Lunar Domes near the craters Luther and Hall: a preliminary report

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The current study describes two lunar domes, located near the craters Luther and Hall (which we termed Luth1 and Hall1). The morphometric characteristics of the domes have been examined by making use of a combined photoclinometry and shape from shading approach [1-2] and Lunar Reconnaissance Orbiter (LRO) WAC image, including LOLA DEM data set. In the LRO WAC imagery the examined domes are not as prominent as in the telescopic CCD images taken under lower solar illumination angle.

Ground-based observations

A telescopic CCD image of the examined lunar region, near the crater Luther located to northwest of Posidonius, is shown in Fig. 1.

The image was taken on October 18, 2019 at 00:21 UT by Zannelli using a DK 20” telescope with aperture of 508 mm f/14. For image acquisition a GS3-U32356M-C camera was employed.

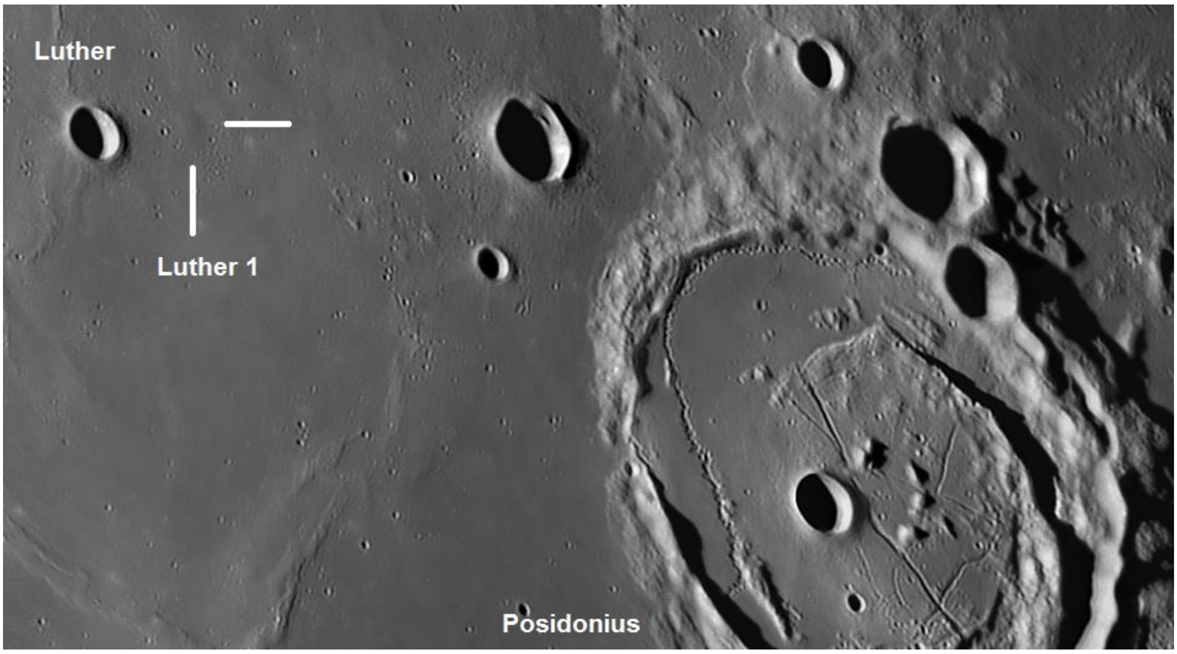

Figure 1: Telescopic CCD image made on October 18, 2019 at 00:21 UT by Zannelli. Crop of the original image. The dome Luther 1 (Luth1) is marked with white lines.

Another image of the dome Luther 1 was made by Teodorescu on October 10, 2017 at 04:02 UT using a 355 mm Newtonian telescope and ASI 174MM camera (Fig. 2).

Fig. 3 displays the second examined dome, termed Hall 1. The image was taken on October 18, 2019 at 00:21 UT by Zannelli.

