MAGNESIUM ISOTOPIC COMPOSITION OF CAIs AND CHONDRULES FROM CR CHONDRITES. B. Mimoun[1], M. Gounelle[1], E. D. Young[2,3], A. Shahar[3], and A. T. Kearsley[4]. [1]Laboratoire d'Étude de la Matière Extraterrestre, Muséum National d'Histoire Naturelle, 57 rue Cuvier, CP52, 75005 Paris, France (gounelle@mnhn.fr). [2]Institute of Geophysics and Planetary Physics, Los Angeles, CA 90095, USA. [3]Department of Earth and Space Sciences, University of California–Los Angeles, Los Angeles, CA 90095, USA. [4]Impacts & Astromaterials Research Centre, Department of Mineralogy, The Natural History Museum, London SW7 5BD, UK.

Introduction: The magnesium isotopic composition of primitive extraterrestrial materials is worth measuring for at least two reasons. First, Mg is the lightest of the major refractory lithophile elements. Variations in its Mg isotopic composition due to mass-dependent fractionation can therefore reach as much as 10 ‰/amu [1], providing important clues on physical processes in the protoplanetary disk [2]. Second, ^{26}Mg is the decay product of the short-lived radionuclide ^{26}Al (T = 0.74 Myr), whose distribution and abundance in the protoplanetary disk constrains the astrophysical environment of our solar system's birth and the chronology of its first Myr [e.g. 3]. ^{26}Al was present in the formation region of a multitude of asteroids [4], though its homogeneity was never demonstrated [5].

CR chondrites are characterized by a high abundance of Fe-Ni grains, large chondrules and abundant matrix [6]. They contain isotopically anomalous organic matter [7], suggesting that they suffered little metamorphism on their parent-asteroid [8]. Thus, these very primitive chondrites probably more accurately record the physical conditions in the disk, as opposed to the altered CV3 chondrites [9] on which Mg isotopic studies focused so far [e.g. 1, 2, e.g. 10].

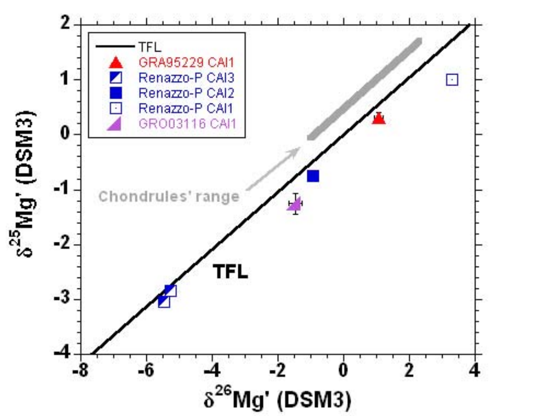

Figure 1: The magnesium isotopic composition of CAIs in CR chondrites. Error bars are 1σ.

Experimental methods: Mineralogy of CR chondrites, chondrules and CAIs was performed in Paris and London using conventional SEM and EMPA techniques. Magnesium isotope measurements were obtained at UCLA using *in situ* UV laser ablation Multiple-Collector Inductively Coupled Plasma source Mass Spectrometry (MC-ICPMS). Laser spot size was between 50 and 100 μm and laser pulse repetition rates varied between 1 and 2 Hz, depending on the magnesium content of the considered phase. Laser fluences varied between 20 and 25 J/cm^2. A sample-standard bracketing approach was adopted. The magnesium isotopic composition is reported relative to the DSM3 standard using the δ^iMg' notation with δ^iMg' = 1000 x $\ln((^i\mathrm{Mg}/^{24}\mathrm{Mg})_{sample}/(^i\mathrm{Mg}/^{24}\mathrm{Mg})_{DSM3})$, i representing the masses 25 and 26. On the DSM3 scale, bulk chondrites have δ^{25}Mg' ~ δ^{26}Mg' ~ 0. Deviations from mass-dependent fractionation, noted δ^{26}Mg*, are calculated as δ^{26}Mg* = δ^{26}Mg'- δ^{25}Mg'/β where β = 0.521. The external reproducibility of δ^{26}Mg*, δ^{25}Mg' and δ^{26}Mg' values is better than 0.25 ‰ (2σ).

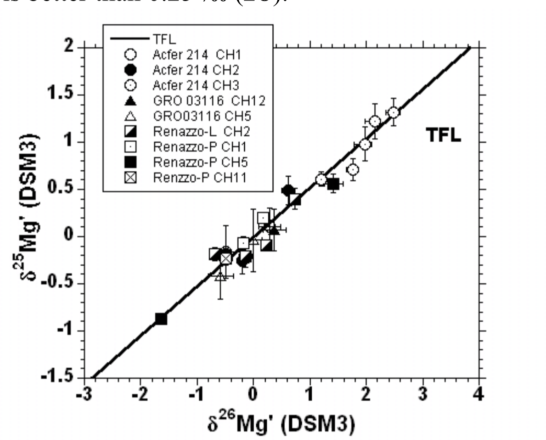

Figure 2: The magnesium isotopic composition of chondrules in CR chondrites. Error bars are 1σ.

Results: We studied the detailed mineralogy and magnesium isotopic composition of 5 CAIs and 9 chondrules belonging to 4 CR chondrites: Acfer 214 (1 Paris Museum section), GRA95229 (1 MWG section), GRO03116 (1 MWG section), Renazzo (1 Paris Museum (P) section and 1 London Museum (L) section).

