High Precision ^{26}Al-^{26}Mg Systematics of A New Eucrite Northwest Africa 10919 and the Brachinites Northwest Africa 4882 and Brachina. D. R. Dunlap[1], V. K. Rai[2], and M. Wadhwa[2], [1]Center for Meteorite Studies, School of Earth and Space Exploration, Arizona State University Tempe, AZ 85287. (drdunlap@asu.edu).

Introduction: Achondrites, as samples produced by igneous processes on asteroidal bodies, provide powerful insights into the earliest epochs of planetesimal accretion and differentiation in our Solar System [1]. An understanding of the timescales for the formation of these samples is best obtained by employing high resolution extinct chronometers (with sub-Ma precision) [2]. One such chronometer is based on the decay of ^{26}Al whose short half-life ($t_{1/2}$ = 0.705 Ma [3]) is idealy suited for this purpose and has been successfully applied to a variety of differentiated meteorites in recent years [4-7].

High precision ^{26}Al-^{26}Mg systematics are presented here for three achondrites: the recently recovered Northwest Africa (NWA) 10919 eucrite and two brachinites (NWA 4882 and Brachina). Eucrites are basaltic achondrites which are part of the well characterized Howardite-Eucrite-Diogenite (HED) group believed to originate on the asteroid 4 Vesta [8-10]. The NWA 10919 eucrite was recently classified [11]. Notable characteristics of this eucrite include shock veins and scalloped grain boundaries between plagioclase and pyroxene. Brachinites are a small group of dunitic achondrites whose petrogenesis is not well understood. Originally, the brachinites were suggested to form as residues from partial melting of a chondritic precursor [12], but subsequent work indicated that they may have originated as cumulates [13]. More recently, [14] performed a detailed petrologic, thermodynamic, and experimental study and hypothesized that brachinites formed as partial melt residues of a relatively FeO-rich, R chondrite-like starting material. Few high precision ages have been reported for the brachinites. As such, these samples have been the focus of our recent investigations (this study; [15,16]).

Methods: Interior pieces, free of fusion crust, of the NWA 10919 eucrite and the brachinite NWA 4882 were acquired from the Center for Meteorite Studies collection at ASU; the Brachina sample was obtained from the South Australian Museum. All sample handling and chemical procedures were performed in the class 1000 Isotope Cosmochemistry and Geochronology Laboratory (ICGL) at Arizona State University (ASU). For preparing mineral separates from the NWA 10919 eucrite, a ~500 mg fragment of this sample was crushed and sieved. Mineral separates were obatained using heavy liquids, followed by careful hand picking. We obtained two pyroxene (Px1 and Px2) and two plagioclase (Plag1 and Plag2) separates from NWA 10919. Interior fragments of NWA 10919, NWA 4882 and Brachina (~50 mg each) were additionally powdered and dissolved to obtain whole rock (WR) samples. Each of the mineral separates and whole rock samples was digested in an HF:HNO_3 mix, and ultimately brought into solution in HNO_3.

Prior to chemical purification of Mg, a ~1% aliquot of each of the dissolved samples was reservered for measuring Al and Mg concentrations using a Thermo ICAP-Q quadrupole mass spectrometer in the Keck Laboratory at ASU. Subsequently, Mg was purified from the remaining solutions following the procedure of [5]. Magesium isotopes were measured on the ICGL's Thermofinnagan Neptune multi-collector inductively coupled plasma mass spectrometer (MC-ICPMS). An Aridus II desolvating nebulizer was used for sample introduction, with a flow rate of ~50 µl/min. The concentrations of the sample and standard solutions were typically ~1.5 ppm (matched to within ~10%). The mass-independent effects on the ^{26}Mg/^{24}Mg ratio were determined using sample-standard bracketing and internal normalization of both samples and bracketing standard (DSM-3) to a ^{25}Mg/^{24}Mg = 0.12663 [17] using an exponential fractionation law. Radiogenic excesses in ^{26}Mg are reported in ppm notation where $\mu^{26}Mg^* = [(^{26}Mg/^{24}Mg)_{sample}/(^{26}Mg/^{24}Mg)_{DSM\text{-}3}\text{-}1]\times10^6$. Based on repeated analyses of the DSM-3 Mg standard and the BCR rock standard over the course of the past year, our external reproducibility (2SD) on $\mu^{26}Mg^*$ is ± 7 ppm. For all Mg data, we report either the 2SE for repeat runs of the samples or the 2SD long-term reproducibility, whichever is larger. The slopes and intercepts of isochron regressions were calculated using ISOPLOT [18].

Results: Thus far we have completed Al-Mg analyses for the mineral fractions (Px1, Px2, Plag1 and Plag2) of the eucrite NWA 10919, as well for the whole rocks of the brachinites NWA 4882 and Brachina; we have also measured the Al/Mg ratio in the NWA 10919 WR, but have not yet completed analyses of Mg isotopes in this sample.

The ^{26}Al-^{26}Mg internal isochron for NWA 10919 is shown in Fig. 1 and yields an initial $\mu^{26}Mg^*_0$ = 15.3 ± 5.7 ppm. The slope of the isochron is unresolved from zero, and corresponds to an upperlimit on ^{26}Al/^{27}Al $\leq 1.9 \times 10^{-8}$. Relative to the D'Orbigny angrite age an-

chor [5,7,19], this upperlimit on the $^{26}Al/^{27}Al$ translates to a ^{26}Al-^{26}Mg age of ≤4560.2 Ma.

