INTRUSIVE LUNAR DOMES: MORPHOMETRY AND MODE OF EMPLACEMENT

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Introduction: Lunar domes have formed as effusive shield-like volcanoes, or the magma remained subsurface as laccoliths. In the former case, lava flows accumulated around the vent, building up a volcano on the lunar surface. In the latter case, magma accumulated within the lunar crust, slowly increasing in pressure and causing the crustal rock above it to bow upward. Most lunar domes which are hemispherical and have summit pits are formed by outpouring of magma from a central vent (effusive eruption). The profile of domes that are flat suggests that there was no gradual inclination at the vent (the rising lava did not build up the dome in a series of flows) but a subsurface intrusion of magma (intrusive origin) [1,2]. To date, only a fairly small number of intrusive domes has been examined in detail with respect to their morphometric properties. Common properties of and differences between intrusive lunar domes and possible equivalent features on the Earth are not yet fully understood. In this contribution we examine two presumably intrusive lunar domes which have not previously been studied in detail. They are situated in two well known volcanic regions of the Moon. We provide a comparison of their spectral and morphometric properties to other intrusive domes regarded in previous studies.

General description: The dome Gambart 1 (Ga1) is located in the southern part of Mare Insularum at longitude 14.84° W and latitude 0.75° S, having a diameter of about 30 km (Figs. 1 and 2). It is not shown in USGS lunar geologic map I-458 of the Riphaeus Mountains region of the Moon [3]. Several individual rilles can be distinguished on its surface. In the northern part of this dome there is a straight rille, likely due to tensional stresses, consistent with laccolith formation. Hence the magma accumulating beneath the surface produced not only an upbowing of the surface rock layers but also failures in the rock strata (fracturing). Further rilles are visible on the surface of the ridge located nearby in southwestern direction but not on the dome itself. Possibly the structure extends into the ridge [4]. It would then be the manifestation of a subsurface volcanic dike with sill formation [5]. As a classical example of intrusive domes we show for comparison the Valentine dome (V1) situated in western Mare Serenitatis along with a smaller dome (V2) to its north [6,7]. The second examined dome, with a diameter of 10 km, is situated near Promontorium Laplace in Sinus Iridum (Fig. 3). This dome, named Laplace 6 (L6), is located at 29.16° W and 47.08° N just to the west of Laplace 5 (L5), which is a dome of effusive origin [8]. USGS lunar geologic map I-602 of the Sinus Iridum quadrangle [9] does not show the domes L5 and L6 but only reports a dome as an Id unit at 27.83° W and 40.66° N nearly 200 km to the south.

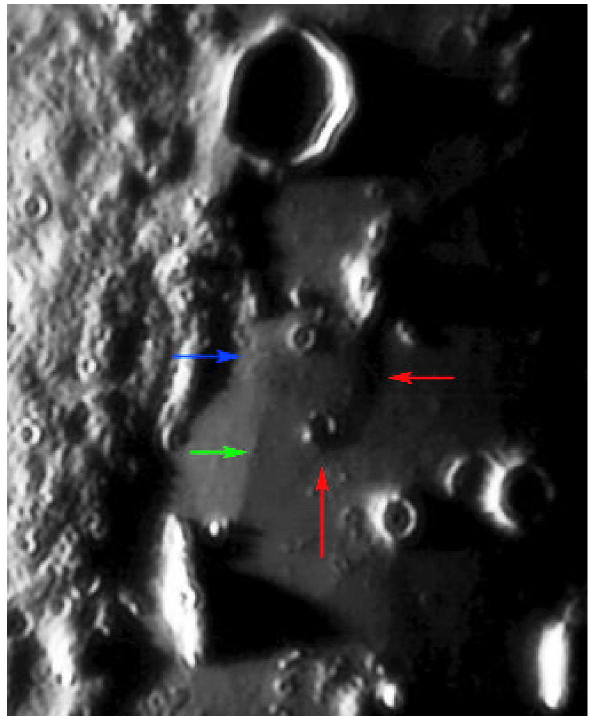

Fig. 1: Telescopic CCD image of the intrusive dome Ga1 near the crater Gambart. North is to the top and west to the left. The blue arrow marks a rille, the green arrow a ridge.

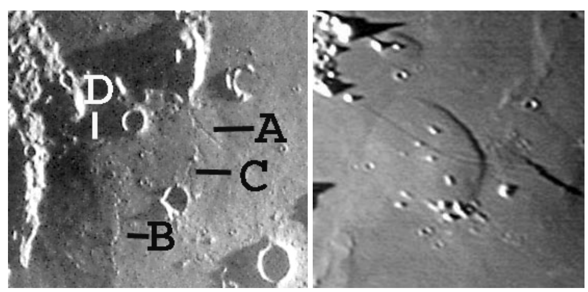

Fig. 2: Left: Apollo image AS12-50-7438 of the intrusive dome Ga1. The letters A-D identify several rilles on and close to the dome. Right: Intrusive domes V1 (centre) and V2 (upper left). Image courtesy K. C. Pau.

Spectral properties: Clementine UVVIS data reveal that the surface of the dome Ga1 consists of spectrally red mare lava. The observed 950/750 ratio implies a weak mafic absorption, suggesting a high soil maturity (Table 1). The low 415/750 ratio suggests a moderate TiO_2 content. The dome L6 in Sinus Iridium is spectrally red with a high 750 nm reflectance of 0.1204, a rather low 415/750 value, indicating a low TiO_2 content, and a weak mafic absorption suggesting a high soil maturity.

