Lithos 202–203 (2014) 85–99

Contents lists available at ScienceDirect

Lithos

journal homepage: www.elsevier.com/locate/lithos

Petrogenesis of a Late Carboniferous mafic dike–granitoid association in the western Tianshan: Response to the geodynamics of oceanic subduction

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ARTICLE INFO

Article history:
Received 30 January 2014
Accepted 20 April 2014
Available online 2 May 2014

Keywords:
Mafic dike
Granite
Petrogenesis
Slab roll-back
Western Tianshan

ABSTRACT

Mafic dike–granitoid associations are common in extensional tectonic settings and provide important opportunities for understanding mantle and crust melting during the tectonic evolution of host orogenic belts. We report results of petrologic, whole rock geochemical, Sr–Nd isotopic data and in situ zircon U–Pb and Hf isotopes for a mafic dike–granitoid association from the Zhongyangchang pluton in the western Tianshan, in order to constrain their petrogenesis and tectonic significance. The intrusive rocks are mainly composed of granodiorite, monzogranite, and minor granitic dikes, with mafic dikes intruded into the pluton. Zircon LA-ICP-MS U–Pb ages indicate that the Zhongyangchang intrusive rocks were all emplaced during a short interval in the Late Carboniferous (317–310 Ma), establishing that the mafic and felsic magmas were coeval. The mafic rocks have low SiO_2 and high MgO concentrations, with low $^{87}Sr/^{86}Sr$ ratios from 0.7048 to 0.7053 and positive $\varepsilon_{Nd}(t)$ and zircon $\varepsilon_{Hf}(t)$ values from +2.9 to +3.8 and +12.2 to +13.6, respectively. They are enriched in large ion lithophile elements (LILEs) and depleted in high field strength elements (HFSEs), which can be explained by an origin from melting of a depleted lithospheric mantle source and source fluxing by fluids derived from the down-going slab. Granitoids from the pluton have high SiO_2 contents and low MgO concentrations, suggesting that they were mainly derived from crustal sources. They also have positive whole rock $\varepsilon_{Nd}(t)$ and zircon $\varepsilon_{Hf}(t)$ values ranging from +0.2 to +2.8 and +6.6 to +15.3, respectively, similar to those of the mafic dikes. They were generated by partial melting of juvenile basaltic lower crust as a result of magma underplating. The Late Carboniferous mafic dike–granitoid association was not related to a post-collisional setting, but rather formed in an arc environment related to oceanic subduction. The most likely tectonic model accounting for the genesis of these rocks involves an extensional environment in the western Tianshan during the Late Carboniferous as a tectonic response to the roll-back of subducted Junggar oceanic lithosphere, which could also account for the "flare-up" of Late Carboniferous magmatism.

1. Introduction

Mafic dike–granitoid associations are common in extensional tectonic settings and provide important opportunities for understanding the sources of mantle magmas, crust–mantle interaction processes, crustal melting, and the tectonic evolution of orogenic belts. It is generally accepted that mafic dike–granite associations were emplaced in extensional tectonic regimes linked to post-collisional or intraplate extensional settings (Eby, 1992; Said and Kerrich, 2010; Xu et al., 2008; Yang et al., 2007b). However, the genetic relationship between granites and mafic rocks is a matter of much current debate. Three very different processes proposed for the generation of granites include: (1) fractional crystallization of parental basic melts of mantle-derived magmas with a range of pressures and compositions; (2) partial melting (anatexis) of pre-existing lower crust mafic sources such as basaltic rocks or amphibolites, or a protolith of hornblende-rich diorite to granodiorite in the mid- to upper crust; (3) mixing between mafic and felsic magmas derived from mantle and crustal sources, respectively, where mafic dikes represent the mafic magma.

The Tianshan Orogen extends from west to east for over 2400 km through Uzbekistan, Tajikistan, Kyrgyzstan, and Kazakhstan to Xinjiang in northwestern China and developed by multiple subduction events in the Junggar–Balkhash and South Tianshan Oceans (Paleo-Asian Ocean) for the north and south parts of Tianshan, respectively (Charvet et al., 2011; Gao et al., 2009; Xiao et al., 2010, 2013) (Fig. 1a). An extensive

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http://dx.doi.org/10.1016/j.lithos.2014.04.010
0024-4937/

