Lithos 127 (2011) 261–281

Contents lists available at SciVerse ScienceDirect

Lithos

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

Geochronology, petrogenesis and tectonic significance of peraluminous granites from the Chinese Altai, NW China

Keda Cai [a], Min Sun [a,*], Chao Yuan [b], Guochun Zhao [a], Wenjiao Xiao [c], Xiaoping Long [b], Fuyuan Wu [c]

[a] Department of Earth Sciences, The University of Hong Kong, Pokfulam Road, Hong Kong, China
[b] Key Laboratory of Isotope Geochronology and Geochemistry, Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou 510640, China
[c] State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China

ARTICLE INFO

Article history:
Received 7 March 2011
Accepted 4 September 2011
Available online 10 September 2011

Keywords:
Geochronology
Geochemistry
Peraluminous granite
Chinese Altai
CAOB
Ridge subduction

ABSTRACT

The Paleozoic granites in the Chinese Altai are important for the study of tectonic evolution and crustal growth in the Central Asian Orogenic Belt (CAOB). Four representative peraluminous granitic intrusions were selected for systematic studies of zircon U–Pb and Hf isotopic compositions and whole-rock geochemical and Nd–Sr isotopic analyses. These rocks have high ASI (Alumina Saturation Index, $Al_2O_3/(CaO+Na_2O+K_2O)=1.01–1.46$ molecular ratios), with 0.6–5.6 wt.% of normative corundum, and are characterized by moderately negative Eu anomalies ($Eu/Eu^*=0.38–0.98$) and strong depletion in Ba, Nb and Sr elements. Our data suggest that these intrusions were emplaced from 419 to 393 Ma, consistent with a period of intensive magmatic activities and high temperature metamorphism in the Chinese Altai. While in situ zircon Hf isotopic analyses for these granites give predominantly positive $\varepsilon_{Hf}(t)$ values (+0.8 to +12.8), a few inherited zircons yield negative $\varepsilon_{Hf}(t)$ values from −12.5 to −1.53. The U–Pb age and Hf isotopic data of these inherited zircons are similar to that of the widespread metasediments. In addition, the peraluminous granitic rocks have near-zero or negative $\varepsilon_{Nd}(t)$ values (−3.3 to −0.5) and relatively high initial $^{87}Sr/^{86}Sr$ ratios (0.7079–0.7266), distinct from those of the I-type granites in the study region, but similar to the Early Paleozoic Habahe sediments. These isotopic compositions suggest that the newly accreted metasediments of Habahe Group may be the major source rock of the peraluminous granites. The geochemical compositions indicate that their precursor magmas were derived from a relatively shallow crustal level ($P \leq 5$ kbar) and zircon saturation temperatures suggest that these granitic intrusions were emplaced at 672–861 °C. The peraluminous granitic magmas were generated by dehydration melting of newly accreted materials, which were possibly brought to at least middle crustal depth by subduction-related processes in an active margin, and were subsequently molten by strikingly high ambient temperature probably caused by upwelling of the hot asthenosphere associated with ridge subduction in the Paleozoic.

1. Introduction

The Central Asian Orogenic Belt (CAOB), also called Altaids or Altai orogenic collage (Sengör et al., 1993; Yakubchuk, 2004), covers a vast area of central Asia and represents significant crustal growth in the Phanerozoic (Jahn, 2004; Jahn et al., 2000a, 2000b; Sengör et al., 1993; Windley et al., 2007; Xiao et al., 2004). The juvenile nature of the gigantic CAOB challenges the perception that the growth of the continental crust was mostly completed in the Precambrian and the amount of juvenile crust produced in the Phanerozoic was insignificant (Jahn et al., 2000b). In the long-lasting evolutionary history of the CAOB, the growth of the continental crust was represented not only by lateral amalgamation of different oceanic blocks, including island arcs, ophiolitic complexes, oceanic islands, seamounts, accretionary wedges, and oceanic plateaus (e.g., Badarch et al., 2002; Khain et al., 2002; Windley et al., 2007; Xiao et al., 2004), but also by substantial vertical addition of juvenile material derived from the upper mantle (e.g., Chen and Jahn, 2002; Han et al., 1997; Jahn, 2004; Jahn et al., 2000a, 2000b). The vertical crustal growth is supported by the study of isotopic geochemistry, such as the positive whole-rock $\varepsilon_{Nd}(t)$ and/or zircon $\varepsilon_{Hf}(t)$ values of granitoids in the CAOB (e.g., Cai et al., 2011; Chen and Jahn, 2002; Han et al., 1997; Jahn, 2004; Long et al., 2007, 2010; Sun et al., 2008; Wang et al., 2009; Yuan et al., 2007). These granitoids not only provide critical information on the Phanerozoic crustal growth, but also place important constraints on the tectonic evolution of the CAOB, since they were produced at different evolutionary stages, under different tectonic conditions and from different magmatic sources (e.g., Geng et al., 2009; Jahn, 2004; Jahn et al., 2000b).

