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Provenance of Ediacaran (Sinian) sediments in the Helanshan area, North China Craton: Constraints from U–Pb geochronology and Hf isotopes of detrital zircons

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A B S T R A C T

The tectonic relationship between the Alxa Block and the North China Craton has long been controversial. The Helanshan area lies at the western margin of the Ordos Block and to the east of the Alxa Block, and it contains Eidacaran Zhengmuguan Formation and Tuerkeng Formation. The Zhengmuguan Formation is made up of tillites, limestone and dolomite, and the Tuerkeng Formation consists of silty slate. A parallel unconformity marks the boundary between the Tuerkeng Formation and the Early Cambrian Suyukou Formation, which is composed mainly of phosphatic pebbly sandstone and sandstone. U–Pb dating ages of detrital zircons in the Zhengmuguan and Suyukou Formations reveal two Neoproterozoic age peaks of 818 ± 4 Ma (n = 88) and 905 ± 8 Ma (n = 20). Neoproterozoic magmatic events have yet been reported in the basement of the Ordos Block, while some Neoproterozoic igneous rocks have been found in the basement of the Alxa Block. Moreover, the two Neoproterozoic age peaks correspond well with the ages of Neoproterozoic igneous rocks in Alxa Block. The Hf isotopic characteristics of a part of Neoproterozoic zircons from the Ediacaran Zhengmuguan Formation in the Helanshan area ($\varepsilon_{Hf}(t)$ = −7.812 to 3.274, T_{DMC} = 2211–1578 Ma, n = 10) are similar to those Neoproterozoic igneous zircons from the Langshan area ($\varepsilon_{Hf}(t)$ = −1.105 to 5.928, T_{DMC} = 1.75–1.38 Ga, n = 23) and Bayinnuoergong area in the Alxa Block. The parental magmas had a long residency time in the crust. It seems, therefore, that Alxa Block provenance provided Neoproterozoic clastics for Helanshan area in Ediacaran, and Alxa Block had already been a part of the North China Craton by the late Neoproterozoic, even earlier.

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1. Introduction

Continent–continent or arc–continent collisions commonly produces orogenic belts, as in the Central Asian Orogenic Belt (Jahn et al., 2000; Windley et al., 2007; Kröner et al., 2008), the Qinling–Dabie Orogenic Belt (Hacker et al., 1998, 2004; Wu and Zheng, 2013), and the Himalaya Orogenic Belt (Yin and Harrison, 2000), and so on. However, there is no typical orogenic belt that marks the amalgamation of the Alxa Block and the North China Craton (NCC) (Zhang et al., 2012; Dan et al., 2016). The tectonic evolution and timing of amalgamation of the Alxa Block and the NCC are debated because of a lack of reliable geological evidence, and six main models have been proposed, as follows: (1) All the microblocks in the NCC, such as the Alxa, Jining, Ordos, Xuchang, Xuhuai, and Jiaoliao blocks, were welded by late Archean greenstone belts at the end of the Neoarchean (Zhai and Bian, 2000; Zhai, 2011, 2014; Zhai and Santosh, 2011) (Fig. 1), as evidenced by the Longshoushan complexes along the southern margin of the Alxa Block sharing a similar history of evolution with the Paleoproterozoic basement of the NCC (Gong et al., 2011, 2016). (2) The Yinshan Block, to which the Alxa Block belongs, amalgamated with the Ordos Block to form the Western Block of the NCC at 2.0–1.9 Ga (Zhao et al., 2005) (Fig.2). (3) The Alxa Block and the Hexi Corridor Terrane rotated counterclockwise by about 15° with respect to the NCC during the Middle to Late Cambrian, which means that the Alxa Block and Hexi Corridor were accreted to the west of the NCC by the Late Cambrian (Huang et al., 1999, 2000). (4) The linear distribution of early Paleozoic to early Carboniferous granitoids, the high $\delta^{18}O$ values in zircons from late Silurian quartz diorites, Early Devonian metamorphism, and a foreland basin system that formed between the Alxa Block and NCC all suggest the occurrence

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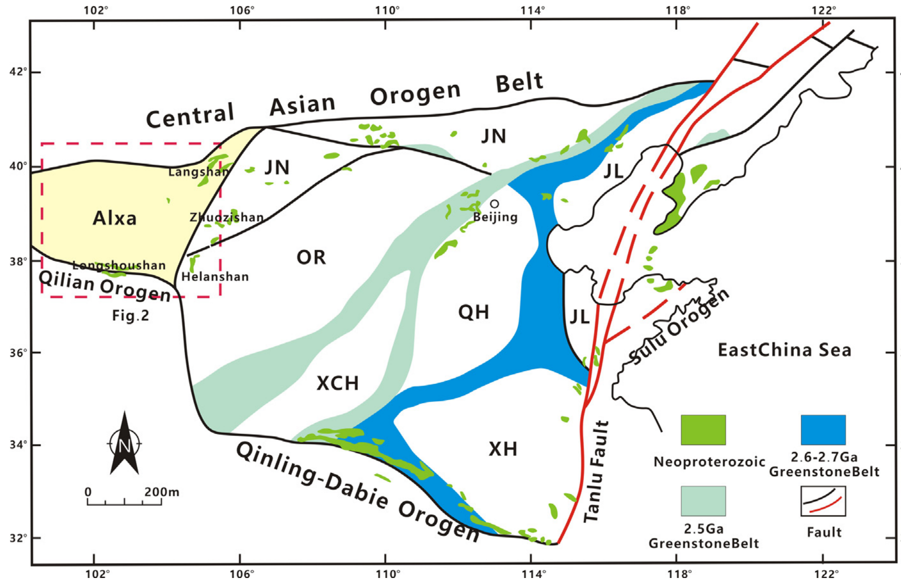

