# APOLLO IMPACT BASIN: PROBING THE DEPTHS OF THE LUNAR FARSIDE.

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**The South Pole-Aitken Basin:** Materials excavated by the ~2200 km South Pole–Aitken (SPA) impact basin, the largest well-preserved impact basin on the Moon [1-3] (Fig. 1-4) are considered to be some of the most extensive, deepest lunar materials exposed. Recently, a combined compositional and geophysical assessment of SPA [4] showed evidence for large-scale exposure of subcrustal materials in two distinct SPA regions: 1) The laterally extensive, vertically thick OPX annulus (OPX-A) (Figs. 2-3) exhibits a homogeneous composition dominated by Mg-rich pyroxenes and is interpreted to correspond to the position of a remnant portion of the SPA transient cavity that excavated through the ~40 km feldspathic crust. 2) Exterior to OPX-A, localized areas with mafic signatures are heterogeneously mixed with more feldspathic regions and this area is denoted "Heterogeneous Annulus" (HET-A), with the dominant mafic component similar to materials in the OPX-A [4]. This is interpreted to be ejected sub-crustal materials mixed with feldspathic crust during ejecta emplacement and basin modification. The Mg-rich pyroxenes are interpreted to represent upper mantle compositions since they originate from subcrustal regions. The "central SPA Compositional Anomaly" (SPACA) region (Figs. 2-3), dominated by materials indicating an average pyroxene composition with significant CPX, are interpreted to represent either impact melt or early volcanic deposits [4].

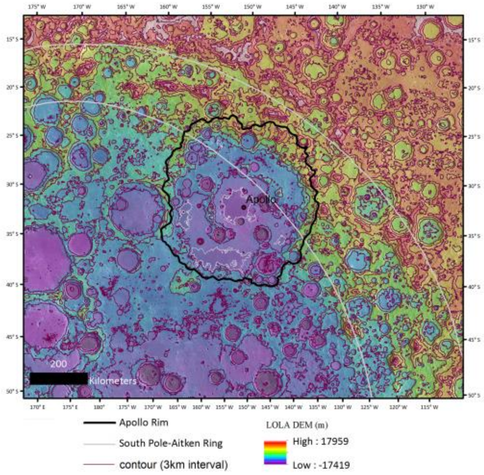

Fig. 1. Topography of the South Pole-Aitken impact basin and the superposed Apollo basin (black line). Two rings of the SPA basin (white lines) are seen; Apollo is superposed on the inner ring. LOLA altimetry data.

**The Apollo Basin:** Subsequent to the formation of the SPA Basin, and prior to the Nectarian period, the ~500 km diameter Apollo peak-ring basin formed on the north-northeastern interior of the SPA Basin, superposed on one of its major inner rings and straddling the HET-A and OPX-A units, and adjacent to the SPACA terrain (Fig. 1-3). A variety of spectroscopic, morphometric, and gravity analyses [e.g., 1-2,5-6] underline the distinctive nature of Apollo:

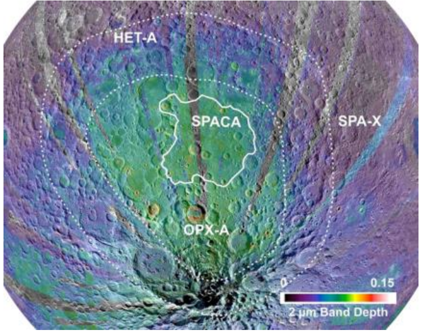

Fig. 2: $M^3$-derived band depth with boundaries of SPACA, OPX-A, HET-A, and SPA-X shown [4]. Base is WAC mosaic.

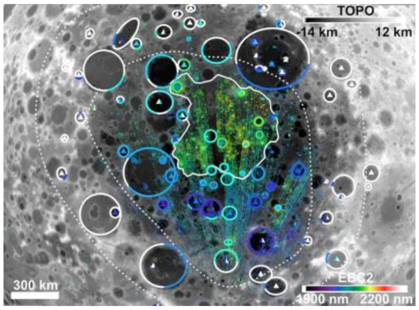

Fig. 3: $M^3$-derived 2 µm absorption band center (EBC2) showing local compositional diversity and stratigraphy. Symbol colors correspond to an EBC2 map [4]; white indicates presence of feldspathic materials, ellipses are crater rims and walls, triangles correspond to central peaks. Extents of SPACA (solid), OPX-A, HET-A, and SPAX (dashed) are given [4]. Base is LOLA topography.

1) *Noritic and basaltic materials* are found to the south and west of the basin, while anorthositic materials are found to the north and east [2], a pattern interpreted to be due to the basin straddling the boundary between SPA transient crater and its modification zone, a conclusion supported by numerical modeling [7].

2) The *peak-ring of the Apollo basin* rises 1-2 km above the floor (dominated by mafic materials [3,6]); $M^3$ data suggest that the Apollo basin peak ring is dominated by Class C spectra [6] (it contains <95% pure plagioclase and has no clear 1.25 µm plagioclase absorption signature) [8].

3) The *thin crust beneath the basin center* (<5 km), as well as the possible presence of a SPA melt sheet beneath [6] could also provide mafic signatures.

