Gondwana Research 29 (2016) 168–180

Contents lists available at ScienceDirect

Gondwana Research

journal homepage: www.elsevier.com/locate/gr

Latest Early Permian granitic magmatism in southern Inner Mongolia, China: Implications for the tectonic evolution of the southeastern Central Asian Orogenic Belt

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ARTICLE INFO

Article history:
Received 3 August 2014
Received in revised form 6 November 2014
Accepted 6 November 2014
Available online 4 December 2014

Handling Editor: I. Safonova

Keywords:
Continental arc
Magmatic flare-up
Tectonic switching
Extension to contraction
Closure of Paleo-Asian Ocean

ABSTRACT

Latest Early Permian (277–275 Ma) magmatic episode is one of the most important tectono-magmatic events in southeastern Central Asian Orogenic Belt (CAOB), recording a tectonic transition from accretionary to post-accretionary evolution of the Paleo-Asian Ocean. The latest Early Permian granitoids along the Solonker suture zone in southern Inner Mongolia were emplaced between 275 Ma and 277 Ma as determined by SHRIMP zircon U–Pb dating. They are characterized by variable alkali contents, a range from calcic to slightly alkalic compositions, and are magnesian I-type granitoids. Their $\varepsilon_{Nd}(t)$ values from −0.4 to +3.1 record predominantly juvenile crustal sources with moderate involvement of old crustal components. Furthermore, these granitoids show positive zircon $\varepsilon_{Hf}(t)$ values of +7.6 to +10.7 that are also indicative of predominantly juvenile nature. Their high zircon $\delta^{18}O$ values of 6.29‰ to 8.13‰, suggest significant involvement of supracrustal materials in their generation. These characteristics imply they were derived from an already hybrid andesitic magma in active continental margin. The resultant composite magmas were finally attached (relaminated) to the lower crust, where they produced segregated melt, to rise with minor assimilation of supracrustal materials, and to form these granitic plutons. The outboard migration of continental arc in response to slab roll-back, from the Late Carboniferous to the latest Early Permian, and tectonic switching from this prolonged extension to the short-lived contraction resulting from slab break-off and final amalgamation of the southeastern CAOB in the Middle-Late Permian lead to efficient continental growth in the southeastern CAOB.

1. Introduction

Granitic magmatism is one of the major mechanisms for the generation of continental crust on Earth (Condie et al., 2009). Granitoids of I-type affinity (mostly granodiorites and tonalites), form at active continental margins and along intra-continental collisional belts, representing the most outstanding magmatic episodes in the continental crust (e.g., Brown, 2013; Castro, 2013; Clemens, 2014). The orogenic collage of the Altaids (e.g., Şengör et al., 1993; Xiao et al., 2004, 2009b) or Central Asian Orogenic Belt (CAOB; e.g., Jahn et al., 2000, 2004; Kovalenko et al., 2004; Windley et al., 2007; Kröner et al., 2014) is recognized for its accretionary tectonics and production of massive juvenile crust in the Phanerozoic, especially in the Paleozoic (Şengör et al., 1993; Jahn et al., 2000; Kovalenko et al., 2004; Windley et al., 2007; Cawood et al., 2009; Xiao et al., 2009b; Wilhem et al., 2012; Xiao and Santosh, 2014). The tectonic evolution of the CAOB is characterized by a combination of Paleozoic multiple accretionary, collisional processes and intra-continental deformation during the closure of the Paleo-Asian Ocean (Khain et al., 2002; Windley et al., 2007; Xiao et al., 2009b; Wilhem et al., 2012; Safonova and Santosh, 2014). Voluminous studies have focused on the role of Paleozoic oceanic arcs in continental growth by subduction–accretion and by production of magmas in oceanic arcs (e.g., Windley et al., 2007; Kröner et al., 2008; Xiao et al., 2009b; Wilhem et al., 2012; B. Xu et al., 2013). However, the post-Archean accretionary orogens commonly comprise <10% of accreted oceanic arcs, whereas continental arcs compose 40–80% of these orogens (Condie and Kröner, 2013). Nd and Hf isotopic data with positive $\varepsilon_{Nd}(t)$ values and zircon $\varepsilon_{Hf}(t)$ (Han et al., 1997; Jahn et al., 2000; Chen and Jahn, 2004; Kovalenko et al., 2004; Yuan et al., 2007; Seltmann et al., 2011; W. Liu et al., 2012), suggest that accretionary orogens include 40–65% juvenile crustal components, with most of these (>50%) produced in continental arcs (Condie and Kröner, 2013). Continental arc, or Andean-type magmatism, in the southeastern

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http://dx.doi.org/10.1016/j.gr.2014.11.006
1342-937X/

CAOB, however, remains poorly documented, and hence the Late Paleozoic, particularly Permian, tectonic evolution of the belt has long been controversial.