As an important portion of the CAOB, the Chinese Altai, situated on the northern Xinjiang Uygur Autonomous Region of China, is strikingly characterized by voluminous granitic intrusions that occupy more than 40% of the exposed rocks (Fig. 1, Zou et al., 1989). Most of these intrusions are geochemically characterized by metaluminous

* Corresponding author. Tel.: +852 28592194 or 62746604; fax: +852 25176912.
E-mail address: minsun@hku.hk (M. Sun).

0024-4937/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.lithos.2011.09.001

compositions and commonly contain hornblende, thus are generally considered as syn-orogenic I-type granites (e.g., Wang et al., 2006, 2009; Yuan et al., 2007; Zou et al., 1989). Recently, zircon U–Pb dating results demonstrate that these granitic intrusions were mainly emplaced in the early Paleozoic (e.g., Cai et al., 2011; Sun et al., 2008; Wang et al., 2006; Yuan et al., 2007), and elemental and isotopic studies indicate that they were derived from juvenile sources with some assimilation of old materials (e.g., Chen and Jahn, 2002; Jahn, 2004; Sun et al., 2008; Wang et al., 2006; Yuan et al., 2007). However, the S-type peraluminous granites do occur in the region, but most of them are Mesozoic small granitic plutons and formed in a post-orogenic setting (e.g., Wang et al., 2010). Paleozoic S-type peraluminous granites however have been rarely studied previously (e.g., Qiu et al., 2007; Yuan et al., 2001). In this paper, we present new geochemical, zircon U–Pb and Hf and whole-rock Nd–Sr isotopic data for the representative Paleozoic peraluminous granitic intrusions in the central Chinese Altai (Figs. 1 and 2), and aim: (1) to constrain their emplacement ages, (2) to understand their petrogenesis and magma source, and (3) to reveal their implications for tectonic setting and geodynamic evolution.

2. Geological background

The northwest-trending Altai Orogenic Belt, a major part of the CAOB, extends for more than 2500 km, from Russia, Eastern Kazakhstan, through Northwest China to Southern Mongolia. The Chinese Altai is a type region of this orogenic belt, distributed in Xinjiang Uygur Autonomous Region, northwestern China (Fig. 1). It is situated between the Sayan and associated blocks in the north and Kazakhstan— Junggar block in the south (Windley et al., 2002; Xiao et al., 1992; Xiao et al., 2004). The geology of this region is characterized by voluminous granitoid intrusions and NW-trending faults (Fig. 1). The central Chinese Altai (units 2 and 3 of Windley et al., 2002) occupies the major part of this region with widespread sedimentary rocks termed Habahe Group. These sedimentary rocks are intruded by voluminous granitic intrusions, indicating that granitic magmatism played an important role in the evolutionary history of the Chinese Altai.

The Habahe Group, considered as the oldest sedimentary sequence in this area, is mainly composed of a thick sequence (>6000 m) of slate, phyllite and schist (e.g. BGMRX, 1993; GCRSX, 1981; Long et al., 2007, 2008, 2010; Windley et al., 2002). The detrital zircons from these rocks yield $^{206}Pb/^{238}U$ ages predominantly between 540 and 460 Ma and mostly give positive $\varepsilon_{Hf}(t)$ values, suggesting that their protoliths were generated on an active margin in the early Paleozoic (Long et al., 2007, 2010). The local high-grade metamorphic rocks in this region, such as banded para-gneisses, have zircon age populations (528 to 466 Ma) comparable to the Habahe Group, and thus they are considered to be the high-grade equivalents of the Habahe Group (Sun et al., 2008). The petrological studies of these high-grade rocks show high temperature and low pressure metamorphism with temperature estimates of ~720 °C by using the Ti-in-zircon thermometer (Jiang et al., 2010). U–Pb isotopic data for zircon overgrowth rims imply that the metamorphism was roughly coeval with widespread intense granitic magmatism in the period of 420–390 Ma (e.g., Cai et al., 2011; Jiang et al., 2010; Long et al., 2007; Sun et al., 2008, 2009).

