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Local modification of the lithosphere beneath the central and western North China Craton: 3-D constraints from Rayleigh wave tomography

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ABSTRACT

We have imaged the lithospheric structure beneath the central and western North China Craton (NCC) with Rayleigh wave tomography. The Rayleigh waveforms of 100 teleseismic events recorded by 208 broadband stations are used to yield high-resolution phase velocity maps at 13 periods from 20 s to 143 s. A 3-D S-wave velocity model is constructed based on the phase velocity maps. Our S-wave velocity model is broadly consistent with the results of previous tomography studies, but shows more detailed variations within the lithosphere. The Trans-North China Orogen (TNCO) is generally characterized by low-velocity anomalies but exhibits great heterogeneities. Two major low-velocity zones (LVZs) are observed in the north and south, respectively. The northern LVZ laterally coincides with sites of Cenozoic magmatism and extends to depths greater than 200 km. We propose that a small-scale mantle upwelling is present, confined to the north of the TNCO. A high-velocity patch in the uppermost mantle is also observed between the two LVZs adjacent to the narrow transtensional zone of the Cenozoic Shanxi–Shaanxi Rift (SSR). We interpret this as the remnant of a cratonic mantle root. The Ordos Block in the western NCC is associated with high-velocity anomalies, similarly reflecting the existence of cratonic mantle root, but a discernible low-velocity layer is observed at depths of 100–150 km in this location. We interpret that this mid-lithospheric structure was probably formed by metasomatic processes during the early formation of the NCC. Based on the observations from our S-wave velocity model, we conclude that the current highly heterogeneous lithospheric structure beneath the TNCO is the result of multiphase reworking of pre-existing mechanically weak zones since the amalgamation of the craton. The latest Cenozoic lithospheric reworking is dominated by the far-field effects of both Pacific plate subduction and the India–Eurasia collision.

1. Introduction

The North China Craton (NCC) is traditionally divided into two major Archean blocks, namely the Eastern Block (EB) and the Western Block (WB), separated by a Paleoproterozoic orogen called the Trans-North China Orogen (TNCO) or the Central Orogenic belt (Fig. 1) (Zhao et al., 2001; Kusky and Li, 2003; Zhao et al., 2005; Santosh, 2010). The whole craton was tectonically stable until the Middle Ordovician (e.g., Menzies et al., 1993; Griffin et al., 1998; Gao et al., 2002). From the Ordovician to Cenozoic, the cold, thick and refractory lithosphere of the EB was intensively reactivated and destructed, and has been replaced by a hot, thin and fertile lithosphere (e.g., Fan and Menzies, 1992; Menzies et al., 1993; Griffin et al., 1998; Fan et al., 2000; Xu, 2001; Wu et al., 2005; Chen et al., 2006; Menzies et al., 2007; Chen et al., 2008; Wu et al., 2008; Zhang et al., 2011; Zhang, 2012). In contrast, the central and western NCC remains stable and exhibits sparse magmatism, relatively low heat flow (J.Y. Wang et al., 1996; Hu et al., 2000), and generally thick crust (Ma, 1989; Li et al., 2006; Chen et al., 2010; Wei et al., 2011) and lithosphere (Chen et al., 1991; Zhu et al., 2002). These remarkable tectonic contrasts make the NCC unique amongst cratons worldwide, and ideal for studying the stabilization and destruction of old cratons.

Previous research interest in the NCC has primarily focused on the lithospheric architecture of the EB due to the abundant petrological and geochemical data derived from its widespread suites of xenoliths and xenocrysts (e.g., Menzies et al., 1993; Griffin et al., 1998; Fan et al., 2000; Xu, 2001; Wu et al., 2005; Menzies et al., 2007; Zhang et al., 2011; Zhang, 2012). Subsequent geophysical investigations (e.g., Chen et al., 2006; Zhao et al., 2007; Chen et al., 2008; Zheng et al., 2008a,b; Chen, 2009; Li et al., 2009) have provided important constrains on the spatial extent of lithospheric thinning and destruction. In combination with multidisciplinary observations, several model, including the deep subduction of the Paleo-Pacific plate (Griffin et al., 1998; Wu et al., 2003; Sun et al., 2007), collision of an amalgamated

