Pb-Pb AGE OF THE UNGROUPED ACHONDRITE NORTHWEST AFRICA 11119: TIMING OF EXTRATERRESTRIAL SILICA-RICH VOLCANISM. D. R. Dunlap[1*], P. Koefoed[2], Y. Amelin[2], M. Wadhwa[1], C. B. Agee[3] [1]Center for Meteorite Studies, Arizona State University, Tempe AZ 85287, [2]Research School of Earth and Space Sciences, Australian National University, Acton, ACT 2601 [3]Institute of Meteoritics, University of New Mexico, Albuquerque, NM 87131 (drdunlap@asu.edu)

Introduction: Achondrites are the products of planetesimal melting that record fundamental information about conditions during accretion, differentiation, and the diversity of igneous processes active in the early Solar System [1]. Investigations of the chronology of several achondritic meteorites have revealed that melting and differentiation processes were initiated on their parent bodies early in Solar System history [2].

The chronology of early Solar System events is challenging given the necessity of resolving events that occurred over relatively short timescales (i.e., within ~5-10 Ma) close to the beginning of the Solar System at ~4.56 Ga. While short-lived chronometers, such as ^{26}Al-^{26}Mg ($t_{1/2}$ = 0.72 Ma) and ^{53}Mn-^{53}Cr ($t_{1/2}$ = 3.7 Ma), can provide sub-Ma time resolution for early Solar System events, at best they can only provide relative ages for these events. At the present time, the Pb-Pb system is the only chronometer capable of providing the temporal resolution for high precision absolute chronology for events occurring in the early Solar System. We report here the Pb-Pb isotope systematics of a new achondrite Northwest Africa (NWA) 11119 which is unusual in being one of the most silica-rich achondrites ever found.

The NWA 11119 achondrite is a chemically evolved porphyritic extrusive volcanic rock that has a silica-rich (andesite-dacite) bulk composition [3,4]. The major mineralogy of this achondrite includes phenocrysts of anorthitic plagioclase, Cr-bearing pyroxenes and silica. In fact, NWA 11119 contains the highest modal abundance (~30 vol.%) of free silica (i.e., tridymite and cristobalite) of any known achondrite. Texturally, this achondrite contains vesicles and cavities, as well as a fine grained matrix. These bulk chemical and textural characteristics all provide evidence for its production by extrusive silicic volcanism on an asteroidal body. We recently reported a high precision ^{26}Al-^{26}Mg internal isochron for NWA 11119 which indicates an ancient crystallization age of 4564.8 ± 0.3 Ma assuming the D'Orbigny age anchor [3,5]. By investigating the Pb-Pb systematics in this unusual achondrite, we seek to 1) assess the concordance between the high-resolution ^{26}Al-^{26}Mg relative chronometer and the Pb-Pb absolute chronometer, and 2) obtain the precise and absolute timing of silica-rich volcanism in the early Solar System.

Methods: The sample of NWA 11119 used in this study was obtained from the meteorite collection at the Institute of Meteoritics at the University of New Mexico. All sample handling and chemical processing was performed under clean laboratory conditions at Arizona State University (ASU) and Australian National University (ANU). A ~200 mg interior chip of NWA 11119 was crushed in a clean agate mortar and pestle in the Isotope Cosmochemistry and Geochronology Laboratory (ICGL) at ASU. Subsequently, a ~9 mg aliquot of this crushed sample was taken as a whole rock (WR) fraction. Two clean pyroxene separates (PxA ~4 mg and PxB ~10 mg) were acquired by sieving, followed by heavy liquid separation and hand picking of the coarsest size fractions (100–200 µm grains). Chemical processing of these fractions was performed at ANU. Each of these three fractions (WR, PxA and PxB) were ultrasonicated in distilled acetone prior to leaching. The samples were subsequently leached using a procedure designed to remove the common Pb component with progressive washes. Prior to digestion and dissolution of the residues, the WR fraction underwent 5 leaching steps, while 3 leaching steps were performed on the Px fractions. The WR was initially leached with two steps involving Milli-Q H_2O and 0.3M HBr. All fractions were then progressively leached in 0.5M HNO_3, 7M HNO_3, and 6.2M HCl before complete digestion in a 2:1 HF:HNO_3 mix. All fractions were spiked with a ^{202}Pb-^{205}Pb-^{229}Th-^{233}U-^{236}U tracer prior to column chemistry. Chemical purification of Pb and U was performed following previously described procedures [6]. The Pb isotope compositions were measured at ANU using a Thermo Triton Plus Thermal Ionization Mass Spectrometer (TIMS). Samples were typically run in both static mode on multiple faraday cups and by peak jumping on the secondary electron multiplier, depending on the beam intensity. The EARLYTIME [7] and SRM981 Pb standards (spiked in a similar manner to our samples) were run along with the samples to verify the accuracy of our analyses. The U isotopic compositions will be measured in the near future at in the ICGL at ASU using a Thermo Neptune Multi Collector Inductively Coupled Plasma Mass Spectrometer (MC-ICPMS) using methods similar to those described previously [8,9].

