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Mantle dynamics and Cretaceous magmatism in east-central China: Insight from teleseismic tomograms

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ABSTRACT

Both the rich mineralization in the Lower Yangtze Block (LYB) and the post-collisional mafic rocks in the Dabie Orogen (DBO) are closely related to the Cretaceous magmatism in east-central China. Various geodynamic models have been proposed for explaining the mechanism of the Cretaceous magmatism, but these models are controversial and even contradictory with each other, especially on the mechanism of adakites. A unified geodynamic model is required for explaining the magmatism in east-central China, in particular, the spatial and temporal correlations of magmatic activity in the DBO and that in the LYB. For this purpose, we apply teleseismic tomography to study P-wave velocity structure down to 800 km depth beneath east-central China. A modified multiple-channel cross-correlation method is used to collect 28,805 high-quality P-wave arrival-time data from seismograms of distant earthquakes recorded by permanent seismic stations and our temporary stations in the study region. To remove the influence of crustal heterogeneity on the mantle tomography, we used the CRUST1.0 model to correct the teleseismic relative residuals. Our tomography revealed distinct high-velocity (high-V) anomalies beneath the DBO and two flanks of the LYB, and low-velocity (low-V) anomalies above the high-V zones. Combining our tomographic images with previous geological, geochemical and geophysical results, we infer that these high-V and low-V anomalies reflect the detached lithosphere and upwelling asthenospheric materials, respectively, which are associated with the Late Mesozoic dynamic process and the Cretaceous magmatism. We propose a double-slab subduction model that a ridge subduction yielded the adakitic rocks in the LYB during 150–135 Ma and the subsequent Pacific Plate subduction played a crucial role in not only the formation of igneous rocks in the LYB but also remelting of the subducted South China Block beneath the DBO during 135–101 Ma.

1. Introduction

The present study region, east-central China, consists of the southeastern part of the North China Block (NCB), the South China Block (SCB, including the Yangtze Block and the Cathaysia Block), and the Qinling–Dabie–Sulu Orogen (Fig. 1a). In the Lower Yangtze Block (LYB), there exists an important metallogenic belt that contains more than 200 polymetallic deposits, such as Cu, Au, Mo, Fe, Zn, Pb and Ag (Pan and Dong, 1999). Most of these deposits are clustered in a narrow zone which contains several mineralization districts (Fig. 1c). Previous geological, geochemical and geophysical studies have suggested that these rich mineral resources in the LYB are closely associated with the extensive magmatic activity in the Late Mesozoic (e.g., Hou et al., 2007; Ling et al., 2009; Lü et al., 2005, 2013; Mao et al., 2011a; Sun et al., 2013; Wu et al., 2012). The Early Cretaceous magmatic rocks are also widespread in the Qinling–Dabie–Sulu Orogen which is not only one of the largest ultra-high pressure (UHP) metamorphic belts in the world (Ling et al., 2011; Liu et al., 2006; Yang et al., 2008) but also the world famous molybdenum (Mo) ore district (Mao et al., 2011b). Zircon U–Pb geochronological studies demonstrate that post-collisional mafic igneous rocks in the Dabie Orogen (DBO) were mainly emplaced during 140–110 Ma (Zhao et al., 2013). In addition, the eastern NCB experienced strong destructions of craton in the Late Mesozoic, especially peaked in the Early Cretaceous, because of the destabilization of mantle convection caused by the subduction of the Pacific plate (e.g., He, 2014; Huang and Zhao, 2006, 2009; Kameyama and Nishioka, 2012; Lei and Zhao, 2005; Tian and Zhao, 2011, 2013; Tian et al., 2009; Wang et al., 2013, 2014; Xu and Zhao, 2009; Zhao, 2015; Zhao et al., 2004, 2007, 2009). The craton destructions finally resulted in a thinned lithosphere of NCB from 200 km thick in the

