^{26}Al/^{27}Al RATIO IN THE EARLY SOLAR SYSTEM: CANONICAL OR SUPRA-CANONICAL? Benjamin Jacobsen[1], Qing-zhu Yin[1], Frederic Moynier[1] Alexander N. Krot[2], Yuri Amelin[3], Kazuhide Nagashima[2] Ian D. Hutcheon[4] and Herbert Palme[5]. [1]Department of Geology, University of California Davis, Davis, CA 95616, USA (jacobsen@geology.ucdavis.edu, yin@geology.ucdavis.edu) [2]HIGP, University of Hawaiʻi at Manoa, Honolulu, HI 96822, USA [3]Geological Survey of Canada, 601 Booth Street, Rm. 693, Ottawa, ON, Canada K1A 0E8, and Research School of Earth Sciences, Australian National University, 61 Mills Road, Canberra, ACT 0200, Australia. [4]Glenn T. Seaborg Institute, Lawrence Livermore National Laboratory, Livermore, CA 94551, USA [5]Institut für Geologie und Mineralogie, Universität zu Köln, 50674 Köln, Germany

Introduction: Ca-, Al-rich inclusions (CAIs) in primitive meteorites (chondrites) play a pivotal role in the high-resolution chronology of the early Solar System. They are the oldest solids formed within the Solar System and thus mark the beginning of Solar System evolution 4567.2±0.6 million years (Myr) ago 1. Over three decades of research using ^{26}Al-^{26}Mg chronometry (^{26}Al decays to ^{26}Mg with $t_{1/2}$ = 0.73 Myr) has revealed that most CAIs contain excess radiogenic ^{26}Mg* from the decay of ^{26}Al and define an initial ^{26}Al/^{27}Al ratio of ~5×10^{-5}, commonly referred to as the solar system "canonical" value [2,3]. The "canonical" ^{26}Al/^{27}Al ratio has recently been revised upwards to a "supra-canonical" value of $(5.8\text{-}7.0)\times10^{-5}$ [4-9]. Here we report new high precision ^{26}Al-^{26}Mg isotopic analyses of several coarse-grained, igneous CAIs and for mineral separates from one CAI from the Allende (CV) chondrite using multicollector inductively-coupled plasma mass-spectrometry (MC-ICP-MS). We show that our new results for both bulk CAIs and mineral separates are in excellent agreement with the data originally reported by Bizzarro et al. [4; Fig. 1a], but disagree with both the revised data presented in a corrigendum [5] as well as recent new data [6, Fig. 1b]. Our results do not support the supra-canonical ^{26}Al/^{27}Al ratio [4-9]; instead, they are consistent with the canonical value of 5×10^{-5} [2,3].

Suggested explanation for differences: Differences in slope on an Al-Mg evolution diagram may be due to (i) differences in age, (ii) spatial heterogeneity in ^{26}Al or (iii) systematic differences in analytical procedures. The first two possibilities are very unlikely, as both would posit two distinct populations of CAIs characterized by different ^{26}Al/^{27}Al ratios, one population analyzed by Bizzarro and co-workers and the other by us, with no intermingling. The third possibility, that the difference in slope is an artifact, due to analytical procedures and inadequate intercalibrations, must be critically evaluated.

The ^{27}Al/^{24}Mg ratios in [4] appear to have omitted the factor of At_{Mg}/At_{Al} = 0.9008 (or = 1/1.11, as in [5], where At_{Al} and At_{Mg} refer to the atomic weights of Al and Mg, respectively. This apparent error was corrected in a corrigendum [5], leading to an 11% increase in the inferred initial abundance of ^{26}Al. Our data, however, fail to reproduce the revised ^{26}Al/^{27}Al initial value (Fig. 1b). This discrepancy needs to be resolved through bilateral sample exchange and careful calibration against standards. We note that the Mg isotopic composition (δ^{26}Mg*) for one of the bulk CAI samples, A44A, has been reproduced by Bizzarro et al. to within 30 ppm (Fig. 1a); possible differences in ^{27}Al/^{24}Mg ratios await resolution

