ARTEMIS III SCIENCE AND TOOLS EXPLORATION SCIENCE FOR A NEAR SOUTH POLE CREWED LANDING.
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Introduction: Continued synthesis of observations and sample analyses, resulting from Apollo missions to the Moon, have identified a significant number of specific objectives for future exploration and sampling at a potential near-South Pole Artemis landing site. Of particular importance are samples that expand our knowledge of the Moon outside the partially explored, nearside, upper few hundred kilometers of the lunar globe. That sector would be dominated by the effects of a possible Procellarum basin-forming event [1], complicated further throguh re-working by many other near-side impacts, and the existence and extended influence of the Procellarum KREEP Terrain. Near-South Pole exploration by Artemis not only expands field geological and geophysical coverage of the lunar nearside, but it would examine materials dominated by ejecta from the South-Pole Aitken basin [2]. Younger South-Pole Aitken melt-breccia either covers or mutes the effect of any potential Procellarum-related effects.

In addition, a near-South Pole location provides the opportunity to compare the abundance and characteristics of potential lunar resources located there with those identified at locations nearer the lunar equator [3]. Not only are there potential resources associated with permanent shadow, but there are theoretical analyses and observational data that strongly suggest ancient pyroclastic and solar wind volatiles will migrate to high latitudes [4].

High Priority for a Crewed Rover: Crewed rovers on Apollo 15, 16 and 17, the Lunar Roving Vehicle, vastly expanded the area for exploration of the landing areas and led to discoveries and associated samples that would never have been possible with foot traverses alone. Almost certainly, Artemis crews will need access to a crewed rover if ejecta from the South Pole-Aitken basin are to be found at the base of massifs distant from the Artemis landing sites [5] or if samples of permanently shadowed regolith are to be obtained with certainty.

Sampling Tools and Dust Elimination: The primary suite of sampling tools used on the last three Apollo missions represent an excellent starting point for Artemis. These consisted of the following: geology hammer with striking wedge, sampling scoop, sampling rake (sieve), drive tubes, easily accessible sample bags, rover sampler for quick sample from seated position, PLSS-mounted sample containers, and special vacuum-preservation sample containers. Although serviceable for Apollo, improvements can be made as detailed below:

1. Geology hammer – Handle should be sized for each crew hand and covered with a more dust resistant coating.
2. Sample scoop – Adjustable angle joints and connection to an extension handle should be protected from dust penetration.
3. Sampling rake – Width between tines should be adjustable to account for variable average fragment sizes, adjustment mechanism should lock into detents and be dust tolerant, indications of detent being used should be readily visible for reporting, and connection to an extension handle should be protected from dust penetration.
4. Drive tubes – Apollo design (35 and 70 cm cores) is excellent; however, add intermediate tubes that will allow greater coring depths. 105 cm should be possible in some regolith and pyroclastic deposits, if warranted.
5. Sample bags – Apollo design adequate, but 10 or so larger bags for “football-sized rocks” would have been desirable. It is not yet clear where these bags would be mounted on the Artemis xEMU.
6. Rover sampler – Design was very satisfactory.
7. PLSS-mounted sample containers – container cover design needs improvement so as to stay firmly closed at all times when not in use.
8. Vacuum-preservation sample containers – significant design work is needed to prevent dust from gloves from interfering with the container seal. Preventing leaks is more important that maintaining the *in situ* thermal conditions. Consideration might be given putting sample in a bag and handling with a disposable cover-glove before inserting into vacuum container.

If hand-held analytical tools are to be considered for Artemis exploration, it is important to have them provide relevant data very quickly or, if this is not possible, design such tools to be temporarily “left and forgotten” so as to not use valuable exploration time, unnecessarily. Powered rock and regolith coring drills should similarly be left and forgotten until coring is completed.

Documentation, Experience and Training: Crew experience in the field and monthly simulation-based training are the most important components of sample documentation. Informed, on the spot decisions by the crew and their coherent description of geologic context and associated features are of great importance to interpreting later petrologic, chemical and isotopic analyses. Photographic documentation also is critical in this regard as post-mission interpretation and spectrographic analyses of images often reveal information that cannot be observed by the crew due to time or vision constraints.

