Lithium isotope fractionation at magmatic temperatures; evidence for diffusional fractionation in phenocrysts

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Recent studies of lithium diffusion in silicate melts have discovered diffusion can produce significant (20-30‰) variations in lithium isotope compositions at magmatic temperatures [1]. There are also signifiicant difference between the δ^7Li composition of mantle derived melts, which are relatively uniform, and mantle peridotites which extend to very light δ^7Li values. It is possible that these differences relate to diffusional processes during melt/mantle interaction (see [2]).

To test the proposition that the lithium isotope can also be fractionated during diffusion in minerals we analysed the composition of clinopyroxene and olivine phenocrysts by ion microprobe. These phenocrysts are from ankaramitic arc lavas from New Georgia in the Solomon Islands. Both minerals have low Mg# rims indicating a final interaction with an evolved melt prior to eruption.

Clinopyroxene phenocrysts display a variety of Li isotope and concentration variations from rim to core. Li concentrations at the rims are between 2-8 times that of the cores. Li isotope profiles have characteristic low δ^7Li troughs of up to -33‰ and heavy cores of between +4 to +12‰ that over-print macroscopic major element zoning. Clinopyroxene profiles illustrate the inward migration and broadening of the δ^7Li trough and concomitant flattening of Li concentration gradient. These data are consistent with preferential diffusion of ^{6}Li into the grain from a Li-enriched rim zone.

We have calibrated the Li diffusion rates using Fe-Mg profiles in the olivines, which give Li diffusion rates in olivine slightly slower than Fe-Mg in olivine and Li diffusion in clinopyroxene significantly faster than Fe-Mg in olivine. The Li isotope profiles can be successully modelling using Fick's second law. They are produced in 4-100 days prior to eruption. Numerical modelling confirms that the size of the trough is related to the concentration gradient and that ^{6}Li diffuses ~3% faster than ^{7}L in silicate minerals [1]. Diffusion is an effective mechanism for modifying the Li isotope composition of minerals at magmatic temperatures.

References

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