Journal of Asian Earth Sciences 81 (2014) 105–114

Contents lists available at ScienceDirect

Journal of Asian Earth Sciences

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

Crustal structure beneath the Weihe Graben in central China: Evidence for the tectonic regime transformation in the Cenozoic

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ARTICLE INFO

Article history:
Received 19 July 2013
Received in revised form 28 October 2013
Accepted 13 November 2013
Available online 1 December 2013

Keywords:
Central China
Crustal structure
Seismic array
Receiver functions
Crustal extension
Continental collision

ABSTRACT

In central China, Weihe Graben (WG) and its adjacent area suffered intensive compressional tectonics in the Paleozoic and the Mesozoic. Then, this region was dominated by extensional tectonics due to the far-field effect of the India–Eurasia collision in the Cenozoic. We deployed a portable broad-band seismic array in this region to investigate the crustal structure by using receiver functions. Integrated with regional geophysical and geological characteristics, the analysis of the receiver functions reveals that, the Moho is 32–37 km, 25–41 km, and ~ 41 km depth beneath the northern Qinling terrane, the WG, and the southern margin of the Ordos block, respectively. The Moho depth increases beneath the southern boundary of the WG, while decreases ~10–15 km beneath the northern boundary of the WG. The Moho discontinuity beneath the WG is not a fully mirror image of the crystalline basement, because the thickest sediments (~10 km) is in the south of the WG. The crustal structure in this region reveals how the crust responds to the tectonic regime transformation. The effect of the Cenozoic crustal extension was top-down. However, the Cenozoic crustal extension has limited effect on the Moho deformation. We suggested that the compressional tectonics before the Cenozoic dominated the lateral variation of the Moho.

1. Introduction

The India–Eurasia collision not only constructed the highest orogen and plateau in the world, but also dominated the intra-continental tectonics due to the extrusion of the Tibet plateau. As the far-field effect of the India–Eurasia collision, a number of huge strike-slip systems and some rifts spread into East Asia, e.g. the Altyn Tagh strike-slip fault system and the Shanxi rift system (Molnar and Tapponnier, 1975; Peltzer and Tapponnier, 1988). The Altyn Tagh strike-slip fault system extends from the West Kunlun to the East Qinling. The Shanxi rift system is located on the southeast of the Ordos Block (OB). The Altyn Tagh strike-slip fault system and the Shanxi rift system meet at the Weihe Graben (WG) in the central China (Fig. 1a). The formation of the WG was dominated by the far-field effect of the India–Eurasia collision, and there was significant crustal extension and thinning in the Cenozoic (Peltzer and Tapponnier, 1988; Zhang et al., 1998). Therefore, the crustal structures beneath the WG and its adjacent area are important to understand the intra-continental deformation due to the far-field effect of the India–Eurasia collision.

In the study region, the southern margin of the OB and North Qinling Terrane (NQT) are on the north and the south of the WG, respectively (Fig. 1b). Before the Cenozoic extensional deformation, this region suffered three periods of intensive compressional tectonics (Dong et al., 2011; Meng and Zhang, 1999; Ratschbacher et al., 2003; Zhang et al., 2001, 2008). During the convergence of the North China plate and the Yangtze block, the Sangdan Ocean and Erlangping back arc basin subducted beneath the NQT in the middle and late Paleozoic; the Mianlue Ocean subducted beneath the south Qinling terrane in the Triassic. The broad and intensive multi-directional compressions in the North China plate resulted in intra-continental orogeny and exhumation in the study region in the Jurassic. Then, in the Cenozoic, the tectonic regime transformed from compressions to extension (Molnar and Tapponnier, 1975; Peltzer and Tapponnier, 1988; Zhang et al., 1998). This tectonic regime transformation increases the difficulty of understanding the far-field effect of the India–Eurasia collision in the study region. Meanwhile, the question of how the crustal structure responds to the tectonic regime transformation is very interesting.

Here, we investigated the crustal structure beneath the study region by using receiver functions. The result was consistent with previous geophysical studies, which indicate uplifted Moho beneath the WG (Bao et al., 2013, 2011; Liu et al., 2009; Pan and Niu, 2011; Shi et al., 2008; Zhang et al., 1985; Zheng et al., 2010).

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http://dx.doi.org/10.1016/j.jseaes.2013.11.010

