EPSC Abstracts
Vol. 6, EPSC-DPS2011-1850, 2011
EPSC-DPS Joint Meeting 2011

Surface age and morphology of Hermite crater of lunar North Pole using high resolution datasets.

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Abstract

The lunar poles feature a mini-environment that is almost entirely unknown to planetary scientists. Hermite crater (104 km, diameter) is an impact crater located close to the north pole of the Moon. Some of the portions are permanently shadowed regions including the coldest place in the solar system. This region was studied using high resolution data sets of TMC images and LOLA topography, recently acquired by Chandrayaan-1 and Lunar Reconnaissance orbiter (LRO) respectively. Age of the Hermite crater was determined by crater size frequency technique using TMC images, which is about 3.91 Ga (~Nectarian age). Morphology/ morphometry of the crater is also studied using high resolution LOLA topography data.

1. Introduction

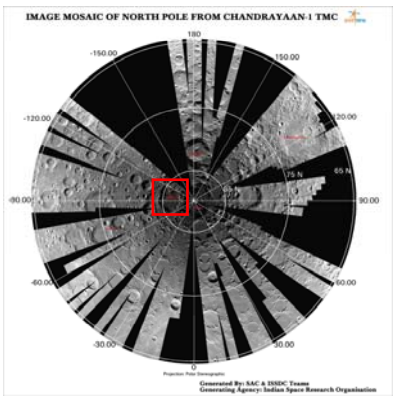
Chandrayaan-I, the first Indian planetary mission to Moon (22nd October, 2008) carried eleven different payloads. One of the sensors is Terrain Mapping Camera (TMC) having 5 m with spatial resolution[1]. The TMC imaged in push-broom mode in the panchromatic spectral band of 0.5–0.75µm with a stereo view in the fore, nadir and aft directions of the spacecraft movement and has a base to height ratio of one. A detailed study and exploration with high spatial and altitude sampling for scientific studies of polar regions were one of the objectives of the Mission. Lunar Orbiter Laser Altimeter (LOLA) of Lunar Reconnaissance Orbiter (LRO) has acquired the high resolution topographic data. Polar data used in this study was provided at 5m grid spacing [2].

The lunar poles feature a mini-environment that is almost entirely unknown to planetary science [3]. Because of a small tilt of the Moon's axis with respect to the Sun, craters and other depressions near the poles are permanently shaded from direct sunlight. As a consequence, these surfaces should have maintained extremely low temperatures, well under 100 K, for billions of years. There is some evidence that these surfaces act as cold traps, capturing and sequestering volatiles from the Moon and elsewhere. Most popular attention has focused on the possible presence of water ice/volatiles that might be used by astronauts in the future, offering a unique scientific resource. Thus polar regions are believed to be potential sites for future scientific explorations and resource utilizations [3,4,5,6].

Hermite crater (104 km diameter) is an impact crater located along the northern lunar limb, close to the north pole of the Moon. In 2009, NASA's Lunar Reconnaissance Orbiter discovered that the Hermite crater is the coldest place in the entire solar system, with temperatures at 26 kelvin (-248^0 C) [7]. Such cryogenic conditions in permanently shadowed region (PSR) can provide information about the volatile flux to the Earth-Moon system over past couple of billion years, linking this record to its bombardment history. The materials in the PSRs may have been redistributed and modified over the time, providing information about the geological processes that have been important on the Moon and by implication elsewhere in the solar system [8]. In view of these important scientific facts, the authors initiated this study.

2. Analysis and Discussion

The Chandrayaan-I TMC's view of Hermite crater is shown in Fig. 1 with the TMC's view/coverage of lunar North Pole. The image is a radial mosaic of TMC orbits 2975, 3245, 4600, 5290, 3897, 2965, 1828, 5438, and 1945. The precision of the image is 10m.



(a)

(b)

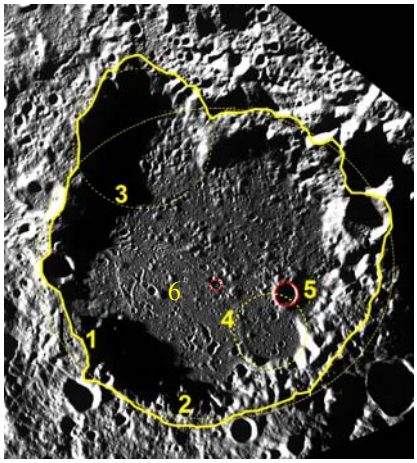


Fig. 1. (a) The Chandrayaan-I TMC coverage of lunar north pole showing the location of Hermite crater in red box outline and (b) TMC mosaic of Hermite crater. The irregular outline of Hermite crater appearing as a polygon. (1-The irregular outline/rim of Hermite carter; 2-proposed initial outline of Hermite crater; 3-Lenard crater, super-imposed over Hermite crater and the floor merging with Hermite crater; 4-submerged crater in Hermite crater, having faint irregular crater rim; 5 and 6-permanently shadow regions [9] which are reported and believed to be sites for ice/water-ice)

As is shown in Fig. 1b, Hermite crater is having an obliterated rim outline with several superimposed post-impact secondary craters which modified and distorted its original shape and the rim. Lenard crater is superimposing over south-western part of the rim of Hermite crater and the floor is also submerged with each other. Another crater is in the north-eastern part of the floor of Hermite crater with its faintly visible rim outline, and submerged/flooded floor. The floor of the Hermite crater is more or less flat (as is shown in the topographic profile). In the floor, along the southern part, some linear trough like features are there. As seen in the images, a range of craters exist signifying younger to older age (very simple fresh craters and eumorphic craters, shallow profile craters, sub merged/super imposed craters altering their shape and sizes well as hummocky and odd shaped craters). The two craters marked with 5 and 6 are permanently shadow areas reported [9] for having potential sources of ice/water-ice and volatiles. There are other craters also as visible in the image which could be the sites for permanently shadow regions [10]. The shadow regions along the southern periphery of the rim and floor is reportedly the coldest place in the solar system, and mentionably it may be due to the permanently shadows, steep slopes and the geographical location.

