REVISITING THE ORIGIN OF CENTRAL SOUTH POLE-AITKEN BASIN COMPOSITIONAL ANOMALY (SPACA) AND THE ENIGMATIC MAFIC MOUND (MONS MARGUERITE).

Xing Wang[1,2,3], James W. Head[3], Yuan Chen[1], Yuqi Qian[4], Jianjun Liu[1,2], Chunlai Li[1,2], [1]Key Laboratory of Lunar and Deep Space Exploration, National Astronomical Observatories, Chinese Academy of Sciences, Beijing, China. (wangx01@nao.cas.cn), [2]School of Astronomy and Space Science, University of Chinese Academy of Sciences, Beijing, China, [3]Department of Earth, Environmental, and Planetary Sciences, Brown University, Providence, USA, [4]Department of Earth Sciences, University of Hong Kong, Hong Kong, China.

Overview of SPACA: Within the South Pole-Aitken (SPA) basin, the largest impact basin on the Moon, numerous outstanding questions await definitive answers. One of them is the origin of SPACA [1]. On the basis of the evolution of other large lunar basins, significant volumes of mare volcanic deposits appear on the basin floor forming maria [2] or cryptomaria [3]. An unusual pervasive High-Ca pyroxene (HCP)-bearing feature was indeed discovered in the central region of SPA basin, but the albedo here is higher than typical mare basalt and lower than the surrounding Mg-pyroxene annulus [1]. Moreover, a layer with a composition similar to the Mg-pyroxene annulus could underlie the SPACA region since the central peaks of several craters within this region exhibit Mg-pyroxene signatures [1]. The thorium abundance across SPACA is relatively lower than the surroundings, which may result from impact cratering excavation and redistribution from surrounding units [4]. A relatively low crater density within SPACA also suggests that a potential resurfacing event may have occurred in this area [5]. In terms of these characteristics, cryptomaria could be a plausible interpretation of SPACA [3]. However, the appearance of Mafic Mound (aka., Mons Marguerite) [5] introduces an uncertainty to the cryptomeria hypothesis. Mafic Mound is a distinctive circular structure located on the southern portion of SPACA, the origin of which has been interpreted as an unusual nonmare volcanic construct resulting from melting and extrusion related to the SPA impact [6]. In this study, we reassess the cryptomaria hypothesis for SPACA and Mafic Mound.

Topography and morphology of SPACA: The topographic characteristics of the SPACA region are shown in Figure 1a. The southern portion of SPACA is generally ~1 km lower than the northern portion. Crustal thickness derived from the Gravity Recovery and Interior Laboratory (GRAIL) mission also reveal a north-south thinning of the crust to the south. The thin crust suggests that the southern portion of SPACA is near the center of the target area of the SPA basin-forming impact. We also discover the superpositions of several circular structures within SPACA, suggesting the presence of a sequence of degraded craters modified by sequential flooding and impact ejecta. The regional crustal thickness may also exhibit some spatial correlations with the surface morphology. The lower terrain corresponding to thinner crust is consistent with a series of sequentially flooded ancient craters (now embayed to several levels). Based on the mapped remnants of several large impact structure now exposed on the surface of SPACA, the locations and sizes of candidate ghost craters can be inferred (Fig. 1). In the SPACA cryptomaria origin scenario, these ghost craters may have further shaped the depressions required for the sequential subsequent basalt filling after the formation of the SPA central low relief.

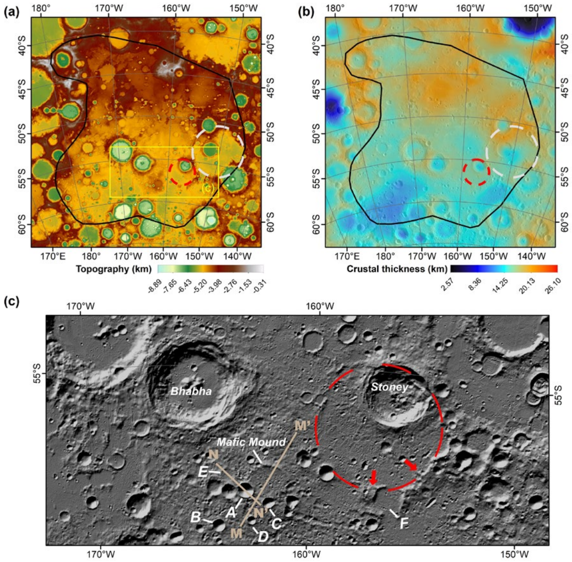

Figure 1. North-South difference and potential existence of ghost craters within SPACA. (a) Topographic map of the SPA center based on the Chang'E-2 DEM data [7]. The black line outlines the distribution of SPACA. (b) Crustal thickness (Model 1) of SPA center derived from GRAIL data [8]. The two dashed circles marked in (a) and (b) are the examples of possible ghost craters. (3) The shaded relief map of a ghost crater (dashed red circle) near Mafic Mound based on the SLDEM data [9]. The red arrows indicate the potential rim remnants of the ghost crater.

Revisiting the enigmatic Mafic Mound: A detailed summary of the nature of Mafic Mound was given in [6] (relatively high albedo, homogeneous HCP-bearing composition, positive topography and positive Bouguer anomaly). Here we focus on possible ejecta deposits for craters around Mafic Mound. As shown in Fig. 1c, the surface of Mafic Mound area is fairly rough, implying a complex impact and ejecta deposition history. Multiple pronounced impact rays and secondaries cross over Mafic Mound and can be traced back to several large distant impact craters, such as the Imbrian-aged crater Minnaert [10] shown in Fig. 2. Using the superposition relationship, we can constrain the formation time of Mafic Mound to before Imbrian. In addition, we note another impact ray, also from Minnaert, extends into the SPACA region on the western Mafic Mound area (blue box in Fig. 2), suggesting the basalt-filled event may also have occurred prior to the formation of crater Minnaert.

