GEOLOGICAL INVESTIGATION OF CLASS-3 LUNAR FLOOR-FRACTURED CRATER THEBIT.

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Introduction: The study of lunar floor-fractured craters (FFCs) provides clues to understand and unravel the diverse mineralogical entities in spatial context that are having implications on the magmatic and thermal evolution of lunar surface with time [1-6]. These FFCs could be divided into eight subclasses based on their varied morphological features [7]. In this study, we have conducted spectral vis-à-vis morphological analyses of Thebit crater, a class-3 lunar FFC, characterized by prominent polygonal fractures and the moat area. Crater Thebit (22°S, 04°W) is situated on the eastern bank of Mare Nubium and south-west of crater Arzachel. It is an Upper Imbrian aged, nearly circular, degraded crater with a diameter of ~60 km. This crater has a tormented floor with no central peak. Two subsequently generated craters (named, Thebit-A and Thebit-L) with less than ~20 km diameter have been placed on the north-west side of the rim of Thebit.

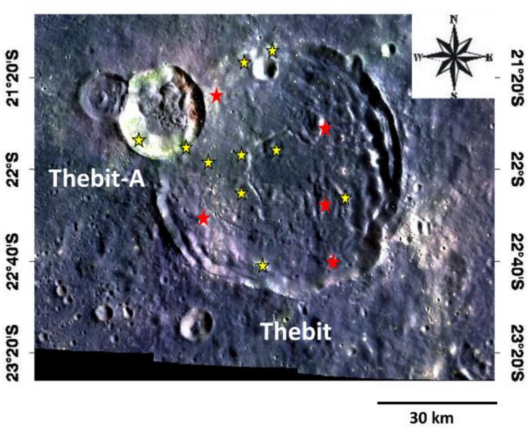

Figure 1: FCC mosaic of crater Thebit from M^3 datasets.

Dataset used and Methodology: In this study, we analysed the mineralogy as well as morphology of the crater floor. For mineralogical analysis, the photometrically and thermally corrected level-2 hyperspectral datasets of Moon Mineralogy Mapper (M^3) on-board Chandrayaan-1 have been used [8]. To study the morphological features, the global datasets with 100-m spatial resolution from Wide Angle Camera of NASA's Lunar Reconnaissance Orbiter (LROC-WAC) have been used [11]. We have also used the Lunar Orbiter Laser Altimeter-Digital Elevation Model (LOLA-DEM) datasets with 30-m spatial resolution for topographic study of the crater [11, 12]. To understand the mineralogical variation, a false colour composite (FCC) mosaic (Fig. 1) has been prepared by assigning the 930-nm, 1249-nm and 2137-nm spectral bands of M^3 strips in red, green and blue channel, respectively. Subsequently, we have obtained the reflectance spectra from this FCC image to discriminate various mineralogical constituents (Fig. 2).

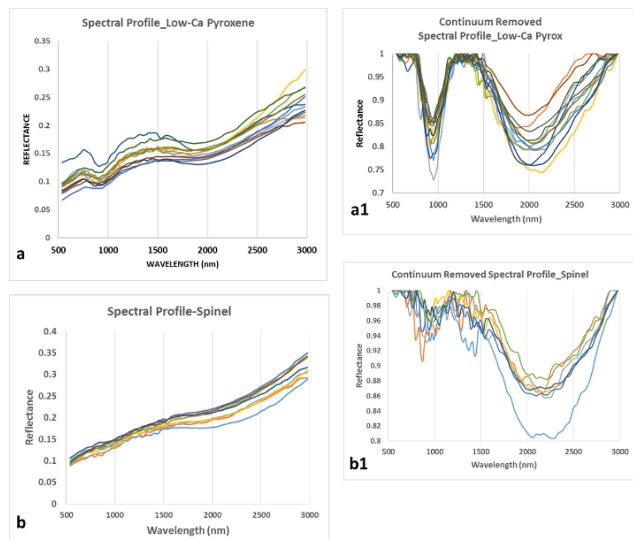

Figure 2: (a-b1) Representative reflectance spectra and continuum-removed spectra derived from FCC mosaic of crater Thebit.

Results and discussions: Reflectance spectra of the study area suggest primarily a bimodal mineralogy for the crater floor manifested mostly by low-Ca pyroxene- (marked by yellow star) and spinel-bearing lithologies (marked by red star). These low-Ca pyroxenes (LCPs) and spinels appear in the shades of green and pink respectively as shown in Figure 1. The LCPs can be characterised by strong dual spectral absorptions near 940- and 2018-nm. (Figs. 2a & a1). The spinel is identified based on its relatively strong absorption near 2000-nm as compared to a weak to non-existent (sometimes) absorption near 1000-nm (Figs. 2b & b1). The presence of a weak 1000-nm suggests that either the spinel is Fe-bearing or it could be mixed with minor quantities of LCPs. Both of these mineralogies are deposited within some hummocky materials and are scattered all over the crater floor. The reflectance spectra derived from crater Thebit-A indicate that the crater floor is mainly composed of the LCP-bearing noritic lithologies. However, the crater floor does not show any spectral signature of pyroclastic deposits. In terms of morphology, the LROC-WAC image (Fig. 3d) shows the presence of prominent polygonal fracture system within the central area of the crater floor. Few minute degraded radial fractures also can be seen, dispersed over the region. The topographic relief of the crater floor is highly tormented. The LOLA-DEM spatial profiles (Figs. 3a & b) suggest that the western and southern rim have more extended and broad wall terraces. However, the slope gradients of the northern and eastern wall are relatively steeper with minute to non-existent (some areas) wall terraces. In case of crater Thebit-A, it also has steep crater wall in association with some probable signatures of wall slump over the NE flank of the floor (Fig. 3c). This analysis indicates the possibility of landslide that might have occurred along the NE crater wall of Thebit-A [13]. The spatial profiles also highlight the fact that the crater floor is uplifted on the eastern and northern flank (Figs. 3a & b). From this observation, it can be inferred that there might be a laccolith type of deposit intruded underneath the eastern and northern parts of the crater floor [2]. Later on, the elevated surface has been fractured due to the tensile stress produced during the upliftment [1, 2, and 7]. Additionally, a conspicuous moat region has been identified in the spatial profile along the peripheral region where the crater floor meets the wall (Fig. 3).

