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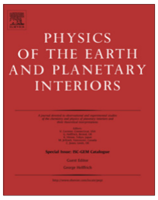

Crustal structure beneath northeast India inferred from receiver function modeling

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ABSTRACT

We estimated crustal shear velocity structure beneath ten broadband seismic stations of northeast India, by using H-Vp/Vs stacking method and a non-linear direct search approach, Neighbourhood Algorithm (NA) technique followed by joint inversion of Rayleigh wave group velocity and receiver function, calculated from teleseismic earthquakes data. Results show significant variations of thickness, shear velocities (Vs) and Vp/Vs ratio in the crust of the study region. The inverted shear wave velocity models show crustal thickness variations of 32–36 km in Shillong Plateau (North), 36–40 in Assam Valley and ~44 km in Lesser Himalaya (South). Average Vp/Vs ratio in Shillong Plateau is less (1.73–1.77) compared to Assam Valley and Lesser Himalaya (~1.80). Average crustal shear velocity beneath the study region varies from 3.4 to 3.5 km/s. Sediment structure beneath Shillong Plateau and Assam Valley shows 1–2 km thick sediment layer with low Vs (2.5–2.9 km/s) and high Vp/Vs ratio (1.8–2.1), while it is observed to be of greater thickness (4 km) with similar Vs and high Vp/Vs (~2.5) in RUP (Lesser Himalaya). Both Shillong Plateau and Assam Valley show thick upper and middle crust (10–20 km), and thin (4–9 km) lower crust. Average Vp/Vs ratio in Assam Valley and Shillong Plateau suggest that the crust is felsic-to-intermediate and intermediate-to-mafic beneath Shillong Plateau and Assam Valley, respectively. Results show that lower crust rocks beneath the Shillong Plateau and Assam Valley lies between mafic granulite and mafic garnet granulite.

1. Introduction

The Earth's crust is the upper rigid part of the lithosphere. There are three crustal divisions – oceanic, transitional, and continental; of these, oceanic and continental crusts dominate. Compared to oceanic crust, continental crust is thick (~40 km on average), less dense (~2.7 g/cm^3), and is composed of highly diverse lithologies that yield an average intermediate or andesitic bulk composition (Taylor and McLennan, 1985). The continental crust has age varying from ~4.0 Ga to the recent. Thus the continents preserve a rich geological history of Earth's evolution. Following the compilations of the seismic velocity structure of the continental crust based on seismic surveys across the globe, continental crust is divided into sediment, upper, middle, and lower crust with the corresponding shear wave velocity of <3.0, ~3.0–3.5, 3.5–3.8, 3.8–4.2 km/s, respectively (Christensen, 1996; Rudnick and Gao, 2003). Rudnick and Fountain (1995) and Rudnick and Gao (2003) argued that Vp higher than 7.0 km/s (Vs $\geqslant$ 4.0 km/s) corresponds to mafic rocks. For a variety of mafic lower crustal rocks, the Vs increases to 3.8 km/s for felsic granulite, 3.9 km/s for mafic granulite, and >4.1 km/s for garnet granulite rocks. The upper crust being the most accessible part of the Earth has been the subject of numerous direct geological investigations. So, rock types in the upper continental crust are reasonably well known. On the other hand lower continental crust is less accessible than the upper crust and hence the distribution of rock types in the lower crust remains uncertain. Our view of the lower continental crust is based chiefly on a few uplifted slices of the crust in collisional orogens and from xenoliths brought to the surface in young volcanics. The most important and globally correlated boundary within the Earth's lithosphere is the transition from the crust to the mantle, known as the Mohorovicic discontinuity (Moho). Steinhart (1967) provided a globally consistent definition, which stated that the Moho to be the depth at which the Vp increases rapidly or discontinuously to 7.6–8.6 km/s. If steep velocity gradient are not present, then the Moho is interpreted as the level at which Vp > 7.6 km/s (Vs > 4.3 km/s) (Steinhart, 1967; Jarchow and Thompson, 1989). This has been

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adopted as the definition of the Moho by the geophysical community.

The northeastern region (NER) of India is jawed between the Himalayan frontal arc to the north and the Indo-Burmese arc to the east, is a seismically active region, which is manifested by the ongoing India-Asia collision to the north and Indo-Burmese subduction to the east (Bilham and England, 2001; Angelier and Baruah, 2009; Kayal et al., 2010, 2012). The region has experienced two great earthquakes, the 12 June, 1897 Shillong earthquake of Ms ~8.7 (Oldham, 1899) and the 15 August, 1950 Assam earthquake of Mw ~8.6 (Poddar, 1950, 1952; Ambraseys and Douglas, 2004) and more than 20 large ($M > 7.0$) earthquakes, for e.g. the 1869 Cachar earthquake (Mw ~7.4), the 1930 Dhubri earthquake (Mw 7.1) etc (Oldham, 1883; Gee, 1934; Nandy, 2001; Ambraseys and Douglas, 2004; Kayal, 2008). The Shillong Plateau is separated from Mikir Hills by the NW-SE trending Kopili fault, which is a major active fault of the northeast region (Fig. 1). GPS velocities show that up to 5 mm/yr of shortening is taken up across the plateau and its borders, along with moment-frequency relations suggests that the interval between great earthquakes in the region is several thousand years but that earthquakes of magnitude 7 or greater should occur roughly once per century (England and Bilham, 2015). They also found that it is a region of high seismic hazard. Recent studies report that Kopili fault is transverse to the Himalayan arc (Kayal et al., 2006, 2012) probably divides Assam Valley into two separate blocks (Vernant et al., 2014). The difference in the rate of clockwise rotation of these two block result ~2–3 mm/yr dextral motion in the Kopili fault (Vernant et al., 2014; Barman et al., 2014). These plate motion of northeast India both at the plate margins and at plate interior stresses the lithosphere leading to strain accumulation and hence capable of generating a great earthquake. Recent space geodetic measurement by Bilham and England (2001) suggests a significant slip deficit in this segment of the Himalaya, capable of generating a great earthquake in the near future.

