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Crustal structure and tectonic study of North China Craton from a long deep seismic sounding profile

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ABSTRACT

In this paper, we present the results of modeling refracted and reflected waves employing 2D ray tracing for a 1600-km long refraction/reflection profile that extends E–W across the entire North China Craton (NCC). The resulting P-wave velocity models reveal substantial structural variations among different geological units of the NCC. The Taihangshan Mountains are the geographical and geological demarcation lines of the NCC. In the eastern part of the NCC, Bohai Bay basin, the craton appears to be destructed as evidenced from the widespread of crust thinning (~30 km), development of large sedimentary basins and weaken of crust–mantle boundary coupling. These features indicated that Cenozoic tectonic reactivation succeeded Mesozoic destruction in the eastern part of NCC. In the western part of NCC, the craton remains high crustal P wave velocity, stable, cold, and strongly crust–mantle boundary coupling crust. The Tanlu Faults and the Taihangshan Faults are the tectonic boundaries in the NCC and play important roles in the process of cratonic destruction. The structural feature of the east secondary tectonic differential settlement in the process of basin extension is that the most faults in Bohai Bay basin are the boundaries between the depression basin and uplift area. Comprehensive study found an apparent difference between the north and south part in eastern NCC destruction in that the large-scale Cenozoic stretching mainly occurred in the Bohai Bay basin and the weakly existed only in the local area and in Hehuai basin. We discussed the crust and upper mantle tectonic evolution of NCC under the action of the convergence of regional tectonic stress field in different geological periods since the Mesozoic era. The plate movement around NCC affects the lithospheric and crustal modification of the eastern North China, and controls the deep structural background of seismicity and metallogenesis.

1. Introduction

The North China Craton (NCC) is composed of three main Archean elements including the Eastern Block, the Western Block, and the intervening Central Orogenic Belt (Kusky et al., 2007; Li et al., 2002; Zhao et al., 2001). Recently, comprehensive geoscience technique combining geophysical, geochemical, geological, geotectonic, and GPS has been used to understand the destruction in the NCC and has obtained impressive progress about temporal and spatial extent, shallow effects and deep structural response, and dynamic mechanism of the craton deformation (Zhu et al., 2012). Recent studies have suggested that the Eastern Block of NCC underwent widespread reactivation and destruction. This process resulted in the Paleozoic lithosphere, which was thick (>180 km), cold (40 mW/m^2), and stable being replaced by the Cenozoic-resent lithosphere which is thin (<100 km) and hot (65 mW/m^2) (e.g., Chen et al., 2006a, 2008; Fan et al., 2000; Gao et al., 2004; Griffin et al., 1998; Menzies et al.,1993; F.Y. Wu et al., 2005; Xu, 2001; Zhu et al., 2004).

Active source seismic research about the North China Craton (NCC) has provided abundant knowledge in the past decades (Jia et al., 2001, 2005, 2009; Ma, 1989; Sun et al., 1991; Teng et al., 1975; Zhang et al., 1998). Deep seismic sounding research focused on the eastern part, especially the depression basin of the North China. A 900-km seismic sounding profile has been implemented which Pn can be traced in 500 km and the lithospheric differences between both sides of south Taihang Mountains have been modeled (Li et al., 2011). The gap of lateral resolution still existed corresponding to a huge empty area of deep seismic sounding in Central block of the NCC. A long seismic sounding profile whose length is up to 1650 km has been executed supported by the NSFC in 2009. This wide angle reflection/refraction seismic profile is the longest deep seismic sounding profile in China, and it covered all NCC tectonic units from Rongchen in the Shandong peninsula on the east to Alashan in Inner Mongolia on the west (Fig. 1). Here we present the modeling results of the crustal P-velocity structure and discuss the differences between the Eastern and Western blocks of the NCC.

