Goldschmidt2020 Abstract

Diffusivity of phosphorous in olivine revisited: A joint experimental and modeling approach

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Intricate heterogeneities in the phosphorous (P) contents of olivine [1,2,3] are consistent with the observation that P diffuses slowly in olivine when compared to other elements [4]. This relatively low mobility presents an opportunity to resolve the time scales of magmatic events that trigger rapid olivine growth (and thus P-uptake) via diffusion chronometry. However, application of the sole published P diffusion coefficient [4] yields timescales that are far shorter than those generated by other chronometers applied to the same mineral or sample [5]. That the published P-diffusion coefficients (D_P values) could be too high is further confirmed by the presence of P concentration heterogeneities in slowly cooled samples, such as gabbros [2]. As P evidently occupies the tetrahedral site [6], its mobility in olivine may be similar to that of the tetrahedrally-coordinated cation, Si, and thus several orders of magnitude lower than posited by [4].

We approach the problem from two angles. First, we solve for the D_P required to match the timescales derived from 2D P concentration maps using Fe-Mg interdiffusion in the same crystal. Preliminary modeling of an olivine crystal from Kilauea's Pu‘u‘Ō‘ō eruption zoned in Mg-Fe and containing fine lamellae enriched in P yields a P-diffusion time that matches the Mg-Fe diffusion time when $D_P=3.26*10^{-20}$ m^2/s. This value is two orders of magnitude lower than previously suggested for 1498K: $(10.29\pm10.26)*10^{-18}$ m^2/s [4]. In our second approach, we will progressively map the distribution of P in cut surfaces of natural olivine crystals before and after prolonged heating at magmatic temperatures, and calculate the D_P that accounts for the observed relaxation. These two methods should provide independent evaluations of P-diffusivity in olivine.

[1]Milman-Barris et al.(2008) Contrib Mineral Petrol 155 739-765. [2]Welsch et al.(2014) Geology 42 867-870. [3]Shea et al. (2016) Geology 44 518-518 [4]Watson et al.(2015) Am. Mineral. 100 2053-2065 [5] Nelson et al. (2019) AGU 2019 Fall Meeting V51F-0114 [6]Buseck et al.(1977) Geochim. Cosmochim. Acta 41 711-740.