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Zircon U–Pb age and Hf isotopic compositions of Mesozoic granitoids in southern Qiangtang, Tibet: Implications for the subduction of the Bangong–Nujiang Tethyan Ocean

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ABSTRACT

The southern Qiangtang magmatic belt was formed by the north-dipping subduction of the Bangong–Nujiang Tethyan Ocean during Mesozoic. To better understand the petrogenesis, time–space distribution along the length of this belt, 21 samples of several granitoid bodies, from west to east, in the Bangong Co, Gaize, Dongqiao and Amdo areas were selected for in-situ zircon U–Pb dating, Hf isotopic and whole-rock chemical analyses. The results suggest a prolonged period of magmatic activity (185–84 Ma) with two major stages during the Jurassic (185–150 Ma) and the Early Cretaceous (126–100 Ma). Both the Jurassic and Cretaceous granitoids are high-K calc-alkaline I-type rocks, except the Cretaceous two-mica granite from Amdo in the east, which belongs to S-type. The granitoids are generated from different source materials as indicated by zircon Hf isotopic compositions. The Bangong Co and Dongqiao granitoids show high zircon $\varepsilon_{Hf}(t)$ values of −1.3–13.6 with younger T^{C}_{DM} ages of 293–1263 Ma, suggesting a relatively juvenile source; whereas the Gaize and Amdo granitoids have low $\varepsilon_{Hf}(t)$ values of −16.1–2.9 with older T^{C}_{DM} ages of 999–2024 Ma, indicating an old crustal contribution. These source rocks melt at different P–T conditions as suggested by Sr/Y ratio and T_{Zr}. The Sr/Y ratio of both stage granitoids increases with decreasing age. However, the T_{Zr} of the Jurassic granitoids decreases, whereas the T_{Zr} of the Cretaceous granitoids increases with decreasing age. The contrasting geochemical signatures of these granitoids may be controlled by the varying contribution of slab-derived fluids involved in the generation of the Jurassic and Cretaceous granitic magmas; i.e. increasing amount of fluids in the Jurassic, whereas decreasing amount of fluids in the Cretaceous. Therefore, it is proposed that the Jurassic and Cretaceous magmatism may be related to subduction and closure of the Bangong–Nujiang Tethyan Ocean, respectively. The age pattern of the Jurassic and Cretaceous granitoids suggests an oblique subduction of the Bangong–Nujiang Tethyan Ocean and a diachronous collision between the Lhasa and Qiangtang blocks.

1. Introduction

The Tibetan Plateau is the largest uplifted area on Earth, and was formed by sequential amalgamation of blocks over several orogenic cycles since the Paleozoic (Chang, 1996; Yin and Harrison, 2000; Zhang and Santosh, 2012; Zheng et al., 2013; Zhu et al., 2013) (Fig. 1a). Although it is widely accepted that the high topography and thick crust were the results of the Cenozoic Indo-Asia collision (Xia et al., 2011; Replumaz et al., 2014; Zhao et al., 2014), how the contribution of the pre-Cenozoic tectonism in building the early Tibetan Plateau is still a hot topic of debate. The Bangong–Nujiang Tethyan Ocean (BNT) separated the Qiangtang block to the north and the Lhasa block to the south during the Mesozoic (Allegre et al., 1984; Girardeau et al., 1985). It is generally accepted that the subduction and closure of the BNT led to the amalgamation of the Lhasa block onto the margin of the southern Asia (Zhu et al., 2013). However, the timing and process of the BNT subduction is still poorly constrained.

Arc magmatic rocks are important in understanding the subduction process and the growth of the crust (Kogiso et al., 2009; Chernicoff et al., 2010; Ernst, 2010; X.R. Zhang et al., 2010; Z.M. Zhang et al., 2010; Eyuboglu et al., 2011; Korsch et al., 2011; Stern, 2011; Straub and Zellmer, 2012; Chen et al., 2014; Deng et al., 2014; Ma et al., 2014; Ortega-Gutiérrez et al., 2014; Shellnutt et al., 2014; Wang et al., 2014). Granitoids are the plutonic part of most continental arcs. They commonly contain zircon as a primary accessory mineral which is useful for constraining the timing of the magma emplacement and the nature of the source for the magmas. Granitoids related to the Tethyan subduction in southern Tibet include those from the Jurassic–Early Tertiary

