Journal of Asian Earth Sciences 116 (2016) 69–80

Contents lists available at ScienceDirect

Journal of Asian Earth Sciences

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

Structure of the mantle transition zone beneath the North China Craton

Shaokun Si [a], Yanpeng Zheng [b], Baohua Liu [a], Xiaobo Tian [c,d,*]

[a] National Deep Sea Center, State Oceanic Administration, Qingdao 266061, China
[b] First Institute of Oceanography, State Oceanic Administration, Qingdao 266061, China
[c] State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China
[d] CAS Center for Excellence in Tibetan Plateau Earth Sciences, Beijing 100101, China

ARTICLE INFO

Article history:
Received 26 June 2015
Received in revised form 17 October 2015
Accepted 13 November 2015
Available online 14 November 2015

Keywords:
North China Craton
Pacific plate subduction
Receiver function
Discontinuous thickening
Mantle transition zone

ABSTRACT

Detailed information on deep structural features can improve current understanding of lithospheric thinning and destruction of the North China Craton. In this study, we analyzed receiver functions (RFs) from teleseismic P waveforms recorded by 246 seismic stations beneath the North China Craton (NCC) to determine the topography of the mantle transition zone (MTZ). The results reveal specific features in the 410 and 660 km discontinuities and outlined MTZ thickness beneath the study area. The MTZ structure shows two anomalously thickened regions beneath the NCC (up to 30–40 km thicker than the global average), which are mainly concentrated in the eastern and western sections of the eastern NCC (ENCC). The thickened regions are discontinuous and separated by a distance of about 400 km. Double 660 km discontinuities also appear in the southeastern ENCC. Combining these results with previous findings, we propose a model in which MTZ thickening is caused by discrete remnants of the subducted western Pacific slab. Discontinuities resulting from the stagnant slabs may retain evidence of changes in the rate of Pacific plate subduction as well as the phase transition of the subducted slabs within the MTZ.

1. Introduction

The North China Craton (NCC) in East Asia consists of two major blocks (Fig. 1), the Western Block (WB) and the Eastern Block (EB), which collided along the Trans-North China Orogen to form a coherent craton at ~1.85 Ga (Santosh et al., 2013; Zhai, 2008; Zhao et al., 2005). The NCC is unusual among existing cratons for its long and complex Phanerozoic evolution, intensive contemporary tectonism, high heat flow (Hu et al., 2000) and frequent intra-plate earthquakes (Liu et al., 2007). The NCC also contains classic evidence for the destruction of an ancient craton, which was stable from its formation until the Early Mesozoic (Menzies et al., 1993). The mechanism that caused the destruction of this craton remains controversial however. Previous studies have advocated lithospheric delamination (Deng et al., 2004, 2007; Gao et al., 2002, 2004; Wu et al., 2005), thermo-chemical erosion (Fan and Menzies, 1992; Fan et al., 2000; Griffin et al., 1998; Menzies et al., 2007; Xu, 2001; Zheng et al., 2006) or hydrolytic weakening of the subcontinental lithosphere (Niu, 2005, 2006). Recent research has suggested that the destruction of the eastern NCC (ENCC) was closely linked to subduction of the Pacific plate beneath East Asia (Xu et al., 2009; Zhao et al., 2007, 2009; Zhu et al., 2011, 2012a, 2012b; Zhu and Zheng, 2009). The formation and evolution of shallow structural features appear to be closely related to deep-level structural activity. For example, the collision between the Indian plate and the Asian plate causing the uplift of the Tibetan plateau (Allégre et al., 1984; Yin and Harrison, 2000); the mantle plume forming the Hawaii-Emperor seamounts (Tarduno et al., 2003; Wilson, 1963). Therefore understanding the extent to which deep-level structural activity influenced the destruction of the NCC requires more detailed knowledge of the structure and properties of the deep mantle beneath the NCC. The structural features in and around the MTZ are particularly crucial to this understanding, due to their role in linking the upper and lower mantle.

