



## **LUNAR SECTION CIRCULAR**

### **Vol. 58 Nos 8-9 August-September 2021**

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#### **FROM THE DIRECTOR**

After more than twelve years as Director of the Lunar Section I have decided that it is time for me to step down and have informed the BAA President accordingly. This was not an easy decision since it is a role I have enjoyed greatly and an office I have held with great pride. However, advancing years along with personal and family considerations have had a cumulative effect and I find I can no longer give the role the attention and care it deserves. Under those circumstances it is only right to hand over to someone else. It is also probably time for a new approach.

It is for BAA Council to decide upon an eventual successor, but in the meantime Tony Cook and Tim Haymes have agreed to provide cover. Future correspondence should be sent to Tony. I imagine there will be few observations submitted over the summer months. There will inevitably be some disruption to the monthly Circular, but hopefully this will not last long. The present issue is a stop-gap produced by Tony and designed to cover the immediate period of August and September.

I am very grateful to both Tony and Tim for stepping up to the plate in this way.

I am also grateful to Section members for the support and friendship they have offered me over many years. I have valued that greatly.

I certainly hope to continue as an active foot-soldier in the Section and I hope my eventual successor derives as much satisfaction from the role as I have done.

With very best wishes,

*Bill Leatherbarrow*

## MESSAGE FROM TONY AND TIM

We would like to thank Bill for his enormous effort and wisdom over the last 12 years and wish him well in his retirement. Please bear with us in the Lunar Section as we adapt - Bill is a hard act to follow. In the meantime, email all observations to Tony, apart from occultation results that should be forwarded onto to Tim. Our email addresses are at the end of the circular. The deadline for observations to be sent in for consideration for inclusion in the next circular is 20<sup>th</sup> September.

## OBSERVATIONS RECEIVED

Observations have been received from the following: Paul Brierley (UK), Dave Finnigan (UK), Clyde Foster (South Africa), Les Fry (UK), Massimo Giuntoli (Italy), Rik Hill (USA), Rod Lyon (UK), Tor Scofield (Austria). The best observation from each will be shown, interspersed within the circular.

## CLAVIUS

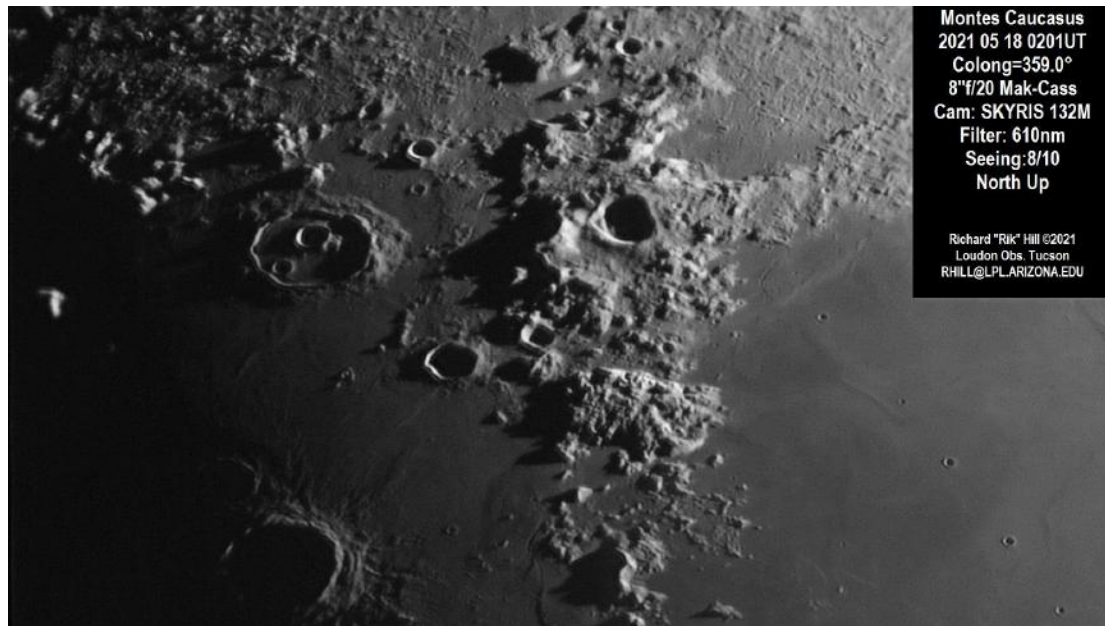
Imaged by Clyde Foster



Clavius is about 230 km in diameter, which is 70 km shy of being impact basin in size. This image clearly shows a spiral of five (or possibly 6?) ever shrinking floor craters. Not much evidence remains of a central peak/ring of peaks, so the floor may have been modified over time, though interestingly not much evidence of rilles on a floor flooded crater such as this. In 2020 a DLR/NASA airborne observatory found the presence of water in Clavius, though the amount was a miniscule concentration of 0.04%. – Tony Cook.

## MONTES CAUCASUS

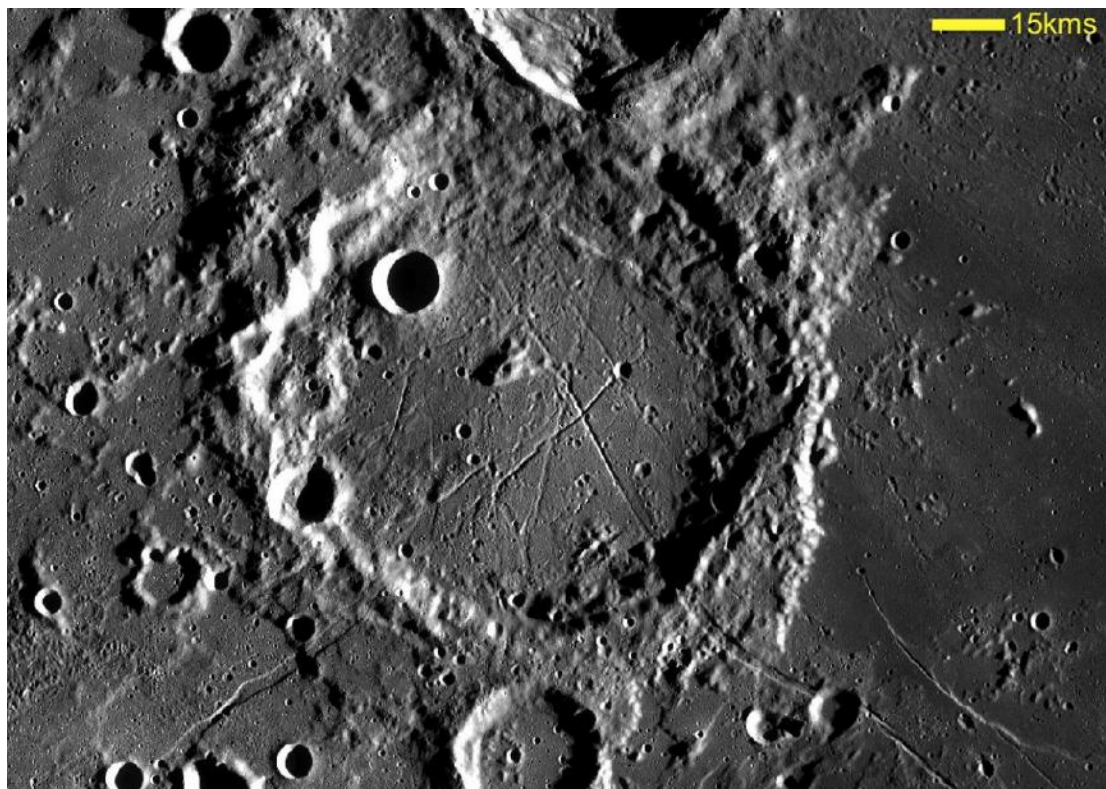
Imaged by Rik Hill



I've said it before, and I'll say it again, the Montes Caucasus are the most attractive mountain group on the moon. Home to spectacular cliffs and peaks that jut up from the floor of the Mare Serenitatis on the east side (right) and Mare Imbrium on the west (left). Note the wonderful shadows cast by these mountains! The large shadow filled crater in the north of these mountains is Calippus (34 km dia.). The large flat area north of that is Alexander (85 km) listed as a circular feature but it only is barely so. Just below Alexander in the mare to the east of the Montes you can see a short rima, Rima Calippus only 41 km long and only 1.6 km wide. South of Calippus is a magnificent unnamed massif and to the west of it is another shadow filled crater, just beyond the tips of the shadows of the Montes. This is Theaetetus (26 km) and it points the way to the much larger crater Cassini (60 km) further west. This latter crater is very identifiable with two interior satellite craters A and B and great ejecta blanket tight about the crater. On the left edge of this image is the lone peak, Mons Piton rising 2250 m above Mare Imbrium. Then next is the great crater Aristillus just coming in to the sunlight at the bottom of this image. Look at the spidery splash pattern of the ejecta. To the east of Aristillus notice the swelling as you approach the Montes Caucasus. This is Aristillus 1 a lunar dome 54x35 km in size and only 85 m high. Moving slightly further east, you see the fantastic cliff just coming into view in the morning light. It would be fun to stand on top of this mountain and survey these wonderful sights!

This image was made from merged parts of two 1800 frame AVIs stacked with AVIStack2 (IDL), merged with MicroSoft ICE and further processed with GIMP and IrfanView. – Rik Hill

At 113 kms in diameter the crater Hevelius is slightly larger than Gassendi (111 kms) and lying on the edge of Oceanus Procellarum the two should share many similarities. They are however very different, and the more photogenic Gassendi is far better known than its northern neighbour. Hevelius's claim to fame however is that it gives its name to the widespread 'Hevelius Formation', which consists of 'hummocky to lineated to swirl-textures deposits, and represents the distal ejecta of the Orientale Basin<sup>[1]</sup>. The lineated and swirl-textured deposits can be seen in and around Riccioli, but by the time we reach out as far as Hevelius (~ 700 kms) the deposits lack these unusual textures and are more hummocky to smooth. The depth of these deposits within Hevelius itself is estimated to be somewhere around 100 m<sup>[2]</sup> and they probably obscure a large part of the crater floor. Ejecta from the neighbouring Cavalerius, which is perched on the northern rim adds to the general mantling of material on the crater floor, as well as contributions from smaller intruders such as Hevelius A. Despite all of this however the floor of Hevelius is full of detailed structures which reveal something about its geological past.



