$(^{26}Al/^{27}Al)_0$ OF THE SOLAR NEBULA INFERRED FROM AL-MG SYSTEMATIC IN BULK CAIS FROM CV3 CHONDRITES.

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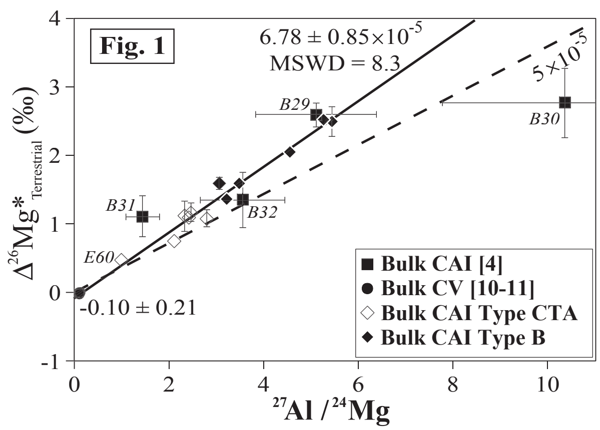
Introduction: ^{26}Al decays to ^{26}Mg with a short half-life of 0.73 Ma; an ^{26}Al/^{27}Al canonical value of 5×10^{-5} has been inferred by studies of CAIs among many different meteorites [1-3]. This canonical value is, however, determined by internal isochron in CAIs and relies on a) relatively few data bulk data [4] and b) the average of punctual analyses [5]. On that basis, the evidence for 1) possible heterogeneity in the isotopic composition of Mg of solar system material, and 2) the dating of the segregation of the CAI precursor material from the solar nebula has been elusive. Because of isotopic and elemental diffusion, the internal isochron and inferred $(^{26}Al/^{27}Al)_0$ corresponds to the last thermal event affecting each individual CAI. This interpretation has led to the determination of the timing of multi-stage formation events of some CAI [6], and also implies that $(^{26}Al/^{27}Al)_0$ values of > 5×10^{-5} are artifacts resulting from the local redistribution of ^{26}Mg excesses. The aim of this study is to investigate the Mg isotope composition in bulk CAIs and determine when the CAI precursor material has been segregated from the rest of the solar nebula.

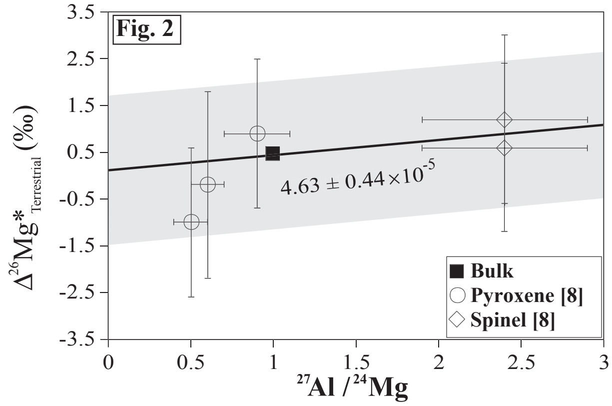
Material & Method: 5 CAIs from Efremovka (4 compact type A and 1 type B), 5 from Allende (1 compact type A and 3 type B) and one from Leoville (type B) were ground into a homogeneous powder and divided into aliquots [7]. A forsterite-bearing inclusion (E60) already studied for Al-Mg isotopic composition of individual mineral [8] has also been studied. 2 to 10 mg of the CAI samples were dissolved in an HNO_3 – HF – $HClO_4$ acid solution at ~150ºC in sealed Teflon vials, taken to dryness and then digested a second time in an HCl – HNO_3 acid solution. The samples were converted to chlorate with HCl. No insoluble residues were observed after centrifugation. Mg was purified from the dissolved fraction on AG50W-X12 resin columns with quantitative recovery.

High-precision Mg isotopic abundances were obtained by multicollector inductively coupled mass spectrometry (MC-ICPMS) [9-10]. The excess of ^{26}Mg, quoted Δ^{26}Mg*, is the permil deviation from the terrestrial fractionation curve and calculated by the relationship: $\Delta^{26}Mg^* = \delta^{26}Mg - (1/0.5189) \times \delta^{25}Mg$, where 0.5189 is the slope of the terrestrial fractionation curve, when δ^{26}Mg and δ^{25}Mg are expressed against the reference DSM3 [10-12]. The bulk composition of AG178, a bulk CAI previously measured [11] has been recalculated according to [12]. The lack of Al, Ca, Fe and alkaline elements in the Mg fractions and the constancy of the value of the Cambridge 1 standard mixed with Ca, Al and Fe and thereafter processed through the chemistry implies that the results are free of any matrix effect and/or interference. The Al/Mg has been measured by MC-ICPMS and the external uncertainty is less than 2% relative.



