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Sedimentary response to the paleogeographic and tectonic evolution of the southern North China Craton during the late Paleozoic and Mesozoic

De-Bin Yang *, Hao-Tian Yang, Jiang-Peng Shi, Wen-Liang Xu, Feng Wang

College of Earth Sciences, Jilin University, Changchun 130061, PR China

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ABSTRACT

With the aim of constraining the influence of the surrounding plates on the Late Paleozoic–Mesozoic paleogeographic and tectonic evolution of the southern North China Craton (NCC), we undertook new U–Pb and Hf isotope data for detrital zircons obtained from ten samples of upper Paleozoic to Mesozoic sediments in the Luoyang Basin and Dengfeng area. Samples of upper Paleozoic to Mesozoic strata were obtained from the Taiyuan, Xiashihezi, Shangshihezi, Shiqianfeng, Ermaying, Shangyoufangzhuang, Upper Jurassic unnamed, and Lower Cretaceous unnamed formations (from oldest to youngest). On the basis of the youngest zircon ages, combined with the age-diagnostic fossils, and volcanic interlayer, we propose that the Taiyuan Formation (youngest zircon age of 439 Ma) formed during the Late Carboniferous and Early Permian, the Xiashihezi Formation (276 Ma) during the Early Permian, the Shangshihezi (376 Ma) and Shiqianfeng (279 Ma) formations during the Middle–Late Permian, the Ermaying Group (232 Ma) and Shangyoufangzhuang Formation (230 and 210 Ma) during the Late Triassic, the Jurassic unnamed formation (154 Ma) during the Late Jurassic, and the Cretaceous unnamed formation (158 Ma) during the Early Cretaceous. These results, together with previously published data, indicate that: (1) Upper Carboniferous–Lower Permian sandstones were sourced from the Northern Qinling Orogen (NQO); (2) Lower Permian sandstones were formed mainly from material derived from the Yinshan–Yanshan Orogenic Belt (YYOB) on the northern margin of the NCC with only minor material from the NQO; (3) Middle–Upper Permian sandstones were derived primarily from the NQO, with only a small contribution from the YYOB; (4) Upper Triassic sandstones were sourced mainly from the YYOB and contain only minor amounts of material from the NQO; (5) Upper Jurassic sandstones were derived from material sourced from the NQO; and (6) Lower Cretaceous conglomerate was formed mainly from recycled earlier detritus.

The provenance shift in the Upper Carboniferous–Mesozoic sediments within the study area indicates that the YYOB was strongly uplifted twice, first in relation to subduction of the Paleo-Asian Ocean Plate beneath the northern margin of the NCC during the Early Permian, and subsequently in relation to collision between the southern Mongolian Plate and the northern margin of the NCC during the Late Triassic. The three episodes of tectonic uplift of the NQO were probably related to collision between the North and South Qinling terranes, northward subduction of the Mianlue Ocean Plate, and collision between the Yangtze Craton and the southern margin of the NCC during the Late Carboniferous–Early Permian, Middle–Late Permian, and Late Jurassic, respectively. The southern margin of the central NCC was rapidly uplifted and eroded during the Early Cretaceous.

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1. Introduction

Sedimentary sequences preserved in basins record the processes of basin formation and uplift, and the unroofing history of adjoining regions of tectonic uplift; e.g., orogenic belts. Provenance analysis of sedimentary rocks is useful for identifying sediment source areas and tracking changes in source areas over time, which in turn enables reconstructions of paleogeography (Richards et al., 2005; Yang et al., 2006, 2012a, 2013, 2014a; Dickinson and Gehrels, 2008; Li et al., 2010, 2013; Zeh and Gerdes, 2012; Li and Huang, 2013; Zhu et al., 2014a). Detrital zircon U–Pb ages and Hf isotopic data of sedimentary rocks can yield reliable information on sediment provenance, paleogeographic changes, and tectonic evolution (Richards et al., 2005; Yang et al., 2006, 2012a, 2013, 2014a; Dickinson and Gehrels, 2008; Zeh and Gerdes, 2012).

The North China Craton (NCC) is surrounded by the Xing–Meng Orogenic Belt (XMOB; the eastern part of the Central Asian Orogenic Belt) to the north and the Qinling–Dabie–Sulu Orogen to the south and southeast. The northern margin of the NCC is marked by the Yinshan–Yanshan Orogenic Belt (YYOB; Fig. 1a, b). These three orogenic belts

* Corresponding author at: College of Earth Sciences, Jilin University, 2199 Jianshe Street, Changchun, Jilin 130061, PR China.
E-mail address: yangdb@jlu.edu.cn (D.-B. Yang).

