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Thermochronological constraints on the late Paleozoic tectonic evolution of the southern Chinese Altai

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ABSTRACT

The Chinese Altai, as an accretionary orogen developing from the Cambrian to Carboniferous, was modified by Permian deformation, metamorphism and magmatism in response to the collision with the East Junggar. The tectonic processes of the collision and the timing of related deformation and metamorphism are still enigmatic. Here we present new $^{40}Ar/^{39}Ar$ dating results for granitic gneisses and amphibolites exposed in the Qiongkuer Domain in two areas (Alahake and Fuyun) of the southern Chinese Altai. The amphiboles from both Aalaheke and Fuyun areas yield consistent $^{40}Ar/^{39}Ar$ plateau ages at 265.9 ± 1.7 Ma and 270.1 ± 3.1 Ma. In contrast, the biotites from two areas show distinct $^{40}Ar/^{39}Ar$ ages of 232.0 ± 2.1 Ma and 226.8 ± 1.7 Ma for the Alahake area, and 245.1 ± 1.5 Ma and 264.5 ± 2.2 Ma for the Fuyun area, respectively. Given that $^{40}Ar/^{39}Ar$ ages are younger than the Permian high temperature metamorphism at ~299–277 Ma as constrained by metamorphic zircons in the Qiongkuer Domain, we interpret these $^{40}Ar/^{39}Ar$ ages to record the cooling history of two areas. Compatible amphibole ages in both areas indicate a similar exhumation age along the Qiongkuer Domain cooling through 550 °C at ~270–265 Ma, which may have been associated with the development of the sinistral Erqis Shear Zone during the collision between the Chinese Altai and the East Junggar. The subsequent exhumation processes were variable in different areas of the Qiongkuer Domain as showed by the distinct biotite ages, which may indicate along-strike variation of cooling processes from 550 °C to 300 °C in the Qiongkuer Domain.

1. Introduction

The Central Asian Orogenic Belt (CAOB), as one of the largest accretionary orogenic systems in the world, records complex geodynamic processes during the Phanerozoic continental growth of Central Asia (Coleman, 1989; Zonenshain et al., 1990; Şengör et al., 1993; Jahn, 2004; Windley et al., 2007). The formation of such an orogenic belt involved the episodic accretion of island arcs, ophiolites, accretionary complexes, seamounts and micro-continental blocks along the continental margin (Khain et al., 2002; Buslov et al., 2004; Xiao et al., 2004; Zhang et al., 2011), oroclinal bending (Abrajevitch et al., 2008; Xiao et al., 2010; Yi et al., 2013) and the final collision of the Siberian, Baltic, Tarim and North China cratons (Şengör et al., 1993; Xiao et al., 2003; Windley et al., 2007; Eizenhöfer et al., 2014). The mechanism of accretionary orogenesis has been controversial, and may have involved the strike-slip duplication and oroclinal bending of a single arc system (Şengör et al., 1993; Şengör and Natal'in, 1996) or the amalgamation of multiple arc systems (Windley et al., 2007; Xiao et al., 2010). Given that the final collision of distinct arc systems or cratons has widely overprinted the earlier accretion-related tectonics, it is vital first to unravel the collisional processes in order to understand the earlier accretion and growth mechanisms of the CAOB.

The Chinese Altai is located at a key region between Siberia and Kazakhstan, recording the collisional processes between peri-Siberian and Kazakhstan-South Mongolian orogenic systems (Fig. 1a) (Windley et al., 2002). The collisional zone, as represented by the Erqis Shear Zone in the southern Chinese Altai (Fig. 1a), includes a series of folded zones bounded by narrow mylonitic belts or thrusts (Qu and Zhang, 1991, 1994; Laurent-Charvet et al., 2002; Briggs et al., 2007, 2009). The exact collisional processes along the Erqis Shear Zone are still poorly understood due to limited

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spatial and temporal constraints on the related deformation, metamorphism and magmatism. In order to unravel the collisional processes, it is crucial to firstly determine the exact time of various magmatic, structural, and metamorphic events.

Here we focus on the thermal evolution of the southern Chinese Altai in an attempt to unravel its relationship with regional tectonic evolution using $^{40}Ar/^{39}Ar$ step heating technique. Previous $^{40}Ar/^{39}Ar$ work has demonstrated the widespread effect of the Permian thermal events on the southern Chinese Altai (Laurent-Charvet et al., 2003; Briggs et al., 2007, 2009). However, such work has mainly focused on the Fuyun area (Fig. 1) across the Erqis Shear Zone. It is necessary to provide the thermochronological constraints along the strike of the orogenic belt to check the effect of Permian thermal events in an orogenic scale. The aim of this paper is to provide $^{40}Ar/^{39}Ar$ age constraints on the Qiongkuer Domain of the southern Chinese Altai in both Alahake (in the west) and Fuyun (in the east) areas (Fig. 1) in order to constrain the regional thermal evolution along the southern Chinese Altai. The result of this paper shows that amphiboles in both Fuyun and Alahake areas yield a consistent age at ~270 Ma, indicating a similar exhumation age along the Qiongkuer Domain cooling through 550 °C. We attribute this stage of cooling to the regional uplift associated with the development of the Erqis Shear Zone.

2. Geological setting

The Chinese Altai represents a segment of the Altai-Mongolian terrane in the CAOB (northernmost Xinjiang Uygur Autonomous Region, China), which comprises of the southwestern part of the peri-Siberian orogenic system and is separated from the Kazakhstan-South Mongolian orogenic system (i.e. East Junggar and West Junggar in China) further southwest by the Erqis Shear Zone (Fig. 1) (Şengör et al., 1993; Windley et al., 2007; Xiao et al., 2010). The Chinese Altai records early Paleozoic accretionary history of the peri-Siberian orogenic system and the late Paleozoic collisional processes with the Kazakhstan-South Mongolian orogenic system (Fig. 1) (Windley et al., 2002; Cai et al., 2011a; Long et al., 2012).