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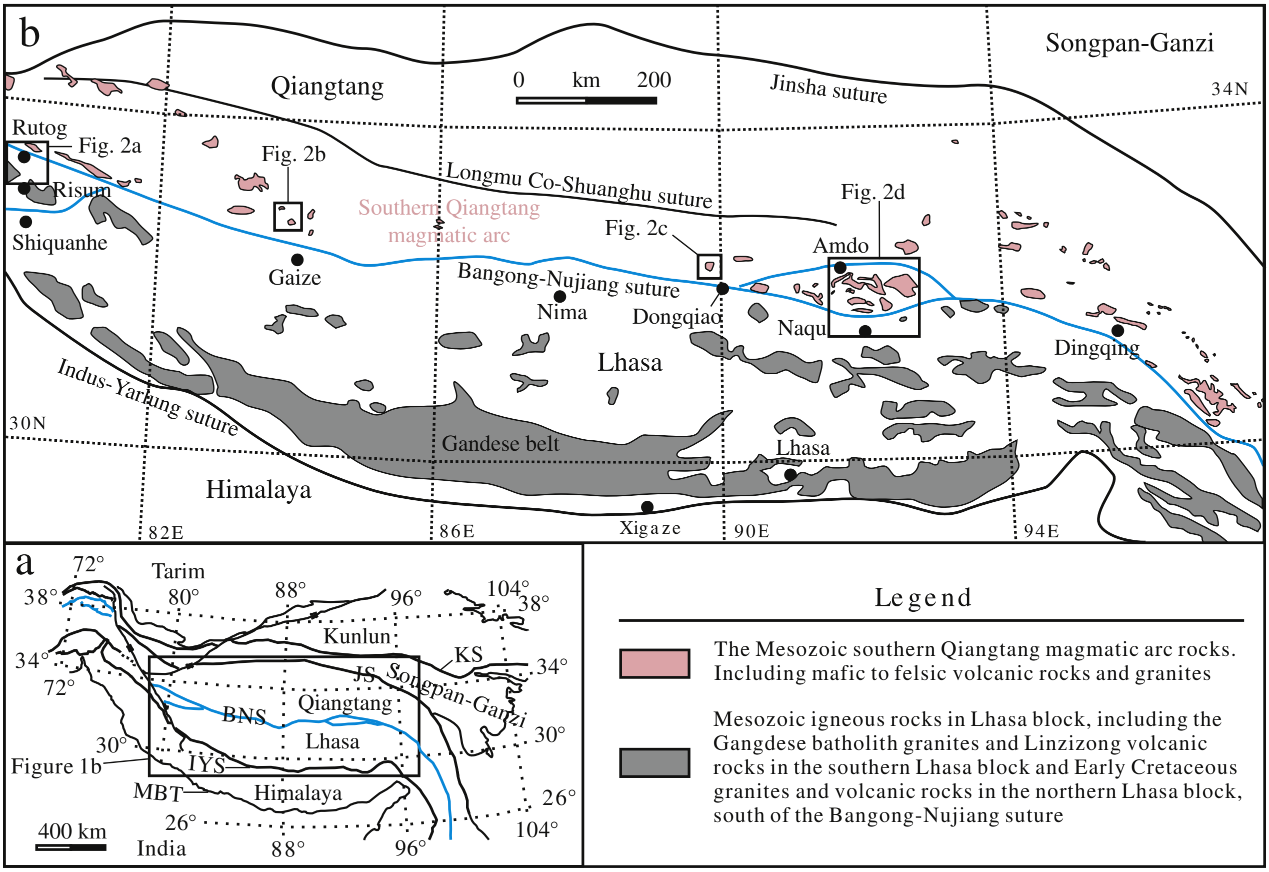

Fig. 1. (a) Tectonic outlines of Tibet and the adjacent areas, showing from south to north: India continent, the Main Boundary Thrust (MBT), Himalaya block, Indus-Yarlung suture (IYS), Lhasa block, Bangong–Nujiang suture (BNS), Qiangtang block, Jinsha suture (JS), Songpan–Ganzi block, Kunlun suture (KS), and Kunlun block. (b) A simplified geological map showing the Mesozoic magmatism in the Qiangtang and Lhasa blocks (modified after Pan et al. (2004)).

