BAA Lunar Section
British Astronomical Association
Director: Bill Leatherbarrow

# LUNAR SECTION CIRCULAR

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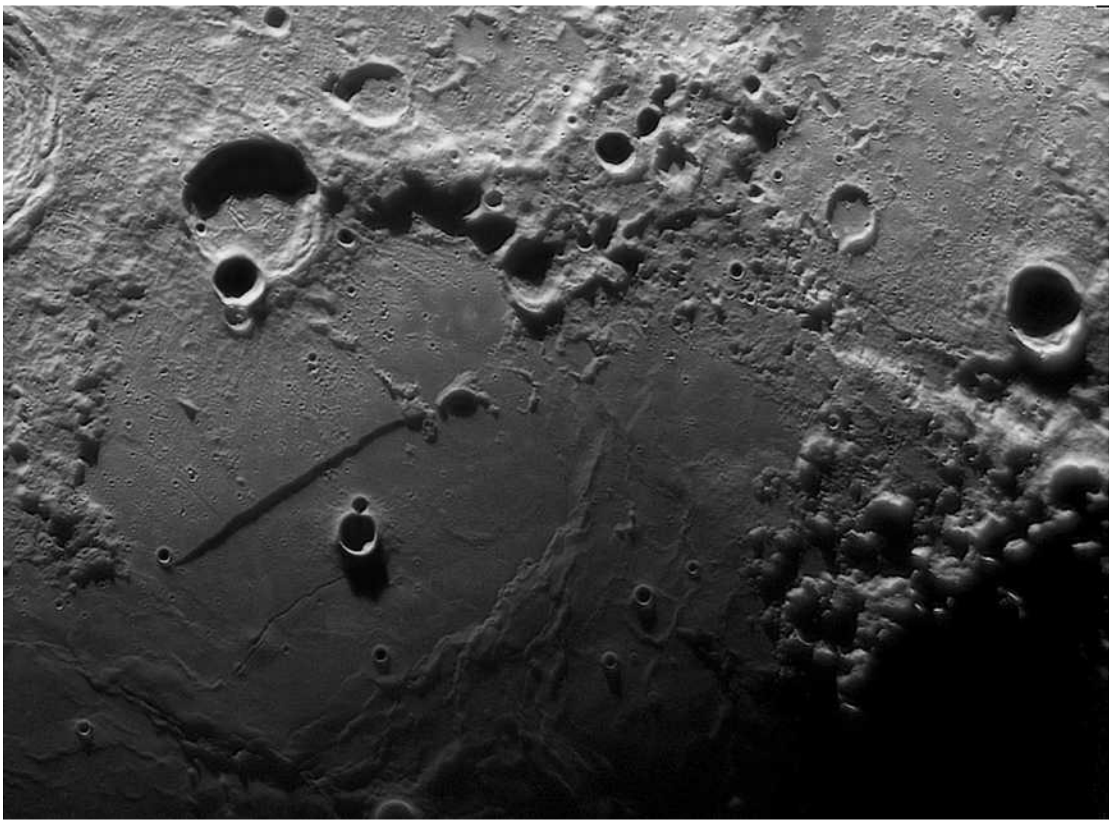
## FROM THE DIRECTOR



*Rupes recta, 1 April 2020, C14 (imaged by Leo Aerts)*

As the period of lockdown and restrictions continues across the world it is pleasing to see that observers are still able to get out and pursue their activities. Despite all the concerns and anxieties, we should be grateful for the distraction this offers us and make the most of it. The improving weather in the northern hemisphere has meant that Lunar Section contributors have been able to submit a good collection of images over the past month, as the superb capture of the Rupes recta area by Leo Aerts (above) illustrates. We may not be able to emulate Leo's incredible skills, but we can certainly follow his example, and I shall do the best I can to present a selection in the Circular each month. Of course, I cannot reproduce every image I receive, but I am grateful for each and every one of them, and they are all archived in the Section records. Generally speaking, I try to include in the Circular images that make or illustrate a point of observational interest, along with a selection of others as space permits.

This brings me to the following point. As well as submitting images to me, it would be very helpful if you could also post them to your Member's Page on the BAA website. Not only will this bring your images before a wider audience, but it will also help in a Section project we have in mind. Our stalwart Section Website Manager, Stuart Morris, is hoping to create an extensive gallery of lunar images on the Section website, and it would be convenient if he could take suitable images directly from the Members' Pages. So do consider setting up and posting to your own page, as well as continuing to send them to me. If you have not already done so, the first step is to register for online access (top right of BAA Home Page). In the setup process you need to tick the 'Show profile' box to activate your Member's Page.

If you have an account but it is not set up to show your Member's Page, then you need to click on 'My Account' in the top right. Then click 'Edit account details'. To have a member account the 'Show profile' box needs to be ticked.

Meanwhile, continue to stay safe!

*Bill Leatherbarrow*

## OBSERVATIONS RECEIVED

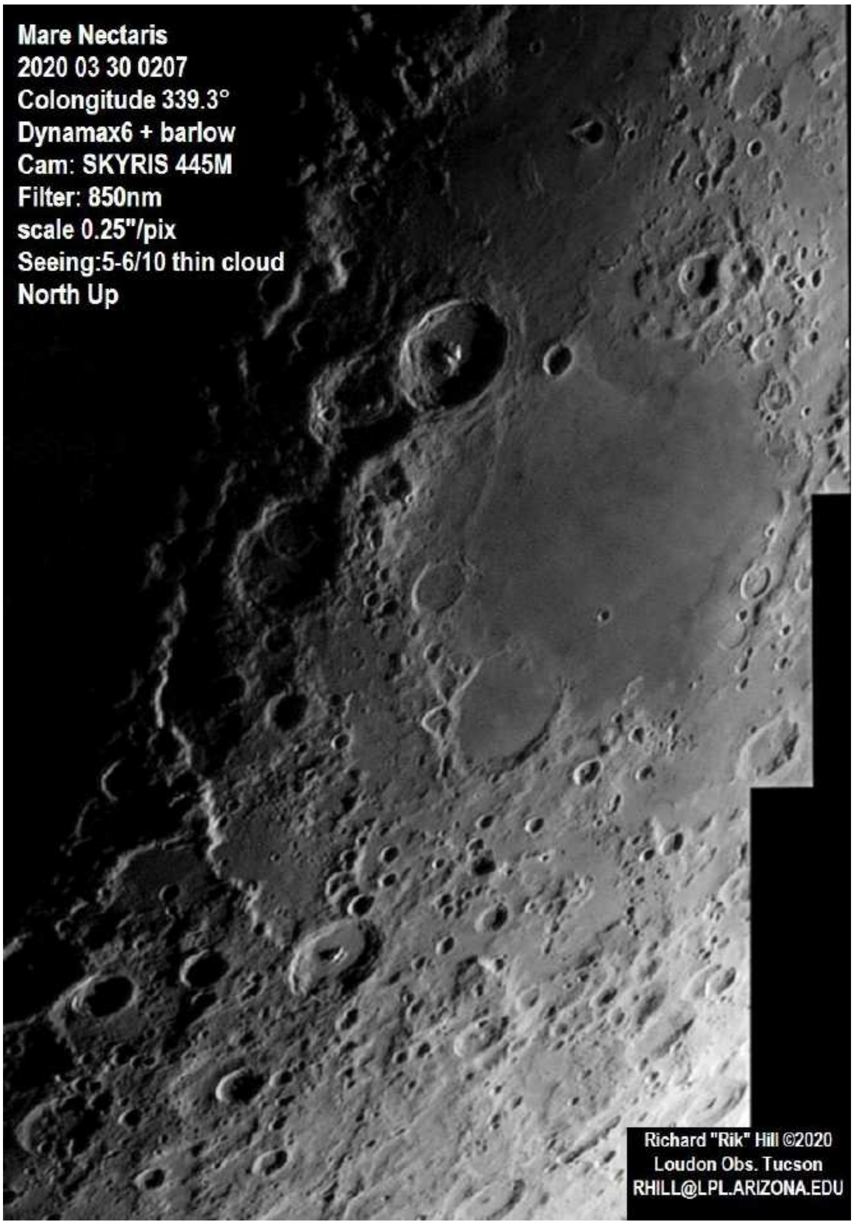
Images have been received from the following observers:

Leo Aerts (Belgium), John Axtell, Paul Brierley, Maurice Collins (New Zealand), Dave Finnigan, Rolf Hempel (Germany), Rik Hill (USA), Rod Lyon, Chris Mann, Dave Scanlan, John Tipping, Ivan Walton, Derrick Ward, and the Director.

Among other images **Rik Hill** has submitted the following study of the Mare Nectaris region. He writes:

'One of the more spectacular regions on the moon is that of Mare Nectaris, pure nectar to the lunar observer! Two things catch the eye right off: Rupes Altai, which we old timers used to call the Altai Scarp, and the Theophilus trio of craters. The weather was very hazy with rapidly moving cirrus and mediocre seeing but I gave it a go anyway.

Rupes Altai is the bright jagged line that appears to emanate from a fairly good-sized crater at the lower middle of this image and meanders off to the northwest (upper left). The crater is Piccolomini (90km diameter) with a flat floor and a nice central peak casting its shadow almost to the western wall. The Rupes is concentric with the lava-filled basin of Mare Nectaris that dominates the upper right of this image. It is literally a partial crater wall to this large basin rising 3-4 km as it snakes northward. Notice the sinuosity of the uppermost end! It ends in this image just west of the large crater Catharina (104km) which is overlain by a smaller "satellite" crater Catharina P (46km). A little farther north and we see Cyrillus (100km) which is overlain by the majestic Theophilus (104km) with its beautifully terraced walls and pingo-like central peak. It's a little counter-intuitive but the north wall of this monster crater is actually about 1km *lower* than the south crater wall. Note the wonderful field of ejecta from this crater to the north filled with thousands of secondary craters up to and past the small pear-shaped crater at the top of this image. This crater, filled with shadow, is Torricelli (12x24km) sitting in a larger 87km diameter ghost crater ring Torricelli R. To the east of Theophilus is the crater Mädler (29km) roughly the same age as its big brother. Then on the other side of Theophilus is a bright massif Mons Penk rising some 4km above the floor around it. What a sight you would have to the southeast if you could stand on top of this massive mountain.



We have seen the spectacular features that cup Mare Nectaris on the south and southwest side but there are several very interesting "U" shaped features in the middle. In just about the middle of this image is a large crater Fracastorius (128km), a crater whose lower north wall was flooded by lava during the Nectaris impact, filling the floor of this crater. There is an interesting rima or rille in the center of this crater, running east-west, that I did not catch in this image due to weather conditions. Just north and west of Fracastorius is an almost identical crater but under half its diameter. This is Beaumont (54km). It lies on the south end of an unnamed dorsum that connects it with Theophilus. There are a lot of other interesting features in this region for you to discover showing that even on so-so nights you can enjoy the Moon!'

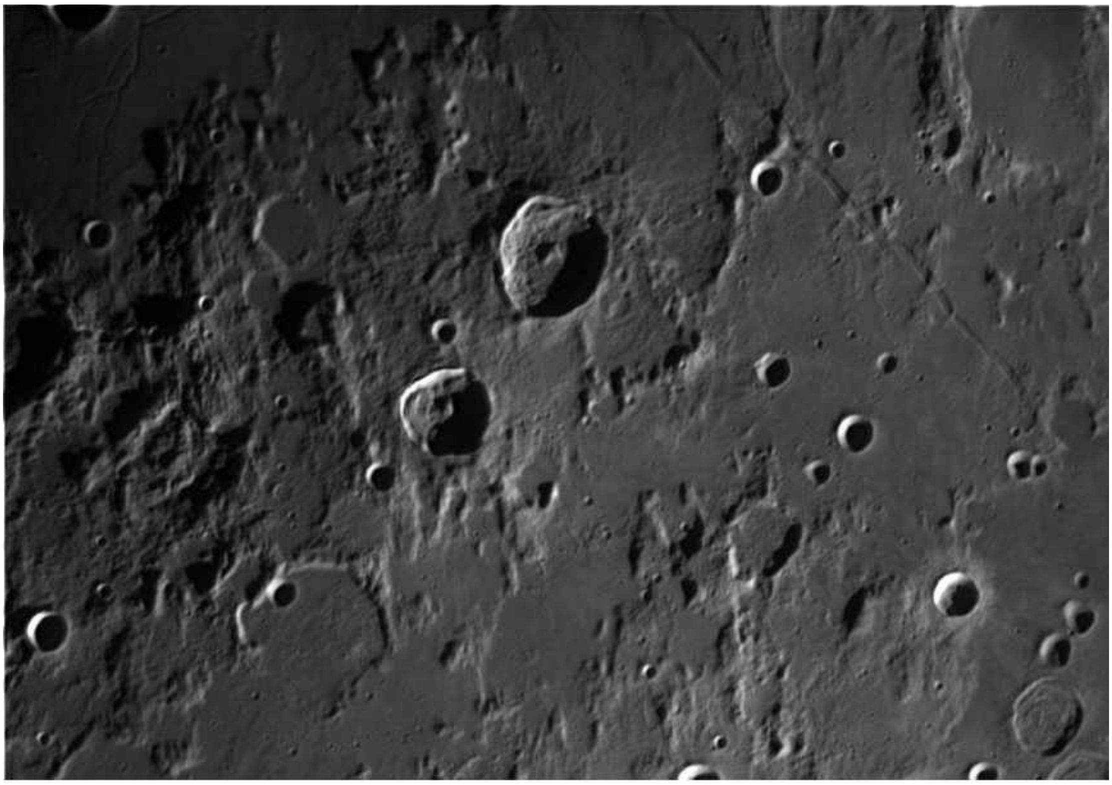
## IMAGE GALLERY

Here is a selection of images received this month.

*Region around Tycho, 6 March 2020, 22.11 UT, 200mm SCT (Ivan Walton)*

***Montes Recti, Montes Teneriffe*** 2020.04.03 20:23-24 UT, S Col. 38.1°, seeing 5/10, transparency good
Libration: latitude -03°54', longitude -07°05'
305mm Meade LX200 ACF, f 25, ZWO ASI 120MMS camera, Baader IR pass filter: 685nm.
A composite of two images, 1240 frames processed in Registax 6 and Paintshop Pro 8.
*Dave Finnigan, Halesowen*

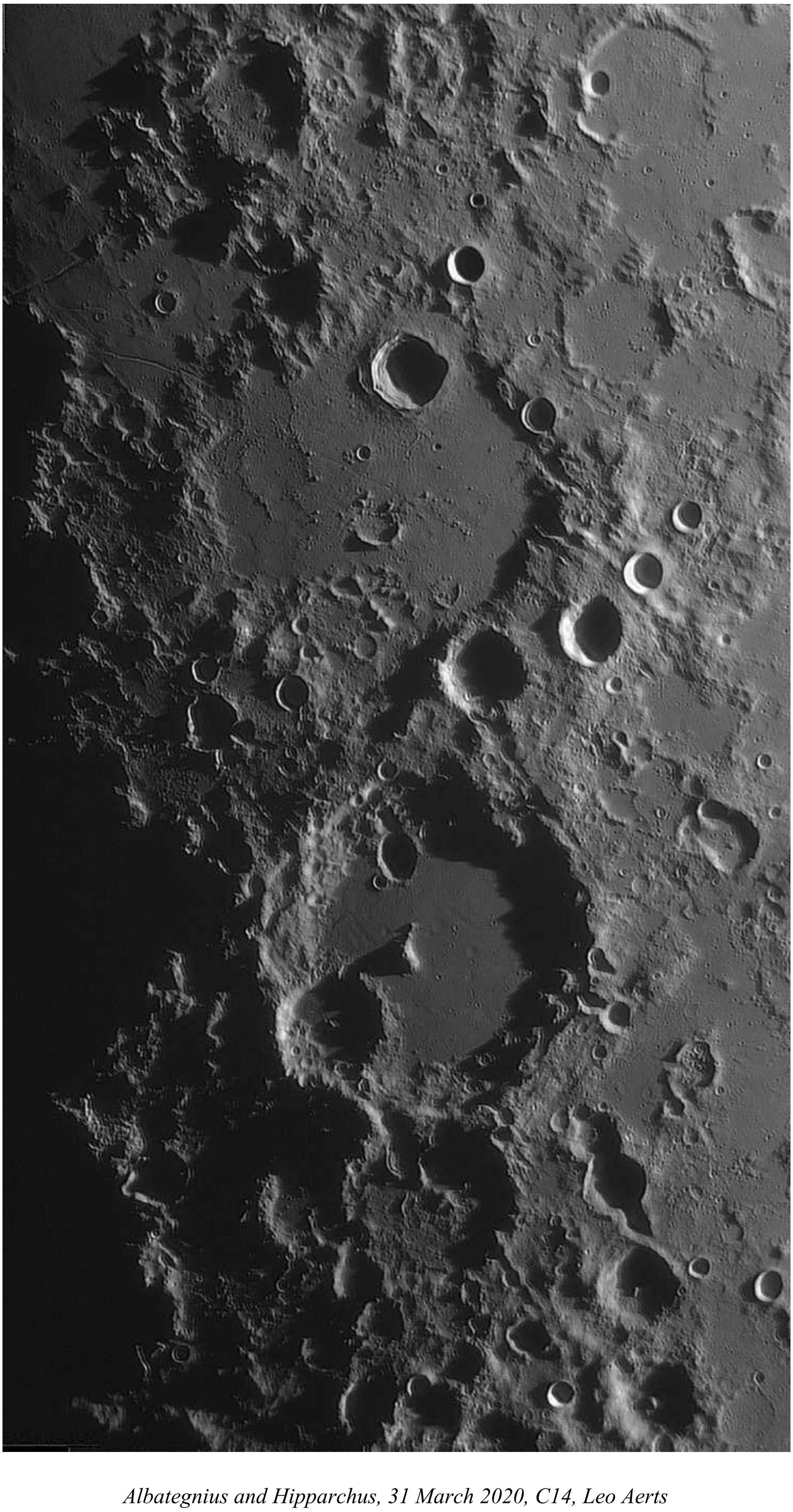
**Rupes Liebig** 2020.04.04 20:29 UT, S Col. 50.4°, seeing 4/10, transparency fair.
Libration: latitude -04°58', longitude -05°40'
305mm Meade LX200 ACF, f 25, ZWO ASI 120MMS camera, Baader IR pass filter: 685nm.
640 frames processed in Registax 6 and Paintshop Pro 8.
*Dave Finnigan, Halesowen*



Agrippa & Godin with Rima Ariadaeus 2020.03.31 - 19.19 UT
300mm Meade LX90, ASI 224MC Camera with Pro Planet 742nm I-R Pass Filter. 750/5,000 Frames. Seeing: 7/10 with some turbulence.

