HIGH PRECISION RELATIVE AND ABSOLUTE AGES FOR ASUKA 881394, A UNIQUE AND ANCIENT BASALT. M. Wadhwa[1], Y. Amelin[2], O. Bogdanovski[3], A. Shukolyukov[4], G. W. Lugmair[3,4] and P. Janney[1], [1]Dept. of Geology, The Field Museum, 1400 S. Lake Shore Dr., Chicago, IL 60605, USA and The Chicago Center for Cosmochemistry, 5640 S. Ellis Ave., Chicago, IL 60637, [2]Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8, Canada, [3]Max-Planck-Institute for Chemistry, 55020 Mainz, Germany, [4]Scripps Inst. of Oceanography, University of Calif. San Diego, La Jolla, CA 92093, USA.

Introduction: The applicability of short-lived radionuclides as high precision chronometers for early solar system events can be assessed only if there are multiple "anchors", i.e., events for which high precision absolute (U-Pb) ages can be obtained and, at which times, the abundances of various short-lived radionuclides can additionally be determined. Currently there are few such anchors since it is difficult to find samples suitable for the application of multiple high precision relative and absolute chronometers. Therefore, we have chosen to study Asuka 881394, a unique magnesian basaltic eucrite in which there is clear evidence of live ^{26}Al ($t_{1/2}$ ~0.72 My) and ^{53}Mn ($t_{1/2}$ ~3.7 My) at the time of its crystallization [1]. We have performed high precision Mg, Cr and Pb isotopic analyses of this sample with the goal of testing the concordance of the ^{26}Al-^{26}Mg and ^{53}Mn-^{53}Cr chronometers with the U-Pb chronometer.

^{26}Al-^{26}Mg Systematics: The initial results of our investigation of ^{26}Al-^{26}Mg systematics of Asuka 881394, using multicollector ICPMS at the Field Museum, were reported last year [2].

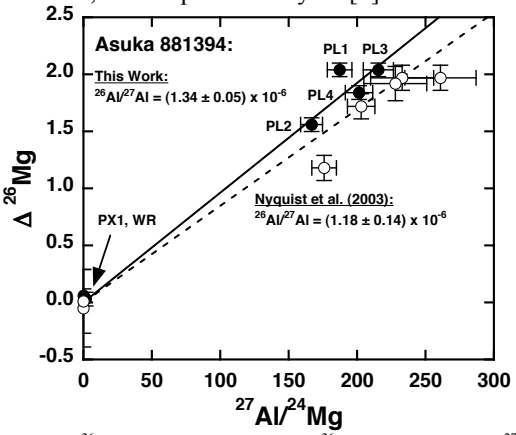

Figure 1. ^{26}Mg excesses in per mil (Δ^{26}Mg) plotted versus ^{27}Al/^{24}Mg ratios in whole rock (WR), pyroxene (PX) and plagioclase (PL) fractions of Asuka 881394. Δ^{26}Mg is determined by sample-standard bracketing and correcting the measured ^{26}Mg/^{24}Mg ratios for mass bias by normalization to a ^{25}Mg/^{24}Mg ratio of 0.12663 using the exponential law. Our data are shown as solid symbols; errors are 2σ. For comparison, the data of [1] are shown as open symbols.

We have since analyzed two additional plagioclase fractions, and the results obtained thus far are shown in Fig. 1. The slope of the isochron in Fig. 1 corresponds to a ^{26}Al/^{27}Al ratio of (1.34 ± 0.05) × 10^{-6} at the time of last equilibration of Mg isotopes in Asuka 881394.

^{53}Mn-^{53}Cr Systematics: We have measured the Cr isotopic compositions and Mn/Cr ratios in two chromite fractions (CHR1 and CHR2), a silicate fraction (SIL) and a bulk sample (TR1) of Asuka 881394 (at the MPI and UCSD) using analytical methods similar to those described in [3]. As shown in Fig. 2, the bulk and mineral fractions define a good isochron corresponding to a ^{53}Mn/^{55}Mn ratio of (4.02 ± 0.26) × 10^{-6} at the time of last equilibration of Cr isotopes.

