^{40}AR-^{39}AR AGE OF AN IMPACT-MELT LITHOLOGY IN DHOFAR 961. B. Frasl[1], B. A. Cohen[2], Z.-H. Li[2], B. Jolliff[3], R. Korotev[3], R. Zeigler[4], [1]University of Alabama Huntsville; [2]NASA Marshall Space Flight Center, Huntsville AL 35812; [3]Washington University in St. Louis; [4]NASA Johnson Space Center.

Introduction: The South Pole–Aitken (SPA) basin is the stratigraphically oldest identifiable lunar basin and is therefore one of the most important targets for absolute age-dating to help understand whether ancient lunar bombardment history smoothly declined or was punctuated by a cataclysm. The SPA basin also has another convenient property, a geochemically distinct interior, unobscured by extensive mare basalt fill [1, 2]. A case has been made for the possible origin of the Dhofar 961 lunar meteorite in the South Pole-Aitken (SPA) basin, based on comparing its composition with Lunar Prospector gamma-ray data for the interior of the SPA basin [3, 4] (Fig. 3).

Dhofar 961 contains several different impact-melt (IM) lithologies [5, 6]. Jolliff et al. [5] described two classes of mafic impact-melt lithologies, one dominated by olivine (Lithology A) and the other by plagioclase ($An_{95\text{-}96.5}$) (Lithology B). Broad-beam analyses of these lithologies yielded ~14.0 wt% FeO, 11.7 wt% MgO, and 15.4 wt% Al_2O_3. Lithologies A and B differ by ~2.5% Al_2O_3, 1.5% FeO and 1.5% MgO, consistent with the occurrence of olivine phenocrysts in A and plagioclase clasts in B. Both lithologies are considerably more mafic than the Apollo mafic impact-melt breccias, corresponding to olivine gabbronorite.

Joy et al. [6] used U-Pb dating to investigate phosphate fragments in the Dhofar 961 matrix and impact-melt clasts. Matrix phosphates have 4.34 to 4 Ga ages, consistent with ancient KREEP-driven magmatic episodes and Pre-Nectarian (>3.92 Ga). Phosphates found within Dhofar 961 crystalline impact melt breccia clasts range from 4.26 to 3.89 Ga, potentially recording events throughout the basin-forming epoch of lunar history. The youngest reset ages in the Dhofar 961 sample represent an upper limit for the time of formation of the meteorite. Joy et al suggested this age represents the final impact that mixed and consolidated several generations of precursor rocks into the Dhofar meteorite group, although they note that further age dating of all the stones is required to test this hypothesis.

Figure 1. Slice of Dhofar 961 showing the predominant impact-melt lithology (1 mm tick marks; photo by Randy Korotev).

We received a split of Dhofar 961 from R. Zeigler consisting of a large clast of IM Lithology B, with some light-colored, friable matrix clinging to the external margins of the impact-melt clast. This lithology was not present in the samples investigated by Joy et al. [6] (Joy, pers. comm.) and thus does not have corresponding U-Pb ages on it. We created multiple subsplits of both the IM and matrix lithologies, each weighing several tens of micrograms. We conducted $^{40}Ar\text{-}^{39}Ar$ dating of this candidate SPA material by high-resolution step heating and comparing it with the regolith that surrounds it.

Methods: Noble gas analyses were conducted at the MSFC Noble Gas Research Laboratory (MNGRL) at Marshall Space Flight Center. MNGRL consists of a Nu Noblesse magnetic sector mass spectrometer with a high-voltage Nier source fitted with four discrete dynode ion-counting multipliers and a Faraday cup, coupled to a custom-built ultra high vacuum gas extraction system. Our system has been extensively characterized and calibrated using standard gas mixtures; one pipette tank has been cross-calibrated with the Washington University noble-gas laboratory. A Photon Machines FUSIONS.970 laser heating system with confocal optics and two-color infrared pyrometer heats the samples and complete system automation is achieved using the Mass Spec software package written by Al Deino of the Berkeley Geochronology Center.

