Summer Research Internship Report

CSIR-National Geophysical Research Institute (NGRI), Hyderabad

Mentor:- **Dr. Ravi Kumar Muppidi**

Senior Scientist, Gravity and Magnetics Group

Title:- Lithospheric Structure and Intermediate Seismicity in the Hindu-Kush and Pamir region: Insights from Geophysical data

Name: Sobhit Soni

Institute: Indian Institute of Technology Roorkee

Department: Earth Sciences

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Title: Lithospheric Structure and Intermediate Seismicity in the Hindu-Kush and Pamir region: Insights from Geophysical data

Abstract: **Investigating deep crustal and lithospheric structures is essential to understanding the nature of tectonic processes beneath the Himalayas. The difference in the depth-wise seismicity in the Northwestern Himalayas marks the difference in the geotectonic framework beneath the Himalayas. Hindu Kush and Pamir region was observed to be predominant with intermediate to deep seismicity (>80 km) indicating the involvement of Indian and Eurasian lithosphere.** Free air anomaly map of Hindukush - Pamir and adjoining regions derived from global models including satellite observations reflect most of the tectonic elements of this region. Fold and thrust belts and suture zones are characterized by small wave length free air high anomalies representing shallow high density mafic/ultramafic rocks including ophiolitic mélange. On the other hand, medium to large wavelength negative gravity anomalies which are related to crustal thickening due to isostatic compensation are better visualized in the Bouguer anomaly map. This emphasizes the importance of both free air and Bouguer anomaly maps of complex orogenic belts. The prominent negative free air, Bouguer and geoid anomalies are observed over the Hindu Kush – Pamir Seismic Zone between the Kohistan arc towards the south and Pamir towards the north suggesting predominance of low-density rocks approximately at a depth of ~ 120 km in the lithospheric mantle. **Airy's and flexural isostatic analysis finds that the region is uncompensated, our 2D cross-section along the 1D profiles incorporating velocity model shows the Lithosphere configuration where it is found high angle fast rate (maintaining brittle nature) underthrusting of Indian and Eurasian plate causing intermediate (~100 km) seismicity, Bouguer inverted and Crust 1.0 crustal thickness seems consistent but at some region offset in models combined with the results of focal mechanism solution showing the following findings: settling of high-density crustal melt material below the Moho and the slab-break off phenomena at depth >200 km causing deep focused seismicity. Excellent correlation between effective elastic thickness derived from the Bouguer Coherence method and lithospheric thickness predicts hot and deformable lithosphere in the northwestern Himalayas.**

1. Introduction

The collision between the Indian and Eurasian plates marks one of the major geological events in Cenozoic time. This is the youngest active continental-continental collision forming the largest orogens (Figure 1a) on the globe — the Himalayan orogen (e.g., Zhang et al., 2010a, Zhang et al., 2011, Aitchison et al., 2011)., these characteristics and the youngest collision made this region an area of research for several years. The collision helps us understand the rheological and structural evolution of mountains with time and Geodetic measurements suggest that the convergence between India and Eurasia is not only interplate but also intraplate within the Tibetan plateau (Gan et al., 2007; Ge et al., 2015).Many workers have also used the Himalayan knowledge to infer the evolution of other mountain belts: the Altai system in central Asia (Yang et al., 1992, Qu and Zhang, 1994), the Trans-Hudson orogen and Canadian Cordillera in North America (e.g., Nabelek et al., 2001, Norlander et al., 2002).

Despite being heavily researched for over 200 years, the exact cause of mountain building is still an enigma. Is the lithosphere playing any role in mountain building, or is it just a result of the India–Asia collision zone?

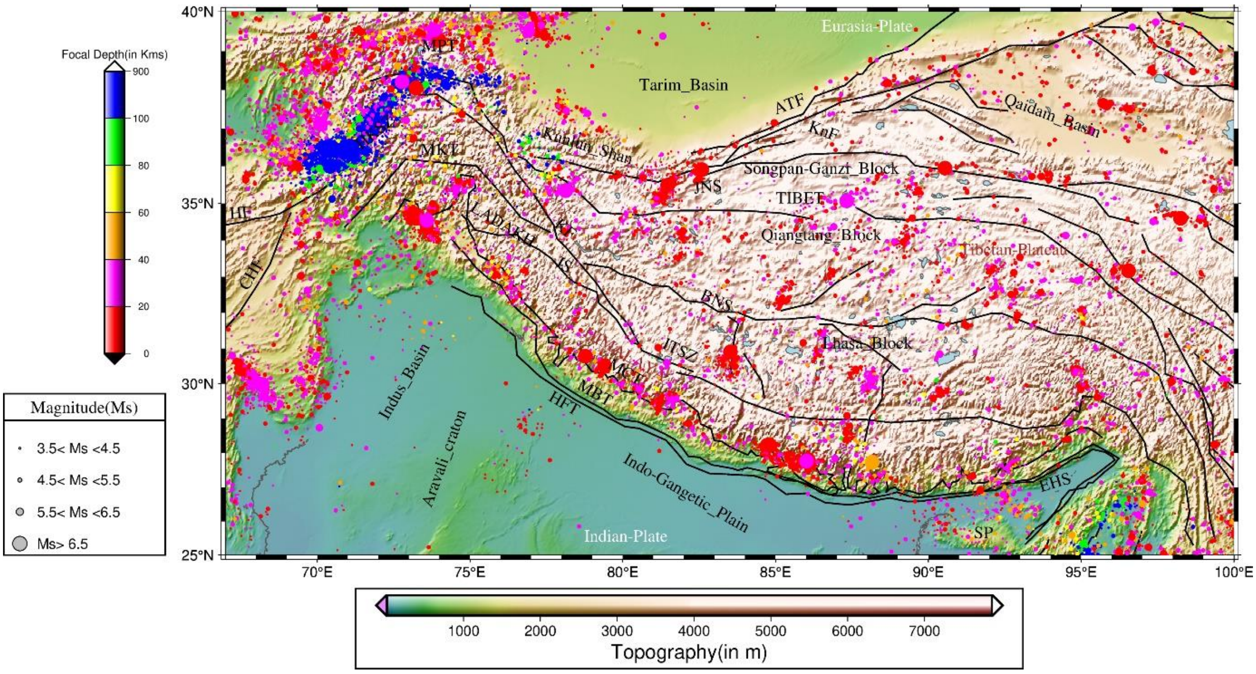


Figure 1a). Seismicity and Topographic map of Himalaya, Tibetan plateau, and surrounding regions (SRTM-2' data) with important tectonic elements of Tibet adopted from Yin and Harrison (2000) and Taylor and Yin (2009). Indus-Tsangpo Suture Zone (ITSZ) separates the Himalayas towards the south and the Lhasa block of Tibet towards the north. Himalayan Frontal Thrust (MFT), Main Boundary Thrust (MBT), and Main Central Thrust (MCT) are important units of the Himalayas with the Ganga basin (GB) south of it representing a foreland basin. Bangong-Nujiang Suture (BNS), Jinsa Nujiang Suture (JNS); Kunlun Fault (KnF) and Altyn Tagh Fault (ATF) represent important units of Tibet. MKT, Main Karakoram Thrust; IS, Indus suture; MPT, Main Pamir Thrust; HKSZ, Hindu Kush Seismic Zone; KF, Karakoram Fault; CF, Chamman Fault; HF, Herat Fault.

