American Mineralogist, Volume 101, pages 222–230, 2016

SPECIAL COLLECTION: RATES AND DEPTHS OF MAGMA ASCENT ON EARTH

Timescales of magma storage and migration recorded by olivine crystals in basalts of the March-April 2010 eruption at Eyjafjallajökull volcano, Iceland

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ABSTRACT

The early eruptive phase of the 2010 eruption at the Fimmvörðuháls Pass, east of Eyjafjallajökull volcano, produced poorly evolved basalts with mildly alkaline affinity, and benmoreitic tephra were emitted during the second explosive phase from the summit vent of the volcano. In this study, textural features and chemical zoning preserved in olivine crystals of the early erupted basalts have been used to define the timescales of differentiation processes and magma ascent before the eruption. These lavas contain a mineral assemblage constituted by olivine ($Fo_{70–88}$) and plagioclase ($An_{57–83}$) in similar proportions with scarce clinopyroxene and opaque oxides. Olivine occurs as euhedral or embayed crystals characterized by different core compositions and zoning patterns. Three main olivine populations have been found, namely crystals with: (1) wide Fo_{88} cores with normal zoning toward narrow rims (P1); (2) ~Fo_{81} cores with either no zoning or slight reverse zoning patterns toward the rims (P2); (3) ~Fo_{77} cores with reverse zoning at the rims (P3). The olivine reverse zoning indicates that these poorly evolved magmas experienced mixing processes in addition to limited fractional crystallization at different levels of the plumbing system. Timescales of transfer dynamics before the eruption have been estimated through Fe-Mg diffusion modeling on these olivine populations. The olivine-melt equilibration through diffusion was triggered by interaction of magmas differing in their evolutionary degree. P1 and P2 crystals recorded a first event of interaction in a ~22 km deep reservoir that took place about one month before the emission of the analyzed products. Only part of P2 crystals records reverse zoning due to interaction with more basic magma bearing P1 crystals (which consequently develop normal zoning), suggesting fast timescales of magma mixing that prevented the complete homogenization. A second mixing event, which is evident in the P3 olivines, occurred at shallower levels (5–6 km of depth) ~15 days before the emplacement and can be considered the triggering mechanism leading to the eruption at the Fimmvörðuháls Pass. Integration of our timescales with seismic data relative to the hypocenter migration indicate rates of magma ascent throughout the deep plumbing system of ~0.01 m/s. This study provides evidence that magmas emitted at Eyjafjallajökull volcano, and more in general at similar other volcanic systems in ocean ridge settings, can undergo complex processes during their storage and transport in the crust, chiefly due to the presence of a multilevel plumbing system.

Keywords: Eyjafjallajökull, olivine, diffusion modeling, magma mixing, ascent dynamics