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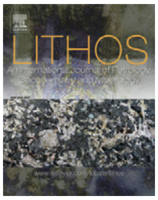

Metasomatized lithosphere–asthenosphere interaction during slab roll-back: Evidence from Late Carboniferous gabbros in the Luotuogou area, Central Tianshan

Gong-Jian Tang [a,b], Qiang Wang [a,*], Derek A. Wyman [c], Zheng-Xiang Li [d], Yi-Gang Xu [a], Zhen-Hua Zhao [a]

[a] *State Key Laboratory of Isotope Geochemistry, Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou 510640, PR China*
[b] *Graduate University of Chinese Academy of Sciences, Beijing 100049, PR China*
[c] *School of Geosciences, The University of Sydney, NSW 2006, Australia*
[d] *ARC Centre of Excellence for Core to Crust Fluid Systems (CCFS) and The Institute for Geoscience Research (TIGeR), Department of Applied Geology, Curtin University, GPO Box U1987, Perth,WA 6845, Australia*

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ABSTRACT

Late Carboniferous igneous rocks are widespread in the western Tianshan, but the tectonic settings for these rocks remain controversial. We report a plagioclase $^{40}Ar/^{39}Ar$ age, and geochemical, Sr–Nd isotope and LA–ICPMS clinopyroxene trace element data for gabbros in the Luotuogou region. The tholeiitic Luotuogou gabbros give a Late Carboniferous (312 ± 1 Ma) $^{40}Ar/^{39}Ar$ age and are characterized by high and variable $\varepsilon_{Nd}(t)$ values ranging from +3.7 to +7.8. They have geochemical features of both intra-plate and island arc magmatic rocks, i.e., relatively high TiO_2 (0.6–2.2 wt.%), Nb (4.2–24 ppm) and Zr (51.4–283 ppm) contents combined with variable and slightly high Nb/La ratios (0.24–1.8, mostly > 0.7), and negative to positive Nb anomalies. The gabbros contain zoned clinopyroxenes, with Mg- and Cr-rich cores. Their parental magmas, as calculated using trace element data from Cr-rich (> 3000 ppm) clinopyroxene cores and clinopyroxene/basaltic liquid partition coefficients, show enrichments in incompatible elements, and prominent negative to slightly positive Nb anomalies, indicative of the influence of subduction-related compositions in their mantle source. These features indicate that the Luotuogou gabbros were most likely formed by interactions between asthenospheric and metasomatized lithospheric mantle. They were most plausibly formed by mixing between the asthenospheric mantle-derived and metasomatized lithosphere mantle-derived melts. Mixing was the result of asthenosphere upwelling triggered by roll-back of the subducted Paleo-Junggar Oceanic Plate rather than mantle plume-related rifting or post-collisional break-off during the Late Carboniferous.

1. Introduction

Continental basaltic magmas record critical information regarding the chemical composition of the sub-continental mantle and regional tectonic evolution. Several distinct mantle components can contribute to continental basalts, such as subcontinental lithospheric mantle, plume-related OIB (oceanic island basalt)-type mantle sources, or depleted MORB (middle oceanic ridge basalt)-type asthenosphere mantle (Garfunkel, 2008; Saunders, 2005). Popular tectonic models for continental volcanism include decompressional melting as a result of lithospheric mantle removal (detachment) and upwelling asthenosphere mantle (Hoernle et al., 2006; Timm et al., 2009), lithosphere extension induced by continental rifting and breakup (McKenzie and Bickle, 1988), high temperature melting of mantle owing to elevated mantle temperature by deep-seated mantle plume head impinging on the lithosphere (Campbell and Griffiths, 1990), and the roll-back and/or foundering of flat-subducted oceanic plateaus or aseismic ridges (Coney and Reynolds, 1977; Li and Li, 2007). Identifying the primary magmas for continental basaltic magmas thus has the potential of deciphering their petrogenesis and related tectonic processes.

