VOLUME OF IMPACT MELT GENERATED BY THE FORMATION OF THE SOUTH POLE-AITKEN BASIN.

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Introduction: The South Pole-Aitken Basin (SPA) is the largest, deepest, and oldest identified basin on the Moon and as such contains surfaces that are unique due to their age, composition, and depth of origin in the lunar crust [1-5] (Figure 1). SPA has been a target of intense interest as an area for robotic sample return in order to determine the age of the basin and the composition and origin of its interior [6-8]. In response to this interest there have been several efforts to estimate the likely provenance of regolith material within central SPA [9-12]. These model estimates suggest that, despite the formation of basins and craters following SPA, the regolith within SPA is dominated by locally derived material. An assumption of these models has been that the locally derived material is primarily SPA impact-melt as opposed to local basement material (*e.g.* unmelted lower crust). However, the definitive identification of SPA derived impact melt on the basin floor, either by remote sensing [5, 13] or via photogeology [2, 14] is extremely difficult due to the number of subsequent impacts and volcanic activity [4].

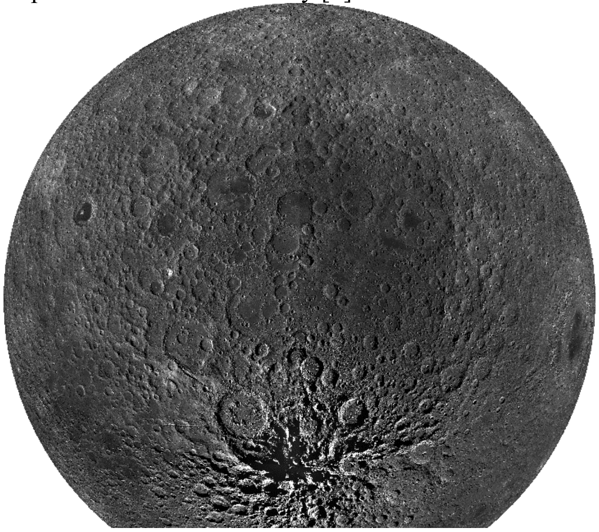

Figure 1. LRO Wide Angle Camera mosaic centered on SPA. Interior of SPA contains several smooth, flat regions (Figure 2), interpreted to contain either ancient mare basalts or SPA melt.

Here, the total volume of impact melt generated by the formation of SPA is estimated based on existing crater scaling models, as well as the relative proportion of melt retained within the basin [15, 16]. The ultimate distribution of melt, based on these models, will also be described.

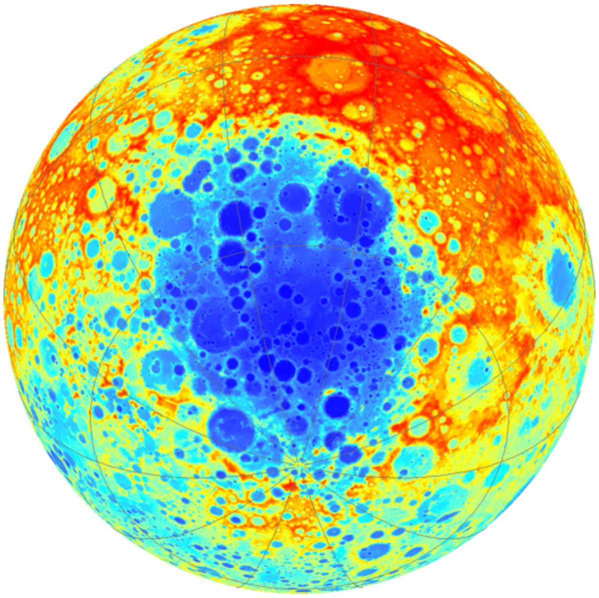

Figure 2. LOLA Topography centered on SPA. Models of impact melt generation predict that the deepest, central portion of the basin is almost completely covered by melt produced by SPA's formation.

Volume of Melt Produced by SPA: Prior studies of the production of SPA impact melt [16] focused on the depth of melting and the possible amount of mantle melted during basin formation. Warren et al. [16] concluded that, assuming a transient cavity 1,170 km in diameter, melt produced by SPA would be nearly completely of mantle origin, and that SPA melt (from both crust and mantle) would comprise approximately one-third of the total ejecta volume. However, how much melt is retained within SPA proper?

Cintala and Grieve [15] state that "…the relative volume of impact melt remaining inside the final crater increases with crater size." Subsequently, they show that, for craters larger than 10 km in diameter, the volume of melt retained within the crater is larger than 40% of the total melt. Extrapolating their data out to a basin the size of SPA (Figure 3), and assuming a transient cavity diameter of 2,099 km [17] suggests that nearly 80% of the impact melt that is produced is retained within SPA. Clearly such models, applied to a basin as large and unusual as SPA, should be treated carefully. However, even if the formation of is more like a smaller basin, then perhaps only 60% of the melt is retained [15]. Even in this extreme case a significant volume of the roughly 8×10^8 km^3 of melt would still be retained. Assuming that 80% of the melt is indeed retained within SPA, that volume is roughly 50% of the entire volume of the transient cavity. Such melting would likely reach deep into the mantle, which would be incorporated into SPA's melt.

