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Petrogenesis of the Ramba leucogranite in the Tethyan Himalaya and constraints on the channel flow model

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ABSTRACT

The Himalayan leucogranites are critical for understanding the geodynamic process of Himalayan orogenesis. In this article, we present petrological, geochronological and geochemical results of the Ramba leucogranites that crop out in the center of the Ramba dome within the Tethyan Himalaya. U–(Th)–Pb dating of zircon, monazite and xenotime revealed three episodes of leucogranitic magmatism in the Ramba dome at ca. 44 Ma, ca. 28 Ma and ca. 8 Ma, respectively. The ca. 44 Ma and ca. 28 Ma magmatisms are both represented by strongly deformed porphyritic two-mica granite gneiss dykes that intruded into the margin of the dome. These granite gneisses have high CaO and Sr contents, relatively high Na/K, Sr/Y and low Rb/Sr ratios, and much lower initial $^{87}Sr/^{86}Sr$ ratios but higher $\varepsilon_{Nd}(t)$ and $\varepsilon_{Hf}(t)$ values than the ancient Indian crustal material. These results indicate that the granite gneisses were not derived from metasedimentary rocks of the High Himalayan Sequence but most likely were derived from partial melting of mafic rocks at a thickened crustal condition. The ca. 8 Ma leucogranites consist of a two-mica granite pluton in the core of the dome and garnet-bearing granite dykes in the margin of the dome. Major and trace element compositions indicate that these Miocene leucogranites are typical S-type granites and were most likely derived from muscovite and/or biotite dehydration melting of metapelites. The relatively lower TiO_2, TFeO, MgO and CaO contents, higher Rb concentration and Rb/Sr ratio, and more strongly negative Eu anomaly of the garnet-bearing granite indicate that it was more evolved than the coeval two-mica granite. The non-CHARAC (CHarge-And-Radius-Controlled) trace element behavior and the tetrad effect of the REE distribution of the garnet-bearing granite further suggest that it is a highly fractionated granite.

Besides, our study detected some Asian-like materials in the Ramba leucogranites, such as Mesozoic-aged inherited zircons and the relatively depleted Sr–Nd–Hf isotopic compositions of some leucogranite samples. These features of leucogranites in the Tethyan Himalaya have been previously considered as direct geological evidence for the channel flow model. However, detailed geochronological and geochemical studies of the country rocks suggest that these Asian-like materials are most likely sourced from the country rock rather than the Asian lithosphere, thus they may not be used as solid evidence for the channel flow model.

1. Introduction

Tertiary leucogranites in the Himalayan orogen record the most important magmatic events since the India–Asia continental collision. A comprehensive knowledge of the petrogenesis of these rocks is critical for understanding the postcollisional tectono-magmatic evolution of the Himalayan belt and for testing and further formulating geodynamic models of the Himalayan orogenesis and uplift of the Tibetan Plateau. Leucogranites in the Himalayan orogen are typically composed of three types: two-mica leucogranite, tourmaline–muscovite granite and garnet-bearing granite (garnet + muscovite ± tourmaline ± biotite leucogranite). The different types of leucogranites have been considered to be derived from different protoliths (e.g., Guillot and Le Fort, 1995), from the same protolith under different P–T conditions (Visonà and Lombardo, 2002) or from different degrees of fractional crystallization of the magma (e.g., Scaillet et al., 1990). Obviously, the petrogenetic relationships between the different types of leucogranites are still not well-resolved. According to this study, the two-mica granite and garnet-bearing granite from the Ramba dome are cogenetic, but the garnet-bearing granite shows an evolved composition that implies a highly fractionated granite. Furthermore, the Sr–Nd–Hf isotopic characteristics suggest that some external components from the country rocks might have been included in the leucogranite and driven the crystallization of garnets.