In western Himalaya, the tectonic regime can be broadly categorized into (i) the Himalayan collision zone, orthogonal to the plate convergence, (ii) the western syntaxis including Pamir, Nanga Parbat, and the Kashmir – Hazara syntaxis and (iii)the Western Fold Belt (WFB) of the Kirthar and Sulaiman ranges until the Chaman Fault, which marks the boundary of the Indian plate towards the west (Figure 1a). The Hindu Kush – Pamir section (Figure 1b) shows complex tectonic features associated with the Kohistan arc in between the Indian and the Asian plates forming two sutures viz. Main Mantle Thrust (MMT) that is the westward extension of the ITSZ and Main Karakoram Thrust (MKT) or Northern Suture where Kohistan arc (Indian plate) subducts northwards. It also shows Tien Shan and Pamir Main Thrust (MPT) where Asian plate subducts southwards. The Chamman fault (CF) along the western fold belt (Pakistan) is a strike slip transform fault that separates the Afghanistan block to the west from the Indian plate to the east with several exposed ophiolite belts along it. The Chamman fault extends northwards as Panjshir fault (PF) and their junction is a highly disturbed section with several faults like Herat fault (HF) originating from here. Heart fault separates Afghanistan block to the south and Asian block to the north originate from this region. The Hindu Kush Seismic Zone (HKSZ) where the epicenters of intermediate to deep focus earthquakes (yellow dots; depth = 100-250 km) of magnitude > 4 since 1975 (http://earthquake.usgs.gov/earthquakes) are concentrated is also marked in this figure. They are concentrated in an S-type band (Pegler and Das, 1998) extending from the Hindu Kush to the south of Pamir. Based on tomographic imaging of the Indian lithosphere, Koulakov and Sobelev (2006) had suggested faster subduction and break off under the Hindu Kush region to account for deep focus earthquakes in mantle. Based on tomography results and thermo mechanical modeling, Negredo et al (2007) had also suggested faster subduction at high angle and slab break off Indian lithosphere under Hindu Kush region (Mishra et al., 2012).

Convergence estimates based on paleomagnetic studies indicate that it varies along the Himalayan arc, increasing from 1800 km in the western to 2475 km in the central reaching 2800 km in the east (Johnson, 2002). It is widely speculated that the lithosphere mantle processes accommodate the total convergence (Chen et al., 2017). Since the entire lithosphere is involved in the deformation, studying crust and lithosphere is significant to understanding continental rheology and its evolution—differences in convergence rate and plate configuration cause different seismic zones. Our Study aims at the Hindu-Kush and Pamir regions of western syntaxis (Figure 1b) indicating a deep lithospheric plate interaction between India and Eurasia causing deep to intermediate (>80km) focus earthquakes.

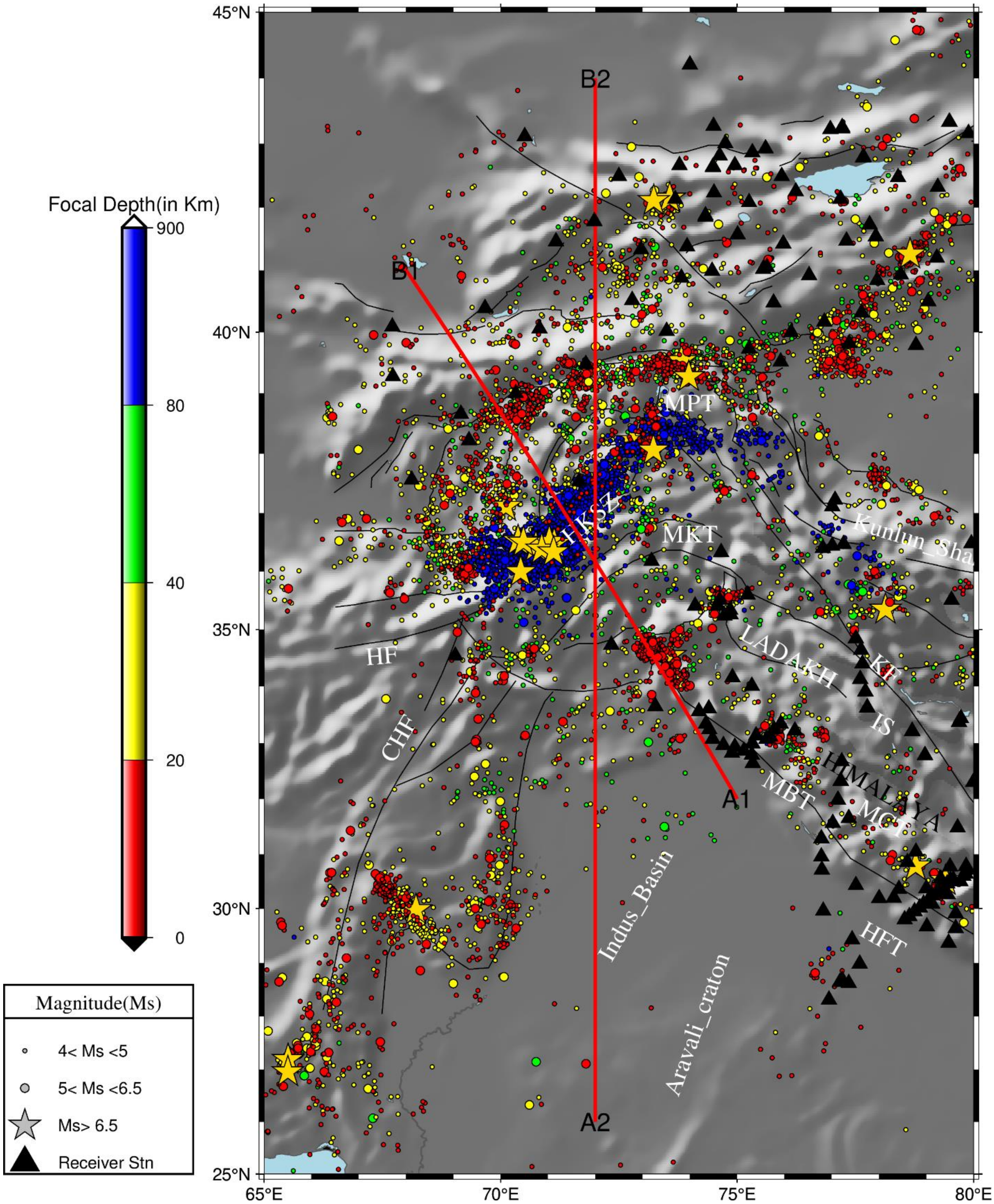


Figure 1b). Seismicity of the Northwestern Himalayas showing deep to intermediate (>80 km) focus earthquakes in the Hindu-Kush and Pamir region. Receiver Function data is incorporated from the EARS at these stations and two profiles A1-B1 and A2-B2 are extracted for the current study.

2. Geotectonic Background

The NW Himalayas can be separated into five principal lithologic-tectonic provinces, including the Sub-Himalaya, the Lesser Himalaya, the Higher Himalaya, and the Tethyan Himalaya (Gansser, 1964). These tectonic provinces (Figure 1a) are fault-bounded and accommodate nearly 30%-50% of the Indian-Eurasian plate convergence (Banerjee and Bürgmann, 2002; Zhang et al., 2004), named, from south to north: (1) Himalayan Frontal Thrust (HFT), formed at about 4–2 Ma along which Siwalik sediments of Plio Quaternary times are emplaced over the recent sediments of Ganga basin; (2) Main Boundary Thrust (MBT), formed at about 12 Ma along which the Palaeozoic and the Proterozoic metasediments are thrust over the Plio-Quaternary Siwalik sediments to form Lesser Himalaya; (3) Main Central Thrust (MCT) formed at about 20 Ma along the northern margin of the Indian plate when the crystalline rocks of

Higher Himalaya are thrust over the Palaeozoic and the Proterozoic metasediments (Mishra et al., 2012; Yin & Harrison, 2000) (Figure 1a). Thrusting caused by the underthrusting of India beneath Eurasia since the collision at around 55 Ma (Klootwijk et al., 1985). This process has been associated with a stepwise southward migration of thrust systems. The Western sector shows complex depth-wise tectonics (Figure 2) due to the occurrence of the Kohistan arc in between the Indian and the Eurasia plates forming two sutures, namely, Main Mantle Thrust (MMT) which is the westward extension of ITSZ, and Main Karakoram Thrust (MKT) or northern suture where the Indian plate subducts northward.
The arc-shaped intermediate (>80 km) seismic distribution (Figure 2) in the NW Himalayas region possibly marks the two different lithospheric plate configurations, between the Hindu-Kush and Pamir regions and between the Ladakh and Karakoram regions.

