Journal of Asian Earth Sciences 73 (2013) 48–56

Contents lists available at SciVerse ScienceDirect

Journal of Asian Earth Sciences

journal homepage: www.elsevier.com/locate/jseaes

Crustal structure in the Tengchong volcanic area and position of the magma chambers

Haiyan Yang, Jiafu Hu, Yili Hu, Yuanze Duan, Guangquan Li *

Department of Geophysics, Yunnan University, 2 North Green Lake Rd., Kunming, Yunnan 650091, PR China

ARTICLE INFO

Article history:
Received 16 December 2012
Received in revised form 31 March 2013
Accepted 14 April 2013
Available online 27 April 2013

Keywords:
Receiver functions
Tengchong volcanic area
Moho
Poisson's ratio
Magma

ABSTRACT

In this paper, we extract 1500 P receiver functions in the Tengchong volcanic area from 211 teleseismic events recorded at nine digital seismic stations. A common conversion point stacking technique is used to improve the signal-to-noise ratio and to get the time delays of the Ps, PpPs, PsPs + PpSs phases within grids of 10 km × 10 km. Finally, the crustal thickness and Poisson's ratio are calculated. The results show that the crustal thickness ranges from 28 to 40 km and the Poisson's ratio ranges from 0.28 to 0.36. There exist two mantle-uplifting sites each with a horizontal scale of about 30 km × 30 km, one in Mazhan–Tengchong–Maanshan and the other in Wuhe–Longjiang–Tuantian. The high Poisson's ratio is consistently located within these two sites. Recorded shocks with *Ms* > 2.0 reveal that most of the shocks are distributed around the two sites and few are located at the centers. The shocks, the geothermal distribution, and the crustal structure suggest that the magma is still active, and the two mantle-uplifting sites detected may be the positions of two magma chambers in the crust.

1. Introduction

Yunnan is located on the southeast edge of Tibetan Plateau (see the rectangle in Fig. 1). Due to the collision between the Indo-Australian Plate and the Eurasian Plate, this region is mainly affected by the tectonic stress field (Hu et al., 2008) induced by the northeastward collision. The Tengchong volcanic area in western Yunnan (98°15′-98°45′E, 24°40′-25°30′N) is located on the east side of the collision zone, about 300 km away from the east boundary of the Indo-Australian Plate. Volcanoes in Tengchong are widely distributed, forming by the eruptions in different epochs. Wang et al. (2007) suggested that the volcanic eruptions in this area since the Late Pleistocene can be divided into four periods, the first about 5.5–4.0 Ma ago, the second about 3.9–0.9 Ma ago, the third about 0.8–0.1 Ma ago and the latest less than 0.01 Ma. The volcanic activity started in the Miocene of the Tertiary, with a climax in the Late Pleistocene (Mu and Tong, 1987), and there exist only four volcanoes in the Holocene Epoch. According to the analysis from the thermoluminescence dating of volcanic samples, the latest eruption of Maanshan Volcano occurred in the Holocene Epoch, about 2500–3500 years ago (Yin and Li, 2000). Han et al. (1996) thought that a small-magnitude eruption in 1609 recorded in Xiake Xu's travel notes is true. Therefore, Tengchong volcanoes are one of the latest volcanoes in mainland China.

Aiming to explore the rich geothermal resources and to prospect the magma conduits in the Tengchong volcanic area, seismic soundings with active sources (e.g., Wang et al., 2002, 2003; Wang and Huangfu, 2004; Lou et al., 2002), as well as that with passive sources (He et al., 2004; Yang et al., 2011a) have been conducted in the recent years. The results from artificial seismic prospecting (Wang and Huangfu, 2004; Zhang et al., 2005) indicated that there exists an area with a low P-wave velocity in the upper crust, with the lowest velocity concentrated in the northeast of the Hot Sea (near the RH station; see Fig. 1) where hot springs and hot ponds are so rich that this place is called the Hot Sea. The results from tomography indicated that there probably exists a magma chamber (Lou et al., 2002) in Wuhe–Tuantian (Fig. 1). He et al. (2004) used the receiver function technique to invert for the S-wave velocity structure in the crust, and draw a conclusion that the low S-wave velocity in this area is probably related to the geothermal activity. By analyzing the data of magnetotelluric sounding, Bai et al. (1994) thought that there probably exists a magma chamber around the Hot Sea (near the RH station) From the horizontal deformation observations, Li et al. (1998) discovered that there is an obvious ground dilatation around Maanshan and Town of Tengchong, probably related to magma. By analyzing the feature of seismic waveform, Ye et al. (2003) concluded that there exist two magma chambers in the crust, south of the Dayingshan Mountain.

Tomography has achieved a good result in searching for the source of volcanic heat (Zhao et al., 2011). However, because Tengchong volcanoes are distributed in an area of 100 km × 100 km, the achieved tomographic result (Huang et al., 2002; Huang and Zhao,

* Corresponding author. Tel.: +86 87165032983 22.
E-mail address: guangquanli74@gmail.com (G. Li).

