DO MAGNESIUM ISOTOPE SYSTEMATICS OF Al-RICH CHONDRULES OFFER INSIGHTS INTO THE HISTORY OF CHONDRULE FORMATION IN GENERAL? Samantha C. Ingalls[1], Edward. D. Young[1] and Matthieu Gounelle[2], [1]Department of Earth and Space Sciences, University of California Los Angeles, Los Angeles, CA, USA, eyoung@ess.ucla.edu, [2]Laboratoire de Minéralogie et Cosmochimie du Muséum, Département Histoire de la Terre, Muséum National d'Histoire Naturelle, Paris, FR, gounelle@mnhn.fr.

Introduction: The ^{26}Al-^{26}Mg* chronometer is providing evidence that chondrules generally crystallized several million years post CAI [1, 2]. These findings have important consequences for our understanding of the formation of planetesimals in the early solar sytem and so deserve further investigation. For example, relatively late crystallization of chondrules requires commensurately late accretion times for their host rocks which in turn constrains mechansims and locations of planetesimal formation. Aluminum-rich chondrules are complicated objects but nevertheless have potential for providing new information about the nature and timing of the chondrule-forming process and planetesimal formation in general. We present newly acquired Mg isotope ratio data that illustrate the potential of Al-rich chondrules as tools for probing early solar system processes.

Data: We analyzed 8 samples comprising 6 chondrules using solution MC-ICPMS. All but one of the chondrules is Al rich relative to solar Al/Mg. Two chondrules are from the Krymka LL3 meteorite and the other 4 are from the Allende CV3 meteorite. Results are summarized in Figure 1. Regression of all of the data in ^{27}Al/^{24}Mg vs. δ^{26}Mg* space yields an initial ^{26}Al/^{27}Al of 1.25 +/- 0.08 (1σ) x10^{-5} with an MSWD of 1.6. Such a low reduced chi square value suggests it is not unreasonable to lump these data. The initial ^{26}Al/^{27}Al corresponds to a crystallization age of ~ 1.5 Myr post CAI. One of the chondrules, Allende CH2, was divided into three fragments (Figure 1). These fragments yield a shallower internal isochron corresponding to an initial ^{26}Al/^{27}Al of 0.81 +/- 0.18 x 10^{-5}. This initial ^{26}Al/^{27}Al corresponds to a crystallization age of ~2.0 Myr post CAI.

Discussion: Preliminary interpretations of the Al-rich chondrule data are described here. An important feature of the internal isochron for Allende CH2 is the positive δ^{26}Mg* intercept of 0.47 +/- 0.022 1σ. This intercept can be translated into a time interval between initial crystallization and resetting using the expression

$$\Delta^{26}\mathrm{Mg}^* = \left(\frac{^{27}\mathrm{Al}}{^{24}\mathrm{Mg}}\right)_{\mathrm{bulk}} \frac{10^3}{0.13983}\left(\frac{^{26}\mathrm{Al}}{^{27}\mathrm{Al}}\right)_0 (1-\exp(-\lambda\Delta t))$$

where in this simple interpretation it is assumed that the chondrule was Al-rich throughout the vast majority of its evolution (but see below). With this interpretation, the time interval between initial formation and later resetting manifest as the large positive intercept in Figure 1 is ~150,000 years.

