A PRELIMINARY EVALUATION OF RESURFACING SCENARIOS ACROSS THE SOUTH POLE – AITKEN BASIN INTERIOR FROM A MINERALOGICAL ASSESSMENT OF CRATERS. D. P. Moriarty III[1,2,3], M. Milla[4,5], R. N. Watkins[6], D. L. Domingue[7], S. N. Valencia[1,2,3], J. L. Whitten[8], F. C. Chuang[7], N. E. Petro[1] and B. L. Jolliff[9], [1]NASA GSFC (daniel.p.moriarty@nasa.gov), [2]University of Maryland, College Park, [3]Center for Research and Exploration in Space Science & Technology II, [4]University of Albany, [5]Nyack High School, [6]NASA HQ, [7]Planetary Science Institute, [8]Tulane University, [9]Washington University in St. Louis.

Introduction: South Pole – Aitken Basin (SPA) is one of the oldest and largest impact structures in the solar system, and serves as a cornerstone for understanding fundamental planetary processes including differentiation, thermal evolution, and the wide-ranging effects of large impacts. Sample return from SPA is one of the highest-priority goals in planetary science, with implications for understanding solar system impact chronology as well as the thermal and geochemical evolution of the Moon. Optimal sampling strategy and interpretation is contingent on understanding the extent, distribution and character of resurfacing across SPA.

SPA exhibits a low degree of mare basalt fill compared to other lunar basins[1,2]. However, recent analyses have determined that a ~700 km region in central SPA (SPA Compositional Anomaly (SPACA)) has been resurfaced, exhibiting both compositional (Ca,Fe-rich pyroxenes) and geomorphological (smooth plains, volcanic constructs, and modified impact craters) indicators[3–7]. The nature of this resurfacing is unclear, particularly its apparent distinctions from typical mare basalts. Some of these differences may be due to surficial obscuration of mare emplacements by redistributed crustal materials, a process resulting in relatively high-albedo smooth plains referred to as "cryptomare"[7,8].

However, the volcanic history of the SPA interior is diverse and complex. In particular, Mons Marguerite (formerly Mafic Mound) near the center of SPA appears to be a volcanic construct with a distinctive mineralogy[4]. Mons Marguerite is spectrally similar to some SPACA deposits, and similar mineralogies are observed in crater walls and ejecta sampling depths of several km[3,6]. This suggests that SPACA was at least partially resurfaced by a magmatic product distinct from typical mare basalts, perhaps related to the unique geophysical environment underlying the Moon's largest impact structure [3,9,10].

SPACA therefore exhibits at least three distinct styles of volcanic deposits: (1) mare basalts, (2) cryptomare, and (3) Mons Marguerite Mafic Magmas (M^4), in addition to infill by later basin ejecta[7]. Our analysis focuses on delineating between cryptomare and M^4 through mineralogical evaluation of impact craters both pre- and post-dating volcanic resurfacing.

