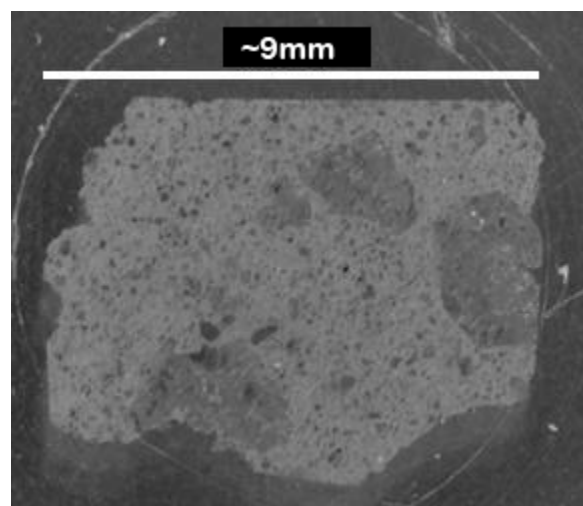


**LITHIUM ISOTOPE ANALYSIS OF EUCRITE MINERALS: IMPLICATIONS FOR THERMAL HISTORY OF 4 VESTA.** K. D. Rieck, R. L. Hervig and T. G. Sharp, Arizona State University, School of Earth and Space Exploration, P.O. Box 871404, Tempe, AZ 85287-1404, [Karen.Rieck@asu.edu](mailto:Karen.Rieck@asu.edu).

**Introduction:** Richter et al. [1] were the first to show that  $^7\text{Li}$  diffuses more slowly than  $^6\text{Li}$ . Because lithium isotopes diffuse at different rates, initially isotopically homogeneous grains may become zoned as lithium concentrations attempt to diffusively equilibrate during subsolidus cooling. Such isotope ratio variability has been used to infer cooling rates of Martian meteorites [2], and might be useful in inferring cooling rates on the eucrite parent body. Zoned pyroxene crystals in the eucrite meteorite Pasamonte indicate a history of chemical and thermal disequilibrium. Li zoning patterns (nonisotopic) provide evidence of subsolidus modification [3]. Here we present data on  $\delta^7\text{Li}$  variability in Pasamonte for the purpose of determining cooling history. Preliminary  $\delta^7\text{Li}$  measurements on Juvinas minerals are provided for comparison.



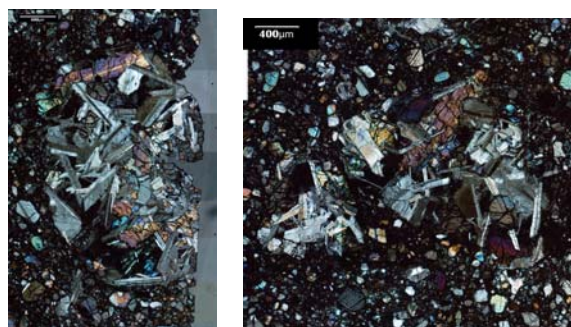
**Fig. 1.** Pasamonte. Reflected-light image of the thin-section analyzed. Large dark-gray portions are clasts of relatively large pyroxene and plagioclase crystals. Lighter gray portions represent a brecciated matrix.

**Approach:**  $\delta^7\text{Li}$  in pyroxene and plagioclase crystals from two clasts in Pasamonte (Figure 2) were measured with Cameca IMS 3f and 6f Secondary Ion Mass Spectrometers. One other pyroxene grain isolated in the matrix was also analyzed. In addition, the  $\delta^7\text{Li}$  content of the matrix was measured. However, the mineralogy represented in those matrix analyses could not be determined.

$\delta^7\text{Li}$  values (in ‰) for all phases were calculated from the raw  $^7\text{Li}/^6\text{Li}$  ratios by comparison to a bulk-analyzed basaltic glass, BHVO-2g [4] studied in each

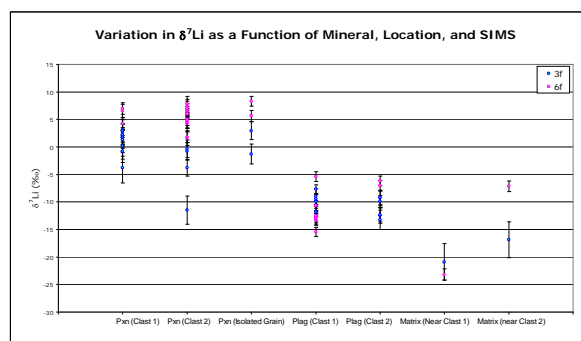
analysis session. The error for each analysis ranged from 1-3‰ ( $2\sigma$ ).

A similar procedure was followed to measure  $\delta^7\text{Li}$  in pyroxene and plagioclase crystals from the monomict Main Group eucrite, Juvinas.