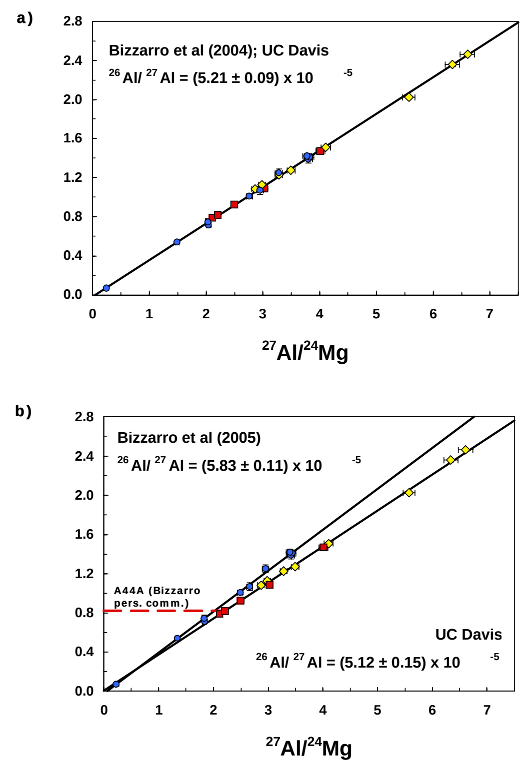

Fig. 1. ^{26}Al-^{26}Mg systematics in CAIs from the Allende CV3 carbonaceous chondrite. a) Summary of data from Bizzarro et al. [4] and the current study. The red squares (bulk CAIs) and yellow diamonds (mineral separates from the CAI, A44) are from this study. The blue dots are from [4]. The precision for both ^{27}Al/^{24}Mg and δ26Mg* (*denotes the radiogenic ^{26}Mg component, as deviations in parts per 1000 from a terrestrial standard) is comparable in both studies. The plot shows excellent agreement between the current study and the original data of Bizzarro et al [4]. b) Summary

of data from Bizzarro et al. [5], as reported in the corrigendum and the current study. In contrast to Fig. 1a, the systematic difference in slope is apparent. We provided A44, one of our CAI samples, to Bizzarro and co-workers to establish an inter-calibration between our laboratories. The Mg-isotopic composition ($\delta^{26}Mg^*$) of A44 measured by us and by Bizzarro et al. agrees to within 0.03‰; a comparison of $^{27}Al/^{24}Mg$ values is underway.

Discussion: In principle, Al-Mg isotope data can be used to constrain the timing of evaporation and condensation events, recorded in bulk CAI data, compared to melting and crystallization events, recorded in data for primary igneous minerals (e.g., whole rock vs. internal mineral isochrons). In addition to the bulk CAIs discussed above, we analyzed mineral separates for one coarse-grained Type B CAI (A44). While the full details will be published elsewhere given the space limitation of this short communication, the internal mineral isochron for A44 yields an initial $^{26}Al/^{27}Al$ ratio of $(5.12\pm0.18)\times10^{-5}$, indistinguishable within analytical uncertainty from the value inferred from our bulk Allende CAI measurements. Based on these observations, we infer that the formation of Allende CAIs, including processes of evaporation, condensation, melting and crystallization, occurred over a very short time interval (no more than 29 Kyr). These new data also underscore the need to understand more quantitatively the extent to which the deviations from an isochron often found with in situ measurement techniques (laser ablation MC-ICP-MS [7] and ion microprobe [8]) reflect spatially localized diffusion and transport of Mg isotopes.

Accurate knowledge of the Solar System initial $^{26}Al/^{27}Al$ ratio is crucial if we are to use CAIs as the "time zero" age-anchor to guide future work with other short-lived radio-chronometers, such as the ^{41}Ca-^{41}K system ($t_{1/2}$ = 0.1 Myr). Well established abundances of ^{26}Al and ^{41}Ca will significantly limit the possible sources of ^{41}Ca, ^{26}Al and other shortlived radionuclides in the early Solar System (e.g., energetic particle irradiation near the proto-Sun [10,11] vs. injection from nearby stars [12,13]). Differences between the canonical and supra-canonical $^{26}Al/^{27}Al$ ratios have led some authors to adjust the solar initial $^{41}Ca/^{40}Ca$ ratio by a factor of 26 to accommodate the ^{41}Ca overproduction problem encountered in the X-wind model [11]. However, the tightly constrained initial $^{26}Al/^{27}Al$ ratio reported here, with an age uncertainty of only 29 Kyr (Fig. 1), provides little support for this suggestion.

References: [1] Amelin, Y. et al. (2002) *Science* 297, 1678-1683. [2] Lee, T. et al. (1977) *ApJL* 211, L107-L110. [3] MacPherson, G.J. *in Meteorites, Comets and Planets (ed. Davis, A. M.) 201–246, Vol. 1 of Treatise on Geochemistry (eds Holland, H. D. & Turekian, K. K.) (Elsevier-Pergamon, Oxford, 2003).* [4] Bizzarro, M. et al. (2004) *Nature* 431, 275-278. [5] Bizzarro, M. et al. (2005) *Nature (Corrigendum)* 435, 1280. [6] Thrane, K. et al. (2006) *ApJL* 646, L159-162. [7] Young, E. et al. (2005) *Science* 308, 223-227. [8] Taylor, D. et al. (2005) *LPSC* 36, A2121. [9] Galy, A. et al. (2004) *LPSC* 35, A1790. [10] Shu, F. H. et al. (1996) *Science* 271, 1545-1552. [11] Gounelle, M. et al. (2006) *ApJ* 640, 1163-1170. [12] Wasserburg, G. J. et al. (2006) *Nuclear Physics* A 777, 5-69. [13] Sahijpal, S. et al. (1998) *Nature* 391, 559-561.