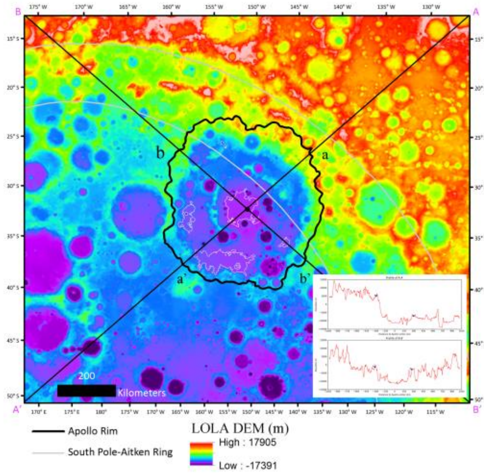

Fig. 4. Topographic profiles across NE SPA and through the Apollo peak-ring basin illustrating the peak ring structure.

4) The floor of the Apollo basin contains several *patches of maria* (Figl 5), estimated to be of Imbrian age in early studies [9]. Data from Galileo [10] dated the Apollo maria as 3.63 (+0.05; -0.06) Ga. Haruyama et al. [11] estimated the Apollo basin maria age with 10 m/pixel resolution SELENE Terrain Camera images, and divided the maria into two parts, Apollo N and Apollo S. According to their results, Apollo N, the ~1540 km$^2$ easternmost mare deposit in the SPA basin, was given a 3.51 Ga model age dated from craters larger than 700 m in diameter. However, the age can be 2.49 Ga if dated from craters larger than 500 m in diameter [11]. They interpreted the two distinct model ages as being caused by multiple eruptions in this area, and the thickness of the younger deposit can be estimated as <40 m [11]. Apollo S, 778.4 km$^2$ in area, was estimated to be ~2.44 Ga [11]. Their results indicate that mare volcanism on the lunar farside lasted longer than was previously considered and may have occurred episodically.

The iSALE shock physics code has been used to model the formation of Apollo [7, 12] leading to the interpretation that the Apollo basin-forming impact would have excavated mantle material if crustal thickness was <~30 km. For the 40 km crust scenario, a thin (1-2 km thick) layer of crustal material is present on the basin floor and some impactor (and mantle) material are mixed in [12]. This material is highly shocked (>35 GPa) and melted. These high surface shock pressures continue out to the peak ring (~100-120 km radius). The peak ring consists of crustal material from a variety of depths up to 55 km. Beyond the peak ring, peak shock pressures are lower (<25 GPa); this includes the basin rim material which is composed of crustal material originally from depths <30 km [12].

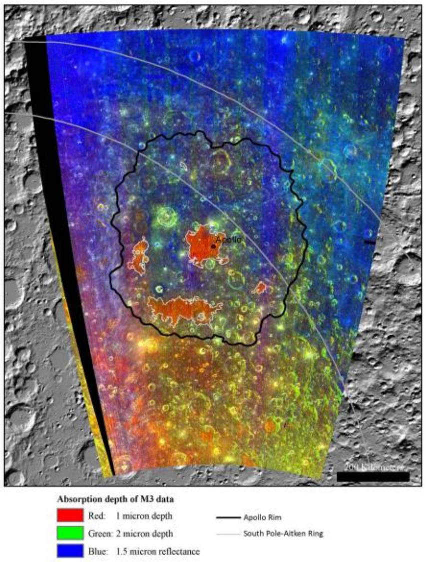

Fig. 5. M3 data illustrating the location and nature of the mare patches.

**Future Exploration Goals and Objectives:** The age, geology and structure of Apollo make it a strong candidate for both robotic and human exploration missions focused on early lunar processes and the structure of the SPA terrain. China has placed the Apollo Basin as a top candidate for its future landing and roving missions [13]. Among the goals for observations for future missions aree: 1) analysis of sub-SPA mantle material; 2) assessment of the mineralogy of the peak ring to constrain basin numerical models; 3) analysis of the mineralogy and age of farside mare basalts derived from unsampled deep mantle and erupted through thin to nonexistent crust; 4) mineralogy and petrology of unique farside materials; 5) Geophysical structure of a peak ring basin; 6) further understanding of the nature of the South-Pole Aitken Basin. Future exploration of the Apollo basin would complement the proposed MoonRise sample return mission to the SPA interior [14].

**References:** 1) Pieters et al., 2001, *JGR* 106, 28001; 2) Petro et al., 2010, LPSCXLI 1802; 3) Klima, et al., 2011, *JGR* 116, E00G06; 4) Moriarty and Pieters, 2016, LPSC 47 1763; 5) Wieczorek, et al., 2013, *Science* 339, 671; 6) Baker & Head, 2015, *Icarus* 258, 164; 7) Potter et al., 2012, *Icarus* 220, 730; 8) Cheek et al., 2013, *JGR* 118, 1805; 9) Wilhelms, 1987, *USGS PP* 1348; 10) Greeley et al., 1993, JGR 98, 17183; 11) Haruyama et al., 2009, *Science* 323, 905; 12) Potter and Head, 2017, *LPSC 48*; 13) Wang & Liu, 2016, *Acta Astron.* 127, 678; 14) Joliff et al., 2017, *LPSC 48* 1300.