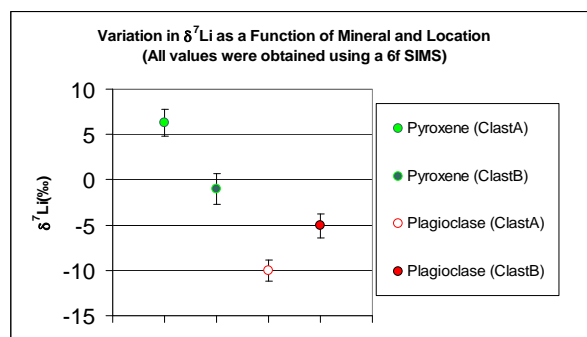
**Fig. 2:** Two clasts from Pasamonte. (Each scalebar represents 400µm.) Pyroxene and plagioclase crystals from Clast 1 (on left) and Clast 2 (on right) were subjected to  $\delta^7\text{Li}$  analysis (see Figure 3). The “isolated grain” refers to an apparently zoned pyroxene crystal fragment below and just left of center of Clast 2.

**Results:** SIMS analyses of Pasamonte pyroxenes reveal little zoning in  $\delta^7\text{Li}$ ; the maximum variation within any pyroxene crystal in a clast was ~3.5‰ (a slightly larger range was observed in the isolated crystal in the matrix: 4.3‰). Total range of values was ~10‰ (with 1 outlier) (Fig. 3). Pasamonte plagioclase crystals also show little  $\delta^7\text{Li}$  zoning, with a total range in  $\delta^7\text{Li}$  of ~10‰. Surprisingly,  $\delta^7\text{Li}$  appears to be 10 to 20‰ heavier in pyroxene than in plagioclase or in the brecciated matrix.



**Fig. 3.**  $\delta^7\text{Li}$  in Pasamonte crystals. Note the relatively higher  $\delta^7\text{Li}$  values measured in pyroxene crystals relative to plagioclase crystals. These differences were independent of the particular mass spectrometer used, or the clast analyzed.

A few preliminary measurements on Juvinas pyroxene and plagioclase crystals produce similar results, albeit with some scatter (Fig. 4).



**Fig. 4.** Preliminary  $\delta^7\text{Li}$  analyses in Juvinas crystals. Note relatively higher  $\delta^7\text{Li}$  values for pyroxene relative to plagioclase.

**Discussion and Conclusions:** While our analyses of Pasamonte pyroxene crystals showed relatively small isotopic variations, Herd et al. [3] observed core to rim changes in Li concentration. We determined that plagioclase and the surrounding matrix is 10 to 20% lighter than pyroxene. While we have no Li isotope standard for plagioclase, Beck et al. [5] suggest that matrix effects between these minerals are small. If our analyses of all phases are taken at face value, our observations suggest at least 3 steps in the meteorite's thermal history:

1.) There was a high temperature equilibration of all phases with a Li source having  $\delta^7\text{Li}$  of  $\sim 3 \pm 3\%$ , or about the same as the terrestrial mantle and other bulk-analyzed meteorites. This equilibration likely occurred just prior to eruption, while these basalts were still molten. Source Li concentrations may have varied during crystal growth or during a thermal event after growth producing the zoning patterns observed by Herd et al. [3].

2.) After thorough equilibration there was relatively rapid cooling to lower temperatures ( $\sim 500^\circ\text{C} > T > \sim 250^\circ\text{C}$ ). Given: 1) typical grain sizes 400-800  $\mu\text{m}$  (see Figure 2), cooling rate estimate by Schwartz and McCallum [6] of  $10^{-2}^\circ\text{C/day}$ , and 3) diffusion coefficients from Coogan et al. [7] and Giletti and Shanahan [8] we calculate closure temperatures of  $\sim 500^\circ\text{C}$  for pyroxene and  $\sim 250^\circ\text{C}$  for plagioclase. Rapid cooling to temperatures between  $\sim 500^\circ\text{C}$  and  $\sim 250^\circ\text{C}$  would have halted migration of Li into or out of the pyroxene, preserving the near-terrestrial  $\delta^7\text{Li}$  values observed in these crystals. Rapid cooling is consistent with eruption onto the surface of the eucrite parent body.

3.) Rapid cooling was likely followed by a low temperature event with an isotopically light Li source. Pyroxene would have limited opportunity to partici-

pate in Li exchange, while plagioclase (at temperatures above its closure temperature) could still lose or gain Li from its surroundings, causing the observed  $\delta^7\text{Li}$  departure from near-terrestrial values.

Schwartz and McCallum [6] suggest a complex history for Pasamonte while it existed on the surface of 4 Vesta: rapid cooling, burial, exhumation by impact and brecciation, mixing, reburial, and partial equilibration during thermal annealing; these events were likely followed by an additional impact that liberated Pasamonte from the surface of 4 Vesta. Some of these events may have prompted Li isotope redistribution. Additional work using Li isotope distributions in eucrite minerals to constrain the magnitude and duration of heating events is indicated.

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