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Late Cretaceous crustal growth in the Gangdese area, southern Tibet: Petrological and Sr–Nd–Hf–O isotopic evidence from Zhengga diorite–gabbro

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ABSTRACT

Recent studies of Gangdese granitic magmatism demonstrate a mantle contribution to crustal growth in southern Tibet during the Jurassic–Early Eocene. However, the specific mechanism for adding such juvenile crust has been disputed owing to a lack of reliable evidence for contemporaneous deep mantle geodynamic processes. Here, we report on the Zhengga diorite–gabbro suite from the Gangdese area. They consist of plagioclase (labradorite and anorthite), amphibole, clinopyroxene, biotite and minor magnetite, epidote, zircon and apatite. LA-ICP-MS zircon U–Pb dating for two samples gives a ca. 94 Ma age for the Zhengga intrusive rocks, i.e., the Late Cretaceous. Apart from one high-SiO_2 (52.2 wt.%) diorite sample with slightly high K_2O (1.72 wt.%) and initial $^{87}Sr/^{86}Sr$ (0.7068) and low $\varepsilon_{Nd}(t)$ (−5.6) values, the gabbro samples are geochemically characterized by low SiO_2 (39.8–50.1 wt.%) and K_2O (0.3–1.1 wt.%), strongly negative Nb–Ta and positive Sr anomalies, and uniform initial $^{87}Sr/^{86}Sr$ (0.7043–0.7048). The gabbros can be divided into two groups: Group I gabbros with relatively low total rare earth element (REE), Rb and SiO_2 contents and positive Eu anomalies, and Group II gabbros with slightly higher total REE, Rb and SiO_2 contents and negative Eu anomalies. The Group I gabbros have $\varepsilon_{Nd}(t)$ (+1.7 to +4.1), and zircon $\varepsilon_{Hf}(t)$ (+6.5 to +11.1) and $\delta^{18}O$ (5.89 to 7.24‰) values, which are slightly different to those of the Group II gabbros (−0.2 to +2.0, +2.9 to +6.5 and 6.24 to 7.05‰). Trace element compositions of amphibole and clinopyroxene grains suggest that the Zhengga mafic magmas contained a significant fluid-transported component, probably released from subducted oceanic lithosphere. We suggest that the parental magmas of the Zhengga gabbros were generated by the hydrous partial melting of lithospheric mantle metasomatized by sediment melts/fluids. The Group I gabbros were likely generated by the fractional crystallization of olivine or clinopyroxene from such parental magmas, with insignificant crustal contamination, whereas the Group II gabbros were probably produced by assimilation and fractional crystallization (AFC) processes from mafic magmas that were geochemically similar to the Group I gabbros. Pre-collisional underplating of mantle-derived mafic magmas likely played an important role in crustal growth and supplied the source materials for some late Late Cretaceous–Cenozoic granitoids of the Gangdese batholiths. This study also demonstrates that the hydrous partial melting of mantle wedge triggered by the dehydration in a subduction setting has a capacity to create significant volumes of juvenile continental crust.

1. Introduction

The Earth differs from the other planets in our Solar System in that it contains continental crust (e.g., Hawkesworth and Kemp, 2006a). However, how the continental crust formed remains the topic of considerable debate (e.g., Rudnick, 1995; Hawkesworth and Kemp, 2006a). In the past, a consensus was nearly reached that the growth of the continental crust was essentially completed in the Precambrian, especially prior to 2.5 Ga (e.g., Fyfe, 1978; Armstrong, 1991; Jahn et al., 2000a). However, in recent decades, isotope investigations in western North America (Sierra Nevada, Peninsular Range, and Canadian Cordillera), eastern Australia (Lachlan and New England Fold belts) and the Central Asian Orogenic Belt (CAOB) have revealed that a substantial proportion of the Phanerozoic crust is juvenile (e.g., DePaolo, 1988; Landoll and Foland, 1996; Sengör and Natal'in, 1996; Jahn et al., 2000a,b).

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The famous Gangdese batholith in the southern Lhasa block mainly consists of Jurassic–Early Eocene intermediate–felsic intrusive rocks (especially granites) with high and positive $\varepsilon_{Nd}(t)$ (up to +5.5) and $\varepsilon_{Hf}(t)$ (up to +16.5) values (Debon et al., 1986; Harris et al., 1988; Chung et al., 2005; Chu et al., 2006; Mo et al., 2007; Wen et al., 2008a, b; Ji et al., 2009a,b; Zhu et al., 2011; Chu et al., 2011; Zhu et al., 2012, and references therein), indicating important mantle input. However, mechanisms for the generation of the mantle-derived magma as well as the associated geodynamic processes in the mantle have been disputed (Mo et al., 2005; Chu et al., 2006; Ji et al., 2009a; Lee et al., 2009; Mo et al., 2009; Zhu et al., 2011, 2012; Lee et al., 2012). The underlying cause of these disputes is that most studies focused on intermediate–felsic intrusive rocks (especially granites) of the Gangdese batholith, apart from some mafic enclaves in granites (Mo et al., 2005, 2007). Exposures of contemporaneous mantle-derived mafic rocks in the Gangdese area are very sparse but critically important because they record information regarding the chemical composition of the mantle and regional tectonic evolution.

In this study, we present the detailed petrology, geochronology, major and trace element, and Sr–Nd–Hf–O isotopic data for the Zhengga pluton, an example of the rare diorite–gabbro suite from the southern Gangdese batholith. Identifying the parental magmas for these mafic rocks has the potential to delineate their mantle source characteristics and petrogenesis and to resolve genetic relationships between geodynamic processes in the mantle and crustal growth in southern Tibet.

