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Precambrian evolution of the Quanji Block, northeastern margin of Tibet: Insights from zircon U–Pb and Lu–Hf isotope compositions

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ABSTRACT

The Quanji Block, a cratonic fragment, has been discovered between the north Qaidam HP-UHP metamorphic belt and the Qilian orogenic belt in northwestern China. This fragment has a pre-Neoproterozoic crystalline basement overlain unconformably by Neoproterozoic, Paleozoic and Mesozoic sedimentary strata. Pervasive anatexis of the basement produced extensive leucosomes in mafic and felsic migmatites. Zircons from the leucosomes yielded upper intercept and weighted mean $^{207}Pb/^{206}Pb$ ages of ~1950 Ma, indicating that anatexis occurred in the late Paleoproterozoic, during regional high-grade metamorphism. Hf model ages (T_{DM2}) for these zircons suggest that protoliths of the felsic and mafic migmatites had crustal residence time of ~2.80 and ~2.65 Ga, respectively. The basement rocks of the Quanji Block are compositionally similar to those of the Yangtze Craton, and may have been involved in assembly of the late Paleoproterozoic global supercontinent, Columbia.

1. Introduction

Zircon is a refractory accessory mineral that is chemically and physically resistant to crustal melting, thermal reworking and alteration, thus it can withstand a variety of geological processes including weathering, erosion, transportation, deposition, metamorphism and even crustal anatexis. Because zircon has high U/Pb ratios, it is ideal for dating a variety of rocks, and its low Lu/Hf ratios (<0.01) mean that its Hf isotope composition can provide information about its source. Alteration or metamictization generally does not affect its Hf-isotopes, thus zircon is particularly useful in constraining the initial Hf isotope compositions of its parent-rock, even if this rock no longer exists and the zircon is now in a sedimentary or magmatic lithologic environment (Patchett et al., 1981; Fujimaki, 1986). The U–Pb ages and Hf isotope compositions of zircon grains provide important tools for constraining the sources of magmatic rocks and the provenance of sediments (Patchett et al., 1981; Amelin et al., 1999; Griffin et al., 2004; Davis et al., 2005; Harrison et al., 2005; Nebel-Jacobsen et al., 2005; Schmidberger et al., 2005; Flowerdew et al., 2006; Hawkesworth and Kemp, 2006; Zhang et al., 2006a,b, 2008; Zheng et al., 2006, 2007; Nebel et al., 2007).

A small continental block, the Quanji Block (QB), was recently recognized along the northern margin of the Qaidam terrane, China (Lu et al., 2002). Although numerous studies of this block have been undertaken (Zhang et al., 2000; Lu et al, 2002, 2003, 2006a,b, 2008; Xiao et al., 2004; Hao et al., 2004; Wan et al, 2006; Wang et al., 2006; Chen et al., 2007a,b; Li et al., 2007; Wang et al., 2008), the nature of its basement, timing of its multiple tectono-thermal events, and its early crustal evolution are not well constrained. Here we report U–Pb and Lu–Hf isotope compositions of zircons from leucosomes of felsic and mafic migmatites, and use these data to determine the nature of the QB basement and to constrain the timing of peak metamorphism and anatexis.

2. Geological setting

The QB is located on the northeastern margin of the Qinghai-Tibetan Plateau in western Qinghai Province, northwest China (Fig. 1). It is bounded on the south by an early Paleozoic high-pressure to ultrahigh-pressure metamorphic belt (Yang et al., 1998; Lu et al., 2002; Song et al., 2003, 2005; Zhang et al., 2001, 2005). The QB contains a medium- to high-grade metamorphic basement complex, previously included in the Dakendaban Supergroup (QBGMR, 1991), unconformably overlain by Neoproterozoic to

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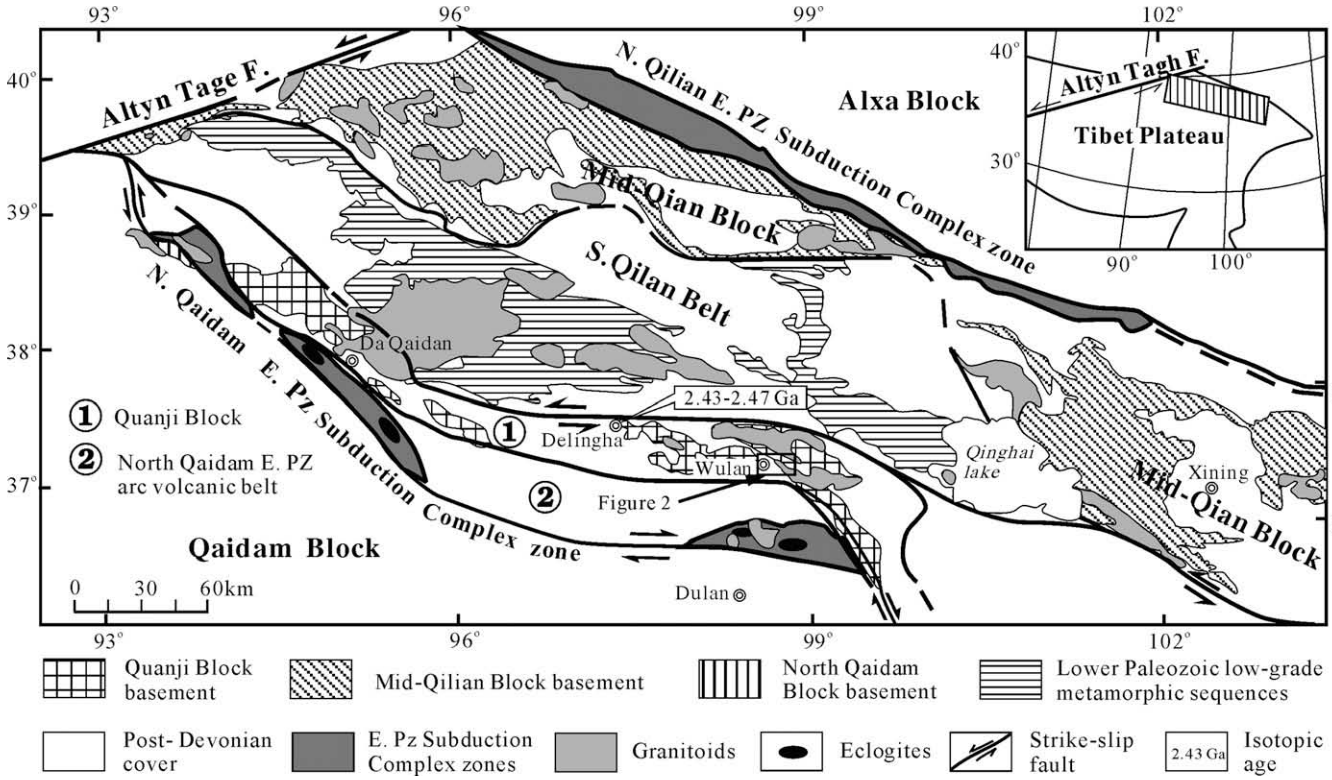

