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Carbonatites of Tarim (NW China): First evidence of crustal contribution in carbonatites from a large igneous province

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ABSTRACT

Many carbonatites are associated both spatially and temporally with large igneous provinces (LIPs), and considered to originate from a mantle plume source lacking any contribution from recycled crustal materials. Here, we report an occurrence of carbonatite enriched in rare-earth elements (REE) and associated with the Tarim LIP in northwestern China. The Tarim LIP comprises intrusive and volcanic products of mantle plume activity spanning from ~300 to 280 Ma. The carbonatites at Wajilitage in the northwestern part of Tarim are dominated by calcite and dolomite varieties, and contain abundant REE minerals (principally, monazite and REE-fluorcarbonates). Th–Pb age determination of monazite yielded an emplacement age of 266 ± 5.3 Ma, i.e. appreciably younger than the eruption age of flood basalts at ~290 Ma. The carbonatites show low initial $^{87}Sr/^{86}Sr$ (0.7037–0.7041) and high $\varepsilon_{Nd(t)}$ (1.2–4) values, which depart from the isotopic characteristics of plume-derived basalts and high-Mg picrites from the same area. This indicates that the Wajilitage carbonatites derived from a mantle source isotopically distinct from the one responsible for the voluminous (ultra)mafic volcanism at Tarim. The carbonatites show $\delta^{26}Mg_{DSM3}$ values (−0.99 to −0.65‰) that are significantly lower than those in typical mantle-derived rocks and rift carbonatites, but close to marine sediments and orogenic carbonatites. We propose that the carbonatites in the Tarim LIP formed by decompressional melting of recycled sediments mixed with the ambient mantle peridotite. The enriched components in the Tarim plume could be accounted for by the presence of recycled sedimentary components in the subcontinental mantle.

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1. Introduction

Carbonatites are mantle-derived carbonate-rich igneous rocks commonly occurring in intracontinental rift settings and associated with alkaline silicate rocks. Carbonatites provide valuable information on the composition of their mantle source because: (1) their Sr–Nd–Hf isotopic characteristics are generally inherited from, and representative of, the source owing to the initially high concentrations of Sr, rare-earth and high-field-strength elements (REE and HFSE, respectively) in their parental magmas (e.g., Chakhmouradian et al., 2016; Eby, 1975; Nelson et al., 1988), and (2) these magmas have extremely low viscosities (Treiman, 1989), which facilitate their rapid ascent to the surface. Carbonate melts also play a significant role in mantle metasomatism and as a result, are intimately linked to the secular evolution of the subcontinental mantle (-Rudnick et al., 1993). There is increasing evidence that many carbonatites around the world are linked to mantle plume activity (Bell and Tilton, 2001; Ernst and Bell, 2010). Evidence for the involvement of plumes in carbonatite petrogenesis includes the spatial and temporal association between these rocks and large igneous provinces (LIPs), and similarities in Sr, Nd, Hf and Pb isotopic characteristics between young carbonatites and ocean island basalts (OIBs) (Bell and Tilton, 2001; Ernst and Bell, 2010; Nelson et al., 1988). Examples, summarized by Bell (2001), Bell and Simonetti (2010) and Ernst and Bell (2010), include the Paraná-Etendeka (South America and southwestern Africa), Keweenawan (Canada), Maimecha–Kotuy portion of the Siberian Trap (Russia) and Deccan (India) LIPs. It was proposed that carbonatitic magmas in these regions were formed by low-degree partial melting of volatile-rich and colder outer edges of the plume, and without any contribution from recycled crustal materials (Bell and Simonetti, 2010). The LIPs

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and carbonatites have been considered to evolve along different pathways, representing a single magma-generation process (Ernst and Bell, 2010). However, Fischer et al. (2009) found that $^{3}He/^{4}He$ ratios of carbonatite lavas in Oldoinyo Lengai, Tanzania, show considerable overlap with those for samples of mid-ocean ridge basalts (MORB) and lithospheric mantle. Here, we report newly discovered carbonatites associated with the Tarim LIP of northwestern China. The major objective of the present work is to use geochronological and isotopic data for constraining the relationship (if any) between the carbonatites and other igneous rocks in the Province.

