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Elemental and Sr–Nd isotope geochemistry of microgranular enclaves from peralkaline A-type granitic plutons of the Emeishan large igneous province, SW China

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A B S T R A C T

Microgranular enclaves are common within intermediate to felsic granitic rocks that have I- and S-type affinity however they are rare within alkaline anorogenic granitoids of A-type affinity. The Permian (~260 Ma) Emeishan large igneous province (ELIP) of southwest China contains two peralkaline silica saturated A-type granitic plutons that host microgranular enclaves. The enclaves from the Baima pluton are intermediate in composition and have lower SiO_2 and higher TiO_2, CaO and Mg# (SiO_2 = 57.2 to 63.0 wt.%; TiO_2 = 0.8 to 1.8 wt.%; CaO = 1.7 to 3.3 wt.%; Mg# = 28 to 44) than their host (SiO_2 = 62.6 to 67.8 wt.%; TiO_2 = 0.5 to 1.4 wt.%; CaO = 0.4 to 1.8 wt.%; Mg# = 15 to 31). The enclaves from the Taihe pluton are more felsic (SiO_2 = 63.8 to 71.3 wt.%; TiO_2 = 0.3 to 0.6 wt.%; CaO = 0.6 to 2.3 wt.%; Mg# = 8 to 22) but are still less evolved than their host (SiO_2 = 69.8 to 75.1 wt.%; TiO_2 = 0.2 to 0.6 wt.%; CaO = 0.4 to 0.8 wt.%; Mg# = 3 to 12). In both cases, the enclaves have very similar $\varepsilon Nd_{(T)}$ values (Baima $\varepsilon Nd_{(T)}$ = +2.8 to +3.2; Taihe $\varepsilon Nd_{(T)}$ = +1.0 to +2.0) as their hosts (Baima $\varepsilon Nd_{(T)}$ = +3.0 to +3.2; Taihe $\varepsilon Nd_{(T)}$ = +1.5 to +1.9). The major and trace element trends of the enclave-host pairs suggest that fractional crystallization occurred and that element diffusion was likely minimal. The enclaves are interpreted as entrained accumulations of early formed crystals of a silicic magma which was originally produced by fractional crystallization of a mafic magma.

1. Introduction

Microgranular enclaves are dark, fine grained, rounded to elongate inclusions which are common within intermediate to felsic igneous rocks. The study of enclaves offers potentially important information on the origin and history of the magmatic systems in which they are found (Didier, 1973, 1987; White and Chappell, 1977; Cantagrel et al., 1984; Vernon, 1984; Bacon, 1986; Vernon et al., 1988; Barbarin and Didier, 1991; Waight et al., 2001; Barbarin, 2005; Garcia-Moreno et al., 2006; Ventura et al., 2006). Enclaves encompass a broad range of textures, structures and compositions and are often characterized according to their structural relationship to the host rock. They are often interpreted as xenoliths, co-mingled magmas, restites or autoliths (Holland, 1900; White and Chappell, 1977; Vernon, 1983; Vernon et al., 1988; Bonin, 1991; Barbarin and Didier, 1991). Xenoliths are foreign lithic fragments, usually country rock, that were incorporated during emplacement and/or crystallization of the host magma (Domenick et al., 1983; Vernon, 1983; Bacon, 1986). Xenoliths are comparatively easy to identify because they often have magmatic reaction textures. Some enclaves are interpreted as mingled globules of magma that were entrained while the host was still partially liquid (Cantagrel et al., 1984; Vernon, 1984; Bacon, 1986; Barbarin, 2005). In contrast, restites are considered to represent pods of the original refractory magma composition of the host granite which did not reach a critical melt fraction during differentiation (White and Chappell, 1977; Chappell and White, 1991). Some enclaves or 'autoliths' are interpreted to represent accumulations of early formed genetically-related crystals that were trapped within its own residual liquid (Fershtater and Borodina, 1977; Jones, 1979; Tindle and Pearce, 1983; Ridolfi et al., 2006; Schonenberger et al., 2006). Although enclaves are ubiquitous within peraluminous and metaluminous granitic rocks of I- and S-type affinity, they are rarely found within peralkaline granitic rocks of A-type affinity (Bonin, 1991; Barbarin, 1999).

The examination of enclaves from peralkaline A-type granitoids may provide valuable insight into a rare phenomenon and also assist in understanding the chemical evolution of their magma systems. The Late Permian Emeishan large igneous province (ELIP) of southwest China, contains at least three (i.e. Baima, Taihe and Panzhihua) peralkaline silica saturated A-type granitic plutons that formed by fractional crystallization of mafic magmas (Shellnutt and Zhou, 2007;

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Shellnutt et al., 2009; Shellnutt and Jahn, 2010). The Baima and Taihe peralkaline plutons contain microgranular enclaves whereas the Panzhihua pluton does not. In this paper we present new major and trace element data and Sr–Nd isotopic data of the enclaves from the Baima and Taihe plutons in order to understand the formation of enclaves within peralkaline silica saturated A-type granitoids.

2. General geology

The Late Permian ELIP is located in a region covering an area of ~0.3×10^6 km^2 in the western part of the Yangtze Block, eastern part of the Songpan–Ganze terrane and northern part of Vietnam (Fig. 1). The ELIP was modified by Mesozoic and Cenozoic faulting associated with the eastward extrusion of the Tibetan Plateau during the South China Block–North China Block collision (~220 Ma) and again during the Indo-Eurasian collision (~50 Ma). The ELIP consists of flood basalts, trachytes, felsic plutons and mafic-ultramafic intrusions which host either Ni–Cu–(PGE) sulfide deposits or giant Fe–Ti–V oxide deposits (Ali et al., 2005; Zhou et al., 2008). The age of the ELIP is constrained to the Late Permian with radiometric ages ranging from ~260 Ma to ~251 Ma (Zhou et al., 2002; Ali et al., 2005; Shellnutt et al., 2008). Previous interpretations suggest that ELIP-magmatism is related to partial melting of a mantle plume source (Chung and Jahn, 1995; Chung et al., 1998; Xu et al., 2001; Ali et al., 2005).

