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Article

Neoproterozoic magmatism in eastern Himalayan terrane

Yuhua Wang [a,b,c,*], Lingsen Zeng [a], Li-E Gao [a], Chunli Guo [d], Kejun Hou [d], Lifei Zhang [c], Wei Wang [e], Huiyi Sun [f]

[a] Institute of Geology, Chinese Academy of Geological Sciences, Beijing 100037, China
[b] Key Lab of Submarine Geosciences and Prospecting Techniques, Ministry of Education, and College of Marine Geosciences, Ocean University of China, Qingdao 266100, China
[c] Key Laboratory of Orogenic Belts and Crustal Evolution, School of Earth and Space Sciences, Peking University, Beijing 100871, China
[d] Institute of Mineral Resources, Chinese Academy of Geological Sciences, Beijing 100037, China
[e] Institute of Geology, China Earthquake Administration, Beijing 100029, China
[f] Beijing SHRIMP Centre, Chinese Academy of Geological Sciences, Beijing 100037, China

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ABSTRACT

Geochronological investigation on gneisses of granitic to leucogranitic compositions in Cuona, south Tibet, reveal that their protoliths formed at 808.8 ± 7.9–816.4 ± 3.4 Ma and 855.8 ± 7.0 Ma, respectively. Zircon rims from the granitic gneiss record a metamorphic age of 739.4 ± 4.3 Ma. Lu-Hf isotopic analyses on zircon grains with Neoproterozoic ages yield negative $\varepsilon_{Hf}(t)$ values from −9.0 to −4.2, and the corresponding two-stage Hf model ages are 1965–2228 Ma. Whole-rock geochemical data indicate that all granitic gneisses are K-riched calc-alkali series. These new data together with literature data show that (1) the Himalayan terrane experienced an episode of Neoproterozoic magmatism at 850–800 Ma; (2) the Neoproterozoic magma of granitic compositions were derived from partial melting of ancient crusts, possibly due to the thermal perturbation related with the breakup of the Rodinia supercontinent.

1. Introduction

The Himalayan orogenic belt, a typical example of continent–continent collisional orogen worldwide, hosts a large number of granitoids (granitic gneiss and leucogranites) with different ages and different geochemical characteristics [1–20]. These rocks provide an important opportunity to investigate the tectonic framework and evolution of Himalayan terrane. Insights acquired from studies on various types of granitic rocks might be applied to other orogenic belts to promote our understanding on the magmatic as well as metamorphic reactions associated with the collisional processes.

A large number of previous studies [21–25] have been focused on the geochemical nature of rocks in the Lesser Himalayan Sequence (LHS), the Greater Himalayan Crystalline Sequence (GHC), and the Tethyan Himalayan Sequence (THS), intending to address and test the tectonic models of their tectonic settings and relationships. The LHS are mainly composed of thick Precambrian to late Lower Cambrian rocks and overlying Permian and younger rock strata. The THS mainly comprise late Proterozoic to Eocene sedimentary rocks. The GHC are located between LHS and THS and separated by the Main Central Thrust (MCT) to the south and Southern Tibet Detachment System (STDS) to the north. It comprises meta-sedimentary and meta-igneous rocks with protolith ages ranging from late Proterozoic to early Cambrian. The original deposit relationship between THS and LHS, as well as the protolith of GHC is still an outstanding issue that is hotly debated. Three models have been proposed to explain the tectonic relationships of the three tectonic units. Such models include: (1) successive continental margin model (Model-1), all three tectonic units constitute a continuous passive continental margin sequence of northern Indian continent [26–30]; (2) crystalline rock axis model (Model-2), LHS and THS represent individual sedimentary basin separated by the basement of GHC [31,32]; and (3) accreted terrane model (Model-3), the GHC is an allochthonous crustal segment that was accreted onto northern Indian margin during late Cambrian to early Ordovician, whereas the THS represents the overlying sedimentary strata [21]. Different from Model-3, both Model-1 and -2 predict that LHS, GHC, and THS should experience similar tectonic processes before late Cambrian to early Ordovician. Documenting the granitic gneisses with similar protolith age and geochemical nature throughout the three tectonic units could provide important constraints to test models as outlined above.

