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Early Neoarchean (~2.7 Ga) tectono-thermal events in the North China Craton: A synthesis

Yusheng Wan[a,b,c,*], Shiwen Xie[a,b], Chonghui Yang[a], Alfred Kröner[b], Mingzhu Ma[a,b], Chunyan Dong[a,b], Lilin Du[a], Hangqiang Xie[a,b], Dunyi Liu[a,b]

[a] Institute of Geology, Chinese Academy of Geological Sciences, Beijing 100037, China
[b] Beijing SHRIMP Center, Beijing 100037, China
[c] State Key Laboratory for Continental Tectonics and Dynamics, Institute of Geology, Chinese Academy of Geological Sciences, Beijing 100037, China

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ABSTRACT

The North China Craton (NCC) is characterized by major ~2.5 Ga tectono-thermal events and is thus different from many other cratons worldwide where ~2.7 Ga events are well developed. However, whole-rock Nd and Hf-in-zircon isotopic compositions of ~2.5 Ga crustally derived granitoids reveal that they mainly formed through reworking of late Mesoarchean to early Neoarchean continental material. We review the spatial distribution, rock types, geochemical and Nd–Hf isotopic compositions of ~2.7 Ga granitoids that are widely identified in the NCC, including eastern Shandong, western Shandong, Huoqiu, Hengshan, Fuping, Zanhuang, Zhongtiao and Wuchuan. These granitoids are mainly tonalitic in composition and frequently underwent strong metamorphism, deformation and anatexis. They show large variations in SiO_2, total FeO, MgO and CaO, and can be subdivided into two types in terms of their REE patterns. More importantly, whole-rock Nd and Hf-in-zircon isotopic compositions indicate that the strong ~2.7 Ga tectono-thermal event mainly involved juvenile additions to the continental crust. The early Neoarchean was the most important period for rapid production of new continental crust in the NCC. The main difference of the NCC from many other cratons worldwide is a strong and widespread superimposed tectono-thermal event at ~2.5 Ga that stabilized the cratonic assemblage.

1. Introduction

Although the earliest continental crust is considered to have formed some 4.4 Ga ago (Wilde et al., 2001), the Neoarchean is considered to have been the most important period of continent crust formation globally (Condie, 2000; Condie et al., 2009). Such events more widely occurred in the early Neoarchean than in the late Neoarchean worldwide (Fig. 1a). Based on zircon dating, only a few areas such as the North China Craton (NCC), southern India, Antarctica, Brazil and northwestern Australia show evidence of strong tectono-thermal events in the late Neoarchean (Jayananda et al., 2000; Condie et al., 2005; Shen et al., 2005; Drüppel et al., 2009; Clark et al., 2009; Veevers and Saeed, 2009; Wan et al., 2011a). However, zircon ages provide records of igneous and/or metamorphic events but do not always record the time of crustal growth, i.e. the addition of new material from mantle. Late Neoarchean events widely occurred in the NCC (Fig. 1b), and evidence shows that both juvenile crustal additions and reworking of older material occurred at that time (Wilde et al., 2005; Wan et al., 2010a, 2012a). However, more work is required to determine which process was more important. Significant progress in early Precambrian studies was made in recent years by the discovery of early Neoarchean rocks in many areas of the NCC (Dong et al., 2012a; Han et al., 2012; Jahn et al., 2008; Jiang et al., 2010; Kröner et al., 2005a,b; Lu et al., 2008; Ma et al., 2013; Wan et al., 2011b; Yang et al., 2013; Zheng et al., 2004, 2009; Zhu et al., 2013). We review the spatial and temporal distribution and geochemical features of these rocks and report new whole-rock Nd and Hf-in-zircon isotopic data and further discuss the role of ~2.7 Ga tectono-thermal event in the formation of continental crust in the NCC.

2. Geological background

The NCC is one of the largest cratons in eastern Eurasia and its major tectonic structures are cut off by young orogenic belts at the craton boundaries. Therefore, as is the case with many other cratons, the NCC is most likely a fragment of a once

* Corresponding author at: Institute of Geology, Chinese Academy of Geological Sciences, Beijing 100037, China. Tel.: +86 010 68999762.
E-mail address: wanyusheng@bjshrimp.cn (Y. Wan).

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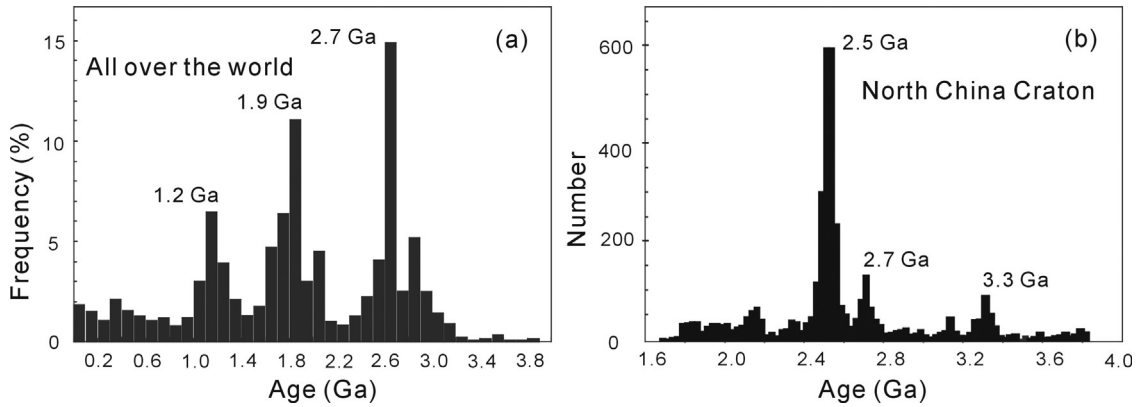

