**EFFUSIVE LUNAR DOMES IN MARE TRANQUILLITATIS: MORPHOMETRY AND MODE OF EMPLACEMENT.** K. C. Pau[1], R. Lena[2], C. Wöhler[3], M. T. Bregante[4], G. Sbarufatti[5] – Geologic Lunar Research (GLR) Group. [1]Flat 20A, Fook Chak House, Tung Fai Gardens, 17 Po Yan Street, Sheung Wan, Hong Kong; kcpaulhk@yahoo.com.hk; [2]Via Cartesio 144, sc. D, 00137 Rome, Italy; lena@glrgroup.org; [3]Daimler Group Research, P. O. Box 2360, D-89013 Ulm, Germany; christian.woehler@daimler.com; [4]Via Antica Romana Occ. 13, 16039 Sestri Levante Genova, Italy; breterrimar@yahoo.it; [5]Via Cabrini 10, 26842 Caselle Landi, Lodi, Italy; elyx69@libero.it

**Introduction:** Lunar mare domes are smooth low features with gentle convex upward profiles. They are circular to elliptical in shape. Isolated domes may be found in almost all maria, but significant concentrations occur in the Hortensius region, Oceanus Procellarum, and Mare Tranquillitatis [1]. These domes are commonly interpreted as shield volcanoes or laccoliths [2]. Recent studies about lunar domes are based on the evaluation of their spectrophotometric and morphometric properties, rheologic parameters, and their classification based on the spectral properties and three-dimensional shapes of the volcanic edifices [3,4,5]. In this contribution we provide an analysis of three domes located in Mare Tranquillitatis, which have previously not been examined in detail.

**General description:** Mare Tranquillitatis is situated on the site of an ancient pre-Nectarian impact basin [1]. The first examined dome is located inside the crater Carrel (Jansen B) at longitude 27.08° E and latitude 10.10° N (Figs. 1–4). It is a previously unreported dome with a diameter of 8.6 km, which we named Carrel 1 (Ca1). Lunar Orbiter imagery acquired under a moderate solar elevation angle does not show the dome clearly but a small positive relief on its flank is visible. It likely represents a pre-existing small peak embayed by the dome. A narrow rille lies just to the south of the dome. Possibly this linear feature is a graben formed by the stress field built up by a pressurised dike that did not reach the surface but ascended through a crustal fracture to a shallow depth, a mechanism suggested for the formation of narrow linear rilles like Rima Sirsalis or Rima Parry V [6,7,8]. Another low dome, located at 24.15° E and 11.29° N and having a diameter of 6.3 km, has been termed Arago 7 (A7), consistent with the designation of other domes in this region in our preceding study [5]. The third examined dome is situated in the region around the 12 km crater Cauchy in northeastern Mare Tranquillitatis, where the well known tectonic features Rima Cauchy (a graben) and Rupes Cauchy (a fault) are situated. This dome, termed C13, is located at longitude 39.32° E and latitude 13.50° N and has a diameter of 11 km (Figs. 5 and 6). It displays a summit vent and two protrusions which probably are pre-existing non-volcanic hills. Several other domes are apparent along Rupes and Rima Cauchy, which are in turn oriented radial to the Imbrium basin.

**Spectral properties:** The older lavas in Mare Tranquillitatis are spectrally reddish and thus characterised by a low Titanium content, while the youngest lavas erupted in this region are spectrally blue (high Titanium content) [4,5]. The Carrel complex largely represents the eastern rim of a ruined crater nearly completely buried by mare lava. In the Clementine colour ratio image, the crater ruin and ejecta from Carrel have the same reddish color as the mare surface around Jansen. The soil around Ca1 and also C13 is spectrally bluish, indicating a moderate $TiO_2$ content, while the dome A7 appears strongly blue, indicating basalts of high $TiO_2$ content (Figs. 4 and 5, Table 1).

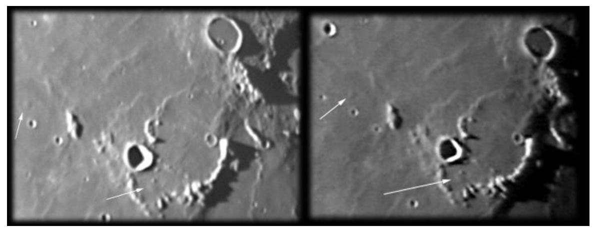

**Fig. 1:** Telescopic CCD images of the domes A7 (left arrow) and Ca1 (right arrow). For all images, north is to the top and west to the left.

