Supplementary Materials

Mixing of cogenetic magmas in the Cretaceous Zhangzhou calc-alkaline granite from SE China recorded by in-situ apatite geochemistry

Xiaobing Zhang [1, 2], Feng Guo[1]*, Bo Zhang[1, 2], Liang Zhao[1], Guoqing Wang[1, 2]

1 State Key Laboratory of Isotope Geochemistry, Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou 510640, China

2 College of Earth and Planetary Sciences, University of Chinese Academy of Sciences, Beijing 100049, China

Corresponding author: Feng Guo *(guofengt@263.net)*

Origin of geochemical variations in zircon, titanite and plagioclase

Previous studies have shown that plagioclase, titanite, zircon and apatite have the potential to give insights into the nature and the petrogenesis of their host rock (e.g., Ginibre et al. 2007; Streck 2008). The compositional variations in a single apatite crystal are expected to be accompanied by similar features in other minerals, as further evidence for the compositional variation of mixed magmas. For example, Bruand et al. (2014) showed that the abrupt REE changes in apatite is coordinated with that of titanite to record a magma mixing event. In the following context, we will discuss the texture and composition of zircon, titanite and plagioclase.

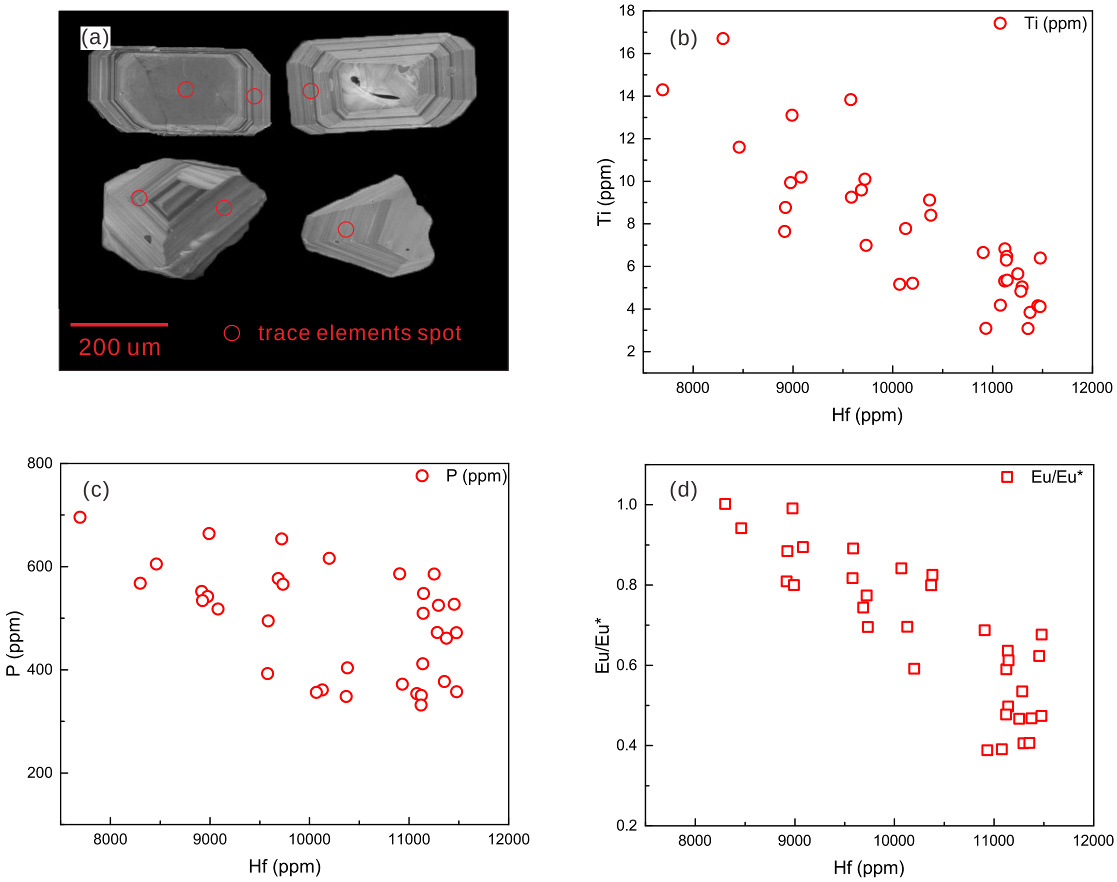

Fig. S1 (a) Representative CL images of zircon from Zhangzhou calc-alkaline granite. Plots of Hf (ppm) vs. Ti (ppm) (b), Hf (ppm) vs. P (ppm) and Hf (ppm) vs. Eu/Eu* (d).

