PLANETARY SCIENCE GOALS AND OBJECTIVES FOR ARTEMIS III SURFACE ACTIVITIES. Brett W. Denevi[1], Lauren A. Edgar[2], Caleb I. Fassett[1], Juliane Gross[3,4], Jennifer L. Heldmann[5], Dana M. Hurley[1], José M. Hurtado, Jr.[6], Bradley L. Jolliff[7], Katherine H. Joy[8], Yang Liu[9], Gordon R. Osinski[10], and Mark S. Robinson[11], [1]Johns Hopkins University Applied Physics Laboratory, Laurel, MD, USA (brett.denevi@jhuapl.edu), [2]United States Geological Survey Astrogeology Science Center, Flagstaff, AZ, USA, [3]Rutgers University, Piscataway, NJ, USA, [4]NASA Johnson Space Center, Houston, TX, USA, [5]NASA Ames Research Center, Mountain View, CA, USA, [6]The University of Texas at El Paso, El Paso, TX, USA, [7]Washington University in St. Louis, St. Louis, MO, USA, [8]The University of Manchester, Manchester, UK, [9]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA, [10]University of Western Ontario, London, ON, Canada, [11]Arizona State University, Tempe, AZ, USA.

Introduction: Artemis III will provide the first opportunity for geologic fieldwork on the Moon since the Apollo 17 crew departed in 1972. Here we present science goals and objectives that will guide the fieldwork performed by the Artemis III crew in the south circumpolar region (SCPR). We seek to maximize the Artemis III science return by soliciting input as we finalize and prioritize these goals and objectives.

Philosophy: The Artemis III Geology Team goals and objectives are designed to capture the importance and breadth of community science priorities and are informed, in particular, by the *Artemis III Science Definition Team* report [1], with the benefit of new guidance from the *Origins, Worlds, Life* Decadal Survey [2]. We streamlined these priorities to a set of goals that is relevant to the geology of the SCPR and focused the objectives to those that will drive decisions about sampling and crew activities or help in prioritization among potential landing sites. The goals and objectives are currently designed to be site agnostic so that they remain stable even as implementation details evolve (e.g., choice of landing site, landing date and lighting conditions, constraints on traverse capability).

The goals and objectives are organized and prioritized in a science traceability matrix (STM). The Flight Operations Directorate at NASA Johnson Space Center has embraced the STM as a driver for extravehicular activities (EVA) and decision making [3]. Though we focus here on the site-agnostic goals and objectives, they will ultimately trace to site-specific requirements (e.g., development of science stations and traverses, selection of tools and sampling containers, sampling and in-situ activities). Thus, the STM will be used to track critical factors needed to accomplish the geologic science of the Artemis III mission. Ensuring that the STM efficiently communicates the science goals and objectives is vital for successful implementation.

Goal A. Understand the Early Evolution of the Moon as a Model for Rocky Planet Evolution.

Objective A1. Evaluate magma ocean models for the timing and processes that led to the formation of the crust, mantle, and core. The Lunar Magma Ocean (LMO) model is the paradigm for understanding early crustal formation on terrestrial planets. The LMO model is supported by many but not all observations (e.g., nearside–farside asymmetry), leading to alternate hypotheses (for each objective, see [4–6] and references therein). Comparing ages and chemical and isotopic compositions of LMO products sampled in the polar region to Apollo samples will help to evaluate alternate or more complex LMO models.

A2. Constrain the composition and diversity of the lunar mantle and lower crust. Despite information gleaned from mare basalt source regions, we do not know how representative lower crustal materials (e.g., Mg-Suite) in the Procellarum KREEP Terrane (PKT) are of early global magmatic processes that operated during and after the LMO (e.g., lower crust or late-stage cumulates (KREEP); cumulate overturn). Determining the composition and compositional stratigraphy of the lower crust (and mantle materials if present) would provide key information about bulk silicate composition, degree of equilibration with Earth, and late-/post-LMO magmatic processes.

A3. Establish the composition and abundance of volatiles in the lunar interior and characterize the depletion history of endogenic volatiles. Causes for volatile depletion on the Moon remain unknown, and depletion may be related to the giant impact, inherited from the impactor, or be unique to the PKT; the LMO may also have been chemically modified by the addition of H_2O-rich impactors. Establishing the composition and abundance of volatiles in the lunar interior and the origin of their depletion will help trace the origin of volatiles in the Earth–Moon system.

A4. Test the giant impact hypothesis for the origin of the Earth–Moon system. Isotopic similarities between the Earth and Moon are hard to reconcile with the canonical model that predicts the majority of the Moon's material should originate from the impactor. This "isotopic crisis" has spurred a variety of models (e.g., more complete mixing, high angular momentum, more oblique or multiple impactors). Artemis III samples will allow new assessments of the formation process and age of the Moon.

Goal B. Determine the Lunar Record of Inner Solar System Impact History.

