Lithos 245 (2016) 34–46

Contents lists available at ScienceDirect

Lithos

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

Late Jurassic sodium-rich adakitic intrusive rocks in the southern Qiangtang terrane, central Tibet, and their implications for the Bangong–Nujiang Ocean subduction

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ARTICLE INFO

Article history:
Received 31 March 2015
Accepted 22 October 2015
Available online 10 November 2015

Keywords:
Adakitic granodiorites
Late Jurassic
Bangong–Nujiang Ocean
Northward subduction
Central Tibet

ABSTRACT

The lack of magmatic records with high-quality geochronological and geochemical data in the central segment of the southern Qiangtang subterrane in central Tibet inhibits a complete understanding of the subduction polarity of the Bangong–Nujiang Ocean lithosphere during the Mesozoic. In this study, we present the zircon U–Pb age as well as geochemical and Sr–Nd–Pb isotopic data for the Late Jurassic pluton from the Kangqiong area in the central segment of the southern Qiangtang subterrane. The Kangqiong pluton primarily consists of granodiorites ($SiO_2 = 62.87$–65.17 wt.%) and was emplaced in the Late Jurassic (147.6 ± 2.4–149.9 ± 2.1 Ma). The granodiorites display high Na_2O numbers ($Na_2O/K_2O = 1.75$–2.24) as well as high MgO (2.21–3.14 wt.%) and Mg-numbers (53–58), are characterized by a low abundance of heavy rare earth elements (e.g., Yb = 1.05–1.92 ppm) and Y (12.63–17.52 ppm), and high Sr/Y (29–61) and La/Yb (14–18) ratios, which are comparable in composition to those of slab-derived adakitic rocks. The Kangqiong adakitic granodiorites have initial $(^{87}Sr/^{86}Sr)_i$ ratios of 0.70611 to 0.70669, negative $\varepsilon_{Nd}(t)$ values (-1.06 to -0.25), $(^{206}Pb/^{204}Pb)_t$ ratios of 18.42 to 18.47, $(^{207}Pb/^{204}Pb)_t$ ratios of 15.62 to 15.63, and $(^{208}Pb/^{204}Pb)_t$ ratios of 38.50 to 38.60. These geochemical signatures indicate that the magmas were most likely derived from the partial melting of the subducted Bangong–Nujiang oceanic crust and minor contaminants from the accretionary complex. Our results, in combination with the coeval magmatism in the western segment of the southern Qiangtang subterrane, indicate that the Bangong–Nujiang oceanic lithosphere was subducted northward beneath the Qiangtang Terrane, forming a west-east magmatic arc over 800 km during the Late Jurassic.

1. Introduction

The Tibetan–Himalayan orogen, the widest mountain chain on Earth, has long been considered to be the result of continental collisions and accretions in sequence since the Paleozoic (Yin and Harrison, 2000; Zhu et al., 2013). However, the details of such sequential collisional and accretion events remain unclear. For example, the Bangong–Nujiang suture, located between the Qiangtang Terrane to the north and the Lhasa Terrane to the south in present-day central Tibet (Fig. 1a), is generally accepted as representing a good recording of the subduction history of the Meso-Tethyan (Bangong–Nujiang) Ocean and subsequent Qiangtang–Lhasa collision (cf. Dewey et al., 1988; Girardeau et al., 1984; Guynn et al., 2006; Kapp et al., 2005; Pearce and Deng, 1988; Zhang et al., 2012, 2014; Zhu et al., 2011, 2013, 2015). Although numerous studies have proposed that the Bangong–Nujiang oceanic lithosphere have subducted northward beneath the Qiangtang Terrane (cf. Allègre et al., 1984; Girardeau et al., 1984; Guynn et al., 2006; Kapp et al., 2005, 2007; Li et al., 2014a,c,d, 2015; Yin and Harrison, 2000; Zhang et al., 2012; Zhu et al., 2013), the available data mostly come from the western segment (west of Gerze) of the southern Qiangtang subterrane. Additional data, especially the data from the central segment of the southern Qiangtang subterrane in central Tibet, are required to provide vital constraints on this model.