**Figure1.** LRO WAC image of Hevelius with low illumination from the east showing the network of graben and fractures crossing the walls and crater floor. Note some of the swirl-textured Hevelius Formation deposits towards the lower left of the frame.

Fig.1 shows some of the wealth of detail within Hevelius, particularly the graben and fractures that appear to criss-cross its floor. Telescopic observers and imagers will also know that the floor of Hevelius is domed upwards, with the S.W. floor apparently more affected than the eastern floor, as can be seen in Fig.2. This form of modification is frequently observed in large craters on the edges of the maria, and

particular in Floor Fracture Craters (FFC's) that are frequent inhabitants of these borderlands.



**Figure 2.** *Telescopic image of Hevelius by Mark Radice showing the domed crater floor, particularly noticeable to the S.W.*

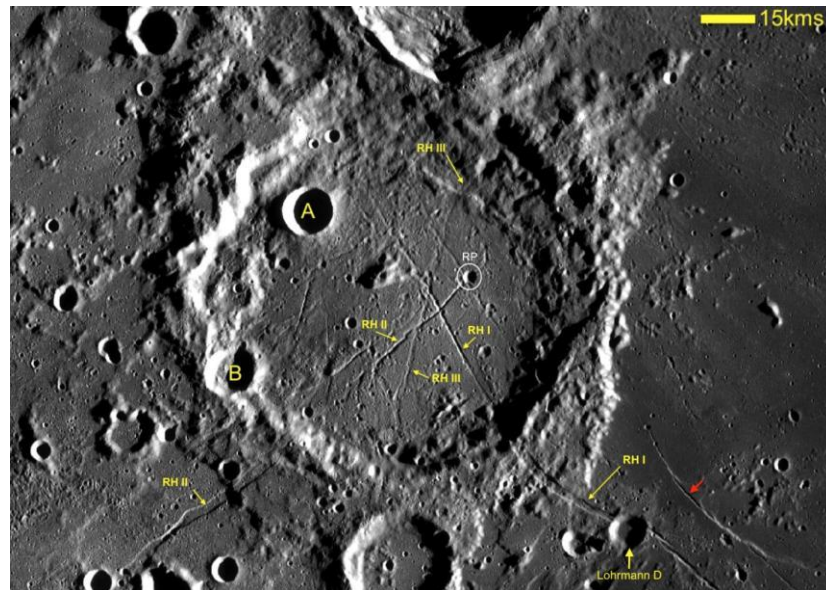
The graben crossing the floor of Hevelius are however nothing to do with this inflation of the crater floor, as FFC fractures are confined within the crater, but here the graben extends out over the crater rim and onto the adjacent highlands to the S.E and S.W.

As can be seen in Fig.3, the most prominent graben are named Rima Hevelius I, II and III. Rima Hevelius I (RH I) trends in a S.E. to N.W. direction and extends beyond the crater to the S.E where it cuts through the northern rim of Lohrmann D. Beyond Lohrmann D, RH I transforms into a series of 3 smaller sections of graben arranged en-echelon. A similar arrangement of fractures and short graben sections can be seen just to the north where a curving array appears to have been the focus of pyroclastic eruptions with dark mantle deposits draped over the low lying margin of Mare Procellarum (Fig.4).

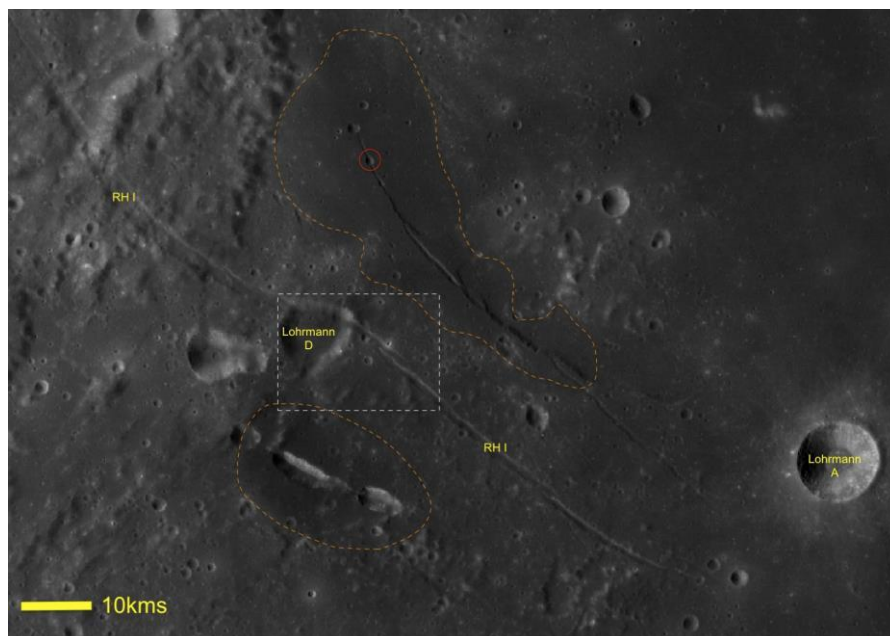
There are a number of other much fainter graben and fractures crossing the floor (and probably rim) of Hevelius on the same orientation as RH I, but none are as conspicuous, particularly where RH I crosses the S.E. crater rim. This suite of graben and fractures may have formed in response to the crustal loading within the adjacent mare as it filled with basalt lavas, comparable to the concentric graben forming Rimae Hippalus around Mare Humorum. Alternatively, they may be related to a set of



graben including Rima Grimaldi, that skirt the southern and eastern edges of the Grimaldi Basin, but any connections are now lost beneath the lavas between Lohrmann A and Grimaldi C.



**Figure 3.** LRO WAC image of Hevelius with the various Rima Hevelius identified (RH I to III). A rimless pit (RP) along the line of RH II is shown. Red arrow indicates fault/graben complex possibly associated with RH I with dark mantling deposits (and rimless pit) at its northern end.



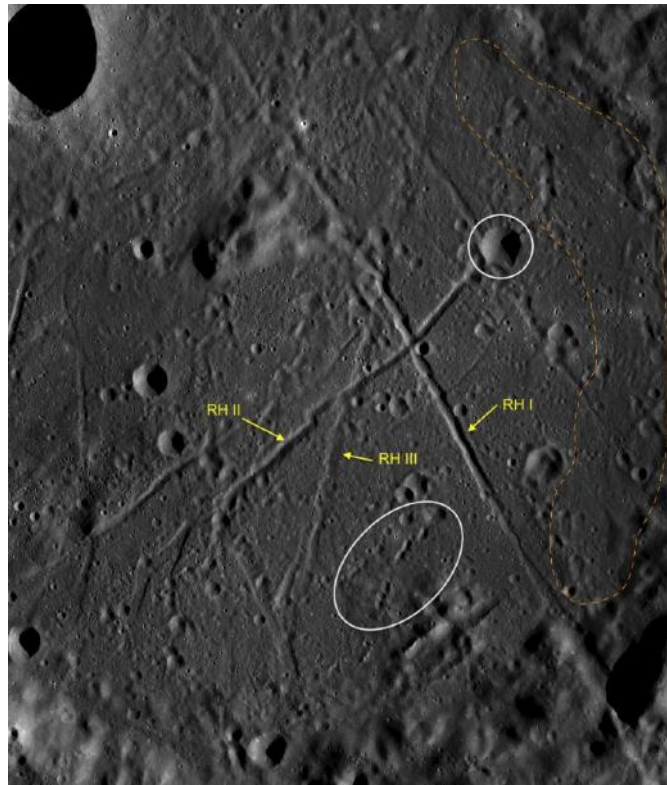
**Figure 4.** Area to the S.E of Hevelius showing RH I as a series of partially overlapping graben where individual faults formed parallel to each other under the effect of crustal tension. The graben/fault complex to the north of RH I is surrounded by dark mantle deposits (area within orange line line) and hosts a rimless pit (red circle) which is a possible vent or collapse structure. A further volcanic pit complex and dark mantle deposits can be seen immediately south of Lohrmann D (orange dashed circle).

Where RH I crosses the rim of Hevelius it takes on more of a continuous appearance, but this may just be result of the graben increasing in width to some 3 km, which makes individual sections more difficult to identify. As it crosses the crater floor RH I reduces in width to 1 km. This indicates that the faults, either side of the graben, slope inwards at some  $60^\circ$ , and may converge at a depth of some 3 kms beneath the surface, which is thought to correspond to level of the base of the mega-regolith layer<sup>[3]</sup>. As a result of this geometry, where the faults cut higher ground, they are more widely separated than lower down – hence we see broad grabens across crater rims or other elevated terrain.

RH II trends from S.W. to N.E and can be traced as far away as the floor of Riccioli where it cuts across the Hevelius Formation deposits filling that crater. Immediately to the S.W. of Hevelius it reaches a width of 3.5 kms, but becomes less distinct as it crosses the crater rim. On the crater floor the width of the graben reduces to 1 km, suggesting a similar fault geometry to that seen in RH I. There are also a number of much fainter graben sharing this orientation, which is radial to the Orientale Basin, indicating that their formation probably relates to the presence of that basin. Indeed, the Orientale Basin is surrounded by radial as well as concentric graben which can be seen intersecting in a complex lattice pattern of the floor of Riccioli and in the surrounding terrain. RH I and RH II cross each other almost at right angles some 20 kms to the S.E of the central peak. It appears that RH I cuts across, and is therefore younger than RH II, but a rather inconsiderately placed crater at the intersection makes the precise relationship tricky.

RH III is a bit of an oddity both in terms of its orientation and morphology. As can be seen from Fig.5, it is orientated N.N.E to S.S.W and has a rather moth-eaten appearance. This can be explained by the fact that it is obscured in the north by ejecta from Cavalerius, and the fact that it cuts through a number of very obscure fractures, which are only apparent in the walls of RH III, and result in a rather 'saw toothed' appearance. Something similar can be seen along the course of RH II where at one point it executes a short  $90^\circ$  dog-leg to the north, followed almost immediately by another dog-leg taking it back on to its original course. This appears to be due to RH II being temporarily diverted along the line of a buried graben that follows the same orientation as RH I before resuming its original course (Fig.5). RH III is cut by both RH I and II showing that it is the older of the three, and does not appear to be related to either the Orientale Basin or Oceanus Procellarum. To the north RH III curves to the east up the inner crater wall and may even cross the N.E crater rim.

