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Crustal structure and continental dynamics of Central China: A receiver function study and implications for ultrahigh-pressure metamorphism

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ABSTRACT

The Qinling–Tongbai–Hong'an–Dabie–Sulu orogenic belt records the tectonic history of Paleozoic convergence between the South China and North China Blocks. In this study, the distribution of crustal thickness and *P*- and *S*-wave velocity ratio (*Vp*/*Vs*) is obtained by using the *H*–*k* stacking technique from the Dabie–Sulu belt in central China. Our results show marked differences in the crustal structure between the Dabie and Sulu segments of the ultrahigh-pressure (UHP) orogen. The lower crust in the Dabie orogenic belt is dominantly of felsic-intermediate composition, whereas the crust beneath the Sulu segment is largely intermediate-mafic. The crust of the Dabie orogenic belt is thicker by ca. 3–5 km as compared to that of the surrounding region with the presence of an 'orogenic root'. The crustal thickness is nearly uniform in the Dabie orogenic belt with a generally smooth crust–mantle boundary. A symmetrically thickened crust in the absence of any deep-structural features similar to that of the Yangtze block suggests no supportive evidence for the proposed northward subduction of the Yangtze continental block beneath the North China Block. We propose that the collision between the Yangtze and North China Blocks and extrusion caused crustal shortening and thickening, as well as delamination of the lower crust, resulting in asthenospheric upwelling and lower crustal UHP metamorphism along the Dabie Orogen. Our results also reveal the presence of a SE to NW dipping Moho in the North China Block (beneath the Tran-North China Orogen and Eastern Block), suggesting the fossil architecture of the northwestward subduction of the Kula plate.

1. Introduction

The Dabie–Sulu orogenic belt, which is divided into two domains and separated by the Tanlu fault, is one of the major continental collision zones on the globe. The belt is inferred to have formed at ca. 230 Ma (Ames et al., 1996; Chavagnac and Jahn, 1996; Hacker et al., 1998; Jahn et al., 1996; Li et al., 1993, 1994, 2000, 2011; Wu and Zheng, 2013) during the Triassic collision between the North China and Yangtze Blocks (Cong, 1996; Hacker et al., 1995; Jahn et al., 1996; Li et al., 1993, 1999; Zhang et al., 2002). This collision zone preserves one of the largest UHP metamorphic orogens in the world and has therefore been the focus of several investigations focusing on the deep subduction of continental lithosphere (Carswell and Compagnoni, 2003; Chopin, 2003; Dobrzhinetskaya, 2012; Liou et al., 2004, 2007; Yang et al., 2002, 2003).

The formation of continental collisional orogens involves subduction and exhumation of continental crust (Carswell and Compagnoni, 2003; Chopin, 2003; Coleman and Wang, 1995; Hacker and Liou, 1998; Kawai et al., 2013; Liou et al., 2004). The traction of high-density oceanic lithosphere leads to the subduction of continental lithosphere, down to depths of 80–120 km, where coesite- and diamond-bearing ultrahigh-pressure (UHP) metamorphic rocks are generated. The presence of exhumed UHP rocks has been taken as evidence for the deep subduction of continental material and their subsequent exhumation (Cui et al., 2009; Dobrzhinetskaya, 2012; Griffin, 2008; Hacker et al., 1997; Hwang et al., 2000; Li et al., 2012a, b; Liou and Zhang, 1996; Wu et al., 2003; H. Xu et al., 2012; S.T. Xu et al., 2012; Zhang et al., 2011). The exhumation of UHP rocks from great depths is aided by the low-density of the subducted plate and buoyancy of the continental crust, together with the lubrication provided by the subduction channel (Andrew et al., 2012; Liu et al., 2010; Yuan, 2003; Zheng, 2008). The recognition of UHP metamorphic rocks in zones of continental deep-subduction has been one of the important advancements in understanding continental dynamics (e.g., Babuska and Plomerova, 2012; Cong et al., 1995; Dobrzhinetskaya, 2012; Faryad et al., 2012; Jin et al., 1998; Unsworth, 2010; Xu, 2004; Zhang et al., 2004; Zheng et al., 2003).

Traditional concepts of the plate tectonics theory have long held that the low density continental crust is buoyant (Dobrzhinetskaya and Green, 2007; Ernst et al., 1997; Whitney et al., 2009). However, the discovery of high pressure minerals including coesite and microdiamond

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in UHP rocks has radically revised this concept and confirmed that continental deep subduction and exhumation occur in some of the major collision zones (Chopin, 1984; Ji and Wang, 2011; Wu and Chi, 2003; Xia et al., 2012).

Alternate possibilities also exist for the formation of UHP minerals if appropriate temperature and pressure conditions are attained, without having the necessity to subduct continental crust to depths more than 100 km. The 'plutonic' model of UHP metamorphism employs Pascal's law to calculate the depth of the rock (H), which is equal to the pressure of the rock (P) divided by the rock pillar density and acceleration due to gravity on its top (σ) ($H = P / g * \sigma$). However, Pascal's law is only applicable to the hydrostatic model and is not suitable for solid earth. The pressure gradient of the earth is much greater than that from the computations based on Pascal's law (Yan and Chen, 2007). Some workers have therefore evaluated additional parameters such as tectonic stress and temperature anomalies from laboratory experiments and numerical simulations, demonstrating that the UHP metamorphism of the continental crust can also be achieved at a depth of 20–30 km (Faure et al., 2001; Foland and Allen, 1991), 32 km (Irvine and Baragar, 1971), or at a maximum depth of no more than 45 km (Kay and Gast, 1973). These models argue that UHP metamorphic rocks are produced at the base of the crust (Yan and Chen, 2007). The wide occurrence of UHP metamorphic rocks in various collisional orogenic belts with no robust evidence for continental deep subduction supports this view (Jin, 1999; Zhong and Ding, 1995).

