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Geochronology, geochemistry and petrogenesis of Neoproterozoic basalts from Sugetbrak, northwest Tarim block, China: Implications for the onset of Rodinia supercontinent breakup

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ABSTRACT

Two layers of basaltic flows intercalated with Late Neoproterozoic (Sinian) sandstones have been identified in the Sugetbrak region in the northwest Tarim block, Northwest China. The basaltic rocks are composed of augite and plagioclase phenocrysts set in a groundmass of plagioclase laths with interstitial subophitic clinopyroxene grains and minor anhedral opaque minerals (magnetite and ilmenite). LA-MC-ICP-MS U–Pb dating of zircons from the lower basaltic flows yields a crystallization age of 783.7 ± 2.3 Ma. Both layers of the basaltic rocks are characterized by low SiO_2 and high total FeO (>12 wt.%), TiO_2 (>3 wt.%) and P_2O_5 (>0.5 wt.%) contents and extremely high Na_2O/K_2O ratios, and display a Fenner trend of differentiation that could be ascribed to significant fractional crystallization of clinopyroxene and plagioclase. The mineralogical and geochemical characteristics suggest the affinities of a transitional series between alkaline basalt and tholeiite. However, the lower basaltic flows have higher Nb/Y ratios than the upper ones, indicating that they are more alkaline. Positive age-corrected Nd isotope ratios [$\varepsilon_{Nd}(t)$ = +0.24–1.07] and positive $\varepsilon_{Hf}(t)$ values (+1.1–4.5) of the basaltic rocks suggest absence of any significant crustal contamination. High $\varepsilon_{Nd}(t)$ lavas are isotopically similar to those of several modern oceanic hotspots, and have ocean island-like patterns of incompatible elements. The estimated potential mantle temperature is ~100–150 °C higher than normal asthenospheric mantle, consistent with a plume-head origin. Moderate ratios of light rare earth elements (REE) to heavy REE indicate that the source magma was probably generated by partial melting of garnet–spinel transition facies of peridotite, but the upper basaltic rocks were derived from a relatively shallower mantle source, reflecting progressive lithosphere thinning possibly through plume–lithosphere interaction. We correlate the Sugetbrak basalts to the second Neoproterozoic mantle plume event (780–745 Ma) related to the breakup of the Rodinia supercontinent.

1. Introduction

The reconstruction of supercontinents provides important insights into global tectonic framework, mantle dynamics and surface geological features (e.g., Rogers and Santosh, 2004; Santosh, 2010; Meert, 2012). Studies on the assembly and breakup of the Neoproterozoic supercontinent Rodinia have greatly advanced in recent years through multidisciplinary research in the various constituent fragments of this supercontinent (e.g., Li et al., 2008 and references therein; Hofmann et al., 2011; Bhowmik et al., 2012). New observations and age data from Australia and South China suggest that the breakup of Rodinia supercontinent started with a plume-related magmatism during 800–830 Ma (e.g., Zhao et al., 1994; Li et al., 1999, 2002, 2003; Wingate et al., 1998; Ling et al., 2003), followed by a rift-related magmatism at 750–780 Ma (e.g., Evans et al., 2000; Preiss, 2000; Wingate and Giddings, 2000). The Tarim block, one of the three major continental blocks in China (the other two being North China and South China), is considered to have been located on the periphery of the Rodinian plume (e.g., Park et al., 1995; Li et al., 1999, 2003, 2008; Chen et al., 2004; Wang et al., 2009; Zhang et al., 2009a, 2012; Xia et al., 2012). Three major types of Neoproterozoic magmatism have been documented from the northeast and southwest parts of the Tarim block in response to the breakup of Rodinia (Fig. 1b). The first type is characterized by mafic dyke swarms such as those in West Kunlun Mountains, southwest Tarim (Zhang et al., 2004), in Korla, northeast Tarim block (Zhu et al., 2008, 2011a), and in Quruqtagh, northeast Tarim block (Zhang et al., 2009a,c). The second type is bimodal volcanic rocks in the Xinger