Fig.5 shows a profusion of inconspicuous short graben, some orientated with RH I, some with RH II, and some roughly with RH III. There are however no obvious fractures that follow radial or concentric polygonal pattern typical of FFC's. We have already noted the fact that the floor of Hevelius is domed (albeit somewhat unevenly), rising to some 600 m from the edges to the summit of the uplift (which translates to a slope of some  $11^\circ$ ) so an FFC pattern of fractures would be expected to exist.

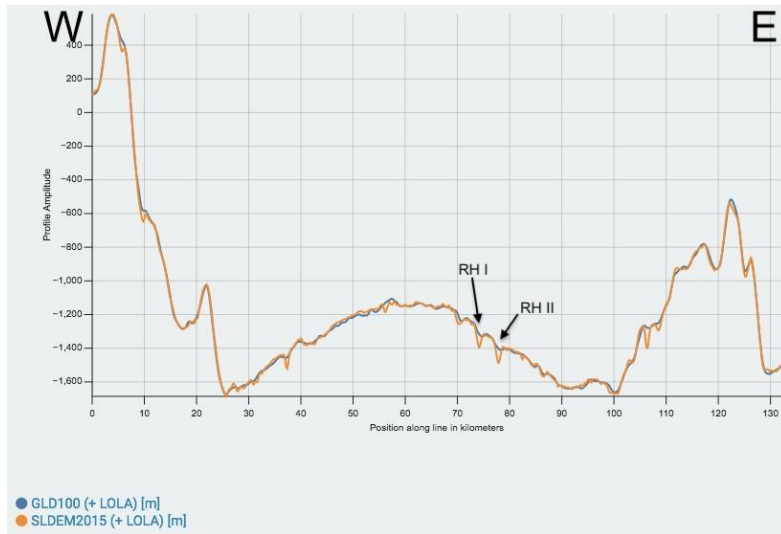


**Figure 5.** *SELENE morning image of the floor of Hevelius showing the numerous orientations taken by fractures and graben, few of which reflect the typical FFC. Possible volcanic features circled in white, and an area of dark mantling deposits is marked with dashed orange line. Note the dog-leg along the course of RH II.*

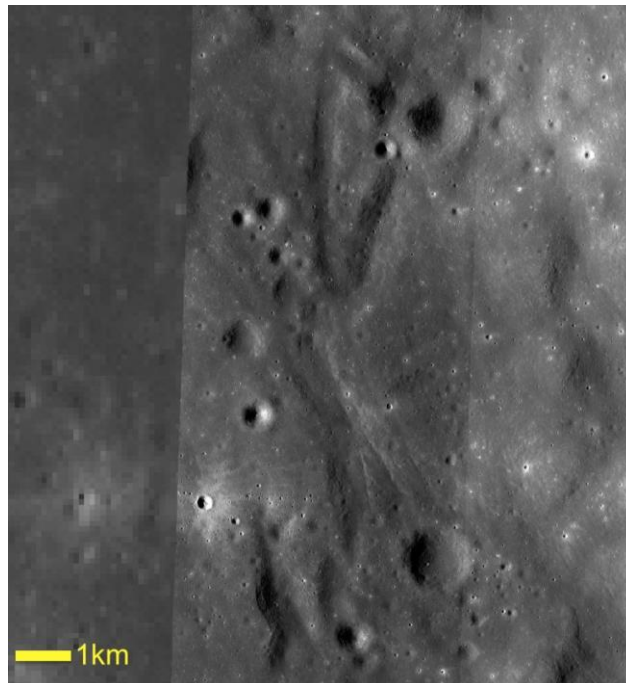
A possible explanation is that some of the original FFC fracture system is obscured by thick Hevelius Formation deposits which are piled up across the southern crater floor. Of course, to the north, Cavalierius ejecta drapes the crater floor and would obscure any features there. One area where some FFC fractures may be preserved is within the patch of dark mantle deposits located between the domed floor and the eastern crater wall. (Fig's 5 and 7). A number of short graben sections can be seen within this dark mantled area, many filled in with what appears to be pyroclastic deposits. Similar deposits can be seen around the edges other FFC's such as Lavoisier, where the fractures have provided routes for ascending volcanic material to reach the surface and erupt.

In addition, there is evidence of volcanism more widely over the Hevelius crater floor. A 4 km diameter circular depression located towards the northern end of RH II may not be an impact crater, as it lacks a raised rim which would be expected be somewhere in the region of 100 – 200 m high in a crater of this size (Fig.5 white circle and Fig.8a). This might support an interpretation as a volcanic collapse pit or a vent of some form, but if so, it is quite a whopper. To the south of this there are a number of linear arrangements of rimless depressions (Fig.5 white oval and Fig.8b) which may represent collapses pits arranged along the line of a volcanic fissures. This includes the southern end of RH III which appears to transform into a line of separate pits.

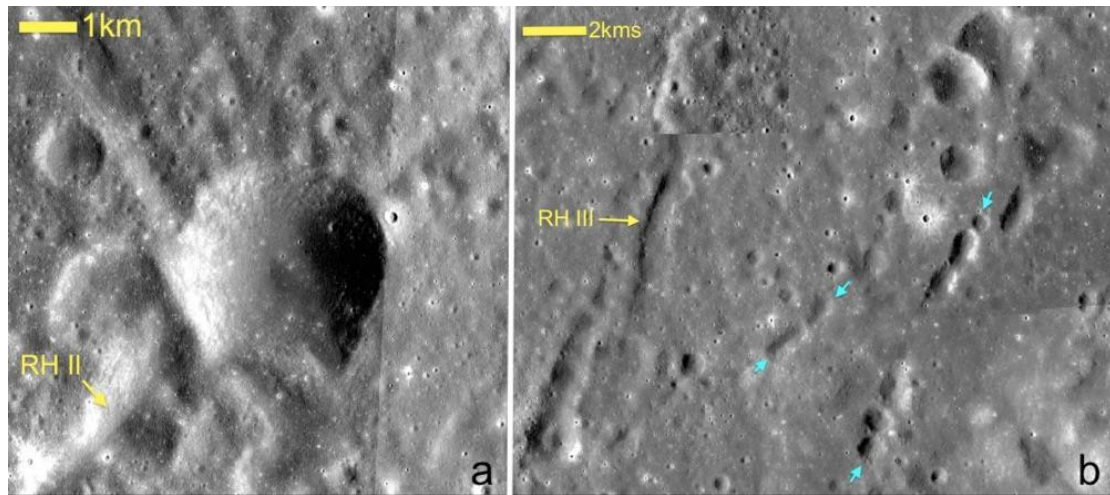




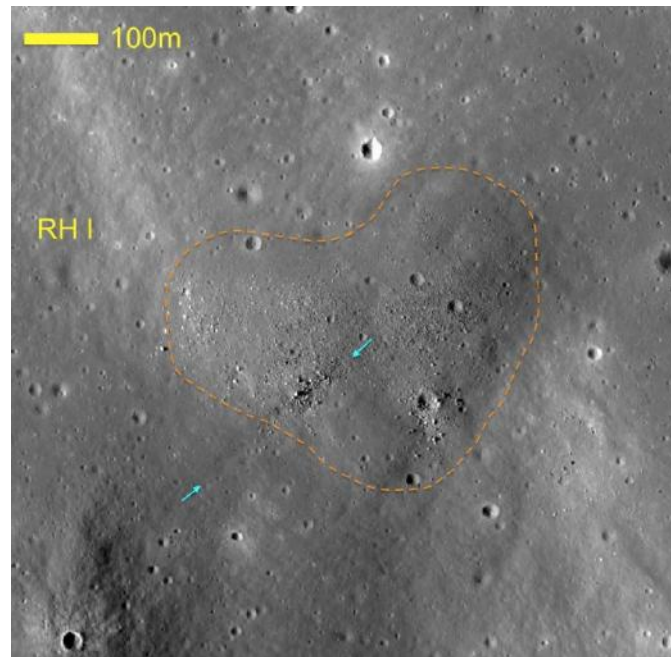
**Figure 6.** Topographic cross section W. to E. across Hevelius. Note the E. rim is depressed probably as a result of the subsidence of the adjacent mare under the weight of its basalt infilling. Note the wider 'edge' to the dome to the E. corresponding to an area of dark mantle deposits.



**Figure 7.** LROC – WAC image of a section of the crater floor of Hevelius between the uplifted central part (to the left) and the E. crater wall (to the right). Note the numerous short partially buried sections of graben.



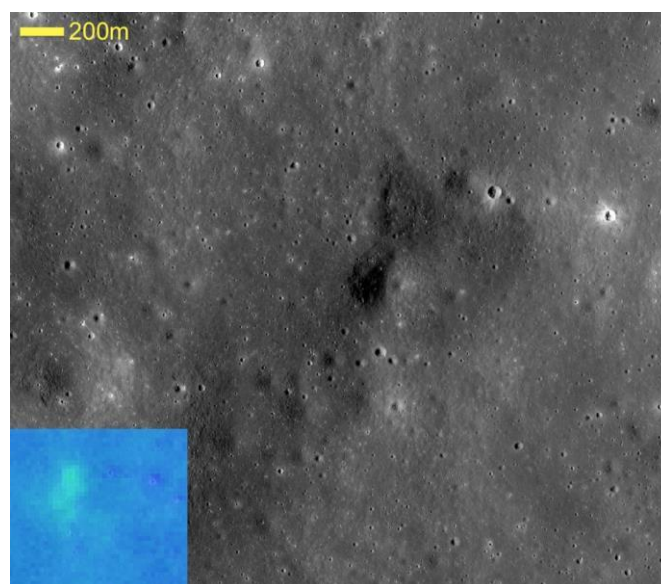
**Figure 8.** LROC NAC image of a 4km rimless pit at the northern end of RH II (a) and a number of rimless pits arranged in possible lines along a fissure (blue arrows) to the east of the southern end of RH III (b). Also note the pit like nature of the southern end of RH III.



**Figure 9.** Small patch of rocky, olivine rich material (orange dashed line) associated with a fracture (blue arrows) cutting across RH I.

