28. Geological Observations From Lunar Orbit

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Visual observations from orbit were first considered as a mission objective on Apollo 15. The concept and means of achieving the objective are described in reference 28-1, and summaries of the results have been published (refs. 28-2 to 28-4). Observations were also made from the command module (CM) during the Apollo 16 mission, and the results provided additional data which complemented the photographs and the geochemical remote sensing (refs. 28-5 and 28-6).

As on previous missions, the Apollo 17 crew (the command module pilot (CMP) in particular) was trained during a 2-yr period before the flight for the task of making the observations. During this training, the CMP conducted simulations of the task by studying aerial photographs of geologically complex regions in the United States and by flying over these regions to make on-the-scene interpretations.

Because the Apollo 17 groundtracks repeated approximately 80 percent of the lunar surface area previously overflown on Apollo 15, much was already known about the features in question. For this reason, emphasis was largely placed on color tones of geologic units and details of small-scale features.

Observations were made from the CM windows without disturbing the operations of the scientific instrument module. The tools available were limited to a booklet of graphics (some of which are shown here as examples), a pair of 10-power binoculars, a reference color wheel, two hand-held cameras (Hasselblad and Nikon), and voice-recording equipment.

The Apollo 17 crew made observations from orbit of 14 lunar surface areas (fig. 28-1). As shown in table 28-I, four of these targets were not formally scheduled in the flight plan. A brief summary of visual observations during the Apollo 17 lunar orbit has been recently published (ref. 28-7).

The following paragraphs give detailed descriptions of the observation sites arranged from east to west as they are numbered in figure 28-1; some of the sites are grouped together for convenience. Excerpts from the Apollo 17 real-time air-to-ground transcript are given after editing for clarity. The edited quotations are followed by identification of the source of the statement (e.g., CMP, command module pilot; LMP, lunar module pilot; and CDR, commander) and the lunar revolution (rev) during which the observation was made. By consulting figure 28-1, the reader may check the Sun elevation angle at the time the observation was made. The terminators of revolution 1 (at long. 152° W and 29° E) shift westward one lunar degree for each additional revolution; the terminators of revolution 75 (at long. 134° E and 45° W) shift eastward for each preceding revolution.

KOROLEV, GAGARIN, AND PASTEUR

The largest light-plains-filled basin that was overflown on Apollo 17 is Korolev. This double-ring basin is approximately 450 km in diameter and a few kilometers deep (fig. 28-2). Its interior is filled with a generally smooth but intensely cratered light albedo unit that resembles the Cayley Formation mapped on the near side of the Moon and presumably sampled during the Apollo 16 mission to the Descartes highlands. The origin of the Cayley Formation remains enigmatic.

On Apollo 17, the sites Korolev, Gagarin, and Pasteur were studied from orbit to examine the detailed characteristics of the light plains fill. The smoothness of that fill was most striking:

> We all had an opportunity to look at Korolev, at a very low grazing Sun. One of the striking things was the extreme absence of relief; the very smooth surface that existed in Korolev, independent, of course, of the craters that penetrate

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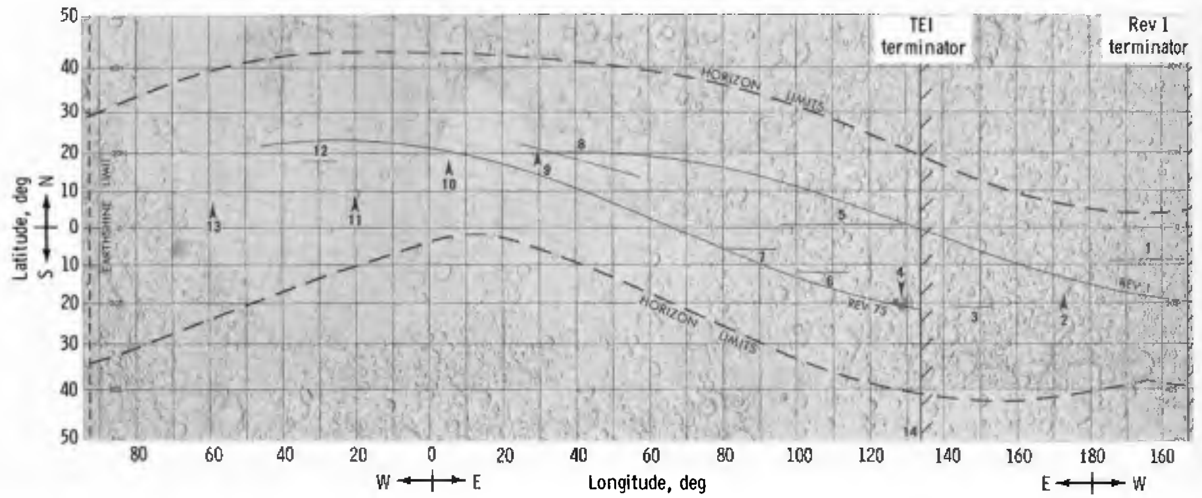

1. Korolev
2. Aitken
3. Gagarin
4. Tsiolkovsky
5. Al-Khwarizmi (formerly Arabia)
6. Pasteur
7. Mare Smythii
8. Crisium-Serenitatis
9. Landing site
10. D-Caldera
11. Copernicus
12. Euler hills
13. Reiner γ
14. Post-TEI view

FIGURE 28-1.–Index map of Apollo 17 visual observation targets. The groundtracks for the first and last (75th) lunar revolutions are shown on the far side by vertical lines; the end points of the tracks on the near side delineate terminators of the respective revolutions. The dashed vertical line near longitude 95° W indicates the limit of earthshine illumination. The horizon limits enclose the maximum area of visibility from the CM windows throughout the mission.

its surface. And there was a ring in the floor next to the wall, about maybe one-sixth of a crater radius, that was somewhat brighter at the low grazing Sun, suggesting it may have had a different slope. And I believe I am correct in saying that the inner floor may be slightly raised. (LMP, rev 1)

Light plains materials were also observed and described in smaller craters west of Korolev:

There is a sequence of different kinds of crater filling on the far side, and I think that, as the orbital stay progresses, we may be able to pin down the relative age relationships and the characteristics of those crater-filling episodes. Whether they are single episodes that happen in a variety of craters or whether they are a function of the age and characteristics of the craters in which you find them is not clear right now. But they seem to form fairly distinct groupings of crater fill materials. (LMP, rev 5)

This indicates that there appears to be several generations of light plains fill rather than fill from a single event. This is confirmed by the orbital photographs of the area around Aitken Crater (part B of sec. 32). Some of the units observed and photographed on Apollo 17 appear to be even smoother than mare surfaces (fig. 28-3):

TABLE 28-I.–*List of Apollo 17 Visual Observation Targets*

Target	*Coordinates*	*Revolution*
Copernicus	10° N, 20° W	1, 28
Landing site	20° N, 30° E	15, 40, 62
Aitken	15° S, 173° E	27
Al-Khwarizmi (formerly Arabia)	1° N, 130° to 95° E	27
Crisium-Serenitatis	15° N, 55° E to 20° N, 25° E	27
Reiner γ	8° N, 58° W	28
D-Caldera	18° N, 5° E	40
Mare Smythii	4° S, 95° to 80° E	62
Tsiolkovsky	20° S, 132° to 125° E	64
Euler hills	18° N, 25° to 35° W	[a]73, 74
Korolev	5° S, 155° to 172° W	[a]2 to 5
Gagarin	20° S, 153° to 145° E	[a]55, 61 to 63
Pasteur	12° S, 115° to 100° E	[a]55, 61 to 63
Post-TEI areas	[b]N/A	[b]N/A

[a]Target not nominally scheduled in flight plan.
[b]N/A = not applicable.

One of those crater fill units that you also see in depressions other than craters is a very smooth, light, plains-forming material. And it is, although cratered, when you see it at the terminator, it is smoother than the mare; that is, it does not seem to have the swell, the sea swell characteristics or ridges or any other features other than the craters superimposed on it. (LMP, rev 5)

An observation that I think is significant is that most of the 30-km craters on the far side of the Moon seem to be fairly fresh. By fresh, I mean you do not have any real definite ray pattern to them, but streaked, 45° slope on the crater walls. On the bottom of the crater is a flat floor, or sometimes there is a domical type (domed up) floor. And the domical floor does not resemble anything like what slumped down the sides. (CMP, rev 27)

Few additional comments were made during the flight concerning the light plains materials. However, apart from the aforementioned characteristics, little could be added that would resolve the problem of their origin:

Pasteur and Hilbert make a pair of big craters that we spent some time studying . . . Both appear to be very old, much older than Tsiolkovsky and they have a plains-forming fill, very flat looking at this distance, and very light colored. It is an event on the Moon of which we have relatively little understanding at this time, but possibly the Apollo 16 results, when they are fully known, through the analysis of the samples and other data, may shed some light on that event. (LMP, post-transearth-injection (TEI))

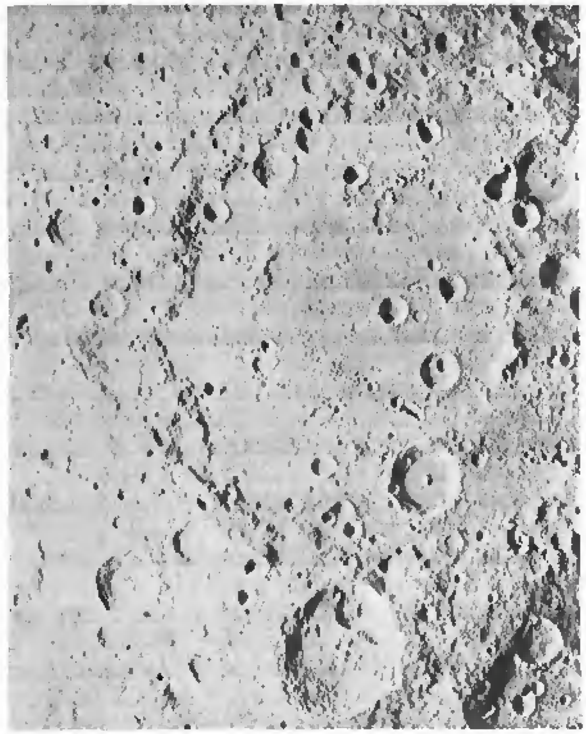

FIGURE 28-2.–Korolev basin: a double-ringed, light-plains-filled, 450-km-diameter crater. The right edge of the photograph coincides with the far-side terminator of the first lunar revolution of Apollo 17 (Lunar Orbiter I frame 35-M).

FIGURE 28-3.–Smooth light plains fill in an irregular structure near Sniadecki Crater on the lunar far side (AS17-151-23191).

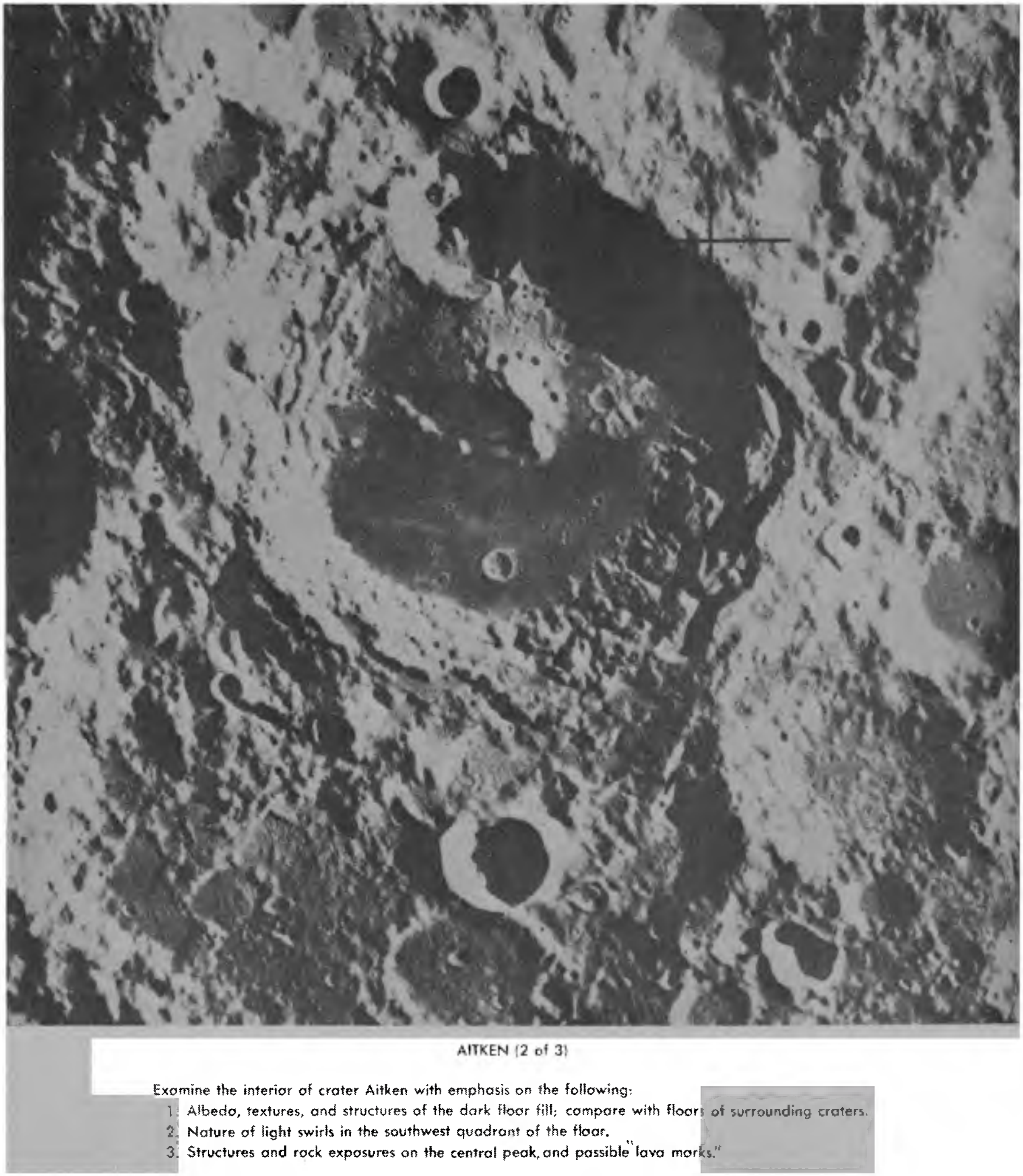

FIGURE 28-4.—Example of onboard graphics in support of visual observations from lunar orbit. This Zond 8 metric photograph of Aitken Crater (150 km in diameter) represents the same view of the crater as that seen by the Apollo 17 crew.

AITKEN

Aitken Crater, 150 km in diameter, is one of the few craters that display a dark mare-like floor. Observations were made to better understand the crater and its surroundings, the dark floor material, and the many interesting small-scale features in the floor (fig. 28-4).