*Rod Lyon*

*Schiller, 4 April 2020, 20.17 UT, 200mm Newtonian, Derrick Ward*



*Albategnius and Hipparchus, 31 March 2020, C14, Leo Aerts*

**PLANETARY SYSTEM STACKER** Rolf Hempel

I don't know if Lunar Section members are aware of my current *PlanetarySystemStacker* software project. I started the development some two years ago with the aim to create a modern stacking program, using state-of-the-art software technology. From the beginning the goal was to at least match the image quality of AutoStackert!3. Since my own focus is lunar photography, the Moon was my primary design target. I finally met this goal with Version 0.7.0. In hundreds of lunar test cases PSS at least matched the AS!3 quality. In most cases the results were slightly better.

PSS runs on any operating system where Python 3 is available, which is almost everywhere. Therefore, in particular many users on Linux and MacOS now are happy to have a stacking program without the need to use a virtual Windows machine on their computer. The software is fully documented. I put much effort into good documentation, including the code itself, because I would be happy to share the further development of PSS with other professional software developers.

If anyone wishes for further details contact Rolf Hempel at: RolfHempel@gmx.de

**SOME THOUGHTS ON COLOURED TRANSIENT LUNAR PHENOMENA**

Peter Anderson

Since the 1960s there have been many reports of transient phenomena visible on the Moon. These are often coloured glows and obscurations of finer detail that should have been visible. Another manifestation is anomalous colouring, shadings, and shadows. The transient phenomena are not limited to these types but in this instance I merely propose to address the issue of coloured glows and shadings, often reported as red or reddish. (I do not address the use of coloured 'Moonblink' filters.)

The first point to examine in the case of visual observations is the state of the observer's eyes. It is interesting to compare the colour balance between your eyes. One eye may provide a more vivid, contrasty or clearer image and, for example, the Moon may appear a little more yellow or blue. This can affect your visual impression if you suspect something anomalous. You probably prefer to use the same eye when observing because, for whatever reason, it gives better results.

Quite apart from this, as we age the lens of the eye tends to slowly discolour, resulting in a grey/green 'filter' with subsequent shift in colour balance and loss of sharp contrast. Apart from other effects, cataracts can give rise to a 'greying' of the image. (The cataract operation, which involves replacing the lens with a specially made artificial one, totally and permanently rectifies the problem. After cataracts, I have had this operation performed on first the right eye in 2005, and then the left eye in 2019.)

However any 'visual' variability is removed if imaging or other measurements are undertaken.

The next variable are the weather conditions. High pressure systems are reported to produce a slight bluish cast and I have seen astrophotographs where weather has produced a small bluish or brownish bias. Advanced astrophotographers have investigated this very real but subtle phenomenon. Dust in the atmosphere in my area (near Brisbane, Australia) will produce a slightly washed out grey/brown bias. There is also the whole range of atmospheric 'seeing' and transparency to deal with and account for in reporting.

Then there are instrumental effects. Shorter focal ratio standard refractors exhibit considerable chromatic aberration which is the failure to bring the various visible wavelengths to a common focus. A standard formula for the minimisation of chromatic aberration is to provide a focal length at least three times focal ratio of the aperture in inches. (e.g. F9 for a 3" refractor and F12 for a 4".) Even then some colour remains. Cheaper refractors, even of long focal ratio, may display more annoying colour and are not to be trusted. The current crop of standard larger refractors (around F8), will display a blue/purple haze over bright objects, often a yellow/green pastel cast over areas of the Moon and colour fringing of brighter crater edges and the limb. (In the last two years I have owned both 12cm F8.33 and a 15cm F8 standard achromats which by the formula quoted above should have been at least F14.1 and F17.7 respectively. I have recently replaced my 15cm F8 achromat with an ED unit of the same specifications.)

ED glass versions largely address but do not totally eliminate chromatic aberration, and a triplet system is likely necessary to approach perfection.

ED units, and certainly my 15cm Skywatcher F8, produce a slightly brighter image biased towards the blue (like aluminised surfaces), whereas standard refractors are slightly biased towards the yellow. I first discovered this in the 1960s when I was left alone with an excellent Unitron 4" F15 refractor for some hours.

Therefore reports made using refractors need to be carefully weighted depending upon the instrument employed.

Reflecting systems, including Schmidt Cassegrains and Maksutovs are largely exempt from spurious colour issues, though it should be noted that when assessing colour, aluminised surfaces have a blue bias and silvered surfaces a yellow one. Of course, any such biases affect the whole image and an astute observer should account for this and not report any anomaly in a specific feature or area as a result.

The next factor is the eyepiece, and Barlow lens (if applicable). In the 1960s and earlier, simple single-element Barlows introduced considerable colour, but equipment has improved tremendously since then. However, there is still the odd bad example in use. One dealer sent me a lovely wide field 10mm eyepiece, but the images were fringed with colour. (Perhaps an element had been inserted back to front at manufacture.) I thought I would try it on my standard refractor and it might cancel out some of the chromatic aberration. No such luck. (This is not as silly as it sounds. Back in the ATM days of the 1950s and 60s, according to Bill Newell (d.1971), a respected Queensland astronomer, one gentleman had made a shocking mirror, but he had an equally defective diagonal and they 'cancelled out' to produce good images much to everyone's amazement! Okay, this is a highly unlikely occurrence.) Nevertheless, simple eyepieces are more likely to produce some colour effects and fringing and an observer should be on guard for these.

Of course in all cases a necessary starting point is that an instrument be well aligned. Misalignment can give anomalous shape to focussed images, flaring, and spurious colour. Similarly for those using eyepiece prisms and diagonal mirrors, a simple test can be to rotate the unit a considerable angle and see if the appearance of the suspected anomaly has changed. Also rotate the eyepiece in its holder to see if the eyepiece could be the culprit.

Very little can be done about atmospheric dispersion. This effect, on steroids, produces the 'green flash' at sunset. Lunar and planetary imagers use a corrector as a matter of course, and so should visual solar system observers seeking fine resolution. Atmospheric dispersion smears the light into its constituent wavelengths by differential refraction, with blue at the top and red at the bottom. The effect becomes noticeable around 60 degrees altitude, getting steadily worse as altitude decreases, and the corrector referenced is adjustable for varying altitudes. Without such a corrector the upper limb or bright surface is fringed with blue and the lower with red and this increases dramatically as low altitudes are approached. A colleague of mine who did not realise what was happening thought it was an alignment issue. He kept trying to adjust the optics of his large SCT to eliminate it, but to no effect.

All of these factors can give rise to spurious reports. When imaging is employed, it is relatively easy to compare the suspect area with another similar one nearby, which will either support the contention or negate it. Not so with purely visual reports, but these can first be filtered by the observer, by considering the various factors and comparing the suspect area to similar areas before finalising any report.

## LUNAR DOMES (part XXXVII): Domes in Caucasus Montes, including the Valentine dome

Raffaello Lena and KC Pau

Some flat domes, of elongated shape, are located within the Serenitatis Basin, in the surroundings of the Caucasus Montes. Their characteristics could imply an origin due to a subsurface intrusion of a large magmatic body. The top of these domes are flat, suggesting that there was not a gradual inclination at the vent (the rising lava did not build up the dome in a series of flows) but a possible subsurface intrusion of magma, where lavas accumulate within the lunar crust increasing in pressure slowly, causing the crustal rock above it to bow-outward. Fig. 1 displays the dome termed V1 (unofficially designed as *Valentine dome*) and the domes termed V2-V5.

*Figure 1: KC Pau, domes termed V1-V5. Telescopic image acquired on September 11, 2017 at 21:05 UT, Newton 250mm telescope.*

Another image of the examined domes is shown in Fig. 2. The domes termed V1 and, to the north, V2 have been measured in previous studies [1]. The heights of the domes V1 (located at 10.20° E 30.70° N) and V2 (located at 10.26° E 31.89° N) correspond to 130m ± 10m and 80m ± 10m, resulting in average flank slopes of 0.55° and 0.80°, respectively [1].

A long curvilinear rille can be distinguished on the surface of the dome V1, bisecting the summit, which is likely due to tensional stress consistent with laccolith formation. In this scenario fracturing and faulting of the crust occurred, weakening the strength of the crust and thus facilitating the uplift of large volumes of crustal material visible as a large intrusive dome; hence the uplift resulted from the rise of magma that did not erupt onto the surface, producing a vertical rupture of the surface. Regarding the morphometric properties, V1 is a typical representative of class In1, while the shape of the steeper and smaller dome V2 (of class In2) indicates that laccolith formation preceded until the stage characterized by flexure of the overburden [1].

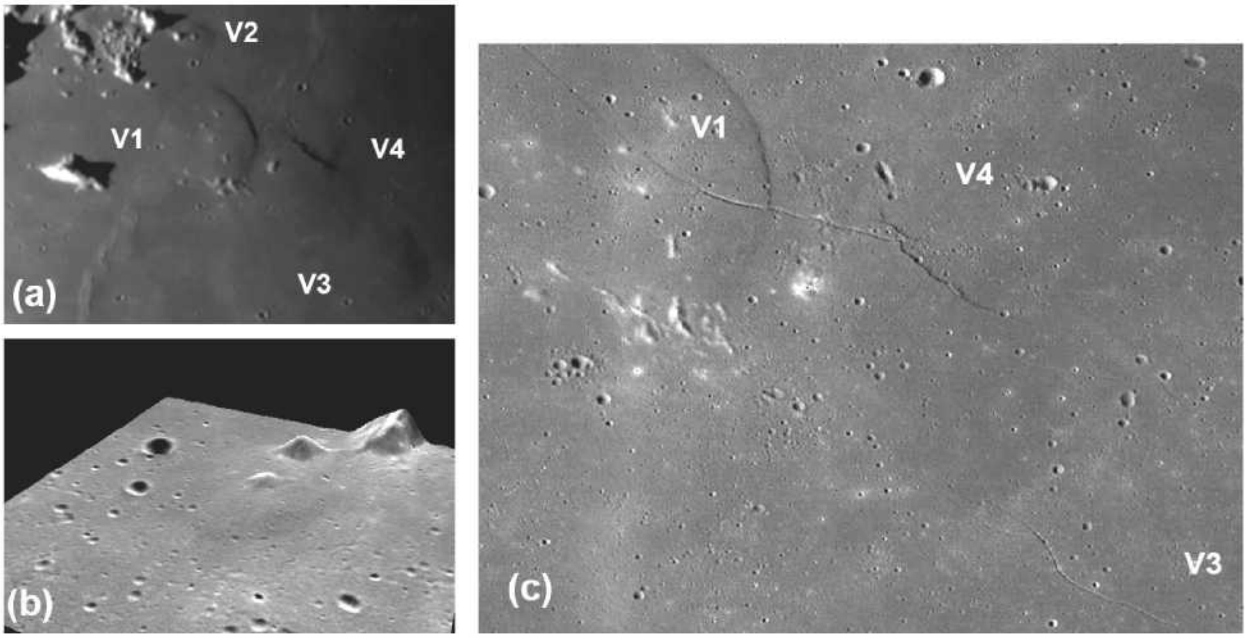



*Figure 2: (a) Telescopic image acquired on August 27, 2013 at 09:27 UT with a 250mm aperture Cassegrain (Phillips); (b) WAC derived elevation model (GLD100) of the dome V2. View from north western direction. The vertical axis is 10 times exaggerated; (c) Crop of the LRO WAC image M117420283ME.*

The dome termed V3 is located at 29.33° E and 11.73° N and has an elongated base area of 29 x 23 km² (cf. Fig. 1). A straight rille can be distinguished on its surface, which is likely due to tensional stress consistent with laccolith formation. The dome termed V4 is located to the east of V1 dome, at 30.65° E and 11.23° N, and has an elongated base area of 36 x 24 km². Based on GLD100 dataset, the heights of the domes V3 and V4 are determined to 100m ± 10m and 85m ± 10m, resulting in average flank slopes of 0.5° and 0.3° respectively (Fig. 3). Furthermore, the dome V4 is limited by a fault, about 90 m high, which may indicate the beginning of the piston-like uplift of a laccolith [1-2]. Assuming a parabolic shape the estimated edifice volumes correspond to about 27.0 and 29.2 km$^3$ for the domes V3 and V4, respectively.

They are typical representatives of class In1. It is unlikely that they are *kipukas* as no spectral contrast is apparent between them and the surrounding surface. V5 is another low dome, located south west of V1. The height of V5 (located at 10.20° E, 30.70° N) corresponds to 65m ± 5m, resulting in average flank slope of 0.4° determined by using photoclinometry and SfS from telescopic images and the GLD100 dataset (Figs 4-5). Thus this low dome belongs to class In2, like V2.

Another excellent image of the examined region has been acquired by Pau, under strongly oblique illumination solar angle (Fig. 6) on March, 1, 2020 at 11:33m UT with a 250mm Newtonian reflector, 2.5X barlow and QHYCCD290M camera. A suspected dome, provisionally termed V6, is emerging from the terminator. Preliminary analysis would indicate that V6 (32.99° N and 9.98° E) has an elongated base area of 18 x 27 km². The height of V6 corresponds to 100m ± 10m, resulting in average flank slope of about 0.5° (Fig. 7). Further hi-resolution images will be necessary in order to have more significant data and consolidated measurements about this suspect feature.

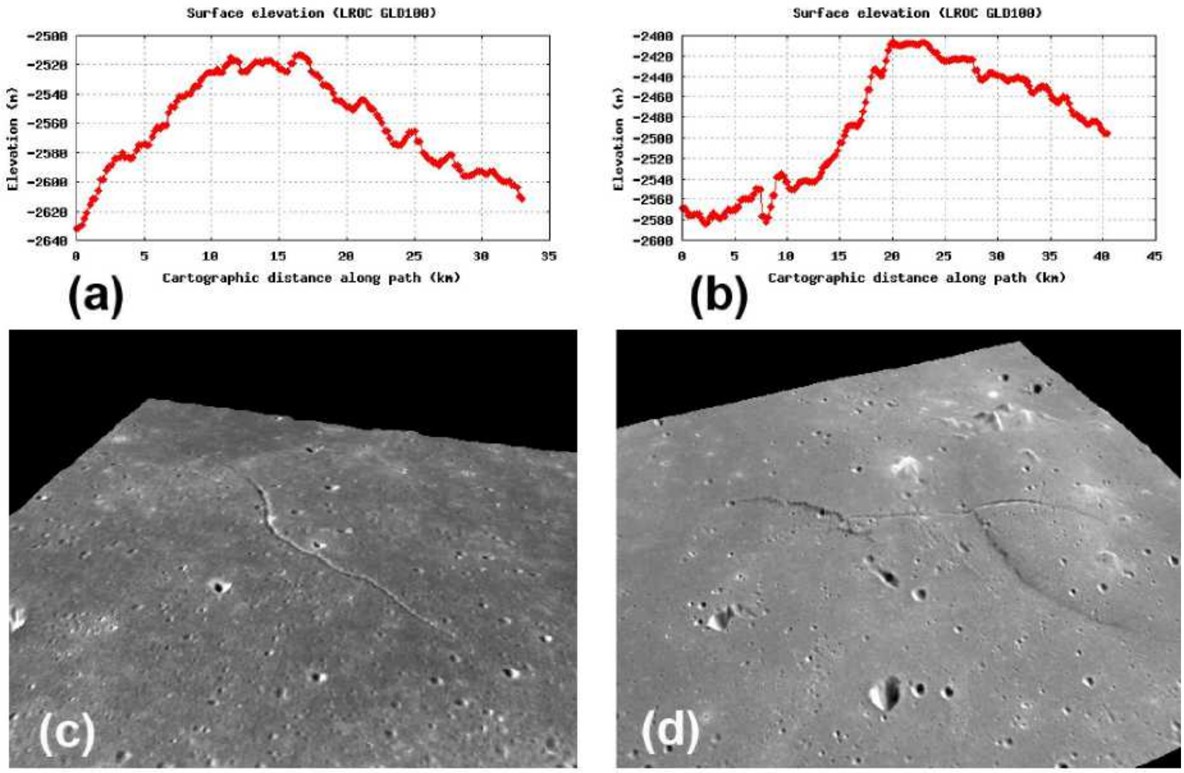



*Figure 3: Top- Cross-sectional profile in east-west direction derived with the ACT-REACT Quick Map tool of the domes (a) V3 and (b) V4, described in the text. Bottom: WAC derived elevation model (GLD100) of the domes (c) V3 (View from north western direction. The vertical axis is 10 times exaggerated) and (d) V4 and V1 (View from north western direction. The vertical axis is 10 times exaggerated).*


*Figure 4: Cross-sectional profile in east-west direction derived with the ACT-REACT Quick Map tool of the dome V5. It belongs to class In2 of putative intrusive domes.*

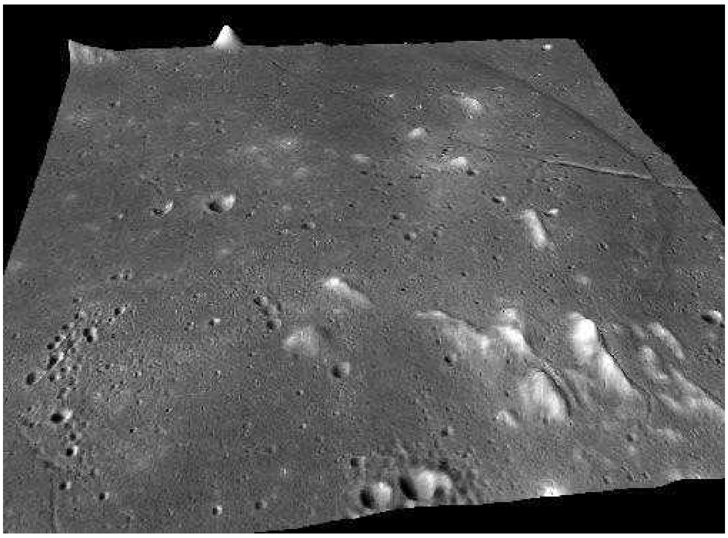


*Figure 5: WAC derived elevation model (GLD100) of the dome V5 and V1 (View from south western direction. The vertical axis is 10 times exaggerated).*