If these are volcanic features, they may have erupted material within Hevelius that obscured any FFC fractures. The flaw in this argument however is the lack of obvious volcanic surface deposits within the crater, with the exception of those up against the eastern crater wall and possibly some deposits to the S.W of the central peak. There are however indications of the mineral pyroxene in the walls of RH I as well as associated with the pits shown in Fig.8, which may represent volcanic deposits. If this is the case, these more mafic deposits are now draped in a more widespread light plains material of a non-volcanic, highland composition. One possible solution to this may be a period of volcanism early in Hevelius's history, with any widespread

volcanic deposits being concealed by later ejecta from nearby craters and basins, as well as lateral movement of highland material off the crater rim. An inconspicuous cryptomare volcanic dome Cavalerius 1, located just to the west of Hevelius<sup>[2]</sup> and apparently draped in Hevelius Formation deposits, shows that buried volcanic structures do exist in this area that pre-date the emplacement of Orientale Basin ejecta. Isolated patches of material showing a more 'volcanic' spectral profile can also be found in Hevelius which offer tantalising hints of more recent activity on the crater floor, such as the olivine rich patch of rocky material shown in Fig.9.

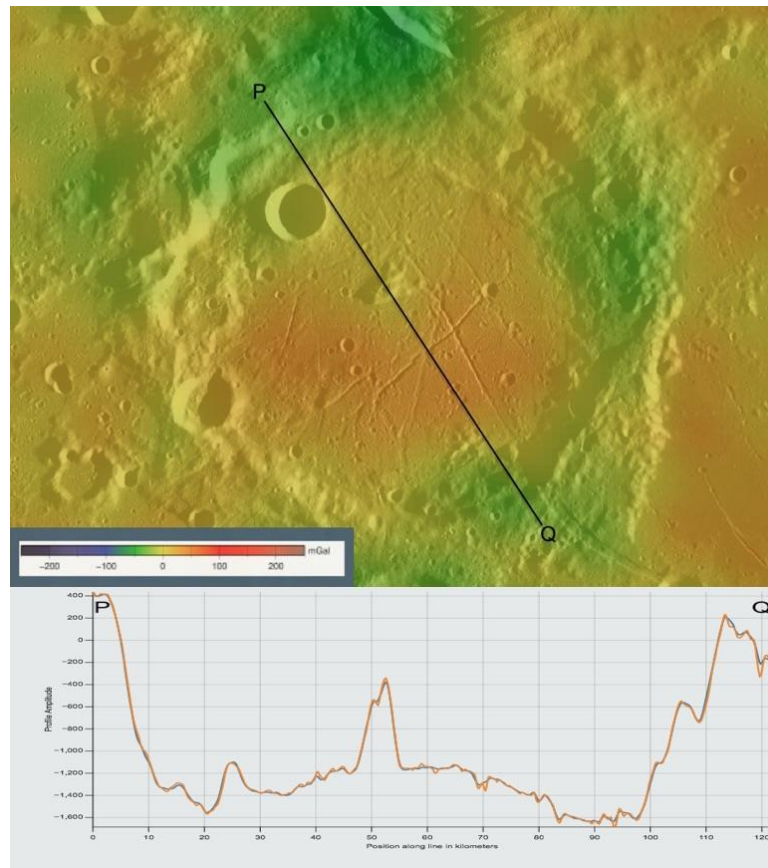


**Figure 10.** Small possible volcanic vent at the northern end of RH III where a small rimless pit is surrounded by deposits with an elevated abundance of FeO and olivine as shown in the Kaguya Mineral Map overlays in Quickmap. The inset is the area around the pit at a reduced scale and with the FeO (wt %) Abundance layer enabled. Yellow indicates high levels of FeO.

This small heart shaped patch lies on the eastern wall of RH I at a point where the graben appears to be slightly offset, and indeed traces of a feint fracture crossing the graben at 90° can be seen on the surface. This may represent 'last gasp' volcanic eruptions of limited extent, but it demonstrates that the floor of Hevelius has hosted volcanism, albeit on a small scale up until recent geological times. Another small possible volcanic feature can be seen at the northern end of RH III where it bends to the east and starts to climb up the N.E. crater wall (see Fig.2). Here a small 40 m deep rimless pit is surrounded by deposits with an elevated iron oxide and olivine signature (Fig.10) which drape the surface which consist of Hevelius crater wall material with a covering of Cavalerius ejecta. This indicates that the volcanic activity postdates the impact of the latter crater and is probably more likely to be contemporary with the widespread eruptions along the eastern crater margin.

One curious feature that some FFC's exhibit is an offset central peak<sup>[4]</sup> and Hevelius is no exception. Having said that, it is only slightly offset towards the N.W by between 4 and 6 kms, with a bit of uncertainty in the measurement because of the poorly preserved rim (Fig.11). As noted above, the inflation of the crater floor appears more prominent in the S.W, showing that the crater floor is far from symmetrical. The GRAIL Bouguer gravity overlay in Quickmap shows a positive gravity anomaly to

the east, south and west of the central peak. This type of anomaly may correlate with the presence of a dense volcanic intrusion below the crater, and which was responsible for the doming of the crater floor. In some FFC's this uplift may have caused the crater floor and central peak to separate from the crater itself and 'float' on the plug of magma pushing upwards, with the potential existing then for it to drift away from its position in the middle of the crater. Has this happened in Hevelius – it is possible but I must admit highly speculative?

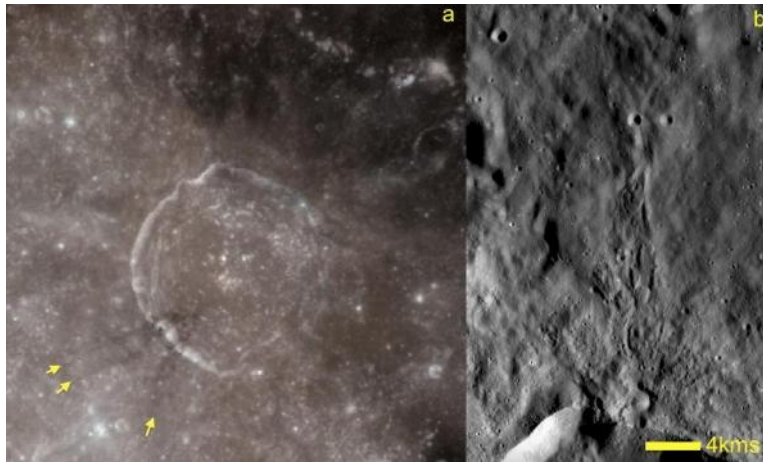


**Figure 11.** GRAIL Bouguer gravity (degrees 60 to 600) overlay from Quickmap and topographic profile along line P-Q below. Note the slight offset of the central peak towards the N.W and the positive gravity anomaly over much of the southern crater floor.

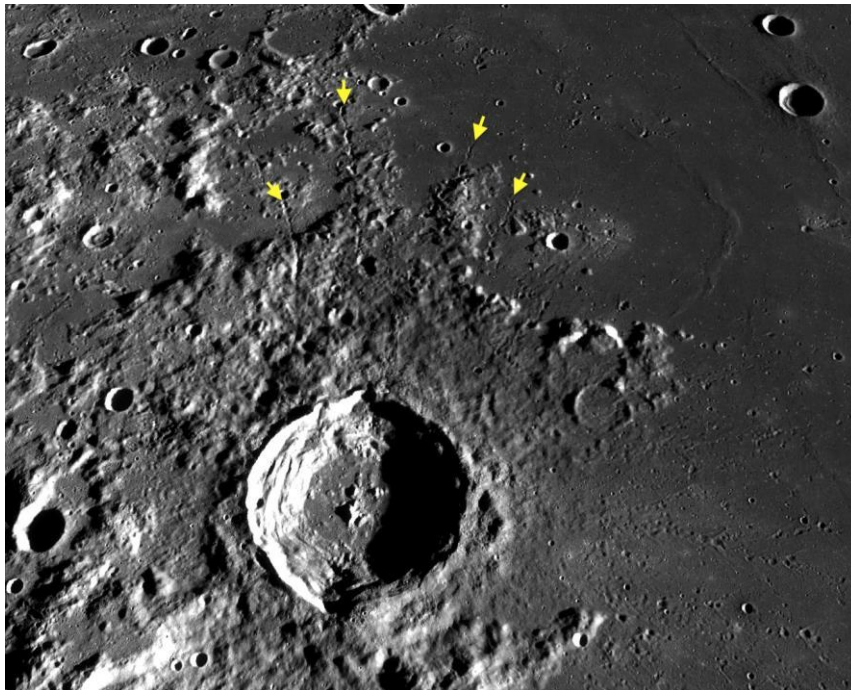
It is not possible to leave Hevelius without touching on its northern neighbour Cavalerius. This crater is perched on the northern glaxis of Hevelius and has draped ejecta extensively over the northern floor of the latter.

It has also excavated dark volcanic rocks which are evident in the form of three tendrils of dark olivine rich ejecta which climb up and over the crater's S.W. rim and drape the highlands just to the north of Hevelius (Fig.12). This is probably comparable to the dark ray's which emerge from the crater Aristillus and extend over the mare surface to the N.E. This is a neat demonstration that volcanic rocks underly this highland area, either in the form of plutonic bodies or 'cryptomare' deposits.





**Figure 12.** WAC Hapke Normalized three colour mosaic of Cavalerius showing the spray of probable volcanic rock (yellow arrows) to the S.W. (a) and a wedge of impact melt with numerous flow channels extending from the northern rim (b).



**Figure 13.** LRO WAC 3D rendition of Cavalerius viewed from the south showing a fan of secondary crater chains to the north. Note the somewhat lemon shaped outline to the crater.

A 25 km plus long wedge of impact melt extends outwards from the northern rim, showing conspicuous channels carved by the outflowing molten rock produced during the impact. A fan like array of secondary crater chains also extend away to the north (Fig.13), which together with the distribution of the melt suggest that the crater was formed by a low angle impact from the south. This is also suggested by the slightly lemon shaped outline of the crater, with the pointy bits of the lemon to the north and south, which is an outline suggested to be produced during oblique impacts<sup>[5]</sup>. This might be true, but it is worth considering an alternative and that Cavalerius formed on the sloping glaxis of Hevelius, which would in itself affect the distribution of ejecta



and possibly replicate some of the effects of a low angle impact. A similar scenario could apply to Rutherford which lies on the southern inner wall of Clavius, and exhibits an ejecta pattern that looks as if it were formed by a low angle impact, but which might have more to do with the sloping surface the crater formed on.