The rim crest of Aitken Crater is very sharp and its secondary crater chains are distinct. However, it was not possible from the available photographs to establish without doubt whether or not the rim deposits are brighter than the surrounding highlands. When the CMP was queried about this particular aspect, he replied:

> The rim deposits are a little bit brighter than the surrounding area. Where you would put it [place the crater in the lunar stratigraphic time scale] is probably early Eratosthenian. It is definitely not Copernican because I cannot see, at least at that low Sun, I cannot see any rays around it. But probably Eratosthenian—or somewhere in that area—because of the fresh slumping; it is not subdued at all. The walls of the crater themselves are not subdued. They are fairly fresh, but not as fresh as to be Copernican. And it seems to me like it was brighter at the higher Sun angles around there [on earlier revs], which indicates that there would still be some remnants of a bright rim around it.
>
> On the side of crater Aitken, there are no visible rays that I can see at this low Sun angle. There is definitely a mare floor in there. It is a dark, low-albedo-type flat floor with swirls in it; no definite [topographic] expression to the swirls. One thing that is quite apparent is a flow scarp in the northeast corner, coming out of a little cloverleaf-like area. I am going to have to look the next pass over it to see if the south domical structure that is in there is breached. And I cannot tell whether the material is flowing to the east out of that domical structure or if it is flowing into the domical structure. (CMP, rev 27)

When the CMP was queried at that time whether or not he was able to distinguish high lava marks on the lower part of the crater wall, he replied:

> The lava mark is what I would call a lava scarp in the northeast corner. There are some lava marks along the central peak. They are not nearly as apparent as the one up in the northeast corner. In the northeast corner is definitely a flow front, a lava flow front, that [laps up against] the older interior wall of the crater. (CMP, rev 27)

Some of the craters in the floor of Aitken, informally named on Apollo 17 the "cloverleaf cluster," display domical structures of unknown origin (fig. 28-5). An attempt was made to determine whether information could be gathered relative to the

FIGURE 28-5.—Cluster of small craters (4 to 8 km in diameter) in the floor of Aitken Crater. Note the interior domical structures, the breaches in the walls, and the ridges and scarps in the dark floor material (lower right) (Apollo 17 panoramic camera frame AS17-1915).

color tone and the detailed characteristics of these domes:

> The color of the domes in Aitken, although these colors are hard to visualize, is essentially the same as the surrounding material around [the crater]. Maybe a little bit lighter, a little bit lighter than the surrounding material. Of course, it is definitely lighter than the floor. The floor itself, is [somewhat] tan. (CMP, rev 27)
>
> . . . at the cloverleaf cluster in Aitken [part B of sec. 32]. The southern domical crater of the cloverleaf has a breach on

the east side . . . The domical structures themselves are younger than the floor . . . Also, the texture is a coarser texture than the floor itself. In other words, the floor, to me, is kind of a standard flat mare floor. And I have to compare the texture of the domical hills to what I would imagine is some of the dacite flows that I have seen out in California, the heavy viscous-type flows . . . Well, I am pretty sure they have got to be volcanic in origin. (CMP, rev 28)

TSIOLKOVSKY

The 200-km crater Tsiolkovsky was studied thoroughly on the Apollo 15 mission, and the results of these observations are available in references 28-1 and 28-4. On Apollo 17, further study was made of the crater and its many interesting features, especially the flow-like units on the northeast part of the crater rim (fig. 28-6 and 28-7).

The visual of Tsiolkovsky is hopefully pretty much recorded on the recorder. In summary, I concentrated primarily on the flow up in the northeast corner. To me, that particular piece in the crater on picture Tsiolkovsky, 4 of 5 [fig. 28-7(a)]. The piece that is down in the crater is on the right-hand side of the page, [must have been] in somewhat of a molten state. It looks like it is a landslide that has slid down the wall of the crater and was detached from the molten material, the rough-looking material that's on the rim of the crater Tsiolkovsky. (CMP, rev 64)

A similar flow unit occurs on the southern rim of the crater Tsiolkovsky. This unit apparently originated at a graben bounded by two parallel faults on the rim and flowed into the crater Waterman (ref. 28-1). The two units were thought to be similar in nature:

The flow that goes down into Waterman . . . I did not get a chance to look at until I got to the west of it . . . But the material that is in the floor of the crater Waterman is the same type of material as that in the little flow on the northeast corner. (CMP, rev 64)

The lineated unit on the northwest rim of Tsiolkovsky Crater was interpreted as a landslide on Apollo 15. One of the problems was the fact that there appeared to be a larger crater population on that unit than on the older floor materials of Fermi Crater (ref. 28-1). More information was required to fully understand this and the detailed characteristics of these small craters:

In the first observation of the mass of material that goes out into the crater Fermi, it looks like there is a whole bunch of craters in there that are essentially rimless. However, on close examination with the binoculars, I could not see any that did not have at least a slight indication of a rim. The rims were essentially very subdued. They extended out to about a half a crater diameter; and these are the craters in the

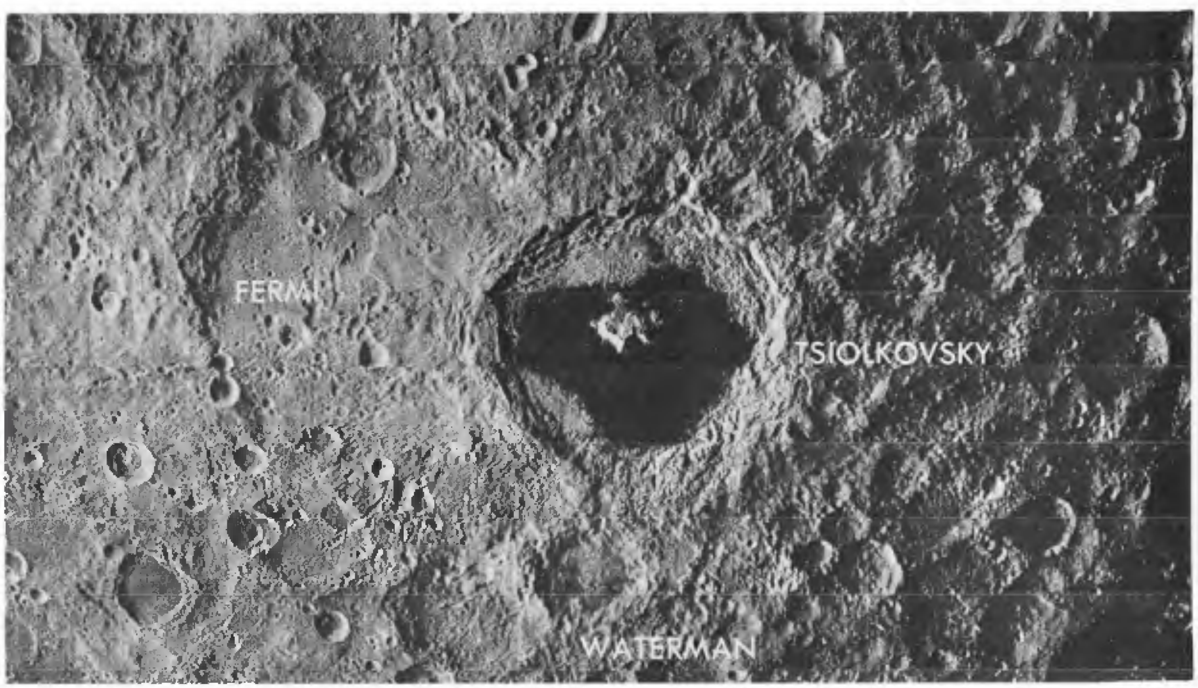

FIGURE 28-6.–Tsiolkovsky Crater (200 km in diameter) and its surroundings (Lunar Orbiter III frame 121-M).

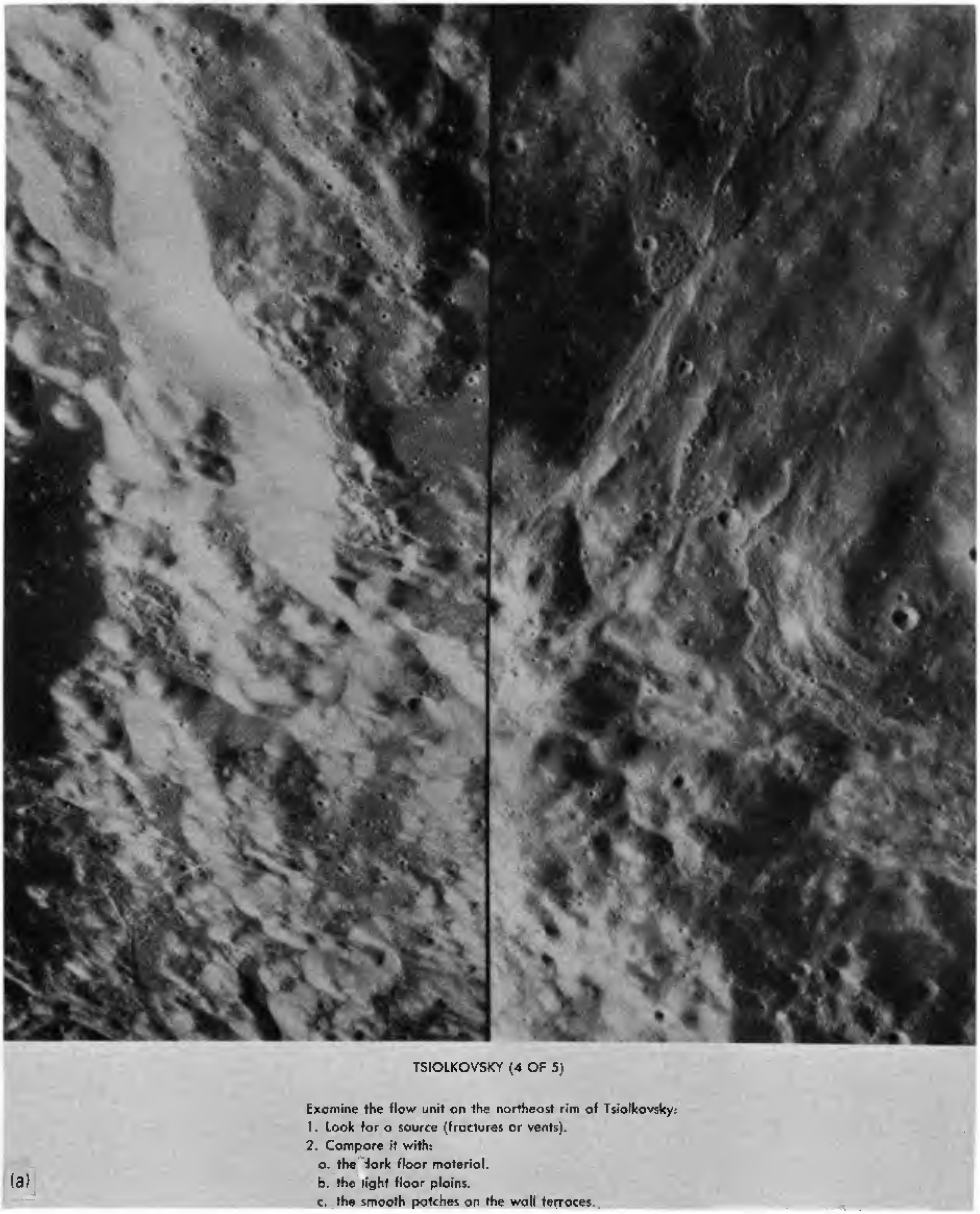

FIGURE 28-7.–Rim deposits of Tsiolkovsky Crater as seen on Apollo 17 onboard graphics compared to Apollo 17 photograph of a flow unit. (a) Hummocky rim deposits of Tsiolkovsky Crater as depicted on the onboard graphics in support of Apollo 17 visual observations.

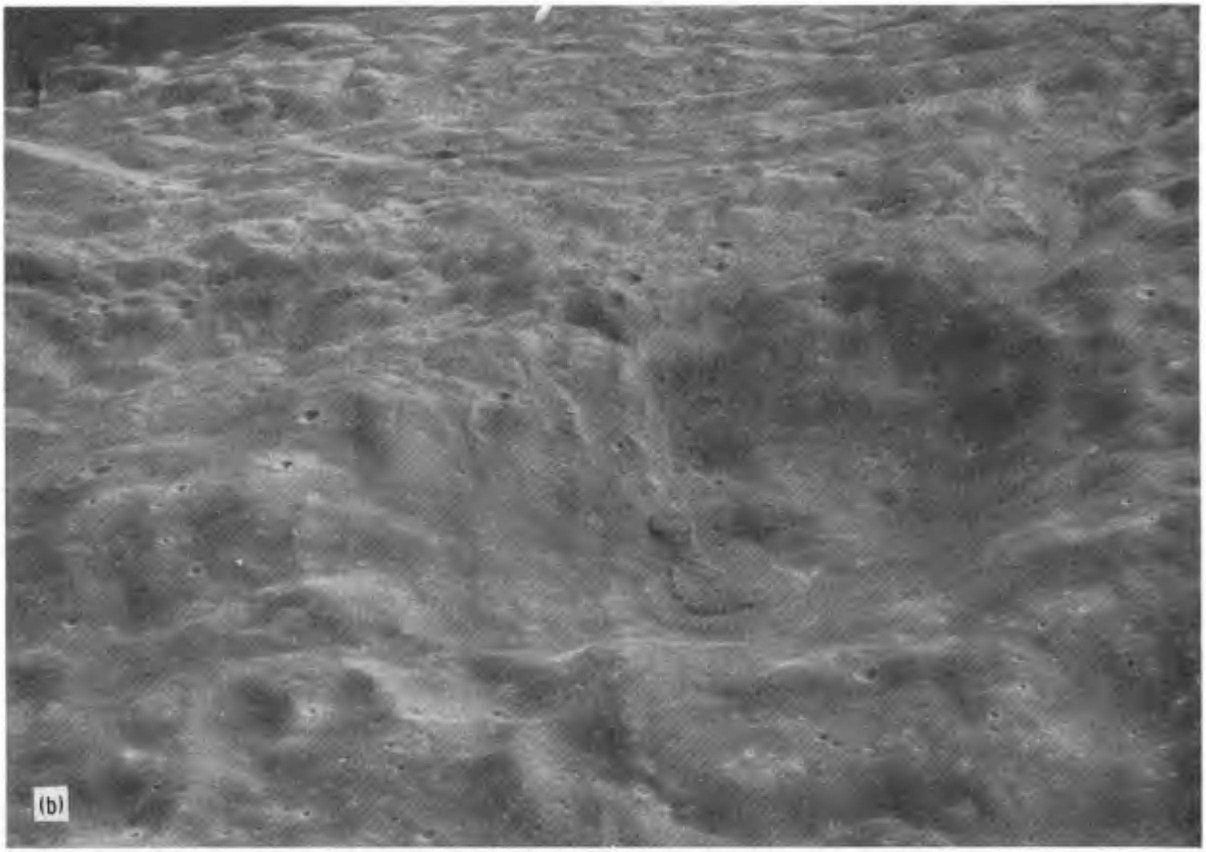

FIGURE 28-7.–Concluded. (b) Flow unit on the northeast rim of Tsiolkovsky Crater (background) as seen from orbit during Apollo 17. Note that the material appears to have flowed downslope into the crater in foreground (AS17-151-23212).

500- to 1000-m size. I did not get a chance to look at them, looking straight down the craters, to see if there was any type of a structure in the bottoms. But I get the impression that they primarily all look like cones, with no flat bottoms at all. (CMP, rev 64)

It was visually confirmed on the Apollo 17 mission that the floor of Tsiolkovsky is filled with basalt-like mare material. The central peak was also described in much the same way as on Apollo 15, including the sightings of large block fields atop and near the base of the peaks. Marks on the central peak indicating a "high lava mark" were also sighted in two places:

There seems to be high lava marks around the western and northern sides of the central peak. For some reason, it is not evident or visible on the south side of the central peak. Also, there seems to be high lava marks on the raised portion of the floor on the contact between the dark material on the floor and the lighter, rough-looking unit on the northern side of the crater. (CMP, rev 64)

AL-KHWARIZMI (FORMERLY ARABIA)

An old and subdued multi-ringed basin, centered at latitude 2° N and longitude 120° E, was discovered on the Apollo 16 photographs (ref. 28-8). The name Arabia was recommended for the basin to the Committee on Nomenclature of the International Astronomical Union (IAU). After discussions concerning the newly adopted rules of the IAU, the name Al-Khwarizmi was substituted (ref. 28-9). However, the previously recommended name of Arabia was used on the Apollo 17 mission, during which the basin rings as well as the light-colored swirls in its northern part (fig. 28-8) were studied.

Basin Rings

You can see the topographic rise in the Saenger area, especially. It is a little bit higher to the west of Saenger than to the east. But you can still see a general rise in that area.

