

Li as a Barometer for Bimimetic Eclogites

M. Hanrahan, G. Brey, A. Woodland

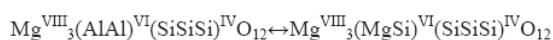
Institut für Geowissenschaften, Goethe-Universität, Frankfurt, Germany

High Pressure eclogitic xenoliths, megacrysts and inclusions in diamond (DIs) occur in kimberlites and other volcanic rocks. Eclogites reside through the depth profile of the continental lithosphere, asthenosphere and transition zone of the mantle and are a major source of information about the physical and chemical properties and processes of the upper mantle.

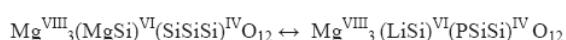
With such a ubiquitous range in pressure (P), temperature (T) and setting, it has long been a goal to formulate an accurate barometer for this rock type in order to gain a better understanding of mantle and kimberlite processes. The vast majority of kimberlitic eclogites are bimimetic consisting of Cr poor garnets and omphacitic clinopyroxenes (cpx) and no suitable barometer exists for such rocks (Schmickler et al. 2004, Jacob 2004). Currently equilibration temperatures for eclogitic xenoliths from kimberlites are calculated using an assumed P of 50kbar, however, as eclogite resides throughout a significant cross section of the inner earth, this assumption is highly incorrect. Correspondingly, not only is a precise geobarometer lacking, but much of the published temperature data that has been calculated for eclogites is expected to be misleading or potentially erroneous due to this incorrect assumption (Jacob 2004).

Seitz et al. (2003) suggested that the partitioning of Li between garnet and cpx is P dependent and may serve as a barometer for eclogites. This suggestion was based on the analysis of natural rocks (eclogitic kimberlitic xenoliths and DIs), the fact that Li is a faithful follower of Mg into octahedral sites and that only garnets with a majoritic component have Mg^{VI}. Since there is always phosphorous present in garnet we assume the following incorporation mechanism:

Majorite:



Lithium:



Experiments and Results:

In order to simplify the experimental system and lower the number of variables, experiments were performed in CMAS (CMAS = CaO, MgO, Al₂O₃, SiO₂) using an eclogitic bulk composition. This system accounts for

98% of the composition of the earth's mantle (McDonough and Sun 1995) if complete substitution is assumed to occur between MgO and FeO. Lithium was added to this CMAS bulk composition through the use of Li₃PO₄. Reversal Multi-anvil experiments were carried out from 4 - 13 GPa, 1100 -1400° at pressure intervals of 2 GPa, and temperature intervals of 100°C. The run products from over 20 reversal experiments were analyzed by EPMA (Electron Probe Microanalysis) and SIMS (Secondary Ion Mass Spectrometry). The results from these experiments in synthetic systems are shown in Fig. 1 and display an irrefutable P dependence on Li partitioning between cpx and garnet in eclogitic assemblages, with a less pronounced T dependence.

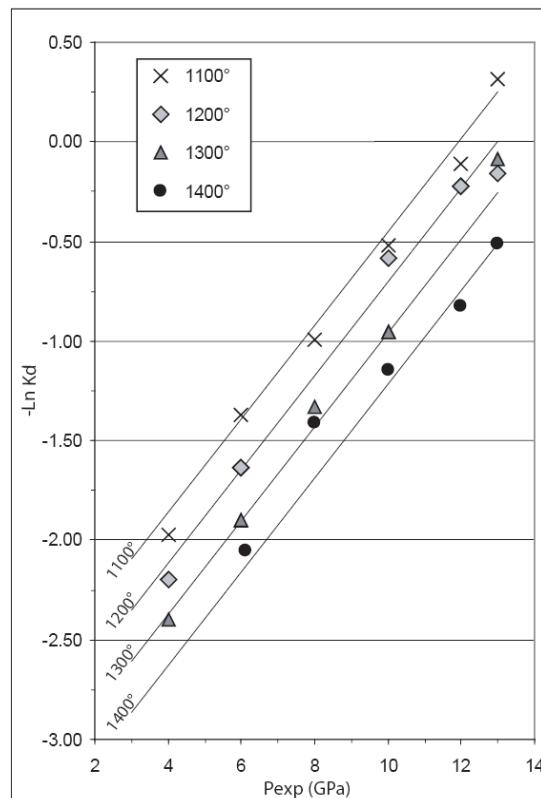


Fig. 1 The negative of the natural logarithm of the partitioning coefficient (Kd) of Li concentration of cpx over garnet is plotted against the experimental P.

In experiments where larger grains were obtained, negligible differences were measured in Li concentrations from core to rim in both garnet and cpx.

