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Crustal shear-wave velocity structure beneath Sumatra from receiver function modeling

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ABSTRACT

We estimated the shear-wave velocity structure and Vp/Vs ratio of the crust beneath the Sumatra region by inverting stacked receiver functions from five three-component broadband seismic stations, located in diverse geologic setting, using a well known non-linear direct search approach, Neighborhood Algorithm (NA). Inversion results show significant variation of sediment layer thicknesses from 1 km beneath the backarc basin (station BKNI and PMBI) to 3–7 km beneath the coastal part of Sumatra region (station LHMI and MNAI) and Nias island (station GSI). Average sediment layer shear velocity (Vss) beneath all the stations is observed to be less (~1.35 km/s) and their corresponding Vp/Vs ratio is very high (~2.2–3.0). Crustal thickness beneath Sumatra region varies between 27 and 35 km, with exception of 19 km beneath Nias island, with average crustal Vs ~3.1–3.4 km/s (Vp/Vs ~1.8). It is well known that thick sediments with low Vs (and high Vp/Vs) amplify seismic waves even from a small-magnitude earthquake, which can cause huge damage in the zone. This study can provide the useful information of the crust for the Sumatra region. Since, Sumatra is an earthquake prone zone, which suffered the strong shaking of Great Andaman–Sumatra earthquake; this study can also be helpful for seismic hazard assessment.

1. Introduction

The Sumatra region, one of the most seismically active zones on earth, has produced three of the largest mega-thrust earthquakes in the past decade along different segments, the 26th December 2004, devastating Andaman–Sumatra earthquake of Mw ~9.1; the 28th March 2005, Nias earthquake of Mw ~8.7 (Ammon et al., 2005; Lay et al., 2005; Konca et al., 2007; Lange et al., 2010; Harmonn et al., 2012) and the 12th September 2007, Benkulu earthquake of Mw ~8.5 (Konca et al., 2008). These great earthquakes have ruptured most of the segments of the fault that have produced earthquakes of similar magnitude over the past 300 years, except one remaining segment of the fault, centered on Siberut Island. This segment produced an earthquake of Mw > 8.7–8.9 in 1797 but has not ruptured since (Chlieh et al., 2008).

Many of the techniques for quantifying seismic hazards, such as ground-motion simulations and earthquake locations, require realistic earth models as an input (Magistrale et al., 2000). However, very little is known about the crustal and upper mantle shear wave velocity structure of the whole region from global surface wave studies with very poor resolution (Ritzwoller et al., 2002).

For the Sumatra region, velocity data is available in the form of low-resolution global data sets such as CRUST1.0 (Laske et al., 2013). In recent years extensive reflection seismic studies in the region were carried out by different researchers, namely, Kopp et al. (2001), Singh et al. (2008), and Franke et al. (2008) to image the uppermost crust (10–20 km) of offshore Sumatra, the previously published receiver function study by Kieling et al. (2011), Macpherson et al. (2012), and ambient noise study by Harmonn et al. (2012). In addition to these studies, an effort has been made for details investigation of shear-wave velocity structure beneath the Sumatra region by applying Receiver Function (RF) analysis to the new data set recorded at five broadband seismographs (Fig. 1). The additional dataset presented in this paper provides new information constraining shear-wave velocity structure beneath the study region.

2. Geologic and tectonics

The island of Sumatra lies along the southwestern boundary of the Sunda Craton (Sundaland), forming an Andean continental margin (Fig. 1) (Milsom, 2005). The geology of the region is characterized by forearc and backarc basins associated with the subduction front. These basins are filled primarily with sedimentary and volcanic material of Tertiary age (Barber et al., 2005). Pre-

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