AVERAGE CRUSTAL THICKNESS AND POISSON'S RATIO BENEATH A BROADBAND SEISMOLOGICAL PROFILE ALONG THE KALI RIVER VALLEY, KUMAON HIMALAYA

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Abstract

The ongoing collision, convergence and northward underthrusting of the Indian plate beneath the Eurasian plate resulted in large lateral variations in crustal thickness and composition beneath the Himalaya.The Kumaon Himalaya lies in the central part of the Himalayan orogeny and provides unique opportunity to study typical characteristics of the underlying crustal structure of the Himalayan fold-thrust-belt system. In the present study, crustal thickness and Poisson's ratios were estimated at 13 broadband seismological stations established in a profile along the Kali river valley, Kumaon (Central) Himalaya. The seismological profile extends from the Indo-Gangetic plain (IGP) in the south to the Higher Himalaya in the north, passing through the Sub and Lesser Himalaya. The Receiver Function (RF) method has been adopted to investigate the crustal structure beneath the profile. Time domain iterative deconvolution method has been adopted for RF computation. The H-k stacking method has been adopted to analyze the RFs for obtaining average crustal thickness and Poisson's ratio (s) of the crust beneath each station. The study reveals that the crustal thickness beneath the IGP is ˜38 km which gradually increases up to ˜41 km at the northernmost station located in the Higher Himalaya. The value of s varies within the range 0.23 – 0.28. Low values of s are observed in the Sub-Himalaya and outer Lesser Himalaya suggesting more of a felsic composition of crust in the region. Significantly high value of s (˜0.28) is observed in the Dharchula region. Such high Poisson's ratio cannot be explained by the presence of solely dry crustal rocks. Presence of mid-crustal fluid/partial melts beneath the region can be the possible cause of high Poisson's ratio. The recent seismicity suggests a large number of micro-to-moderate magnitude earthquakes forming a cluster at shallow down to mid-crustal depths beneath the Dharchula region. Presence of fluids influences the rheological property and controls the mechanical and shear strength of crustal rocks producing the cluster of seismicity observed beneath the Dharchula region. Keywords: Receiver function, Crustal Thickness, Poisson's Ratio, Kumaon Himalaya.

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ABSTRACT

Crustal thickness and Poisson's ratios were estimated at 13 broadband seismic stations established along the Kali river valley, Kumaon (Central) Himalaya. The receiver function (RF) method has been adopted to study the structure and composition of the crust beneath the profile, and is computed by time domain iterative deconvolution method. The H-k stacking method has been adopted to analyze the RFs for obtaining average crustal thickness and Poisson's ratio (σ) of the crust beneath each of the stations. The study detects a minor change in the crustal thickness beneath the IGP is ~38 km up to ~41 km at the northern most station of Sobla. Also, the σ varies within the range 0.23 – 0.29. Low values of σ are recorded in the Sub-Himalaya and inner Lesser Himalaya, as compared to exceptionally high σ value in the Dharchula region (~0.29). This high σ value in the inner Lesser Himalaya, in proximity to the MCT, provides linkage to possible presence of mid-crustal fluid/partial melts beneath the region. Also, analysis of about 200 local earthquakes during 2016-17 show a large number of micro-to-moderate magnitude earthquakes forming a cluster at shallow depths beneath the region. Presence of fluids influences the rheological property, thus modulating the mechanical and shear strength of crustal rocks, producing cluster of observed seismicity beneath the Dharchula region.