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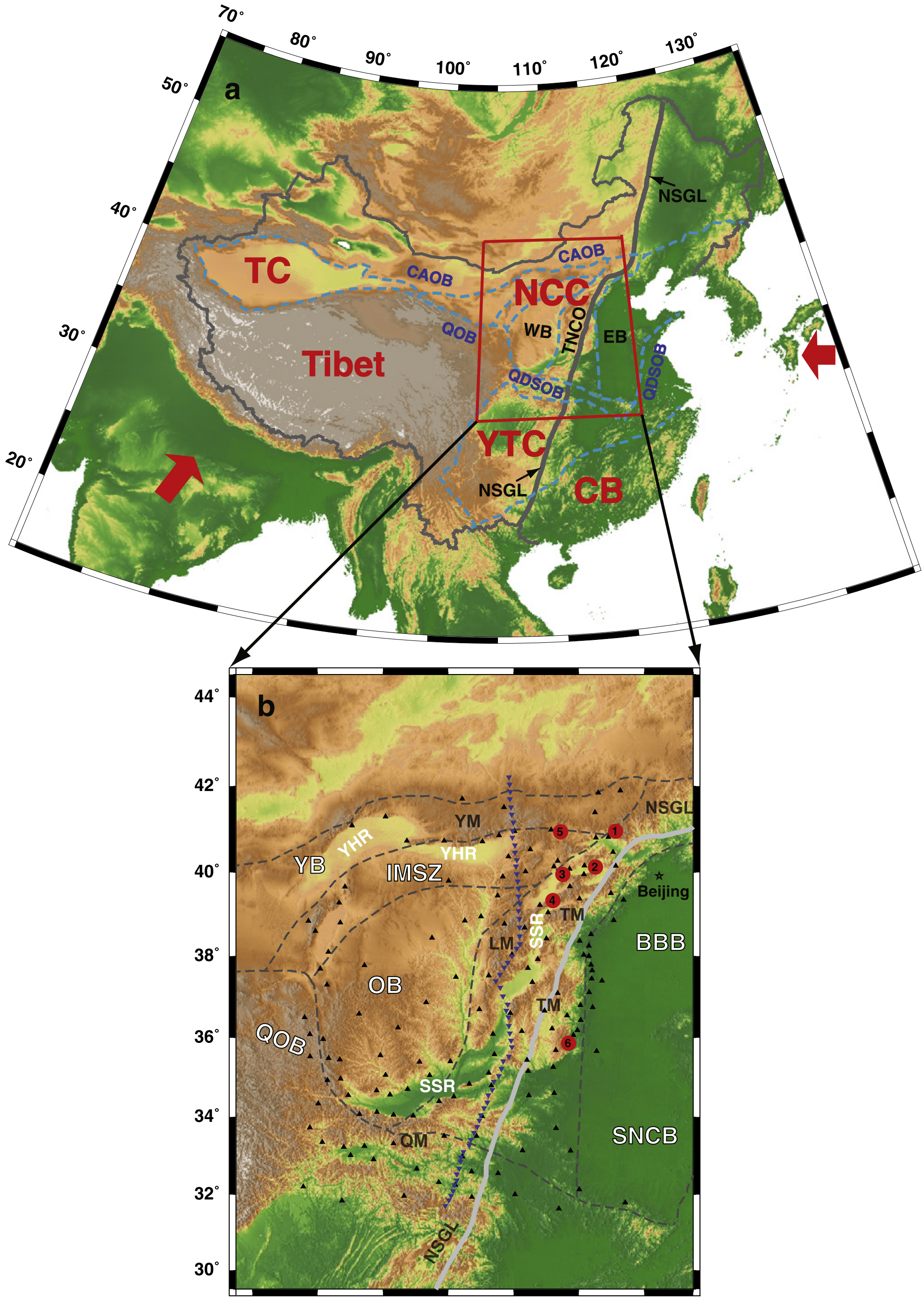

Fig. 1. (a) Topographic map of China and neighboring regions. Blue dashed lines outline the North China Craton, Yangtze Craton and Tarim Craton. Thick gray line marks the North–South Gravity Lineament that separates two topographically different domains. Red arrows show the subduction direction of the Pacific plate in the east and the indentation direction of the Indian plate in the southwest. NSGL, North–South Gravity Lineament; NCC, North China Craton; EB, Eastern Block of the North China Craton; WB, Western Block; TNCO, Trans-North China Orogen; CAOB, Central Asian Orogenic Belt; QOB, Qilianshan Orogenic Belt; QDSOB, Qinling–Dabie–Sulu Orogenic Belt; TC, Tarim Craton; YTC, Yangtze Craton; CB, Cathaysia Block. (b) Topographic map of the central and western North China Craton, showing the location of the seismic arrays. The black triangles mark the permanent stations of the China National Seismic Network (CNSN) and the blue inverted triangles mark the stations of the seventh sub-array of the North China Interior Structure Project (NCISP-VII). The thick gray line marks the North–South Gravity Lineament. The red-filled circles with numbers mark the locations of Cenozoic xenolith-bearing basalts: 1. Hannuoba; 2. Yangyuan; 3. Datong; 4. Fansi; 5. Jining; 6. Hebi (Wu et al., 2008, and references therein). The dashed lines mark the primary tectonic boundaries (after Zhao et al., 2005). BBB, Bohai Bay Basin; SNCB, South North-China Basin; IMSZ, Inner Mongolia Suture Zone; YB, Yinshan Block; OB, Ordos Block; TM, Taihang Mountains; LM, Lvliang Mountains; YM, Yinshan Mountains; QM, Qinling Mountains; SSR, Shanxi–Shaanxi Rift; YHR, Yinchuan–Hetao Rift.

North China–Mongolian plate with the Siberian plate (Davis et al., 2001), enhanced mantle temperatures associated with plumes (Deng et al., 2004), the India–Eurasia collision (Menzies et al., 1993) and the North–South China collision (Yin and Nie, 1993; Zhang, 2007), have been proposed to interpret the dynamic processes and mechanisms involved in lithospheric destruction of the EB. However, these models have difficulty in interpreting the contrasting responses of the three NCC domains to the lithospheric reactivation processes from the Late Mesozoic to Cenozoic. How the lithosphere of the central and western NCC evolved in response to this reactivation or other tectonic events