COMPOSITIONAL MIXING MODEL FOR ESTIMATING PROPORTIONS OF SOUTH POLE AITKEN BASIN MATERIAL AT ARTEMIS 3 CANDIDATE LANDING REGIONS.

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Introduction: The study of samples containing material from the South Pole Aitken (SPA) basin has been included as one of the high priority goals in the 2023-2032 Planetary Science Decadal Survey [1], as well as in two previous Decadals. As the largest and most ancient confirmed impact basin on the Moon, sampling material from SPA presents several opportunities for increasing our fundamental understanding of the early Solar System and formation of the early Earth-Moon system. An impact as large as SPA would have potentially excavated material from deep within the Moon, allowing for direct samples of the lower crust and lunar mantle. Chronological measurements of impact-melt samples from SPA will also help constrain the timing of the Late Heavy Bombardment. Results of such chronological measurements would have significant implications for the accuracy of relative age-dating methods used for the Moon and other Solar System bodies, as well as models for the migration of the giant planets early in the history of the Solar System [2]. The proposed Artemis 3 candidate landing regions are located on or near the topographic rim of SPA, and therefore present an opportunity to collect samples excavated and deposited around the south circumpolar region by the subsequent impact craters and basins within SPA [3]. Indeed, one of the science objectives of Artemis 3 will be to collect samples that may contain SPA-derived materials. Here we present results of a simple compositional mixing model to estimate the proportions of SPA material expected in each Artemis 3 candidate landing region.

Methods: To determine the proportion of SPA material present at each Artemis 3 candidate landing region, we used a two-component mixing model, which incorporated Lunar Prospector Gamma Ray Spectrometer (LP-GRS) iron and thorium abundances for the south circumpolar region [4, 5]. Paths from the interior of SPA to the Feldspathic Highlands (FH) on the southern nearside were traced through each candidate landing region using Lunar QuickMap, as shown in Figure 1. For each trace, we averaged the FeO wt% and Th abundance for the SPA, FH, and landing regions of the traces. The proportions of SPA and FH material were then found through a mass balance that produced the closest match to the average measured LP-GRS composition for each region. The proportions were determined from the FeO and Th data separately, then optimized by minimizing the sum of squares to produce the final proportions for each landing region.

Results: From the mixing model, landing regions on the Earth-facing side of the South Pole contain deposits with ~30% SPA basin material on average, while landing regions on the farside of the pole, closer to SPA, contain deposits with ~45% SPA basin material on average. The de Gerlache-Kocher Massif region, which is the closest region to SPA, is predicted to contain deposits with as much as 60% SPA material. A complete list of SPA/FH proportions is in Table 1.

Discussion: While the calculated endmember proportions are promising, the SPA proportion calculated from the Th abundances was significantly higher than that calculated from the FeO data for several regions. This difference likely results because the most Fe-rich SPA materials may not be the most Th-rich. There are also high uncertainties in the averages of the FeO and SPA sections of each trace. To further constrain the SPA/FH proportions, other datasets from the LP-GRS, such as MgO, can be added to the mixing model. However, if the FeO-derived SPA proportions are to be taken as a lower limit, this still shows a >20% SPA material proportion for the majority of the candidate landing regions.

These results show a high, non-trivial amount of SPA material is likely to occur at the Artemis 3 candidate landing regions. While this material has likely been mixed into secondary breccias from the subsequent impacts in the region as opposed to monomict igneous rocks from the original basin formation, a large and diverse collection of samples returned to Earth for statistical and compositional analysis will aide in distinguishing SPA material. Any samples could also be combined with samples returned by the Endurance-A robotic mission to the central SPA recommended in the 2023-2032 Decadal Survey [1].