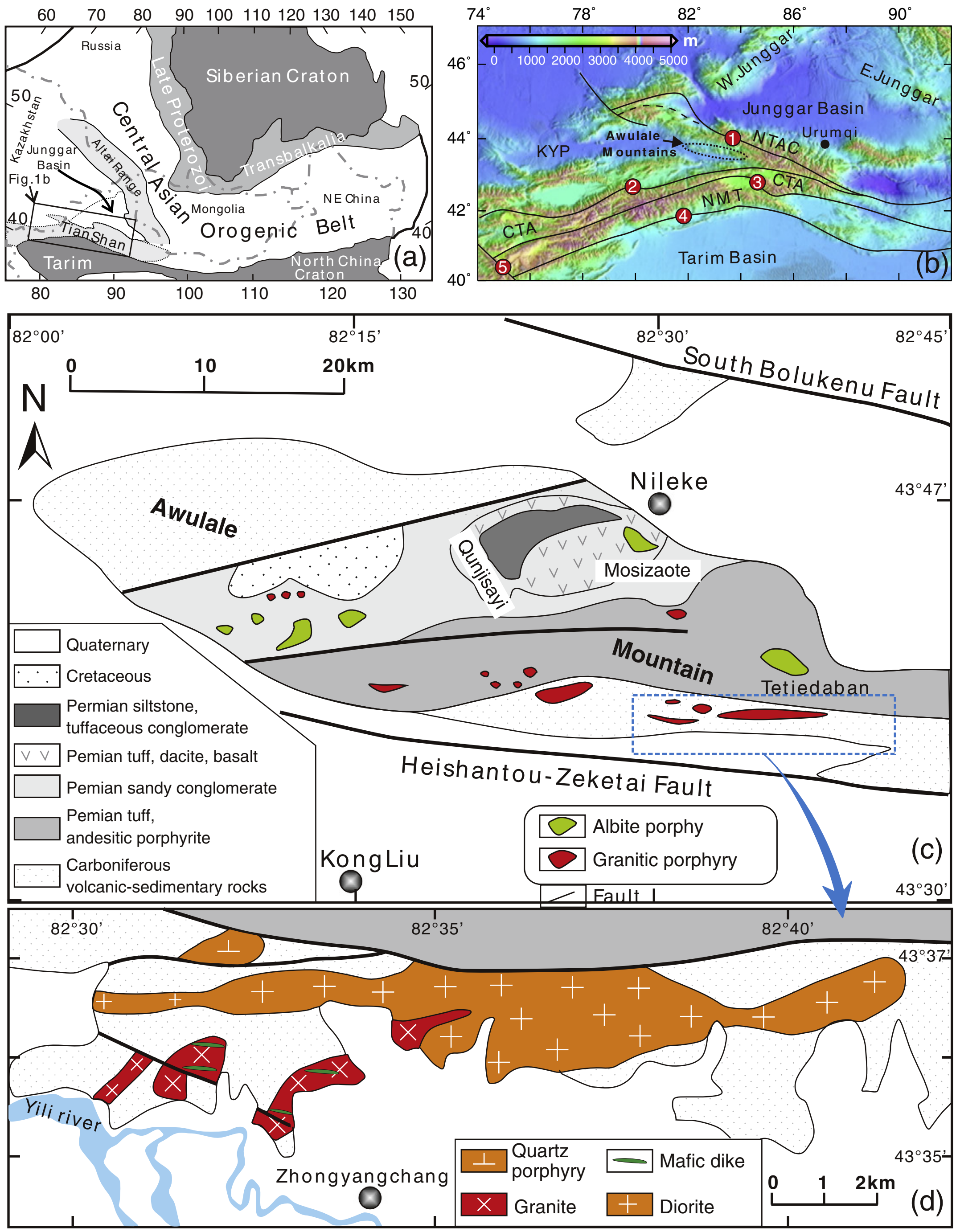

Fig. 1. (a) Tectonic sketch map of the Central Asia Orogenic Belt and the location of the Tianshan orogen (modified after Jahn et al., 2000). (b) Digital topography of the Tianshan Orogenic Belt (original data from U.S. Geological Survey [http://eros.usgs.gov/products/elevation/gtopo30.html]) showing the Awulale mountains in the core of the Tianshan, the tectonic elements are after Gao et al. (2009). (c) Geological map of the west part of the Awulale mountains (after Zhao et al., 2008). (d) Simplified geological map of the Zhongyangchang area.

belt of Paleozoic magmatic rocks was associated with subduction of oceanic lithosphere beneath continental lithosphere, corresponding to a major part of the southwestern Central Asian Orogenic Belt (CAOB) (Jahn et al., 2000; Xiao et al., 2004, 2013; Windley et al., 2007; Gao et al., 2011). There is a debate, however, on the timing of final closure of the Junggar Ocean, with estimates ranging from Early Carboniferous to Late Permian (Allen et al., 1993; Carroll et al., 1995; Gao et al., 1998; Han et al., 2010; Tang et al., 2010; Wang et al., 2007; Xiao et al., 2008, 2013). Furthermore, the tectonic settings and magma sources of Late Carboniferous mafic and felsic rocks of the western Tianshan remain controversial, although they potentially can provide important information concerning the tectonic evolution of the Tianshan Orogen. Most research in the region has focused on the petrogenesis of Late Carboniferous granitic rocks (Long et al., 2011; Tang et al., 2010). However, little is known concerning the geodynamic and genetic relationships between the temporally and spatially related Late Carboniferous mafic and granitic rocks.

In this contribution we report new whole rock geochemical and Sr–Nd isotopic data and zircon U–Pb age and in-situ Hf isotopic compositions for a representative Late Carboniferous batholith (the Zhongyangchang batholith) in the western Tianshan, consisting of coexisting mafic dikes and granitoids, in order to constrain the sources and genetic relationship between them and to resolve the geodynamic environment at the time of emplacement.