INITIAL $^{26}Al/^{27}Al$ RATIOS OF CHARACTERIZED CHONDRULES FROM CV CHONDRITES BY MC-ICP-MS. J. L. Claydon[1], Y.–J. Lai[2*], C. D. Coath[2], T. Elliott[2], C. A. Taylor[2], S. Strekopytov[3], J. Spratt[3], A. T. Kearsley[3] and S. S. Russell[1]. [1]Department of Earth Sciences, Natural History Museum, Cromwell Road, London, SW7 5BD, U.K. [2]Bristol Isotope Group, School of Earth Sciences, University of Bristol, Wills Memorial Building, Bristol, BS8 1RJ, U.K. [3]Science Facilities, Natural History Museum, Cromwell Road, London, SW7 5BD, U.K. *Now at Institut für Geochemie & Petrologie, ETH Zürich, 8092 Zürich, Switzerland. Email: j.claydon@nhm.ac.uk.

Introduction: Chondrules are the dominant component in most chondritic meteorites. They formed during flash-heating events in the early Solar System but the mechanism of their formation is not well understood. Constraining the chronology of chondrules can help shed light on these thermal events. It has long been thought that chondrules formed 1-3 Myr after CAIs. However, more recent work using the Pb-Pb [1], Mn-Cr [2] and Al-Mg [3, 4] systems indicates that chondrule formation started at the same time as CAI formation. We aim to better understand the Al-Mg systematics of chondrules by applying two techniques to separate aliquots of the same samples: high-precision MC-ICP-MS measurements on bulk aliquots and ion microprobe measurements on phases with high Al/Mg ratios. By doing so, we can measure the bulk $^{26}Al/^{27}Al_0$ of the samples along with the internal $^{26}Al/^{27}Al_0$ of individual mineral phases.

Our initial focus is on CV chondritic meteorites that have experienced little post-accretion thermal alteration. We have measured Mg isotopes using MC-ICP-MS in aliquots of chondrules from Allende (BM1969, 148), Mokoia (BM1910, 729) and Vigarano (BM1911, 174). A study by [5] indicates that, whilst the matrix has been altered, Mokoia's chondrules are relatively pristine. Fractions of each chondrule not used for Mg isotopic analyses by MC-ICP-MS have been characterised and prepared for SIMS analyses.

Methods: Bulk meteorite samples were lightly crushed to separate chondrules from the matrix. The chondrules were then split using an agate mortar and pestle. One aliquot of the chondrule was mounted in a polished resin block. Back-scattered electron images and X-ray element maps were obtained using the Zeiss EVO 15LS Scanning Electron Microscope at the Natural History Museum, London (NHM) using an operating potential of 20 kV. Quantitative elemental analyses of individual minerals were carried out using the Cameca SX100 Electron Microprobe at the NHM using a beam current of 20 nA at 20 kV and appropriate mineral standards.

The remaining aliquot from each chondrule was used for MC-ICP-MS analysis. All wet chemistry was carried out at the University of Bristol in a HEPA filtered clean laboratory using class 10 laminar flow hoods. Aliquots of chondrules with estimated $^{27}Al/^{24}Mg$ >0.2 were washed by ultrasonication in 18 MΩcm H_2O followed by acetone, repeated three times. The aliquots were dissolved in HF-HNO_3 acid at 130°C followed by 6M HCl at 130°C to remove fluorides. A sample of JP-1 peridotite reference material (used to approximate the matrix of chondritic meteorites) and a procedural blank were prepared using the same methods.

The aliquots were re-dissolved in 2% HNO_3 then 20% of each was removed for elemental measurements of Al and Mg by quadrupole ICP-MS (Agilent 7700x) at the NHM. Mg was separated from the remaining 80% of the dissolved aliquots using a two-step 2M HNO_3-based cation exchange column described in [6]. Ni is not effectively removed by the cation exchange process described, so it was eluted on a third column by using a mixture of 12M HCl and dimethylglyoxime in an acetone solution [e.g. 7]. Following Mg separation the aliquots were refluxed with H_2O_2 and HNO_3 to destroy any organics.

