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Continental dynamics of Eastern China: Insights from tectonic history and receiver function analysis

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ABSTRACT

East Asia records a complex sequence of tectonic processes, with the mosaic of cratonic blocks and orogenic belts in China preserving evidence for multiple episodes of amalgamation and reworking from the Archean to Cenozoic. The prolonged subduction of the Pacific plate from the east has been invoked to explain the volcanic activities in the NE China region and in the Songliao Basin, as well as the extensive destruction of the sub-continental lithospheric mantle of the North China Craton (NCC). The collision between the NCC and the Yangtze Craton involved deep subduction and exhumation of ultrahigh-pressure metamorphic orogen. In the South China Craton, the Yangtze and Cathaysia blocks collided along the Shaoxing-Jiangshan-Pingxiang suture. Here we present an overview of the results from multidisciplinary studies on the major tectonic events in the eastern China region and evaluate the geodynamics of these in the light of our recent work based on receiver function analysis. The compression induced by the westward subduction of the Pacific plate in the NCC and South China appears to have triggered lower crustal and lithospheric delamination. We also identify mantle upwelling as a dominant trigger for the major tectonic process in this region.

Contents

1. Introduction

Plate tectonics and convergent margin processes make Earth a unique planet in the Solar System (Angiboust et al., 2011; Maruyama et al., 2013), leading to the formation and destruction of continental crust and lithosphere (e.g., Stern, 2011; Kawai et al., 2013). Understanding these processes has significant implications in various branches of Earth sciences including mantle dynamics and the assembly and disruption of supercontinents (e.g., Nance et al., 2014), as well as in the formation of major metallogenic belts (e.g., Goldfarb and Santosh, 2014; Goldfarb et al., 2014).

The geological framework of East Asia preserves the records of complex crustal evolution and related tectonic and metallogenic processes (e.g., Li et al., 2012a,b; Goldfarb et al., 2014; Zaw et al., 2014), within which the continental crust of China incorporates a mosaic of cratonic blocks and orogenic belts built through multiple episodes of amalgamation and reworking from the Archean to Cenozoic (Zhao et al., 2001; Zhai and Santosh, 2011; Zheng et al., 2013). The Precambrian nuclei in China include three major cratons – the North China, Tarim and South China (Santosh, 2010; Zhai and Santosh, 2011; Zhao and Cawood, 2012; Zheng et al., 2013). The major Phanerozoic tectonic domains in

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this region are the Paleo-Asian, the Western Pacific and the Tethys (Li et al., 2012a). Continental-scale compressional and extensional tectonics have been identified from the Late Mesozoic–Cenozoic geology of East Asia (Davis et al., 2001; Ritts et al., 2001; Zhao et al., 2004a; Lin et al., 2013).

The Mesozoic framework of eastern China is composed of the Central Asian Orogenic Belt and the North China Craton in the north, the Dabie–Sulu orogenic belt in the central part and the South China Block in the south (Chen et al., 2014; Xiao and Santosh, 2014). The collision of the North and South China blocks closed the eastern segment of the Paleo-Tethys in the Early Triassic (Meng and Zhang, 1999; Weislogel et al., 2006), and the collision of the North China and Siberian Cratons marked the demise of the Mongol–Okhotsk Ocean in the Triassic–Early Jurassic (Şengör et al., 1993; Zorin, 1999; Badarch et al., 2002; Windley et al., 2007; Xiao et al., 2010a,b; Safonova and Santosh, 2014; Xiao and Santosh, 2014). These two collisions built the Jurassic–Early Cretaceous active margin of East Asia facing the subducting Izanagi Plate from the east (Safonova and Santosh, 2014). The tectonic units in East China can be divided into four segments: the Songliao basin in NE China, North China Craton, Central Orogenic Belt (Qinling-Dabie-Sulu orogenic belt) and South China Craton.

Investigations on the evolution of the continental crust and lithosphere rely mostly on surface exposures or on xenoliths scavenged by volcanic rocks (Zheng et al., 2012; Replumaz et al., 2014). However, the deep exploration techniques from geophysics such as seismology provide windows into the earth's interior. In this overview, we synthesize the recent information from receiver function analysis to evaluate some of the debated issues on continental dynamics in eastern China.

2. Geological and tectonic background

NE China forms part of the Paleo-Asian tectonic domain and was overprinted by circum-Pacific orogens during the Mesozoic and Cenozoic (Meng et al., 2011; Zhang et al., 2011c). The region represents a key for understanding the tectonic fabric of Asia, where the Central Asian Orogen and the Circum-Pacific Orogen overlap (Yakubchuk, 2002; Zhang et al., 2011a). The NE China and adjacent regions (including the Songliao Basin), together with the Russian Far East, located between the Siberia and North China Cratons have traditionally been considered as the eastern segment of the Central Asian Orogenic Belt (Şengör and Natal'in, 1996; Jahn et al., 2000; Windley et al., 2007; Xiao and Santosh, 2014). This region incorporates Paleozoic accretionary margins to the Siberia and the North China Cratons, terminated to the east by the Paleo-Pacific tectonic system (Xu et al., 2013; Zhou and Wilde, 2013; Wang et al., 2014b). The NE China region incorporates a collage of micro-continental blocks (Wu et al., 2007a,b; Zhou and Wilde, 2013; Wang et al., 2014a). Since late Paleozoic, this region witnessed long-term plate subduction and continent–arc and/or microcontinent–continent collisions before the terminal collision between the North China–Mongolian Block and the Siberian Craton (Li et al., 2010). Thus, this region records two stages of evolution, the first one in the Paleozoic, associated with the closure of the Paleo-Asian ocean and the amalgamation of microcontinental blocks including the Erguna, Xing'an, Songnen, and Jiamusi (Ye and Zhang, 1994; Wilde et al., 2001; Yu et al., 2014), and the second one during Mesozoic–Cenozoic associated with the development of the circum-Pacific tectonic system (Li et al., 2014a).

