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Geochemistry and SHRIMP U–Pb zircon geochronology of the Korla mafic dykes: Constrains on the Neoproterozoic continental breakup in the Tarim Block, northwest China

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ABSTRACT

The Kuruktag uplift is located to the north of the Tarim Block, NW China. At the western end of the Kuruktag uplift, mafic dykes crop out in the Korla area, which were rarely subjected to deformation and metamorphism in contrast to their metamorphic wall-rocks that were strongly deformed and metamorphosed to amphibolite facies. A SHRIMP U–Pb zircon age of 634 Ma was obtained for a spessartite dyke, documenting the youngest known igneous activity associated with rifting in the Tarim Block during the Neoproterozoic. Most samples of the Korla mafic dykes show clear enrichments in Th, La, and variable depletions in Nb, Ta and Ti, except for samples 08T-14 and 08T-19 that display incompatible element distribution patterns similar to those of OIB without obvious depletions in Nb, Ta and Ti. The geochemical signatures suggest that the Korla mafic dykes were formed in an intra-plate setting and their primary magama was possibly produced by partial melting of a sub-continental lithospheric mantle that has been metasomatized by previous subduction processes, and then heated by a rising mantle plume. In combination with previous geochronological data of Neoproterozoic igneous rocks throughout the Tarim Block, at least three pulses of magmatic activity, from ca. 830 to 800 Ma, from ca. 790 to 740 Ma and from ca. 650 to 615 Ma, are recognized, which reveal that multiple episodes of rifting occurred within the Tarim Block, implying that the breakup of the Rodinia supercontinent in the Tarim Block may have been a long-lasting process.

1. Introduction

Neoproterozoic world-wide spread magmatic rocks, including mafic dykes, large igneous province and bimodal volcanic rocks, play a key role in understanding the breakup and reconstruction of the Rodinia supercontinent. Some hypotheses suggest that mafic igneous rocks on many old cratons, together with ultramafic–mafic intrusions and alkaline granites (resulting from crustal melt or magma differentiation), were generated by mantle superplumes (Li et al., 2003, 2008 and references therein). Neoproterozoic mafic magmatism in the Rodinia supercontinent mostly spans from ca. 860 to 720 Ma, with three broad peaks at ca. 830–790 Ma, 780–755 Ma and 745–720 Ma. The ca. 830–790 Ma mafic magmatism is represented by the 824 ± 4 Ma Amata Dyke Swarm in central Australia (Sun and Sheraton, 1996), the 827 ± 6 Ma Gairdner Dyke Swarm and 827 ± 9 Ma Little Broken Hill gabbro in southeastern Australia (Wingate et al., 1998) and the 828 ± 7 Ma mafic to ultramafic dykes and sills in the northern Guangxi Province, South China (Li et al., 1999b). These mafic magmatic events are interpreted as the first sign of a superplume activity which causes the initial breakup of Rodinia. The ca. 780–755 Ma mafic magmatism is represented by the 755 ± 3 Ma Mundine Well Dyke Swarm (MDS) in Western Australia (Wingate and Giddings, 2000; Li et al., 2006), the ca. 780 Ma Gunbarrel mafic magmatic event in western Laurentia (Harlan et al., 2003), the 778 ± 3 Ma Little Dal quartz diorite plug in the Mackenzie Mountains (Jefferson and Parrish, 1989), and the ca. 780 Ma radiating mafic dyke swarms (Park et al., 1995) which include the Tsezotene sills/dykes and the Hottah dykes in the Mackenzie Mountains, and the Tobacco Root Mountains dykes, Beartooth Mountains dykes and the Teton Range dykes in the Wyoming Province and the ca. 780–760 Ma dolerite dykes within the Kangding Rift along the western margin of the Yangtze Block in South China (Li et al., 2003; Lin et al., 2007). These age data may record the onset of rifting of Australia or South China from Laurentia (Park et al., 1995; Rainbird et al., 1996; Pisarevsky et al., 2003). The ca. 745–720 Ma mafic magmatism is documented

