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SH wave structure of the crust and upper mantle in southeastern margin of the Tibetan Plateau from teleseismic Love wave tomography

Yuanyuan V. Fu[a,*], Ruizhi Jia[b], Fengqin Han[c], Anguo Chen[a]

[a] Institute of Earthquake Forecasting, China Earthquake Administration, Beijing, China
[b] Peking University, Beijing, China
[c] Hebei University of Engineering, Handan, Hebei, China

ABSTRACT

The deep structure of southeastern Tibet is important for determining lateral plateau expansion mechanisms, such as movement of rigid crustal blocks along large strike-slip faults, continuous deformation or the eastward crustal channel flow. We invert for 3-D isotropic SH wave velocity model of the crust and upper mantle to the depth of 110 km from Love wave phase velocity data using a best fitting average model as the starting model. The 3-D SH velocity model presented here is the first SH wave velocity structure in the study area. In the model, the Tibetan Plateau is characterized by prominent slow SH wave velocity with channel-like geometry along strike-slip faults in the upper crust and as broad zones in the lower crust, indicating block-like and distributed deformation at different depth. Positive radial anisotropy ($V_{SH} > V_{SV}$) is suggested by a high SH wave and low SV wave anomaly at the depths of 70–110 km beneath the northern Indochina block. This positive radial anisotropy could result from the horizontal alignment of anisotropic minerals caused by lithospheric extensional deformation due to the slab rollback of the Australian plate beneath the Sumatra trench.

1. Introduction

Regional investigation of the lithospheric structure in southeastern margin of the Tibetan Plateau dates back over 25 yr (e.g. Liu et al., 1989), since it is a unique place to study the interaction between the collision of the Burma microplate and Eurasian plate and the eastward or southeastward extrusion of material from the central and eastern part of the plateau (Fig. 1). Refraction studies have been conducted across some large strike-slip faults (e.g. Kan and Lin, 1986; Xiong et al., 1993). Receiver functions have provided valuable constraints on crustal thickness, which decreases gradually from the Tibetan Plateau to the northern part of the Indochina block (NIB) and the Yangtze craton (e.g., Xu et al., 2007). Seismic tomographic models suggest that significant lithospheric heterogeneity exists (Huang et al., 2002; Li et al., 2008; Yao et al. 2008; Lei et al., 2009; Huang et al., 2015; Yang et al., 2015). Body wave (Li et al., 2008; Huang et al., 2015) and surface wave tomography (Yang et al., 2015) both reveal extensive slow velocity in the upper mantle beneath the Tengchong volcano (TV), northern part of the Indochina block (NIB) and the eastern Yangtze craton (EYC). However, the interpretations for the anomaly are not consistent among these studies. Huang et al. (2015) interpreted the low velocity anomaly as the extruded mantle flow from the Tibetan Plateau and proposed the mantle extrusion in southeast Tibet. In contrast, Li et al. (2008) and Yang et al. (2015) suggested that the low velocity of TV was related to the subduction beneath the Burma arc. For the west of the Yangtze craton (WYC), there are different features in several models. Li et al. (2008) found fast upper mantle P wave velocity in the WYC. Yao et al. (2008) also imaged a similar fast velocity in the WYC from Rayleigh wave tomography. However, Huang et al. (2015) observed a low velocity anomaly of P wave in the upper mantle of the WYC. The main difference among these studies is the geometry of the velocity anomaly. More information is needed to constrain the anomaly.

Surface wave tomography has been widely used to determine the structure of the Earth on both global and regional scales (e.g. Ritzwoller et al., 2002; Bensen et al., 2009; Fu et al., 2010). Most of these studies have concentrated exclusively on Rayleigh wave. The relative weak and complex waveform of Love wave and correspondent method restriction result in the limited application of Love wave data. However, Love wave can provide independent information about the subsurface structure, especially the radial anisotropy. Recent studies have shown that the two-plane-wave (TPW) method could also be used for Love wave through some modifications, although it is originally developed for Rayleigh waves (Li and Li, 2015; Fu et al., 2015; 2016). Fundamental mode Love wave amplitude on the transverse component is

* Corresponding author.
E-mail address: fuyuanies@163.com (Y.V. Fu).

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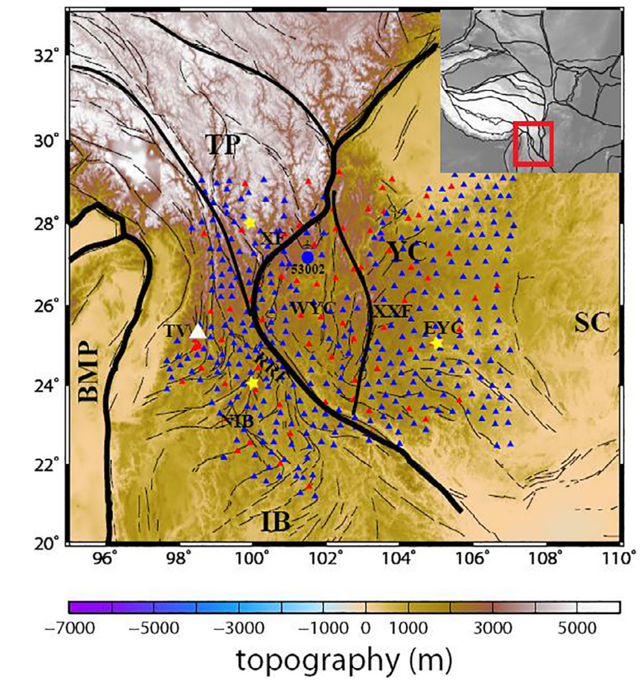