The full realization of the potential of future lunar landings depends on the presence of at least one experienced field geologist on the landing crew as well as, at a minimum, an Apollo 13-17 style simulation-based terrestrial training program [6] that provides both realistic training on the use of sampling and documentation equipment and exposure to new geological challenges.

The photographic documentation technique for sampling on Apollo consisted of placing a gnomon in the field of view, taking pairs of before and after stereo photos by side stepping between each shot, and taking a locator photo to some large, identifiable object such as the Rover or Lunar Module. The gnomon provided scale, a vertical reference, and color and gray chips for image control. The gnomon's shadow also gave an azimuth reference. Although this techniques was very effective; it may be that new digital imaging and software techniques will eliminate the primary photographic control purpose of the gnomon [7]; however, having color and gray scale chips and a dimension scale in photographs may remain desirable. A trade study on this issue should be undertaken.

Potential Lunar Science: In addition to the primary lunar scientific return probably with a near-South Pole Artemis landing, as discussed above, the following returns are also expected.

Mg-Suite and FAN Samples: Borg's continued refinement of isotopic ages for Mg-suite and FAN samples, as well as ages for the sources of mare basalt magmas, indicate a coincidence of formation at 4.35 Ga [8]. Additional, more globally distributed samples of these materials will be critical in explaining whether 4.35 Ga is the age of a Moon-forming giant impact [9] or that of a Procellarum-induced isotopic homogenization of the Moon's near-side upper mantle [1].

Deep Drill Cores: Schmitt's synthesis of data on maturity indexes and nitrogen isotopic ratios for ejecta units in the Apollo 17 deep drill core (70001/9) [10] indicate that δ^{15}N‰ increases with increased maturity. This correlation permits calculation of the δ^{15}N‰ for the solar wind at times when the earliest ejecta units were deposited. For most of the core's depositional history the solar wind's δ^{15}N‰ was -105 ± 5 and its average energy level was constant. At about 0.5 ± 0.2 Ga, however, it appears that the rate of regolith maturation increased by a factor of ~1.7, if that solar δ^{15}N‰ remained constant. Testing these conclusions with a deep drill core sample at a near-South Pole location would be invaluable in continuing the deciphering of the lunar regolith's record of solar history.

Regolith Resources: Not only do water ice and other solid forms of normally volatile compounds and elements exist in permanently shadowed locations near the South and North Poles of the Moon [4], but cold trapping of solar wind volatile resources at high latitudes may enhance their concentrations in regolith. Sampling and/or three-dimensional analysis of regolith near the South Pole will contribute to future trade studies on the economics of high latitude resource production versus that in equatorial locations.

Unknown-Unknowns: Exploration of previously unexplored regions of the Moon has and will invariably produce surprises. This is the nature of science.

References: [1] Schmitt, H. H. (2016) LPSC 46. [2] Wilhelms, D. E. (1987) USGS Prof. Paper 1348. [3] Schmitt, H. H., (2006) *Return to the Moon*, Springer. [4] Watson, K., et al. (1961) *J. Geophys. Res*., 66, 3033-3945; Shuai, L., et al. (2018) PNAS, 115, 8907-8912. [5] Schmitt, H. H., et al. Icarus, (2017) Icarus, 298, 3-10. [6] Schmitt, H. H., et al. (2011) *Geol. Soc. Amer. Spec. Paper 483,* 1-16. [7] Wells, R. A., and Schmitt, H. H., Geol. Soc. of America, (2018) Abs. 166-11. [8] Borg, L. E., et al. (2019) *Earth Planet. Sci. Ltrs.,* 523, 115706 . [9] Canup, R. and Asphaug, E. (2001) Origin of the Moon, *Nature*, 412, 706-712. [10] Schmitt, H. H., (2019) Mursurky Lecture, *LPSC 53*.