The 410 and 660 km seismic discontinuities that define the upper and lower boundaries of the MTZ represent phase transitions from olivine to wadsleyite (410 km) and from ringwoodite to perovskite + magnesiowustite, (660 km) (Ito and Takahashi, 1989; Jackson, 1983; Ringwood, 1968). An important characteristic of these phase transitions is the Clapeyron slope, the temperature derivative of the pressure at which the transition occurs. The olivine to wadsleyite Clapeyron slope is positive (Helffrichl, 1994; Katsura and Ito, 1989), meaning that a low-temperature anomaly causes local elevation of the 410 km discontinuity. Conversely, a high-temperature anomaly can cause local depression of the

* Corresponding author at: No. 19, Beitucheng Western Road, Chaoyang District, China.
E-mail address: txb@mail.iggcas.ac.cn (X. Tian).

http://dx.doi.org/10.1016/j.jseaes.2015.11.006
1367-9120/

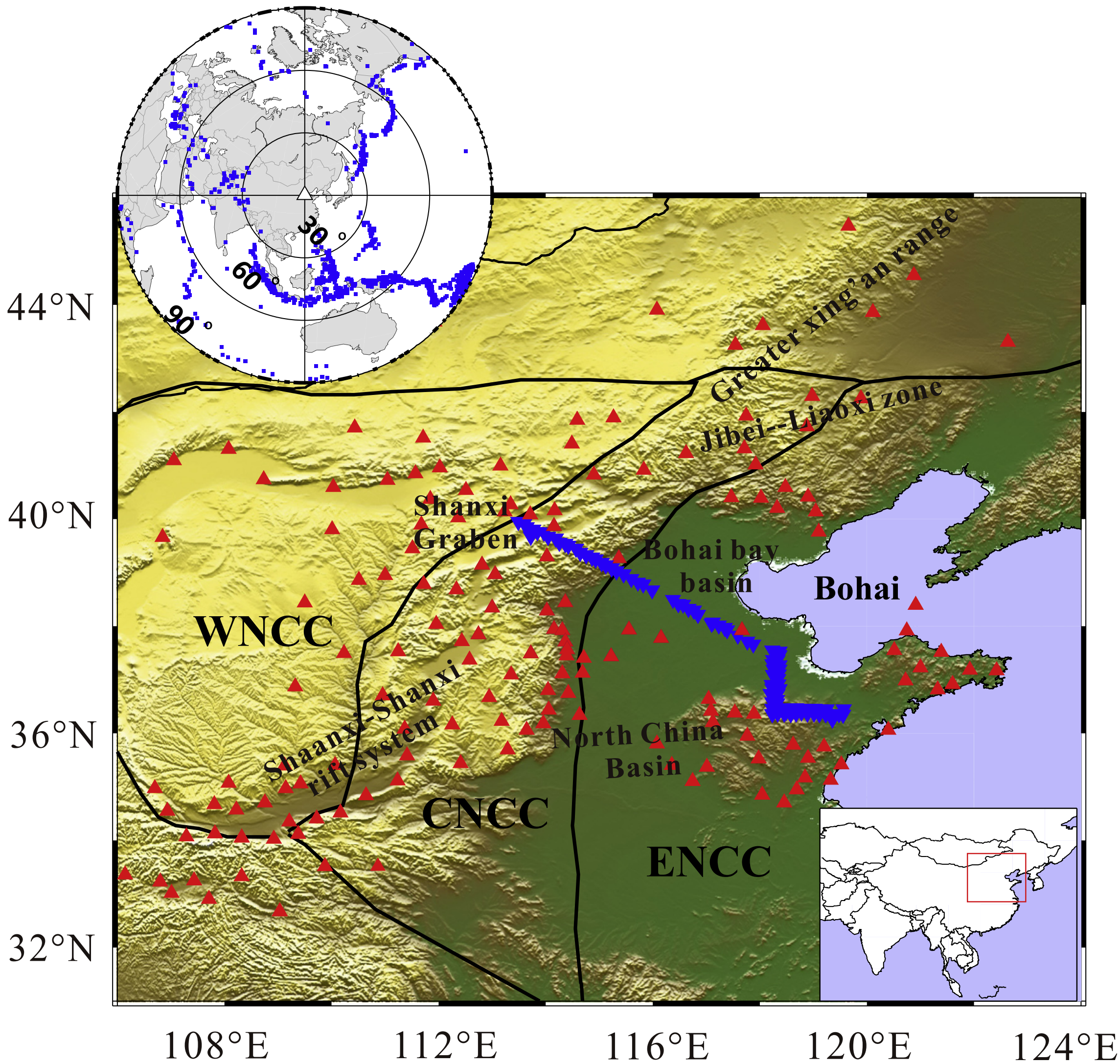

Fig. 1. Topographic map of the study area showing tectonic province and the distribution of seismic stations used. Thick lines denote the boundaries of Eastern, Western and Central NCC (ENCC, WNCC and CNCC); Red triangles and blue inverse triangles denote the permanent and temporary stations, respectively. The inset in the top-left corner shows the epicenters of the earthquakes used in the study, and the white triangle denotes the center of the study area; the inset in the bottom-right corner shows the location of the study area. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

410 km discontinuity. The ringwoodite to perovskite + magnesiowustite Clapeyron slope is negative (Bina and Helffrichl, 1994; Ito and Takahashi, 1989), which implies depression of the 660 km discontinuity in a low-temperature environment and elevation under high-temperature conditions. Given the respective positive and negative Clapeyron slopes of these two phase transitions, relatively low temperatures would elevate the 410 km discontinuity and depress the 660 km discontinuity. The apparent thickening of the MTZ associated with