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Plate interactions, crustal deformation and magmatism along the eastern margins of the Tibetan Plateau

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ABSTRACT

In order to investigate the deep structure and dynamics of the triangular colliding system of the eastern Tibetan Plateau (TP), as well as the Yangtze Platform and the Qinling-Dabie Fold Belt, a large number of P- and S-wave arrival times from both local and teleseismic earthquakes were used to generate high-resolution tomographic images beneath the eastern margins of TP. The results of this study show that the western margin of the Minjiang fault is characterized by low velocity (low-V) anomalies in sharp contrast to the high velocity (high-V) anomalies that are derived from the eastern part. This means that the Minshan uplift zone is imaged as high-V and acts as a barrier to the eastward escape crustal flow, which leads to obvious segmentation of the Longmenshan fault (LMSF) zone between velocity belts that are concatenated into the Minjiang fault. Because high-V anomalies are clearly imaged in this study to extended depths of ca. 450 km, we consider the Yangtze Platform (containing the Sichuan Basin) to comprise craton-like lithosphere. This study reveals the presence of a low-V belt extending to a depth of ca. 250 km between the Sichuan basin and the Ordos Block which probably represents the migration pathway of upwelling asthenosphere materials from Tibet. At the same time, low-V zone with a downdip depth of ca. 500 km accompanied by an approximately 400 km rectangular high-V body is imaged under the Tengchong volcano. We interpret the high-V body and the low-V zone as evidence for the subducted Indian plate and the volcanic magma source, respectively. The results of this study reveal a number of new features of structural heterogeneities relative to deep coupling between the Tibet and the Yangtze platform, as well as the relationship between the Sichuan Basin and the Ordos Block, and the original source of the Tengchong volcano. The results presented here enable us a better understanding of the plate interaction, crustal deformation, and magmatism of the Tengchong volcano along the eastern margins of TP.

1. Introduction

Continental collision and convergence between the Indian and Eurasian plates led to the uplift of the TP, associated crustal thickening, and extruded the substance from the TP to the Southeast. This tectonic region therefore exhibits a complicated fracture and fold system and is characterized by high seismic activity along the eastern margin of the TP (Fig. 1). Subsequent to collision between the Indian and Eurasian plates, the TP, a region often referred to as the 'roof of the world', began to form approximately 50 million years ago (Royden et al., 2008; Clark et al., 2005; C.Y. Wang et al., 2010; Z. Wang et al., 2010). As a result of the subduction of Indian Plate lithosphere under this plateau, a highland was uplifted and developed; the lithosphere of this region is therefore strongly deformed and has a crustal thickness that is twice that of normal crust, while adjacent blocks also played an important role in uplift and movement (Tapponnier et al., 2001; C.Y. Wang et al., 2010; Z. Wang et al., 2010). The region discussed here thus comprises a complicated junctional zone with strong interactions between the eastern TP and several other relative fold systems and blocks (Fig. 1). As this region is a key area for studying and exploring the remote effects of the collision between the Indian and Eurasian plates, we consider that the high-resolution seismic structures of the crust and upper mantle within this area have key implications for plate interactions and crustal deformation accompanying large crustal seismicity, activity, and magmatism.

The eastern margins of TP are characterized by complex topography and tectonic structures as several tectonic blocks interact with each other in this region leading to a large number of almost north-south trending strike slip faults (Fig. 1). The main tectonic blocks within this system include the Ordos Block, the Qilian Fold System, the Qinling-Dabie Fold Belt, the Songpan-Ganzi Block, the Sichuan Basin, the Chuan-Dian Fragment, and the Yangtze Platform. There are also a

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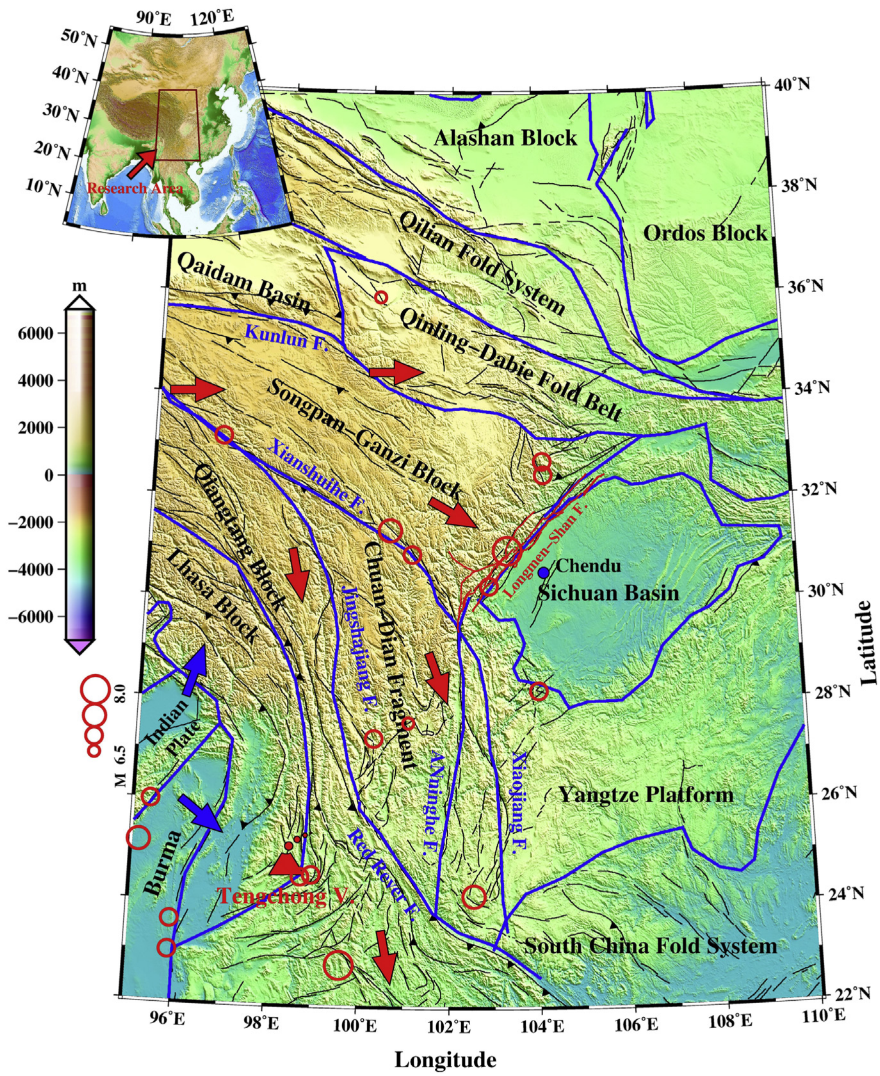

