Goldschmidt 2022 Abstract
https://doi.org/10.46427/gold2022.11382

Growth-induced Mg-Fe zoning in a skeletal olivine

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KÄ«lauea Volcano in Hawai'i is one of the most studied active volcanic systems. Olivine is the dominant phenocryst phase in its basaltic eruptions. In Keanakāko'i Tephra Unit E (~1650 C.E.), olivines display different morphologies and styles of zoning [1], providing an excellent opportunity to study olivine growth. We performed electron microprobe analyses on a skeletal olivine (0.4 by 0.8 mm) surrounded by glass. Normal zoning is recorded (Fo_{78-82}) within the crystal, while concentrations of Mg decrease and Al increase in the glass towards the glass-olivine interface. These findings indicate that this crystal grew in the diffusion-limited regime, in which nutrients (e.g. Mg) cannot be supplied to the growing crystal fast enough, while unwanted components (e.g. Al) cannot leave the melt-crystal interface fast enough. The Fo# zoning recorded in this skeletal olivine, therefore, represents a snapshot of the crystal undergoing diffusion-limited growth.

The observation that crystal growth can be accompanied by zoning in Fo# contrasts with a previous observation [2], in which no Fo# zoning was found in a skeletal olivine. They hypothesized that either (1) rapid growth in a large volume of melt does not induce Fo# zoning in olivine, or (2) growth-induced zoning is not preserved due to fast Mg-Fe re-equilibration. Our study lends support to their latter interpretation and warns against interpreting all Fo# zoning to be the result of intracrystalline Mg-Fe interdiffusion. Growth-induced Fo# zoning has also been previously reported by [3], who demonstrated that rapid growth onto a pre-existing olivine phenocryst can result in a subhedral crystal with a Fo# profile that mimics a diffusion-profile. Assumptions on the nature of Fo# zoning in olivine must therefore not rely solely on crystal morphology or chemical analyses—they must be substantiated by crystallographic arguments (due to the anisotropy of diffusion [4]) or Mg-Fe isotope analyses (due to diffusive isotope effects [3]).

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[2] Shea et al. (2015). *Geology*, *43*(10), 935-938.

[3] Sio et al. (2013). *Geochim Cosmochim Acta*, *123*, 302-321.

[4] Costa & Chakraborty (2004). *Earth Planet Sci Lett*, *227*(3-4), 517-530.