As discussed in [6], Mafic Mound does not match the typical features of well-known lunar dome or volcanic complexes due to its size, elevated nature and circular shape. Here we reassess the possibility that Mafic Mound could be an old filled crater elevated on crater ejecta. If we consider Mafic Mound as a crater with a diameter of ~32 km [6], the absolute height of its rim crest could be ~-4.4 km (Fig. 3a). According to the flooding model [11], we assume basalt can be filled in the center of Mafic Mound to the maximum height of ~-5.3 km, which is approximately the floor height of a similar-sized crater in the east (crater F) and the typical elevation of the surrounding area. Within Mafic Mound, the profile in Fig. 3a shows that the topography on the SW part is relatively higher, probably assisted by uplift and ejecta deposition during the formation of the two nearby craters (cater A and C). We thus choose the lowest value (~-4.7 km) in the center of this profile as the maximum filling height to remove the effect of these two impact craters. In order to fill the Mafic Mound crater to its present state, a minimum of 600 m of other material is required. Ejecta from Bhabha may blanket the Mafic Mound area [12]. To estimate the effect of Bhabha and other nearby large craters, we analyze a filled small crater on the west of Mafic Mound (crater E). We compared its floor depth (~300 m) with that of the nearby similar-sized "fresh" crater (crater A, ~2.3 km) and find that ~2 km thick materials might be infilling crater E (Fig. 3b). This scale of filling suggests that Mafic Mound may also be filled with materials of a considerable thickness.

Summary: We assess an alternative view of the formation of Mafic Mound, concluding that it may simply be an old crater highly modified and filled by large volumes of crater ejecta (and some volcanic material). If this is the case, then combined with our regional analysis of SPACA, we find support for a cryptomaria interpretation for the origin of SPACA. In addition, this interpretation places SPACA in the population of virtually all other impact basins in having been filled with cryptomaria and maria; this interpretation is further supported by the fact that SPA mare emplacement continued well beyond the formation of Apollo and Orientale, subsequent basins that appear to have elevated the SPACA albedo with their distal ejecta.

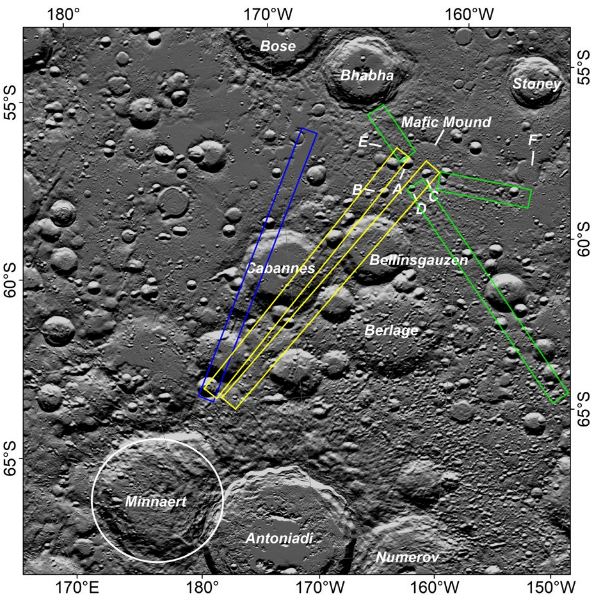

Figure 2. Examples of the impact rays observed around Mafic Mound on the shade relief map. Yellow and blue boxes indicate obvious impact rays which can be traced back to crater Minnaert. Green boxes indicate the impact rays from other source craters.

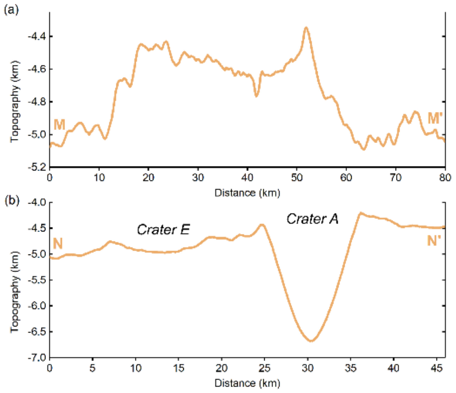

Figure 3. Topographic profiles for MM' and NN' in Figure 1.

Reference: [1] Moriarty, D. P. & Pieters, C. M. (2018), *JGR: Planets*, *123(3)*, 729-747. [2] Hiesinger, H. et al. (2011). *Recent advances and current research issues in lunar stratigraphy*, *477*, 1-51. [3] Whitten, J. L. & Head, J. W. (2015). *Icarus*, *247*, 150-171. [4] Moriarty, D. P. et al. (2021), *JGR: Planets*, *126(1)*, e2020JE006589. [5] Head, J.W. et al. (2010), *Science*, *329*,1504-1507. [6] Moriarty, D. P. & Pieters, C. M. (2015). *GRL*, *42(19)*, 7907-7915. [7] Li, C. et al. (2018). *Geomatics Inf. Sci. Wuhan Univ.*, *43(4)*, 485-495. [8] Wieczorek, M. A. et al. (2013), Science, 339(6120), 671-675. [9] Barker, M. K. et al. (2016). *Icarus*, *273*, 346-355. [10] Fortezzo, C. M. et al. (2020), *51st LPSC* (No. 2326, p. 2760). [11] Whitten, J.L. & Head, J.W. (2013), *Planet. Space Sci.*, *85*, 24-37. [12] Petro, N. E. et al. (2011). *Spec. Pap. Geol. Soc. Am*, *477*, 129-140.