No. 3. SOME SYSTEMATIC VISUAL LUNAR OBSERVATIONS*

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December 8, 1961

1. Introduction

SINCE the visual observer obtains a resolution some three times that obtained photographically with the same telescope, justification of this method of getting data on the lunar surface is quite unnecessary. Visual observations have the well-known drawbacks of subjectivity and selectivity and are also positionally inaccurate. These defects can be controlled and their effects reduced by repetition and by appropriate observation routines.

The observations of this paper were made with the 40 in. refractor of the Yerkes Observatory and the 82 in. reflector of the McDonald Observatory. The full apertures were rarely brought into play and the bulk of the observing was performed at 24 in. aperture because of imperfections in the seeing. Even with these reduced apertures the observer may be presented with such intricate masses of detail that he is obliged to be very selective in what he records.

2. Observational Techniques

In the case of topographic and cartographic research the observations were entered directly on the sheets of the *Photographic Lunar Atlas,* thus following the example of Krieger. Slope and shadow observations were used to investigate the detailed topography of craters, rilles and domes.

In shadow observations of small craters, the shadows are estimated as fractions of the diameters of the crater. These estimates are affected by strong subjective errors and can be made only in the very best conditions. In my case, poor seeing has the effect of making the estimated fraction too small, but the effect is reversed for certain other observers. These shadow estimates permit the determination of the depth-diameter ratios and for diameters less than 5 km the results are as trustworthy as micrometric or photographic determinations.

The slope estimates are even more delicate and are perhaps the most difficult of all lunar observations. Here the observer must decide on the moment of transition from black to grey of the lunar shadows. Since this transition is continuous the moment is indeterminate and all one can do is to "box" it between two moments, one corresponding to a definitely grey shadow and the other to a black.

3. Cartographic and Topographic Observations

These are necessary to supplement the defective resolving power of available photographs. A glance through the *Photographic Lunar Atlas* will soon convince anyone that even with relatively small apertures it is possible, in large areas of the disk, to add to the photographic data. An example of one evening's work is shown for the Aristarchus region (Plate 3.1).

The observer starts with the photograph as a base, adds details which are missing and sharpens up those details which are hazy or doubtful in the photographic image. Very often, the photograph will give a faint and vague marking, so that in clarifying this the observer retains much of the positional accuracy of the photograph.

4. Crater Observations

These were usually limited to establishing general characteristics such as the determinations of the depth-diameter ratio, the external and internal

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* Paper presented at the Symposium No. 15 of the International Astronomical Union at Leningrad, December, 1960.

slopes and the nature of the central peak when present.

Examination of the interiors of the smaller craters with large apertures has enforced a change in my opinions. At one time I believed that the interiors of most of these were smooth hemispherical or paraboloidal bowls, but recent work with the 40 in. contradicts this. It now appears that all craters, except the very smallest (< 2 km), have interior forms which are inverted truncated cones, with floors which are somewhat darker than the walls. In the smaller sizes these floors are difficult to detect since they may be no more than a kilometer across. They are most easily seen at full when they appear as dusky spots in the centers of the bright patches of the craters.

One peculiarity of these observations is that a practised observer soon finds that the cast shadows are transparent and that he can look down through them and see the entire floor, even though most of this is in shadow. Clarity rather than steadiness is the prerequisite for this type of observation, which was aimed at estimating the size of the floor and its cross-section. Very often, when the floor is convex, the illuminated wall will cause a shadow to be thrown in the reverse direction, forming a crescent of shadow along the edge of the floor nearest to the Sun. The concavity or convexity can also be detected by comparing the curvature of the end of the shadow with that of the rim, but this depends on the assumption that the rim is level, which is frequently not the case. The floor diameter is about ½ of the rim diameter for craters of 15 km in diameter and appreciably less, say about ¼, for craters of 10 km diameter. These floors tend to be level or concave but examples of convexity were noted.

