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Magmatic zircons from I-, S- and A-type granitoids in Tibet: Trace element characteristics and their application to detrital zircon provenance study

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ABSTRACT

This study reports a dataset of 21 trace elements of magmatic zircons from typical I-type (93 analyses) and S-type (73 analyses) granitoids from the Lhasa and Himalayan terranes, southern Tibet, and A-type granitoids (21 analyses) from the Songpan–Ganzi terrane, eastern Tibet. Our results indicate that magmatic zircons from the I-type granitoids are characterized by relatively lower Pb concentrations and higher $(Nb/Pb)_N$ ratios, distinct from those of the S-type granitoids that reveal higher Pb, lower $(Nb/Pb)_N$ and significant Eu negative anomalies ($Eu/Eu^* \leqslant 0.3$); while these values are transitional in zircons from the A-type granitoids. Such differences, most likely governed by compositional variations in the host magmas, are considered as a useful tool, in addition to U–Pb and Hf isotopes, for tracing the source provenance of detrital zircons. Consequently, the trace element compositions of detrital zircons with a diagnostic age peak (~1170 Ma) from the Lhasa Terrane indicate the presence of coeval S-type magmatism in their source region. This study exemplifies the usefulness of zircon trace element geochemistry in investigating sedimentary source provenance and paleogeographic reconstruction.

1. Introduction

The zircon isotope has been widely used as a geochronological (U–Pb dating) and geochemical fingerprint (Hf-isotope determination) useful to determine the nature of magmatic source regions and the petrogenesis of host rocks (cf. Kemp et al., 2007; Zhu et al., 2011a; Chu et al., 2011). Recent studies indicate that these two types of applications related to zircon composition are crucial for tracing the provenance of sediments and for paleogeographic reconstruction (cf. Veevers et al., 2005; Yu et al., 2008; Howard et al., 2009; Duan et al., 2010). Previous studies have identified a variety of rock types in different source regions (Belousova et al., 2002) and the differences between ocean- and continent-derived zircons (Grimes et al., 2007) in terms of their zircon trace element. However, the role of zircon trace element in exploring the nature of magmatic source region of host rocks (i.e., I-, S-, or A-type magmatism) remains unclear.

For genetic types, granitoids are typically divided into I-, S-, A-, and M-types, in which I- and S-type granitoids generally dominate in surface outcrop areas and in total volume on the earth. These different genetic types of granitoids record different information on magma source region, magmatic process, and tectonic setting (e.g., Pearce et al., 1984; Liegeois et al., 1998; Sylvester, 1998; Barbarin, 1999; Patino Douce, 1999). Accessory minerals (e.g., zircon, apatite) are crystallized from the same magmatic system as the main rock-forming minerals and similarly document the composition, nature, and tectonic setting of those systems (e.g., Chu et al., 2009). Identifying the compositional difference of trace elements in zircons from different genetic types of granitoids enables its use as a new geochemical tracer to determine the nature of magmatic activity in the provenance of detrital zircons, thereby providing new constraints from zircon composition for paleogeographic reconstruction. Recent study indicates that detrital zircons are derived primarily from granitoids and tend to be preserved at the end of the subduction-related and collisional mountain building stages (Hawkesworth et al., 2009). Such a new understanding for the preservation of detrital zircons formed the basis of this study.

In this study, we report a dataset of 21 trace elements in zircons from typical I- and S-type granitoids in southern Tibet. We also

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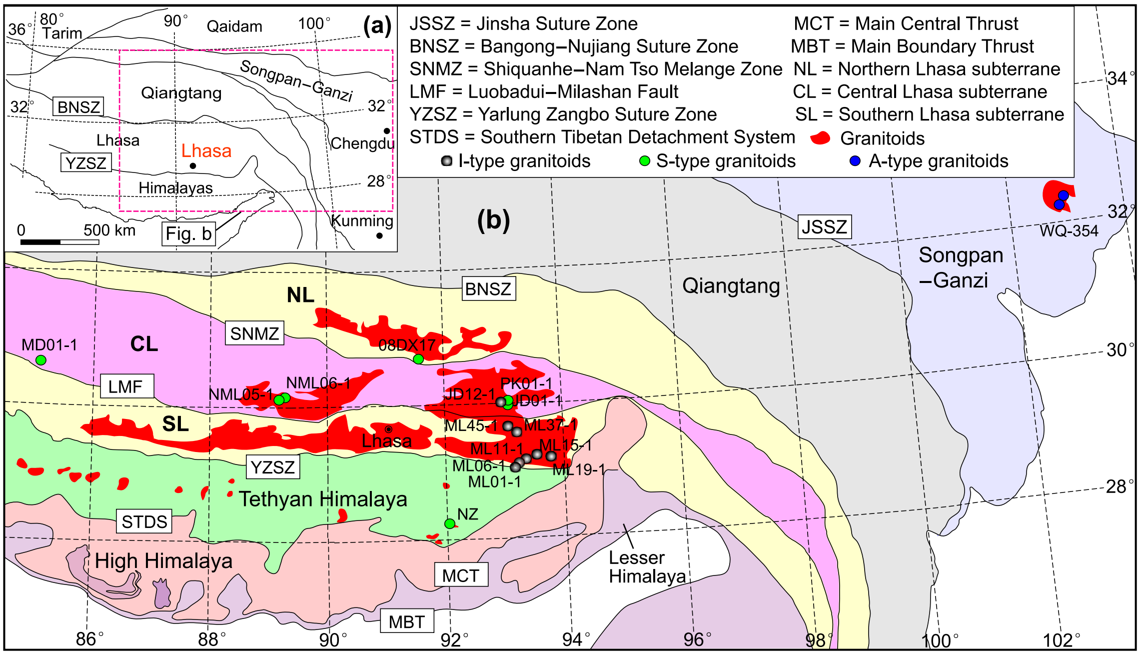

