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Shoshonitic- and adakitic magmatism of the Early Paleozoic age in the Western Kunlun orogenic belt, NW China: Implications for the early evolution of the northwestern Tibetan plateau

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ABSTRACT

The Western Kunlun orogenic belt in the northwestern margin of the Tibetan plateau contains two magmatic belts; early Paleozoic belt in the northern part of Western Kunlun Terrane (WKT), and early Mesozoic belt in the southern part of WKT. Both formed from northward subduction of the Paleo-Tethys. The early Paleozoic belt contains large Datong and Qiukesu igneous complexes and many smaller plutons. The Datong complex is mainly composed of dark-colored porphyritic syenite and monzonite with minor light-colored dykes of granite and monzonite. The dark-colored rocks are characterized by moderate SiO_2 (58.2–69.3 wt.%), and high Al_2O_3 (15.3–17.1 wt.%), total alkali ($Na_2O + K_2O = 8.07–10.2$ wt.%) and ratios of K_2O/Na_2O (0.77–1.83). They plot in "shoshonite" field, and show high abundances of LILE including LREE ($(La/Yb)_n = 15.4–26.2$; mean 20.2) with pronounced negative anomalies of Nb–Ta–P–Ti in normalized trace elemental patterns and weak negative anomalies of Eu ($\delta_{Eu} = 2Eu_n/(Sm_n + Gd_n) = 0.68–0.80$). The light-colored rocks contain slightly higher concentrations of SiO_2 (60.3–72.0 wt.%), similar Al_2O_3 (14.7–17.6 wt.%), and slightly lower total alkalis (6.57–9.14 wt.%) than dark-colored rocks. They show adakitic geochemical signatures with low Y (5.80–17.2 ppm) and Yb (0.63–1.59 ppm), and high Sr/Y (>40). U–Pb zircon dating indicates that shoshonitic rocks and adakitic dykes formed at ~444 Ma to ~443 Ma, and a separate small adakitic plug at ~462 Ma. The mean $\varepsilon_{Hf}(t)$ values of zircon range from −1.6 to −0.94 (n = 14) with T_{DM2} of ~1.5 Ga for shoshonitic rocks and $\varepsilon_{Hf}(t)$ values from −1.8 to +0.72 (n = 12) with T_{DM2} of 1.4 to 1.5 Ga for adakitic rocks. Shoshonitic rocks show initial $^{87}Sr/^{86}Sr$ and $\varepsilon_{Nd}(t)$ of 0.7092–0.7100 and −3.9 to −3.2, respectively, and adakitic rocks yield initial $^{87}Sr/^{86}Sr$ and $\varepsilon_{Nd}(t)$ of 0.7099–0.7134 and −3.6 to −3.1, respectively. Similar Sr, Nd, and Hf isotope compositions for the shoshonitic and adakitic rocks suggest similar ancient rocks as their sources.

Combined with the geological development of the area, we propose that a local extension in the WKT over the subducting Paleo-Tethys has induced the upwelling of asthenospheric mantle and partial melting in the lower crust during mid-Ordovician to early Silurian. The primary shoshonitic melt evolved into the parental magmas for the shoshonitic rocks and adakitic rocks through fractional crystallization of hornblende.

1. Introduction

Shoshonites are K-rich igneous rocks and reported in many orogenic belts, including the Andes (Kay and Kay, 1993), Sierra Nevada (Manley et al., 2000), central Mexican volcanic belt (Blatter et al., 2001), Carpathians (Seghedi et al., 2004), and Tibet (Campbell et al., 2014; Turner et al., 1996). However, their sources and tectonic settings have been in discussion. Proposed sources include subcontinental lithospheric mantle (Rogers, 1992), metasomatized subarc mantle (e.g., Bloomer et al., 1989; Müller and Groves, 1995; Wyman and Kerrich, 1993), and delaminated or thickened lower crust (Chen et al., 2010; Wang et al., 2006). Fractional crystallization and crustal assimilation are also considered as possible processes in forming shoshonitic compositions (e.g., Feeley and Cosca, 2003; Meen, 1987). The origin of adakitic rocks is also in debate. Adakitic melt may be formed by partial melting of young subduction slab (Defant and Drummond, 1990), partial melting of delaminated or thickened crust in collisional zone (e.g., Chung et al., 2003; Gao et al., 2004; Wang et al., 2006), and fractional crystallization of water-rich arc magmas (e.g., Richards and Kerrich, 2007).

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The Western Kunlun orogenic belt is a large subduction–accretion belt in northwestern Tibet and located between the Tarim Block to the north and the Kohistan belt in Lhasa Terrane to the south (Fig. 1a). There are abundant intermediate to felsic igneous rocks in the Western Kunlun orogenic belt, which contain key information related to the evolution of the belt. The information is also important in understanding the evolution of the northwestern Tibetan plateau as well as Gondwana (e.g., Yin and Harrison, 2000; Yuan et al., 2002), but little studies have been carried out on these rocks partly because of their remote locations at high altitudes, over 5000 m, with no road access to the area. Furthermore, the area has poor rock exposures with thick cover of "yellow soil" and permanent snow. The Western Kunlun orogenic belt contains two large NW-SE trending parallel magmatic belts which extend over 300 km between the sutures of Oytag–Kudi and Mazha–Kangxiwa; the early Paleozoic belt in the north and the early Mesozoic belt in the south (Fig. 1b). The former contains the Datong and Qiukesu igneous complexes, and the latter contains the Muztagata and Kongur granitic complexes (Fig. 1b, c). Many smaller plutons are also present in the above two magmatic belts. Previous works show that igneous rocks in early Paleozoic magmatic belt in the area have crystallization ages of 435–473 Ma (e.g., Jia et al., 2013; Liao et al., 2010). The Datong igneous complex contains both shoshonitic and adakitic rocks. Adakitic rocks occur either as plugs or as dykes of variable width (up to 2 m width) cutting the shoshonitic rocks. The close association of shoshonitic and adakitic rocks suggests a genetic relationship between the two. This paper presents the petrology, geochronology and geochemistry of the shoshonitic and adakitic rocks of the complex, proposes their source, and discusses the tectonic evolution of the area.

