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Early Permian post-collisional high-K granitoids from Liuyuan area in southern Beishan orogen, NW China: Petrogenesis and tectonic implications

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ABSTRACT

Early Permian magmatism is one of the most important tectonothermal events in the Central Asian Orogenic Belt (CAOB). Early Permian granitic magmatism has been recognized from southern Beishan, NW China and they were emplaced between 275 Ma and 279 Ma according to LA-ICPMS zircon U–Pb dating. They are mainly metaluminous I-type and belong to the high-K calc-alkaline and shoshonitic series. The granitoids have calc-alkalic and alkali-calcic features. Their Sr_i values range from 0.7028 to 0.7047, $\varepsilon_{Nd}(t)$ values from −2.5 to +1.2 with Nd model ages (T_{DM}) of 1.06–1.25 Ga, suggesting a mixed magma source of juvenile material with old continental crust. Furthermore, some granitoids have weak heterogeneous zircon $\varepsilon_{Hf}(t)$ values (−1.7 to +9.6) and Hf model ages (T_{DM2} = 0.84–1.57 Ga) that are also indicative of juvenile components with a small involvement of old continental crust. Based on geochemical and isotopic features, these high-K granitoids were derived from melting of heterogeneous crustal sources or through mixing of old continental crust with juvenile components and minor AFC (assimilation and fractional crystallization). The juvenile components probably originated from underplated basaltic magmas in response to asthenospheric upwelling. These Early Permian high-K calc-alkaline granitoids in the southern Beishan orogen were probably emplaced in a post-collisional extensional setting and suggest vertical continental crustal growth in the southern CAOB, which is the same or similar to most granitoids in CAOB. This study provides new evidence for determining the post-accretionary evolution of the southern CAOB.

1. Introduction

The Altaids (e.g., Şengör et al., 1993; Xiao et al., 2008, 2009) or Central Asian Orogenic Belt (CAOB; e.g., Jahn et al., 2000a,b, 2004; Kovalenko et al., 2004; Windley et al., 2007), is a complex collage of microcontinental blocks, island arcs, oceanic crustal remnants and continental marginal facies rocks developed between the Siberia Craton to the north and the Tarim and North China cratons to the south. It is one of the largest and most complex Phanerozoic accretionary orogenic belts on Earth, recording considerable juvenile crustal growth (Cawood et al., 2009; Jahn et al., 2000a,b, 2004; Kovalenko et al., 2004; Şengör et al., 1993; Wilhem et al., 2012; Windley et al., 2002, 2007; Xiao et al., 2009). The orogenic belt is considered to have evolved from the Early Neoproterozoic (ca. 1000 Ma) to the Permian, through multiple accretion of arc/backarc systems, ophiolites and microcontinental fragments during the closure of the Paleo-Asian Ocean (Khain et al., 2002; Kovalenko et al., 2004; Wilhem et al., 2012; Windley et al., 2007; Xiao et al., 2008, 2009). The tectonic evolution of the Central Asian Orogenic Belt is characterized by a combination of accretionary, intra-continental, and collisional processes. Voluminous Early to Middle Paleozoic syn-orogenic (accretionary) intrusions of arc-affinity have been widely studied (e.g., Jahn et al., 2004; Kovalenko et al., 2004; Liu et al., 2012; Seltmann et al., 2011; Sun et al., 2008; Wang et al., 2006; Yuan et al., 2007). Following closure of the Paleo-Asian Ocean, the CAOB was affected by the Late Paleozoic (syn- or post-collisional) magmatism, and was reworked by a Mesozoic–Cenozoic intracontinental orogeny (Jahn et al., 2000a; Kröner et al., 2007; Wang et al., 2009; Wartes et al., 2002; Windley et al., 1990). The Late Paleozoic in the CAOB is characterized by tectonic transition and crustal growth with intrusions of voluminous juvenile granitoids with positive $\varepsilon_{Nd}(t)$ values and low initial $^{87}Sr/^{86}Sr$ ratios (Chen and Jahn, 2004; Han et al., 1997; Jahn et al., 2000a, 2004; Seltmann et al., 2011; Yuan et al., 2007). Many studies have been carried out on the Permian magmatisms in Altai (Cai et al., 2011; Liu et al., 2012), Junggar (Chen and Jahn, 2004; Han et al., 1997) and Tianshan (Seltmann et al., 2011; Yuan et al., 2010) orogens in the western

