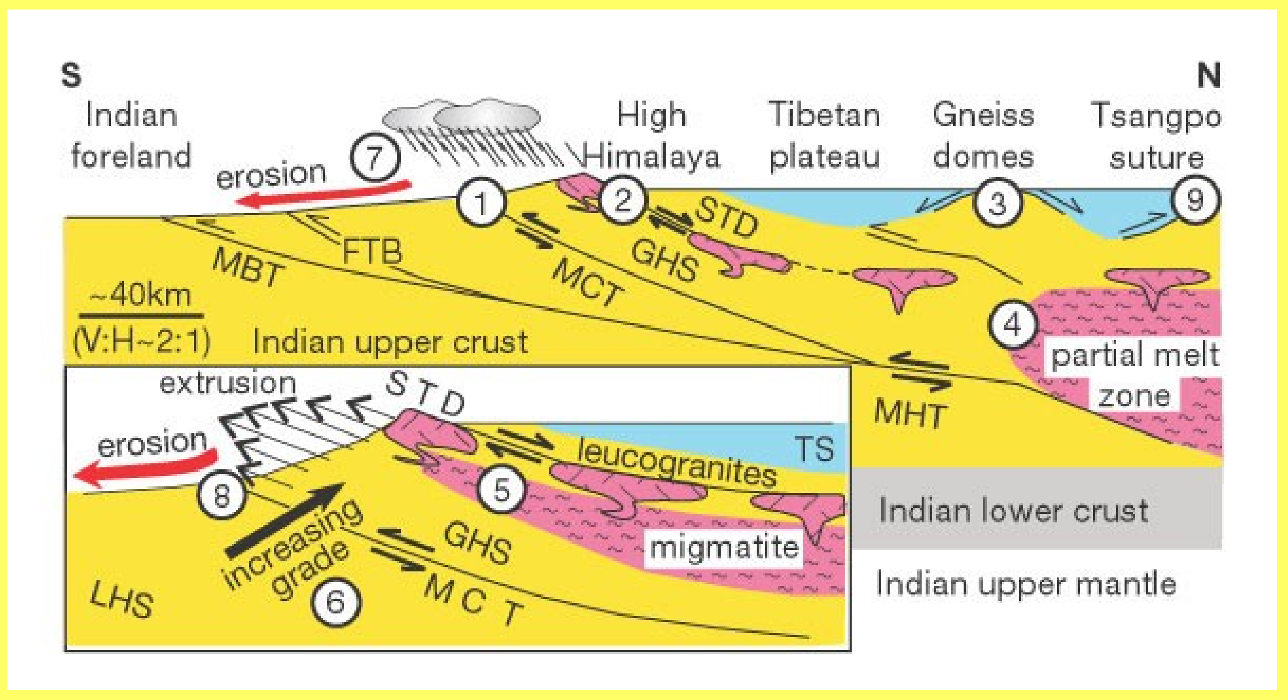
Geologic Setting

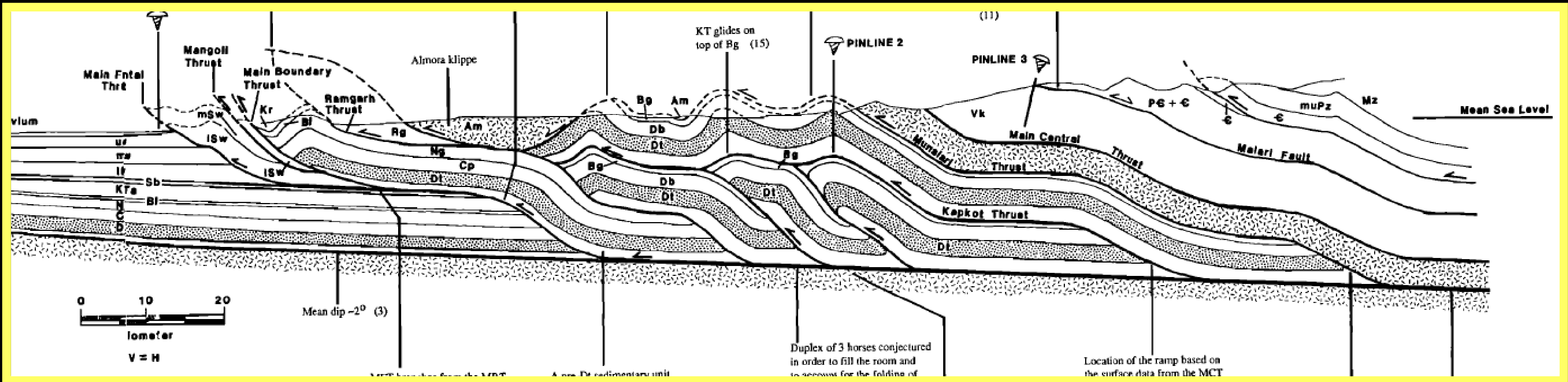




Motivation: Competing models of deformation



- Channel flow (e.g. Beaumont *et al.*, 2001)
- Brittle thrust faulting (e.g. Srivastava and Mitra, 1994)



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Background: Surface wave dispersion

- Dispersion is the variation of velocity with period:
  - Longer period waves displace the deeper earth, which has a higher seismic velocity, and therefore travel faster.
- Sensitive primarily to shear wave velocity.
- Types of surface waves:
  - Rayleigh waves / Love waves
  - Fundamental mode / higher modes
  - Group velocity / phase velocity

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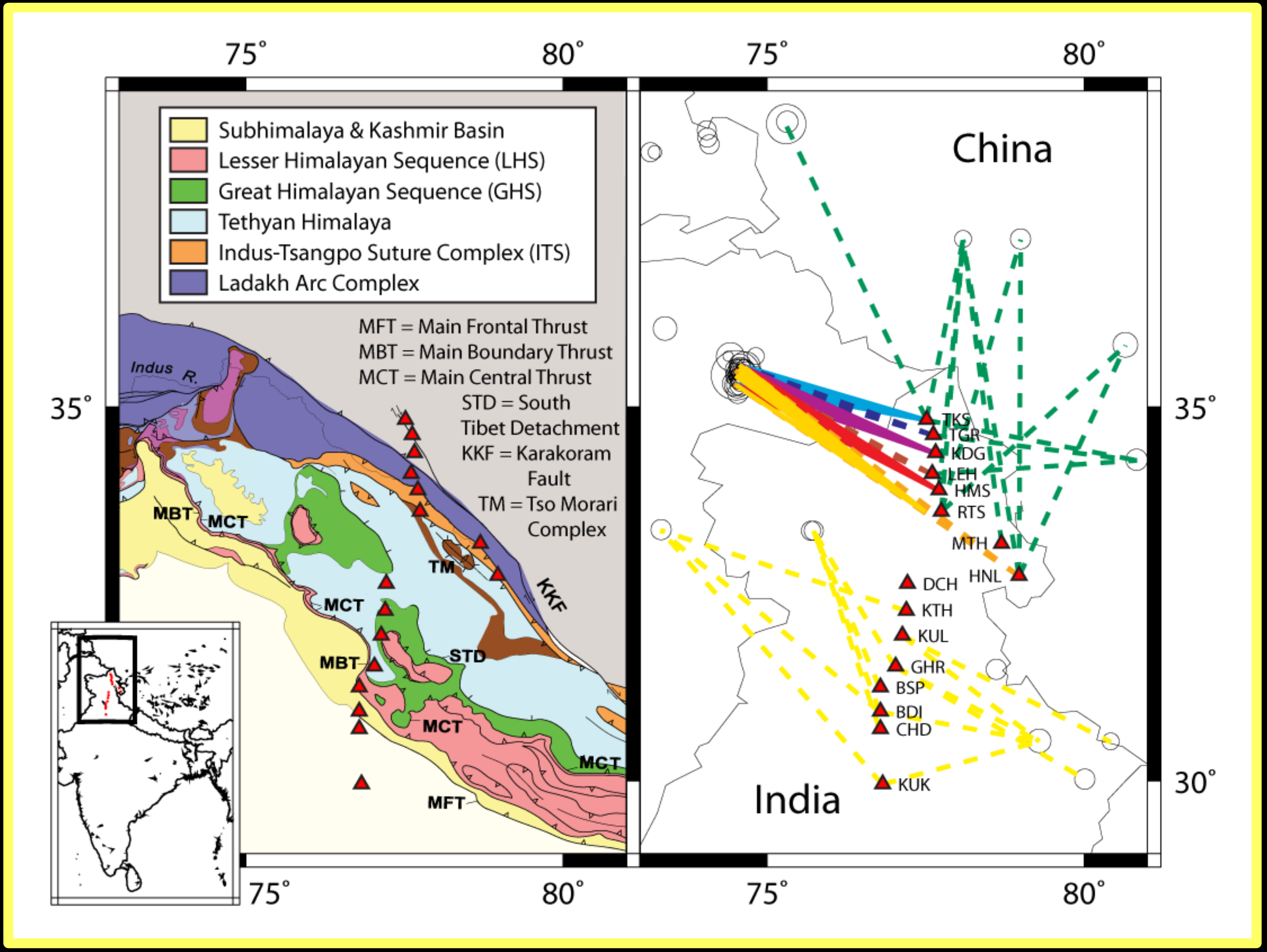
Event selection & categorization I