The Solonker suture zone in southern Inner Mongolia of the southeastern CAOB, between the Tianshan Orogenic Belt to the west and the Songliao Basin to the east, recorded the final closure of the Paleo-Asian Ocean and termination of accretionary events within the CAOB (Xiao et al., 2003; Kovalenko et al., 2004; Li, 2006; Xiao et al., 2009a; Jian et al., 2010; Windley et al., 2010). The Early-Middle Paleozoic oceanic subduction/arc magmatisms in the southeastern CAOB have been documented (e.g., Xiao et al., 2003; Jian et al., 2008; Windley et al., 2010; B. Xu et al., 2013), but, the tectonic setting of the Early Permian magmatism in the area is still disputed. Accordingly, the studies on the origin and petrogenesis of the Early Permian magmatism can provide key evidence for constraining the Late Paleozoic tectonic evolution of the southeastern CAOB. This paper presents new zircon U–Pb ages, Hf–O isotopes and whole-rock major and trace element compositions and Sr–Nd isotopic characteristics for Early Permian I-type granitoids in the Linxi area of southern Inner Mongolia (Fig. 1), and evaluates their petrogenesis and tectonic implications, in order to shed light on the evolution of the southeastern CAOB.

2. Geological setting

The southeastern CAOB was mainly constructed by convergent processes between the active southern margin of the South Mongolia terranes to the north and the northern margin of the North China Craton to the south (Xiao et al., 2003; Jian et al., 2008; Xiao et al., 2009a; Jian et al., 2010; B. Xu et al., 2013) (Fig. 1a).

The study area is situated in southern Inner Mongolia and consists, from north to south, of the northern continental block, the Solonker suture zone and the southern continental block (Xiao et al., 2003; Jian et al., 2008, 2010; Li et al., 2013c) (Fig. 1b). The northern continental block consists mainly of the Early Paleozoic Hutag Uul Block in southern Mongolia (Badarch et al., 2002), Late Cambrian to Late Silurian (ca. 498–420 Ma, Jian et al., 2008) subduction–accretion complexes associated with some accreted Precambrian blocks (e.g., Xilin Gol complex) (Chen et al., 2009; Li et al., 2011; B. Xu et al., 2013) and Carboniferous–Early Permian arc rocks (Shi et al., 2004; Zhang et al., 2008; Chen et al., 2009; Liu et al., 2013). The southern continental block between the North China Craton and the Solonker suture zone is characterized by an Early Ordovician to Early Silurian (ca. 488–438 Ma) subduction–accretion complex and arc-related igneous rocks (Xiao et al., 2003; Jian et al., 2008; B. Xu et al., 2013). The final closure of the Paleo-Asian Ocean in the Middle Permian led to formation of the Solonker suture zone (Li, 2006; Chen et al., 2009; Jian et al., 2010). The sequence of tectono-magmatic events in Permian occurred in response to block amalgamation and intra-continental shortening, whereas those in Triassic to post-collisional or post-orogenic extension and collapse in southern Inner Mongolia (Jian et al., 2010; Li et al., 2012, 2013a, 2014).

The oldest rocks exposed in the study area are Proterozoic metamorphic rocks of the Baoyintu 'Group' (BGMRIM, 1991, 1996; B. Xu et al., 2013). Paleozoic strata are dominated by volcano-sedimentary sequences of the Lower Permian Dashizhai Formation, sedimentary sequences of the Middle Permian Zhesi Formation and the Upper Permian Linxi Formation, all of which are unconformably covered or intruded by Mesozoic volcanic and granitoid rocks (Mueller et al., 1991; Shen et al., 2006; Wu et al., 2011).

