MOON UNITED: MEASURING COSMIC-RAY EXPOSURE AGES OF PRISTINE APOLLO 17 SAMPLES.
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Introduction: During the last ~4.5 Gyr, particles from the solar wind and the wider galaxy, as well as gases from the lunar interior (e.g., solar cosmic rays, galactic cosmic rays, micrometeorites) have directly interacted with and/or been implanted into regolith exposed at the lunar surface [1-2]. Over this time, volatiles (such as water) and organic compounds have also been exogenically and endogenically added to the lunar surface [3-5]. Volatiles have been implanted in the regolith by the solar wind [6, 7] and trapped as they escape the lunar interior [5, 8, 9]. Both volatiles and organic molecules have been delivered by asteroidal and cometary impacts over time [10-13]. Furthermore, volatiles and organics may be produced or destroyed during the interaction of the solar wind and cosmic rays with surface exposed material [14-17].

Noble gases can be used as a powerful tracer for measuring these inputs as well as their potential destruction via different surface processes. The noble gas inventory of the regolith helps decipher how long a sample was exposed to the space environment (cosmic ray exposure (CRE) age), how much gardening and overturn was experienced (maturity), and the timing of breccia formation or soil appearance (antiquity age). These noble-gas derived quantities give crucial context to the history of volatile and organic compounds in the regolith.

The Moon United Team: The Moon United team (as part of the Apollo Next Generation Sample Analysis (ANGSA) consortium) will analyze a variety of particles (impact-melts, basalts and regolith breccias) and bulk soils from several regolith samples collected during the Apollo 17 mission, including two shadowed soils (72320 and 76240) and a double-drive tube (73001/2). These samples provide the opportunity to assess the input budget from the solar wind and exogenous sources, understand exposure histories with depth, and explore how the local region has evolved over time. The petrology (scanning electron microscope), mineral and bulk rock chemistry (electron microprobe), and noble gas budget (mass spectrometry) will be measured for each particle and soil sample. These data will be used to determine parent lithology and constrain the regolith history (e.g., cosmic ray exposure age, maturity, gardening history) of the samples and provide crucial context to the exposure history experienced by volatile and organic compounds within them. These measurements will offer significant value to the ANGSA consortium efforts to understand the complete geologic history of the samples, the Apollo 17 landing site, and lunar processes. In this project, we will use a combination of noble-gas isotopic ratios and abundances to decipher the importance of each input source and help answer the following geologic questions.

What does the petrology and noble gas inventory tell us about the geologic history of the Apollo 17 landing site? The noble-gas parameters of exposure age, maturity, antiquity, and abundance on different rock types, originating from different depths, will allow us to acquire a range of information from different periods of lunar history. These parameters will enable us to describe the geologic history of the Apollo 17 landing site and address what properties govern the volatiles and organics budgets at the site, including lithologic types, geologic setting, and regolith processes such as landslides and impacts.

What are the relative contributions to the noble-gas inventory from solar wind and micrometeorite bombardment in shadowed soils? Permanently shadowed regions (PSRs) at the lunar poles are key sites for the retention of volatiles. They are incredibly cold (<110K), enabling them to sequester exogenously-added components from volatile-rich asteroids and/or comets, as well as endogenic noble gases [11, 18-23]. However, their geometry shields them from the solar wind. Partially shadowed soil samples 72320 and 76240 provide a useful opportunity to isolate the effect of shielding from the solar wind on the input budgets of noble gases and other volatiles. These "permanently"/partially shadowed soils record the most recent history (last few tens of millions of years) at the Apollo 17 landing site.