- 36 local events
- Source-receiver spacing < 900km
  - Minimize path averaging over longer paths
- All events magnitude 4 to 6+
- Only source-receiver paths lying mostly or fully within four geologic provinces:
  - Tibetan Plateau
  - Ladakh arc complex
  - Indus Tsangpo Suture
  - Himalayan thrust belt (GHS, LHS, Subhimalaya)

Event selection & categorization II



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Methods I: Pick dispersion curves

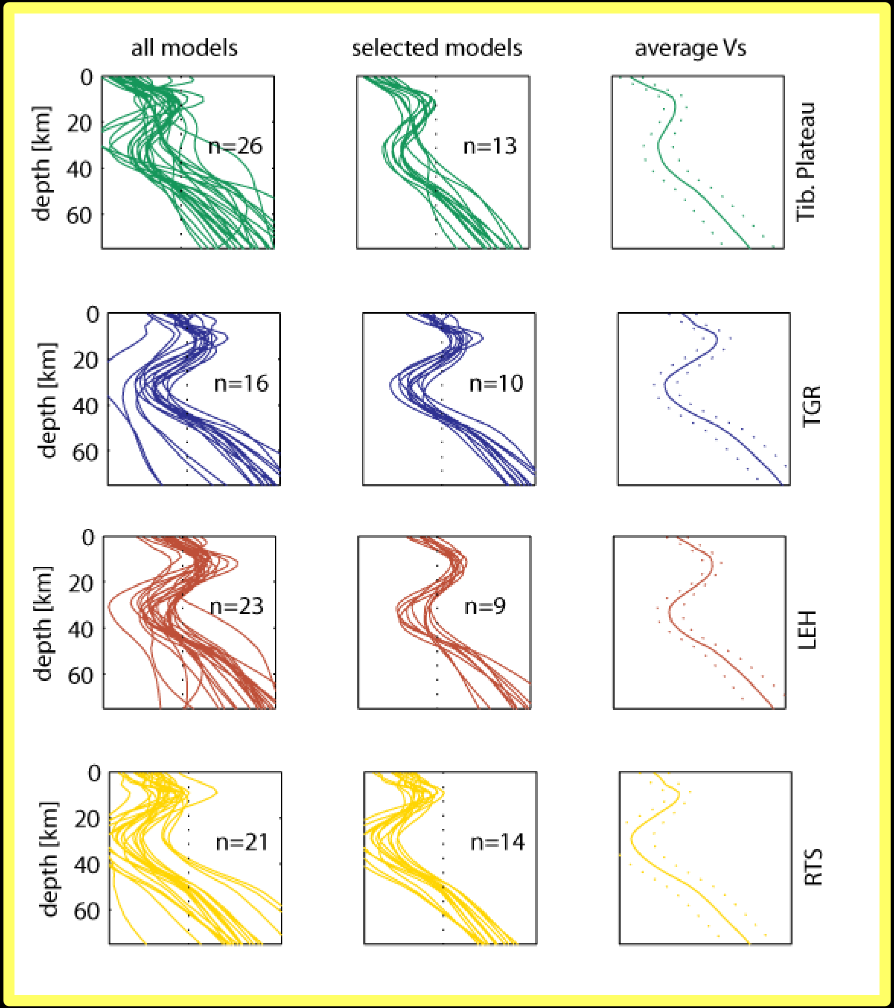
- Pick Rayleigh wave group velocity dispersion curves.
  - multiple filter technique (Dziewonski *et al*., 1969)
  - phase-matched filter (Herrin and Goforth, 1977)
  - implementation of Herrmann and Ammon (2002)
- Typical dispersion curve: 6 < T < 50 sec.
  - Corresponds roughly to sensitivity in the 9 – 75 km depth range.

