$^{40}Ar/^{39}Ar$ AGES OF AN EL6 CHONDRITE CLAST FROM ALMAHATA SITTA.

B. D. Turrin[1], F. N. Lindsay[2], G. F. Herzog[2], J. Park[2], J. S. Delaney[1], and C. C. Swisher, III[1], [1]Rutgers University, Earth & Plant. Sci., 610 Taylor Rd, Piscataway, NJ 08845 USA. (bturrin@rci.rutgers.edu), [3]Rutgers University, Dept. of Chem & Chem. Biol., 610 Taylor Rd, Piscataway, NJ 08845 USA

Introduction: The Asteroid 2008 TC_3 entered the Earth's atmosphere on 10/7/2008 and commenced to breakup at ~37 km above the Earth's surface, distributing meteoritic debris across the Nubian Desert, northern Sudan. Over 700 fragments (~11 kg), recovered from Almahata Sitta (AhS) meteorite fall [1] represent several different lithologies, ranging from ureilites to chondrites [2]. AhS is a polymict ureilite [3], but also includes (20-30%) EH and EL chondrites and some H- and L- chondrites [4]. We present newly obtained $^{40}Ar/^{39}Ar$ results from an AhS EL6 chondrite (fragment MS-D).

Sample: We received an approximately 20mg piece of the MS-D fragement from A. Bischoff (Fig. 1). The MS-D fragment, a 17.34 g highly metamorphosed EL6 chondrite breccia, is a recrystallized enstatite-rich (Fs <0.3) rock, containing several clasts up to 5mm in size [2]. The clasts contain abundant Ca-pyroxene, metal, sulfides (troilite, oldhamite, Zn-alabandite, and keilite) and more importantly for $^{40}Ar/^{39}Ar$ dating, plagioclase.

Figure 1: Photograph of the EL6 MS-D fragment allocated for $^{40}Ar/^{39}Ar$ dating. The MS-D fragment shows a S2 level of shock and a W0/1 degree of terrestrial weathering [2].

Procedures: The MS-D fragment was crushed and sieved. Plagioclase grains were separated from the crushed material using heavy liquid LST (Li-heteropolytungstates) density separation techniques (ρ = 2.85 g/cm^3, T = 25 °C).

Backscatter imaging and energy-dispersive spectroscopy (EDS) were used to characterize predominantly mono-mineralic mineral grains. Four pure plagioclase grains (3 μg) were isolated and analyzed as sample split (22319). An additional eight composite grains (10 μg) were also selected and measured as sample split (22318).

Ar analysis: The samples were loaded into a well in an Al disk, sealed in an evacuated quartz tube, and co-irradiated with Fish Canyon sanidine (28.201 Ma, [5] and Hb3gr (1080 Ma, [6]) for 80 hours, without Cd shielding at the USGS Triga reactor of USGS in Denver. Decay constants are from [7]. Argon isotopes were analyzed using a modified MAP 215-50 mass spectrometer with a CO_2 laser [8, 9]. The samples were step-heated to fusion in 8 to 9 heating steps, sample split 22319 and 22318, respectively. Argon isotopes were analyzed with typical system blanks (laser off) of (10^{-18} mol): ^{40}Ar = 272±6; ^{39}Ar = 7.6±0.6; ^{38}Ar = 2.3±0.3; ^{37}Ar = 36±0.4; ^{36}Ar = 6.7±0.3. Uncertainties are expressed as 1σ unless otherwise specified.

The isotopic data were cast on an inverse isotope correlation diagram (Fig. 2) to determine the "trapped" Ar isotopic ratio and an "isochron" age. The "trapped" Ar isotopic value and the associated error are then used to calculate apparent ages and errors for the individual heating steps and plotted on a standard "step-heating diagram" (Fig.3).

Results: The Ar isotopic data for sample split 22318, when cast on an isotope correlation diagram (Fig. 2) indicate that the first two low T steps (A and B) do not lay along the mixing line defined by remaining steps (C throuth I). With these two steps included, non-physically possible negative $^{40}Ar/^{36}Ar_{tr}$ ratio of -10 ± 4 is indicated with a excessive MSWD of 2.9, suggesting that there is more scatter in the data set than indicated by the measurement errors. Without these two points, the MSWD (0.32) indicates that the scatter about the mixing line can be accounted for by measurement error. The mixing line defined isotope data indicate a $^{39}Ar/^{40}Ar$ ratio that corresponds to an age of 4494 ±85 Ma and an indicated $^{40}Ar/^{36}Ar_{tr}$ ratio of 86 ±49 (This value is analytically indistinguishable at the α-95% confidence level from the nebular value (~1x10^{-4}). This is our preferred result.

When the Ar isotopic data for sample split 22319 are cast on an isotope correlation diagram, all of the data (including the fusion step "H"), define a mixing line that corresponds to an age 4420 ±200 Ma, an indicated $^{40}Ar/^{36}Ar_{tr}$ ratio of 199 ±41, and a MSWD value of 1.2. With the fusion step "H" excluded, the mixing line indicates an age 4440 ±210 Ma, an indicated

$^{40}Ar/^{36}Ar_{tr}$ ratio of 202 ±48, and a MSWD of 0.62. This value is analytically distinguishable at the α-95% confidence level from the nebular value (~1x10^{-4}), indicating the presence of a "trapped" Ar component.