Fig. 1. Tectonic framework of the Tibetan Plateau (a) and subdivisions of the Lhasa and Himalayan terranes showing the sample locations of this study (b) (modified from Pan et al., 2004; Zhu et al., 2011a).

present data of zircons obtained from A-type granitoids from the Songpan–Ganzi belt in eastern Tibet for comparison with the southern Tibetan samples (Fig. 1). Our results indicate that several geochemical indicators of zircons (e.g., Pb and Th concentrations and Eu/Eu* and $(Nb/Pb)_N$ ratios) characterize the differences of trace elements in zircons from I-, S-, and A-type granitoids. Our work provides a useful geochemical method for tracing the provenance of detrital zircons, in addition to the zircon U–Pb age and Hf-isotope methods, and it may have a broad significance for determining the nature of magmatic activity of detrital zircon provenance and for paleogeographic reconstruction.

2. Geological background and samples

The Southern Tibetan Plateau consists mainly of the Lhasa and Himalayan terranes separated by the Yarlung-Zangbo suture zone (YZSZ) (Fig. 1a). The Lhasa Terrane to the north of the YZSZ can be divided into southern, central, and northern subterranes (Zhu et al., 2009a, 2011a). The literature generally refers to the latter two as the northern Lhasa magmatic belt (Coulon et al., 1986; Chung et al., 2005; Kapp et al., 2005; Chu et al., 2006), and the southern Lhasa subterrane, or Trans-Himalaya (Yin and Harrison, 2000), is characterized by the existence of juvenile crust (cf. Zhu et al., 2011a). The Gangdese Batholith in the southern Lhasa subterrane consists predominantly of gabbro, diorite, tonalite, and granodiorite, in which the Cretaceous granitoids with geochemical compositions of typical I-type granitoids are generally thought to have been generated by the northward subduction of the Neo-Tethyan oceanic floor (cf. Chu et al., 2006; Wen et al., 2008; Zhu et al., 2011a). To the north, the existence of ancient basement rocks as old as Archean characterizes the central Lhasa subterrane (cf. Zhu et al., 2011a). The granitoids widely exposed in this subterrane (Fig. 1b) are composed primarily of granodiorite, syenogranite, monzogranite, and two-mica granite, which represent the rock association of S-type granitoids (Chu et al., 2006, 2009; Zhang et al., 2007a; Zhu et al., 2008).

The Tethyan Himalaya immediately south of the YZSZ is located on the northern margin of Indian plate, was part of the passive continental margin south of the Neo-Tethyan Ocean during the Mesozoic (Yin and Harrison, 2000; Zhu et al., 2011a) and was an active post-collisional orogen in response to the India–Asia continental collision during the Cenozoic. Miocene leucogranite domes (including two-mica granite, muscovite-granite, etc.) exposed in this terrane are typical post-collisional S-type granites (Sylvester, 1998; Zhang et al., 2004, 2005).

Representative I- and S-type granitoid samples were collected from the southern and central Lhasa subterranes and the Tethyan Himalaya in southern Tibet (Table 1; Fig. 1b). The field occurrence of each studied pluton appears in several separate papers (cf. Chu et al., 2006; Zhang et al., 2007a; Wen et al., 2008; Zhu et al., 2009b, 2011a).

2.1. I-type granitoids

Eight samples collected mainly from the southern Lhasa subterrane (e.g., Nang, Mailing) (Fig. 1b) show SiO_2 of 66.19–70.96%, K_2O of 1.78–3.40%, and Na_2O of 3.07–5.24% (except sample JD12-1 < 3.2%) (Table A1). The A/CNK values (<1.1), minor normative corundum (0–0.93%), and positive zircon $\varepsilon_{Hf}(t)$ (Table 1) indicate that the rocks are derived mainly from partial melting of the intra-crustal metamorphosed mafic to intermediate igneous rocks, although a few samples likely contain contributions from ancient crustal materials (Chappell and Stephens, 1988; Zhu et al., 2009c). These features are consistent with I-type granitoid origin (Chappell and White, 1974, 2001).

2.2. S-type granitoids

Six samples from the central Lhasa subterrane (JD01-1, MD01-1, NML05-1, NML06-1, PK01-1, and 08DX17) (Fig. 1b) have SiO_2 of 69.85–74.58%, K_2O of 4.33–5.99%, and Na_2O of 2.40–3.69% (except sample NML06-1 > 3.2%) (Table A1). The high A/CNK values (1.10–1.23), presence of high normative corundum (1.54–3.48%), absence of normative diopside, and negative zircon $\varepsilon_{Hf}(t)$ (Table 1) of these rocks identify them as strongly peraluminous S-type granites with mature crustal protoliths.