This created an interest to determine the age of the Hermite crater which was determined by Crater Size Frequency Distribution (CSFD) technique using 'craterstat' tool [11]. Craters were mapped using 'cratertools' in ARCGIS-9.2 [12], thus the age of the floor of Hermite crater is found to be 3.91 Ga, i.e Nectarian age. It is noteworthy that the USGS map, I-1062 suggests that the floor of the Hermite crater belongs to Imbrian age as "IP_1; Older plains material-light, fairly, smooth, flat to locally undulatory surface, crater density like that on Fra Mauro Formation; Contacts locally diffuse"[13]. Further refinement of our result is going on and the age dating of the rim and nearby regions are to be attempted.

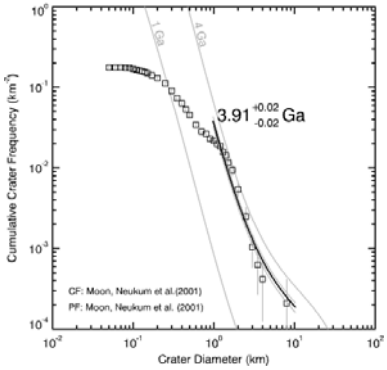


Fig. 2: CSFD plot showing the age of the floor

As a part of the initiation of the study, LOLA (LRO) topography is taken to complement the study, so as to understand the topographic variations. Three profiles are shown, showing variation from rim to floor, and also the depth/topographic profile of the permanent shadow region as well the deepest portion in Hermite crater. The deepest crater is located in the SE portion of the Hermite crater, showing a very sharp non-degraded circular rim outline suggesting younger age compared to the Hermite crater. Although the floor is having a rugged topography with uneven depressions and mounds, it is almost flat.

The floor and the craters, labeled as 5 and 6, are having depths of approximately -2000 m, -3500 m and -2700 m respectively, while the rim is at a height of about 500 m. The rim height from crater floor is about 2500 m.

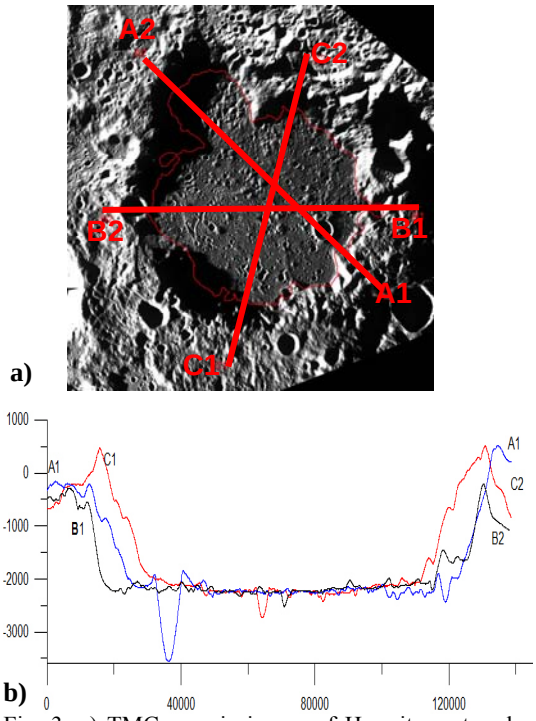


Fig. 3. a) TMC mosaic image of Hermite crater showing the profiles and b) Topographic profiles across the Hermite crater with red outline showing the floor.

There are no signs of central peak, concentric rim structure or step-faulted outer rim. This is interesting as the size of the crater is significantly large and equitable with complex craters. It is evident that no matter what the original shape and structure of this crater might have been, it has degraded over the period of time loosing the sharpness and original elevations of the rim, thus suggestive of very old age of this crater which has been quantitatively established using CSFD technique. The smaller simple craters on the floor, showing very sharp and non-degraded rim structures, suggests much younger age and more interestingly they engulf cryogenic conditions within. It will desirable determine the absolute age of this craters and map all such craters as they seem to be water-ice traps. An absolute age estimation of the floor, the outer rim and the surrounding regions will also improve the results establishing a chronology of events in this polar area. Compositional analysis is also initiated. Such an integrated analysis of morphology, composition and chronology will give a holistic understanding of permanently shadowed regions and extreme polar regions of the Moon. The large polygonal craters are interesting and needs to be understood well in time and space to un-reveal the scientific secrets of the polar regions which has remained virtually unexplored by planetary scientists so far.

Acknowledgements:

The authors express sincere gratitude to Dr. R. R. Navalgund, Director, Space Applications Centre (SAC), Ahmedabad for his encouragement and guidance. We are thankful to Greg Michael, Freie Universitat, Germany for his immense help in implementing CSFD. We are also thankful to SPDCG-SIPA/SAC for providing relevant TMC datasets. Authors are thankful to NASA teams of Lunar Orbiter Laser Altimeter (LOLA/LRO) and Lunar Orbital data explorer for providing high resolution data sets used in this study.

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