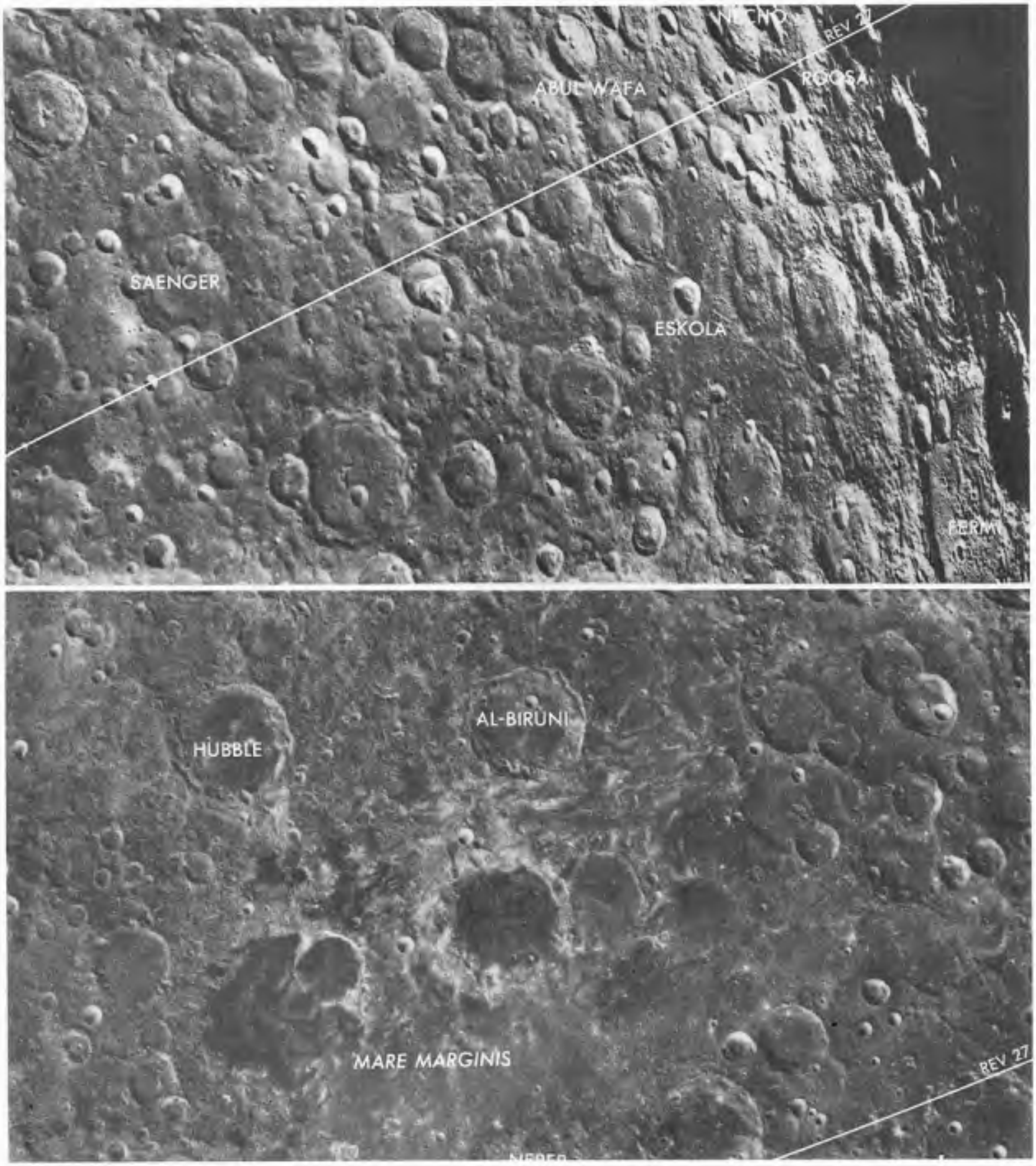

FIGURE 28-8.–The extensive field of light-colored swirls in the northern part of the Al-Khwarizmi (formerly Arabia) basin (top) and in the northern part of Mare Marginis (bottom).

You get a kind of a hint of the second ring of Arabia. (CMP, rev 29)

Examinations of the old and subdued rings of the basin resulted in observation of interesting small-scale features on the western part of the second ring, near Saenger Crater (fig. 28-8):

In some of the Eratosthenian craters around Saenger, you can still have a little bit of a hint of layering, or broken-up different-colored material at the top of all these craters. (CMP, rev 27)

Near Abul Wáfa on the first ring of Arabia, there is [a crater that should be] on the panoramic camera photographs. Look for a small crater just to the east of Abul Wáfa, about 200 to 400 m in diameter. And there is a black strip right on the western wall, going down the western wall of the crater. It does not look like that strip extends beyond the rim at all; just down inside the crater wall. (CMP, rev 29)

This is the first time I have really been able to see that first ring of Arabia. And it shows up as, the way the Sun is shining on the darn thing, it shows up as a bright–I'll be darned! That is amazing! It shows up as a bright ring, just like we got it drawn on the map. You know, I get a brighter albedo all the way around to the top of the ring. (CMP, rev 40)

Visibility of the basin rings was enhanced by the decrease in Sun elevation angles. As shown in the previous quotations, only the western part of the second ring was visible during most of the mission. However, as the Sun elevation angle decreased, the eastern part was clearly visible, especially post-TEI:

Also, be advised the inner ring of the basin Arabia is quite visible. It looks like there is a shallow depression outside the inner ring and when you get up at this altitude right around Saenger, it looks like a raised-up plateau crossing Saenger. And, also, in the vicinity of King–King is almost going into the terminator now, well, it is 10° or 15° from the terminator–you can see a little bit of a raised-up plateau, that takes in the crater King and goes about a crater diameter and a half or maybe two diameters to the south, and a crater and a half to the north of King. (CMP, post-TEI)

Light-Colored Swirls

The light-colored sinuous markings in the northern part of Arabia form part of a large field that extends westward into Mare Marginis (ref. 28-10). The nature of these swirls is not well understood, and observations from orbit at varying Sun elevation angles were made in an effort to better characterize them:

We are abeam of Al-Biruni and coming up on Goddard and Marginis right now. Al-Biruni has got variations in its floor, variations in albedo. It almost looks like a pattern as if water were flowing on a beach–it is that irregular. Not in great areas, but in small areas around on the southern side, and the part that looks like it is a water-washing pattern is of a much lighter albedo, although I cannot see any real source for it. The texture, however, looks about the same. (LMP, rev 2)

And [more on] the question of these irregular swirls that we have in Mare Marginis, and we are looking just north of Neper now. In the mare, there just is no visible relief. Although there seem to be some sinuous systematics anyway to the distribution. Like, having a very dark area associated with the light area. And that dark area is darker than the [surrounding] mare. I think the pictures will show that. Now, in the highlands, however, the light albedo areas, which are very comparable, that appear to be swirl-like patterns of the same type, seem to be associated with a crest of crater ridges and other high points. We are right over a concentration of these now in the northern part of Marginis, where the rule is that the light areas are associated with either symmetrically around a much darker area than the normal mare, or on one side, and in this case, generally the south side. That rule is very clear. And that also seems to hold in the far side where there was a slightly darker region between areas of light-colored swirls. (LMP, rev 2)

Houston, there seem to be two general kinds of ray patterns: those associated with a lot of secondaries and those that have no visible secondaries. And that is independent, yet, from the irregular light-colored areas we have been calling swirls. There is a lot more of that light-colored swirl-like irregular material, or discoloration, or whatever you want to call it, in the far-side highlands, particularly as we approach Marginis, than I have previously gathered from the available photography. (LMP, rev 3)

Let me reiterate something that I have been watching this revolution; that is this relationship of the light-colored or light-gray swirl patterns on the surface to associated patterns or parallel patterns that are darker than the average of the surrounding area. And this is true both in Mare Marginis and in most cases on the far side. Although these are very irregular patterns, there is roughly a concentric zoning of dark to light within an intermediate albedo surface. There are variations on that theme; sometimes you do not get the symmetry quite as good, but it is common enough that I think it is worth noting. (LMP, rev 5)

Later during the mission, the CMP made additional observations of this extensive swirl field. The alternating bands of dark and light were obvious despite the variation in Sun elevation angle. When he was queried about the swirls west of the crater Abul Wáfa (fig. 28-8), he stated:

Yes, I really saw them that time. And where the swirls really show up is about a crater diameter from Firsov, crater diameter to the east. And I talked about it on the tape. But, basically, they are kind of concentric swirls in that area, with light and dark [bands]. And the contrast between the light and dark is something tremendous. The dark is not a mare dark, but a tan that comes real close to it. (CMP, rev 29)

You could really see the swirls in Marginis; [I am] trying to compare them with the same type of swirls back there in Arabia . . . But in the case of Marginis, there is a crater [Goddard] just in the northwest quarter . . . That is what is causing all the swirls going across Marginis . . . There is a dark gray, and the swirls seem to be around the dark-gray areas. The swirls are a light tan. The swirls in Marginis . . . seem to be emanating essentially radially from that bright crater, going out across the mare. (CMP, rev 38)

The newly found association between the swirls and the darker bands added a new dimension of mystery to the problem. The relationship between the physical presence of a small crater on the rim of Goddard and a portion of the swirl field in Mare Marginis did not resolve the original problem: that of the lack of identifiable features that may have caused the surface brightening. Alteration of the surface material by gases escaping from the lunar interior had been suggested as a possible cause (ref. 28-11).

MARE SMYTHII

Mare Smythii is a relatively old circular basin on the eastern limb of the Moon. The basin is characterized by several discrete units with different albedo and textural patterns. The mare also contains a unique population of multi-ringed craters, some of which are polygonal in outline (fig. 28-9). The objective of making observations of Mare Smythii from orbit on Apollo 17 was to study the multi-ringed craters to determine their probable origin:

On the crater to the north of the Wright Brothers, the slope of the walls is steep, probably 45° on the inside. It is a gradual slope on the outside, slipping away from the crater. There is no apparent albedo difference in the ejecta or patterned annulus around the crater itself, and we are looking specifically at the one to the northwest of the Wright Brothers now. There is a definite mare flow that is inundated, and it is a different color and has a light albedo to it now. It is kind of a grayish tan. It is a light-grayish-tan material that has flowed, and–I cannot tell–it almost looks like it is flowed down to the crater. There is an impact crater right in the breach in the wall, which has nothing to do with the flow itself. The material in the inner crater–in these double-ring structures down there–is comparable to the hummocky, bumpy-looking-type stuff that is not really the mare; not the smooth mare of Smythii, but the other part of the mare of Smythii. (CMP, rev 62)

The walls [of the multi-ringed craters] are not delta-shaped at all. The one directly north [of the Wright Brothers (fig. 28-9)] we will say is 12 o'clock; the other one is 1 o'clock; and then a 2-o'clock crater. The 1-o'clock crater, as it looks to me, has a high lava mark around the outer ring of the crater itself. The one at 12 o'clock is the one I was talking about, has the breach on it with the later impact, the small impact crater on it. And without the binoculars I could not tell flow direction, whether they were flowing into the double-ring basin from that mare patch on the outside or vice versa, so I am going to try to check that out the next time around. (CMP, rev 62)

The crater just above the "rev 62" line in figure 28-9 displays a multi-ring structure. From the center of the structure to the inner ring, the surface slopes upward at 15° to 20°. On the outside of that ring, the surface drops steeply, at about 45°. (Paraphrased from CMP, rev 64)

I still want to talk a little bit about these polygonal craters and Smythii. The one right above revolution 62 has kind of an inundated old depression there with a mare, very smooth mare floor, with two old craters. And that is definitely a younger flow than whatever made the polygonal crater-like depression. Right above the 'rev 62' number [fig. 28-9]. The thing that bothers me about that is that they look like if you threw a rock in the mud, and you get a wave or a ripple going out from there. In other words, you have got a high wavefront going out from a circular direction with a slight sloping up to that wavefront. That is on the inner ring of the thing. The outer ring, of course, is a typical ring that you get from an impact-type operation. It looked like the rough-looking floors of those ring basins essentially have the same albedo, the same characteristics, as the rougher-looking floor in Mare Smythii itself. (CMP, rev 66)

Rims on the Wright Brothers crater pair have a structure similar to that of the crater above the "rev 62" line in figure 28-9. A cross section of the rim would display a steep outer slope (as much as 45°) and a lower inner slope (approximately 20°), a configuration opposite to that of the majority of craters. The western portion of one of these craters is an exception in that the rim is almost delta-shaped; that is, it has the same slope inside and outside the crater. (Paraphrased from CMP, rev 73)

CRISIUM-SERENITATIS

As illustrated previously, much emphasis was placed on color tones of the observed features. As a result of Earth-based studies of the near side of the Moon, the lunar surface units had been mapped as red, intermediate, and blue (fig. 28-10) depending on their response to the solar spectrum. These color units appear to correlate with compositional variations (ref. 28-12). Visual study of actual colors of representative areas was expected to help in interpreting the color variations and in extrapolating to other areas of the Moon.

The region designated 8 in figure 28-1 was considered of high priority in the discussion of the colors of the surface units. The region encompasses the western half of Mare Crisium through the eastern part of Mare Serenitatis. At one time, the CMP commented:

To me, the Moon has got a lot more color than I had been led to believe. I kind of had the impression that everything was the same color. That is far from being true.

This being the case, the area of observation was

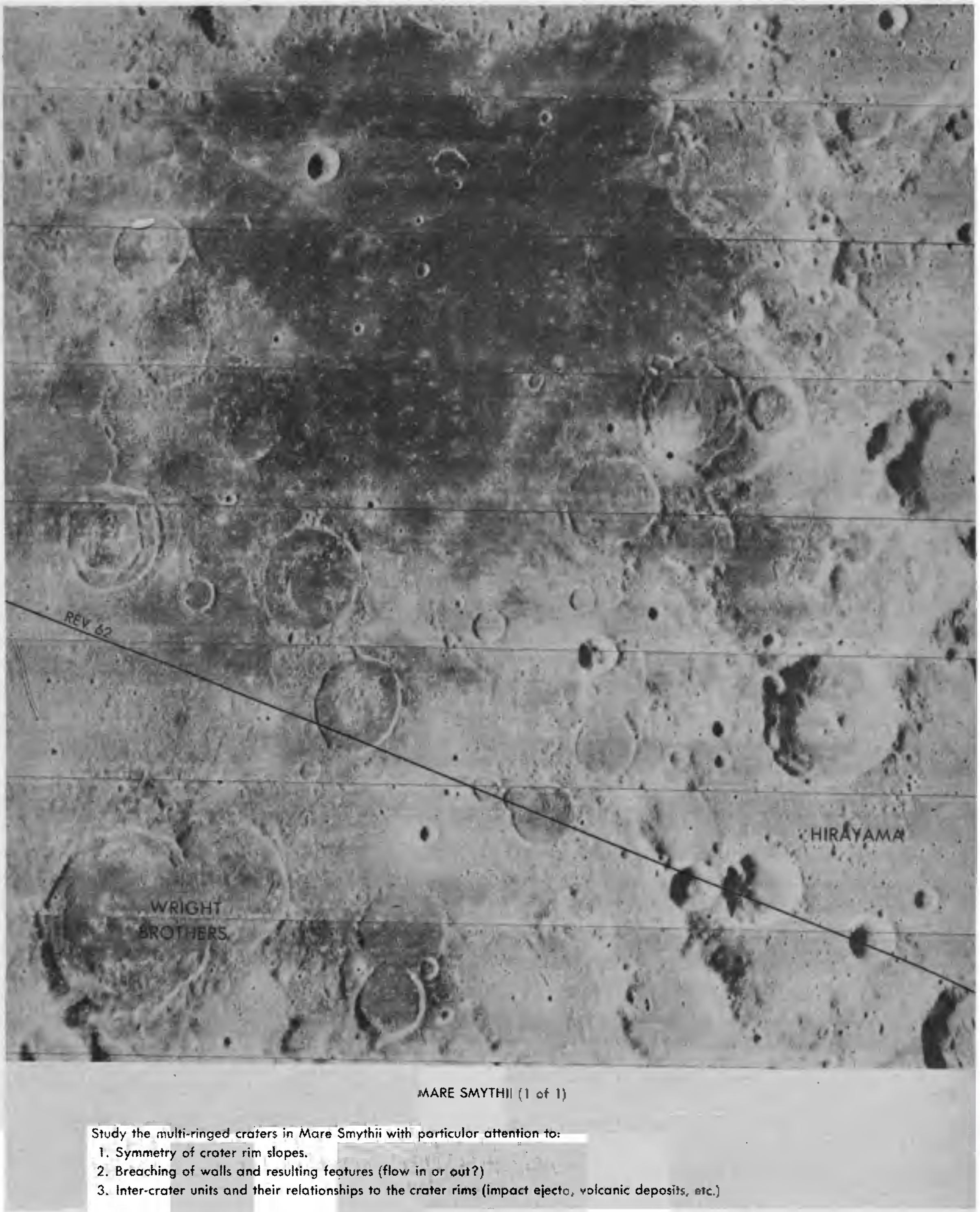

FIGURE 28-9.—Numerous multi-ringed craters in Mare Smythii on the eastern limb of the Moon were the object of visual observation from orbit. Rim materials of these craters were compared to the hummocky units in the southern part of the basin.

