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Intraplate earthquakes and their link with mantle dynamics: Insights from P-wave teleseismic tomography along the northern part of the North–South Tectonic Zone in China

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ABSTRACT

The North–South Tectonic Zone (NSTZ) running across the Chinese continent is an important earthquake-prone zone. Around one third of the strong earthquakes (> 7.0) of China in the past occurred in this region. Receiver function study has imaged vertical convection in the mantle beneath the northern part of the NSTZ (NNSTZ), which might be related to stress accumulation and release as well as related earthquakes. Here we perform a P-wave teleseismic tomographic analysis of this region. Our results reveal prominent low-velocity and high-velocity perturbations in the upper mantle beneath this region, which we correlate with mantle upwelling, possibly resulting from lower crustal and (or) lithospheric delamination. Our results also reveal significant contrast in the velocity perturbation of the lithosphere along the two sides of this tectonic zone, suggesting possible material exchange between the eastern and western domains and lithosphere-scale control on the generation of earthquakes.

1. Introduction

The northern part of the North-South Tectonic Zone in China (NNSTZ), located along 102°–106° east longitude, includes the Alashan block, Yinshan block, Qilian block, Ordos block, Qaidam block, Songpan-Ganzi block, South China block, and Qinling orogenic belt (Fig. 1) (He et al., 2014; Li et al., 2006; Zhang and Wang, 2009; Zhang et al., 2013). This zone divides China into an eastern segment with a crustal thickness of 30–44 km and a western segment with a thickness of 54–70 km (He et al., 2014; Li et al., 2006) with a strong lateral gradient in crustal thickness and north–south-trending gravity anomaly (He et al., 2014; Li et al., 2006; Zhang et al., 2013).

The NNSTZ preserves a complex tectonic history. In its eastern side, the Ordos and Yinshan blocks amalgamated at ca. 1.95 Ga (Dan et al., 2012; Zhao et al., 2010). The collision zone between the two blocks is popularly known as the Khondalite Belt or the Inner Mongolia Suture Zone (Santosh, 2010; Santosh et al., 2007, 2013; Zhao et al., 2005). The Ordos basin (within the Ordos block) in central China is a large intracratonic compressional basin (Li, 1996; Wang et al., 2005), and its tectonic evolution was affected by both the Triassic collision between North and

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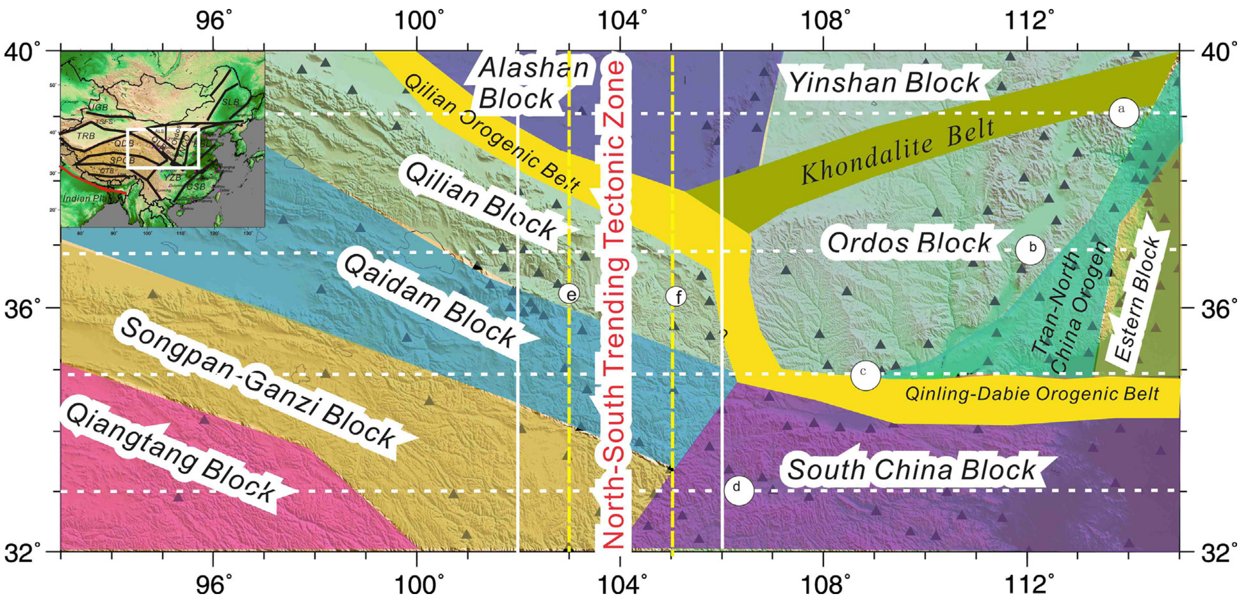

