AN EFFUSIVE LUNAR DOME IN THE LIGHT PLAINS OF THE CRATER METON

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Introduction: Due to the inferred non-uniform surface ages of the lunar light plains in northern-nearside latitudes, the origin of these regions cannot be exclusively attributed to Imbrium or Orientale impact ejecta and subsequent processes. More diverse modes of formation are indicated by multispectral data for many of these plains [1]. Their widespread distribution north of Mare Frigoris, smooth surfaces surrounded by much rougher highland areas, and albedo values significantly lower than those of the surrounding surface but higher than those typically observed for mare basalt suggest that light plains are important for understanding the geologic history of the Moon during and after the period of late heavy bombardment.

A stratigraphically and morphologically bimodal distribution of the smooth highland units north and northeast of Mare Frigoris is described in [2]. Nearside craters such as Meton, Barrow, and Goldschmidt display rim topographies showing evidence of lineated troughs associated with the Imbrium basin. The light plains in Meton are mapped as light, fairly smooth, flat to locally undulatory surfaces in USGS map I-1062. In this region, a surface type with typical highland characteristics and a second one with similarities to mare basalt are described in [1, 3]. The second type is mainly found close to the basaltic plains of Mare Frigoris, leading to the assumption that cryptomaria may be hidden under the light plains material. However, the existence of cryptomare units could not be verified so far by a detection of dark-haloed impact craters.

In this context, we identify a typical lunar effusive dome on the floor of Meton on typical light plains material, suggesting the occurrence of non-mare volcanism in the light plains regions.

Morphometric and rheologic dome properties: The selenographic position of the lunar dome on the floor of the crater Meton, which we termed Meton 1, is 19.73° E and 73.02° N. For the determination of its morphometric properties, we rely on telescopic CCD images acquired at oblique solar illumination (cf. Fig. 1), applying the combined photoclinometry and shape from shading technique described in [4] to generate the local DEM shown in Fig. 2. We found that the dome diameter corresponds to 14.5 km and its height to 90 m, resulting in an average flank slope of 0.71°, and the dome volume amounts to 4.5 km³. Accordingly, the rheologic model introduced in [5] yields a magma viscosity of 1.4×10^4 Pa s, an effusion rate of 1900 $m^3 s^{-1}$, and a duration of the effusion process of 0.07 years. Based on the viscoelastic dike model proposed in [6], a magma rise speed of 7.3×10^{-3} m s^{-1}, a width of the feeder dike of 7.7 m and a length of 34 km can be inferred. According to its morphometric properties, the viscosity of the dome-forming magma, and the dike geometry, Meton 1 resembles lunar mare domes of class B_2 observed in the Hortensius region, western Mare Crisium, and Mare Undarum [4, 7].

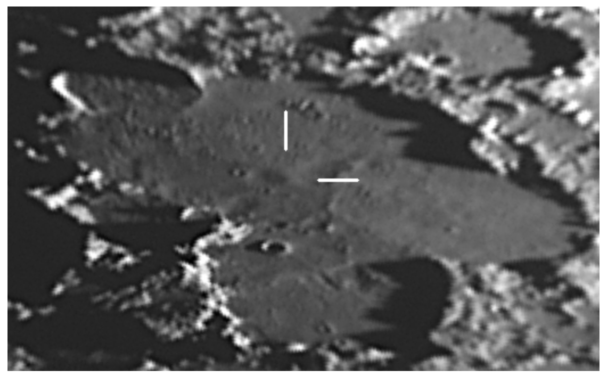

Fig. 1: Telescopic CCD image of the dome Meton 1, acquired on June 28, 2009, at 20:40 UT.

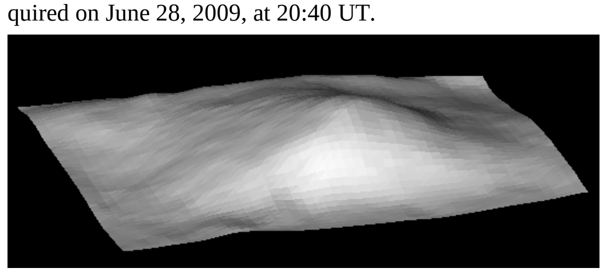

Fig. 2: Local DEM of the dome Meton 1. The vertical axis is 20 times exaggerated.

Spectral properties and elemental abundances: We estimated the abundances of the elements Ca, Al, Fe, Mg, Ti, and O of the light plains material on the floor of Meton based on characteristic spectral features extracted from Clementine UVVIS+NIR multispectral imagery (www.mapaplanet.org) [8], mapping them to Lunar Prospector gamma ray spectrometer data using the second-order polynomial regression method introduced in [9]. The utilised spectral features are the continuum slope of the spectrum, the width of the ferrous absorption trough around 1000 nm, and the wavelengths and relative depths of the individual absorption minima and inflection features. Furthermore, we determined the petrographic map shown in Fig. 3, which indicates the relative fractions of the three end-members mare basalt (red channel), Mg-rich rock (green channel), and ferroan anorthosite (blue channel) as proposed in [10]. The elemental abundance maps are shown in Fig. 4.