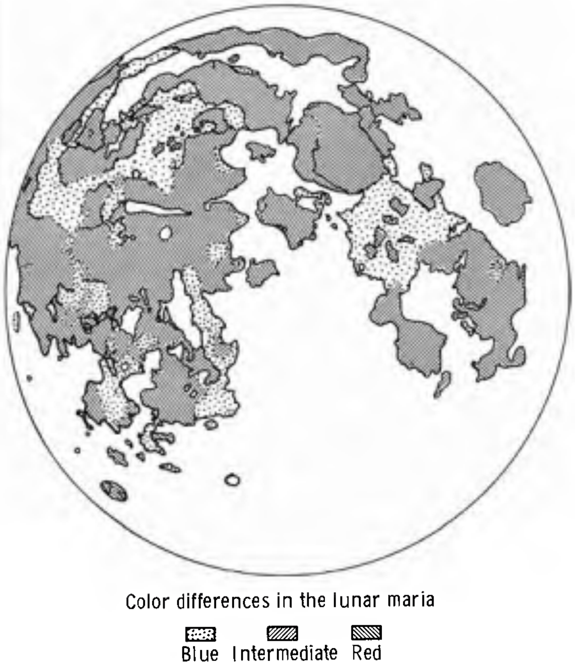

FIGURE 28-10.—Generalized map of color differences in the lunar maria (ref. 28-12, p. 199).

extended, in real time, both to the east (to include eastern Mare Crisium, fig. 28-11) and to the west (to include the western rim of Mare Serenitatis, fig. 28-11). For clarity, the region will be divided into seven segments in the following discussion.

Mare Crisium

Some patches in Mare Crisium appear to have lower albedo than the rest of the mare. Boundaries between these units are difficult to draw, based on available photographs. Also, the relationship between the discontinuous circumbasin mare-ridge system and these units was not clear. The CMP was asked to study these relationships within the basin and report on the color tone of the mare materials:

I am looking at the eastern edge of Crisium now. As you come across there, it looks a little bit darker; I keep seeing browns all the time up here instead of gray tones. Maybe that is just the way I interpret them. They have kind of a brownish tint to them, and it is a darker brown than south of the ridge system there. (CMP, rev 27)

The CMP noted that the crater Condorcet H on the southeastern rim of Crisium displays an unusual diamond-shaped floor; he also noted a probable landslide in the adjacent Condorcet A Crater (fig. 28-12):

I am just now passing that crater I took a picture of on the last time [Condorcet H]. And instead of having a round bottom, it has a diamond-shaped fill in the bottom. And the diamond, itself, is about one-half of the crater diameter. (CMP, rev 27)

Condorcet A [appears to have] a landslide on it. And it does not look like a crater on the side of the wall, on the northwest wall of the crater . . . The area is oval or ellipse shaped. Of course, the top of the ellipse is toward the top of

FIGURE 28-11.—Lunar near-side region encompassing Mare Crisium (right) and Mare Serenitatis (left). Note the albedo boundaries in both maria (AS13-60-8696).

FIGURE 28-12.–On the eastern rim of Mare Crisium, a landslide was described in Condorcet A Crater, and a diamond-shaped floor was found in a fairly fresh crater (arrow) near Condorcet H (AS17-149-22787).

the crater. And it looks like almost a flow out of the bottom of the ellipse, which is about a fourth of the way up from the bottom of the crater . . . The hole or the slope or the slide, or whatever you want to call it, down through there, is maybe one-eighth of the crater diameter. And the floor area is only just a real small portion of one-eighth size . . . There were some lineaments in the area; and, again, they are vertical-type lineaments downslope. (CMP, rev 28)

Picard Crater

Picard Crater, 30 km in diameter, is located in western Mare Crisium and displays a somewhat dark rim (fig. 28-13). Although the crater appears to be younger than the surrounding mare material, there are no rays and crater chains associated with its relatively smooth ejecta blanket. Detailed study of its characteristics from orbit was planned to aid in deciphering its origin. The similar, but smaller, Peirce Crater to the north was also studied for the same reason. The most obvious first question was related to the color of their rim deposits relative to the surrounding mare:

All those dark and light albedo changes around Picard and Peirce are not obvious at this particular angle yet. There is some hint of them . . . We are just about over the top of Picard; and the rim materials, which go out about a third of a crater diameter, as near as I can tell, are distinctly darker but not by much. They are more gray than the gray tan, or tannish gray of the rest of the mare. (LMP, rev 1)

Coming up at Picard now. Looking at it, a little bit from a distance, there is a darker albedo that goes about one-half a crater diameter. And then, on top of that darker albedo, it

FIGURE 28-13.–Picard Crater in western Mare Crisium (AS17-150-23038).

only goes out maybe a fourth of a crater diameter, there is a lighter-type material that seems to be covering it up. The lighter-type material though only goes in a generally westerly, from the south around to the west side and then from the northeast around to the northwest side, and it leaves the dark material draping down on the east side of Picard.

You can pretty well carry a light layer in the top portion of the wall all the way around to that part where the light part stops. And then you come to a dark layer again. And then, as you continue around from the west to go to the north side, it is a little bit in shadow on the east side, so I cannot tell for sure whether that light layer is in there or not. But starting on the south side, going around to the west again, you can see a layer of dark material, although there does not seem to be a change in the slope or the inner wall of the crater.

Just below the dark layer, there is a change in slope a little bit. It maintains that slope all the way down to the crater floor, where you get into the slump blocks. And then in the center of the crater, it looks like a mare-like fill with, I am about to lose sight of it again, something comparable to a central peak in it. (CMP, rev 24)

When queried as to whether or not the Crisium mare ridge system corresponds to the color boundary, and if not, does the ridge cross any color boundaries, the CMP stated:

This ridge system is running east and west down here. The color boundary is not nearly as apparent in Crisium as it is in Serenitatis, except that right under me right now, there is a subdued crater with a southern part of a ridge. The ridge runs east-west, and it looks like we have got a flow coming out of it . . . The zero-phase point is following me right along here in Crisium, so I get a different color straight out from the window than I do out from the edge of it. So I think that is going to influence my thinking.

You can see some of the rays from the crater Proclus have spread out all the way across here. And they completely cover up the ridge system, so I cannot see any color distinction on the western edge of Crisium. (CMP, rev 27)

On the following revolution, the color tones around and within Picard Crater were again and more fully described:

Sure hope that color difference shows up in Picard . . . There is black material now you get on up here, the darker tannish-gray material covers essentially from the east all the way around to the south. It goes outside the rim as well as inside the rim. It drapes over the rim. That cannot be a shadow effect. (CMP, rev 28)

Additional details of the crater and its surroundings were also obtained on later revolutions:

You know you could, even as the zero phase went right across Picard, you could still see the darkness on the east from 9 o'clock around to 6 o'clock, if north is zero. And if north is zero as you look at the crater, then over about 1 o'clock there is some kind of a fault zone in the side of the rim, and that is another spot where the dark material drapes down into the rim and also outside of the rim. And then you have that same type of impression at about 11 o'clock. You have got a black streak going down inside the rim, and then it widens out going toward a little crater outside of the rim. (CMP, rev 36)

In the eastern wall of Picard—I am looking at it with the binoculars now—you can definitely see the first part of it up there has some vertical escarpments along the edge. And the vertical escarpments are in irregular layers, just like you would suspect if you eroded out a bunch of lava layers. In other words, they are discontinuous, but they are kind of intermingled along, and they go about a third of the way down from the top of the rim, down to where the talus starts sliding into the crater. (CMP, rev 40)

At a Sun angle of 50° to 55° (rev 50), the crater Picard still displays a dark halo. The dark halo appears slightly smaller, extending perhaps to one crater diameter, and is less distinct. (Paraphrased from CMP, rev 50)

Western Crisium

In the western part of the Crisium basin, observations were made of (1) the dark-halo craters in the mare fill and (2) the rim materials as displayed in massif units and in the ejecta blanket, including Proclus Crater and its bright rays.

Small, dark-halo craters in Mare Crisium.—The mare surface northwest of Yerkes Crater includes several dark-halo craters (fig. 28-14). Some of these display smooth rim deposits and are believed to be volcanic in origin (ref. 28-13), and others have hummocky ejecta blankets and are probably produced by impact. The following observations were made from orbit during the Apollo 17 mission.

West of Yerkes, there is a real small crater I am looking at with the binoculars. And the reason it stands out is because it is a fresh crater and yet there is a dark halo all the way around it. And it is also dark down on the inside of it. I still

FIGURE 28-14.—Dark-halo craters in western Mare Crisium. The ejecta blanket of the circled crater was described as having an orange-tinted color (AS17-150-23044).

do not have a feeling for the relative size of things. I will try to get that one on the next pass. (CMP, rev 24)

All these dark-halo craters by Yerkes! The one that is farthest to the south looks like an impact-type crater. In other words, you have a definite ejecta blanket around it. The one that is hard to look at is in the middle of the field, but I think it is probably the second one down from the top. It has rounded ridges, and a rounded rim. The ejecta pattern or the dark halo is about twice the crater diameter. And it is either a highly eroded impact-type crater, or it is a volcanic-type structure. And, to me, it does not look like a highly eroded impact one. (CMP, rev 40)

The rays and ejecta blanket surrounding the bright-rayed crater in the area (fig. 28-14) were described as orange in color. The crater was compared to others in the Taurus-Littrow landing site and in the Sulpicius Gallus area (as discussed in the following paragraphs).

In the north, east, and west quadrants of that little crater, there is very clearly an orange pattern, an orange color to the ejecta. The other quadrant is a lighter color, a light gray. (LMP, rev 64)

In addition to the orange-tinted ejecta, blocks with a greenish hue were observed around impact craters in western Crisium. These observations may be important in establishing the importance and distribution of colored glasses collected on Apollo missions 11, 15, and 17.

I get the impression that these bright ones, see the bright one right down there in front of us [fig. 28-14], have a dark greenish-black or blackish-green [color], yes, a green cast to the rocks. The big blocks that are laying around in the crater and also the ones that are down in the bottom, a greenish cast to them. (CMP, rev 64)

Houston, we are just passing over a little polygonal crater that is maybe 15 km in diameter. It, again, has that dark greenish-black rock that is collected down at the bottom of it, and you also see it streaking down the side of it. But, I think one of the most significant features about the crater itself is that it has a swirl, and this looks like swirls rather than rays. It has a swirl pattern, radial from that most recent impact. (CMP, rev 66)

Rim materials of the Crisium Basin.—The sharpness of the massif units that ring the circular basins is one of the factors to be considered in deducing the relative age of the basin. The mountain rings of large circular basins and those of Imbrium were compared during the flight, based on what is known about their positions in the lunar stratigraphic sequence (ref. 24-14). The following are selected comments that compare Crisium with other overflown basins:

While we are in a relatively quiet period, we are going to make a few comments about some of the things that cross the two big basins that we are getting very familiar with, actually, three: Smythii, Crisium, and Serenitatis. [The obvious features are] the degradation of the walls of the major ring and the lack of any obvious blanket structures, in contrast to Imbrium and Orientale, which we have also had a pretty good look at. That contrast is quite striking.

The fronts of the major ring in Crisium are strikingly different from those of the Apennines in their general slopes; sharpness of topographical features; and in any appearance of having even a hint of boulder fields on their slopes like we observed, say, on the South Massif, anything like that. At least Serenitatis massifs seem to locally show fairly major boulder fields on their flanks. And I have not seen any around Crisium yet.

A crater, a fresh crater in the mare or a fresh crater in the rim area will have boulders, do not misunderstand me. But the front faces, the ring front faces, do not have boulders that I can see. And I think boulders are pretty obvious when they are there. We have seen them well defined on the central peaks of Tsiolkovsky, and I think any time you have a major boulder field, you can see it with the binoculars. (LMP, rev 62)

Proclus Crater, 35 km in diameter, was studied during Apollo 15, and its ray-excluded zone was attributed to shadowing at the time of impact (ref. 28-1). The rays of Proclus were studied during Apollo 17 to determine whether or not there is any similarity in appearance between those rays and the swirls of light-colored markings discussed in the section on Arabia:

I am looking north along Crisium, and there is Picard and Peirce. And you get the same pattern that looks like a swirl. The same type of albedo as a swirl with light places and dark places. The only difference being that you can definitely tell that these are ejecta from Proclus because the pattern is somewhat radial to Proclus itself. And then you have the same thing; there is a crater up on the north rim of Crisium, just outside of it is a 50-km crater. And it is a very bright one. And there the rays cross the Proclus swirls or rays. Here you have to definitely call them rays instead of swirls, and yet they look the same way. And the only distinction is that in Crisium they go essentially radial. They have a direction to them, whereas the ones over there in Marginis and next to Firsov do not have any particular direction to them. (CMP, rev 38)

On Apollo 17, an effort was made to study the unit in which Proclus Crater is located and to compare that unit to other hilly terra units in the vicinity of the Serenitatis and Imbrium basins.

There is a crater just on the west rim of Crisium, [with a] relatively fresh rim, fairly crisp rim, but no strong ray pattern. There is no ray pattern apparent at all. It looks like it predates the plains material around it, since they come right up to the edge of the crater in one spot. That is [Proclus]! (LMP, rev 1)

The highlands look essentially the same as you pass from Crisium on across to Fertility. Again, they look so much like the Sculptured Hills . . . What I am referring to are the highlands bordering Crisium, in all of them you do see a definite radial pattern upslope and downslope, from the center of Crisium. But none of the lineaments look like Fra Mauro [the Fra Mauro Formation, bordering the Imbrium basin]. (CMP, rev 62)

Getting into areas that resemble, in their surface texture, the Sculptured Hills of the Taurus-Littrow landing area. Here we are just passing Proclus, so it is in the ray-excluded zone of Proclus where there is a mare surface projecting up into terrain that looks like Sculptured Hills. And that mare has a distinct bluish-gray color, in contrast to the regolith associated with the Sculptured Hills, between the Hills at least, which is a brown, let us call it a tannish gray. Quite a sharp color hue contrast to my eyes, at any rate. (LMP, rev 63)

Macrobius A Area

West of Macrobius Crater and especially in the vicinity of Macrobius A are several small cone-shaped craters that display dark halos (fig. 28-15). The Apollo 17 crew was asked to study these craters from orbit to determine whether they are volcanic cinder-cone-like features, or impact craters that excavated dark material from beneath a lighter mantle:

Next to Macrobius A, there is a dark halo crater, a very small one. And it does not have the appearance of a hummocky crater rim to it, at all. It looks like the material just kind of spreads out all over the area, but it does not have a hummocky appearance to it. I am going to take a look at that again when I come back around. On the other side, there is a small mound down in the bottom of the crater, also. It is a dome-shaped structure in the bottom of that small crater. It is right next to J-3, north of J-3 [fig. 28-15]. (CMP, rev 15)

I was looking at the dark rimmed craters, and some of them have what I would call an ejecta pattern around them; and the others just have kind of a raised rim with no apparent blocks. The one to the southwest of that hill by Yerkes looks like it has an ejecta pattern around it with blocks.