Previous studies have shown that the Himalayan terrane experienced a major episode of pan-African to Caledonian magmatism represented by the widespread granitic gneisses with protolith

* Corresponding author.
E-mail address: wangyuhua87@163.com (Y. Wang).

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ages ranging from ~520 to ~480 Ma [14,33–41]. All these granites experienced Cenozoic metamorphism and occur as typical augen granitic gneiss [39]. For example, the protolith of augen granitic gneiss in Yardoi area formed at 518.4 ± 8.3 Ma (zircon U-Pb age) with a metamorphic age of 47.6 ± 8.3 Ma [39]. In addition, the augen granitic gneiss in Yadong formed at 512.0 ± 10.0 Ma and experienced an episode of metamorphism at 27.0 ± 1.2 Ma [39]. Recent studies have documented that zircon grains in the Cenozoic Himalayan leucogranites frequently contain inherited magmatic zircon grains with ages of ~520–480 Ma and 800–900 Ma [42,43], implying that the source regimes for the Cenozoic leucogranites contain not only the late Cambrian to early Ordovician magmatic components but also the Neoproterozoic magmatic components. Indeed, some of the protoliths (e.g. garnet amphibolite or retrograded eclogite and some of granitic gneisses) within the GHC have been suggested to be formed in the Neoproterozoic [22,34,39,44–49]. However, most of the available studies do not provide geochemical data to constrain the nature of Neoproterozoic magmatism.

In this contribution, we present whole-rock element and zircon U-Pb dating data on a series of granitic gneiss from Mama Valley, Cuona, southern Tibet. These new data together with literature data show that (1) the Himalayan terrane experienced an episode of Neoproterozoic magmatsim at 850–800 Ma; (2) melting of ancient crustal rocks, possibly due to the thermal perturbation associated with the breakup of the Rodinia supercontinent, might be the primary mechanism for the formation of Cuona Neoproterozoic granitoids.

2. Geological setting and sample description

The Himalayan orogen is bounded by the Main Front Thrust (MFT) to the south and the Yalung-Tsangpo Suture (YTS) to the north. It can geographically be subdivided into three tectonic units (Fig. 1b) separated by South Tibetan Detachment System (STDS) and Main Central Thrust (MCT) from the north to the south, respectively. GHC rocks occurred south of Cuona and are separated by STDS from THS (Fig. 1c). The hanging wall of STDS is late Triassic sandstone and slate and intruded early Cretaceous diabase dike swarm [50] and Miocene leucogranites [6,7], whereas the footwall is the GHC. GHC rocks in the Cuona area consist of intensively deformed granitic gneisses, sillimanite-garnet-biotite gneisses, cal-silicates, and garnet-graphite schists (Fig. 1c) [51].

Samples investigated in this study were collected from a transect extending from Cuona and down to Mama Valley (Fig. 1c). Garnet-bearing granitic gneiss (T0713-A) comprise quartz, K-feldspar, plagioclase, biotite, muscovite, garnet, kyanite and sillimanite, with minor apatite, zircon, and monazite (Fig. 2a). Kyanite grains occur as inclusion in garnet and plagioclase, and some biotite grains were transformed into sillimanite (Fig. 2b). Granitic gneisses (T0713-1 and -2, T0713-GN) consist of quartz, plagioclase, biotite, muscovite, K-feldspar, kyanite, and sillimanite, with accessory phases of monazite, apatite, zircon, and sulfide. Locally, these samples again show textures of kyanite-sillimanite transformation (Fig. 2c, d). Samples T0713-3 and -4 are metapelite and consist of quartz, K-feldspar, plagioclase, garnet, and biotite, (Fig. 2e). Leucogranitic gneiss (T0713-G) consists of quartz, plagioclase, K-feldspar with minor muscovite and biotite (Fig. 2f).