2. Tectonic setting

The Rongcheng–Xinzhou–Alashan profile crossed four tectonic units: Bohai Bay Basin (BBB) on the east, Shanxi Plateau, Ordos Plateau, and Alashan plateau to the west (Fig. 1). The Shandong Peninsula (Sulu uplift)

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bounds the BBB on the east. The major feature of the Shandong Peninsula is the exposed Proterozoic crystalline basement, along with very thin late Mesozoic-Cretaceous igneous and sedimentary rocks. Within the BBB, a series of Cenozoic basins of different depths bounded by uplifts lie along the profile (Fig. 1) (Jia et al., 2001; Li, 1981; Liu, 1988; Ye et al., 1985, 1987). The North China basins underwent NW–SE shear-compression during the Early Cenozoic, forming a series of active faults (Li, 1981; Liu, 1988; Ye et al., 1985, 1987). Since the Mid-Cenozoic, the BBB has experienced extension, crustal uplift and faulting, and widespread extension of the upper and middle crust took place during right-lateral extensional shearing. This tectonism resulted in all the structures of the BBB being NE–SW oriented. The Shanxi Plateau is the another name of the central block of NCC ,which is composed of Taihang Mountains (TM), Shanxi graben, and Lyuliang Mountains (Fig. 1). A NEE-ending gravity lineament located along the east edge of TM is generally proposed to be the boundary between the central and the eastern NCC. The Ordos plateau is the western end of the NCC, it has an Archean (~3.6 Ga) basement and has remained tectonically stable since the final amalgamations of the NCC.

3. Data acquisition and features of seismic phases

The P-wave seismic data used in our study were acquired from a 1650-km long wide-angle reflection/refraction profile obtained during April to June 2009. The profile had its azimuth at approximately N75° W, and ran between Rongcheng of Shandong Province (Eastern end), Xinzhou of Shanxi Province and Alashan of Inner Mongolia (western end). Shots were fired at the 11 sites (Fig. 2). For each shot, 4–8 holes were drilled to a depth of about 60 m and loaded with 2000–10,200 kg of explosive charge. A total of 550 portable three-component digital meters/geophones were used to acquire seismic data along a long-offset profile. The station spacing was 3 km. The three-minute-long seismic signals were initially sampled at a rate of 200 sps, and then band-pass filtered within the 1–10 Hz frequency band for P-waves. Fig. 2 shows the data acquisition geometry.

Fig. 3 shows the record sections of shots in a distance 1 of 48 km, 385 km west branch, 951 km, and 1429 km using a reduced velocity of 6.0 km/s. The refractions above the crystalline basement of the crust (the Pg phase), the refractions from the uppermost mantle (the Pn Phase), and the reflections from the Moho (the PmP or simply Pm phase) can be easily traced in all the sections (Fig. 3). The record sections show the feature of the wide angle reflection/refraction dataset: (a) very strong Pm reflections from the crust–mantle boundary; (b) clear differences between the intra-crustal reflections, labeled as P1, P2 and P3, when these phases originate from progressively deeper interfaces, from different shot points. Relatively stronger intra-crustal reflections P1 and P2 are apparent from shot in a distance of 148 km, and P3 is apparent from shot in a distance of 1429 km east branch; (c) clear first arrival Pn onset from the uppermost mantle, the longest tracing distance more than 400 km, and (d) clear differences between the intra-crustal reflections, labeled as P2, P3 and P4, when these phases originate from progressively deeper interfaces, from different shot points (Fig. 3).