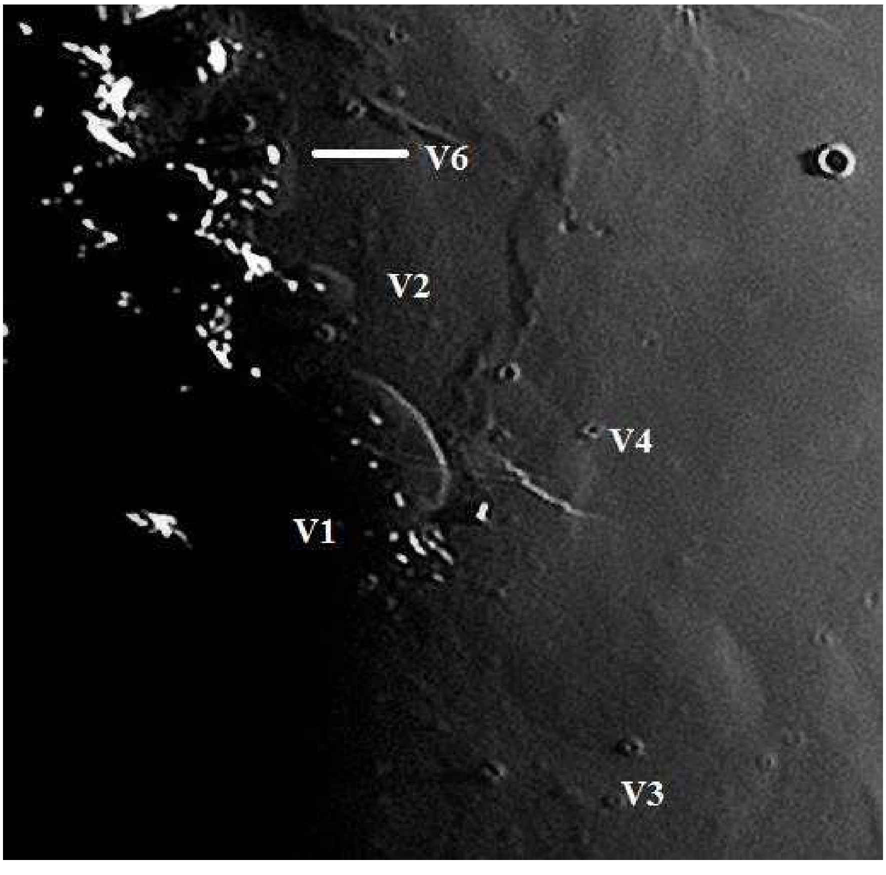



*Figure 6: KC Pau image taken on March, 1, 2020 at 11:33m UT. Another suspected dome is termed V6.*

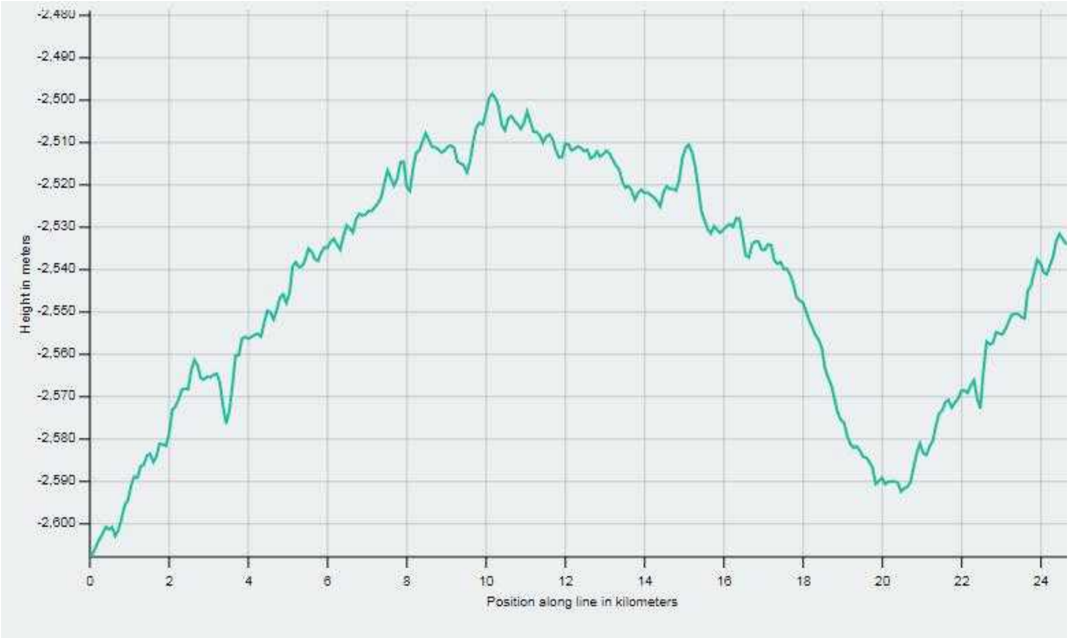



*Figure 7: Cross-sectional profile derived with the ACT-REACT Quick Map tool of the suspected dome provisionally termed V6.*

Please check your past imagery and send them to me for the ongoing study. Likely V6 is another exemplar of class In2 based on the morphometric data.

The examined domes are positioned in the surroundings of Caucasus Montes and their characteristics would imply on origin due to a subsurface intrusion of a large magmatic body.

References

[1] Lena, R., Wöhler, C., Phillips, J., Chiocchetta, M.T., 2013. *Lunar domes: Properties and Formation Processes*, Springer Praxis Books.

[2] Phillips, J., Lena, R., Lunar domes in the Caucasus Montes: Morphometry and mode of formation. 45th Lunar and Planetary Science Conference (2014). https://www.hou.usra.edu/meetings/lpsc2014/pdf/1011.pdf

## LARS's PANCAKE

Barry Fitz-Gerald

In the March 2020 LSC the Director asked for comments on a pancake-like feature observed by Lars Lindhard to the west of Norman and Euclides C and described by Lars as resembling *'a round disc that has a crack in the middle - just in the diameter - so the sides appear to bend slightly up'*. I think the correct interpretation was given at the time by the Director, in that it was a partial ghost crater, but here is a brief analysis of the area which turned up some other features worthy of note.

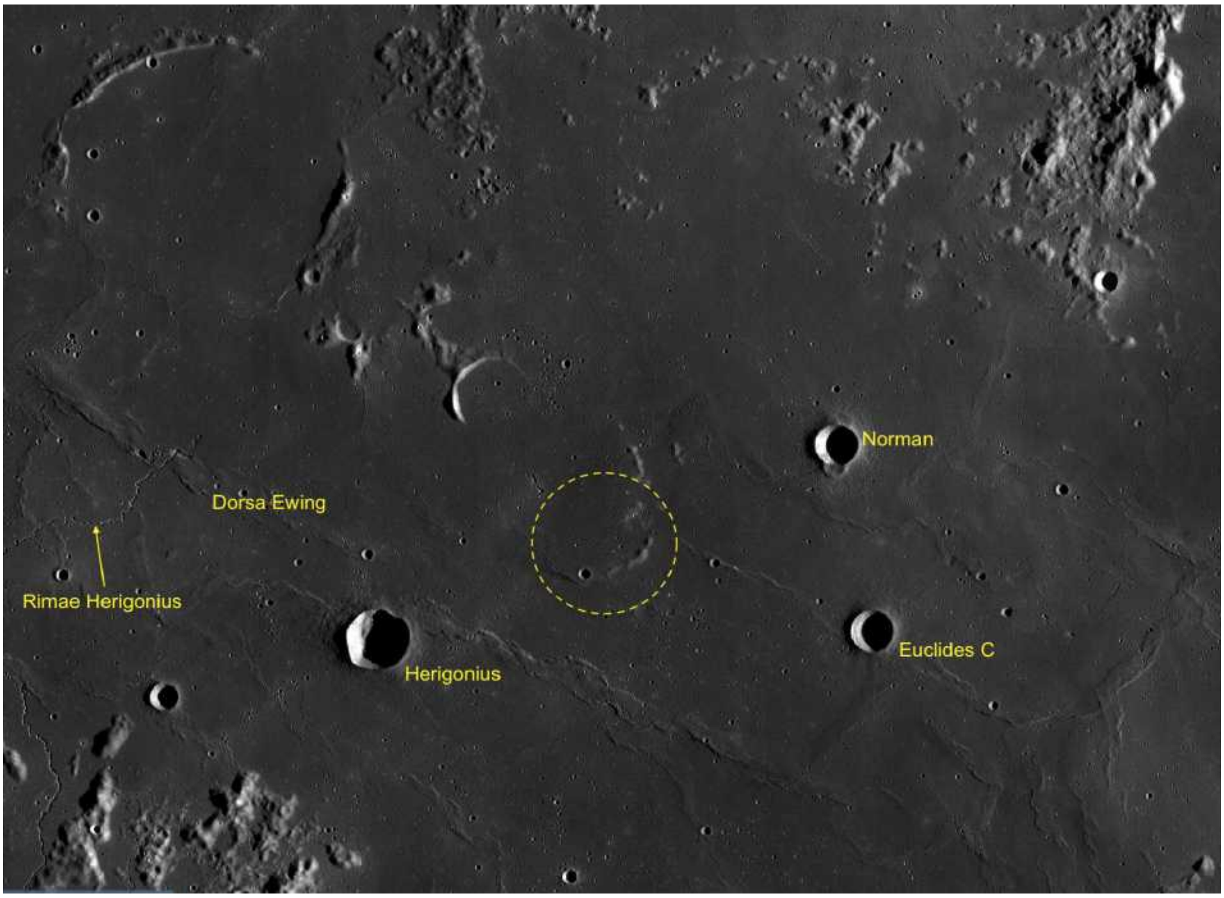



*Fig. 1. LROC WAC image of the Herigonius/Euclides C area showing the position of the feature observed by Lars Lindhard (yellow circle). The partially submerged crater in the top left corner is 65kms in diameter.*

Fig. 1 is a LROC-WAC image of the area Lars observed showing the location of the feature; Mare Humorum and Gassendi are just out of the frame to the south-west. As can be seen, this area of mare has a number of wrinkle ridges trending in a northwest-southeast direction, the most prominent being Dorsa Ewing which passes to the north of Herigonius. These show that the mare has been subject to compression probably related to crustal downwarping under the weight of the erupted basalt lavas. An indication of the depth of the mare lavas here can be gained observing that some sizeable craters have been almost completely submerged, with two good examples visible to the north of Herigonius, the largest being 65kms in diameter which equates to an original depth of some 3.5kms.

Fig. 2 shows a detailed SELENE view of the feature observed by Lars, where it can be seen that it is another partially submerged crater, with an original diameter of some 26kms, and a depth somewhere in the order of 2.5kms. Sections of the eastern rim are preserved, these are plagioclase rich and of a highland crust composition. To the southwest the rim has been submerged and is replaced by a mare ridge, and to the northwest and north there is not trace of a rim whatsoever, so it appears the western half of the crater has been down-faulted and completely submerged by lavas whilst the remaining eastern half dips downwards to the south albeit at a very shallow angle.

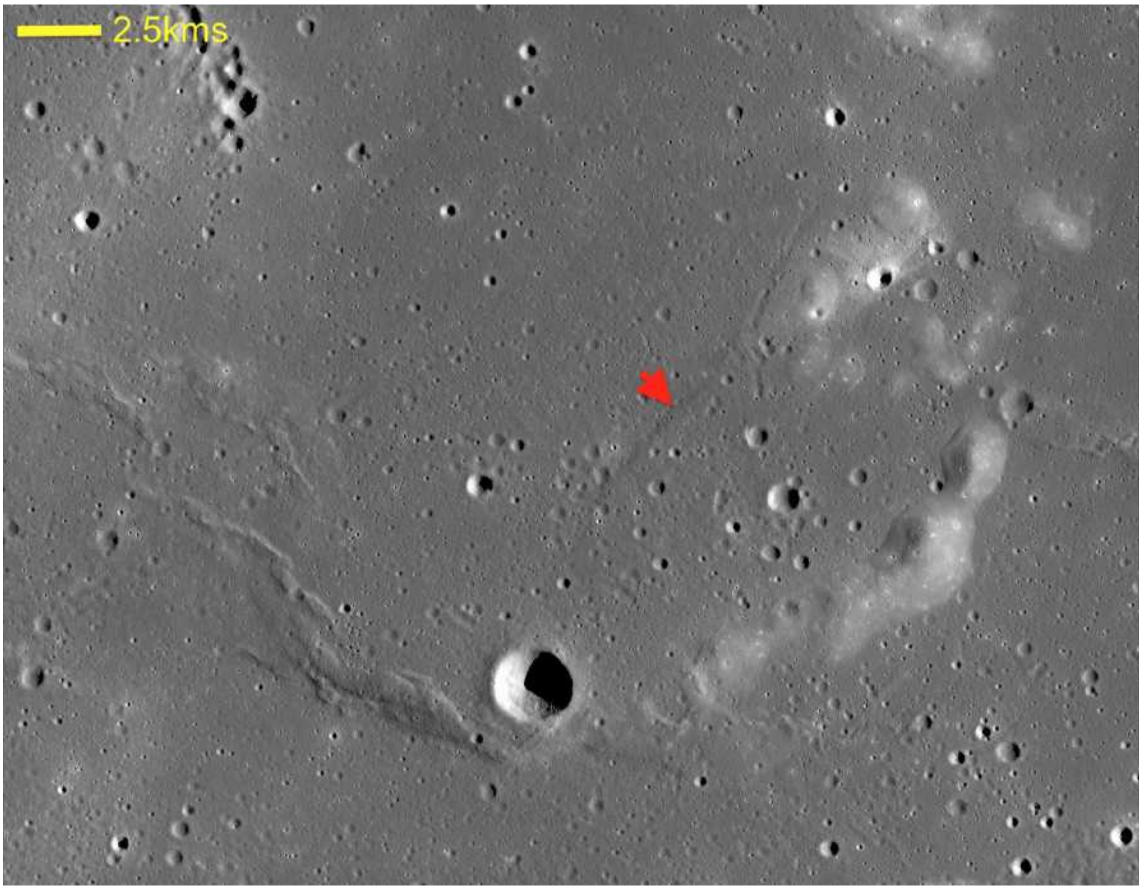



*Fig. 2. JAXA/SELENE image of the 'pancake' showing remnant highland crater rim to the south-east and mare ridge replacing the rim to the south-west. The red arrow shows the approximately 30m high scarp which represents a fault running northeast-southwest. The surface of the 'pancake' slopes at approximately 0.5° to 1° to the northwest.*

The fault along which the crater fractured is visible as a west-facing scarp some 30m high crossing the mare surface in a northeast to southwest direction. This is the crack in the disc observed by Lars.

The fact that many of the submerged craters in this region are only represented by partial rings shows that uneven subsidence and down-faulting was extensive as these area sank under the accumulated weight of the mare basalts. The GRAIL gravity data also indicates that the terrain on which the original crater formed was an area of highland, possibly surrounding an even older large crater or small basin to the east (see Fig. 12). Evidence for this can be seen to the east of Euclides C where a roughly circular arrangement of wrinkle ridges or a Mare Ridge Ring Structure or MRRS marks the presence of a large submerged impact structure. The MRRS is some 65kms across, and so the diameter of submerged crater would be this size at a minimum. This would imply an original crater depth of some 3.5kms, and by inference the mare lavas here must also be at least 3.5kms deep (Fig. 3).

Many large ancient (~ 3.5Ga) impact structures exist on the Moon and are implicated as being focal points for magmatic activity and the eruption of mare lavas. This took place as their fractured and brecciated basements trapped magmas ascending from the mantle in subsurface reservoirs which then reached the surface and erupted (ibid). The ridges that define the MRRS probably formed as the mare lavas which filled the original crater caused the central part to down-warp generating wrinkle ridges via horizontal compressional forces. More widespread (and probably later) regional subsidence was probably responsible for the wrinkle ridges trending in other directions such as Dorsa Ewing and those south of the MRRS which trend more north-south.

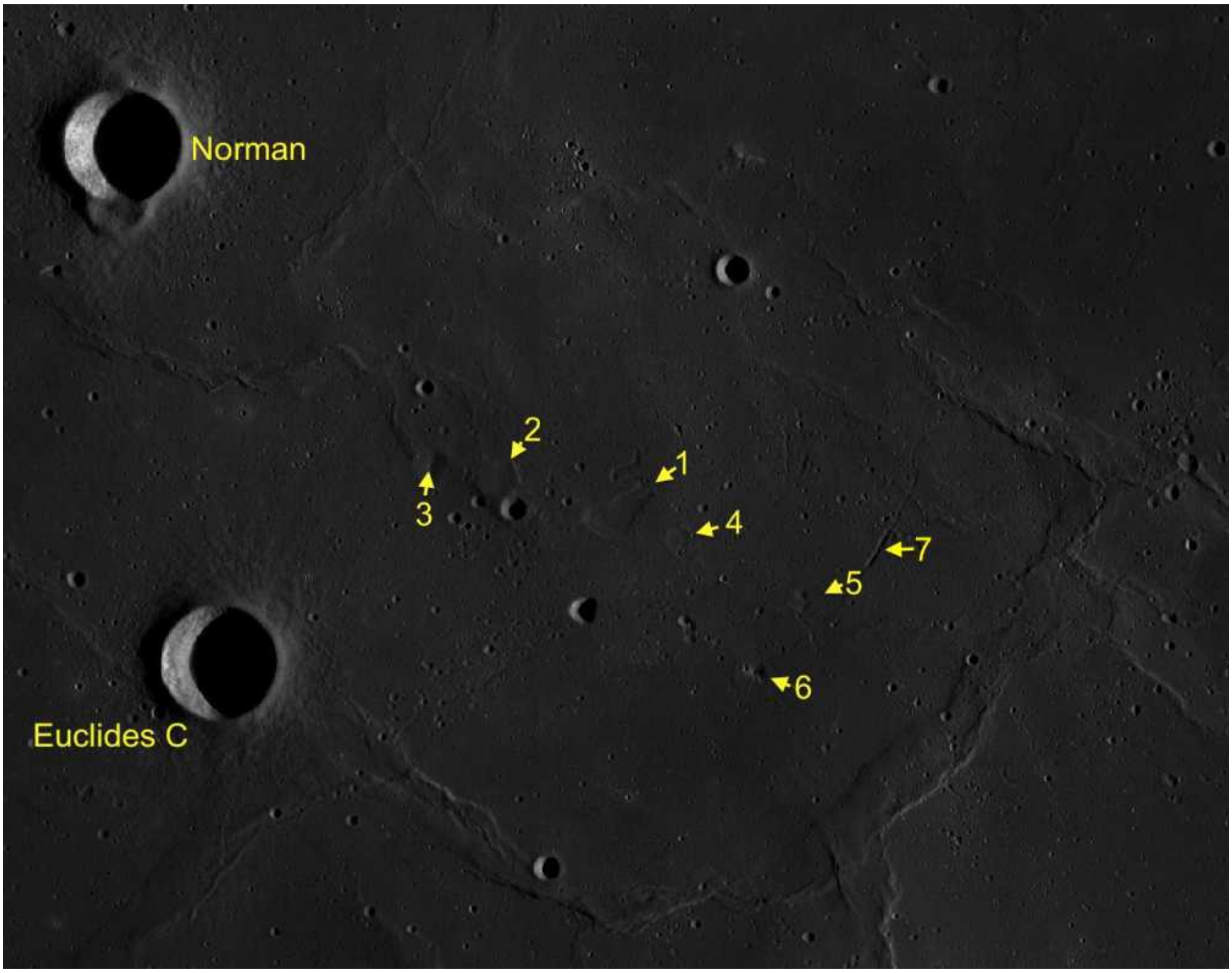



*Fig. 3. LROC WAC image of the Mare Ridge Ring Structure. Yellow arrows indicated volcanic structures which are discussed individually in the text. Note the slight diamond shaped outline to the wrinkle ridges.*

The Quickmap overlays of the GRAIL gravity data shows that this MRRS corresponding to an area of reduced crustal thickness (Fig. 4) is a similar situation to that seen in Lamont (Mare Tranquillitatis) which is another, much larger MRRS. This anomaly extends beyond the wrinkle ridge ring itself, and so the diameter (and consequent depth) of the original crater may well be greater than suggested by the visible ridges. Other GRAIL data sets suggest the presence of intrusive volcanic rocks in the crust beneath this structure, an observation which is borne out by the presence of some interesting volcanic structures in the middle of the MRRS.