Measuring the noble gas contents of these soils using modern techniques will shed light on these apparent discrepancies and give a fuller picture to the processes taking place in these small, shadowed regions. To minimize potential ambiguity in the results when comparing shadowed soils from our lab with noble gas analyses of non-shadowed soils in other labs, we will also request and measure the same quantities from nearby, unshadowed soils. Soil sample 76260 (Is/FeO = 58, agglutinates 45% agglutinates), has a very similar petrology and maturity to 76240 (Is/FeO = 56, agglutinates 48% agglutinates) [24, 25] and sample 72501 is very similar to 72320. We will examine both crystalline fragments and bulk soil from shadowed and unshadowed samples to determine their exposure and maturity histories, as well as the total inventory as a proxy for micrometeorite input, to understand how shadowing has affected the relative inputs of volatiles to these soils.

What is the variation in exposure ages and maturity with depth? As lunar soil matures at the surface by micrometeorite comminution and agglutination, it can be overturned or buried by larger processes of movement and turnover collectively known as gardening. The movement of material by large impacts is the dominant mode but slumping and landslides can also be locally important. The formation of layers can aid preservation of molecules by removing them from direct surface interaction, but organic molecules may continue to degrade as cosmogenic effects are still felt meters into the regolith. Determining the exposure age, antiquity, maturity, and abundance of noble gases in these horizons will allow us to address how long organic molecules have been exposed to potentially damaging cosmic rays, and when volatiles and organics were gardened back into the soil column and protected from escape.

Table 1: List of samples allocated for this work.

Sample	**73002**	**72320**	**76240**	**72501**	**76261**
Type	Double drive tube (3 depths)	Shadowed soil	Shadowed soil	Sunlit soil	Sunlit soil
Particles	21	0	12	0	12
Soil(mg)	50	20	20	20	20

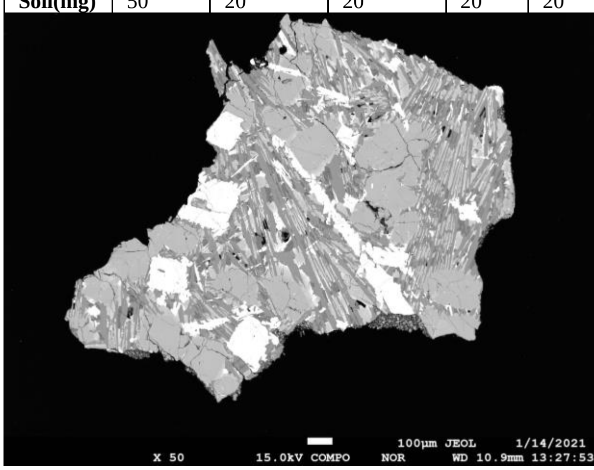

Fig 1: Back scattered electron image of particle 73002,186A.

Current and Pending Work: Samples allocated (Table 1) to the Moon United team range from lithic fragments of basalt and noritic nature to breccias including impact melts and regolith breccia. These have all been characterized by X-ray computed tomography (XCT), Scanning electron microscopy (Fig 1), and electron microprobe analysis (Fig 2) to determine the petrologic, mineralogic, and chemical makeup of the particles and soil samples. Work has begun on the noble gas content of the soils and will be presented here.

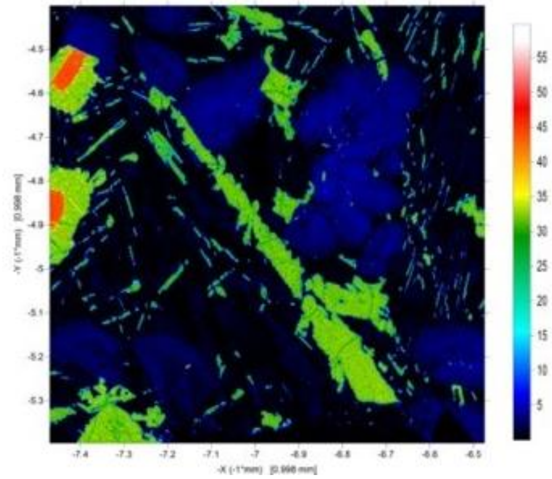

Fig 2: Example of a quantitative compositional map of a basaltic fragment collected from sample 73002,186A. Each pixel in this map corresponds to the intensity of Ti characteristic x-rays and is fully quantitative.

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