In order to resolve this enigma, in this study we characterize the distribution of the crustal thickness and P- and S-wave velocity ratio (*Vp*/*Vs*) by employing the *H*–*k* stacking technique of the receiver function (Zhu and Kanamori, 2000) in the Central China. We analyze the crustal features of the Dabie–Sulu orogenic belt and their implications on continental dynamics with perspective on the Pacific (Kula) plate subduction.

2. Methodology and data

Teleseismic receiver functions (Langston, 1979) are sensitive to the S-wave velocity beneath the station and have proven to be a useful tool for estimating crustal thicknesses and *Vp*/*Vs* ratios beneath individual seismic stations (Chevrot and van der Hilst, 2000; Zandt et al., 1995; Zhu and Kanamori, 2000). The *P*-to-*S* converted phase at the Moho and first reverberated phases in the crust are generally apparent in the receiver function waveforms, and their relative travel times can then be employed to constrain the crustal thickness and the bulk *Vp*/*Vs* ratio below the recording station (Zandt and Ammon, 1995; Zandt et al., 1995).

Deciphering the geological evolution of the Earth's continental crust requires knowledge of its bulk composition and global variability (Zandt and Ammon, 1995). Average *Vp*/*Vs* or Poisson's ratio, can be used to complement petrological studies of crustal composition (Chevrot and van der Hilst, 2000). Moreover, the values of bulk crustal *Vp*/*Vs* ratio are slightly less than that of lower crustal *Vp*/*Vp* ratio (by ~0.2) (Christensen, 1996; Nair et al., 2006; Niu and James, 2002; Zandt and Ammon, 1995). Therefore, bulk crustal *Vp*/*Vs* ratio can be used to estimate the lower crust *Vp*/*Vs* ratio (He et al., 2013a, b, c; Niu and James, 2002; Thompson et al., 2010).

In order to characterize the bulk seismic properties of crust with local estimates for the crustal thickness and *Vp*/*Vs* ratio in Central China (including the Dabie–Sulu orogenic belt, the North China Block, and the Yangtze Block), we apply the stacking procedure of Zhu and Kanamori (2000) to 201 seismic stations (valid seismic stations: 176) located in this area (Figs. 1, 2). These permanent stations have been in operation from July 2008 to present by the China earthquake Network. We selected a total of 424 events (sampling rate: 50 Hz or 100 Hz) with magnitude mb ≥ 5.8 recorded by those stations (Zheng et al., 2010) (Fig. 3). For each event-station pair, data were selected within the

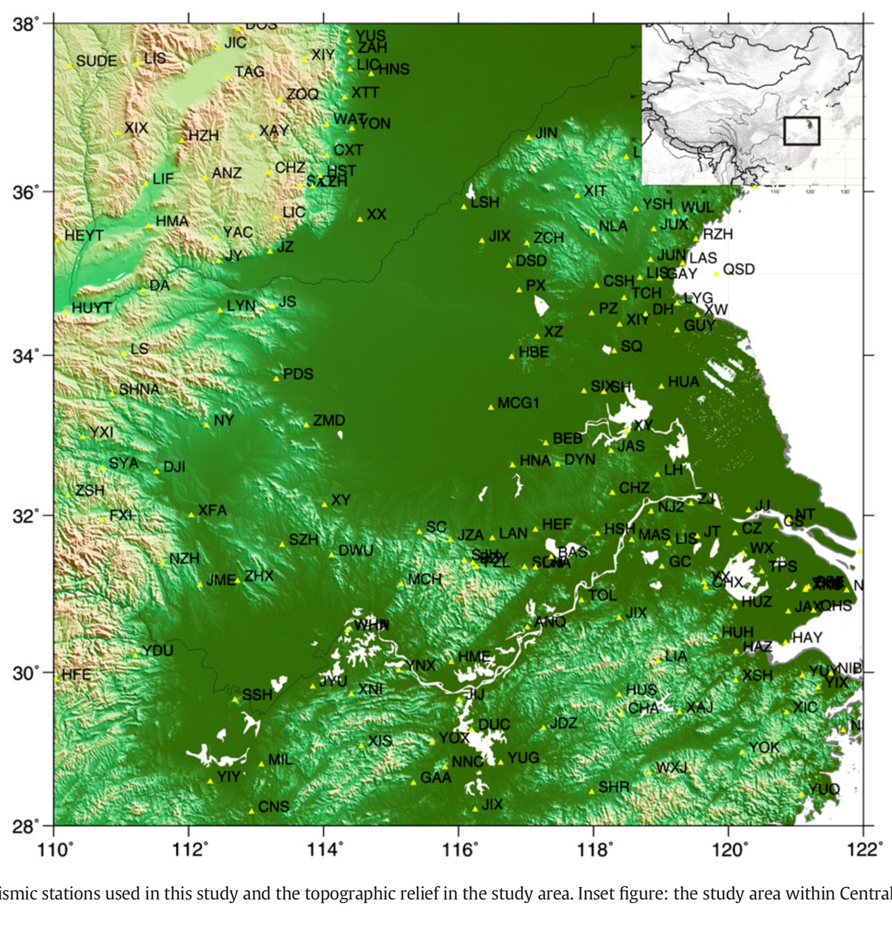

Fig. 1. Distribution of seismic stations used in this study and the topographic relief in the study area. Inset figure: the study area within Central China (marked by box).