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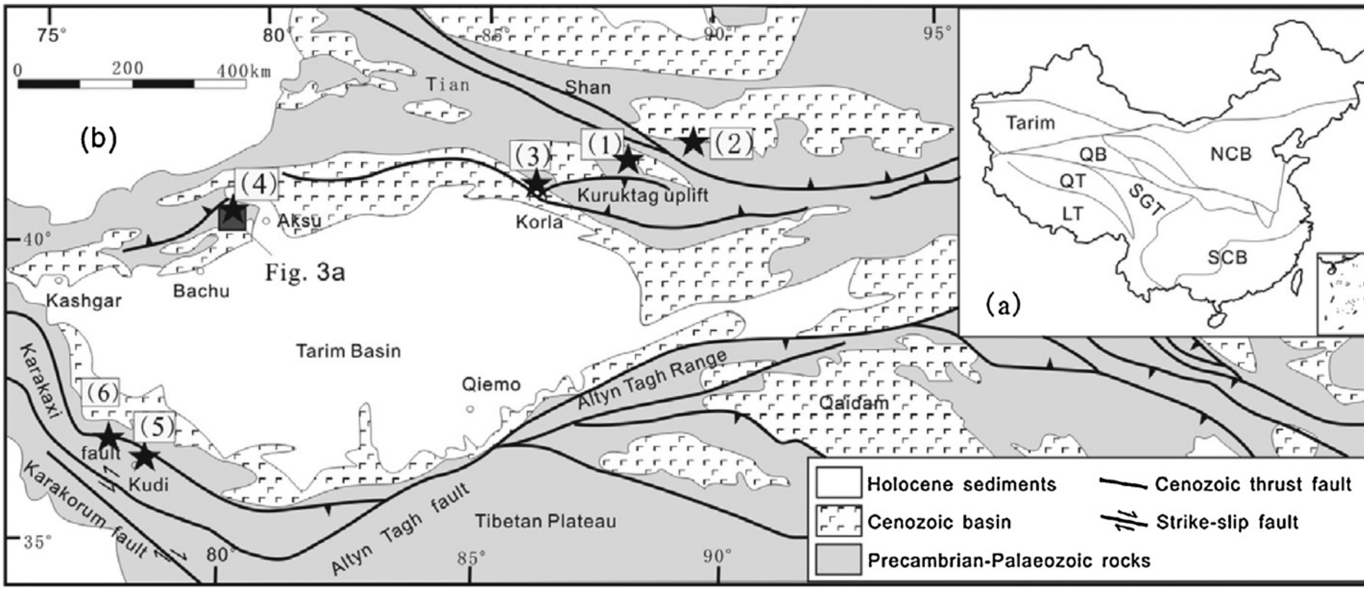

Fig. 1. (a) Main tectonic elements of China. NCB: North China block, SCB: South China block, SGT: Songpan-Ganzi terrane, QB: Qaidam basin, QT: Qiangtang terrane, LT: Lhasa terrane (modified after Li et al., 2007). (b) Sketch map showing the Precambrian geology on the Tarim Craton and adjacent areas (modified from Zhu et al., 2011a). The study area and the ca. 820–750 Ma igneous rocks related to the breakup of Rodinia supercontinent are also shown (black stars): (1) ca. 820–800 Ma mafic–ultramafic–carbonatite complex (Qieganbulake) and granites in Quruqtagh (Zhang et al., 2007); (2) ca. 755 Ma bimodal volcanic rocks (Xu et al., 2005); (3) ca. 650–630 Ma Korla mafic dykes (Zhu et al., 2008); (4) ca. 783 Ma Sugetbrak basalts (this study); (5) ca. 780 Ma alkaline bimodal intrusive complex in southwest Tarim (Zhang et al., 2006a); (6) Neoproterozoic mafic dyke in West Kunlun (Zhang et al., 2004).