Methods II: Invert to get 1-D Vs

- Invert each dispersion curve to obtain a 1-D shear wave velocity model.
- Invert to 150km depth, but only consider upper 75 km.
- Starting model based on average crustal value.

Methods III: Calculate final models

- Sort models into geologic regions.
- Discard outlying models within each region.
- The mean of the remaining models in each group represents the velocity structure for that region.



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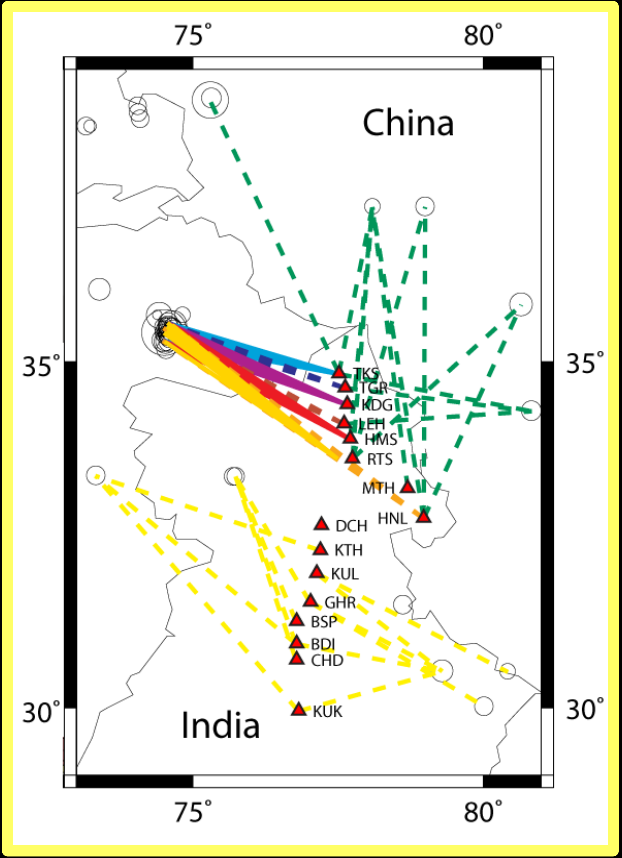
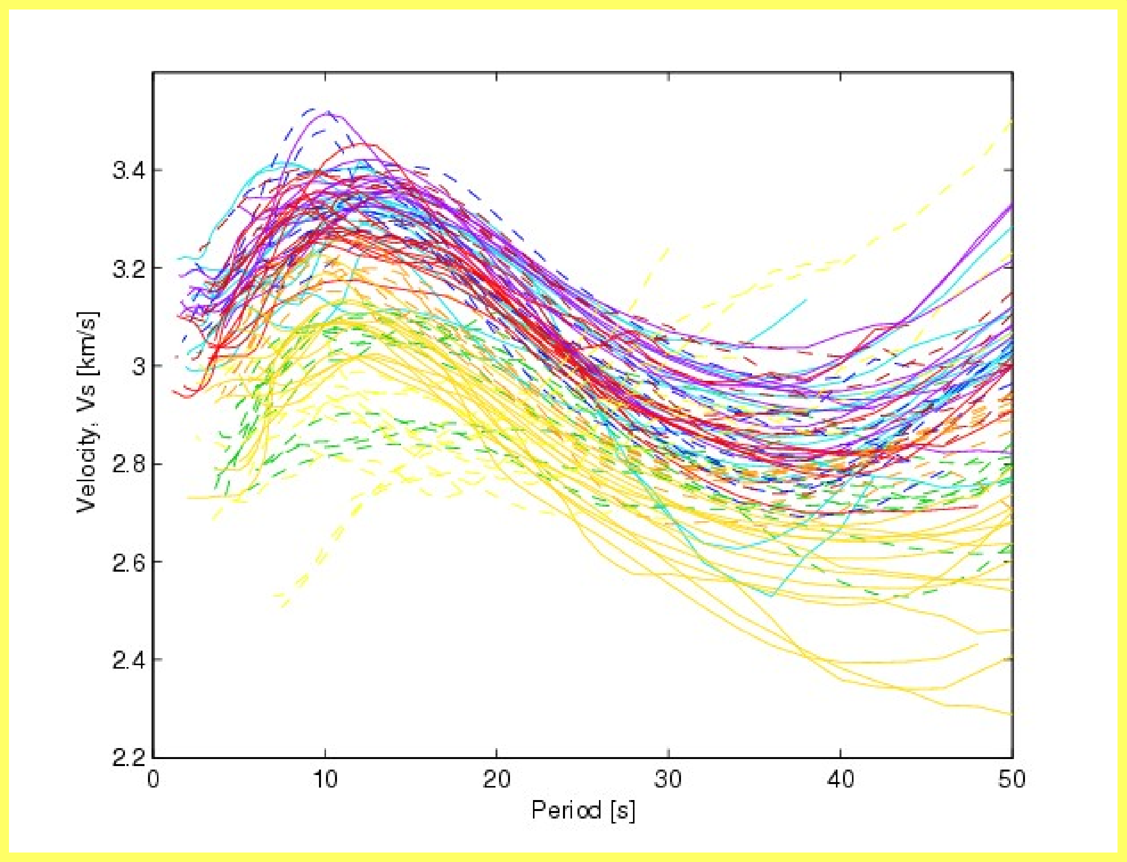
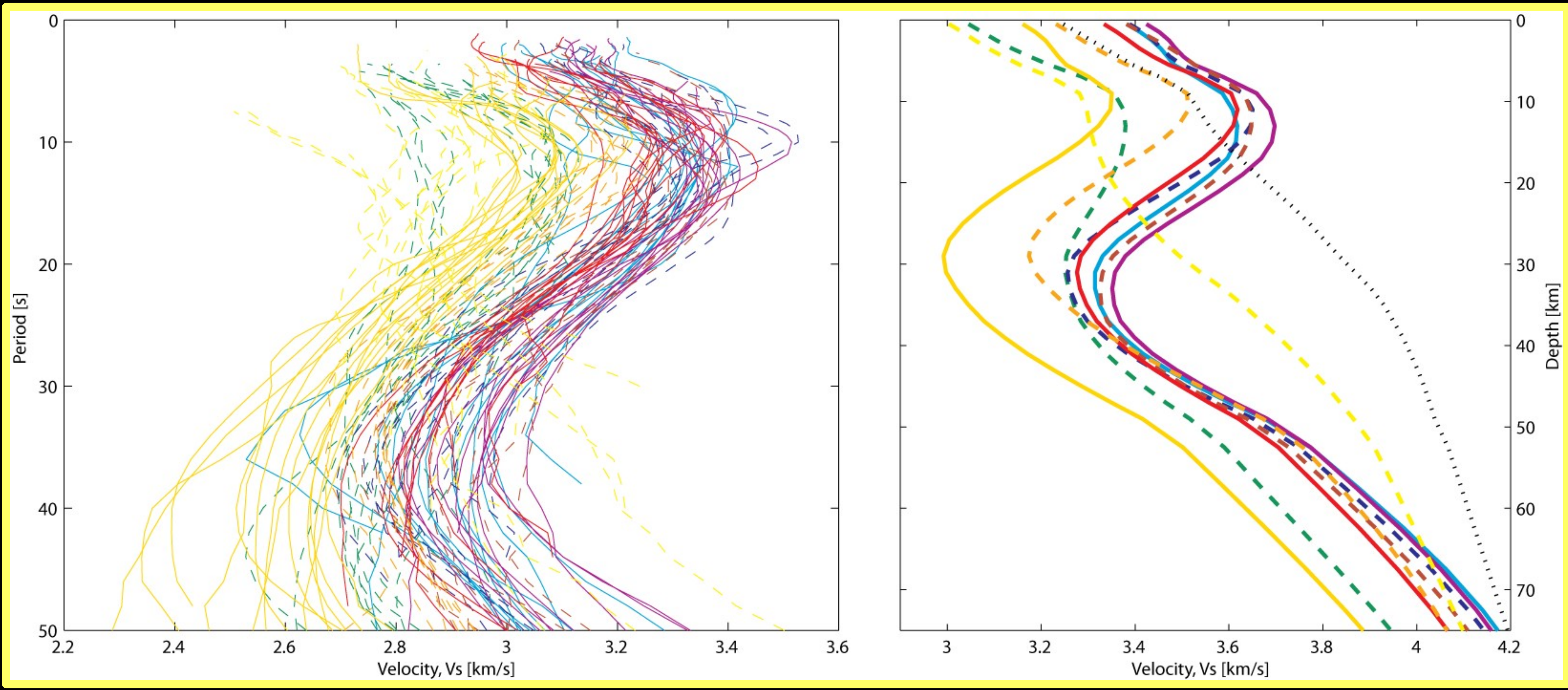
Results: Dispersion curves