The trace elements in magmatic zircon can indicate geochemical features of their host magmas (Belousova et al. 2002). The zircons in our study show typical oscillatory zoning (Fig. S1a) and high Th/U (>0.5), reflecting a magmatic origin. In contrast with apatite, however, the zircon lacks obvious compositional variations in a single grain. Hafnium, Th/U, and Yb/Gd in zircon generally reflect the degree of crystallization in the silicic magma whereas Eu/Eu* reflects the extent of plagioclase fractionation (Claiborne et al. 2010). Hafnium concentration of zircon is a conventional monitor of the evolution of parent melt where high Hf concentration in zircon corresponds to mineral growth in a relatively evolved melt. The negative correlations between Hf and Ti in zircon (Fig. S1b) probably reflect the continuous evolution of magma because the

Ti content in zircon is a function of magma temperature (Barth and Wooden 2010). Apatite is the principal carrier of phosphorus in magmas, the P shows the negative correlation with Hf concentrations in zircons (Fig. S1c), which can be explained by co-crystallization of apatite. The Eu/Eu* show an obviously positive correlation with Hf in zircons (Fig. S1d), indicating the role of plagioclase fractionation. These features show that compositional variations in zircon can be explained by fractional crystallization.

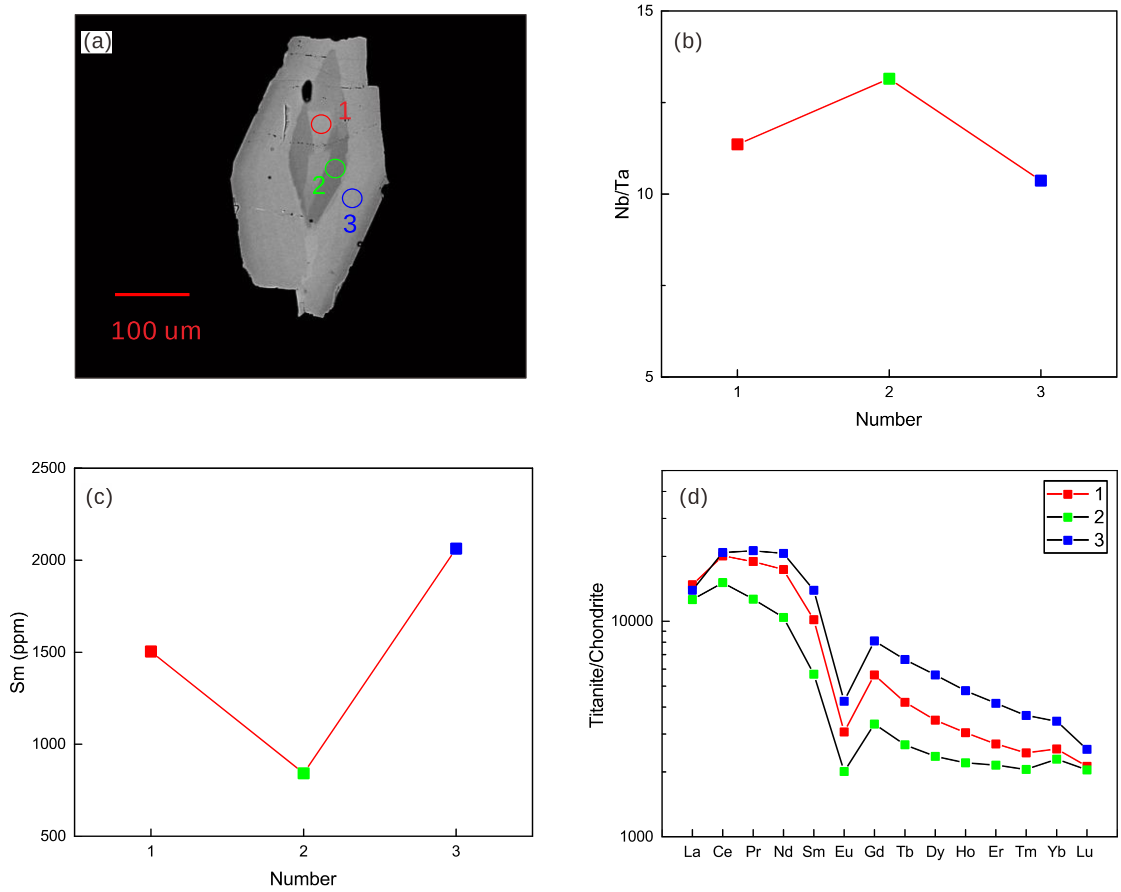

Fig. S2 (a) Representative BSE images of titanite from Zhangzhou calc-alkaline granite. Plots of positions vs. Nb/Ta (b) and positions vs. Sm (ppm, c). (d) Chondrite-normalized REE patterns of corresponding spots in titanite. Normalization values are from McDonough and Sun (1995).