Most of the previous studies (De and Kayal, 1990; Kayal and Zhao, 1998; Rai et al., 1999; Sitaram et al., 2001; Bhattacharya et al., 2005, 2008, 2010) were focused on the crustal structure of the NER India in general and Shillong-Mikir Plateau (SMP), in particular. Moho depth estimated from receiver function approach show north dipping Moho, ~35 km beneath the Shillong Plateau, 40 km beneath the Assam Valley, and reaching a depth of 48 km beneath Lesser Himalaya (Kumar et al., 2004; Mitra et al., 2005; Bora et al., 2014). Their results also show relatively high shear

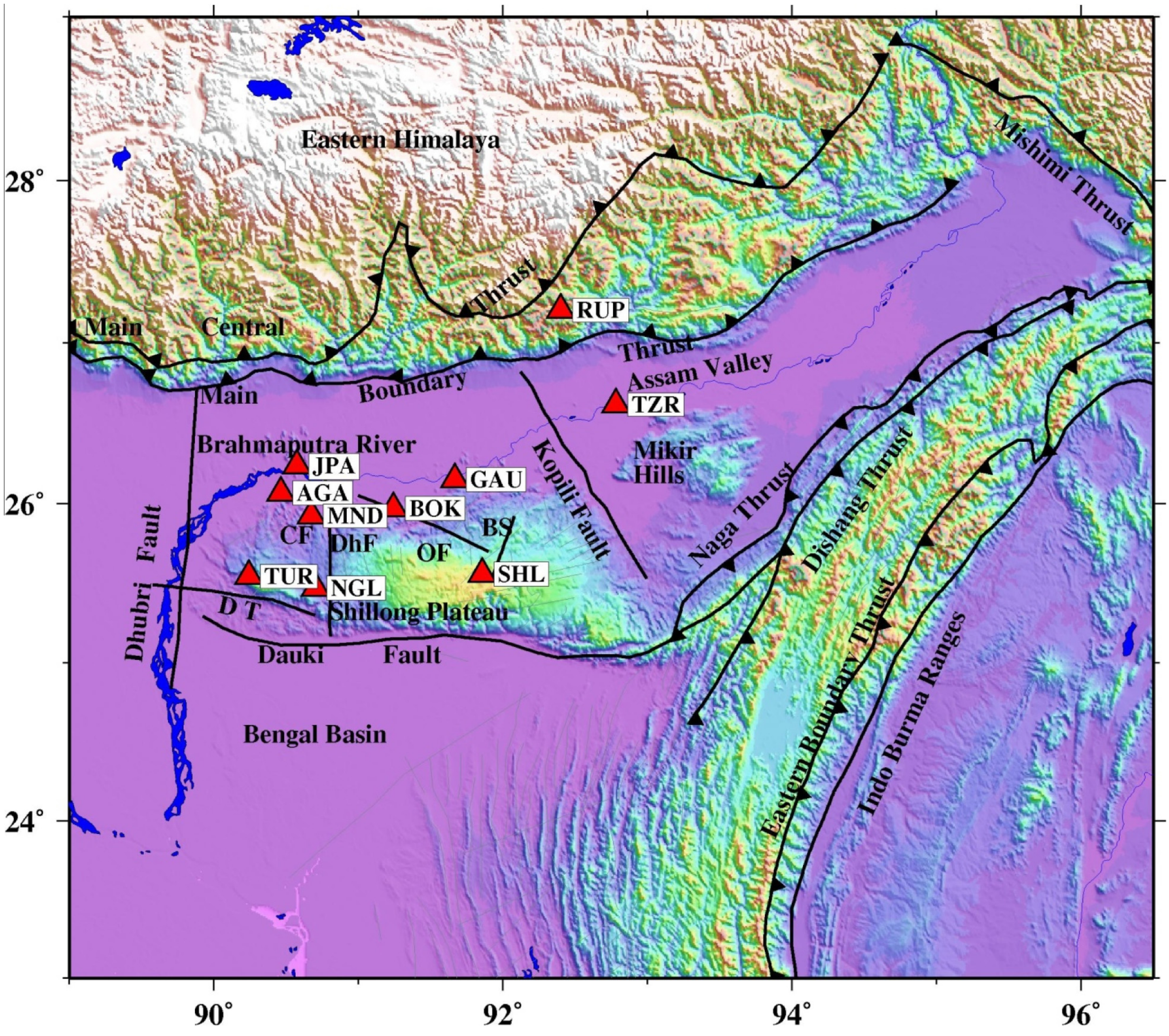

Fig. 1. Major tectonics features of the study region along with broadband seismic stations, shown by red triangles. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)