Journal of Geodynamics 52 (2011) 389–405

Contents lists available at ScienceDirect

Journal of Geodynamics

journal homepage: http://www.elsevier.com/locate/jog

Late Neoproterozoic thermal events in the northern Lhasa terrane, south Tibet: Zircon chronology and tectonic implications

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ARTICLE INFO

Article history:
Received 29 July 2010
Received in revised form 16 May 2011
Accepted 20 May 2011
Available online 27 May 2011

Keywords:
Lhasa terrane
Precambrian metamorphism
Zircon U–Pb dating
Rodinia supercontinent
Tibetan Plateau

ABSTRACT

The high-grade metamorphic rocks from the Lhasa terrane, south Tibet, have been traditionally grouped as the Precambrian metamorphic basement. However, a number of recent studies show that these metamorphic rocks from the southern part of Lhasa terrane, including granulite- and eclogite-facies rocks, were metamorphosed during the Mesozoic and Cenozoic. Based on the LA–ICP–MS in situ zircon U–Pb chronology, we report for the first time late Neoproterozoic metamorphic and magmatic events from the Lhasa terrane. The rocks analyzed in this study occur in the northern part of Lhasa terrane, and include amphibolite, garnet-bearing muscovite schist and marble, with the mineral assemblages of hornblende + andesine + quartz, muscovite + garnet + plagioclase + quartz and calcite + diopside + quartz, indicating an amphibolite-facies metamorphic event. Zircons from a marble and an amphibolite sample show typical features of metamorphic origin, and yield peak-metamorphic ages of ca. 676 Ma and ca. 661 Ma, respectively. Zircons from another amphibolite sample possess inherited magmatic cores and metamorphic overgrown rims, yielding a protolith age of ca. 856 Ma and a metamorphic age of ca. 683 Ma. Zircons from the schist include detrital magmatic cores showing a wide spectrum of Proterozoic ages from ca. 1747 to 789 Ma, representing derivation from multiple sources. However, the metamorphic rims of these zircons yield an age population of ca. 690 Ma. Based on the geochemical and geochronological data presented in this work and from a synthesis of data from previous studies, we propose the location of the Lhasa terrain in a reconstruction of the Neoproterozoic Rodinia supercontinent. We correlate the late Neoproterozoic metamorphic and magmatic events with an Andean-type orogeny that resulted from oceanic subduction beneath the northwestern margin of the Rodinia supercontinent. We correlate the orogeny with a global-scale late Proterozoic arc magmatism widely represented in the Seychelles, Madagascar, northwestern India and South China.

1. Introduction

The Tibetan Plateau is principally a collage of four terranes, and from north to south these are the Songpan–Ganzi, Qiangtang, Lhasa and Himalaya terranes. These terranes are separated by the Jinsha Suture (JS), Bangong–Nujiang Suture (BNS), and Indus–Tsangpo Suture (ITS) zones. These suture zone contain fragments of Paleo-, Meso-, and Neo-Tethyan ocean basins existing before suturing, respectively (Fig. 1) (e.g., Yin and Harrison, 2000; Xu et al., 2006 and references therein). The Lhasa terrane, located in the southern part of Tibet, is a large crustal segment with a width of 100–300 km and a length of ca. 2000 km. Previous studies identified the Lhasa terrane to be dominantly constituted of Precambrian metamorphic basement, Paleozoic to Mesozoic sedimentary rocks and Mesozoic and Cenozoic igneous rocks (e.g., Yin and Harrison, 2000; Metcalfe, 2006; Pan et al., 2006). Most of the previous works were focused on the Mesozoic and Cenozoic igneous rocks of the Lhasa terrane, which provided important constraints on the Andean-type and Himalayan-type orogenies in southern Tibet (e.g., Chung et al., 2003, 2005; Ding et al., 2003; Mo et al., 2005, 2006, 2007, 2008; Booth et al., 2004; Hou et al., 2004, 2009; Zhang et al., 2004, 2007, 2010a; Chu et al., 2006; Pan et al., 2006; Zhu et al., 2008a,b, 2009; Wang et al., 2008; Wen et al., 2008a,b; Ji et al., 2009; Zhao et al., 2009; Wu et al., 2010; Aitchison et al., 2011; Xia et al., 2011).

