Trace element partitioning—new developments building on the lattice strain model

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The lattice strain model, in which crystal-melt partitioning of trace elements has a parabolic dependence on ionic radius is now generally accepted as describing the behaviour of many elements entering liquidus silicates. Given that we can, for ions of a fixed charge, characterise partitioning in terms of the 3 parameters, E (Youngs Modulus of the crystal site), r_o (radius of the ion which enters the site without strain) and D_o (partition coefficient for ions of radius r_o) the next steps are:

(a) determination of the relationships between D_o for ions of different charge entering the same site i.e the relative heights of the parabola for different charged ions. (b) determination of the effects of melt composition on partition coefficients and (c) separation of the effects of pressure, temperature and H_2O content of the melt.

We approached these questions in two ways. Firstly we considered crystal-liquid partitioning in terms of the transfer of a 'molecular' component from melt to crystal such as:

$$\underset{\text{liquid}}{REEMgAlSiO_6} = \underset{\text{cpx}}{REEMgAlSiO_6}$$

This approach has enabled us to achieve separation of the effects of P,T and H_2O-content.

The second approach is unconventional and involves considering transfer of an ion (e.g REE^{3+}) between melt and crystal. This approach enables us to work out how charge and melt composition affect D_o by considering the energies of substitution of the ion into 'holes' of different type in liquid and crystal. We are now at the point where prediction of partition coefficients for ions of given size and charge is feasible.

Li as an indicator of petrogenetic processes in the Earth's mantle

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The concentration of Li in minerals and its intercrystalline distribution are potentially sensitive tracers of magmatic and metasomatic processes. As D_{Li} for olivine/cpx, opx/cpx and garnet/cpx are found empirically (using SIMS) to be essentially independent of T and P for mantle peridotite and eclogite bulk compositions (Seitz & Woodland 2000; Woodland et al. in press), this permits direct comparison of samples without having to correct for differences in their respective T and P of equilibration.

The bulk Li content of fertile to moderately depleted peridotite is 1.0-1.5 μg/g, with the following partitioning relationship: ol>cpx≥opx>>sp,grt. Partial melting leads to systematic Li-depletion in the residual peridotite. Li contents of cumulate phases in mafic dikes are usually low, being controlled by the same crystal–melt partitioning behaviour as for partial melting. Some elevated contents are probably due to equilibration with trapped melt.

Metasomatism leads to general Li-enrichment, and frequently to a disequilibrium distribution of Li between coexisting phases. Seitz and Woodland (2000) reported that metasomatism by mafic silicate melt leads to preferential incorporation of Li in cpx compared to ol, while the opposite behaviour is observed for carbonatitic metasomatism. A detailed case study of 18 xenoliths from Victoria, Australia confirms this observation and reinforces the utility of using Li as a geochemical tracer. The cause of this behaviour remains elusive, however.

A suite of eclogites reveals a bimodal distribution of Li content in cpx: 1) high (8.6-80 μg/g) and variable contents in eclogites that are demonstrably metamorphosed oceanic crust and 2) low contents (<2.5 μg/g), like those found in mantle peridotites and grt-pyroxenites (Woodland et al. 2002). The low-Li group is considered to represent high-P cumulates. Thus, Li provides a further chemical discriminant for assessing the origin of eclogite samples. Additionally, non-trivial quantities of Li can evidentally be retained in basalts during subduction and metamorphism. Cpx is the major host for Li in eclogites.

References

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