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# Metamorphism and tectonic evolution of the Lhasa terrane, Central Tibet

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ABSTRACT

The Lhasa terrane in southern Tibet is composed of Precambrian crystalline basement, Paleozoic to Mesozoic sedimentary strata and Paleozoic to Cenozoic magmatic rocks. This terrane has long been accepted as the last crustal block to be accreted with Eurasia prior to its collision with the northward drifting Indian continent in the Cenozoic. Thus, the Lhasa terrane is the key for revealing the origin and evolutionary history of the Himalayan–Tibetan orogen. Although previous models on the tectonic development of the orogen have much evidence from the Lhasa terrane, the metamorphic history of this terrane was rarely considered. This paper provides an overview of the temporal and spatial characteristics of metamorphism in the Lhasa terrane based mostly on the recent results from our group, and evaluates the geodynamic settings and tectonic significance. The Lhasa terrane experienced multistage metamorphism, including the Neoproterozoic and Late Paleozoic HP metamorphism in the oceanic subduction realm, the Early Paleozoic and Early Mesozoic MP metamorphism in the continent–continent collisional zone, the Late Cretaceous HT/MP metamorphism in the mid-oceanic ridge subduction zone, and two stages of Cenozoic MP metamorphism in the thickened crust above the continental subduction zone. These metamorphic and associated magmatic events reveal that the Lhasa terrane experienced a complex tectonic evolution from the Neoproterozoic to Cenozoic. The main conclusions arising from our synthesis are as follows: (1) The Lhasa block consists of the North and South Lhasa terranes, separated by the Paleo-Tethys Ocean and the subsequent Late Paleozoic suture zone. (2) The crystalline basement of the North Lhasa terrane includes Neoproterozoic oceanic crustal rocks, representing probably the remnants of the Mozambique Ocean derived from the break-up of the Rodinia supercontinent. (3) The oceanic crustal basement of North Lhasa witnessed a Late Cryogenian (~650 Ma) HP metamorphism and an Early Paleozoic (~485 Ma) MP metamorphism in the subduction realm associated with the closure of the Mozambique Ocean and the final amalgamation of Eastern and Western Gondwana, suggesting that the North Lhasa terrane might have been partly derived from the northern segment of the East African Orogen. (4) The northern margin of Indian continent, including the North and South Lhasa, and Qiangtang terranes, experienced Early Paleozoic magmatism, indicating an Andean-type orogeny that resulted from the subduction of the Proto-Tethys Ocean after the final amalgamation of Gondwana. (5) The Lhasa and Qiangtang terranes witnessed Middle Paleozoic (~360 Ma) magmatism, suggesting an Andean-type orogeny derived from the subduction of the Paleo-Tethys Ocean. (6) The closure of Paleo-Tethys Ocean between the North and South Lhasa terranes and subsequent terrane collision resulted in the formation of Late Permian (~260 Ma) HP metamorphic belt and Triassic (220 Ma) MP metamorphic belt. (7) The South Lhasa terrane experienced Late Cretaceous (~90 Ma) Andean-type orogeny, characterized by the regional HT/MP metamorphism and coeval intrusion of the voluminous Gangdese batholith during the northward subduction of the Neo-Tethyan Ocean. (8) During the Early Cenozoic (55–45 Ma), the continent–continent collisional orogeny has led to the thickened crust of the South Lhasa terrane experiencing MP amphibolite-facies metamorphism and syn-collisional magmatism. (9) Following the continuous continent convergence, the South Lhasa terrane also experienced MP metamorphism during Late Eocene (40–30 Ma). (10) During Mesozoic and Cenozoic, two different stages of paired metamorphic belts were formed in the oceanic or continental subduction zones and the middle and lower crust of the hanging wall of the subduction zone. The tectonic imprints from the Lhasa terrane provide excellent examples for understanding metamorphic processes and geodynamics at convergent plate boundaries.