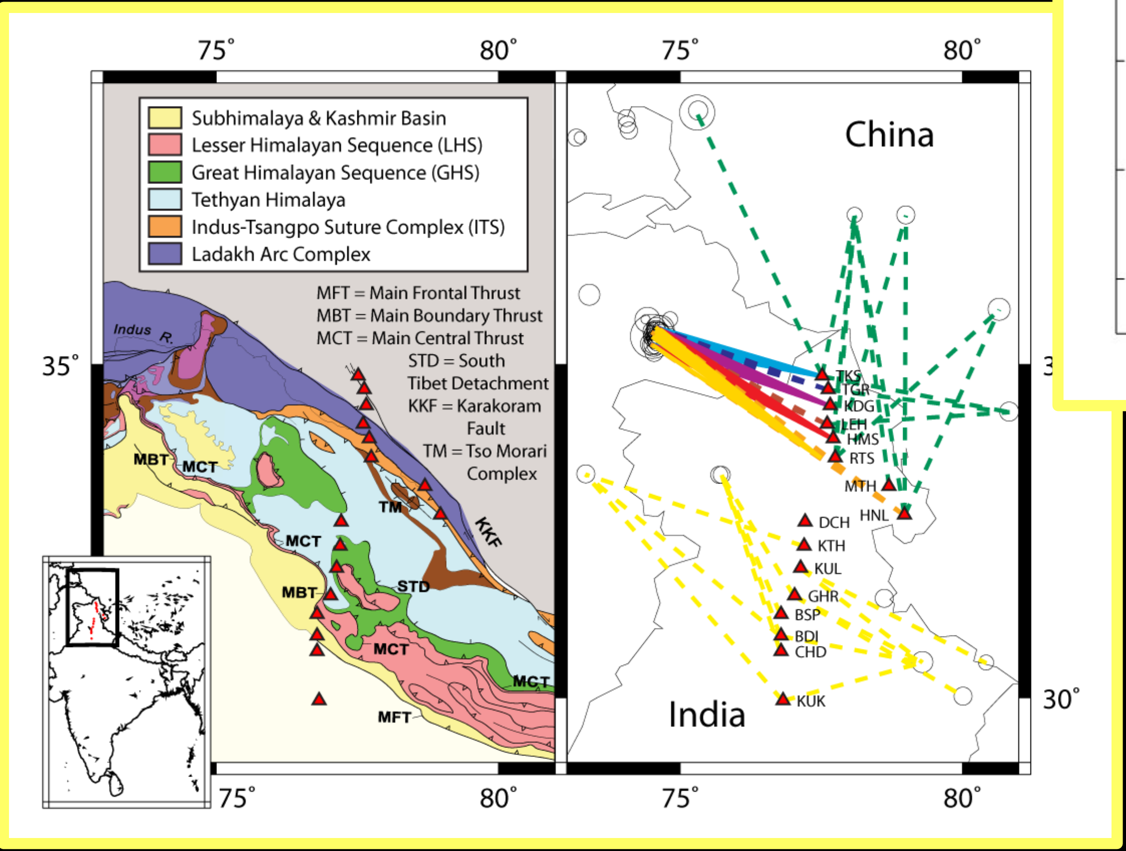
- Higher velocities in the Ladakh arc complex, lower in all other regions.