1367-9120/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jseaes.2013.04.027

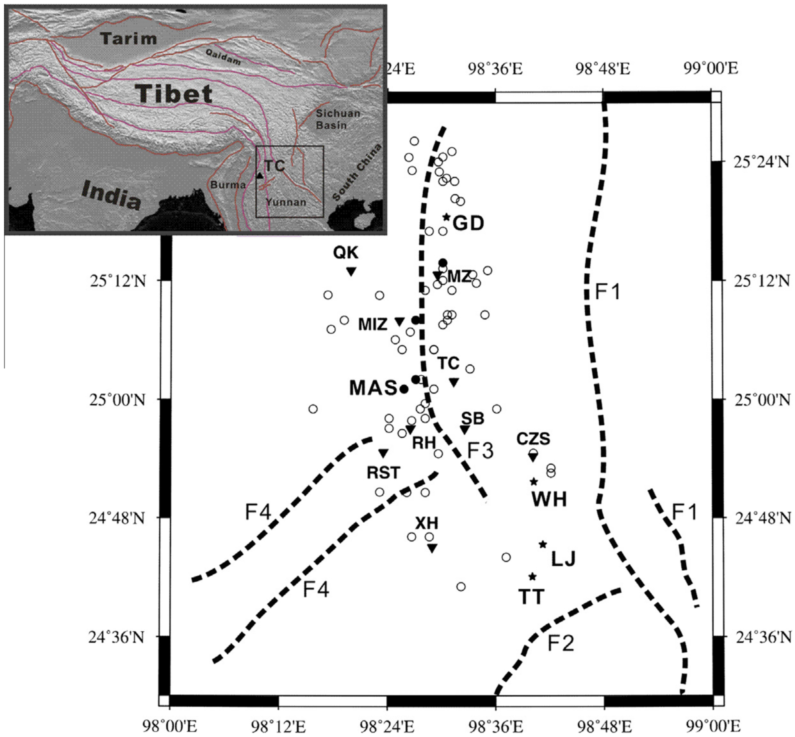

Fig. 1. Distribution of seismic stations and volcanoes in the Tengchong volcanic area. Triangles represent the stations with letters for the names. Circles denote the volcanoes, with the solid ones for those in the Holocene Epoch (from the north to the south) are Maanshan, Laoguipo, Dayingshan and Heikongshan sequentially). Dashed lines represent the faults, F1: Nujiang Fault, F2: Longling–Ruili Fault, F3: Tengchong volcano Fault, F4: Yingjiang–Longchuan Fault. Stars are the places, GD: Gudong, MAS: Maanshan, WH: Wuhe, LJ: Longjiang, TT: Tuantian.

2006; Wang et al., 2003; Wang and Huangfu, 2004; Li et al., 2008; Lei et al., 2009) could not determine the precise position and size of the low velocity area, due to the limitation of resolution.

P-wave receiver function obtained by deconvolution of the vertical component from the radial component of teleseismic waves, can effectively remove the influences from the source function and propagating path. It is especially sensitive to the Ps wave generated by the structure beneath station, thus providing a powerful tool to detect crustal structure (Langston, 1977; Yuan et al., 1997). In the last 5 years, nine digital seismic stations have been deployed in Tengchong, facilitating study of the fine crustal structure. In this paper, we use teleseismic data recorded at the nine stations to reconstruct the distributions of the crustal thickness and Poisson's ratio, as well as to detect the location and size of the magma chambers precisely.

2. Geotectonic background

Tengchong is located between the Indo-Australian Plate and the Eurasian Plate. Its western part is separated from the Burma microplate by the Myitkyina–Mandalay suture, while the eastern part is separated from the Baoshan block by the Nujiang suture (Han et al., 1996; Kan et al., 1996). Driven by the Himalaya movement starting in the Neogene Period, the Tengchong block, acting as the west boundary of the Indochina block, was involved in two strong tectonic movements, and the major faults (i.e., Nujiang Fault, Longling–Ruili Fault, Tengchong Volcano Fault and Yingjiang–Longchuan Fault) are strong right-lateral slips (Wan, 2004). The active faults in the Quaternary Period mainly strike in the north-south direction, or secondarily in the north-east direction.

Magma activity in Tengchong was strong, resulting in an extensive distribution of mid-acid intrusive rocks (Jiang et al., 2000). Due to the continuous pushing by the Indo-Australian Plate, the Burma micro-plate dived beneath Tengchong, which was the origin of the volcano activity (Lei et al., 2009; Zhao and Liu, 2010). The tectonic stress field indicates that Tengchong is under the back-arc extensional environment generated by the subduction of oceanic crust, which caused magma to erupt onto the ground surface along extensional fissures. When the uprising magma channel was blocked, it would produce diapir in the crust, forming the magma chambers (Lei et al., 2009). This makes Tengchong a high-risk area with earthquakes, volcanoes, and hot springs all together.

3. Technical method

Receiver function is especially sensitive to the Ps wave generated by the interface beneath station. Supposing that the Moho is the deepest interface, time delay $t_{Ps} - t_P$ is related to crustal thickness H (Zandt and Ammon, 1995) as follows.

$$H = \frac{t_{Ps} - t_P}{\sqrt{V_s^{-2} - p^2} - \sqrt{V_p^{-2} - p^2}}, \tag{1}$$

where p is ray parameter, and V_p and V_s are velocities of P-wave and S-wave, respectively. Similarly, time difference between the PpPs and the PpSs + PsPs is related to H as follows.

$$H = \frac{2t_{PpPs} - t_{PpSs+PsPs}}{2\sqrt{V_p^{-2} - p^2}}. \tag{2}$$

Thus the velocity ratio takes

$$\frac{V_p}{V_s} = \left\{ \left(1 - p^2V_p^2\right)\left[2\left(\frac{t_{Ps} - t_P}{t_{PpPs} - t_{Ps}}\right) + 1\right]^2 + p^2V_p^2 \right\}^{1/2}. \tag{3}$$

In a horizontally layered uniform media, we have

$$t_{PpSs+PsPs} - t_{PpPs} = t_{Ps} - t_P. \tag{4}$$