MAGNESIUM ISOTOPIC COMPOSITION OF THE JUVINAS EUCRITE: IMPLICATIONS FOR CONCORDANCE OF THE AL-MG AND MN-CR CHRONOMETERS AND TIMING OF BASALTIC VOLCANISM ON ASTEROIDS. M. Wadhwa[1], C. N. Foley[1], P. Janney[1], and N. A. Beecher[2], [1]Department of Geology, The Field Museum, 1400 South Lake Shore Dr., Chicago, IL 60605, [2]Department of Geophysical Sciences, The University of Chicago, Chicago, IL 60637.

Introduction: In recent years, several extinct chronometers have found extensive application towards defining high-resolution time scales of events in early solar system history. However, where sufficient data are available to compare the relative time scales provided by more than one such chronometer, these are not always in agreement (e.g., [1, 2]). Possible explanations for such discrepancies could be that: (1) the initial abundances of one or more of the extinct radionuclides under consideration may not have been uniform in the early solar system; (2) the radiometric systems under consideration may have different closure temperatures; (3) one or more of these chronometers may have been reset at a later time by secondary reheating events such as impacts. It is important to establish which of the above may be responsible since this has implications for the sources and distributions of short-lived radionuclides in the early solar system, and consequently for obtaining the precise timing of events in the early solar system.

In this work, we report new high precision Mg isotopic data for Juvinas. Previous investigations have shown the presence of live ^{53}Mn and ^{60}Fe in this basaltic eucrite [3, 4]. An earlier search for excess ^{26}Mg in feldspar separates from Juvinas indicated an upper limit of ~2.6×10^{-7} for the ^{26}Al/^{27}Al ratio in this meteorite [5]. However, if Al-Mg systematics are concordant with Mn-Cr systematics (which indicate an age of 4562.5±1.0 Ma [3]), Juvinas may have a ^{26}Al/^{27}Al ratio as low as ~1.8×10^{-7}, assuming an initial ^{26}Al/^{27}Al ~5×10^{-5} at ~4567 Ma when CAIs formed [6]. Given recent advances in multicollector ICPMS techniques (e.g., [7]), it is possible to detect excesses in ^{26}Mg corresponding to a ^{26}Al/^{27}Al ratio of ~1×10^{-7} in phases with a minimum ^{27}Al/^{24}Mg ratio of ~60 (with correspondingly lower detection limits for higher Al/Mg ratios). Therefore, we have initiated a study of Al-Mg systematics in Juvinas with the goal of assessing whether or not the Al-Mg systematics are concordant with Mn-Cr systematics.

Analytical Techniques: All sample preparation and chemical procedures were carried out under clean laboratory conditions. ~200 mg of Juvinas was crushed in a boron carbide mortar. After sieving, pyroxene and plagioclase separates were obtained from 75-100 and 100-200 mesh size fractions with a clean Frantz magnetic separator, followed by hand-picking. Two pyroxene separates (Px1 from the 75-100 mesh fraction; Px2 from the 100-200 mesh fraction) and two plagioclase separates (Pl1 from the 75-100 mesh fraction; Pl2 from the 100-200 mesh fraction) were thus obtained. Mineral separates were washed in ultra-clean water, dried and weighed; subsequently, they were dissolved by treatment with an HF/HNO_3 mixture, and finally brought into solution in dilute HNO_3. A 10% aliquot of each mineral separate solution was taken for measurement of ^{27}Al/^{24}Mg ratios. Mg was separated from aliquots of the remaining solutions using cation exchange AG×8 200-400 mesh resin, eluted with 1N HNO_3. Only a single column was necessary for pyroxenes, but for the plagioclases (estimated to contain ~2500 ppm Mg) two columns were required to obtain adequate removal of Al and Ca from the Mg. In all cases, >98% of the Mg was recovered. With the use of ultraclean water and double-distilled acids, our total procedural blanks for Mg are of the order of a few ng and are insignificant.