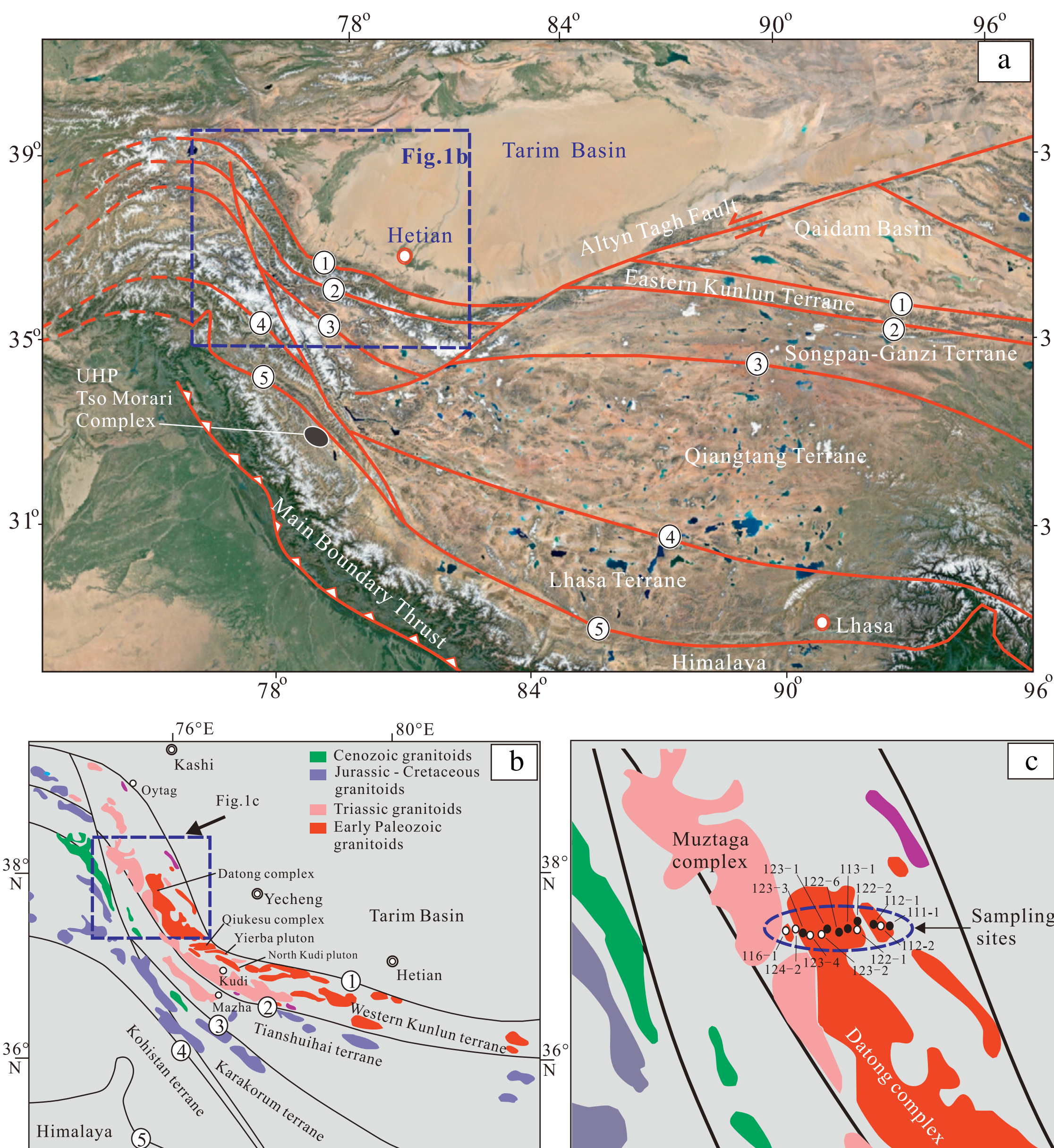

Fig. 1. (a) Map showing the locations of Kunlun orogenic belt, Tibetan plateau and major sutures; (b) Sketch map showing the distribution of granitic belts of different ages in the northwestern Tibetan Plateau (modified after Jiang et al., 2013); (c) simplified geological map of the Datong pluton with sampling sites on it. In Fig. 1a, ① = Oytag-Kudi suture; ② = Mazha-Kangxiwa suture; ③ = Hongshanhu–Qiaoertianshan suture; ④ = Bangong–Nujiang suture; and ⑤ = Indus–Yarlung– Zangbo suture. In Fig. 1c, the solid circles with labeled number refer to shoshonitic rocks, and those empty circles with labeled number refer to adakitic rocks.