Lunar Domes in Cauchy Region: Morphometry and Mode of Emplacement. R. Lena[1] and J. Phillips[2] - Geologic Lunar Research (GLR) Group. [1]Via Cartesio 144, sc. D, 00137 Rome, Italy; r.lena@sanita.it ; [2]101 Bull Street, Charleston, SC 29401, USA; thefamily90@hotmail.com .

Introduction: Lunar mare domes are smooth low features with gentle convex upward profiles. In previous works we have introduced a novel classification scheme and have examined for a variety of lunar mare domes the relationship between the conditions in the magma source regions and the resulting eruption conditions at the surface [1-3]. The typical hemispherical or flat mound with summit pit is widely accepted to be the lunar equivalent of terrestrial small shield volcanoes [4]. Many other lower rises have more gentle slopes and lack the summit pit and sometimes the roughly circular outlines of classical domes. Some of these domes are exceptionally large, strongly elongated, characterised by very low flank slopes in the range 0.1°–0.9°, and most of them are associated with faults or linear rilles of presumably tensional origin [5-6]. These domes might be interpreted as surface manifestations of laccolithic intrusions formed by flexure-induced vertical uplift of the lunar crust.

Laccoliths have recently been proposed to explain various geological features such as domes or floor-fractured craters on the surface of the Moon and also Mars and Mercury [7]. The Geologic Lunar Research (GLR) group has an ongoing project to study lunar domes with the purpose of their classification [8]. In this contribution we thus provide an analysis of four domes located in Mare Tranquillitatis, near Rima Cauchy, which have previously not been examined in detail in a previous work [1]. Accordingly we termed the examined domes as C14-17 (fig. 1).

dome	R_{750}	R_{415}/R_{750}	R_{950}/R_{750}
C14	0.0864	0.6437	1.0484
C15	0.0896	0.6355	1.0542
C16	0.0908	0.6452	1.0419
C17	0.0871	0.6434	1.0667

Table 1: Albedo at 750 nm and the spectral ratios R_{415}/R_{750} and R_{950}/R_{750} of the examined lunar domes.

General description: The examined domes are situated in the region around the 12 km crater Cauchy in northeastern Mare Tranquillitatis. These domes are approximately aligned parallel to the Cauchy rille and Cauchy fault (Fig. 1), demonstrating that they may have been emplaced along a fracture system.

Like the distribution of domes, this system of rilles is radial to the Imbrium basin and may have resulted from a reactivation of the structural weaknesses produced by the impact that formed the Imbrium basin 3.85 Ga ago.

Lunar Orbiter imagery acquired under a moderate solar elevation angle does not show these domes clearly but the vent of C15 is visible (cf. Fig 1).

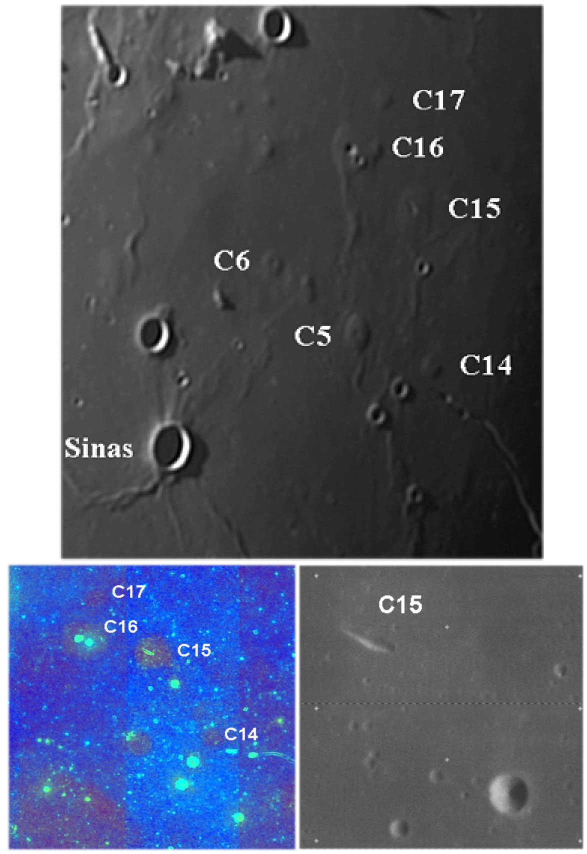

Fig. 1. Top: Telescopic image acquired on August 08, 2009, at 08:51 UT with a 200 mm aperture refractor. Bottom row: (left) Clementine colour ratio image of the examined region; (right) Lunar Orbiter image IV-073-H2 of C15 and the vent. Further domes in Cauchy region (e.g. C5-C6 domes in the telescopic image) have been described in a previous study [1].

Spectral properties: The older lavas in Mare Tranquillitatis are spectrally reddish and thus characterized by a low Titanium content, while the youngest lavas erupted in this region are spectrally blue (high Titanium content) [1,2]. For both domes, Clementine UVVIS spectral data (Table 1) indicate a R_{415}/R_{750} ratio of about 0.63-0.64 and furthermore reveal a 750 nm reflectance R_{750} of about 0.09 and a weak mafic absorption with R_{950}/R_{750} = 1.04-1.06, suggesting a high soil maturity.

