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Late Triassic melting of a thickened crust in southeastern China: Evidence for flat-slab subduction of the Paleo-Pacific plate

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ABSTRACT

The Dashuang complex in Zhejiang Province of southeast China is composed of two distinct lithologies: syenite in the west and quartz monzonite in the east. They record similar zircon U–Pb ages of 224 ± 3 Ma (syenite), and 226 ± 2 Ma and 227 ± 1 Ma (quartz monzonite), respectively, but are notably different in petrography, magnetic susceptibility, whole-rock chemistry, zircon Hf isotope and zircon trace element characteristics. The west Dashuang syenitic pluton (the west body) has high modal alkali feldspar, high zircon saturation temperatures, high whole-rock and zircon MREE/HREE ratios, low Fe–Mg–Ti contents, and is depleted in Ba, Sr and Eu. It also has low magnetic susceptibilities, belongs to the ilmenite-series, and is a peraluminous and ferroan granitoid. The east Dashuang quartz monzonitic pluton (the east body) has abundant K-feldspar megacrysts, with hornblende, titanite and biotite being the major ferromagnesian minerals. In contrast to the west body, the east body has lower zircon saturation temperatures, lower whole-rock and zircon MREE/HREE ratios, higher Fe–Mg–Ti contents, and shows no depletion in Ba, Sr or Eu. The east body has higher magnetite contents, high magnetic susceptibilities and belongs to the magnetite-series. It is a metaluminous and magnesian granitoid of arc-affinity. Zircon Hf isotopic data reveal that both bodies were derived from partial melting of Paleoproterozoic igneous protoliths in the lower crust, but the east body possibly incorporated subducted terrigenous sediments. Both bodies have higher melting temperatures and pressures than adjacent Cretaceous granitoids, reflecting their origin in a thickened, hotter lower crust. The most feasible model to explain their differences is variations in water content during crustal melting, resulting in different melting and crystallization behaviors. Such melting in a Triassic thickened crust with variable water involvement, followed by Cretaceous magmatism in an extensional setting, is consistent with the flat-slab subduction model proposed for South China. The model involves crustal thickening and partial melting, with mantle and lower crustal metasomatism during flat-slab propagation in the Triassic–Early Jurassic, and crustal thinning and extension from the mid-Jurassic to the Cretaceous.

1. Introduction

The continental lower crust is commonly considered “dry” (Yardley and Valley, 1997). However, underplating of hydrous basaltic–andesitic magma produced in active continental arc settings will release water originating from the subducting slab, and can cause water-fluxed melting in the crust (Whitney, 1988). Under low-temperature conditions, water can be transferred directly from the subducting slab to the lower crust without triggering melting in the mantle wedge (Wyllie et al., 1989). Both dehydration melting and water-fluxed melting play important roles in granite petrogenesis and crustal reworking (Sawyer et al., 2011).

Mesozoic granitoids are widely distributed in the South China Block (SCB, Fig. 1A) and the petrogenesis of these granitoids is important for understanding the Mesozoic tectonic evolution of the block. One important question is when the Paleo-Pacific plate started to subduct beneath the South China Block: was it in the Permian (Li and Li, 2007), the Early Jurassic (Zhou et al., 2006), the Early Cretaceous (Chen et al., 2008), or was there no subduction at all (Hsü et al., 1990)? The other question is what tectonic environment(s) controlled the generation of the widespread Mesozoic magmatism: an active continental margin with normal subduction angle (Jahn et al., 1990), with shallow subduction (Zhou et al., 2006) or flat-slab subduction (Li and Li, 2007)? In this paper, we report petrographic, geochemical, zircon U–Pb age, Hf isotope and

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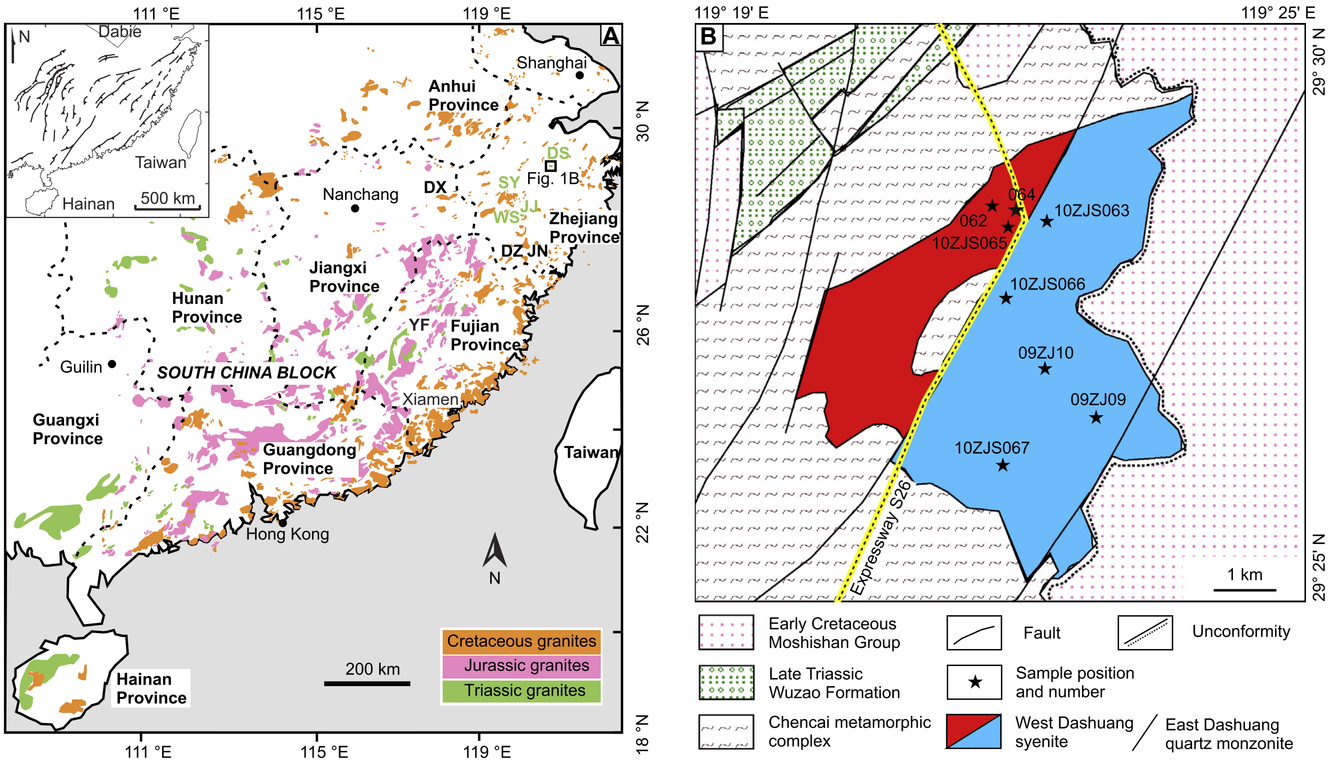