3. Data and Methodology

3.1 Data

The elevation data used for our current study is taken from the Shuttle Radar Topography Mission (SRTM15) has a ~3.70 km (2 arc min) resolution. The elevation ranges up to (~5100 m) at the thrust systems: MPT (Main Pamir Thrust) and MKT (Main Karakoram Thrust), and Hindu-Kush Suture Zone (HKSZ) (Figure 1a) inferring the cause of their uplifting. Hindu-Kush, Pamir, Ladakh, and Karakoram are highly elevated regions surrounded by many thrust systems resulting in building the arc-shaped mountain chain in North-Western Himalaya.

The Free-Air anomaly data obtained from Global Grids: World Gravity Map (WGM2012). [model]. BGI https://doi.org/10.18168/bgi.23 has a 02x02 arc min resolution to study the isostasy of the region by using the zero free-air technique. The FAA (Figure 3.1b) map shows the high anomaly values in the high topographic regions indicating the active orogeny building or uncompensated region and near-zero values in the Indus basin.

The Bouguer anomaly data was obtained from Global Grids: World Gravity Map (WGM2012). BGI https://doi.org/10.18168/bgi.23 has a 02x02 arc min resolution to compute the Effective Elastic thickness to determine the Lithospheric strength, and to compute moho undulations from the inversion technique. The most prominent feature of the BA (Figure 3.1c) map is the long wavelength gravity low along the Himalayas encompassing the Pamir and Ladakh regions and negatively correlating with topography. The Sediment Corrected Bouguer Anomaly is derived by adding the removed access mass effect by assuming the density of sedimentation as 2.3 gm/cc and the thickness of sedimentation is derived from the crust 1.0 model.

The Seismic Earthquake Catalog (Figure 2) from 1990-2024 is taken from the USGS.gov website(https://www.usgs.gov/) to see the tectonic activity caused by different components of structural deformation. In the Hindu Kush and Pamir region, there is locally dominant intermediate to deep focused seismicity observed possibly indicating the Lithosphere deformation. Based on Focal mechanism solutions, the CMT Catalog meca data of the period from 1990 to 2024 is taken from the Global CMT, main CMT web page: www.globalcmt.org to understand the Geodynamics and focal mechanism of deformation in determining stress accumulation.

The Receiver Function data (Figure 1b) is taken from previously published results and IRIS DMC (2010), Data Services Products: EARS EarthScope Automated Receiver Survey, https://doi.org/10.17611/DP/EARS.1 to map the 2D Velocity model along the 1D profiles for comparing the Lithospheric thickness model obtained from Data Products at the IRIS DMC: https://doi.org/10.1785/0220120032 and understanding the crustal and Lithospheric structures.

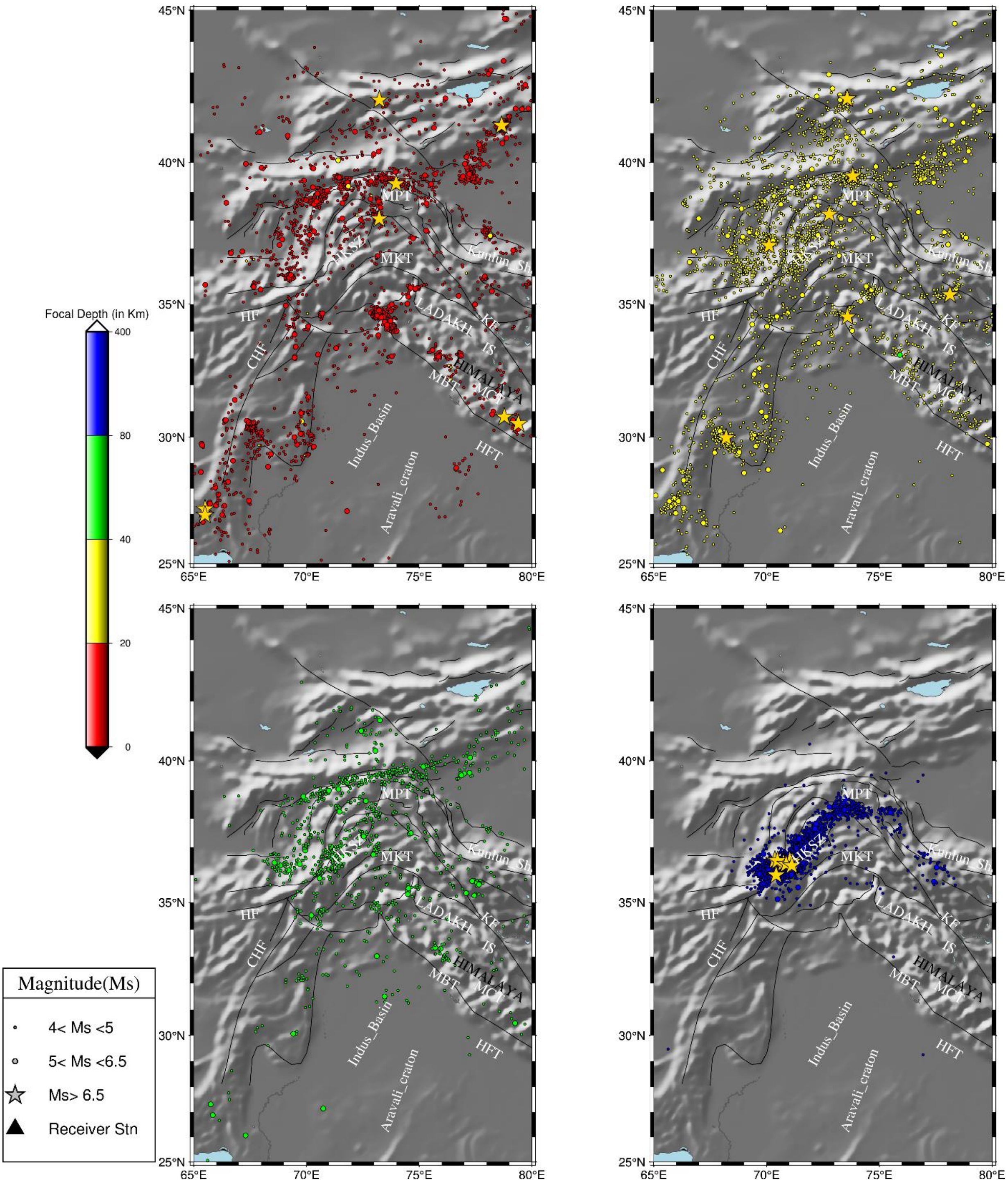


Figure 2). Depth-wise seismicity (USGS.gov: https://www.usgs.gov) in the Hindu-Kush and Pamir regions reflects different components of the geotectonic framework in the area.