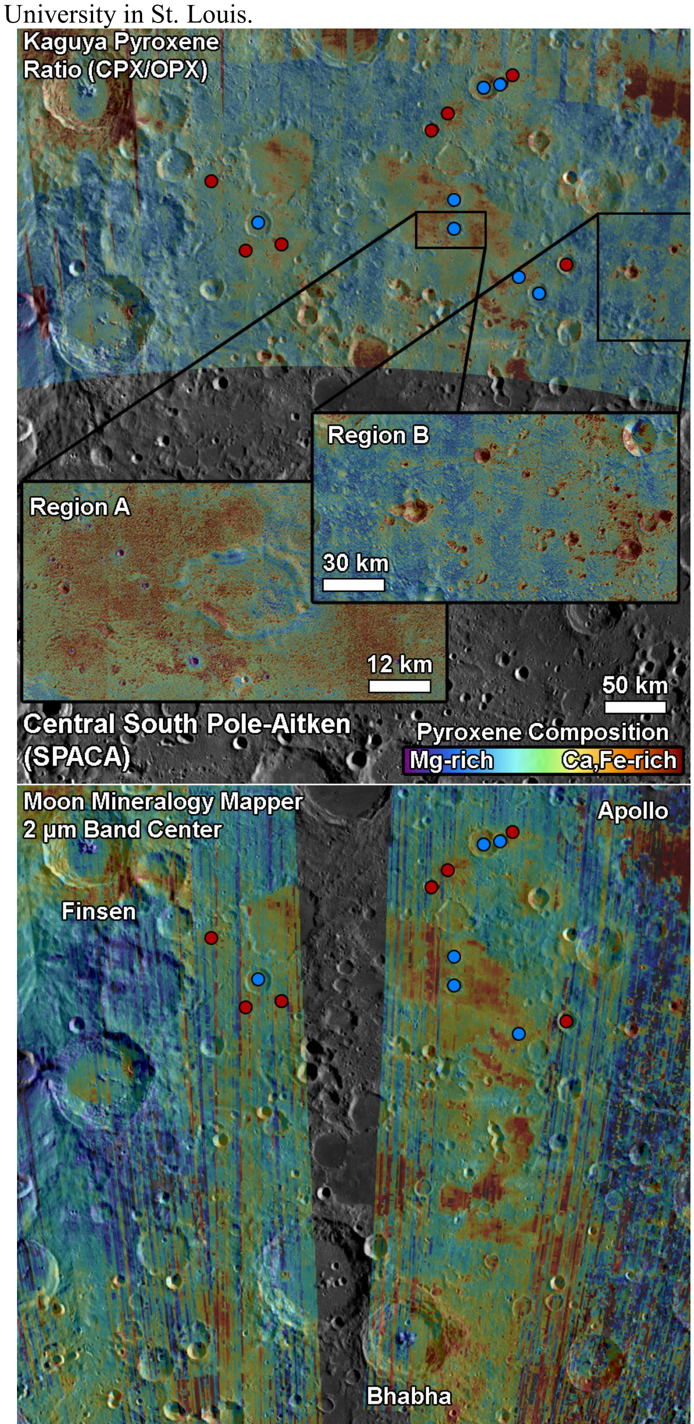
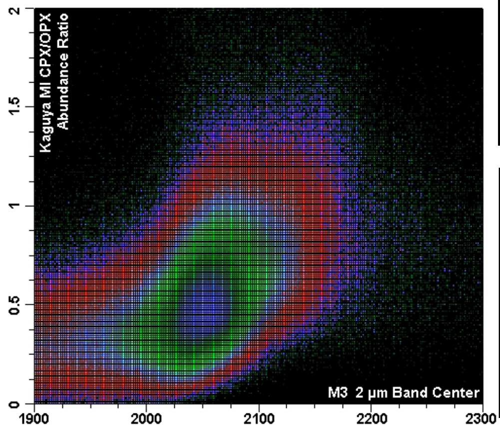
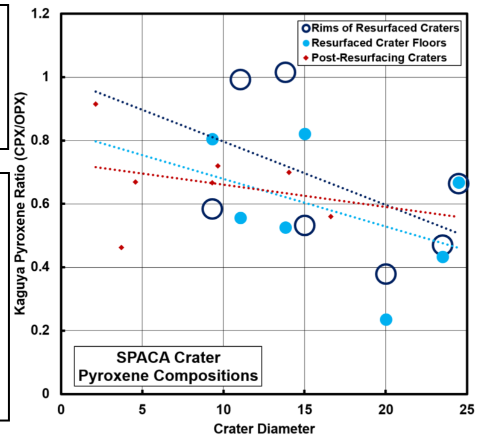


Fig. 1: MI (top) and M^3 (bottom) mineralogy for SPACA. The locations of pre- and post-resurfacing craters analyzed in Fig. 3 are given by blue and red circles, respectively.



◀**Fig. 2:** MI CPX/OPX ratio vs. M^3 2μ band center for overlapping regions in Fig. 1.

Fig. 3▶**:** MI CPX/OPX ratio vs. crater diameter for pre- and post-resurfacing crater structures for the features indicated in Fig. 1, with linear regressions.



Methods: Cryptomare and M^4 emplacements are associated with significant stratigraphic differences. Cryptomare deposits exhibit a veneer of high albedo, feldspathic material obscuring buried mare basalts (low albedo, mafic, typically ~100 m in thickness[11]). M^4 deposits exhibit a single stratigraphic layer with a higher albedo, perhaps linked to lower Fe,Ti content[3,4].

