Journal of Asian Earth Sciences 125 (2016) 100–116

Contents lists available at ScienceDirect

Journal of Asian Earth Sciences

journal homepage: www.elsevier.com/locate/jseaes

Full length article

Amphibole-bearing migmatite in North Dabie, eastern China: Water-fluxed melting of the orogenic crust

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ARTICLE INFO

Article history:
Received 11 March 2016
Received in revised form 9 May 2016
Accepted 10 May 2016
Available online 11 May 2016

Keywords:
Water-fluxed melting
Amphibole
Migmatite
Geochemistry
North Dabie

ABSTRACT

Amphibole-bearing migmatites from the North Dabie Zone in the Dabie Mountains were investigated in order to constrain the partial melting process. These migmatites are characterized by large euhedral poikilitic amphiboles with abundant inclusions of plagioclase, biotite, and quartz in leucosome and melanosome. The amphiboles show large variations in REE compositions, which is interpreted as the result of equilibration with different melts during melting and crystallization. Hornblende-plagiocase thermobarometry indicates that the migmatites formed at P-T conditions of ~700–750 °C and 5 kbar, suggesting partial melting of a biotite + plagioclase + quartz-bearing protolith under water-fluxed conditions. The leucosomes range from tonalitic to granitic in composition having higher SiO_2, Na_2O, Sr, and Ba contents than the mesosome, but lower contents of CaO, FeO, MgO, TiO_2, and MnO_2. The granitic leucosomes are enriched in Ba, Rb, and K_2O compared to the tonalitic leucosomes. The leucosomes have variable rare earth element patterns, which is attributed to different degrees of amphibole entrainment into the leucosome and feldspar fractionation during partial melting.

1. Introduction

The process of crustal anatexis is fundamental during the collision of continents (e.g., Foster et al., 2001; Brown, 2001a) and has significant impact on the rheology of the orogenic crust (Brown, 2001a; Whitney et al., 2003; Vanderhaeghe, 2009). During the initial stage of anatexis, melts are present at grain boundaries and result in a drastic weakening of the crust (Rosenberg and Handy, 2005), which effectively promote the deformation of the crust and may eventually lead to orogenic collapse (Rey et al., 2001; Vanderhaeghe and Teyssier, 2001a, 2001b). Anatectic melts not only influence the thermal conditions of the crust by their low thermal diffusivity (Whittington et al., 2009), but also play a profound role in the internal chemical differentiation of the Earth crust (Sawyer, 2010; Sawyer et al., 2011; Brown, 2010).

Crustal melting is driven by dehydration reactions involving the breakdown of a hydrous phase, such as muscovite, biotite or amphibole (Sawyer et al., 2011; Brown, 2010). The addition of water, known as water-fluxed melting, increases the amount of melt (Weinberg and Hasalová, 2015). Water-fluxed melting however is thought to be limited because of the low water content in the middle or lower crust (Clemens and Vielzeuf, 1987; Brown, 2010). On the other side, migmatites with high leucosome fractions that formed under P-T conditions below the hydrate phase solidus have been regarded as products of water-fluxed melting (Mogk, 1992; Berger et al., 2008; Sawyer, 2010; Weinberg and Hasalová, 2015).

Amphibole-bearing migmatites frequently occur in orogenic belts; they are regarded as products of anatectic melting (Slagstad, 2005; Berger et al., 2008; Cruciani et al., 2008, 2014; Lee and Cho, 2013; Wang et al., 2013; Reichardt and Weinberg, 2012). It is generally accepted that amphibole is the product of incongruent melting that was triggered by a water fluxed melt regime (Slagstad, 2005; Berger et al., 2008; Cruciani et al., 2008). Fractionation of amphibole has significant impact on the melt composition and can give rise to high Sr/Y and $(La/Yb)_N$ signatures, similar as observed in Archean TTGs and adakites (Tiepolo and Tribuzio, 2008; Reichardt and Weinberg, 2012).

Amphibole-bearing migmatites are widespread in the North Dabie Zone of the Dabie orogen. They provide an excellent opportunity to investigate the generation and evolution of this specific migmatite type. Here we present the results of an integrated petrologic, chemical and mineralogical study of amphibole-bearing migmatites from the North Dabie Zone. The results help to better

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http://dx.doi.org/10.1016/j.jseaes.2016.05.018
1367-9120/

understand the partial melting regime, the nature of the protolith and the role of amphibole on leucosome composition.

2. Geological setting

The Dabie orogenic belt was formed by the continental collision between the North China and the Yangtze blocks during the Triassic (Okay et al., 1993; Zhang et al., 1996; Li et al., 1993; Meng and Zhang, 2000). The orogenic belt can be divided into five fault-bounded tectonic zones with different metamorphic grades which are, from north to south (Zheng et al., 2005): (1) the Beihuaiyang low-grade metamorphic zone; (2) the North Dabie high-T ultrahigh-pressure (UHP) migmatite zone; (3) the Central Dabie medium-temperature UHP zone; (4) the South Dabie low temperature UHP zone and (5) the Susong low-temperature HP zone. All these zones were intruded by Cretaceous granitoids (Zhao et al., 2007; Wang et al., 2007; Xu et al., 2007; He et al., 2011). Coesite and micro-diamond bearing eclogites and gneisses demonstrate that the Dabie continental crust was subducted to the mantle depth during the collision (Xu et al., 1992; Wang et al., 1998). Detailed geochronological studies have shown that the UHP metamorphism occurred during the Triassic between 240 and 226 Ma (e.g., Ayers et al., 2002; Liu et al., 2007). The crust was exhumed to shallow crustal levels before the Early Jurassic. Zircon U-Pb isotopic dating gave ages mostly of 800–700 Ma for protoliths of eclogites and gneisses (e.g., Zheng et al., 2009). These ages bracket the timing of bimodal magmatism along the northern and western margins of the Yangtze block related to the breakup of Rodinia (Zheng et al., 2004, 2005, 2006; Zhao et al., 2008).