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could have provided sedimentary material to nearby basins within the NCC. During the late Paleozoic to Mesozoic, the NCC experienced several collision and aggregation events with multiple surrounding plates, resulting in intraplate deformation (Davis et al., 2001; Li et al., 2010). In recent years, the tectonic evolution of the NCC during the late Paleozoic–Mesozoic has been extensively investigated, and many results have been obtained from the integration of petrological and geochemical data from igneous rocks with geophysical data (Menzies et al., 1993; Davis et al., 2001; Zhang et al., 2007, 2009; Xu et al., 2008, 2013; Yang et al., 2010, 2012b). In contrast, the sedimentary response to the influence of the surrounding plates on the paleogeographic and tectonic evolution of the NCC has been relatively neglected. Previous studies on detrital zircon geochronology focused on upper Paleozoic and lower Mesozoic sandstones of the Jiyuan Basin in the Jiyuan area (Li et al., 2010; Li and Huang, 2013; Yang et al., 2014a) and the Qinshui Basin in the Yangcheng area (Zhu et al., 2014a) of the southern NCC. However, the sediment source area of the upper Paleozoic–lower Mesozoic strata is controversial, and the provenance of the upper Mesozoic strata is unknown. For example, Li and Huang (2013) suggested that detrital zircons from Upper Triassic to Middle Jurassic sediments in the Jiyuan Basin were sourced mainly from the YYOB and XMOB, whereas Yang et al. (2014a) favored an origin from the Qinling Orogen and the Precambrian basement of the NCC. These competing interpretations indicate the uncertainties in our current knowledge of the paleogeographic and tectonic evolution of the southern NCC.

Herein, we present new detrital zircon U–Pb and Hf isotope data for upper Paleozoic–Mesozoic sediments in the Luoyang Basin and Dengfeng area at the southern margin of the central NCC, adjacent to the northern end of the Northern Qinling Orogen (NQO; Fig. 1b). These data are integrated with previous data from upper Paleozoic–lower Mesozoic sediments in the southern NCC, with the aims of elucidating the provenances of the sediments and determining the influence of the surrounding plates on the paleogeographic and tectonic evolution of the southern NCC during the late Paleozoic–Mesozoic.

2. Geological setting and sample descriptions

The NCC is bordered by the XMOB to the north and the Qinling–Dabie–Sulu Orogen to the south and southeast (Fig. 1b). The Paleo-Asian Ocean Plate (PAOP) started to subduct beneath the northern margin of the NCC during the late Paleozoic (Xiao et al., 2003; Wang et al., 2015; Wilde and Zhou, 2015; Liu et al., 2017). The micro-continental massifs in the XMOB collided with the NCC prior to the Late Permian–Early Triassic (Davis et al., 2001; Xiao et al., 2003; Li, 2006; Zhang et al., 2007, 2009; Cao et al., 2013; Zhou et al., 2017). The northern margin of the NCC is marked by the YYOB. The YYOB is divided into the Inner Mongolia Paleo-uplift to the north and the Yanshan Fold-and-Thrust Belt to the south, separated from each other by the Pingquan–Gubeikou–Chicheng–Shangyi Fault (Yang et al., 2006; Xu et al., 2017). The Yangtze Craton (YC) collided with the eastern NCC during the Middle–Late Triassic and finally amalgamated with the southern NCC prior to the Early Jurassic (Li et al., 1993; Meng and Zhang, 1999; Ratschbacher et al., 2003; Yang et al., 2010, 2012b; Dong et al., 2011; Wu and Zheng, 2013). The Qinling Orogen is divided by the Shangzhou–Danfeng Suture Zone into the NQO and the Southern Qinling Orogen (SQO; Fig. 1b; Meng and Zhang, 1999; Li et al., 2007; Wu and Zheng, 2013). The Izanagi Plate started to subduct beneath the eastern Asian Plate during the Early–Middle Jurassic, and the direction and rate of subduction changed several times (Maruyama et al., 1997; Wang et al., 2017). In summary, the tectonic evolution of the NCC during the late Paleozoic–Mesozoic was closely related to interactions between several adjacent plates (Davis et al., 2001; Li et al., 2010).

