REVIEWING THE GEOCHRONOLOGIC CONSTRAINTS FROM SAMPLES OF BOULDERS AT APOLLO 17 STATIONS 2, 6, AND 7: IMPLICATIONS FOR UNDERSTANDING THE STRATIGRAPHY OF THE NORTH AND SOUTH MASSIFS IN THE VALLEY OF TAURUS-LITTROW. C. M. Mercer[1*], K. V. Hodges[1], B. L. Jolliff[2], M. C. van Soest[1], and C. S. McDonald[1]. [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ, USA, (*cameron.m.mercer@asu.edu), [2]Department of Earth & Planetary Sciences and the McDonnell Center for the Space Sciences, Washington University, St. Louis, MO, USA

Introduction: The Apollo 17 astronauts visited the Taurus-Littrow Valley situated at the southeast rim of the 740 km-diameter primary Serenitatis impact basin. The valley itself is an east-southeast trending graben oriented radially to the Serenitatis basin, and is bounded by large highland massifs to the north and south [1,2]. The massifs are generally interpreted to have been emplaced by the impact that formed the primary Serenitatis basin, and some researchers have postulated that they contain materials from multiple impact basins (see discussions and references cited by Wilhelms [1] and Schmitt et al. [2]). The Sculptured Hills physiographic unit, which is superposed on the Taurus highlands, is now generally interpreted to have been emplaced by the Imbrium basin-forming impact [3]. While Spudis et al. [3] suggested the possibility that all the Apollo 17 impact melt rocks (IMRs) may have been derived from Imbrium, Hurwitz and Kring [4] used high resolution Lunar Reconnaissance Orbiter Camera images and petrologic and geochemical observations to argue that the boulders sampled at the North and South Massifs comprise materials that predate the Sculptured Hills (i.e., Imbrium).

These competing stratigraphic interpretations have formed the backdrop against which basin-age interpretations, primarily of Serenitatis and Imbrium, have been made from geochronologic datasets for Apollo 17 samples [e.g., 2–5]. In addition, there have been a number of recent U/Pb studies of accessory phases (e.g., zircon and phosphates) in IMRs from the Apollo 12 and 14 landing sites and lunar meteorites that have also variably been interpreted as indicating the ages of major impact basins, especially of Serenitatis and Imbrium [5–10]. One hypothesis of particular interest raised by these studies is the possibility that the Imbrium basin may have formed ca. 3.92 Ga, which is older than estimates based on other geochronologic datasets, such as $^{40}Ar/^{39}Ar$ [e.g., 11–13]. This discrepancy has variably been attributed to the use of outdated ^{87}Rb and ^{40}K decay constants [e.g., 7] and $^{40}Ar/^{39}Ar$ monitor mineral age calibrations [e.g., 9].

To address these concerns for the Apollo 17 site, we are compiling geochronologic data for samples collected from boulders at the bases of the South (Station 2) and North (Stations 6 and 7) Massifs. In addition, we have integrated petrologic and ultraviolet laser ablation microprobe (UVLAMP) $^{40}Ar/^{39}Ar$ geochronologic investigations of several Apollo 17 boulder samples, including: sample 72255 from boulder 1 at Station 2; sample 76315 from block 2 of the Station 6 boulders; and samples 77075, 77115, and 77135 from the Station 7 boulder [e.g., 14, 15].

Data Compilation and Recalculation: We are compiling U/Pb, Rb/Sr, Sm/Nd, and $^{40}Ar/^{39}Ar$ data for 22 samples collected from boulders at Stations 2, 6, and 7. So far, we have identified 92 datasets for these 22 samples, of which 64 % are $^{40}Ar/^{39}Ar$, 18 % are U/Pb, 16 % are Rb/Sr, and the remainder (~1 %) are Sm/Nd. Unfortunately, to the best of our knowledge, 13 $^{40}Ar/^{39}Ar$ datasets (representing 22 % of the available $^{40}Ar/^{39}Ar$ data and ca. 14 % of the total number of geochronologic datasets identified thus far) were only presented in short abstracts as figures of incremental release spectra, or otherwise lack tabulated isotopic data, severely limiting their utility. We encourage all researchers who may have unpublished geochronologic isotope data for priceless Apollo samples to submit their datasets to the MoonDB project [www.moondb.org] for preservation and reuse by future generations of scientists. We used the *ArAR* software of Mercer and Hodges [16] to ensure all $^{40}Ar/^{39}Ar$ dates have been determined using a consistent set of ^{40}K decay constants and monitor mineral ages, and we have ensured all Rb/Sr dates have been determined with a consistent ^{87}Rb decay constant.

