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How reliable are melt inclusions in olivine for mantle study?

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During last decades melt inclusions were repeatedly used to address composition of mantle sources and processes of mantle melting. Important implication of these studies has been that the melt inclusions are actually representative of the source rocks in the mantle rather than being products of crustal interactions with the magma chamber. Another implicit assumption has been that such melt inclusions can preserve chemical characteristics of parental melts formed in the mantle, thus delivering information about the chemical (and isotopic) composition of magma sources in the mantle. Both of the above assumptions have recently been challenged. Danyushevsky et al. (2005) [1] have interpreted the diversity of melt inclusion compositions as being caused by "side reactions," with the idea that crystallization in a magma chamber occurs preferentially in the temperature gradient near the relatively cool chamber wall. As a result, the composition of crustal wall rocks and their compositional heterogeneity would be significantly and systematically overrepresented in the melt inclusions. Spandler et al. (2007) [2] have measured unexpectedly high diffusivities of rare-earth elements in olivine and thus show potential level of REE mobility in olivine during magmatic time scales. As a result, Spandler et al. (2007) [2] concluded that some of the more unusual melt inclusion compositions are actually introduced by interaction of magma chamber with their crustal wall rocks. Both of these studies, and especially any combination of the effects proposed by their authors would, if justified, seriously undermine the usefulness of melt inclusion studies for any assessment of mantle compositions and

their heterogeneity.

In this study, we assess both of these challenges, using both new data and published results. We demonstrate that olivines generally trap their melt inclusions during shallow crystallization in the crust and that the likely reason of inclusions trapping is fast olivine growth in the thermal boundary layers of mixing magma batches. We show that the “exotic”, Sr-rich end member of all Mauna Loa melt inclusions contributes fully 19-20% to the bulk melt found in erupted lavas and can not be produced by shallow reaction with plagioclase bearing lithologies. We also demonstrate that some highly unusual melt inclusions from Iceland do show clear major and trace element evidence for assimilated plagioclase. Compositions of these inclusions also illustrate post-trapping modification of heaviest REE by volume diffusion through host olivine as predicted by the high diffusion coefficients for these elements in olivine [2]. However diffusion through the olivine has not affected the abundances of most of the incompatible trace elements. The compositional heterogeneities of the “middle” and light REE, as well as those of all highly incompatible trace elements are fully preserved. We conclude that (1) time scales in the magmatic system are short enough to preserve the abundances of highly and moderately incompatible elements inherited from primary melts, and (2) there is no evidence that wall-rock interaction has contributed significantly to the incompatible-element composition of Hawaiian melt inclusions.

[1]L. V. Danyushevsky et al, Journal of Petrology 45, 2531 (2004), [2] C. Spandler et al, Nature 447, 303 (2007).