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in Laurentia by the 723 Ma Franklin dyke swarms (Heaman et al., 1992), in south Siberian craton by the 741 Ma mafic intrusion in the Biryusa metamorphic massif (Gladkochub et al., 2006) and the 743 Ma mafic dykes in the Sharyzhalgai massif (Sklyarov et al., 2003).These mafic igneous events provide evidence to place Siberia some distance to the northwest of Laurentia (present coordinates) and are interpreted as of mantle plume origin related to the breakup between Laurentia and Siberia (Heaman et al., 1992). In addition to 860–720 Ma mafic magmatism, a number of the younger mafic magmatic events have been revealed that are also considered to be generated by mantle plume and related to breakup of Rodinia. For example, the 615 ± 2 Ma Long Range dykes in Newfoundland and Labrador of eastern Laurentia are considered to be related to the initial lithospheric sketching in northeast Laurentia and Baltica (Kamo et al., 1989; Kamo and Gower, 1994; Bingen et al., 1998). Keppie et al. (2006) presented the new data of ca.546 Ma mafic dykes in the Novillo Gneiss of East-Central Mexico and suggested that mafic dykes are mantle plume origin and a marker of separation between Avalonia and Oaxaquia. Recently, Zhu et al. (2008) reported 650–630 Ma SHRIMP U–Pb zircon ages of the Korla mafic dykes, which document the youngest known igneous activity associated with rifting during the tectonic development along the northern margin of the Tarim Block, and discussed the relationship between the protracted rifting history of the Tarim Block and the late Neoproterozoic breakup of Rodinia. These younger geochronological data imply that the mafic magmatic events related to mantle superplume activity extend over at least 200 Ma. The mantle superplume provided large and sustained heat source for the widespread occurrence and protracted duration (ca. 200 million years) of such anorogenic magmatism and was responsible for the breakup of Rodinia during the Neoproterozoic (Li et al., 2003).

In this paper, we present new petrological, geochemical and geochronological data for the Korla mafic dykes to evaluate the processes involved in the geochemical evolution of these rocks, constrain the composition of their sources, and determine their petrogenesis and tectonic setting, and then to provide important insights into understanding of the late Neoproterozoic evolution of the Tarim Block.

2. Geological setting

The Tarim Block located in northwestern China, is one of the largest cratons in China, which was placed on the periphery of the Rodinia supercontinent (Li et al., 1996). Precambrian rocks are mainly presented along both the northern and southern margins of the Tarim Block, which record the tectonothermal events correlated to the assembly and break-up of Rodinia. Previous studies suggested that Late Mesoproterozoic to Neoproterozoic tectonothermal events can be subdivided into two major periods (Lu et al. 2008; Zhang et al. 2009a). The first period of events (1.05–0.90 Ga), e.g., the Late Mesoproterozoic to Early Neoproterozoic amphibolite-facies metamorphic rocks with metamorphic hornblende and biotite ^{40}Ar–^{39}Ar ages between 1050 Ma and 1020 Ma, and the tightly-folded metamorphic rocks with metamorphic zircon U–Pb ages of 1000–900 Ma along its southwestern margin (Zhang et al., 2009a), and ~950 Ma ophiolites along its southeastern margin (Guo et al., 1999), reflects a compressional regime corresponding to the final assembly of Rodinia. The second period of events recorded by the Neoproterozoic widespread mafic dyke swarms, ultramafic–mafic intrusions, alkaline granites, and bimodal volcanic rocks occurring in the Tarim Block and lasting from 0.84 Ga to 0.63 Ga (Table 1), suggests a multiple episodes of rifting related to the break-up of Rodinia (Zhu et al., 2008).