CAIs. CAIs have sizes ranging from 80 to 500 μm. They have fluffy (Renazzo CAIs) to compact textures (other CAIs). Their δ^{25}Mg' values range from -3 ‰ to +1 ‰ (Fig. 1). All have positive δ^{26}Mg*.

Chondrules. Chondrules have sizes ranging from 600 μm to 1.2 mm. They have porphyritic and barred olivine textures. Their δ^{25}Mg' values range from -1 ‰

to +1.5 ‰ (Fig 2). One chondrule has a clearly resolvable ^{26}Mg excess (within 2σ, Fig. 4). One spinel grain enclosed in a chondrule has a clearly resolvable ^{26}Mg deficit (within 2σ, Fig. 4).

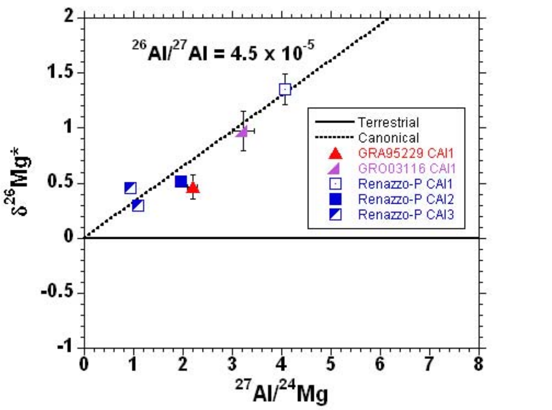

Figure 3: Al-Mg isochron diagram for CAIs in CR chondrites. Error bars are 1σ.

Discussion: All 5 CAIs contained live ^{26}Al when the Al-Mg system was closed to subsequent disruption. Assuming δ^{26}Mg* = 0 for a ^{27}Al/^{24}Mg ratio of 0, we obtain initial ^{26}Al/^{27}Al ratios of (3 ± 0.7) x 10^{-5}, (4.2 ± 0.8) x 10^{-5}, (4.6 ± 0.5) x 10^{-5} and (5.7 ± 2.9) x 10^{-5} at the time of closure of the CAIs (errors are 2σ). If all CAIs are regressed together, we obtain an initial ^{26}Al/^{27}Al ratio of (4.3 ± 1.5) x 10^{-5} (MSWD = 2.2).

For the chondrule Renazzo-L-CH2, the Al-Mg system closed when the ^{26}Al/^{27}Al ratio was equal to (1.0 ± 1.8) x 10^{-5}. Three chondrules (Acfer217-CH2, Acfer217-CH3 and Renazzo-P-CH5) possibly contained some ^{26}Al at the time of their closure of the Al-Mg system (Fig. 4), though their δ^{26}Mg* value is compatible with 0 within 2σ.

The ^{26}Al/^{27}Al ratio of CR CAIs is close to the canonical ratio of 4.5 x 10^{-5} [10]. There is no evidence for a supercanonical abundance of ^{26}Al in CR CAIs [11]. The lower initial ^{26}Al/^{27}Al ratio in CR CAIs compared to CV CAIs can be due either to formation in a different region, or to formation at earlier times. If homogeneous distribution of ^{26}Al is assumed, CR CAIs formed some kyr after CV CAIs [12] and CR chondrules some Myr after CR CAIs.

The canonical (low) ^{26}Al/^{27}Al ratio found in the CAIs (chondrules) we studied is compatible with recent studies with the ion microprobe [13-15].

The deficit of ^{26}Mg (δ^{26}Mg* = -0.33 ± 0.08 ‰) found in a spinel grain enclosed in chondrule Renazzo-L-CH2 (Fig. 4) might have an origin similar to that of hibonite grains with δ^{26}Mg* ~ - 4 ‰ found by [16] in CM chondrites.

The range of mass-dependent fractionation (δ^{25}Mg' varying from -1 ‰ to 1.5 ‰) for CR chondrules is comparable to that of CB$_b$ chondrules [17] and CV3 chondrules [18, 19]. It is striking that chondrules having different mineralogy, chemistry and oxidation state have such a similar Mg isotopic composition. It indicates that special conditions are needed to produce the light compositions observed in some CR CAIs.

CAIs in CR chondrites are characterized by negative and positive δ^{25}Mg' values. There is no obvious correlation with texture. CAI3 from Renazzo-P has a remarkably light Mg isotopic composition (δ^{25}Mg' ~ -3 ‰). It compares to the values measured for fine-grained CAIs in CV3 chondrites [20] and to a putative type B inclusion in Allende [18]. This light composition might indicate a recondensation origin [20].

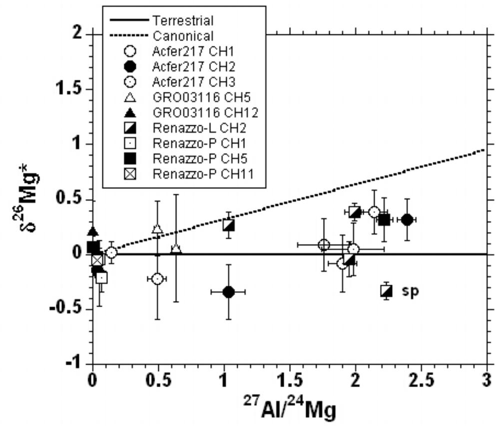

Figure 4: Al-Mg isochron diagram for chondrules in CR chondrites. Error bars are 1σ.

References:

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