EVIDENCE OF GLACIATION BASED ON PEAK RING MORPHOLOGY OF HUYGENS BASIN

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Introduction: Huygens crater is a giant impact crater centred at 13.5°S, 55.5°E lying within the Iapygia quadrangle of Mars in the south-western side of Syrtis Major planum between Terra Sabaea and Terra Tyrrhena. It penetrates the ejecta blanket of Hellas basin thereby exposing pre-Hellas crust, which is the oldest crust in the region. Post-impact the surface has been subjected to aqueous activity leading to formation of various alteration minerals such as Fe/Mg phyllosilicates present in small outcrops [1].

A very unique feature of Huygens is its peak ring structure. Unlike other craters in the surrounding region, this ring is not well preserved. This unique peak ring structure is an important feature as it helps in understanding the process of basin formation, the emplacement of the old and newer crust as well as the geological processes which occurred over time.

Data set and Methods: We have utilized data from Mars Colour Camera (19.5m/pix) aboard Mars Orbiter Mission, Context camera (6m/pix) aboard Mars Reconnaissance Orbiter and other global datasets which include basemaps of Thermal Emission Imaging System (THEMIS) day and night IR (100 m/pix), HRSC and MOLA Blended Digital Elevation Model (200m/pix). Each basemap was imported into ArcGIS 10.1 and THEMIS map was overlaid on HRSC MOLA Blended DEM for delineating various morphological features inside the peak ring of Huygens crater.

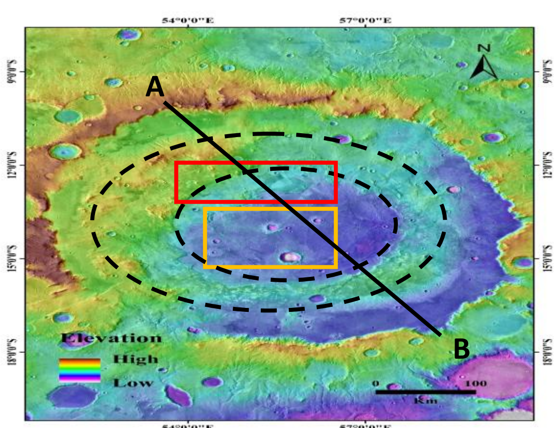

Fig. 1. THEMIS Day IR overlaid on HRSC MOLA Blended DEM showing Huygens crater. Dashed black lines are the peak rings of the crater. Solid black line is the cross-section along AB which profile graph in Fig. 2. is drawn. Yellow and red box show the location of Fig. 3. And Fig. 4. respectively.

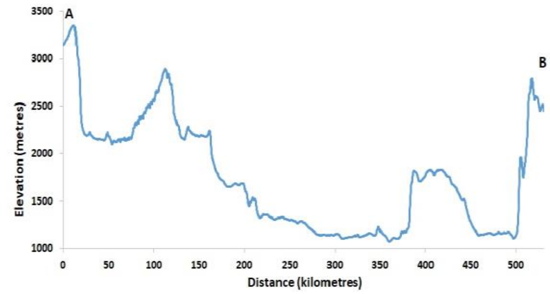

Fig. 2. Profile graph along AB the solid black line shown in Fig. 1. drawn using HRSC MOLA blended DEM

Observations: *Peak Ring.* It is a rugged circular structure comprising of disrupted peaks and massifs that rise above the surrounding crater basin area. Huygens appears to be a multi ring basin crater with inward facing scarp rings. Exterior to the peak ring, the basin is smooth and relatively flat whereas the central basin within the peak ring is filled with sediments of effusive volcanic events that took place in the later part of the Noachian period interpreted as younger mafic plains [1-2]. The crater rim and peak ring show decrease in elevation of around 550m and 400m respectively in the south-east direction. The graph (Fig. 2.) shows two scarp faces in the north-west direction, however distinction between the outer and inner peak ring is obscured on the opposite side. This may be due to erosional and/or volcanic activity in the later stages. Remnants of the peak ring are visible on the north-west side of the crater along with drainage channels.

Inner diameter of such craters depends on gravity of the planetary body, mean impact velocity as well as target properties of the material [3]. Various theories for the formation of the peak ring structure in large impact craters include collision of outward collapsing central uplift material with inward collapsing crater rim [4]. At the time of impact, the target material behaves like a fluid owing to stress higher than elastic stress limit [5]. This results in the emplacement of the basement crustal rocks over the collapsed transient cavity rim of the crater [6]. Following this theory, basin exterior to the peak ring is the older crust, part of which has slumped beneath the basement material of the peak ring. This peak ring is however different from the one observed in the nearby Schroeter crater. This further proves modification of the original basement material by volcanic activity in the later period.

Rampart craters. Single as well as double layered ejecta craters of varying size are found inside the peak ring of the Huygens crater. Circular, sinuous, pancake, radial type of morphologies are observed in the ejecta blankets of these craters. Even craters of comparable size show different lobate morphologies in the same area pointing towards decreasing volatile content over the impact times of these craters.

