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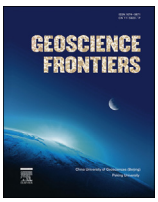


Research Paper

# Geochemistry, geochronology and Hf isotope of granitoids in the Chinese Altai: Implications for Paleozoic tectonic evolution of the Central Asian Orogenic Belt

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ABSTRACT

The Chinese Altai in northwestern Xinjiang has numerous outcrops of granitoids which provide critical information on accretionary orogenic processes and crustal growth of the Central Asian Orogenic Belt. Zircon U–Pb ages, Hf-isotopic compositions and whole-rock geochemistry of monzogranite and granodiorites in the Qinghe County are employed to elucidate Paleozoic tectonics of the Chinese Altai. Granodiorites have crystallization ages of 424.6 ± 3.1 Ma (MSWD = 0.23) and 404.0 ± 3.4 Ma (MSWD = 0.18); monzogranite was emplaced in the early Permian with a crystallization age of 293.7 ± 4.6 Ma (MSWD = 1.06). Both granodiorites and monzogranite are I-type granites with A/CNK ratios of 0.92–0.97 and 1.03–1.06, respectively. They also show similar geochemical features of high HREE and Y contents, low Sr contents and Sr/Y ratios, as well as enrichment of Cs, Rb, Th and U, and depletion of Nb, Ta, P and Ti. These geochemical features indicate that the monzogranite and granodiorites were formed in an arc setting related to subduction. The gneissic monzogranites display high $SiO_2$ and $K_2O$ contents, and belong to the high-K calc-alkaline series. In the chondrite normalized REE distribution pattern, the monzogranite samples exhibit enrichment of LREE with strong negative Eu anomalies ($\delta$Eu = 0.44–0.53), zircon $\varepsilon_{Hf}(t)$ values from +7.24 to +12.63 and two-stage Hf model ages of 463–740 Ma. This suggests that the monzogranite was generated from the mixing of pelitic and mantle material. The granodiorite samples are calc-alkaline granites with lower contents of $SiO_2$ and $Na_2O + K_2O$, higher contents of $TiO_2$, $Fe_2O_3^t$, MgO and CaO compared to the monzogranite samples. They also show enrichment of LREE and moderate negative Eu anomalies ($\delta$Eu = 0.54–0.81), as well as slightly higher differentiation of LREE than that of HREE. The 425 Ma granodiorite has zircon $\varepsilon_{Hf}(t)$ values from −0.51 to +1.98 and two-stage Hf model ages of 1133–1240 Ma, whereas the 404 Ma granodiorite displays those of +2.52 to +7.50 and 816–1071 Ma. Geochemistry and zircon Hf isotopic compositions indicate that granodiorites were formed by partial melting of juvenile lower crust. Together with regional geology and previous data, the geochemical and geochronological data of the monzogranite and granodiorites from this study suggest long-lived subduction and accretion along the Altai Orogen during ca. 425–294 Ma.



## 1. Introduction

The Central Asian Orogenic Belt (CAOB), located between the Siberian Craton to the north and North China-Tarim cratons to the south, is the largest Paleozoic to Mesozoic accretionary orogenic belt in the world (Carroll et al., 1990; Mossakovsky et al., 1993; Sengor et al., 1993; Jahn et al., 2000a,b; Khain et al., 2002; Windley et al., 2007; Xiao et al., 2004, 2009a,b,c; Safonova, 2014).

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Numerous tectonic units document the long-lasting subduction-accretion process experienced by the CAOB; these units include island arcs, seamounts, ophiolites, accretionary complexes, and continental blocks or microcontinents (Sengor et al., 1993; Xiao et al., 2004, 2009a,b,c; Windley et al., 2007; Sun et al., 2008; Shen et al., 2009; Zhang et al., 2009; Cai et al., 2011a).

The Chinese Altai in the northwestern Xinjiang Province is the most important part of the CAOB, and is considered as a key to understanding its accretionary orogenic processes (e.g., Sun et al., 2008; Xiao et al., 2010; Xiao and Santosh, 2014). Geological mapping has revealed that more than 40% of the exposed rocks in the Chinese Altai are granitoids (Zou et al., 1989) which provide critical information on the tectonic evolution and crustal growth of the CAOB (Jahn et al., 2000a,b; Sun et al., 2008; Cai et al., 2011b,c). Several precise zircon U–Pb ages, as well as geochemical and isotopic compositions of these granitoids have been published in recent years (Wang et al., 2006, 2007, 2010; Yuan et al., 2007; Sun et al., 2008, 2009; Cai et al., 2011a,b,c; He et al., 2015; Xue et al., 2016; Yu et al., 2017), suggesting prolonged Paleozoic magmatism (Sun et al., 2008; Cai et al., 2011b) related to the subduction of Paleoasian oceanic crust (Xiao et al., 2004; Domeier and Torsvik, 2014). These studies focused mostly on large batholiths, such as the plutons in the Habahe, Youyifeng, Chonghur, Qinggeli, Tarlang, Hanasi, Qiemuqieke, and Keketuohai areas (Windley et al., 2002; Wang et al., 2006; Yuan et al., 2007). However, the emplacement ages and magma sources of some small plutons are still controversial, questioning whether the plutons and batholiths are products of the same magmatic event or if they represent different magmatic and tectonic events.

In this study, zircon U–Pb geochronological, Lu–Hf isotopic and whole-rock geochemical data of three small plutons from the Qinghe County, in the southeast Chinese Altai, are employed to reveal their emplacement ages and nature of their magma sources. Based on this new dataset, we decipher further details of the tectonic setting and evolutionary history of the CAOB.