We irradiated the samples in the University of Oregon TRIGA reactor cadmium-lined core position for 375 hours to achieve a J-factor of ~0.1. K_2SO_4 and CaF_2 salts and a flux standard (Mmhb-1 hornblende and PP-20 hornblende) were simultaneously irradiated to correct for reactor-induced interferences and derive the neutron fluence. We encased each conducted step-heat experiments using a diode laser using Pt/Ir tubes or foils as microfurnaces. The sample or sample grains are encased in the tube or foil, and the sample placed in a fused silica planchet in the extraction line. The encasing Pt metal can then be heated very precisely and reproducibly, enabling the data to be used in Arrhenius plots to recover detailed diffusion domain

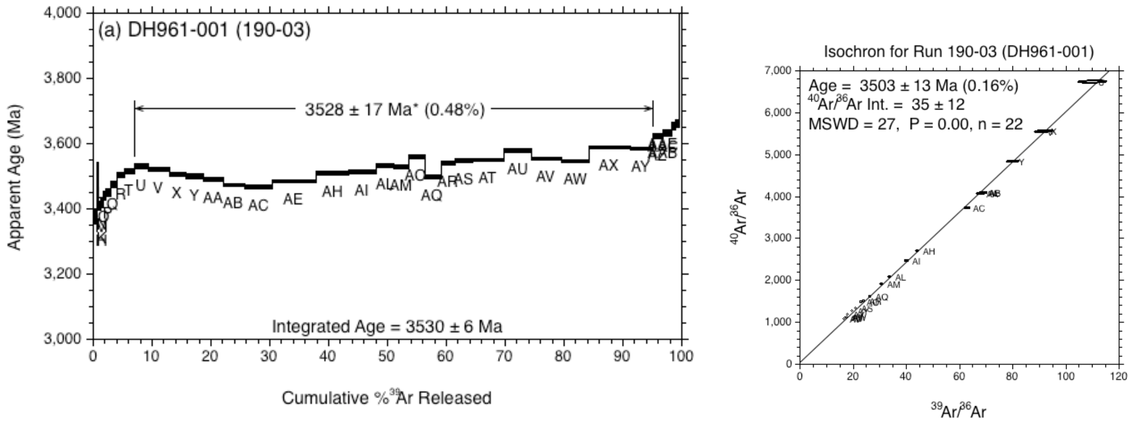

Figure 2: A) step-heat profile and b) isochron for Dhofar 961 impact-melt lithology.

information. For all samples, we measured ^{40}Ar, ^{39}Ar, ^{38}Ar, ^{37}Ar, and ^{36}Ar, though the samples' reactor-induced ^{37}Ar had fully decayed by the time of analysis. We used ^{38}Ar/^{36}Ar ratios to understand the contribution of solar wind and cosmic-ray contributed isotopes and also corrected for any trapped terrestrial atmosphere. We determined the age of the impact melt using step-heating plateaus and isochrons.

Preliminary Results: We achieved >50 heating steps on one split of the IM lithology, though not every step degassed significant ^{39}Ar. A step-heating profile (Fig. 2a) shows three main features: (1) Ar loss in the low-temperature steps, (2) a broad set of nearly-congruent release steps, and (3) an upturn in apparent ages in the last 10% of ^{39}Ar degassing at high temperatures. The upturn in apparent ages is likely related to recoil of ^{39}Ar into neighboring locations due to the long irradiation. Though the degassing steps don't form a good plateau, the sum of the degasing from the middle steps yields an age estimate of 3.528 ± 17 Ma. An isochron (Fig. 2b) shows that these same steps have an age derived from the slope of 3.471 ± 13 Ma. The isochron age is slightly younger and shows that there is a trapped component with an ^{40}Ar/^{36}Ar ratio of ~70. This is significantly less than terrestrial atmosphere but higher than typical trapped solar wind at the Moon (~10). This value will need to be refined to do a proper trapped correction to bring the two estimates in line with each other. The downturn in apparent ages at low temperatures is consistent with Ar diffusive loss from the fine-grained matrix of the IM lithology. Extrapolating the slope of the downturn predicts that this loss occurred on the lunar surface around 3.37 Ga.

Future work: Our age for this Dhofar 961 lithology is younger than any of the U-Pb ages reported for phosphates in this meteorite by Joy et al. [6]. However, U-Pb ages are commonly slightly older than their Ar-Ar counterparts, having a higher closure temperature and being less susceptible to low-temperature losses. Additionally, this particular lithology was not sampled by Joy et al. [6], so it is possible that it could be recording the youngest age for the meteorite, though our work is currently too preliminary to make this conclusion. We have two more splits of the Dhofar 961 IM material, plus one split of material external to the impact-melt lithology that we will conduct further experiments on. These will include cyclic heating schedules to enable thermal diffusion studies of the impact melt lithology and cosmic-ray exposure age determinations for both lithologies.

Joy et al. [6] concluded that there are multiple potential source locations for the Dhofar 961 group of meteorites on the Moon, including but not necessarily limited to the South Pole-Aitken basin. However, the meteorites likely originate from outside the (likely Imbrium-dominated) Procellarum KREEP Terrane [7]. Therefore, the range of impact-melt ages within these meteorites needs to be further explored for clues to the impact history of the Moon in regions beyond where we have directly sampled.

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