Mg isotopes were measured using the Thermo Finnigan Neptune MC-ICP-MS, s/n 1002, at the University of Bristol. Samples were bracketed with the DSM-3 isotopic reference standard for Mg [8]. Excesses of ^{26}Mg are expressed as $\mu^{26}Mg^*$, or deviations in parts per million from $^{26}Mg/^{24}Mg$. The exponential law was used to correct for mass fractionation.

Results and discussion: We have separated 21 chondrules (of which, 8 chondrules showed significantly super-chondritic $^{27}Al/^{24}Mg$ ratios) and 1 amoeboid olivine aggregate (AOA). Here we focus on results from the super-chondritic chondrules, along with the AOA, as they are more likely to show radiogenic Mg isotopic ratios.

Sample descriptions and mineralogy: YJ1 is an AOA consisting of olivine (zoned Fo_{60-85}), diopside and spinel set in an Al- and Na- rich mesostasis. YJ10 is an Al-rich chondrule dominated by Ti-bearing diopside, anorthite with minor olivine, spinel and hedenbergite; the fine-grained (<5 µm) mesostasis is composed of sodalite (replacing anorthite), albite and some olivine. All other chondrules (YJ8, MOK2, MOK3, MOK4, MOK5, VIG1 and VIG2) show porphyritic olivine pyroxene (POP) textures, dominated by olivine (Fo_{86-94}) and low-Ca pyroxene (Wo_{2-8}). High-Ca pyroxene is also present as overgrowths on low-Ca pyroxene. Crystals of calcic plagioclase (An_{87-90}) are found in YJ8, MOK2 and MOK5. The remaining POP chondrules contain glassy or fine-grained Al-rich

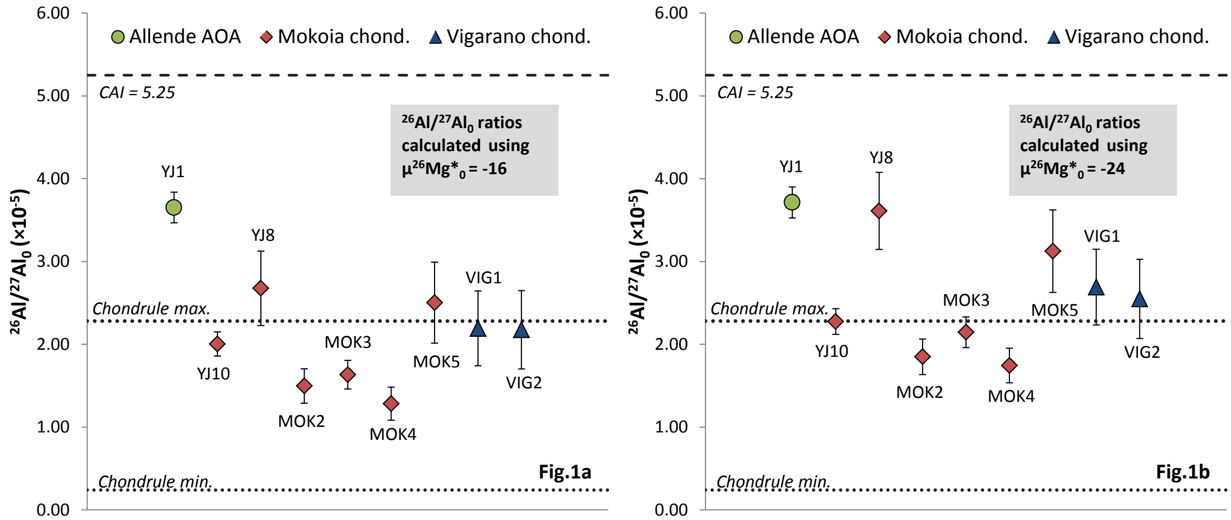

Figure 1. *Initial $^{26}Al/^{27}Al_0$ ratios from MC-ICP-MS analyses of Mg in samples from CV meteorites. Initial $^{26}Al/^{27}Al_0$ ratios have been calculated using $\mu^{26}Mg^*_0$ = -16 [9]* ***(Fig.1a)*** *and using $\mu^{26}Mg^*_0$ = -24 [3]* ***(Fig.1b)****. Also shown are the CAI $^{26}Al/^{27}Al_0$ of 5.25×10^{-5} [9] and the maximum (Bishunpur, LL [10]) and minimum (Yamato 81020, CO [11]) reported $^{26}Al/^{27}Al_0$ ratios by SIMS for chondrules.*

