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Heritage and residence of olivines based on Fe-Mg diffusion from the August-November 2015 eruption at Piton de la Fournaise, La Réunion

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Modelling magma residence times based on diffusion profiles across zoned crystals is an important tool to understand volcanic plumbing systems. Piton de la Fournaise volcano (La Réunion Island, Indian Ocean) had frequent eruptions during the past decades feeded from shallow magma reservoirs located close to sea level and connected to a sill and dyke system. Mafic magmas from deeper levels periodically rise into the shallow part of the plumbing system, mixing with more evolved resident magmas and reactivating older olivine crystals. The August-November 2015 eruption, one of the most productive eruptions (45 million m3) of the past 35 years, produced a range of olivine compositions. The timing of (re-)activation of different crystal populations can be linked – via Mg-Fe diffusion modelling – to the timing of prior eruptive events, ground deformation, soil CO_2 flux, and seismic signals.

Zonations in rims of olivine crystals result from magma mixing, reactivating older magma batches and residual crystals. Line profiles were measured by electron microprobe in 74 olivines from six quenched basaltic lava and tephra samples covering the entire August-November 2015 eruption. Three types of zoning (normal, reverse, and complex) and different olivine core compositions (Fo78-88) were found. Low-Fo olivine cores (Fo78) dominated the early erupted August 28th lava. On 15th September unusually high forsteritic olivine cores (Fo87-88) became a second species and their emission was associated with an increase in magma output rate. Both low- and high-Fo olivine cores shifted to an intermediate composition (Fo86.5) with ongoing eruption and zoning patterns became weaker until they nearly disappeared when approaching the end of the eruption on 24th October. During the final and pulsating eruption phase on 31st October low- and high-Fo olivines occured again.

Residence times obtained by diffusion modelling show different olivine populations: Low-Fo olivine cores have short diffusion times from days to one month and were reactivated shortly prior to or during the August-November eruption. High-Fo olivines indicate diffusion times from a few days to eight months and were reactivated mainly during and after the May 2015 eruption. Intermediate olivine cores can still be older up to 14 months matching a long sequence of shallow seismicity and inflation prior to February 2015 eruption.

This timing indicates that olivines from the August-November 2015 eruption were reactivated by magma mixing significantly earlier during previous eruptive phases in February, May and July 2015, all being younger than the June 2014 eruption, which occurred after four years of inactivity. Diffusion times of olivines increase with ongoing eruption, culminating in oldest olivine cores being erupted during the final phase of the eruption sequence (second half of October 2015). Only the last eruption (31st October) incorporates crystals again that have been reactivated shortly before eruption by new mafic recharge intruding into the drained shallow system.