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Age and tectonic implications of Paleoproterozoic Deo Khe Granitoids within the Phan Si Pan Zone, Vietnam

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ABSTRACT

We report the first U–Pb zircon ages of 1855–1873 Ma for the Deo Khe Granitoids (DKG) in the Phan Si Pan Zone (PSPZ) of northern Vietnam. The DKG are medium-grained two-mica granitoids predominantly composed of quartz, K-feldspar, and muscovite. Trace element analyses indicate that the DKG are enriched in large ion lithophile elements but depleted in high field strength elements. Zircons from the granitoids have negative $\varepsilon_{Hf}(t)$ values ranging from −23.6 to −17.5. The magmatic zircons from the DKG have single-stage Hf model ages (T_{DM1}) that range from 3.3 to 2.8 Ga and their $\varepsilon_{Hf}(t)$ data all plot well below the evolution trend of 2800 Ma average juvenile mantle. Observed Hf model ages are contemporaneous with the emplacement of 2.90–2.84 Ga tonalite–trondhjemite–granodiorite (TTG) gneiss observed in a nearby Ca Vinh Complex, suggesting that PSPZ in northern Vietnam is a product of partial melting of Archean crust. A sequence of similar tectonic events including initial emplacement of TTG protolith at 2.8–2.9 Ga, metamorphic development of TTG gneiss at 1.9–2.0 Ga, and magmatic activity at 1.8–2.0 Ga are now recognized both in northern Vietnam and Yangtze block which we interpret to indicate basement rocks in northern Vietnam are similar to those found along southern China.

1. Introduction

The North China craton, Tarim craton, South China craton, and Indochina block are four major Precambrian geologic lithotectonic units in central and eastern Asia (Fig. 1a). The South China craton consists of the Cathaysia block to the southeast and the Yangtze block to the northwest (Fig. 1a). These five Precambrian geologic units were assembled by accretion of smaller fragments of sub-continents during the Proterozoic and Phanerozoic (e.g., Santosh, 2010; Zhao and Cawood, 2012; Zhao and Zhai, 2013; Zheng et al., 2013; Zhai, 2014). Studies that focus on characterizing the basement rocks of these ancient terranes add to our understanding of the accretion and break-up of ancient supercontinents (e.g., Rogers and Santosh, 2002, 2003, 2009; Meert, 2012; Nance et al., 2014). This study focusses on furthering the knowledge of the Precambrian basement rocks which are exposed in northern Vietnam.

The Phan Si Pan Zone (PSPZ) in northern Vietnam represents one of the oldest basement zones of the southeastern Asia (Fig. 1b). The PSPZ underlies the Cenozoic Tu Le volcanics to the southwest and the Permo-Triassic Song Da Ultramafic Complex to the northeast. Among various igneous units in PSPZ, the granitoids in Deo Khe (DKG for abbreviation) area deserve special attention because of their controversial magmatic age. The DKG are traditionally regarded as a fraction of the middle Proterozoic Xom Giau Complex based on cross-cutting relations/stratigraphy (Huu and Tien, 1977; Tri, 1977; Thuc and Trung, 1995; Son, 2012). Despite intensive geologic investigations, the age of the Xom Giau Complex is still debatable because of a general lack of high precision geochronological data (The, 1999; Nam, 2001).

The present study was intended to report petrographic descriptions, zircon U–Pb ages, and Hf-isotopic analyses of several igneous rocks in northern Vietnam for the first time. Confirmation of the existence of Paleoproterozoic rocks in northern Vietnam will provide a valuable first order constraint on the tectonic evolution of the central and eastern Asia and these results can be compared with similar studies of rocks in other major Precambrian units found across Asia (e.g., Lan et al., 2003, 2011; Trung et al., 2006; Aihara et al., 2007; Hieu et al., 2009, 2012, 2013; Kohn et al., 2010; Zhang et al., 2011; Otofuji et al., 2012; Qi et al., 2012, 2014; Jiang et al., 2013; Lai et al., 2014; Santosh et al., 2014).

