Mg ISOTOPIC CONSTRAINTS ON THE ORIGIN OF Mg-RICH OLIVINES IN ALLENDE MATRIX AND PORPHYRITIC TYPE I CHONDRULES. T.-H. Luu[1,2], M. Chaussidon[1] and J.-L. Birck[2], [1]Centre de Recherches Pétrographiques et Géochimiques (CRPG)-Université de Lorraine-INSU CNRS, UPR 2300, 15 Rue Notre-Dame des Pauvres, BP 20, 54501 Vandoeuvre-lès-Nancy, France, [2]Laboratoire de Géochimie et Cosmochimie, Institut de Physique du Globe de Paris (IPGP), Sorbonne Paris Cité, 1 rue Jussieu 75238, Paris cedex 05, France. (luu@crpg.cnrs-nancy.fr)

Introduction: Because of the short half-life of ^{26}Al (0.72 Myr), the ^{26}Al-^{26}Mg system [1] could give the best time resolution for the earliest solids, such as CAIs and chondrules, formed within the first 5 Myr. But the ^{26}Al-^{26}Mg system can be used as a chronometer only under the assumption that ^{26}Al and Mg isotopes were once homogenized in the accretion disk. Recently, high-precision Mg isotopic measurements, below the per mil level, either in bulk using HR-MC-ICPMS [2], or in in-situ using SIMS [3] were developped. In the latter case, a recent study has provided data in agreement with an homogeneous distribution of ^{26}Al and Mg isotopes, at a level of ± 10%, in the inner Solar System, at the time of type B CAI formation [3].

A protosolar nebula evolution model (growth curve) of Mg isotopes can be calculated. Then, comparing directly the ^{26}Mg excesses or deficits of meteoritic materials to this solar nebula theoretical growth curve, one can (i) better constrain their origin, and (ii) calculate their ^{26}Al model ages of crystallization (Fig. 1). Thus, very negative δ^{26}Mg* values would imply that the system closed very early. Otherwise, the closure age would be younger.

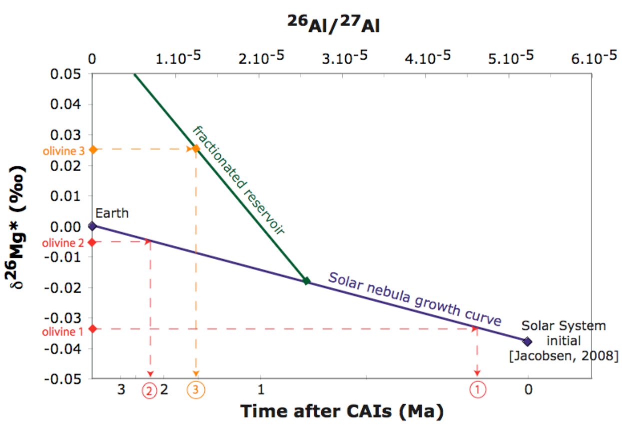

Fig.1: Theoritical growth curve of Mg isotopes, anchored by the ($^{26}Al/^{27}Al)_0$ and $\delta^{26}Mg^*_0$ of bulk CAIs, which are 5.23(±0.13).10^{-5} and -0.040(±0.029)‰ respectively [2], and calculated for a chondritic $^{27}Al/^{24}Mg$ ratio (0.101 [4]). $\delta^{26}Mg^*$ values plotting above this line corresponds to a Mg isotopic reservoir which must have undergone an early fractionation of the Al/Mg ratio.

Samples: Mg isotopic measurements were performed in Mg-rich isolated olivines, and Mg-rich olivines in porphyritic type I chondrules, from the Allende CV3.2 carbonaceous chondrite. Because of some petrologic, chemical and isotopic features, these olivines, for a large fraction of them, are thought to be relict [5-9]. However, Mg-rich olivines in some type I chondrules have Δ^{17}O values which are not different from that of the surrounding pyroxene and glass [10]. In those latter cases, the relict character of the olivines cannot be established from the Δ^{17}O values.

The origin of the large range of Δ^{17}O values in these olivines is unknown. It is classically considered to reflect Δ^{17}O variations in the accretion disk through one or several generations of chondrules [10-12]. The finding of some modes in the Δ^{17}O distribution indicates either formation from several distinct gaseous reservoirs, or crystallization in the mantle of an early generation of planetesimals which would have been disrupted and would have populated the disk with fragments such as Mg-rich olivine grains or aggregates [7-9].

Thus, because olivines are virtually devoid of Al, their measured Mg isotopic composition will reflect that of their source, i.e the one they have inherited during condensation directly from the nebular gas, or during crystallization, either in an earlier generation of chondrules, or in early differentiated planetesimals, depending on their exact origin. The potential of this approach has been explored in [13]. The goal of the present study is to produce a large set of high precision Mg and O isotope data for Allende Mg-rich olivines.

Analytical techniques: Mg isotopic measurements were performed using the CRPG-CNRS (Nancy) ims 1270 ion microprobe. We used a ~30nA O^- primary beam, accelerated at 13kV, giving a ~30-40µm spot. The generated secondary ions of Al and Mg isotopes were measured at a mass resolution M/ΔM = 2500, in multi-collection mode using 4 Faraday cups: L'2, C, H1 and H'2, for $^{24}Mg^+$, $^{25}Mg^+$, $^{26}Mg^+$ and $^{27}Al^+$, respectively. The counting rate was typically kept higher than 1.2x10^9 counts per second (cps) on $^{24}Mg^+$, in olivines. One single analysis lasts 425s, including a total of 150s of pre-sputtering and 275s of data acquisition (25 scans integrated over 11s).