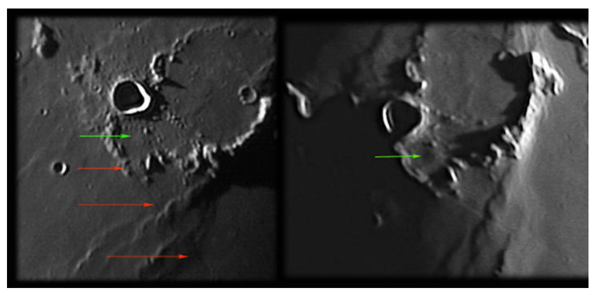

**Fig. 2:** Telescopic CCD images of the dome Ca1 (green arrow) and a linear rille south of it (red arrows), acquired at local sunset (left) and local sunrise (right).

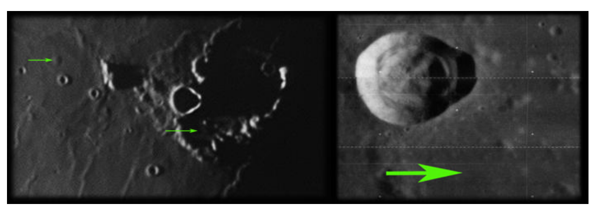

**Fig. 3:** Left: Telescopic CCD image of the domes A7 and Ca1 under strongly oblique illumination. Right: Lunar Orbiter image IV-178-H2.

**Morphometric dome properties:** Based on the telescopic CCD images we obtained DEMs of the examined domes by applying the combined photoclinometry and shape from shading method described in [5]. The flank slopes, diameters, heights, and edifice volumes of these domes were extracted from the DEMs (Table 2). According to [4,5] the low domes Ca1 and A7 belong to class A, while the dome C13 is of subclass $C_2$ with a tendency towards class A due to its somewhat larger diameter and high edifice volume.

