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The obscuring effect of magma recharge on the connection of volcanic-plutonic rocks

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Abstract

The current debate on volcanic-plutonic connection is centered on whether efficient liquid-crystal segregation dominates the evolution of a mushy reservoir to produce evolved, crystal-poor rhyolite and cumulate leftover. However, magma recharge may remarkably influence the evolution of a mushy reservoir and obscure the evidence of liquid-crystal segregation. This complexity poses a challenge to exploring the connection of volcanic-plutonic rocks. This study investigates the Qinzhou Bay granitic complex (~250–248 Ma) from South China, which contains crystal-poor (<19 vol%) peraluminous rhyolites and subsequent crystal-rich (28–54 vol%) porphyries. Although the rhyolite and porphyry units have a close spatio-temporal link, they do not share a fractionation trend and similar whole-rock Sr-Nd-O isotopic compositions; thus, a direct connection is not evidenced. We further present textural analyses, mineral and melt inclusion compositions, thermobarometry (the combination of Ti-in-zircon thermometer and Ti-in-quartz thermobarometer), and thermodynamic modeling to examine the alternative interpretations, i.e., the two units may have intrinsically independent origins or the connection of the two units has been obscured. For the rhyolite unit, thermobarometric results reveal a polybaric storage system consisting of middle (>600 ± 80 MPa) and upper (~150 ± 40 and ~60 ± 20 MPa) crustal reservoirs. Variations in quartz Fe content and chlorine-rich, metaluminous melt inclusions suggest that magma hybridization with less-evolved metaluminous magmas occurred at both crustal levels. In particular, the elevated Fe contents in the quartz population that crystallized at the shallowest level (~60 ± 20 MPa) suggest that recharge magmas were directly injected into the shallowest reservoir. Deviation of the whole-rock composition from the liquid evolution trend recorded in melt inclusions suggests a combined effect of magma mixing and crystal-melt segregation processes in upper crustal reservoirs. Thermodynamic modeling and mass balance calculations suggest that the whole-rock composition of the rhyolite could be reproduced by mixing between regionally exposed dacites and segregated melts at crystallinities of 50–60% (using parental magma represented by the least-evolved melt inclusion). For the porphyry unit, thermobarometric results reveal magma storage at middle (more than 450 ± 40 to 550 ± 40 MPa) and upper (110 ± 20 to 140 ± 20 MPa) crustal levels. The small-scale oscillatory zonation of plagioclase, the pervasive resorption of quartz and alkali feldspar, and the presence of peraluminous microgranular enclaves in the porphyries suggest a recharge event of metasediment-sourced magmas, triggering reactivation and convection of the reservoir. Autoclastic and overgrowth textures of quartz, plagioclase, and alkali feldspar phenocrysts and development of columnar jointing suggest that the reactivated porphyritic magmas ascended and emplaced at ultrashallow levels (~30 ± 10 MPa).

Because of the similar storage pressures, the porphyries may represent remobilized cumulates of rhyolitic magmas, whereas the texture and geochemistry of the cumulate-liquid pair were modified, a key factor rendering a cryptic connection between the rhyolite and porphyry. Alternatively, the plumbing systems feeding the rhyolite and porphyry units are horizontally independent or vertically discrete, but this circumstance is inconsistent with the same evolution trend of quartz Fe and Al contents of the rhyolite and porphyry. Our study highlights that whole-rock composition may record blended information of complex processes, and caution should be taken when whole-rock composition is used to extract information of a single process. Multi-method constraints are required to evaluate the influence of recharge processes on the modification of liquid-cumulate records, and big data analysis on the basis of geochemistry should be conducted with caution to avoid biased understanding.

Keywords: Liquid-crystal segregation, magma recharge, peraluminous rhyolite, porphyry, thermodynamic modeling