I was looking for any dark-halo craters in this area that might be sticking through the Proclus rays. You compare on either side of the Proclus ray, and the same size crater . . . You get the same albedo of ray material from the small craters in either case . . .

The two dark craters, the one just north of Macrobius A, and also north of J-3, that is the one that has the dark mound around it, it has got a small dome down in the center. It does not have any ejecta pattern around it; no rays, no nothing. To me, that sure looks like a cinder cone. The dark halo around it goes out for at least a crater and a half diameter. The raised dome down in the center of the crater is about a fourth of a crater diameter. And there are no rays. (CMP, rev 27)

The CMP at this point characterized the color of the dark-halo craters near Macrobius A as similar to that of Maraldi and the landing site; he characterized the color as "dark tannish gray." (Paraphrased from CMP, rev 27)

Maraldi Area

Before Apollo 17, the origin of the Sculptured Hills on the eastern rim of the Serenitatis basin was not fully understood. One of the possibilities was a volcanic, constructional origin (ref. 28-15), and the example usually given was the dome-shaped, isolated structure Maraldi γ (fig. 28-16). An objective of the Crisium-Serenitatis visual observations was to determine the nature of that structure.

From the pictures of Maraldi γ, it looked to me like it might have been a volcanic dome of some kind. Now when you look at it and compare it with the rest of the surrounding material, it looks just like any of the other Sculptured Hills. The domical structures on it are the same type of material that carries on through south of Maraldi. (CMP, rev 17)

The floor material of Maraldi Crater east of Mare Serenitatis was also studied from orbit, and some interesting color tones were discovered and later compared to materials in the Taurus-Littrow landing site and on the western rim of Mare Serenitatis.

It looks like maybe some kind of a mare fill has come in and filled up Maraldi itself. You can see flow lines, going down into Maraldi from Tranquillitatis. The impact craters inside Maraldi have a definite bluish tint to the halo that comes out as opposed to the bright or the white-type craters. Those have more of a darkish bluish tint to them. Oddly enough, that is the same type of bluish tinge that I see right in the landing site right now. In the Pentagon Complex, MOCR shows up that same type of a bluish tint. (CMP, rev 17)

Again, the fresh craters in Maraldi still look kind of bluish to me, not as much as they did yesterday, but they still have a bluish tint to them from the reflection of the Sun. In other words, they are fresh craters and one of them is about the size of MOCR, and the other one is about the size of Sherlock or Camelot. (CMP, rev 27)

Houston, even at the high Sun angle here, the ejecta of the four or five recent craters around Maraldi, still are bluish gray, light bluish gray. The floor of the crater Maraldi is essentially a darker gray today, I guess, than anything. And the ejecta patterns on that are the same albedo and color distinctions as the ones in the landing site. (CMP, rev 74)

When he was asked to compare the floor fill of Maraldi to that of the light plains materials in Maraldi E, the CMP replied:

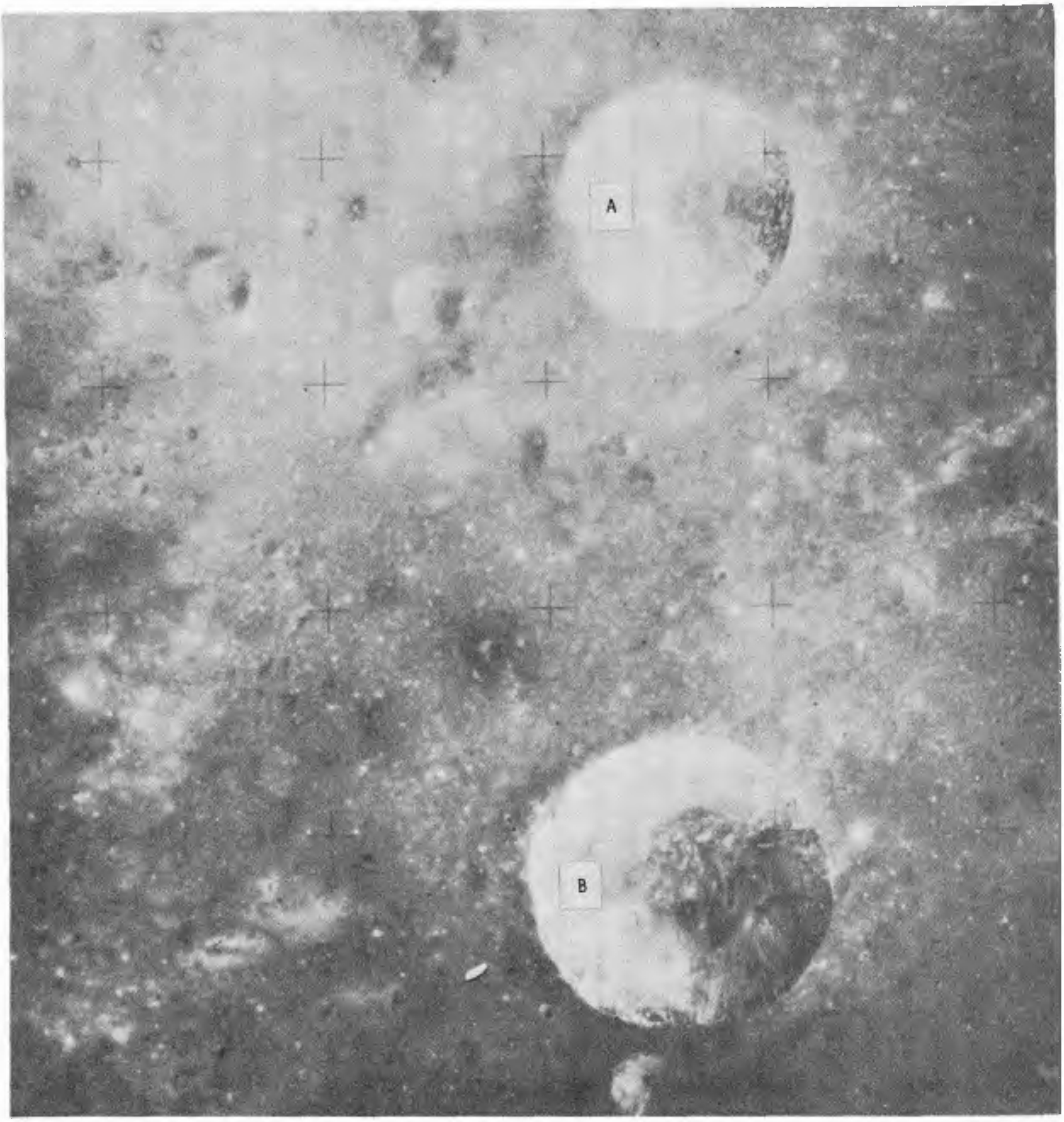

FIGURE 28-15.–Dark-halo craters near Macrobius A and B Craters (Apollo 15 metric camera frame AS15-557).

The floor fill in Maraldi is definitely a darker color. The light plains in Maraldi E are the light-tan material. And the floor of Maraldi looks just like the landing site. (CMP, rev 27)

Mare Serenitatis

As an additional tool for the extrapolation of ground-truth data, observations were made of the relationship of the dark material in the Taurus-Littrow landing site and the dark annulus of Mare Serenitatis (fig. 28-11). The following discussion will start with the eastern border of Mare Serenitatis, followed by observations of the color/stratigraphic units in the southern part of the mare. Detailed descriptions of the landing site area itself are given under a separate heading of this report.

Eastern Mare Serenitatis.–It was previously stated

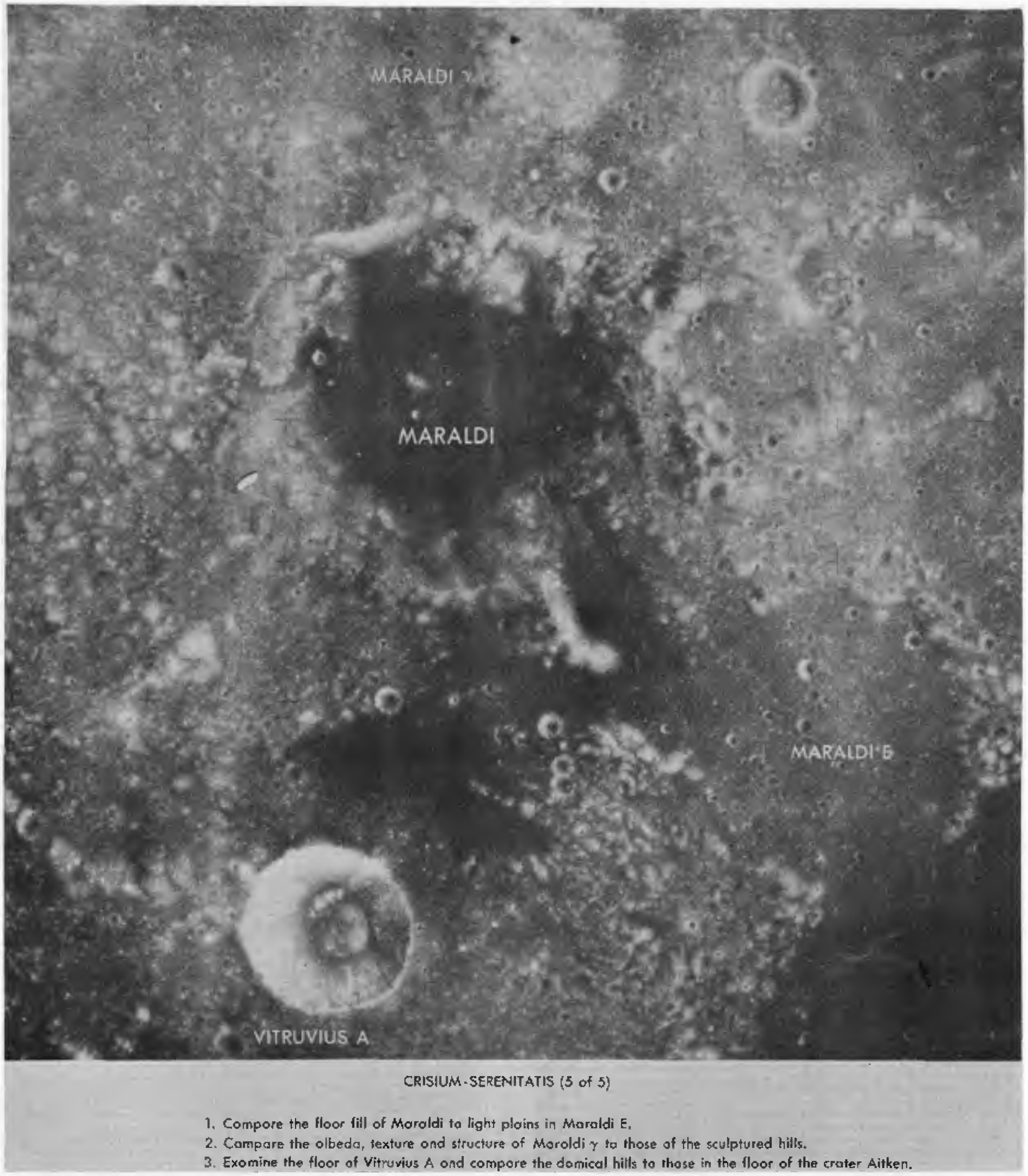

FIGURE 28-16.—Apollo 17 onboard graphic in support of visual observations of the Maraldi Crater area.

that the dark fill of Maraldi resembles that in the landing site area including a few craters with a bluish tint. The dark materials of the Taurus-Littrow area appear in photographs to continue into the Serenitatis basin and show intricate relationships with the mare ridges in the dark annulus. The following observations are descriptions of these relationships as seen from orbit.

Right now, I am looking at the ridge system around the annulus of Serenitatis. And the dark material stops before you get to the crater that sticks into the eastern edge of Serenitatis. (CMP, rev 27)

The dark annulus around Serenitatis, as you look north, and I am kind of looking back, that dark has no continuity with the ridges at all. It [the color boundary] goes right down the middle of the ridges. As you look directly west of Littrow, the wrinkle ridge is there, and you have the dark tannish gray. And then you get out to the light tan of the Mare Serenitatis itself. (CMP, rev 35)

I am looking out of window 2 now, and you can definitely get three different color units: You have the light tan of Serenitatis; and then you have the darker annulus that stops somewhere in about the middle of the two ridge systems that go around; and then you come down south in the landing site area and the two dark units change. The landing site area is a darker gray. (CMP, rev 38)

The same color differences were amplified and more fully described at higher Sun angles (25° higher):

This is not a good viewing attitude at all, but we get a few isolated views that may be worth commenting on. The contrast, to my eye anyway, between the three color units around the landing site is a medium bluish gray to gray for the dark mantle; a light blue gray for the annulus around Serenitatis; and then, a tan gray for Mare Serenitatis proper.

The light-blue-gray annulus is also the locus of most of the circumferential grabens, that Serenitatis is noted for, in that area. And that is nothing new! But, in one place, there is a very subdued, flooded crater which seems to control a circular projection of the light blue gray out over the tan-gray mare. Most of the major wrinkle ridge system of Serenitatis, of course, is outside the annulus of blue gray, except locally, and one of those places was to the west of the Taurus-Littrow site. Although that wrinkle ridge system does, in the southern portions of Serenitatis, cross the contact between the light blue gray and the tan gray.

The impression I have had by looking at all the mare wrinkle ridge systems is that they are a late feature. They, at least at low Sun, and sometimes even at high Sun, they have very sharply defined ridges with steep slopes on either side that, in general, give me the impression that they are constructional, possibly associated with some thrusting movement. (LMP, rev 62)

Southern Mare Serenitatis.—An interesting observation was made of apparent layering in Dawes Crater (fig. 28-17) that is related to the units in southern Mare Serenitatis and their color boundaries:

The crater Dawes has, starting from the top going down the rim, a light-tan layer; it is a concentric layer all the way around. And then you come into a lighter one, almost like on the hills all around the landing site. The first layer goes down maybe about a third of the depth; and then the white

FIGURE 28-17.—Layering in Dawes Crater on the southeastern corner of Mare Serenitatis as seen from lunar orbit (AS17-150-23066).

concentric layer, in the western wall, goes down to not quite half of the distance from the top of the rim down to the bottom. The lower portion, a little better than a half, is kind of a tannish gray. It is all streaked. And the bottom of the crater itself is filled with, oddly enough, the same color of material as that lying around the edges of the crater. It has some radial rings, which give an indication of a subsidence of some kind, or of sliding downhill. That is really the first crater where I have been able to see any sort of layering in the walls. Now the first layer on the north side and also on the south side, in the dark-brownish layer of the thing, you can see parts that are jagged. In other words, there is a slight change in slope. That looks like it is a very steep slope, which would indicate that it is a fairly compacted type of material in the first layer. And then the slope changes in the white layer on down a little bit more. And the white layer seems to sort of maintain the same slope as the dark-gray layer. (CMP, rev 39)

At higher Sun angles and to another observer, the sequence of layers in the walls of Dawes Crater suggested overturning of strata:

In Dawes, I think you can see the overturned [units]. The rim materials are made up of the brownish-gray material, and the walls underneath these are the bluish gray, which is the age relationship suggested by topography; that would be the lower unit is forming the rim, with inverted stratigraphy. (LMP, rev 62)

Layering was also noted in segments of the Rimae Menelaus that appear to have raised rims when observed at low Sun elevation angles:

Those rilles to the north of [Menelaus], there is a bunch of them crisscrossing. One is right on the edge of the Serenitatis basin. But they have got slightly raised rims around the edges. You can see some layering down inside the rille itself, in the one that runs in the east-west direction. (CMP, rev 15)

The color boundaries in southern Mare Serenitatis, particularly north of Menelaus Crater (fig. 28-18), received much discussion throughout the mission. The following observations were made of this area:

When I take a look at it from this angle, the ejecta from Plinius covers up the rilles and the annulus around Serenitatis . . . Now, we are getting into a relatively low Sun. And Serenitatis is a lot lighter colored than the light tan, to me. At this low Sun, you look out into Tranquillitatis, across Plinius, and that turns out to be the same kind of gray tan, it is darker . . . There is a definite color difference between them [Tranquillitatis and Serenitatis]. And it almost looks as if the color from Tranquillitatis extends on over, or kind of drapes over the edge, and covers up part of Serenitatis.

