

**VARIATIONS IN LIGHT LITHOPHILE ELEMENTS (Li, B, Be) AND LITHIUM ISOTOPES IN MARTIAN PYROXENES AND OLIVINES: ROLES OF DEGASSING AND DIFFUSION.** M. Anand<sup>1,2</sup> and I. J. Parkinson<sup>1</sup>, <sup>1</sup>Department of Earth and Environmental Sciences, CEPSAR, Open University, Milton Keynes, MK7 6AA, UK ([m.anand@open.ac.uk](mailto:m.anand@open.ac.uk)) <sup>2</sup>Department of Mineralogy, The Natural History Museum, London, SW7 5BD, UK.

**Introduction:** The zoning patterns of light lithophile elements (LLEs: Li, Be, B) in pyroxenes of some Martian meteorites have been used to suggest that the parent basalts were water-saturated, which exsolved and lost an aqueous phase through degassing and eruption, causing depletion in LLEs in the pyroxene rims [1]. In contrast, other investigators have suggested a diffusion controlled fractionation in Li isotopes and LLE distribution pattern in Martian minerals [e.g., 2]. Therefore, the main aims of our project were to determine the LLEs and Li isotopic composition in pyroxenes and olivines from newly discovered Martian meteorites and then model and assess the roles of various processes involved in Martian magmatic history.

**Samples:** We selected two Martian meteorites (LAR 06319 and MIL 03346) for our initial ion-microprobe investigations. LAR 06319 is a phenocryst-rich basalt belonging to the olivine-phyric shergottite group of Martian meteorites [3]. Olivine is the main phenocryst phase followed by low-Ca pyroxene (Fig. 1). The groundmass is feldspathic in composition and occurs as diaplectic glass (a result of impact which

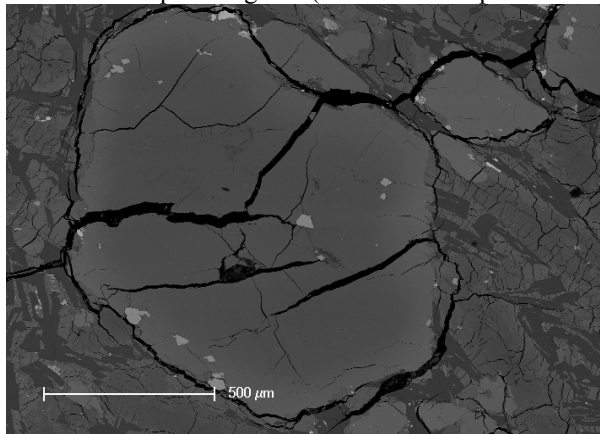


Fig. 1 BSE image of an area in LAR 06319. An olivine phenocryst (~ 1 mm wide) with chromite inclusions is surrounded by pyroxene (light grey) and feldspathic glass (dark grey) in the groundmass.

liberated this sample from Mars). Both olivine and pyroxenes show normal chemical zonations from the cores to the rims in terms of Mg and Fe. The cooling history of this sample is intermediate between the basaltic shergottites and the lherzolithic shergottites, and corresponds to the final crystallization in a thick lava lake. The second sample, MIL 03346 belongs to the

Nakhlite group of Martian meteorites and is one of the fastest cooled basaltic sample that we currently have from Mars (Fig. 2). Clinopyroxene (cpx) phenocrysts dominate this sample with minor olivine occurrences as fayalitic grains. The groundmass is partly-recrystallized glass, mainly feldspathic in composition, with skeletal grains of fayalite, magnetite, ilmenite, and sulfides [4].

**Measurements:** Li isotopic ratios, and Li, Be and B concentrations were determined along a number of

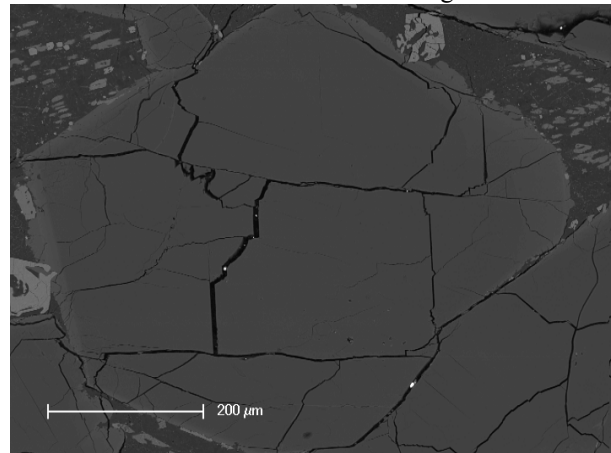


Fig. 2 BSE image of an area in MIL 03346. A cpx phenocryst (~ 0.5 mm wide) is surrounded by partially-recrystallized glass (dark grey).

rim to core profiles in 7 olivine and pyroxene grains from LAR 06319 and 6 cpx grains in MIL 03346 using Cameca ims 4f SIMS at the NERC ion-microprobe facility at the University of Edinburgh. Full details of the analytical technique employed for these measurements have been described elsewhere [5, 6].

