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Plagioclase population dynamics and zoning in response to changes in temperature and pressure

Benjamin J. Andrews[1,*]

[1]Global Volcanism Program, Smithsonian Institution, Washington, D.C. 20560, U.S.A.

Abstract

Zoned plagioclase crystals are often interpreted as proxies for magmatic history because the mineral is present in most silicic magmas and has compositional sensitivity to magmatic conditions (pressure, temperature, and composition) with slow internal diffusion that preserves compositional zones. Changes in growth rates and crystal dissolution present challenges to quantitatively relating time to particular zoning patterns. The numerical model SNGPlag uses Rhyolite MELTS to determine the equilibrium phase assemblage and compositions for a user-defined magma composition experimentally determined instantaneous nucleation and growth rates, and reasonable dissolution rates to examine plagioclase crystallization and population dynamics through time. The model tracks the numbers, sizes, morphologies, and compositional zoning of plagioclase crystals through time in response to changes in pressure, temperature, and volume or mass inputs. Model results show that significant fractions of time are functionally missing from the crystal record because of effectively zero growth rates or erased from the record through dissolution; in some instances, those processes can together remove >>50% of time from the crystal record. The results show that temperature- (or pressure-) cycling alone will not produce substantial compositional zoning but that the addition of new magma is required to grow complexly zoned phenocrysts. Comparison of the input pressure-temperature-time series with compositional transects shows that the crystal record is biased toward more recent intervals and periods of decreasing temperature (i.e., neither the peak temperatures nor intervals of prolonged, cool storage are favored). Crystallization (or dissolution during heating) acts to return magmas to near-equilibrium crystal fractions within hundreds of days.

Keywords: Plagioclase, zoning, nucleation, growth, dissolution, numerical model, crystal population