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# Neoproterozoic subduction-related basaltic magmatism in the northern margin of the Tarim Craton: Implications for Rodinia reconstruction

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A B S T R A C T

A single mantle plume model for the Neoproterozoic mafic-ultramafic intrusive rocks (760–820 Ma) in the northern rim of the Tarim Craton (Kuluketage, Xinjiang, China) is not supported by the protracted nature of magma emplacement that does not show a hot spot track, and whole-rock trace element compositions that clearly show arc signatures. New and previous zircon U-Pb age data reveal an age difference of up to 11 myr for a single mafic-ultramafic intrusive complex and an age difference of up to 32 myr for two mafic-ultramafic intrusive complexes separated by only ~10 km. Such age differences are more than 2–5 times the analytical uncertainties. No major faults are present between the two intrusive complexes with different ages so their original distance is still well preserved. In addition, the age change of the mafic-ultramafic intrusive rocks in the region occurs in different directions. The temporal-spatial distribution of these rocks can be well explained by subduction-related magmatism that can last for a very long period of time at the same location. The protracted Neoproterozoic mafic-ultramafic intrusive rocks in the Kuluketage district are all characterized by moderate light rare earth element enrichments, pronounced negative Nb-Ta anomalies and low $\varepsilon_{Nd}(t)$ values (1 to −11) coupled with elevated initial $^{87}Sr/^{86}Sr$ ratios (0.706–0.71), which are consistent with the products of arc basalts contaminated with crustal materials. The results from this study support the notion that the northern margin of the Tarim Craton was part of the Neoproterozoic Circum-Rodinia Subduction System.



## 1. Introduction

Several clusters of Neoproterozoic mafic-ultramafic intrusions in the margins of the Yangtze, Tarim and North-China Cratons (Fig. 1) have been studied extensively, mainly because the timing of their emplacements broadly coincided with the breakup of Rodinia (e.g., Li et al., 1999, 2010), plus the occurrence of economically valuable Fe-Ni-Ni sulfide mineralization in some of these intrusions (e.g., Munteanu et al., 2010; Li and Ripley, 2011). The long-lasting debate on the geodynamic settings of these mafic-ultramafic intrusive clusters became really intriguing after some researchers (Li et al., 1999) suggested that the Neoproterozoic mafic-ultramafic intrusions in the southern margin of the Yangtze Craton (northern Guangxi, see Fig. 1) are the products of a hypothetical super mantle plume (referred to as the South China mantle plume by these authors) that are thought to be responsible for Rodinia breakup. Subsequently, the proponents of this hypothesis (e.g., Li et al., 2005, 2006, 2010; Zhang et al., 2007, 2009) proposed that the Neoproterozoic mafic-ultramafic intrusions in the western margin of the Yangtze Craton (Hannan, Yanbian) and in the western part of the North China Craton (Jinchuan) are also the products of the so-called South China mantle plume, primarily based on their apparent temporal correlation with the northern Guangxi cluster (Fig. 1). The single mantle plume model for all of the above-mentioned clusters has been criticized by many other researchers. For examples, some researchers (Li and Ripley, 2011; Tang et al., 2014) argued against the notion that the Jinchuan and northern Guangxi clusters belong to the same super mantle plume based on contrasting Precambrian geological records for these two different regions; other researchers used holistic geological and petrological constraints to argue for an alternative, subduction-related origin for the circum-Yangtze clusters (Hannan, Yanbian, northern Guangxi) (e.g., Zhou et al., 2002, 2006; Yao et al., 2014).

Similarly, the geodynamic processes for the Neoproterozoic mafic-ultramafic intrusions and dykes in the Kuluketage district, Tarim Craton (Fig. 1) has also been debated for some time. Some

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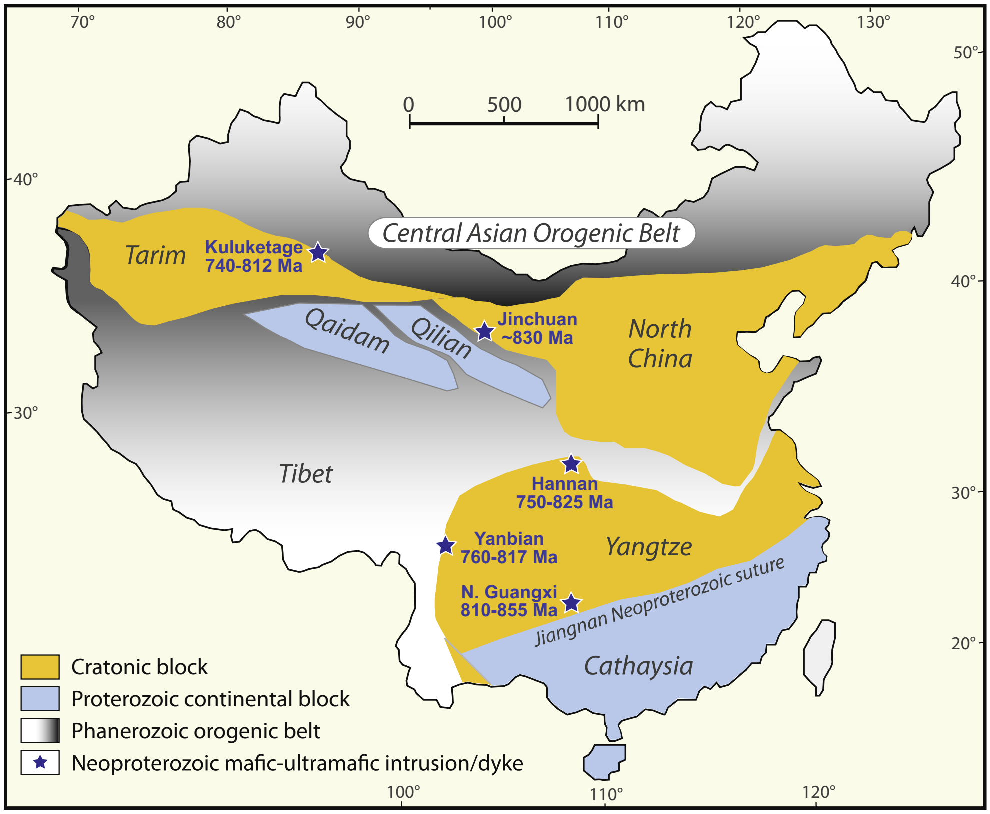