The $\mu^{26}Mg^*$ value for the NWA 4882 WR ($^{27}Al/^{24}Mg$ ~0.02) is -21.6 ± 7.2 ppm. The $\mu^{26}Mg^*$ for the Brachina WR ($^{27}Al/^{24}Mg$ ~0.06) is -9.6 ± 9.9 ppm.

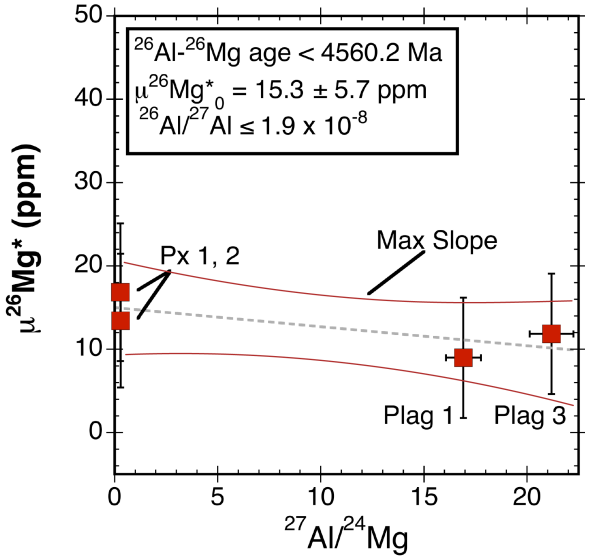

Figure 1. The Al-Mg internal isochron for the eucrite NWA 10919.

Discussion: Magnesium isotopes in the eucrite NWA 10919 are equilibrated and reflect the complex thermal history experienced by this sample on its parent body, presumably the asteroid 4Vesta. The inferred upperlimit on the $^{26}Al/^{27}Al$ of ≤1.9×10^{-8} indicates that this equilibration occurred at ≤4560.3 Ma, when ^{26}Al was extinct. Basaltic eucrites have all experienced varying degrees of thermal metamorphism, which presumably resulted following early emplacement at or near the surface of 4 Vesta. The NWA 10919 eucrite in particular shows clear signs of at least two post-crystallization heating events. The presence of shock veins suggests that this sample, like most other eucrites, was likely heated during impacts [20]. The scalloped margins in NWA 10919 minerals may reflect longer duration, subsolidus heating event(s) such that some grain boundary migration occurred [21]. Such heating might be envisioned to be the consequence of rapid crust growth and serial magmatism that likely occurred during basaltic eucrite formation; after eruption, lavas are cooled at the surface, but experience subsequent burial and reheating by fresh lava flows [22].

The initial $\mu^{26}Mg^*_0$ = 15.2 ± 5.7 for this eucrite is within the range of values observed for whole rock samples of other HED meteorites [6], and it may be assumed that its WR has this same Mg isotope composition (since Al-Mg isotope systematics appear to be thoroughly equilibrated in this sample). Assuming a bulk chondritic Al-Mg composition for the NWA 10919 parent body (i.e., $^{27}Al/^{24}Mg$~0.1; $\mu^{26}Mg^*$ = 0), the super-chondritic $^{27}Al/^{24}Mg$ ratio (~1.8) for NWA 10919 WR then yields an Al-Mg model age (relative to the D'Orbigny age anchor) of 4564.6 ± 0.5 Ma, which agrees with similarly calculated model ages for other eucrites [6]. As discussed in [6] for other basaltic achondrites, if the elevated Al/Mg for NWA 10919 resulted primarily from fractionation during differentiation and progressive crystallization of a magma ocean, then this ancient age likely post-dates the formation of the magma ocean but predates NWA 10919 crystallization/reequilibration.

The ^{26}Al-^{26}Mg systematics in the NWA 4882 WR reported here can be used similarly to calculate a WR-chondrite model isochron which yields a very ancient Al-Mg model age (relative to the D'Orbigny age anchor) of 4568.0 ± 0.5 Ma. If brachinites are partial melt residues [14], this age could date the timing of Al/Mg fractionation in its source during that partial melting event. A meaningful Al-Mg model age for Brachina could not be obtained since its WR ^{26}Al-^{26}Mg systematics are close to chondritic values.

Brachina has an ancient ^{53}Mn-^{53}Cr age of 4564.8 Ma [15] while NWA 4882 has a significantly younger ^{53}Mn-^{53}Cr age of 4550.0 Ma [16]. A previous study of the ^{26}Al-^{26}Mg systematics of Brachina [24] was unable to confirm the presence of live ^{26}Al at the time of its crystallization, but placed an upperlimit on the $^{26}Al/^{27}Al$ ratio of ≤4×10^{-7} (significantly lower than the anticipated value if both the Mn-Cr and Al-Mg systems were concordant in this sample). Since the Mg data reported by [24] were relatively lower precision, we plan to determine a high precision Al-Mg internal isochron for Brachina in the near future to verify whether or not the Mn-Cr and Al-Mg systems are concordant. This may have implications for the distribution of ^{26}Al in the early Solar System.

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