SAMPLING THE SOUTH POLE-AITKEN BASIN: OBJECTIVES AND SITE SELECTION CRITERIA.

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Introduction: Exploring the South Pole-Aitken (SPA) Basin is a high priority for lunar and solar-system science [1-3]. The high priority derives from its role in providing both a window to the interior of the Moon and a portal to the early history of the Solar System, especially relating to the heavy impact bombardment that occurred during the first ~600 my [4-6]. Recent remote-sensing missions provide much valuable new data from orbit about the diversity of materials within and around SPA Basin and the geophysical context of this enormous basin. However, achieving the highest-priority science objectives requires sample return. Addressed in this abstract is how and where best to sample materials of the SPA Basin to address the prime science objectives. Data from the recent missions play a key role in defining the best potential sample locations. We summarize the driving science objectives as well as the datasets that are now available to support an optimized SPA sample-return site assessment.

Science Objectives: The principal planetary science reasons for undertaking an SPA sample return mission fall into three categories: (1) testing the impact cataclysm hypothesis, (2) understanding basin impact processes, and (3) improving our understanding of the Moon's crust and mantle, i.e., how the crust and mantle of a differentiated planet vary with depth and laterally on a global scale.

The first objective is to determine the chronology of the SPA Basin and thereby place constraints on the timing and duration of early, heavy impact bombardment of the Moon and inner Solar System. Knowing the timing and duration of the heavy impact period also would constrain models for the origin of the impactors [7-9]. If the SPA Basin formation was relatively close to 4 Ga, then a cataclysm or spike in the heavy impact bombardment at that time is supported. This outcome would be reflected not only by the formation age of SPA itself but also by the range of ages of the several smaller basins that occurred subsequent to SPA and prior to Imbrium (the youngest of the dated impact basins). To determine this chronology, a statistically large number of *impact-melt rocks* must be analyzed for their age and compositional characteristics.

The second objective, understanding basin impact processes, relies on an integration of data, including the ages, compositions, and lithologies of rocks of the basin, remote sensing of rock types across the basin, and topography and geophysics of the basin. At the present time, the mafic geochemical character of the basin is ambiguous as to whether it includes a mantle component, reflects lower crust only, or is an integration of the entire crustal column [e. g., 10,11]. This objective can be addressed from a sample perspective by determining the diversity of rock types found in the regolith of the basin, excavated from a wide variety of depths, mixed, and dispersed over wide areas by billions of years of smaller impacts. Determining the key lithologies in the basin regolith will enable interpretation of remote compositional, mineralogical, and lithological data in terms of rock types and components. Knowing the chronology of the basin coupled with improved geophysical data will help constrain the redistribution of materials and mass by giant impacts, the thermal state of the Moon at the time of basin formation, and how giant basins disrupt and affect early planetary crusts [e.g., 12].

The third objective aims at a better understanding of how the crust and mantle of the Moon vary laterally and with depth. This objective addresses key aspects of lunar evolution: a) the lower crust of the Moon and how it transitions to mantle, as recorded in igneous rocks, melt rocks, and mineral and lithic clasts in melt breccias; b) the deeper mantle beneath the SPA Basin (and the far side in general) by sampling mantle-derived basalts; and c) a better understanding of the distribution of radiogenic elements in the Moon's crust globally and at depth, as seen through the SPA Basin "window." The global expression of these elements is well known at low spatial resolution from the Lunar Prospector gamma-ray spectrometer results, but we do not know the concentration of these elements in the deep crust. Improved knowledge of the distribution of Th, U, and K is needed to determine the thermal evolution and bulk composition of the Moon.

Site selection Criteria: Consideration of these science objectives leads to the following guiding principles for the characteristics of the samples to be returned for analysis in Earth-based laboratories: (1) crystalline impact-melt rocks and breccias are needed for age determinations by several different radiometric methods; (2) there must be a large number of rocks represented in the sample to ensure statistical significance; (3) there must be a wide diversity of rocks that represent a large area, (4) the diversity should also represent variations of rock types with depth; (5) the returned sample should include rocks that represent basalt flows within the SPA Basin.