3.2 Methodology

State of Isostasy

The surface elevation, the density difference between the lower crust and the upper mantle, the configuration of the crustal root, and the rigidity of the lithospheric plate are closely linked through the phenomenon of isostasy and best reflected in the gravity data.

3.2.1 Airy Isostasy

Isostatic compensation is a well-known physical process, in which the earth's responds to any load (surface or subsurface) over the geological time scale and try to restore the equilibrium. The concept of isostasy originated in India as early as in the eighteenth century, from the observations of anomalous deflection of plumb line near Himalaya (Pratt, 1855). This has led to the development of Airy and Pratt model of isostatic compensation and the first isostatic anomaly map of India was produced as early as in 1939 (Daly, 1939).

During the early seventies of the last century, National Geophysical Research Institute, Hyderabad in collaboration with other institutions of India, published the first Airy's isostatic anomaly map of India at 10 mGal contour interval (NGRI, 1975). During the recent years, number of hypotheses have been proposed for isostatic compensation of continental and oceanic regions from different parts of the world (Watts, 2001). The mode of isostatic compensation can be broadly classified under; (i) **Local compensation**: Where the topographic mass is compensated by the presence of the crustal root whose thickness varies in proportion to the elevation of the topography. This is referred as Airy model of compensation where the depth of compensation broadly agrees with the seismic evidence. Yet another model of local compensation was proposed by Pratt, in which the topography is compensated by the lateral variation of subsurface density which varies proportional to topography that is largely prevalent in oceans (Tiwari et al., 2008). (ii) **Regional compensation**: The local compensation models are based on the assumptions that lithosphere does not have any strength and consider that all the topographic masses, surface or subsurface, are compensated locally. However, in regional isostatic model, also known as flexural model, lithosphere acts like an elastic plate where the inherent rigidity of the floating crust on a substratum spreads topographic loads over a broader region. Thus, the Airy model is a special case of flexural compensation with no strength.

In this study, we have calculated crustal root based on Airy Isostatic model and compared those results with the Crust 1.0 Global model which is derived from the Global seismic velocities (Figure 3.1c).

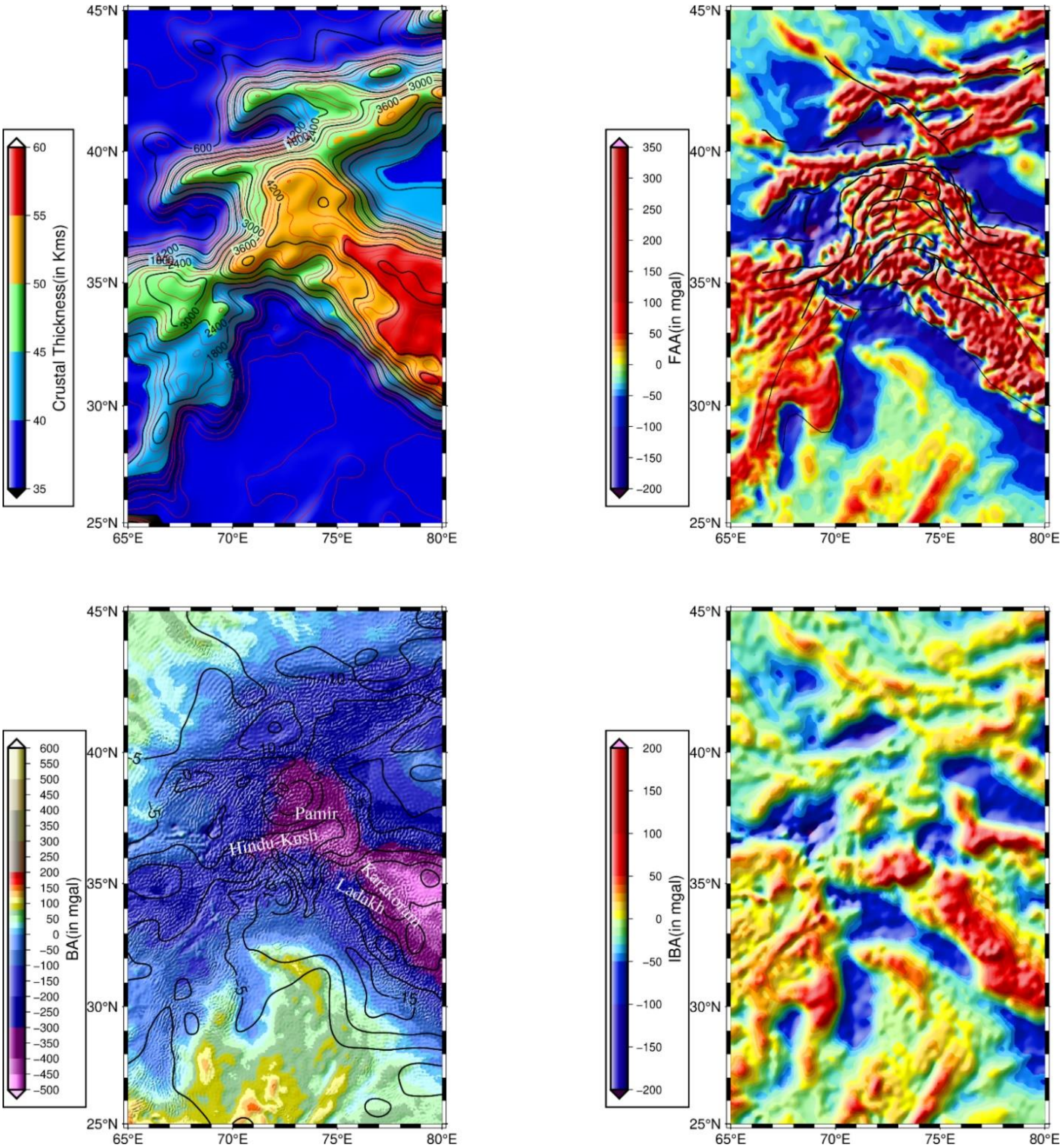


Figure 3.1 a). Airy's crustal model, derived from the topography data, b). Free-air anomaly map of Northwestern Himalaya and Indo-Gangetic Plain obtained from World Gravity Map (WGM2012). C). Bouguer anomaly data was obtained from the World Gravity Map (WGM2012) along with contours marking the difference between Airy's crustal model and Crust 1.0 model, d). Isostatic Bouguer anomaly, obtained from the World Gravity Map (WGM2012) indicates the shallow mineral-rich zones causing high Free Air anomaly.

, Isostasy is a regional phenomenon and manifests over a region having a large topographic load of wavelength greater than 250 km. Therefore, a regional topography map using a low pass filter with a cutoff wavelength of 250 km is used to compute the Airy (1855) crustal root (Figure 3.1a) assuming a density of mantle as 3.30 gm/cc, density of crust as 2.67gm/cc with a reference crustal thickness of 35km as per seismic results, the Hindu-Kush and Pamir region shows a near-zero offset in crustal root difference and high free air anomaly while on the other hand, the Ladakh and Karakoram region shows a high negative offset and relatively low free air anomaly indicating an overcompensated root zone confirmed by the very low Bouguer gravity anomaly (Figure 3.1c) enveloping this region.

The Bouguer anomalies are Inverted to compute Moho based on the Parker and Oldenburg Inversion method to check the calculated air predicted root depth and also the Crust 1.0.