The first feature appears to be an irregular-shaped drained lava lake, some 7km long and 4kms wide, but only 20m deep (Fig. 5, feature 1). This represents a volcanic vent where a fire fountain erupted and the molten lava fell back to accumulate into a lake. An outflow channel in the form of a short sinuous rille to the north shows where the lake drained out in that direction, the shortness of the channel possibly indicating that the lava eventually ponded to the north and drowned the distal part of the channel that fed it. This lake sits on the eastern edge of a raised area which gives way to the west to a wrinkle ridge. The raised area may have been volcanically uplifted, but this is speculation based on the number of volcanic features within close proximity to it.

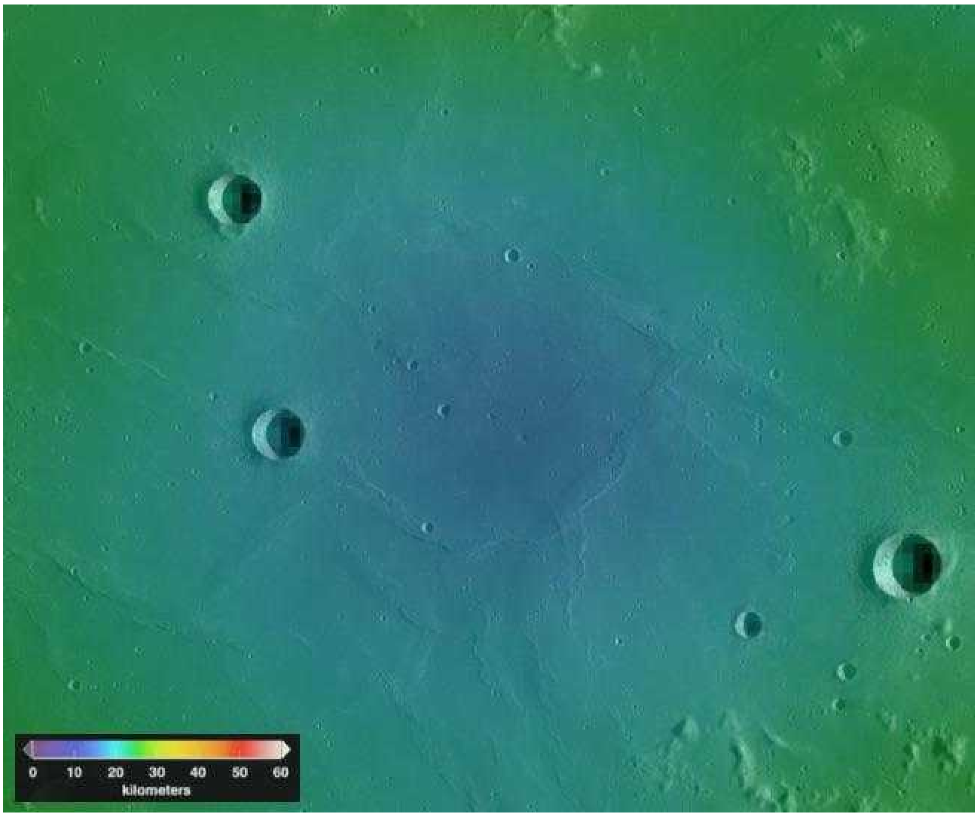



*Fig. 4. GRAIL crustal thickness map of area shown in Fig. 3 indicating the presence of a submerged impact structure. . Note that the area of thin crust extends beyond the wrinkle ridge circle.*

Enigmatic features called irregular mare patches or IMPs are found within the Lamont MRRS (Fitz-Gerald, 2015 and Zhang et.al., 2017), and so it is interesting to find examples here as well, suggesting a possible correspondence between the structures and the type of activity that took place in them. There has been a variety of explanations for these landforms, such as extrusion of frothy magmatic foams within lava lakes or from thick lava flows (Qiao et.al., 2017) or as inflated lava flows (Garry et.al., 2012) but the front runner and most parsimonious interpretation is that they represent sites where the fine regolith has been blown away by gas venting from below, leaving the larger regolith fractions and boulders behind (Schultz et.al., 2006 and Elder et.al., 2017). The origin of the gas is open to speculation, but in a volcanic setting the money would obviously be on volcanically derived gasses trapped beneath the surface and later vented at highly localised sites. Due to their youthful appearance and lack of superimposed crater, these structures have been suggested as being some of the youngest features on the Moon, possibly only 100million years (Braden et.al.,

2014) whilst other hypotheses suggest they are the same age as the mare lavas and only appear youthful due to their novel mode of formation and morphology.

Just outside the eastern rim of the lake a small field of IMPs can be seen, one or two patches apparently within small impact craters but others scattered on the mare surface (Fig. 5). The association between IMPs and small impact craters is a repeat of what is observed in Lamont, and it is possible that the concentric fractures associated with small craters provides easy routes to the surface for escaping gas. Interestingly no IMPs occur within the drained lake itself, only on the adjacent mare, an observation that argues against these features being associated with the eruption of foamy lavas from lava lakes.

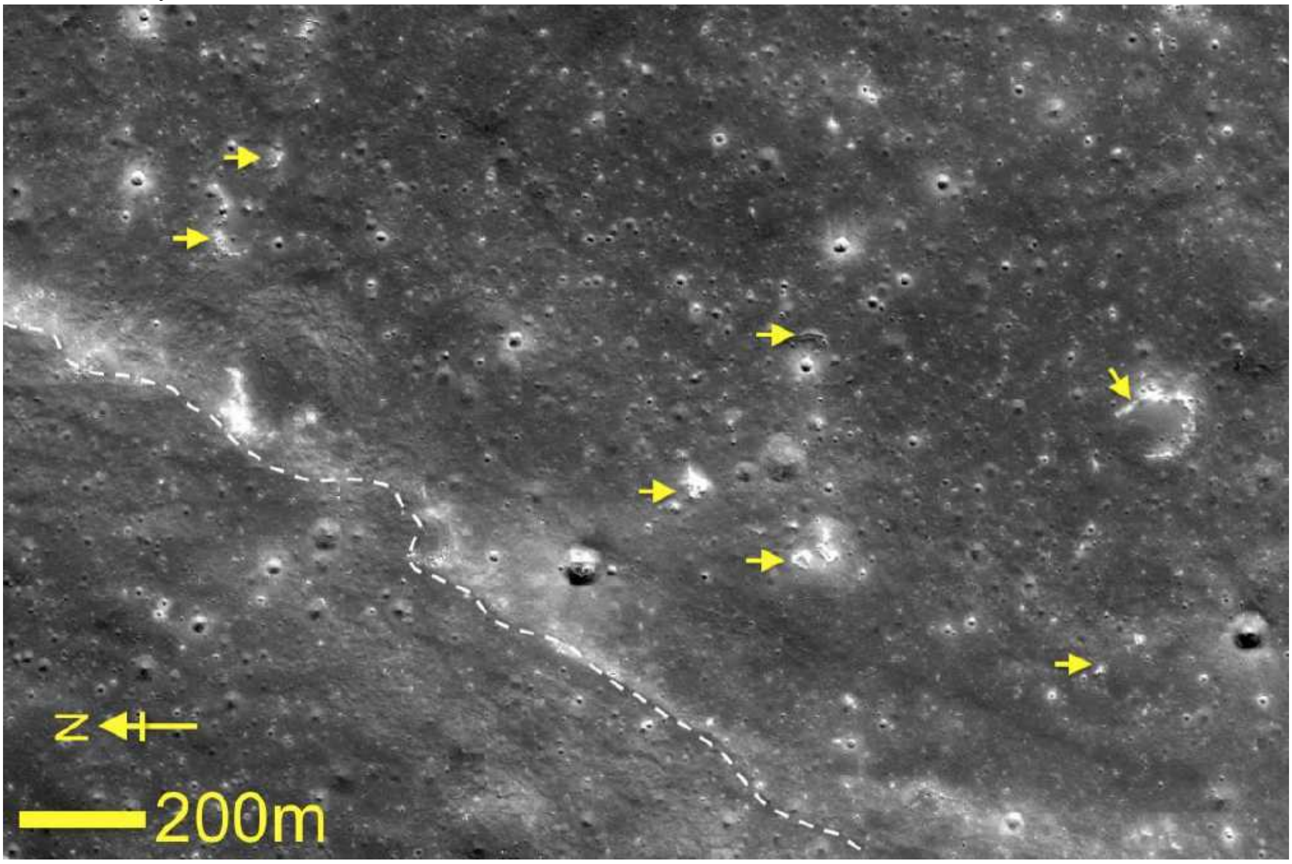



*Fig. 5. Eastern edge of the drained lava lake, the dashed white line marks the 'shoreline' with the lake surface below the line, and mare above. IMPs are marked by yellow arrows – note the horseshoe shaped IMP within the small impact crater.*

A number of circular structures (Fig. 3, features 2-6) can be seen within a radius of about 20kms of the lava lake. These appear to be either collapse features or impact craters that have been modified by volcanic activity. Immediately west of the drained lake is a flat disc-like structure about 4kms in diameter and approximately 100m high that may represent a modified crater of some sort (Fig. 3, feature 2). There are hints of a rim and a very shallow central depression, which supports the modified crater interpretation, but if it is a crater it has been intruded by lavas from below or filled with the same lavas that form the surrounding mare plains. If the latter case applies then it must have subsequently been uplifted above the level of the mare or the mare surface has subsided to leave it standing above the surface. A volcanic origin is suggested by the presence of some IMPs around the periphery of the structure, which would also support the idea that it is a modified crater, as IMPs appear to form preferentially around crater margins.

On the south-eastern edge of feature 2 is a crater approximately 2kms in diameter (Fig. 6). A detailed view (Fig. 7) shows several areas of IMPs along the crater's northern rim and wall, with lots of bright rocky patches surrounded by smoother darker deposits. The lighter patches are rich in rocks and boulders, many of which have rolled down the inner wall towards the crater floor. The darker patches have irregular edges and a fine texture with fewer craters than the unmodified surface nearby. The gas escape hypothesis most comfortably accounts for this surface modification, the bright areas being where the finer regolith has been blown away, whilst the darker areas represent where this finer material is still present, and probably added to by material blown off the adjacent bright areas. This would explain the subdued surface of these darker areas as they are in effect mantled by an extra layer of regolith.

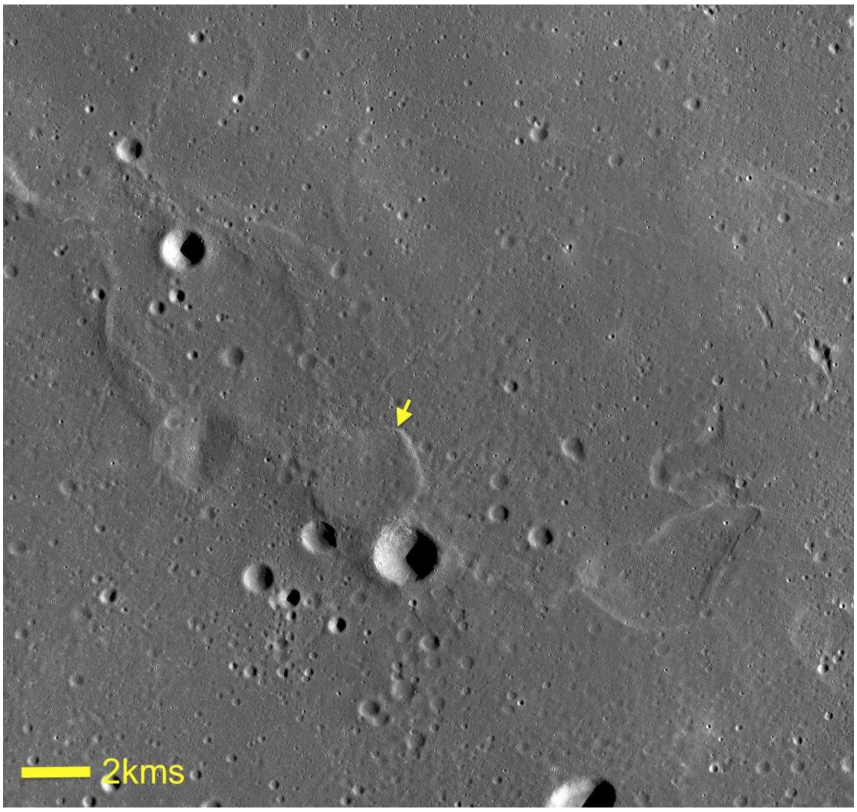



*Fig. 6. A SELENE/JAXA image of the central part of the MRRS showing features 1 - 4 from Fig. 3. The drained lava lake (feature 1) with the short sinuous rille to the north is to the right of the frame centre, and the suspected modified crater (feature 2) just to the left (yellow arrow). Note the 2 craters along the southern margin of feature 2, one ~ 1km and the other ~ 2kms in diameter.*

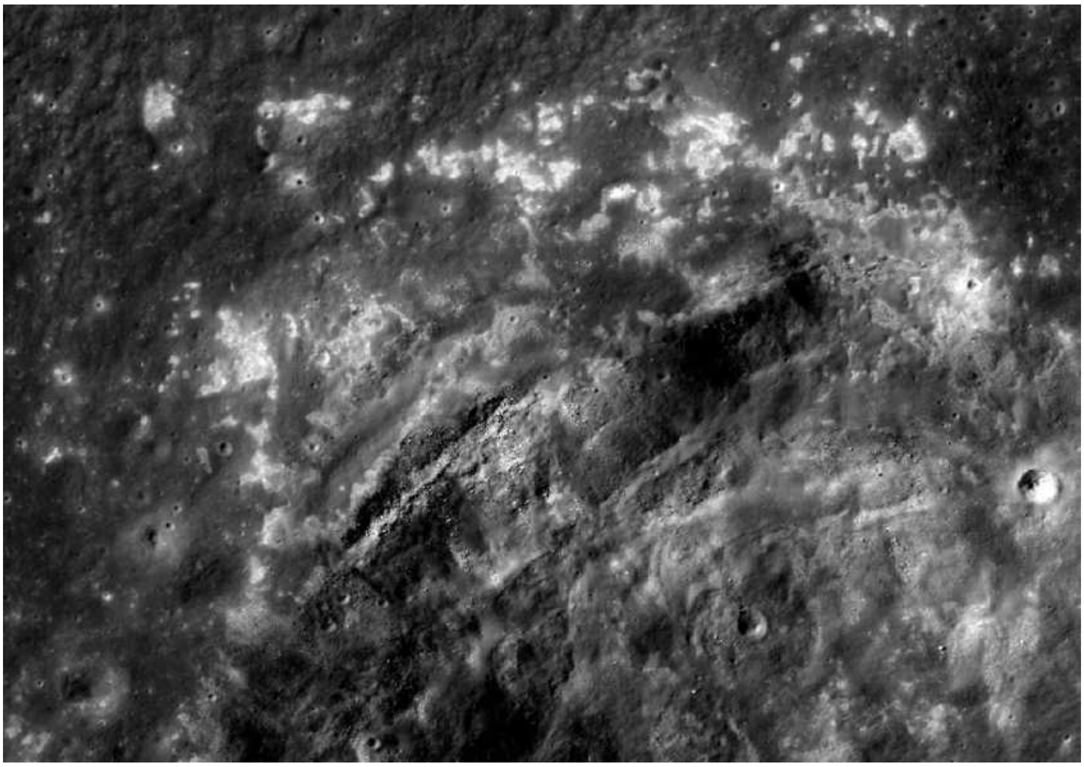


*Fig. 7. LRO-NAC image of the northern rim of the crater along the southeastern margin of feature 2. Note the irregular etched appearance of the bright areas and the smoother texture to the dark areas in between. The more 'normal' surface of the crater/dome surface can be seen in the top left of the frame.*

The approximately 1km diameter crater to the southwest of feature 2 is similarly affected, with again the bulk of the modification having taken place at the interface with feature 2. In addition some smaller craters on the mare surface, between 1 and 2kms to the east and north of feature 2 show IMPs. Interestingly there are no such patches on the surface of the crater/dome. This may reflect the fact that the interior of feature 2 is filled  mare lavas which might inhibit upward migration of gases whereas its periphery would be concentrically and radially fractured, providing the necessary conduits for gas to reach the surface.

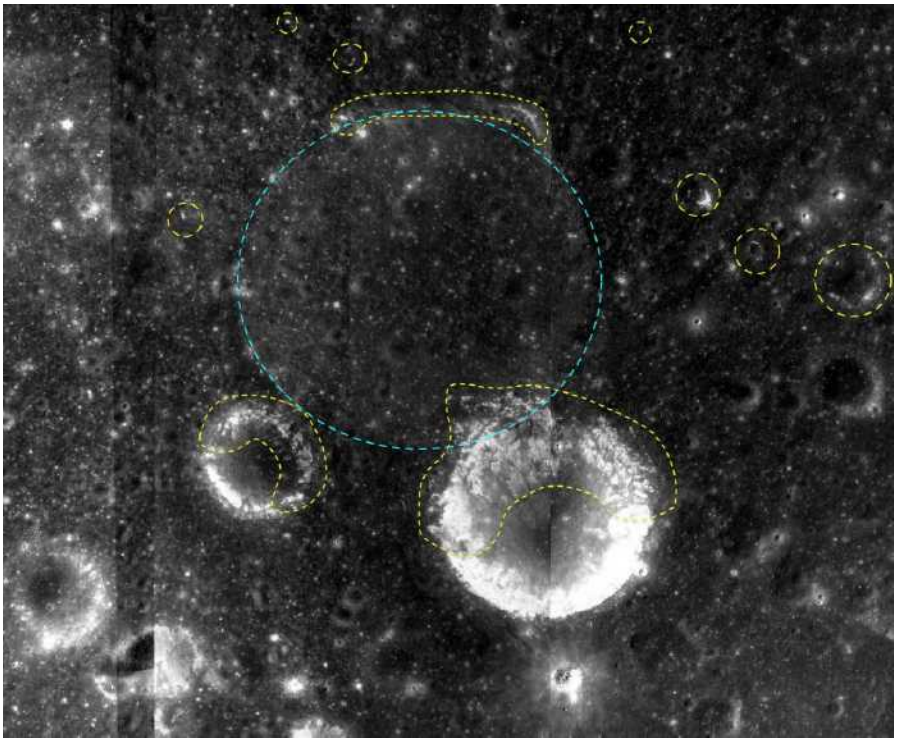


*Fig. 8. Feature 2 with blue dashed circle and the IMP patches surrounding it identified with yellow dashed lines. Note the absence of IMPs on the crater/dome itself.*

Another circular structure (Fig. 3, feature 1) showing IMP activity can be seen some 25kms away to the southeast of feature 2 (Fig. 10). This structure is roughly circular and in the region of 2.5kms in diameter, and contains a depression 50m deep which could represent a collapse feature. It shows little topography other than this depression, but it has a rim-like periphery which might suggest a buried impact crater, but it is also slightly elongated in the northwest-southeast direction which may indicate some other mode of formation. The IMPs in this case are clustered around an irregularly shaped crater adjacent to the southern edge, and whilst they not as extensive or well developed as those already discussed they are still unmistakeably IMP in nature (Fig. 11).