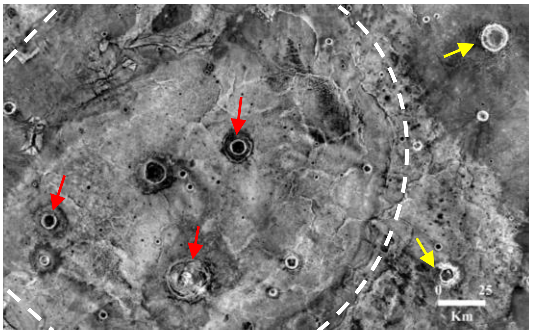

Fig. 3. *THEMIS Night IR showing rampart crater inside and outside the peak ring (dashed white lines). Note the bright rim of the craters and dark basin and ejecta layers interior of the peak ring (red arrows) and comparitively brighter basins and ejecta to the outside of the crater peak ring (yellow arrows).*

Generally, the edges of the ejecta layer appear brighter in THEMIS night IR than the inner part due to segregation of coarse particles at the periphery owing to kinetic sieving process [7]. However, rampart craters in this area lack thermal distinction between their lobes and ejecta boundaries. The rims appear bright but the inward face of the craters is dark and is barely visible in the thermal images (Fig. 3.). This suggests that the ejecta including the edges and insides of some craters are covered with thick dust mantling indicating topo-graphically influenced dust deposition inside the peak ring. Rampart craters however exterior to the peak ring have bright crater basins which implies that particle distribution during the ejecta emplacement in the high-er regions has not been completely overshadowed by dust deposition and still retains original characteristics.

Eskers. The sinuous ridges, or eskers, seen in the northern side of the peak ring basin are an outcome of fluvio-glacial activity in the area. These are branched and often interrupted in places (Fig. 4.). They seem to have formed due to melting of basal ice as a result of internal heating and as the ice melted over time, sub-glacial tunnels filled with deposits remained forming long winding ridges [8-9].

Discussion: Even though most of the bedrock and pre-Hellas crust exposed at the time of impact is now buried under layers of alteration minerals and dust, some remnants are still visible. The channels on the north-west peak ring and crater rim show dendritic patterns not typical of lava flow. This confirms fluvial activity in the later stages of the modification process. However, we propose a period of glaciation wherein Huygens was covered with ice.

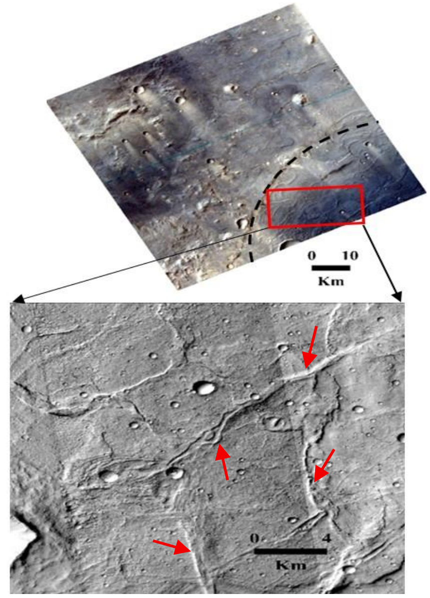

Fig. 4. (A) *MOM image showing sinuos ridges, or eskers, inside the peak ring (dashed black line)* ***(B)*** *Zoomed in high resolution CTX mosaic of the region highlighted in Fig. 4(A).*

The channels appear deep and resistant to erosional activities and may thus be result of repeated freezing and thawing of ice and its movement downhill. This is also in agreement with the fact why morphology of peak ring of this crater differs substantially from Schroeter crater in the area. Further, high resolution gravity anomalies and seismicity records may help in better understanding of the formation of the peak ring and give us insight into the early history of Mars. Moreover, channels and eskers observed within the crater basin might be suitable regions harbouring life and therefore may serve as unique areas to search for biosignatures in future exploratory missions.

References: [1] Ackiss et al. (2015), *First Landing Site/Exploration Zone Workshop for Human Missions to the Surface of Mars*, 1879(1032). [2] Morgan et al. (2000), *Earth Planet Sci Lett*, 183(3), 347-354. [3] Baker et al. (2011), *Planet Space Sci*, *59*(15), 1932-1948. [4] Morgan et al. (2000), *Earth Planet Sci Lett*, 183(3), 347-354. [5] Collins et al. (2002), *Icarus*, 157(1), 24-33. [6] Morgan et al. (2016), *Sci*, 354(6314), 878-882. [7] Baratoux et al. (2005), *JGR: Planets*, 110(E4). [8] Munro-Stasiuk et al. (2009), *Megaflooding on Earth and Mars*, 78. [9] Gallagher, C. and Balme, M. (2015), *Earth Planet Sci Lett*, 431, 96-109.