As a special rock type with distinct geochemical signatures (e.g., high Sr/Y ratios, low Y and heavy REE), adakitic rocks can form in varying tectonic settings (cf. Cooke et al., 2005; Defant and Drummond, 1990, 1993; Jiang et al., 2012; Martin et al., 2005; Oyarzun et al., 2001; Reich et al., 2003; Wang et al., 2008a; Zhu et al., 2009b). However, according to the original definition by Defant and Drummond (1990), if adakitic rocks were derived from the partial melting of the subducted oceanic (slab-derived) crust, they can be considered a vital petrological constraint on the presence of oceanic subduction. However, adakitic rocks that have a Jurassic age have not been identified to date in the southern Qiangtang subterrane.

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http://dx.doi.org/10.1016/j.lithos.2015.10.014
0024-4937/

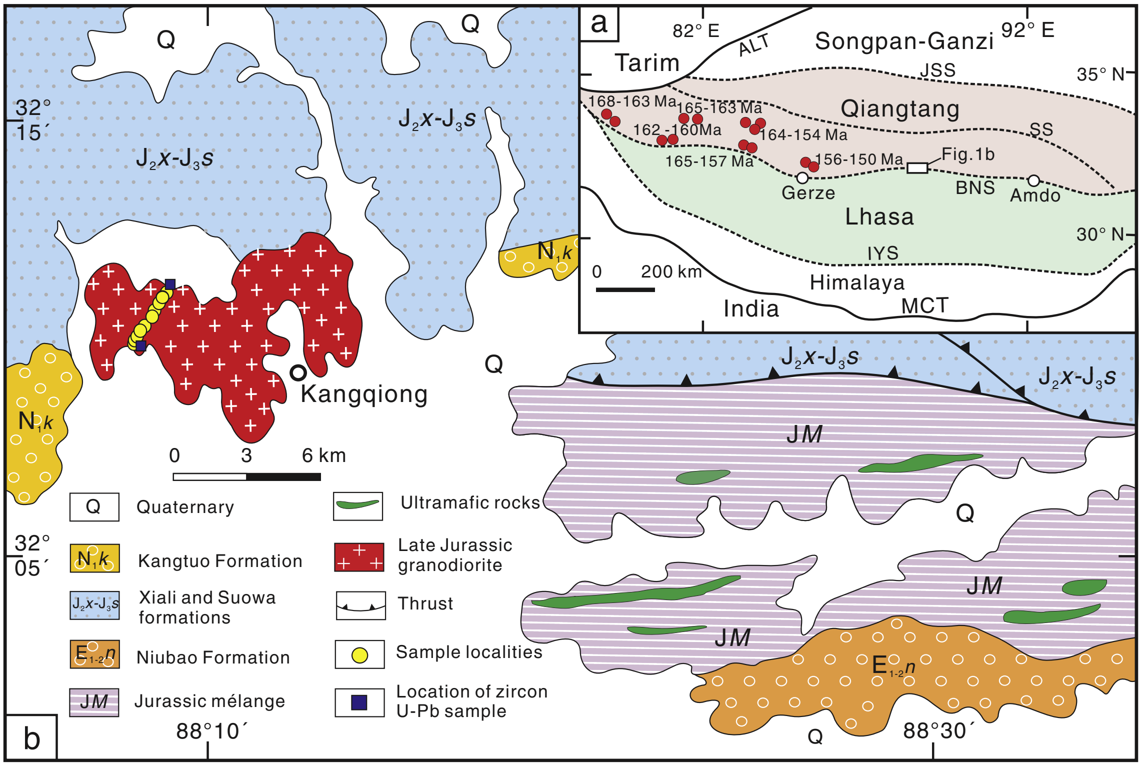

Fig. 1. (a) Tectonic outline of the Tibetan plateau showing major tectonic units and the localities of the Jurassic arc-related rocks in the western segment of the southern Qiangtang subterrane (after Li et al., 2014a,c; Zhu et al., 2015). IYS, Indus–Yarlung Zangbo suture; BNS, Bangong–Nujiang suture; SS, Longmu–Shuanghu suture; JSS, Jinshajiang suture; ALT, Altyn Tagh fault; MCT, Main Central thrust. (b) Geological map of the Kangqiong area.