We are at the same Sun angle, and there is no doubt about it from Tacquet on up to Menelaus, there is a group of small rilles and those rilles have ejected material, around and over the rilles; not impact-type ejecta. It has got to be a volcanic ejecta of some kind. It is a darker brown than the tan of Serenitatis. (CMP, rev 28)

Going to come across the Tacquet area again, and there is a bright crater, a recent crater, in that dark annulus in the southern part of Serenitatis. It shows up again as that kind of a blue-gray brightness, as opposed to the tannish brightness of the bright craters in Serenitatis. There is still no apparent color tone or differentiation in the wrinkle ridge in this part of it. The only differentiation is that it looks like south of Tacquet you get the same color tone on over into Tranquillitatis as you get between Tacquet and Menelaus. (CMP, rev 35)

Looking at Menelaus, you can see where the dark edge of Serenitatis goes through the crater. And, the north wall is quite distinctly grayer, let us say bluish gray, than the south wall, which is very light gray in the talus. My guess is that it is a very nearly vertical contact at that point. (LMP, rev 66)

FIGURE 28-18.–Contact between two mare units in southern Mare Serenitatis. The older and darker unit near the rim of Menelaus Crater (lower edge) displays rougher topography; the younger and lighter unit contains a broad wrinkle ridge (AS17-150-23069).

Sulpicius Gallus Area

The dark mantling materials on the western rim of the Serenitatis basin are more varied and perhaps more complex than on the southeastern rim. Materials of the dark mare annulus in southern Serenitatis appear to be overlain by younger mare materials that also postdate the dark mantling units of the Sulpicius Gallus area on the western rim of Serenitatis. These rough and textured materials are to be contrasted with the patches of dark units between Montes Haemus and Montes Apenninus to the west (fig. 28-19). The objective of this observation was to compare these units to the Serenitatis mare materials, with emphasis on the color tones. (This task was added to planned observations in real time.)

When we are coming around the dark annulus, follow it around, by Menelaus and Tacquet, it seems to change colors a little bit when we get up to the Sulpicius Gallus. I guess the only thing you can say is that the southern part there, in the Tacquet region, has a more of a bluish tint. And, then to me, this has more of a brownish tint to it when you get to the Sulpicius Gallus region.

I am just passing Menelaus . . . and Sulpicius Gallus is just now coming up. I think the Sun angle has a lot to do with that, because this whole Sulpicius Gallus region looks kind of brownish to me. I will have to check that when the Sun gets a little bit higher. (CMP, rev 24)

I am just passing over Sulpicius Gallus, now. And just beyond Sulpicius Gallus, you got a gentle slope of the massif coming down and then it changes slope a little bit. And that might be what we have at one time or another called the high water mark, but I believe that is just a talus change in the slope. But as soon as you cross that area, we have a dark-tan material that essentially covers the highland. It is a hummocky material. There are a few rilles just north of Sulpicius Gallus; those rilles, again, have the dark-tan material on them. (CMP, rev 36)

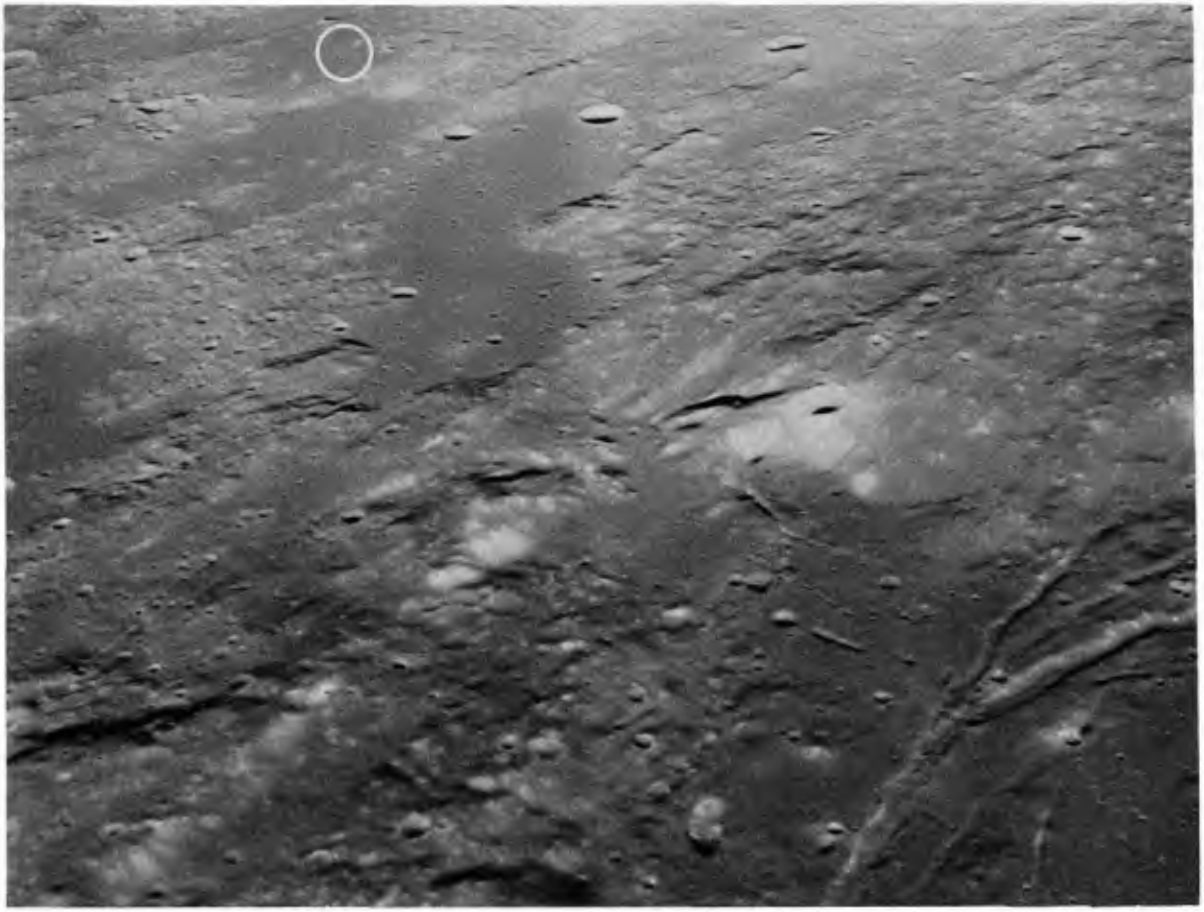

FIGURE 28-19.–Oblique view looking westward from the dark mantling deposits on the western rim of Mare Serenitatis. Rimae Sulpicius Gallus are in the lower right corner; D-Caldera (circled) is near the upper left edge of the photograph (AS17-153-23572).

As will be discussed later, the CMP noted an orange zone on the northeast rim of Shorty Crater. Ejecta blankets of several craters of comparable size and larger also displayed an orange color. Referring to these craters later in the mission, the LMP added:

Ron says that he already commented on those, and they look very obvious to me . . . [The color] is a light orange, in contrast to the brown gray of the dark mantle in the vicinity of Sulpicius Gallus. There is a good one right down there. Now, that one looks like a constructional cone that is orangish. And that is right out on a raised projection of the brown-gray dark mantle out onto the light-blue-gray annulus material. (LMP, rev 62)

In addition to the constructional-appearing, orange-tinted craters and the many orange-colored blankets around small impact craters in the Sulpicius Gallus region, an elongate depression with orange-related colors was also discovered (fig. 28-20).

There is a large gouge just south of the Sulpicius Gallus rille. The gouge is a rimless depression, and streaming down from the upper portion of that depression are not only our old friend the orange gray, but some would be a red brown gray, very clear coloration . . . There is another crater we will have to look at . . . There is a whole bunch of them down there . . . Yes, we are seeing an orange Moon now. In this whole dark mantle in here around Sulpicius Gallus there are scattered craters with a variety of orange to red-brown hues. And they all, except for that large rimless depression, which looked as if it was exposing some layers which were streaming those colors, all the other craters seem to be small impacts that apparently are penetrating just far enough into the dark mantle material to tap this zone of orange to red-brown material. (LMP, rev 64)

That rimless, V-shaped depression [fig. 28-20(b)] that had the streaked talus on it has a mottled rim area that has the orangish-tan or orangish-gray color as the spot. And it looked as if the more red-gray, red-brown-gray, if you will, material was lower in the section within the walls of the depression. This is a very steep-walled depression, by the way. It has talus

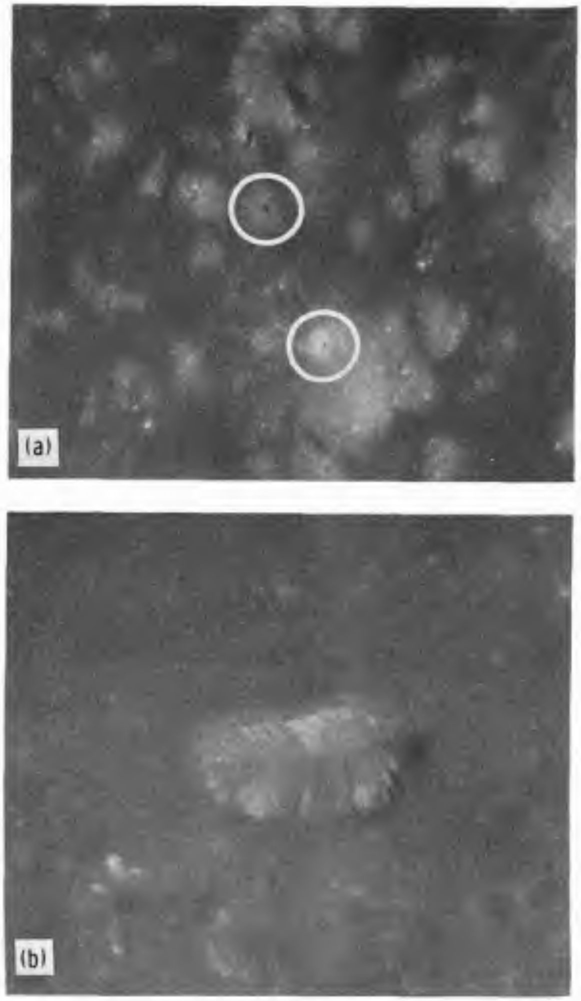

FIGURE 28-20.–Apollo 17 photographs of Sulpicius Gallus formation where orange-tinted material was observed during lunar orbit. (a) Two 0.5-km-diameter craters. The upper crater is an impact in the dark plain and exhibits orange-tinted ejecta (AS17-148-22771). (b) Elongate depression, approximately 6 km long, showing orange-tinted walls (AS17-149-22880). For general setting, see figure 28-19.

streaming down the sides of it, and the coloration streams in this same direction. It looks as if there may be layers or roughly horizontal zones that have the coloration that we are seeing, which are forming the talus slopes down below them. (LMP, rev 65)

These observations of the orange materials were also confirmed by the third crewmember:

Just so you are fully aware, we are not sort of just leaning and getting colorblind up here, I tell you, the last one Jack was talking about [the small impact crater, fig. 28-20(a)] was not even subtle. Its entire ray pattern was this color material, with a definite contact between it and the dark material around it, and it had that orange-brown hue to it, without any question at all. (CDR, rev 64)

LANDING SITE AREA

The Taurus-Littrow landing site on the southeastern rim of Mare Serenitatis was studied from orbit for (1) regional characteristics that may reflect on the sampling area and (2) details of local structures that may help decipher the setting of explored sites.

General Setting

Observations from orbit began very early during the mission and continued throughout the orbital period. One of the more interesting problems was to see whether or not it is possible to define a source point for the landslide or white mantle on South Massif (figs. 28-21 and 28-22). The slide itself and the scarp that goes through it were obvious even at very low Sun elevation angles:

With respect to the landing site, when I first had it in view, there was a clear lightening in the area of the light mantle. It was not sharply defined; but around the crater Lara and Nansen and to the west of the scarp, there was very clearly, slightly brighter reflectivity. (LMP, rev 2)

I can now see down in through the shadow. I can see Bear Mountain. I cannot really make out the slide yet. Most of the North Massif is still in shadow due to the Sculptured Hills . . . But, I did see some sort of albedo change that went across the canyon about in the vicinity of the scarp. (CDR, rev 2)

You could really see a difference between South Massif and the mantle material through there. The mantle is not nearly as dark as it looks on the pictures, though. But South Massif, especially, looked whitish in color. I guess it is because the Sun was shining on it . . . You can see the slide and definitely see the scarp going across through there. (CMP, rev 3)

I got the landing site. We are right over the top of it, and the scarp is fantastically detailed at this [Sun angle] . . . The light unit is very obviously mantling the area. The scarp is very detailed, and, so far, [I] could not see any structure in the massifs at all . . . From this altitude and with that low Sun, there is no question of the sharpness of the topographic features in the landing area. The scarp, and even some of the apparent backflow features, that is, apparent flows to the west in the light mantle area, were extremely sharp, even those fronts going west were sharp. It looked even more like a mare ridge than it ever did before. (LMP, rev 5)

The scarp definitely cuts up through the North Massif. I cannot see a continuation into the South Massif at all. And it almost looks like a flow coming from the direction of Family Mountain, lapping up on the side of the North Massif. That is

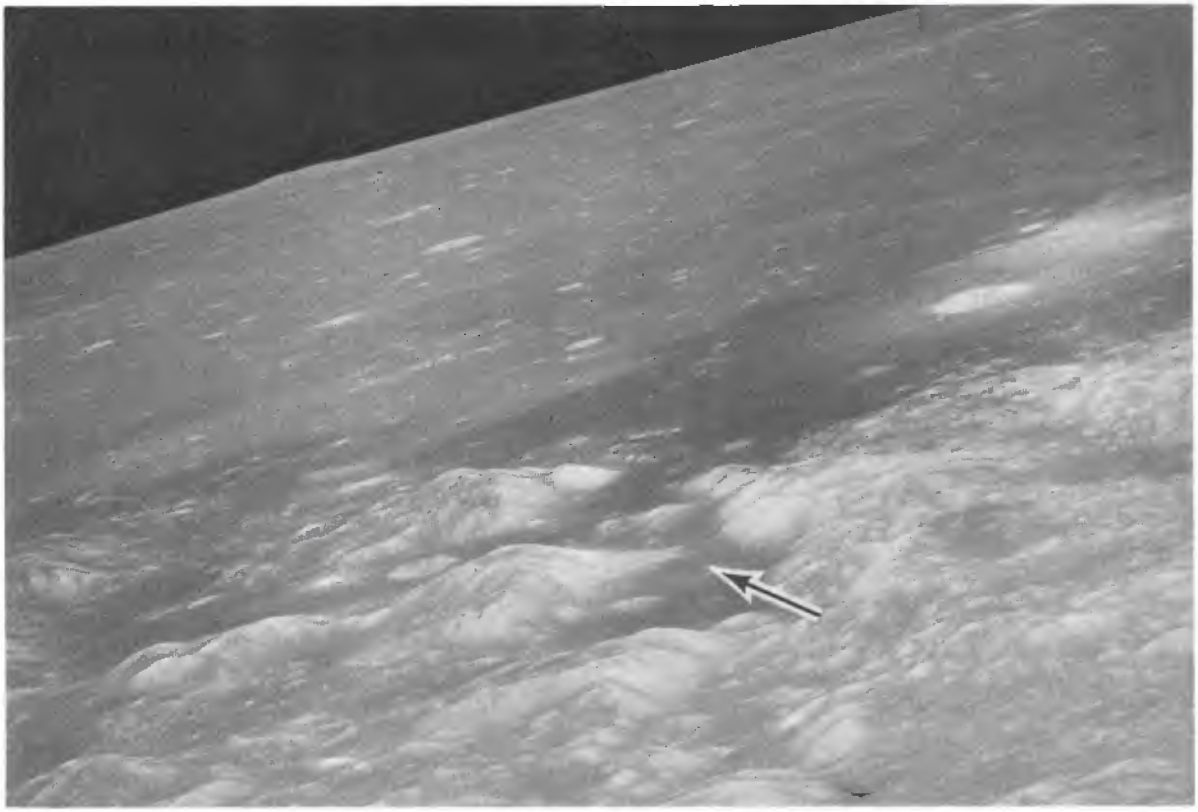

FIGURE 28-21.—Oblique view looking westward from the Taurus-Littrow landing site. Arrow, showing the direction of flight, indicates the landing point (AS17-148-22770).

the way it looks as you go on by it. I could not see anything that would lead you to believe that the slide area, so to speak, would come on across anything that would be the source of that slide area. (CMP, rev 15)

As discussed in earlier sections of this report, blue-gray rocks were sampled at several localities in the landing site. The same color tone was described from lunar orbit in the vicinity of larger craters in the subfloor materials as well as on the slide.

