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Geochemical and geochronological evidence for a former early Neoproterozoic microcontinent in the South Beishan Orogenic Belt, southernmost Central Asian Orogenic Belt

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ABSTRACT

The South Beishan Orogenic Belt (SBOB) in the southwestern Central Asian Orogenic Belt (CAOB) is thought to be an eastern extension of the Eastern Tianshan Orogen. Up to now, it has been suggested to consist of a well-preserved Paleozoic magmatic and sedimentary sequence with a possible former Neoproterozoic microcontinent. We provide new geochemical and geochronological data for gneissic granites of the SBOB in order to constrain its tectonic evolution and setting. The gneissic granitoids belong to the high-K, calc-alkaline series and are characterized by an enrichment of light rare earth elements (LREE) and large ion lithophile elements (LILE), a depletion of Nb, Ta, Ti, Sr, and Ba and a positive Pb anomaly. The petrography and geochemical signatures reveal a possible I-type granite affinity and are in accordance with typical Andean Arc granites. Zircon grains, yielding $^{206}Pb/^{238}U$ magmatic crystallization ages of 933 ± 2 Ma and 900–890 Ma for the Shibanshan and Huaniushan arc granites, respectively, manifest the former presence of an early Neoproterozoic Precambrian microcontinent in the SBOB. Zircon $\varepsilon_{Hf}(t)$ values range from −16.1 to 10.2, indicating that juvenile material and reworked ancient crust were involved in the source of the gneissic granites. Furthermore, in conjunction with studies of the adjacent regions, the results of the present study suggest that the former Precambrian microcontinent in the SBOB neither belonged to the nearby Dunhuang Block nor the Tarim Craton, but has a common affinity with the Central Tianshan Arc Terrane. It is also suggested that the 900–890 Ma plutons originated from the mixing of juvenile material with older crust in an Andean-type active continental arc setting during the assembly of Rodinia. Thus the SBOB plays a key role in understanding the tectonic evolution of the CAOB.

1. Introduction

The Central Asian Orogenic Belt (CAOB), also known as Altaids, that is surrounded by the Siberian, Baltic, Tarim and North China Cratons, is one of the largest and most complex accretionary orogenic belts in the world (Jahn et al., 2000, 2004; Sengör et al., 1993; Windley et al., 2007; Xiao et al., 2009). The CAOB, is thought to have been formed by a complicated process of subduction, collision and amalgamation of numerous island arcs, seamounts and microcontinents, with the concomitant formation of accretionary complexes and ophiolitic mélanges from the early Neoproterozoic to the late Paleozoic (Coleman, 1989; Glorie et al., 2011; Sengör et al., 1993; Song et al., 2013b; Windley et al., 2007; Xiao et al., 2008). The South Beishan Orogenic Belt (SBOB) is a complex convergent extension zone of the Eastern Tianshan Orogen and is thought to have formed by early subduction–accretion processes along the continental margin at the southernmost edge of the CAOB (Coleman, 1989; Liu et al., 2011; Zuo et al., 1991). Therefore, the SBOB plays a key role in understanding the tectonic evolution of the southern CAOB and its relationship with the adjacent Central Tianshan Arc Terrane (CTA), the Dunhuang Block and the Tarim Craton. However, up to now reliable geochemical and geochronological data have been rarely obtained for Precambrian, especially Neoproterozoic magmatic rocks in the SBOB (Jiang et al., 2013; Ye et al., 2013) and their ages and geotectonic settings are still disputed and ambiguous.

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Several former geological and geochronological studies mainly focused on the Paleozoic rocks of the SBOB (Ao et al., 2012; Li et al., 2012; Zhang et al., 2011, 2012b,c). In comparison with the geochronologically well-constraint Precambrian crystalline basements of the adjacent CTA, the Dunhuang Block and the Tarim Craton (e.g. Gao et al., 2015; Ge et al., 2012, 2013a, 2014; He et al., 2014a,b; Hu et al., 2006; Huang et al., 2014a,b; Long et al., 2010, 2011; Shu et al., 2011; Wang et al., 2014a,b; Zhang et al., 2013; Zhao et al., 2013, 2015; Zhu et al., 2011.), the geochronology of the SBOB Precambrian evolution was largely neglected and less well understood. High-grade metamorphic rocks such as gneisses, quartz schists and amphibolites have been previously described as Neoarchean–Paleoproterozoic Beishan Complex and are generally regarded as Precambrian rocks (Dai and Gong, 2000; Yue et al., 2001; Zuo and He, 1990). Moreover, the limited geochronology of these rocks mainly involved Sm–Nd whole-rock isochron ages, upper intercept U/Pb zircon ages, inherited U/Pb zircon ages or zircon Hf model ages (Mei et al., 1997; Sun et al., 2005; Wei et al., 2000; Zuo and He, 1990), while direct magmatic U/Pb zircon crystallization ages are largely absent (Jiang et al., 2013; Mei et al., 1999b; Ye et al., 2013). In particular, Song et al. (2013a) reported magmatic zircon U–Pb data with age peaks at 494, 464, and 375 Ma for the Beishan Complex in the Mazongshan block and suggested that it formed in a Paleozoic subduction–accretion environment during progressive accretionary tectonics.