Subduction of the Paleo-Pacific Plate beneath the Siberian paleoplate, and in NE China and adjacent regions to the south commenced during Devonian. These convergent margin processes exerted significant influence on the Permian crustal evolution of NE China and adjacent regions (Li, 2006). The subduction of Pacific slab towards the northeast of Asia is considered as the main trigger for lithospheric delamination since Mesozoic, triggering voluminous magmatism, related metallogeny, extensional tectonics generating major rift basins, large scale upwelling of the asthenosphere, and extensive lithospheric thinning (Deng et al., 1996; Zhang et al., 2011b; Li et al., 2012c; Guo et al., 2013; Zhai and Santosh, 2013; Goldfarb and Santosh, 2014; Li and Santosh, 2014; Yang et al., 2014; Yang and Santosh, 2015).

Seismic tomographic studies have imaged low-velocity anomalies in the mantle transition zone beneath northeast China, which have been correlated to deep dehydration of the subducted Pacific Plate and the convective circulation in the mantle wedge (Zhao et al., 1994; Zhao et al., 1997; Stern, 2002; Maruyama et al., 2009). A large-scale upwelling of the hot asthenospheric materials beneath NE Asia, which caused continental rifts and intraplate volcanism in the region has also been identified (Komabayashi et al., 2004; Zhao and Ohtani, 2009; Guo et al., 2013; Zhao et al., 2013).

The North China Craton (NCC) is among the oldest Archean cratons on the globe, with vestiges of ≥3.6 Ga old crust (Liu et al., 1992; Zheng et al., 2004; Zhai and Santosh, 2011; Ma et al., 2012). The NCC was cratonized during the Neoarchean–Paleoproterozoic (Zhai and Santosh, 2011; Yang and Santosh, 2014) and remained stable since then for several million years, unlike the other Archean cratons of the world (e.g., Morgan, 1984; Boyd et al., 1985; Pollack, 1986; Grand, 1987; Jordan, 1988; Nyblade and Pollack, 1993; Ling et al., 2009). The NCC is bound by the Early Paleozoic Qilianshan Orogen to the west, the Late Paleozoic–Late Mesozoic Central Asian Orogenic Belt to the north and the Qinling–Dabie–Sulu ultrahigh-pressure metamorphic belt to the south (Ren et al., 1987; Zorin et al., 2001; Santosh and Somerville, 2013; Xiao et al., 2013). The NCC incorporates two major Precambrian blocks, the Eastern Block and the Western Block, sutured along a Paleoproterozoic collision zone known as the Trans-North China Orogen (central NCC) (Zhao et al., 2005; Zhai and Santosh, 2011; Zhao and Zhai, 2013; Zheng et al., 2013; Yang and Santosh, 2014). After a prolonged period of quiescence, subduction and collision of the surrounding blocks during Phanerozoic led to significant modification of the cratonic architecture of the NCC (Ren, 1991; Zheng et al., 2007).

The eastern part of the NCC underwent extensive reactivation since the Mesozoic (Griffin et al., 1998; Wu et al., 2005a; Menzies et al., 2007; Gao et al., 2008; Yu et al., 2012a; Yang et al., 2014). Multi-disciplinary studies have demonstrated significant destruction of the cratonic keel with a dramatic change in lithospheric architecture during the early Paleozoic to the Cenozoic (Chen, 2009; Zheng et al., 2009; Chen, 2010; Santosh, 2010). Among the various models proposed for the destruction of the eastern NCC are: (1) thermal/mechanical and/or chemical erosion, and (2) lower crustal and (or) lithospheric delamination (Menzies et al., 1993; Gao et al., 1998; O'Reilly et al., 2001; Xu et al., 2002; Foley, 2008; Aulbach, 2012). The erosion model envisages thinning of the NCC lithosphere through chemical and/or mechanical interactions of lithospheric mantle with melts or hydrous fluids from the asthenosphere through upwelling mantle plume or collisional tectonics (Ritsema et al., 1998; Gao et al., 2002; Griffin et al., 2003; Aulbach, 2012). Deep subduction of the Pacific Plate underneath East Asia since Mesozoic has also been proposed as an important trigger for lower crustal delamination (Griffin et al., 1998; Wu et al., 2003a; Li and Yang, 2011). The delamination model envisages lithospheric thinning through the foundering of eclogitic lower crust together with the recycling of lithospheric mantle (Gao et al., 2002; Morency et al., 2002; Ling et al., 2009; Komiya, 2011).

To the south is the Dabie-Sulu orogenic belt, which is widely accepted as representing the Triassic suture zone between the North China and Yangtze Cratons (Li et al., 1993; Jahn et al., 1996). This belt extends for about 3000 km westward from the Kunlun mountains, through the Qinling belt, to the Tongbai–Dabie belt, and then continues northeastward through the Sulu area of the Shandong Peninsula for another 500 km into the Odsean fold belt of Korea (Li et al., 2011a,b). This collision zone preserves one of the largest ultrahigh-pressure metamorphic orogens in the world (Yang et al., 2002; Liou et al., 2007; Dobrzhinetskaya, 2012; Li et al., 2012a).

The Dabie–Sulu orogenic belt is considered to have formed through multistage amalgamation process of the South China Block, the North