STUDY AREA

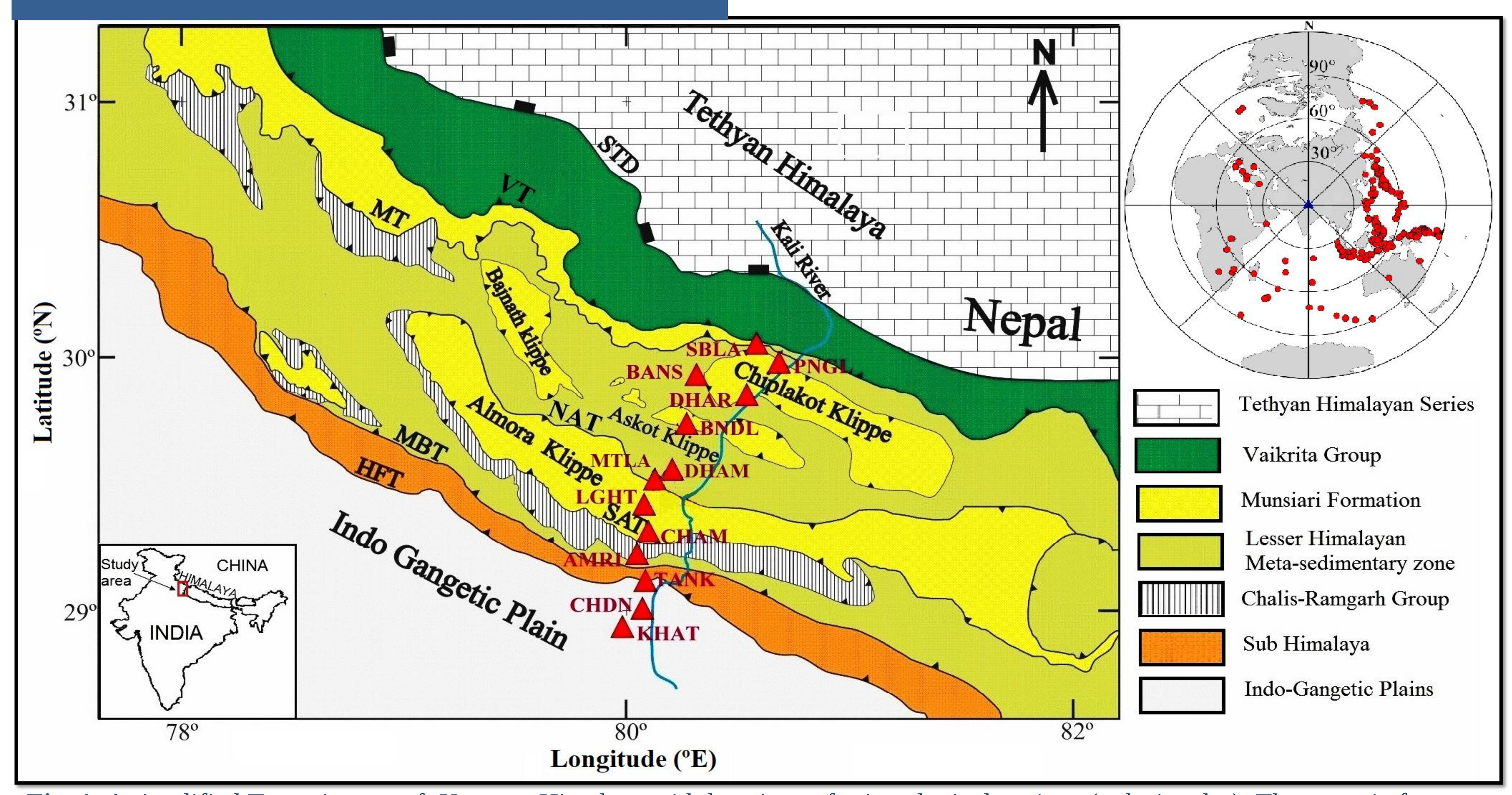

Fig. 1. A simplified Tectonic map of Kumaon Himalaya with locations of seismological stations (red triangles). The tectonic features HFT - Himalayan Frontal Thrust, MBT - Main Boundary Thrust, MT- Munsiari Thrust/MCT-I, VT-Vaikrita Thrust/MCT-II, STD–South Tibetan Detachment, SAT-South Almora Thrust, NAT-North Almora Thrust, and IGP - Indo Gangetic plain are shown. The inset shows the azimuthal distributions of teleseismic earthquakes (red dot) used in this study with the profile in centre (blue triangle).

