Melting and melt segregation processes controlling granitic melt composition

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ABSTRACT

Several important processes in the petrogenesis of granite are still debated due to a poor understanding of complex interactions between minerals during the melting and melt segregation processes. To promote an improved understanding of the mineral-melt relationships, we present a systematic petrographic and geochemical analysis for melanosome and leucosome samples from the Triassic Jindong migmatite, South China. Petrographic observations and zircon U-Pb geochronology indicate that the Jindong migmatite was formed through water-fluxed melting of the Early Paleozoic gneissic granite (437 ± 2 Ma) during the Triassic (238 ± 1 Ma), with the production of melt dominated by the breakdown of K-feldspar, plagioclase, and quartz. The Jindong leucosomes may be divided into lenticular and net-structured types. Muscovite, plagioclase, and K-feldspar in the net-structured leucosome show higher Rb and much lower Ba and Sr contents than those in the lenticular leucosome. This may be attributed to the elevation of Rb and decreasing Ba and Sr abundances in melts during the segregation process due to early fractional crystallization of K-feldspar and plagioclase. These leucosomes show negative correlation between $\varepsilon_{Nd}(t)$ and $P_2O_5$, reflecting increasing dissolution of low-$\varepsilon_{Nd}(t)$apatite during the melting process. The continuous dissolution of apatite caused saturation of monazite and xenotime in melt, resulting in the growth of monazite and xenotime around apatite in the melanosome. This process led to a sharp decrease of Th, Y, and REE with increasing $P_2O_5$ in the leucosome samples. This complex interplay of accessory mineral reactions in the source impacts REE geochemistry and Nd isotope ratios of granites. As the granites worldwide exhibit similar compositional and isotopic patterns to the Jindong leucosomes, we suggest that both the melting and melt segregation processes strongly control the granitic melt compositions.

Keywords: Migmatite, crustal anatexis, disequilibrium melting, chemical fractionation, granite

INTRODUCTION

Anatexis and the generation of felsic melts are fundamental processes for chemical differentiation of the continental crust (Kemp and Hawkesworth 2003; Rudnick and Gao 2003; Korhonen et al. 2010). Compositions of granite vary significantly due to complex reactions between minerals and melts during processes involved in the generation and segregation of granitic melts (Le Breton and Thompson 1988; Wyllie and Wolf 1993; Kriegsman 2001; Kemp and Hawkesworth 2003; Farina and Stevens 2011; Brown 2013; Clemens and Stevens 2016). For example, residual K-feldspar and plagioclase after the dehydration melting of biotite and amphibole (Le Breton and Thompson 1988; Wyllie and Wolf 1993) will cause elevation of Rb and decreases in Ba and Sr in the melt due to high compatibility for Ba and Sr in these feldspar minerals (Zhang et al. 2004; Gao et al. 2017). On the other hand, K-feldspar and plagioclase may preferentially break down during water-fluxed melting processes (e.g., Vernon et al. 2003), releasing more Ba and Sr than Rb into melts and resulting in low-Rb/Ba and low-Rb/Sr ratios of granite.

The behaviors of minerals during the melting and melt segregation processes are still poorly understood, which has caused continued debate on petrogenesis of granite (Zeng et al. 2005; Farina et al. 2014; Clemens and Stevens 2016). For instance, experimental results suggest that garnet will be a major residual phase during high-pressure melting of metasedimentary (5–7 kbar) and metagneous rocks (>10 kbar; Le Breton and Thompson 1988; Wyllie and Wolf 1993), which may result in low heavy rare earth element (HREE) abundances and high-La/Yb ratio in granitic magmas due to high compatibility of HREE in garnet (e.g., Moyen 2009). However, a school of researchers argue that rare earth element (REE) abundance in granites could be dominated by dissolution of phosphate minerals (monazite, xenotime, and apatite) during melting in the source (Ayres and Harris 1997; Zeng et al. 2005; Farina and Stevens 2011; Farina et al. 2014). This may be deduced by the negative correlation between $\varepsilon_{Nd}(t)$ and $P_2O_5$ for granites worldwide (Online Materials1 Fig. S1; Zeng et al. 2005). On the other hand, felsic melts would be segregated away from the source (Sawyer 2001; Brown 2013; Clemens and Stevens 2016), after