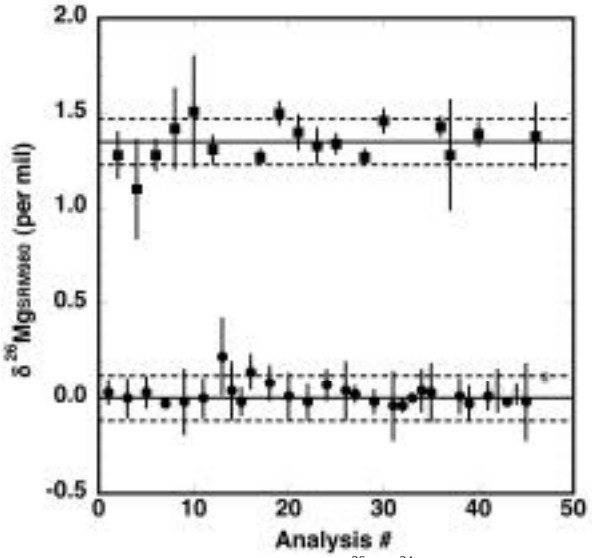

Figure 1. Long term reproducibility of ^{26}Mg/^{24}Mg measurements of SRM 980 (circles) and SPEX (squares) Mg solutions. Open circles show data for SRM 980 processed through primary column chemistry (analyses #42 and #44) and through primary and clean up column chemistry (analysis #47). Each data point represents the average of a minimum of five sample-standard brackets.

The clean Mg obtained from each mineral separate was diluted in 3% nitric to a concentration of 1 ppm and analyzed with the Micromass IsoProbe multicollector ICPMS in the Isotope Geochemistry Laboratory

at The Field Museum. Sample solution was introduced into the plasma through a CETAC Aridus desolvating MCN, which minimizes molecular interferences (such as MgH, NaH, C_2, and CN) at the Mg masses. Using ultraclean reagents and the CETAC MCN, the background at mass 24 is always $<5 \times 10^{-16}$ A (which was insignificant compared to our typical optimized signal intensity of $\geq 4 \times 10^{-11}$ A for the $^{24}Mg^{+}$ beam). The array of 9 Faraday collectors allows simultaneous collection of the 3 Mg isotopes (^{24}Mg on the extreme low mass side; ^{25}Mg on the axial; ^{26}Mg on the high mass side) and monitoring of ^{27}Al on the extreme high mass side collector. Our analytical protocol consists of alternating between standard (NIST SRM 980) and sample solutions, with each being measured for 200 seconds. Each 200 s measurement (consisting of 20 cycles of 10 s integrations) is preceded by ~5 minutes of wash-out and a 45 s integration of the background. Each reported data point (Figs. 1 and 2) comprises an average of a minimum of five sample-standard brackets. Using this methodology, the reproducibility for Mg isotopic analyses over the last 9 months has been well within ~0.06‰/amu (95% confidence limits) (Fig. 1); errors in δ^{25}Mg and δ^{26}Mg are correlated, and thus 2σ reproducibility for Δ^{26}Mg is typically better than that for δ^{26}Mg by a factor of two (~0.06‰).

Results and Discussion: The results obtained for the two pyroxene and two plagioclase mineral separates from Juvinas are shown in Table 1 and Fig. 2.

Table 1. Al-Mg data for Juvinas pyroxenes and plagioclases.

	Weight (mg)	$^{27}Al/^{24}Mg$ (±2%)	$\delta^{25}Mg$ (±2σ)	$\delta^{26}Mg$ (±2σ)	$\Delta^{26}Mg$ (±2σ)
Px1	5.96	0.125	2.62± 0.03	5.14± 0.05	-0.02± 0.06
Px2	8.34	0.163	2.50± 0.06	4.88± 0.08	-0.02± 0.06
Pl1	13.28	57.1	2.98± 0.05	5.80± 0.08	-0.04± 0.06
Pl2	12.83	56.2	2.81± 0.06	5.47± 0.10	-0.04± 0.06