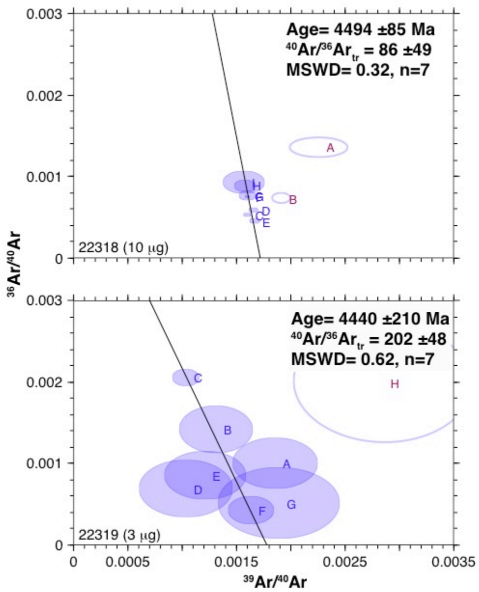

Figure 2: Ar isotope correlation diagram from plagioclase separated from the AhS fragment MS-D.

Step-Heating Spectra: Sample split 22318 produced concordant plateau and total intergrated gas ages of 4494 ± 17 Ma consisting of 87.5% of the total $^{39}Ar_K$ and 4448 ±22 Ma, respectively. (Fig. 3). The overall K/Ca ratios for sample split 22318 range from 0.1 to 0.4 and typical have errors of about 10-20%. Our preferred age for this sample is 4494 ± 17 Ma.

Similarly, sample split 22319 also produced concordant plateau total intergrated gas ages. The plateau age of 4450 ± 140 Ma consisting of 80.8% of the total $^{39}Ar_K$ and 4340 ±150 Ma, respectively. Our preferred age for this sample is 4450 ± 140 Ma.

The overall K/Ca ratios for sample split 22319 are about a factor of 10 less that sample split 22318 and range from 0.01 to 0.02 and typical have errors of about 25-50%.

Discussion and Conclusions: The larger error of sample split 22319 compared to 22218 are attributed to the smaller gas volumes due to both smaller sample size (3mg versus 10 mg, respectively) and to a lower K content as indicated in the K/Ca ratios.

Our results for this EL6 chondrite fragment and the previously reported $^{40}Ar/^{39}Ar$ ages for the other AhS-fragments; #25 (H5 chondrite; 4506 ±15 and 4565 ±9 Ma [10]) and #100 (L4 chondrite; 4525 ±7 Ma [10]), indicate that the Ar/Ar system in Asteroid 2008 TC_3 had not been disturbed for the last 4500 Ma. Further, the Ar/Ar closure ages for the EL6, the H5, and the L4 chondrites fragments are all within a 60 Ma window. This suggests either early metamorphism of the H, L, and E chondrites or a complex history of disassembly and re-accretion.

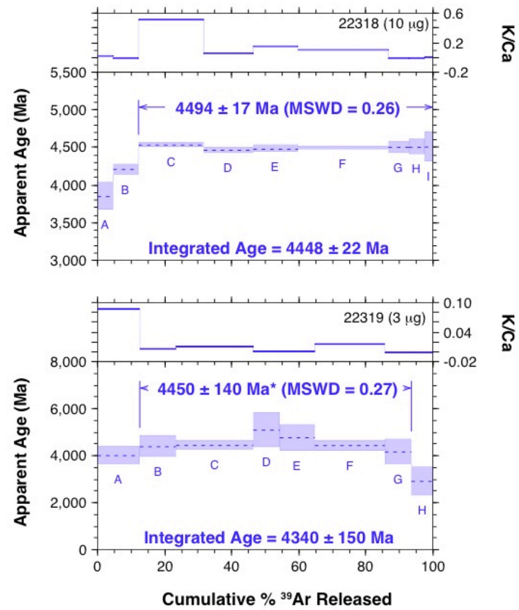

Figure 3: Step-heating diagram from plagioclase separated from the AhS fragment MS-D.

References: [1] Jennisken P. et al., 2009, Nature 458:485-488. [2] Bischoff et al., 2010, MAPS 45:1638-1656. [3] Jennisken P. et al., 2010, MAPS 45:1590-1617 [4] Horstmann, M., et al., 2010, MAPS 45:1657-1667. [5 Kuiper et al., 2008]. [6 Jordan and Renne 2007 (GCA 71:387-402 [7] Steiger and Jäger (1977) [8]Turrin B.D. et al. 2010. *Geochem. Geophy.s Geosys. (G^3)* 11, doi:10.1029/2009GC003013. [9] Lindsay et al., 2014 [10] Turrin et al., 2013 76th Annual Meteoritical Society Meeting.