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Magma ascent and residence times in monogenetic volcanism of Kamchatka

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Introduction

We present the geochemical profiles across the olivine phenocrysts in four different magmatic regimes at Kamchatka: (a) maars and tuff rings, (b) monogenetic cones, (c) dikes formation, and (d) lavas of stratovolcanoes. Each volcanic-magmatic regime is characterized by their specific olivine zoning history, size and shape of the crystals, ascending and residence times. 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.

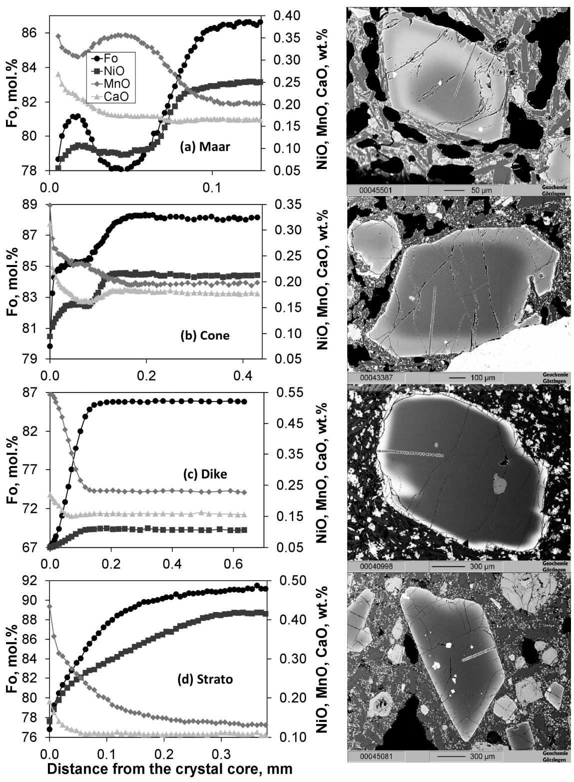

Fig. 1 – Fo, NiO, MnO and CaO in representative Kamchatka olivine crystals from different magmatic regimes.

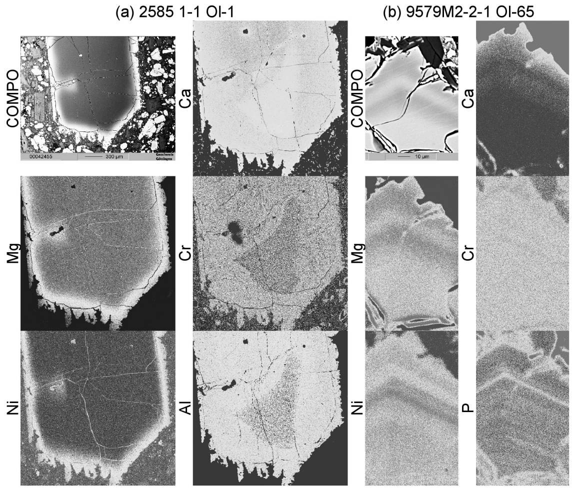

Fig. 2 – Mg-, Ni-, Ca-, Cr-, Al-, and P-distribution maps in the olivine crystals from Kamchatka. (a) element maps showing Ca-Cr-Al enriched core in olivine phenocryst from stratovolcano where diffusion has partially erased Mg/Fe and Ni zoning patterns; (b) olivine rim from maar, showing distinct growth zones, which due to fast magma ascend rate can be still recognized even in elements with high diffusivity such as Mg and Ni.

Results

Olivine crystals in basalts erupted from of maars preserved the most diverse types of compositional zonation – normal, inverse, and even oscillatory in Fo78 to Fo92 olivine crystals (Fig. 1 a; Fig. 2 b). 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 (Fig. 1 b). The majority of crystals from dikes and stratovolcanoes 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 (Fig. 1 c, d; Fig. 2a).

The size of olivine crystals in maar eruptions is small (<0.3 mm) compared to olivine crystals from other eruptive regimes, which indicates short crystal growth times. The size of the crystals in monogenic cones is larger than for maar lavas (<0.5 mm). 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 (Fig. 3).

Crystal residence times and time of magma ascent for maars and tuff rings are estimated at 100-

2000 and 1-10 days, respectively. Magmas erupted in maars thus move most rapidly to the surface. The time of magma ascent for monogenetic volcanoes varies from 10 to 60 days (Fig. 4). Residence time, estimated for few crystals lasted up to 300 days.

Conclusions

Maar eruptions are fed from rapidly ascending magmas that do not reside, cool and fractionate during ascent fast from their mantle reservoirs.