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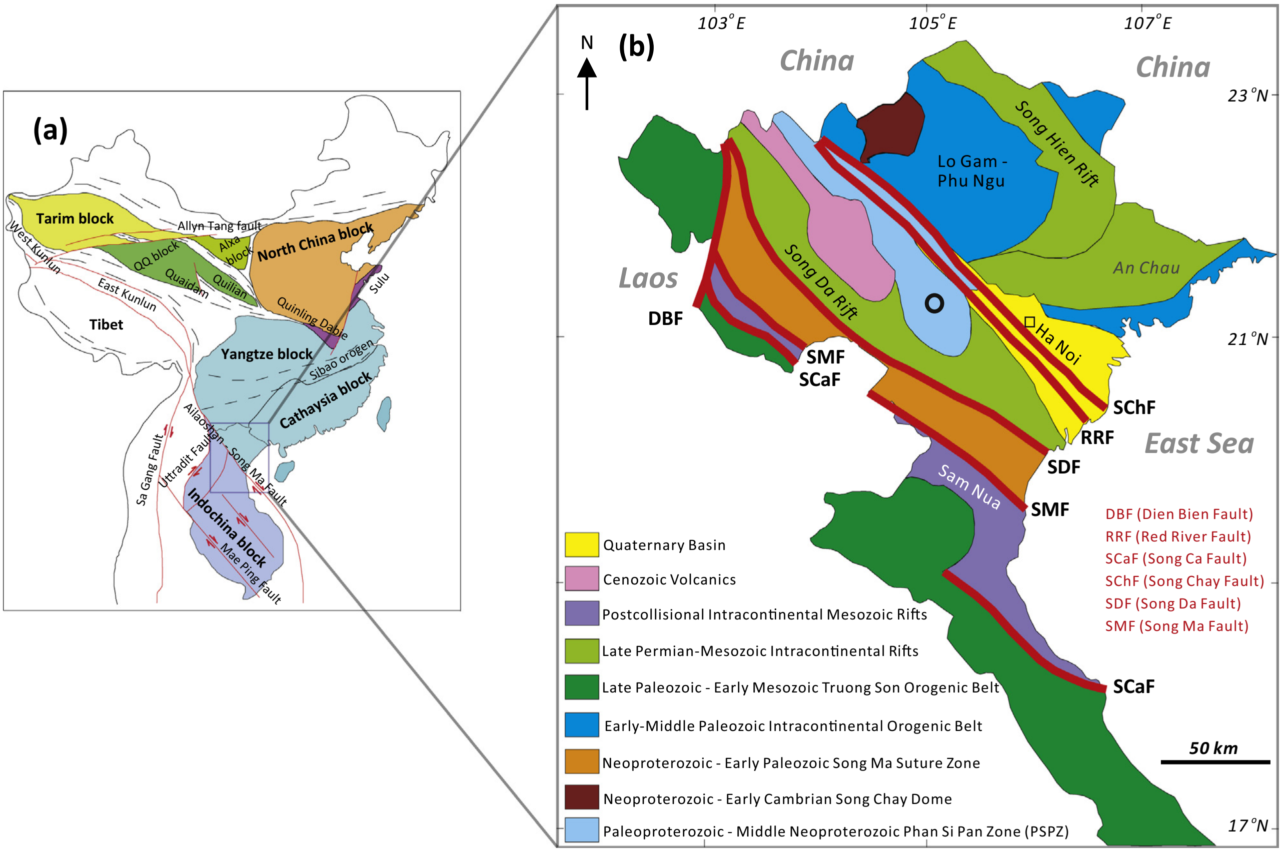

Fig. 1. (a) Major geologic terranes and tectonic framework of central and eastern Asia. (b) Simplified map of northern Vietnam (after Hieu et al., 2012) showing the six main faults (DBF: Dien Bien Fault; RRF: Red River Fault; SCaF: Song Ca Fault; SChF: Song Chay Fault; SDF: Song Da Fault; SMF: Song Ma Fault). The Phan Si Pan Zone (PSPZ) is located at the junction of the Song Chay Fault (SChF) to the northeast, the Song Da Rift to the south, and the Cenozoic Tu Le Volcanics to the southwest. A northwest-southeast trending RRF bisects the PAPZ. An open dark circle represents the location of the Deo Khe Granitoids.