Data processing: Firstly, the measured $^{25}Mg/^{24}Mg$ and $^{26}Mg/^{24}Mg$ ratios were corrected for the variations of the Faraday cups' background. Then, they were corrected for Mg isotopic instrumental mass fractionation α, which is expressed using the exponential law as $\alpha^{25/24}_{inst} = (\alpha^{26/24}_{inst})^{\beta}$, or in logarithmic notation: $\ln(\alpha^{25/24}_{inst}) = \beta \times \ln(\alpha^{26/24}_{inst})$ (+b), with $\alpha^{x/24}_{inst} = (^{x}Mg/^{24}Mg)_{measured}/(^{x}Mg/^{24}Mg)_{reference}$, where the reference is the San Carlos olivine, $(^{25}Mg/^{24}Mg)_{ref} = 0.126389$, $(^{26}Mg/^{24}Mg)_{ref} = 0.138812$. The value of β was precisely determined from repetitive analyses of a set of standards (here, San Carlos olivine (Fa12), Burma spinel and synthetic pyroxene). During the last analytical sessions, β varied between 0.511 and 0.521, and b was close to -0.0003.

After corrections for $\alpha^{25/24}_{inst}$ and $\alpha^{26/24}_{inst}$, ^{26}Mg excesses ($\Delta^{26}Mg$, this notation expresses the deviation from the instrumental mass fractionation line, in ‰), were calculated using β = 0.521 for terrestrial standards, or β = 0.514 [14] for meteoritic olivines. The external reproducibility on standards was better than 0.05‰ (2s.d, n=23), consistent with their terrestrial origin (Fig. 2).

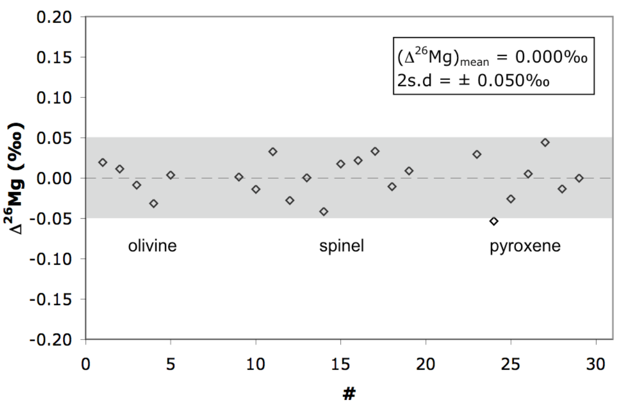

Fig.2: Typical external reproducibility for $\Delta^{26}Mg$ values on terrestrial standards.

Preliminary results: Mg-rich olivines (>Fo95) were first analyzed to determine their O isotopic composition. Five (perhaps 6) modes were found for the $\Delta^{17}O$ values, in agreement with [15].

The present Mg data set corresponds to 14 olivines belonging to the six $\Delta^{17}O$ modes (Fig. 3). Work is in progress to extend the data base and will be shown at the meeting. The 14 olivines analyzed (in average 7 spots per olivine) have mean $\Delta^{26}Mg$ values ranging from -0.05(±0.02)‰ to +0.09(±0.03)‰.

The positive $\Delta^{26}Mg$ values indicate for these olivines that they could not directly condense from the nebular gas since no positive $\delta^{26}Mg^*$ can develop with a solar Al/Mg ratio (see Fig. 1). These olivines most probably cristallized from Al/Mg fractionated liquids in which ^{26}Mg excesses can develop rapidly.

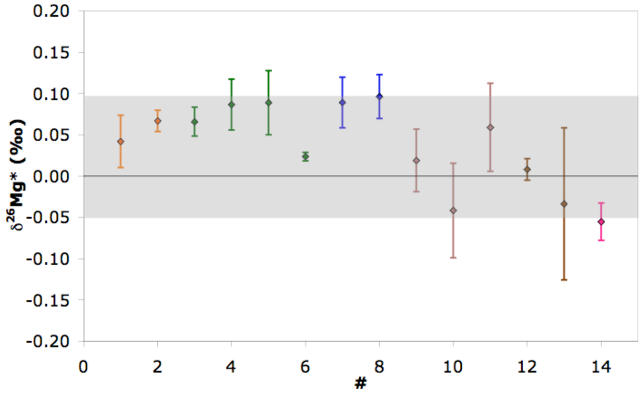

Fig.3: Average $\delta^{26}Mg^*$ values for 14 Mg-rich olivines (each color corresponds to one mode of $\Delta^{17}O$ value).

The olivines have $^{27}Al/^{24}Mg$ ratio from 0.0026 to 0.0195, implying parent liquids with $^{27}Al/^{24}Mg$ ratio from 0.43 to 3.2 (with an Al partition coefficient between forsterite and liquid of 0.006 [16]). These Al/Mg ratios are much higher than that of typical bulk type I chondrules. For a parent melt with $^{27}Al/^{24}Mg = 2.5$ produced 1 Myr after CAIs, a ^{26}Mg excess of 0.1‰ would take ~.4 Myr to develop (only ~ 0.17 Myr is needed if the liquid is contemporaneous with CAIs). This duration of 0.1-0.4 Myr could be an estimate of the life times of the parent planetesimals (if the olivines are fragments of their disrupted mantles). Other arguments constraining the origin of olivines come from relationships between $\Delta^{17}O$, $\Delta^{26}Mg$, $\delta^{25}Mg$ and $\delta^{18}O$ values, which can be related to processes such as mixing, condensation, volatilization or magmatic differentiation.

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