The significance of this particular IMP field is that the irregular crater they have modified appears to be an outlier of a secondary crater chain where the parent crater is Tycho. The chain is some 4kms long, orientated northwest to southeast and is associated with a bright ray heading off to the northwest, indicating that the debris that caused it arrived from the southeast, which is where Tycho is located some 1000kms away. The conventionally accepted age for Tycho is 108 million years, which would imply that the IMPs formed some time after this, which supports the hypothesis that these are geologically youthful features. This chain of reasoning depends on the irregular crater being an outlier of the secondary crater chain, but this area is fairly well plastered with Tycho secondary craters and rays (Fig. 12) and so the interpretation is not too unreasonable.

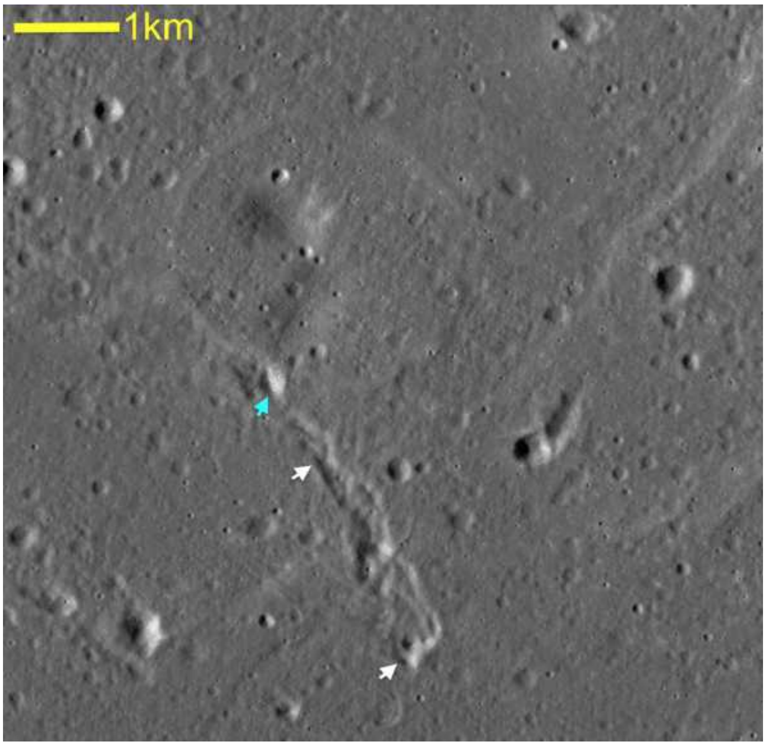



*Fig. 10. SELENE/JAXA image of feature 5 showing trace of a rim and pit like feature within. White arrows indicate a Tycho secondary crater chain, and blue arrow indicates another possible secondary at the end of the chain. This crater has IMP modification.*

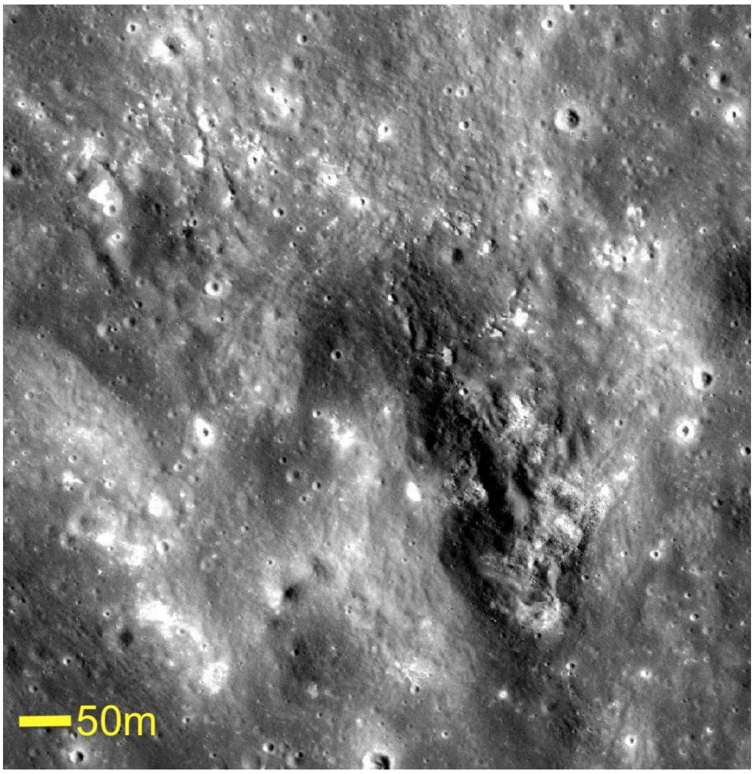



*Fig. 11. LROC NAC image of irregular crater to the southwest of feature 5 with associated IMPs.*

There appears to have been a number of active volcanic episodes during the history of the MRRS as is shown by the diversity of basalt types within it. Fig. 13 is a TiO2 abundance overlay, showing that the mare basalts within the MRRS are low titanium basalts, with mostly higher titanium basalts outside. The fact that Euclides C, Norman and the many small craters that lie on the high titanium basalts have excavated low titanium basalts (blue spots on the yellow and red) suggests

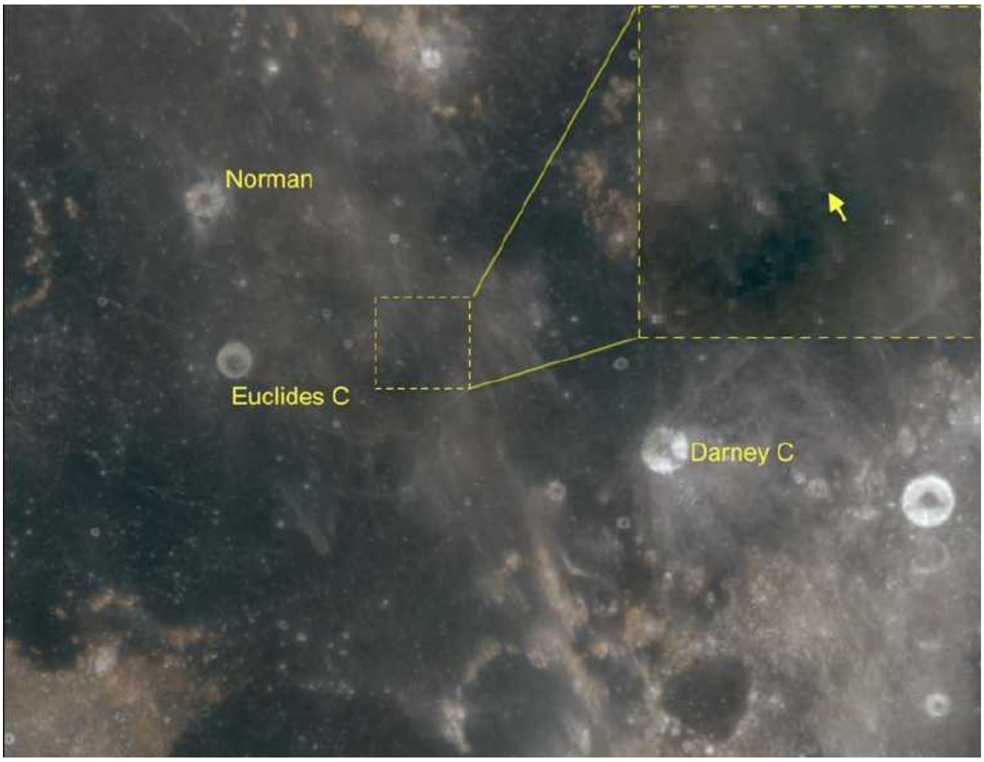



*Fig. 12. WAC Hapke-Normalized Colour overlay from Quickmap showing the rays from Tycho extending across the MRRS, with the dashed box showing the location of the secondary crater chain and its associated bright ray.*

that younger basalts of the former type lie on older basalts of the latter type. This may indicate that the basalts within the MRRS are therefore older than those surrounding it. The situation is complicated by the presence of areas of high titanium basalt around features 2, 5 and 6, even though they themselves show a low titanium signature. Additional circular patches showing a low titanium signature can be seen within the high titanium areas, which may be later eruptions of low titanium basalts from vents, one of which takes the form of a 4km long elongated cleft (Fig. 3, feature 7) which appears to be part of a much longer rille-like feature crossing the eastern part of the MRRS. Clearly a lot has been going on here over the course of lunar history and the area is a real palimpsest of geological activity and features and would probably take quite a bit of unravelling.

GRAIL Bouguer gravity gradients show an anomaly beneath the MRRS, indicating the presence of dense mantle rocks. This anomaly is orientated roughly northwest to southeast and has 5 arms radiating out which correspond in places to wrinkle ridge systems visible on the mare surface such as Dorsa Ewing (Fig. 14). Mantle rocks can reach towards the surface when large impacts remove a considerable depth of the crust, allowing a plug of dense mantle material to rise upwards in compensation. This produces the positive gravity anomaly that exists under many large impact structures such as Grimaldi. Alternatively the early history of the Moon was a time of global heating and expansion, and numerous positive gravity anomalies appear to have formed at this time as mantle rocks exploited fractures and rose vertically into the overlying crust.

The positive Bouguer gravity anomaly under this MRRS may well be of the latter sort as it appears to form part of a network of such anomalies and is not simply concentrated beneath the former crater. The anomaly is however more intense beneath the MRRS and so it is possible that the formation of the original crater re-activated the fractures and resulted in additional upwelling of magma. These magmas may or may not have reached the surface in the past to produce mare basalt flows, or they may have 'stalled' in the crust to form a reservoir which fed later surface volcanism.

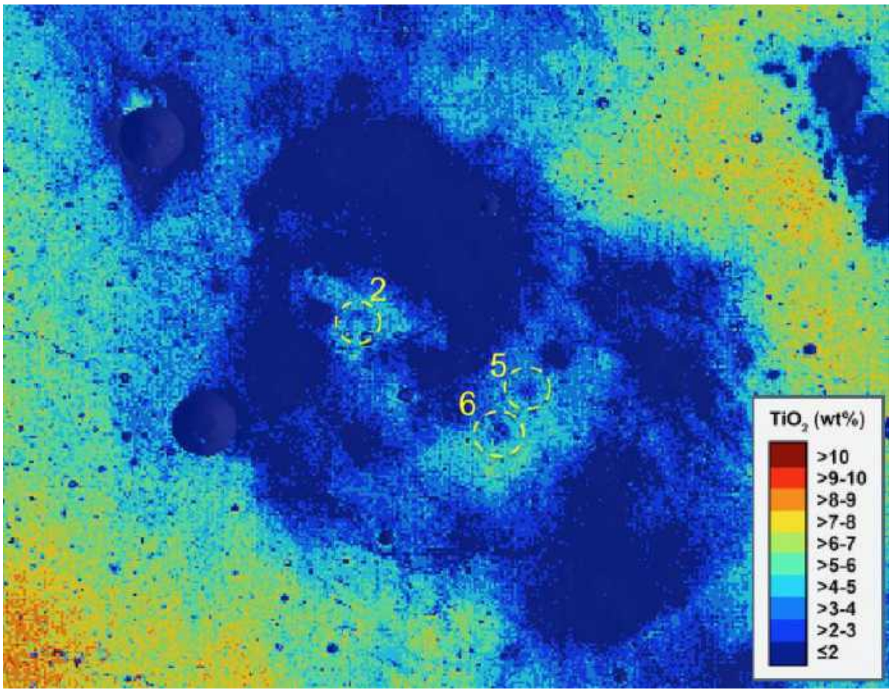



*Fig. 13. Quickmap TiO2 abundance overlay showing the diversity of basalts in and around the MRRS.*

At shallower levels the gravity data indicates the presence of a body of dense solidified magma beneath the central part of the MRSS. This may represent such a magma reservoir that formed in the fragmented breccia lens of the original crater, and which later produced the lavas that erupted onto the surface (forming the lava lake) via vertical dikes. De-gassing of this magma in such a reservoir and in dikes reaching towards the surface may also have been the source of the gas which eventually escaped to produce the IMPs. This MRRS, which sadly appears not to have its own name, is something of a smaller version of structures like Lamont. They may well be important as the source of the basalts that drowned the topographic lows to produce the extensive mare, and as such are important geological features.

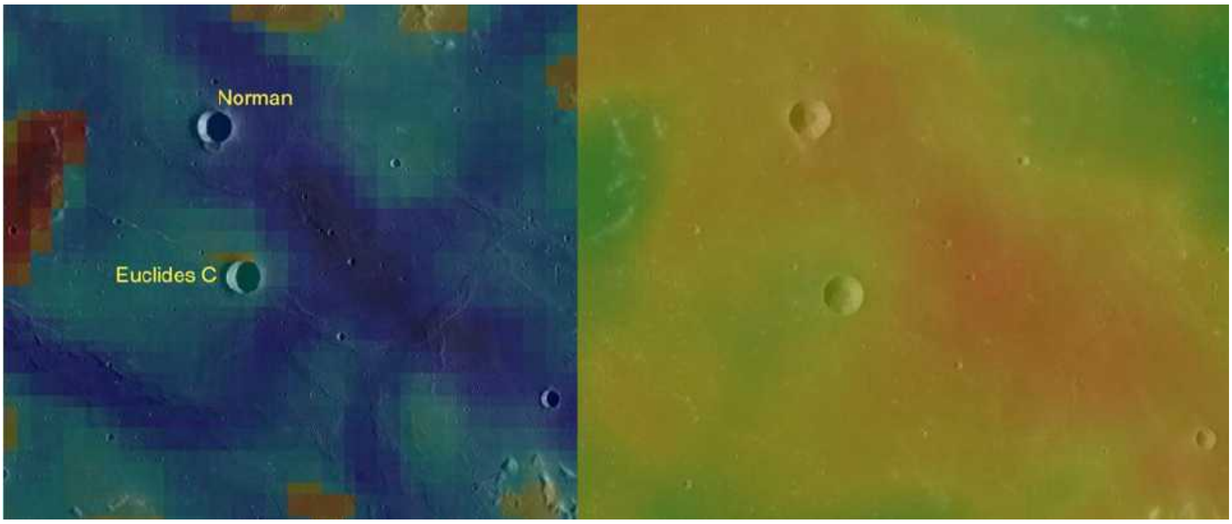



*Fig. 14. Left - Bouguer gravity gradients overlay from Quickmap showing dense probably mantle rocks in blue beneath the MRRS. Right - Bouguer gravity filtered from degree 60 to 660 overlay showing a possible crustal body of solidified magma in red. Note the 'pancake' on the extreme left of each panel, which shows up as less dense indicating a greater highland contribution to the signal.*

**Acknowledgements:**

LROC images reproduced by courtesy of the LROC Website at http://lroc.sese.asu.edu/index.html, School of Earth and Space Exploration, University of Arizona.

Selene images courtesy of Japan Aerospace Exploration Agency (JAXA) at:
http://l2db.selene.darts.isas.jaxa.jp

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**LUNAR OCCULTATIONS** **May 2020** Tim Haymes

**Dear Observers**

A reminder that graze predictions for 2020 are available to download from the Lunar Section link here:
https://britastro.org/downloads/17673

**The Virtual 14th Trans-Tasman Symposium on Occultations April 13th**

With the COVID-19 corona virus restrictions in place, this meeting by Australian and New Zealand observers was on-line via Meetcheap. This coordinator was logged in; however, the on-line meeting room filled up and the meeting was re-transmitted over Zoom until the problem was solved. Details of the excellent presentations can be accessed from this link:
http://www.occultations.org.nz/meetings/TTSO14/Schedule.htm

**April Observations**

The Graze occultation of SAO 109952 on Feb 27 which the coordinator observed in good conditions was reported to Japan and a preliminary reduction was received on April 4th. A report was also sent to Guy Hurst Editor of TA (2020 April issue).

The observation was made before Government restriction in the UK. I had planned to observe this last year, but since the weather was so bad over Jan and Feb, I had given up hope of attempting the graze - then the skies cleared and I was lucky. The observation site was about 20min drive from home.