The North Dabie Zone (NDZ), located in the northern part of the Dabie Mountain (Fig. 1), is bounded by the Xiaotian-Mozitan shear zone in the north, the Wuhe-Shuihou shear zone in the south, and the Shangcheng-Macheng shear zone in the west (e.g., Faure et al., 2003; Hacker et al., 1998; Zheng et al., 2005). It is mainly composed of dioritic to granitic orthogneisses, migmatites and Early Cretaceous granites with minor eclogites, amphibolites, marbles, quartzites, and mafic to felsic granulites (Chen et al., 2002; Zhang et al., 2002; Bryant et al., 2004). Geochronological studies have demonstrated that the orthogneiss and migmatite precursors are mainly Neoproterozoic in age and this finding was taken as evidence that, prior to collision, the NDZ was part of the Yangtze block. In the NDZ, numerous Triassic metamorphic ages have been obtained for various lithologies by zircon U-Pb and mineral Sm-Nd isotopic dating (e.g., Li et al., 1993; Liu et al., 2007, 2011). Coupled with the diamond and coesite inclusions found in eclogites and gneisses, it has been suggested that the NDZ experienced UHP metamorphism during Triassic deep subduction of the Yangtze block, similar to the South and Central Dabie Zones. However, comprehensive studies of petrology, geochemistry and geochronology have shown that the three UHP metamorphic zones were largely decoupled during subduction and exhumation (Li et al., 2003; Liu et al., 2007). Based on the crustal structure and tectonic model, the NDZ was located at the middle crustal level beneath the Central Dabie zone prior to Cretaceous magmatism (Zhao et al., 2008).

Cretaceous thermal overprinting and magmatism played a crucial role to the present architecture of the NDZ. The early Cretaceous post-collisional magmatism in the NDZ is dominated by voluminous granitoids and minor mafic-ultramafic rocks and they intruded into UHP orthogneiss. Based on ages and geochemical discrepancy, the granitoids can be divided into two groups. The early granitoids (145–130 Ma) show high Sr/Y and $La/Yb_{(N)}$ ratios with positive Eu and Sr anomalies, which are generated from partial melting of thickened orogenic lower crust; while the later

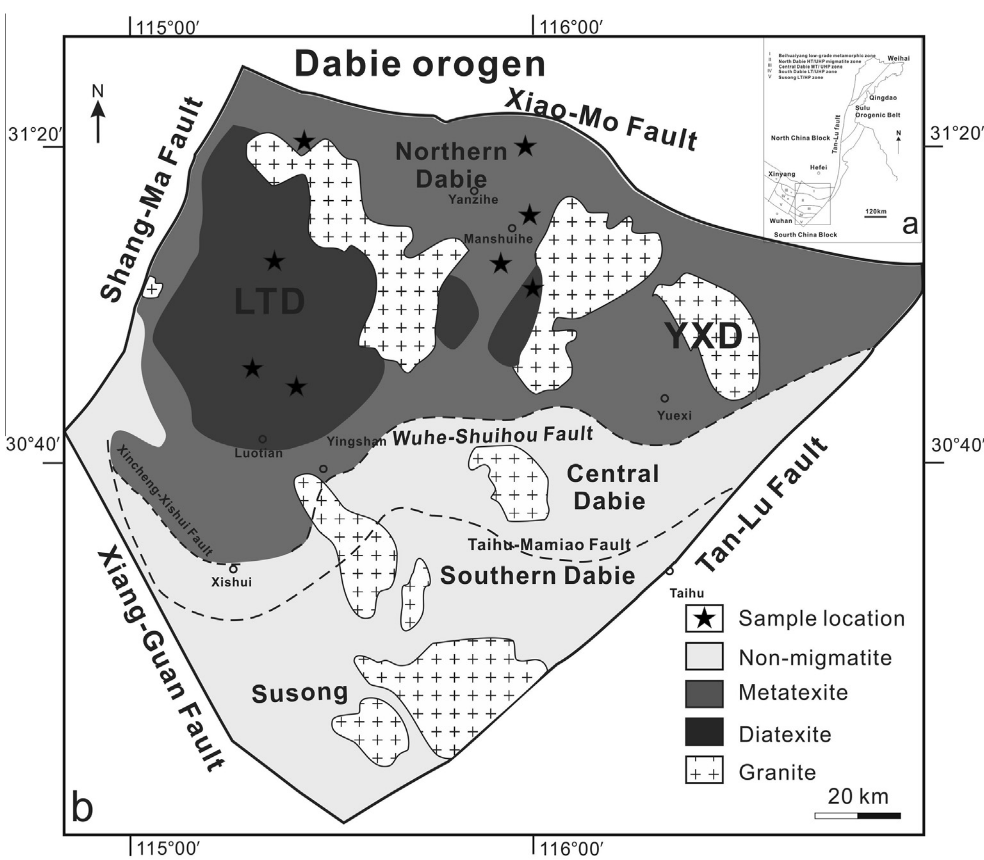

Fig. 1. Geological sketch map of the North Dabie Zone. LTD - Luotian dome; YXD - Yuexi dome.