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Early Mesozoic retrograded eclogite and mafic granulite from the Badu Complex of the Cathaysia Block, South China: Petrology and tectonic implications

Lei Zhao [a,b], Mingguo Zhai [a,c], M. Santosh [d,e], Xiwen Zhou [b,*]

[a] State Key Laboratory of Lithospheric Evolution, Institute of Geology and Geophysics, Chinese Academy of Science, Beijing 100029, China
[b] Institute of Geology, Chinese Academy of Geological Sciences, Beijing 100037, China
[c] Key Laboratory of Mineral Resources, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China
[d] School of Earth Sciences and Resources, China University of Geosciences Beijing, 29 Xueyuan Road, Beijing 100083, China
[e] Centre for Tectonics, Resources and Exploration, Department of Earth Sciences, University of Adelaide, SA 5005, Australia

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ABSTRACT

The high-grade metamorphic terrane in the Badu region along the northeastern Cathaysia Block in South China preserves retrograded eclogites and mafic granulites. Here we present the petrology, mineral phase equilibria and P-T conditions based on pseudosection computations, as well as zircon U-Pb ages of these rocks. Mineral textures and reaction relationships suggest four metamorphic stages for the retrograded eclogite as follows: (1) eclogite facies stage (M1), (2) clinopyroxene retrograde stage (M2), (3) amphibole retrograde stage (M3), and (4) chlorite retrograde stage (M4). For the mafic granulite, three stages are identified as: (1) plagioclase-absent stage (M1), (2) granulite facies stage (M2) and (3) amphibolite facies stage (M3). Metamorphic evolution of both of the rock types follows clockwise *P-T* path. Conventional geothermometers and geobarometers in combination with phase equilibria modelling yield metamorphic *P-T* conditions for each metamorphic stage for the eclogite as 500–560 °C, 23–24 kbar (M1), 640–660 °C, 14–16 kbar (M2), 730–750 °C, and 11–13 kbar (M3). The chlorite retrograde stage (M4) is inferred to have occurred at lower amphibolite to greenschist facies conditions. Phase equilibria modelling of the mafic granulite shows *P-T* conditions for each metamorphic stage as 600–720 °C, >13 kbar (M1) and 860–890 °C, 5–6 kbar (M2) and M3 at amphibolite facies conditions. LA-ICPMS zircon U-Pb dating and trace element analysis show that the high pressure metamorphism occurred at 245–251 Ma. Protolith age of the mafic granulite is 997 Ma, similar to that of the mafic to ultramafic rocks widely distributed in the Cathaysia Block and also along the Jiangnan belt. Subduction of ancient oceanic lithospheric materials (or crustal thickening) during Mesozoic and formation of eclogites suggest that the Cathaysia Block was perhaps in the Tethyan oceanic domain at this time. The granulite formation might have been aided by Mesozoic mafic magma underplating associated with lithospheric delamination, heating and retrogression of the eclogite accompanied by rapid uplift.

1. Introduction

The South China Block (SCB) covering the southern and southeastern parts of China is an important constituent of the Eurasia continent. It is believed that the SCB is formed through the amalgamation of the Yangtze and Cathaysia Blocks during Neoproterozoic along the Jiangnan orogen (Fig. 1, Chen et al., 1991; Li et al., 2009; Shu et al., 1994; Wang et al., 2013e; Zhang et al., 2015a; Zhao, 2015). In addition to the Neoproterozoic accretionary event, two Phanerozoic tectonothermal events during Paleozoic (also known as the Kwangsian, the Chinese Caledonian) and early Mesozoic (Indosinian) also extensively influenced the SCB, resulting in strong deformation, extensive magmatism and high grade metamorphism (Guo et al., 1989; Jiang et al., 2015; John et al., 1990; Li et al., 2012a; Li and Li, 2007; Mao et al., 2013; Ren and Chen, 1989; Shu et al., 2008b, 2014; Wang et al., 2013d; Yu et al., 2014). In the Cathaysia Block, granulite facies metamorphism and charnockite magmatism have been recorded along the Paleozoic belt (Fig. 1) (Wan et al., 2010; Wang et al., 2013a; Yu et al., 2003, 2005, 2014; Zhao et al., 2015b). However, Mesozoic high grade metamorphism in this block has only been documented in few places (Fig. 1) and the metamorphic grade reported is mostly amphibolite facies (Wang et al., 2012; Zhao et al., 2015c). Also, previous studies on the Mesozoic Cathaysia mainly focused on the geochronology and geochemistry of the widespread Mesozoic granites and the strong deformation recorded by the pre-Triassic rocks (Chen et al., 1991; Gupta et al., 1989; Hsü et al., 1988;