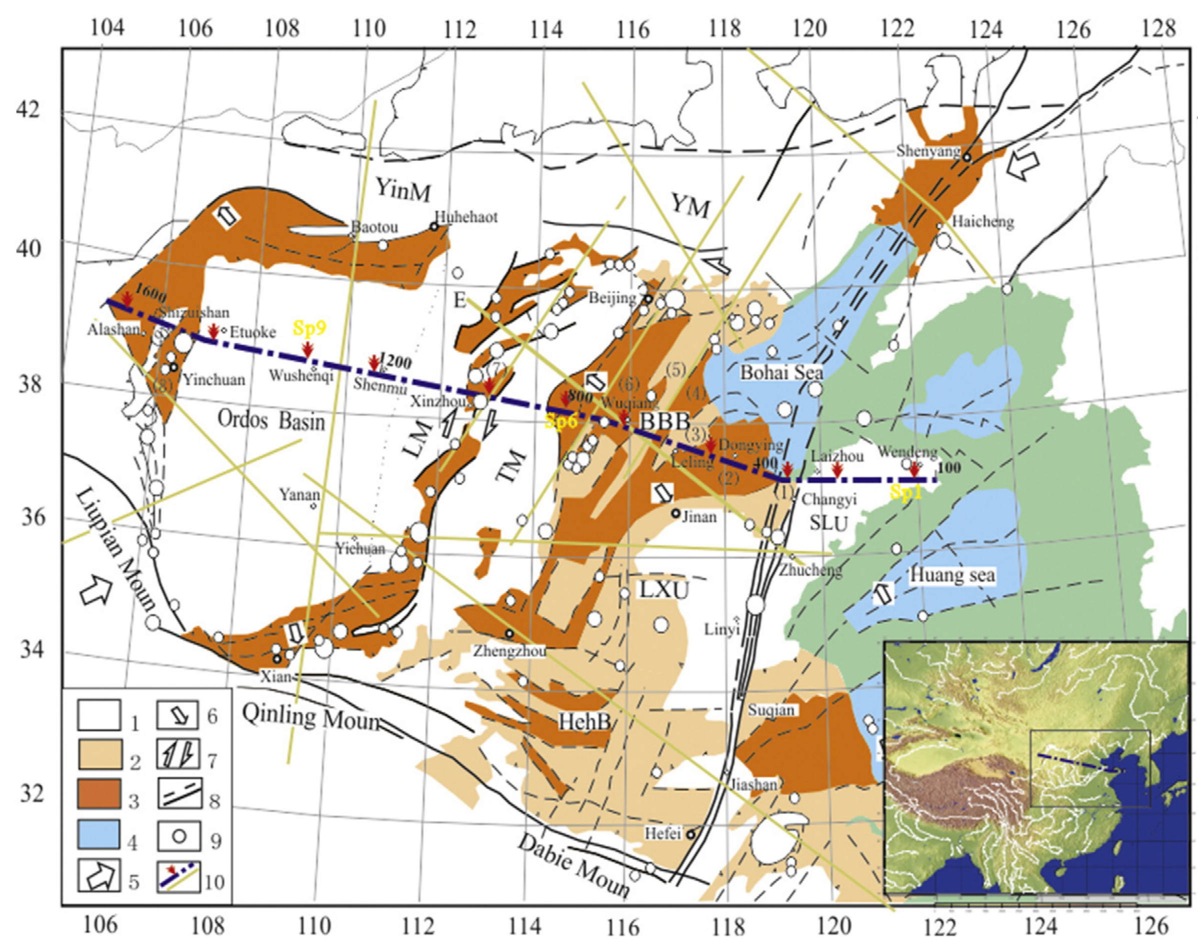

Fig. 1. Active tectonic of the blocks and DSS lines in the North China Craton. 1 Uplifted regions, 2 uplifts within basins, 3 depression within basins, 4 depressions within seas, 5 direction of plate motion, 6 direction of basin extension, 7 direction of block shearing, 8 Faults, 9 Earthquakes, 10 DSS line and shot-points. Major tectonic units in the North China Craton are also marked, including the Yin Mountains (YinM), the Yan Mountains (YM), the Bohai Bay Basin (BBB), the Taihang Mountains (TM), Lyuliang mountains (LM), the LuXi Uplift (LXU), the SuLu Uplift (SLU), the Hehuai Basin (HehB), and (1) Tanlu faults zone (TFZ), (2) Jiyang sag, (3) Chengning uplift, (4) Huanghua depression, (5) Cangxian uplift,(6) Jizhong depression, (7) Shanxi depression, (8) Yinchuan graben, (9) Helan Mountains.