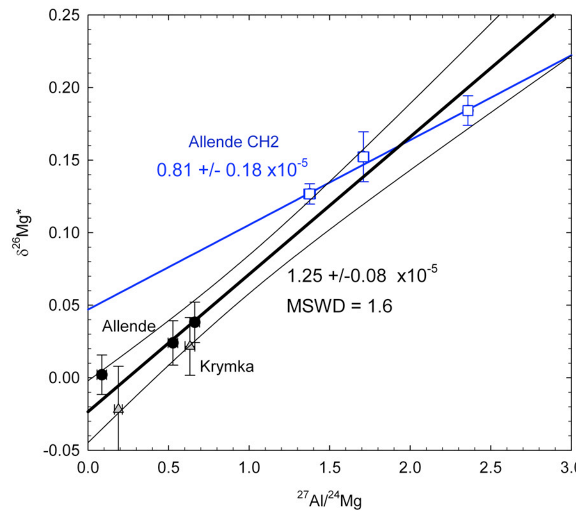

Figure 1. δ^{26}Mg* vs. ^{27}Al/^{24}Mg for chondrules from Krymka (triangles) and Allende (circles and squares). Error envelope for the regression of the data combined is shown in the thin black lines. Open squares are three fragments for a single Allende chondrule, CH2. The blue line is the internal isochron for Allende CH2.

We investigate the timing of Al enrichment of these objects using the Mg isotope-time evolution diagram (Figure 2) [2]. Being mindful of the uncertainties in the data, extrapolation back to a solar δ^{26}Mg* vs. time evolution path suggests a "separation time" from the solar Al/Mg reservoir of about 0.75 to 1.0 Myr post CAI (Figure 2). These separation ages are only meaningful if the Al-rich chondrules did not acquire their Al rich character and a radiogenic ^{26}Mg component by contamination with CAI material. The possibility that Al-rich chondrules are the result of CAI contamination was addressed quantitatively previously [3]. Simple mixing lines in δ^{26}Mg* vs. ^{27}Al/^{24}Mg space argue against CAI pollution. On the other hand, there is no clear evidence for evaporation of these chondrules in the form of elevated $^{25}Mg/^{24}Mg$ in these objects (the highest $\delta^{25}Mg$ relative to chondritic is 0.5 per mil).

Conclusions: A more detailed analysis of the data should include combining the effects of Al enrichment and resetting. For example, the resetting event in Allende CH2 could have corresponded with the Al enrichment event, altering the calculations accordingly. For now, a simple interpretation of the data is that these chondrules experienced Al enrichment ~ 0.75 to 1.0 Myr post CAI and crystallized for the last time ~ 1.5 to 2.0 Myr post CAI. The object for which we have an internal isochron experienced resetting about 150,000 years after formation, though the reference time-zero for this resetting event is ambiguous. Identification of the nature of the Al enrichment event would lend important insights into the processes attending chondrule formation. Further investigations into the possibility for CAI contamination as the origin of Al-rich chondrules in general will be critical for assessing the utility of these objects for probing early solar system processes.

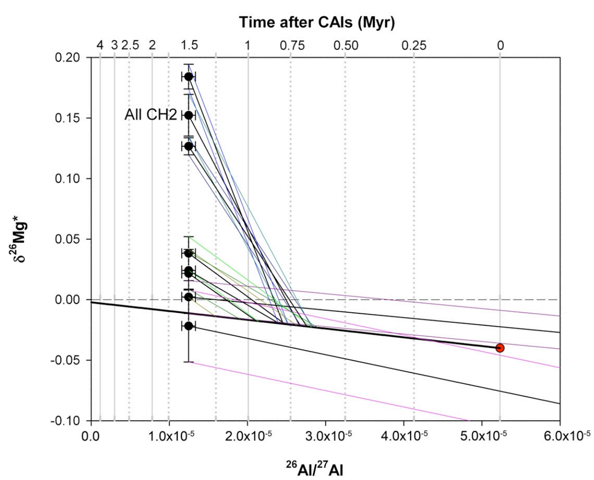

Figure 2. Magnesium isotope vs. time evolution diagram illustrating extrapolation of Al-rich chondrule data to a solar evolution line (bold black line). A solar separation age of about 0.75 to 1.0 Myr is implied assuming no contamination by radiogenic CAI material. Consideration of resetting for Allende CH2 moves those data to the left on the diagram by a few 10^5 years.

References: [1] Krot A.N. et al. (2009) *GCA* 73, 4963-4997. [2] Villeneuve J. et al. (2011) *Science* 325, 985-988. [3] Galy A. et al. (2000) *Science* 290, 1751-1753.