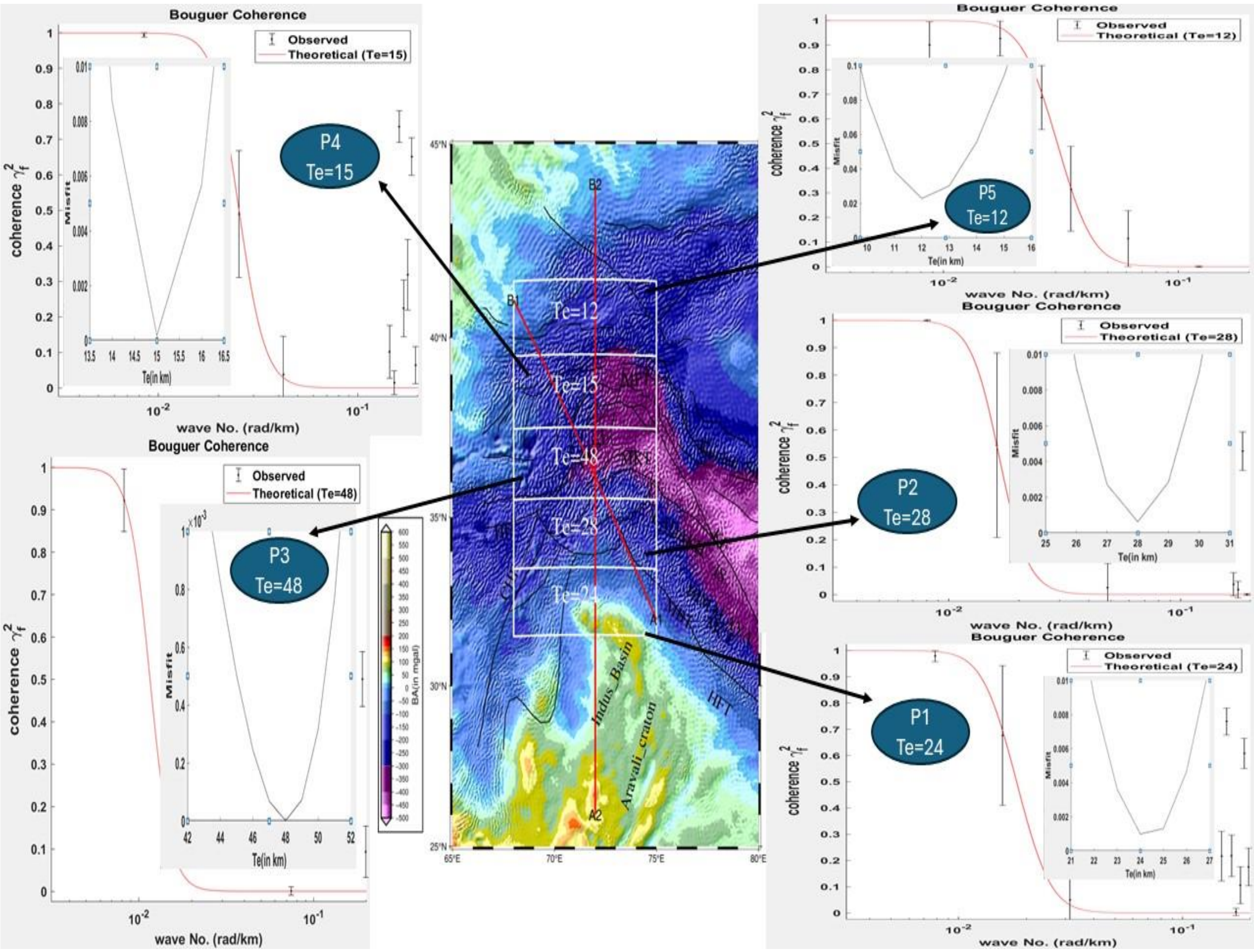


Figure 3.2). Complete Bouguer anomaly map of Northwestern Himalaya and Indo-Gangetic Plain obtained from World Gravity Map (WGM2012). It shows the smallest (<-500 mgal) long wavelength gravity lows over Karakoram related to deep-seated mass deficiency caused due to isostatic compensation. This figure also shows the effective elastic thickness (Te) of the Hindu Kush and Pamir region based on the coherence between the Bouguer anomaly and topography method (using Forsyth 1985). The intercomparison between Airy, Bouguer Inversion and Crust 1.0 models described in results section.

3.2.2 Flexural Isostasy

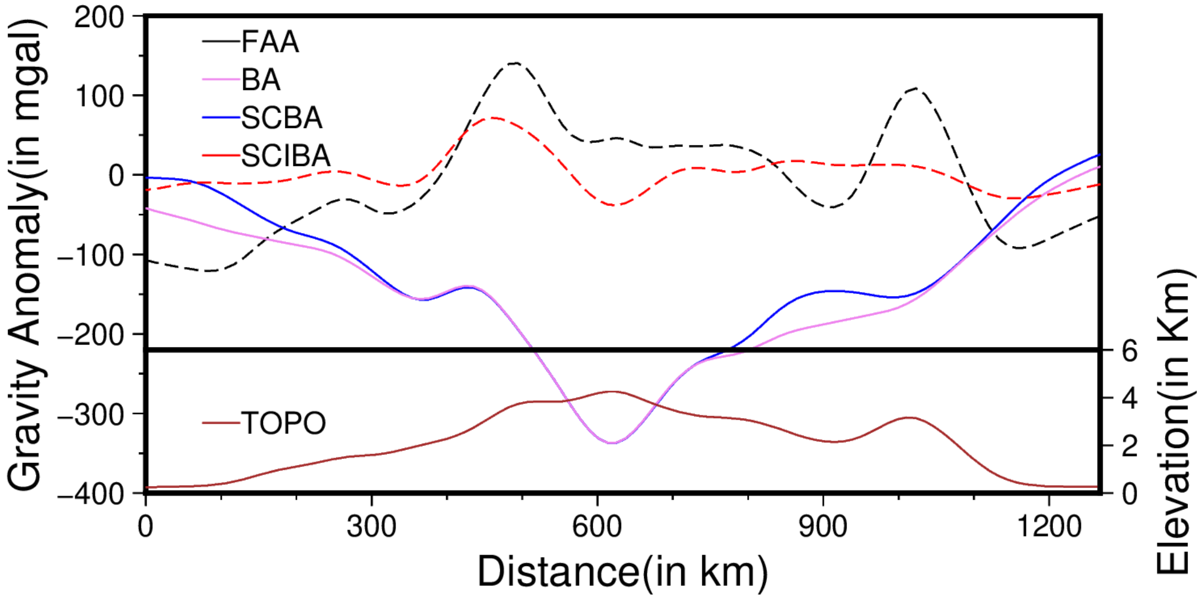
Flexural isostasy implies that topographic load is supported by flexure of the lithosphere instead of its root as suggested in Airy's model of isostasy. As stated earlier, Airy's model of isostasy assumes that the lithosphere does not have any strength and all the loads are supported by crustal root. Part of the lithosphere that behaves elastically over geological time is termed Effective Elastic Thickness (EET) and is often referred to as a measure of the strength of the lithosphere. (Watts, 2001).

Two spectral methods are commonly used to estimate EET. In first approach, the linear transfer function (admittance between topography and gravity anomaly) are computed and fitted with the admittance values of elastic plate model, which is referred to as admittance analysis (McKenzie and Bowin; 1976). Our basic assumptions while estimating the effective elastic thickness (Te) from Bouguer coherence analysis is that long-wavelength topography is isostatically compensated, mean topography and Bouguer gravity anomaly are coherent, and short-wavelength topography is uncompensated, that is, Bouguer anomaly is incoherent with topography (Forsyth, 1985). We divided the study area (longitude: 68°E–75°E, latitude: 31.5°N–41.5°N) into five (5) equal blocks and computed Te for each block, and the results are shown in Figure 3.2. The parameters used for calculating Te are (i) Young's modulus E=10^11 Pa and (ii) Poisson's ratio v = 0.25 with a reference depth of 40 km.

