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Origin of high Sr/Y-type granitic magmatism in the southwestern of the Alxa Block, Northwest China

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A B S T R A C T

The petrogenesis of high Sr/Y-type magmas is still open to debate. Usually, such magmas could result from melting under high-pressure settings (>12 kbar). In this paper, we gave an example that some high Sr/Y-type magmas could originate from melting of crustal materials at pressure of 10–12 kbar. We carried out a study of petrogenesis for Devonian high Sr/Y granites from the Beidashan batholith (397–411 Ma), southwestern Alxa Block, Northwest China. The Beidashan granites have SiO_2 (69.21–74.60 wt.%) and Al_2O_3 (14.01–16.20 wt.%) with A/CNK ratios of 0.99–1.08. According to their trace element compositions and whole-rock zirconium saturation temperatures (T_{Zr}), the Beidashan granites can be divided into two groups: Group I ($(Dy/Yb)_N$ = 1.2–3.0, Eu/Eu* = 0.77–1.3, T_{Zr} = 761–856 °C), resulted from fluid-absent partial melting of mafic to intermediate crustal materials leaving garnet residuum at pressure of ~12 kbar, and Group II ($(Dy/Yb)_N$ = 0.76–2.16, Eu/Eu* = 1.7–5.3, T_{Zr} = 651–785 °C), formed by fluid-present melting of mafic to intermediate crustal materials with residual amphibole in the source at pressure of ~10 kbar. Both Group I and Group II show high Sr/Y and $(La/Yb)_N$ features. They show I_{Sr} = 0.7134–0.7180, $\varepsilon_{Nd}(t)$ = −6.61 to −9.71, T_{2DM} = 1.7–1.9 Ga; $\varepsilon_{Hf}(t)$ = −5.6 to −9.9 and T^C_{DM} = 1.7–2.0 Ga, indicating that the Beidashan high Sr/Y granites were derived from melting of crustal basement materials. Our results suggest that some high Sr/Y-type granites formed under relatively lower pressure conditions (~10–12 kbar), and they could not be an indicative of partial melting of thickened crust.

1. Introduction

"Adakite" was initially used to describe a group of Cenozoic arc intermediate to felsic volcanic rocks, with high Sr/Y and $(La/Yb)_N$ ratios (Defant and Drummond, 1990). Martin et al. (2005) further classified them into two groups: high-SiO_2 adakites (HSA) and low-SiO_2 adakites (LSA). The geochemical composition of Archean tonalite–trondhjemite–granodiorites (TTGs) are closely similar with the HAS, indicating their petrogenetic analogy (Martin et al., 2005). They are generally thought to be derived from partial melting of basaltic rocks at high pressure (>12 kbar) with garnet amphibolite or eclogite as a residue (Moyen and Stevens, 2006; Qian and Hermann, 2013; Rapp and Watson, 1995; Rapp et al., 1991; Wolf and Wyllie, 1994). The term "adakite" has been extendedly applied to many intermediate to felsic igneous rocks in continental settings (Atherton and Petford, 1993; Chung et al., 2003; He et al., 2011; Hou et al., 2004; Wang et al., 2007a, 2007b; Xu et al., 2002). These continental "adakites" or high Sr/Y magmas are not consistent with the original definition of "adakite" (Defant and Drummond, 1990), and their petrogenesis are still in hotly debated.

Many studies indicated that melts with high Sr/Y and $(La/Yb)_N$ signatures were generated in high-pressure condition (Atherton and Petford, 1993; Gao et al., 2004; He et al., 2011; Hou et al., 2004; Wang et al., 2005). However, other mechanisms can also account for the magma generation of the high Sr/Y-type granites, such as partial melting of a high Sr/Y (and La/Yb) source (Moyen, 2009) and hornblende fractionation of hydrous mafic and intermediate magmas (Castillo et al., 1999). For the hornblende fractionation model, fluids play an important role in the evolved high Sr/Y magmas (Davidson et al., 2007). Analogously, fluid-present melting may be also important for the high Sr/Y magma generation. Experimental studies on melting of mafic to intermediate rocks have proposed that fluid-present melting at low temperature would leave a residuum dominated by amphibole, clinopyroxene, Fe-Ti oxides and minor plagioclase, and produce melts with high SiO_2 and Al_2O_3, and low FeOt and MgO contents (Beard and Lofgren, 1991; Moyen and Stevens, 2006). Field observations and geochemical studies also have suggested that fluid-present melting of mafic to intermediate source at relatively low pressure would have abundant amphiboles in the residual and form leucosomes with high Sr/Y and $(La/Yb)_N$ ratios similar to Archean TTGs and adakites (Reichardt and Weinberg, 2012). Therefore, the high Sr/Y igneous rocks can generate not only in high-pressure condition but also in low pressure condition. For the high Sr/Y-type magma generation, we

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need to discuss the roles of source inheritance, melting conditions and magmatic differentiation.