The Chinese Altai can be divided into several fault-bounded tectonic domains based on distinct sedimentary and structural styles, which include, from north to south, the Northern Altai Domain, the Central Altai Domain, the Qiongkuer Domain and the Southern Altai Domain (He et al., 1990; Windley et al., 2002; Cai et al., 2011a). The Northern Altai Domain mainly includes Devonian to Carboniferous metasedimentary and metavolcanic rocks with the metamorphic grade up to sub-greenschist facies (Windley et al., 2002). The Central Altai Domain predominantly contains Cambrian to Silurian turbiditic and pyroclastic sequence (Habahe and Kulumuti groups), with the metamorphic grade varying from greenschist to upper amphibolite facies (Windley et al., 2002; Long et al., 2007, 2008). Further south, the Qiongkuer Domain is characterized by the Devonian metavolcanic rocks of the Kangbutiebao Formation and metasedimentary/volcanic sequence of the Altai Formation. Rocks in the Qiongkuer Domain widely experienced high temperature metamorphism with local metamorphic grade up to granulite facies (Fig. 1b), which has been constrained at ~299–277 Ma by metamorphic zircons (Li et al., 2014; Wang et al., 2014a; Yang et al., 2014) though an earlier high temperature event may also develop as indicated by ~390 Ma metamorphic zircons (Jiang et al., 2010). The Southern Altai Domain is the southernmost tectonic unit of the Chinese Altai. Rocks in this unit are represented by the Erqis Complex, which is characterized by a heterogeneous sequence of foliated amphibolite-grade schists, para- and ortho-gneisses, amphibolites and metachert (Briggs et al., 2007). Structurally, rocks in the Southern Altai Domain was widely affected by the sinistral Erqis Shear Zone (Qu and Zhang, 1991), in which one high strain mylonitic belt (the Erqis Fault, Fig. 1a) is generally considered to be the boundary between the Chinese Altai and the East Junggar.

The Chinese Altai is characterized by the widespread occurrence of granitic intrusions with two major age groups of ~400 Ma and ~280 Ma (Wang et al., 2006; Yuan et al., 2007; Sun et al., 2009; Cai et al., 2011b). The older group was normally represented by orthogneiss or gneissic granitoid and widely distributed across the whole Chinese Altai (Cai et al., 2011a). The intrusion of these rocks was accompanied by the regional high temperature metamorphism (Jiang et al., 2010), and was proposed to be associated with the ridge-trench interaction (Sun et al., 2009; Cai et al., 2010). The Permian granitoids are generally non-deformed and often occur in rounded shape in the southern Chinese Altai (Fig. 1). The occurrence of this group of granitoids was also overlapped in time with the Permian high temperature metamorphism (Li et al., 2014). The geodynamic setting of the Chinese Altai in the Permian has been in debate, and may involve the activity of mantle plume (Zhang et al., 2012; Tong et al., 2014; Yang et al., 2014; Zhang et al., 2014), slab breakoff (Li et al., 2014), post-collisional extension (Wei et al., 2007; Wang et al., 2014a) and/or large scale strike-slip shearing (Qu and Zhang, 1991, 1994; Laurent-Charvet et al., 2003).

3. Field geology and sample description

3.1. Alahake area

In the area of Alahake, rocks mainly include high grade metavolcanic/sedimentary rocks of the Altai Formation (part of the Qiongkuer Domain) (Fig. 2a), in which the internal stratigraphy is not well defined due to the absence of reliable stratigraphic markers and intense deformation. Rocks in this unit are characterized by a penetrative foliation (S1) steeply dipping to north, and the presence of foliated amphibolite layers indicates up to amphibolite facies metamorphism. The sheeted granitic gneiss widely occurs in the southern part of the Altai Formation (Fig. 3a), with the foliation sub-parallel to the regional dominant fabric (S1). To the north of the Altai Formation, the gneissic granitoid of the Taerlang Batholith (Figs. 1 and 2a) was dated to be 460–380 Ma (Wang et al., 2006; Yuan et al., 2007; Cai et al., 2011b). The gneissic granitoid in the area close to the Altai Formation (Fig. 2a) shows the north-dipping fabric consistent with the regional foliation (S1, Fig. 3b) of the Altai Formation, indicating that both of them may be subject to the same deformation event.

Three samples were collected for $^{40}Ar/^{39}Ar$ analysis in this area (Table 1, Fig. 2a). Sample Alt-79 and Alt-129 are granitic gneisses from the Taerlang Batholith to the north of the Altai Formation (Fig. 2a). Sample Alt-115 is a granitic gneiss within the Altai Formation (Fig. 2a), which yielded a U–Pb zircon age of 412 ± 6 Ma (Yuan et al., 2007).

3.2. Fuyun area

In the Fuyun area, the Qiongkuer Domain is separated from the neighboring domains by thrust/strike-slip faults and mainly includes two litho-stratigraphic units of the Altai Formation and the Kangbutiebao Formation (Fig. 2b). Spatially, the Kangbutiebao Formation occurs under the Altai Formation, but the exact timing relationship between them is enigmatic due to the scarcity of chronological data.

The Altai Formation is represented by a metasedimentary and metavolcanic sequence in the Fuyun area. Li and Sun (2014) recognized three major lithostratigraphic units, including interlayered