However, continental basaltic magmas generally show variable chemical compositions due to contamination by continental crustal components or fractionation during their ascent (Dorais and Tubrett, 2008). One approach that overcomes these problems uses clinopyroxene chemical composition and basaltic liquid partition coefficients to model the most primitive liquids to have been in equilibrium with the clinopyroxenes (Tribuzio et al., 2008, 2009). The results are then compared with various mantle-derived basaltic magmas to draw inferences about the primary magma compositions (Chen et al., 2009; Dorais and Tubrett, 2008; Tribuzio et al., 2008, 2009).

The Tianshan Orogen, extends from west to east for over 2500 km through Uzbekistan, Tajikistan, Kyrgyzstan, and Kazakhstan to Xinjiang in northwestern China (Fig. 1a). It is a major part of the southwestern Central Asian Orogenic Belt (CAOB) (Jahn et al., 2000; Sengör et al., 1993; Windley et al., 2007; Xiao et al., 2004). It mainly consists of microcontinents, ophiolite and mélange belts, continental island arcs, and remnant seamounts and oceanic plateaus, accreted

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* Corresponding author at. Tel.: +86 20 85290277; fax: +86 20 85290130.
E-mail address: wqiang@gig.ac.cn (Q. Wang).

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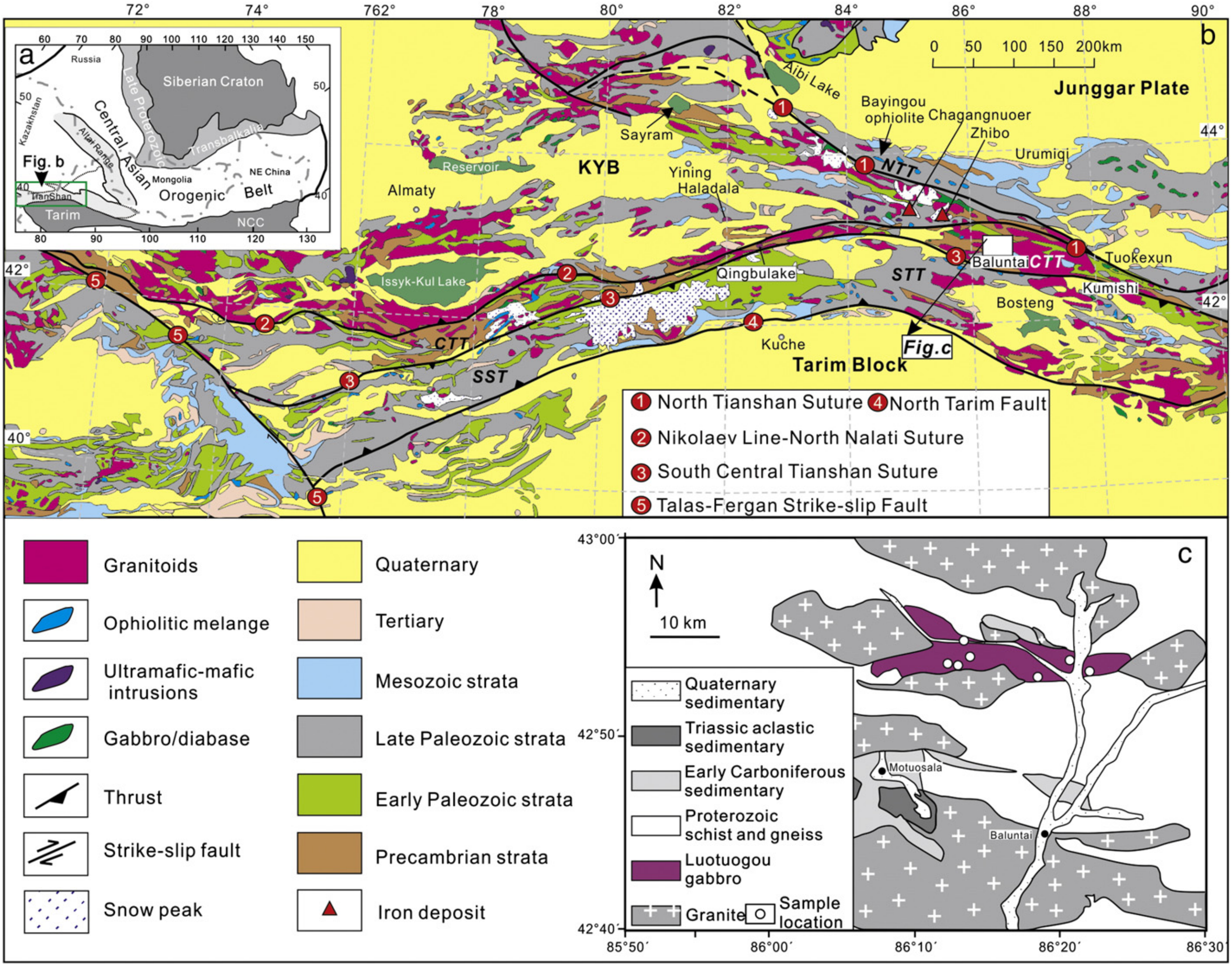