Cpx in all of the runs below 10 GPa have higher Li abundances than coexisting garnet. Generally, garnets have less variability in their Li contents compared to cpx.

Multiple linear regression was applied to all of the Kds (with the exception of the experiment performed at 8 GPa, 1400°, the Kd for which is still shown in Fig. 1) and supplies the formula:

$$P = (0.00255 * T - \ln Kd) / 0.2351$$

Where P is in GPa, T is in °C and Kd is defined as the partitioning coefficient of Li obtained by dividing the concentration of Li in cpx by the concentration of Li in garnet. The above regression provides an R^2 of 99.6 (R^2 is a goodness of fit for a formula). The resulting linear regression is shown in Figure 1 and labelled according to T. A standard deviation of 0.38 is obtained when comparing the calculated Ps to the experimental Ps (Fig. 2).

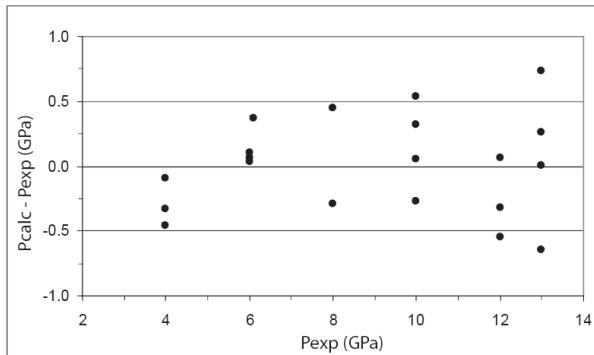


Fig. 2 P calculated from the Li Barometer minus experimental P plotted vs experimental P to show the degree of error of the fit.

Application:

Problems in the application of a Li barometer may arise from a presumed rapid diffusion of Li in certain minerals, and the high concentration of Li in kimberlitic melts. To judge the extent of diffusion of Li in natural samples, Li profiles (using SIMS) were obtained on pristine natural samples from Roberts Victor (SA), Finch (SA) and the Lake Ellen Kimberlite (USA). These profiles show slight Li enrichment at mineral rims, with Li plateaus in the cores. Thus, when attempting to extract Li concentrations from garnet and cpx in kimberlitic eclogites only core values should be used. Fig. 3 shows a sample profile from the diamond bearing eclogite RV-1 sourced from Roberts Victor. Profiles were made on other cpx and garnets within RV-1 and strikingly consistent Li values were found in the cores of all the cpx and garnets studied. This suggests that kimberlite ascent is sufficiently rapid to preserve original equilibrated mantle Li signatures.

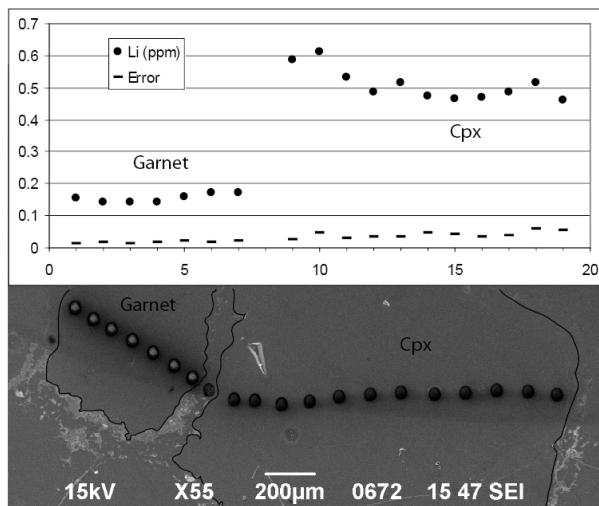


Fig. 3 Li profile performed by SIMS analysis across touching cpx and garnet grains from the diamond bearing eclogitic xenolith RV-1. Analysis points on the upper graph correspond to the points on the underlying SEM image. The sample point in the middle of the grains, which likely represents the kimberlitic melt, has a Li concentration of 150 ppm.

Further Work:

Any thermobarometers calibrated experimentally are only applicable to the bulk composition and system in which they are calibrated, thus, the above formula is only applicable to CMAS until proved otherwise. Experiments in natural systems are currently being performed and support the applicability of the barometer to natural samples, albeit with a correction factor. These experiments are especially needed to check the effect of Na on the observed Li Kd trend as the jadeite component in cpx has a large influence on the pressure of majorite formation and stability (Bobrov et al. 2008). Such a Li-geobarometer when fully calibrated would not only have profound importance in the study of upper mantle processes, but may also have potential application to diamond prospecting and exploration as it could help assign a depth of origin to eclogitic heavy mineral concentrate.

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