CANONICAL ANORTHITE IN A GROSNAJA FORSTERITE-BEARING CAI

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Introduction: Forsterite-bearing Ca,Al-rich inclusions (FoB's) are a small subset of CAIs most notable for the fact that more than half of reported examples are FUN inclusions with significant mass dependant fractionation effects [1,2]. Recent petrographic studies of 10 FoB's in a CV chondrite confirmed that many of them experienced extensive evaporation of Mg and Si during crystallization [3]. However, very limited Mg isotopic studies have been carried out on FoB's in general. We report oxygen isotopic ratios and UV laser ablation MC-ICPMS measurements of Mg isotope ratios in a Grosnaja FoB (63624-1) that was initially thought to be a FUN inclusion. Studies of rare inclusions like FoB's affords precise tests of models predicting correlations between mineral or whole-rock chemistry, isotopic fractionation and chronologies [e.g. 4, this meeting].

Sample description: Grosnaja 63624-1 is an irregular fragment measuring ~ 3 x 2 mm. It consists mainly of Ti-Al diopside (or fassaite~60%) and melilite (~20%) with subordinate spinel, olivine, anothite and diopside (~20%). Olivine and spinel are poikilitacally enclosed within Ti-Al diopside and rarely melilite. The olivines occur as equant to subhedral grains (up to 60 µm). Melilite does not exhibit any obvious zoning from core to rim ($Åk_{80-90}$). The anorthite occurs mainly at the periphery of the inclusion and within the the Wark-Lovering (WL) rim either individually (40-70 µm) and/or mixed with other phases notably Ti-Al diopside and melilite. Most of the mineral grains exhibit minimal alteration. The WL rim (80-100 µm) is composed of an inner layer (up to 60µm) of spinel, middle layer of mixtures of anorthite, Al-diopside and melilite and an outer layer of spinel and olivine (Figure 1).

Methods: The Mg isotopes were obtained using a Neptune multiple-collector inductively coupled plasma-source mass spectrometry (MC-ICPMS) and a 213 UV solid laser following the approach of [5]. All the isotopic data have been normalized to the DSM3 standard. *In situ* analyses were performed as spots or line scans. Laser spot size was typically 50 to 75 µm with pit depths on the order of 20 µm. Sample standard bracketing affords precision of less than 0.2 ‰ (2σ) for δ^{25}Mg and 0.3 ‰ (2σ) for δ^{26}Mg using our technique. Oxygen isotopic ratios were measured using the methods described in [5].

Results: The oxygen isotopic composition of Grosnaja 63624-1 lies on the slope ~0.95 CCAM line defined by 'normal' CAI's confirming that it is not a FUN inclusion.

Figure 2 shows the Mg isotopic evolution of Grosnaja 63624-1. Weighted linear regression [6] of all the data defines an $(^{26}Al/^{27}Al)_0$ value of 5.26 (±0.03 2σ) x 10^{-5} with an intercept of 0.085 (±0.12 2σ) per mil and an MSWD of 0.454. The isochron is defined by anorthite on one end and low Al-phases on the other. The anorthite falls on the canonical slope with an $(^{26}Al/^{27}Al)_0$ value of 4.44 (±0.013 2σ) x 10^{-5} and an essentially zero intercept. The other dominant phases i.e. Ti-Al diopside and melilite by themselves define slopes within uncertainties of the overall $(^{26}Al/^{27}Al)_0$.

Figure 3 shows the Mg isotopic evolution in the three-isotope space. In general, the data yields δ^{25}Mg values that show slight to marked enrichment relative to those determined for terrestrial objects. The enrichment, however subtle, is consistent with mass dependant fractionation. Excluding anorthite, the isotopic data can be divided into two distinct populations. The first type defined by 'heavier' (>2 ‰) δ^{25}Mg values and the other by 'lighter' (<2 ‰) δ^{25}Mg values. The heavier values correspond to the core phases i.e. melilite, Ti-Al diopside, diopside, olivine and their mixtures. The 'lighter' δ^{25}Mg values correspond to the rim phases notably the mixed phases in the middle layer and the spinel and olivine in the outer layer. These rims were analysed as line scans but two spot analyses of olivine and spinel grains within these layers also showed similar 'lighter' values. Edgeward depletion in δ^{25}Mg values is also obvious in some traverse plots across the object (not shown).

It is unclear why the inner spinel layer within the WL rim shows δ^{25}Mg values that are similar to those from the core of the object. It is possible that this band crystallized as part of the mantle rather than rim although this is not obvious petrographically.

Discussion: Grosnaja 63624-1 exhibits rimward depletion in δ^{25}Mg values consistent with formation of rims as condensates [e.g. 7]. The forsterite grains are in isotopic equilibrium with the rest of the object, suggesting contemporaneous crystallization. This puts to rest earlier speculations that forsterite grains in FoB's might be exogenous.

The canonical initial $^{26}Al/^{27}Al$ of anorthite in Grosnaja 63624-1 supports a new model for CAI evolution in objects that show evidence for supercanonical initial $^{26}Al/^{27}Al$ values of at least 6.0 x 10^{-5} [4]. Grosnaja 63624-1 shares the same general petrographic and Mg isotopic characteristics as Efremovka E44 (E44) reported therein. The anorthites in E44 are canonical but the melilites show a non-zero initial $\delta^{26}Mg^*$ of 0.7 ‰, higher than the 0.085 ‰ for Grosnaja 63624-1. The canonical values in anorthites are interpreted as recording ^{26}Al-$^{26}Mg^*$ closure with a common solar system initial $^{26}Al/^{27}Al$ that followed resetting of the ^{26}Al-$^{26}Mg^*$ system. The resetting of anorthites translates to a residence time (τ) of 300,000 years for CAI's in the nebula [4]. We suggest that the canonical initial $^{26}Al/^{27}Al$ shown by anorthites in Grosnaja 63624-1 is a product of closure after t = τ years. The intercept indistinguishible from zero is a consequence of its higher whole-rock Mg-Al ratios relative to E44 (anorthites and melilites in E44 are orders of magnitude larger in size). More analysis of FoB's is planned to confirm if they exhibit similar behavior.

