Lithos 234–235 (2015) 79–92

Contents lists available at ScienceDirect

Lithos

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

Early Paleozoic intracontinental felsic magmatism in the South China Block: Petrogenesis and geodynamics

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ARTICLE INFO

Article history:
Received 22 March 2015
Accepted 10 August 2015
Available online 28 August 2015

Keywords:
Intracontinental felsic magmatism
Crust–mantle interaction
Rift
Early Paleozoic
South China

ABSTRACT

Intraplate magmatism is generally anorogenic in nature, characterized by geochemical and isotopic signatures that are indicative of mantle sources. However, the early Paleozoic intracontinental magmatic rocks in the South China Block, which cover an area of ~22,000 km^2, are mainly granitoids with fertile isotopic signatures. Based on mineral assemblages, these early Paleozoic granitoids are divided into three groups: Group A (amphibole-bearing granitoids) characterized by relatively low initial $^{87}Sr/^{86}Sr$ ratios (0.705227–0.711639), high $\varepsilon_{Nd}(t)$ values (−7.0 to −3.0), and high $\varepsilon_{Hf}(t)$ values (−8.6 to −1.2, average −5.0); Group B (two-mica granites) that have high initial $^{87}Sr/^{86}Sr$ ratios (0.715335–0. 721933), low $\varepsilon_{Nd}(t)$ values (−9.4 to −7.3), and low $\varepsilon_{Hf}(t)$ values (−15.4 to −4.4, average −8.7); and Group C (biotite granites) that have geochemical and isotopic compositions that are roughly intermediate between those of Group A and Group B. The Group A granitoids show weak negative Eu anomalies, whereas Group B and Group C granitoids show moderate to strong negative Eu anomalies. A mafic microgranular enclave from the Guantian quartz dioritic pluton (Group A) shows Sr–Nd isotopic signatures similar to its host, but higher $\varepsilon_{Hf}(t)$ values (−2.3 to −0.2, average −1.1). These early Paleozoic intracontinental granitoids generally contain considerable amount of mafic microgranular enclaves and have varied chemical compositions, indicating that they are more likely the result of mixing between mantle-derived mafic magmas and crust-derived felsic magmas, as opposed to being derived solely from crustal anatexis without any mantle contribution. Petrogenetic models suggest these early Paleozoic intracontinental felsic magmatic rocks are linked to lower- to middle-crustal anatexis, triggered by underplating and/or intraplating of mantle-derived magmas. This early Paleozoic intracontinental granitoid province represents large-scale crustal growth and reworking, possibly associated with the unique tectonic environment of the early break-up of Gondwanaland in this region.

1. Introduction

Intraplate magmatism takes place far from plate margins, in both intraoceanic and intracontinental settings (e.g., Pirajno et al., 2009). The products of intraplate magmatism (e.g., continental and oceanic flood lavas, layered mafic-ultramafic intrusions, A-type granitoids, and alkaline complexes) are anorogenic in nature and characterized by geochemical and isotopic signatures indicating mantle sources that can be linked to mantle plumes, mantle upwelling, and/or edge-driven convection (e.g., Hanson et al., 2006; Pirajno, 2007; Pirajno et al., 2009; Davies and Rawlinson, 2014; Pirajno and Santosh, 2014). In general, intraplate magmatic rocks are mafic in nature, with felsic magmatic rocks commonly present as only a minor component. In recent years, however, some major provinces of predominantly silicic magmatism (i.e., silicic magmatism with $SiO_2 > 65$ wt.% is dominated; e.g., the Whitsunday, Chon Aike, and Gawler provinces) have been recognized to have a non-subduction-related origin, and they are termed silicic large igneous provinces (SLIPs) (e.g., Bryan, 2007; Bryan and Ferrari, 2013; Ernst, 2014).

