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The Triassic reworking of the Yunkai massif (South China): EMP monazite and U-Pb zircon geochronologic evidence

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ABSTRACT

Geohistory of the Yunkai massif in South China Block is important in understanding the geodynamics for the build-up of this block during the Phanerozoic orogenies. To investigate this massif, we conduct EMP monazite and U-Pb zircon geochronological determinations on mineral inclusions and separate for seventeen samples in four groups, representing metamorphic rocks from core domain, the Gaozhou Complex (amphibolite facies, NE-striking) and the Yunkai Group (greenschist facies, NW-striking) of this massif and adjacent undeformed granites. Some EMP monazite ages are consistent with the NanoSIMS results. Monazite inclusions, mostly with long axis parallel to the cleavage of platy and elongated hosts, give distinguishable age results for NW- and NE-trending deformations at 244–236 Ma and 236–233 Ma, respectively. They also yield ages of 233–230 Ma for core domain gneissic granites and 232–229 Ma for undefomed granites. Combining U-Pb zircon ages of the same group, ~245 Ma and ~230 Ma are suggested to constrain the time of two phases of deformation. Aside from ubiquity of Triassic ages in studied rocks, ages of detrital monazite in the meta-sandstone match the major U-Pb zircon age clusters of the metamorphic rock that are largely concentrated at Neoproterozoic (1.0–0.9 Ga) and Early Paleozoic (444–431 Ma). Based on these geochronological data, Triassic is interpreted as representing the time for recrystallization of these host minerals on the Early Paleozoic protolith, and the also popular Neoproterozoic age is probably inherited. With this context, Yunkai massif is regarded as a strongly reactivated Triassic metamorphic terrain on an Early Paleozoic basement which had incorporated sediments with Neoproterozoic provenances. Triassic tectonic evolution of the Yunkai massif is suggested to have been controlled by converging geodynamics of the South China and Indochina Blocks as well as mafic magma emplacement related to the Emeishan large igneous province (E-LIP).

1. Introduction

South China and Indochina blocks are two continental pieces welded together after the closure of the Paleo-Tethys Ocean (e.g. Roger et al., 2014 and references therein). This geodynamic event took place during the Early to Middle Triassic resulting in the formation of metamorphic rocks and generation of magmatic rocks close to the suture zone. The entire process of amalgamation is commonly referred to as Indosinian orogeny in both the blocks. Various age dating systems have been applied to know the timing of syn-tectonic metamorphism and post-orogenic magmatism for elucidating the geodynamics of this orogeny. Although the U-Pb zircon age dating becomes popular, its application to orogenic metamorphic and magmatic rocks may encounter difficulties when recrystallization or melting of pre-existing crustal materials is highly involved with inherited zircons. Yunkai massif in the southern South China may be one of the cases.

Yunkai massif has long been regarded as a Precambrian basement in the South China Block. Recently, based on a large number of age results concentrating in the Early Paleozoic for granitic and metamorphic rocks in this massif, a concept of the Early Paleozoic Wu-Yun metamorphic belt (orogen) that spreads from the Wuyishan massif in the northeast, through the Baiyun massif, and further extends southwesterly to the Yunkai massif (Fig. 1a), was established (Lin et al., 2008; Faure et al., 2009; Li et al., 2010; Yang et al., 2010; Wang et al., 2011; Yao et al., 2012; Chu et al., 2012b; Wang et al., 2013). The most significant evidence came from a reconnaissance on gneissoid granite samples that gives rise to similar zircon U-Pb dates of 457–410 Ma for Wuyishan and 450–415 Ma for Yunkai massifs, respectively (Wang et al., 2011).

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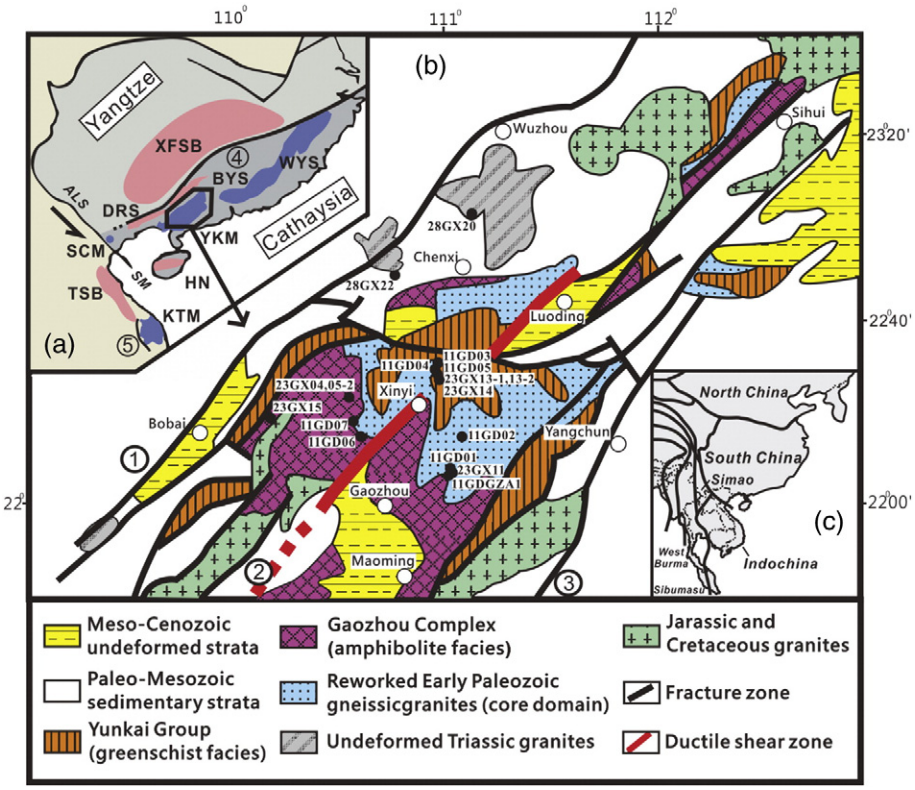

