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Ages and tectonic implications of Neoproterozoic ortho- and paragneisses in the Beishan Orogenic Belt, China

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ABSTRACT

The Beishan Orogenic Belt (BSOB) in China plays a pivotal role in understanding the tectonic evolution of the southern Central Asian Orogenic Belt. Despite numerous studies primarily emphasizing on Phanerozoic events, the existence and significance of Precambrian rocks in the BSOB still remain controversial. Here we report new geochemical and zircon U–Pb–Hf isotopic data for the Gubaoquan ortho- and paragneisses in the BSOB and the comparable Xingxingxia orthogneisses in the Central Tianshan Orogenic Belt to constrain their age, petrogenesis and tectonic implications.

New LA-ICPMS U–Pb zircon dating results of zircon reveal that the protoliths of the Gubaoquan orthogneisses crystallized at 905–871 Ma, while the Gubaoquan paragneisses yielded an age peak at 1040–910 Ma with a maximum depositional age of ~871 Ma. They are the oldest rocks discovered in the BSOB, mainly distributed in the southern units and interpreted as primary sources for the local Phanerozoic igneous and sedimentary rocks. The intrusion age of the Xingxingxia orthogneisses was ~1014 Ma. All the Gubaoquan and Xingxingxia orthogneisses show low A/CNK, Rb/Sr and Rb/Ba ratios and similar depletion of Nb, Ta and Ti, akin to I-type granitoids related to subduction. However, the former have much lower Sr contents and Sr/Y ratios, lower light to heavy rare earth element fractionation (LREE/HREE = 4.43–10.12), and weaker negative Eu anomalies, related to a back-arc setting at low pressures, whereas the latter formed at high pressures in a continental arc setting. Zircon Hf-isotope compositions in the Gubaoquan ortho- and paragneisses exhibit a large range of $\varepsilon_{\rm Hf}(t)$ values from −3.77 to +5.29, and two-stage model ages ($T^{\rm C}_{\rm DM}$) of 1.98–1.44 Ga, while those in the Xingxingxia orthogneisses are clustered with slightly higher $\varepsilon_{\rm Hf}(t)$ values (+4.02 to +8.53) and younger $T^{\rm C}_{\rm DM}$ ages (1.60–1. 34 Ga). The protoliths of both the Gubaoquan and Xingxingxia orthogneisses were derived from the mixing of basaltic magmas and those derived from the partial melting of meta-greywackes. Based on a review of Neoproterozoic events, the BSOB tends to closely link with the Chinese Tianshan Orogenic Belt and Tarim Craton. They were most likely located in the periphery of the already assembled Rodinia supercontinent.

1. Introduction

The identification of Precambrian crustal components is critical to understand the generation and evolution of Phanerozoic continental crust. More than 60% of the global continental crust was generated in Archean, which was largely recycled and mixed with younger crust by subsequent subduction and orogenic processes at convergent margins, shear zones and rifts (e.g. Armstrong, 1991; Goodwin, 1991; Gorbatschev and Bogdanova, 1993; Rao et al., 1996; Wu et al., 2000; Belousova et al., 2010 and references therein). Thus, Phanerozoic tectonic activities probably have a close link to Precambrian rocks in the region.

The Central Asian Orogenic Belt (CAOB), situated between the southern margins of the Siberian and East European Cratons to the north and the northern margins of the Tarim and North China Cratons to the south (Fig. 1a), is one of the largest Phanerozoic accretionary orogens in the world. Geochronological, geochemical, structural and geophysical studies have mainly been conducted on Phanerozoic tectonics (Mossakovsky et al., 1993; Şengör et al., 1993; Şengör and Natal'in, 1996; Jahn et al., 2000; Windley et al., 2007; Xiao et al., 2009, 2010a, 2013; Schulmann and Paterson, 2011; Wilhem et al., 2012; Eizenhöfer et al., 2014, 2015; Han et al., 2015; Zhang et al., 2015). However, there is only limited knowledge regarding the Precambrian rocks. The presence of

