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The early Jurassic mafic–ultramafic intrusion and A-type granite from northeastern Guangdong, SE China: Age, origin, and tectonic significance

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ABSTRACT

The early Yanshanian geology of Southeastern (SE) China is characterized by widespread igneous rocks consisting predominantly of granites and rhyolites, and subordinate mafic intrusive and volcanic rocks. However, the onset time, petrogenesis, and tectonic implications of the early Jurassic magmatism in SE China remain highly controversial. We report here zircon U–Pb ages, geochemistry, and Nd–Sr isotopic data for the Fe–Ti–V oxide-bearing Xianlan mafic–ultramafic intrusion and the Wengong granitic pluton in northeast Guangdong. SHRIMP and Cameca SIMS U–Pb zircon ages indicate that the Xialan gabbros and the Wengong granites were emplaced at 194 ± 1 Ma and 192 ± 1 Ma, respectively. Although the field observations show that the granitic pluton intruded the mafic–ultramafic intrusion, the dating results suggest that they were formed almost contemporaneously.

The ore-barren gabbros of the Xialan intrusion are commonly high in Fe_2O_3, CaO and Al_2O_3 contents, with variable SiO_2, TiO_2, and MgO contents. In contrast, the Fe–Ti–V-bearing gabbros have higher Fe_2O_3, TiO_2 (3.5–5.4%) and V contents. These gabbros with high $\varepsilon_{Nd}(T)$ values (+1.7 to +6.2) and low initial I_{Sr} values (0.704 to 0.706), are characterized by LREE-enriched and "convex upwards" incompatible trace-element patterns with slightly negative Nb–Ta anomalies. The parental magma for the gabbros exhibits affinity with a high-Ti subalkaline basaltic magma generated by melting of a depleted OIB-like mantle source. We suggest that the gabbros originated by fractional crystallization of the parental magma plus varying degrees of crustal contamination.

The Wengong granites have high SiO_2 and ($Na_2O + K_2O$) contents, are LREE-enriched and show relatively flat-HREE patterns and significantly negative Eu, Nb, Sr, P and Ti anomalies in the primitive mantle-normalized spidergrams. These granitic rocks display geochemical characteristics of A_2-type granites including high FeO^T/MgO ratios (7.6–14.7), elevated high-field-strength element (HFSE) contents, and high Ga/Al ratios (2.75–3.49). The Wengong granites exhibit variably initial $\varepsilon_{Nd}(T)$ values ranging from −2.8 to +1.2, whereas the initial I_{Sr} values show large uncertainties due to relatively high Rb/Sr ratios. The parental magma for these rocks exhibits affinity with a mildly alkaline magma, which was probably generated by partial melting of the regional Paleoproterozoic amphibolites and thereafter mixed with various amounts of the early Jurassic basaltic magmas. The granites were then formed by extensive crystal fractionation of the mildly alkaline magma.

The Xialan mafic–ultramafic intrusion and the Wengong granitic pluton were formed in an anorogenic extensional environment. It is therefore suggested that ca. 194 Ma is an important onset timing of widespread anorogenic magmatism in SE China. We interpret the early Jurassic mafic–ultramafic intrusion and A-type granites to represent an anorogenic magmatism in response to an onset of asthenospheric mantle upwelling due to the break-up of a subducted flat-slab beneath the SE China continent.

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1. Introduction

The Mesozoic geology of Southeastern (SE) China is characterized by widespread igneous rocks consisting predominantly of granites and rhyolites, and subordinate mafic intrusive and volcanic rocks. In addition to the sporadically-distributed Triassic (referred to as "Indosinian" in the Chinese literature) intrusions (Wang et al.,

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2005a; Li et al., 2006), the late Mesozoic ("Yanshanian") igneous rocks fall into two main age groups: the Jurassic ("Early Yanshanian") and the Cretaceous ("Late Yanshanian") (e.g., Li, 2000; Zhou and Li, 2000; Zhou et al., 2006a; Li et al., 2007a) (Fig. 1). However, the protrogenesis of the Yanshanian magmatism and its tectonic implications has been a matter of extensive debate. Two major competing models exist, i.e., the subduction-related model (e.g., Jahn et al., 1976; Holloway, 1982; Jahn et al., 1990; Charvet et al., 1994; Martin et al., 1994; Lan et al., 1996; Lapierre et al., 1997; Sewell and Campbell, 1997; Zhou and Li, 2000; Zhou et al., 2006a), and the extension- and/or rift-related model (e.g., Gilder et al., 1991; Li and McCulloch, 1998; Chen et al., 1999; Li, 2000; Li et al., 2003, 2004; Wang et al., 2004, 2005b). More recently, Li and Li (2007) proposed a flat-slab subduction and slab-foundering model to account for both the wide Indosinian orogen and the broad Mesozoic magmatic province.

Based on compilation of published isotopic data (Zhou et al., 2006a), there appears to have been a magmatic quiescence during the early Jurassic (205–180 Ma) in SE China. Conversely, recent studies indicate that the early Yanshanian igneous rock in SE China might have initiated ca. 190 Ma (Ding et al., 2006; Li et al., 2007b; Yu et al., 2009). Thus, the onset time of the early Yanshanian magmatism in SE China is still controversial.