Fig. 1. (a) Relevant tectonic units in the Yangtze and Cathaysia sub-blocks of the South China Block, including Yunkai massif (YKM), Song Chay massif (SCM), Darongshan (DRS), Xuefengshan Belt (XFSB), Hainan Island (HN), Wuyishan (WYS)-Biyunshan (BYS) massif in the South China, and Kontum massif (KTM) and Truong Son Belt (TSB) in the Indochina Block. The formerly proposed Early Paleozoic units are marked by blue and Triassic units, by pink colors. Ailaoshan (ALS)-Song Ma (SM) zone is the collision boundary between the South China and Indochina (+Simao) Blocks. (b) The simplified geological map of the Yunkai massif (modified from Zhou, 1995) and sample localities. (c) Relative position of major tectonic blocks in East Asia. Names of fault are 1: the Wuzhou-Bobai Fault, 2: the Luoding-Yuocheng Fault (one of the major shear zones), 3: the Wuchuang-Sihui Fault, 4: Chenzhou-Linwu Fault, and 5: Poko Zone (Ferrari et al., 2008).

Along with some extrusive rocks in the Baiyun massif (ca. 435 Ma), the importance of the Early Paleozoic event for the development of this orogen was reinforced (Yao et al., 2012).

However, $^{40}Ar/^{39}Ar$ mineral dating (mostly biotite) shows different results. For example, thirteen biotite analyses on granite, gneiss and migmatite over the entire Yunkai massif, although mostly mylonitized, all yielded Triassic ages (Wang et al., 2007a). Further by compiling multi-system geochronology on the Yunkai massif, Chu et al. (2009) indicated that ages obtained from the $^{40}Ar/^{39}Ar$ mineral dating (biotite and muscovite) for high-grade metamorphic rocks are again exclusively Triassic. The Triassic age given by these minerals may be meaningful to account for the complete reset of mineral ages by the mylonitization near shear zones, but difficult to apply to a cooling history for the transformation from the Early Paleozoic prograde- to the Triassic retrograde-metamorphism in the Yunkai area (e.g. Wang et al., 2012). One more concern is the existence of thin Triassic-aged rim on the Early Paleozoic zircon core in some gneissic granites (Wang et al., 2007b; Chen et al., 2012) and supracrustal gneisses (Wan et al., 2010) within the massif. To date the only explanation is ascribed to "overprinting of the Indosinian orogeny", yet details of overprinting are not known.

The use of some other dating methods would be helpful to provide more age constraints, and the EMP monazite age determination is an easy and efficient one for this purpose (e.g. Catlos, 2013). This technique has been applied to granitic plutons in the neighboring Darongshan area and high-grade metamorphic rocks (granulite and charnockite) near the Gaozhou Reservoir previously, by which large amounts of the EMP monazite ages of ~230 Ma and ~440 Ma were obtained (Chen et al., 2011, 2012). For this study, we chose some representative metamorphic and granitic rocks from Yunkai massif to demonstrate the powerfulness of using the EMP monazite dating to tackle with the petrographic relationship and age results. U-Pb zircon ages are also determined for same samples to provide constraints from direct comparisons.

2. Geological backgrounds and samples

South China Block is composed of Yangtze and Cathaysia sub-blocks (Fig. 1a) with the characterization of Phanerozoic granitic rocks exposing in the Cathaysia. Ages for these granitic rocks are concentrated at Early Paleozoic, Late Permian-Early Triassic, Jurassic and Cretaceous time, marking the episodic thermal events on this terrain (e.g. Zhou and Li, 2000). The Yunkai massif is bounded by the Wuchuang-Sihui fault in the east and the Wuzhou-Bobai fault in the west with a total area of about 2500 km^2 (Fig. 1b). It is a conventional thought that this massif is built up by the Paleo- to Mesoproterozoic high-grade basement rocks that had been modified by Neoproterozoic and Early Paleozoic thermal events, the Late Neoproterozoic to Early Paleozoic low-grade basement rocks, and the cover rocks composed of slightly metamorphosed to unmetamorphosed Cambrian to Devonian strata (Zhong et al., 1996). Lithologies of the exposed basement rocks in this massif mainly include gneissic granites, migmatites and orthogneisses in the center, and supracrustal paragneiss, amphibolite, schist, quartzite and marble (roughly the metapelite assemblage) relatively in the peripheral of the massif. Some of these rocks have later been intruded by the Triassic, Jurassic and Cretaceous granitoids. Recently, a short time span (443 to 430 Ma) was suggested for the formation of these gneissic granites and supracrustal rocks as constrained by the youngest zircon U-Pb age clusters, and the also abundant older ages (mainly 1.1 to 0.8 Ga) were attributed to the inherited ones (Wan et al., 2010).

The Yunkai massif is composed of two tectonic units: the Gaozhou Complex and Yunkai Group. Although the Yunkai Group is loosely defined, we retain the usage of this term same as those in Wan et al.