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A geochemical study of syn-subduction and post-collisional granitoids at Muzhaerte River in the Southwest Tianshan UHP belt, NW China

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ABSTRACT

A combined study of zircon U–Pb ages and Lu–Hf isotopes, whole-rock elements and Sr–Nd isotopes was carried out for two granitic intrusions at Changawuzi and Alasan in Muzhaerte River of Southwest Tianshan (NW China). SHRIMP zircon U–Pb dating gave two $^{206}Pb/^{238}U$ ages of 333 ± 3 Ma and 326 ± 3 Ma for the Changawuzi pluton. LA-ICP-MS zircon U–Pb dating yielded two $^{206}Pb/^{238}U$ ages of 293 ± 3 Ma and 294 ± 2.2 Ma for the Alasan pluton. The two groups of ages predate and postdate the UHP metamorphic event at 320–305 Ma in this region, respectively, registering to syn-subduction and post-collisional magmatism. The Changawuzi pluton is composed of gneissic porphyritic tonalite and garnet-bearing gneissic granitoids, having SiO_2 of 55.1–64.5 wt.%, $K_2O + Na_2O$ of 2.58–5.07 wt.%, MgO of 2.07–4.32 wt.%, and Al_2O_3 of 17.4–19.9 wt.% with A/CNK ratios of 0.99 to 1.27. They show arc-like geochemical affinity, with enrichment of LILE (K, Rb, Sr and Ba) and depletion of HFSE (Nb, Ta and Ti) and P, and moderate initial $^{87}Sr/^{86}Sr$ ratios of 0.7062–0.7071 and neutral $\varepsilon_{Nd}(t)$ values of −1.5 to 1.6. Except for one zircon with a negative $\varepsilon_{Hf}(t)$ value of −3.5, the others have positive $\varepsilon_{Hf}(t)$ values of 2.5–11.4 and single-stage Hf model ages of 509 to 869 Ma. The Changawuzi pluton would be formed by partial melting of possible juvenile arc-derived rocks with minor involvement of ancient continental rocks during subduction of the paleo-South Tianshan oceanic crust and subsequent arc–continent collision. The Alasan pluton consists of medium-grained and porphyritic granitoids. The medium-grained granitoids are composed of granodiorite, quartz monzodiorite and quartz monzonite, displaying SiO_2 of 59.37–65.49 wt.%, $K_2O + Na_2O$ of 6.24–8.2 wt.% and MgO of 1.45–3.06 wt.%, with A/CNK ratios of 0.87–1.04. They have relatively high initial $^{87}Sr/^{86}Sr$ ratios of 0.7082–0.7103, negative $\varepsilon_{Nd}(t)$ values of −5.9 to −5.6 and negative $\varepsilon_{Hf}(t)$ values of −4.5 to −1.1. The porphyritic granitoids consist of granite, granodiorite and quartz monzonite, with relatively high SiO_2 (65.94–75.27 wt.%) and $K_2O + Na_2O$ (7.55–9.13 wt.%), low MgO (0.18–1.22 wt.%), and A/CNK ratios of 0.82–1.11. They also have relatively high initial $^{87}Sr/^{86}Sr$ ratios of 0.7073–0.7103, negative $\varepsilon_{Nd}(t)$ values of −6.0 to −0.5 and neutral $\varepsilon_{Hf}(t)$ values of −1.4 to 2.8. Both of them also display arc-like patterns of REE and trace element distribution. They belong to post-collisional granitoids and were produced by partial melting of the Paleo-Mesoproterozoic crust of obducted Central Tianshan block with minor involvement of juvenile crust. The geological occurrences of both the syn-subduction and post-collisional granitoids in this region suggest differential tectonic processes during the Late Paleozoic collision between the Tarim and Yili-Central Tianshan Blocks. It is inferred that slab breakoff occurred subsequent to the UHP metamorphism, resulting in partial melting of the subducted upper crust and the overlying lower crust and thus formation of voluminous granitoids like the Alasan pluton.

1. Introduction

The Central Asian Orogenic Belt (CAOB), also named as the Altaid Tectonic Collage, is one of the largest accretionary orogens in the world. It is situated between the Siberian–Russian Block and the Tarim-North China Block, and characterized by the Phanerozoic continental growth (Jahn et al., 2000; Kovalenko et al., 2004; Mossakovsky et al., 1994; Sengör and Natal'in, 1996; Sengör et al., 1993; Windley et al., 2007). It was suggested that the CAOB was formed through successive subduction–accretion of island arcs, oceanic islands, seamounts, ophiolites, accretionary complexes and micro-continents during the closure of paleo-Asian Ocean in the Paleozoic (Coleman, 1989; Jahn et al., 2000; Khain et al., 2002; Kröner et al., 2008; Windley et al., 2007; Xiao et al., 2010). High proportion of juvenile crustal components occurs in voluminous granitoids of Paleozoic to Mesozoic ages that were emplaced throughout the CAOB during its long formation history (Chen and Arakawa, 2005; Jahn et al., 2000; Kovalenko et al., 2004; Sengör et al., 1993). These granitoids can provide important constraints on the tectonic evolution of the CAOB because of their differences in tectonic setting

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and magma source (Geng et al., 2009; Jahn et al., 2000; Kovalenko et al., 2004; Kröner et al., 2008).