The Kuruktag uplift is located to the north of the Tarim Block (Fig. 1). Abundant Neoarchaean gneisses, derived from tonalite–trondhjemite–granodiorite-type granites and minor supracrustal rocks, are preserved in the Kuruktag uplift (Hu et al., 2000; Zhu et al., 2007, 2010; Lu et al., 2008). The Neoproterozoic strata present in the western Kuruktag, which unconformably overlies the Paleoproterozoic-to-Mesoproterozoic gneisses, amphibolites, marbles and schists, are unconformably overlain by early Palaeozoic rocks. The Neoproterozoic strata are characterized by several horizons of glacial deposits and rift volcanic rocks with SHRIMP U–Pb zircon ages between 615 Ma and 755 Ma (Xu et al., 2005, 2009; Huang et al., 2005), separated by thick layers of shale, sandstone and limestone (Gao and Qian, 1985; Brookfield, 1994; Xiao et al. 2004; Xu et al. 2005). Three glaciations (Beiyixi, Tereeken and

Table 1
Ages of rifting events in the Tarim Blocks.

Rocks/locations	Age (Ma)	Dating method	References
Ultramafic intrusion/Kuruktag	818 ± 11	U–Pb on zircons	Zhang et al. (2007)
Mafic dyke/Kuruktag	823.8 ± 8.7	SHRIMP U–Pb on zircons	Zhang et al. (2009b)
Mafic dyke/Kuruktag	776.8 ± 8.9	SHRIMP U–Pb on zircons	Zhang et al. (2009b)
Mafic dyke/Kuruktag	773 ± 3	SHRIMP U–Pb on zircons	Zhang et al. (2009a)
Granodiorite/Kuruktag	820 ± 10	SHRIMP U–Pb on zircons	Zhang et al. (2007)
Granite/Kuruktag	795 ± 10	SHRIMP U–Pb on zircons	Zhang et al. (2007)
Volcanics/Xishankou	727 ± 10	SHRIMP U–Pb on zircons	Huang et al. (2005)
Volcanics/Kuruktag	755 ± 15	SHRIMP U–Pb on zircons	Xu et al. (2005)
Volcanics/Kuruktag	740 ± 7	SHRIMP U–Pb on zircons	Xu et al. (2009)
Volcanics/Kuruktag	725 ± 10	SHRIMP U–Pb on zircons	Xu et al. (2009)
Volcanics/Kuruktag	615 ± 6	SHRIMP U–Pb on zircons	Xu et al. (2009)
Mafic dyke/Korla	642.8 ± 6.8	SHRIMP U–Pb on zircons	Zhu et al. (2008)
Mafic dyke/Korla	628.7 ± 6.6	SHRIMP U–Pb on zircons	Zhu et al. (2008)
Mafic dyke/Korla	652.0 ± 7.4	SHRIMP U–Pb on zircons	Zhu et al. (2008)
Mafic dyke/Aksu	759 ± 7	SHRIMP U–Pb on zircons	Zhang et al. (2009a)
Mafic dyke/Aksu	807 ± 12	SHRIMP U–Pb on zircons	Chen et al. (2004)
Mafic dyke/Aksu	785 ± 31	SHRIMP U–Pb on zircons	Zhan et al. (2007)
Alkaline diorite/Central Tarim	790.0 ± 22.1	$^{40}Ar/^{39}Ar$ on hornblende	Guo et al. (2005)
Alkaline diorite/Central Tarim	754.4 ± 22.6	$^{40}Ar/^{39}Ar$ on hornblende	Guo et al. (2005)
Alkaline diorite/Central Tarim	744.0 ± 9.3	$^{40}Ar/^{39}Ar$ on hornblende	Guo et al. (2005)
Layered mafic intrusive complex/Central Tarim	825.0 ± 2.0	$^{40}Ar/^{39}Ar$ on gabbro	Li et al. (1999a)
Layered mafic intrusive complex/Central Tarim	837.3 ± 2.0	$^{40}Ar/^{39}Ar$ on gabbro	Li et al. (1999a)
A-type granite/West Kunlun	803 ± 23	U–Pb on zircons	Zhang et al. (2006)
A-type granite/West Kunlun	783 ± 10	SHRIMP U–Pb on zircons	Zhang et al. (2006)