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CAOB, Mongolia (Jahn et al., 2009; Yarmolyuk et al., 2008) in the central CAOB as well as the Xing'an orogen in the eastern CAOB (Jian et al., 2010; Wu et al., 2011). Now, much attention has been paid on the Beishan Permian magmatism (Zhang et al., 2011, 2012) in the southwestern CAOB.

The Beishan orogen is located in the southern margin of the CAOB and connects the Eastern Tianshan orogen to the west with the Xing'an orogen to the east (Fig. 1). It is a key area to understand the tectonic evolution of the southern CAOB (Xiao et al., 2010). The Early Paleozoic orogeny has been studied and voluminous syn-orogenic granitoids have been recognized here (Li et al., 2006; Wang et al., 2007; Xiao et al., 2010; Zuo and He, 1990; Zuo et al., 1991). By comparison, the Late Paleozoic, especially Permian post-collisional/orogenic processes, including magmatism and tectonic evolution, are still poorly constrained due to the scarcity of geochemical and geochronological data (Hsü et al., 1992; Liu and Wang, 1995; Mu et al., 1994; Nie et al., 2002; Zuo and He, 1990). Although voluminous Early Paleozoic granitoids are predominant in southern Beishan (Li et al., 2009, 2011; Mao et al., 2009; Zhao et al., 2007), the Permian granitoid magmatism with predominantly high-K calc-alkaline affinity still remains little understood (Su et al., 2011a; Zhang et al., 2012). Accordingly, the precise age and petrogenesis of the Permian granitoids can provide key evidence for constraining the tectonic evolution of southern Beishan. This paper shows new zircon U–Pb ages, Hf isotopes and whole-rock major and trace element compositions and Sr–Nd isotopic characteristics for the high-K calc-alkaline granitic plutons, and evaluates their petrogenesis and tectonic implications. This study will provide new evidence for determining the post-accretionary evolution of the southern CAOB.

2. Geological setting

The Beishan orogen is located at the southern margin of the CAOB (Fig. 1a), and tectonically is regarded as the eastern extension of the Chinese Tianshan (Liu and Wang, 1995; Xiao et al., 2010; Zuo and He, 1990). The orogen consists of Precambrian rocks, Paleozoic arcs, ophiolitic mélange, accretionary complexes and arc-related basin sediments (Gong et al., 2002; He et al., 2005; Hsü et al., 1992; Liu and Wang, 1995; Wang et al., 2007; Xiao et al., 2010; Zhang et al., 2005; Zuo and He, 1990). The southern Beishan orogen is divided, from north to south, into the Xingxingxia–Hanshan block (the northern block), the Huaniushan–Baishantang arc (the central massif), the Daqishan–Zhangfangshan rift zone (the southern massif) and the Dunhuang block (Gong et al., 2002; He et al., 2005; Li et al., 2006, 2012; Wang et al., 2007; Xu et al., 2009; Zhang et al., 2005; Zuo and He, 1990) (Fig. 1b). The northern block is separated by the Hongliuhe–Niujuanzi–Xichangjing collisional zone from the central massif, and mainly comprises Late Precambrian massifs, Ordovician to Silurian arc assemblages and Late Paleozoic sedimentary sequences (Gong et al., 2002; Nie et al., 2002; Zuo and He, 1990). The Hongliuhe–Niujuanzi–Xichangjing collisional zone consists of Early Paleozoic clastic rocks, many ophiolitic tectonic slices and Carboniferous to Permian clastic rocks (Ao et al., 2012; Gong et al., 2002; Hsü et al., 1992; Nie et al., 2002; Zuo and He, 1990). Zircons from a gabbro of the ophiolites in the Hongliuhe area yielded a SHRIMP U–Pb zircon age of 516 ± 7 Ma (Zhang and Guo, 2008). The SIMS U–Pb zircon age of a plagiogranite from the Yueyashan–Xichangjing ophiolite is 533 ±2 Ma (Ao et al., 2012). This collisional zone also contains Permian turbidites and pillow basalts, and Permian–Triassic molasse-like clastic