2. Geologic background and petrography

Tibet consists of the Himalaya, Lhasa, Qiangtang and Songpan–Gangzi blocks (Fig. 1b). The Lhasa block is bounded by the Indus-Yarlung Tsangpo suture (IYTS) to the south and the Bangong–Nujiang suture (BNS) to the north (Fig. 1b) (Yin and Harrison, 2000). Based on the distribution of different sedimentary cover rocks and ophiolites, it has recently been divided into northern, central, and southern sub-blocks, separated by the Shiquan River–Nam Tso Mélange zone (SNMZ) and

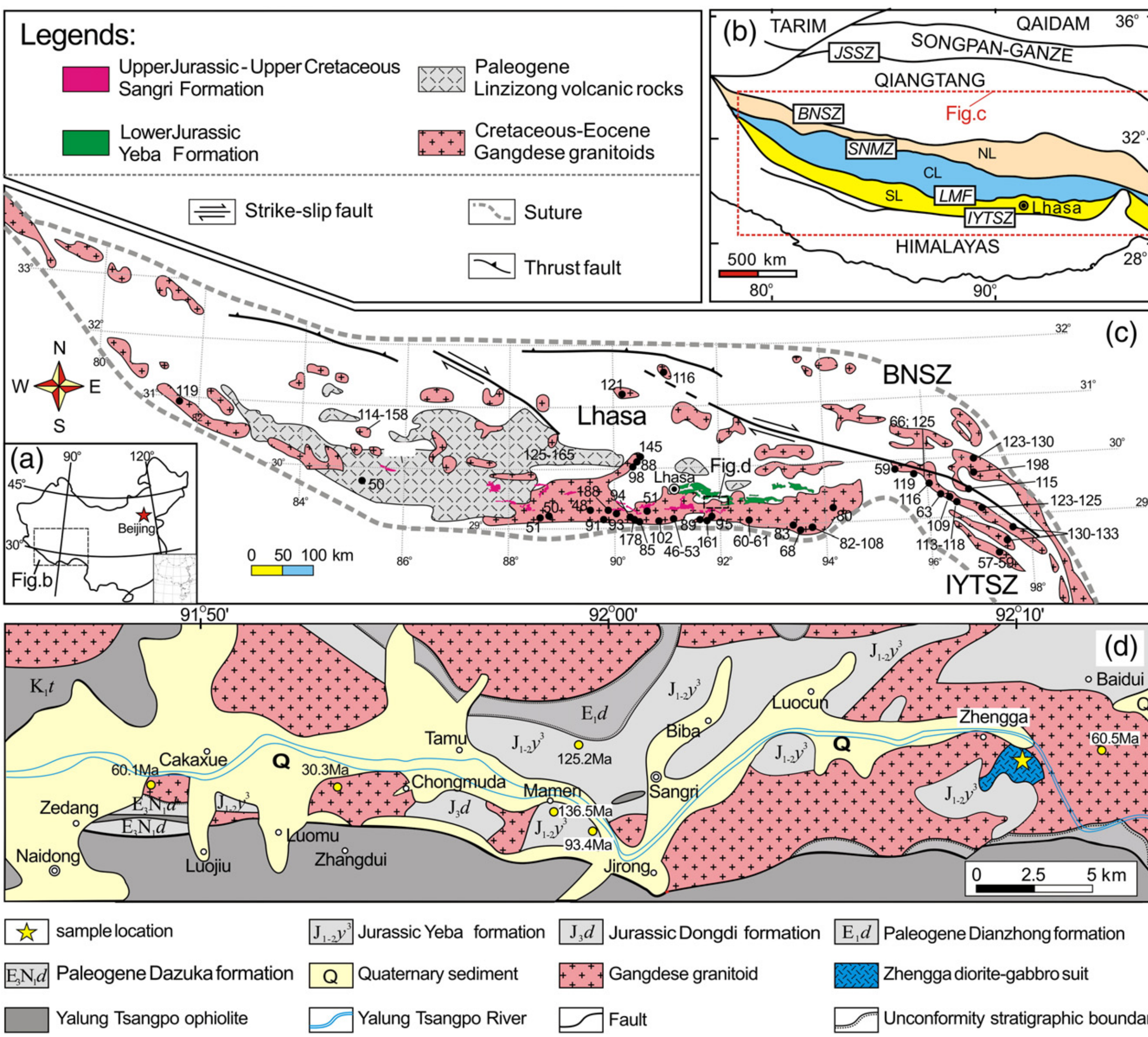

Fig. 1. Sketch maps of the Tibetan Plateau, the Lhasa Block and the studied area. (a) Inset of China with outline of (b). (b) The Lhasa Block in the context of the Tibetan Plateau (modified from Zhu et al., 2011). (c) Geological map of the Lhasa Block (modified from Chung et al., 2009). (d) Geological map of the studied area. Ages are given in Ma and the data sources include Murphy et al. (1997), Miller et al. (2000), McDermid et al. (2002), Kapp et al. (2003), Schwab et al. (2004), Chu et al. (2006), Volkmer et al. (2007), Wen et al. (2008a), Chiu et al. (2009), Chung et al. (2009), Ji et al. (2009a), Zhu et al. (2009), Kang et al. (2010). Abbreviations here: JSSZ = Jinsha suture zone; BNSZ = Bangong–Nujiang suture zone; SNMZ = Shiquan River-Nam Tso Mélange Zone; LMF = Luobadui-Milashan Fault; IYTSZ = Indus-Yarlung Tsangpo Suture Zone. SL = Southern Lhasa sub-block, CL = Central Lhasa sub-block, NL = Northern Lhasa sub-block.