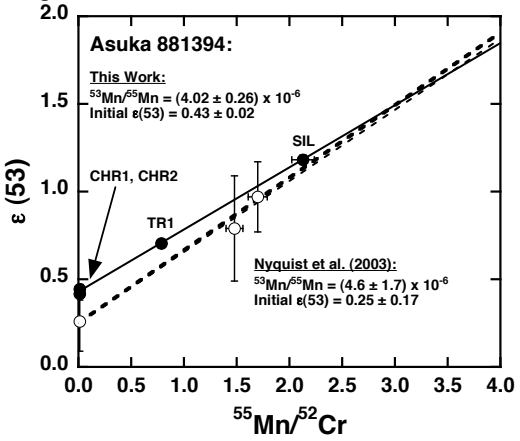

Figure 2. Excesses in the ^{53}Cr/^{52}Cr ratio in epsilon units (parts per 10^4) relative to a terrestrial standard versus ^{55}Mn/^{52}Cr ratios in chromite (CHR1 and CHR2), silicate (SIL) and bulk (TR1) fractions of Asuka 881394 (solid symbols); errors are 2σ. For comparison, the data of [1] are shown as open symbols and thin dashed line; the bulk HED isochron of [3] is shown as the thick dashed line.

The bulk sample, TR1, unambiguously falls above the bulk HED isochron of [3]. The Mn/Cr ratio of TR1 is significantly lower than that of the bulk sample analyzed by [1] and it is unlikely to be representative of the whole rock of Asuka 881394 (which is a coarse-grained sample containing mm-sized chromite grains). If, as indicated by its oxygen isotope systematics [4], Asuka 881394 originated on the HED parent body, our Mn-Cr data in Fig. 2 suggest that its whole rock should have a ^{55}Mn/^{52}Cr ratio of ~3 to lie on the bulk HED isochron. This is significantly higher than the range measured so far in various "bulk" fractions of Asuka 881394 (i.e., 0.79-1.48; this work and [1]) and suggests that this unique magnesian basalt may have originated on a parent body distinct from that of the HEDs. Further analyses will be required to resolve this issue.

Pb-Pb Systematics: Six pyroxene and two whole rock fractions from Asuka 881394 were washed in distilled acetone, followed either by repeated ultrasonic agitation in 2M HCl and 1M HBr (procedure adapted from [5]) or by heating in 6M HCl and 7M HNO_3 (procedure similar to that of [6]). Both leaching methods were found to be equally efficient in removing common Pb from these fractions. In addition to the pyroxene and whole rock fractions, three plagioclase fractions were also included in this investigation. Since tests showed that the Asuka 881394 plagioclase dissolved relatively easily in hot concentrated HNO_3, these plagioclase fractions were only washed in distilled acetone and dilute acids. Chemical procedures following the leaching and removal of common Pb were similar to those described by [6,7]. Pb isotopic analyses were preformed on a Triton TI mass spectrometer at the Geological Survey of Canada.

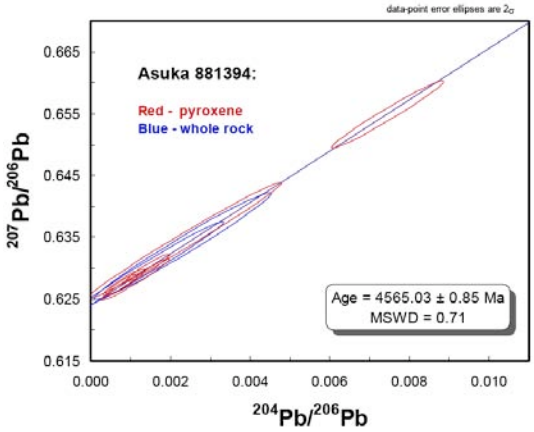

Figure 3. $^{207}Pb/^{206}Pb$ versus $^{204}Pb/^{206}Pb$ ratios in six pyroxene (red) and two whole rock (blue) fractions of Asuka 881394.

