

# Lithium and Beryllium abundances in peridotitic, pyroxenitic and eclogitic mantle assemblages

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## Introduction

Magmatic processes such as e.g. partial melting, crystal fractionation and mantle metasomatism variably modify the inventory of lithium and beryllium in the lithospheric mantle. During these processes  $\text{Li}^+$  is likely to behave as a moderately incompatible element because  $\text{Li}^+$  has a similar ionic radius to  $\text{Mg}^{2+}$  or  $\text{Fe}^{2+}$  which permits a coupled substitution in olivine, pyroxenes and garnet, potentially with trivalent cations, such as  $\text{Al}^{3+}$ ,  $\text{Fe}^{3+}$ ,  $\text{Cr}^{3+}$ ,  $\text{Sc}^{3+}$ ,  $\text{V}^{3+}$  and  $\text{REE}^{3+}$ . From ionic radius and ionic charge considerations,  $\text{Be}^{2+}$  is expected to be strongly incompatible.

We have undertaken a detailed study of the Li and Be abundances in olivine, orthopyroxene, clinopyroxene, garnet and spinel from various mantle lithologies and tested their partitioning behavior as a function of P, T and bulk composition. Over 17 well equilibrated spinel- and garnet-peridotite, garnet-pyroxenite and eclogite samples (800° - 1400°C and 10 - 38 kbar) were analyzed by Secondary Ion Mass Spectrometry (SIMS). These mantle xenoliths (from the East African Rift, Massif Central, Mongolia, Vitim & Pali Aiki) establish a baseline with which to compare samples from the Finero and several Pyrenean massifs that have been metasomatically overprinted (Seitz & Woodland, in prep.).

In addition we investigated eclogitic samples from Roberts Victor and Obnazhennaya (Russia) which are believed to have mantle origin (group A eclogites).

## Analytical Technique

Analyses of Li and Be were accomplished using a modified CAMECA 3f-IMS ion microprobe at the Mineralogisches Institut, Universität Heidelberg. Analyses were made using a  $^{16}\text{O}^-$  primary beam at an acceleration voltage of 12.5 kV. A focused beam with an intensity of 10 nA gave a beam diameter of  $\approx 20 - 25 \mu\text{m}$ . Samples were coated with a layer of gold ca. 50 nm thick. Positive secondary ions were accelerated through a nominal 4.5 kV. The energy window was set to 40 eV. We employed energy filtering technique with an offset of -75 V combined with a mass resolution of  $\approx 800$ . The combination of these two techniques suppresses interfering molecules, discriminates between element peaks, such as  $^9\text{Be}$  and  $^{27}\text{Al}^{3+}$ , and minimizes the matrix effects (Ottolini et al. 1993). Ion yields of  $^7\text{Li}$  and  $^9\text{Be}$ , were normalized to  $^{30}\text{Si}$  for silicates and to  $^{26}\text{Mg}$  for spinel. A NIST SRM-610 glass was used as a primary standard. Major element peaks ( $^{30}\text{Si}$  and  $^{26}\text{Mg}$ ) were measured for 2 sec and 8 sec were applied for  $^7\text{Li}$  and  $^9\text{Be}$ . Long term reproducibility of the SRM-610 standard is within 10%. In run precision is 2-15% for  $^7\text{Li}$  and 5-20% for  $^9\text{Be}$ .

## Results

*Lithium* abundances vary with bulk chemistry. Pyroxenes from peridotitic xenoliths have Li concentrations on the order of several hundred ppb, while pyroxenes from pyroxenites have somewhat higher abundances (1-3 ppm with a maximum of 21 ppm). Clinopyroxenes from eclogites have Li concentrations comparable to those from peridotites (400 - 970 ppb). Li in spinels from different localities is greatly variable with abundances, ranging from concentrations below the detection limit ( $< 1$  ppb) up to 750 ppb. Garnets from peridotites and pyroxenites contain  $\leq 120$  ppb Li, whereas those from eclogites have up to 430 ppb Li.