One common characteristic of SLIPs is they comprise >80 vol.% of dacite–rhyolite (e.g., Bryan, 2007). However, the extensively distributed early Paleozoic intracontinental magmatic rocks (~22,000 km^2, Fig. 1a) in the South China Block (SCB) consist mainly of massive granitoids and gneissic granites (Sun, 2006). A considerable proportion of these magmatic rocks have fertile elemental and Sr–Nd–Hf isotopic compositions analogous to S-type granite, and contemporaneous volcanic rocks and mafic-ultramafic intrusions are absent, leading to the prevailing view that these rocks originated from Proterozoic metapelite and metaigneous rocks, with only a limited mantle contribution at most (e.g., Li and Gui, 1991; Chen and Jahn, 1998; Wu et al., 2008; Li et al., 2010b; Wang et al., 2011; Zhang et al., 2012; Shu et al., 2014). However, in light of the required heat budget, it is difficult to envision a process that would generate such voluminous magmas without a mantle contribution, especially in an intracontinental setting. Additional cases of mafic rocks and I-type granitic rocks contemporaneous with the massive granitoids and gneissic granites in the SCB have been reported in recent years (e.g., Peng et al., 2006; He et al., 2010; Wang et al., 2013b;

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http://dx.doi.org/10.1016/j.lithos.2015.08.006
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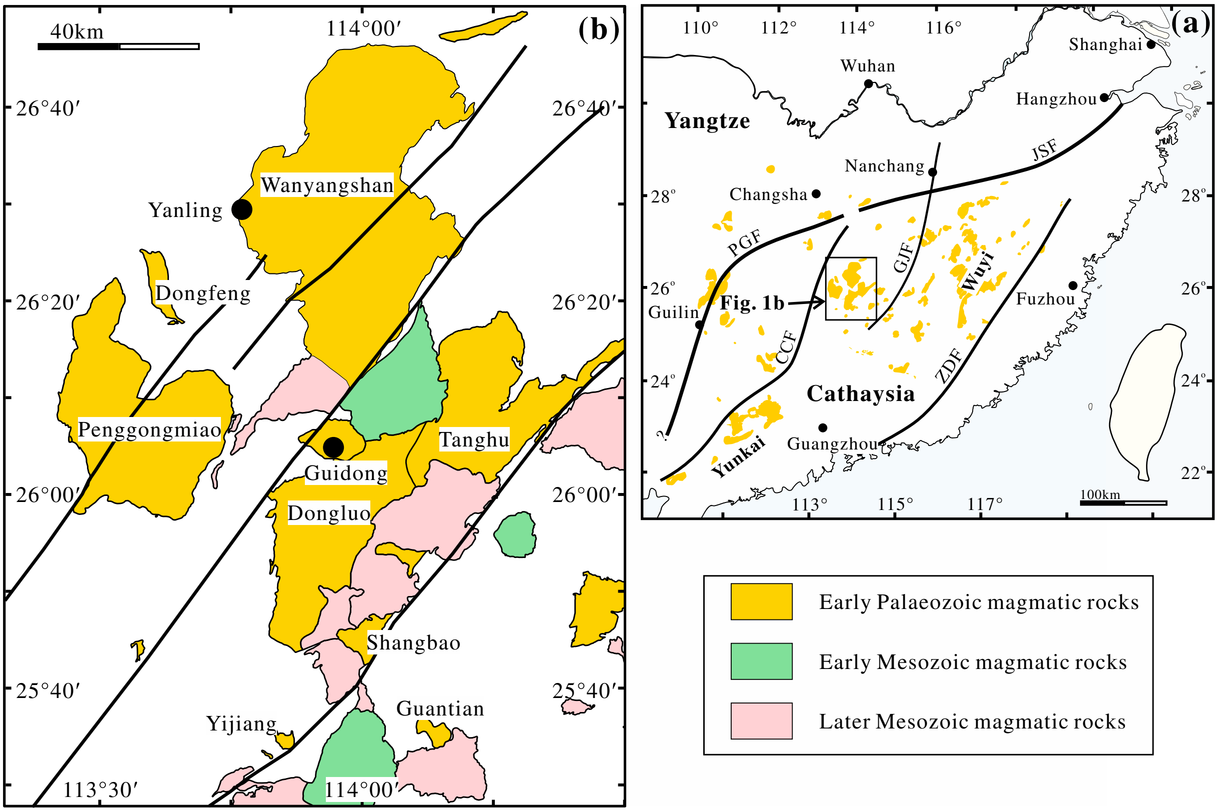

Fig. 1. (a) Schematic map showing the distribution of early Paleozoic igneous rocks in the South China Block (modified after Sun, 2006). (b) Details of the plutons in the studied area. Group A: amphibole-bearing granitoids comprising the Yijiang and Guantian quartz dioritic plutons, the Shangbao granitic pluton, and the Guidong granodioritic pluton. Group B: two-mica granite comprising the Penggongmiao and Wanyangshan plutons. Group C: biotite granite comprising the Dongluo, Tanghu, and Dongfeng plutons. Abbreviations: CCF, Chaling–Chenzhou Fault; GJF, Ganjiang Fault; JSF, Jiangshan–Shaoxing Fault; PGF, Pingxiang–Guilin Fault; ZDF, Zhenghe–Dapu Fault.