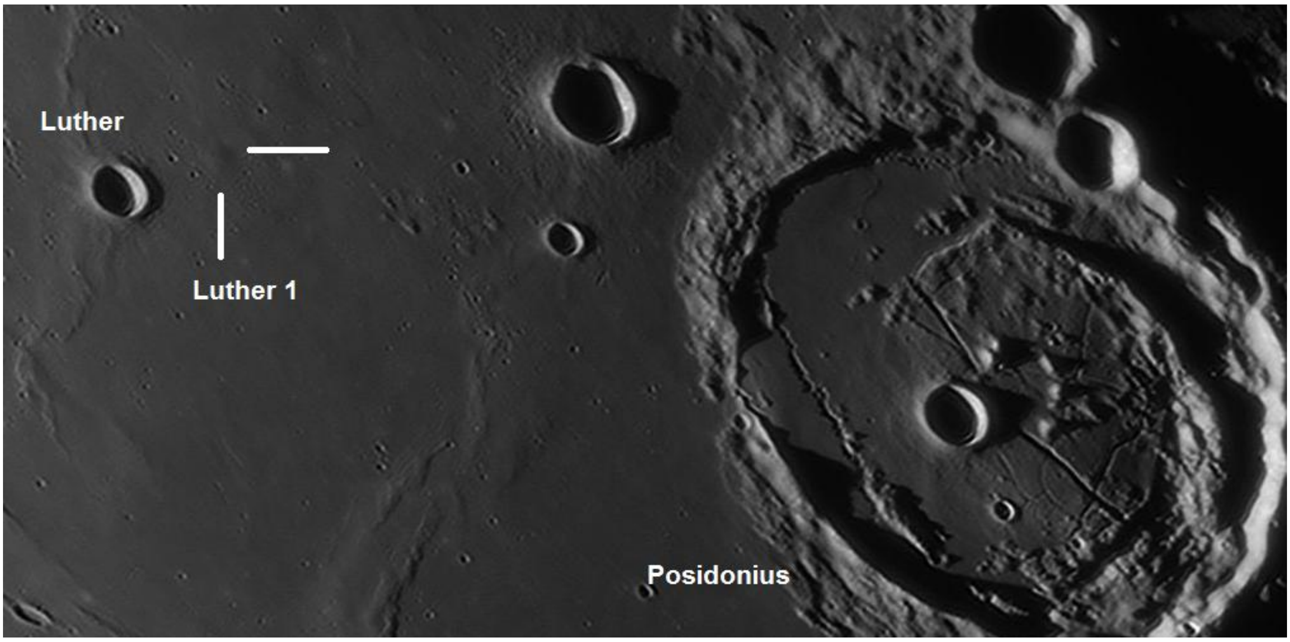

Figure 2: Telescopic CCD image made on October 10, 2017 at 04:02 UT by Teodorescu. Crop of the original image. The dome Luther 1 (Luth1) is marked with white lines.