METHODOLOGY

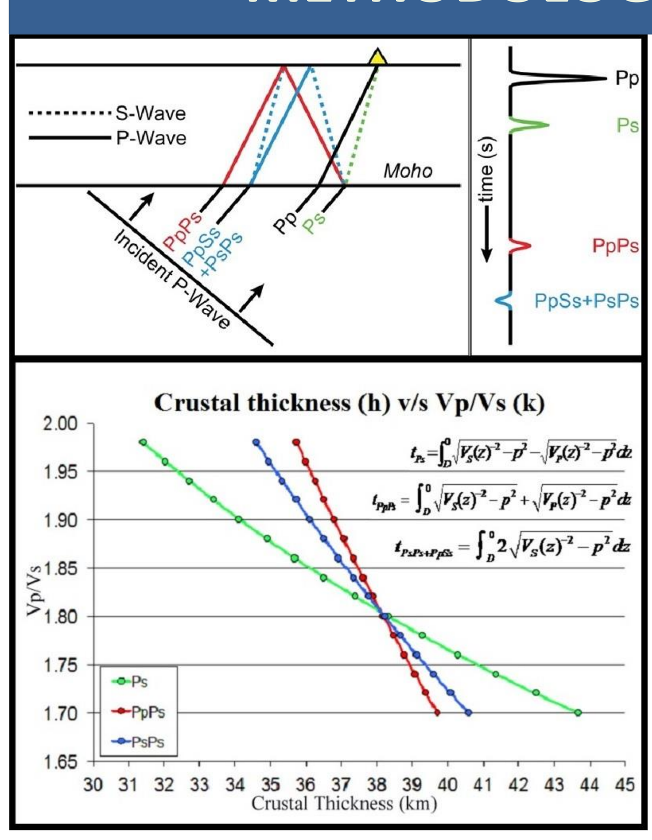

Fig. 2. (Up) The arrival time of different phases (marked in colors) as recorded by seismograph (yellow triangle) and in their order of appearance in RF plot (right). (Down) Stack of the phases converge to a point which gives the value of H and k.

P-wave RF method (Langston, 1979; Vinnik 1977) has been used to analyze about 246 teleseismic earthquakes (M ≥5.5, Δ=30°-90°) recorded during May 2016-June 2017 by 13 broadband seismological stations along Kali river valley.

The h-k stacking method (Zhu & Kanamori, 2000) uses the arrival times and amplitudes of the above phases to determine Moho depth (H) and Vp/Vs ratio (*k*).

In the travel-time equation in the figure alongside, t_x is the travel-time of the phase x, Vp and Vs are the crustal P and S-wave velocities, p the ray parameter and z the crustal depth.

The significance of the different phases in calculation are represented by their weighing factors:

$$S(z, V_P/V_S) = w_1 r(t_1) + w_2 r(t_2) - w_3 r(t_3)$$

Where, $\sum W = W_1 + W_2 + W_3 = 1$.

Poisson's ratio is related to crustal Vp/Vs as:

$$\sigma = 0.5 X [1 - 1/(k^2 - 1)]$$

RESULTS

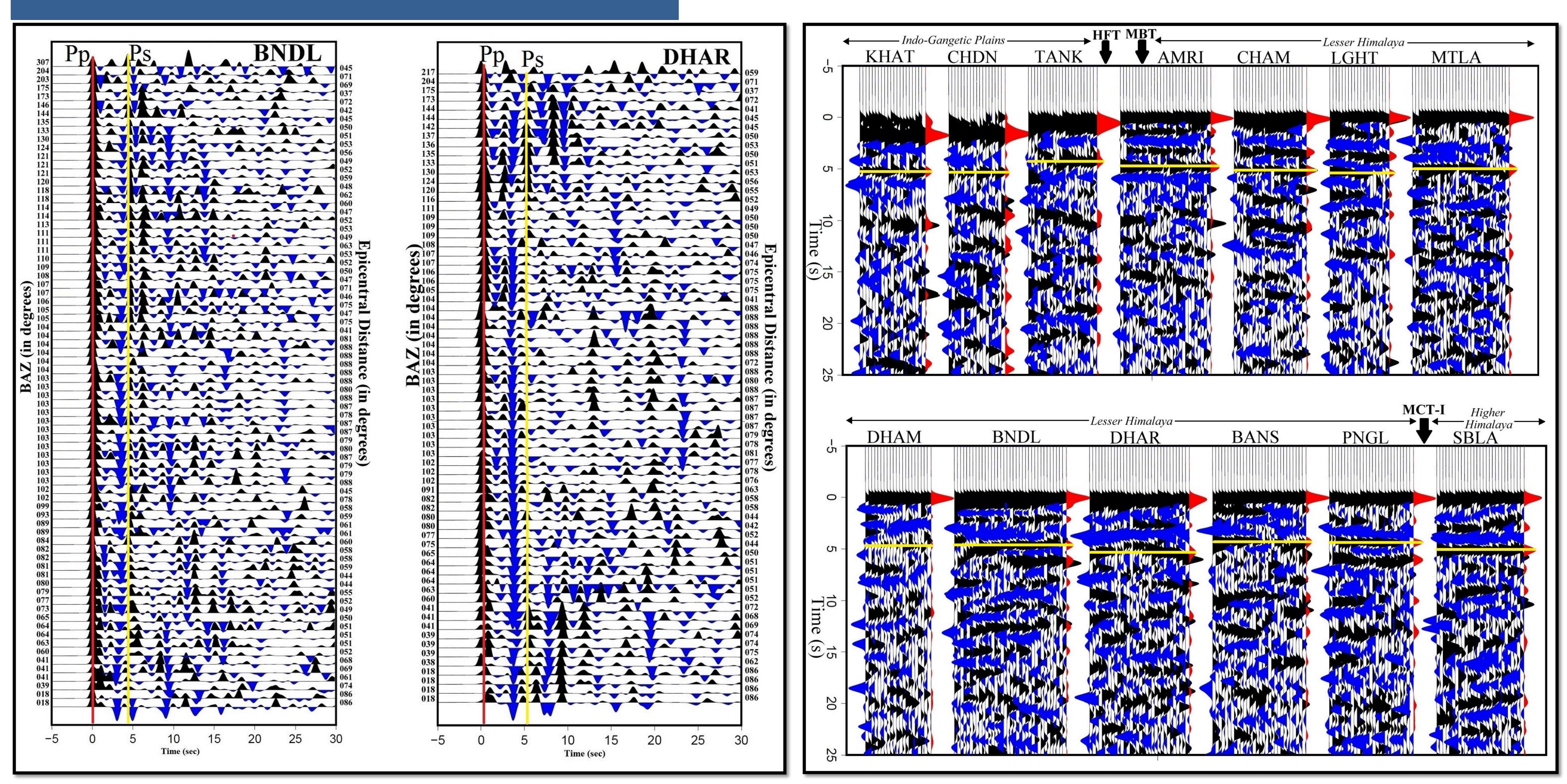

Fig. 3. (Left) Example of individual RFs of BNDL and DHAR stations. The direct P and Moho converted phases are marked by red and yellow lines respectively. (Right) RF time sections of all 13 stations arranged from south to north along profile AB of (Fig. 5a). The variation in the occurrence of Moho along the profile as obtained from RF is indicated by solid yellow line.