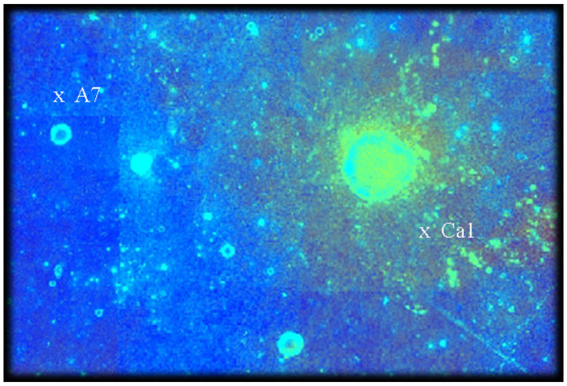


**Fig. 4:** Clementine colour ratio image of the Carrel region with the domes A7 and Ca1.

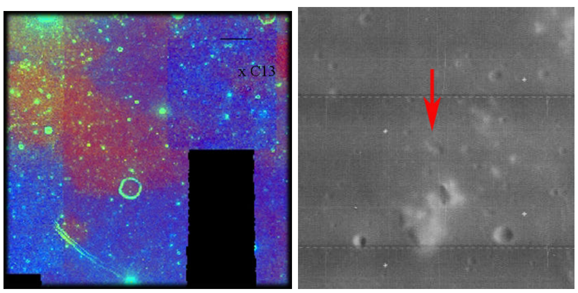


**Fig. 5:** Left: Clementine colour ratio image of the dome C13. Right: Effusive vent of dome C13 (LO-IV-73-H2).

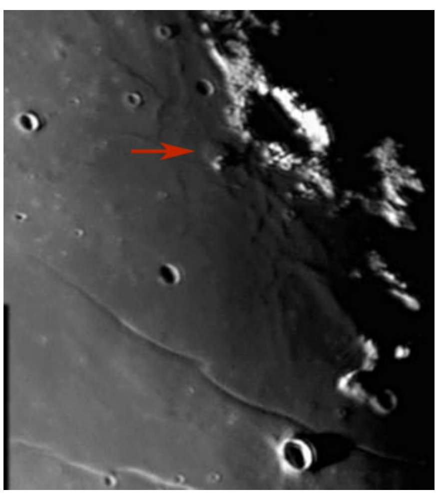

**Fig. 6:** Telescopic CCD image of the dome C13 (marked by red arrow).

| dome | long. | lat. | 750 | 415/750 | 950/750 |
|---|---|---|---|---|---|
| A7 | 24.15° | 11.29° | 0.0804 | 0.6794 | 1.0604 |
| C13 | 39.32° | 13.50° | 0.0867 | 0.6396 | 1.0686 |
| Ca1 | 27.08° | 10.10° | 0.0955 | 0.6402 | 1.0264 |

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

**Rheologic properties:** The rheologic model developed in [9], which depends on the morphometric dome properties, yields estimates of the lava viscosity $\eta$, the effusion rate E, and the duration T of the effusion process for a monogenetic lava dome. Using the morphometric values listed in Table 2, we obtained lava viscosities between 2 x $10^3$ and 4 x $10^4$ Pa s, effusion rates between 260 and 360 $m^3$ $s^{-1}$, and short durations of the effusion process between 0.07 and 0.6 years (Table 3). Furthermore, we estimated the magma rise speed U and the dike geometry (width W and length L) according to the model developed in [9]. We found that the magma ascended at comparably high speeds between 3 x $10^{-3}$ and 4 x $10^{-4}$ m $s^{-1}$ through dikes of widths between about 3 and 11 m (Table 3). Like the other known domes of class A [5], A7 and Ca1 are typical representatives of rheologic group $R_2$ as defined in [4], while C13 belongs to group $R_1$, being similar to the well-known dome Diana in northern Mare Tranquillitatis. Assuming that the vertical extension of a dike is similar to its length L [7], the magma reservoirs are located in the upper crust for the domes A7 and Ca1 and in the lower crust for C13, according to the thicknesses of the total crust and the upper crust in northern Mare Tranquillitatis given in [10].

| dome | flank slope [°] | D [km] | h [m] | V [$km^3$] | class | rheol. group |
|---|---|---|---|---|---|---|
| A7 | 0.82 | 6.30 | 45 | 0.6 | A | $R_2$ |
| C13 | 1.00 | 11.00 | 95 | 5.0 | A–$C_2$ | $R_1$ |
| Ca1 | 0.59 | 8.60 | 45 | 0.7 | A | $R_2$ |

**Table 2:** Morphometric properties of the examined domes.

| dome | $\eta$ [$10^3$ Pa s] | E [$m^3$ $s^{-1}$] | T [years] | U [$10^{-3}$ m $s^{-1}$] | W [m] | L [km] |
|---|---|---|---|---|---|---|
| A7 | 3.7 | 317 | 0.07 | 4.0 | 4.2 | 19 |
| C13 | 35 | 269 | 0.59 | 0.54 | 11 | 47 |
| Ca1 | 1.8 | 356 | 0.07 | 7.8 | 3.2 | 14 |

**Table 3:** Rheologic properties and dike geometries inferred for the examined domes in Mare Tranquillitatis.

**Conclusion:** To date, mare domes like those examined in this study, formed by lavas of high $TiO_2$ content and low viscosity ascending at high speeds through narrow dikes, have only been found in Mare Tranquillitatis (cf. [5]). The low lava viscosities may be partially due to the high $TiO_2$ content but also, at least for the domes A7 and Ca1, to the shallow depth of the magma reservoir, which prevents cooling and crystallisation of the magma during its ascent to the surface.

**References:** [1] Wilhelms (1987) *USGS Prof. Paper 1348*; [2] Head and Gifford (1980) *Moon and Planets 22*; [3] Lena et al. (2007) *Planetary and Space Science 55*; [4] Wöhler et al (2007) *Icarus 189*; [5] Wöhler et al. (2006) *Icarus 183*; [6] Head et al. (1980) *LPSC XI*; [7] Jackson et al. (1997) LPSC *XXVIII*; [8] Petrycki and Wilson (1999) *LPSC XXX*; [9] Wilson and Head (2003) *J. Geophys. Res. 108 (E2)*; [10] Wieczorek et al (2006) *Rev. Mineral. Geochem. 60*.