2. Geology

The PSPZ in northern Vietnam is located at the junction of the Song Chay Fault (SChF) to the northeast, the Song Da Rift to the south, and the Cenozoic Tu Le Volcanics to the southwest (Fig. 1b). A northwest-southeast trending Red River Fault (RRF) bisects the PAPZ (Fig. 1b). The RRF is a 600 km long Cenozoic sinistral fault zone that developed from 27 to 22 Ma (e.g., Leloup et al., 1995; Anczkiewicz et al., 2007; Lepvrier et al., 2008; Trinh et al., 2012). As an anticlinorium, the PSPZ's nuclei are Precambrian crystalline schists and their limbs are Neoproterozoic to Paleozoic tectono-stratigraphic sequences (Tri and Khuc, 2009).

The DKG are sporadically exposed in a prolonged range over 20 km in length and 4 km in width in central PSPZ (Fig. 2). The contact between the DKG and country rocks is generally sharp and clear. Devonian limestone and Paleozoic sequences are fault-bounded with Archean or Paleoproterozoic metasedimentary rocks (Fig. 2). The 2.90–2.84 Ga tonalite–trondhjemite–granodiorite (TTG) gneiss (pink[1] colors in Fig. 2) is a few kilometers to the northeast of the DKG (orange colors in Fig. 2). Individual intrusive units of the DKG are distorted and elongated to the northwest-southeast, parallel to other major tectonic boundaries in northern Vietnam (Fig. 2). The DKG vary in areal extent from several tens of m^2 to 0.25 km^2, with associated veins of a few meters thick (Fig. 2). Although the DKG are mostly weathered (Fig. 3a), relatively fresh exposures (Fig. 3b) are available from several construction ramp sites. We collected five relatively fresh fist-sized in-situ samples for further investigations (Fig. 3c). Details of the location of the sample sites are provided (Table 1).

The DKG are medium-grained two-mica granitoids, but a coarser grained samples display a slight foliation. Major rock-forming minerals of the DKG are quartz (30–45%), K-feldspar (35–55%), plagioclase feldspar (10–25%), muscovite (5–10%), and biotite (3–5%). Biotite is dark brown to dark green and commonly replaced by chlorite. Other accessory minerals include apatite, epidote, titanite, and zircon.

Under the microscope, the freshest outcrop (V0857) shows well-grown muscovite (Fig. 4a). For weakly altered samples (V0859, V061), K-feldspar is non-perthitic orthoclase (Fig. 4b and c) and quartz is strained (Fig. 4c and d). The plagioclase is slightly deformed and wedge-shaped twins are disconnected (Fig. 4e). In somewhat altered samples (V0858, V0860), transformation from plagioclase feldspar to sericite (Fig. 4f) is observed. In these samples, the perthite texture develops as microline is replaced by orthoclase or plagioclase feldspar (Fig. 4g and h). They also show exsolution lamellae, probably as a result of ductile deformation (Fig. 4g and h).

Plagioclase feldspar is replaced by sericite and K-feldspar along the fractures or crystal edges (Fig. 4b, e and f). Plagioclase feldspars of pure igneous origin would commonly show primary twins with sharpened twin edges. Under metamorphic conditions, deformation twins develop with tapered twin ends. In the present study, deformation twins of plagioclase feldspars are absent (V0857), weakly developed (V0859, V0861), and present (V0858, V0860) (Fig. 4). We therefore tested whether the least (V0857) and most

[1] For interpretation of color in Fig. 2, the reader is referred to the web version of this article.

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