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INVESTIGATING PETROLOGIC INDICATORS OF MAGMATIC PROCESSES IN VOLCANIC ROCKS

The cooling kinetics of plagioclase feldspar as revealed by electron-microprobe mapping†

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ABSTRACT

In this study, we have used electron-microprobe mapping to investigate plagioclase compositional evolution due to cooling kinetics. We re-analyzed five run-products from a prior study (Iezzi et al. 2011), crystallized by cooling a natural andesitic melt from 1300 to 800 °C at 25, 12.5, 3, 0.5, and 0.125 °C/min under atmospheric pressure and air redox state. As the cooling rate decreases, the texture of large plagioclases changes from skeletal to hollow to nearly equant. In this study, we use X-ray map data to obtain a database of 12 275 quantitative chemical analyses. The frequency of An-rich plagioclases showing disequilibrium compositions substantially increases with increasing cooling rate. At 25 and 12.5 °C/min the distribution is single-mode and narrow, at 0.5 and 0.125 °C/min is single-mode but very broad, whereas at the intermediate cooling rate of 3 °C/min two distinct plagioclase populations are present. This intermediate cooling rate is fast enough to cause departure from equilibrium for the crystallization of the An-rich population but also sufficiently slow that An-poor plagioclases nucleate from the residual melt. We interpret our findings in the context of time-temperature-transformation (TTT) diagrams, and infer the crystallization kinetics of plagioclase in the experiments. Compositional trends and our inferences regarding TTT systematics are consistent with two discrete nucleation events that produced separate populations of plagioclase (i.e., An-rich and An-poor populations) at 3 °C/min. Using plagioclase-melt pairs as input data for the thermometric reaction between An and Ab components, we find that plagioclase mirrors very high- (near-liquidus) crystallization temperatures with increasing cooling rate. These results have important implications for the estimate of post-eruptive solidification conditions. Lava flows and intrusive bodies from centimeters to a few meters thick are characterized by a short solidification time and a significant thermal diffusion. Under such circumstances, it is possible to crystallize plagioclases with variable and disequilibrium chemical compositions simply by cooling a homogeneous andesitic melt. X-ray element maps enrich the study of plagioclase compositional variations generated under conditions of rapid cooling.

Keywords: Andesite, plagioclase, EPMA map, cooling, crystallization, thermometer