MG ISOTOPE RATIO ZONATION IN CAIS—NEW CONSTRAINTS ON CAI EVOLUTION.

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Introduction: We report *in situ* UV laser ablation MC-ICPMS measurements of Mg isotope ratios from two CV3 CAIs, Allende 3576B and Leoville 144A. Sample-standard bracketing affords precision of less than 0.2 ‰ (2σ) for δ^{25}Mg and 0.3 ‰ (2σ) for δ^{26}Mg. The precision is sufficient to resolve mass dependent variations within distinct CAI domains that are difficult to obtain by bulk methods (e.g., TIMS) and are not presently achievable with other *in situ* methods due to instrumental fractionation (e.g., SIMS). The aim of this work is to provide tests of recently proposed models for the chemical and isotopic evolution of CAIs involving volatilization of precursor solids and melts in the solar nebula.

Sample Description: Allende USNM 3576B is a ~4 mm x 3.5 mm Type B CAI composed of intergrown melilite and Ti, Al-rich diopside surrounded by a mantle dominated by melilite. Mg-rich spinel is abundant throughout the inclusion. Leoville 144A is a compact Type A measuring ~10 mm x 6 mm. It is composed of fine grained intergrown melilite and Ti, Al-rich diopside that enclose abundant micron-sized perovskite grains. Mg-rich spinel is distributed throughout the inclusion. Leoville 144A has a Wark-Lovering (W-L) rim composed of an inner layer of intergrown hibonite and spinel and an outer layer of Al-diopside.

Analysis: Mg isotopes were measured at UCLA by UV laser ablation MC-ICPMS using a Finnigan Neptune instrument following the approach of [1]. All Mg isotope data have been normalized to the DSM3 standard [2]. Typical pit sizes are ~75-100 µm, although spots less than 50 µm were also achieved (Figure 1). *In situ* oxygen isotope ratios and REE abundances have been reported previously for Leoville 144A [3].

Mg Isotopes: Measuring radiogenic ^{26}Mg (^{26}Mg*) in low-Al minerals (e.g., Ti, Al-diopside, Mg-rich melilite) is difficult with other analytical methods. Laser ablation combined with MC-ICPMS gives one the ability to address features of the ^{26}Al-^{26}Mg isotope system as preserved in the volumetrically dominant low-Al minerals. Figure 2 shows the Mg isotope evolution of the Leoville 144A CAI. The low-Al phases exhibit a trend with a slope that corresponds to an initial ^{26}Al/^{27}Al that is indistinguishable from the canonical value of 5 x 10^{-5}. Several analyses fall below the canonical line, suggesting hints of disturbances in the Mg-Al isotope system. The causes of these disturbances might be addressed with more study.

In detail, USNM 3576B exhibits marked (2-3 ‰) edgeward deceases in δ^{25}Mg with increasing Al/Mg. The pattern of light isotope enrichment toward the margin is robust; three traverses from the interior to edge show remarkable concordance between distance and Mg isotope composition (Figure 3). This fractionation trend towards isotopically light Mg is unexpected since the CAI exhibits typical edgeward increasing Al/Mg ratios commonly believed to represent evaporative loss of Mg.

In contrast to the Allende Type B CAI, the compact Type A CAI Leoville 144A has more subtle Mg isotope fractionation effects that are consistent with conventional models for evaporative enrichment of both δ^{25}Mg and Al/Mg values towards the margin (Figure 3) [4]. Measurements of areas within 100 µm of the W-L rim of Leoville 144A have δ^{25}Mg values ~0.5-1.0 ‰ greater than the interior of the object. These enrichment trends are consistent with evaporative loss of Mg at the margins. A previous study has shown that the W-L rims of this CAI are enriched in REEs by a factor of 10x [3], suggesting that at least parts of the rims are evaporative in origin.

Preliminary results on the W-L rim of the Leoville CAI show radiogenic ^{26}Mg signatures (≥0.3-0.8 ‰ δ^{26}Mg*) and relatively low δ^{25}Mg values. We have some concern that the W-L rim analyses impinged on underlying mineral phases and we are presently honing the ablation method to accommodate the rapid ablation rate of these materials. Nevertheless, two rim analyses (spots 25 and 77) appear to be informative and reliable. Spot 25 may be a mixture between W-L rim material and the adjacent melilite margin, but no matrix was included in this ablation pit. Therefore, its relatively low δ^{25}Mg value indicates a lower δ^{25}Mg signature for the W-L rim (Figure 2). The second reported W-L rim analysis, spot 77, may include some matrix with no resolvable ^{26}Mg*. Unlike spot 25, spot 77 is clearly outside of the neighboring melilite margin (Figure 1) but could have clipped underlying matrix material. In this case the fact that the analysis still falls on the canonical Mg isotope isochron is preliminary evidence that the W-L rims formed with the full compliment of ^{26}Al present throughout the rest of the object. We expect that further UV laser ablation MC-ICPMS measurements of rims will be sufficient to confirm or contravene these preliminary conclusions.