4. Results

4.1 Moho and Lithospheric Mantle Undulations beneath the Hindu-Kush and Pamir

Moho derived from various models, Airy's moho and crust 1.0 model seem consistent beyond 500 to 1000 km in distance (Figure 4a) marking a compensated region whereas, within this range, it shows a small deviation or upwarp indicating an under-compensated root zone in active orogeny region as stated by V.M. Tiwari (2019) and support by the high value of Te (48 km) obtained in this region shows high lithospheric strength. The Bouguer Inverted Moho departing from the other Moho models within this range gives insights into the subduction of melted crustal material below the moho. The remarkable feature is the deep-focused linear trend in seismicity present beneath the active region in the Hindu-Kush and Pamir revealing a cause of an interaction between the Indian and Eurasian Lithosphere.



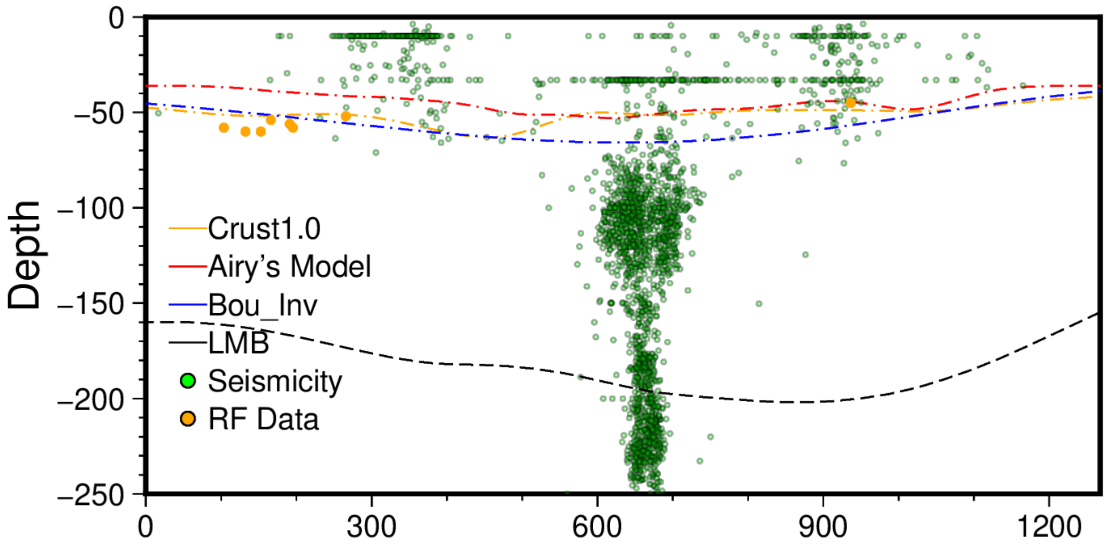


Figure 4a). The 2D cross-section compares gravity anomalies, topography, crustal and lithosphere models, Receiver Function data, and seismicity data along 1D Profile 1(i.e. A1B1). Bou_Inv, FAA, BA, SCBA, SCIBA, LMB, and RF Data stand for Bouguer Inverted, free air anomaly, Bouguer anomaly, sediment corrected Bouguer anomaly, sediment corrected isostatic Bouguer anomaly, Lithosphere-Mantle Boundary, and Receiver Function Data respectively.

4.2 Moho and Lithospheric Mantle Undulations beneath the proximity of Hindu-Kush and Pamir

Similarly, Airy's Moho and crust 1.0 model seems consistent beyond 1100 to 1600 km in distance (Figure 4b) marking a compensated region whereas, within this distance, it shows a small deviation or upwarp indicating an under-compensated root zone in active orogeny region, and the Bouguer Inverted Moho departing from the other Moho models within this range possibly confirms the subduction of melted crustal material below the moho. The remarkable feature is the lithosphere plate interaction at a depth of around 100 km, which is shown by a velocity model (Vp%) (chosen this profile in the proximity of Hindu Kush and Pamir as the global velocity data is available only for either Lattitude or Longitude) and a deep-focused linear trend in seismicity perfectly fitting at a collision boundary beneath the Hindu-Kush and Pamir region.

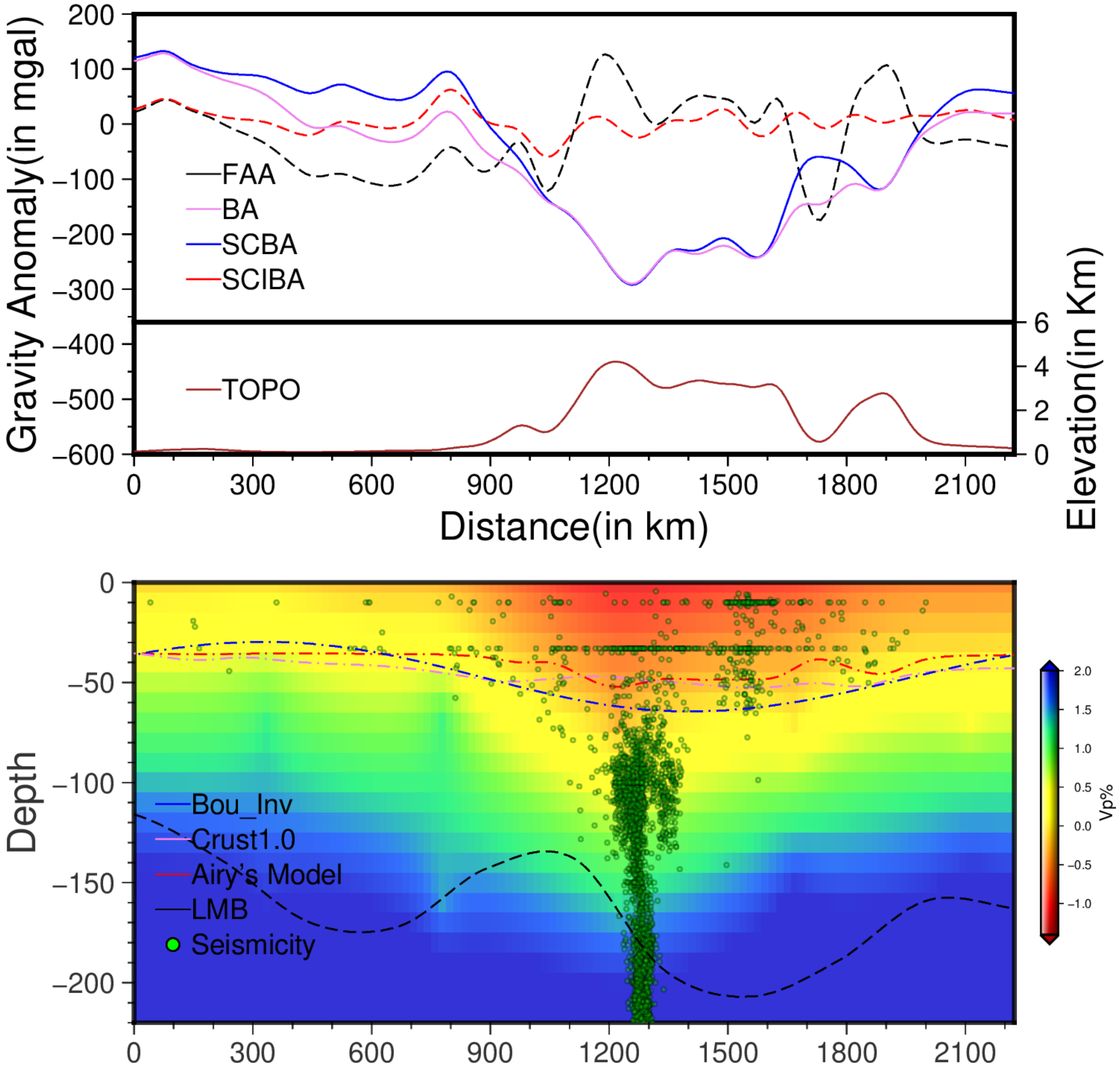


Figure 4b). The 2D cross-section shows Gravity anomalies, topography, crustal and lithosphere models comparison, velocity model(i.e. Vp%), Receiver function data, and seismicity data along 1D Profile 1(i.e. A2B2).