Most of the depth-diameter ratios for craters in the range 5 to 15 km fall between the limits of 0·15 and 0·23. The ratio is not very sensitive to size in this range and indeed this insensitivity is demonstrated by the following averages:

Diameter Range	Average Ratio
5—10 km	0·194
10—15 km	0·193

The external heights of the rims of smaller craters were also investigated by means of shadow estimates. Over the range 0 to 20 km there appears to be quite a definite correlation between the diameter and the external height of the rim, the corresponding regression being:

$$\text{Rim height (meters)} = 49.416 \text{ Diam} - 68$$

in which the diameter is in kilometers. The crater Birt deviates from the regression and is exceptional in this respect, as well as others. Its rim rises almost 1000 m. above the surrounding plain and is abnormally high.

The slope estimates were aimed at the physical values, not at the average straight-line values obtained by Fauth. Particular attention was given to the inner and outer slopes immediately adjacent to the rim. The inner slopes were found to be quite consistent, lying between 30° and 40°, with 35° as a fair average. This accords with earlier results. In contrast with this, the estimates of the outer slopes did not agree with earlier work. In a large number of cases I noted a very thin crescent of black shadow immediately adjacent to the rim and indicating a brief slope with values lying between 10° and 20°. This contradicts impressions obtained from photographs, but it must be remembered that with any loss of resolution this thin black band of shadow is smeared into a grey tone. The much lower values of 3° to 6° quoted by other authorities no doubt refer to the average slope from rim to base. The brief steep slopes may correspond to an overturn region immediately adjacent to the rim of the crater.

Observations of the central peaks added nothing of value. These features have a heterogeneity which makes classification and systematization difficult. Craterlets were often noted on the summits of the peaks, as in the case of Albategnius, but with attention they could also be detected on the flanks. Further work in the way of craterlets counts, on the peaks and in their immediate vicinity on the floors, will be necessary to make any headway in this topic.

5. Lunar Rilles

The rilles were observed in order to improve the picture of their distribution and structure. Unfortunately, it is much easier to detect a narrow rille than to see the details of even the broadest specimens; therefore, most of the new results are additions to the list of known rilles. However, it has been possible to confirm Fielder's median ridge in the Ariadaeus Rille and to detect similar ridges in three other rilles. This median ridge is by no means characteristic of all the broad rilles but it is a peculiarity which will have to be taken into account in any theories concerning the lunar rilles.

The rilles are evidently not a homogeneous group. The Ariadaeus Rille has clear-cut graben features since its floor has dropped between parallel bounding faults. These can be seen as fine dark lines cutting through the overlying blocks whose central portions have subsided with the floor of the rille. This rille is almost alone in that its walls are visible as bright lines at full Moon. Other rilles have graben features, but the Triesnecker rilles appear to be very different. These are shallow and rather blurred grooves with no definite line between wall and floor. The row of brilliant white pits along the interior of the Hyginus Rille are now well-known and are even recorded on one Pic du Midi photograph, but this appears to be an exceptional feature. Almost all the broader rilles appear to have nearly level floors (except when the median ridge is present) meeting the walls in quite well-defined lines. At moments of good seeing, one can sometimes detect craterlets and other small features on these floors. The impression is that fusion, or some other levelling agency has acted on these rille-floors as it has undoubtedly done in the interiors of many craters.

Shadow estimates of the depths of both major and minor rilles were made when the shadow occupied one-half of the apparent width of the rille. The results were surprisingly uniform and the depth came out at 15 to 20% of the width. These findings do not agree with the deeper estimates of other authorities. Further observations of this sort are therefore necessary.

The study of the distribution of the rilles confirmed the impression that the major systems are associated with the edges of the dark areas, whether these are maria or the interiors of certain large craters. The distribution is illustrated in Plate 3.2. Near Marius in Oceanus Procellarum is a long rille with abnormal siting since long rilles are usually absent from the interiors of the maria. This is a serpentine type of rille. Another of this type has been found in the central M. Imbrium and still another near Letronne.

