

Lunar domes: a generic classification of the dome near Valentine located at 10.26°E and 31.89°N

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We describe a lunar dome located at longitude 10.26°E and latitude 31.89°N ($\xi = +0.151$ and $\eta = +0.528$), including data about slope and height. An image-based three-dimensional reconstruction of the eastern part of the dome is performed based on shape using a shading approach. This has made it possible to extract additional information for its classification and interpretation in geological terms.

1. Introduction

Lunar domes are formed either by outpouring of magma from a central vent or by a subsurface accumulation of magma that causes an up-doming of the bedrock layers, creating a smooth, gently sloping positive relief.¹

In a prior paper, recently published in the journal of the ALPO,² some of us described a dome, not listed in the ALPO catalogue, located at longitude 10.26°E and latitude 31.89°N ($\xi = +0.151$ and $\eta = +0.528$). The dome, with a dimension of 14×11 km, appears flat and elliptical in shape as a miniature of the famous Valentine dome. The name 'Valentine dome' was coined by Alike Herring for the well known dome at longitude 10.18°E and latitude 30.66°N.³

This elusive dome was added to the unpublished revised lunar dome catalogue by Robert A. Garfinkle, FRAS and to the unpublished revised list by Charles Kapral.⁴

In this study we report further measurements and include new CCD imaging of the lunar dome located at 10.26°E and 31.89°N. This has made it possible to extract additional information (slope and height) for its classification and interpretation.

2. Instruments and measurements

Table 1 lists the 13 observers who supplied a total of 29 observations. This report is based on an analysis of 8 visual observations and 21 images taken under different solar altitude (Table 3). We strongly encouraged observers to participate in organised, simultaneous observations. Such effort significantly reinforced the level of confidence that we have in our data. The images and the shadow analysis were consistent and, in some cases, the images were obtained in contemporaneous and independent sessions.

For each of the observations, the local lunar altitude of the Sun (Alt), the azimuth of the Sun (Az), and the Sun's

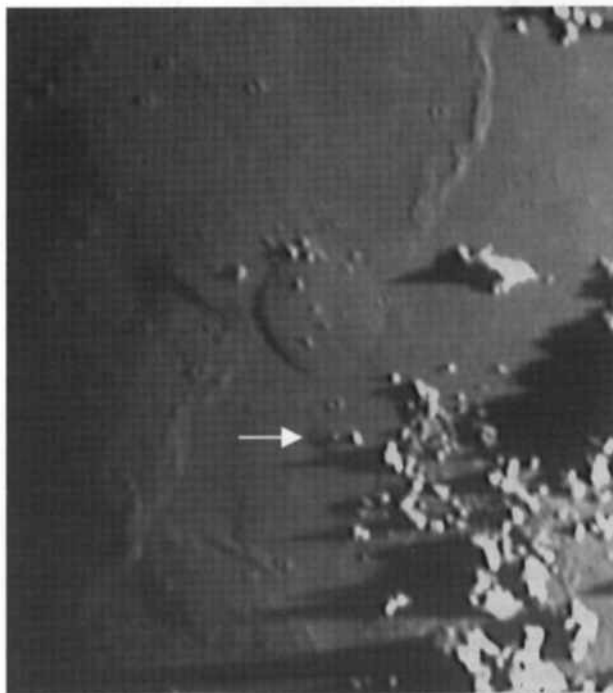


Figure 1. Image by Phillips on 2004 August 7 at 10:23 UT (Alt=1.98°, Col=168.36°, Az=270.57°; seeing II Antoniadi scale). 203mm f/9 refractor. South is up and west (IAU) to the right in all images.

selenographic colongitude (Col) were calculated using the *Lunar Observer's Toolkit* by H. D. Jamieson (ALPO).⁵ Table 2 reports the position of the dome and the coordinates of the hill that lies on its north-west (IAU) flank. The coordinates were obtained by superimposing our images onto Rukl's map (chart #13). Furthermore, we were able to distinguish between the black shadow and the dark grey shading (penumbra) of the dome's flank which represents grazing illumination by sunlight. On the best images, the dome diameter and the length of its shadow were both measured in pixels. The corresponding scale of the image was obtained, allowing diameters and shadow lengths to be expressed in kilometres. The measured heights were also calculated using the *Lunar Observer's Toolkit* software. The results are summarised in Table 4.

3. Vertical cross-section of the dome

Information about the vertical cross-section was obtained using three methods, as follows:

a) Maximum slope

The dome located at 10.26°E, 31.89°N has a flat summit with low height. The flank steepness 's' is equal to the solar height when the black shadow cast by the flank appears (in sunset) or disappears (in sunrise). It corresponds to the maximum slope angle. The average east flank width 'w' can be estimated using high resolution images (Table 4).