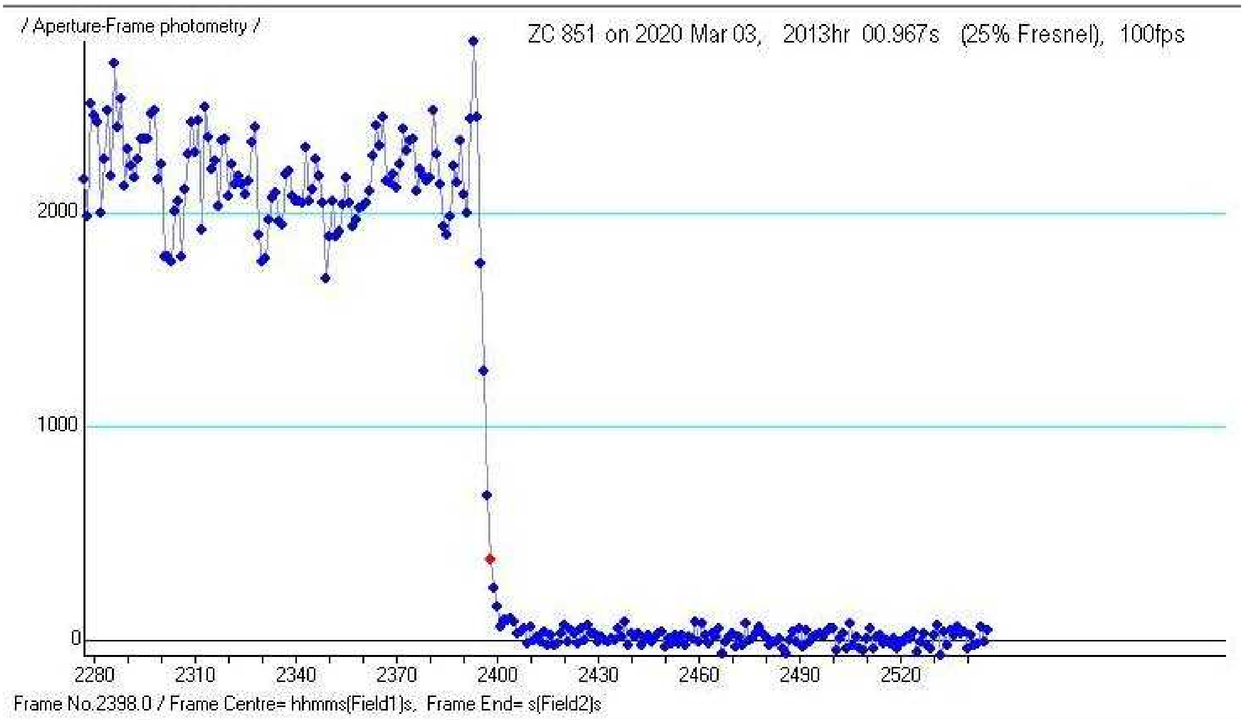
I recorded 8 contacts in good conditions from a location near South Leigh, Oxfordshire. No unusual phenomena were detected, and the preliminary reduction is very close to the LOLA Limb using analysis with Occult4. The graze was recorded with a driven 8" F/4 reflector and video at 25fps. Frame timing was via GPS. A Video is here:
https://www.youtube.com/watch?v=j5JLZOoByik&t=0s

**Diffraction at the lunar limb**

Most observers will be aware of the Airy disk and diffraction rings for a point source such as a star. The Airy disk contains 85% of the light, and the first diffraction ring contains about 2%. To record details in the Airy disk by an occultation, we need to time-resolve better than 50fps (0.02s). This is the fastest rate by analogue video where the fields are separated. Diffraction effects are exaggerated at grazing angles. At 100fps it will be possible to record some features of the diffraction pattern at most cusp angles.

Fig. 1 is a light curve for the star ZC851 occulted and observed with a 20cm aperture using a USB3 digital camera. Now we see that a point source is not an instantaneous event. The point of geometric occultation is at 25% flux indicated by the red dot. A diffraction pattern with good signal/noise contains information on the diameter of the source or if it is more than one source

*Fig. 1. Occultation of ZC851 recorded at 100fps ( 10ms )*




Some helpful reading is provided in Solar System Photometry Handbook: Edited by R.M Genet(1983).

The Very Large Telescope (VLT) was used up to 2014 to study the lunar occultation of close binary stars. A near-infrared detector was used at 3ms cadence. This paper (link below) described the results of 1226 occultations of which 8% were binary out of a random selection.
https://iopscience.iop.org/article/10.1088/0004-6256/147/3/57/meta

## **2020 May predictions for Manchester** (Occult4 by D.Herald)

W. Long. 002d 15’, N Lat. +53 25’, Alt. 50m
Events excluded: Daytime, Bright-limb. Magnitude limit 9.0

| y | m | day d | Time h | m | s | P | Star No | Sp | Mag v | Mag r | % ill | Elon | Sun Alt | Moon Alt | Az | CA o | Notes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | May | 1 | 20 | 32 | 38.7 | D | 98818 | B9 | 8.6 | 8.5 | 61+ | 103 | -8 | 51 | 208 | 31S | |
| 20 | May | 1 | 23 | 18 | 17 | m | 1462 | K0 | 7.3* | 6.6 | 62+ | 104 | | 32 | 254 | 3N | |
| 20 | May | 2 | 0 | 27 | 9.0 | D | 98892 | K0 | 7.7* | 7.1 | 63+ | 105 | | 22 | 267 | 84N | |
| 20 | May | 2 | 0 | 54 | 49.2 | D | 98897 | K0 | 7.6* | 7.0 | 63+ | 105 | | 18 | 273 | 74S | |
| 20 | May | 2 | 21 | 58 | 22.2 | D | 1578 | K0 | 6.9 | 6.2 | 73+ | 117 | | 43 | 216 | 59S | |
| 20 | May | 2 | 22 | 43 | 50.0 | D | 99330 | K0 | 8.0 | 7.4 | 73+ | 117 | | 39 | 229 | 32S | |
| 20 | May | 2 | 23 | 5 | 0.0 | D | 99337 | G5 | 8.4 | 8.1 | 73+ | 117 | | 36 | 234 | 44S | |
| 20 | May | 3 | 21 | 22 | 55.1 | D | 1702 | M0 | 4.0* | 3.3 | 82+ | 130 | | 43 | 185 | 48N | nu Vir |
| 20 | May | 5 | 21 | 1 | 57.6 | D | 1950 | G6 | 5.7 | 5.2 | 96+ | 158 | -10 | 27 | 150 | 19N | 80 Vir |
| 20 | May | 7 | 22 | 6 | 58.8 | R | 2213 | K0 | 5.8 | 5.3 | 100- | 173 | | 13 | 143 | 41N | 34 Lib |
| 20 | May | 7 | 23 | 17 | 18.4 | R | 2218 | B3 | 5.5 | 5.6 | 100- | 172 | | 18 | 160 | 40N | zeta Lib |
| 20 | May | 8 | 2 | 39 | 2.9 | R | 2232 | G8 | 7.2 | 6.6 | 99- | 171 | | 15 | 209 | 88N | |
| 20 | May | 25 | 21 | 15 | 38.0 | D | 78771 | A0 | 6.8* | 6.8 | 10+ | 36 | -7 | 14 | 290 | 57S | |
| 20 | May | 25 | 22 | 3 | 41.2 | D | 78802 | G5 | 7.9 | 7.7 | 10+ | 37 | -11 | 8 | 299 | 74N | |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20 | May | 26 | 22 | 22 | 6.4 | D | 79705 | G5 | 8.5 | 8.0 | 17+ | 49 | | 12 | 292 | 36S | |
| 20 | May | 26 | 22 | 47 | 48.0 | D | 79732 | K0 | 7.8 | 7.1 | 17+ | 49 | | 9 | 297 | 47N | |
| 20 | May | 27 | 21 | 18 | 19.5 | D | 80379 | M4 | 8.8 | 8.0 | 26+ | 61 | -7 | 27 | 269 | 46S | |
| 20 | May | 27 | 21 | 34 | 38.7 | D | 80388 | K0 | 8.1 | 7.5 | 26+ | 61 | -8 | 25 | 272 | 55N | |
| 20 | May | 27 | 22 | 23 | 47.8 | D | 80401 | A5 | 8.5 | 8.4 | 26+ | 61 | | 17 | 281 | 31S | |
| 20 | May | 27 | 22 | 25 | 52.2 | D | 1315 | A2 | 7.1 | 7.1 | 26+ | 61 | | 17 | 281 | 82N | |
| 20 | May | 27 | 22 | 36 | 9.8 | D | 80413 | F8 | 7.6 | 7.3 | 26+ | 62 | | 16 | 283 | 55S | |
| 20 | May | 27 | 22 | 56 | 57.1 | D | 80421 | F0 | 8.8 | 8.6 | 26+ | 62 | | 13 | 287 | 34S | |
| 20 | May | 27 | 23 | 27 | 59.0 | D | 80439 | K2 | 8.2 | 7.5 | 27+ | 62 | | 9 | 293 | 73S | |
| 20 | May | 28 | 22 | 46 | 50.8 | D | 1431 | B9 | 8.3 | 8.3 | 36+ | 74 | | 19 | 273 | 31S | |
| 20 | May | 29 | 22 | 33 | 10.9 | D | 1553 | A0 | 7.8 | 7.8 | 47+ | 87 | | 25 | 257 | 57S | 78 Leo |
| 20 | May | 29 | 23 | 17 | 23.8 | D | 99227 | K0 | 8.2 | 7.6 | 48+ | 87 | | 19 | 266 | 77S | |
| 20 | May | 30 | 22 | 48 | 55.1 | D | 118905 | K0 | 7.9 | 7.4 | 59+ | 100 | | 26 | 246 | 69N | |
| 20 | May | 30 | 23 | 48 | 48.6 | D | 1673 | K0 | 8.2* | 7.6 | 59+ | 101 | | 18 | 258 | 59S | |
| 20 | May | 31 | 23 | 31 | 11.3 | D | 1783 | A0 | 7.3* | 7.3 | 70+ | 114 | | 22 | 241 | 56N | |
| 20 | Jun | 2 | 23 | 4 | 33.0 | D | 2032 | F0 | 7.2 | 7.0 | 89+ | 141 | | 24 | 204 | 60S | 97 Vir |

Predictions up to June 5th

Notes on the Double Star selection:

Doubles are selected from Occult 4, where the fainter companion is brighter than mag 10, and the time difference(dT) is between 0.1 and 10 seconds. **Please report double star phenomena.**

Key:

P = Phase (R or D), **R** = reappearance **D** = disappearance
M = Miss at this station, Gr = graze nearby (possible miss)
CA = Cusp angle measured from the North or South Cusp.
Dbl* = A double star worth monitoring. Details are given for selected stars.
Mag(v)* = asterisk indicates a light curve is available in Occult-4
Star No:
1/2/3/4 digits = Zodiacal catalogue (ZC) referred to as the Robertson catalogue (R)
5/6 digits = Smithsonian Astrophysical Observatory catalogue (SAO)
X denotes a star in the eXtended ZC/XC catalogue.
The ZC/XC/SAO nomenclature is used for Lunar work. The positions and proper motions of the stars in these catalogues are updated by Gaia.

*Detailed predictions at your location for 1 year are available upon request.*
**Occultation Subsection Coordinator**: Tim Haymes
tvh.observatory@btinternet.com

## LUNAR GEOLOGICAL CHANGE DETECTION PROGRAMME May 2020

Tony Cook

Reports have been received from the following observers for Mar: Jay Albert (Lake Worth, FL, USA - ALPO) observed: Aristarchus, Censorinus, Gassendi, Promontorium Agarum, Taruntius, and Torricelli B. Anunziato (Argentina - SLA) observed: Aristarchus, Atlas, Copernicus, Fracastorius, Grimaldi, Mutus F, Piccolomini, and Taruntius. Catrin Ashcroft (Rhayader, UK) imaged the SW quadrant of the Moon. Sergio Babino (Uruguay, SAO/LIADA) imaged: Clavius, Fracastorius, Gassendi, Kepler, Maurolycus, Theophilus and Tycho. Kevin Berwick (Ireland – ALPO) observed Daniell. Aylen Borgatello (Argentina – AEA) imaged: Plato. Tony Cook (Newtown, UK – ALPO/BAA) imaged several features and captured earthshine video. Maurice Collins (New Zealand, ALPO/BAA/RASNZ) imaged: the Moon at moonrise. Phil Deyner (Hornchurch, UK – BAA) imaged: Herodotus. Walter Elias (Argentina – AEA) imaged: Aristarchus, Mons Vinogradov, Proclus, Promontorium Agarum, Schickard, Tycho and several features. Les Fry (Mid West Wales, UK – NAS) imaged Gassendi. Victoria Gomez (Argentina – AEA) imaged: Aristarchus. Abel Gonzalez Cian (Argentina – AEA) imaged: Mare Crisium, Moretus, Tycho and several features. Facundo Gramer (Argentina – AEA) imaged: Atlas, Copernicus, and Mare Serenitatis. Gracie Jones (Rhayader, UK) imaged the neighborhood around Mare Humorum. Gabriel Re (Argentina – AEA) imaged: Mare Crisium and Tycho. Trevor Smith (Codnor, UK - BAA) observed: Aristarchus, Censorinus, Halley, Maskelyne, and Torricelli B. Bob Stuart (Rhayader, UK – BAA/NAS) imaged: Clavius, Copernicus, Goldschmidt, Lansberg, Montes Riphaeus, Plato and T Mayer. Sophie Stuart (Rhayader, UK – NAS) imaged: the Tycho ray system. Franco Taccogna (Italy – UAI) imaged: Herodotus. Aldo Tonon (Italy – UAI) imaged: the Full Moon. Gary Varney (Pembroke Pines, FL, USA – ALPO) imaged: Lamont, Mare Crisium, Petavius, Schiller, Theophilus and several features. Freya Williams (Rhayader, UK) imaged: the Imbrium Impact basin.

**News:** Readers of the BAA Lunar Section Circular should take a good look at Peter Anderson's article in this issue on false atmospheric and telescope optical colour effects on the Moon - as these have caused no end of false reports of coloured TLPs in the past. The main point to consider after reading the article is that if you ever think that you see, or image colour on the Moon, is to: a) check other similar looking craters, b) see if the effect worsens as the Moon reduces in altitude, and c) move the lunar surface around in the field of view to see if the amount of colour changes as would be the case with chromatic aberration. This kind of advice on how to avoid seeing false TLP is covered on the BAA Lunar Section website under the TLP side of things. There are also a series of flow charts in the Appendix of *The Hatfield Lunar Atlas – A Digitally Remastered Edition* with the intention to help observers avoid mis-interpreting false effects for TLP.

**TLP reports:** No TLP were reported in March.

**Routine Reports:** Below are a selection of reports received for March that can help us to re-assess unusual past lunar observations – if not eliminate some, then at least establish the normal appearance of the surface features in question.

**Censorinus:** On 2020 Mar 01 UT 19:48-20:02 Trevor Smith (BAA) observed visually this crater under similar illumination (within ±0.5°) to the following report:

*On 1983 Apr 19 at 21:45UT M.C. Cook (Frimley, UK) reported that Censorinus' exterior white patch was grayish at this time and there was a "momentary glow outside the crater to the North West. The Crater Extinction Device brightness measurement for Censorinus was 4.0 whereas Proclus was 4.4. Cook was expecting a lower CED brightness measurement. Foley notes that Censorinus is usually brighter than Proclus. On 1983 Jan 29 Chapman obtained a very high brightness measurement for this spot. The Cameron 2006 catalog extension ID=212 and the weight=3. The ALPO/BAA weight=2.*

Trevor was using a 16" reflector, but was hampered by Antoniadi IV (Poor) seeing conditions. Nevertheless, he was able to note that no sign of spurious colour (an old general term for atmospheric spectral dispersion or chromatic aberration) was seen on the crater floor or rim. Neither was any spurious colour seen elsewhere on the Moon, despite the observing conditions. We shall leave the weight of this 1983 report as it was.

**Littrow:** On 2020 Mar 03 UT 23:51 Facundo Gramer (AEA) imaged the Mare Serenitatis and captured within this the region around Littrow crater that matched the illumination (within ±0.5°) of the following Brazilian report:

*On 1980 May 23 at UT 21:14-21:18 Marco Petek (Porto Alegre, Brazil) saw in the region of Littrow and an area of dark mare south west from Littrow to Mons Argaeus, abnormal darkness, and a rapid change of form. Cameron 2006 catalog ID=96 and weight=0 or 1. ALPO/BAA weight=1.*

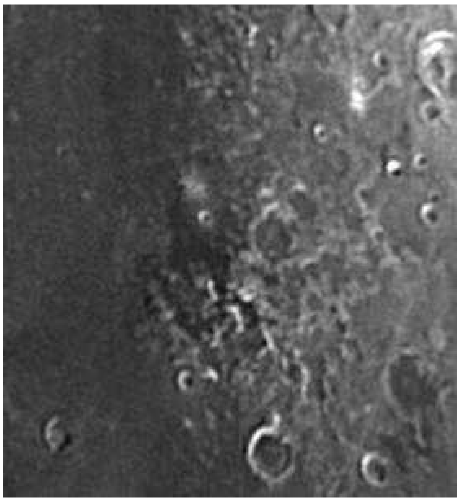


***Figure 1.*** *The area around Littrow, as imaged by Facundo Gramer (AEA) on 2020 Mar 03 UT 23:51 and orientated with north towards the top.*

As you can see from Fecundo's image in Fig. 1, there is a dark area SW of Littrow – whether one regards this as abnormally dark I suppose would depend upon the magnification that Petek used – I suppose a low magnification will improve the contrast and exacerbate the difference between dark mare and darker pyroclastic deposits. I cannot really comment on the rapid change of form described in the 1980 report – maybe Peter was referring to the morphology of the dark material – it would certainly change shape if the seeing conditions were poor? I will lower the weight to 0 and remove this from the ALPO/BAA database.

**Proclus:** On 2020 Mar 04 UT 01:43 Gabriel Re (AEA) imaged the region around this crater under similar illumination (within ±0.5°) to the following report:

*Proclus 1969 Nov 18 UT 20:00? Observed by Classen (Pulnitz, Czechoslovakia, 8" refractor) "Brightened, exceeded normal. Brightness is monitored relative to Censorinus. (started July, 1969) Obs. thinks all bright craters are variable. (Apollo 12 watch)." NASA catalog weight=2. NASA catalog ID #1216. ALPO/BAA weight=2.*

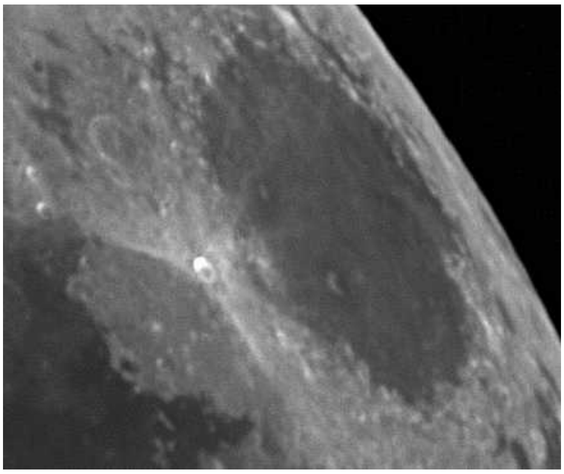


***Figure 2.*** *Mare Crisium and Proclus as imaged by Gabriel Re (AEA) on 2020 Mar 04 UT 01:43 and orientated with north towards the top.*

Gabriel's image (Fig. 2) shows Proclus as very bright but his original image (not shown here) does not include Censorinus. Even if it did the perceived brightness to the human eye depends upon the size of the crater and atmospheric seeing conditions affecting the point-spread function. Also, the topocentric libration angle or slant of the illuminated crater to the observer), can also affect observed brightness. Upon reading the Cameron TLP description again I think I will lower the weight of the 1969 report to 1 as Classen seems to have some strange ideas that all bright craters are variable?