Recent zircon U–Pb dating results demonstrate a continuous granitic magmatism from the early to the middle Paleozoic in the Chinese Altai (e.g., Briggs et al., 2007; Cai et al., 2011; Sun et al., 2008, 2009; Tong et al., 2007; Yuan et al., 2007). Most of these granitoids

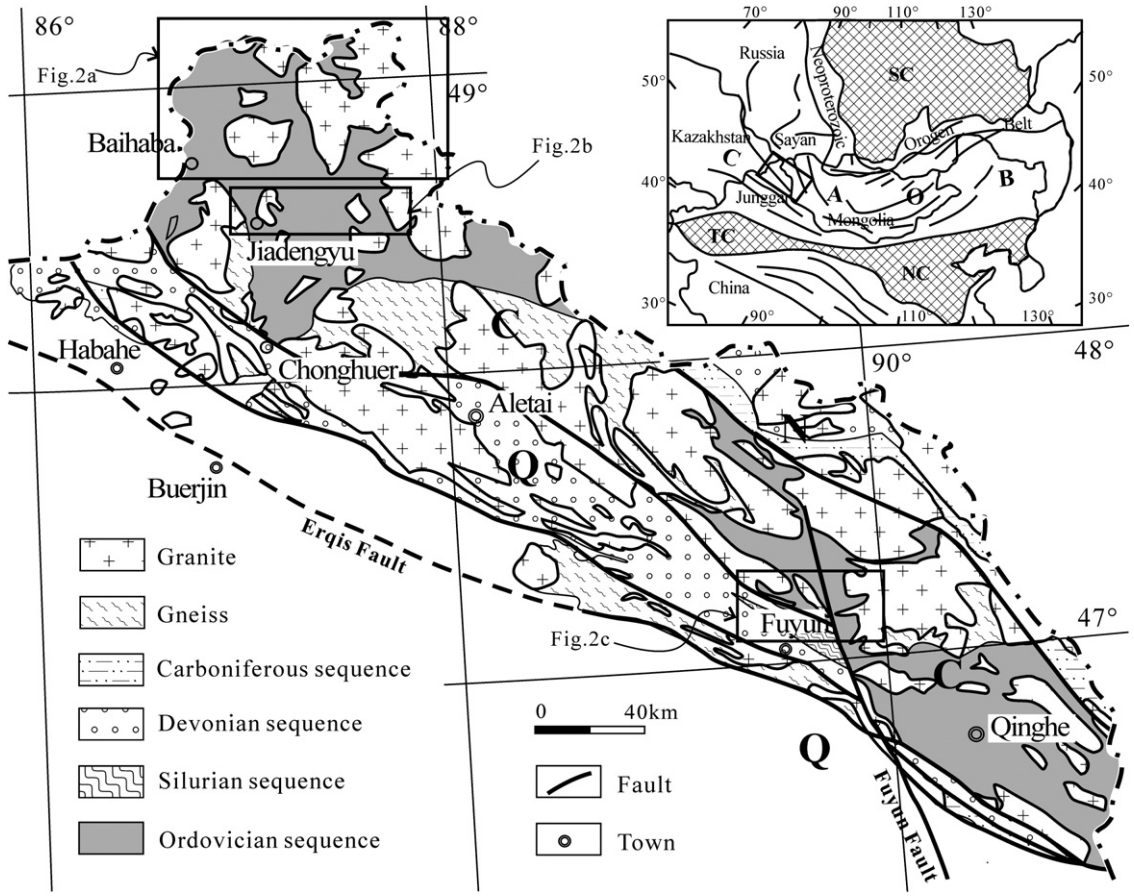

Fig. 1. Simplified geologic map of the Chinese Altai (He et al., 1990; Windley et al., 2002). N — Northern Domain, C — Central Domain, Q — Qiongkuer Domain. Inset figure shows the extension of the CAOB. The Chinese Atlai is indicated by a box. SC — Siberia Craton, TC — Tarim Craton, NC — North China Craton.