Fig. 1. Tectonic position of the Quanji Block and adjacent tectonic units (modified after Xu et al., 2006).

Mesozoic sedimentary strata. Another unconformity occurs between the Silurian and Devonian strata.

Basement rocks include the gneissic Delingha complex, the medium- to high-grade metamorphic Dakendaban Group, and the greenschist-grade Wandonggou Group (Lu et al., 2002, 2003). Using data from both detrital and magmatic zircons, Wang et al. (2008) determined that the Dakendaban Group was deposited at ~2.47 Ga and was intruded by pegmatites at ~2.43 Ga. Wan et al. (2006) showed that the high-grade basement Nd crustal resident ages (T_{DM}), ranging from Neoarchean to late Paleoproterozoic, are similar to those in the Yangtze Block. Granitoid plutons in the QB, ranging in age from Paleoproterozoic to early Mesozoic, are also geochemically and isotopically similar to intrusive rocks in the Yangtze Block (Chen et al., 2007b).

The basement complex was intruded by granodiorite and adamellite plutons in the early Paleoproterozoic (Lu et al., 2002; Li et al., 2007) and by rapakivi granites in the Mesoproterozoic (Xiao et al., 2004). High-grade metamorphism thermally reworked the basement rocks in the late Paleoproterozoic and early Neoproterozoic (Zhang et al., 2000; Hao et al., 2004; Wang et al., 2006).

3. Sample description

Samples were collected from the Dakendaban Group in the eastern segment of the QB southeast of Wulan (Fig. 2). The Dakendaban Group in this area consists mainly of felsic gneiss, mica schist and amphibolite with minor marble, all of which were intruded by the ~2.47-Ga Mohe gneissic granodiorite (Li et al., 2007) and ~2.35-Ga gneissic adamellite (Hao et al., 2004). These basement rocks were intensely, ductility deformed, and have well-developed augen gneissic textures and bands or lenses of migmatite. Paleozoic intrusions include Devonian gabbro and granodiorite, Late Permian adamellite, Early Triassic granodiorite and Early Jurassic syenite.

Sample 03WL-7 was taken from a leucosome in a banded felsic migmatite (Fig. 3a). The mesosomes of the banded migmatites are characterized by gneissic structures, and consist chiefly of plagioclase, quartz, biotite and garnet. Much of the biotite has been replaced by chlorite, suggesting a retrograde greenschist facies overprint. The garnet, which is typically subhedral and 3–10 mm in size, makes up ~40 vol.% of the melanosomes. Interestingly, the modal percentage of garnet decreases gradually away from the melanosomes and disappears in the original mesosomes, suggesting that the garnet formed during anatexis and migmatization. The leucosomes occur as 1–4-cm-thick bands composed of quartz, plagioclase, potassium feldspar and minor garnet, and have massive textures indicating little or no later deformation.

Sample 03WL-4 was taken from a leucosome in a mafic migmatite (Fig. 3b). The amphibolite of the mafic migmatites also display gneissic textures, and consist dominantly of plagioclase and hornblende with minor of garnet and quartz. Leucosome patches are ~10 cm thick, and contain rare pieces of relict mesosome (Fig. 3b). They consist chiefly of plagioclase and quartz with minor garnet. The garnet is ~3 mm in size and forms poikilitic crystals with quartz inclusions. Such poikilitic garnet is not observed in the mesosomes, suggesting it grew during crystallization of the leucosomes.

4. Analytical procedures

Zircons were separated employing heavy liquid and magnetic techniques and then hand-picked under a binocular microscope, enclosed in epoxy resin and polished to about half their thickness. The grain mounts were photographed in reflected and transmitted light; cathodoluminescence (CL) was used to investigate their structure, and to choose points for U–Pb and Hf analyses.