Furthermore, no consensus has been reached regarding the geodynamic setting of the SBOB. It has been usually regarded as a continental fragment that was separated from the Tarim Craton during the Precambrian (Dai and Gong, 2000; Dai and Tan, 2008) or the Dunhuang Block (Xiao et al., 2010). However, Jiang et al. (2013) concluded that the tectonothermal evolution of the Shibanshan arc, which is a part of the SBOB, had little in common with that of the Dunhuang Block.

In this study, we present new geochemical and (robust) geochronological data of early Neoproterozoic gneissic granites of the SBOB in order to constrain the geotectonic framework of the southernmost CAOB.

2. Geological setting and sample characteristics

The Beishan Orogenic Belt is located in the Xinjiang–Gansu–Inner Mongolia border region and constitutes an eastern extension of the Eastern Tianshan Orogen from which it is separated by the Ruoqiang–Xingxingxia fault (Liu et al., 2011; Xiao et al., 2010). The North Beishan Orogenic Belt is characterized by a complicated collage accretion system of several late Paleozoic island arcs, while the South Beishan Orogenic Belt (SBOB) may record the collision and subduction of several ancient microcontinents (Cleven et al., 2013; Liu et al., 2011; Qu et al., 2011; Song et al., 2013a; Tian et al., 2014; Xiao et al., 2010). The Huaniushan and Shibanshan arcs of the SBOB are the topic of the present study (Fig. 1a). Neoproterozoic gneissic granitoids have been reported to occur in the Huaniushan and Shibanshan arcs (Jiang et al., 2013; Mei et al., 1999a; Ye et al., 2013) and early Paleozoic eclogites lenses are exposed in the gneissic rocks of the Huaniushan arc (Liu et al., 2011; Qu et al., 2011). The Dunhuang Block to the south of the SBOB is thought to be an eastern part of the Tarim Craton (He et al., 2013; Lu et al., 2008). In the present study, we investigated gneissic granitoid samples from the Gubaoquan (Huaniushan arc) and Yadan (Shibanshan arc) areas, respectively (Fig. 1a and b).

Seven representative gneissic granitoids, six samples (X10-27-2, X11-97-2, X11-99-1, X11-100-1, X11-99-2, X11-101-1) from the Gubaoquan area and one sample (X10-7-4) from the Yadan area, were selected for major and trace element whole-rock analysis and *in situ* U–Pb dating as well as trace-element and Hf isotope analysis of zircon. The selected gneissic granites are grey or light red in color. Samples X10-7-4, X10-27-2, X11-99-1 and X11-100-1 have a granoblastic texture and are characterized by a well-developed gneissosity. Samples X11-97-2, X11-99-2 and X11-101-1 are mylonitic and the K-feldspar phenocrysts always occur as oriented augens (Fig. 2), indicating an intense deformation. All samples show a similar mineral assemblage and mainly consist of K-feldspar, plagioclase, quartz, and in places orientated biotite and/or rare muscovite as well as accessory titanite, apatite and zircon (Fig. 3). It is worth to note that only the Gubaoquan samples have rare muscovite (Fig. 3c–f), which is absent in the Yadan sample (Fig. 3a and b). However, the gneissic Gubaoquan granitoids probably underwent high-grade metamorphism during intensive deformation, which is in accordance with the presence of early Paleozoic high-pressure eclogites in the Gubaoquan area (Liu et al., 2011; Qu et al., 2011). Consequently, we suggest that these muscovite grains are of metamorphic origin and cannot be used to identify the protolith of these gneissic granitoid.

3. Analytical methods

3.1. Major element analysis of whole-rock

The rock samples were first crushed to less than 5 mm in a corundum jaw crusher. About 100 g was powdered in a vibratory disc mill (RS200, Retsch GmbH, Germany) equipped with a tungsten carbide milling cup to less than 200 mesh. The major element compositions were measured by X-ray fluorescence (XRF) using fused glass disks at the State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Wuhan. The analytical precision was checked by repeated sample measurements (one in ten samples). USGS standard AGV-2 and Chinese National standards GSR-1 and GRS-7 were used. The detailed sample-digesting procedure for XRF analyses and analytical precision and accuracy for major element compositions are the same as described by Ma et al. (2012a).

3.2. Trace element analysis of whole-rock

About 50 mg sample rock powder was digested by $HF + HNO_3$ in Teflon bombs and analyzed for trace elements by inductively coupled plasma mass spectrometry (Agilent 7500a ICP-MS) at the State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Wuhan. For the detailed sample-digesting procedure and analytical precision and accuracy for the trace elements see Liu et al. (2008b).

3.3. Zircon cathodoluminescence (CL) images

Zircons were extracted by standard density and magnetic separation techniques. The selected zircon grains were hand-picked under a stereoscopic mircroscope and were mounted in epoxy resin before polished to section the crystals in half for analysis. CL images of analyzed zircon grains were obtained employing a Hitachi S2250-N scanning electron microscope at the SHRIMR unit in the Institute of Geology, Chinese Academy of Geological Sciences, Beijing.

3.4. U–Pb dating and trace element analysis of zircon by LA-ICP-MS

U–Pb dating and trace element analyses of zircon grains were conducted simultaneously by LA-ICP-MS at the State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Wuhan. Detailed operating conditions for the laser ablation system and the ICP-MS instrument and data