these features is typical of subduction zones (Chen and Ai, 2009; Li et al., 2000). In contrast, relatively high temperatures would result in a thinner MTZ, resembling a feature such as a deeper mantle plume (Fee and Dueker, 2004; Shen et al., 1998). Lateral variations in discontinuity depths thus provide information on lateral temperature variations in the MTZ. The topography of the 410 and 660 km discontinuities as well as the MTZ thickness constrain the upper mantle temperature regime and help link mantle dynamics to regional tectonics (Lebedev et al., 2002; Owens et al., 2000; Revenaugh and Jordan, 1991).

Numerous studies have used receiver function analysis and tomography to image the North China region (Ai et al., 2003; Chen, 2009, 2010; Chen et al., 2006, 2014; Fukao et al., 2001; He, 2014; Huang and Zhao, 2006; Lei, 2012; Li and Yuan, 2003; Tian and Zhao, 2011; Tian et al., 2009; Xu and Zhao, 2009; Zhao et al., 2007). The crustal thickness of the NCC generally increases from east to west. The thickness is about 25–35 km beneath the eastern plains area, 35–40 km beneath the central NCC and 40–42 km beneath the Ordos block, to the west. The NCC's lithospheric thickness is highly variable. A significantly thinned lithosphere (60–100 km) exists beneath the ENCC, having an average depth of 80 km around the Bohai Bay Basin. By contrast, the central and western NCC have both a vestigially thickened and dramatically attenuated lithosphere (Chen, 2009; Chen and Ai, 2009). Tomographic images show that high velocity anomalies, reaching thicknesses of over 100 km, overlie the 410 km discontinuity just beneath a relatively thin section of the lithosphere. This indicates that lithospheric delamination occurred in localized areas rather than throughout the ENCC (Xu and Zhao, 2009). Two prominent low velocity anomalies also appear beneath ENCC (Tian et al., 2009), which may indicate asthenospheric upwelling associated with on-going subduction of the Pacific plate. Both global and regional tomographic imaging results reveal a horizontally