THE LUNAR DOME COMPLEX MONS RÜMKER: MORPHOMETRY, RHEOLOGY, AND MODE OF EMPLACEMENT.

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Introduction: The lunar volcanic complex Mons Rümker (sometimes spelled "Rumker") is situated in the northwestern part of Oceanus Procellarum. With a diameter of about 65 km, it is the largest known contiguous volcanic edifice on the Moon. According to [1], the plateau is composed of a series of overlapping lava flows interrupted by local extrusions related to domes and to a ring surrounding the central portion. Scarps and ridges on the plateau are preferrably oriented in northeastern and northwestern direction, with the northeastern direction dominating. Mons Rümker is aligned with the Aristarchus plateau and the Marius Hills along the axis of Oceanus Procellarum. Several individual domes can be distinguished on the plateau surface. A scarp separates the plateau from the surrounding mare plains.

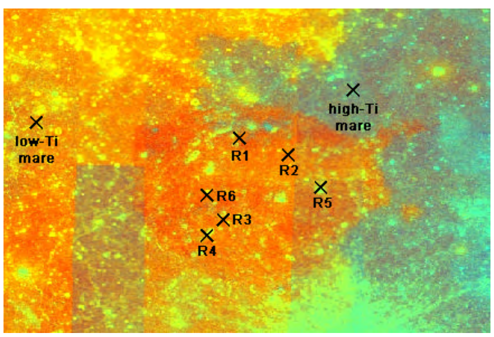

Fig. 1: Clementine colour ratio image of the Rümker dome complex, appearing as a strongly red unit. North is to the top and west to the left; 6° x 4°, centred at 58° W and 41° N.

Stratigraphic Relations, Spectral Properties: Clementine UVVIS data reveal that the surface of Mons Rümker appears largely uniform and consists of spectrally strongly red mare lava. A FeO content of about 18 wt% is given in [2]. The observed 950/750 ratios (Table 1) imply a weak to moderate mafic absorption, suggesting an overall high soil maturity. The low 415/750 ratios of 0.56-0.57 suggest a low TiO_2 content around 1 wt% [3]. Rümker is spectrally slightly redder than the low-Ti mare to its west and northwest. On its eastern side, the plateau is surrounded by spectrally bluer basaltic mare plains with a higher TiO_2 content of several wt%. According to [1], crater counts reveal that most of the plateau is made up by strongly cratered, smooth to gently undulating terrain (Fig. 2). A moderately cratered, younger unit near the centre has scarp contacts with the first units which are of lobate shape and interpreted as lava flows. A more lightly cratered and thus still younger unit situated in the western part of the plateau is characterised by northeast trending, gently undulating ridges.

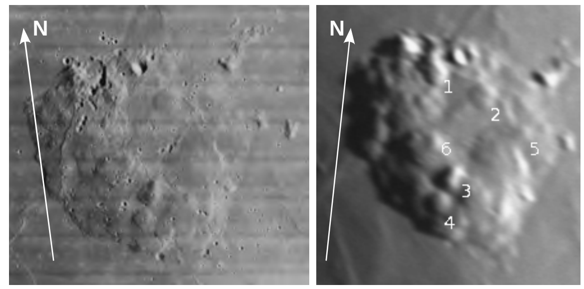

Fig. 2: Left: Section of Lunar Orbiter image IV-163-H2. Right: Telescopic CCD image of Mons Rümker, rectified to simple cylindrical projection. Image acquired on November 24, 2004, at 22:38 UT with a 250 mm aperture reflector. The individual domes R1-R6 are marked.

dome	750	415/750	950/750
R1	0.1127	0.5667	1.0410
R2	0.1166	0.5607	1.0305
R3	0.1104	0.5643	1.0369
R4	0.1124	0.5751	1.0013
R5	0.1162	0.5955	0.9718
R6	0.1072	0.5622	1.0428
high-Ti mare	0.1135	0.6205	1.0180
low-Ti mare	0.1095	0.5725	1.0218

Table 1: Albedo at 750 nm and the spectral ratios 415/750 and 950/750 of the six examined individual domes of the Rümker plateau and two locations in the mare plains northeast (high-Ti mare) and northwest (low-Ti mare) of the Rümker plateau (cf. Fig. 1).

Digital Elevation Map (DEM), Morphometric Dome Properties: Based on the telescopic CCD image shown in Fig. 2, acquired under oblique solar illumination, we obtained a DEM of Rümker by applying the combined photoclinometry and shape from shading method described in [4] (Fig. 3). To cope with the large size of the reconstructed surface part, we employed this technique as a multi-resolution approach to stabilise the convergence behaviour and facilitate at the same time the reconstruction of small-scale surface features. The DEM shows that the height of the plateau amounts to about 900 m in its western and northwestern part, 1100 m in its southern part, and 650 m in its eastern and northeastern part. The overall volume of erupted lava corresponds to about 1800 km^3. About 30 individual domes on the Rümker plateau are reported in [1], six of which are sufficiently well resolved in our telescopic image for morphometric evaluation. The flank slopes, diameters, heights, and edifice volumes of these six domes (cf. Fig. 2) were extracted from the DEM (Table 2). It has been shown in [4] that the relative error of the height and slope values amounts to 10% while the relative accuracy of the dome volumes is about 20%. A classification of the domes according to the scheme introduced in [4], relying on the spectral and morphometric dome properties, yields that due to their rather small diameters and spectrally red soils they belong to classes B_1, denoting steep flank slopes >2°, and B_2, representing lower slopes. Only the very small dome R5 is similar to the "cone-like" domes encountered in Mare Insularum near Tobias Mayer [4].

