SIMS ANALYSIS OF THE ISOTOPIC COMPOSITION OF LITHIUM IN METEORITES. D. R. Bell[1,2], P. R. Buseck[1,2], M. Channon[2,3], R. L. Hervig[2], K. Rieck[2], and S. J. Singletary[4], [1]Dept. of Chemistry & Biochemistry, [2]School of Earth and Space Exploration, Arizona State University, Box 871404, Tempe AZ 85287; [3]Div. Geological & Planetary Sciences, Caltech 170-25, Pasadena CA 91125; [4]Dept. Natural Sciences, Fayetteville State University, 1200 Murchison Rd., Fayetteville NC 28301 (david.r.bell@asu.edu)

Introduction: The solar system appears to be relatively homogeneous in Li isotopic composition on a scale from planets to bulk meteorites and even chondrules [1-3]. However, large variations in δ^7Li and Li content of minerals in meteorites have been shown to exist on small spatial scales [4,5]. These variations have potentially wide-ranging application to tracing the origin of meteoritic components, constraining evaporative volatile loss, cooling rate studies, and tracing various alteration processes. A range of meteorite types are being investigated by SIMS analysis at ASU in order to better understand the range of δ^7Li in meteorites and the origins of micro-scale δ^7Li variations. The major focus has been on olivine because of its widespread occurrence and major element compositional simplicity, which has proved important in the evaluation of composition-dependent instrumental fractionation of ^{7}Li/^{6}Li (matrix effects).

Samples: (1) *Pallasites*. 79 analyses were performed without regard to spatial context on olivines separated from 13 pallasites. These samples were chosen to obtain an initial overview of ^{7}Li/^{6}Li in pallasites. (2) *Carbonaceous chondrite*. Olivines of variable composition from a variety of petrographic associations within the Allende CV3 carbonaceous chondrite were analyzed. Results of 89 SIMS analyses from 19 chondrules or isolated matrix olivines are reported here. These included olivine within porphyritic and barred chondrules, and isolated euhedral and subhedral olivines in the matrix. (3) *Eucrite*. Pigeonite and plagioclase from the Pasamonte eucrite were analyzed. (4) *Ureilite*. Primary olivine and pigeonite and secondary forsterite rims on primary olivine were analyzed from the El Gouanem ureilite.

Analytical Techniques: ^{7}Li/^{6}Li and ^{7}Li/^{28}Si ratios were measured on the Cameca IMS-6f secondary ion mass spectrometer (SIMS) at Arizona State University. A 15-30 nA primary O^- ion beam was used to generate secondary ions from craters ranging from ~30-50 μm in diameter. Mass resolution was set at ΔM/M of 600 – 2000 because $^6LiH^+$ (potentially interfering with $^7Li^+$) was not observed. A total of 100 cycles were analyzed per spot, with 3-5 minute presputter. In cases where ^{7}Li/^{28}Si was aquired these were determined prior to isotope analysis in the same crater, with each reported ratio the average of 20 cycles. Each 100 cycle analysis was processed manually to remove outliers and monitor count rate variation due to surface contamination or instrument fluctuations.

The Li isotope compositions were determined relative to standard materials of known ^{7}Li/^{6}Li. For olivine this was the internal standard KBH1, an olivine of composition Fo90.5 from a terrestrial spinel lherzolite xenolith. For the eucrite study the basalt glass standard BHVO-2G was used. Contrary to frequent assumption, matrix effects in SIMS analysis of ^{7}Li/^{6}Li can be severe, particularly in olivine. The matrix effect was calibrated by independent analysis of a series of terrestrial olivines. From Fo74 – Fo94 the effect of composition on ^{7}Li/^{6}Li is linear, with the instrumental fractionation decreasing at a rate of 1.30 ‰ in δ^7Li per increase in Mg# (Fo) unit (or increasing at 1.46 ‰ per wt. % FeO) At FeO contents higher than ~24 wt. % (Fo74) the effect becomes non-linear, and the trend appears to reverse, so that at ~Fo52 the fractionation is similar to that at Fo86. Furthermore, it was found that the compositional limit to the linearity of the matrix effect was different for the IMS-3f at ASU to that described above for the IMS-6f used in this study. This complex behavior illustrates the need for precise calibration of the matrix effect, particularly where traverses in zoned crystals are concerned. Because the non-linearity of matrix effects at Fo<~73 has not been calibrated, analyses of the Allende matrix and of Fe-rich olivine with <Fo73 are not reported. The olivine composition at each SIMS crater was determined by electron microprobe.

Results: *Pallasites.* δ^7Li is homogeneous within the olivine grains, but small differences may exist between the meteorites. From 3 to 12 analyses were performed for each meteorite (Fig. 1) and in almost all cases the internal variability was within analytical uncertainty. The only exception is Eagle Station where the total range of 8 ‰ from 11 analyses exceeds overlap at the level of ± 2σ. The mean δ^7Li for Eagle Station [2.3 ± 1.5 ‰ (2se)] does not differ significantly from the mean of all pallasites [1.62 ± 0.5 ‰ (2se)] indicating no difference in Li isotope composition from the Main Group. This average pallasite composition is closer to that obtained for ordinary chondrites than for carbonaceous chondrites [1]. The result for Admire [δ^7Li = 2.8 ± 3.1 ‰ (2sd, n=3)] is in agreement with the published value of 3.4 ± 0.3 ‰ [1]. Within the Main Group small differences are apparent

between a subgroup comprising Esquel, Admire, and Springwater, with mean δ^7Li in the range 2.8 to 4.6 ‰ and Otinapa, Rawlinna, and Dora (-0.8 to 0.6 ‰). In addition, there is a general negative correlation between the average δ^7Li and Li contents for all the pallasites. This suggests that the various pallasite parents could be related by differential degrees of Li loss, with preferential loss of ^{6}Li giving rise to the highest δ^7Li at the lowest Li contents. However more extensive sampling and analysis is required to test whether or not this is merely local redistribution of Li.