3. Analytical methods

3.1. Major and trace element analysis

Bulk rock major elements were obtained by X-ray fluorescence (XRF) with analytical uncertainties <5%. Trace and rare earth element (REE) were analyzed by inductively coupled plasma mass spectrometry (ICP-MS). Both experiments were conducted at the National Research Center for Geoanalysis, Chinese Academy of Geological Sciences (CAGS), Beijing. Analytical uncertainties for trace and rare earth elements are 10% for those with abundances

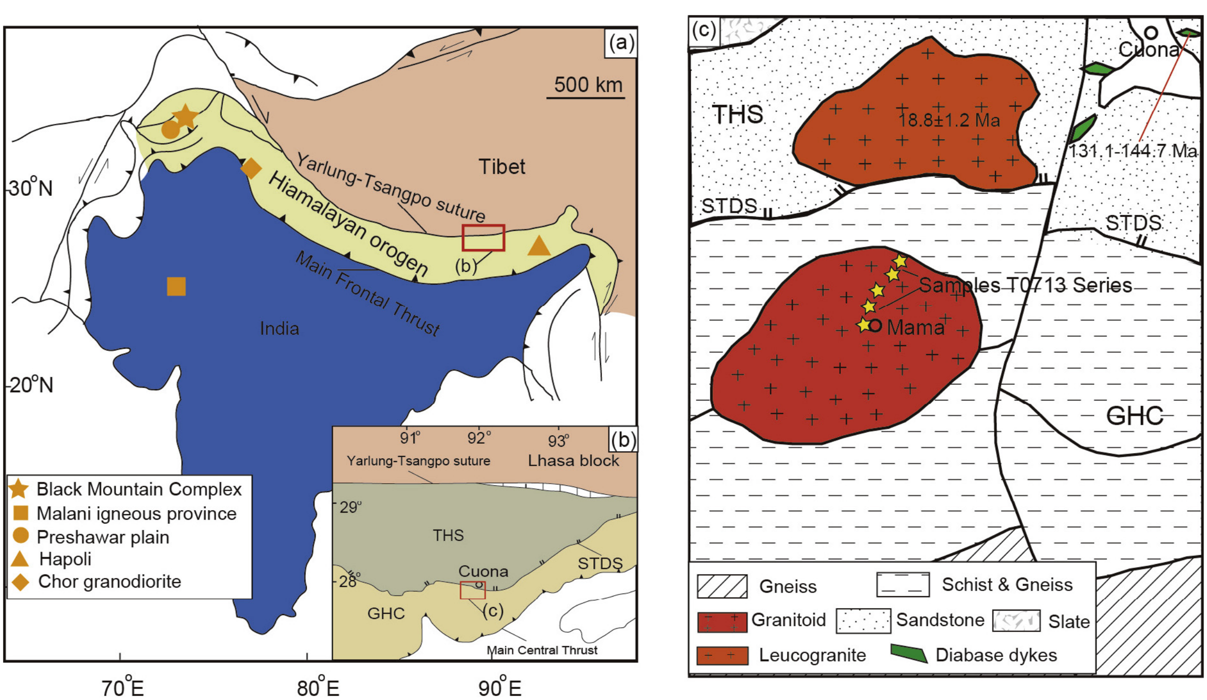

Fig. 1. (a) Simplified geological map of Tibetan Plateau, Himalayan orogen and Indian craton showing the Neoproterozoic (800–900 Ma) magmatic rocks occurred in the Himalayan terrane as well as in the Indian craton. (b) Simplified geological map of the eastern Himalayan orogen showing the location of studied area. (c) Geological map of Cuona area (Modified from Xu et al. [51] and unpublished geological investigation report of Yunnan Province, 2005). Note that the leucogranite, southwest of Cuona, formed at 18. 8 ± 1.2 Ma [6,7] and a number of dolerite dikes formed at ~131–144 Ma [50].