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Crustal structure and tectonics of Bangladesh: New constraints from inversion of receiver functions

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ABSTRACT

An understanding of the sedimentary and crustal structure of the Bengal Basin and of the tectonics deforming it remains elusive due to lack of seismic data from Bangladesh. Taking advantage of recently available data from 11 seismic stations deployed over Bangladesh, we determine the crustal structure beneath each station using 2768 high quality receiver functions (RFs). Inversion of the RFs reveals a highly variable thickness of the overlying sediments beneath the Bengal Basin. The thickness of the sediments increases dramatically across the Hinge Zone of the Early Cretaceous passive margin from 3 to 17 km. The thick sediments partly represent progradation of the continental margin due to the influx of clastic sediments from the Himalayas. The Moho shallows across the region. This reflects thinning of the crystalline crust from 38 km in the Indian Craton to 34 km at the Hinge Zone to <16 km in the Bengal Basin. The thickness of the sediments increases dramatically from 3 to 17 km south of Madhupur tract which reflects the regions of highest influx of clastic sediments from the Himalayan collision zone. RFs display strong dipping reflectors (strike 67°) for a station over Hinge Zone and seem to be associated with the transition from continental to oceanic crust. The thinning of significant crustal thickness (16–19 km) beneath 15–17 km of sediment and associated velocities (>4.0 km/s) at lower crustal levels supports an influence of the Kerguelen plume igneous activity during rifting. We invert data for a station near the Dauki Fault, which marks the southern boundary of the uplifted Shillong plateau, for dip and anisotropic effects. Our results show the Dauki as a north-dipping thrust fault at Jaflong with a dip angle of 32° and strike (110°) close to its surficial expression. A strong anisotropy (~15%) and the sense of shear (plunge: 24°, trend: 79°) compliment the dipping geometry and deformation seems to be related to the initiation of the Dauki Fault.

1. Introduction

The Bengal Basin is a region with extreme sediment thickness (>12 km, Murphy, 1988; Johnson and Nur Alam, 1991) situated between the Indian Craton (Singhbhum) in the west, the highly deformed Indo-Burmese subduction zone towards its east (Fig. 1) and the elevated (~1.2 km) Shillong plateau and Mikir Hills to the north. The Bengal Basin was formed by the rifting of Antarctica from India in the Early Cretaceous (Storey et al., 1992; Coffin et al., 2002). The NNE–SSW striking Hinge Zone, the trace of the Eocene shelf edge, also marks the start of the transition from the thick continental crust to thinned, extended crust of the continental margin. The location of the transition from attenuated continental crust to oceanic crust is unknown, but often associated with the Barisal–Chandpur gravity high (Fig. 1; Alam et al., 2003). Mitra et al. (2008) identified a high velocity lower crust at Agartala (AGT) that they associated with oceanic crust.

Since the Eocene, sediments from the Himalaya carried primarily by the Ganges and Brahmaputra Rivers have prograded the shelf edge by 3–400 km from the Hinge Zone to its present location at 20–20.2°N filling the Bengal Basin. Previous geophysical studies from the Bengal Basin do not provide strong constraints on its total sediment thickness and or the nature of the crust beneath the thick sediments. Lindsay et al. (1991) image basement increasing from 3–5 km landward of the Hinge Zone to >10 km east of it. Offshore refraction data suggest 16–22 km (Curray, 1991) and reflection data indicate >15.5 km (Maurin and Rangin, 2009). Gravity modelling across the Bengal Basin suggests 13–14 km (Khan and Agarwal, 1993), (Rajasekhar and Mishra, 2008). Stratigraphic reconstructions involving well and seismic data suggest 13 to 16 km of sediments (Johnson and Nur Alam, 1991). Receiver functions (RFs) along the northern and eastern edges of the Bengal Basin indicate 21–24 km for the sediment thicknesses. Thus the total thickness of strata is large, but poorly constrained in the center of the Bengal Basin.

The Indo-Burmese subduction zone obliquely overthrusts the Bengal Basin from the east (Fig. 1). About 20 mm/y of the shear motion is