Fig. 1. Tectonic background and topographic relief of the eastern Tibet. Red circles represent the large historic earthquakes (M > 6.5) in the past five decades. Blue solid lines show the main tectonic boundaries and sutures. Black solid lines indicate the active faults in the region. Red solid lines show the faults along the LMSF zone. Possible lower crustal flow and Indian plates are labeled by red and blue arrows respectively. Magnitude scale of the earthquakes and map colour standard are shown on the left. The red box in the inset map shows the present study region. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

number of active faults in this region, including the Minjiang Fault, the Xianshuihe Fault, the Longmenshan Fault (LMSF), the Anninghe Fault, the Xiaojiang Fault, and the Red River Fault. In addition, a young modern volcano, Tengchong, is also located on the Indochina Block in southeastern Tibet (Fig. 1). A number of previous geophysical studies have shown that the eastern margins of the TP provide an important channel for material extruding from this plateau (Bai et al., 2010; Wang et al., 2011, 2012; Hu et al., 2017), while along the eastern margins of TP, strong mountain building and active faulting have resulted in strong crustal deformation and frequent intense earthquake activity, such as the 2008 Wenchuan and the 2013 Lushan earthquakes within the LMSF zone and the 2017 Jiuzhaigou earthquake.

The rapid development of seismic networks in this region over the last decade has provided us with an opportunity to determine the high-resolution structures under the eastern margins of TP using seismic tomography. Numerous geophysical studies have been carried out in this region and have focused on the inversion of the lithosphere and associated deep structures since 2000. Although artificial deep seismic explorations have revealed crustal and upper mantle velocity structures across the eastern margins of this plateau, these studies have been limited by the anomalous morphology of velocity structures in both the crust and uppermost mantle (Liu et al., 2006; Wang et al., 2007; Z. Wang et al., 2009; C.Y. Wang et al., 2009; X.B. Wang et al., 2009; Zhang et al., 2011). Nevertheless, local seismic and teleseismic tomography (Wang et al., 2003; Huang and Zhao, 2006; Z. Wang et al., 2009; C.Y. Wang et al., 2009; X.B. Wang et al., 2009; C.Y. Wang et al., 2010; Z. Wang et al., 2010; Lei et al., 2009; Lei and Zhao, 2016) as well as Pn-wave and surface wave imaging have been used to image crustal and mantle structures at high resolution including revealing the velocity characteristics of each block (Liang and Song, 2006; Li et al., 2011; Huang et al., 2014; Z.W. Li et al., 2014; Y.H. Li et al., 2014; Wang et al., 2015). Background noise tomography has therefore become a common method for studying crustal velocity structures across small areas(Yao et al., 2006, 2008; Yang et al., 2010; Wu et al., 2017), while SKS wave splitting measurement and receive function tomography have also contributed to the study of the eastern margins of TP (Chang et al., 2006; Wang et al., 2013; Li et al., 2009; Xu et al., 2013; Zheng et al., 2016). All these studies have led to a general consensus regarding the successful imaging of the eastern margins of TP and has contributed to a detailed working understanding of the structure and seismotectonics of this region. However, because of the uneven distribution of seismic stations, their spacing, and limitations of travel-time data, previous studies on the TP and adjacent areas have obtained different resolutions. In addition, the vast majority of previous studies have generated just Vp or Vs structures and their resolution has not been high enough to get reveal fine structures along the eastern margins of TP. Thus, in order to visualize both P- and S-wave structures at high-resolution in the crust and upper mantle under the eastern margins of TP, we utilized a denser array of seismic stations and a larger volume of data than previous studies to image and invert local and teleseismic travel times