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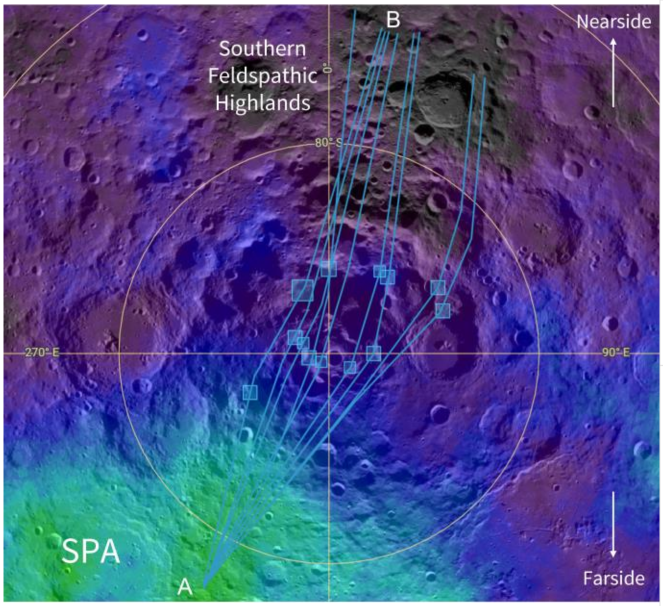
References: [1] NRC (2022) Origins, Worlds, Life: A Decadal Strategy for Planetary Science and Astrobiology. [2] *NASA Press Release* (Aug 19, 2022). [3] Jolliff, B. L., et al. (2021) *Bulletin of the AAS,* **53(4)**. [4] Lawrence, D. J., et al. (2002) *JGR* **107**. [5] Lawrence, D. J., et al. (2007) *Geophys. Res. Lett.* **34.**



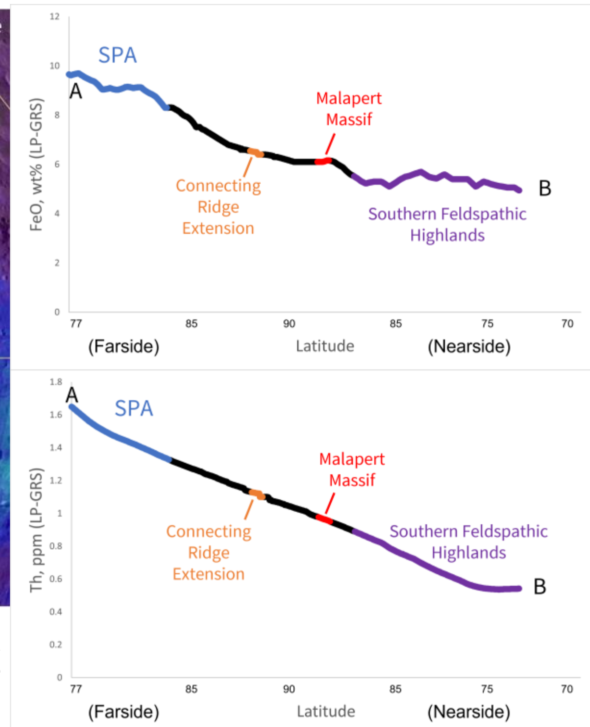


Figure 1: (Above) South Circumpolar region with traces from SPA to FH and Artemis 3 candidate landing regions (blue squares). LP-GRS FeO [4] overlaid on LROC WAC basemap (NASA/GSFC/ASU) (https://bit.ly/3ZtIsPG). (Right) LP-GRS FeO [4] and Th [5] data along trace through Connecting Ridge Extension and Malapert Massif landing regions.

Region	SPA Fraction (from FeO)	FH Fraction (from FeO)	SPA Fraction (from Th)	FH Fraction (from Th)	Optimized SPA Fraction	Optimized FH Fraction
Malapert Massif	0.21	0.79	0.37	0.63	0.31	0.69
Connecting Ridge	0.32	0.68	0.57	0.43	0.47	0.53
Connecting Ridge Extension	0.3	0.7	0.56	0.44	0.46	0.54
de Gerlache-Kocher Massif	0.57	0.43	0.64	0.36	0.62	0.38
Haworth	0.2	0.8	0.45	0.55	0.35	0.65
Peak Near Shackleton	0.33	0.67	0.58	0.42	0.48	0.52
Leibnitz Beta Plateau	0.36	0.64	0.365	0.635	0.36	0.64
Faustini Rim A	0.32	0.68	0.54	0.46	0.46	0.54
Nobile Rim 1	0.365	0.635	0.37	0.63	0.37	0.63
Nobile Rim 2	0.2	0.8	0.32	0.68	0.28	0.72
Amundsen Rim	0.12	0.88	0.36	0.64	0.27	0.73
de Gerlache Rim	0.29	0.71	0.54	0.46	0.44	0.56
de Gerlache Rim 2	0.29	0.71	0.53	0.47	0.43	0.57

Table 1: Table of estimated SPA/FH proportions for each Artemis 3 candidate landing regions.