References: [1] Clayton R.N. et al. (1984) *GCA, 48,* 535-548. [2] Davis, A.M. et al. (1991) *GCA, 55,* 621-637. [3] Krot, A.N. et al. (2000) *MAPS, 35,* A93-A94. [4] Young, E.D. et al. (2005; this meeting) [5] Young, E.D. et al. (2002) *GCA, 66,* 683-698. [6] Mahon, K.I. (1996) *IGR, 38*, 293-303. [7] Simon, J.I. et al. (2004) *LPSC XXV*, 1684.

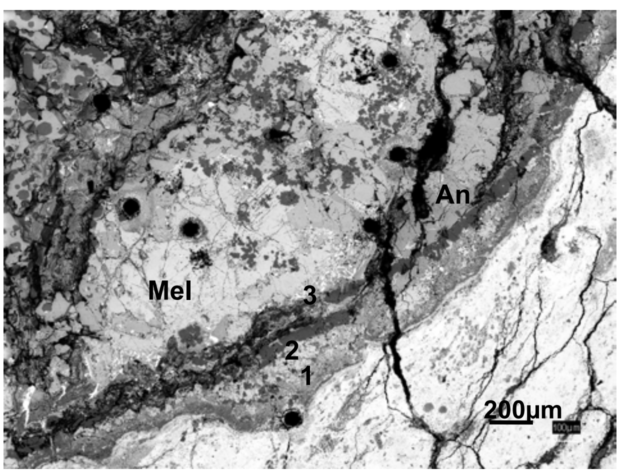

Figure 1. SEM BSE image of a section of Grosnaja 63624-1 showing the rim and area adjacent to it. The rim is composed of an outer layer of spinel and olivine (1), middle layer of mixtures of anorthite (An), melilite (Mel), and Al-diopside (2) and an inner layer of spinel (3).

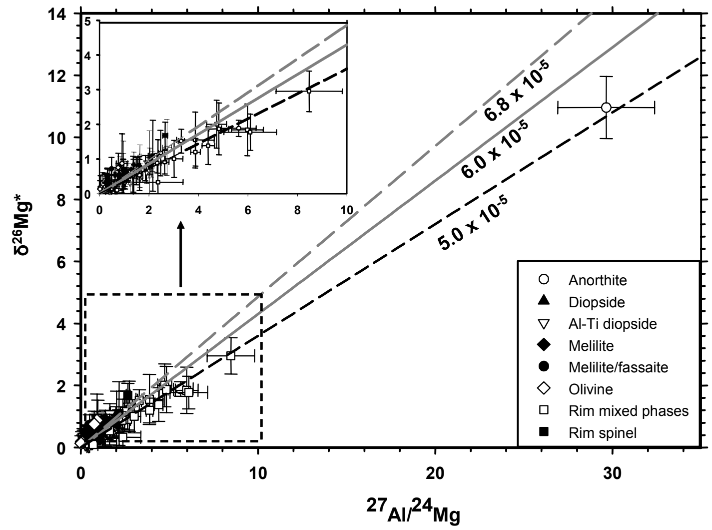

Figure 2. ^{26}Al-$^{26}Mg^*$ evolution diagram of Grosnaja 63624-1. Canonical $(^{26}Al/^{27}Al)_0$ = 5.0 x 10^{-5}, and supercanonical lines i.e. 6.0 x 10^{-5} and 6.8 x 10^{-5} reported in [4] are shown for comparisons. Errors are 2σ.

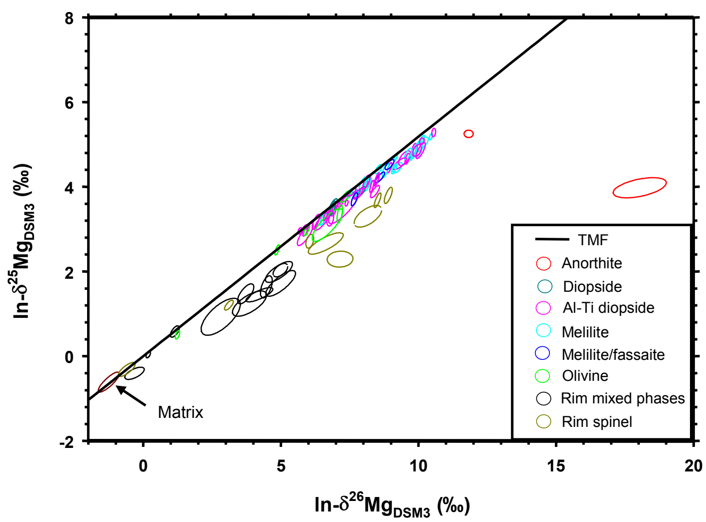

Figure 3. Three-isotope representation of the Mg isotope ratios for Grosnaja 63624-1. The measurements are expressed as linearized δ values relative to DSM3 standard. The solid line corresponds to the terrestrial mass fractionation (TMF) line with a slope of 0.521.