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Times of magma ascent and residence reflected in Mg/Fe and Ni diffusion in olivine from arc lavas in Kamchatka

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Time scales of residence and ascent for Kamchatka magmas are presented based on zoned olivines from basalts of distinct volcanic modes: maars, monogenic cones, dikes and stratovolcanoes.

The time scales were estimated by Ni-Mg/Fe diffusion modeling of zoning in olivine crystal cores and outer rims by quantitative geochemical profiles. Modeling is based on the analytical solution of diffusion equation to approximate measured geochemical profiles and estimates for P and T from Al-in-olivine thermometry and cpx-melt barometry.

Olivine crystals in basalts erupted from of maars preserved the most diverse types of compositional zonation – normal, inverse, and even oscillatory in Fo_{78} to Fo_{92} olivines. The size of olivine crystals in maar eruptions is small (<0.3 mm) compared to olivines from other eruptive regimes, which indicates short crystal growth times. Crystal residence times and time of magma ascent are estimated at 100-2000 and 1-10 days, respectively. Magmas erupted in maars thus move most rapidly to the surface.

In lavas erupted at monogenic cones, oscillatory zonation in olivine is absent, but normal and inverse zoning are found in all samples, with sharp gradients between the cores and outer parts of crystals. The size of the crystals in monogenic cones is larger than for maar lavas (<0.5 mm). The time of magma ascent varies from 10 to 60 days. Residence time, estimated for few crystals lasted up to 300 days.

The size of olivine crystals in dikes and stratovolcanoes are larger (0.8-1 mm), which indicates a relatively longer time of crystal growth in their feeding systems. The majority of crystals show normal zoning. Compositional gradients in Fo and Ni between the olivine cores and outer parts are smoother, indicating longer diffusion times. Also, olivine with reverse zoning and compositional gradients in their cores are rare in samples from stratovolcanoes. Diffusion therefore probably erased earlier zonation gradients. The diffusion times for dikes and stratovolcano lavas were estimated up to 200 and 1500 days, respectively.

The implication of these results is as follows: Maar eruptions are fed from rapidly ascending magmas that do not reside, cool and fractionate during ascent fast from their mantle reservoirs. Monogenetic cones are similarly sourced from magmas that ascended relatively fast. By contrast, lavas erupted in stratovolcanoes and those that ascended through their feeder dikes have longer residence times in crustal magma systems, where crystallization, mixing and magma processing occurs.

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