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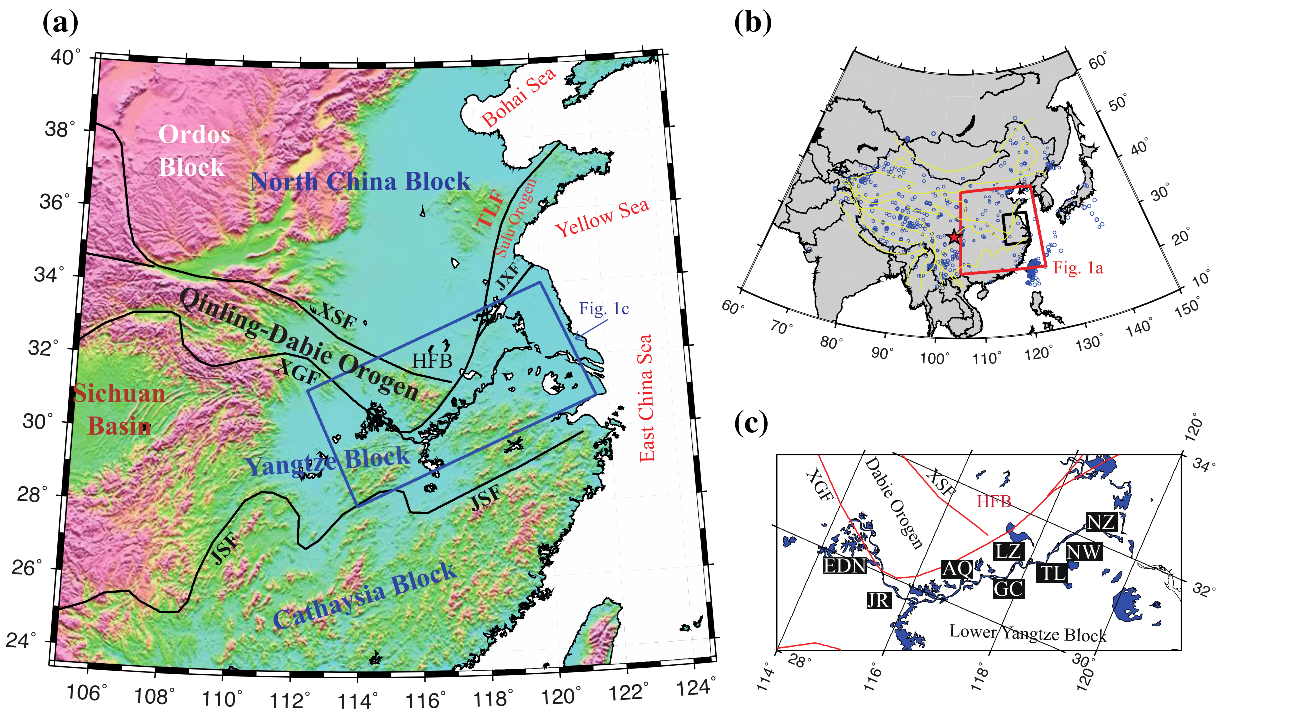

Fig. 1. (a) Tectonic background and the surface topography of the study region. The black curved lines represent the boundaries between different blocks. The blue box depicts the region of panel c. (b) The red and black boxes denote the present and the previous study regions, respectively. The blue dots denote epicenters of regional earthquakes; the red star denotes the 2008 Wenchuan earthquake (M 8.0). The national boundaries are shown by the black curved lines. The yellow lines denote the faults. (c) The distribution of primary deposits of the metallogenic zone in the Middle-Lower Yangtze River. HFB: the Hefei Basin; JSF: the Jiangshan–Shaoxing Fault; JXF: the Jiashan–Xiangshui Fault; TLF: the Tancheng–Lujiang Fault; XGF: the Xiangfan–Guangji Fault; XSF: the Xinyan–Shucheng Fault; AQ: Anqing; EDN: Edongnan; GC: Guichi; JR: Jiurui; LZ: Luzong; NW: Ningwu; NZ: Ningzhen; TL: Tongling.