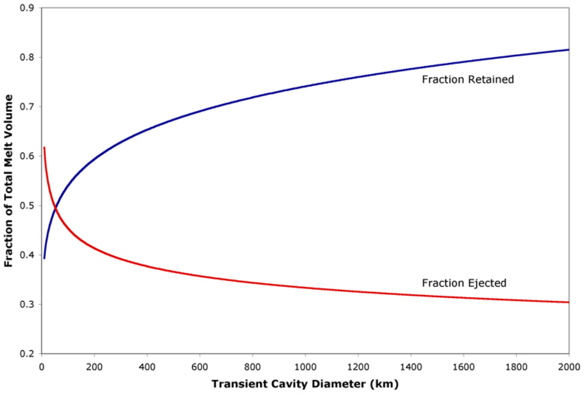

Figure 3. Estimated fraction of melt ejected and retained within the final crater, based on the modeling of Cintala and Grieve [15]. Here the curves have been extended well beyond the original modeling, in order to illustrate the melt fate for a basin as large as SPA.

Melt Distribution Within SPA: As stated above the definitive identification of SPA is difficult, however, by comparison to other large basins, such as Orientale [18], we assume that much of the interior of SPA was covered by impact melt. Based on the above conclusion that much of the melt generated by SPA was derived from the lower crust or upper mantle, we infer that the melt from SPA would be iron rich. Indeed the interior of SPA is well known to be iron rich (Figure 4), yet lacks significant deposits of mare basalt [4, 5, 19, 20]. Some portion of the iron enhancement may be due to ancient basalts [4, 5].

Conclusions: A large volume of material was melted during the formation of SPA, and a significant proportion, a modeled 80% is retained within the basin. The origin of melt, likely lower crust or upper mantle, is a likely source for the iron enhancement across the basin. Given the relatively minor contamination by subsequent events [9, 10, 11], it is very likely that the regolith inside SPA, in many areas, is dominated by melt from the SPA event.

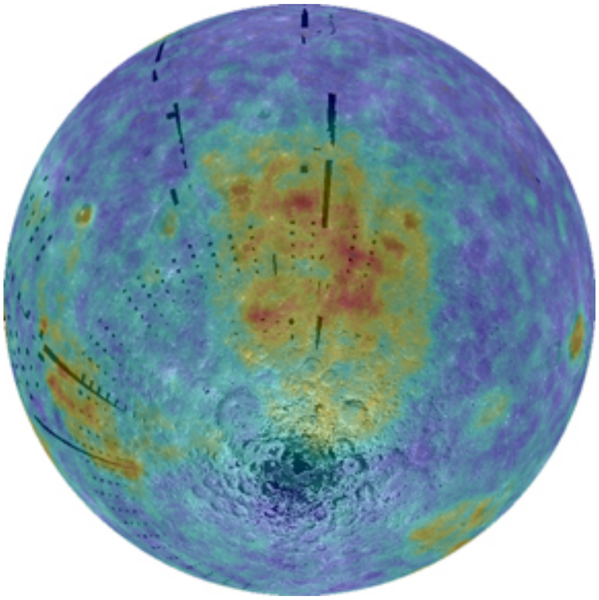

Figure 4. Map of FeO abundance, from Lunar Prospector, showing the enhancement of iron within SPA.

References: [1] Wilhelms, D. E., (1987) *The Geologic History of the Moon*, 327 p. [2] Wilhelms, D. E., et al., (1979) Geologic map of the South side of the Moon, I-1162. [3] Haruyama, J., et al., (2009) *Science*, 323, 905-908. [4] Petro, N. E., et al., (2011) *Recent Advances and Current Research Issues in Lunar Stratigraphy: Geological Society of America Special Paper 477,*, Geomorphic terrains and evidence for ancient volcanism within northeastern South Pole–Aitken basin, doi:10.1130/2011.2477(1106). [5] Pieters, C. M., et al., (2001) *JGR*, 106, 28001-28022. [6] Jolliff, B., et al., (2010) MoonRise: A US Robotic Sample-Return Mission to Address Solar System Wide Processes, 42, [7] Jolliff, B. L., et al., (2010) *AGU Fall Meeting Abstracts*, 43, 01. [8] Jolliff, B. L., et al., (2010) *LPI Contributions*, 1595, 31. [9] Haskin, L. A., et al., (2003) *LPSC*, 34, 1434. [10] Haskin, L. A., et al., (2003) *MAPS*, 38, 13-33. [11] Petro, N. E. and C. M. Pieters, (2004) *Journal of Geophysical Research*, 109(E6), E06004, doi:06010.01029/02003JE002182. [12] Petro, N. E. and B. L. Jolliff, (2011) Basin and Crater Ejecta Contributions to the South Pole-Aitken Basin (SPA) Regolith: Positive Implications for Robotic Surface Samples, 42, 2637. [13] Lucey, P. G., et al., (1998) *JGR*, 103, 3701-3708. [14] Stuart-Alexander, D. E., (1978) Geologic map of the central far side of the Moon, I-1047. [15] Cintala, M. J. and R. A. F. Grieve, (1998) *MAPS*, 33, 889-912. [16] Warren, P. H., et al., (1996) *GSA Special Paper*, 307, 105-124. [17] Wieczorek, M. A. and R. J. Phillips, (1999) *Icarus*, 139, 246-259. [18] Head, J. W., (1974) *Moon*, 11, 327-356. [19] Yingst, R. A. and J. W. Head, (1999) *JGR*, 104, 18957-18979. [20] Jolliff, B., et al., (2000) *JGR*, 105, 4197-4216.