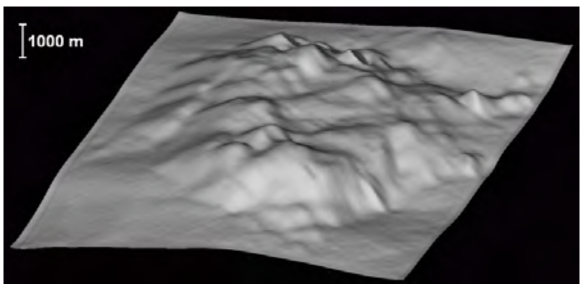

Fig. 3: DEM of Mons Rümker, viewed from south-eastern direction. The vertical axis is 10 times exaggerated.

dome	slope [°]	D [km]	h [m]	V [km^3]	class
R1	2.7	8.4	200	5.7	B_1
R2	1.6	9.1	130	4.3	B_2
R3	3.0	9.1	240	7.6	B_1
R4	2.7	7.3	170	3.7	B_1
R5	1.5	5.5	70	0.9	"cone-like"
R6	1.7	6.9	100	2.2	B_2

Table 2: Morphometric properties of the examined domes on the Rümker plateau.

Rheologic Properties: The rheologic model developed in [5], which depends on dome diameter, height, and volume, yields estimates of lava viscosity η, effusion rate E, and duration T_e of the effusion process for a monogenetic lava dome. We obtained values for η between 4 x 10^4 and 5 x 10^6 Pa s, E between 50 and 110 m^3 s^{-1}, and T_e between 0.4 and 4 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 [5]. In this model the ratio L/W is estimated based on the viscoelastic approach outlined in [6]. As suggested in [6], we set the ratio between magma pressure and elastic rock stiffness to $10^{-3.5}$. Under the assumption that the average dike length for the domes R1-R6 corresponds to the diameter of the Rümker plateau, we obtained a driving pressure gradient of the ascending magma of 689 Pa m^{-1}. For comparison, a minimum excess pressure gradient of 328 Pa m^{-1} is necessary for the magma to erupt on the surface [7]. A value of 1300 Pa m^{-1} is inferred in [5] for the Gruithuisen and Mairan highland domes due to the considerable positive buoyancy of the non-basaltic highland dome magma in the lunar crust [5,7]. We found that the magma ascended at low speeds between 2 x 10^{-5} and 5 x 10^{-4} m s^{-1} through dikes of widths between 6 and 39 m (Table 3). A pressure gradient of 328 Pa m^{-1} would lead to W and L values about twice as high as those listed in Table 3 and four times lower values for U. The dome pairs R2+R6 and R3+R4 are aligned in the same direction as the northeast trending linear features (Fig. 2). These pairs share similar rheologic properties and possibly originate from a common feeder dike, respectively (cf. Table 3).

dome	η [10^5 Pa s]	E [m^3 s^{-1}]	T_e [years]	U [10^{-5} m s^{-1}]	W [m]	L [km]
R1	24	61	3.0	2.4	29	88
R2	2.5	111	1.2	19	11	51
R3	48	60	4.0	1.8	39	85
R4	15	55	2.1	2.5	24	89
R5	0.4	75	0.4	55	6	25
R6	1.4	83	0.8	23	9	40
R2+R6	1.9	193	-	40	10	46
R3+R4	32	115	-	4.1	33	87

Table 3: Rheologic properties and dike geometries.

Conclusion: The examined domes on the Rümker plateau are typical mare domes [8] morphometrically similar to the class B domes in the Hortensius/Milichius/T. Mayer region [4]. Our rheologic modelling results confirm the qualitative suggestion in [9] that the domes were produced by low effusion rates, possibly during the terminal phases of the eruptions emplacing the plateau. The significant differences among the lava viscosities inferred for the domes cannot be attributed to compositional effects due to the observed spectral homogeneity but are more likely caused by different lava eruption temperatures and degrees of crystallisation (cf. [8]). Under the assumption that the vertical dike extension is similar to the dike length L [10], the magma sources were mostly located at the bottom of or below the lunar crust when a crustal thickness of ~50 km is assumed for the Rümker region [11].

References: [1] Smith (1974) *The Moon 10*; [2] Lucey et al. (1998) *J. Geophys. Res. 103 (E2)*; [3] Gillis and Lucey (2005) *Lunar Planet. Sci., XXXVI, #2252*; [4] Wöhler et al. (2006) *Icarus 183*; [5] Wilson and Head (2003) *J. Geophys. Res. 108 (E2)*; [6] Rubin (1993) *Earth Planet. Sci. Lett. 119*; [7] Wilson and Head (1996) *Lunar Planet. Sci., XXVII, 1445-1446*; [8] Whitford-Stark and Head (1977) *Lunar Sci. Conf. 8th, 2701-2724*; [9] Weitz and Head (1999) *J. Geophys. Res. 104 (E8);* [10] Jackson et al. (1997) *Lunar Planet. Sci., XXVIII, #1429*; [11] Wieczorek et al. (2006) *Rev. Mineralogy and Geochemistry 60*.