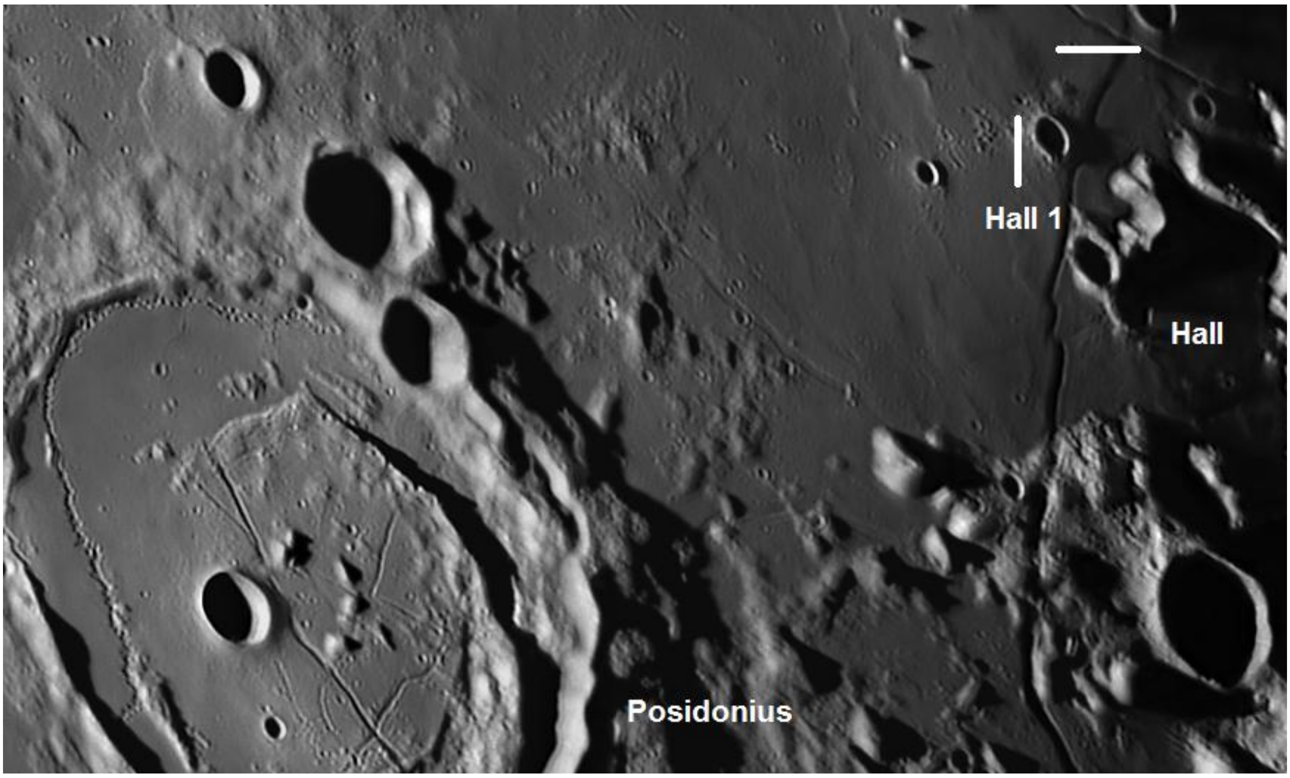

Figure 3: Telescopic CCD image made on October 18, 2019 at 00:21 UT by Zannelli. Crop of the original image. The dome Hall 1, located to the north of the crater Hall, is marked with white lines.

Digital elevation map based on telescopic CCD imagery

Generating an elevation map of a part of the lunar surface requires its three-dimensional (3D) reconstruction. A well-known image-based method for 3D surface reconstruction is shape from shading (SfS). It makes use of the fact that surface parts inclined towards the light source appear brighter than surface parts inclined away from it. The SfS approach aims for deriving the orientation of the surface at each image location by using a model of the reflectance properties of the surface and knowledge about the illumination conditions, finally leading to an elevation value for each

image pixel [3]. The SfS method requires accurate knowledge of the scattering properties of the surface in terms of the bidirectional reflectance distribution function (BRDF).
The iterative scheme used for photoclinometry and SfS approach is described in previous articles published in [4-6].
The height h of a dome was obtained by measuring the altitude difference in the reconstructed 3D profile between the dome summit and the surrounding surface, considering the curvature of the lunar surface. The average flank slope ζ was determined according to: $\zeta = \arctan 2h/D$. The uncertainty results in a relative standard error of the dome height h of ±10 percent, which is independent of the height value itself. The dome diameter D can be measured at an accuracy of ± 5 percent. The 3D reconstruction of the dome Luther 1 is reported in Figs. 4-5, while the 3D reconstruction of Hall 1 is shown in Fig. 6.