You still get that same bluish tint from the area in the landing site. At station number 2, on the landslide, it is going to be a pretty good little depression there. (CMP, rev 24)

Areas in the landing site where we now know there are extensive blocks of the subfloor material, particularly in the walls of the larger craters, I have the impression that those block fields, from this altitude, give a light bluish-gray appearance. (LMP, rev 66)

Just north of the bright-rayed craters in the Littrow area, there are five craters, probably in the range of 500 to 1000 m; and all five have the sequence of colors in the walls, from rim down, of a brown gray, blue gray, and then brown gray. They are all identical in that and quite clear. And that blue gray is comparable to the blue gray that is visible in the craters such as Sherlock in the landing area. (LMP, rev 72)

The differences in albedo, color tone, and texture between the massif units and the Sculptured Hills were obvious from orbital altitude both at low and high Sun elevation angles:

I can see the landing site now quite well. The slide area definitely shows up. The South Massif seems to have the Sun shining right on the walls. I am looking for any type of layering, or anything like that, and cannot see anything. The big difference between the massif structures and the Sculptured Hills is that the massifs look like they have a steeper slope. And they do not seem to have that type of covering over them, like the Sculptured Hills do. (CMP, rev 15)

The albedo differences are very definite: one is the dark mantle on the floor; one is the South and North Massifs; and the other is the Sculptured Hills. And the Sculptured Hills have a light-gray albedo between the Massifs and the dark mantle. This line is very evident and there is a definite break in slope that you can see between the South Massif and the white mantle out on the valley floor. (CDR, rev 62)

To me, the Sculptured Hills incorporate the albedo both of the North Massif, or South Massif, and the mantle area and combine them to give you a generally in-between gray albedo, but the sculpturing is produced by the darker albedo that looks like the mantle, and the lighter albedo that looks like the massifs. (CMP, rev 62)

FIGURE 28-22.–Taurus-Littrow landing site. Note that the scarp displays mare ridge characteristics between the North Massif (top) and the South Massif (lower half); it also appears as a flow that laps up against the North Massif (AS17-150-23006).

SHORTY CRATER

Much excitement was generated during the mission by the finding of orange soil on the rim of Shorty Crater (fig. 28-22). The CMP was asked, after the discovery, to determine whether the orange soil could be observed from orbit. An orange-tinted zone was described particularly on the north rim of Shorty. This finding also led to further concentration on craters of a similar size in western Mare Crisium, in the Littrow B area, and in the Sulpicius Gallus area.

The orange-tinted zone was obvious at intermediate Sun elevation angles (on rev 40) but harder to discern at high illumination (on rev 65):

I have got Shorty in the picture. It is a sharper crater than any of them . . . Did they find that orange stuff on the north side of it? . . . I would say they just barely got into the [orange] stuff, then, because the north rim has more of a tint of a different color to it . . . Would you believe an orangish tan through these binoculars? (CMP, rev 40)

Through these glasses, Shorty still looks light tannish orange. And it does not come all the way down to the center of the crater. It is tangent to the north edge or perpendicular to the scarp. (CMP, rev 41)

On Shorty, I still have that light-orangish-tan material. It is essentially perpendicular to the line of the slide area there in the northern semicircle of the rim. (CMP, rev 62)

My impression of Shorty from the other day, and also from seeing these craters that seem to have orange around them, they look very much like impact craters from orbit. At any rate, if that is an alteration phenomenon, it is being localized around the structure created by the impact. But in this latter case, it looks as if the impact itself penetrated into a zone of that color. (LMP, rev 64)

The craters we are seeing around Sulpicius are very clearly orange gray and the whole, or at least most of the crater, is that way. We looked at Shorty today, and Ron said that even the little bit of orange that he saw the other day is not visible, and I agree with that. The amount of orange we saw on the surface certainly would not be comparable to what we are seeing around Sulpicius Gallus . . . And on a couple of quick scans, on previous revs, of the area, the dark mantle, near Littrow, I did not notice any obvious orange-gray craters. (LMP, rev 65)

I still get a feeling that there is just a tinge of the orange or tannish orange around Shorty, looking at it with the binoculars. (CMP, rev 74)

D-CALDERA

The low hills between the Montes Haemus to the east and Montes Apenninus to the west are interspersed with patches of superposed dark material (fig. 28-19). In one of these patches is a D-shaped depression (fig. 28-23) that was previously interpreted as a volcanic caldera (ref. 28-16). The structure is unique, with no equivalent formations on the Moon. It was studied from orbit to further characterize its nature:

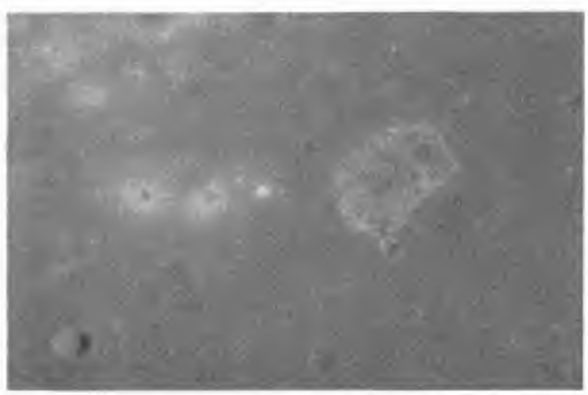

FIGURE 28-23.–The D-shaped depression in the dark mantling material west of the Montes Haemus exhibits a light-blue-gray tint. A darker bluish tone is also exhibited in the crater in the lower left corner (AS17-152-23286).

The D-Caldera is sure a depression. Like nothing I have ever seen before . . . At this point, you get a dark tan, a mare-type material. And then it is a light gray down in the D-Caldera itself. But it is a light gray down inside. It has got bumps that stick up, and the bumps themselves . . . are light tan. And down between the bumps in the caldera is a rough, blocky, gray material. (CMP, rev 28)

At higher Sun elevation angles, the floor of the depression was found to have a bluish tint to it that is also apparent in the Hasselblad color photographs.

D-Caldera is sure fascinating. I will try and take a quick look with the binoculars on that one . . . I hope the pictures will confirm a little bit of a topographic rise around the D-Caldera, just a slight one, and it is about half the width of the "D." And there seems to be a raised, flat rim around it. The color of the raised bumps down in the D-Caldera is the same as the surrounding material. The bumps that are raised up are smooth looking and the depression (floor material) is light bluish gray, very light bluish gray. (CMP, rev 36)

There is nothing surrounding D-Caldera that looks anything like the silver-gray material that was depressed with respect to the surrounding terrain. (CMP, rev 40)

Flow structures were also observed in the interior of the depression:

I was looking at D-Caldera and you got a lobate flow front sticking down in the crazy thing. (CMP, rev 42)

The light-blue-tinted materials observed in the D-Caldera were compared earlier to the somewhat darker tints of blue gray in the floor of Maraldi as well as in the Taurus-Littrow area. This comparison was also evident as the Sun elevation angle increased:

Ron's D-Caldera–I am just correlating apparent colors now, or hues–and the lighter-colored material there is comparable in hue to the subfloor color at the landing site. (LMP, rev 66)

COPERNICUS

Copernicus Crater was studied from orbit mainly in earthshine (fig. 28-24). In addition to details of the ejecta and interior, emphasis was placed on the central peaks and on a possible extension of the dark and blocky band that was observed in Lunar Orbiter II frame 162-H. Apparently, the viewing conditions were not adequate for this. Several other features of Copernicus were discussed throughout the orbital period of the flight:

I have got a visual on Eratosthenes and Copernicus. They are obviously different age craters in this light. You can see the ray patterns of Copernicus moderately well. You can even tell that they do cross Eratosthenes . . . On the upper portion of the rim and on the benches, there are the dark spots of lower albedo material. They form linear patterns along the benches, although the topography is not too clear. But the dark spots are in arcuate linear arrangement parallel to the rim. And they appear to be elongate along the radius of the crater [Copernicus].

Copernicus H is also very obvious as a dark-rimmed crater, relative to the albedo of the ejecta blanket. And the northwest quadrant, which we mapped as a smooth floor material and somewhat darker albedo, is just as apparent here, although all the contrasts, of course, are less. The main thing that you can pick out in earthshine are albedo distinctions. (LMP, rev 1)

Additional details of the dark zone in the southern wall of Copernicus were provided under faint earthshine illumination conditions:

On the south side of Copernicus, you can see albedos real well, and there is a dark area that extends maybe half a crater diameter to three-quarters of a crater diameter to the south, and it carries down the crater wall to the crater floor. And this is in the south maybe from about 4:30 to 7:30. And in the rest of the crater, all the way you can see light albedo.

When asked if he was able to see any structure in the central peaks (both in earthshine and in sunlight), the LMP replied:

No, I cannot . . . The central peaks do stand out, though, as a much lighter albedo area within the crater. It looks to me like the best thing you can do in earthshine is work with albedos. Knowing the general topography from earlier photography. (LMP, rev 1)

And this is a good view of the central peaks, although from some distance; and, as Ron and I were discussing earlier, it is not at all clear that, in fact, that so-called dike does not come through as a unit that is clearly defined. (LMP, rev 65)

The CMP also confirmed that the structure in the central peak could not be studied:

I just got a real good view of Copernicus, but I am afraid I cannot help you out on that structure in the central peak. Just a little too dark. (CMP, rev 4)

I was looking at it through the binoculars last time, and I could not really see anything that was really defined as coming on through there. (CMP, rev 65)

Dark deposits both to the southeast (Copernicus CD area) and north (Montes Carpatus) were described from orbit. The relationships of these deposits to other units on the Moon have been previously discussed (ref. 28-13).

One of the things that we mapped on the southeast and south rim of Copernicus were dark-albedo areas within the ejecta. And those are apparent here very clearly. (LMP, rev 1)

And some of the dark-halo craters that we mapped originally on the north portion of the ejecta blanket, which were similar to Copernicus H, are very clearly darker halo, or have darker blankets around them than the ejecta blanket from Copernicus. (LMP, rev 65)

FIGURE 28-24.—Oblique view looking southward from Copernicus Crater (AS17-151-23265).

One of the questions we asked ourselves years ago, when we mapped the Copernicus area, was were we really seeing dark mantling deposits on some of the massifs of the Carpathians, and looking at it obliquely here, some of those areas that we have mapped as dark mantling are distinctly brownish gray versus the normal tan gray of most of the Carpathians. It looks like it is about the same color—extrapolating—as the dark mantle around Sulpicius and Taurus-Littrow. (LMP, rev 73)

EULER AREA

Near the end of the mission, very little time was available for observing some of the interesting features in the Euler area. Many structures believed to be volcanic occur to the south of Euler Crater (fig. 28-25), including what seems to be a main source of some of the Imbrium lava flows (ref. 28-17). There appears to be a color boundary within the walls of Euler itself as observed from orbit:

The lower part of Euler is blue gray, and the upper is a very light gray, from the talus slope up to the rim. (LMP, rev 66)

Large boulders were observed on the central peaks of Euler. The observation was made possible by the low Sun illumination angle.

I can just start to see the peaks of Euler now. The tops of them are exposed in the sunlight, and it looks like there are massive quantities of large boulders on the peaks. (CDR, rev 66)

A chain of low-rimmed structures and collapse depressions forms a semicircle due west of Euler P (fig. 28-25). These landforms were interpreted as being extrusive, volcanic in origin:

That is my little [C] crater chain down there. Looks like a cinder cone chain. (CMP, rev 66)

As seen in figure 28-25, there are numerous sinuous rilles and arcuate depressions in the area. There appears to be intricate relationships between

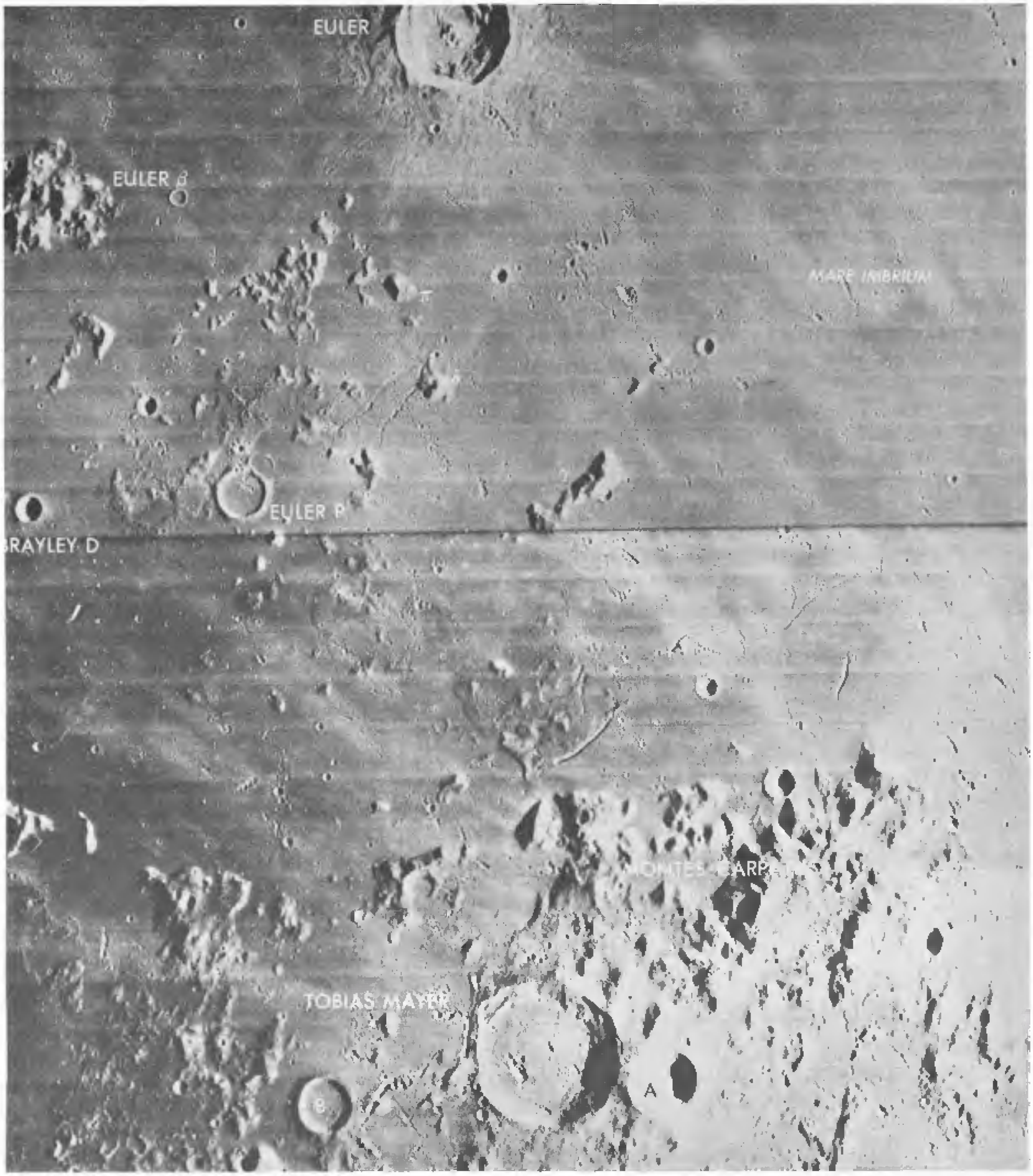

FIGURE 28-25.–Portion of Lunar Orbiter IV frame 133-H showing the southern part of Mare Imbrium, south of Euler Crater (30 km in diameter).

the rilles and the mare ridges and other scarps as described by the LMP:

I might summarize my impression of the rilles in the vicinity of Euler and their relationship to the mare ridges. I have been able, over the last day, to find rilles that clearly cross and separate portions of ridges. And ridges that clearly cross and partially bury rilles. And in another third case, a rille that appears to be leveed, that is, have flat banks on either side, but near the end of it, it transitions into a mare ridge, very clearly. It looks as if, to me, that the rille and ridge problem in here is just one of repetitive compression and extension within the surficial flows of the Imbrium basin. And that, possibly during the compressive stages, there were extrusions locally along the ridge system; but in the main part, the ridge systems represent, I think, a doming. It looks like just a doming of the mare surface except for these local ridge-like extrusions.