The geodynamic mechanism involved in the generation of the Himalayan leucogranites is also controversial. A southward-extruding mid-continental crustal channel flow, which is known as the “channel flow” model, was favored by many geologists in recent years (e.g., Beaumont et al., 2001; Godin et al., 2006; Grujic et al., 2002;

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Jamieson et al., 2004; Searle et al., 2010). This model describes a ductile extrusion of a partially molten low-viscosity layer of the middle-lower crust between a coeval normal-sense shear zone (South Tibetan Detachment, STDS) above and a thrust shear zone (Main Central Thrust, MCT) below. The Higher Himalayan Sequence (HHS) is inferred as the channel, and the migmatites and leucogranites within the Higher Himalaya and the Tethyan Himalaya are interpreted as the southward-flowing materials in the channel (e.g., Lee et al., 2004, 2006; Nelson et al., 1996; Searle et al., 2003). However, this model has been questioned by some geologists (e.g., Harrison, 2006). The channel flow model predicts that migration of the melt-weakened Asian crustal material could occur via ductile flow in a southward-propagating channel driven by a lateral pressure gradient imposed by the thickened Asian crust (Beaumont et al., 2004; Jamieson et al., 2006), but there is insufficient direct evidence of southward-extruded Asian material (e.g., zircons of Cretaceous–Eocene age) in the Himalayan leucogranites.

The Ramba leucogranite, which consists of two-mica granite and garnet-bearing granite, is ideal for research on the petrogenesis and relationships between the different types of leucogranites. In addition, as the nearest Himalayan leucogranite to the Yarlung–Zangbo suture zone, the Ramba leucogranite provides a good opportunity to test the validity of the channel flow model. In this paper, we conducted U–(Th)–Pb dating of zircon, monazite and xenotime, whole-rock major and trace element analyses and whole-rock Sr–Nd–Hf isotope analyses of the Ramba leucogranite to constrain its emplacement ages, petrogenesis and geodynamic setting.

2. Geological setting

The Himalayan orogen is the result of the convergence between the Indian and Eurasian continents that has been ongoing since the early Tertiary (e.g., Yin and Harrison, 2000). The Indian-affinity rocks deformed within the Himalayan fold-thrust belt are exposed in four lithotectonic domains that form parallel belts bounded by three major fault zones (Yin, 2006 and references therein) (Fig. 1a). From south to north and increasing in structural elevation, these domains are 1) the Sub-Himalaya unit, which consists of Miocene–Pliocene foreland basin deposits; 2) the Lesser Himalaya, which is a sequence of Paleoproterozoic to Mesoproterozoic metasedimentary, sedimentary, volcanic and plutonic rocks that are separated from the underlying Sub-Himalaya unit by the MBT and are incorporated into the footwall of the south-vergent MCT; 3) the Higher Himalaya, which is a Late Proterozoic–Early Cambrian high-grade metasedimentary sequence that has been exhumed between the reverse-sense MCT to the south and normal-sense STDS to the north; and 4) the Tethyan Himalaya, which is composed of Paleozoic to Paleogene clastic and carbonate rocks. The Middle–Upper Triassic strata (Langjiexue Group) in the eastern Himalaya have been considered as part of the Tethyan Himalayan Sequence. New provenance data suggest that the strata have detrital zircon geochronology, Nd–Hf isotopes and model ages that are similar to those of the Lhasa block but different from those of typical Tethyan rocks (e.g., Dai et al., 2008; Li et al., 2010; Webb et al., 2012).

Two sub-parallel belts of Cenozoic leucogranites have been identified within the Himalaya (Fig. 1a). The High Himalayan leucogranites