A sequence of high-grade metamorphic rocks which formed under amphibolite-facies conditions occurs in the eastern part of Lhasa terrane (Fig. 1). These rocks have been referred to as the Nyainqentanglha Group, Nyingtri Group or Bome Group in various

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0264-3707/$ – see front matter
doi:10.1016/j.jog.2011.05.002

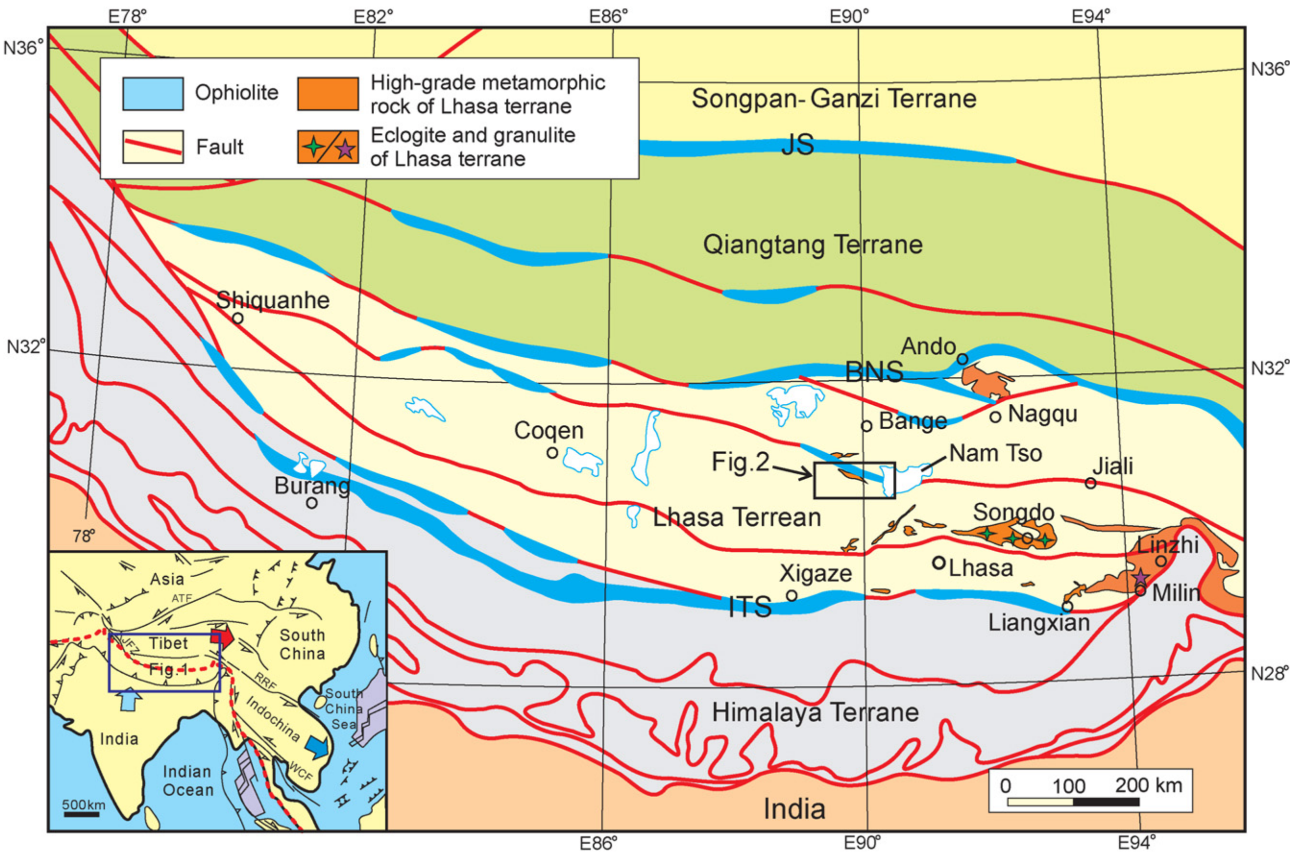

Fig. 1. Simplified geological map of the Tibetan Plateau, showing the distribution of high-grade metamorphic rocks and eclogite in the Lhasa terrane (modified after Zhang et al., 2010c). BNS: Bangong–Nujiang Suture; JS: Jinsajiang Suture; ITS: Indus–Tsangpo Suture.