Conclusion: From this study, it can be concluded that crater Thebit has a nearly circular rim, uplifted crater floor, polygonal and radial fractures with a prominent moat region; which characterize it as a class-3 lunar floor-fractured crater. The compositions have been identified in this study specify the presence of major mafic mineralogies, namely, LCPs, and Spinels. Based on these mineralogies, we can conclude that the LCPs could be pigeonitic in composition and the spinel bearing minerals may signify the presence of Fe-Mg spinels within the studied site [14, 15]. All these mafic mineralogies suggest either a Mg-pluton at shallow subsurface or it might represent the excavated mid to lower crustal lithology associated with noritic and pink spinel anorthositic assemblages. However, unlike other classes of FFCs, no signature of late-stage pyroclastic activity has been observed in this crater during the spectroscopic analysis. Further detail studies are envisaged for understanding the litho-evolutionary mechanisms of these FFCs.

References: [1] Jozwiak et al. 2012, JGR, Vol. 117, E11005. [2] Jozwiak et al. 2015, ICARUS 248, 424-447. [3] Bennett et al. 2016, Icarus, 273, 296-314. [4] Martinot et al., JGR, doi:10.1002/2017JE005435. [5] Pathak et al. 2015, EPSC, Vol. 10, EPSC2015-550. [6] Pathak et al. 2018, LPSC, XXXXIX, 2046. [7] Schultz 1976, The Moon, Vol. 15, 241-273. [8] Goswami and Annadurai, 2009; Curr. Sci., 96(4), 486-961. [9] Green et al. 2011, JGR, Vol. 116, E00G19. [10] Boardman J. et al. (2011) *JGR* 116, E00G14. [11] Robinson et al. 2010, 38th COSPAR Scientific Assembly, 15–18 July 2010. Bremen, Germany, 11. [12] Smith et al. 2010, GRL, 37(18). [13] Lunar Source Book-A User's Guide to the Moon, 1991; ISBN 0-521--33444-6, pp. 61-116. [14] Dhingra et al. 2011, GRL, Vol. 38, L11201. [15] Klima et al. 2011, JGR, Vol. 116, E00G06.

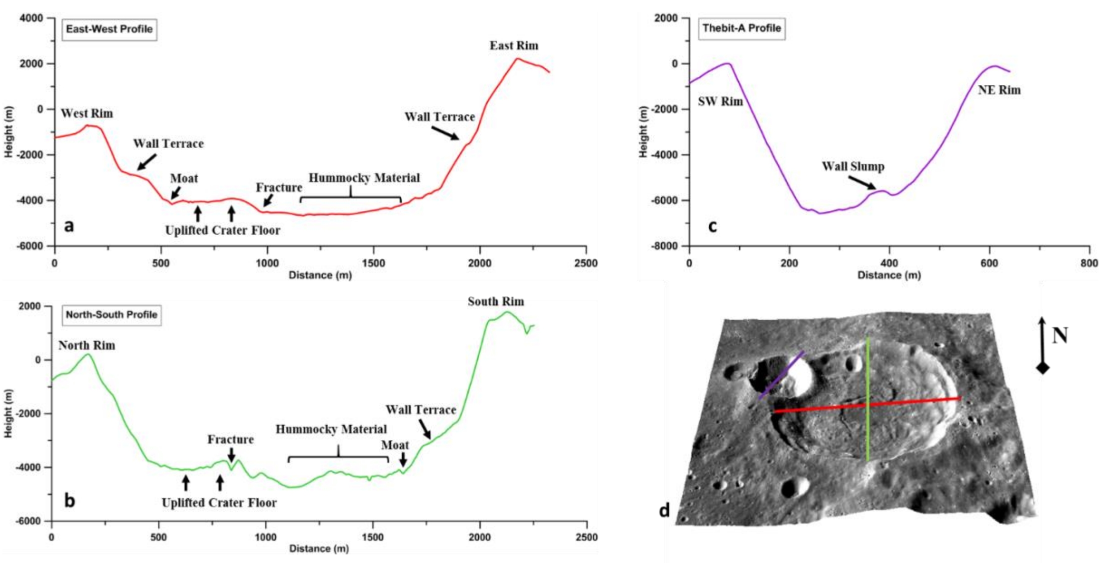

Figure 3: The figures show the (a) East-West and (b) North- South spatial profile of crater Thebit derived from LOLA-DEM data. (c) LOLA-DEM spatial profile of crater Thebit-A shows the steep crater wall. (d) The 3D image of crater Thebit has been prepared for topographic analysis.