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Early Silurian (~440 Ma) adakitic, andesitic and Nb-enriched basaltic lavas in the southern Altay Range, Northern Xinjiang (western China): Slab melting and implications for crustal growth in the Central Asian Orogenic Belt

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ABSTRACT

As an important part of the Central Asian Orogenic Belt (CAOB), the Altay Range contains large-scale Paleozoic magmatic rocks. However, owing to the lack of precise age constraints, the tectonic setting and petrogenesis of the magmatic rocks in this area have been controversial, which has led to the debate on Phanerozoic crustal growth mechanisms and accretionary orogenic processes in the CAOB. Herein, we report geochronological and geochemical data of the Suoerkuduke adakitic, andesitic and Nb-enriched basaltic (NEB) lavas in the southern margin of the southern Altay Range. LA-ICP-MS zircon U–Pb analyses for five adakitic, andesitic and NEB samples indicate that they were coevally generated in the Early Silurian (~440 Ma). The adakites and basaltic andesites are geochemically characterized by high Na_2O/K_2O, Sr/Y, Al_2O_3, Sr, $\varepsilon_{Nd}(t)$ and zircon $\varepsilon_{Hf}(t)$ values and relatively low $(^{87}Sr/^{86}Sr)_i$ ratios. The NEBs are sodium-rich and have higher TiO_2, P_2O_5, Zr, Nb, and Nb/U values than those of typical arc basalts. They also have positive $\varepsilon_{Nd}(t)$ values and positive and variable zircon $\varepsilon_{Hf}(t)$ values. We suggest that the Suoerkuduke adakites were derived by a partial melting of the subducted oceanic crust with minor overlying sediments, and the continuous compositional variations between adakites and basaltic andesites confirm that the interaction between slab melts and mantle peridotite played an important role in the formation of basaltic andesites. The associated NEBs were possibly generated by a partial melting of mantle wedge peridotites metasomatized by slab-derived adakitic melts and minor fluids. In combination with the occurrence of voluminous Silurian–Devonian granitoids, coeval ophiolite mélanges, and a series of intra-arc basins, a slab window model triggered by slab tearing is proposed to account for the formation of the Suoerkuduke adakite–basaltic andesite–NEB suites. The upwelling of the asthenospheric mantle through the slab window probably caused significant extension in the overlying lithosphere; extensive melting of the subducted oceanic crust, mantle and juvenile lower crust; and intense interaction between slab-derived melts or fluids and the mantle wedge. Slab tearing and subsequent asthenospheric upwelling possibly played an important role in the crustal growth of the CAOB during the Phanerozoic.

1. Introduction

The Central Asian Orogenic Belt (CAOB) (Fig. 1a) is one of the most remarkable sites of juvenile crustal growth in the world during the Phanerozoic (Jahn et al., 2000; Sengör et al., 1993; Windley et al., 2007; Xiao et al., 2009). However, the mechanism responsible for continental crustal growth in the CAOB has long been the subject of debates. Sengör et al. (1993) hypothesized that nearly half of the giant CAOB was derived from the mantle by successive subduction accretion and arc collision during the Paleozoic. Conversely, many researchers suggest that the formation of Phanerozoic granitoids with positive ε_{Nd} values in the CAOB was related to basalt underplating in a post-collisional or an intraplate extensional setting (Chen and Jahn, 2004; Han et al., 1997; Jahn et al., 2000). Jahn et al. (2004) argued that the aforementioned two processes probably played equally important roles in the Phanerozoic crustal growth in the CAOB. More recently, some studies indicate that Late Paleozoic mantle plume activity (Zhang et al., 2014) and spreading ridge subduction (Cai et al., 2011a; Sun et al., 2009; Tang et al., 2012; Windley et al., 2007) also played an important role in the crustal growth in the CAOB.

As an important part of the CAOB, the southern Altay Range mainly consists of large-scale volcanic rocks, granitoids, metamorphic rocks, sedimentary sequences, and blocks of ophiolites. However, the tectonic