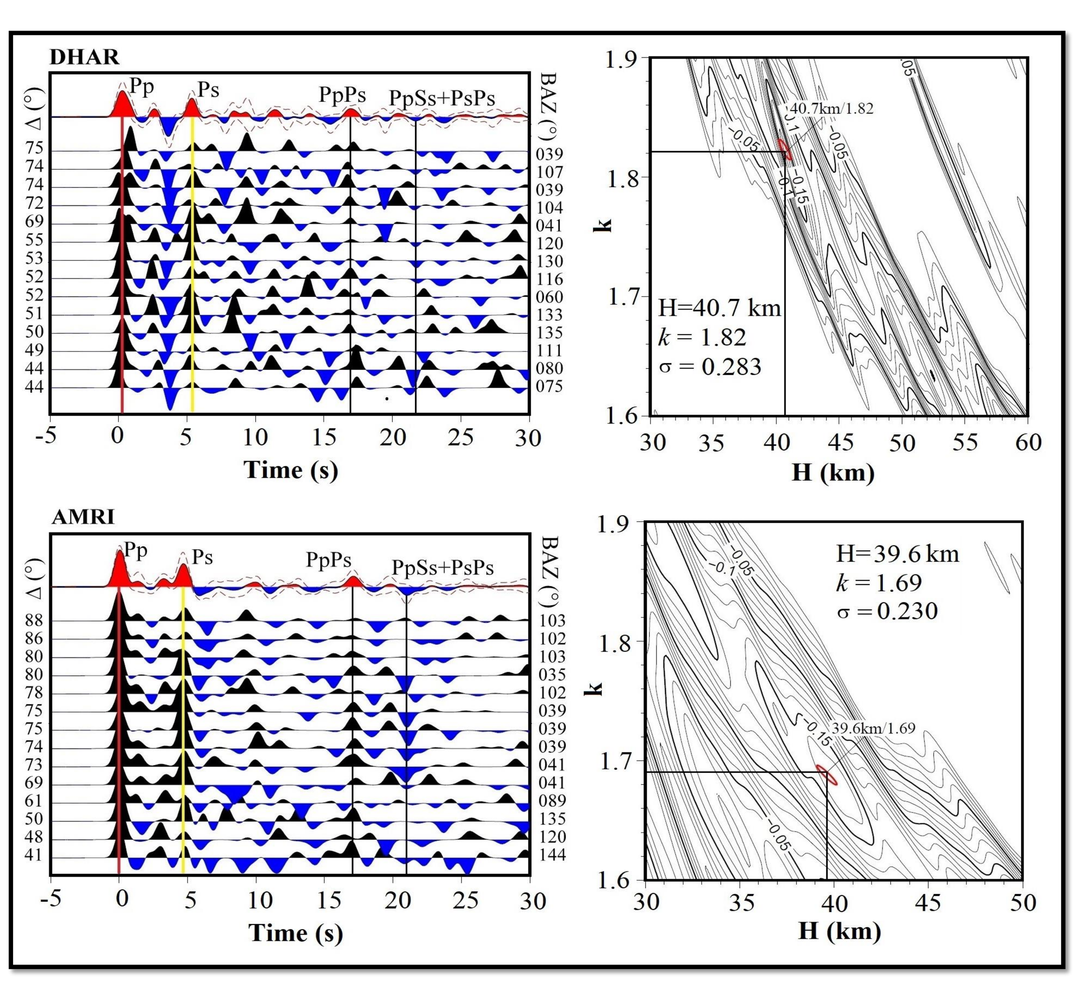

Fig. 4. Example of H-*k* stacking results at DHAR & AMRI stations. The selected waveforms along with their stack (red) are in the left.