mesostasis material. Olivines in MOK4 and MOK5 contain the highest FeO content seen in these samples ($Fo_{<90}$). Both Vigarano chondrules show Fe-rich rims. All chondrules, except for MOK5, contain rounded grains of Fe, Ni and Fe, Ni, S metals.

Al-Mg system: To establish initial $^{26}Al/^{27}Al_0$ ratios, a two-point model "isochron" can be constructed from the measured $\mu^{26}Mg^*$ of the sample and knowledge of the initial $\mu^{26}Mg^*_0$ at the time of formation. In **Fig.1a** we have assumed $\mu^{26}Mg^*_0$ = -16, the value of which has been constrained using bulk CAI and AOA data [9]. In **Fig.1b** we have used $\mu^{26}Mg^*_0$ = -24, which has been derived from measurements of CAIs and was used to calculate $^{26}Al/^{27}Al_0$ ratios for Allende chondrules [3].

The use of different $\mu^{26}Mg^*_0$ has little effect on the $^{26}Al/^{27}Al_0$ ratio of the Allende AOA (YJ1), which shows a sub-canonical $^{26}Al/^{27}Al_0$ ratio of $3.65\pm0.19\times10^{-5}$. If this AOA formed from a reservoir with the same initial $^{26}Al/^{27}Al_0$ of CAIs (5.25×10^{-5} [9]) then this result gives an age of 0.35±0.08 Myr after CAIs. Petrologic examination of YJ1 showed evidence for alteration. If the Al-Mg system here is recording secondary alteration then it must have been an open system process in order to change the model age. This is most likely to have occurred on the parent body.

The $^{26}Al/^{27}Al_0$ of the chondrules show much more dependence on the chosen initial $\mu^{26}Mg^*_0$. In **Fig.1a** all chondrules plot below the AOA data point, whereas in **Fig.1b** chondrule YJ8 approaches the AOA value.

MOK2, MOK3 and MOK4 show $^{26}Al/^{27}Al_0$ within error of each other that fall within the range previously measured for chondrules by SIMS (dotted lines on Fig.1). $^{26}Al/^{27}Al_0$ ratios of YJ10, YJ8, MOK5, VIG1 and VIG2 plot around the maximum reported SIMS value of 2.28×10^{-5} [10] in **Fig.1a** but in **Fig1.b** MOK5, VIG1 and VIG2 plot above this value. However, these high $^{26}Al/^{27}Al_0$ ratios ($2.5\text{-}3.6\times10^{-5}$) are still at the lower end of the range of $^{26}Al/^{27}Al_0$ ratios published for Allende chondrules [3, 4] of $1.5\text{-}6.4\times10^{-5}$; also calculated using $\mu^{26}Mg^*_0$ = -24.

The higher Fe contents of MOK3 and MOK4 and VIG1 and VIG2 indicate they may have experienced thermal alteration; however, the model $^{26}Al/^{27}Al_0$ ratios of these samples are not significantly lower than the other, more primitive, chondrules.

Conclusions and future work: Model $^{26}Al/^{27}Al_0$ ratios of chondrules are compromised by lack of knowledge of the $\mu^{26}Mg^*_0$ at the time of closure to Mg loss. High-precision, independent measurements of individual Mg-rich phases could be extremely useful in constraining the $\mu^{26}Mg^*_0$. Our next step is to measure Mg isotopes in the remained aliquots of these samples using SIMS to establish internal Al-Mg isochrons.

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