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An Early Devonian to Early Carboniferous volcanic arc in North Tianshan, NW China: Geochronological and geochemical evidence from volcanic rocks

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ABSTRACT

The Late Paleozoic volcanic and sedimentary rocks are widespread in the North Tianshan along the north margin of the Yili block. They consist of basalt, basaltic andesite, andesite, trachyandesite, dacite, rhyolite, tuff, and tuffaceous sandstone. According to zircon sensitive high-resolution ion microprobe (SHRIMP) dating, the age of the Late Paleozoic volcanic rocks in Tulasu basin in western part of North Tianshan is constrained to be Early Devonian to Early Carboniferous (417–356 Ma), rather than Early Carboniferous as accepted previously. Geochemical characteristics of the Early Devonian to Early Carboniferous volcanic rocks are similar to those of arc volcanic rocks, which suggest that these volcanic rocks could be the major constituents of a continental arc formed by the southward subduction of North Tianshan Oceanic lithosphere. Geochemical studies indicate that the magma source of the volcanic rocks might be the mantle wedge mixed with subduction fluid, which is geochemically enriched than primitive mantle but depleted than E-MORB. The calculation shows that the basalt could be formed by ~10% partial melting of subduction fluid modified mantle wedge. Andesites with high initial $^{87}Sr/^{86}Sr$ (0.7094–0.7104) and negative $\varepsilon Nd(t)$ (−4.45 to −4.79) values reveal the contribution of continental crust to its source. The calculation of assimilation–fractional crystallization (AFC) shows that the fractional crystallization process of the basaltic magma, which was accompanied with assimilation by different degree of continental crust, produced andesite (7–9%), dacite (~12%) and rhyolite (>20%).

1. Introduction

The Central Asian orogenic belt (CAOB) between Siberian craton to the north and Tarim craton to the south is the largest Phanerozoic accretionary orogen in the world (e.g., Jahn et al., 2000; Kovalenko et al., 2004; Windley et al., 2007; Kröner et al., 2007; Dong et al., 2011; Long et al., 2012; Kröner et al., 2013; Ma et al., 2013). Some micro-continents or block had been identified in the CAOB, such as Kazakhstan, Junggar, and Yili blocks. The closure of the Paleo-North Tianshan Ocean and the final collision between Junggar and Yili blocks results in the formation of the North Tianshan Orogenic belt in China (e.g., Jahn et al., 2000; Windley et al., 2007). Many studies about the North Tianshan have been done to reconstruct the evolutionary history of the Paleo-North Tianshan Ocean, including the petrology and geochemistry of volcanic rocks (e.g., Xia et al., 2004; Wang et al., 2006, 2007a; An and Zhu, 2008), intrusions (Han et al., 2010; Tang et al., 2010; Long et al., 2011) and ophiolite (Xu et al., 2005, 2006) outcropped in North Tianshan. Previous studies provided controversial conclusions about the tectonic setting of the volcanic rocks. Some suggest that the volcanic and sedimentary rocks in the North Tianshan formed in a continental rift setting (Che et al., 1996; Xia et al., 2004, 2008), while the others consider that a continental island arc setting is more reasonable (Wang et al., 2006, 2007a; An and Zhu, 2008). Therefore, in order to reconstruct the evolutionary history of the Paleo-North Tianshan Ocean and the collision between the Junggar and Yili blocks, a reasonable interpretation of the genesis of the volcanic rocks in North Tianshan is essential. This work reports the geochronology and geochemistry of volcanic rocks from Tulasu basin in the west part of the north margin of Yili block, and discusses their genesis and tectonic implications. By combination with data from literatures, a preliminary discussion about the evolution history of the North Tianshan Ocean is presented.

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2. Geological setting

The Western Tianshan Orogenic Belt consists of North Tianshan Orogenic Belt, Yili Block and South Tianshan Orogenic Belt from north to south (Fig. 1). It was formed due to the collision of Yili, Tarim and Junggar blocks (Xiao et al., 1992; Gao et al., 1997; He et al., 2005; Windley et al., 2007; Xiao et al., 2008, 2013; Yang et al., 2012; Zhu et al., 2005, 2009). The Yili block is wedge-shaped and disappears to the east in Xinjiang (Fig. 1a). Two Late Paleozoic accretionary complexes have been found at both the north and south sides of the Yili block: North Tianshan accretionary complex (NTAC) and South Tianshan accretionary complex (STAC), which are separated from the Yili block by the North Tianshan fault (F_1) and the South Tianshan fault (F_2), respectively (Fig. 1a).