A number of Jurassic (178–165 Ma) A-type granites and alkaline syenites exist within the E–W trending Nanling Range from southern Jiangxi to southwestern Fujian province (Chen et al., 1998; Kong et al., 2000; Chen et al., 2002c; Li et al., 2003; Chen et al., 2005). Some mafic–ultramafic intrusions are associated spatially with these A-type granites in northeastern Guangdong and southern Jiangxi provinces, including the Xialan (~11.8 km^2), Yonghe (~18.8 km^2), and Changan (~8 km^2) intrusions (Xing et al., 2001; Chen et al., 2002a,b; Sun et al., 2002; Li et al., 2003; Yu et al., 2009). Studies on these mafic–ultramafic intrusions are important in understanding the role of mantle-derived magmas in the origin of the early Yanshanian magmatism and tectonic evolution of SE China. However, several studies have focused on the petrogenesis of the Xialan mafic–ultramafic intrusion, showing very different ages and Nd isotopic compositions (Xing et al., 2001; Yu et al., 2009). Yu et al. (2009) suggested that the Xialan intrusion was slightly younger than the Wengong granitic pluton in the Xingning area of NE Guangdong province, which is contrary to the field relationship. Thus, systematically geochronological, elemental and Nd–Sr isotopic investigations on the rocks are required to elucidate the genetic relationship between the Xialan and Wengong intrusions.

In this study, comprehensive analyses of precise SHRIMP and SIMS U–Pb zircon ages, geochemistry and Nd–Sr isotopes have been conducted on the Fe–Ti–V oxide ore-bearing Xialan mafic–ultramafic intrusion and the adjacent Wengong granites. The aims are to (1) determine the crystallization age for the mafic–ultramafic intrusion and spatially associated granitic pluton, (2) constrain the genetic link between the mafic–ultramafic rocks and the granites, and (3) shed new lights on the regional Jurassic magmatic–tectonic evolution.

2. Geological background and petrography

The Mesozoic granitoids and volcanic rocks are widespread in the southeast part of the South China block (Fig. 1; Zhou et al., 2006a; Li et al., 2007a). Among them, the early Yanshanian (ca. 190–150 Ma) granitoids are distributed mainly in the hinterland along the EW-trending Nanling Range and the NE-trending Wuyishan Mountains and in adjacent regions (Fig. 1), with a total exposed area of ca. 75,000 km^2 (Zhou et al., 2006a).

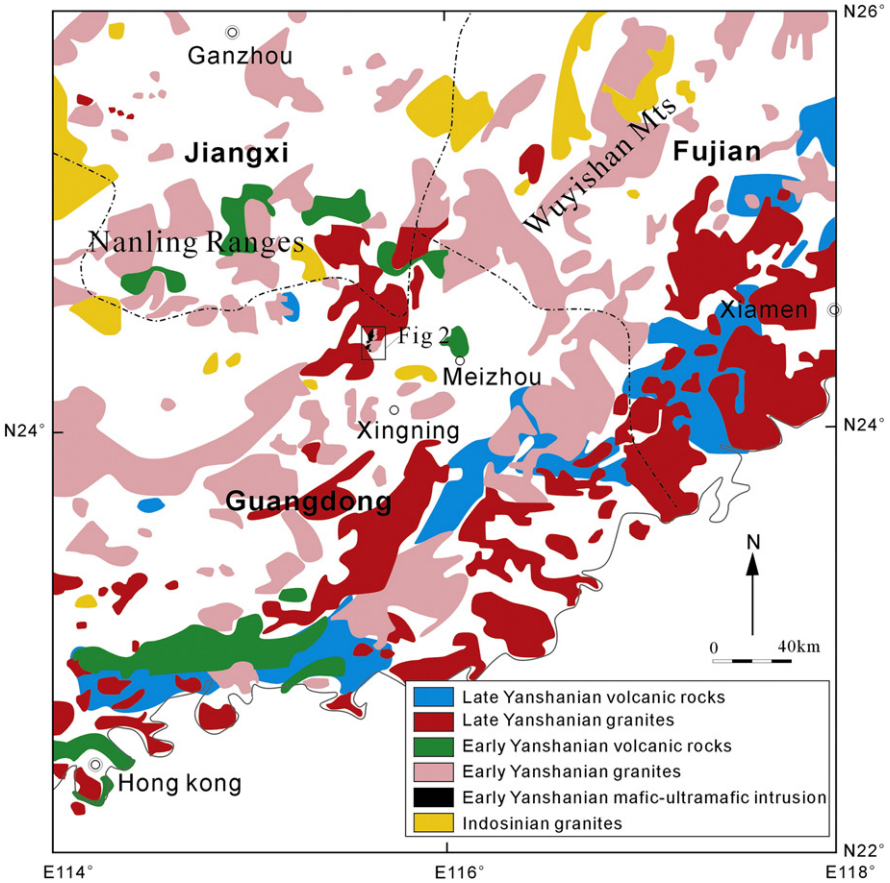

Fig. 1. Distribution of the Mesozoic igneous rocks in northeastern Guangdong, southern Jiangxi and southwestern Fujian region, southeastern China (modified after Zhou et al., 2006a; Li et al., 2007a).

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