MAGNESIUM ISOTOPES CONSTRAINTS ON THE ORIGIN OF REFRACTORY OLIVINES FROM THE ALLENDE CHONDRITE: NEBULAR VERSUS PLANETARY?

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Although extensively studied, the origin of chondrules remains highly debated, e. g. [1]. As an example is the question of the origin of refractory, i. e. Mg-rich, olivines in porphyritic type I chondrules. It has been shown that these olivines are relict in chondrules [2, 3] but their origin remains unknown [4, 5]. Since it has been demonstrated that the ^{26}Al distribution was homogeneous in the inner solar system [6] and since olivine does not contain Al, the Mg isotopic composition of refractory olivines may give clues on their ^{26}Al model ages of crystallization.

Here we report high precision Mg isotope measurements by multi-collector ion microprobe which show that refractory olivines from the Allende chondrite, either olivines isolated in the matrix (2 samples studied) or olivines in type I chondrules (6 samples studied), have variable deficits and enrichments in ^{26}Mg (noted δ^{26}Mg*) relative to the Earth. Most average δ^{26}Mg* (noted $\delta^{26}Mg^*_{av}$) values (between 10 and 20 analyses per chondrule) are negative but the total range is from -0.033 ± 0.011‰ (2 sigma errors) to +0.013 ± 0.008 ‰ with, in addition, one olivine at +0.043 ± 0.002‰. These variations in $\delta^{26}Mg^*_{av}$ reflect the formation of the olivines from reservoirs variously enriched in ^{26}Mg by the decay of short-lived ^{26}Al ($T_{1/2}$ = 0.73 My). Similarly, 17 analyses of olivines from the Eagle Station pallasite show a $\delta^{26}Mg^*_{av}$ value of -0.032 ± 0.009 ‰, as negative as some olivines from Allende chondrules and the Solar system initial δ^{26}Mg* value of -0.038 ± 0.004‰ (defined at the time of formation of type B Ca-Al-rich inclusions - CAIs - when $^{26}Al/^{27}Al = 5.23\times10^{-5}$, [7]).

Because olivines are Al-poor and because their Mg isotopic compositions are not reset during the chondrule forming events, their $\delta^{26}Mg^*_{av}$ can be used to calculate model crystallization ages relative to various theoretical Mg isotope growth curves. The two end-member scenario considered are (i) a "nebular" growth curve in which the Al/Mg ratio remains chondritic and (ii) a "planetary" growth curve in which strong enrichments of the Al/Mg ratio can be produced by, for instance, olivine magmatic fractionation. The low $\delta^{26}Mg^*_{av}$ value of olivines from the Eagle Station pallasite demonstrate that metal-silicate differentiation occurred as early as ~ 0.15 My after CAIs whatever the growth curve considered. Similarly the variable $\delta^{26}Mg^*_{av}$ values of refractory olivines can be understood if they were formed in planetesimals which started to differentiate as early as the Eagle Station parent body. Accretion of these planetesimals must have been coeval to the formation of CAIs and their disruption could explain why their fragments (Mg-rich olivines) were distributed in the chondrule forming regions of the disk.

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