4.3 Effective Elastic Thickness (Te):

The estimated Te values (Figure 3.2) are high (~48 km) over the Hindu-Kush region and agree with the estimates of Bo-Chen (2015) using the fan wavelet coherence method with central wavenumber (|ko|) values higher than 3. In the north of Hindu Kush, Te values are generally low indicating that the lithosphere is thin in the northern western Himalayas. The Te values obtained from the Bouguer coherence method show an initial increment in values as we go north reach maxima and then start dropping, which is confirmed by the Lithosphere model derived along the Profile 1.

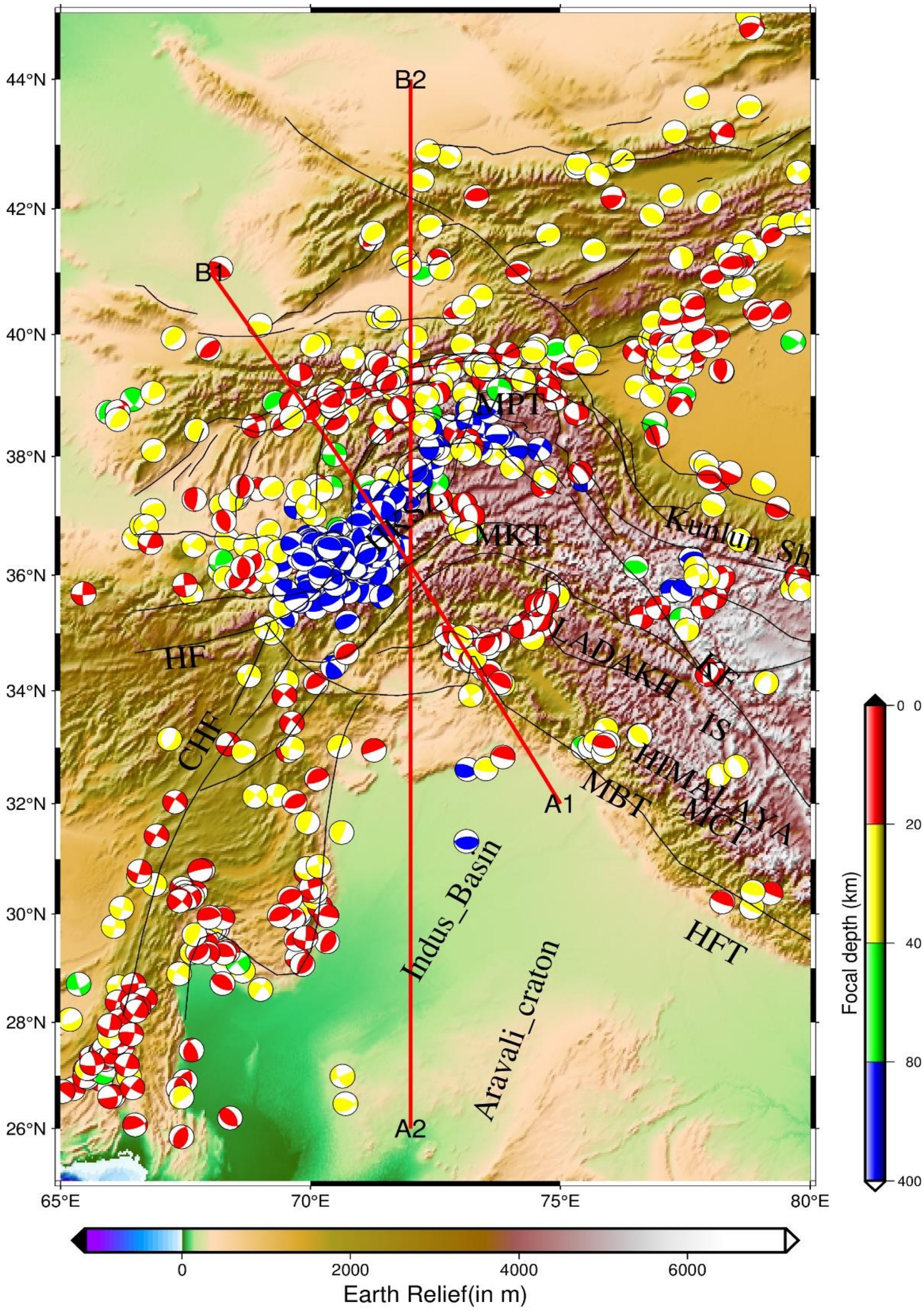


Figure 4c). The focal mechanism solution was obtained from the Global CMT catalog of the period 1990-2024 to study the stress pattern with depth in the Northwestern Himalayas.

4.4 Focal Mechanism Solution

The focal solutions (Figure 4c) observed in western India are major strike-slip faults that demark the Chaman fault, the major strike-slip structural western boundary between the Indian and Eurasian plates (WD Barnhart). The Pamir and Ladakh regions are characterized by reverse fault systems building high topography. The cross-sectional focal solution was plotted to study the nature of stress at depths, (Figure 4d) showing reverse faulting (high pressure) beneath the Hindu Kush and Pamir collision zone at a depth (>30 km) above Moho creating high pressure and temperature environment favourable for crustal melting. Reverse to strike-slip fault observed at a depth around ~100 km and Normal faulting at a depth (>200 km) beneath the collision zone confirms the slab break-off, where high temperature weakens the lithosphere and gravity pulls it apart.