* Corresponding author at: Institute of Geology, Chinese Academy of Geological Sciences, No. 26, Baiwanzhuang Road, Beijing 100037, China.
E-mail address: xwzhou@cags.ac.cn (X. Zhou).

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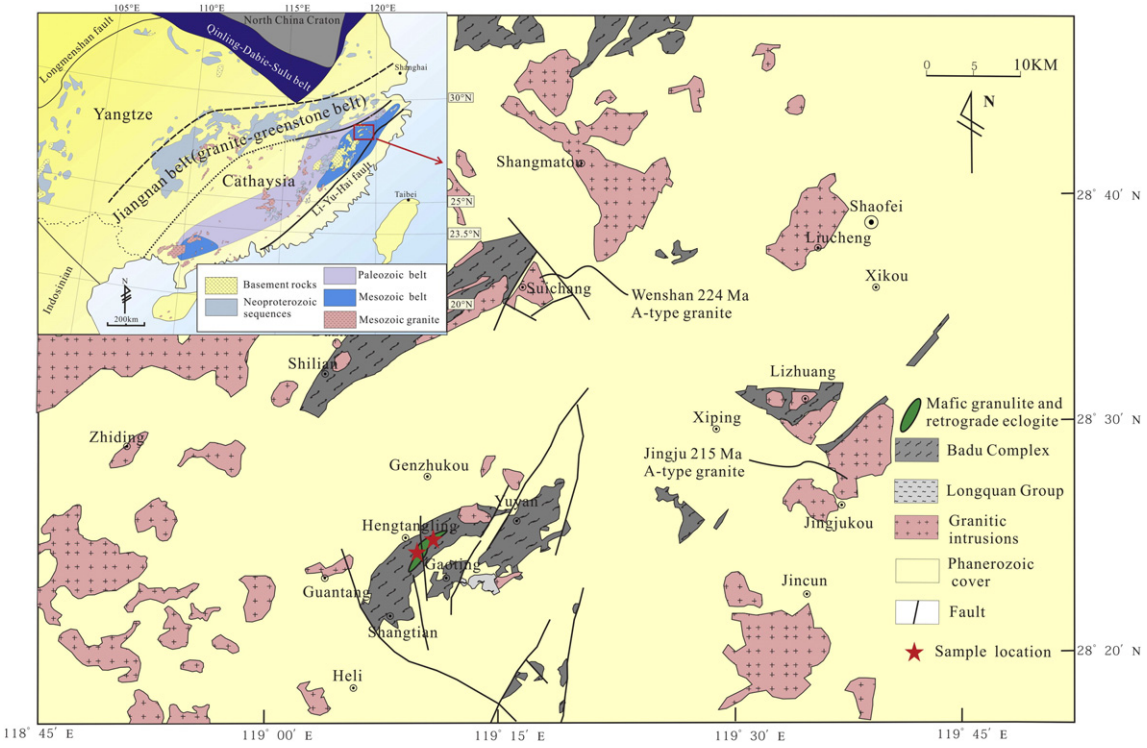

Fig. 1. Simplified geological map of South China and the north part of Badu region.
The maps are modified after Zhao and Zhou (2012) and Zhao et al. (2015b and 2015c).