Li is preferentially incorporated into olivine, typically ranging between 1 and 4 ppm. The following partitioning relationship has been established:  $\text{ol} > \text{cpx} \geq \text{opx} \gg \text{grt}$  for grt-peridotites,  $\text{ol} > \text{cpx} \geq \text{opx} \gg \text{sp}$  for sp-peridotites,  $\text{cpx} \geq \text{opx} > \text{grt}$  for grt-pyroxenites and  $\text{cpx} > \text{grt}$  for eclogites. Similar relationships have been observed for sp-peridotites by Ottolini & McDonough (1996). Partition coefficients for Li range between 0,4 - 1,1 for  $\text{opx/cpx}$ , 1,5 - 2,8 for  $\text{ol/cpx}$  and 0,06 - 0,4 for  $\text{grt/cpx}$  (Fig. 1).

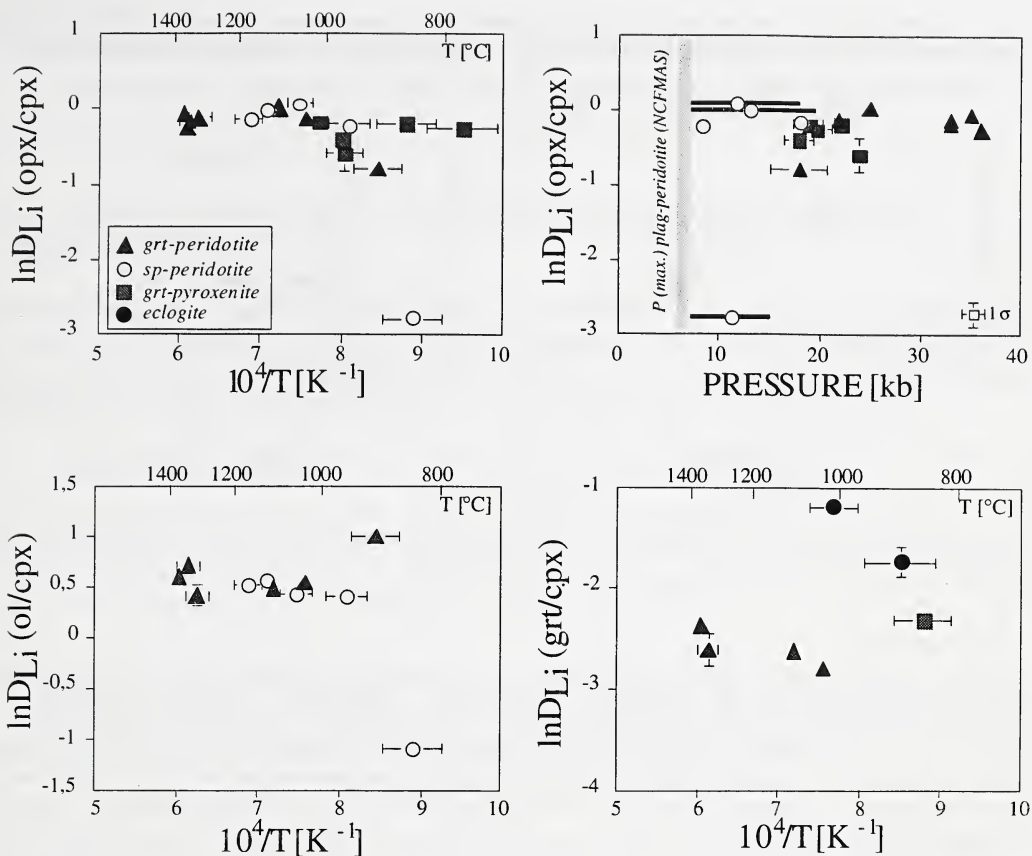


Fig. 1: Temperatures were calculated using thermometers of Brey & Köhler (1990) and Krogh (1988). For grt-bearing samples, the pressure was determined with the Al-in-opx barometer of Brey & Köhler (1990) and for sp-peridotites pressure was estimated using the barometer of Webb & Wood (1986) giving P max. Ca-in-olivine barometer of Köhler & Brey (1990) was applied to 2 samples. Minimum pressure is constrained by the plag- to sp-peridotite transition in the NCFMAS-system (min. to max. pressures are indicated by black bars).

