American Mineralogist, Volume 104, pages 1750–1764, 2019

Intra-eruptive trachyte-phonolite transition: Natural evidence and experimental constraints on the role of crystal mushes

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Abstract

The generation of silica undersaturated phonolite from silica saturated trachytes is uncommon, as it implies the crossing of the thermal barrier and critical plane of silica undersaturation. Nevertheless, a co-genetic suite displaying compositional transition from benmoreite-trachyte to phonolite has been observed within the Al Shaatha pyroclastic sequence in the Harrat Rahat Volcanic Field (Kingdom of Saudi Arabia). We performed crystallization experiments on benmoreite and trachyte starting compositions to simulate the pressure-temperature-volatile conditions that generated the observed liquid line of descent. The experimental conditions were 200–500 MPa, 850–1150 °C, 0–10 wt% H_2O, 0.0–0.5 wt% CO_2, and NNO+2 oxygen buffer. The experimental mineral assemblage consists of clinopyroxene, feldspar, and titanomagnetite, as well as glass in variable proportions. The degree of crystallinity of hydrous runs is lower than that of anhydrous ones at analogous pressure and temperature conditions. Clinopyroxene crystallizes with compositions diopside-augite and augite-hedenbergite, respectively, at 500 and 200 MPa. The saturation of feldspar is primarily controlled by temperature and volatile content, with the more potassic composition equilibrating at low temperature (850–900 °C) and anhydrous (for benmoreite) or hydrous (for trachyte) conditions. At low pressure (200 MPa), temperatures below 850 °C, and anhydrous conditions, the degree of crystallization is extremely high (>90%), and the residual glass obtained from trachyte experiments is characterized by peralkaline and sodic affinity. This finding is consistent with natural eruptive products containing interstitial phonolitic glass within an anorthoclase framework. The shift from trachyte to phonolite is therefore interpreted as the result of open system interaction between trachytic magma and intercumulus phonolitic melt, as well as of dissolution of anorthoclase from a crystal mush.

Keywords: Trachyte, phonolite, crystallization experiments, intercumulus melt, crystal mush; Dynamics of Magmatic Processes