Results: The first washes (W1a-W1b) for each of the three fractions have relatively low $^{206}Pb/^{204}Pb$ ratios of 19–104, the second washes (W2a-W2b) have $^{206}Pb/^{204}Pb$ ratios of 141–489, and the residues (R) have $^{206}Pb/^{204}Pb$ ratios of 65–386. In each leaching step, the washes for the WR fraction were more radiogenic than those for the Px fractions indicating the presence of U-enriched phase(s) in the WR. An isochron calculated using data from the most radiogenic fractions (W2b and R) yields a Pb-Pb age of 4563.3 ± 2.9 Ma (MSWD = 3.7, n = 6) (Fig. 1). For this age calculation, the average Solar System $^{238}U/^{235}U$ ratio of 137.794 was used [9]. We note that this Pb-Pb age for NWA 11119 will be refined in the near future by measuring of the $^{238}U/^{235}U$ ratio in a WR sample as well as by targeting the U-rich phase(s) in the WR for Pb isotope analyses.

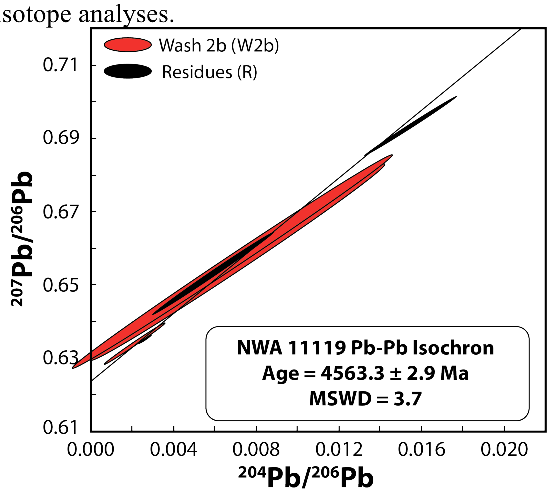

Fig. 1 The Pb-Pb isochron for NWA 11119. The data plotted here include the most radiogenic washes (W2b) and residues (R) for two pyroxene separates (PxA and PxB) and a whole rock (WR) fraction.

Discussion: The silica-rich (andesite-dacite) bulk composition of the ungrouped achondrite NWA 11119 is unique among known achondrites. However, this silicic achondrite shares some textural and geochemical similarities (e.g., bulk oxygen isotope compositions, and presence of Cr-bearing pyroxenes) to the ungrouped achondrite NWA 7325 and the trachyandesitic clast ALM-A from Almahata Sitta ([3,4] and references therein). High precision ^{26}Al-^{26}Mg and Pb-Pb ages of ~4563 Ma have been reported for both NWA 7325 [6] and ALM-A [10,11].

Currently our preferred Pb-Pb age for NWA 11119 is 4563.3 ± 2.9 Ma (Fig. 1), which is based on the most radiogenic fractions analyzed thus far. The relatively low precision of this age is a reflection of the low U concentration in this sample. While the uncertainty on our preferred Pb-Pb age is significantly larger than on the ^{26}Al-^{26}Mg age of 4564.8 ± 0.3 Ma [3,5], these ages are concordant. The high precision ^{26}Al-^{26}Mg internal isochron age of NWA 11119 is one of the oldest recorded achondrite ages along with that of the ungrouped achondrite Asuka 881394 (~4565 Ma) [12,13].

The origin of silicic volcanism required to produce andesitic crusts in a terrestrial environment is debated; it is thought to occur either by primary melting of the upper mantle or as a secondary product of basaltic partial melts [14]. Additionally, plate tectonics and mantle volatile contents are thought to play important roles in andesite formation on Earth [15]. The petrogenesis of NWA 11119 cannot be easily linked to melting of any known chondrite type [3]. As such, NWA 11119 could have formed from melting of an unknown chondrite type which produced its unique mineralogy. Alternatively, if NWA 11119 is a secondary product of an originally basaltic partial melt, then it represents the first evidence of tertiary crust formation well before terrestrial planet formation.

Several recent chronologic investigations show that basaltic volcanism on planetesimals took place well within ~3-5 Ma of the beginning of the Solar System. The Pb-Pb age reported here along with the ^{26}Al-^{26}Mg isotope systematics and bulk composition of NWA 11119 demonstrate unambiguously that andesitic-dacitic crusts were also forming on a differentiated planetesimal within the first ~3 Ma of Solar System history. This extends both the age and degree of chemical evolution of planetary crustal materials on differentiated bodies.

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