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Early Jurassic high-pressure metamorphism of the Amdo terrane, Tibet: Constraints from zircon U–Pb geochronology of mafic granulites

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ABSTRACT

The Amdo terrane holds one of the important keys to understand the tectonic evolution of Central Tibet. Here we report the results from a combined study of Cathodoluminescence imaging, LA–ICPMS U–Pb dating, and trace element analysis of zircons from high-pressure (HP) mafic granulites from the Amdo terrane. Zircons from the mafic granulite are rounded or anhedral and show sector or planar domains with low Th/U ratios, low REE contents, and flat HREE patterns, and can be divided into two types. The first type of zircons shows negative Eu anomalies, indicating that they coexisted with garnet and symplectitic plagioclase during the retrograde stage of metamorphism, whereas the second type possesses positive Eu anomalies, implying that they formed during the peak-metamorphic stage of the HP granulite. U–Pb data yielded a weighted mean $^{206}Pb/^{238}U$ age of 190.7 ± 3.0 Ma (MSWD = 2.8, n = 8) for zircons with positive Eu anomalies, interpreted as the time of the peak metamorphism, and a mean age of 181.4 ± 1.8 Ma (MSWD = 2.2, n = 16) for zircons with negative Eu anomalies corresponding to the amphibolite-facies retrogression. Combining with previous data, we suggest that the Amdo terrane became a microcontinent in the Tethys Ocean during the Permian–Triassic rifting between the Lhasa and Qiangtang terranes, and then the Amdo terrane subducted to about 50-km-depth beneath the Qiangtang terrane experiencing HP granulite-facies metamorphism in the Early Jurassic at 190 Ma. The region was then uplifted to the mid-crustal levels (~20 km) with an exhumation rate of ca. 3 mm/year. The presence of Early Jurassic HP granulite shows that the Amdo terrane is related to the Bangong–Nujiang Suture zone instead of with the Mid-Qiangtang Suture zone.

1. Introduction

The Himalayan–Tibetan orogen, created by closure of the Tethys Ocean between Laurasia to the north and Gondwana to the south, is one of the youngest continent–continent collisional belts on the Earth and the subject of many investigations for understanding processes of continental tectonics and mountain building (e.g., Chang and Zhen, 1973; Girardeau et al., 1984; Chang et al., 1986; Chang, 1992; Yin and Harrison, 2000; Kapp et al., 2003; Pan et al., 2004, 2012; Pullen et al., 2008; Xia et al., 2011; Zhang et al., 2012, 2014; Zhu et al., 2013). However, the specific mechanisms of magmatic, metamorphic, and tectonic processes in response to the multistage orogenesis in this region, particularly within its interior domains, are still controversial (e.g., Girardeau et al., 1984; Kapp et al., 2003; Li et al., 2008, 2009; Guynn et al., 2012; Zhang et al., 2012, 2014). In central Tibet, the Bangong–Nujiang Suture (BNS) between the Lhasa terrane to the south and the Qiangtang terrane (QT) to the north can be subdivided into the western (Bangong Lake–Gaize), the middle (Dongqiao–Amdo), and the eastern (Dingqing–Nujiang) sectors (Fig. 1; Huang and Chen, 1987; Dewey et al., 1988; Yin and Harrison, 2000). North of the BNS, the newly discovered Mid-Qiangtang Suture (M-QTS) subdivides the Qiangtang terrane into the North-Qiangtang terrane (N-QT) and the South-Qiangtang terrane (S-QT; Li et al., 1995, 2006a, 2006b, 2008; Zhang et al., 2006; Pullen et al., 2008). Many issues related to the two sutures, such as the relationships between them and their tectonic evolution, remain controversial (Girardeau et al., 1984; Kapp et al., 2003; Li et al., 2008, 2009). Zhang and Tang (2009) suggested that the S-QT, associated with the Lhasa terrane, was separated from the N-QT by the Shuanghu–Dingqing Paleotethyan Ocean (dotted line in Fig. 1) before the Early Mesozoic. However, further evidence is required to support this hypothesis.

The Amdo terrane, mainly composed of strongly foliated gneisses with large volumes of granitoid intrusions and surrounding sedimentary/metasedimentary rocks (Xu et al., 1985; Coward et al., 1988; Bureau of Geology of Tibet Autonomous Region, BGTAR, 2005; Guynn et al., 2006, 2012), lies in the middle sector of the BNS and adjacent to the M-QTS