area, northeast Tarim (Xu et al., 2005), and bimodal intrusive complexes in the Kudi area, southwest Tarim (Zhang et al., 2006a). The third type is represented by ultramafic–mafic–carbonatite complex in the Quruqtagh region, northeast Tarim block (Zhang et al., 2007, 2011). However, the above three types of magmatic rocks also display arc-like geochemical characteristics including prominent negative Nb, Ta and Ti anomalies on the primary mantle normalized incompatible element patterns (e.g., Xu et al., 2005; Zhang et al., 2004, 2006a, 2007, 2011), challenging the mantle plume model. Recent studies have led to the finding of two layers of basaltic flows interbedded with the Neoproterozoic succession in the Keping area, northwest Tarim (Fig. 1). These basaltic rocks have distinct OIB-like geochemical features that may represent a magmatic expression of the plume events. Precise geochronologic and geochemical data and a comprehensive petrogenetic study of the petrogenesis of these basaltic rocks would provide important constraints in evaluating the tectonic framework of the magmatic events associated with the Rodinia supercontinent breakup. In this study, we present geochronological and geochemical data for these basaltic flows, and discuss the implications for mantle-source composition and the breakup of Rodinia.

2. Geological setting

The Tarim block covers an area of more than 600,000 km^2 and is located between the Tianshan Mountains in the north and Kunlun Mountains in the south (Fig. 1a).

Precambrian rocks in the Tarim block are mainly exposed along its northern and southern margins and record the early tectonic evolution of this block (Lu et al., 2008; Zheng et al., 2008; Zhang et al., 2009c, 2011; Zhu et al., 2010, 2011a). The Archean–Paleoproterozoic basement, which consists of tonalite–trondhjemite–granodiorite (TTG) gneisses and supracrustal rocks, has been recognized in the Kuluketage area, northern Tarim Craton (e.g., Lu et al., 2008; Shu et al., 2011; Long et al., 2010), whereas late Mesoproterozoic to earliest Neoproterozoic strata have been mapped along both the northern and southern margins of the block. Late Mesoproterozoic to early Neoproterozoic amphibolite-facies metamorphic rocks and metavolcanics with metamorphic hornblende and biotite ^{40}Ar–^{39}Ar ages of between 1050 and 1020 Ma, and tightly folded metamorphic rocks with metamorphic zircon U–Pb ages of 1000–900 Ma are exposed along its southwestern margin (Zhang et al., 2007). The Precambrian Aksu blueschist outcrops along the northern margin of the block, although its metamorphic age has not been well determined (e.g., Nakajima et al., 1990; Liou et al., 1996). Unconformably overlying these late Mesoproterozoic to early Neoproterozoic metamorphic rocks are a succession of little-metamorphosed Neoproterozoic volcaniclastic units and glacial deposits, similar to those in South China, possibly formed during the breakup of Rodinia (Xu et al., 2005).

In the Keping area, which is located in the northwestern part of the Tarim block (Fig. 1b), continuous outcrops of both the metamorphic basement and the Upper Neoproterozoic to Early Paleozoic successions are well exposed. The stratigraphic successions contain the pre-Sinian Aksu Group of metamorphic rocks, the Sinian (Late Neoproterozoic) Qiaoenbrak, Youermeinak, Sugetbrak and Chigebrak Formations (Fms.), and the Lower Cambrian Yuertus Formation (Figs. 2 and 3a).

The metamorphic basement rocks of the Aksu Group include a series of glaucophane schist and greenschist, and the protolith is bathyal–abyssal facies mudstone, sandstone, tuff, mafic lava and abyssal sediments. The precise age of these units has not been determined, and remains controversial. Whole-rock Rb–Sr geochronological data indicate a Paleoproterozoic age, with isochron ages of 1720–1907 Ma (Xiong and Wang, 1986). In contrast, a protolith Sm–Nd isochron age of 890 ± 23 Ma for the Aksu bluschists was also reported (Zheng et al., 2010). In another study, Zhu et al. (2011a) obtained a maximum depositional age of ca. 730 Ma for the protolith of the metasedimentary rocks on the basis of detrital zircon U–Pb geochronological study. The SHRIMP U–Pb zircon dating of the metabasalts (amphiboles) of the Aksu Group from the Baicheng area, 120 km NE Aksu, yield a mean of 844 ± 11 Ma (12 analyses, the original data and zircon concordia