I might also add that the rilles, to me, seem to be made up of zigzag straight-line segments rather than being truly sinuous. They appear sinuous because of the rounding of the corners, but my impression is that they are really made up of straight-line segments. (LMP, rev 73)

REINER γ

Reiner γ remains one of the most enigmatic structures on the Moon. It is similar in gross characteristics to the light-colored swirls discussed under the heading entitled "Al-Khwarizmi (Formerly Arabia)." However, it is only one feature with no obvious source. Even if the swirls near the eastern limb of the Moon are interpreted as unusual ray materials, the Reiner γ structure is harder to interpret because of its shape (fig. 28-26) and the complete lack of association with any impact structures. Observations from orbit during Apollo 17 added details that do not solve the problem but may add to the constraints on the theories of origin:

I am able to see some of the Reiner γ materials, and it is awful hard to say more than just the fact there is a very clear light-colored pattern off to the north of our position. (LMP, rev 1)

[The brightness of] Reiner γ from here almost looks like ejecta from a crater . . . The γ itself is dark . . . Zero phase is going right through it right now; it did not blot out the dark at all . . . The only light-colored stuff that you can see is right around Reiner γ itself. And intermixed within that is the dark. It is a dark annulus, except the annulus is on the inside of the white. And it looks like–I do not know if your eyes deceive you in this darkness or not–but the light-colored stuff is raised up with respect to the dark.

The light material around it . . . does not look like a ray. In other words, it does not thin out in different parts like a ray does. (CMP, rev 28)

I was trying to think if there was anything I could add to the Reiner γ observation. I am right over the light-albedo material that goes between Reiner and Reiner γ. It is kind of crooked; it goes for a little ways, and then it breaks off in another direction. So, it does not look like a straight ray at all.

Looking right down on Reiner now, and you sure have that dark annulus. The lighter-albedo stuff is essentially in the middle of it, is about half of the width, and it is lighter on the outside than it is on the inside.

It is very hard to see any great topographic expression to it. The reason I say that is because it blends in with everything. (CMP, rev 36)

MISCELLANEOUS OBSERVATIONS

Flashes of Light

On the first lunar revolution, the LMP reported seeing a flash of light north of Grimaldi Crater (21:11:09 G.m.t. on Dec. 10). It is interesting to note that this is the same area where the CMP during Apollo 16 also reported seeing "a flash of bright light" (Riccioli). The following descriptions were made during Apollo 17 orbit:

Hey, I just saw a flash on the lunar surface! It was just out there north of Grimaldi. You might see if you got anything on your seismometers, although a small impact probably would give a fair amount of visible light. It was a bright little flash near the crater at the north edge of Grimaldi; the fairly sharp one to the north [small crater north of Grimaldi B] is where there was just a thin streak of light. (LMP, rev 1)

On the following day, the CMP also reported seeing a flash, this time near the rim of Mare Orientale (22:28:27 G.m.t. on Dec. 11):

Hey! You know, you will never believe it. I am right over the edge of Orientale. I just looked down and saw a light flash myself. Right at the end of the rille that is on the east of Orientale. (CMP, rev 14)

Visibility in Earthshine

The Earth disk was almost full at the beginning of the orbital period, and light reflected from the Sun by the Earth to the Moon was enough to study features on the surface but not in great detail. Following are some comments on the lighting conditions:

There is no question that right at the terminator you pick up relief that you normally would not believe is there in the mare. I remember Bill Anders talking about the appearance of a sea swell within the mare itself and that is certainly clearly shown right at the terminator. Unless you start to see the shadows from all the very small craters that otherwise do not show up as much more than just little depressions, if that. (LMP, rev 1)

Kepler ray pattern is very striking in this light; an anastomosing series or bands which only average being radial. In most cases, they are a little off radial, but by joining together, they give you a general radial pattern . . . Once again, albedo differences are very clear, such as the distinction between the wall or brighter wall materials and the rim which is brighter than the surrounding mare. (LMP, rev 1)

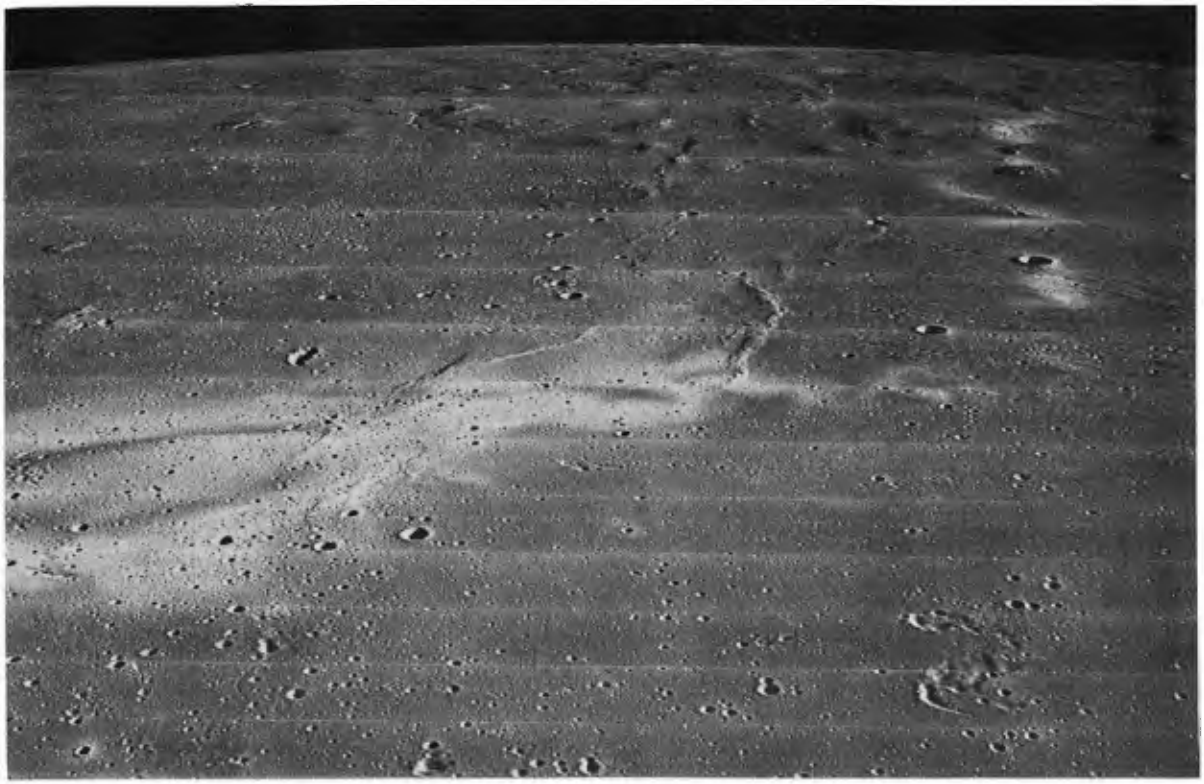

FIGURE 28-26.–North-looking Lunar Orbiter oblique view of the Reiner γ structure in western Oceanus Procellarum.

Looking at Oceanus Procellarum. And now, up to the northwest, Grimaldi is starting to show up. A very obvious dark area within the highlands of that part of the Moon, and one of the darkest mare regions that we have seen on the Moon. It is comparable, at least in the photographs, to that of Tsiolkovsky. (LMP, rev 1)

Amazing how much of the highlands to the west of Procellarum is still bright, and the contrast between fresh craters and the normal highland is very obvious still in earthlight, particularly along the zero-phase point with respect to the Earth. (LMP, rev 1)

This is a spectacular sight, you ought to take a look at Orientale. One of the largest fresh basins on the Moon. It still is probably 4 billion years old, or 3.8 at any rate, if our dating criteria are any good. It has the outer Cordillera ring and the inner ring called the Rook Mountains, very nicely shown . . . As we approach the terminator, the lighting is still excellent. Matter of fact, it appears brighter than what we were looking at over at Copernicus. Now, part of that may be we are seeing much sharper relief since the slopes, Earth-facing slopes, are nicely lit, and the backfacing slopes, of course, are in shadow. (LMP, rev 1)

You can even see a horizon in earthshine out there. (LMP, rev 1)

You sure can. You can see an earthlit horizon out there into the dark part of the Moon. (CDR, rev 1)

I noticed there is even a lot of difference in earthshine and in the double umbra. You get in earthshine and it is hard to see the stars even if you do not have the Earth in there . . . The double umbra on the back side of the Moon is even better than the simulator! (CMP, rev 14)

Lineaments

Much discussion about small-scale lineaments on lunar slopes followed the description and photographs of the ones observed on Mons Hadley during the Apollo 15 mission. During Apollo 16, similar features were described in many regions of the Moon, on slopes as well as on flat surfaces (ref. 28-5). During Apollo 17, lineaments were observed and photographed during the surface stay time; some were also described from lunar orbit:

In a place where the Sun is just grazing the slope, it is a steep slope on the north rim of Crisium, I can see the horizontal lineaments that were such a controversy on [Apollo] 15 . . . There are some very steep slopes that just have grazing Sun on them now, and with the binoculars, you can see that horizontal lineation pattern.

Also, on that lineation question, not only where the Sun grazes a slope do you see the horizontal lineations, but they are at the southern end of the shadowed area on a slope. You get a couple other lineations showing up at least in a couple of places I saw. One would be parallel to the slope, that is cross-contour, and the other was at an angle to that direction, say of about 30°. (LMP, rev 3)

Craters

Observations were made of various types of lunar craters. The first unplanned observation was that of Kopff Crater at latitude 17° S and longitude 90° W in Mare Orientale:

Delta-rim crater—just as has been, I think, discussed in the literature—has no obvious ejecta blanket around it, compared to other larger craters within the basin. We are directly over that crater right now. It is filled with mare, very smooth mare. Matter of fact, within that fill, I can see no craters. Getting very close to the Earth terminator, but you see good texture in the ejecta blanket of the large crater in the north part of the inner basin of Orientale. The radial ridge and valley patterns are very clear; the concentric coarse hummocks near the rim are apparent; and you can even see the patterns of secondaries. (LMP, rev 1)

Numerous craters on the far side display flat, somewhat dark floors; these floors are commonly domed in smaller craters. In larger and fresher craters (e.g., "The Bright One" in ref. 28-18), there are scarps and fronts indicative of fluid flow. During Apollo 17, the first impression of these features from orbit was that these floors were volcanic; however, the original melts were later (and after repeated observation) attributed to shock melting by impact.

Fresh, rayless craters on the far side, probably Eratosthenian in age, all appear to have a mare-type or volcanic-type floor, suggesting the possibility that a liquid mantle existed during the Eratosthenian era and was penetrated by these craters. (Paraphrased from CMP, rev 48)

I guess the feeling I was getting is that most of the [Eratosthenian] age craters all have some sort of a mound, a domical structure, down in the bottom of the crater. Even the smaller ones, some of the 30- to 50-km-size class. And the flat floors look volcanic. Some of the bigger ones, of course, are volcanic, the lava flows on the floor of these big craters. (CMP, rev 48)

While we are waiting for the site to come up again here, which seems to interest us every time we go over it, I think we sort of came to a general consensus on the problem of the smaller cone-shaped craters on the far side that have the little pool-like concentrations of material in the bottom. If you look at the freshest of those craters, there seems to be continuity between the streaks of very dark material that cover the walls and the rim of the fresh cone-shaped craters. As the crater gets older, that distinction becomes less obvious; however, the pool remains, and all you lose is the dark streaks on the rim and on the walls of the crater. I think we sort of suspect that the pool in the bottom of the fresh craters is just the concentrated impact melt that some of which stayed there during the impact and others drained back after the impact from the walls. And then, with time, that pool may be subdued some. The structures in it, the swirls and little domes in that pool, are subdued possibly not only by the impact but by debris, slides, and avalanches off the walls of the crater. (LMP, rev 64)

Features of the large crater Archimedes (100-km diameter) were described in the context of lunar stratigraphy as seen within the Imbrium basin:

Archimedes is one of those craters that, in the early days of the lunar mapping program, helped establish some of the fundamental age relationships between the various units that were visible in the Earth-based photographs. In this particular case, it related to the sequence of events that created Imbrium and then flooded it with mare. And Archimedes is completely circular and it is filled with mare. And it, in itself, is superimposed on one of the main benches of the Imbrium basin. Now, to have mare filling of approximately the same level in the vicinity of a large mare region is one of the things that has suggested to many people that rather than single sources for mare lavas, you have a multitude of sources in a very fractured lunar crust. The ultimate source at depth, though, is still certainly a subject of controversy. (LMP, rev 62)

Unique features of the elongate Messier Crater, which is believed to be the result of an oblique impact (fig. 28-27), were described from orbit by the CDR:

It has got a very sharply raised lip, and it has got some very dark and rough rim deposits. It has also a very obvious

FIGURE 28-27.—Part of Apollo 15 panoramic camera frame AS15-127 showing the elongate Messier Crater in Mare Fecunditatis.

furrow, looks like it is elongated, generally to the east and west. I cannot tell, but because of the shape of it and because of those dark rim deposits, I am sure there must be a vent there somewhere, but it is too dark down in there. I cannot really see for sure whether there is one or not. But, if there is, I imagine it is pretty big. And I imagine the elongation was produced during the thrust of the initial dynamics, the formation by the impact. (CDR, rev 73)

Finally, during the post-TEI television transmission, the following statement was made by the LMP, summarizing the lunar surface history and pointing out the importance of that history to the study of the Earth:

... basalt flows, that some 3 to 4 billion years ago, in round numbers, were erupted on the Moon and filled many of the low areas that existed at that time. Not an awful lot has happened to the Moon since, except for the impact craters, some of the younger ones, since 3 billion years ago, which is one of the reasons it becomes so interesting to man. It is the Moon's frozen period of history that we cannot recognize very readily on Earth because of the dynamic processes of mountain building and oceans and weathering that are taking place even at the present time. Understanding that early history of the Moon may mean an understanding of the early history of the Earth. And, I think we are well on our way to a first-order understanding of that history as a result of the [Apollo] Program. (LMP, post-TEI)

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