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

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## Abstract

Mixing of cogenetic magmas represents an important process in granite petrogenesis but is difficult to identify and is consequently often overlooked due to the absence of obvious isotopic distinctions between the mixed melts. We have conducted in situ elemental and O isotope analyses on apatite from Cretaceous Zhangzhou calc-alkaline granite in southeast China. We integrated these data with micro-analyses on other minerals (plagioclase, zircon, and titanite) as well as whole-rock geochemistry to decipher the mixing history of this granitic complex. The apatite occurs as an early crystallizing phase forming inclusions in biotite, plagioclase, and titanite, and is characterized by core-rim zonation textures with a dark core and bright rims in backscattered images. The core domains have remarkably higher $SO_3$ and Li concentrations but much lower $SiO_2$, REE, and Y concentrations than the rim domains. However, both the cores and rims show geochemical compositions similar to that from typical I-type granite and also have mantle-like O isotope compositions (the core has $\delta^{18}O$ = 5.3–6.8‰ and the rim has $\delta^{18}O$ = 5.2–6.4‰, respectively), indicating crystallization from granitic melts derived from newly accreted crust. The combined major and trace element and O isotope compositions of apatite and whole-rock geochemistry suggest that compositional evolution of the Zhangzhou granite involved mixing between two cogenetic magma batches, with variable degrees of subsequent differentiation. Batch I magma was a low-$SiO_2$ and high-$SO_3$ melt, whereas Batch II magma was a high-$SiO_2$ and low-$SO_3$ melt that experienced devolatilization. The high-S content in apatite cores further suggests the parental magma of the Zhangzhou granite likely originated from a sulfur-rich source comprising mainly newly accreted arc crust in response to subduction of the paleo-Pacific Ocean. The geochemical records of these magmatic processes are rarely observed in coeval zircon, titanite, and plagioclase. Our study, therefore, demonstrates that apatite geochemistry is potentially a more suitable monitor of complex magmatic evolution, including devolatilization and mixing of isotopically indistinguishable magmas.

**Keywords:** Apatite geochemistry, mixing, devolatilization, cogenetic magmas, Cretaceous, SE China