**Herodotus:** On 2020 Mar 06 UT Franco Taccogna (UAI) and Phil Deyner (BAA) imaged this area under similar colongitude to the following Lunar Schedule request:

*BAA Request: Some astronomers have occasionally reported seeing a pseudo peak on the floor of this crater. However, there is no central peak! Please therefore image or sketch the floor, looking for anything near the centre of the crater resembling a light spot, or some highland emerging from the shadow. All reports should be emailed to: a t c @ a b e r . a c . u k*

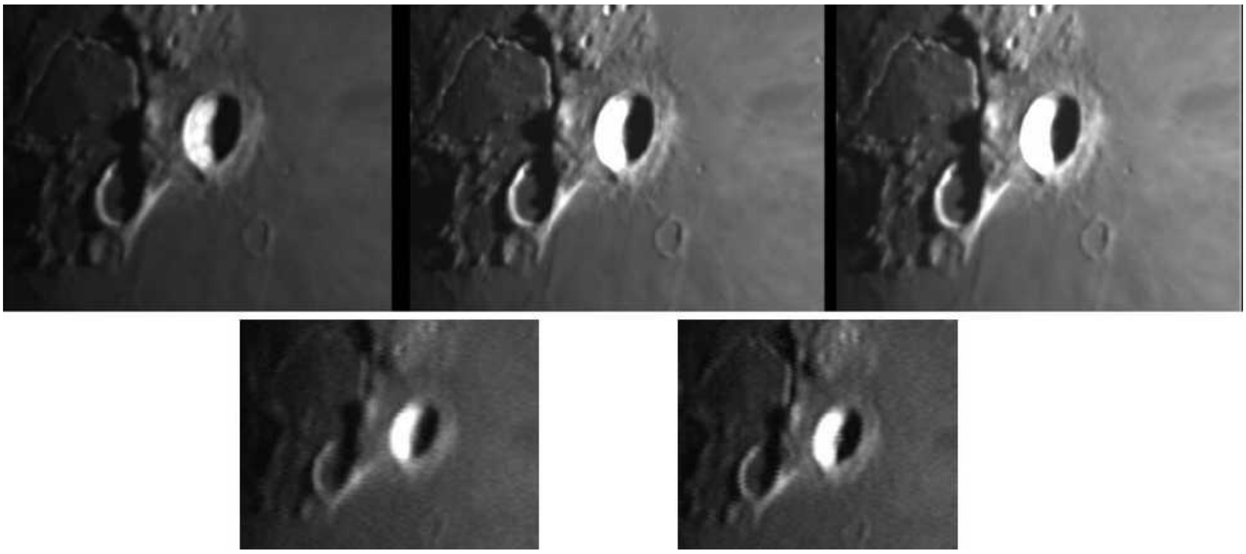


***Figure 3.*** *Herodotus orientated with north towards the top.* ***(Top Left)*** *Image by Franco Taccogna (UAI) taken through a 20cm reflector on 2020 Mar 06 UT 17:41 through an R21 filter.* ***(Top Centre)*** *Image by Franco Taccogna (UAI) taken through a 20cm reflector on 2020 Mar 06 UT 17:43 through an R21 filter.* ***(Top Right)*** *Image by Franco Taccogna (UAI) taken through a 20cm reflector on 2020 Mar 06 UT 17:45 through an R21 filter.* ***(Bottom Left)*** *Image taken by Philip Denyer (BAA) through a*

*C9.25 telescope on 2020 Mar 06 UT 19:03.* ***(Bottom Right)*** *Image taken by Philip Denyer (BAA) through a C9.25 telescope on 2020 Mar 06 UT 19:14.*

Figure 3 illustrates our continuing efforts to see if we can replicate numerous observations of a central pseudo peak on the floor of Herodotus crater that seem to occur very occasionally between selenographic colongitudes of 52.6° and 55.8°. So far, we have had little luck although one theory is that the effect might be linked to image resolution and not being able to resolve the dimple in the shadow on the floor tricking the eye into thinking there is a central spot here. Perhaps another theory is it could be the result of image flare due to atmospheric seeing causing a double image of the bright spot on the NW rim or the even brighter short section of rim on the SE, to be overlaid on the centre of the floor. Both theories seem unlikely as the observers concerned in all past TLP reports of the pseudo peak probably would have noticed effects on other craters too. So, this pseudo peak effect still remains a puzzle!

**Daniell:** On 2020 Mar 06 UT 20:45-21:30 Kevin Berwick (ALPO) observed visually this crater within ±0.5° of a similar illumination observing window for the following report:

*Daniel 1979 Jul 06 Crick of Belgium noticed obscuration on a bright spot on the south east wall. This spot was quite prominent through a red Wratten 25 filter. The floor was very dark. Other craters were checked and were normal. A sketch was supplied and the position was the same as in other earlier reports. Cameron 2006 catalog extension ID=60 and weight=3. ALPO/BAA weight=3. 6" reflector used. Seeing=II and transparency=good.*

Kevin reports that the crater had a dark floor under high illumination surrounded by a bright ring. The bright ring looked slightly pinkish occasionally, however he then goes onto say that he often sees this under these conditions and puts it down to eye fatigue and atmospheric prismatic effects. Kevin was using a TV101 refractor at x180 magnification, under Antoniadi II-III seeing conditions (Good-moderate). Clearly the darkness to the floor that Crick reported was normal – the issue is that Crick checked other craters but did not see a similar effect with the bright spots being more prominent in red light. We shall leave the weight at 3 for now.

**Plato:** On 2020 Mar 06 UT 21:33 Freya Williams imaged the Mare Imbrium area under similar illumination (to within ±0.5°) to the following two reports:

*Plato & Piton 1984 Mar 14/15 UT 19:18-01:48 Observed by Foley (Kent, England, 12" Reflector seeing I, Transparency Very Good) "Obscuration and colour seen on Plato and colouration and brightness seen on Piton (CED used)" BAA Lunar Section Report. The Plato report has an ALPO/BAA weight of 2 and the Mons Piton report a weight of 1.*

*Plato 1987 Feb 10 UT 21:05-22:10 M. Cook of Frimley, "NE ray distinct & also floor E of it, not distinct as on Dec 13 & Jan 11, while March 10, 11 & 12 seen by Price, North, Peters, Foley & M Cook, where rim was clear and sharp." - quote from the 2006 Cameron Catalog extension - TLP ID=297 and weight=5. Cameron gives the observers confirming this TLP as: M. Cook, G. North and Davies.. ALPO/BAA weight=3.*

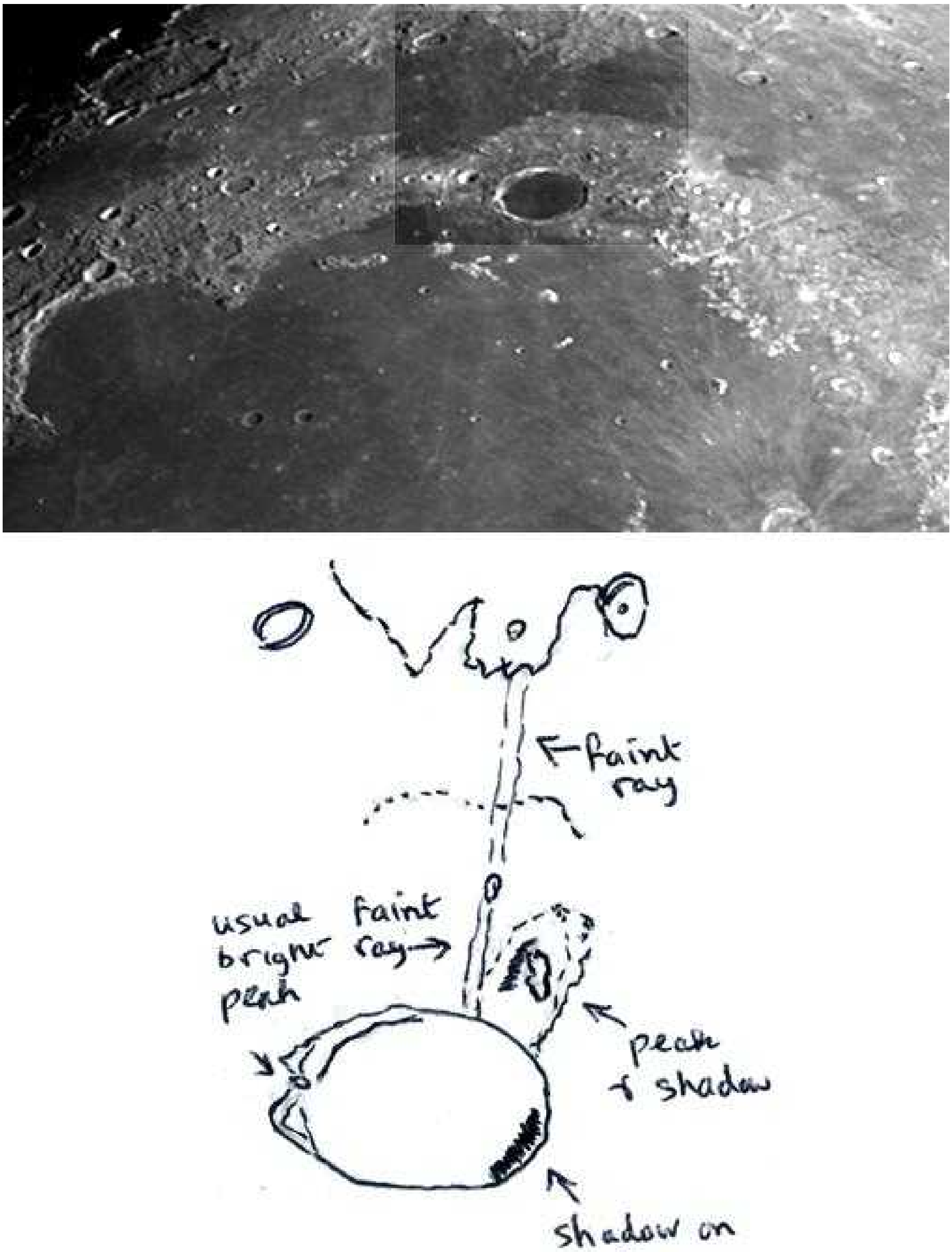



*Figure 4.* *Plato orientated with north towards the top.* ***(Top)*** *An image by Freya Williams taken on 2020 Mar 06 UT 21:33. The shaded rectangle relates to the area in the sketch below.* ***(Bottom)*** *A sketch by Marie Cook made on 1987 Feb 10 UT 21:05-22:10.The sketch has been rotated and the labels turned to match the image above.*

Freya's image (Fig. 4 – Top), although of a much larger area of the Moon, does cover Plato and Mons Piton and therefore provides a useful context image for the Foley report (Fig. 4 – Bottom). Although the image lacks colour and does not have high resolution to confirm the obscuration, it shows at least that Mons Piton, the inverted 'L' shaped mountain peak (below and slightly to the right of the rectangle window), is bright. So at least that aspect of the 1984 report seems normal. The weights I shall leave as they are because I need to check out CED readings of Mons Piton in the archive to be sure that it was brighter than normal for this stage in illumination

Turning to the 1987 report we do at least have a sketch in the archive (Fig. 1 – bottom) to compare Freya's image (Fig. 4 – Top) against. All the labelled features in the sketch show up in the image; even the ray cutting through the dark Mare Frigoris (only the edge of the Mare shown in the sketch) is faintly visible in the image. So the Cameron catalog description above is a bit obscure about what the TLP should be about. Looking at Marie's original notes it seems she did not instigate the TLP alert, so in this context the catalog description is wrong. She does mention a slight mistiness to the NE rim, but concludes this is normal. I shall therefore lower the weight of this report from 3 to 1 and try to find out who made the original TLP observation on that date and precisely what it was. At least we know that the features that are depicted in Marie's sketch are accurate – though of course as is the nature of sketches, not all detail is recorded.

**Kepler:** On 2020 Mar 06 UT 21:38, 21:52, and 21:56 Gracie Jones, Sophie Stuart and Catrin Ashcroft respectively imaged this crater 28, 14 and 10 min before the repeat illumination window (±°0.5) for the following 1954 report:

*Kepler 1954 Nov 07 UT 23:20 Observed by Lugo (Caracas, Venezuela) "Luminous pts. (MBMW say "bright pt.; just outside E.wall). NASA catalog weight=3. NASA catalog ID #580. ALPO/BAA weight=2.*

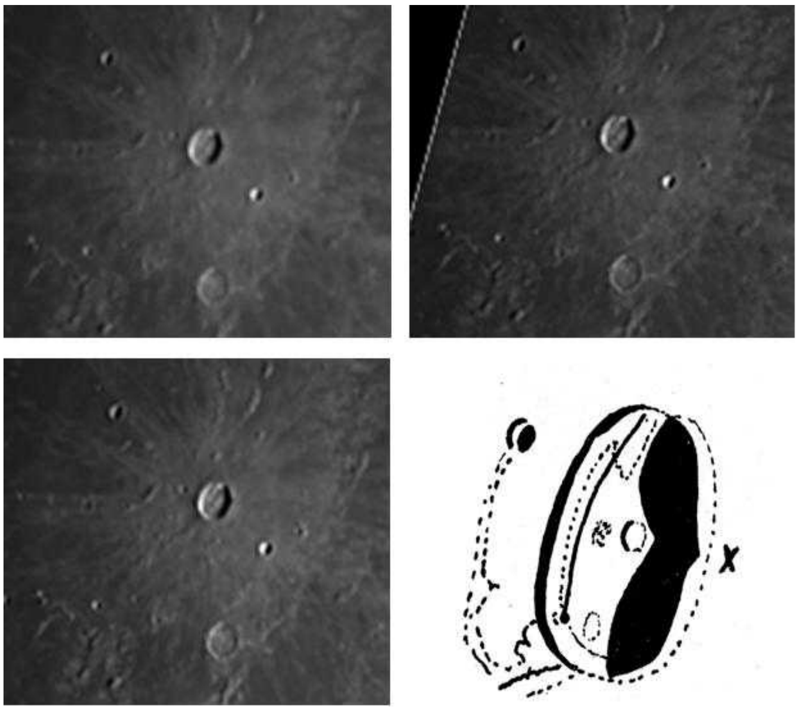



***Figure 4.*** *Kepler orientated with north towards the top.* ***(Top Left)*** *An image taken on 2020 Mar06 UT 21:38 by Gracie Jones.* ***(Top Right)*** *An image taken on 2020 Mar 06 UT 21:52 by Sophie Stuart,* ***(Bottom Left)*** *An image taken on 2020 Mar 06 UT 21:56 by Catrin Ashcroft.* ***(Bottom Right)*** *An outline sketch by H.P. Wilkins with an X that marks the position of the star-like point seen by Dr Francis Aniceto Lugo of Caracas, Venezuela on 1954 Nov 8 at 23:20UT from the 1955 Apr BAA Journal, p189.*

Although these modern-day images were taken before the predicted similar illumination window, it turns out (from consulting the archives) that the Lugo bright spot was visible an hour, so it was probably legitimate to observe earlier than the predicted time. Further details in the archives state that the bright spot as reddish. Although the images by Gracie (Fig. 5 - Top Left), Sophie (Fig. 5 -Top Right) and Catrin (Fig. 5 - Bottom Left) were monochrome, they do resemble the shape, shadow layout and general appearance of Kepler in the sketch by Lugo (Fig. 5 – Bottom Right), with the exception that there is no bright spot at the location marked by an 'X'. Although the telescope that Lugo was using was a relatively small 3.5", I think the description is so unusual that we should leave the weight at 3.

**Aristarchus:** On 2020 Mar 08 UT 01:29 Sergio Babino (SAO/LIADA) imaged this crater under similar illumination (to within ±°0.5) to one of my own observations:

*Aristarchus 1989 Oct 13 UT 21:00 Observed by Cook (Frimley, Surrey, UK, 20cm reflector (visual and video)) "Aristarchus had what appeared to be an outline of a ghost crater on its eastern side - quite large and bright". Cameron 2006 extended catalog TLP ID No=378 and weight=5. ALPO/BAA weight=3.*

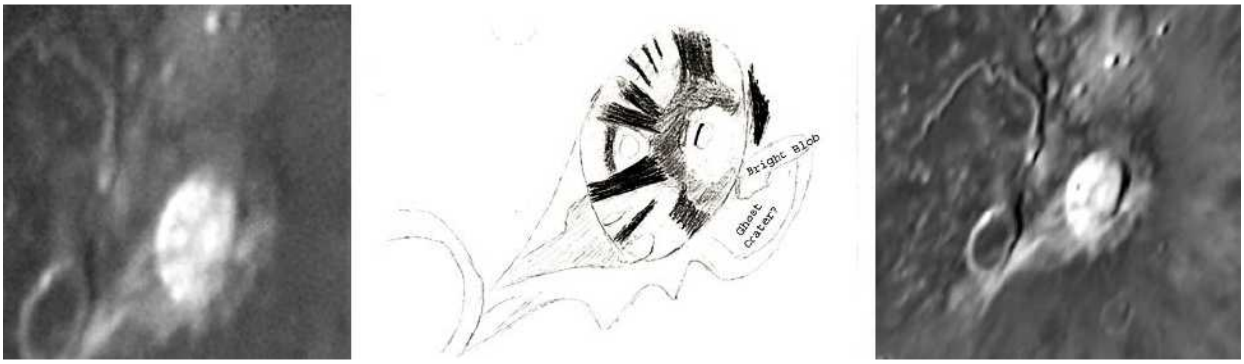



***Figure 6.*** *Aristarchus orientated with north towards the top.* ***(Left)*** *An image taken by Tony Cook from 1989 Oct 13 from video at the tail end of the TLP – reprocessed by Thierry Speth.* ***(Centre)*** *A sketch made by Tony Cook from the video recording at the tail end of the TLP on 1989 Oct 13 with the location of the bright blob outside the east rim, and the location of the "Ghost Crater" effect seen earlier during the TLP.* ***(Right)*** *An image by Sergio Babino (SAO/LIADA) taken on 2020 Mar 08 UT 01:29.*

The important thing to remember with the 1989 TLP report was that the recorded video came after the main event, that was seen visually, which was that the bright blob was a lot brighter than you see in the images, and likewise the outline of the ghost crater 'effect' was a lot more vivid than was captured on video. Sergio's image shows detail of the normal appearance of the Aristarchus region more clearly than you can see in Fig. 6 (Left), but does not show the blob as exceptionally brilliant nor a more prominent ghost crater effect. We shall leave the weight at 3 for now.

