Estimating alkali basalt and kimberlite magma ascent rates using H diffusion profiles in xenolithic mantle olivine

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Olivine, although a nominally anhydrous mineral, can accommodate small amounts of hydrogen (H) in its mineral defects [1]. Olivines from peridotite mantle xenoliths found in alkali basalts (Mexico) and kimberlites (southern Africa) have been analyzed by FTIR to estimate their H content expressed as ppm water (H_2O).

In the Mexican olivines, water contents vary systematically across any given olivine grain, with the highest water content at the centers and the lowest to no water present at the edges. These diffusion profiles were interpreted as H loss from the olivine during xenolith transport by the mafic alkalic basalt from the mantle to the Earth's surface. The diffusion profiles were modelled using 2-dimensional diffusion equations and H diffusion coefficients [2] to estimate the time of H loss. The latter vary from 20 to 100 hours, which, using mantle xenolith depths of origin of 30 to 40 km translates into mafic-alkalic magma ascent rates on the order of 0.2 to 1 $m.s^{-1}$ [3].

In the southern African xenoliths, no water variation is observed across olivine grains except for one sample with water content slightly lower at the olivine edges. This quasi-absence of H diffusion profiles still allows calculation of maximum times for H loss, assuming diffusion at the very edges of the grains only, of at most a few hours. Using depths of origin for the xenoliths of 120 to 150 km yields an ascent rate of the host kimberlite of > 10 $m\ s^{-1}$.

The parameters influencing the diffusion calculations will be discussed, such as temperature (mafic alkaline magmas ascend at >1200ºC, kimberlites at <1100ºC), pressure, and diffusion coefficients. The faster rates of ascent for kimberlite magmas compared to mafic-alkalic magmas could account for the observed difference of water content in their mantle xenolith olivines (10-80 ppm and 1-10 ppm respectively) which is not mirrored in their co-existing pyroxenes.

References

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