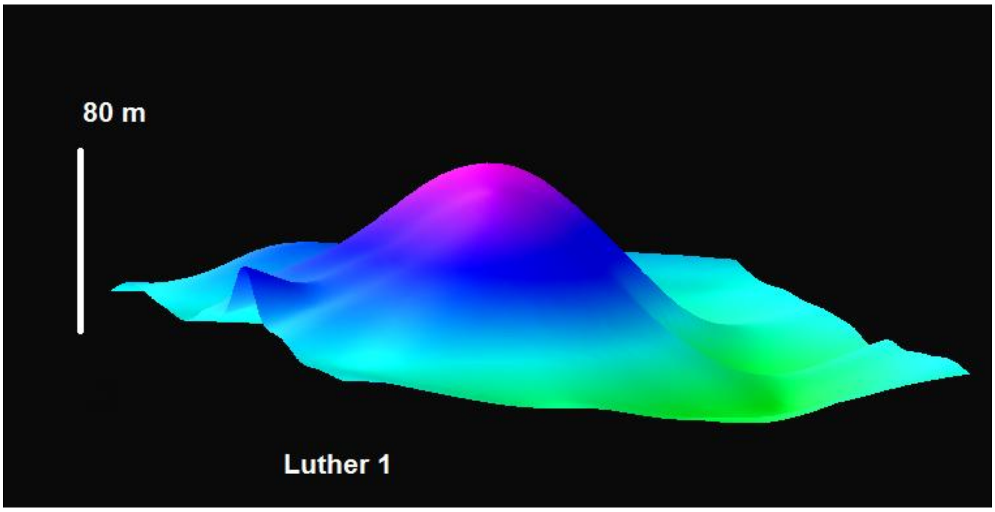

Figure 4: 3D reconstruction of Luther 1 based on terrestrial CCD image of Fig. 1 by photoclinometry and SfS analysis. The vertical axis is 20 times exaggerated.

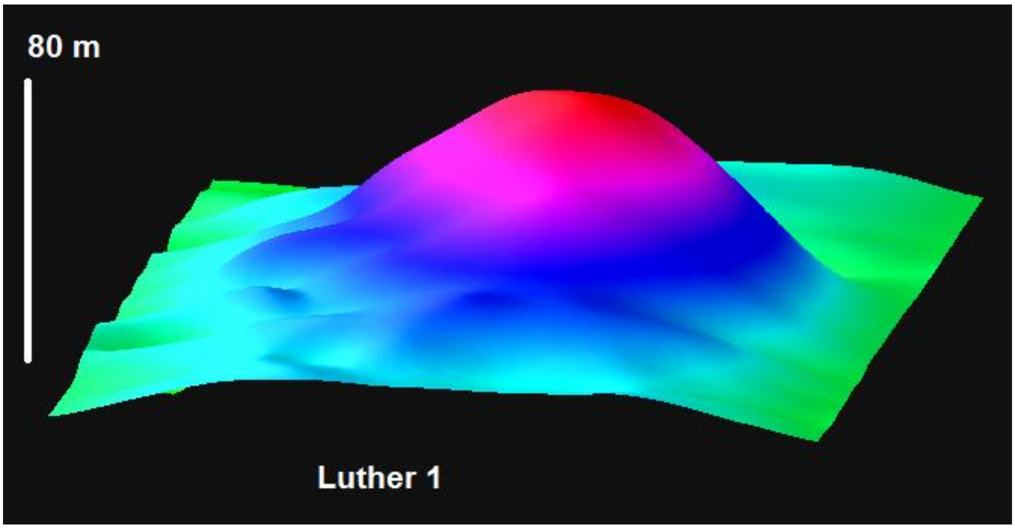

Figure 5: 3D reconstruction of Luther 1 based on terrestrial CCD image of Fig. 2 by photoclinometry and SfS analysis. The vertical axis is 20 times exaggerated.

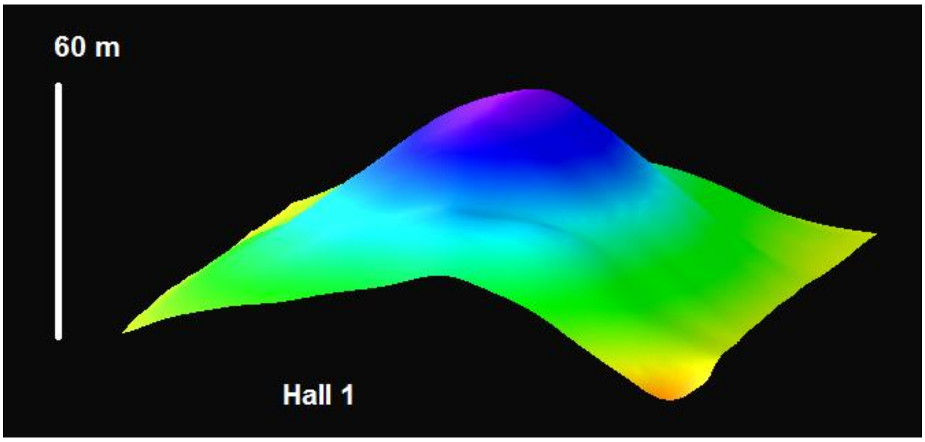

Figure 6: 3D reconstruction of Hall 1 based on terrestrial CCD image of Fig. 3 by photoclinometry and SfS analysis. The vertical axis is 20 times exaggerated.