**Fig. 1.** Precambrian continental blocks in China, showing the locations of some Neoproterozoic mafic-ultramafic intrusive clusters with debated geodynamic models. The base map is modified from Zhao and Cawood (2012). The zircon U-Pb ages for the mafic-ultramafic intrusive rocks are from Dong et al. (2012), Li et al. (2010), Li et al. (1999), Munteanu et al. (2010), Wang et al. (2006), Yao et al. (2014), Zhang et al. (2007, 2009, 2011, 2012), Zhang et al. (2010), Zhu et al. (2008).

researchers suggested that the Neoproterozoic intrusive rocks in this region are the products of the so-called South China mantle plume (Zhang et al., 2007, 2009, 2011) or an independent mantle plume (Ye et al., 2013). Recently, Zhang et al. (2012) modified their original view and suggested that in addition to mantle plume activity, subduction-related basaltic magmatism also contributed to the formation of these mafic-ultramafic intrusive rocks. Since the various geodynamic models have different implications for Rodinia reconstruction, an independent study to evaluate the validity of the competing geodynamic models is needed.

In this study we use new and previous zircon U-Pb age data to determine whether the temporal-spatial distribution of the Neoproterozoic mafic-ultramafic intrusive rocks in the Kuluketage district is consistent with prolonged mantle plume activity or subduction-related magmatism, based on the fundamentals of mantle plume and plate tectonics. We then use whole-rock trace element and Sr-Nd isotope data as consistent arguments to support our new conclusion. The implications of the new results for Rodinia reconstruction is given at the end.

## 2. Geological background

Three major cratonic blocks (North China, Tarim and Yangtze) are present in mainland China (Fig. 1). The Yangtze Craton and the Precambrian Cathaysia continental block were amalgamated at some time between 800 Ma and 850 Ma to form the South China block (Yao et al., 2014). The Tarim Craton is bounded by the Paleozoic Kunlun Orogenic Belt to the south and by the Paleozoic Tianshan Orogenic Belt to the north (Fig. 2a). The Tianshan Orogenic Belt is the southernmost part of the Central Asian Orogenic Belt in northern Xinjiang, western China.

The northern rim of the Tarim Craton was an active continental margin from the Neoproterozoic to the Paleozoic, as indicated by widespread granitic magmatism at 830–820 Ma, 660–630 Ma and 420–40 Ma (Ge et al., 2014) and granulites that formed mostly at 820–790 Ma (He et al., 2012) in the region from Korla to Xingdi (Fig. 2a). In the Kuluketage district (Fig. 2b) the metamorphic rocks are mainly amphibolites (Lu et al., 2008). Archean gneisses and Proterozoic granulites are also present but much less abundant. Clastic and carbonate sedimentary rocks are present in the north (Fig. 2b). These rocks have experienced low-grade metamorphism mostly at the greenschist facies.

The igneous rock suites in the Kuluketage district are volumetrically dominated by Neoproterozoic granitoids and mafic-ultramafic intrusive rocks. A couple of small diorite plutons with unknown ages are also present in the region. Zircon U-Pb dating show that the two granite plutons in the northeastern corner of the region (Fig. 2b) were emplaced at 795 ± 10 Ma and 820 ± 10 Ma (Zhang et al., 2007). Younger granite dykes and entrained granite fragments with zircon U-Pb ages varying from 734 ± 4 to 743 ± 3 are present in some (I, II, IV) of the mafic-ultramafic complexes (Zhang et al., 2012; Cao et al., 2014). The Neoproterozoic granitoids are also present in great abundance farther to the east (Cao et al., 2014) and to the west nearby Korla (Fig. 1a for location) (Ge et al., 2014).

In descending order of abundance, the Neoproterozoic mafic-ultramafic intrusive rocks in the region (Fig. 2b) are mafic-ultramafic complexes, dolerite (mafic) dykes and a pyroxenite-carbonatite complex (Qieganbulake). Baddeleyite U-Pb dating reveals that the carbonatite of the Qieganbulake complex is 810 ± 6 Ma (Zhang et al., 2007). Zircon crystals from the associated pyroxenites yield an age of 816 ± 13 Ma (Ye et al., 2013). The