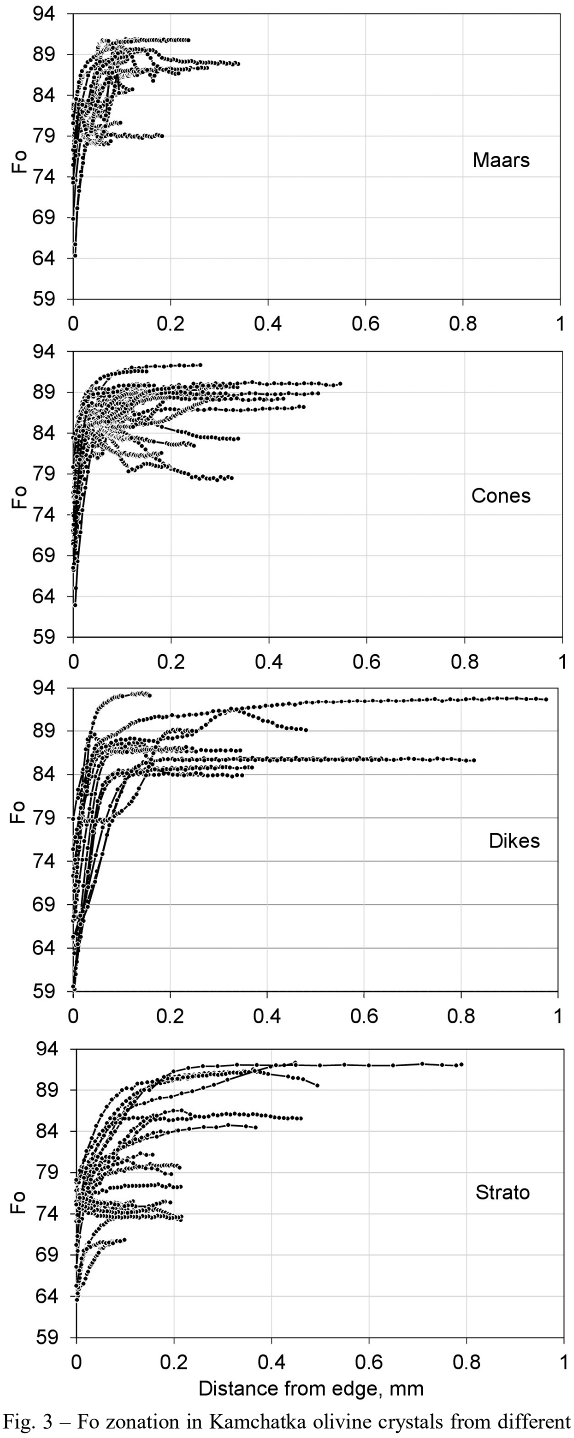

Fig. 3 – Fo zonation in Kamchatka olivine crystals from different magmatic regimes.

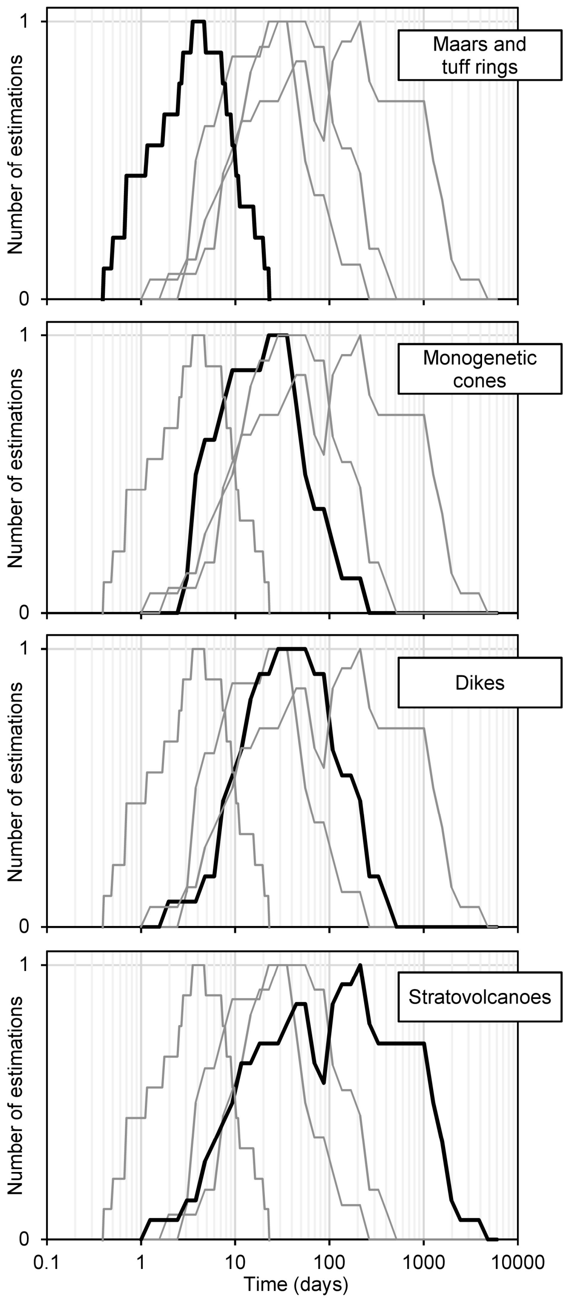

Fig. 4 – Results of ascending time calculations for different magmatic regimes.

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 and mixing occurs.

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