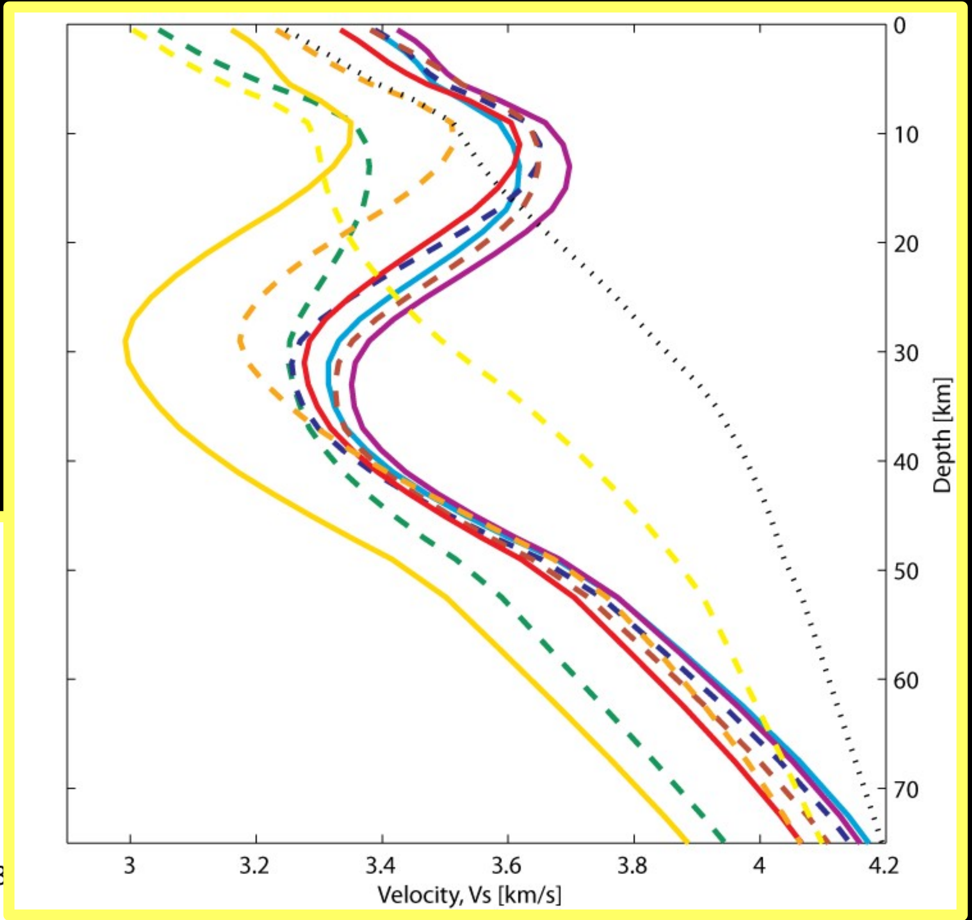
Results: Dispersion and Models



- Low-velocity layer at ~20-40 km depth.
  - Significant deviation from starting model (black).