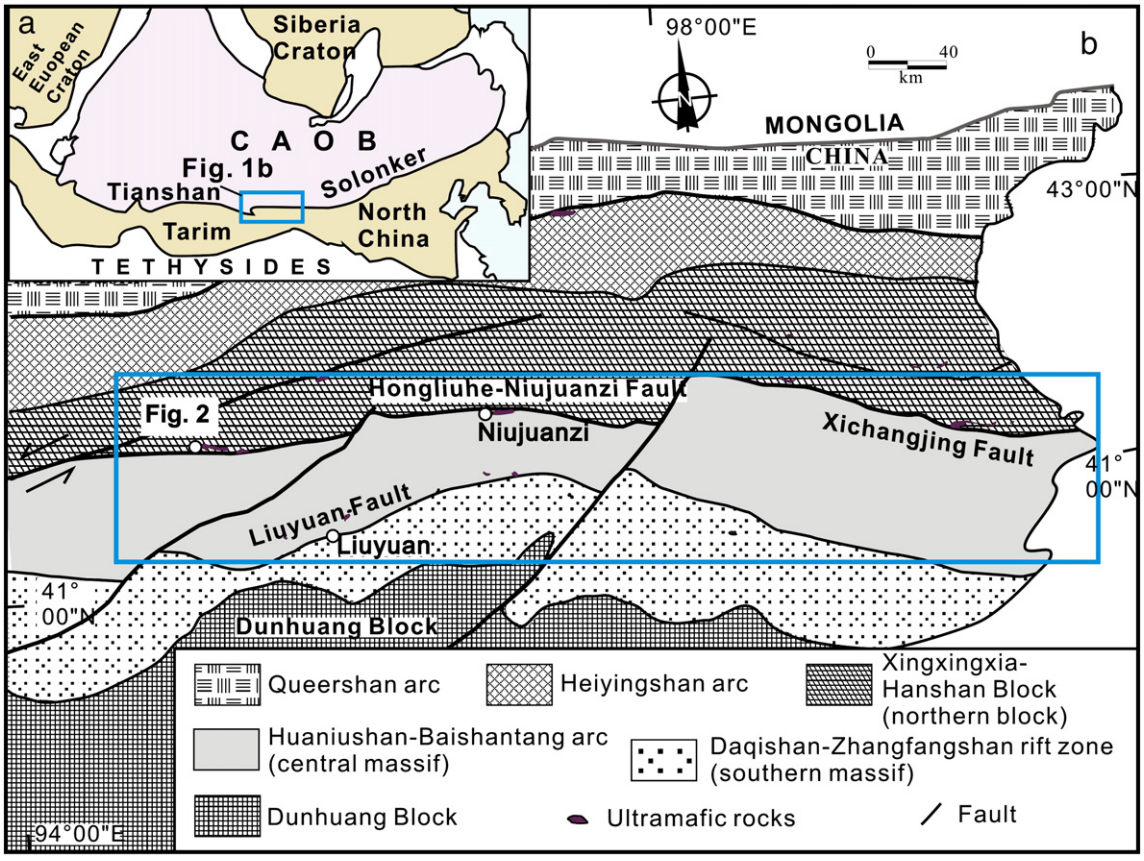

Fig. 1. (a) Location of the study area within the Central Asian Orogenic Belt and (b) simplified tectonic outline of the Beishan orogen and adjacent regions (modified after Li et al., 2012; Wang et al., 2007; Zuo and He, 1990).