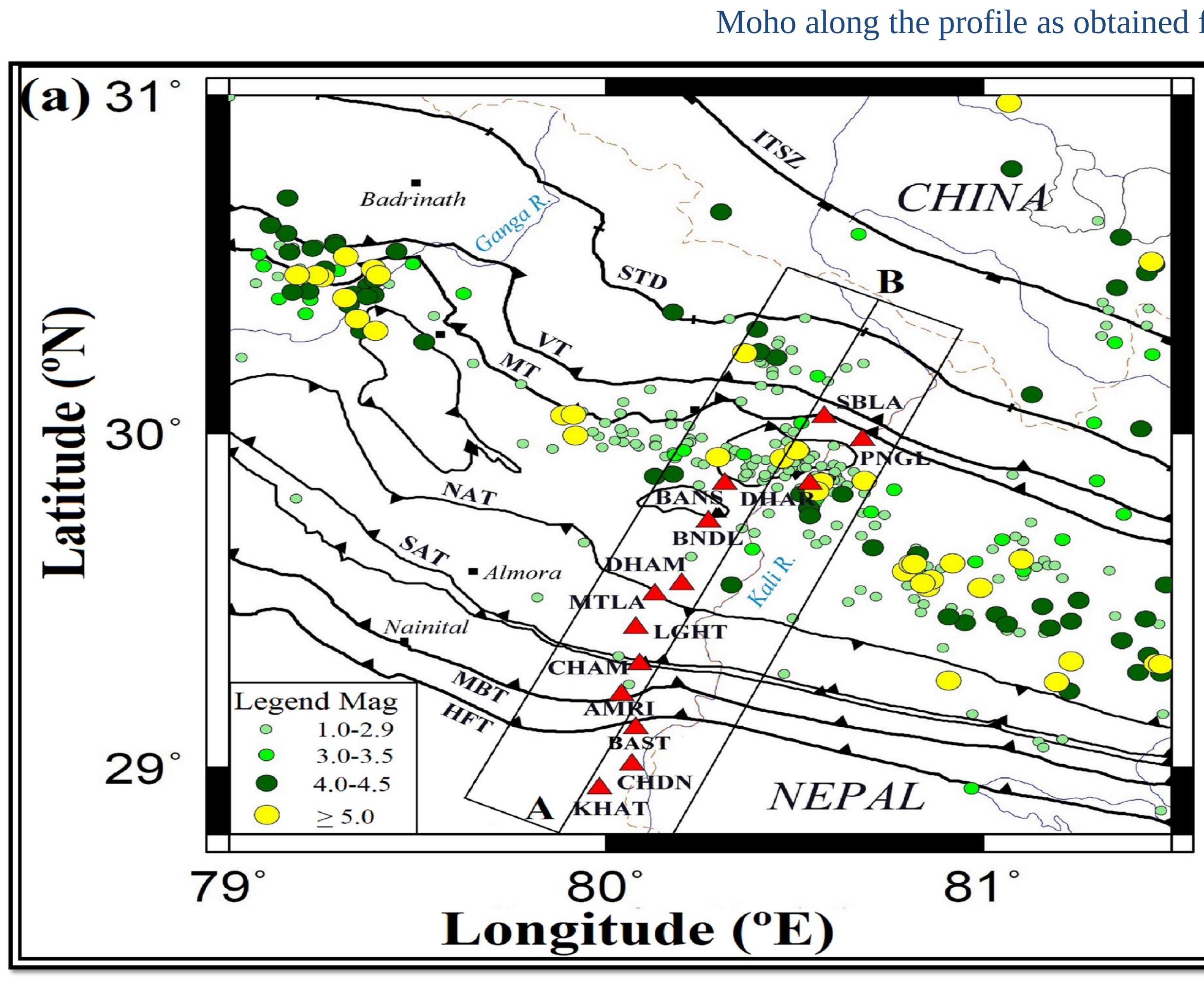

Fig. 5(a). Surface distribution of earthquakes in the Garhwal-Kumaon region.

