Journal of Asian Earth Sciences 73 (2013) 520–539

Contents lists available at SciVerse ScienceDirect

Journal of Asian Earth Sciences

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

Tectonic evolution of high-grade metamorphic terranes in central Vietnam: Constraints from large-scale monazite geochronology

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ARTICLE INFO

Article history:
Received 19 December 2012
Received in revised form 19 April 2013
Accepted 8 May 2013
Available online 28 May 2013

Keywords:
U–Th–Pb monazite age
Pressure–temperature conditions
Kontum Massif
Hai Van Migmatite Complex
Truong Son Belt
Central Vietnam

ABSTRACT

Several metamorphic complexes in Southeast Asia have been interpreted as Precambrian basement, characterized by amphibolite to granulite facies metamorphism. In this paper, we re-evaluate the timing of this thermal event based on the large-scale geochronology and compositional variation of monazites from amphibolite to granulite facies metamorphic terranes in central Vietnam. Most of the samples in this study are from metamorphic rocks ($n = 38$) and granitoids ($n = 11$) in the Kontum Massif. Gneisses ($n = 6$) and granitoids ($n = 5$) from the Hai Van Migmatite Complex and the Truong Son Belt, located to the north of the massif, were also studied. Two distinct thermal episodes (245–230 Ma and 460–430 Ma) affected Kontum Massif gneisses, while a single dominant event at 240–220 Ma is recorded in the gneisses from the Hai Van Complex and the Truong Son Belt. Monazites from granitoids commonly yield an age of 240–220 Ma. Mesoproterozoic ages (1530–1340 Ma) were obtained only from monazite cores that are surrounded by c. 440 Ma overgrowths. Thermobarometric results, combined with concentrations of Y_2O_3, Ce_2O_3, and heavy rare earth elements in monazite, and recently reported pressure–temperature paths suggest that Triassic ages correspond to retrograde metamorphism following decompression from high- to medium-pressure/temperature conditions. Ordovician–Silurian ages reflect low-pressure/temperature metamorphism accompanied by isobaric heating during prograde metamorphism. Some samples were affected by both metamorphic events. We conclude that high-grade metamorphism observed in so-called Precambrian basement terranes in central Vietnam occurred during both the Permian–Triassic and the Ordovician–Silurian, while peraluminous granitoid magmatism is Triassic. Additionally, our preliminary analyses for U–Pb zircon age and whole-rock chemistry of granitic gneisses from the Truong Song Belt suggests the presence of the Ordovician–Silurian volcanic arc magmatism in the region. Based on the pressure–temperature–time–protolith evolutions, metamorphic rocks from central Vietnam provide a continuous record of subduction–accretion–collision tectonics between the South China and Indochina blocks: in the Ordovician–Silurian, the region was characterized by active continental margin tectonics, followed by continental collision during the Late Permian to Early Triassic and subsequent exhumation during the Late Triassic. The results also suggest that the timing of metamorphism and protolith formation as well as the geochemical features in other Southeast Asian terranes should be verified to achieve a better understanding of the Precambrian to Early Mesozoic tectonic history in Asia.

1. Introduction

The Asian continent is a collage of microcontinents including the North China, South China, Tarim, Indochina, Shan-Thai, and West Burma blocks (e.g., Metcalfe, 1996, 2006). All of these microcontinents have been considered to preserve Precambrian basement relicts composed mainly of amphibolite- to granulite-facies metamorphic rocks and granitoid intrusions. In the North and South China, and Tarim blocks, the age of the Precambrian basement has been confirmed by dating of high-grade metamorphic rocks mostly in China, Inner Mongolia, and South Korea (e.g., Kim et al., 2006; Santosh et al., 2007; Zhang et al., 2013a). However,

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http://dx.doi.org/10.1016/j.jseaes.2013.05.010

in the Indochina, Shan-Thai, and West Burma blocks located in Southeast Asia, reported Precambrian ages are very poor.

Recently, Ordovician–Silurian (e.g., Nagy et al., 2001; Lan et al., 2003; Roger et al., 2007; Usuki et al., 2009) and Permian–Triassic (Carter et al., 2001; Lepvrier et al., 2004; Osanai et al., 2004; Maluski et al., 2005; Owada et al., 2006; Nakano et al., 2007b, 2009; Sanematsu et al., 2011) ages were obtained from metamorphic and granitic rocks from the Kontum Massif in central Vietnam, which is one of the best known Precambrian basement terranes in Southeast Asia. Published Precambrian ages are only as Nd model ages (Lan et al., 2003) and detrital zircon U–Pb ages (Carter et al., 2001). Although the ages were reported from a limited area in the massif, the high-grade metamorphism has been considered as the microcontinental collision tectonics in Asia (e.g., Carter et al., 2001; Lepvrier et al., 2004; Osanai et al., 2004). However, it has been controversy regarding the timing of the collision-related high-grade metamorphism. Some studies suggest that it occurred in the Ordovician–Silurian (e.g., Maluski et al., 2005; Roger et al., 2007), whereas others indicate a Permian–Triassic (e.g., Nagy et al., 2001; Lan et al., 2003; Osanai et al., 2004, 2008), while a third option favors two high-grade events, during each of these periods (e.g., Lepvrier et al., 2008).