Fig. 1. Map of tectonics and seismic stations in the southeastern Tibetan Plateau. The broadband stations from the temporary ChinArray and the permanent China Digital Seismic Array are indicated by blue and red triangles, respectively. Large white triangle shows the Tengchong volcano (TV). The yellow stars are the locations for the examples in Fig. 5. The blue circle is the station 53202. TP, Tibetan Plateau; BMP, Burma micro-plate; IB, Indochina Block; YC, Yangtze Craton; SC, South China; NIB, northern Indochina Block; WYC, western Yangtze Craton; EYC, eastern Yangtze Craton; RRF, Red River fault; XF, Xiaojinhe fault; XXF, Xianshuihe-Xiaojiang fault.

decomposed to x and y components in a local coordinate system for each earthquake. The modified TPW method provides a new way to measure long period Love wave phase velocity which is inverted for 3-D SH wave velocity model of the upper mantle. The SH wave velocity from Love wave can provide additional constraints on the lithospheric evolution. With the completion of the ChinArray in this region, phase velocity maps of Love wave with high resolution can be developed to better constrain the structure in the crust and uppermost mantle for the southeastern Tibet.

In this study, we extend the work of Han et al. (2017) to SH wave velocity measurement. Han et al. (2017) adopted the modified TPW technique to estimate the Love wave phase velocity at periods of 20–100 s in southeastern margin of the Tibetan Plateau. Fundamental mode Love wave data from the ChinArray which consists of seismic stations at an interval of 35 km combined with the permanent China National Seismic Network is used to construct Love wave dispersion maps on a 0.5° × 0.5° grid. The model presented here is a 3-D volume of isotropic SH wave velocity inverted from the Love wave phase velocity maps (Han et al., 2017). It is the first time to obtain the SH velocity in the upper mantle with high resolution in southeastern margin of the Tibetan Plateau. This new model will provide useful information to estimate the radial anisotropy in the upper mantle and to constrain the deformation mechanism for the southeastern Tibet.

2. Data and method

Phase velocity maps at each period are inverted from the amplitude and phase of fundamental mode Love wave recorded by the stations shown in Fig. 1 (Han et al., 2017). The modified TPW method is used to simultaneously solve for the incoming wave field and phase velocity. The 1-D average phase velocities at 12 periods from 20 to 100 s are

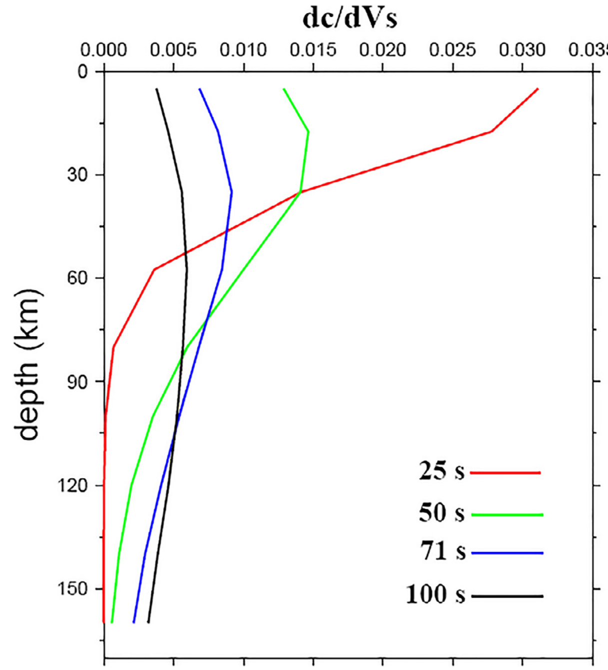

Fig. 2. Sensitivity kernel for Love wave phase speeds at periods of 25, 50, 71, and 100 s. The kernels are calculated based on the shear wave velocity model AK135 (Kennett et al., 1995) using the method of Saito (1988).

determined and then used as initial models in obtaining the 2-D phase velocities with the grid interval of 0.5° in the center and 0.75° at the edge. The standard deviation of phase velocity at each grid is calculated from the model covariance matrix. The resulting bandwidth of Love wave phase velocity measurements has the sensitivity to SH wave velocity from the surface to a depth of ∼150 km in the upper mantle (Fig. 2).

Phase velocities provide integrated information over a broad depth range (Fig. 2). We take a two-step inversion of Love wave phase velocity for 3-D SH wave velocity structure. We first obtain the 1-D average SH wave velocity model from the average phase velocity dispersion curve. Then, we invert phase velocities at each grid point to obtain 3-D SH wave velocity, taking the 1-D average SH wave velocity model as the initial model.

Since the inversion is somewhat non-linear and highly underdetermined due to the limitations of Love wave vertical resolution, the resultant model depend strongly on the initial model. In order to obtain an appropriate initial model for the 1-D inversion, we modified the AK135 reference model (Kennett et al., 1995) based on previous regional models in the study area (Bao et al., 2015; Huang et al., 2015) as the initial model. It contains 16 layers from the surface to 410 km depth with a three-layer crust. The crustal thickness is constrained from receiver functions (Li et al., 2014) and kept as a constant during the inversion since it has a very small effect on the velocity (Fu et al., 2016). We only invert shear wave velocity for each layer. P wave velocity is scaled to shear wave velocity with a constant V_P/V_S ratio of 1.73. The density does not change in the inversion since its effect on Love wave phase velocity is too small. The layer thickness ranges from 10 to 50 km. The model parameters are slightly damped by assigning prior standard deviations in the diagonal terms of model covariance matrix. A general estimate of these values can be made based on the results obtained from previous inversions of fundamental mode surface wave data. Yu and Mitchell (1979) found that the standard deviation of the velocity structure is on the order of 0.02–0.06 km/s depending on the ray path coverage. Since there are quite few earthquakes from west, we choose to use a conservative value of 0.05 km/s as the errors in shear wave velocity. The correlation between two different depths plays an