3D CRUSTAL SHEAR-WAVE VELOCITY MODELS IN THE CENTRAL HIMALAYA-TIBETAN OROGENY, NORTH-EAST INDIA, AND THE INDO-BURMA SUBDUCTION ZONE AND THEIR GEODYNAMIC IMPLICATIONS

Abstract of the thesis submitted in partial fulfilment of the requirements for the award of the degree

of

Doctor of Philosophy

by

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November 2024

Abstract

The Indian tectonic plate has distinct seismotectonic settings, including a continent-continent collision in the Himalaya-Tibetan Plateau to the north and oblique subduction in the Burmese Arc to its east. This study aims to map the 3D shear-wave velocity variations for better understanding the crust and uppermost mantle structure, and present-day seismotectonics of these regions. It focuses on the central Himalayan-Tibetan Orogeny/central Himalayan-Tibetan Collision Zone (HTCZ) and the adjacent Indo-Gangetic Plain (IGP) as **Study area I,** and the broader North-East India Region (NER) and Indo-Burma Subduction Zone (IBSZ) as **Study area II**. The extensive coverage provides a broad understanding for crustal-scale studies and collisional implications of these regions.

The Himalayan-Tibetan orogeny, a complex analog for ancient continent-continent collisions, remains poorly understood, particularly the fate of post-collisional subducted mass at buoyant crustal levels. The NER's diverse geology and topography, coupled with limited understanding of its crustal structure, highlight the need for comprehensive study due to its proximity to two converging margins. Both study areas are seismically active with complex topography, faults, and thick sedimentary deposits. However, rugged terrains and adverse weather have hindered spatial coverage and field experiments, underscoring the challenges in these critical regions.

Surface waves are excellent for imaging crustal and lithospheric structures, unrestricted by station distribution, and rely on cross-path coverage. Enhanced seismic station deployment in recent times has facilitated comprehensive studies in these inaccessible and geologically intricate areas. The present study uses surface wave tomography to provide detailed 3D Shear-wave velocity (V_{SV}) structures of the study areas down to 80 km depth by inverting a new and extensive Rayleigh wave dispersion dataset. Vertical component seismograms (sampling rate 1 Hz) from 1985 to 2023 were used. The dataset comprises over 900 seismic events (Mw > 4.0, focal depths between 7-100 km) recorded by 33 global and regional seismic broadband networks. We manually picked and analyzed ~ 23,500 dispersion curves for Rayleigh wave fundamental mode group velocity across a 5-70 seconds period range. The methodology involved a two-step inversion approach. First, a ***2D Continuous Regionalization*** technique regionalized the dispersion measurements at each time period using an 80 km horizontal correlation length to produce 2D anisotropic tomographic images on a 0.5° x 0.5° grid covering the entire study region. The tomograms were created by integrating isotropic velocity maps with their azimuthal variations. Second, the regionalized dispersion data was inverted for depth using a ***Markov Chain Monte Carlo (McMC)*** sampling scheme within a non-linear ***transdimensional Bayesian*** framework, resulting in our final 3D shear-wave velocity (V_{SV}) model on a 0.5°×0.5° grid. The depth inversion was done separately for the two study areas.

Results indicate a crustal thickness of 42-48 km beneath the Ganga basin, with an overlying sedimentary layer of 6-10 km. Northward dipping Moho, and Main Himalayan Thrust (MHT), are imaged. North of the Kumaon-Garhwal Himalayas, a dome-shaped ‘crustal scale duplex’ with shear-wave velocity (Vsv) ~3.5-3.75 km/s is observed, likely influenced by Indian crustal material moving over the MHT as the Indian plate slides beneath the Eurasian plate. In central Nepal, smaller low-velocity patches are identified at upper-crustal depth near the Gorkha and Kathmandu earthquake locations, with more extensive low-velocity-zones

(LVZs) (Vsv~3-3.2km/s) beneath the Lhasa and Qiangtang terranes indicating aqueous fluids and partial melts at mid-crustal depths. Significant earthquakes in central to eastern Nepal may stem from the combined effects of crustal lithology driven strain accumulation, steep subduction, and MHT geometry, with mobile LVZs beneath this region also playing a role. In contrast, seismicity in western Nepal is characterized by the gradual subduction of the Indian plate. In eastern Nepal-western Sikkim region, overlapping velocity contours of the MHT and Moho, along with thinning of Indian lower crust, are observed under the Tethyan Himalayan sequence, extending to Southern Lhasa, likely marking the northern extent of the Indian crust. Overall, significant Moho deepening from west to east indicates crustal thickening under the Himalaya. A high-velocity anomaly at upper-crustal depth in the Lhasa region, extending along the Bangong-Nujiang Suture zone, bifurcates the LVZs here and possibly linked to exhumed Precambrian basement, remnants of the Bangong-Nujiang Tethyan Oceanic crust, or a batholith body.

Crustal thickness under Bengal Basin (BB) varies widely, with significant uppermost mantle undulations and a highly deformed low velocity structure likely related to the Indo-Burmese deformation front. The Dauki Fault (DF) separates the seismotectonic regions of BB and Shillong Plateau (SP), evidenced by variations in crustal and sedimentary thickness. A slight subsidence in the Moho topography between BB and SP is likely related to the Surma Basin. Our findings indicate that the uppermost mantle beneath the Surma Basin dips downward, suggesting subsidence due to significant pressure from the elevated SP and thick basin sediments. The mantle structure beneath the SP is convex upward, likely due to lithospheric flexing from Himalayan and IBR stresses, supporting the theory of lithospheric buckling and 'pop-up' tectonics, with higher upper-crustal Vsv compared to surrounding regions, indicating a rigid crust. A significantly deformed lithospheric mantle is revealed under the indentation corner at the Eastern Syntaxis, indicating a sharp bend in the plate boundary. The MHT lies at ~18 km depth under the Arunachal Himalaya, which, moving northward dips down to ~28 km under the Greater Himalaya. Significant crustal thickness variations are observed from west to east in the IBR with maximum thickness on the southern IBR, along its eastern edge. Low Vsv in the upper ~10 km of the Central Myanmar Basin (CMB) is associated with thick sediment deposit. A high-velocity eastward-dipping structure (Vsv > 4.0 km/s) observed under the CMB, plausibly suggests the subduction of the Indian plate beneath the Burmese plate. The plate boundaries of India and Burma plate are imaged under CMB, revealing complex interactions and subduction processes that contribute to the region's significant seismic activity. The earthquake pattern of this region highlights significant strain accumulation and potential seismic hazards for surface structures and populations.

Our results correlate well with known geologic and tectonic features, and are consistent with sediment deposits. The velocity models reveal notable along-strike variations in crustal collision within the HTCZ, correlating with spatial variations in the shear-wave velocity of the MHT, Moho, and the underthrusting Indian crust. Additionally, they reveal significant variations in the lithospheric structures of the major seismotectonic domains of NER and IBSZ.

Keywords: 3D Shear-wave velocity models, Transdimensional Bayesian inversion, Himalayan-Tibetan collision zone, North-East India, Indo-Burma subduction zone, Crustal structure, Uppermost mantle.