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Crustally-derived granites in the Panzhihua region, SW China: Implications for felsic magmatism in the Emeishan large igneous province

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ABSTRACT

In the Panxi region of the Late Permian (~260 Ma) Emeishan large igneous province (ELIP) there is a bimodal assemblage of mafic and felsic plutonic rocks. Most Emeishan granitic rocks were derived by differentiation of basaltic magmas (i.e. mantle-derived) or by mixing between crustal melts and primary basaltic magmas (i.e. hybrid). The Yingpanliangzi granitic pluton within the city of Panzhihua intrudes Sinian (~600 Ma) marbles and is unlike the mantle-derived or hybrid granitic rocks. The SHRIMP zircon U–Pb ages of the Yingpanliangzi pluton range from 259 ± 8 Ma to 882 ± 22 Ma. Younger ages are found on the zircon rims whereas older ages are found within the cores. Field relationships and petrography indicate that the Yingpanliangzi pluton must be <600 Ma, therefore the older zircons are interpreted to represent the protolith age whereas the younger analyses represent zircon re-crystallization during emplacement. The Yingpanliangzi granites are metaluminous and have negative Ta–Nb_{PM} anomalies, low $\varepsilon Nd_{(260\ Ma)}$ values (−3.9 to −4.4), and high I_{Sr} (0.71074 to 0.71507) consistent with a crustal origin. The recognition of a crustally-derived pluton along with mantle-derived and mantle–crust hybrid plutons within the Panxi region of the ELIP is evidence for a complete spectrum of sources. As a consequence, the types of Panxi granitoids can be distinguished according to their ASI, Eu/Eu*, $\varepsilon Nd_{(T)}$, $\varepsilon Hf_{(T)}$, T_{Zr}(°C) and Nb–Ta_{PM} values. The diverse granitic magmatism during the evolution of the ELIP from ~260 Ma to ~252 Ma demonstrates the complexity of crustal growth associated with LIPs.

1. Introduction

Large igneous provinces (LIPs) are voluminous (>10^4 km^3), rapidly emplaced, regions of new crust which appear regularly throughout geologic time (Bryan and Ernst, 2008; Coffin and Eldholm, 1994; Ernst et al., 2005). They are found at constructive plate margins, passive continental margins and within-plate settings, both continental and oceanic (Courtillot et al., 1999). The secular variation of LIPs appears to be on the order of 1 per ~10 million years during the past 150 Ma. However based on the known record of continental LIPs, it is probably closer to 1 per ~20 million years (Ernst et al., 2005). It is uncertain if LIP genesis is cyclical but since many continental LIPs (e.g. Central Atlantic Magmatic Province, Siberian Traps, Parana–Etendeka, Ferrar–Karoo, Emeishan) are associated with break-up or amalgamation of supercontinents it stands to reason that more LIPs will form during these events and that there should be a concentration of continental LIPs every 300–500 Ma (e.g. the supercontinent cycle; Coffin and Eldholm, 1994; Nance et al., 1988). Furthermore, many LIPs show internal secular variations which correspond to magmatic peaks occurring for a few million years at different intervals during their formation (Bryan and Ernst, 2008).

The study of LIPs is important because they contain diverse igneous rock assemblages, are associated with important mineral deposits, are major crust building episodes and, are correlated with mass extinctions (Courtillot et al., 1999; Ernst et al., 2005; Richards et al., 1989). The mantle plume model is one explanation for the petrogenesis of some LIPs, however, it is not universally accepted (Campbell and Griffths, 1990; Foulger and Anderson, 2005; Foulger and Natland, 2003; Griffiths and Campbell, 1990, 1991; King and Anderson, 1995; Morgan, 1971, 1972; Richards et al., 1989; White and Mckenzie, 1989, 1995; Wolfe et al., 2009). The anomalously high-temperature conditions required to generate thick piles of basaltic rocks have implications for crustal recycling, as the injection of mafic magmas can induce melting of the overriding lithosphere, and generate plutonic rocks of crustal affinity in addition to those generated by differentiation of basaltic magmas (Annen and Sparks, 2002; Annen et al., 2006; Bergantz, 1989; Hill et al., 1992; Huppert and Sparks, 1988; White and McKenzie, 1989). However, identifying the compositional differences between crust-derived and mantle-derived granitic rocks is somewhat problematic because assimilation of crustal material is common when mantle-derived magmas are emplaced within continental crust.

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The Late Permian (260 Ma) Emeishan large igneous province (ELIP) of SW China is primarily located within the western part of the Yangtze Block, very near the boundary with the Tibetan Plateau (Ali et al., 2005; Li and McCulloch, 1996; Qiu et al., 2000). There are many published studies which have focused on the genesis of the flood basalts however there are comparatively few studies which focus on the contemporaneous felsic plutonic rocks. Although the majority of Emeishan magmatism occurred between ~260 Ma and ~257 Ma there was sporadic magmatism in the region until ~240 Ma (He et al., 2007; Shellnutt et al., 2008). Lying between the cities of Panzhihua and Xichang (Panxi region), Sichuan Province, there is a bimodal assemblage of felsic plutonic rocks and mineralized gabbroic intrusions (Shellnutt and Zhou, 2007). The composition, age and geological associations of the Panxi granitic rocks indicate that they have variable origins, an observation having a bearing on the formation of the ELIP and the crust in general. Emeishan granitic rocks are identified as originating either by 1) differentiation of mantle-derived basaltic rocks, henceforth known as mantle-derived granites (Shellnutt and Jahn, 2010; Shellnutt and Zhou, 2007, 2008; Shellnutt et al., 2009a,b; Zhong et al., 2007, 2009); 2) melting of the crust (Shellnutt and Zhou, 2007; Xu et al., 2008; Zhong et al., 2007) or; 3) a mixture of crust- and mantle-derived magmas (i.e. hybrid) (Luo et al., 2007; Xu et al., 2008). Furthermore the granitoids appear to correspond to two separate periods of magmatism at ~260 Ma and ~252 Ma, respectively (Shellnutt et al., 2008). Previous studies have focused on the mantle-derived granitoids because they are associated with layered gabbroic rocks that host giant Fe–Ti-oxide deposits, whereas, comparatively, very little is known about the crustally-derived and hybrid granitic rocks.