Results: The measurements of 12 bulk CAIs, bulk Allende and Orgueil meteorites and data from [4] are presented in Fig. 1. The error bars correspond to 95% confidence level. A conservative estimate of the Al/Mg uncertainties from [4] has been set to 25 % relative. The range of Δ^{26}Mg* is 2.05‰. If we exclude B30 from [4], All CAIs lie on or above the isochron defined by the canonical $(^{26}Al/^{27}Al)_0$. This is very similar to previous data [4,11,13]. The bulk Δ^{26}Mg*of a type B CAI from Allende (F2) has been previously reported to be 0.68 ± 0.36 ‰ [13]. Our aliquot of F2 gives a Δ^{26}Mg* of 1.08 ± 0.06 ‰. The corresponding LLNL value is 1.12 ± 0.11 ‰. At 95% confidence the TIMS value [12] and the two MC-ICPMS values are indistinguishable. In addition, the Δ^{26}Mg* and Al/Mg ratio of the bulk E60 (Fig. 2) lies on the previous isochron defined by mineral separate [8].

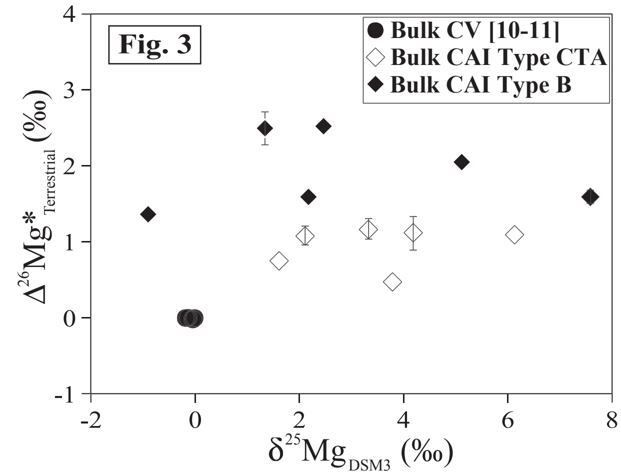
The Δ^{26}Mg* is strongly correlated to the ^{27}Al/^{24}Mg ratio (Fig 1) and independent from the δ^{25}Mg (Fig. 3). In the Al-Mg evolution diagram (Fig. 1), the data-set obtained by MC-ICPMS defines an errorchron with a $(^{26}Al/^{27}Al)_0$ value much higher ($(6.78 \pm 0.85) \times 10^{-5}$) than the canonical value. The $^{26}Mg/^{24}Mg_{initial}$ is not statistically different from the terrestrial/chondritic value (Fig. 1). Since the CAIs are of different types from 3 meteorites, the lack of a true isochron is not astonishing. Assuming an homogeneous $^{26}Mg/^{24}Mg_{initial}$ for the Solar Nebula, we have also calculated the $(^{26}Al/^{27}Al)_0$ of each CAI. As shown on the Fig 1, none of the $(^{26}Al/^{27}Al)_0$ are lower than the canonical value and the highest value is $(7.4 \pm 0.4) \times 10^{-5}$.



Discussion: This difference between the $(^{26}Al/^{27}Al)_0$ inferred from bulk CAIs and the $(^{26}Al/^{27}Al)_0$ defined by internal isochron can be interpreted in 2 different ways.

The first explanation is that the $^{26}Mg/^{24}Mg_{initial}$ was variable (from 0 to + 0.64‰) while the $(^{26}Al/^{27}Al)_0$ was homogeneous and equal to 5×10^{-5}. A Mg-isotopic heterogeneity is rather unlikely, given the lack of $\Delta^{26}Mg^*$ in bulk chondrites, and achondrites [14]. In addition, this inheritance of excess of ^{26}Mg and/or excess of ^{24}Mg would have had to occur only in CAIs and would have to be opposite to the nucleosynthetic effects recorded by the Mg carried by FUN inclusions. The O-isotopic compositions of the CAIs examined in this study should be determined before ruling out this explanation.

The second explanation comes from a direct analogy with isotopic chronology in metamorphic terrestrial rocks. The age defined by the bulk CAIs can be attributed to the closure of a CAIs reservoir within the solar nebula with respect to Al-Mg isotopes, while the canonical $(^{26}Al/^{27}Al)_0$, determined by mineral separates records the youngest resetting of the Al-Mg clock by a thermal event. In that case, the CAIs reservoir has been segregated ~ 0.4 Ma before the youngest melting responsible for the definition of the canonical $(^{26}Al/^{27}Al)_0$ value of 5×10^{-5}. This interpretation is supported by the bulk composition of E60 (Fig. 2) but seems to disagree with the extreme paucity of materials such as single hibonite and corundum crystals, which show little evidence of igneous processing with $(^{26}Al/^{27}Al)_0$ values of >5 x 10^{-5} in CM chondrites [2]. If the initial solar system value was ~7 x 10^{-5}, we would expect to find some unmelted grains carrying this signature only in the case that CAIs from CVs and unmelted grains from CM have been extracted from the main reservoir of the solar Nebula in a single event. Lower $(^{26}Al/^{27}Al)_0$ in CAIs from CM has already been pointed out [2]. High precision Mg-Al data from bulk fluffy type A from CVs are clearly needed.



Conclusion: The solar nebula may have had a $(^{26}Al/^{27}Al)_0$ as high as 7×10^{-5}, in which case the precursor material of CAIs carried by CV chondrites has been segregated from the rest of the solar nebula. ~ 0.4 Ma before its last melting.

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