**Aristarchus:** On 2020 Mar 09 UT 21:54 Aldo Tonon (UAI) imaged the whole lunar disk when the illumination was similar (within ±0.5°) the following report:

*On 2002 mar 29 at 02:20-02:38UT C. Brook (Plymouth, UK, 60mm refractor, x120 - no cloud, slight haze, no wind, seeing good) noticed during first part of observing period that Aristarchus was getting steadily brighter, very much brighter than Proclus. This continued until 02:36UT when it dimmed suddenly over a period of about a minute or so. No colour effects seen. ALPO/BAA weight=2.*

Aldo actually took three sets of whole disk images of the Moon, but only the 21:57 one lay within the repeat illumination window, nevertheless it is possible to measure the relative digital number brightness (a value that ranges from 0 to 255) between the three images for these two features: at 21:54 UT Aristarchus = 170 and Proclus = 162; at 22:13 UT Aristarchus = 182 and Proclus = 209; at 22:47 UT Aristarchus = 171 and Proclus =163. So yes, it looks like the craters can appear to change in measured brightness, however this is quite different to perceived brightness by the eye which compares a crater to its immediate surrounds. Now the most probably reason for Aristarchus being brighter than Proclus except at 22:13 UT was that the image at 22:13 UT was a lot sharper, so small features such as Proclus with bright rims will record brighter than the more spread-out light from Aristarchus. It's all to do with the effective point spread function of the telescope after it has been modified by the atmospheric conditions and also by the fact that I measure the brightest feature on the respective craters. I suspect something similar was going on back in 2002. I will therefore lower the weight of that report to 1 so that we can check out this theory further, The relative brightness of craters can also be affected by how much of their sunlit slopes we can see and that depends on libration, especially the closer they are to the lunar limb.

**Aristarchus:** On 2020 Mar 11 UT 02:25 Victoria Gomez (AEA) imaged the region around the crater under similar illumination (within ±0.5°) to the following 1970's report:

*Aristarchus 1954 Nov 12 UTC 02:20-03:05 Observed by Bartlett (Baltimore, MD, USA, S=5-6, T=3-4) "Blue-violet glare on EWBS & whole length of E. wall. Suspected viol. tint on VA; uncertain @ m" NASA catalog weight=4. This had faded later by 05:07. NASA catalog ID #582. ALPO/BAA weight=2.*

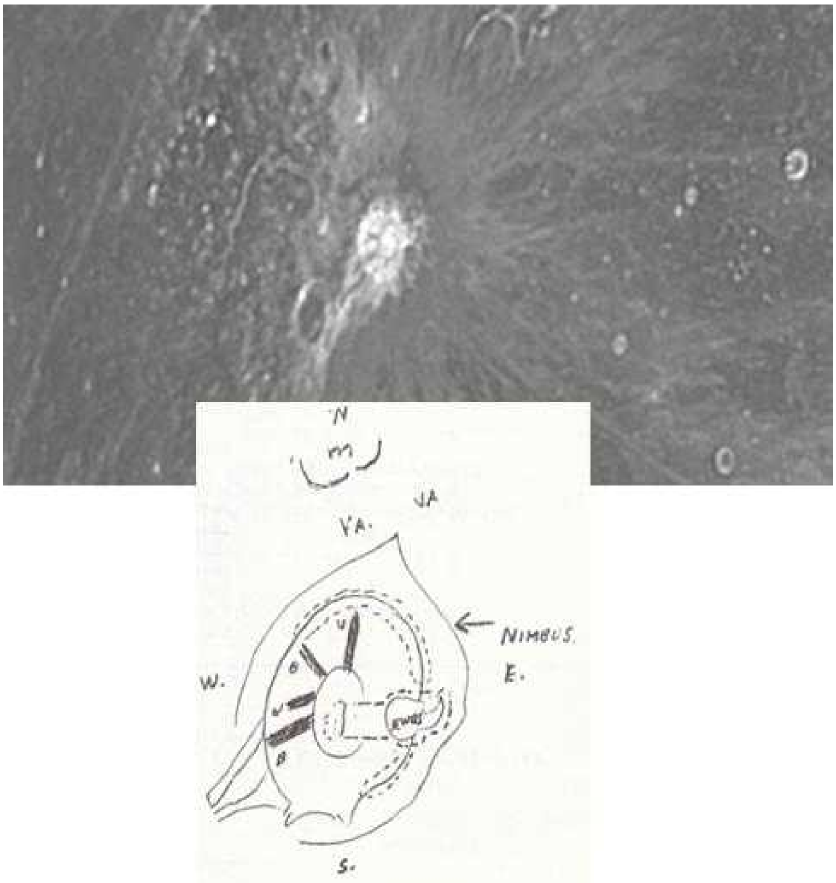



***Figure 7. (Top)*** *Aristarchus as imaged by Victoria Gomez (AEA) on 2020 Mar 11 UT 02:25 and orientated with north towards the top.* ***(Bottom)*** *A sketch by Bartlett from JALPO 1966 P23 – the image has been rotated through 180° and the annotation adjusted accordingly to match north at the top.*

Although the Bartlett TLP report from 1954 was in colour, Victoria's image (Fig. 7 – Top) provides a valuable context image which can be used to identify the features that Bartlett refers to (Fig. 7 – Bottom). We shall leave the ALPO/BAA weight at 2 for now.

**Proclus:** On 2020 Mar 11 UT 03:38 Walter Elias (AEA) imaged the region around the crater under similar illumination (within ±0.5°) to the following 1970s report:

*Proclus 1973 Nov 11 UT 20:40-23:05 Observed by Savill (Cambridge, England, 12" refractor, x100?), Young (Yorks, England), Pedler (Bristol, England, 6" reflector?), Livesey (Scotland). "At 100x showed a bright spot in S.part of crater. At 300x was vis. but power too high. In 8-in refr. at 170x, at 2055h 2 spots present. Confirmed by Young. Seeing was improving. At 2104h in 12-in refr. at 260x the lower spot seemed distinctly enlarged & vaporous. Decided it was due to poor seeing. Later the 2 spots were better defined & separated but lower moved away fr. larger one & they seemed more separated than earlier. Obs. ended at 2305h when they decided it was not an LTP. but was 2 craters instead of humps. There were neg. repts. from others at the same time. (there are no craters in Proclus)." NASA catalog weight=2. NASA catalog ID #1382. ALPO/BAA weight=1.*

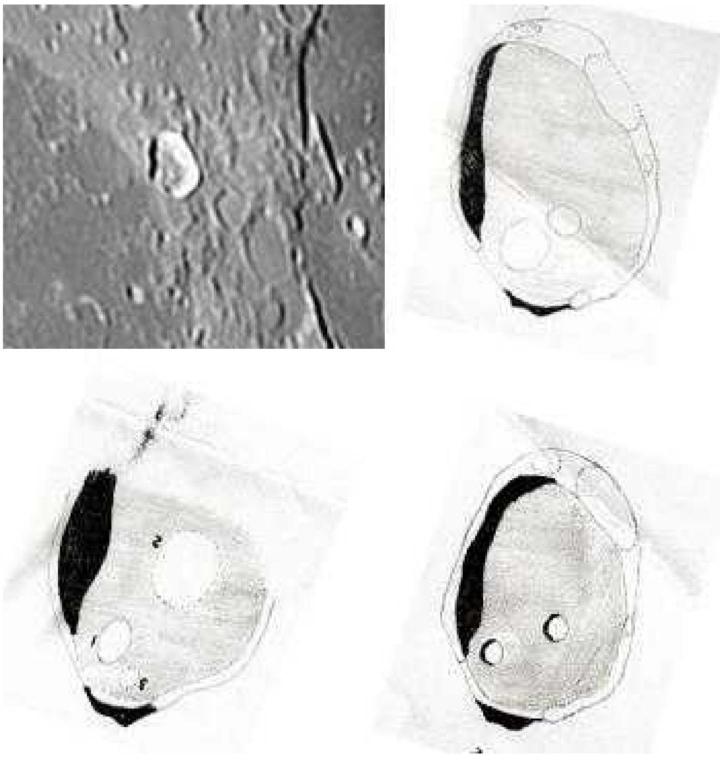


*Figure 8. Proclus orientated with north towards the top.* ***(Top Left)*** *An image by Walter Elias (AEA) on 2020 Mar 11 UT 03:38.* ***(Top Right)*** *A sketch by Mark Savill made on 1973 Nov 11 UT 20:55 with an 20cm refractor x170 magnification under Antoniadi IV (Poor) seeing conditions.* ***(Bottom Left)*** *A sketch by Mark Savill made on 1973 Nov 11 UT 21:40 with an 30cm refractor x260 magnification under Antoniadi IV-V (Poor/Very Poor) seeing conditions.* ***(Bottom Right)****. A sketch by Mark Savill made on 1973 Nov 11 UT 22:55 with an 20cm refractor x170 magnification under Antoniadi III (Moderate) seeing conditions*.

Walter's image (Fig. 8 - Top Left) shows the two light spots on the floor of Proclus depicted in the sketches in Fig. 8 (Top Right, Bottom Left, and Bottom Right). The only difference is that the spots vary in position and orientation slightly – however this can be explained by the difficulty in representing geometry accurately in very small angular diameter features. Likewise, the fuzzy nature of the spots in the sketches can be explained by the atmospheric seeing conditions. Concerning Savill's comments that the two spots might be small craterlets, well there are no craterlets inside Proclus here, but instead there is plenty of hummocky terrain that could cast shadows and make one think that craterlets were present. I will lower the ALPO BAA weight from 1 to 0 and remove it from the ALPO/BAA catalog. The original observers never did think it was a TLP, despite the fact that it ended up in Cameron's NASA catalog.

**Plato:** On 2020 Mar 11 UT 03:42 Aylen Borgatello (Argentina – AEA) imaged this crater under similar illumination (to within ±°0.5) to the following Victorian era report:

*Plato 1870 Mar 19 UT 00:00? Observed by Gledhill? (Halifax, England, 9" refractor) "Same group (of craters) as in Feb. illuminated. (if phase same as Apr. 1970 then date is Mar 19" NASA catalog weight=2. NASA catalog ID #165. ALPO/BAA weight=2.*

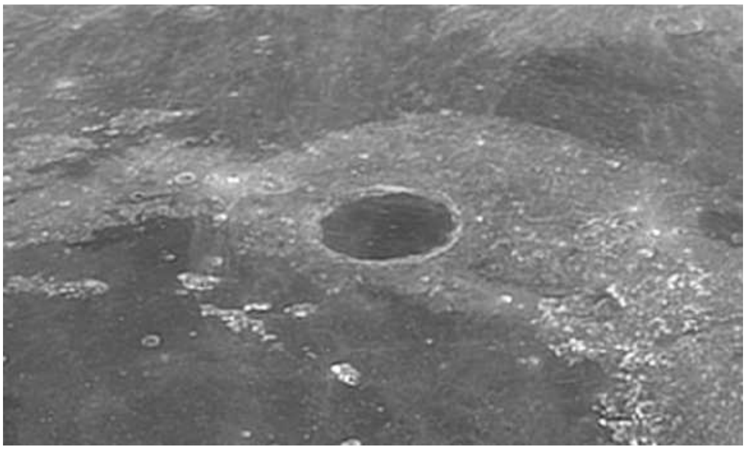


***Figure 9.*** *Plato as imaged by Aylen Borgatello (AEA) on 2020 Mar 11 UT 03:42 and orientated with north towards the top.*

There is not a lot to go on in the vague description in the Cameron catalog as to what was abnormal, but at least with Aylen's image (Fig. 9) we have a good representation of what the crater normally looks like i.e. a bright central craterlet and two other craterlets visible on the floor. I shall lower the ALPO/BAA weight to 1 due to the lack of detail in the Cameron catalog description.

**Copernicus:** On 2020 Mar 16 UT 08:55 Abel Gonzalez Cian (AEA) imaged a region of the Moon that contained Copernicus under similar illumination (±°0.5) to the following report:

*On 1998 May 18 UT 02:00-03:16 C. Brook (Plymouth, UK, 60mm refractor, x112, seeing III) observed an obscuration of the central peaks of this crater. Copernicus ramparts were clearly visible. The ALPO/BAA weight=1.*

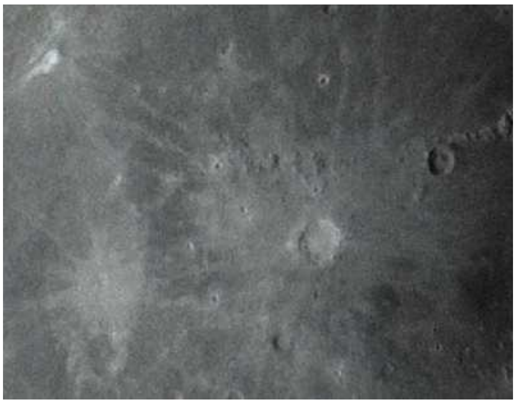


*Figure 10. Copernicus and its neighboring craters: Kepler, Eratosthenes, and Aristarchus, orientated with north towards the top. Imaged by Abel Gonzalez Cian (AEA) on 2020 Mar 16 UT 08:55.*

Gabriel was using a similar sized telescope to Clive Brook, and so should give similar resolution (Fig. 10) – though this could be affected by atmospheric seeing conditions. At this stage in illumination the central peaks appear not to be too well visible – therefore Clive's observation is the normal appearance and we can reduce the ALPO/BAA weight from 1 to 0 and remove it from the database.

**Promontorium Agarum:** On 2020 Mar 28 UT 00:20-00:30 Jay Albert (ALPO) observed this feature visually under similar illumination (to within ±°0.5) to the following report:

*Promontorium Agarum 1967 Jan 14 UT 17:17-17:35 Observed by Middleton, Colchester, England, 4" refractor, x240, S=G) "Cape was hazy or obscured whereas Piccard, Pierce, & Cape Olivium were quite clear. Has seen this area obscured many times" NASA catalog weight=3. NASA catalog ID #1008. ALPO/BAA weight=2.*

Jay, using an 8" SCT, transparency magnitude 3 and seeing 4-5 out of 10, found that contrary to the 1967 report that Promontorium Agarum was clearly seen and sharply detailed despite somewhat rough seeing. As a reference Picard, Pierce and Swift were also easily seen and sharp - hence there was no sign of any haze or obscuration. The weight for the Middleton report will be left at 2.

**Mutus F:** On 2020 Mar 28 UT 22:00-22:30 Alberto Anunziato (SLA) observed visually under similar illumination (to within ±°0.5) to the following 2005 report:

*On 2005 Jan 15 at UT 01:25 R. Spellman (Los Angeles, CA, USA, 8" reflector) observed 4 bright points of light on the crater Mutus F? - see Rukl Atlas page 175, chart 74. If his identification of the crater was correct then he could see no structures in the crater that would yield this effect. It could well be that the 4 bright points are just 4 high peaks on the rim catching the first rays of the Sun. The ALPO/BAA weight=1.*

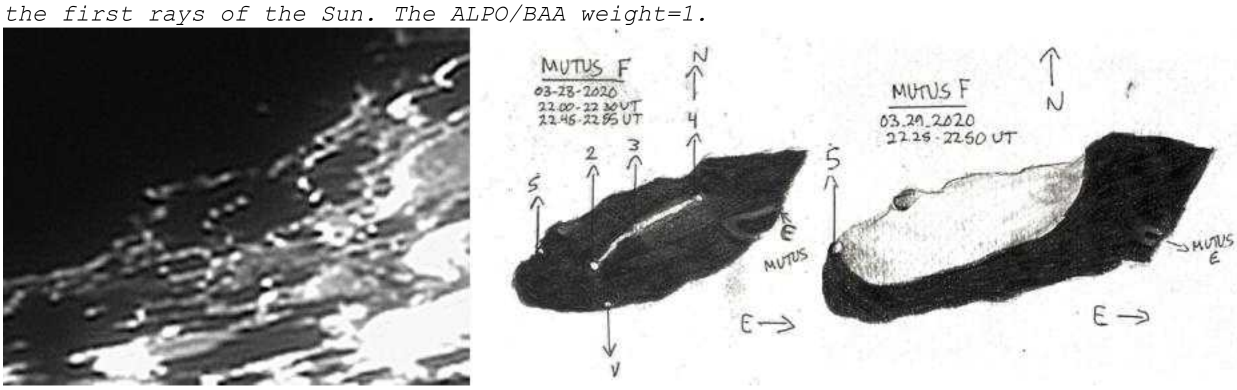



***Figure 11.*** *Mutus F orientated with north towards the top.* ***(Left)*** *Image by Robert Spellman (ALPO) taken 2005 Jan 15 UT 01:24.* ***(Centre)*** *A sketch by Alberto Anunziato (SLA) made on 2020 Mar 28 at the UT given in the sketch.* ***(Right)*** *A sketch by Alberto Anunziato (SLA) made on 2020 Mar 29 at the UT given in the sketch.*

Alberto comments that observing conditions (daylight) were not the best between 22.00 and 22.30 UT. He marked some light spots that he could see in the shadowed interior 1-5 (Fig. 11 - Centre). The bright spots appear to be 3 in the center of Mutus F (marked 2, 3, and 4). There could have been be a point between 3 and 4 but he could not I resolve it. There was definitely a diffuse luminosity that united points 2, 3 and 4. He repeated the observation between 22:45 and 22:55 UT but there were no appreciable changes. The next day he observed Mutus F again (22:25 to 22:50UT). The bright points 1 to 4 were not visible and the shadow now only partially covered the floor (dark grayish), no other details were seen (Fig. 11 – Right). As Alberto's sketch (Fig. 11 - Centre) so closely resembles Robert Spellman's image (Fig. 11 – Left) I think we shall lower the weight to 0 and remove it from the TLP database. However, I will keep it on the Lunar Schedule website so that we can figure out what topography are causing points 1-5.

**General Information:** For repeat illumination (and a few repeat libration) observations for the coming month - these can be found on the following web site: http://users.aber.ac.uk/atc/lunar_schedule.htm . Only by re-observing and submitting your observations can we fully resolve past observational puzzles. To keep yourself busy on cloudy nights, why not try 'Spot the Difference' between spacecraft imagery taken on different dates? This can be found on: http://users.aber.ac.uk/atc/tlp/spot_the_difference.htm . If in the unlikely event you do ever see a TLP, firstly read the TLP checklist on http://users.aber.ac.uk/atc/alpo/ltp.htm , and if this does not explain what you are seeing, please give me a call on my cell phone: +44 (0)798 505 5681 and I will alert other observers. Note when telephoning from outside the UK you must not use the (0). When phoning from within the UK please do not use the +44! Twitter TLP alerts can be accessed on https://twitter.com/lunarnaut .

Dr Anthony Cook, Department of Physics, Aberystwyth University, Penglais, Aberystwyth, Ceredigion, SY23 3BZ, WALES, UNITED KINGDOM. Email: atc @ aber.ac.uk

## BAA LUNAR SECTION CONTACTS

**Director and Circulars Editor**
Bill Leatherbarrow (w.leatherbarrow1 @ btinternet.com)

**Assistant Director**
Tony Cook (Coordinator, Lunar Change project) (atc @ aber.ac.uk)

**Website Manager**
Stuart Morris [contact link via the Section website at https://britastro.org/section_front/16]

**Committee members**
Tim Haymes (Coordinator, Lunar Occultations) (occultations @ stargazer.me.uk)
Robert Garfinkle (Historical) (ragarf @ earthlink.net)
Raffaello Lena (Coordinator, Lunar Domes project) raffaello.lena59 @ gmail.com
Nigel Longshaw
Barry Fitz-Gerald