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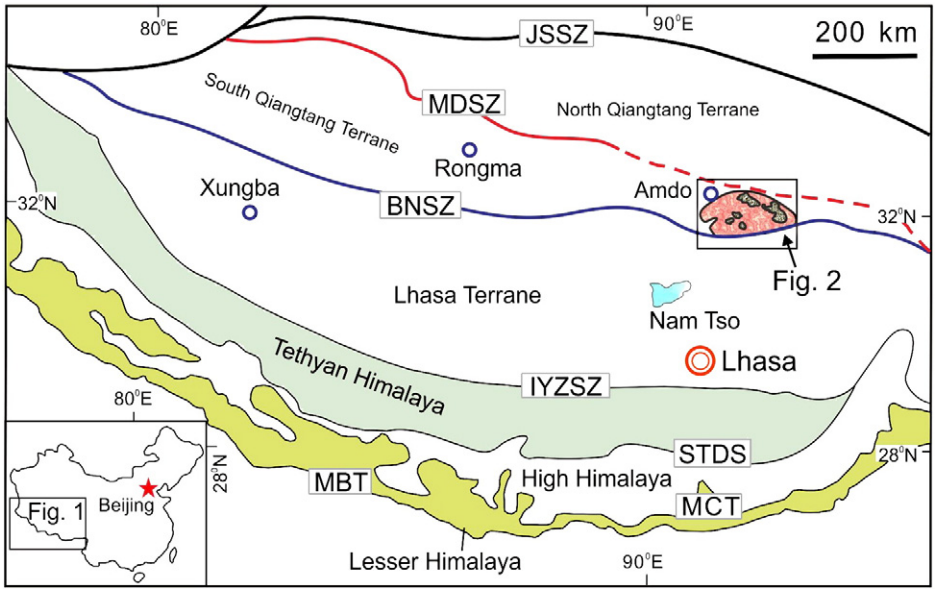

Fig 1. Structural framework of Tibetan Plateau showing position of the Amdo terrane (modified after Zhang and Tang, 2009). JSSZ—Jinsha suture zone; MDSZ—Middle Qiangtang suture zone; BNSZ—Bangong–Nujiang suture zone; IYZSZ—Indus–Yarlung Zangbo suture zone; STDS—southern Tibetan detachment system; MCT—Main Central thrust; MBT—Main Boundary thrust.

(Fig. 1). It is generally agreed that the northward oceanic subduction between the Lhasa and the Qiangtang terranes ceased during the Middle to Late Jurassic (Girardeau et al., 1984; Leeder et al., 1988; Smith and Xu, 1988; Zhou et al., 1997; Guynn et al., 2006), and the Lhasa–Qiangtang collision was marked by the northward underthrusting of the Lhasa terrane beneath the Qiangtang terrane during the Early Cretaceous (Leeder et al., 1988; Kapp et al., 2003; Guynn et al., 2006). However, no consensus has so far been reached about the grade and timing of metamorphism and tectonic evolution of the Amdo terrane.

Recently, Zhang et al. (2010) reported high-pressure (HP) mafic granulites from the Amdo terrane. In this paper, we present the results of the internal texture, compositional features, and U–Pb age of zircons from the Amdo HP granulites. Our study provides precise constraints on the timings of peak- and retrograde-metamorphism of the HP granulites and new insights into the Mesozoic tectonic evolution of the Amdo terrane.

2. Geological background of the Amdo terrane

The Amdo terrane is an east–west-trending lenticular unit covering an area of about 5200 km^2 (Fig. 2). The region is predominately composed of gneisses, undeformed granitoids, metasedimentary rocks and sedimentary cover (Xu et al., 1985; Coward et al., 1988; Kidd et al., 1988; Pan et al., 2004; Bureau of Geology of Tibet Autonomous Region,

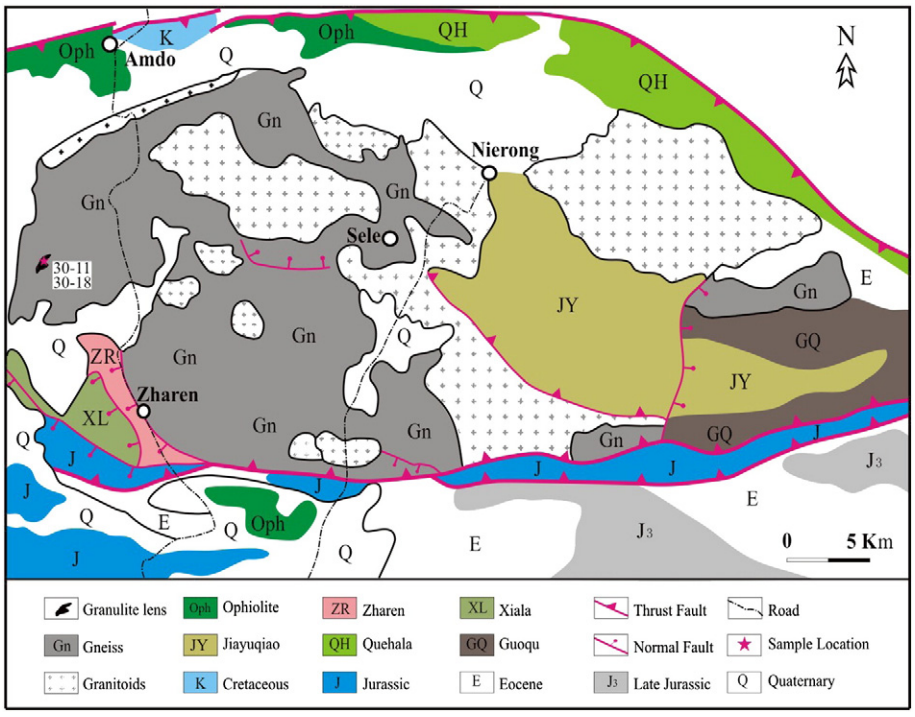

Fig. 2. Geological map of the Amdo terrane (after Bureau of Geology of Tibet Autonomous Region, BGTAR, 2005) showing the location of the HP mafic granulites.