So, in summary Hevelius is probably a FFC but the fractures we see on the crater floor are nothing to do with that phase of activity, and are probably related to regional tectonic forces induced by the formation of the Orientale basin and the crustal loading as southern Oceanus Procellarum filled with basalt lavas. The original FFC fractures were probably obscured by later ejecta, such as the Hevelius Formation as well as that from nearby large craters (such as Cavalerius), as well as a possible contribution from the eruption of volcanic material within the crater itself – possibly related to magma reservoir beneath the crater floor responsible for the floor uplift we see today. This volcanic activity continued to exploit the tectonically formed fractures crossing the crater floor over a protracted period, producing areas of dark mantle deposits and small isolated patches of mafic mineral rich composition, as well as resulting in the creation of pit like depressions where surface regolith drained away into subsurface voids.

### **Acknowledgements.**

Fig.2 courtesy of Mark Radice (RefreshingViews.com)

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>

### **References**

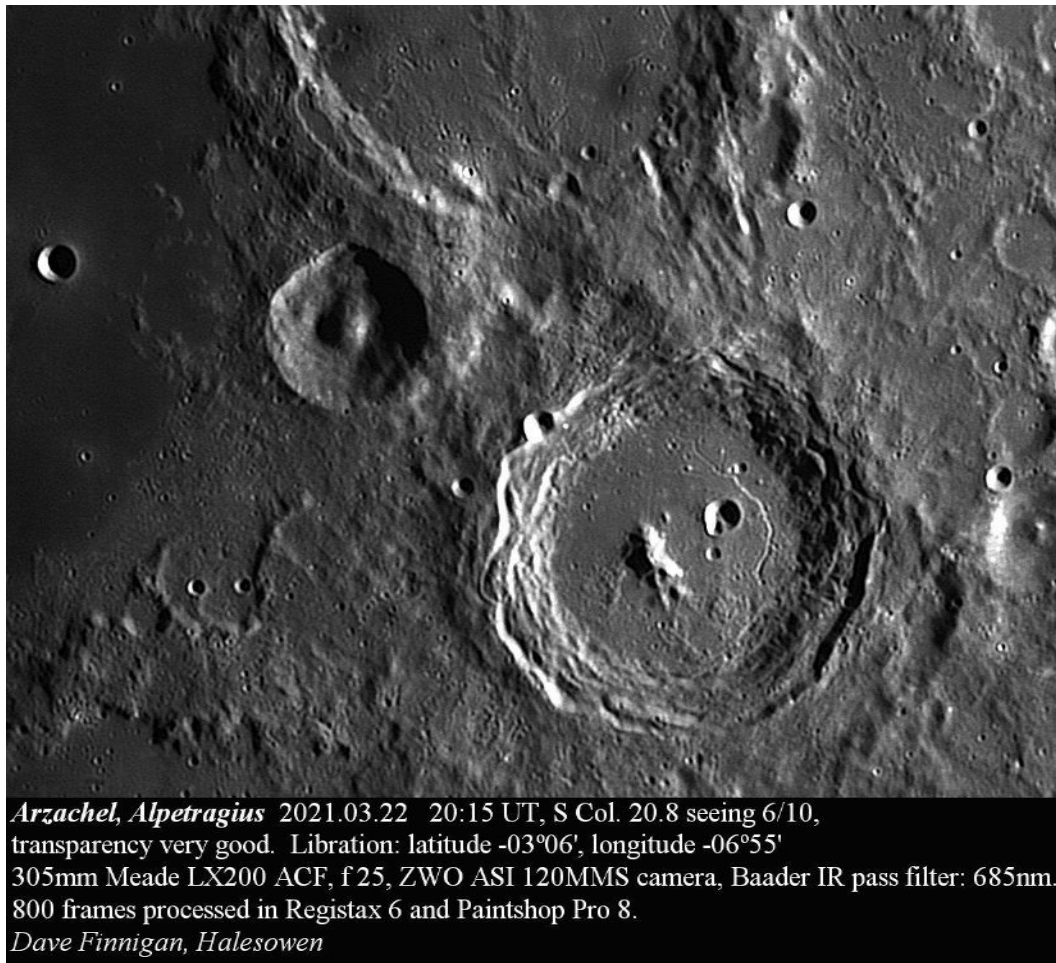
1. Spudis, P. D., Hawke, B. R., & Lucey, P.(1984) Composition of Orientale basin deposits and implications for the lunar basin-forming process. Lunar and Planetary Institute, NASA, American Geophysical Union, et al., Lunar and Planetary Science Conference, 15th, Houston, TX, Mar. 12-16, 1984 Journal of Geophysical Research, Supplement (ISSN 0148-0227), vol. 89.
2. Lena, R. & Pau.K.C (2019) A lunar cryptomare dome near Cavalerius A and Hevelius A. Journal of the British Astronomical Association, vol.129, no.1, p.38-44.

### **ARZACHEL AND ALPETRGIUS**

Imaged by Dave Finnigan

The main crater in this image is Arzachel at around 96 km across with an offset central peak and a sinuous rille in the NW quadrant of the floor. There is a hint of another rille protruding north off of the central peak. In the top left of the image is the more enigmatic Alpetragius crater with a diameter of 39 km, but a 2km high domed

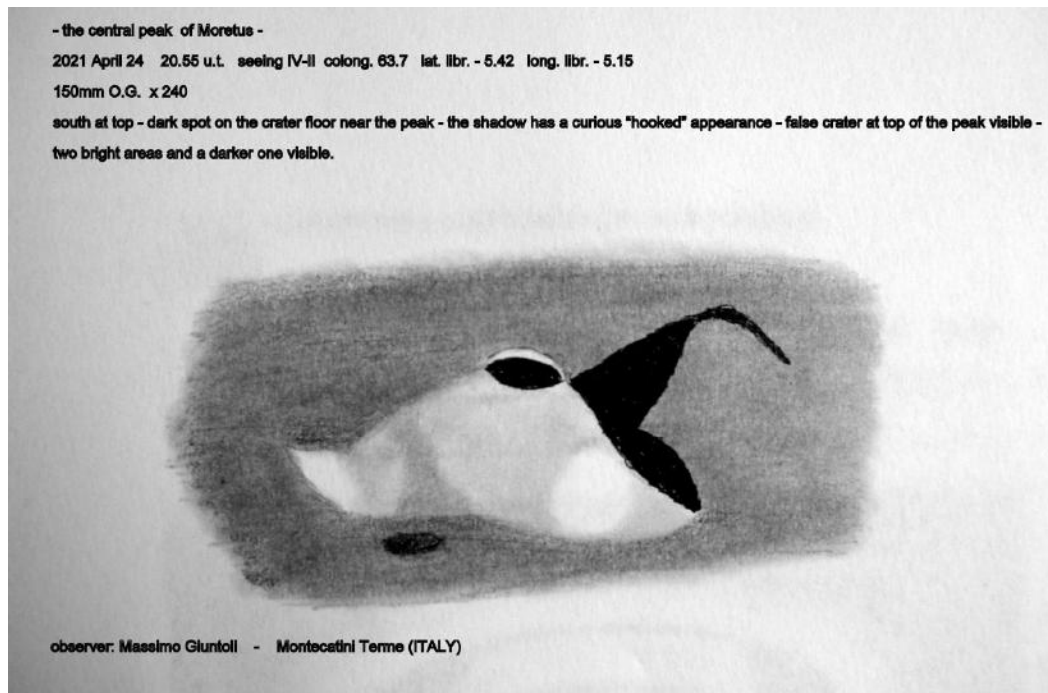
central peak somewhat larger, in proportion to the crater dimensions, than in typical craters. Although not visible in Dave's image, the central peak may have the remains of a vent on top, indicating some past volcanism. The crater is mostly circular apart from an apex distortion on its northern half of the rim.— Tony Cook



## THE CENTRAL PEAK OF MORETUS

Sketched by Massimo Giuntoli

Massimo sketched this crater after reading about an account of a summit crater on the central peak of Moretus, on p122 & 124 in Harold Hill's "A Portfolio of Lunar Drawings". Indeed, Massimo's sketch does capture the appearance that Harold Hill recorded on 1950 Feb 26 & 27. Harold mentions on p122 of his book that overhead views by Lunar Orbiter IV showed the effect was illusory. NASA's LRO QuickMap show a valley running off the SW slopes (hidden behind the peak in this sketch) – but it is difficult to be sure that this is coming from a summit crater due to the amount of shadow present. LOLA altimetry data show that there is a valley present but there is less evidence for a summit craterlet at the head of the valley – Tony Cook



## LUNAR DOMES (PART L): MARIUS HILLS VOLCANIC COMPLEX, DOMES AND CONES

Raffaello Lena

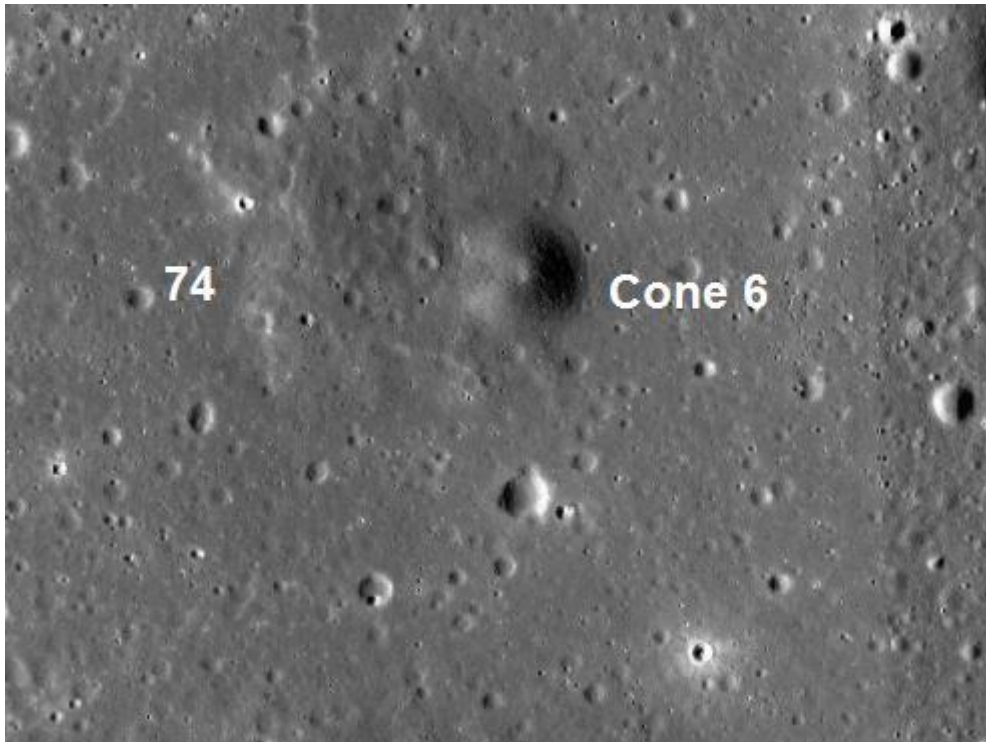
The Marius Hills volcanic complex (MHC) is one of the largest volcanic complexes on the Moon. The diversity of the geologic features (e.g., cones, domes, rilles, lava flows) indicates that volcanic activity was very important and very complex in this area.