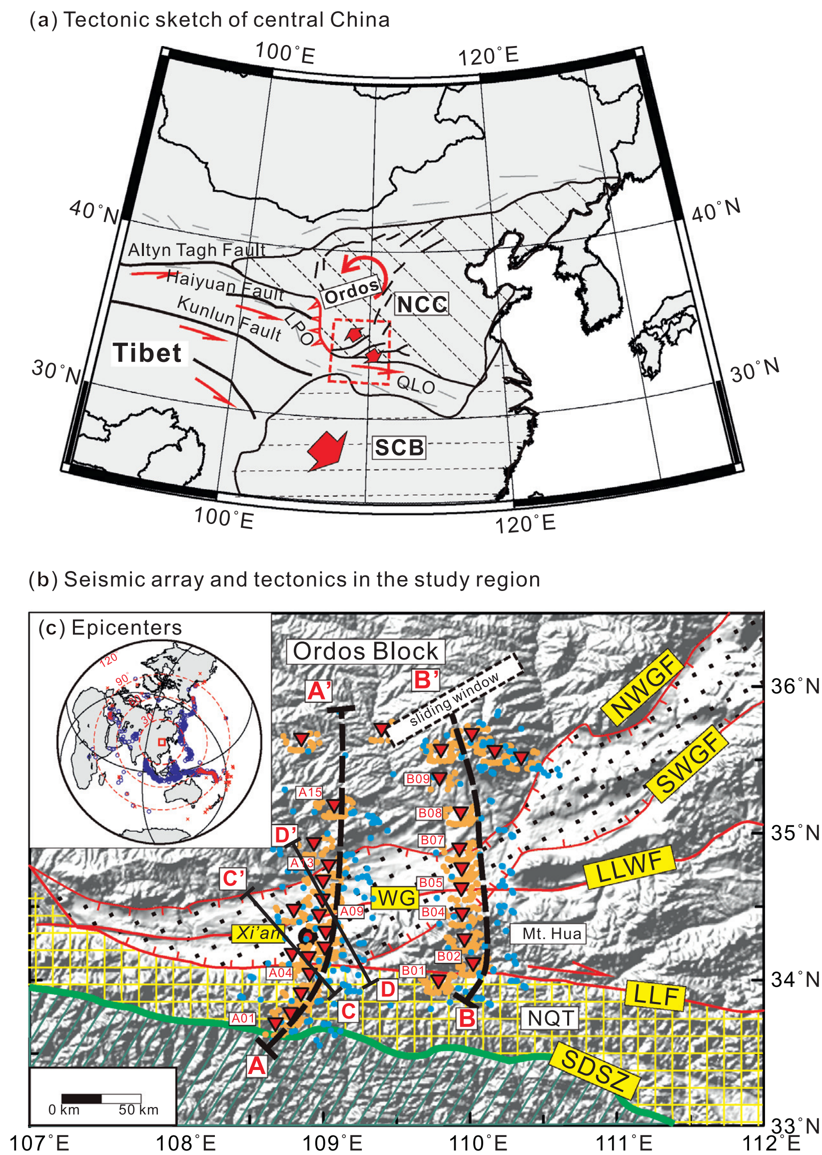

Fig. 1. Background tectonics of the study region; (a) the tectonic sketch of China; NCC, North China Craton; SCB, South China Block; the red box shows the study region; the Altyn Tagh fault system consists of the Altyn Tagh Fault, Haiyuan Fault, LiuPan Orogen (LPO), and the QinLing Orogen (QLO); (b) tectonic units and seismic array; south Qinling Terrane (green diagonal lines), NQT (yellow gridded lines), WG (dotted area), and Ordos block; they are separated by SanDan Suture Zone (SDSZ), Luonan-Luochuan Fault (LLF), Lingbao-Lusan-Wuyang Fault (LLWF), South Weihe Graben Fault (SWGF), and North Weihe Graben Fault (NWGF); the red triangles are seismic array; the brown spots and blue spots are the predicted conversion points at 30 km depth for *Ps* and *Sp* conversion wave, respectively; profiles AA' and BB' are CCP stacking profiles; CC' and DD' are active seismic profiles (Ren et al., 2012; Shi et al., 2008; Zhang et al., 1985); (c) epicenters of earthquakes used to derive the receiver functions; blue circles for PRF, and red crosses for SRF. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Moreover, our result revealed that the shallowest Moho beneath the WG was not right below the deepest crystalline basement, and indicates an asymmetry between the Moho discontinuity and the crystalline basement beneath the WG. It seems that the compressional tectonics has strong effect on the deep structure. This evidence was important to understand the far-field effect of the India–Eurasia collision and the tectonic regime transformation in this region.

2. Data and method

We deployed 30 broad-band seismic stations in the WG and adjacent regions. Here, we obtained two longitudinal seismic profiles across the WG (Fig. 1b). The western profile (AA') extends from Louchuan to Ningshan, and the eastern profile (BB') extends from Huanglong to Hebi. The two longitudinal profiles are about 150 km long and 100 km apart. These 30 seismic stations come from several individual rounds of seismic observations in the WG and adjacent regions from 2004 to 2008. Each round lasted about one year, and the data records for each station is about one year, at least for six months.

Receiver function is an effective technique of detecting velocity discontinuities beneath receivers by using converted waves (Farra and Vinnik, 2000; Langston, 1979). The teleseismic events in the epicentral distance range of 30–90° were selected for *P* wave Receiver Functions (PRF) calculation, and the teleseismic events in the epicentral distance range of 55–100° were selected for *S* wave Receiver Functions (SRF) calculation (Yuan et al., 2006). The high quality records were rotated into the *P–SV* system by using polarization filter to enhance the signal-to-noise ratio (Wang et al., 2013). After applying low pass filter with a Gaussian parameter of 2.5 Hz, the maximum entropy deconvolution (Wu et al.,