Morphometric properties: Based on the telescopic CCD images shown in Figs. 1 and 3 acquired under oblique solar illumination, we computed DEMs of the examined domes by applying a combined photoclinometry and shape from shading method [6]. The flank slopes, diameters, heights, and edifice volumes of the domes were extracted from the DEMs (Table 2). The heights of Ga1 and L6 amount to 140 m and 45 m, respectively. It has been shown in [6] that the relative error of the height and slope values amounts to 10% while the relative accuracy of the dome volumes is about 20%. We also estimated the height of the Ga1 dome based on shadow length measurements in the oblique illumination view shown in Fig. 1, where a height of 140±15 m was obtained. The flank slopes of Ga1 and L6 are very low and correspond to 0.57° and 0.52°, respectively. As a note of interest, the height of the effusive dome L5 (cf. Fig. 3) was determined to 128 m with an average flank slope of 1.6° [8]. For comparison, Table 2 reports morphometric properties of further lunar domes of intrusive nature from preceding studies (cf. [6] and references therein).

dome	750	415/750	950/750
Ga1	0.1129	0.6067	1.0303
L6	0.1204	0.5578	1.0433
V1	0.1194	0.5967	1.0134
V2	0.1116	0.5921	1.0343

Table 1: Albedo at 750 nm and the spectral ratios 415/750 and 950/750 of the intrusive domes examined in this study and the domes V1 and V2.

dome	long.	lat.	slope [°]	D [km]	h [m]	V [km^3]
Ga1	-14.84°	-0.75°	0.57	30	140	50
L6	-29.16°	47.08°	0.52	10	45	1.5
V1	10.20°	30.70°	0.55	30	130	42
V2	10.26°	31.89°	0.62	11	80	1.9
C9	34.66°	7.06°	0.13	13.3	15	0.5
C10	35.19°	10.00°	0.30	19.2	50	10
C11	36.75°	11.06°	0.70	12.2	75	6.4
C12	37.20°	12.37°	0.45	6.3	25	0.5
M13	-31.53°	11.68°	0.41	27.8	100	15
M14	-32.13°	12.76°	0.27	14.8	35	1.7

Table 2: Morphometric properties of the domes Ga1, L6, and other intrusive domes (cf. [6] for further details).

Conclusion: The low flank slopes of the domes regarded in this study suggest a similar origin. Intrusive domes do not have summit pits. They are characterised by low flank slopes always well below 1°, in the range 0.1°–0.7°. Intrusive domes with even lower flank slopes may exist, but such structures would be extremely difficult to observe. Some intrusive domes have large diameters of about 30 km (Ga1, V1, M13), most have moderate diameters in the range 10–20 km (L6, V2, C9, C10, C11, M14), and the dome C12 is rather small with a diameter of only 6.3 km. The edifice volume amounts to large values of 40–50 km^3 for Ga1 and V1, moderate values of 6–15 km^3 for C10, C11, and M13, and is fairly low (< 2 km^3) for L6, V2, C9, C12, and M14. Many domes of intrusive nature are characterised by straight rilles traversing their surface (Ga1 and V1 domes) and/or by the presence of pre-existing engulfed small peaks. Based on the data reported in Table 2, the close resemblance of the domes Ga1 and V1 may indicate a similar mode of emplacement. They appear to represent endmembers of lunar intrusive domes with large diameters and high edifice volumes. The rilles and tensional fractures observed on the surface of these two domes suggest that they are associated with dikes that remained subsurface but ascended to shallow depths below the surface [10]. Future work will include an extension of our analysis to a larger set of intrusive domes as well as additional studies of the mechanisms governing the intrusion of magma under lunar conditions. Our ongoing program of imaging, measuring, cataloging, and mapping of intrusive domes is expected to provide information needed to statistically characterise lunar intrusive domes and to obtain more detailed insights into the global and regional geologic processes responsible for their formation.

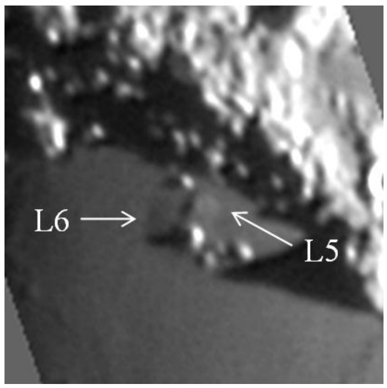

Fig. 3: Telescopic CCD image of the intrusive dome L6, situated near the effusive dome L5. North is to the top and west to the left.

References: [1] Wilhelms (1987) *USGS Prof. Paper 1348;* [2] Head and Gifford (1980) *Moon and Planets 22*; [3] Eggleton (1965) *USGS I-458*; [4] Lena et al. (2005) *JALPO 42-5*; [5] MacDonald (1972) *Prentice Hall*; [6] Wöhler et al. (2006) *Icarus 183*; [7] Lena et al. (2006) *J. Brit. Astron. Assoc. 116-1*; [8] Lena et al (2006) *Selenology Today 1*; [9] Schaber (1969) *USGS I-602*; [10] Wilson and Head (1996) *LPSC XXVII*.