Associated with rilles are the shadow valleys noticed by Krieger and Goodacre. In plan these are large features perhaps 10 to 15 km wide but their inward slopes towards the V-bottom are so gentle that they can be seen only when close to the terminator. Almost all those seen by the writer have a rille along the center of the valley. An easy specimen runs south from the crater Guericke B.

6. *Faults*

There is a temptation to label all linear features as faults, but the writer has not been able to detect many unmistakable fault features on the lunar surface. Apart from the well-known faults near Cauchy and Birt there is a much-mutilated example running south-east across the south end of Mare Humorum, which appears to be quite independent of the nearby rille system. There is an even weaker example across the south end of Mare Crisium and a well-displayed example with a western downthrow near Lubbock. However, the most extensive system of faults lies in the Apennines. Here there are numerous lines parallel to the frontal scarp with a secondary series at right-angles to this.

Many of the rilles were examined to detect fault characteristics. Not one example of horizontal offsetting was found, but downthrows or vertical displacements turned out to be fairly common. As an example of the close association between rille and fault, the Cauchy fault is extremely interesting. A rille runs along the foot of the fault, perhaps a kilometer or so away, while the fault itself appears to turn into a rille at its east end.

7. *The Lunar Domes*

The distribution of these, based on the observations of G. P. Kuiper, E. A. Whitaker and the writer, as shown in Plate 3.3, appears to support the following conclusions: (i) the domes are restricted to the dark areas usually assumed to be lava flows; (ii) the domes are further restricted to areas where one would expect the lava covering to be shallow; (iii) domes usually occur in related groups.

To support these conclusions it may be noted that persistent attempts by the writer to detect domes in Mare Crisium, Mare Nectaris and Mare Humorum have not been successful while the only domes found in Mare Serenitatis and Mare Imbrium are very close to the edges of these maria. The large dome concentrations are found in Mare Nubium, Mare Tranquillitatis and east of Copernicus. In these latter areas, the existence of ghost rings, isolated peaks, and the wrecks of former craters indicate a shallow lava cover.

It is usually accepted that domes have the same tone as the surface on which they stand, but the dome bisected by a rille just north of Menelaus is distinctly darker than the mare and appears as a dark spot at full.

There is considerable variation in the forms of the domes, exemplified by the two near Cauchy. One is a disk-like structure with a central aperture, while the other is conical with a very small bright spine at its summit. Neither of these bears any resemblance to the large complex domes near Arago or the strange complex of swellings which constitutes the feature called Rumker. The disk-type dome near Cauchy and others of the same sort have been observed for height and the typical dimensions of these features are:

base diameter = 6 km.
summit diameter = 4 km.
central aperture = 1 km.
height = 110 m.

The large dome east of Arago was also heighted, at 500 m. In all cases the heights of the domes came out at 2 or 3% of their base diameters. This very gentle relief is confirmed by the slope estimates, which indicate slopes from 2° to 5°30′ for the flanks of the domes. The smallness of the central orifices makes these features difficult to examine. I was unable to detect rims, but by comparing the glimpsed inner shadows with those of nearby craters, it was possible to establish that their depth-diameter ratios are not much different from those established for normal small craters of the same size.

8. *Mare Ridges*

In a few cases it was possible to confirm previous observations by G. P. Kuiper that many of these ridges are cracked open with rille-like openings along the summits. In some there is appreciable downthrow. The easiest example is perhaps the broad ridge north of Spitzbergen.

The plaited ridge running across S. Aestuum shows one remarkable feature. Its structural lines are prolonged into the mass of the Apennines and do not stop at the junction of mountain and mare. These lines, as fugitive markings, run some 60 or 70 km into the mountain mass. This may indicate a deeper seating of the forces which caused these ridges than is commonly supposed.

The relations between the mare ridges and submerged structures is still obscure, but a frequent association between these features has been noted. The most prominent examples are at Lamont in Mare Tranquillitatis and in the very large ring surrounding the Straight Wall. Undoubtedly, the mare ridges tend to follow the lines of submerged objects.