It has been shown that trace element partitioning can be strongly temperature or pressure dependent, and compositional effects have also to be encountered (e.g. Stosch, 1981; Seitz & Altherr, 1996). However, partition coefficients for Li between opx/cpx, ol/cpx and grt/cpx show no dependency upon P or T. With the exception of one amph-sp-peridotite,  $D_{Li} (opx/cpx)$ , for example, exhibits only a limited range; typically 0.7 and 1 (Fig. 1). Preliminary data from metasomatized peridotites and pyroxenites from Finero and several Pyrenean massifs show enrichment of Li in pyroxenes and olivine, whereby Li is preferentially incorporated into clinopyroxene ( $cpx > ol > opx$ ). Calculated Li concentration ratios ( $opx/cpx$  and  $ol/cpx$ ) are significantly lower in these samples compared with 'normal' unmetasomatized peridotites and pyroxenites, suggesting disequilibrium. Thus the Li ratios can only be considered as an indicator of metasomatism rather than being meaningful partition coefficients.

*Beryllium* concentrations in opx and cpx range between 10 and 150 ppb and are close to the detection limit in olivine ( $\approx 2 - 8$  ppb). Beryllium abundances in the garnets and spinels investigated here are at or below the detection limit. Partitioning of Be in pyroxenites and peridotites exhibit following relationship:  $cpx > opx \gg ol$ . The partitioning of Be shows no P

or T dependency for ol/cpx but clearly correlates with temperature for opx/cpx (Fig. 2). The ionic radius of Be is similar to that of Si, suggesting substitution of Be on the tetrahedral site.

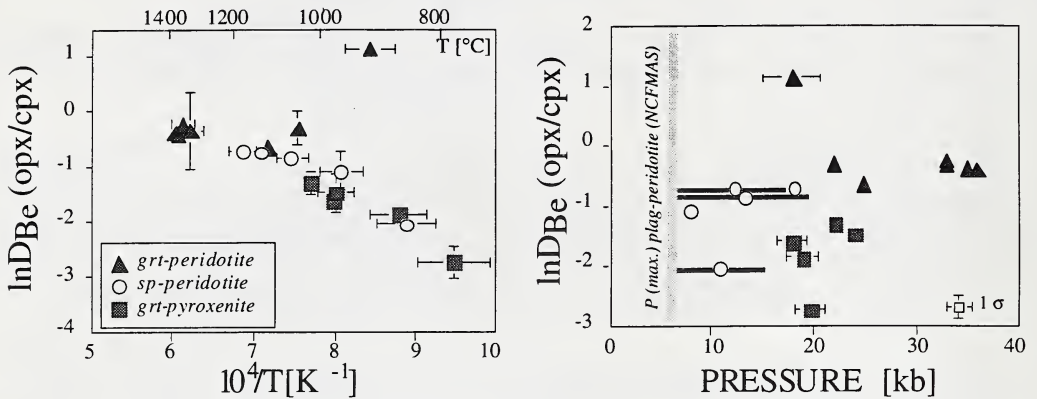


Fig. 2:  $\ln D_{\text{Be}}$  opx/cpx as a function of temperature and pressure (see Fig. 1 for more detailed descriptions).

## Conclusions

Low Li-abundances in mantle peridotites and pyroxenites emphasize its incompatibility during partial melting and fractional crystallization, respectively. However, elevated Li-concentrations are present in some pyroxenites, presumably due to complete crystallization of such partial melts. Disequilibrium is manifested by preferential enrichment of Li in cpx. Since the absolute and intercrystalline partitioning of Li is independent of T, P and bulk composition, Li appears to be a suitable tracer element for chemical processes such as metasomatism.

Our data set indicates that under upper mantle conditions the partitioning of Be has a strong dependence on T and to a lesser extent on P.

## References

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