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**Contents**



## 1. Introduction

The Himalayan–Tibetan orogen is the youngest and the most spectacular of all the continent–continent collisional belts on the Earth (e.g., Yin and Harrison, 2000). This extraordinarily large and complex amalgamated belt is considered to have been built through the closure of the Tethys Ocean between two great landmasses: Laurasia in the north and Gondwana to the south since the Paleozoic. The geologic and tectonic evolution related to the flow of crust and mantle beneath the plateau and its effect on the metallogenesis and the Neogene climate have been the subjects of many scientific investigations (e.g., Yin and Harrison, 2000; Tapponnier et al., 2001; Yin, 2006; Xu et al., 2007a; Clift et al., 2008; Royden et al., 2008; Hou and Cook, 2009; Hou et al., 2009; Liou et al., 2009a; Searle et al., 2011; Chen et al., 2012; Zhang and Santosh, 2012). However, due to its large size, high elevation, and remoteness, as well as the complexities of the styles of deformation, metamorphism and magmatism caused by the multistage ocean-continent and continent–continent convergence, the geology of the Himalayan–Tibetan orogen is still not well understood, particularly within the interior domains (Guynn et al., 2012). Furthermore, the older geological history of the terranes that make up the orogen is obscured by the paucity of basement exposures and the predominance of supracrustal assemblages that are late Paleozoic or younger (e.g., Pan et al., 2004, 2006; Guynn et al., 2012). The precise timing and specific mechanisms of the various magmatic, metamorphic, and tectonic processes in response to the multistage orogenesis in this region thus remains poorly constrained (Pan et al., 2012; Zhu et al., 2012a).

As the main tectonic component of the Himalayan–Tibetan orogen, the Lhasa terrane, located immediately north of the Indus–Yarlung Zangbo suture zone (Fig. 1) has received much attention as it preserves records of the entire history of the orogeny. Most of the previous studies were focused on the Mesozoic and Cenozoic igneous rocks in this region, which form huge, multiple volcanic/plutonic arcs, cored by the Kohistan–Ladakh and Trans-Himalayan (Gangdese) batholiths (e.g., Bard, 1983; Burg and Chen, 1984; Bignold and Treloar, 2003; Chung et al., 2003, 2005, 2009; Ding et al., 2003; Hou et al., 2004, 2009; Pan et al., 2004; Mo et al., 2005, 2007, 2008; Chu et al., 2006; He et al., 2007; Wen et al., 2008a, b; Chiu et al., 2009; Ji et al., 2009a; Khan et al., 2009; Zhao et al., 2009; Zhu et al., 2009a,

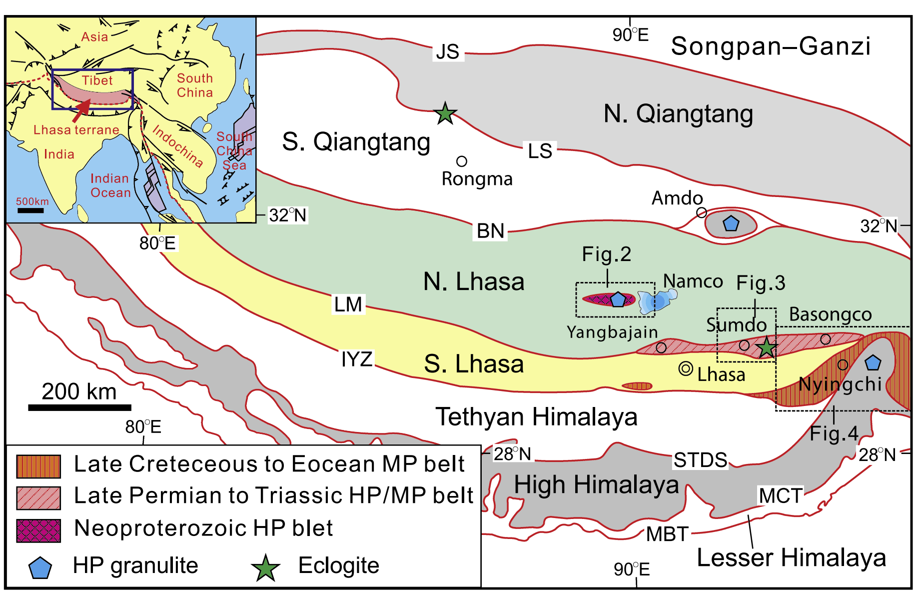


**Fig. 1.** Simplified geological map of the Himalayan–Tibetan orogen, showing the major metamorphic belts of the Lhasa terranes. Suture zones: JS—Jinsha; LS—Longmu Tso-Shuanghu; BN—Bangong–Nujiang; LM—Luobadui–Milashan; IYZ—Indus–Yarlung Zangbo; Fault zones: STDS—Southern Tibetan detachment system; MCT—Main Central thrust; MBT—Main Boundary thrust.