We probe these differences using a suite of impact craters across SPACA, revealing variations in local stratigraphy. Craters excavate material from depths up to ~10% of their final diameter[12]. Therefore, ~1 km craters in mare or cryptomare regions primarily excavate mare basalts, while ~10 km craters and larger primarily excavate substrate lithologies (unless the resurfacing deposit is unusually thick).

Spectral variations across SPA are dominated by differences in the abundance and composition of pyroxenes, reflecting diversity in magmatic processes and resulting mineralogies. We employ two independent products derived from orbital spectrometers to assess variations in pyroxene composition: (1) a ratio of clinopyroxene-to-orthopyroxene abundance maps from the Kaguya Multiband Imager (MI) 1 μm band measurements [13] and (2) 2 μm band center maps from Moon Mineralogy Mapper (M^3)[14] (Fig. 1). Both products exhibit instrument artifacts precluding accurate quantitative interpretation (vertical striping, latitude dependence, etc.), but well-correlated compositional trends are observed for overlapping observations in Fig. 1. This is confirmed by the approximately linear relationship observed in Fig. 2 (although this is less clear for pixels with 2 μm band centers shorter than 2000 nm). MI maps have better spatial resolution (~60 m/pixel), but M^3 covers higher latitudes, providing complementary coverage.

Results: Across SPACA, smooth terrain suggestive of volcanic resurfacing is typically correlated with moderate-to-high Ca,Fe pyroxenes (green-red). With the exception of a few localized mare deposits, SPACA resurfacing deposits are lower in apparent Ca,Fe than mare basalts in Apollo and wall materials in Finsen and Bhabha craters. In fact, the rims of ancient, pre-resurfacing craters exhibit higher average Ca,Fe content than the resurfacing material, as demonstrated in Fig. 3. This indicates that the first few km of the ancient SPA floor (a product of impact melt differentiation and/or ancient volcanic resurfacing (possibly M^4)) is significantly higher in Ca,Fe than younger resurfacing deposits.

For further insight, we examine two resurfaced regions with MI data: Region A (previously mapped as mare basalt[15]) and Region B (previously mapped as cryptomare[8]). Region A surface materials exhibit high Ca,Fe, but ~1 km craters reveal high Mg materials at depths of ~100 m. The flooded and severely degraded ~20 km impact crater in the region center suggests extensive resurfacing in this area. This evidently involved recent mare basalts and prior resurfacing by Mg-rich materials (perhaps ejecta from Apollo Basin).

In contrast, Region B exhibits a relatively Mg-rich surface composition. Craters from ~1-10 km in this area exhume Ca,Fe-rich materials. While this is consistent with a typical cryptomare stratigraphy, the thickness (>1 km) and high albedo of exhumed Ca,Fe-rich materials suggests a non-mare origin (ancient M^4 or differentiated SPA impact melt).

Conclusions: SPA has undergone a complex history of resurfacing involving multiple stages of basin ejecta deposition, mare-, and non-mare volcanism. Non-mare Ca,Fe-rich materials across the basin complicate identifications of candidate cryptomare.

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References: [1]Pieters *et al.*, (2001), *JGR*, 06, E11. [2]Pasckert *et al.*, (2018), *Icarus*, 299, [3]Moriarty and Pieters, (2018), *JGR*, 123, 3, [4]Moriarty and Pieters, (2015), *GRL*, 42, 19, [5]Ohtake *et al.*, (2014), *GRL*, 41, 8, [6]Moriarty and Pieters (2016) LPSC47, [7]Ivanov *et al.*, (2018), *JGR*, 123, 10, [8]Whitten and Head, (2015), *Icarus*, 247, [9]Arkani-Hamed and Pentecost, (2001), *JGR*. 106, E7, [10]Hagerty *et al.*, (2011), *JGR*, 116, E6, [11]Du *et al.*, (2019), *JGR*, 124, 9. [12]Melosh (1989), *Impact Cratering: A Geol. Persp.* [13]Lemelin *et al.*, (2015), *JGR*, 120, 5, [14]Moriarty and Pieters, (2016), *MAPS*, 51, 2, [15]Nelson *et al.* (2014) LPSC #1777.