Granitic plutons of A-type affinity are located between the cities of Panzhihua and Xichang, also known as the Panxi region (Shellnutt and Zhou, 2007; Zhong et al., 2007) (Fig. 1). The plutons are distributed at intervals of tens of kilometers along a narrow belt ~100 km wide and ~200 km long. The regional distribution trend of the plutons changes from northeast–southwest to north–south near the town of Miyi. The plutons are of peralkaline, peraluminous and metaluminous compositions and are spatially and temporally associated with Fe–Ti oxide ore-bearing layered gabbroic intrusions (Shellnutt and Zhou, 2007; Zhong et al., 2007). The peralkaline plutons (e.g. Baima, Taihe, Panzhihua) are genetically related to spatially associated layered gabbroic intrusions and are considered to represent the residual products of fractional crystallization (Shellnutt et al., 2009; Shellnutt and Jahn, 2010). The enclaves from the Baima pluton were observed and collected from one locality (i.e. western outcrop) (Fig. 2). In contrast, enclaves are common throughout the Taihe pluton and were collected at two localities (Fig. 3). Enclaves were not observed within the Panzhihua pluton.

3. Description of the enclaves

Enclaves from the Baima peralkaline pluton were observed at one outcrop (26°57′17″ N, 102°02′44″) (Fig. 2). The enclaves are abundant but represent <5% of the total exposure. They vary in size and shape

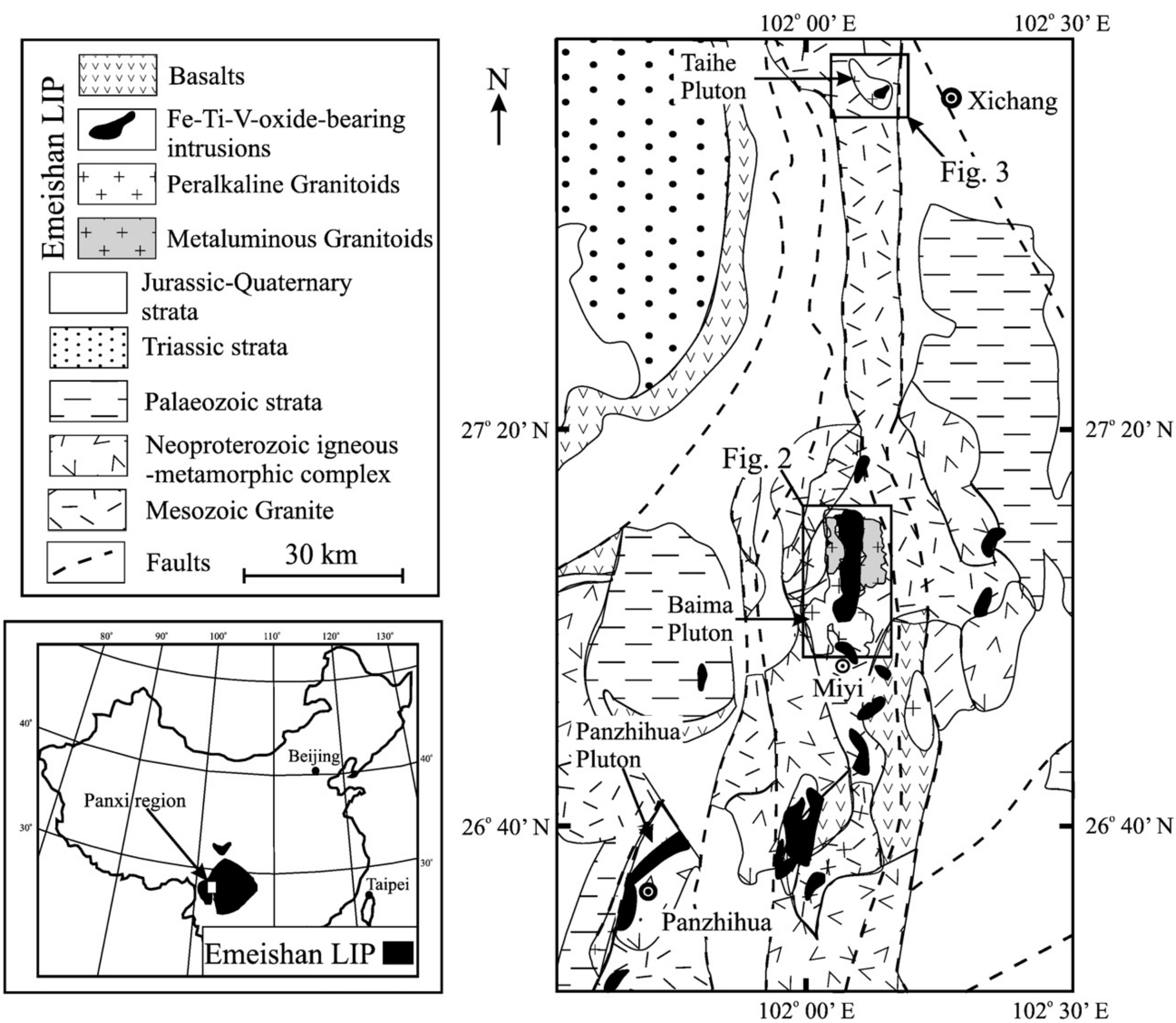

Fig. 1. Simplified geological map of the Panxi region showing the locations of the Panzhihua, Baima and Taihe peralkaline plutons.