The height (H) of the dome can be then calculated by the formula:

$$H = w \times (\tan s) \quad [1]$$

b) Effect of the slope, Hill height method

The height of the dome was also estimated by comparing the shadow lengths of the hill that lies on the northwest flank of the dome (Table 2).

This hill, under evening illumination, casts a shadow on the dome summit while under morning illumination it casts a shadow to the lunar surface.

Obviously the shadow length measured under evening illumination will be shorter (upward slope). It is expected that the hill, under morning illumination, has a larger height value (h_m) because the



Figure 2. Image by Pau on 2003 October 16 at 21:02 UT (Alt=3.44°, Col=166.15°, Az=268.74°; seeing II Antoniadi scale). 250mm f/6 Newtonian.

Table 1. Contributing observers and instruments

Observer	Instrument	Type	No. of reports
			M=Morn. illum. E=Evening illum.
Cicognani M.	410mm Cassegrain f/17	Visual, CCD	4M
Chu A.	250mm Newtonian f/6	CCD	1E
Cocco A.	200mm SCT f/10	CCD	1E
Crandall E.	250mm Newtonian f/6	CCD	1M
Fattinnanzi C.	250mm Newtonian f/5	CCD	1E
Lena R.	100mm refractor f/15	Visual, digital camera	2M, 3E
Nardella S.	180mm Maksutov f/6	CCD	1M
Pau K. C.	250mm Newtonian f/6	CCD	2M, 2E
Phillips J.	203mm refractor f/9	CCD	2M, 1E
Sforza A.	200mm SCT f/10	CCD	1E
Shaw B.	125mm refractor f/8 250mm Newtonian f/12	CCD	4E, 1M
Vignale G.	200mm SCT f/10	CCD	1E
Villares F.	200mm SCT f/10	Digital camera	1M

shadow tip is not on the dome summit but on the lunar surface to the northwest. Using this method we were able to obtain two different height values under morning illumination (h_m)

and evening illumination (h_e) respectively. The height (H) of the dome was then calculated by the formula:

$$H = h_m - h_e \quad [2]$$

The results are summarised in Tables 5 and 6.

c) Image-based 3D reconstruction of the dome

A well-known method for 3D surface reconstruction is shape-from-shading. It makes use of the fact that surface parts inclined towards the light source appear brighter than surface parts inclined away from it. Traditional applications of this technique in planetary science, mostly referred to as photoclinometry, are designed to reveal a set of profiles along one-dimensional lines.⁹ Techniques for 3D reconstruction of complete surfaces have been developed in the field of computer vision,⁷ also dealing with the combination of shading and shadow features.⁸ The shape-from-shading approach described in Ref. 7, which will be used in this paper, aims at deriving the slope of the surface in east-west and north-south directions together with a consistent height value z for each image pixel, based on the pixel intensities of the image.

To determine a shape using shading analysis, the reflectance properties of the surface, describing how it interacts with incident light, must be known. A simple example is a diffusely scattering or Lambertian surface. In this case, the intensity I_{model} of reflected light obeys the Lambert law $I_{\text{model}} = \rho \cos \theta$ with θ as the angle between surface normal and direction of incident light and ρ as the so-called surface albedo, which is assumed to be constant. For oblique illumination as in Figures 1–5, we have values of θ slightly less than 90°. The reflectance behaviour of the lunar surface somewhat differs from the Lambertian model. It can be described by the Lunar-Lambert law which not only shows a dependence of I_{model} on $\cos \theta$ but also on the angle under which the surface is observed.

Table 2. Position of the dome near Valentine and of the hill that lies on its northwest flank

Feature	Position (Lunar orthographic coordinate)		Position (Longitude, Latitude)	
	ξ	η	(°)	(°)
Dome	+0.151	+0.528	+10.26	+31.89
Hill	+0.147	+0.529	+ 9.95	+31.91

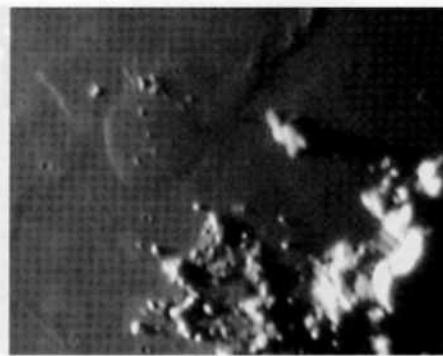


Figure 3. Image by Pau on 2004 December 30 at 11:51 UT (Alt=3.32°, Col=354.39°, Az=93.48°; seeing II Antoniadi scale).

The height (H) of the dome was then calculated by the formula:

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