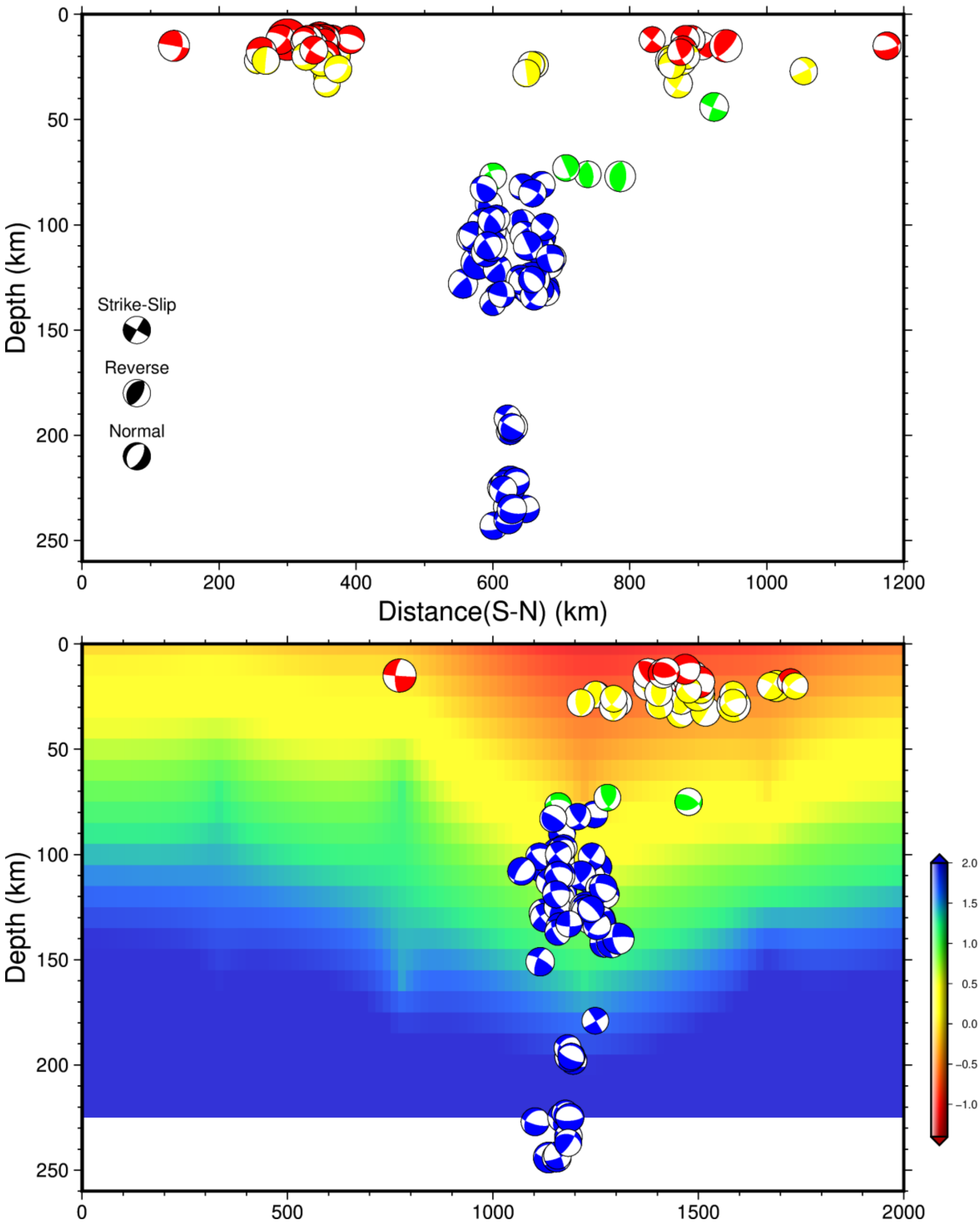


Figure 4d). (i)The cross-sectional focal mechanisms are derived along Profile 1 (i.e. A1B1) and (ii) along Profile 2 (i.e. A2B2).

5. Discussion

5.1 State of Isostasy beneath the Northwestern Himalaya

The high free air anomaly and low crustal thickness derived from the crust 1.0 model beneath the Hindu Kush and Pamir indicate an under-compensated root zone. On the other hand, relatively low free air anomaly and Bouguer anomaly, as well as high crustal thickness indicate an overcompensated root zone beneath the Ladakh-Karakoram region. The rest north and south parts of the subcontinent are compensated (showing near zero free air anomaly) (Figure 3.1 b).

5.2 Lithospheric Configuration

Factor like relatively high-angle subduction (45º and above) are important for deep-focused earthquakes. Many numerical modelling studies suggest the fast rate of subduction causes low temperatures (maintaining the brittle nature, essential for intermediate seismicity to occur) compared to the slow rate of subduction. Collectively the velocity model (Vp%) shows a lithospheric bulge beneath the Hindu Kush and Pamir and seismicity data distribution indicates an underthrusting of the Indian plate from the south across MMT and Eurasian plate from the north across MPT as modelled by V.M. Tiwari (2015). He also stated that a high angle fast rate of subduction causes a slab break-off which induces deep-focused earthquakes.

5.3 Presence of Crustal Melting and Slab Break-off

The offset of the crust 1.0 model from the Bouguer inverted model and low amplitude, medium range wavelength (>150 km) sediment corrected isostatic Bouguer anomaly possibly indicates the presence of subducted melted crustal material below the moho formed due to the high-pressure accumulation as confirmed by the focal mechanism solution, creating a favourable condition to undergo higher grade of metamorphism, changes to the mineralogy possibly (lack of geological insights) of eclogite. The lithosphere underthrusts each other and reaches a depth (>200 km) where the temperature reaches enough to weaken the lithosphere, further breaking apart due to gravity pull resulting in normal faulting and causing a low magnitude deep focused earthquake.

6. Conclusion

The results obtained in this study allow us to make the following conclusions.

The seismically active section in western Himalaya is HKSZ, which is characterized by deep focus earthquakes originating in upper mantle (Chatelain et al., 1980). This section coincides with a large amplitude Bouguer anomaly low. These earthquakes have been considered to originate in the under thrusted crustal slab in the upper mantle.

The Northwestern syntaxial belt observed from the geotectonic framework and seismicity distribution provided an opportunity to explore one of the most complex tectonic setups where the Indian lithosphere interacted with the Eurasian landmass. It is understood from the earthquake distribution and velocity model in the region that the western part of the syntaxial belt along the Hindu Kush – Pamir section involves the deeper and steeper fast rate interaction of the Indian and Eurasian lithosphere. The previous studies and current study contribute to confirming the presence of slab-break-off responsible for deep (>200 km) focused seismicity. Hypocenters of some of the deep focus earthquakes of Asian plate when projected on the crustal model computed along a profile (Fig. 4) coincide with the under thrusted lithospheric mantle confirming their association with under-thrusted rocks

The study also contributes to the crustal structure beneath the Hindu Kush and Pamir by confirming the presence of high-density material beneath the Hindu Kush and Pamir resulting from crustal melting due to stress accumulation and reaching below the moho. This process of settling high-density cool material below the moho at the collision boundary is one of the driving factors or forces of plate tectonics, increasing the rate of subduction due to its weight, the concept is known as Slab pull, the mechanism is led by geologists to explain the continued subduction after slab detachment in a subduction zone.

The EET values obtained contribute to the validation of incorporating the Flexural model for the isostatic compensation in the Himalayan region. The topography is supported by high to medium lithospheric strength in the Himalayas, with lithosphere thickness ranging from 150 km in the Indian basins to 200 km in the Hindu Kush and Pamir regions. The moho undulations are responsible for the long wavelength gravity anomaly.

Gravity anomalies, Crustal structure and other geophysical observables along a profile across HKSZ (Fig. 4) shows relatively high angle subductions of the Indian and the Asian plates across the Main Karakoram Thrust and the Main Pamir Thrust, respectively compared to the east of it as described above (Kumar et al., 2005; Tiwari et al., 2008) causing fast subductions in this section. High angle subductions are usually associated with rapid rate of subduction and slab break off causing deep focus earthquakes as has been observed in case of Mariana type subductions. The subducted Indian and the Asian plates interact with each other at a depth of ~ 100 km that would further facilitate slab break off inducing deep focus earthquakes in the lithospheric mantle. Added to it, are the high-density rocks of the Indian (Kohistan Arc) and the Asian plates (Tien Shan) comprising mafic and ultramafic rocks of volcanic and marine origin, that subduct in this section and would further aid into faster subduction. The gravity lows of Hindu Kush Seismic Zone lie between the Chamman – Panjshir fault towards the west and the Karakoram strike slip fault towards the east, respectively and they would affect the subducting Indian and Asian lithosphere. This would also facilitate slab break off and fast subduction essential for deep focus earthquakes.

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