

LITHIUM CONTENTS IN MANTLE PERIDOTITES AND PYROXENITES: AN INDICATOR FOR MAGMATIC AND METASOMATIC PROCESSES

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ABSTRACT

In the search for a reliable indicator of chemical processes in the Earth's mantle, we have undertaken a study of the Lithium contents in mantle minerals. The motivation behind this investigation is that Li is a relatively mobile alkali metal on the one hand, but its small ionic radius makes it only a moderately incompatible element (e.g., Blundy & Wood, 1994). Such characteristics could make Li a sensitive indicator of metasomatic or magmatic processes. To test this hypothesis, we have measured Li concentrations in orthopyroxene, clinopyroxene, olivine, garnet and spinel from two suites of spinel peridotites, garnet peridotites and garnet pyroxenites; one suite comprises xenoliths that are very well equilibrated in terms of major and a number of minor and trace elements, and the other suite is composed of samples for which there is clear evidence of metasomatism. The metasomatised samples are from several orogenic Iherzolite massifs in the French Pyrenees and the Ivrea Zone (Italy) as well as being xenoliths from Victoria, Australia. The Li concentrations were measured using an ion microprobe (SIMS).

The suite of equilibrated samples indicates that Li is preferentially incorporated into olivine, (1-2 ppm) with lesser concentrations (100s of ppb) in both clinopyroxene and orthopyroxene. The Li contents of garnet and spinel are at or near to the detection level (≈ 10 ppb). The following partitioning relationships are valid for peridotite and pyroxenite bulk compositions respectively: $ol > cpx \geq opx \gg gt, sp$ and $cpx \geq opx \gg gt$. Of particular importance is the observation that the intercrystalline partitioning of Li between these phases is basically independent of temperature and pressure and chemistry, within the limits of such mantle bulk compositions. Combining our results with modal abundances for the samples, the bulk Li content for fertile to moderately depleted lithospheric mantle is 1-1.5 ppm, which is in excellent agreement with other previous estimates for primitive mantle (Jagoutz et al., 1979; Frey et al., 1985; Ryan and Langmuir, 1987; O'Neill, 1991; McDonough and Sun, 1995).

Both the peridotites and pyroxenites display variations in absolute Li abundances, although the partitioning relationships between olivine, clinopyroxene and orthopyroxene are maintained. Lower overall Li abundances in peridotites are consistent with depletion from partial melting and subsequent melt extraction. The pyroxenes in the pyroxenites have variable Li contents with values typically of 1-3 ppm. This is consistent with their origin as cumulates. Some samples have elevated Li contents, which could be due to a higher degree of trapped melt present during crystallisation. Thus the greater variation in Li contents in the pyroxenites can be explained by variable degrees of trapped melt associated with the cumulate crystals, which themselves have rela-

tively low Li concentrations due to the expected melt/solid partitioning behaviour of Li.

The Li contents of the metasomatised samples are generally higher than those observed in the equilibrated samples and usually display much more variability within a single sample. Olivine and/or clinopyroxene can contain in excess of 5 ppm Li in these metasomatised samples. Modal metasomatic phases, such as amphibole and phlogopite also contain Li, but often in concentrations less than in the coexisting olivine or clinopyroxene. Analysis of a hornblendite dike from the Lherz massif indicates that Li is preferentially partitioned into phlogopite compared with amphibole. The most notable feature of the metasomatised samples is that most record a disequilibrium distribution of Li between olivine and the coexisting pyroxenes. Preferential enrichment of Li can occur in either olivine or clinopyroxene apparently depending on the type of metasomatising agent; olivine is preferentially enriched in samples from Victoria, which have been affected by carbonatitic melts and clinopyroxenes are preferentially enriched in samples that have interacted with mafic silicate melts. Samples from Finero (Italy), that apparently interacted with fluids, also Li distributions indicative of moderate disequilibrium. The partitioning of Li between olivine and the pyroxenes provides an additional indicator for recognising cryptic metasomatism. Given the correct conditions (a high enough temperature, long enough time for reaction etc.), an equilibrium distribution can be achieved in metasomatised samples, however, these will still display an overall enrichment in Li compared to 'normal' mantle values.

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