Zhong et al., 2013; Xia et al., 2014), and the presence of volcanic rocks has been confirmed (e.g., Wu et al., 2012; Yao et al., 2012). Therefore, crust–mantle interaction may have played an important role in the generation of early Paleozoic magmatism in the SCB, which is a key factor in our understanding of the early Paleozoic geological evolution of the SCB.

In this paper, we present a detailed investigation of the early Paleozoic granitoids of varying compositions from the SCB (Fig. 1). Combining these results with the findings of previous studies, we discuss the nature of the early Paleozoic magmatism and answer the following questions: 1) Did crust–mantle interaction occur? If so, 2) what roles did such interactions play in generating these voluminous felsic rocks with varied compositions? Finally, 3) how was such extensive intracontinental felsic magmatism generated in the SCB? This latter question is important in understanding the nature of felsic magmatism in intracontinental settings.

2. Geological setting

The SCB is a major continental block in East Asia with a complex tectonic history. The extensive and episodic Phanerozoic magmatism and related polymetallic mineral resources in the SCB have made it the subject of considerable attention. The SCB formed by the amalgamation of the Yangtze block (in the northwest) with the Cathaysia block (in the southeast) in the early Neoproterozoic (e.g., Guo et al., 1989; Charvet et al., 1996; Li, 1998; Zhao and Cawood, 1999; Li et al., 2009). It subsequently experienced three major tectonothermal events in the early Paleozoic (primarily 450–420 Ma), early Mesozoic (primarily 250–220 Ma), and late Mesozoic (primarily 140–90 Ma) (Ren, 1964, 1990; Shu, 2012; Wang et al., 2013a). The present boundary between the two blocks is the northeast-trending Jiangshan–Shaoxing (JS) fault in the east (Fig. 1a), but the southwest extension of this boundary is unclear and remains debated.

Following the amalgamation of the Yangtze and Cathaysia blocks at ~860–800 Ma, the SCB experienced continental rifting due to the breakup of Rodinia (e.g., Li et al., 2008). One of these rift systems is the Nanhua rift, which is located between the Yangtze block and the Cathaysia block, and is filled with bimodal volcanic rocks that yield ages of 830–750 Ma (e.g., Wang and Li, 2003). The rift-related volcanic magmatism in the Nanhua rift ceased at ~750 Ma, and the Nanhua rift basin was created (e.g., Li, 1998; Wang and Li, 2003). In the SCB, the upper Neoproterozoic successions comprise slaty sandstone, siltstone, and mudstone, intercalated with lenticular chert or marble (e.g., Shu et al., 2014). However, the Cambrian to Ordovician depositional facies varies from carbonate sequences in Yangtze, to carbonate–siliceous sequences between Yangtze and Cathaysia, and then graptolite-bearing sandy–muddy sequences in Cathaysia, suggesting a changing depositional environment from platform-margin to slope and then returning to platform-margin (e.g., Chen et al., 2010; Shu et al., 2014). Deposits from the Silurian are absent and early Paleozoic units are uncomfortably overlain by Devonian conglomerate and sandstone (e.g., Rong et al., 2003). Although most of the SCB was above sea level during the Silurian and early Devonian, most areas of the SCB, except for the east margin, were rapidly brought into a littoral-neritic depositional environment during a transgression event (~380 Ma) that began in the south. These areas were subsequently filled with limestone, dolomite, and clastic rocks (e.g., Xun et al., 1996). Furthermore, extension occurred during the Lochkovian (~419–410 Ma) in the SCB (Shen et al., 2008a). Notably, Cambrian–Ordovician fine-grained detrital sedimentary rocks in the SCB are up to 8 km thick or more (e.g., Charvet, 2013; Shu et al., 2014). Collectively, the stratigraphic record suggests that the SCB was relatively stable and unaffected by subduction-related processes during the early Paleozoic.

Examples of Paleozoic ophiolites or arc- and subduction-related magmatic rocks are absent in the SCB. This differs from the other early