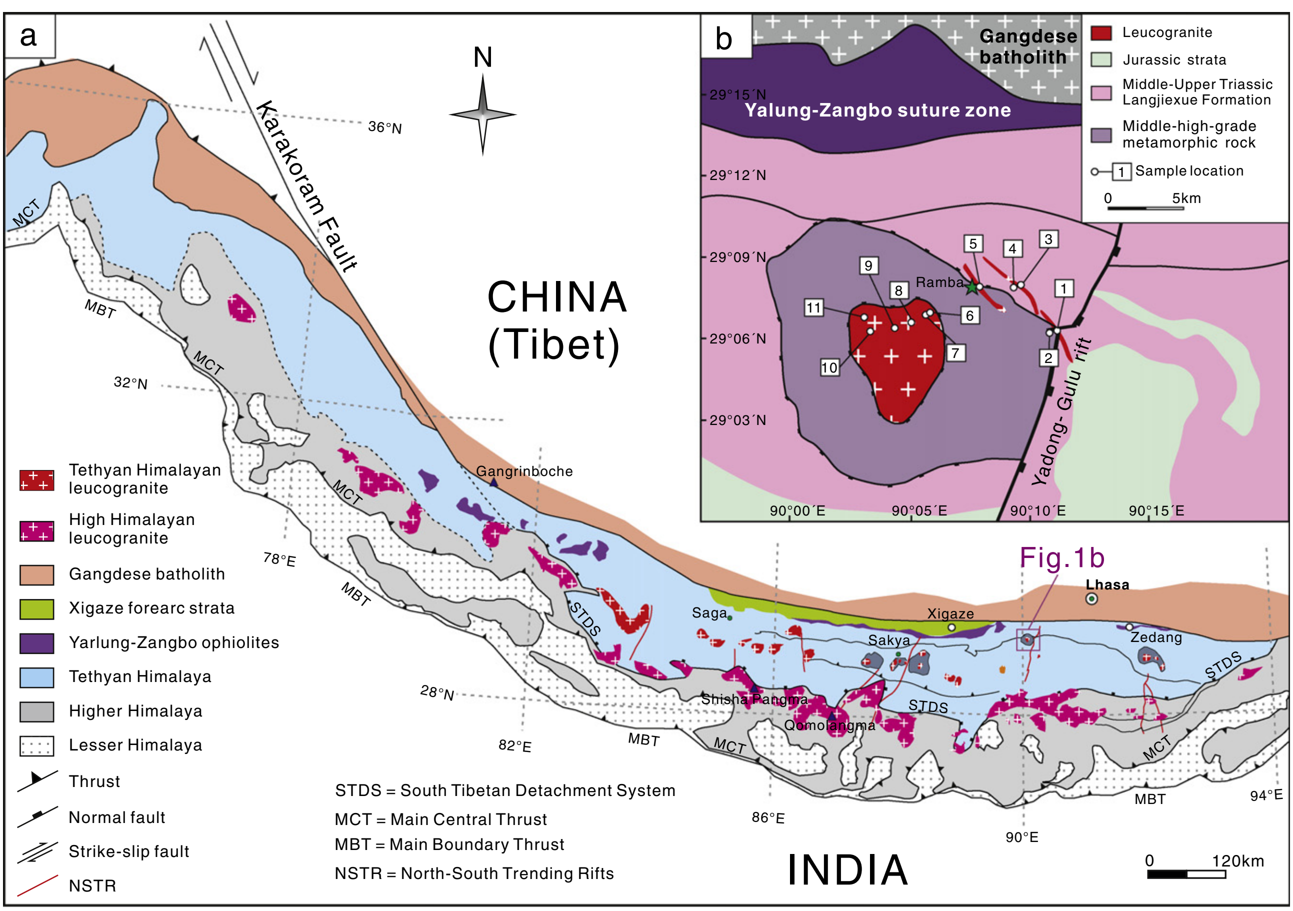

Fig. 1. (a) Simplified geologic map of the Himalayan orogenic belt and southern Tibet Plateau (after Searle and Godin, 2003). (b) Simplified geologic map of the Ramba dome showing the sample locations. Sample locations: 1—samples 12FW101, 12FW102, 12FW103, 12FW104, 12FW105, and 12FW106; location 2—samples 12FW107, 12FW108 and 12FW109; location 3—sample 12FW110; location 4—sample 12FW111; location 5—sample 12FW112; location 6—samples 12FW113 and 12FW114; location 7—samples 09FW115, 09FW116, 09FW117, 09FW118 and 09FW119; location 8—sample 12FW115; location 9—sample 09FW120; location 10—sample 12FW116; location 11—sample 09FW121.