Fig. 1. Tectonic framework in the NNSTZ and near-by area showing profiles for the velocity perturbation (a–f profiles). Black triangle: seismic station. Insert figure (upper left corner): the study area within the East Asian region (marked by box). SLB (Songliao Basin), WBL (Western Block), EBL (Eastern Block), TNCO (Tans North China Orogen), Q-DOB (Qinling–Dabie Orogen Belt), YZB (Yangtze Block or South China Block), CSB (Cathaysia Block), JGB (Junggar Basin), TSFS (Tianshan Fold System), TRB (Tarim Basin), QDB (Qaidam Block), SPGB (Songpan–Ganzi Block), QLB (Qilian Block), QTB (Qiangtang Block), ALS (Alashan Block).

South China Blocks (Ames et al., 1996; Ratschbacher et al., 2000) and the subduction of the Pacific plate since the Mesozoic (Yin and Nie, 1996). In the western part of NNSTZ, the Qilian orogenic belt along the northern margin of the Tibetan Plateau of Caledonian age was formed by the convergence and collision of the Alxa, Qilian and Qaidam blocks during Late Ordovician to Devonian (Xu et al., 2006, 2010). Among these blocks, the Qilian-Qaidam blocks are considered to represent a composite fragment of the Neoproterozoic Rodinia supercontinent and shows affinity with the Yangtze craton in South China (Song et al., 2010). The Kunlun and Qilian orogenic belts represent a suture zone marking the closure of the Proto-Tethyan Ocean (Bian et al., 2004; Tseng et al., 2009; Tung et al., 2007; Xiao et al., 2015).

The critical tectonic feature and cause of frequent earthquakes along the NNSTZ (Deng et al., 2003; Zhang et al., 2003) has been the topic of a series of geophysical studies along this zone in the last decades, such as deep seismic sounding (e.g., Gao et al., 2006; Li et al., 2002), tomography, receiver function and shear-wave splitting (e.g., Ding et al., 1999; He et al., 2014; Liu et al., 1989; Wang et al., 2008), etc. These investigations revealed the crustal and lithospheric structure as well as the upper mantle structure. However, the possible link between the earthquake-prone region and deep continental dynamics has not been well elucidated.

In this study, we employed P-wave teleseismic tomography to evaluate the velocity structure of the lithosphere and upper mantle. Based on tomographic results, in conjunction with those from our previous study (He et al., 2014), we attempt to evaluate the geodynamic processes beneath the NNSTZ in order to gain insights on the relationship between the deep dynamic process and earthquake initiation.

2. Data and method

In the modeling space, a 3-D grid is set up and Vp (P-wave velocity) perturbations at the grid nodes are taken as unknown parameters. The Vp perturbation at any point in the model is calculated by linearly interpolating the Vp perturbations at the eight grid nodes surrounding that point. In our optimal Vp model, the lateral grid interval is 1°, and grid meshes are set at depths of 70, 100, 200, 300, 400, 500, 600, 700, and 800 km. An efficient 3-D ray-tracing technique (Zhao et al., 1992) is used to calculate theoretical travel times and ray paths. A conjugate-gradient inversion algorithm (Paige and Saunders, 1982) with damping and smoothing regularizations is adopted to solve the large and sparse system of observation equations (Zhao et al., 1992, 1994, 2002). The iasp91 1-D Earth model (Kennett and Engdahl, 1991) is taken as the starting model for the 3-D tomographic inversion (e.g., Lei and Zhao, 2007; Yang et al., 2014; Zhao et al., 1992).The first P-wave arrival times are picked from the origin seismograms of teleseismic events (Fig. 2). Travel-time residuals (t_{ij}) are determined by subtracting theoretical travel times and origin times from the observed arrival times. It can be expressed as:

$$t_{ij} = T_{ij}^{OBS} - T_{ij}^{CAL} \quad (1)$$

From the j-th event to the i-th station, where T_{ij}^{OBS} and T_{ij}^{CAL} are the observed and calculated travel times, respectively.Following this, the relative travel-time residuals (r_{ij}) are obtained by subtracting the mean travel-time residual of