Fig. 1. (a) Simplified tectonic divisions of the CAOB (Jahn et al., 2000), (b) geological map of the western Tianshan orogen (Gao et al., 2009) and (c) geological map showing the occurrence of the Luotuogou gabbros. "Snow peak" in Fig. 1a refers to the area with generally high altitude and covered with snow all the year round. NTT, Northern Tianshan Terrane, CTT, Central Tianshan Terrane, KYB, Kazakhstan–Yili Block.

together between the Neoproterozoic and late Paleozoic (Gao et al., 1998; Xiao et al., 2008). Thus, the Tianshan Orogen is a key area for understanding the tectonic evolution and Phanerozoic continental growth of the CAOB.

There are voluminous Silurian–Permian granitoids in the Central Tianshan Terrane, but mafic rocks are rare and most formed during the Late Carboniferous. The origin of these mafic rocks has been a matter of debate in three competing models: 1) mantle plume or crustal rifting (Che and Liu, 1996; Xia et al., 2004b, 2008), which predicts a dominant role for an upwelling deep-seated mantle plume impinging on the lithosphere (Xia et al., 2004b, 2008); 2) an island arc model, which suggests a subduction of the Paleo-Tianshan Oceanic Plate (Wang et al., 2007; Zhou et al., 2004; Zhu et al., 2005, 2009); or 3) a post-collisional model that invokes slab break-off and subsequent asthenospheric upwelling after the collision between the Junggar plate and the Yili terrane (e.g., Han et al., 2010; Yuan et al., 2010). In this study, we determined plagioclase $^{40}Ar/^{39}Ar$ ages and undertook whole rock geochemical and Sr–Nd isotope analyses, electron microprobe analyses of clinopyroxene major element compositions and LA–ICPMS clinopyroxene trace element analyses for the Luotuogou gabbros north of Baluntai town in the Central Tianshan Terrane (Fig. 1). The combined results are used to reveal the mantle source and petrogenesis of the gabbros in order to shed new light on the tectonic evolution of the Tianshan Orogen.

2. Geological background

The Chinese Tianshan, located between the Junggar plate to the north and the Tarim Block to the south, is a ca 300 km-wide Paleozoic collisional orogenic collage (Fig. 1b). It experienced a complex evolutionary history involving Paleozoic subduction and collision, Mesozoic erosion, and Cenozoic thrusting and uplift as a consequence of the India–Eurasia collision that has continued to the present (Allen et al., 1993; Gao et al., 1998; Windley et al., 1990; Xiao et al., 2008). The orogen can be subdivided into several geological domains, which are from north to south, the Northern Tianshan Terrane, the Kazakhstan–Yili Block, the Central Tianshan Terrane (CTT) and the South Tianshan Terrane (Gao et al., 2009). The North Tianshan Terrane represents a Late Paleozoic continental magmatic arc related to south-directed subduction of the Junggar Oceanic Plate during the Late Ordovician–Early Permian (Gao et al., 1998). It is characterized by the presence of Late Devonian–Carboniferous sedimentary sequences and abundant calc-alkaline volcanic and intrusive rocks. The