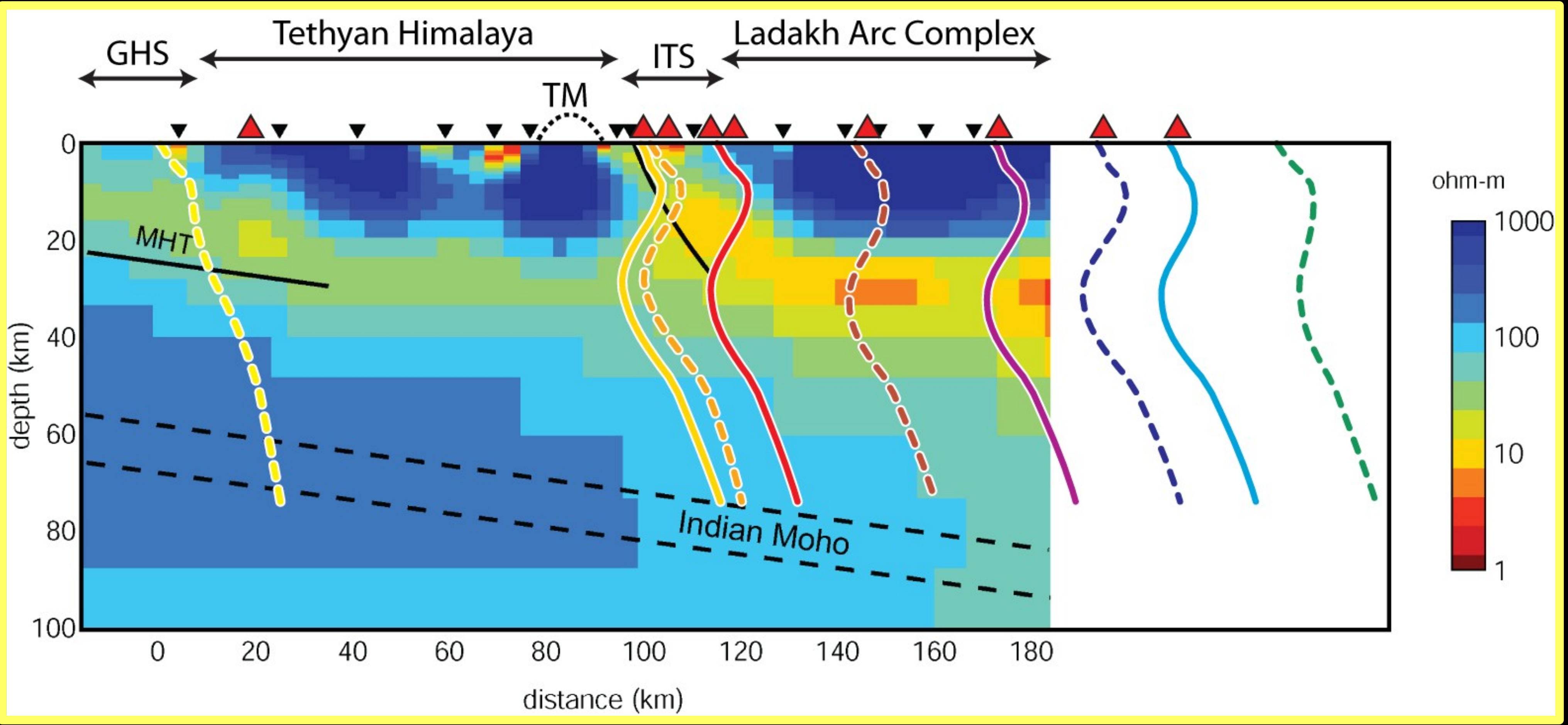
Results: Models and geologic provinces





Low-velocity layer shallows to the south and disappears somewhere south of the Indus Tsangpo Suture.

Results: Comparison to MT



- Spatial correspondence between low-velocity and low-resistivity from MT data of Arora *et al.* (2007).

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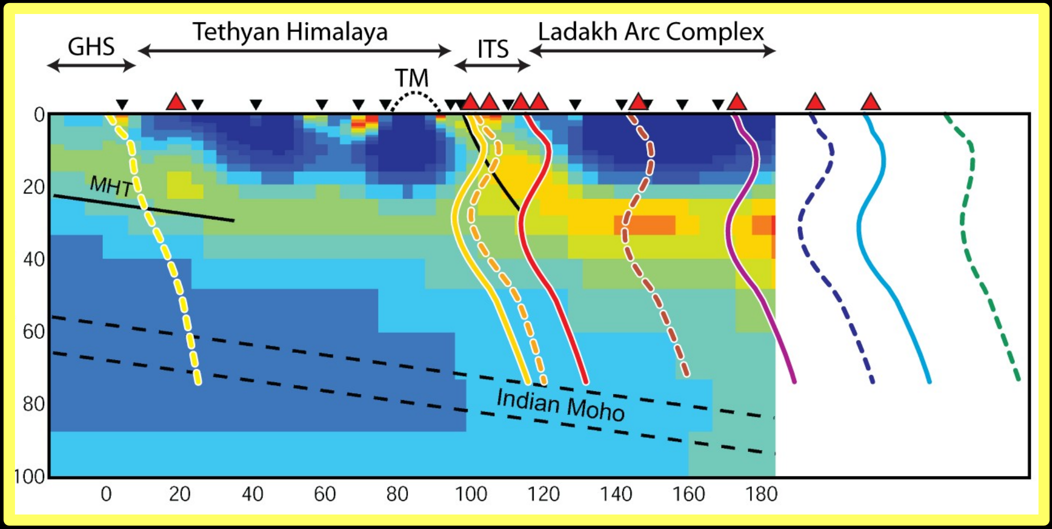
Conclusions I

- No dry, melt-free lithologies can account for the velocities we observe: Vs < 3.4 km/s at 30 km depth.
- Possible explanations for low seismic velocity:
  - Elevated temperature
  - Presence of aqueous fluids
  - Presence of melts
- These three phenomena are interlinked, and force the conclusion that partial melts are present.

Conclusions II



- Spatial correlation of low velocity and low resistivity suggest a common cause.
- Possible causes for low-resistivity:
  - Partial melts
  - Aqueous fluids
  - Graphite
- Partial melts, or partial melts and aqueous fluids, are the only explanations that satisfy both sets of observations.

Thanks again to the NGRI Seismic Tomography Group for collecting and sharing these data.