LOLA DEM

ACT-REACT Quick Map tool [7] was used to access to the LOLA DEM dataset, allowing to obtain the cross-sectional profiles for the examined domes (Figs. 7-8).

Note the agreement of the measurements carried out on CCD telescopic images and the LOLA DEM.

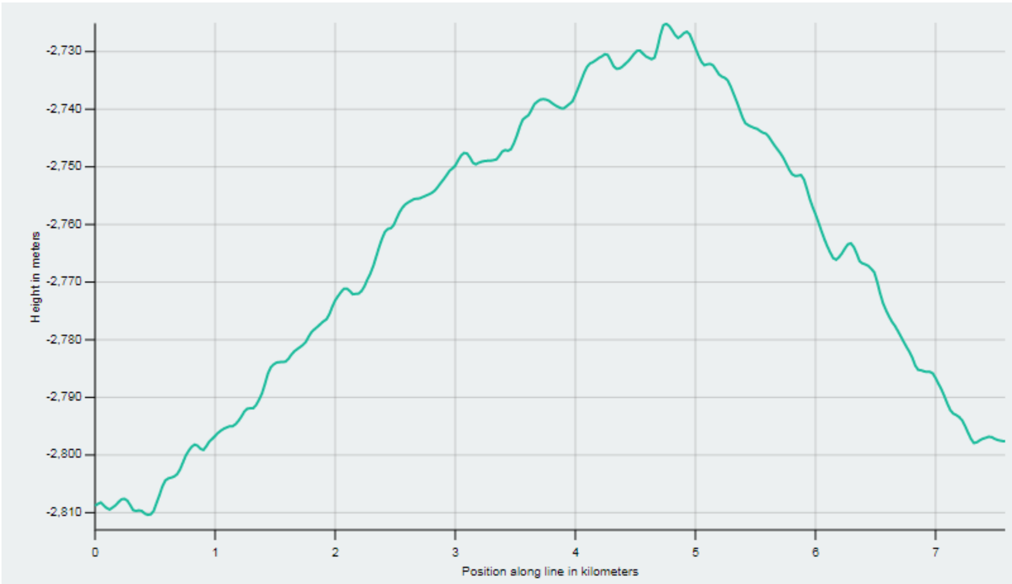

Figure 7: LRO WAC-derived surface elevation plot of Luther 1 based on LOLA DEM.

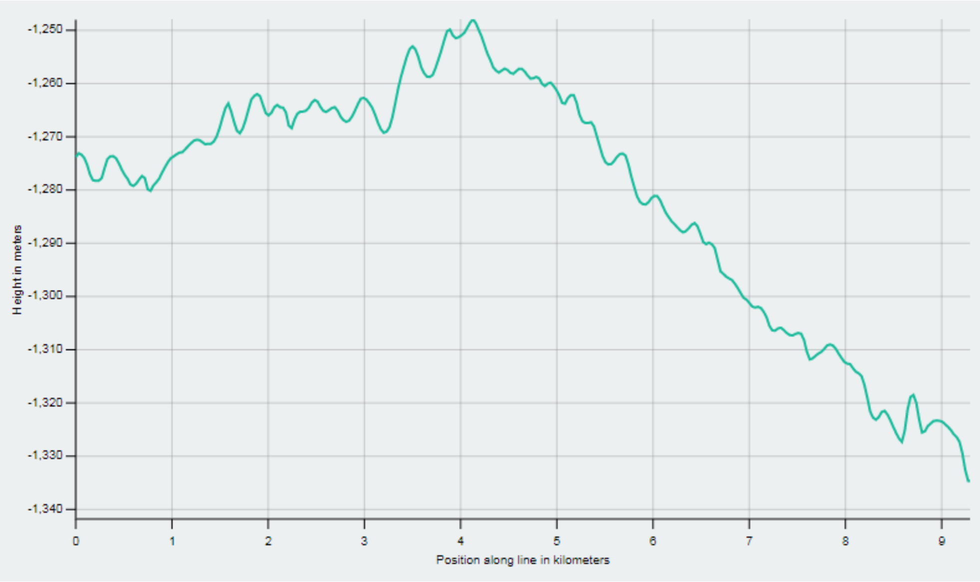

Figure 8: LRO WAC-derived surface elevation plot of Hall 1 based on LOLA DEM.

