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Mantle structure and dynamics beneath SE Tibet revealed by new seismic images

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ABSTRACT

The structure and dynamics in SE Tibet are the key to understand the tectonic evolution of the Tibetan Plateau. In this study we determined high-resolution P-wave seismic images in the upper mantle and transition zone in SE Tibet by jointly inverting the travel-time residuals of local events and the relative travel-time residuals of teleseismic events recorded by very dense seismic stations. We revealed a high-velocity body in the upper mantle beneath South China that represents the root of the Yangtze Craton. The high-velocity body extends in the entire Yangtze Craton at 300–450 km depths, but it is constrained just beneath the Sichuan Basin and surrounded by extensive low-velocity zones to the southwest at 65–250 km depths. We propose that the Yangtze Craton is destructed laterally by the mantle flow extruded from the Tibetan Plateau. We obtain a low-velocity column in the upper mantle under the Tengchong volcano as well as the visible high-velocity bodies in the upper mantle and transition zone below the low-velocity column. The images suggest that the Tengchong volcano is closely related to the subduction of the Burma plate and caused by the dehydration of the subducted slab. The present study reveals unprecedented details of the mantle structures beneath SE Tibet and provides new insights into the geodynamics of the Tibetan Plateau and its interaction with the stable Yangtze Craton.

1. Introduction

The tectonic evolution of the Tibetan Plateau has always been the challenge to most geoscientists. Different models have been proposed to explain the development of the Tibetan Plateau under the Indo-Asian collision, such as extrusion of the rigid plates or blocks (e.g., Tapponnier et al., 1982, 2001), continuous deformation of the entire lithosphere (England and Houseman, 1989), and channel flow in the mid-lower crust (e.g., Royden et al., 1997, 2008).

While these models emphasize the deformation in the lithosphere, recent seismic images indicate that the deep structures play important roles in the tectonic evolution of the plateau. Regional tomography confirmed the northward subduction of the Indian lithosphere under south Tibet (e.g., Huang and Zhao, 2006; Li et al., 2008; Wei et al., 2012). Receiver function analysis revealed significantly lateral variation of the subduction from west to east (Zhao et al., 2010). The subducted Indian lithosphere reaches the northern margin of the plateau where it meets the subducted Asian lithosphere in west Tibet, whereas it is generally located to the south of the Bangong–Nujiang suture under east Tibet (Li et al., 2008; Zhao et al., 2010).

Since the initial Indo-Asian collision at ∼55 Ma (Tapponnier et al., 2001), the post-collisional lateral shortening in the Tibetan Plateau may exceed 700 km (e.g., DeCelles et al., 2002). The accompanying northward subduction of the Indian lithosphere largely compresses the asthenosphere under Tibet (e.g., Huang and Zhao, 2006; Li et al., 2008). Thus the material in the asthenosphere must be extruded to keep the balance of the mantle under the plateau, similar to the extrusion of the lithosphere (e.g., Tapponnier et al., 1982, 2001). As one candidate channel for the asthenosphere flow (e.g., Liu et al., 2004), the detailed images of the deep structure are important for understanding the mantle dynamics in SE Tibet.

On the other hand, the Yangtze Craton (part of South China) is a Precambrian block with widespread Archean and Proterozoic basement (e.g., Chen and Jahn, 1998; Zheng et al., 2006). The low

