Lithos 245 (2016) 118–132

Contents lists available at ScienceDirect

Lithos

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

Two Cenozoic tectonic events of N–S and E–W extension in the Lhasa Terrane: Evidence from geology and geochronology

Feng Huang [a,b], Ji-Feng Xu [a,c,*], Jian-Lin Chen [a,c], Jian-Bin Wu [a,b], Yun-Chuan Zeng [a,b], Qiu-Wei Xiong [a,b], Xue-Feng Chen [d], Hong-Xia Yu [d]

[a] State Key Laboratory of Isotope Geochemistry, Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou 510640, China
[b] University of Chinese Academy of Sciences, Beijing 100049, China
[c] CAS Center for Excellence in Tibetan Plateau Earth Sciences, Beijing 100101, China
[d] School of Earth Science and Guangxi Key Laboratory of Hidden Metallic Ore Deposits Exploration, Guilin University of Technology, Guilin 541004, China

ARTICLE INFO

Article history:
Received 27 April 2015
Accepted 26 August 2015
Available online 2 September 2015

Keywords:
LA–ICP–MS
Zircon
Age of Extension
Tectonic tracks
Southern Lhasa Terrane

ABSTRACT

Cenozoic active structures in the Tibetan Plateau are mainly regional N–S trending extensional faults and grabens, and E–W trending extensional tracks that are related to the transition from syn- to post-collision between India and Asia. E–W trending tracks are parallel to the direction of Neo-Tethyan oceanic convergence and consist of extensional volcanic–sedimentary basins and magmatic dykes in the southern Lhasa Terrane, Tibet. N–S trending tracks comprise faults and grabens, which are widely developed in Tibet. It remains unknown how and when the geodynamic transition from E–W to N–S trending tectonic tracks occurred. This study describes both E–W and N–S trending tectonic tracks identified at Dazi area of southern Lhasa Terrane, where E–W trending mafic dykes intruded a granitoid and late-stage N–S trending felsic dykes cut across E–W trending mafic dykes. Zircons from four granitoid samples yield consistent crystallization ages of ca. 60 Ma and positive $\varepsilon_{Hf}(t)$ values (~+9). An altered dioritic vein, which cuts the mafic dykes, yields an age of ca. 53 Ma. These new dating results indicate that E–W trending dykes, which formed due to regional N–S extension, were emplaced between 60 and 53 Ma. In addition, two N–S trending monzonitic porphyritic dykes, which cut the mafic dykes, yield U–Pb zircon ages of ca. 17 Ma with moderate positive $\varepsilon_{Hf}(t)$ values (+3 to +9.6), as well as a NNE–SSW trending quartz monzonitic dyke, which cuts all other types of dykes, yields U–Pb ages of ca. 13 Ma. This suggests that E–W extension took place between 17 and 13 Ma. These results, in combination with existing age data for Gangdese granitoids and mafic magmatism, indicate the occurrence of two major extensional events at 60–53 Ma and 17–13 Ma. In turn, this implies that the transition from E–W to N–S trending tectonic and the onset of E–W extension occurred at ca. 17 Ma or slightly earlier. Paleocene granitoids have geochemical characteristics that are indicative of both subduction and collision. Miocene felsic dykes show adakitic affinities, which hints the transition from syn-collision to post-collision setting. Break-off of the Neo-Tethyan slab is assumed to have been responsible for the formation of E–W trending dykes and volcanic–sedimentary basins. The N–S trending felsic dykes probably formed in response to the tearing or delamination of lithosphere subducted beneath southern Tibet.

1. Introduction

The Gangdese batholith in southern Tibet is regarded as part of an Andean-type continental margin arc that formed due to the northward subduction of Neo-Tethyan oceanic lithosphere and subsequent collision between India and Asia (Mo et al., 2007; Yin and Harrison, 2000; Zhu et al., 2013). The batholith consists mainly of diorites, granodiorites, and granites that were emplaced in southern Tibet from the Late Triassic to the Miocene (Fig. 1; Chung et al., 2005; Ji et al., 2009; Wen et al., 2008). Previous studies on the history of subduction and collision between India and Asia were based mainly on the chemical compositions of intermediate to felsic magmatic rocks of various ages. Gangdese batholith, especially the intrusive rocks that are associated with extensional or compressive structures, reflect the compositions of the deep mantle and upper crust. In addition, these rocks preserve the imprint of tectonic processes that occurred during formation of the Tibetan Plateau (Mitsuishi et al., 2012; Williams et al., 2001). A geochronological framework based on the timing of intrusive rocks and their cross-cutting relationships would therefore help to better understand the formation and evolution of the Tibetan Plateau.