The Yingpanliangzi granitic pluton has intruded Neoproterozoic granitic gneisses and marble. The marble was deposited during the Late Neoproterozoic and indicates that the Yingpanliangzi pluton must be younger than ~600 Ma. Magmatism in the western Yangtze Block is primarily concentrated during the Neoproterozoic (~850 to ~750 Ma) and the Late Permian (~260 Ma) (Ali et al., 2005; Zhao and Zhou, 2007; Zhou et al., 2002a,b). The geological relationships therefore suggest that the Yingpanliangzi pluton may be related to the ELIP, however, it is compositionally dissimilar to other ELIP granitic rocks (Shellnutt and Zhou, 2007; Xu et al., 2008; Zhong et al., 2007). We present new zircon U–Pb ages, whole-rock major and trace element abundances and Sr–Nd isotopic compositions of the Yingpanliangzi pluton in order to determine its likely origin and assess its association with the other ELIP-related granitoids.

2. Geological overview

Southwestern China comprises the western margin of the Yangtze Block to the east and the eastern most part of the Tibetan Plateau to the west (Fig. 1). The Yangtze Block consists of Mesoproterozoic granitic gneisses and metasedimentary rocks that have been intruded by Neoproterozoic granites (Li et al., 1999; Zhao et al., 2008; Zhou et al., 2002b). The Neoproterozoic granites, gneisses and gabbros are found along the western and northern margin of the Yangtze Block, and range in age from ca. 850 Ma to ca. 750 Ma and have continental-arc geochemical characteristics (Zhao and Zhou, 2007; Zhou et al., 2002b). The Neoproterozoic rocks are overlain by a nearly continuous

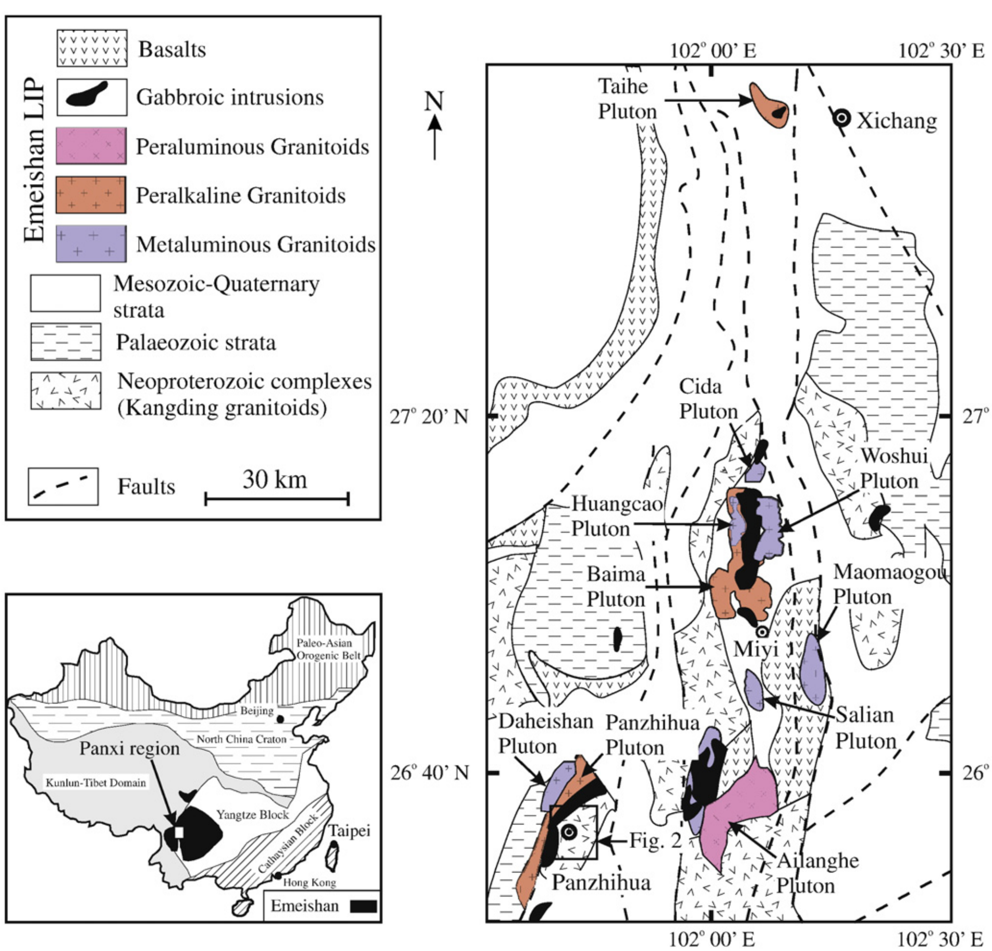

Fig. 1. Simplified geological map showing the distribution of ELIP-related granitic intrusions within the Panxi (Panzhihua-Xichang) region.