Chemical Geology 289 (2011) 179–196

Contents lists available at SciVerse ScienceDirect

Chemical Geology

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

Deconvolving episodic age spectra from zircons of the Ladakh Batholith, northwest Indian Himalaya

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ARTICLE INFO

Article history:
Received 19 October 2010
Received in revised form 11 July 2011
Accepted 25 July 2011
Available online 19 August 2011

Editor: L. Reisberg

Keywords:
SHRIMP
Geochronology
Trans-Himalaya
Episodic
Granite
Zircon

ABSTRACT

We present U/Pb SHRIMP dates of zircons from 7 key samples of the Ladakh Batholith to reconcile the many, often conflicting ages that have been proposed according to various geochronological techniques. Various crosscutting magmatic phases were dated to determine the age of granitoid emplacement. Our results indicate that granitoid emplacement occurred between 66 Ma and 46 Ma. The final phase of magmatism is characterized by the emplacement of crosscutting fine-grained granite (leucogranite), and pegmatite near the village of Chumatang. These dykes are defined as I-type granitoids according to their mineralogy. This indicates that I-type magmatism in the Ladakh Batholith continued until at least ~46 Ma. This implies either that India had not accreted to Eurasia by 46 Ma, or that one of the widely used geological criteria to define the timing of India–Asia collision is incorrect. In addition, SHRIMP analyses of metamorphic zircon rims yield ages between 20 and 10 Ma. These ages may relate to the exhumation of the batholith or to metamorphic activity after exhumation. Evidence of metamorphic zircon growth between 20 and 10 Ma may provide an explanation for many of the similar ages obtained from geochronometers that are affected or reset by temperatures lower than those expected for zircon (e.g. K/Ar and $^{40}Ar/^{39}Ar$ dating of mica).

1. Introduction

The Ladakh Batholith is a component of the Trans-Himalayan Batholith, a northwest–southeast trending belt of granitoids that spans the length of the Himalayan mountain chain (Harris et al., 1988) (Fig. 1). The Trans-Himalayan Batholith is subdivided geographically. It is referred to as the Kohistan Batholith in Pakistan, the Ladakh Batholith/Plutonic Complex in India and the Gangdese/Kangdese Batholith in Tibet (Honegger et al., 1982; Debon et al., 1986; Harris et al., 1988; Ahmad et al., 1998) (Fig. 1). The batholith is 30–50 km wide and ~3000 km long, and lies between the Indus–Tsangpo and Northern/Shyok suture zones (Fig. 1).

The Batholith is considered to have developed at the southern edge of the Lhasa block/Eurasian continent as an intra-oceanic arc in the west (Kohistan/west Ladakh) and as an Andean-style margin in the east (Rolland et al., 2000, 2002). Much work has been devoted to understanding the history of the batholith as many consider that a change from I- to S-type magmatism marks the terminal accretion of India to Asia (Searle et al., 1987, 1988; St-Onge et al., 2010). St-Onge et al. (2010) reported several U/Pb ID-TIMS analyses of zircon from a hornblende-bearing granodiorite and a crosscutting leucocratic dyke near Chumatang. They argued that the change in granite chemistry from an I-type granodiorite at ~57.7 Ma to emplacement of S-type leucocratic dykes at ~47 Ma is indicative of the collision of India and Eurasia.

Many Rb/Sr, K/Ar, $^{40}Ar/^{39}Ar$ and U/Pb dating results have been reported for the granitoids of the Trans-Himalayan Batholith (Desio et al., 1964; Saxena and Miller, 1972; Sharma et al., 1978; Brookfield and Reynolds, 1981; Honegger et al., 1982; Schärer et al., 1984; Petterson and Windley, 1985; Debon et al., 1987; Treloar et al., 1989; George et al., 1993; Sorkhabi et al., 1994; Copeland et al., 1995; Krol et al., 1996; Harrison et al., 2000; Weinberg and Dunlap, 2000; Weinberg et al., 2000; Bhutani et al., 2004; St-Onge et al., 2010; Thanh et al., 2010). The reported ages range between 235 ± 13 Ma obtained from a Rb/Sr isochron from the Gaik Granite (Trivedi et al., 1982) to a number of K/Ar and $^{40}Ar/^{39}Ar$ ages that range between 30 and 17 Ma (Sharma et al., 1978; Petterson and Windley, 1985; Treloar et al., 1989; George et al., 1993; Bhutani et al., 2004). However, Mehta (1980) and Schärer et al. (1984) suggested that the Rb/Sr, K/Ar and $^{40}Ar/^{39}Ar$ systems were likely to re-open during subsequent magmatic, metamorphic and/or hydrothermal episodes, or that the ages determined from these techniques could reflect mixing ages associated with whole-rock measurements. Many recent papers discussing the history of the Trans-Himalayan Batholith report U/Pb ages of

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doi:10.1016/j.chemgeo.2011.07.024

