Lunar domes in the Cauchy shield. Identification of a Lunar dome (C34): Morphometry and mode of Formation.
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Introduction: Important clusters of lunar domes are observed in the Hortensius/Milichius/T. Mayer region in Mare Insularum and in Mare Tranquillitatis around the craters Arago and Cauchy [1-7]. A first map of the area under description, the Cauchy shield, was recently updated by the authors [11], and a classification of these domes was performed based on our previous works [1-6]. In this contribution we provide an analysis of another lunar dome, previously not introduced and described in our maps, termed C34. It lies at $15.98^{\circ} \mathrm{N}$ and $38.14^{\circ} \mathrm{E}$ (Figs. 1-2 and 5).

Morphometric and spectral properties: the WAC imagery displays a small and isolated dome (Fig. 1), with a central vent on the summit, located to the east of Maraldi D and to the north of Lucian crater. Associated topographic profile of the examined dome was extracted from the GLD100 data set (http://target.lroc.asu.edu/da/qmap.html).


Fig. 1: WAC imagery of the examined dome termed C34.
The 3D reconstruction using WAC mosaic draped on top of the global WAC-derived elevation model (GLD100) is shown in Fig. 2. The dome height, determined using GLD100 dataset, amounts to 120 m , its diameter amounts to 3.6 km , while the average slope angle corresponds to $3.8^{\circ}$ (Fig. 3). The volume is determined to $0.9 \mathrm{~km}^{3}$ assuming a parabolic shape. We have used the basic classification and mapping introduced in previous studies [1], including the distinction between effusive domes and putative intrusive domes, based on physical modeling.

Wilson and Head provide a quantitative treatment of such dome-forming eruptions [7]. This model estimates the yield strength, i. e. the pressure or stress that must be exceeded for the lava to flow, the plastic viscosity yielding a measure for the fluidity of the erupted
lava, the effusion rate E , i. e. the lava volume erupted per second, and the duration $T=V / E$ of the effusion process.


Fig. 2: 3D reconstruction. The vertical axis is 10 times exaggerated.


Fig. 3: Cross-sectional profile in E-W direction of the dome C34.

This model relies on the morphometric dome properties and several physical constants such as the lava density, the acceleration due to gravity, and the thermal diffusivity of the lava. In the computation we assume a magma density of $2,800 \mathrm{~kg} \mathrm{~m}^{-3}$. Based on the morphometric properties of the examined dome is inferred a lava viscosity of $3.5 \times 10^{6} \mathrm{~Pa} \mathrm{~s}$, an effusion rate of $\mathrm{E}=$ $24 \mathrm{~m}^{3} \mathrm{~s}^{-1}$, and a duration of the effusion process of $\mathrm{T}=$ 1 year.

The magma rise speed amounts to $\mathrm{U}=2.0 \times 10^{-6} \mathrm{~m}$ $\mathrm{s}^{-1}$ and the dike width and length to 52 m and 180 km , respectively.

With its high lava viscosity of $3.5 \times 10^{6} \mathrm{~Pa} \mathrm{~s}$ and broad $(\mathrm{W}=50 \mathrm{~m})$ and long $(\mathrm{L}=180 \mathrm{~km})$ feeder dike, the dome C34 belongs to rheologic group $\mathrm{R}_{3}$, as defined in [1, 4].

If it is assumed that the vertical extension of a lunar dike is comparable to its length L [8], the magma which formed C34 originated in the upper lunar mantle, well below the crust.


Fig. 4. Clementine colour ratio image of the examined region.


Fig. 5. Telescopic image acquired on April 20, 2018 at 19:18 UT using a Celestron Edge $9.25 "+2 x$ Barlow and Skyris 236 M CCD camera with an IR-Passfilter (Heinen).

Three rheologic groups of effusive lunar mare domes [1] differ from each other by their rheologic properties and associated dike dimensions, where the basic discriminative parameter is the lava viscosity. The first group $\mathrm{R}_{1}$, is characterised by lava viscosities of $10^{4}-10^{6} \mathrm{~Pa} \mathrm{~s}$, magma rise speeds of $10^{-5}-10^{-3} \mathrm{~m} \mathrm{~s}^{-1}$, dike widths around $10-30 \mathrm{~m}$, and dike lengths between about 30 and 200 km . Rheologic group $\mathrm{R}_{2}$ is characterised by low lava viscosities between $10^{2}$ and $10^{4} \mathrm{~Pa} \mathrm{~s}$, fast magma ascent $\left(\mathrm{U}>10^{-3} \mathrm{~m} \mathrm{~s}^{-1}\right.$ ), narrow ( $\mathrm{W}=1-4 \mathrm{~m}$ ) and short ( $\mathrm{L}=7-20 \mathrm{~km}$ ) feeder dikes. The third group,
$\mathrm{R}_{3}$, is made up of domes which formed from highly viscous lavas of $10^{6}-10^{8} \mathrm{~Pa} \mathrm{~s}$, ascending at very low speeds of $10^{-6}-10^{-5} \mathrm{~m} \mathrm{~s}^{-1}$ through broad dikes of several tens to 200 m width and $100-200 \mathrm{~km}$ length. From Clementine color ratio imagery (Fig. 4) the dome is spectrally somewhat redder than the surrounding mare basalts, such that it may be possible that it has been embayed by a layer of younger basalt richer in $\mathrm{TiO}_{2}$. Crater counts in Mare Tranquillitatis yield ages of 3.75 billion years for the redder lavas and 3.57 billion years for the blue lavas [9]. Stratigraphic relations described by Rajmon and Spudis [10] indicate that magmatic activity in Mare Tranquillitatis started with low- $\mathrm{TiO}_{2}$ lavas and gradually changed towards high- $\mathrm{TiO}_{2}$ lavas. The spectrally reddest unit covers the north-eastern and south-eastern corner of Mare Tranquillitatis and is presumably older than the high- $\mathrm{TiO}_{2}$ basalts, according to the different ages of the several units based on crater counts and reported by Hiesinger et al. [9].


Fig. 6. Chandrayaan-1's Moon Mineralogy Mapper $\left(\mathrm{M}^{3}\right)$ spectrum, optical period OP1B.

The examined volcanic dome displays a spectrum (Fig. 6) with a 1000 nm absorption centered at 965 nm and 2000 nm absorption centered at 2220 nm . Thus, the spectrum indicates a classic basaltic signature without evidence of volcanic glasses signature.

Based on the morphometric data obtained in this study, the dome C34 belongs to class $\mathrm{E}_{1}$ in the classification scheme of lunar mare domes [1]. The small dome is detectable in telescopic CCD images (Fig. 5). During our survey in Cauchy region (since 2006) we have identified and characterized a total of thirty-four domes and have updated the lunar domes map [11].

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