B1. Anchor the early Earth–Moon impact flux by determining the age of South Pole Aitken (SPA) Basin. Dating SPA, the oldest recognized lunar impact basin, will provide key new information for determining: when the record of bombardment starts and how complete that early record is; the Moon's early thermal state and evolution; and sources of early impactors. This, in turn, will provide a fundamental benchmark for understanding the ages of surfaces across the Solar System.

B2. Test the Cataclysm Hypothesis by determining the post-SPA impact chronology. With implications for the Solar System at large, and the habitable environment of the Earth as life was emerging, determining whether there was a spike in impacts around 3.9–4.0 Ga is highly consequential. The cataclysm hypothesis is controversial and may be an artifact of the influence of Imbrium on previously returned samples. Determining the chronology of post-SPA impact events in the SCPR, far from the influence of Imbrium, will provide a key test.

B3. Determine the impact stratigraphy in the highlands, how impacts redistribute material, and the provenance of samples at the landing site. Impact mixing determines the nature and origin of the regolith, and understanding mixing with depth and distance is fundamental to inferring sample provenance. Models of ballistic ejecta emplacement predict the fraction of primary vs. "secondary" local material intermixed in ejecta deposits but have large uncertainties, and redistribution of target material as impact melt is poorly known.

Goal C. Determine the Variability of Regolith in the Circumpolar Environment as a Keystone for Understanding Surface Modification of Airless Bodies.

C1. Ascertain polar regolith's physical and geotechnical properties, and the variation in regolith evolution as a function of environment. Most Apollo regolith samples have similar median particle sizes and angularity, and, thus, similar geotechnical and mechanical properties. However, no measurements exist that show this consistency also holds at polar latitudes, and, indeed, remote observations suggest there may be differences in grain size. Such variations are physically plausible in the SCPR due to environmental differences (e.g., impact rate, thermal stresses) and are even more likely to be found in permanently shadowed regions (PSRs) because of continually low temperatures and the potential for admixed ice.

C2. Explore the mechanisms for space weathering in polar regions as a function of local environment. Regolith matures when exposed to the space weathering environment (impacts, solar wind). The largest open question related to this process is the relative roles of these environmental factors and how they work together. This question can be resolved due to the lower effective solar-wind flux at the SCPR, and newly suggested high-latitude weathering processes and products can be investigated.

C3. Characterize meteoritic material, including terrestrial debris, found in the lunar regolith as a record of past lunar impactors. The Moon contains a record of the sources of exogenous material delivered to the inner Solar System, and potentially, variation in these sources with time. Ancient materials sourced from Earth may offer profound rewards: the terrestrial record of the early Earth is largely lost and terrestrial biosignatures could be preserved even after impact transport to the Moon.

Goal D. Reveal the Age, Origin, and Evolution of Solar System Volatiles

D1. Evaluate the nature, origin, and abundance of persistent volatiles in cold traps. Little is known about cold-trapped volatile composition, abundance, age, and the general ability of the Moon to retain volatiles over time. The volatile species expected to be sequestered in cold traps depend on the maximum temperatures the surface/near-surface regolith has experienced over time (18.6-year nodal precession cycle; geologic time). Assessing volatiles in cold traps of varying thermal environments and age will provide key new observations to understand their nature.

D2. Assess the nature, origin, abundance, and transport processes for transient volatiles. Surficial volatiles have been observed to exist outside of PSRs with concentrations that vary throughout the lunar day. Migration of these volatiles is likely driven in large part by diurnal temperature changes, but such transport has yet to be measured on the Moon. If migration of surficial volatiles is efficient, then solar wind and micrometeoroid delivery across the Moon could be a significant contributor of volatiles to cold traps.

D3. Determine how exploration activities modify the record of volatiles at the lunar surface. Another variable must be considered to ensure robust interpretation of measurements for Obj. D1 and D2: the Artemis III mission will inevitably deliver volatile species to the surface, through the rocket exhaust plume and venting from spacesuits and the lander. Whether these volatiles stick to the surface for long durations is an unanswered question, with implications for understanding volatile transport and for how volatile investigations are conducted by any future landed missions.

References: [1] Artemis III Science Definition Team Report (2020) NASA SP-20205009602. [2] National Academies of Sciences, Engineering, and Medicine (2023) Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023–2032, National Academies Press. [3] Achilles C. N. et al. *Lunar Planet. Sci. 55*, this mtg. [4] Jolliff, B.L., Wieczorek, M.A., Shearer, C.K., Neal, C.R. eds. (2006) *New Views of The Moon*, RiM-G Vol. 60. [5] Neal, C.R., Gaddis, L.R., Jolliff, B.L., Mackwell, S.J., Shearer, C.K., Valencia, S.N. eds. (2023) *New Views of the Moon 2* RiM-G Vol. 89. 6] Heiken, G.H., Vaniman, D.T., French, B.M. (1991) *Lunar Sourcebook*, Cambridge University Press.