Implications: These isotopic profiles demonstrate that CAIs can show a wide range in Mg isotope systematics. Both objects exhibit a rimward enrichment in Al/Mg but the attendant Mg isotope fractionations are distinct. Apparently, the Leoville Type A experienced a relatively simple evaporative history during its final stages of formation; it formed in the presence of a Mg-undersaturated gas. The Mg isotope data suggest that the oxygen isotopic composition of Leoville 144A [3] should include several per mil of mass-dependent fractionation due to evaporation. Thus far there appears to be no resolvable difference in $^{26}Al/^{27}Al$ between Leoville 144A and its W-L rim, but verification is warranted. Data for the Allende Type B object can be explained by open-system Mg isotope exchange during the final melting event at higher Mg partial pressures.

References: [1] Young E. D. et al. (2002) *GCA* 66, 683-698. [2] Galy, unpublished value. [3] Russel S. S. et al. (2001) M*et.Soc.* abstr. 5406. [4] Richter F. M. et al. (2002) *GCA* 66, 521-540.

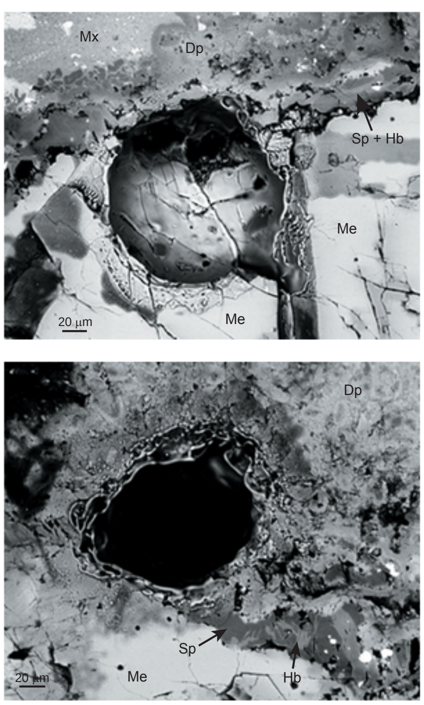

Figure 1. Laser ablation pits in Leoville 144A. Upper panel shows laser ablation pit composed of margin melilite > W-L spinel and hibonite. Lower panel shows W-L rim spot 77 described in the text.

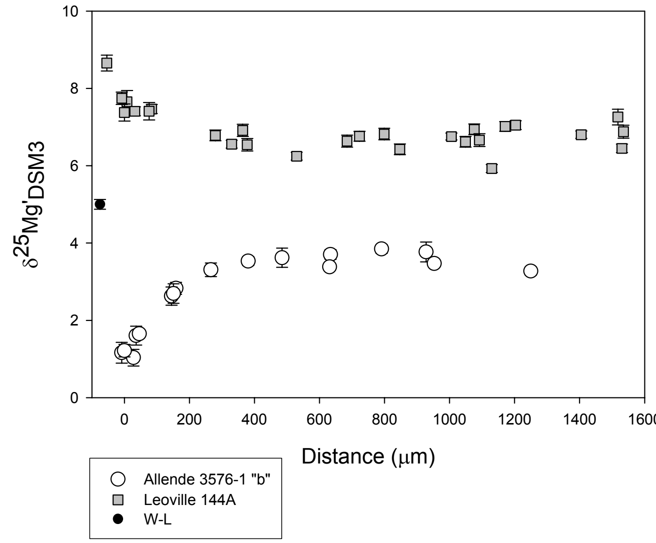

Figure 2. Multiple traverses from interior (right-hand side) to edge (left-hand side) of CAIs Allende 3576B (open circles) and Leoville 144A (grey squares). Errors are 1σ.

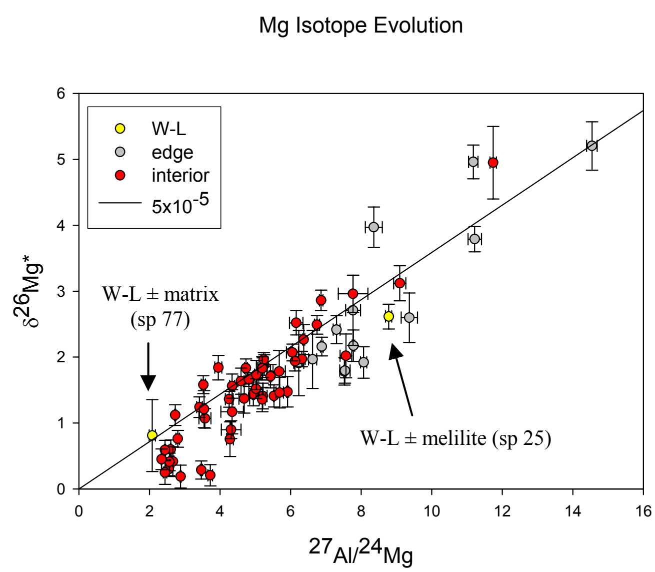

Figure 3. ^{26}Al-^{26}Mg* evolution diagram for the Leoville 144A compact Type A CAI. Conanical $(^{26}Al/^{27}Al)_o$ = 5 x 10^{-5} line is shown for comparison. Errors are 1σ.