The South Tianshan Orogenic Belt (STOB) extends nearly E–W for about 2500 km from NW China, through Kazakhstan, Kyrgyzstan, Tajikistan to Uzbekistan, located in the southern CAOB (Brookfield, 2000; Volkova and Budanov, 1999; Zhang et al., 2007). It was formed by subduction and collision of the Tarim plate northwards beneath the Yili-Central Tianshan block (YCTB) during the closure of paleo-South Tianshan Ocean (PSTO) (Allen et al., 1992; Filippova et al., 2001; Gao et al., 1998; Seltmann et al., 2011; Windley et al., 1990; Windley et al., 2007; Xiao et al., 2009; Zhang et al., 2007), resulting in ultrahigh-pressure (UHP) metamorphic rocks (Lü et al., 2008; Zhang et al., 2002a, b, 2003, 2005). The STOB represents the location where the Tarim plate was docked with the Southern accretionary margin of CAOB, and thus it is a critical area to reveal the amalgamation history of CAOB. Like the continental subduction zone in Dabie–Sulu of east–central China, moreover, it provides us an excellent natural laboratory to understand important geodynamic processes like temporal–spatial transformation from oceanic subduction to continental collision and recycling of the subducted continental crust (Huang et al., 2006; Zhang et al., 2010; Zhao and Zheng, 2009; Zhao et al., 2007; Zheng et al., 2009).

Because of the complex geological phenomena and tough working conditions, however, it is not easy to determine the collision time between the YCTB and Tarim plate and no consensus has been achieved on it in the past decade. Based on the data from their own emphases on the STOB, geologists have reached different conclusions on the collision time, including the late Devonian (Xia et al., 2004; Xiao et al., 1992), late Devonian to Early Carboniferous (Allen et al., 1992; Shi et al., 1994), early Carboniferous (Gao and Klemd, 2003; Gao et al., 1998), late Carboniferous to early Permian (Gao et al., 2008; Konopelko et al., 2007; Ren et al., 2011; Xiao et al., 2006) and Triassic (Brookfield, 2000; Li et al., 2002, 2005; Xiao et al., 2009; Zhang et al., 2007). Granitoid plutons pervasively crop out on the both sides of the South Tianshan Fault and a number of studies have been conducted on their geochronology and geochemistry (Gao et al., 2008; Konopelko et al., 2007, 2009; Long et al., 2008; Seltmann et al., 2011). Nevertheless, there are poor constraints on petrogenesis of these granitoids due to the lack of systematical geochronological and geochemical data.

In this study, we present zircon U–Pb ages and Lu–Hf isotopes and whole-rock geochemical data for granitoids to the north of South Tianshan Fault (STF) in the Muzhaerte River of SW Tianshan, aiming to place constraints on their ages, sources, petrogenesis and tectonic settings. Moreover, we will examine the tectonic evolution of STOB, the basement nature of Central Tianshan plate on the basis of integration of available data from this paper and those published ones for this region.

2. Geological background and samples

The STOB was formed by paleo-South Tianshan oceanic crust subducting northward beneath YCTB and subsequent continental collision with following Tarim plate (Gao and Klemd, 2003; Seltmann et al., 2011; Windley et al., 2007; Xiao et al., 2008; Zhang et al., 2007). Afterwards, it was reactivated during the Cenozoic as a consequence of the India–Eurasia collision (Molnar and Tapponnier, 1975; Yin et al., 1998). The STF (South Nanati Fault or Changawuzi Fault) separates the YCTB in the north from the South Tianshan Fold Belt (STFB) and Tarim plate in the south (Fig. 1b). The YCTB was formed by the final amalgamation of the Yili block and Central Tianshan after the closure of Terskey ocean during the early stage of late Ordovician, with suture zone represented by North Nalati Fault (NNF) (Fig. 1b) (Lomize et al., 1997; Qian et al., 2007). It is composed of LP/HT metamorphic rocks, granitoids, felsic to mafic volcanics, Proterozoic granitic gneiss and sporadic Paleozoic strata. Monazite U–Th–Pb dating obtained the ages of 376 ± 8 Ma and 280 ± 8 Ma for the low-P metapelitic granulite facies rocks from the Muzhaerte River (Gou and Zhang, 2009). The SHRIMP and LA-ICP-MS U–Pb zircon dating indicate that the magmatism in the Southern margin of YCTB continued for a long time from 479 to 275 Ma (Gao et al., 2008; Konopelko et al., 2009; Seltmann et al., 2011), displaying multiple magmatic stages in the Paleozoic. The 430 Ma Jingbulake mafic–ultramafic rocks are continental arc rocks formed during the subduction of paleo-South Tianshan oceanic crust beneath the YCTB (Yang and Zhou, 2009). Felsic to mafic continental arc volcanics have SHRIMP U–Pb zircon ages of 361 to 313 Ma (Zhu et al., 2005, 2009). The Proterozoic granitic gneiss was identified at Laerdundaban along Duku road and to the east of Sailimu lake (Chen et al., 1999b, 2000b).