The Marius Hills region in the Oceanus Procellarum consists of large numbers of lunar domes which formed as a result of multiple volcanic outbreaks. A general overview of the region and a composite drawing of the Marius Hills has been presented and discussed by Phillips [1990]. In the book "Lunar Domes properties and formation processes", Thirty of these domes, termed Ma1-Ma30, were described with tables giving various properties of each of these domes [Lena *et al.*, 2013]. Low domes can be found as well as steep-sided features with rough surfaces, resulting from superposed flow lobes and cones and, often, steep domes are superimposed on low domes [Lena, 2013; Lena *et al.*, 2009]. The Marius Hills presumably consist of several superimposed volcanic constructs, that originated during different effusive phases.

The visible sinuous rilles in the Marius Hills region indicate they were the source of fluid lavas, of basaltic composition. However, spectral studies indicate that some volcanic constructs are coated with volcanic ash suggesting that they resulted from explosive eruptions, demonstrating that complex volcanic activity occurred in several volcanic phases in this region [McBride *et al.*, 2018]. The region of the Marius Group is identified as a volcanic shield by Spudis *et al.* [2013] and occurs on an elongated,

elliptical topographic rise approximately 330 km in extent and rising to about 2.2 km above the surrounding mare plain.

The Marius Hills have been reported in the lunar domes atlas (<http://mariusdomes.blogspot.com/>). In this note I will describe a volcanic construct termed Ma74, based on our survey, which displays the presence of a cone (named Cone 6) superimposed on its flank (Fig. 1).

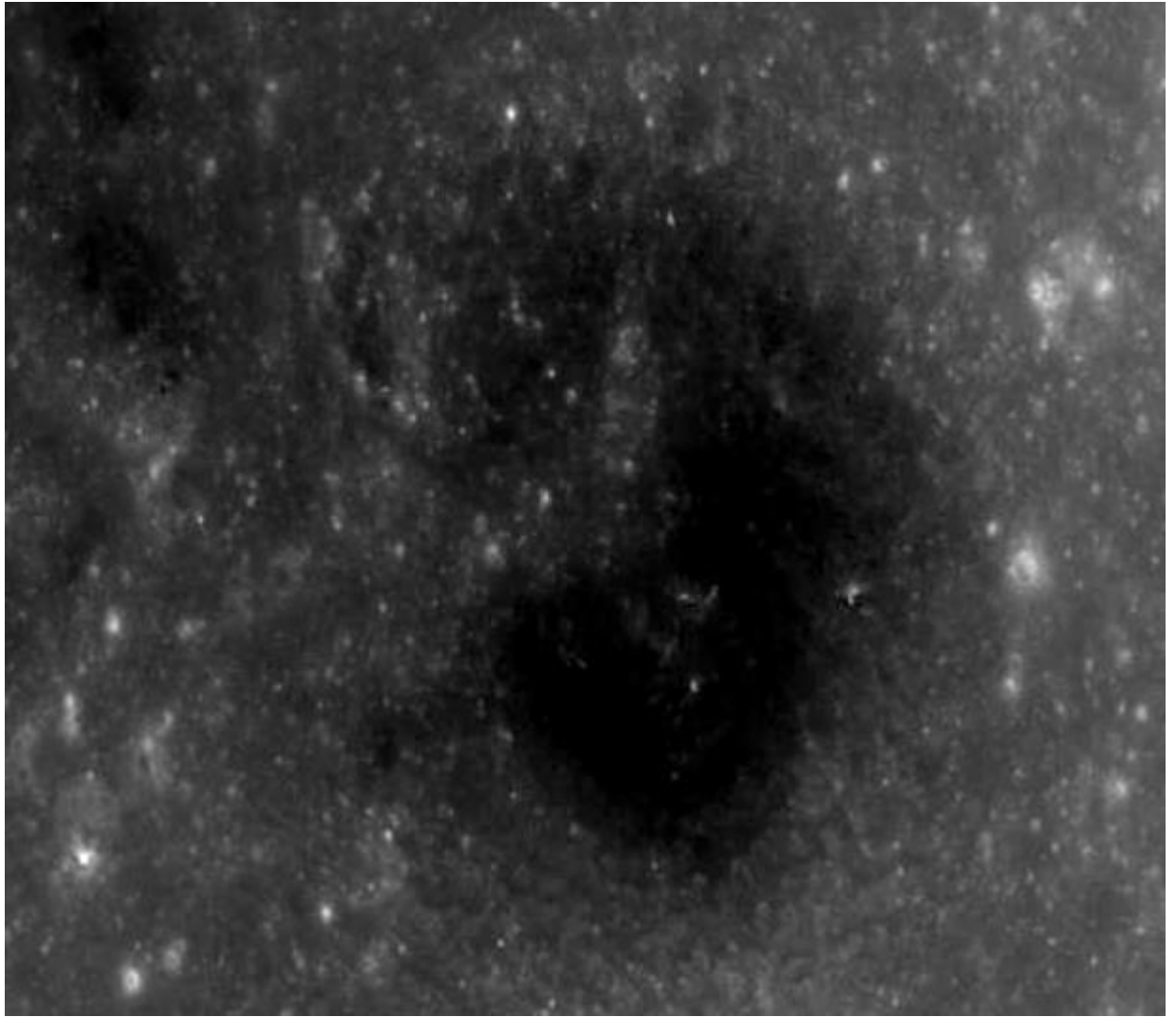


*Figure 1: LROC WAC imagery of the region including Ma74 and Cone 6.*

When cones are found on a dome, the cone formation is an aspect of the dome-building process and represents a change in eruption mechanics produced in pyroclastic and/or spatter eruptive materials.

The wide range of volcanic features, from broad low domes to steep cones, represents a range of variable eruption conditions. Complex morphologies and variable layering show that eruption conditions were variable over the region.

The dome Ma74, located at coordinates 58.66° W and 12.06° N, has a base diameter of 4.5 km, and height of 65 m, yielding an average flank slope of 1.6°. The examined lunar cone has a diameter of 1.55 km; the height amounts to 120 m yielding an average flank slope of 7.6°. The superposition of the cone on the summit of the dome indicates that it is younger than the dome and represents an eruption style during the final stages of volcanism in the Marius region. The presence of pyroclastic deposits is shown in the NAC image reported in Fig. 2.



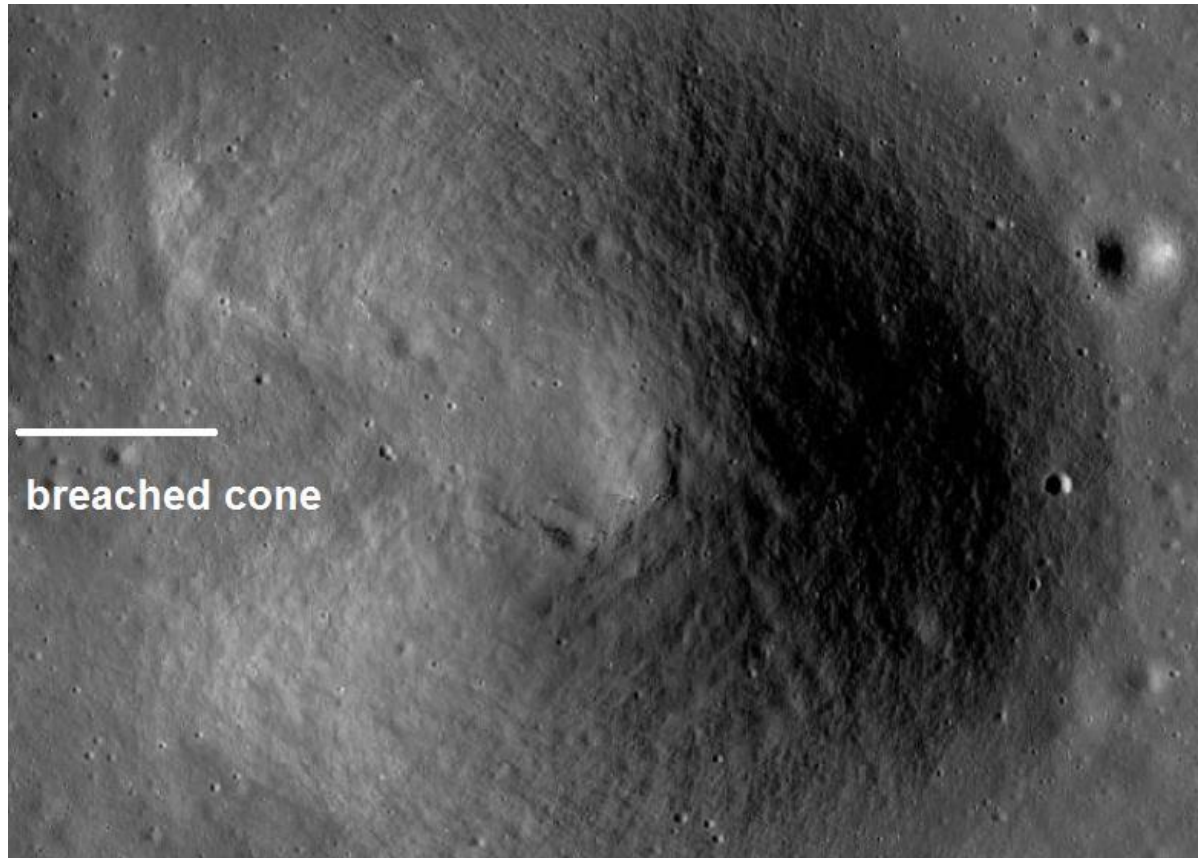
*Figure 2: NAC imagery M1116912735R.*

The examined cone is breached in the west direction and the remaining walls form an amphitheatre or horseshoe shape around the vent (Fig. 3).