Rowley et al., 1989; Guo et al., 1989; John et al., 1990; Li et al., 2012b; Li and Li, 2007; Mao et al., 2013; Ren and Chen, 1989; Wang et al., 2012, 2013c; Zhao et al., 2013; Zhou et al., 2006; Zhu et al., 2013).

Although extensive studies have been carried out on the Mesozoic tectonothermal event, the mechanism and geodynamic settings remain under debate. Hsü et al. (1988) invoked a continental collisional model along the Jiangnan belt to explain the Mesozoic deformation, magmatism and metamorphism. However, this model was challenged by many geologists (Chen et al., 1991; Gupta et al., 1989; Rowley et al., 1989). John et al. (1990) proposed that the whole southeastern China Block (Cathaysia Block) was formed by the serial collision of microcontinental blocks. Zhou et al. (2006) argued that this episode of tectonothermal event was the result of tectonic transition from continent-continent collision within the broad Tethyan oceanic domain to the subduction of Paleo-Pacific plate. Li and Li (2007) suggested that the subduction of Paleo-Pacific plate might have started during Mesozoic and they used the flat-slab subduction model to account for the Mesozoic tectonothermal event in the SCB. Wang et al. (2013c) suggested that the progressive subduction and collision of the Indochina plate with the SCB and the contemporaneous interaction of the SCB with the North China Craton might have both affected the Cathaysia Block.

In order to better understand this episode of tectonothermal event of the Cathaysia Block and that of the SCB, we present the first coherent studies from Mesozoic retrograded eclogite and mafic granulite which were newly identified from the Badu region (Fig. 1). Detailed mineral phase equilibria, reaction textures, mineral chemistry, *P-T* estimates and LA-ICPMS zircon U-Pb ages are presented in this study. Petrography and phase equilibria modelling show that the mafic granulite might also be retrograded eclogite. Our discovery and the new data provide insights into the Mesozoic tectonic processes in the Cathaysia Block, from subduction of cold plates, to high-pressure metamorphism, exhumation and retrogression.

2. Geological background

The Badu complex is located in the northeastern part of the Cathaysia Block (Fig. 1) bounded to the northwest by the Jiangshao fault and to the southeast by the Li-Yu-Hai (Lishui-Yuyao-Haifeng) fault. Jurassic and Cretaceous volcano-sedimentary rocks as well as some Mesozoic granites which experienced little or no deformation constitute the dominant Phanerozoic units in this region (Hu et al., 1991; Zhejiang, 1989; Zhao, 2012, 2014). Precambrian rocks are sporadically exposed and are further divided into the Badu, Chencai and Longquan Groups (Hu et al., 1991; Zhejiang, 1989). The Badu Complex (Group) is mainly composed of Paleoproterozoic metasedimentary rocks and some granitoid intrusions which are generally considered to represent the basement sequences of the Cathaysia Block (Xia et al., 2012; Yu et al., 2009, 2012; Zhao et al., 2014, 2015c). The Badu Complex experienced metamorphic reworking during Paleoproterozoic (Yu et al., 2009, 2012) and was also involved in the Mesozoic tectonothermal event. Metamorphic minerals like garnet, sillimanite and graphite are pervasive in the metasedimentary rocks of the Badu Complex. Some Neoproterozoic mafic rocks were also discovered from the Paleoproterozoic Badu Complex and this is usually interpreted to be related with the Mesozoic tectonothermal event that resulted in the intermixing of rock units belonging to different ages (Yu et al., 2009; Zhao et al., 2015c). The Longquan Group records only the Mesozoic metamorphic reworking. The Chencai Group occurs to the northeast of the Badu region and is mainly composed of meta-pelitic rocks which have undergone Paleozoic high grade metamorphism and anatexis (Zhao et al., 2015b).

Rocks belonging to the Badu Complex were at the beginning termed as part of the Chencai Group (Zhejiang, 1989). Hu et al. (1991) separated these rocks from the Chencai Group and renamed them as the Badu Group because these rocks record higher metamorphic grade and are older as compared to the rocks from type localities of the Chencai Group. Zhao and Sun (1994) studied the metamorphic