The brightness of titanite in BSE image reflects compositional differences (Bauer

2015), and have been used to indicate the magma mixing event (McLeod et al. 2011). The compositional changes in a few zoned titanite grains probably support the magma mixing model. As shown in the Fig. S2, the titanite has an obvious core-mantle-rim texture, where the mantle zone has the highest Nb/Ta and the lowest Y content. Titanite formed in mafic melt has lower Y and higher Nb/Ta ratio than that crystallized in felsic magma as a result of variation in distribution coefficients (Prowatke and Klemme 2005). The intra-grain zoning and compositional variation record a mixing event. Nevertheless, most of the titanite grains are weakly zoned/homogeneous and show small compositional variations. Accordingly, some early titanite crystals might preserve the fingerprints of the mixing event, but the majority of them crystallized after the mixing event.

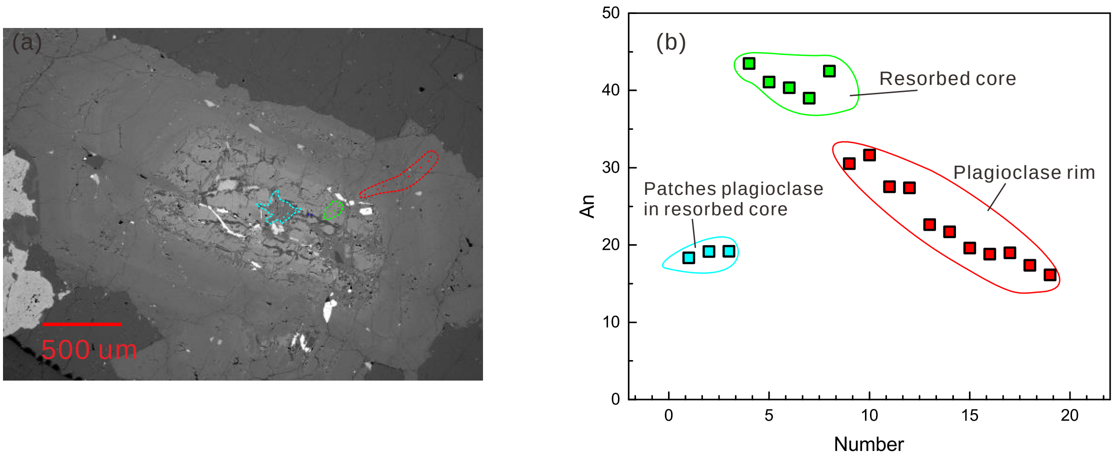

Fig. S3 (a) Representative BSE images of plagioclase from the Zhangzhou calc-alkaline granite. (b) Plot of positions vs. An component.

Plagioclase compositions are strongly controlled by temperature, pressure, and the host melt composition during growth (e.g., Davidson and Tepley 1997; Tepley et al. 2000; Berlo et al. 2007; Viccaro et al. 2010). Plagioclase from the granite shows typical core-rim structure characterized by resorbed high-An core and low-An rim (Fig. S3) with consistent $^{87}Sr/^{86}Sr_{(i)}$. The occurrence of sodic plagioclase along the sieved channel (Fig. S3) in the calcic matrix indicates the growth of the sodic component following the dissolution of the calcic component. A feasible explanation for such sieve-textured cores is that ascent-driven decompression under water-undersaturated conditions increases P_{H2O} of the magma and reduces plagioclase stability (Viccaro et al. 2010; Wu et al. 2020). The less calcic patches and rims might be produced by loss of water from the magma upon water saturation or entering a more evolved magma reservoir.

In summary, crystallization of zircon is co-precipitated with apatite and plagioclase fractionation. However, zircon is less sensitive than apatite in tracking the compositional change of a magma. The texture and compositional variations of some titanite grains support the mixing model for the Zhangzhou granites, but most titanite likely formed after mixing. The compositional changes of plagioclase might have recorded the mixing process, but the compositional change of plagioclase could be also triggered by abrupt physiochemical variations in the magma chamber.

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