## 2. Geological setting and samples

The Chinese Altai in the Xinjiang Uygur Autonomous Region, located in the central part of the CAOB (Fig. 1b), extends eastward to Mongolia, and westward to Kazakhstan and Russia. It is situated to the south of the Siberian Sanyan Block, and north of the Junggar Block from which it is separated by the Erqis Fault (e.g., He et al., 1990; Windley et al., 2002; Xiao et al., 2004, 2010; Sun et al., 2009). Geological investigations have suggested that the Chinese Altai is divided into six NW–SE trending terranes that are bounded by faults (Windley et al., 2002; Xiao et al., 2004; Sun et al., 2009).

Ordovician–Devonian clastic, volcanic and metamorphic rocks, including the Habahe Group, Kangbutiebao and Altai formations, and Paleozoic granitoids are widely distributed in the Chinese Altai (Windley et al., 2002; Li et al., 2003; Xiao et al., 2004; Wang et al., 2006; Yuan et al., 2007; Sun et al., 2008, 2009; Cai et al., 2012). The Habahe Group, suggested as the oldest sedimentary sequence in this region (Sun et al., 2009), consists mainly of low-grade metamorphic sandstone, mudstone and slate. Geochronological and geochemical studies indicate that the sediments of this group were deposited in the Middle Ordovician or later (Long et al., 2007) on an active continental margin (Long et al., 2008; Sun et al., 2008, 2009). The Kangbutiebao Formation outcrops low-grade metamorphic acid volcanic and volcanic-clastic rocks interbedded with clastic rocks (He et al., 2014). Geochronological studies revealed that the depositional age of the clastic rocks is later than early Silurian (Long et al., 2007). Further studies on the acid volcanic rocks suggested that they formed in 400–412 Ma (Chai et al., 2009; He et al., 2015) on an active continental margin (Long et al., 2008; Chai et al., 2009; He et al., 2015). The Altai Formation is composed mainly of clastic rocks, and was also deposited on an active continental margin (Long et al., 2008).

Granitoids in the Chinese Altai played an important role in their tectonic evolution (Zou et al., 1989; He et al., 1990). Numerous new zircon U–Pb, geochemical and Sr–Nd–Hf isotopic data from these rocks, published in recent years (Wang et al., 2006, 2010; Yuan et al., 2007; Sun et al., 2008, 2009; Cai et al., 2011a,b; He et al., 2015; Xue et al., 2016; Yu et al., 2017) indicate the following typical features. The crystallization ages of the granitoids in the Chinese Altai are mostly 360–460 Ma (e.g., Sun et al., 2009, and references therein) implying that they are the products of prolonged magmatism (Sun et al., 2008; Cai et al., 2011b). Metaluminous to weakly peraluminous calc-alkaline I-type granites are dominant (Sun et al., 2009; Wang et al., 2010), most of which

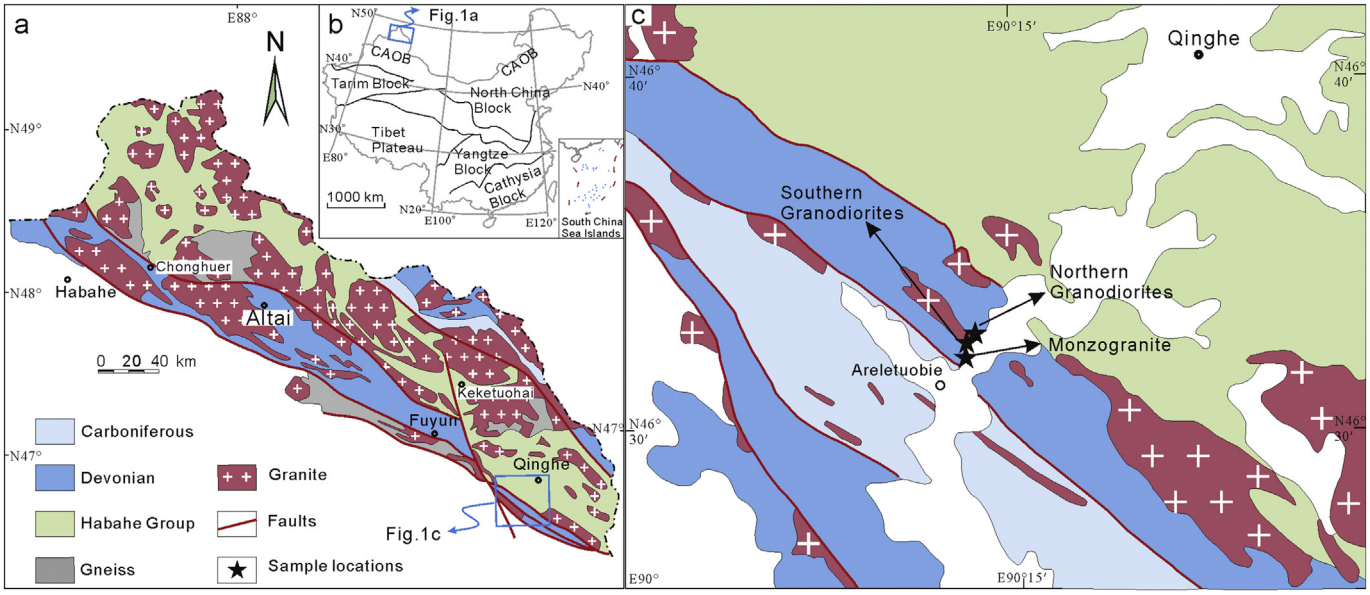


**Figure 1.** Simplified maps showing (a) the location of the Chinese Altai in CAOB (Central Asian Orogenic Belt), (b) the distributions of granitoids and strata in the Chinese Altai (modified after He et al., 1990; Windley et al., 2002; Long et al., 2007), and (c) sample locations in the Areletuobie region, Qinghe County, southeast margin of the Chinese Altai.

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