As can be seen from these data, there appears to be no evidence for the presence of live ^{26}Al in Juvinas, with a strict upper limit on the $^{26}Al/^{27}Al$ ratio of $<8.9\times10^{-8}$ (which is lower than that defined by [5] by a factor of ~3). Using this upper limit, and assuming an initial $^{26}Al/^{27}Al$ ratio of $\sim5\times10^{-5}$ at the time of CAI formation ~4567.2±0.6 Ma ago [6], we estimate that Juvinas has an Al-Mg age <~4561 Ma. This upper limit on the Al-Mg age lies just below the lower limit of the Mn-Cr model age for Juvinas (4562.5±1.0 Ma [3]). This suggests that Al-Mg and Mn-Cr systems in Juvinas are indeed discordant, with the Al-Mg system having been reset at a later time, possibly when the Pb-Pb system in Juvinas was also reset (at 4320.7±1.7 Ma [8]). However, in the case of the only other eucrite for which both Al-Mg and Mn-Cr isotopic data have been reported (Asuka 881394 [9]), it appears that the initial ratios of $^{26}Al/^{27}Al$ and $^{53}Mn/^{55}Mn$ are in fact correlated. This is especially surprising since Asuka 881394 has been classified as a cumulate eucrite and appears to preserve textural evidence of metamorphic recrystallization. If evidence of live ^{26}Al and ^{53}Mn is preserved in this recrystallized cumulate eucrite, it is possible that Al-Mg systematics in less recrystallized noncumulate eucrite Juvinas were not reset and that, in fact, the crystallization age of Juvinas is close to ~4561 Ma (~6.5 Ma after CAI formation). This age would be allowed with the Al-Mg data presented here and is only marginally lower than the Mn-Cr model age [3]. A test of this hypothesis would be to perform high precision Mg isotopic analyses of further purified plagioclase separates with $^{27}Al/^{24}Mg$ ratios approaching ~150 (which, for an Al-Mg model age close to ~4561, would have Δ^{26}Mg ~0.1‰, corresponding to an initial $^{26}Al/^{27}Al$ of $\sim8.5\times10^{-8}$).

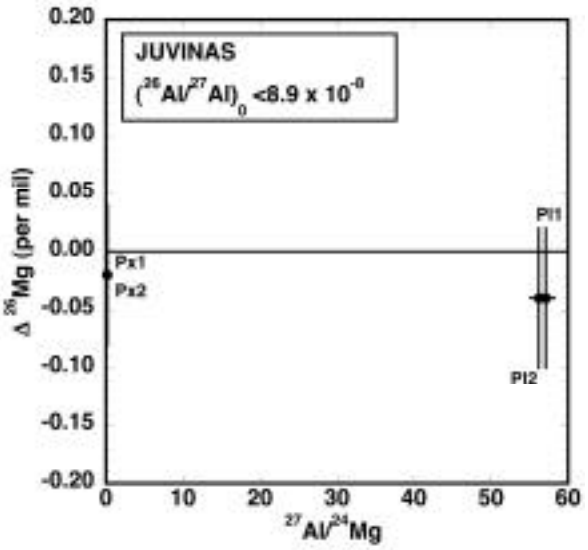

Figure 2. ^{26}Al-^{26}Mg systematics in two pyroxene fractions and two plagioclase fractions from Juvinas.

References: [1] Carlson R. W. and Lugmair G. W. (2001) In *Origin of The Earth & Moon*, 25-44. [2] Wadhwa M. and Russell S. (2000) In *Protostars & Planets IV*, 995-1018. [3] Lugmair G. W. and Shukolyukov A. (1998) *GCA, 62*, 2863-2886. [4] Shukolyukov A. and Lugmair G. W. (1993) *EPSL, 119*, 159-166. [5] Schramm D. N. et al. (1970) *EPSL, 10*, 44-59. [6] Amelin Y. et al. (2002) *Science, 297*, 1678-1683. [7] Galy A. et al. (2001) *Int. J. Mass Spec, 208*, 89-98. [8] Galer S. J. G. and Lugmair G. W. (1996) *Meteoritics, 31*, A47-A48. [9] Nyquist L. et al. (2001) *Antarct. Meteorites XXVI*, 113-115.