THE FOUR COMPOSITIONAL ZONES OF THE SOUTH POLE - AITKEN BASIN AND IMPLICATIONS FOR BASIN EVOLUTION.

D. P. Moriarty III[1], C. M. Pieters[2], N. E. Petro[1], and J. W. Head[2], [1]NASA GSFC [daniel.p.moriarty@nasa.gov], [2]Brown University.

Introduction: The South Pole - Aitken Basin (SPA) is a vast, ancient impact structure on the lunar farside. As noted in the previous two Decadal Surveys, understanding SPA is central to several critical lunar science questions relevant to (1)basin chronology, (2)lower crust/upper mantle stratigraphy and composition, (3)large impact processes, (4)lunar formation/thermal evolution, and (5)lunar volcanism. Recently[1], we used Moon Mineralogy Mapper (M^3) data to evaluate the compositional structure of the basin, identifying four distinct compositional zones. Here, we discuss the properties of these zones, as well as the implications for understanding the formation and evolution of SPA.

Identification and Properties of Compositional Zones across SPA: M^3 data reveal regular patterns of compositional diversity across SPA. Using the Parabolas and two-part Linear Continuum technique (PLC)[2], we map the diagnostic properties of the 1 µm and 2 µm absorption bands. Band depths (sensitive to pyroxene abundance) are shown in Fig. 1, compared to Lunar Prospector Fe abundance[3]. Band centers (sensitive to pyroxene composition) are shown in Fig. 2. Based on these maps, four distinct compositional zones are identified. The properties of these zones are as follows:

SPA Compositional Anomaly (SPACA): SPACA is an approximately ~700 km wide unit located in the central portion of SPA. It exhibits a pervasive elevated pyroxene abundance, and the surface composition is dominated by a pyroxene composition intermediate to mare basalts and Mg-pyroxenes. This non-mare high-Ca pyroxene (NM-HCP) is observed at structures such as Mafic Mound[4], the walls of Finsen, Bhabha, Bose, White, and Stoney, and the central peaks of White and Stoney. However, several large complex craters within SPACA (Bhabha, Finsen, Stoney) exhibit distinctly Mg-rich pyroxenes in their central peaks (Fig. 3). Since central peaks represent the deepest material exposed in any given crater, this suggests the presence of Mg-pyroxenes at depths of >5 km, underlying the surface materials.

Mg-Pyroxene Annulus: The Mg-Pyroxene Annulus surrounding SPACA also exhibits an elevated pyroxene abundance, with Mg-rich pyroxene compositions (Fig. 2). The Mg-Pyroxene Annulus lies directly outside of the SPACA, and represents the remainder of the prominent Pyroxene-Bearing Zone (~1000 km across in total). Mg-pyroxene dominates crater structures over a wide range of crater sizes, indicating the presence of laterally and vertically extensive Mg-Px-bearing materials.