Fig. 1. Distribution of microblocks that make up the North China Craton (NCC), and greenstone belts and Neoproterozoic rocks in the NCC (modified after Zhai and Santosh, 2011; Hu et al., 2014). The seven microblocks are as follows: (1) Alxa = Alxa Block, (2) OR = Ordos Block, (3) JN = Jining Block, (4) XCH = Xuchang Block, (5) QH = Qianhuai Block, (6) XH = Xuhuai Block, and (7) JL = Jiaoliao Block.

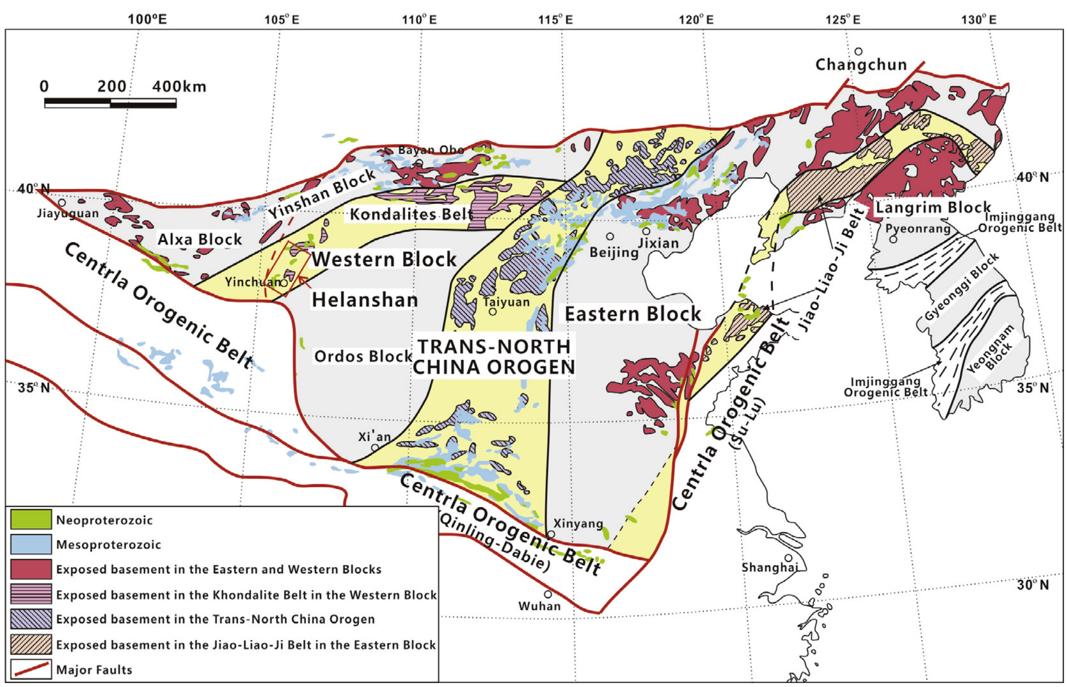

Fig. 2. Tectonic subdivision and meso-Neoproterozoic sedimentary cover of North China Craton (Tectonic subdivision of North China Craton is modified after Zhao et al., 2005, and the distribution of meso-Neoproterozoic sedimentary cover of North China Craton is after Hu et al., 2014).

of collision and the presence of a Paleozoic cryptic suture zone within the Bayanwulashan–Diebusige complexes. Detrital zircon data suggest the initial collision between the Alxa Block and the NCC took place in the Late Ordovician (Dan et al., 2016). (5) The age patterns of detrital zircons in Middle Cambrian to Ordovician strata of the Xiaoluoshan and Niushoushan areas, and in the western part of Helanshan, differ significantly from those in Zhuozishan, which indicates different provenances at that time, suggesting in turn that the Alxa Block had amalgamated with the NCC by the Middle Ordovician (Li et al., 2009, 2012; Zhang et al., 2011, 2012, 2015). The angular unconformity and differences in provenance between the early Paleozoic and Silurian or Devonian strata indicate that the paleo-ocean between the Alxa Block and the NCC closed at the end of the early Paleozoic (Li et al., 2012; Xu et al., 2015). (6) The age patterns of detrital zircons, their Hf isotope characteristics, and paleomagnetic poles for the Middle–Late Devonian to late Permian, as obtained from Niushoushan, all differ significantly from the data of the NCC, indicating that the Alxa Block and the NCC were amalgamated during the Late Triassic to Early Jurassic (Yang et al., 2014; Yuan and Yang, 2015a,b).

The timing of collision between the Alxa Block and the North China Craton is a key issue when discussing the evolution of the

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