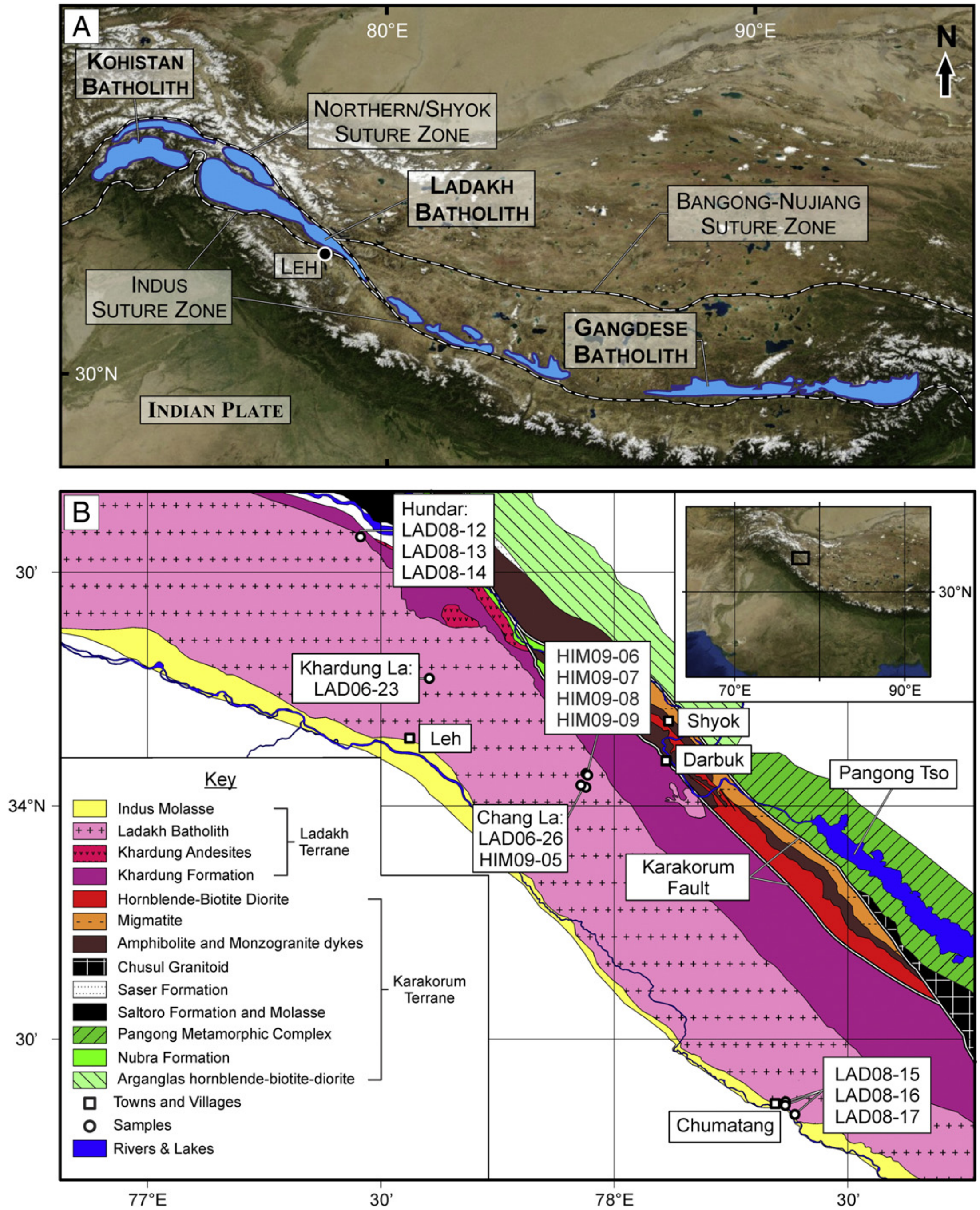

Fig. 1. (A) The Trans-Himalayan Batholith (shaded) spans the length of the Himalayan mountain chain and is subdivided into the Kohistan, Ladakh and Kangdese/Gangdese batholiths. The Trans-Himalayan Batholith is considered to be bounded between the Indus Suture and Northern/Shyok Suture zones (figure adapted from Yin and Harrison, 2000). (B) This study focuses on samples from the Ladakh Batholith. This map shows the location of samples collected close to Hundar village (LAD08-12, 13, 14), Khardung La (LAD06-23), Chang La (LAD06-26, HIM09-05, 06, 07, 08, 09) and Chumatang village (LAD08-15, 16, 17). The map was generated by scanning and rectifying maps by Gansser (1964), Phillips (2008), Thakur and Misra (1984) and modifying geological boundaries in accordance with an aerial photographic interpretation.

zircon and other accessory minerals derived from Isotope Dilution Thermal Ionisation Mass Spectrometry (ID-TIMS), Laser Ablation Inductively-Coupled Plasma Mass Spectrometry (LA-ICPMS) and Secondary Ion Mass Spectrometry (SIMS) measurements (Honegger et al., 1982; Schärer et al., 1984; Weinberg and Dunlap, 2000; Singh et al., 2007; Upadhyay et al., 2008; Ravikant et al., 2009; St-Onge et al., 2010). We focus on the U/Pb age data that have been published on the Ladakh Batholith (Table 1), as these data are most relevant to this manuscript.

The first U/Pb ages obtained for the Ladakh Batholith were derived from ID-TIMS analyses of zircons from a biotite–granodiorite pluton near the town of Kargil (103 ± 3 Ma; 101 ± 2 Ma) and analyses of monazite and allanite from a biotite–granite sample collected near the town of Leh (62.9 ± 0.4 Ma) (Honegger et al.;, 1982; Schärer et al., 1984). Additional ID-TIMS ages have been reported for the Daah–Hanu Tonalite (55–45 Ma), the Hundar Granite (66.6 ± 2.1 Ma) and the Chang La Granodiorite (57.6 ± 1.4 Ma) (Upadhyay et al., 2008). Interestingly, the age obtained for the Hundar Granite sample differs from a K/Ar age reported from the same outcrop (60.8 ± 1.3 Ma), but is within the uncertainty of the K/Ar age obtained from the Hundar Diorite (65.8 ± 1.4 Ma) (Thanh et al., 2010). In addition, an age obtained for the Chang La