American Mineralogist, Volume 104, pages 2–16, 2019

Reconstruction of residual melts from the zeolitized explosive products of alkaline-mafic volcanoes

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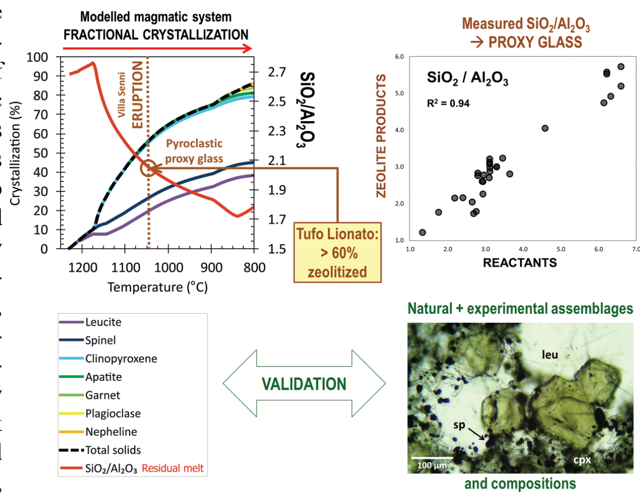
Abstract

Magmatic conditions prior to explosive eruption are often investigated using geochemical signatures in glassy components of pyroclastic deposits and related to magmatic processes at depth. One important process is fractional crystallization, which causes systematic changes to the SiO_2/Al_2O_3 ratio of the residual melt that can be determined by observation of the mineralogy of fully crystallized lavas, by experimental petrology, and by magmatic modeling. However, for many alkaline-mafic pyroclastic deposits, the record of residual melt compositions is obscured by alteration, commonly affecting more than 50% of pyroclastic rock components including reactive glass and some susceptible minerals. In this study, melt signatures of SiO_2/Al_2O_3 represented heterogeneously by the scarce fresh glass and abundant, zeolitized proxy-glass in the alkaline deposits of a major, caldera-forming eruption were used in conjunction with a model system (Rhyolite-MELTS) to reconstruct residual melt compositions and characteristics that existed immediately prior to explosive eruption. Through the model, full major oxide compositions of residual melts and fractionally crystallizing minerals become accessible, with associated constraints on volatiles and physical characteristics (melt temperature, density, viscosity). The use of zeolitized proxy-glass signatures relies on established and deposit-specific evidence for "hydrologically closed" systems that suggests the SiO_2/Al_2O_3 ratio is closely retained through initial alteration reactions and therefore closely representative of SiO_2/Al_2O_3 in the precursor glass (erupted melt). The relationship is supported by a review of available, paired data ($R^2 = 0.94$). Therefore, magmatic system data for the abundant and pervasive fine ash fraction of pyroclastic deposits can be investigated using this method and can progress more deeply beyond the widely used simple affiliation to igneous rock classification. Model-predicted magmatic mineral compositions (clinopyroxene, spinel, and nepheline as demonstrated here) serve to validate a case study reconstruction by comparison with compositions reported from natural and experimental samples. This predictive capability of the novel procedure is demonstrated in the case of a major caldera-forming eruption, the 355 ka Villa Senni event of the quiescent Colli Albani volcano, Rome, Italy, and its pervasively zeolitized *Tufo Lionato* deposit (>50 km³). The key finding is that a more-evolved residual melt fraction has been revealed, based on a reconstructed SiO_2/Al_2O_3 ratio of 2.05 relative to that of the parent magma at 2.68, with implications for a reappraisal of pre-eruptive conditions and eruption mechanisms, and potentially for similar patterns across the volcanic stratigraphy and for other alkaline volcanoes.



Keywords: Pyroclastic deposits, fractional crystallization, natural zeolites, magmatic model, volcanology, Colli Albani; Microporous Materials: Crystal-chemistry, Properties, and Utilizations

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0003-004X/19/0001–002$05.00/DOI: https://doi.org/10.2138/am-2019-6673