Analytical Methods: We characterized the petrographic sections using the JEOL JXA-8200 electron microprobe at Washington University in St. Louis prior to conducting UVLAMP $^{40}Ar/^{39}Ar$ analyses at Arizona State University (see Mercer et al. [14, 15] for details regarding methodology). The UVLAMP system has two major advantages over visible and infrared (IR) lasers: (1) it couples well with most rock-forming minerals and glasses (even those that are transparent at visible and IR wavelengths); and (2) the high energy densities of the beam cause ablation rather than heating or melting, preventing gas release from materials outside the laser footprint. The UVLAMP $^{40}Ar/^{39}Ar$ method is an important complement to incremental heating methods since it allows individual lithologies and minerals to be dated while preserving petrographic context [14, 15, 17, 18].

Preliminary Results Reveal Gremlins: An Example: As noted above, there are commonly discrepancies among dates determined using different mineral isotopic systems in individual samples. For example, Leich et al. [19] reported a $^{40}Ar/^{39}Ar$ plateau date of 4010 ± 30 Ma for a matrix subsample of the clast-rich aphanitic IMR 72255 (split 72255,52). In contrast, Thiessen et al. [5] reported a weighted mean U/Pb date of 3922 ± 5 Ma from six analyses of five phosphate grains in three different subsections (72255,99, 72255,125, and 72255,306). However, the ^{40}K decay constants and age used for the St. Severin monitor in the early 1970's by Leich et al. [19] are outdated. Using values consistent with the 1977 recommendations of the IUGS Subcommission on Geochronology [20], the plateau date for 72255,52 would be 3975 ± 29 Ma. Or, using values recommended more recently by Renne et al. [21], the plateau date for 72255,52 would be 3984 ± 29 Ma. So, regardless of which values are used for the ^{40}K decay constants and age of St. Severin, the incremental heating $^{40}Ar/^{39}Ar$ and phosphate U/Pb dates of Leich et al. [19] and Thiessen et al. [5] appear at odds. Worse, the $^{40}Ar/^{39}Ar$ date is disturbingly *older* than the U/Pb date despite the K-Ar system being significantly more susceptible to thermal resetting than the U/Pb system.

We obtained 23 UVLAMP $^{40}Ar/^{39}Ar$ analyses of the aphanitic melt matrix of 72255,409, and 47 analyses of mineral and lithic clasts that range in age up to ca. 4050 Ma. Twenty of the melt analyses form an isochron with an age of ca. 3815 Ma (using constants consistent with Steiger and Jäger [20]). Our ability to precisely target the aphanitic melt matrix separately from older inherited clasts implies that our isochron date is more likely to reflect the age of the impact that assembled 72255 than published incremental heating datasets for this sample. Our result also resolves the apparent age inversion among incremental heating $^{40}Ar/^{39}Ar$ and U/Pb dates. However, our isochron date is ca. 110 Ma *younger* than the weighted mean U/Pb phosphate date reported by Thiessen et al. [5]. If we were to use the more recent values for the ^{40}K decay constants and monitor age of Renne et al. [21], our isochron date would only increase by 0.2 % (to ca. 3823 Ma). Thus, the gap between the $^{40}Ar/^{39}Ar$ and phosphate U/Pb systems cannot simply be explained by outdated decay constants nor monitor-age calibrations as some have suggested [4, 7, 9].

Potential Implications for Understanding the Stratigraphy of the North and South Massifs: Differences in the apparent ages of multiple chronometric systems (e.g., $^{40}Ar/^{39}Ar$ and phosphate U/Pb) provide an opportunity to constrain the thermal histories of individual samples, with implications for stratigraphic interpretations of basin ejecta at the Apollo 17 site. Continuing with 72255, the existence of lithic clasts with apparent $^{40}Ar/^{39}Ar$ ages > 4 Ga coexisting with an aphanitic melt matrix that yields an isochron age of ca. 3815 Ma implies that the sample cooled rapidly. Thermal-kinematic models that satisfy these $^{40}Ar/^{39}Ar$ constraints suggest that the phosphate U/Pb system would likely not have been fully reset, implying that the phosphates are possibly inherited and may record evidence of an earlier impact event.

This poses a potential problem if we take the phosphate U/Pb dates for Apollo 17 aphanitic IMRs as the age of Imbrium [e.g., 5] because it would require a subsequent impact to have produced the melt component of the aphanitic IMRs. In other words, one of the major petrologic types of IMRs at the Apollo 17 site would have to have been assembled and delivered to the Taurus-Littrow Valley *after* the Sculptured Hills were emplaced. Alternatively, if the melt component of the aphanitic IMRs was produced by Imbrium, then the phosphate U/Pb dates must reflect an earlier impact(s); the two Serenitatis impact basins are obvious potential sources. In a third scenario, if the primary Serenitatis impact produced the melt in the aphanitic IMRs and emplaced the breccias in the massifs, then the phosphate U/Pb dates would likely reflect an even older impact. More work will need to be done to critically examine these possibilities, including new UVLAMP $^{40}Ar/^{39}Ar$ and U/Pb experiments and detailed thermal-kinematic models, but from our compilation of Apollo 17 geochronologic data so far it appears that 72255 is not an isolated case.

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