ORIGIN OF HIGH-FO OLIVINE-PHYRIC VOLCANIC ROCKS: A MELT INCLUSIONS PERSPECTIVE

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Common features of high-Fo olivine-phyric volcanics include (1) large, essentially unzoned cores of olivine phenocrysts; (2) a wide range (up to 15 Fo units) of phenocryst core compositions within a sample; (3) lack of correlation between the maximum Fo and rock MgO content within a cogenetic series; and (4) evolved compositions of groundmass which are often more evolved than what is expected to be in equilibrium with the least magnesian olivine phenocrysts.

Cooling of olivine phenocrysts in the magmatic system prior to eruption results in post-entrapment diffusive reequilibration of their melt inclusions. Analysis of this process reveals that it is rarely completed, suggesting generally short residence times (< 6 months) and fast cooling rates (> 1-2 °C/day) of high-Fo phenocrysts, with diffusion distances of < 100 microns. This implies that the unzoned cores of high-Fo olivines cannot reflect diffusive reequilibration of originally zoned phenocrysts, as often assumed, but instead they are the result of fast efficient separation of olivines from the crystallising magma. Thus, the main source of high-Fo crystals in erupted magmas is the cumulate zone, i.e., olivine-phyric rocks represent mixtures of an evolved transporting magma (forming the groundmass of the rock) with crystals that were formed during crystallisation of more primitive melt(s). Such a mixed magma is formed during the eruption event, but this is only possible when eruption occurs within 6 months after a new batch of primitive magma enters the magmatic system. High-Fo olivines can reside in magma chambers for longer times, however these olivines are unlikely to be erupted as phenocrysts, being efficiently cemented in the cumulate piles. The evolved magma may reside in the chambers for a long time. This reconciles long magma residence times estimated from the compositions of rocks with short residence times of
high-Fo olivine phenocrysts.
The mixed origin of high-Fo olivine-phyric rocks also explains coexistence of vari-
ably re-equilibrated melt inclusions of similar sizes in different grains in a single sam-
ple. This suggests that individual phenocrysts experienced different cooling rates and
must have come from different parts of the magmatic system. A plumbing system
model developed by B. Marsh can explain all observations well. It involves magma
passing through a sequence of interconnected sills or chambers with well-developed
mush columns. These columns consist of a variety of local crystallisation environ-
ments characterised by contrasting cooling rates. During an eruption, magma rising
through such a column can inherit crystals from different pockets, and melt inclusions
within these accumulated phenocrysts may be variably re-equilibrated.