Fig. 1. (A) Distribution of Mesozoic granitoids in the South China Block, modified after Zhou et al. (2006) and Li et al. (2012b). Inset shows the position of the South China Fold Belt, after Li and Li (2007). DS = the Dashuang quartz monzonite/syenite; WS = the Wengshan syenogranite; SY = the Sheyang syenogranite; JJ = the Jingju monzogranite; DX = Dexing; DZ = Danzhu; JN = Jingning; YF = Yangfang. (B) Geological map of the Dashuang complex (after ZGS (1975)).

trace element data for the Triassic Dashuang complex in eastern South China to test if there was evidence for Paleo-Pacific subduction at this time, and what caused the different characteristics of the Triassic and the Cretaceous magmatism in the region.

2. Geological setting and petrography

The Dashuang syenite and quartz monzonite complex is located in central-northeast Zhejiang Province, South China (Fig. 1). It intruded the Chencai metamorphic complex, resulting in contact metamorphism and metasomatism (Wang et al., 1997). The Chencai metamorphic complex consists of greenschist- to amphibolite-facies metavolcanic rocks, metapelites and marbles, with the area having undergone several stages of magmatism, sedimentary deposition and metamorphism from the Paleoproterozoic to the Paleozoic, as described by Li et al. (2010). Both the Dashuang complex and the Chencai metamorphic complex are overlain by felsic volcanic rocks of the Early Cretaceous Moshishan Group (Fig. 1B).

The Dashuang complex is composed of medium-grained syenite in the west and medium- to coarse-grained quartz monzonite in the east, separated by a fault that is followed by Expressway S26 (Fig. 1B). They are referred to in this paper as the west body and the east body, respectively. Large euhedral pink alkali feldspar crystals are well developed in the east quartz monzonitic body and this petrologic characteristic clearly distinguishes it from the west syenitic body (Fig. 2A and C). Wang et al. (1997) reported TIMS zircon U–Pb age, element and Sr–Nd–Pb isotope data for the east body, with a zircon U–Pb age of 239.6 ± 0.6 Ma ($n = 3$), ε_{Nd} (240 Ma) = −12.4 and $^{87}Sr/^{86}Sr$ (240 Ma) = 0.7115. Fig. 2 shows the field and thin section photos of the Dashuang complex. The west body contains 1–2% quartz, 65–70% alkali feldspar (microcline), 25% plagioclase, ~5% biotite and chlorite (Fig. 2B). The accessory minerals are zircon, apatite, epidote, ilmenite (with leucoxene alteration) and magnetite. In the west body, ilmenite is either a primary mineral or was altered from ferromagnesian silicates, and it is approximately 2–3 times more abundant than magnetite. The quartz monzonite of the east body contains 10–15% quartz, 40–45% alkali feldspar, 25–30% plagioclase, 15% hornblende + biotite and 1% titanite. The accessory minerals are zircon, apatite, magnetite and sulfides (Fig. 2D and F).

3. Sample selection and analytical methods

Three samples were collected from the west body and five from the east body for analyses. Magnetic susceptibility measurements were made on flat surfaces of the samples (five measurements for each sample) using a Terraplus KT-10 magnetic susceptibility meter. The measurements effectively distinguished the two intrusive units.

The samples were crushed to 200-mesh using a ceramic ball mill for whole-rock major and trace element analyses. Major element analyses of 09ZJ09, 10ZJS063, 10ZJS065 were conducted on fused glass beads (fused with lithium metaborate, lithium tetraborate) using an ARL-9800 X-ray fluorescence spectrometer at the Centre of Modern Analysis, Nanjing University, with relative standard errors for SiO_2 < 1%, Al_2O_3 < 3%, CaO, K_2O, Fe_2O_3, TiO_2 < 5% and MgO, Na_2O, P_2O_5, MnO < 10%. Major element analyses of 10ZJS062, 10ZJS064, 10ZJS066, 10ZJS067 were conducted on fused glass beads (fused with lithium metaborate, lithium tetraborate and lithium bromide) using an ARL-9900 X-ray fluorescence spectrometer at the State Key Laboratory of Mineral Deposits Research, Nanjing University, with relative standard errors for SiO_2 and Al_2O_3 below 1% and for other elements generally below 5%.

Trace elements in sample 09ZJ09 were analyzed following HF + HNO_3 digestion on a Finnigan MAT Element II ICP-MS at the State Key Laboratory of Mineral Deposits Research, Nanjing University. Digestion procedures are described by Gao et al.