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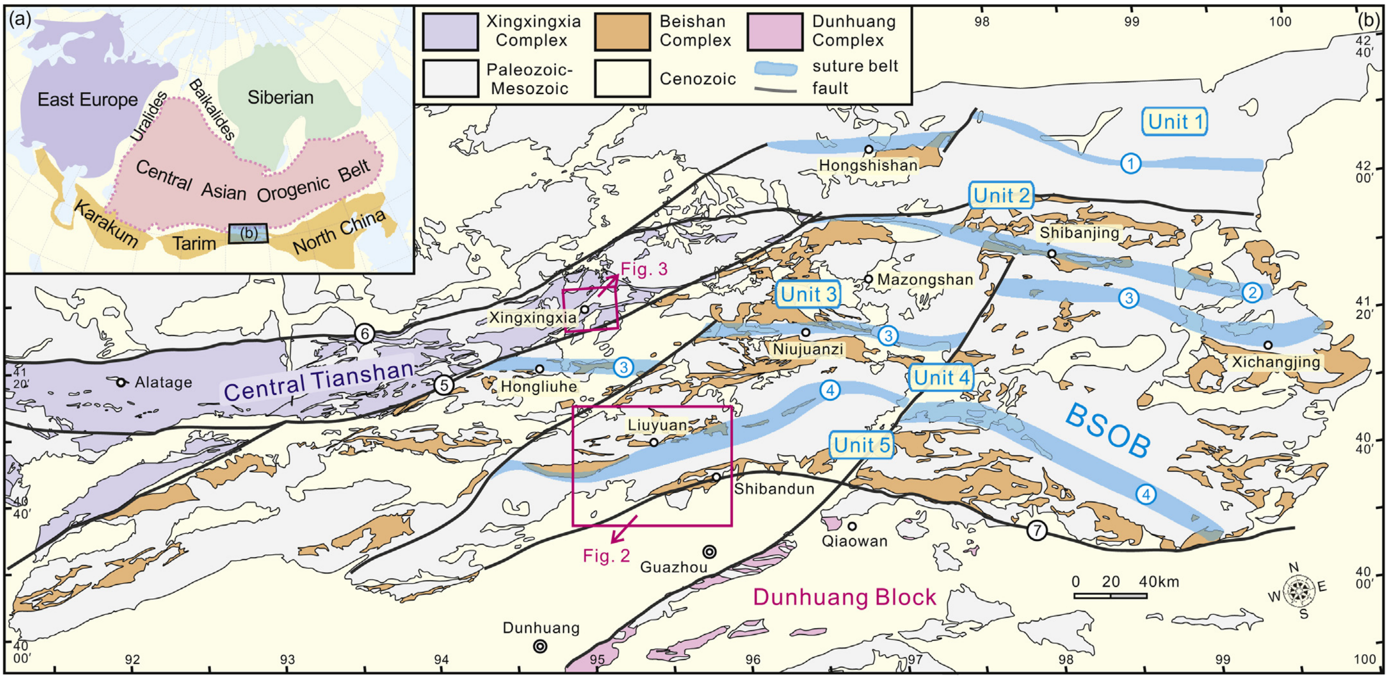

Fig. 1. (a) Simplified tectonic sketch map of the CAOB showing the location of the BSOB and (b) distribution of Precambrian rocks in the BSOB, Central Tianshan Orogenic Belt and Dunhuang Block (modified after Geological map of Tianshan and its adjacent area, 1:1,000,000; Xiao et al., 2010b; Jiang et al., 2013). (1)-Hongshishan mélange, (2)-Xingxingxia-Shibanjing mélange, (3)-Hongliuhe-Xichangjing mélange, (4)-Liuyuan mélange, (5)-Xingxingxia fault, (6)-Shaquanzi fault, (7)-Shibandun fault, Unit 1-Queershan unit, Unit 2-Heiyingshan-Hanshan unit, Unit 3-Mazongshan unit, Unit 4-Shuangyingshan-Huaniushan unit, Unit 5-Shibanshan unit.

Precambrian rocks in the CAOB, and their contributions to Phanerozoic orogeny have been hotly debated in the last two decades and is far from being resolved (Mossakovsky et al., 1993; Şengör et al., 1993; Şengör and Natal'in, 1996; Buslov et al., 2001; Demoux et al., 2009; Xiao et al., 2010a,b, 2013; Glorie et al., 2011; Rojas-Agramonte et al., 2011; Safonova et al., 2011; Kröner et al., 2014). This hinders us to better understand the basic architecture and Phanerozoic tectonic evolution of the CAOB.