Cenozoic tectonics in southern Tibet is dominated by N–S and E–W oriented extension. The N–S trending extension and associated strike-slip faults developed mainly in the Himalaya Terrane between 23 and

* Corresponding author at: State Key Laboratory of Isotope Geochemistry, Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou, 510640, China. Tel.: +86 20 85290282; fax: +86 20 85290130.
E-mail address: jifengxu@gig.ac.cn (J.-F. Xu).

http://dx.doi.org/10.1016/j.lithos.2015.08.014
0024-4937/

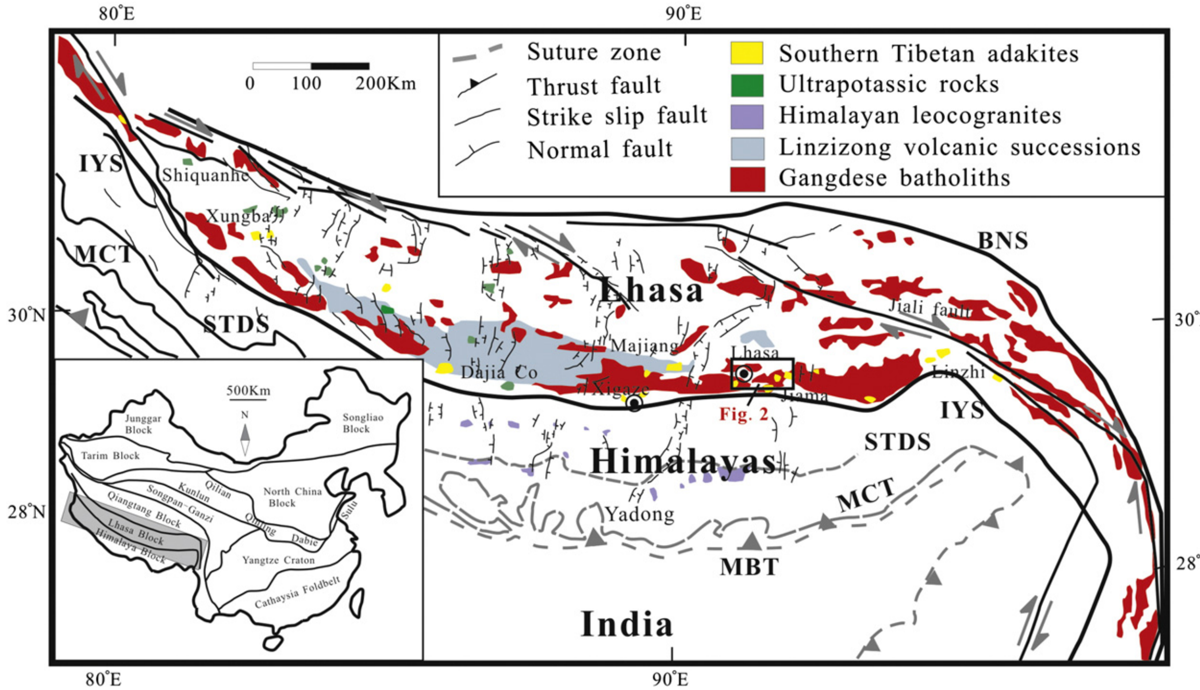

Fig. 1. Sketch map showing the locations of magmatic rocks and faults in the Lhasa Terrane (modified from Blisniuk et al., 2001; Chung et al., 2009). Abbreviations: BNSZ = Bangong–Nujiang suture; IYS = Indus–Yarlung–Zangbo Suture; STDS = South Tibet Detachment System; MCT = Main Central Thrust; MBT = Main boundary thrust.

12 Ma (Guillot et al., 1994; Mitsuishi et al., 2012; Searle, 1999; Viskupic et al., 2005; Zhang and Guo, 2007). N–S extension also affected the Lhasa Terrane during the Paleocene to Eocene and is represented by a series of E–W trending mafic dykes and sedimentary basins (Mo et al., 2008; Yue and Ding, 2006). The E–W extension is represented by N–S trending faults and graben that are assumed to have been active between 19 and 7 Ma or even as young as 4 Ma (Blisniuk et al., 2001; Garzione et al., 2003; Harrison et al., 1995; Maheo et al., 2007; Mitsuishi et al., 2012). The spatial and temporal distribution of these two types of extensional structures indicates the occurrence of two distinct tectonic events (Blisniuk et al., 2001; Mitsuishi et al., 2012).