The six pyroxene and two whole rock fractions yielded radiogenic Pb with measured $^{206}Pb/^{204}Pb$ ratios of 105-695. The Pb-Pb isochron shown in Fig. 3 yields an age of 4565.03 ± 0.85 Ma (MSWD = 0.71). Including the three plagioclase fractions, which have less radiogenic Pb ($^{206}Pb/^{204}Pb$ ratios ~23-35) than the whole rock and pyroxene fractions, yields a more scattered errorchron array that corresponds to a date of 4564.3 ± 3.9 Ma (MSWD = 3.5). Finally, a regression of all the pyroxene, whole rock and plagioclase residues and leachates results in a highly scattered array (MSWD = 252) corresponding to a date of 4561 ± 20 Ma. All of these dates are consistent within errors. These results demonstrate that removal of the common Pb component is as important for the precise Pb-Pb dating of achondrites as it is for CAIs and chondrules (e.g., [7]).

Discussion: The Pb-Pb isochron defined by the most radiogenic (pyroxene and whole rock) fractions gives the best estimate of the crystallization age of Asuka 881394, i.e., 4565.0 ± 0.9 Ma (Fig. 3). This is the oldest high precision absolute age yet determined for an achondrite and is 2.2 ± 1.0 My younger than the formation age of Efremovka CAIs, the earliest formed solids in the solar system [6]. Comparing the $^{26}Al/^{27}Al$ ratio of $(1.34 \pm 0.05) \times 10^{-6}$ with the canonical value of 5×10^{-5} in CAIs results in a ΔT_{CAI} (i.e., time interval since CAI formation) of 3.76 ± 0.04 My. However, while most normal CAIs have been shown to have initial $^{26}Al/^{27}Al$ ratios in the range of 4-5 $\times 10^{-5}$ [8], some recent studies indicate that this ratio may be as high as ~6 $\times 10^{-5}$ (e.g., [9]). Conservatively, considering an uncertainty of ~20% in the canonical $^{26}Al/^{27}Al$ ratio in CAIs results in a ΔT_{CAI} of 3.8 ± 0.2 My. Given the absolute Pb-Pb age of 4567.2 ± 0.6 Ma for CAIs [7], a ΔT_{CAI} of 3.76 ± 0.04 My or 3.8 ± 0.2 My translates to essentially the same Al-Mg age of 4563.4 ± 0.6 Ma, which is only marginally lower than the Pb-Pb age. This minor discrepancy could result from either a slight later disturbance of the Al-Mg system or a subsolidus cooling rate slow enough to allow closure of the Al-Mg and Pb-Pb systems in Asuka 881394 at slightly different times. Comparing the $^{53}Mn/^{55}Mn$ ratio of $(4.02 \pm 0.26) \times 10^{-6}$ with a value of $(1.25 \pm 0.07) \times 10^{-6}$ [3] in the LEW86010 angrite results in a ΔT_{LEW} of –6.2 ± 0.5 My. Given the absolute Pb-Pb age of 4557.8 ± 0.5 Ma for the LEW 86010 angrite [5], this time interval translates to a Mn-Cr age of 4564.0 ± 0.7 Ma, which is in agreement with the Pb-Pb and Al-Mg ages.

Conclusions: Pb-Pb systematics in Asuka 881394 demonstrate that it was formed in the crust of a differentiated planetesimal at 4565.0 ± 0.9 Ma, within at most ~3 My of the formation of the first solids in the solar nebula. At this time, the meteorite-forming region of the solar system was characterized by a $^{26}Al/^{27}Al$ ratio of $(1.34 \pm 0.05) \times 10^{-6}$ and a $^{53}Mn/^{55}Mn$ ratio of $(4.02 \pm 0.26) \times 10^{-6}$. These results indicate concordance of the ^{26}Al-^{26}Mg and ^{53}Mn-^{53}Cr systems with the absolute U-Pb chronometer, thereby supporting the viability of high-resolution chronometers based on the decay of ^{26}Al and ^{53}Mn.

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