Thus, this small cone is interpreted to be constructed from cinder and spatter, with a large contribution from lava flow remnants contributing to the proximal vent morphology (based on rille-like channels, and the C-shape).

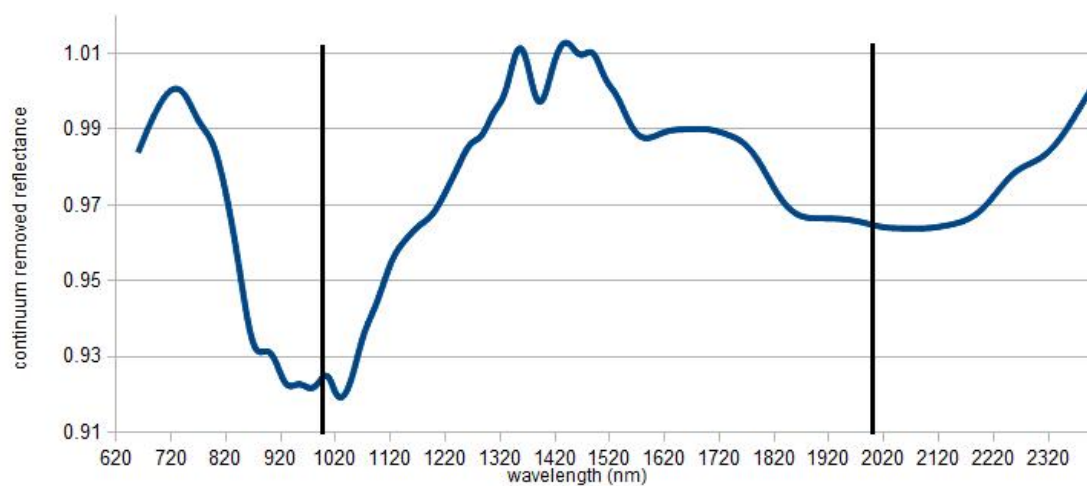
Data obtained using LRO Diviner experiment indicate that the dome is not rich in silica and is not significantly different from surrounding mare materials, based on the 8  $\mu\text{m}$  feature, termed the Christiansen Feature (CF). Silicic minerals and lithologies exhibit shorter wavelength positions at the 8  $\mu\text{m}$  channel. For the study area, CF values of 8  $\mu\text{m}$  are towards longer wavelength (CF~8.35  $\mu\text{m}$ ) indicating less a silicic composition and a basaltic composition [Greenhagen *et al.*, 2010].





*Figure 3: WAC imagery of the examined cone.*

The average CF value of  $8.16\ \mu\text{m}$  is consistent with a mixture of plagioclase and some pyroxene, whilst the average CF values of maria basalts range from  $8.3\text{--}8.4\ \mu\text{m}$ . The cone displays similar CF value ( $8.35\ \mu\text{m}$ ) and no specific signature of olivine is detected ( $\text{CF} > 8.7\ \mu\text{m}$ ). The spectrum derived by  $M^3$  dataset is shown in Fig. 4.



*Figure 4:  $M^3$  spectral analysis of Cone 6.*

Olivine has a complex absorption profile centered beyond 1,000 nm, with weak, or no, absorption at 2,000 nm. Therefore, olivine-rich lunar deposits are characterized by a broad 1,000 nm absorption band which is enhanced relative to the 2,000 nm band.

The mafic minerals (e.g., pyroxene and olivine) of mare basalts can be identified through their characteristic spectral absorption features. Pyroxene displays two absorption peaks at approximately 1,000 nm (Band I) and 2,000 nm (Band II) [Besse *et al.*, 2011]. In contrast, the olivine reflectance spectrum is revealed by a broad and asymmetric 1,000 nm absorption, but lacks the 2,000 nm absorption. The broad Band I absorption in olivine is caused by three distinct absorption bands [Besse *et al.*, 2011]. The central absorption, located just beyond 1,000 nm, is caused by iron in the M2 crystallographic site. The two weaker absorptions near 850 and 1,250 nm are the result of iron in the M1 site. The Band I “secondary” absorption near 1,250 nm allows olivine to be detected when admixed with the spectrally “stronger” pyroxene. The band centers are influenced by the amount of  $\text{Fe}^{2+}$  and  $\text{Ca}^{2+}$ : with increasing  $\text{Fe}^{2+}$  and  $\text{Ca}^{2+}$ , the band centers move slightly to the longer wavelength. However, in the case of olivine-pyroxene mixtures, Band I is dependent on the relative abundances of both olivine and pyroxene.

However, Fe-bearing glass exhibits an absorption band at longer wavelengths, between 1,070 and 1,200 nm [Horgan *et al.*, 2014], and sometimes exhibits a second absorption centered near 2,000 nm. The shape of the absorption band near 1,000 nm (Fig. 4) would include a combination of bands of low calcium pyroxene (OPX) and high-calcium pyroxene (CPX) including Fe-rich glass, which is known to have a broad and shallow band near 1,070 nm [Horgan *et al.*, 2014]. Figure 5 displays the spectral band absorptions in the restricted wavelengths interval comprised from 620 nm to 1380 nm.

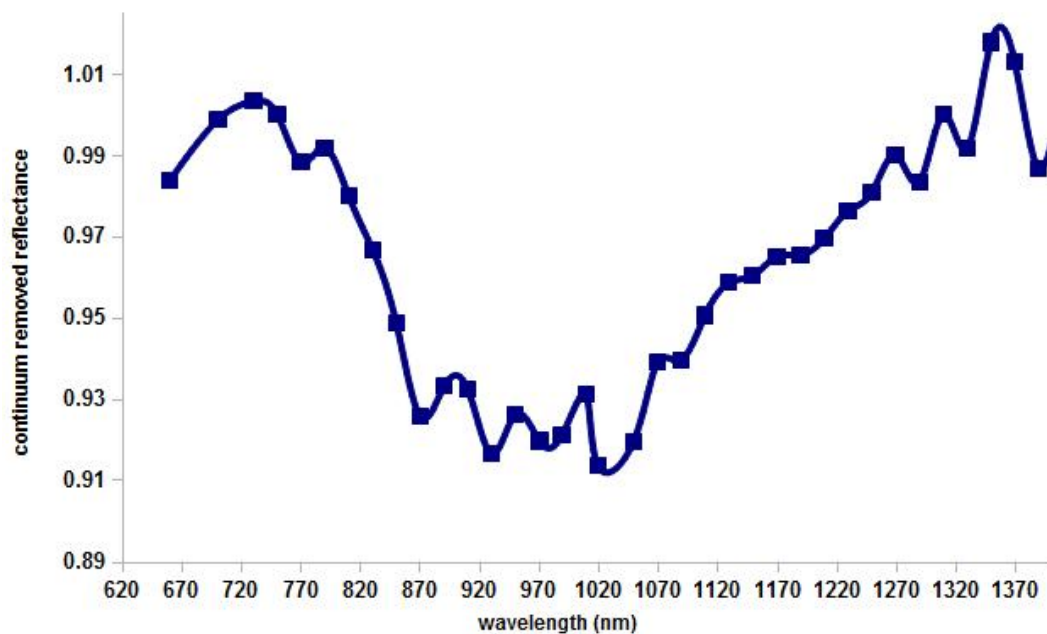


Figure 5:  $M^3$  spectral analysis of Cone 6 in the restricted wavelengths interval comprised from 620 nm to 1380 nm.

Thus, the glass-rich spectral interpretation suggests that the volcanic cone was likely formed in an explosive eruption resulting in cinders. However, spectra of high-calcium pyroxene mixed with Fe-bearing glass can be virtually indistinguishable from common Fe-bearing olivine compositions. This effect, combined with the fact that Fe-bearing glass is generally much more difficult to detect than other ferrous minerals, may be causing glass occurrences on planetary surfaces to be under-reported.

Thus, the localized deposits in Fig. 2 may represent a final effusive product slightly differing in olivine rich basaltic composition (see Fig. 6) or may more likely be constituted by Fe-rich glasses material intermixed with basalts.

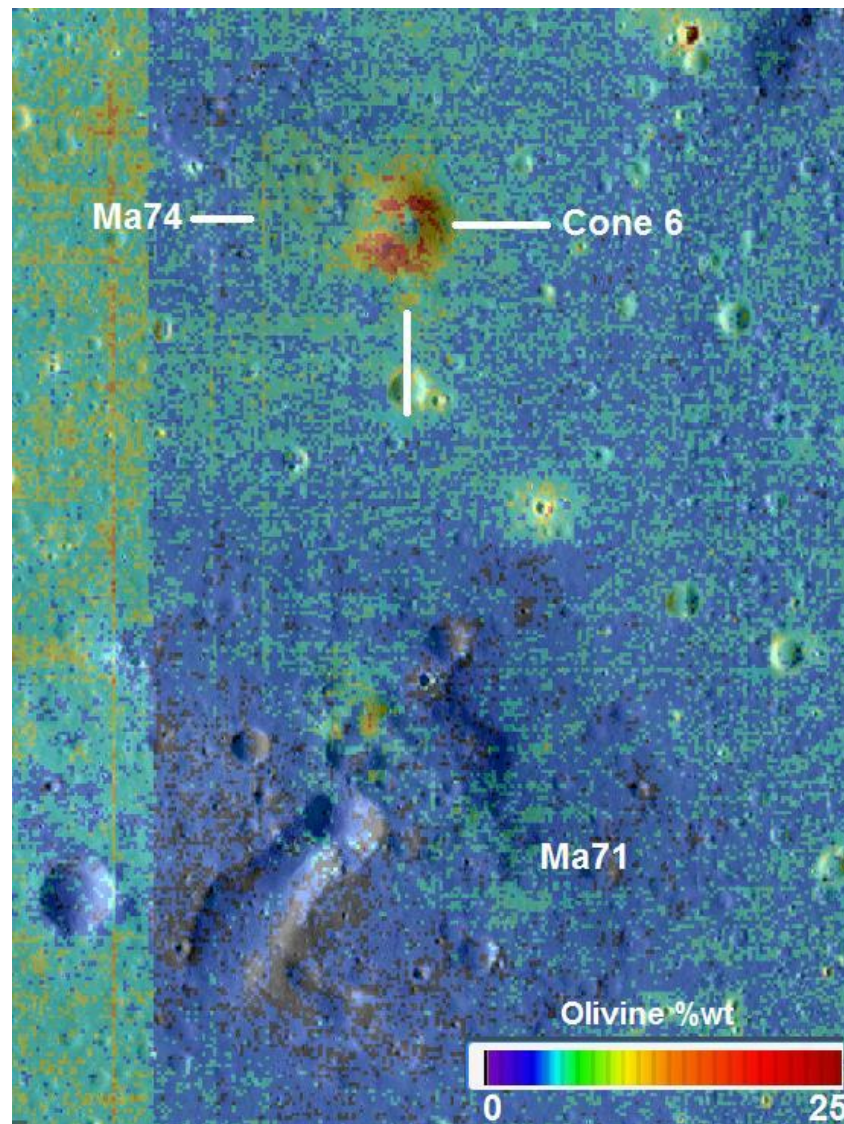


Figure 6: Abundance map in wt% of olivine content using Mineral Mapper reflectance data acquired by the JAXA SELENE/Kaguya mission. The map is extracted using the Quickmap LRO global base map ( <http://target.lroc.asu.edu/da/qmap.html> ). For an interpretation see the text for detail.