The N–S extension (E–W trending tracks) parallel to the subduction direction of Neo-Tethyan oceanic lithosphere is unusual because subduction and collision between the India and Asia plate generally produced E–W oriented compressional structures (Yin and Harrison, 2000). In other words, early Cenozoic N–S extension marks the transition from compression to extension in the Lhasa Terrane, which is crucial for characterizing geodynamic evolution of the collision zone. However, Paleogene N–S extension in southern Tibet has not been concern about except a few studies (e.g., Gao et al., 2008; Mo et al., 2008; Xu et al., 2008; Yue and Ding, 2006). Contrary to the N–S extension, Miocene E–W extension occurred orthogonal to a plate convergence belt. It is also difficult to explain how this orientation resulted from Miocene tectonic movements (Blisniuk et al., 2001; Williams et al., 2001). Previous studies proposed that Miocene extensional dykes were linked to the uplift of the Tibetan Plateau (Coleman and Hodges, 1995; Wang et al., 2010; Williams et al., 2001). Research on E–W extension has focused on southwest Tibet, whereas southeast Tibet has been poorly studied.

This study presents new U–Pb zircon ages and geochemical data of granitoids and related E–W and N–S trending magmatic dykes in Dazi County (southern Lhasa Terrane). These intrusive rocks formed during syn- and post-collision between India and Asia. The data provide robust geochronological constraints on tectonic events that occurred after the main collision between India and Asia, and during intraplate extension. This study also considers geodynamic mechanisms that produced the structural characteristics of these rocks.

2. Geological background

The Lhasa Terrane is located in southern Tibet and is bounded by the Bangong–Nujiang suture (BNS) to the north and the Indus–Yarlung Zangbo suture (IYS) to the south (Fig. 1; Yin and Harrison, 2000; Zhu et al., 2013). It is generally accepted that the BNS represents the collision zone between the Qiangtang and Lhasa terranes and that the BNS formed during the Late Jurassic to Early Cretaceous (Yin and Harrison, 2000). The IYS marks the closure of the Neo-Tethyan Ocean during the Late Cretaceous to Early Paleogene (Yin and Harrison, 2000). This suture lies at the southern boundary of an E–W trending Andean-arc-type calc-alkaline volcanic zone (which includes the Yeba, Sangri, and Linzizong volcanics and the Gangdese batholith; Dong et al., 2006; Zhu et al., 2008; Ji et al., 2009; Lee et al., 2009; Kang et al., 2014; Huang et al., 2015a). Deposition of the Linzizong volcanic succession is believed to represent the transition from a 'soft' phase of India–Asia collision between 70 and 65 Ma to a 'hard' phase between 45 and 40 Ma (Mo et al., 2007, 2008). The magmatic 'flare-up' at ca. 50 Ma is regarded as the result of break-off of the Neo-Tethyan oceanic slab (Ji et al., 2009; Lee et al., 2009; Wang et al., 2015; Wen et al., 2008). However, other studies propose a later slab break-off at ca. 40 Ma (Gao et al., 2006, 2008; Xu et al., 2008). After slab break-off, the Indian lithosphere continued to move northwards and was underthrusted beneath southern Tibet. Today, the Indian lithosphere has extended up to the BNS, and the Tibetan crust has twice normal thickness (Jin et al., 1996; Kapp and Guynn, 2004; Owens and Zandt, 1997; Zhao and Morgan, 1987).

After the collision between India and Asia, three types of post-collisional magmatites were widely emplaced in the Lhasa Terrane: adakitic intrusive rocks, potassic–ultrapotassic volcanic rocks, and peraluminous granites were emplaced between 25 and 10 Ma (Chung et al., 2005, 2009; Hou et al., 2004; Huang et al., 2015b; Liao et al., 2007; Mo et al., 2007; Zeng et al., 2015). The ultrapotassic volcanic rocks were derived from low-degree partial melting of metasomatized lithospheric mantle and are only found west of 87°E (Chung et al., 2005; Huang et al., 2015b; Williams et al., 2001; Zhao et al., 2009). Other post-collisional magmatic rocks occur widely throughout the Lhasa Terrane, although their distributions are locally controlled by N–