Archean/Proterozoic to 60–100 km thick at present (e.g., Chen, 2009). Therefore, the Early Cretaceous was one of the most important periods of magmatic activity in the study region. Many researchers have been studying this region for understanding the mantle dynamics and the Cretaceous magmatism in east-central China.

In terms of the zircon U–Pb dating, the magmatism can be divided into two separated stages: 150–136 Ma and 136–120 Ma in the LYB (Mao et al., 2011a; Wu et al., 2012) and 143–130 Ma and 130–120 Ma in the DBO (Li et al., 2013; Zhao and Zheng, 2009). The distinct two-stage characteristic of the Mesozoic magmatism was also observed in other areas of eastern China (e.g., Mao et al., 2008a,b, 2011a; Wu et al., 2005). Recently, Sun et al. (2013) have further divided the LYB magmatism into four periods: 152–135 Ma, 135–127 Ma, 127–121 Ma and 109–101 Ma. In this study, we adopt the two-stage proposal of the Mesozoic magmatism.

There are some different viewpoints about the mechanism of the two-stage magmatism. The first-stage granitic rocks in the LYB are mostly composed of I-type granodiorite and monzogranite with weak adakitic signature (Mao et al., 2011a), whereas the late stage rocks such as shoshonite and diorite are rarely adakitic and occurred primarily in rift areas such as the Luzong and Ningwu basins (Sun et al., 2013). A slab-tearing window model was proposed by Wu et al. (2012) for interpreting the adakitic feature of the magmatism (150–136 Ma). However, Ling et al. (2009) suggested subduction of a ridge between the Izanagi and the Pacific Plates as a mechanism of the adakitic generation (140–125 Ma), which was supported by Sun et al. (2010). On the other hand, to explain the special K-rich and higher $\delta^{18}O$ of igneous rocks in the LYB and the eastern DBO, Li et al. (2013) proposed a flat-slab subduction model, which was originally proposed for explaining the oceanward younger trending of the Permian–Early Cretaceous magmatism in the Cathaysia Block (Li and Li, 2007; Shan et al., 2014). By comparing the adakites in the DBO with that in the LYB, Ling et al. (2011) found that the DBO adakites contain higher La/Yb and Sr/Y, suggesting that the DBO adakites were likely produced by partial melting of the lower continental crust rather than the oceanic crust.

Many different models have been proposed for explaining the large-scale mineralization in the LYB, such as the crust-detachment model based on linear aeromagnetic anomalies (Li, 1994), the underplating model related to the lithospheric delamination using deep seismic reflection data (Lü et al., 2005), and the MASH model based on observations of the lower crustal seismic anisotropy (Shi et al., 2013). Concerning the formation mechanism of post-collisional mafic igneous rocks in the DBO, there are also several possible models, which can be classified into two types. One type is associated with partial melting of the lower continental crust (e.g., Huang et al., 2008; Ling et al., 2011), possibly accompanied with delamination of the subcontinental lithosphere (Li et al., 2013). The other type is related to the subcontinental crust, suggesting that the subducted SCB in the Triassic had kept stagnant beneath the DBO until its reactivity in the Early Cretaceous (Huang et al., 2014).

Results of these previous studies indicate that the LYB mineralization and the DBO post-collisional mafic rocks were related to the Cretaceous magmatism, but the mechanism of the magmatism is very controversial. We need a unified model to explain both the mechanism of the mineralization and the post-collisional magmatism, because they have close spatial and temporal correlations.

Several researchers have used seismic tomography to study the mantle dynamics in East China. Regional tomography results provide information on large-scale three-dimensional (3-D) velocity features (Huang and Zhao, 2006; Lebedev and Nolet, 2003; Li and van der Hilst, 2010; Wei et al., 2012), but could not reveal the detailed structure. In contrast, local tomography results show more detailed velocity structure such as the detached lithosphere (e.g., Huang and Zhao, 2009; Tian and Zhao, 2011, 2013; Xu and Zhao, 2009; Xu et al., 2001, 2002). Zheng et al. (2012) studied the velocity structure beneath eastern China, but the seismic stations in their study were too sparse to obtain a high-