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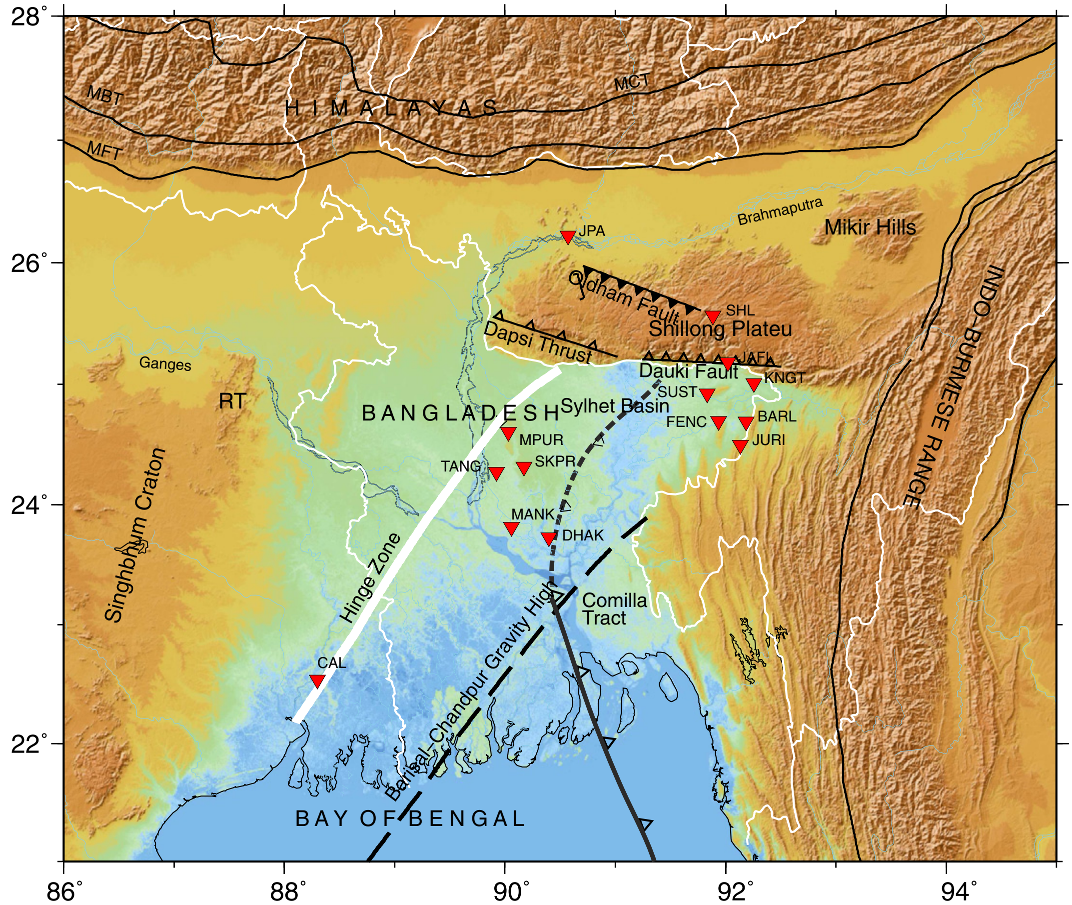

Fig. 1. Tectonic setting and location of broadband seismic stations (inverted triangle) from the Bengal Basin and surrounding region. Faults and other tectonic features, such as the Hinge Zone and Barisal–Chandpur gravity high, are from published sources (Steckler et al., 2008; Alam et al., 2003). The possible thrust front of Comilla tract and its possible extension towards the NE are taken from Steckler et al. (2008). MFT: Main Frontal Thrust; MBT: Main Boundary Thrust; MCT: Main Central Thrust; RT: Rajmahal Traps.

accommodated by the Sagaing Fault (Maurin and Rangin, 2009). Some of the rest is absorbed by faults within the foldbelt, such as the Churachandpur–Mao Fault (Gahalaut et al., 2013). Recent GPS results indicate a convergence rate of 13–17 mm/y in addition to the partitioned shear motion (Steckler et al., submitted for publication). The subduction of the thick strata of the Bengal Basin has built a 250 km wide accretionary prism that extends almost half way across the basin (Steckler et al., 2008). Its front is blind, buried by the Ganges–Brahmaputra Delta sediments.

The Shillong plateau overthrusts the Bengal Basin from the north, depressing the Sylhet Basin (Johnson and Nur Alam, 1991; Najman et al., 2012). The plateau is a large anticlinorium floored by Archean and Proterozoic basement rocks with remnants of the passive margin strata on its steep southern face. The evolution of the Shillong plateau as "pop up tectonics" has been much discussed (Bilham and England, 2001; Kayal et al., 2012), but lacks geophysical observations (apart from seismicity) which may define the structure and mechanism at greater depths (>10 km). The southern side of plateau is demarcated by Dauki thrust fault (Fig. 1), responsible for accommodating part of the shortening between the Himalaya and India (Bilham and England, 2001; Vernant et al., 2014). However the nature of deformation, which includes dextral convergent motion between Shillong and the IndoBurman foldbelt requires more knowledge and understanding. The great Assam earthquake, which occurred on 12 June 1897 (Mw = 8.1, Bilham and England, 2001), affected this region. However, the source of Assam Earthquake has been attributed to multiple faults around the Shillong plateau including the Dauki, Dapsi and Oldham Faults (Fig. 1, Oldham, 1899; Kayal and De, 1991; Bilham and England, 2001).

Most geophysical investigations from the northeast India collision zone are concentrated on either north or further northeast of the Shillong plateau (Singh et al., 2015). The southern side of the Shillong plateau and Bengal Basin are poorly resolved regions due to lack of seismic stations from Bangladesh. To understand the nature and character of faults within the continents with ability to create great earthquakes is of prime concern. The pop up model requires a mechanism where steeply dipping Dauki and Oldham faults bound the popped up structure from south and north respectively. The faults are expected to cross at crustal levels beneath the Shillong plateau with possible slips on Oldham fault extending from 9 to 40 km and dipping SSW at 57° (Bilham and England, 2001). With further constraints on geometry of Oldham fault (dip and depth) based on the extent of exposed basement and sedimentary rocks having a lack of sedimentary deposits surrounding the plateau, it is viewed as a backthrust to a master north-dipping fault based at depth (Clark and Bilham, 2008). Earlier considerations of a 5 to 10° dip on the Dauki Fault require few tens of kilometers of horizontal tectonic transport to attain the present elevation of the Shillong plateau (Johnson and Nur Alam, 1991). These observations lack the information about geometry of faults at depths and are supported with observations with meagre datasets from Bengal Basin.

Previous geophysical studies from the Bengal Basin do not contribute much to the estimation of its sedimentary thickness and nature of the crust beneath Bengal Basin. The gravity modelling across various profiles accounted for a thinner crust (~30 km) with thicker sedimentary deposits (>7 km) (Khan and Agarwal, 1993; Rajasekhar and Mishra, 2008). Sylhet, a complex sub-basin in Bangladesh has been traced through various seismic lines due to hydrocarbon prospects in the region. Stratigraphic reconstructions involving seismic data have