A major compositional signature of the SPA basin is the broad mafic "anomaly" that has been observed to characterize the interior of the Basin (Fig. 1, data from

[13]), some 1400 km across and slightly elliptical with long axis NNW-SSE (see also [14]). Impact-melt from the basin as well as the deepest derived materials are expected to be the most mafic, thus the highest concentration of mafic materials is toward the interior of the basin, and well within the central region of Fig. 1. Away from the center, regolith is progressively more diluted by ejecta from craters that impacted surrounding feldspathic highlands. To maximize diversity, it is best to avoid close proximity to a "recent" large crater whose ejecta deposits might greatly skew the sample diversity (Fig. 2). On the other hand, landing in an area that is likely to contain ejecta from a large, post-SPA crater that would have excavated materials from deep within the SPA melt sheet such as Alder, Bose, or Bhabha (Fig. 3) would be desired.

A simplifying and cost-saving measure in sample collection is to rely on known properties of a well developed lunar regolith. Essentially, the impact process has done the bulk of the sampling by creating a well mixed and diverse regolith that represents a broad distribution of basin materials. There is no advantage with the stated science objectives to having a local roving and sample characterization & caching capability. The requisite rocks and diversity are available in scoops of local regolith by the thousands in size ranges suitable for chemical, isotopic, and lithologic characterization.

New Data Sets: As of this writing, all of the planned recent orbital missions, including SMART-1, Kaguya, Chang'e-1, Chandrayaan-1, and LRO have successfully launched and collect data, with LRO continuing in the first year of its nominal mission. The full range of data collected by these missions will be used to characterize the geology of the SPA Basin. Terrain imaging and topographic mapping are defining the features of the Basin in great detail. Multispectral and hyperspectral sensors have collected data needed to map the diversity of rock types and their distribution within the Basin. Finally, the very high-resolution imaging being taken by LRO coupled with results from the Chandrayaan and Kaguya terrain cameras are more than adequate for complete candidate landing-site safety assessments. The preferred process for selection of landing sites will involve the scientific community to bring all of these data and experience to bear on determining where best to land and return samples to address the science objectives. All these new data are further enhancing the importance of SPA as a scientific linchpin for understanding the Moon and early Solar System history.

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Criteria for landing sites in So. Pole-Aitken Basin

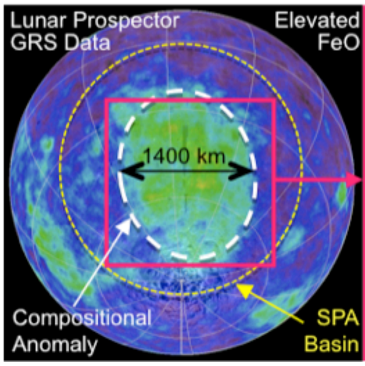

Figure 1. Relatively high FeO is a key signature of the compositional anomaly that defines the interior of the SPA Basin.

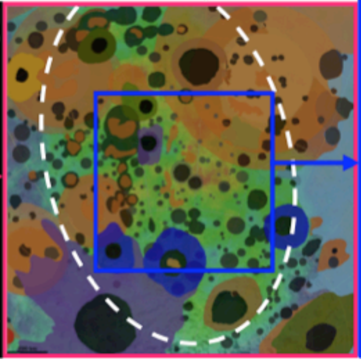

Figure 2. Craters and their proximal ejecta deposits are keep-out zones. Remaining areas (green in this figure) meet the science criteria.

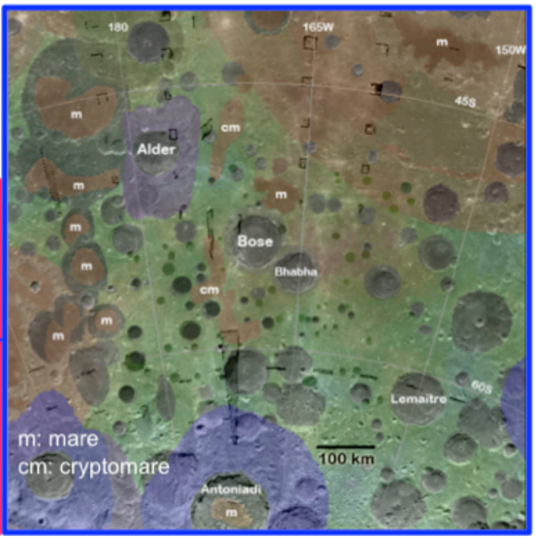

Figure 3. Expanded view of SPA Basin interior where vast regions (light green) meet the science criteria.