The NTAC, a major part of the North Tianshan Orogenic belt, was accreted onto the Yili block when the North Tianshan Ocean crust subducted southward below the Yili block during late Paleozoic. It includes Ordovician limestone, Silurian marine sedimentary rocks, Devonian to Early Carboniferous volcanic rocks and sedimentary rocks (Fig. 1b). The Bayingou ophiolite belt next to the suture zone are interpreted as the obducted North Tianshan Ocean crust (Wu and Liu, 1989; Xu et al., 2005, 2006), which is composed of serpentinized peridotite, gabbro, plagiogranite, pillow lava and siliceous rocks (Wang et al., 2006; Han et al., 2010). Early Carboniferous Radiolarians were found in the siliceous rocks (Xiao et al., 1992). SHRIMP zircon ages of gabbro and plagiogranite are 344 Ma and 325 Ma, respectively (Xu et al., 2005, 2006). Han et al. (2010) dated the post-collisional pluton of 316 Ma, which is intruded into Bayingou ophiolite and placed a narrow constraint of 325–316 Ma on the collisional event between Junggar and Yili blocks.

The Yili block consists of Neoproterozoic basement exposed mainly along its north and south margins, with the zircon U–Pb ages of 882 Ma and 798 Ma (Chen et al., 1999). An upper intercept U–Pb age of 1609 ± 40 Ma for granulite-face gneisses from the basement has been reported as well (Li et al., 2009). Ordovician carbonates, conglomerate, and volcaniclastic rocks (including tuff and tuff sandstone) predominantly outcropped in northern margin of Yili block. Widespread Late Paleozoic volcanic and sedimentary rocks which have been called as the Dahalajunshan Formation unconformably cover the Ordovician sequences, and are overlain by the Early Carboniferous clasolite which contains the Early Carboniferous Visean fossils such as *Siphonodendron* sp., *Caninia* sp., and *Gigatoproductus* sp. (Fig. 1b; Bureau of Geology and Mineral Resource of Xinjiang (BGMRX), 1993). The widespread Late Paleozoic volcanic rocks in south margin of Yili block, which is composed of basalt, andesite, dacite, rhyolite, and a small amount of tuff and volcanic breccia, have been dated as Late Devonian to Late Carboniferous (363–313 Ma, SHRIMP zircon ages, Zhu et al., 2005, 2006, 2009). This indicates that the continental arc was formed by northward subduction of south Tianshan Oceanic crust. Granitoid intrusions are widely

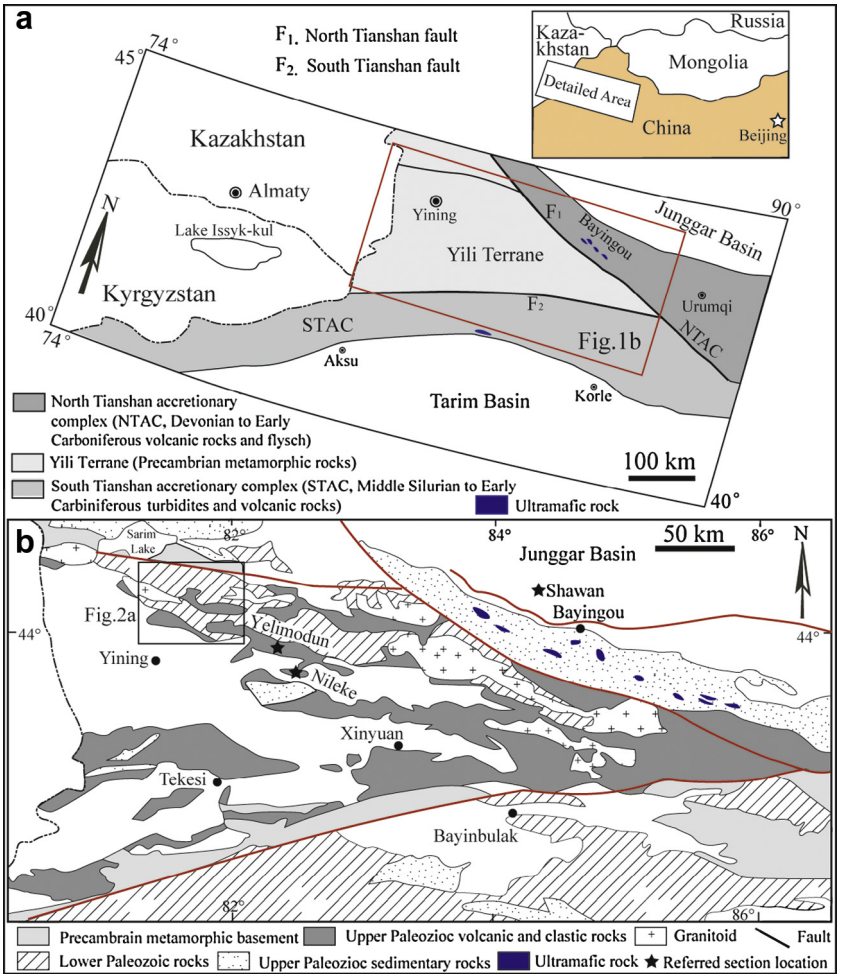

Fig. 1. (a) Generalized tectonic setting of the west Tianshan region (modified from Zhu et al., 2007). (b) Simplified geological map of the west Tianshan (modified BGMRX, 1993; Wang et al., 2007a; Zhu et al., 2009).