As a key area in the southernmost CAOB, the Beishan Orogenic Belt (BSOB) was located between the Chinese Tianshan suture to the west and the Solonker suture to the east (Zuo and He, 1990; Zuo et al., 1990, 1991; Xiao et al., 2010b). Apart from ophiolitic mélanges and accretionary complexes, the BSOB is also composed of Precambrian rocks, commonly termed "the Beishan Complex" (Fig. 1b) (Zuo and He, 1990; Zuo et al., 1990, 1991; Mei et al., 1997; Wei et al., 2000; Xiao et al., 2010b). Thus, it provides an ideal ground to evaluate the tectonic evolution of Precambrian rocks and their contributions during the subsequent Phanerozoic orogeny.

In early Chinese literatures, the BSOB was considered to comprise Archean to Paleoproterozoic basement based on high-grade regional metamorphism and high-strain deformation features (Zuo and He, 1990; Zuo et al., 1990, 1991; BGMRG, 1993; Mei et al., 1997; He et al., 2005), and a few inaccurate whole-rock Sm-Nd isochron and TIMS zircon U–Pb ages of 2.9–1.7 Ga (Li, 1994; Mei et al., 1998; Wei et al., 2000; Sun et al., 2005). In the past few years, high-resolution LA-ICPMS and SHRIMP zircon U–Pb dating analyses were conducted. Song et al. (2013a,b) argued that the granitoid gneisses from the Beishan Complex crystallized at 527–375 Ma, much younger than 2.9–1.7 Ga. Additionally, meta-sedimentary rocks from the Beishan Complex were considered to have been deposited after 476–276 Ma (Song et al., 2013a,b,c). These new data questioned the existence of Precambrian basement in the BSOB, and the previously considered Precambrian Beishan Complex was proposed to be solely the product of Phanerozoic events. However, amphibolites and granitic gneisses with protolith ages of 902–880 Ma were identified (Mei et al., 1999; Jiang et al., 2013; Ye et al., 2013). The maximum depositional ages of 1530–1040 Ma were also reported by Song et al. (2013c), suggesting that some meta-sedimentary rocks might have formed during Precambrian time. As a consequence, the existence and tectonic implications of Precambrian rocks in the BSOB still remains unresolved, and requires further in-depth investigation.

In order to address these issues, we conducted zircon U–Pb–Hf isotope and whole-rock geochemical analyses on the Gubaoquan ortho- and paragneisses in the BSOB, and also compared the results with those from the Xingxingxia orthogneisses in the nearby easternmost Central Tianshan Orogenic Belt. New data provide new constraints on the age, petrogenesis and tectonic setting of the Beishan Complex, and shed new light on the early stage of the tectonic evolution and Phanerozoic orogeny of the BSOB.

2. Geological background

The BSOB is separated from the Central Tianshan Orogenic Belt to the northwest and its eastern part is buried under sand. To the south of the BSOB is the Dunhuang Block and to the north is the Southern Mongolia accretionary collage (Zuo and He, 1990; Zuo et al., 1990, 1991; BGMRG, 1993; Xiao et al., 2010b) (Fig. 1b). In general, the BSOB was divided into five tectonic units separated by four E-W trending ophiolitic mélanges, which are offset by younger NE-SW trending strike-slip faults (Fig. 1b) (Zuo and He, 1990; Zuo et al., 1990, 1991; BGMRG, 1993; He et al., 2002; Xiao et al., 2010b). It is mainly composed of Paleozoic accretionary complexes, Mesozoic post-orogenic igneous, sedimentary and Precambrian Beishan Complex (Xiao et al., 2010b).

The Beishan Complex is widely distributed across the BSOB (Fig. 1b) and contains high- and low-grade metamorphic rocks. The high-grade metamorphic rocks are mainly comprised of granitic gneisses, migmatites, amphibolites and schists, which underwent up to amphibolite-facies metamorphism (BGMRG, 1993). Their protoliths have long been recognized as