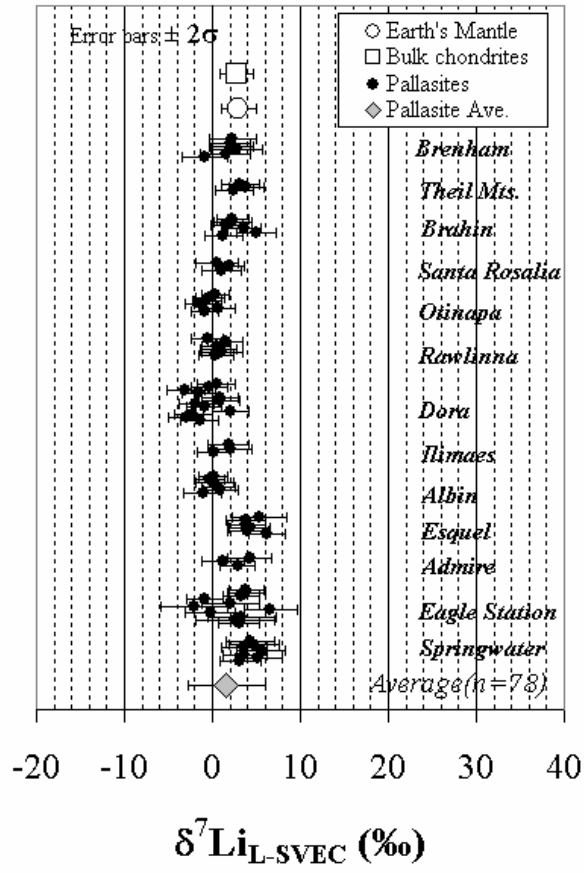

Fig. 1. Li isotope compositions of pallasite olivines

Allende. Li concentrations (0.06 – 4.7 ppm) and ^{7}Li/^{6}Li ratios (δ^7Li from -29 to +30 ‰) vary substantially within and between olivines of the different petrographic components, and are also correlated with composition. The more fayalitic olivines (Fo < 90) generally have high Li concentrations (>0.5 ppm) and δ^7Li similar to bulk chondritic values (i.e. 3 ± 2 ‰) [1-2] (Fig. 2). Significantly higher δ^7Li values (up to 30 ‰) occur in forsteritic olivines (Fo>90) and are associated with Li contents < 1.5 ppm. These features are qualitatively consistent with preferential evaporative loss of ^{6}Li in high temperature chondrule forming events, or possibly in chondrule precursors.

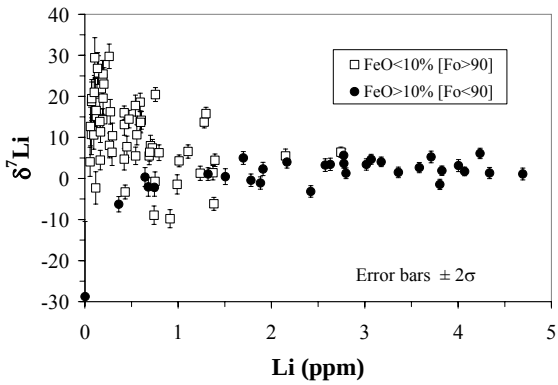

Fig. 2. Li isotope compositions and Li contents of Allende olivines, divided into two groups on the basis of Fe content.

δ^7Li varies by up to 20‰ within individual olivine grains. Zonation patterns were investigated in 11 samples. Of these, five (2 chondrules and 3 olivine grains) clearly show higher δ^7Li in the cores and lower δ^7Li near the rims. In one sample, δ^7Li increases in one direction only, presumably indicating that the isotopic heterogeneity was acquired prior to breakage of the grain and incorporation into the meteorite matrix. The edges of high δ^7Li forsterite grains commonly show higher Li and lower δ^7Li, indicating possible interaction with matrix or the matrix-forming agent. Poor correlation of Li with FeO suggests decoupling due to different diffusion rates of Fe and Li.

Pasamonte eucrite. Pyroxene with δ^7Li of -4 to +10 ‰ is heavier than coexisting ~An_{90} (-15 to -5 ‰), which may signify low-temperature Li exchange with the feldspar. Because coexisting ~An_{42-50} plagioclase and pyroxene give similar δ^7Li [e.g., 5] a matrix effect on An-rich plagioclase must be explored.

El Gouanem Ureilite. Sixty analyses corrected for matrix effects on the basis of FeO content show overlapping δ^7Li for olivine (6.1 ± 2.7‰) and pigeonite (6.7 ± 4.8‰) with markedly heavier δ^7Li in late-stage forsteritic rims (20.2 ± 5.2 ‰). These results will be discussed in further detail [6].

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