In this contribution, we present in situ zircon U–Pb age and geochemical and Sr–Nd–Hf isotope data for the Beidashan batholith in the southwest Alxa Block, Northwest China. Two groups of high Sr/Y granites were indentified. Our data indicate that the granites from the two groups were derived from the same source, but their magma generation mechanisms are distinct (fluid-present and fluid-absent, respectively) at 10–12 kbar. We also use these data to discuss the tectonic implications of the high Sr/Y-type magma generation.

2. Geological backgrounds

The Central Asian Orogenic Belt (CAOB) is regarded as one of the largest and longest-live accretionary orogenic collages, which extends from Urals through northern China Craton (NCC), Mongolia to Okhotsk

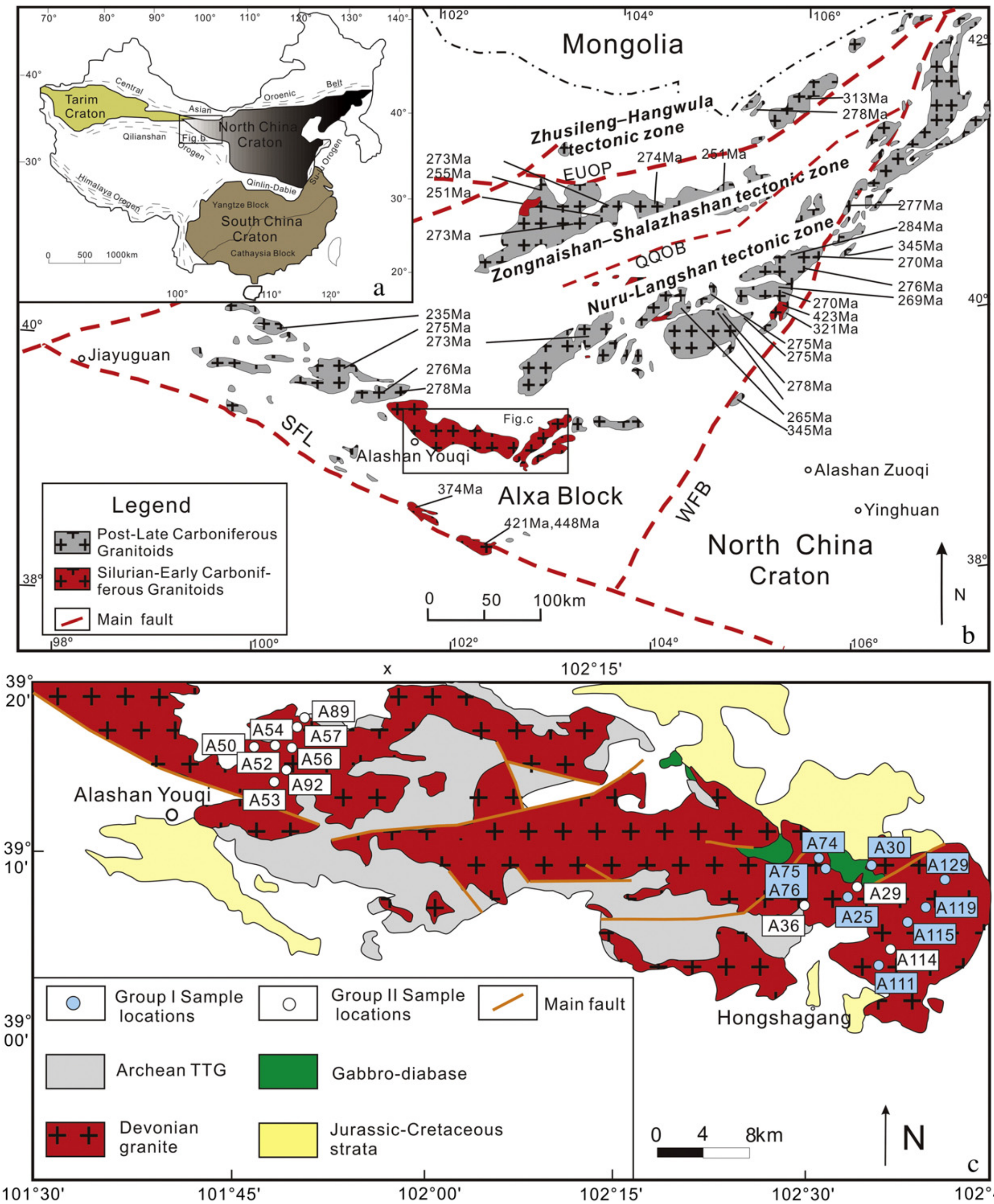

Fig. 1. (a) Simplified geological map of the Alxa Block, northwest China. (b) Simplified geological map of the Alxa Block Phanerozoic granitoids, SFL, southern margin fault of Longshoushan; WFB, western margin fault of Bayanwulashan; EUOB, Enger Us Ophiolite Belt. (Age data sources: Dan et al., 2014a, 2014b; Feng et al., 2013; Ren et al., 2005a, 2005b; Shi et al., 2012; Su, 2012; Yang et al., 2014; Zhang et al., 2012, 2013b; Zheng et al., 2014); (c): Geological sketch-map of the Beidashan area (NMBGMR (Nei Mongol Bureau of Geology and Mineral Resources), 1991), with sample locations.