Results and discussion

Factors governing the morphological development of volcanic edifices are interrelated, including the viscosity of the erupted material, its temperature, its composition, the duration of the eruption process, the eruption rate, and the number of repeated eruptions from the vent. The viscosity of the magma depends on its temperature and composition. Thus, the steeper domes represent the result of cooler, more viscous lavas with high crystalline content. On the Earth, low and flat edifices are formed by basaltic lavas, such as the large Icelandic shield volcanoes, while more viscous lavas (such as andesitic and rhyolitic lavas with higher silica content) tend to build up steep volcanic edifices [8].

Because of the low silica and alumina content and high iron and titanium content the lunar basalt lavas had a higher temperature, lower viscosity, and higher density than terrestrial basalt lavas [8]. Temperature has a strong influence on viscosity: as temperature increases, viscosity decreases an effect particularly evident in the lava flows [9].

Dome Luther 1

The dome termed Luther 1 is located at 24.89º E and 33.39º N, with a diameter of 7.5 km ± 0.3 km. The height amounts to 80 ± 10 m, yielding an average flank slope of 1.2° ± 0.1°. The dome edifice volume is determined to 1.7 km³ assuming a parabolic shape. The rheologic model [1, 10] yields an effusion rate of 168 $m^3 s^{-1}$ and a lava viscosity of 9.5 x 10^4 Pa s. It formed over a period of time of 0.4 years. The Clementine UVVIS spectral data indicate a low to moderate TiO_2 content with a color ratio R_{415}/R_{750} = 0.6028. According to the classification scheme for lunar domes [1] Luther 1 is situated between class C_2 and C_1.

Dome Hall 1

The dome Hall 1, located north of crater Hall, lies at coordinates 35.69 º E and 35.12° N, with a base diameter of 8.0 km ± 0.3 km. The height amounts to 60 m ± 10 m yielding an average flank slope of 0.90° ± 0.1°. The edifice volume is determined to 1.5 km^3. The rheologic model [1, 10] yields an effusion rate of 260 $m^3 s^{-1}$ and lava viscosity of 2.0 x 10^4 Pa s. It formed over a period of time of 0.2 years. The Clementine UVVIS spectral data reveal a colour ratio of R_{415}/R_{750} = 0.5591, indicating a low TiO_2 content.

According to the classification scheme for lunar domes [1] Hall 1 belongs to class C_2.

Diviner Lunar Radiometer Experiment and Christiansen Feature (CF)

The Lunar Reconnaissance Orbiter's (LRO) Diviner Lunar Radiometer Experiment (spatial resolution of 950 m/pixel) produces thermal emissivity data, and provide compositional information from three wavelengths centered around 8 μm that are used to characterize the

Christiansen Feature (CF), which is directly sensitive to silicate mineralogy and the bulk SiO_2 content. These spectral bandpass filters are centered at 7.00, 8.25, and 8.55 μm. The major minerals of lunar soils- plagioclase, pyroxene, and olivine- have different ranges of CF values [11]. The feldspar and high silicic material, including quartz, silica-rich glass, and alkali and ternary feldspars, are characterized by CF values of 7.8-7.3. In case of olivine abundances the CF values is >8.7 [11]. We used the ACT-React Quick Map to infer the CF map derived from Diviner. Analyses of the Diviner CF map for the examined domes reveals that they do not display the short wavelength CF position characterizes silica-rich lithologies like the Gruithuisen domes. The average CF position of Luther 1 and Hal 1 domes is 8.30 ± 0.1; this value is not significantly different from the average CF position of the typical basaltic maria, which is 8.30-8.40. Hence, the examined domes are not enriched in silica relative to the surrounding mare units and display a basaltic composition.

Conclusion

Two low lunar domes, termed Luther 1 and Hall 1, have been characterized in their morphometric properties. A full spectral analysis based on M^3 dataset is in progress. We encourage more high-resolution imagery of this wide lunar region so that we can have more data to identify further lunar domes not characterized in the morphometric and spectral properties yet. Please check also your past imagery and send them to us for the ongoing study (lunar-domes@alpo-astronomy.org).

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