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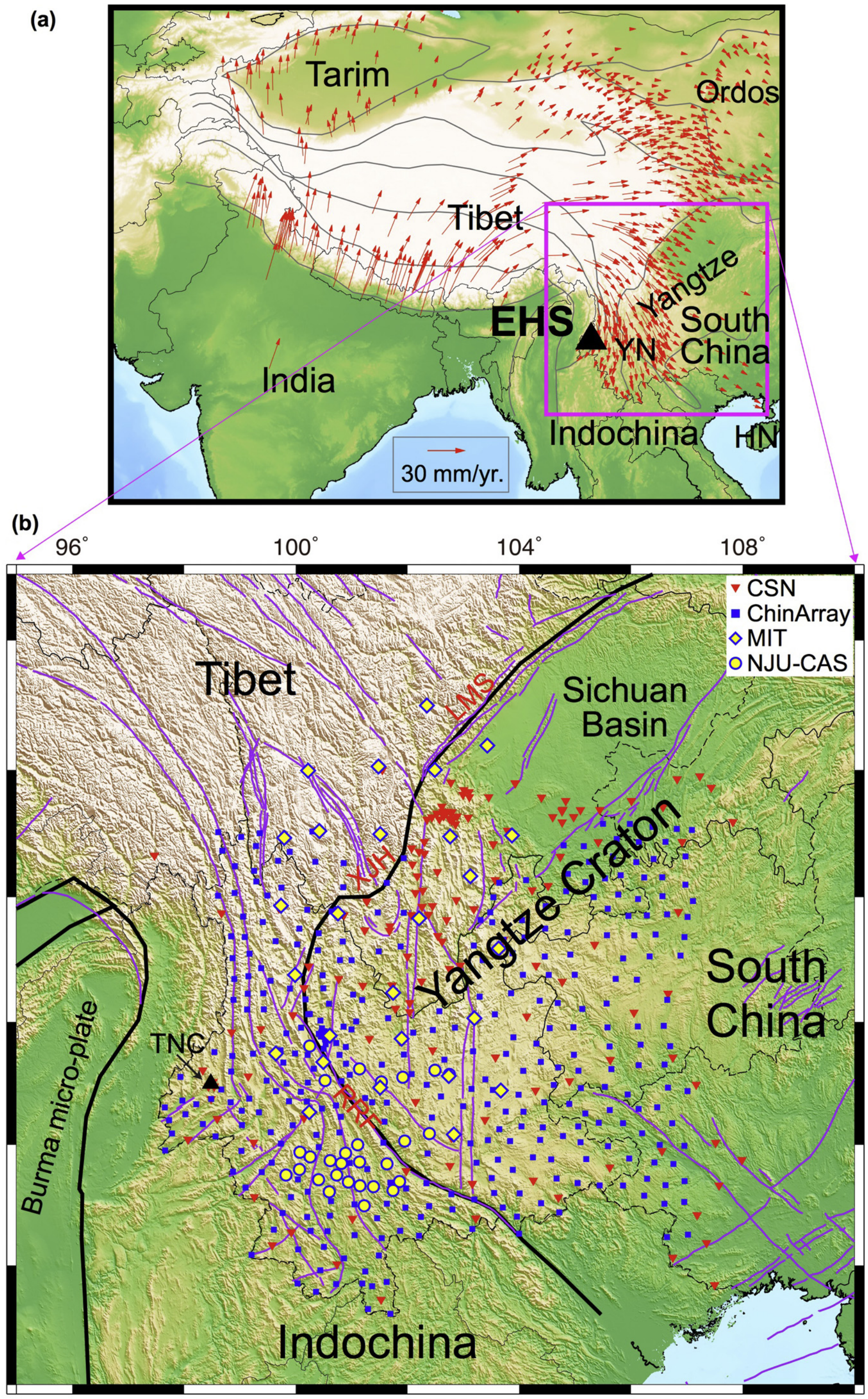

Fig. 1. (a) Tectonics in and around the Tibetan Plateau. The gray curves denote the boundaries between different blocks. Red arrows indicate the crustal motions revealed by GPS observations (Gan et al., 2007). (b) The bold black curves denote the boundary between the major blocks while the purple lines denote the active faults in SE Tibet. The red triangles denote the 163 permanent stations operated by the Chinese Seismic Network (CSN). The blue squares denote the 356 portal stations deployed by the ChinArray program. The yellow diamonds and circles denote the 26 and 29 temporal stations deployed by MIT and Nanjing University (NJU), respectively, during two individual seismic experiments. The abbreviations are: YN, Yunnan; TNC, Tengchong volcano; HN, Hainan; LMS, Longmenshan fault; XJH, Xiaojinhe fault; RRF, Red-River fault. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

heat flow at surface (~40–60 mW/m^2) (Hu et al., 2000; Tao and Shen, 2008) suggests the Yangtze Craton as a very stable block. The west boundary of the craton extends from the Longmenshan (LMS) fault in the north, to the Xiaojinhe (XJH) fault in the middle, and further to the Red-River fault (RRF) in the south (Fig. 1b) (e.g., Zheng et al., 2013). Obviously, the southwest Yangtze Craton has been involved into the tectonic evolution of SE Tibet (e.g., Royden et al., 1997, 2008) while the characteristics of a stable craton could only be identified in Sichuan Basin from surface geology. However, it is still unclear how the deep part of the Yangtze Craton was affected (or destructed) by the active tectonics in SE Tibet.

In this study, we picked the P-wave arrival times in the teleseismic waveforms recorded by the dense stations (Fig. 1b) operated by the ChinArray project and another two temporary seismic networks (NJU-CAS and MIT). Then we combined the relative travel-time residuals of the teleseismic events with the local arrival-time data collected by the Chinese Seismic Network (CSN) and obtained the seismic velocity anomalies in the upper mantle and transition