**Results and Discussion:** In contrast to McSween et al. [1] study, which reported systematic variations in LLEs between the core and rim of pyroxenes in some Martian meteorites, for Be and B we did not observe any such variations and in fact Be concentrations in minerals from both samples were extremely low (~ 0.01 ppm). These new data suggest that previous studies may have over-estimated Be concentrations in Martian pyroxenes. In most cases, we found elevated Li concentrations in the rim zones of clinopyroxenes and olivines. The groundmass measurements made in MIL 03346, next to the rim zones show very little enrich-

ment in Li concentrations but are enriched in B concentrations. This may be explained by the rapid diffusion of Li into the crystals compared to the slow diffusion of B. The measured profiles for Li isotopes in both samples display characteristic negative  $\delta^7\text{Li}$  troughs near the rim zones (Fig. 3-4), consistent with preferential diffusion of  $^6\text{Li}$  into the grain interior. Representative plots of the Li data are shown in Figures 3 and 4.

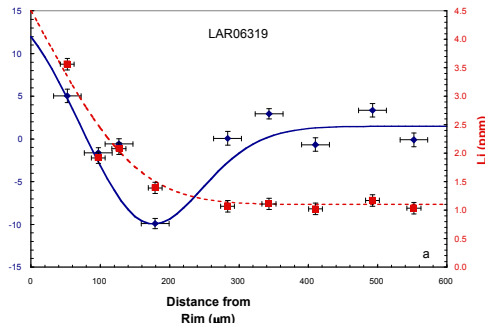


Fig. 3 Plot of  $\delta^7\text{Li}$  and Li concentrations as a function of distance from the rim in an olivine crystal in LAR 06319. Modelled  $\delta^7\text{Li}$  (solid blue) and Li concentrations (dashed red) profiles, represent 100 days of diffusional re-equilibration at  $1150^\circ\text{C}$ .

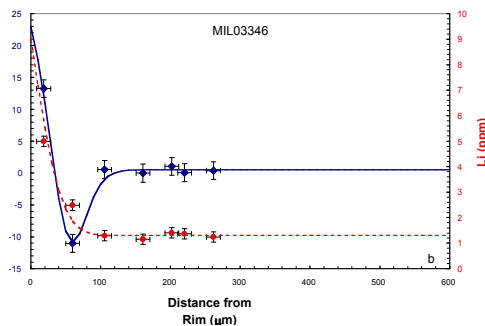


Fig. 4 Plot of  $\delta^7\text{Li}$  and Li concentrations as a function of distance from the rim in a cpx crystal in MIL 03346. Modelled  $\delta^7\text{Li}$  (solid blue) and Li concentrations (dashed red) profiles, represent 5 days of diffusional re-equilibration at  $1000^\circ\text{C}$ .

Modelling [6] of our Li concentration and isotope data suggests that the profiles were produced by diffusional processes. For LAR 06319, modelling of the Li concentration profile in olivine at  $1150^\circ\text{C}$ , yields a diffusional interaction time of 100 days, consistent with Fe-Mg data. MIL 03346 clinopyroxene yields a short interaction time of  $\sim 5$  days, in line with its rapid cooling history. In both samples the crystals interacted with an evolved melt that is both enriched in Li, but also seems to have a heavy Li isotope composition (+12 to +25).

The origin of this heavy Li signature is enigmatic, but consistent with a previous study [2]. We plan to select additional Martian meteorites, different in composition and cooling history from the ones we have analysed, for our future investigations. This will allow us to build up a large database of LLE concentrations and Li isotope data in Martian minerals with which we can model and understand the role of diffusional processes in the evolution of Martian magma.

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**References:** [1] McSween Jr. H. Y. et al. (2001) *Nature* 409, 487–490 [2] Beck P. et al (2006) *GCA* 70, 4813–4825 [3] Anand M. et al. (2005) LPS XXXVI, 1639–1640 [4] Basu Sarbadhikari A. et al. (2009) *GCA* 73, 2190–2214 [5] Kasemann S. et al. (2005) *Anal. Chem.* 77, 5251–5257 [6] Parkinson I. J. et al. (2007) *EPSL* 257, 609–621