The STFB is a large accretionary complex, consisting of HP/UHP metamorphic rocks (blueschist and eclogite), ophiolites, mafic–ultramafic rocks, island arc volcanics and granitoids (Fig. 1b). Gao and Klemd (2003) obtained two Sm–Nd isochron ages of 343 ± 44 Ma and 346 ± 3 Ma for an eclogite and a well-defined $^{40}Ar/^{39}Ar$ plateau age of 331 ± 2 Ma for phengite of an omphacite–phengite-bearing blueschist. They concluded that the HP metamorphic rocks were formed by the subduction of paleo-South Tianshan oceanic crust about 344 Ma ago and exhumed to higher crustal levels during the collision of the YCTB and Tarim plate about 331 Ma ago. Zhang et al. (2007) obtained SHRIMP U–Pb zircon ages of 233 ± 4 to 226 ± 4.6 Ma for four eclogite samples. Recent SIMS U–Pb zircon dating suggest that the UHP ages of eclogite-facies rocks range from 308 to 319 Ma (Su et al., 2010; Zhang et al., 2009). In addition, one eclogite sample in Kyrgyzstan was provided with a Sm–Nd age of 319 ± 4 Ma and a $^{40}Ar/^{39}Ar$ age of 316 ± 3 Ma (Hegner et al., 2010). SHRIMP U–Pb zircon dating obtained 423–425 Ma for island arc volcanics of Kebuerte and Habutengsu valleys (Pu et al., 2011). The Kokshaal post-collisional A-type granites contain coeval mafic microgranular enclaves and possess SHRIMP U–Pb zircon ages of 299 to 279 Ma (Konopelko et al., 2007, 2009). Long et al. (2008) provided a SHRIMP U–Pb zircon age of 285 ± 4 Ma for Heiyingshan hornblende biotite granite.

The North Tarim has Precambrian basement consisting of Archean TTG suite, amphibolite, migmatite, marble, schist and Proterozoic granitic gneisses (Hu et al., 2000; Xiao et al., 1992). Sinian through Devonian rocks consist of shallow marine to nonmarine carbonates and sandstone, and they are unconformably overlain by the Carboniferous and Permian deposits (Carroll et al., 1995). A thick succession of Lower Carboniferous to Lower Permian fluvial and marine sediments distributes in most part of North Tarim (Carroll et al., 1995). Permian strata change upwards from marine and fluvial sediments to upper nonmarine carbonate and siliciclastic sedimentary rocks, and the Early Permian deposition was accompanied by eruption of a bimodal volcanic suite (Carroll et al., 1995; Chen and Shi, 2003).

Our study area is located within the Central Tianshan between NNF and STF in Chinese South Tianshan Orogenic Belt (or Southwest Tianshan Orogenic Belt, NW China), and includes two plutons, Changawuzi and Alasan plutons (Fig. 2). The Changawuzi pluton is a small tonalitic–granodioritic body located in the south of the studied area, and is found for the first time in this study (Fig. 2). Gneissic porphyritic tonalite (Fig. 3a) consists of plagioclase (55–65%, with An = 49–65), quartz (17–25%), hornblende phenocrysts (15–25%), K-feldspar (<5%), chlorite (5–10%), epidote (<2%) and accessory minerals including zircon and Fe–Ti oxides. Garnet-bearing gneissic tonalite and granodiorite are composed of plagioclase (50–60%, with An = 43–60), quartz (15–30%), chlorite (5–10%), hornblende (5%), epidote (<3%), minor biotite and garnet (<1%), and accessory minerals including zircon, Fe–Ti oxides, allanite and apatite. The Alasan pluton crops out over an area of ~45 km^2 and extends sub-parallel to the NNF (Fig. 2). It intrudes into the low-P granulite facies metamorphic rocks, and consists of medium-grained and porphyritic