regions of the Lhasa terrane. Furthermore, these rocks were considered to constitute the Precambrian metamorphic basement of the Lhasa terrane based on radiogenic isotopic ages obtained by traditional dating methods (e.g., Li, 1955; Xu et al., 1985; Harris et al., 1988; Dewey et al., 1988; Xia and Liu, 1997; Hu et al., 2003; Yin et al., 2003; Zheng et al., 2003). Recently, a number of zircon U–Pb ages obtained from the high-grade metamorphic rocks, including eclogite and granulite, of the southern Lhasa terrane have indicated that these rocks were metamorphosed during the Mesozoic and Cenozoic, rather than in the Precambrian as previously conceived (Yang et al., 2006, 2007, 2009; Xu et al., 2007; Chen et al., 2008; Wang et al., 2008, 2009a; Li et al., 2009; Liu and Liu, 2009; Zeng et al., 2009; Dong et al., 2010; Zhang et al., 2010a,b). Thus, the existence of an ancient metamorphic crystalline basement in the Lhasa terrane is still ambiguous.

In this study, we report late Neoproterozoic metamorphic ages from zircons in the high-grade metamorphic rocks located within the northern Lhasa terrane. Our results, together with the preliminary studies (Wang et al., 2003; Wu et al., 2003; Hu et al., 2005; Zhang et al., 2010c), provide new insights into the origin of the Lhasa terrane and the Precambrian tectonic evolution of the region in relation to the history of the Rodinia and Gondwana supercontinents.

2. Analytical methods

Mineral compositions were determined by electron microprobe analysis using a JXA-8100 JEOL Superprobe equipped with WDS/EDS combined micro-analyzer at Institute of Geology, Chinese Academy of Geological Sciences. Analyses were performed on polished sections at 15 kV accelerating voltage, 12 nA beam current and usually 5 μm probe diameter. Standards include silicates and pure oxides.

For bulk rock analysis, 500 g of each sample was crushed into 60 mesh in a steel jaw crusher; and then about 60 g of each crushed sample was powdered in an agate ring mill to less than 200 mesh. All the samples were analyzed in the National Geological Analysis Center of China, Beijing. Major elements were determined by XRF (Rigaku-3080) and the analytical uncertainty is <0.5%. FeO contents were determined by the wet chemical analysis method. Trace elements Zr, Nb, V, Cr, Sr, Ba, Zn, Ni, Rb and Y were determined using a XRF instrument (Rigaku-2100), and the analytical uncertainties are <5% for Ba and <3% for all other elements. Other trace elements were analyzed by ICP-MS (TJA-PQ-ExCell) with the analytical uncertainties of 1–5% at abundances >1 ppm, and 5–10% at abundances <1 ppm.

Zircons for dating were separated by crushing and sieving ~1000 g of each sample, followed by magnetic and heavy liquid separation. Approximately 200 zircon grains from each sample were mounted in 25-mm epoxy discs and polished. Mineral inclusions in zircon were identified using a RENISHAW Raman spectrometer (RM100), at the Key Laboratory for Continental Dynamics, Institute of Geology, Chinese Academy of Geological Sciences. Cathodoluminescence (CL) imaging of zircon was carried out using a HITACHI S2250-N scanning electron microscope at the SHRIMP unit at the Institute of Geology, Chinese Academy of Geological Science.

In situ U–Pb isotope and trace element analyses of the zircons were performed by LA–ICP–MS (GeoLas 2005) equipped with a 193 nm ArF-excimer laser (COMPEXPro) at the State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences. Helium was used as a carrier gas. During experiments, the output energy was set to 60 mJ, with a pulse repetition rate of