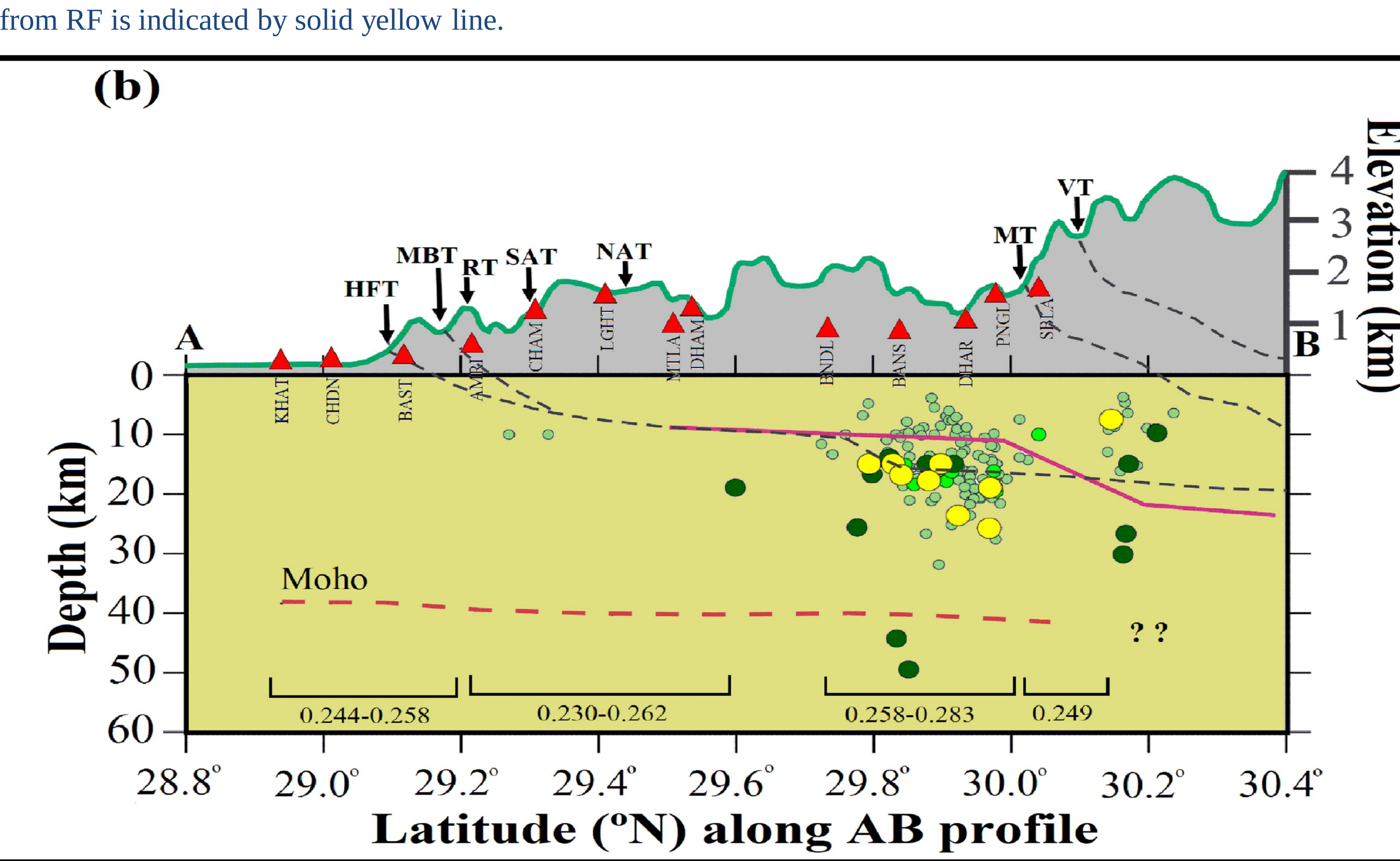

Fig. 5(b). Depth distribution of earthquakes along the AB profile with 50 km swath width. A clustered seismicity is observed at mid-crustal depth near the Dharchula region.

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CONCLUSION

- The H-k stacking analysis shows that the average crustal thickness in the IGP is ~38 km which gradually increases to ~41 km in the Higher Himalaya.
- The Poisson's ratio is comparatively low in the IGP, Sub Himalaya and inner Lesser Himalaya (σ = 0.23-0.25) with and exception at MTLA station (~0.26). The σ is higher (~0.26-0.28) at some stations in the outer Lesser Himalaya i.e. at DHAR, BNDL & BANS stations. Value of σ is ~0.25 at PNGL and SBLA station located near the MT.
- A cluster of seismicity is observed near Dharchula region at mid-crustal depth which is correlated with presence of fluids/partial melt at mid-crustal depth.