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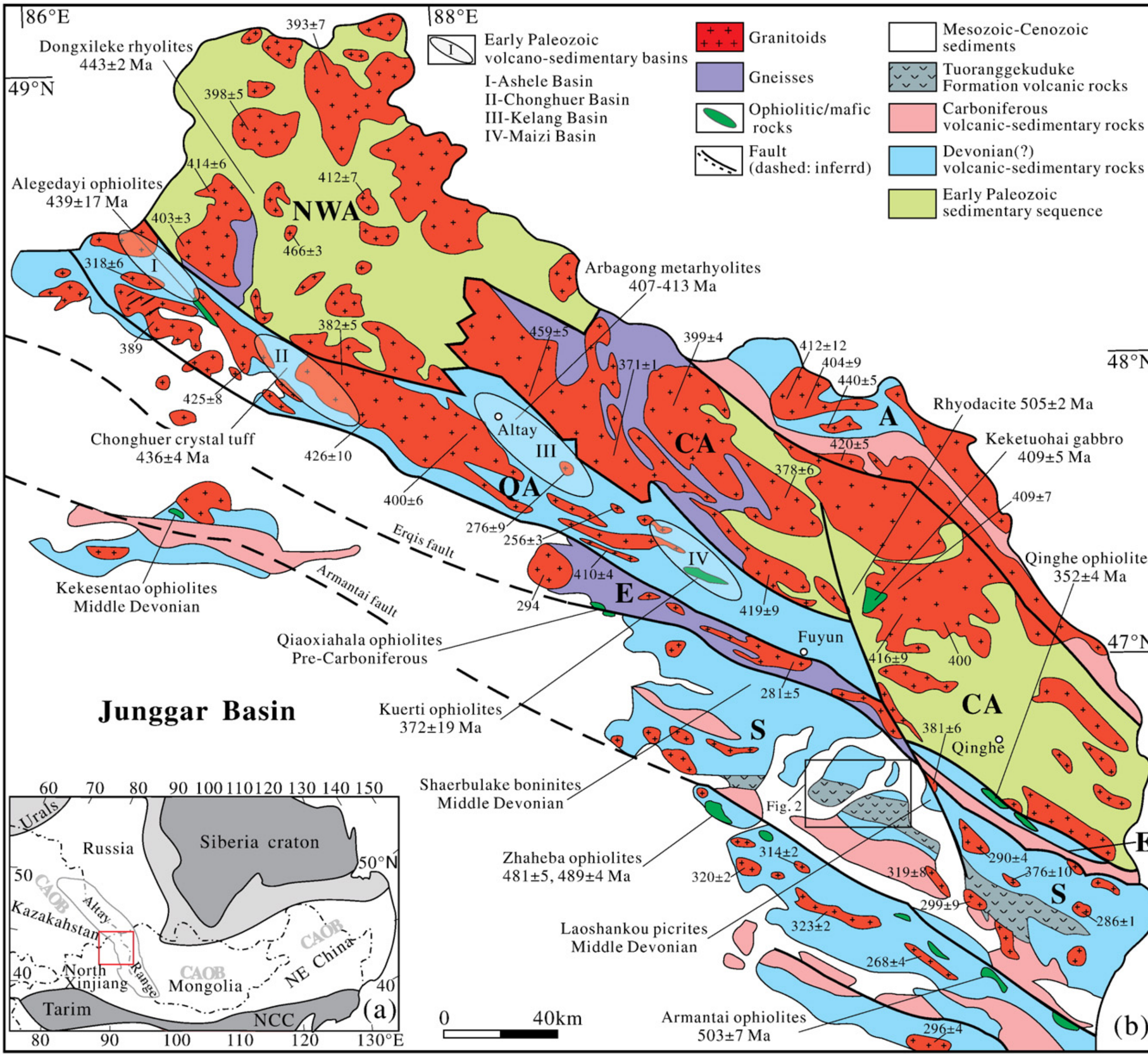

Fig. 1. (a) Location of the study area in the Central Asian Orogenic Belt (modified from Jahn et al., 2000; Sengör et al., 1993). (b) Geological map of the southern Altay Range (modified from Wang et al., 2009; Windley et al., 2002). Ages shown for granitoids are from Cai et al. (2011b), Wang et al. (2009) and references therein. Ages shown for volcanic rocks are from Chai et al. (2009), Zeng et al. (2007), Zhang et al. (2009) and Zhou et al. (2007). Ages shown for ophiolites are from Niu et al. (2006), Wong et al. (2010), Xiao et al. (2008) and references therein. Ages for the Keketuohai gabbro and the Habahe mafic dyke are from Wang et al. (2006) and Wong et al. (2010), respectively. A denotes Altayshan Block; NWA denotes northwest Altayshan Block; CA denotes central Altayshan Block; QA denotes Qiongkuer–Abagong Block; E denotes Erqis Block; S denotes Shaerbulake Block.

setting and evolutionary history of the southern Altay Range during the Paleozoic have been controversial, e.g., its tectonic setting during the Early Paleozoic has been variously envisaged as a passive continent margin (Li and Poliyangsiji, 2001), a Precambrian micro-continent (BGMRX, 1993; Hu et al., 2000),an accretionary complex (Sengör and Natal'in, 1996), a post-collisional setting (Li et al., 2010), and an active continental margin (Long et al., 2007, 2012; Sun et al., 2008; Wang et al., 2006; Windley et al., 2002; Yuan et al., 2007). Each of these models has significantly different implications for both accretionary orogenic processes and crustal growth.

Widespread occurrences of Paleozoic volcanic rocks and granitoids in the southern Altay Range offer an excellent opportunity to examine the tectonic setting and mechanisms of crustal growth in the CAOB. However, the tectonic setting and petrogenesis of the magmatic rocks remain a controversial issue in the region due to the lack of precise age constraints. Recently, we investigated the volcanic rocks in the Suoerkuduke area of the southern Altay Range (Fig. 1b), which were traditionally considered to have erupted in the Devonian. Our new data show, however, that these volcanic rocks erupted in the Early Silurian rather than the Devonian, and they contain adakites, basaltic andesites and Nb-enriched basaltic (NEB) rocks. In this study, we present detailed zircon U–Pb age, major and trace element, and Sr–Nd–Hf isotope data for the adakite–basaltic andesite–NEB suites. We suggest that the formation of these suites was possibly related to the partial melting of subducted oceanic crust in the Early Silurian, which may be the earliest case for slab melting in the CAOB, and thus has important implications for tectonic evolution and crustal growth of the CAOB.

2. Geological setting and characteristics of the Suoerkuduke volcanic rocks

The Altay Range is geographically located along the border regions between Russia and Kazakhstan to the west and western China and western Mongolia to the east. Tectonically, the range lies in the central