Morphometric dome properties: Based on the telescopic CCD image we obtained DEMs of C14-C17 domes by applying the combined photoclinometry and shape from shading method described in [1-3]. The flank slopes, diameters, heights, and edifice volumes of these domes were extracted from the DEMs (Table 2). In the LOLA DEM, the elevation differences between the dome centres of C14-C15 and C17 and the surrounding surface correspond to about 50 m, which is in good agreement with our image-based photoclinometry and shape from shading analysis. The height of the flat and elongated C16 was determined to 90 m, resulting in a flank slope of 0.73°. Due to its elongated outline (circularity of 0.78) and flat summit, C16 is considered a candidate intrusive dome and belongs to class In2 introduced in [5-6].

Rheologic properties: For the examined effusive domes (C14-C15 and C17), the rheologic model developed in [1] yields high effusion rates of 250-780 $m^3 s^{-1}$. They formed from lava of viscosities about 10^3 Pa s, over a period of time of 0.14-0.22 years.

dome	long.	lat.	slope	D [km]	h [m]	V [km^3]
C14	33.92°	10.62°	0.73°	7.0	45	0.8
C15	33.19°	11.76°	0.48°	13.0	55	3.6
C16	32.35°	11.95°	0.73°	16x12.5	90	7.0
C17	32.44°	12.49°	0.82°	7.0	50	0.9

Table 2: Morphometric properties of the examined domes in Cauchy region.

dome	η [10^3 Pa s]	E [$m^3 s^{-1}$]	T [years]	U [10^{-3}Pa s^{-1}]	W [m]	L [km]
C14	2.9	278	0.14	4.0	3.8	17
C15	1.7	780	0.22	16	3.3	15
C17	4.8	250	0.18	2.5	4.7	21

Table 3: Rheologic properties and dike geometries inferred for the effusive examined.

According to [1-2] these low domes belong to class A and are typical representatives of rheologic group R_2. We found that the magma ascended at high speed of 10^{-3} m s^{-1} through dikes of widths between about 3 and 5 m (Table 3).

Assuming that the vertical extension of a dike is similar to its length L [9], the magma reservoirs are located in the upper crust, according to the thicknesses of the total crust and the upper crust in northern Mare Tranquillitatis given in [10].

Dome classification and laccolith modelling for C16: The dome C16 is of strongly elongated shape and a clear boundary is absent. The recent numerical modelling and scaling analysis by Michaut [11] of the magmatic intrusion processes leading to the formation of laccoliths strengthens the hypothesis of an intrusive origin of C16. For lunar laccoliths, an adjustment of the gravitational acceleration and the crustal elasticity (for the dry lunar crust the Young modulus E is assumed to be 2.5 times higher than for the terrestrial crust) leads to characteristic diameters of lunar laccoliths of 12–32 km and similar thicknesses for terrestrial and lunar laccoliths, which is also in accordance with the observational data, including the examined dome.

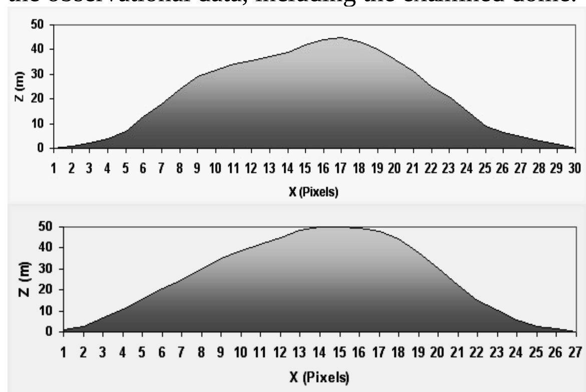

Fig. 2. Cross-sectional profile of C14 (top) and C17 (bottom).

Given the diameter D, the height h, the volume V, and the curvature radius r inferred from the DEM [6], we obtained a minimum thickness of the uppermost mare basalt layer of h1 = 0.19 km, an intrusion depth of d = 0.63 km and a maximum magma pressure of p_0 = 4.9 MPa.

Conclusion: To date, mare domes like those examined in this study, formed by lavas of low viscosity ascending at high speeds through narrow dikes, have only been found in Mare Tranquillitatis [1]. The low lava viscosities of class A domes may be due to the shallow depth of the magma reservoir, which prevents cooling and crystallisation of the magma during its ascent to the surface. According with the results of the laccolith modelling, the candidate intrusive dome termed C16 belongs to group In2 indicating that laccolith formation proceeded until the second stage characterised by flexure of the overburden [12].

References: [1] Wöhler et al. (2006) *Icarus 183*, 237-264; [2] Wöhler et al (2007) *Icarus 189*, 279-307; [3] Lena et al. (2007) *Planet. Space Sci. 55*, 1201-1217; [4] Head and Gifford (1980) *Moon and Planets 22*, 235-257; [5] Lena & Wöhler (2008) *LPSC XXXIX*, Abstract #1122; [6] Wöhler & Lena (2009) *Icarus 204*, 381-398; [7] Head et al. (2009) *Earth and Planet. Sci. Letters 285*, 251–262; [8] Lena & Wöhler (2008) http://digilander.libero.it/glrgroup/cldc.htm; [9] Jackson et al. (1997) *LPSC XXVIII*, abstract #1429; [10] Wieczorek et al (2006) *Rev. Mineral. Geochem. 60*,221-264; [11] Michaut (2011) *J. Geophys. Res. 116*, B05205, doi:10.1029/2010JB008108; [12] Johnson et al. (1973) *Tectonophysic*, *18*, 261–308.