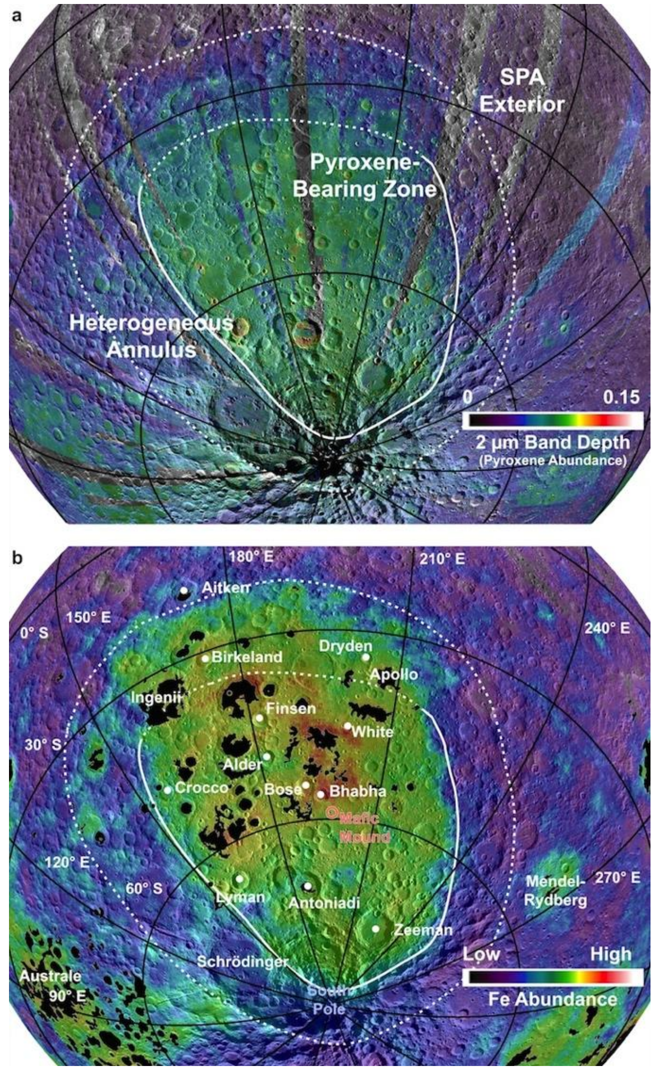

Fig. 1: (A) 2 µm band depths (sensitive to pyroxene abundance). (B) Lunar Prospector Fe abundance [3], with mare basalts masked [5]. Three distinct pyroxene abundance zones are evident, further classified by pyroxene composition in Fig. 2.

Heterogeneous Annulus: The Heterogeneous Annulus is associated with the outer reaches of SPA interior (Figs. 1,2). It is dominated by feldspathic materials, but exhibits localized pyroxene-bearing areas and a variable but typically small mafic component in soils. In general, non-mare mafic materials within the Heterogeneous Annulus are dominated by Mg-pyroxene.

SPA Exterior: Other than isolated mare basalts (mostly within Mare Australe), the immediate SPA Exterior is highly feldspathic and appears mafic-free.

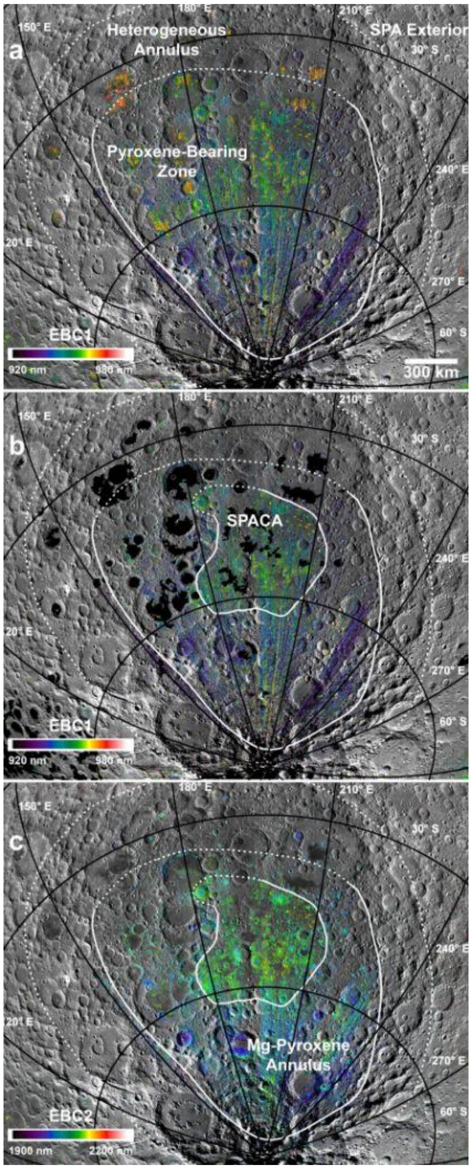

Fig. 2: M^3 band centers across SPA, sensitive to pyroxene composition. Short-wavelengths indicate Mg-rich pyroxenes, longer wavelengths indicate more Fe,Ca-rich pyroxenes. Basemap: LROC WAC. (A) 1 µm band centers. (B) Same as (A) with known mare basalts masked. (C) 2 um band centers with values from known mare

Implications: The four compositional zones across SPA result from specific processes related to basin formation and evolution. Insight into these processes can be gained by understanding the extent, composition, and inferred origin of each zone.