Gangdese belt in the southern Lhasa block and the Jurassic–Early Cretaceous magmatic belt in the southern Qiangtang block (Fig. 1b). The granitoids from the Gangdese belt had been extensively studied (Chu et al., 2006; Pan et al., 2006; Yang et al., 2006; Yue and Ding, 2006; Zhu et al., 2006; Mo et al., 2007, 2008; Wen et al., 2008; X.R. Zhang et al., 2010; Z.M. Zhang et al., 2010; Zhu et al., 2011). On the other hand, those from the southern Qiangtang are still less known, due to the apparent lack of magmatism and the remoteness of the area (Guynn et al., 2006; Li et al., 2014; Liu et al., 2014). Based on geochronological studies of basement rocks and granitoids from the Amdo basement, Guynn et al. (2006) suggested that a Jurassic arc developed in southern Qiangtang during the north-dipping subduction of the BNT and this arc is "missing" between Amdo and Pamir in central Tibet. Recent works on the Late Jurassic to Early Cretaceous felsic rocks in the Banggong Co (i.e. the Banggong Lake) (Liu et al., 2014) and Gaize area (Liu et al., 2012; Li et al., 2013, 2014) further discovered this "missing" arc.

In this paper, we present new LA-ICPMS zircon U–Pb ages and Hf isotopic compositions of 21 granitoid samples from the southern Qiangtang magmatic belt. We characterize the age distribution and variation along the Bangong–Nujiang suture (BNS) and discuss their petrogenesis and tectonic implications for the BNT subduction. This will bring new insights into the early tectonic history of Tibet.

2. Geological background and samples

2.1. The Bangong–Nujiang Tethyan Ocean

The BNS, a >1200 km belt consisting of ophiolitic fragments and thick Jurassic flysch between the Qiangtang and Lhasa blocks, represents the remains of the Mesozoic BNT (Chang, 1996; Yin and Harrison, 2000; Shi et al., 2008). The north-south-extending BNS is wide and consists of two ophiolitic belts in the westernmost Tibet near Rutog and the eastern Tibet near Amdo (Fig. 1b). The Risum micro block in the west between the Bangong Co and Shiquanhe ophiolitic belts was likely an oceanic arc formed by the intra-oceanic subduction of the BNT (Matte et al., 1996; Shi et al., 2004; Shi, 2007). It collided with the Qiangtang and Lhasa blocks when the BNT demised. The Amdo basement in the east was an old continental fragment within the BNT between the Lhasa and Qiangtang blocks. It algamated with the Qiangtang block before the Lhasa–Qiangtang collision (Xu et al., 1985; Guynn et al., 2006).

Several lines of evidence indicate that the BNT started to open during the Late Permian to the Early Triassic period: (1) the Re–Os isochron age (251 ± 65 Ma) obtained from cumulate rocks and a plagioclase-bearing harzburgite near Dongqiao (Shi et al., 2012); (2) the SIMS zircon U–Pb age (217.8 Ma ± 1.6 Ma) of cumulate gabbros from the ophiolitic mélange near Dingqing (Qiangba et al., 2009); and (3) sedimentary facies in the Paleozoic within the Qiangtang and Lhasa blocks are the same, but they became different since the Late Permian–Early Triassic (Pan et al., 2004). Subduction of the BNT began during the Early Jurassic in the Amdo–Dongqiao area, leading to extensive metamorphism, granitoid emplacement (Xu et al., 1985; Zhou et al., 1997; Guynn et al., 2006; X.R. Zhang et al., 2010; Z.M. Zhang et al., 2010) and the development of a backarc basin near Amdo (Lai and Liu, 2003). In contrast, the subduction started during the Middle Jurassic in the Bangong Co area, resulting in the formation of an oceanic arc (represented by the Bangong Co SSZ-type ophiolite with an age of 167 Ma and the Cretaceous Rutog granitoids) (Shi, 2007; Shi et al., 2008; Liu et al., 2014). The youngest ophiolitic rock within the BNS is the 132 Ma (SHRIMP zircon U–Pb dating) OIB-type cumulate troctolite from Dong Co ophiolite