The NCC consists of Archean to Paleoproterozoic basement overlain by Mesoproterozoic to Cenozoic cover successions (Jahn et al., 1988; Zhai and Santosh, 2011; Wan et al., 2012; Yang et al., 2013). The NCC is divided into a number of major crustal blocks separated by three Paleoproterozoic linear tectonic belts in popular tectonic model, i.e., the Inner Mongolia Suture Zone (IMSZ) in the west, the Trans-North China Orogen (TNCO) in the center, and the Jiao–Liao–Ji Belt in the east (Fig. 1a; Yang et al., 2014b). The composite Western Block is composed of the Yinshan Block to the north and the Ordos Block to the south, dissected by the IMSZ (incorporating the Khondalite Belt), a major tectonic divide marking the collisional suture between the two blocks (Santosh, 2010; Santosh et al., 2013; Yang et al., 2014b). The Western Block collided with the Eastern Block along the TNCO to form the coherent basement of the NCC at ~1.85 Ga (Zhao et al., 2001, 2005). However, recent model proposes that the NCC is composed of several Archean microblocks which were amalgamated into large continental masses along zones of ocean closure during Late Neoarchean (Li et al., 2016; Santosh et al., 2016; Yang et al., 2016a; Yang and Santosh, 2017), further, at least seven microblocks have been identified including the Jiaoliao Block, the Qianhuai Block, the Ordos Block, the Jining Block, the Xuchang Block, the Xuhuai Block and the Alashan Block (Zhai and Santosh, 2011; Santosh et al., 2016; Yang and Santosh, 2017). Silurian, Devonian, and Lower Carboniferous strata are absent from the NCC succession because of uplift of the NCC during the late early Paleozoic. The oldest pre-orogenic strata are Cambrian and Lower–Middle Ordovician epicontinental carbonate sediments. The Upper Carboniferous–Lower Permian alternating marine and terrestrial sequence is characterized by coal-bearing strata, overlain by Middle–Upper Permian to Triassic redbeds and conglomerates. Jurassic–Lower Cretaceous terrestrial volcanic and clastic sediments were deposited in intracontinental basins, lying unconformably on the basement or on upper Paleozoic sedimentary rocks (HBGMR, 1989; Li and Huang, 2013). Mesozoic–Cenozoic basins occupy most of the NCC. Phanerozoic magmatism occurred mainly in the marginal and central parts of the NCC (Zhang et al., 2007, 2009; Yang et al., 2010, 2012b, 2016b; Cao et al., 2013). During the Paleozoic–late Mesozoic, the NCC underwent extensive lithospheric thinning from a thickness of ~200 km during the Middle Ordovician to 60–80 km in the Cenozoic (Menzies et al., 1993).

The Luoyang Basin and Dengfeng area are situated at the southern margin of the central NCC, adjacent to the northern end of the NQO and east of the Taihang Mountains (Fig. 1b). Upper Paleozoic–Mesozoic strata are widely exposed at the periphery of the study area (Fig. 2; HBGMR, 1989). The upper Paleozoic strata (from oldest to youngest) are the Taiyuan, Shanxi, Xiashihezi, Shangshihezi, and Shiqianfeng formations with continuous sequences. The Mesozoic strata (from oldest to youngest) are the Ermaying Group and the Xiayoufangzhuang, Shangyoufangzhuang, Chunshuyao, Tanzhuang, Upper Jurassic unnamed, and Lower Cretaceous unnamed formations (Fig. 3; HBGMR, 1989). Actually, an angular unconformity exists between Upper Jurassic and the overlying Lower Cretaceous and a parallel unconformity exists between the Shiqianfeng Formation, Upper Triassic, and Upper Jurassic. According to the age-diagnostic fossils and their lithological associations (HBGMR, 1989), sedimentary units of the Upper Paleozoic–Mesozoic strata in the Luoyang Basin and Dengfeng area have been dated. It remains controversial that the depositional ages of some strata since a lack of precise geochronological data. We collected ten samples from the Taiyuan, Xiashihezi, Shangshihezi, Shiqianfeng, and Shangyoufangzhuang formations in the Dengfeng area, and the Ermaying Group, the Shangyoufangzhuang, Upper Jurassic unnamed, and Lower Cretaceous unnamed formations in the Luoyang Basin. Two samples were obtained from each of the Shiqianfeng and Shangyoufangzhuang formations; one sample was collected from each of the other formations. It suggest that the Taiyuan Formation deposited during the Late Carboniferous and Early Permian, the Xiashihezi Formation during the Early Permian, the Shangshihezi and Shiqianfeng formations during the Middle–Late Permian, the Ermaying Group and Shangyoufangzhuang Formation during the Late Triassic, the Upper Jurassic unnamed formation during the Late Jurassic, and the Lower Cretaceous unnamed formation during

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