EGU21-3172
https://doi.org/10.5194/egusphere-egu21-3172
EGU General Assembly 2021

Insights into timescales of magmatic processes during the 2013-17 eruption at Volcán de Colima, Mexico

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Volcán de Colima is an active stratovolcano in western Mexico. Its 2013-17 eruptive phase was characterised by transitions between effusive and explosive events. This persistent activity, comprising vulcanian explosions, pyroclastic flows, lava flows and ashfall present significant hazards to ~750,000 people near the volcano.

Tracing patterns of magma storage, recharge and mixing through volcanic systems is key to accurately interpreting monitoring data and understanding potential future hazards. However, at many volcanoes, including Colima, these patterns are poorly constrained and the link between monitoring data and magmatic processes is unclear. To better understand the magmatic plumbing system at Colima, mineral chemistry and textural studies were undertaken on representative 2013-17 samples to constrain different magmatic environments and mixing between them.

These samples contain plagioclase, orthopyroxene, clinopyroxene, Fe-Ti oxides, and rare resorbed olivine and amphibole, typical of Colima andesites. Pyroxene phenocrysts have varied core compositions (Mg#~69-88), zoning and textural patterns, reflecting crystallisation from melts within a heterogeneous magma mush. Whilst we interpret the bulk of the system to be relatively evolved, the presence of disequilibrium textures and high-Cr mafic bands and rims reflect periodic recharge of mafic melts and remobilisation of both evolved and mafic mush material prior to eruption.

The mineral chemistry and petrography indicate the presence of two broad magmatic environments crystallising these pyroxenes. An evolved end-member, crystallising Mg#69-75 pyroxene at between 980-1000°C, comprises the bulk of the system. By contrast, the mafic end-member crystallises high-Mg# pyroxene at a temperature typically between 1020-1080°C. Pressure estimates typically vary between 4-6 kbar or c. 12-20 km depth, in agreement with geophysical evidence suggesting a melt-rich mushy body at this depth.

Zoning patterns range from diffuse zoning in normal zoned pyroxenes to sharper core-rim

boundaries in reverse zoned phenocrysts. We applied elemental diffusion modelling to constrain the timescales of pre-eruptive magmatic processes. The modelling indicates relative differences in residence times with long residence timescales typically of decades to centuries for diffuse, normally zoned phenocrysts versus shorter residence timescales of weeks to months in reverse-zoned phenocrysts.

Most notably, an increased frequency of reverse zoned pyroxenes was recorded in lavas erupted after an intense VEI 3 eruption in July 2015. Timescale estimates suggest a recharge and mixing event occurred at approximately this time and estimates from 2016 lavas indicate multiple injection events leading up to the eruption. This suggests that the July 2015 eruption may have been directly linked to this mafic injection.

Despite both eruptions being associated with mafic recharge, the difference in the style of activity between the explosive 2015 and effusive 2016 eruptions suggest other controls on activity. These may include the volume of magmatic recharge, the frequency of injections, ascent rate, or the supply of volatiles from the mafic magmas. Further refinement of the storage timescales and recharge events, and comparison of timescales to monitoring data, also will help clarify the effect of these processes on the eruption timing and style.