The *SPACA* exhibits a surface composition dominated by non-mare HCP. From the estimated local stratigraphy at Bhabha (Fig. 3) and several similar craters, this composition persists to depths of >5 km in places and is underlain by Mg-pyroxene-bearing material. *SPACA* exhibits a paucity of impact craters[6], an abundance of modified/filled craters[4], and is associated with the unusual volcanic construct known as Mafic Mound[4]. While these factors point to volcanic resurfacing, it is unclear if volcanism alone can account for the ~5 km thickness of the *SPACA* surface material. It is possible that additional processes such as impact melt differentiation[7] or post-SPA basin ejecta may also contribute to the observed local stratigraphy[8].

Across the *Mg-Pyroxene Annulus*, large craters are dominated by fairly uniform Mg-rich pyroxenes within their walls, floors, and central peaks. The largest impact structures in this zone (e.g. Poincaré, Apollo, etc.) may have excavated materials from depths of 40 km or greater. The vast extent, significant depth, and relatively uniform composition of the Mg-Pyroxene Annulus suggests that this Mg-pyroxene-bearing material was the primary product excavated, ejected, and melted by the SPA-forming impact. Possible sources of this material include inherently mafic lower crust, Mg-suite materials emplaced at the base of the crust, and/or Mg-pyroxene-bearing upper mantle materials. These band center and depth analyses cannot rule out the presence of olivine within the pyroxene-dominated mineral assemblage. However, there is no evidence for widespread exposures of dunnite or other olivine-dominated assemblages in the SPA interior either in M^3 data or other analyses[9]. If, as expected, SPA exposed mantle materials, this mantle material must include a significant Mg-pyroxene component.

Isolated mafic exposures in the *Heterogeneous Annulus* exhibit similar pyroxene compositions to the Mg-Pyroxene Annulus. These exposures likely arise from mixing of proximal SPA ejecta with the feldspathic crust during collapse of the transient cavity, further commuting the ejecta and crust into a zone within the final topographic rim of SPA.

References: [1] Moriarty, D. P. and Pieters, C. M. (2018) *JGR*, in final review. [2] Moriarty, D. P. and Pieters, C. M. (2016) *Meteoritics & Planet. Sci., 51,* 207-234. [3] Lawrence, D. J. et al. (2002) *JGR 107.* [4] Moriarty, D. P. and Pieters, C. M. (2015) *GRL, 42,* 7907–7915. [5]Nelson et al. (2014) *JGR 111.* [6]Head et al. (2010) *Science 329,* 1504-1507. [7] Morrison, D. A. (1998) *LPSC XXIX,* #1657. [8]Petro, N. E. and Pieters, C. M. (2008), *Meteoritics & Planet. Sci. 43,* 1517-1529. [9]Yamamoto, s. et al. (2012) *Icarus, 218,* 331-344.

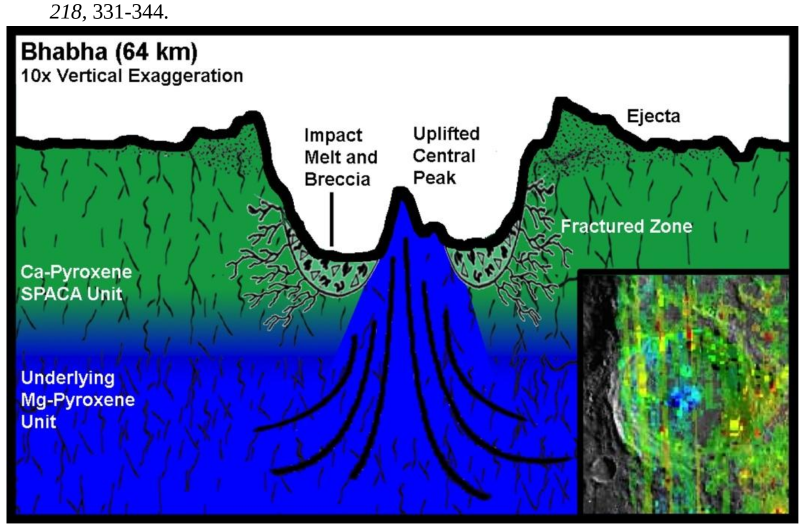

Fig. 3: Schematic cross section of Bhabha, inferred from 2 µm band center values (inset). The walls and floor exhibit non-mare HCP excavated from depths <~6 km, whereas the central peak exhibits Mg-rich pyroxenes from depths >~6 km.