In this paper, we present the zircon LA-ICP MS age as well as whole-rock geochemical, and Sr–Nd–Pb isotopic data for the Kangqiong pluton in the central segment of the southern Qiangtang subterrane (Fig. 1a). Our data indicate that the Kangqiong pluton was emplaced at ca. 149 Ma and displays geochemical affinity with adakitic rocks, most likely resulting from the partial melting of the subducting oceanic lithosphere. Our results reveal the development of a west-east Late Jurassic magmatic arc of over 800 km and provide a robust constraint on the northward subduction of the Bangong–Nujiang oceanic lithosphere in the central segment of the southern Qiangtang subterrane during the Late Jurassic.

2. Geological background

The Tibetan plateau is essentially composed of four continental blocks or terranes: the Songpan–Ganzi, Qiangtang, Lhasa, and Himalaya, from north to south (Fig. 1a). These blocks are separated by the Jinsha, Bangong–Nujiang, and Indus–Yarlung Zangbo suture zones, representing Paleo-, Meso-, and Neo-Tethyan oceanic relicts, respectively (Yin and Harrison, 2000). The Qiangtang Terrane can further be divided into northern and southern subterranes by the Longmu–Shuanghu suture (Fig. 1a) and the Lhasa Terrane can be divided into northern, central, and southern subterranes (Zhu et al., 2009a,b, 2011, 2013). Rock units within the Bangong–Nujiang suture zone and adjacent regions of the southern Qiangtang and northern Lhasa subterranes that are closely associated with the purpose of this study are summarized below.

The southern Qiangtang subterrane investigated in this study is dominated by Middle to Upper Jurassic sediments (Yanshiping Group), with thicknesses of more than 3000 m (Li et al., 2014b; Wang and Qu, 2012), including the Middle Jurassic sequences that mainly consist of clastic rocks and the Upper Jurassic sequences that are composed of carbonates. These Jurassic sequences are unconformably overlain by weakly deformed Upper Cretaceous (i.e., Abushan Formation) continental sediments, which are considered to be the result of the Qiangtang–Lhasa collision (Li et al., 2013, 2015; Zhang et al., 2012). The Jurassic (168–150 Ma) magmatic rocks that are currently reported are mainly exposed in the western segment (west of Gerze) of the southern Qiangtang subterrane (Fig. 1a). These rocks are dominated by intermediate-silicic rocks and show the characteristics of arc-related magmatism, which were interpreted to be the products of the northward subduction of the Bangong–Nujiang oceanic lithosphere (cf. Du et al., 2011; Kapp et al., 2005, 2007; Li et al., 2014a,c; Zhu et al., 2015). No arc-related magmatism has been observed in the central segment (from Gerze to Amdo) of the southern Qiangtang subterrane (Fig. 1a).

The Bangong–Nujiang suture is characterized by a >1400 km-long east–west trending belt that is mainly composed of the accretionary complex and associated ophiolitic fragments (Fig. 1a) (Dewey et al., 1988; Girardeau et al., 1984; Kapp et al., 2005; Schneider et al., 2003; Yin and Harrison, 2000; Zhang et al., 2012; Zhu et al., 2015). Previous studies have shown that most of the ophiolitic fragments have a supra subduction-zone signature (Girardeau et al., 1984; Wang et al., 2008b), while fewer ophiolites show MORB-like and oceanic island basalt (OIB) characteristics (Zhang et al., 2007; Zhu et al., 2006b). The isotopic ages of these ophiolitic fragments show a range from 190 to 108 Ma (Wang et al., 2008b; Zhang et al., 2012; Zhu et al., 2006b), and the youngest ages indicate that the Bangong–Nujiang oceanic crust did not close until the Early Cretaceous. The matrix of the accretionary complex consists of sandstone and siltstone interbedded with shale and fossil-rich limestone that yielded a Jurassic to Early Cretaceous age (Zhang et al., 2012; Zhu et al., 2015). Geological investigation in the Gerze area revealed that the Jurassic sediments (Yanshiping Group) in the southern Qiangtang subterrane have the characteristics of an accretionary complex (Li et al., 2011) with an origin from the southern Qiangtang subterrane (Zeng et al., 2015). The accretionary complex and associated ophiolitic fragments are unconformably overlain by Late Cretaceous terrestrial sediments that were interpreted to