Fig. 1. Age histograms of magmatic zircons. (a) Worldwide (Condie, 2000); (b) North China Craton.
Source: Modified after Wan et al. (2011a).

larger cratonic domain. Archean basement is widely distributed in many areas of the NCC, including Guyang, Wuchuan, Daqingshan, Huai'an, Zhangjiakou, Hengshan, Wutai, Fuping, Lüliang, Zanhuang, Zhongtiao, Dengfeng, Xiaoqinling, Lushan, Chengde, Miyun, eastern Hebei, western Liaoning, southern Liaoning, Anshan, northern Liaoning, southern Jilin, western Shandong, eastern Shandong, Huoqiu and Bengbu. This basement is characterized by well developed late Neoarchean tectono-thermal events, but ≥2.6 Ga rocks and zircons also occur widely in the craton, and >3.8 Ga rocks have locally been identified (Liu et al., 1992, 2008; Song et al., 1996; Wan et al., 2005, 2012b). Following the accumulation of geological and analytical data, the composition, age and evolution of the Archean basement has become better understood, but there are still different opinions and models concerning the late Neorchean evolution (Wu et al., 1998; Zhao et al., 2005; Kusky and Li, 2003; Zhai and Santosh, 2011).

The spatial distribution of ≥2.6 Ga rocks and zircon ages are shown in Fig. 2. Early Neoarchean rocks occur in eastern Shandong, western Shandong, Huoqiu, Hengshan, Fuping, Zanhuang, Zhongtiao and Wuchuan, and their general geological features are summarized below.

2.1. Eastern Shandong

Rocks of the ca. 2.7 and ~2.9 Ga trondhjemite–tonalite–granodiorite (TTG) suite are well developed in the area (Fig. 3). Although there are many zircon geochronological studies (Tang et al., 2004; Jahn et al., 2008; Liu et al., 2011a, 2013), the spatial distribution of these rocks is still uncertain. It is difficult to distinguish between ~2.7 Ga and ~2.9 Ga TTG rocks in field due to strong metamorphism and deformation and similar compositions. Furthermore, based on field observations, most rocks of the Jiaodong (eastern Shandong) "Group" (we use the terms "group" and "formation" with quotation marks and refer to Wan et al. (2006a) for discussion of this issue) are metamorphosed intrusions, whereas only a few belong to supracrustal sequences. Therefore, Fig. 3 should be further revised after more work has been carried out. Nevertheless, we conclude that ~2.7 Ga TTG rocks occur extensively with a total area of >20 km^2. These Archean rocks underwent strong upper amphibolite- to granulite-facies metamorphism at the end of the Neoarchean (Jahn et al., 2008; Liu et al., 2011b; Wan et al., 2011c) with some rocks also recording late Paleoproterozoic metamorphism together with the

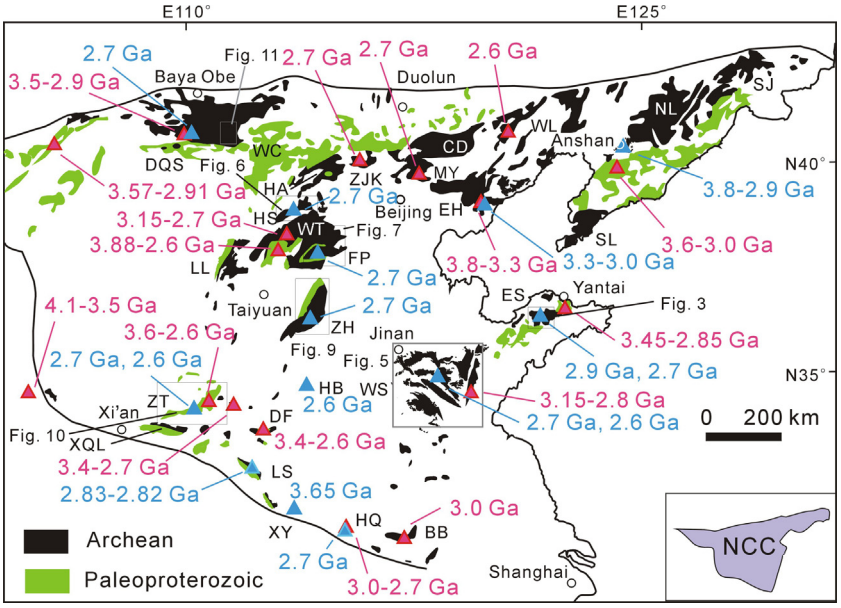

Fig. 2. Geological map of the early Precambrian basement of the North China Craton, showing spatial distribution of >2.6 Ga rocks and zircons.
WC: Wuchuan; HA: Huai'an; ZJK: Zhangjiakou; HS: Hengshan; WT: Wutai; FP: Fuping; LL: Luliang; ZH: Zanhuang; ZT: Zhongtiao; DF: Dengfeng; XQL: Xiaoqinling; LS: Lushan; CD: Chengde; MY: Miyun; EH: eastern Hebei; WL: weastern Liaoning; SL: southern Liaoning; NL: northern Liaoning; SJ: southern Jilin; WS: western Shandong; ES: eastern Shandong; HQ: Huoqiu; BB: Bengbu; Blue triangle: >2.6 Ga rocks; pink triangle: >2.6 Ga zircons.