2. Geological setting

The large volume of Early Permian volcanic rocks in the Tarim Block of northwestern China has been recognized as a LIP (Tian et al., 2010; Y.-G. Xu et al., 2014; Zhang et al., 2013). The Tarim Block is surrounded by the Tianshan Mountains to the north and west, and western Kunlun and Altyn orogenic belts to the south (Fig. 1a). It was amalgamated with the southern part of the Central Asian Orogenic Belt during the Late Paleozoic and is composed of a Precambrian crystalline basement, including volcano-sedimentary and high-grade metamorphic rocks, and a thick Phanerozoic sedimentary cover which comprises Ordovician, Permian and Cretaceous strata (Long et al., 2010). The Block is also the largest basin in China, occupying an area of 600,000 km^2. The LIP consists of voluminous volcanic successions and associated intrusions, including flood basalts, dike swarms, Fe-Ti oxide-bearing mafic-ultramafic intrusions, picrites, porphyritic pyroxenite–dunite, lamprophyres, nephelinites, syenites, A-type granites and rhyolites (Y.-G. Xu et al., 2014). It covers an area of more than 300,000 km^2 with a thickness of igneous package ranging from several hundred meters to 3 km, according to recent geophysical surveys and oil exploration deep-drill logs (Tian et al., 2010; Y.-G. Xu et al., 2014). Drill-hole data indicate that the thickness of

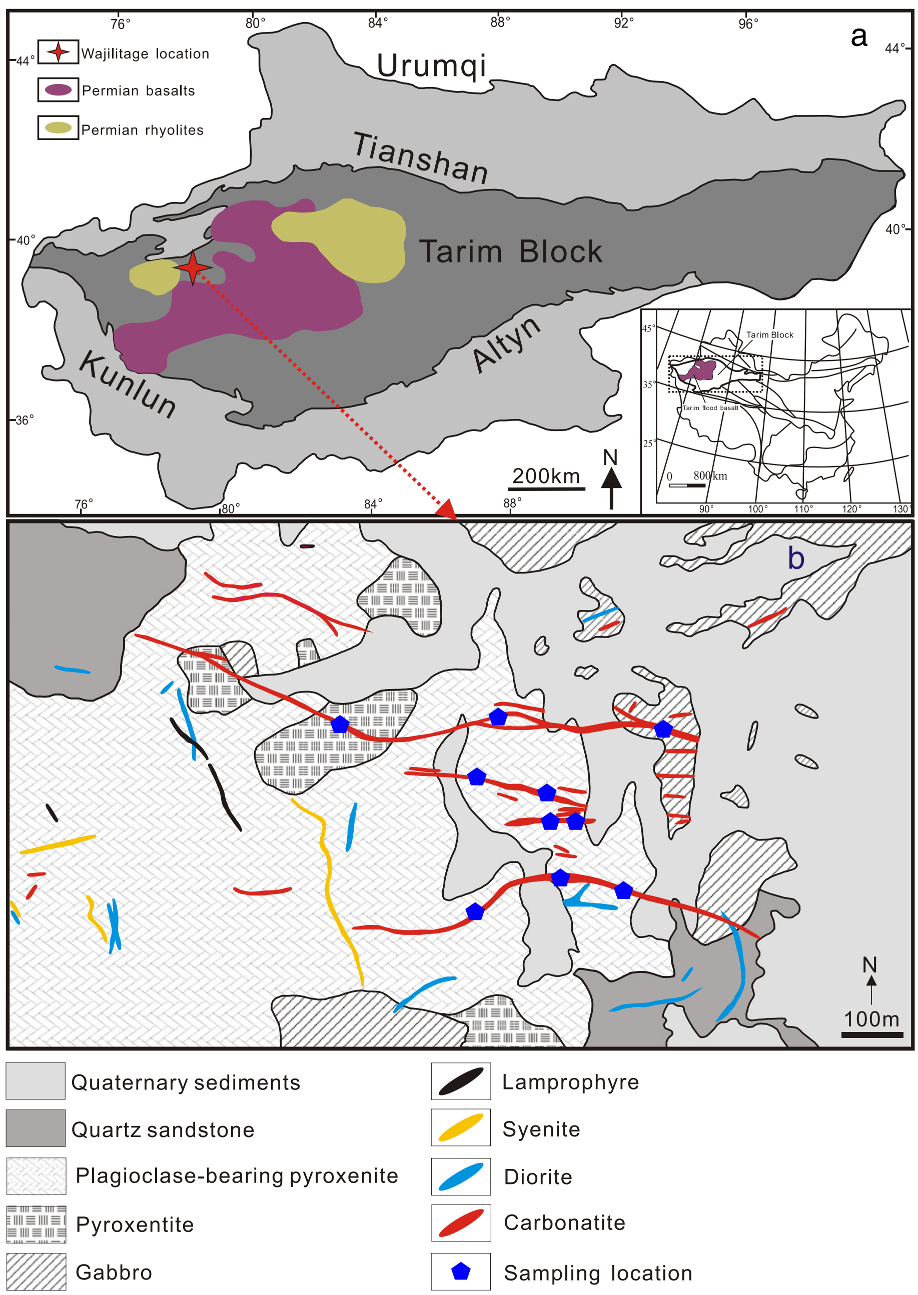

Fig. 1. Schematic location map of the Tarim LIP (a) and geological map of the Wajilitage area (b); modified after Zhang et al. (2013), Y.-G. Xu et al. (2014) and Wang (2014).

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