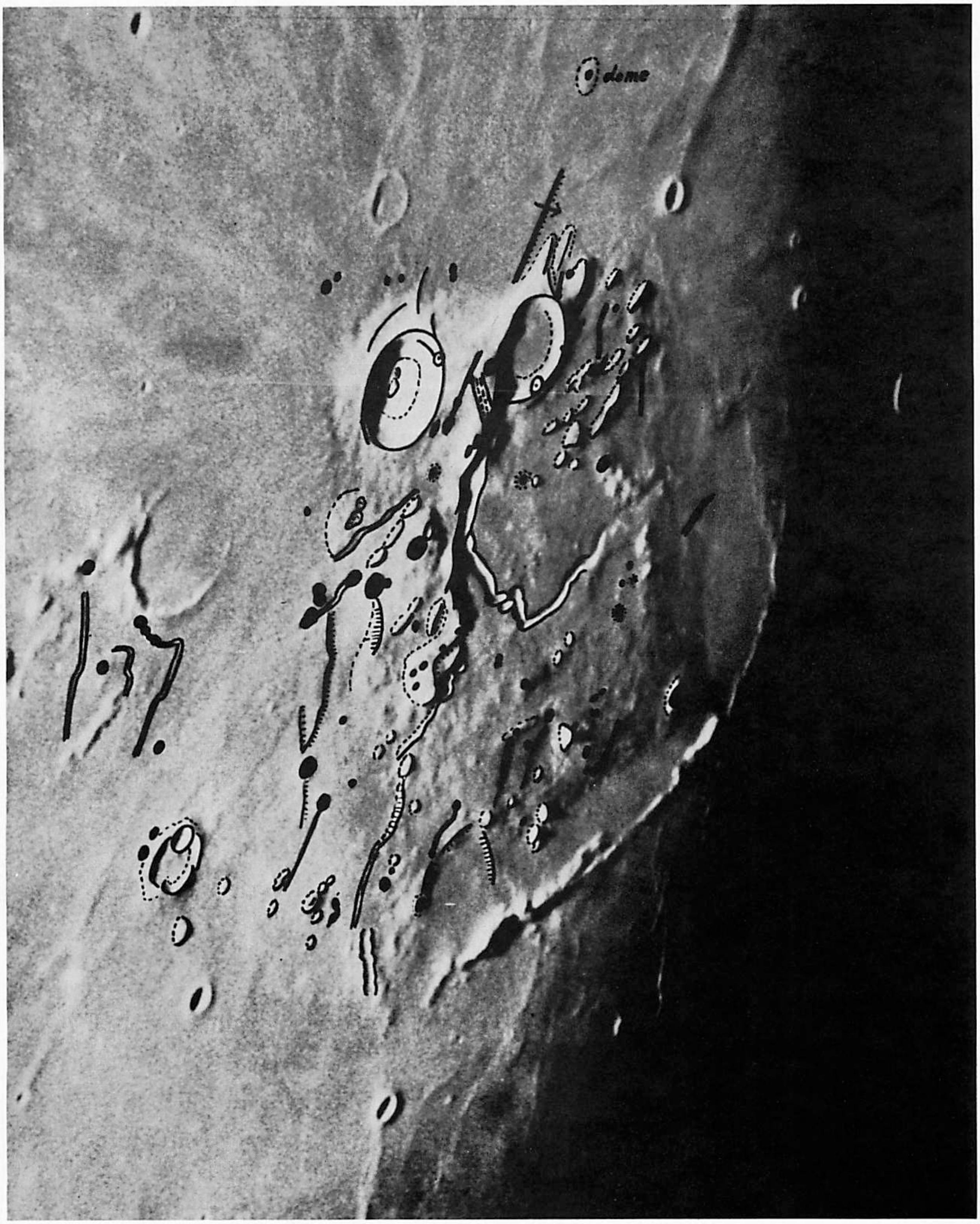

Plate 3.1. Aristarchus region, showing results of one night's topographic observations.

Plate 3.2. Distribution of Lunar Rilles.

Plate 3.3. Distribution of Lunar Domes.