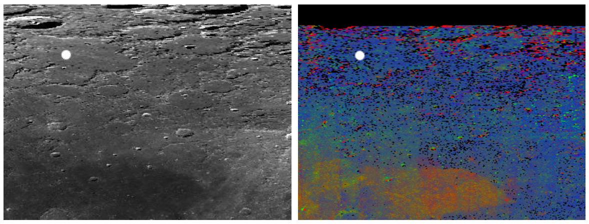

Fig. 3: Left: Clementine 750 nm image of the crater Meton and the region north of Mare Frigoris. Right: Petrographic map. The dome Meton 1 is marked by a white dot.

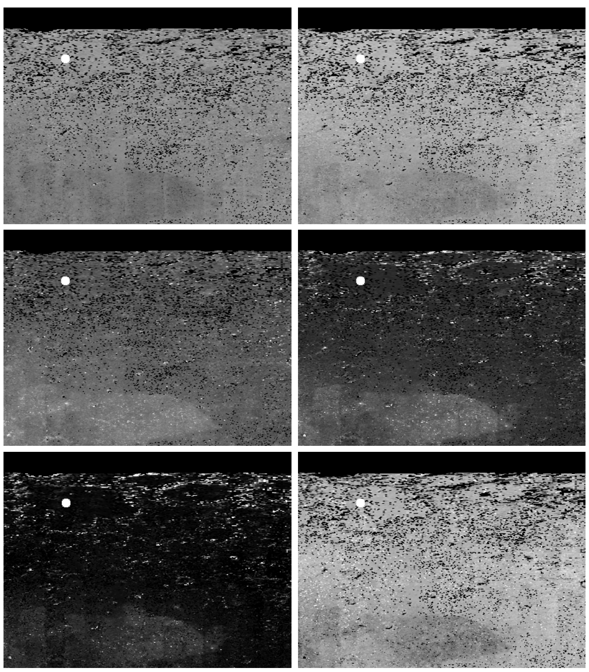

Fig. 4: Elemental abundance maps of (per row, top left to bottom right) Ca (grey value range 2–18 wt%), Al (0–20 wt %), Fe (0–25 wt%), Mg (0–16 wt%), Ti (0–6 wt%), and O (40–47 wt%). Spatial resolution is 0.1° (~3 km). In each map the dome Meton 1 is marked by a white dot.

The continuum-removed spectrum of the dome Meton 1 shows a shallow and narrow absorption trough with a minimum at 940 nm and a full width at half maximum of 170 nm, which is presumably due to pyroxene of moderate Ca content. The overall shape of the spectrum is highland-like, but the albedo at 750 nm is lower than the values measured for nearby highland terrain on the rim of Meton (0.20 vs. 0.31).

According to earlier works [11, 12], the basalts of Mare Frigoris are characterised by low Fe and Ti and high Al abundances. These findings are confirmed by our Fe and Ti abundance maps shown in Fig. 4. The petrographic map shown in Fig. 3 furthermore reveals a high content of Mg-rich rock. Due to the absence of dark halo impact craters in the eastern Frigoris region, the observed spectral properties of the regolith do not appear to be the result of contamination of a typical mare surface by highland material but reflect an atypical composition of the mare basalt itself. The Al abundance map shows that the basalts of eastern mare Frigoris have an extraordinarily high Al content, as the contrast between them and the adjacent highland terrain to the east is unusually low. Aluminous mare basalts have an intermediate elemental composition between Fe-rich mare basalts and ferroan anorthosites [12].

According to Fig. 4, the inferred Al and Mg abundances of the dome Meton 1 are rather similar to those of the Frigoris basalts (14.6 and 5.0 wt% vs. 11.5 and 6.7 wt%), while its Fe and Ti abundances are much lower (3.8 and 0.2 wt% vs. 8.1 and 0.8 wt%). The petrographic map reveals that the Mg-rich rock fractions are similar for the dome Meton 1 and the Frigoris basalts, while the mare basalt fraction of the dome is lower and its ferroan anorthosite fraction is higher.

Conclusion: We have identified a lunar dome on the floor of the crater Meton, which consists of light plains material. The presence of this dome, whose morphometric properties are similar to those of typical effusive lunar mare domes of class B_2, suggests a volcanic origin of the light plains material. Our rheologic modelling results indicate that the dome was formed by low-viscosity lava. When assuming a vertical extension of the dome-forming dike comparable to its inferred length [7], the origin of the dome material is in the lower lunar crust. The basalts of Mare Frigoris as well as the surrounding highland and light plains material are characterised by exceptionally large amounts of Mg-rich rock material. The composition of the dome-forming lava is not typical of mare basalt due to its high Al and low Fe and Ti content. Hence, our results suggest the occurrence of a possibly non-mare volcanic episode in the region north of Mare Frigoris.

References: [1] Koehler et al. (2000), *LPSC XXXI*; [2] Lucchitta (1978), USGS Geol. Sum. Misc. Invest. Set. Map 71062; [3] Koehler et al. (1999), *Workshop New Views of the Moon II*; [4] Wöhler et al. (2006), *Icarus 183*; [5] Wilson and Head (2003), *J. Geophys. Res. 108 (E2)*; [6] Rubin (1993), *Earth Planet Sci. Lett. 199*; [7] Lena et al. (2008), *Planet. Space Sci. 56*; [8] Evans et al. (2009), *LPSC XXXX*; [9] Wöhler et al. (2009), *EPSC 2009*; [10] Berezhnoy et al. (2005), *Planet. Space Sci. 53*; [11] Taylor et al. (1996), *LPSC XXVII*; [12] Kramer et al. (2009), *LPSC XXXX*.