3. Petrography

Granitoid plutonism developed extensively in the study area from the Carboniferous to the Early Cretaceous (Fig. 2). A Late Carboniferous ENE-trending calc-alkaline granitoid belt is distributed in northwest part of the study area (Fig. 2; Liu et al., 2013). To its southeast, the Early Permian to Early Cretaceous granitoids are predominant (Li et al., 2007; Liu et al., 2009; Wu et al., 2011; Li et al., 2013c). Two representative Early Permian granitic plutons in the northwest of the Linxi area were chosen for study: the Beidashan pluton and the Shahutong pluton (Fig. 2).

The Beidashan pluton (Fig. 2) intruded into sandstones of the Middle Permian Zhesi Formation, and the pluton itself was intruded by Early Cretaceous granites. This pluton is mainly composed of gray, fine- to medium-grained granodiorite consisting of euhedral to subhedral plagioclase (45–55%), anhedral alkali feldspar (20–30%), anhedral interstitial quartz (15–25%), biotite (1–5%) and hornblende (0–1%) (Fig. 3a). Accessory minerals include zircon, apatite, titanite and Fe–Ti oxides. Plagioclase has commonly experienced sericitization.

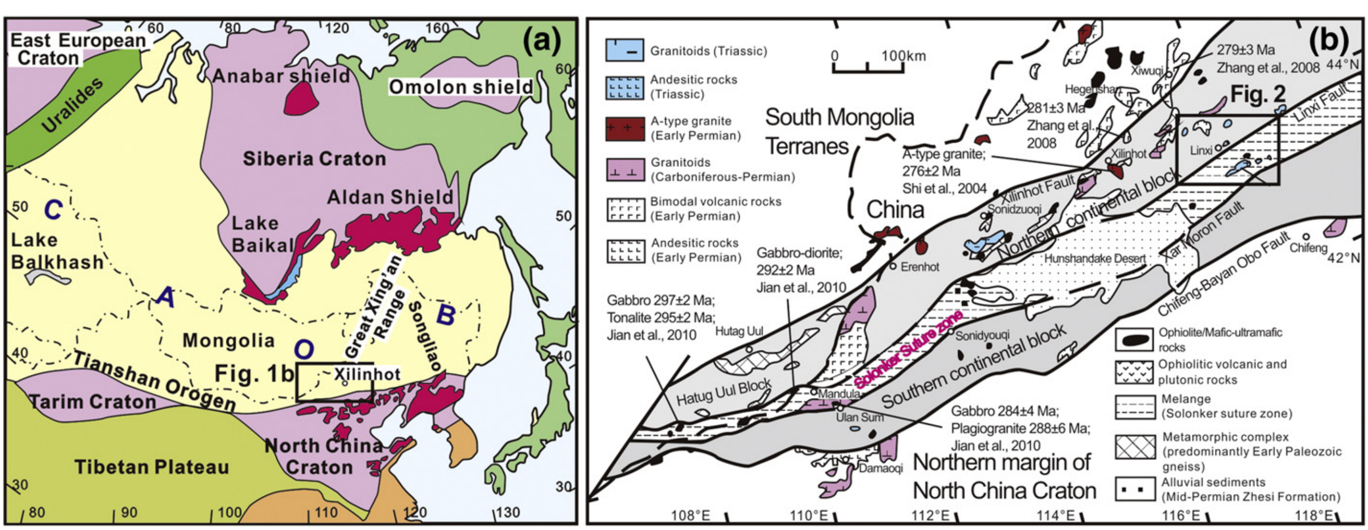

Fig. 1. (a) Simplified geological sketch map of the Central Asian Orogenic Belt (CAOB) showing the main tectonic sub-divisions (modified after Jahn et al., 2000, 2004; Kröner et al., 2008). The location of Fig. 1b is indicated. (b) Simplified tectonic map of the southeastern CAOB showing the main tectonic subdivisions and the location of Fig. 2 (modified after Xiao et al., 2003; Jian et al., 2008, 2010). Light gray zone represents the northern Early-Middle Paleozoic continental block and the Hutag Uul Block (Jian et al., 2008, 2010) or northern accretionary zone of Xiao et al. (2003), whereas the dark gray zone represents the southern Early-Middle Paleozoic orogen (Jian et al., 2008, 2010) or southern accretionary zone of Xiao et al. (2003). Published zircon U–Pb ages for Early Permian magmatic rocks in the region are shown and are from Shi et al. (2004), Zhang et al. (2008) and Jian et al. (2010).