In this study, we carried out a regional study of U–Th–Pb monazite ages on 60 samples from the Kontum Massif, the Hai Van Migmatite Complex, and the Truong Son Belt in central Vietnam (and part of Laos) in order to (1) determine timing of the high-grade event recorded in the Kontum Massif and neighboring central Vietnam, and (2) realize the large-scale distribution of the Ordovician–Silurian and Permian–Triassic with or without Precambrian ages. We also consider (3) the tectonic setting of these periods, based on the ages, monazite chemistries, and geothermobarometric results, which provides critical insight into the role of the high-grade metamorphic terranes in Southeast Asia as well as Asian tectonics during the Precambrian to Early Mesozoic periods.

2. Geological outline

Northwest–southeast (NW–SE) trending shear zones are well developed in northern–central Vietnam, dividing the geology into several units (Fig. 1a). The Kontum Massif, situated in central Vietnam, is subdivided mainly into three complexes based on metamorphic grade: the Kannak (granulite facies), Ngoc Linh (amphibolite facies), and Kham Duc (greenschist facies) complexes (Fig. 1b). Recently, Nakano et al. (2007b) summarized the regional distribution of metamorphic rocks based on their occurrence, microstructures, and metamorphic pressure–temperature (*PT*) conditions. The Kannak Complex is composed of granulite-facies metamorphic rocks, where the eastern portion of the complex experienced lower pressure conditions than did the west. The *PT* conditions of the Ngoc Linh Complex also differ from east to west (Nakano et al., 2007b): the western Ngoc Linh Complex experienced much higher temperatures (up to granulite facies) than did the east (epidote amphibolite to amphibolite facies) (Nakano et al., 2007b). The Kham Duc Complex records greenschist- to amphibolite-facies metamorphism with moderate-pressure conditions (Nakano et al., 2009; Usuki et al., 2009). The metamorphic rocks show layering, migmatitic texture, mylonitic strong deformation, and metamorphosed dyke (see Nakano et al., 2007b in more detail). The Ordovician–Silurian and Permian–Triassic ages have been reported from the complexes (Fig. 1a).

Most of the Truong Son Belt is composed of sedimentary rock, including conglomerate, sandstone, mudstone, and limestone.

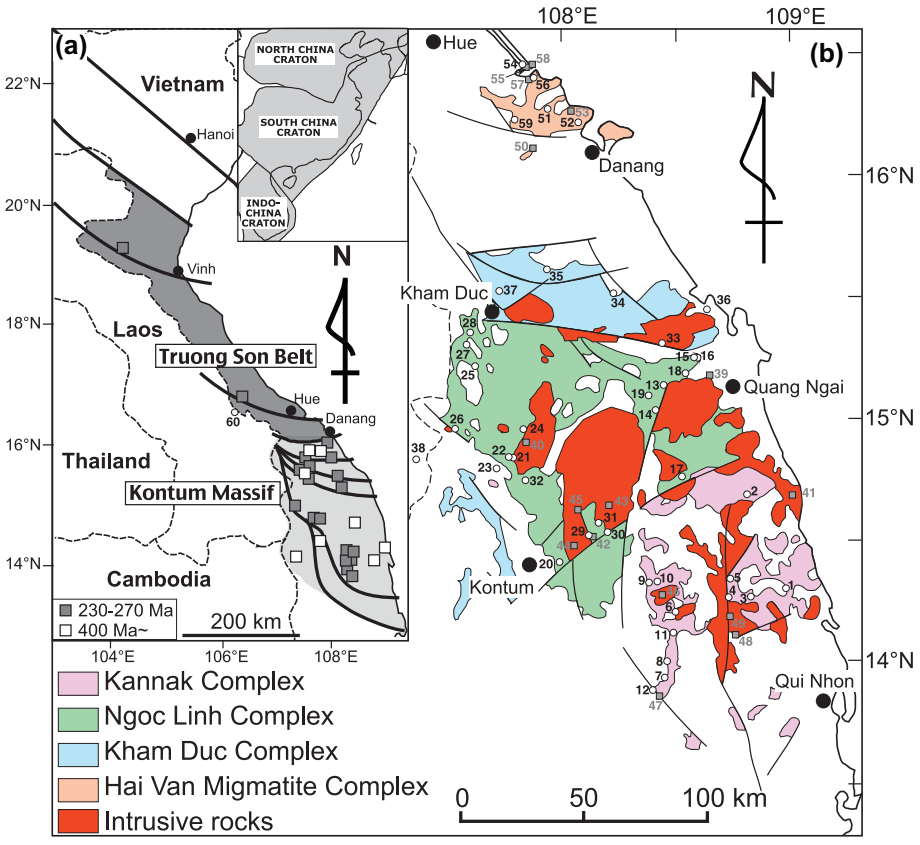

Fig. 1. Locations of the Kontum Massif and Truong Son Belt in Vietnam (a) and distributions of metamorphic and igneous rocks in the Kontum massif and the Hai Van Migmatite Complex (b). Metamorphic ages reported in previous studies (updated after Nakano et al., 2008) are shown in (a). Locations of samples analyzed in this study are also shown as open circles for metamorphic rocks and gray squares for igneous rocks, in which the reference numbers correspond to those in Table 1.