Based on M<sup>3</sup> dataset the localized deposits have more glass rich composition, with 9.6% glass band depth, than the surrounding area. Consequently, the examined cone is a cinder cone displaying associated glass deposits formed via explosive eruptions.

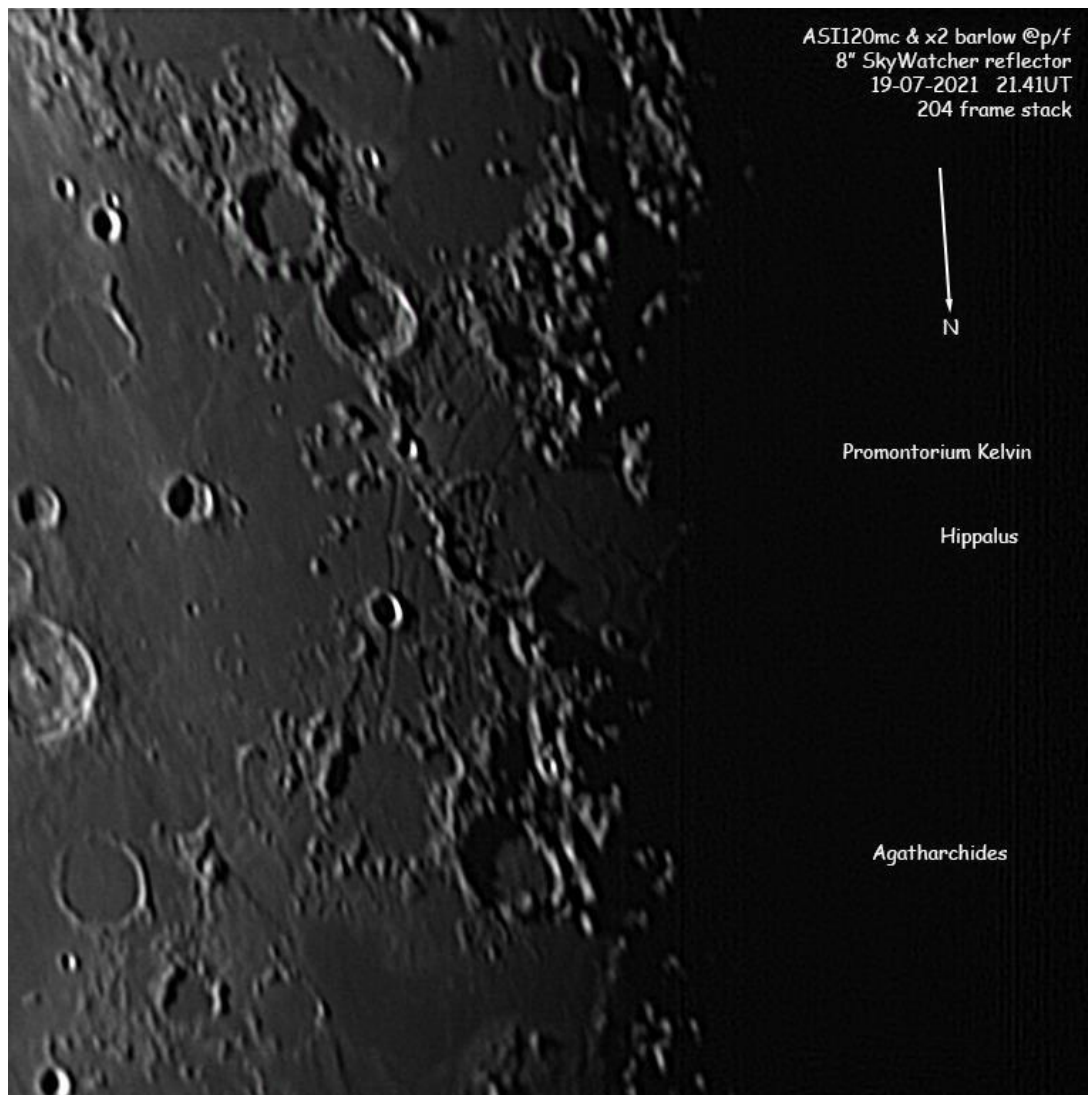
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## PROMONTORIUM KELVIN

Imaged by Les Fry



Promontorium Kelvin is in the SW corner of Mare Humorum (mostly in shadow here) and is a mountain that is about 45 km long and rises nearly 2 km above the mare. In the left side of image in Mare Humorum and three curved rilles in the form of Rimae Hippalus – these are concentric to the Humorum impact basin. – Tony Cook



**Spectacular Graze of eta Leonis (v3.5) on October 3rd at 04hr UT**

The 2021 BAA Handbook page 44 lists grazes for stars brighter than magnitude eight. List entry #11 is for the 3<sup>rd</sup> magnitude star eta Leonis which grazes the northern cusp at crescent phase in the morning sky. Eta is also a close double star which will cause some additional phenomena. (Fade, step, flash...)

The graze path exits Ireland's East coast near Dundalk, passing over Ramsey, Isle of Man (Fig 1) ; and then through the Lake District (Fig 2) passing a few Km South of Whitehaven, Keswick, Penrith and finally Sunderland on the East coast (Fig 3). Our European colleagues in Denmark and Sweden then have their opportunity.

*Figure 1. Isle of Man, (Green line = Mean limb northern limit at sea level)*



*Figure 2. Lake District*



*Figure 3. UK East Coast*



The limb cross-section producing the most D-R events is 0.8km South of the mean limb line illustrated here by the green line: Zero (Fig 4) is the mid time of the graze which for 3.5deg West is at 0402hr 6sec UT.

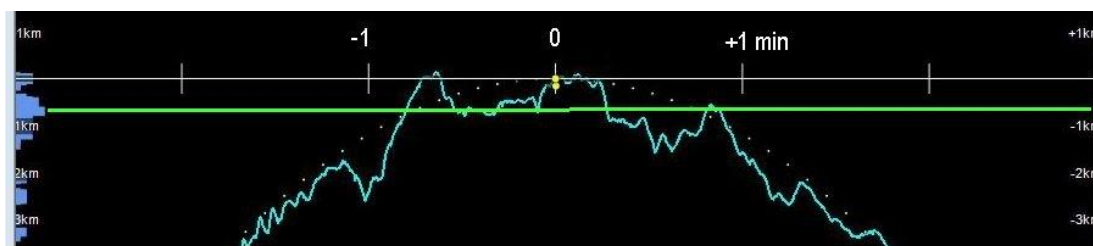


Figure 4. Eta is a double star, with minor companion of mag 8.4, sep 0.1" in PA 240, shown on the diagram as yellow dots in the expected orientation. Zero is the mid point of the graze.

### Planning:

For an observer H meters above sea level, the path is shifted in the direction of the Moon by:  $\text{TanZ} \times H$  meters. Coordinates are referred to the WGS84 datum i.e., GPS and Google Earth. So, this means plotting on an OS map will not give the best line because the OSGB datum is superseded by WGS84 except for printed maps, so I would use Google Earth for terrain and Street Map OS 1:25,000) for the missing information. Google street view is also helpful.

E.	Longit.	Latitude	U.T.	Sun	Moon	TanZ	PA	AA	CA
	° ' "	° ' "	h m s	Alt	Alt Az		°	°	°
-	7 0 0	53 50 39.7	4 0 54		15 82	3.68	16.2	355.40	9.52N
-	6 45 0	53 53 35.7	4 0 59		15 83	3.64	16.3	355.42	9.49N
-	6 30 0	53 56 30.4	4 1 4		16 83	3.60	16.3	355.45	9.47N
-	6 15 0	53 59 23.8	4 1 9		16 83	3.56	16.3	355.48	9.44N
-	6 0 0	54 2 15.7	4 1 14		16 83	3.52	16.3	355.50	9.41N
-	5 45 0	54 5 6.3	4 1 19		16 84	3.49	16.4	355.53	9.38N
-	5 30 0	54 7 55.5	4 1 24		16 84	3.45	16.4	355.56	9.36N
-	5 15 0	54 10 43.3	4 1 29		16 84	3.41	16.4	355.59	9.33N
-	5 0 0	54 13 29.7	4 1 34		16 84	3.38	16.4	355.61	9.30N
-	4 45 0	54 16 14.7	4 1 39		17 84	3.34	16.5	355.64	9.27N
-	4 30 0	54 18 58.4	4 1 45		17 85	3.31	16.5	355.67	9.25N
-	4 15 0	54 21 40.6	4 1 50		17 85	3.27	16.5	355.70	9.22N
-	4 0 0	54 24 21.5	4 1 55		17 85	3.24	16.6	355.73	9.19N
-	3 45 0	54 27 1.0	4 2 1		17 85	3.21	16.6	355.75	9.16N
-	3 30 0	54 29 39.1	4 2 6		17 86	3.18	16.6	355.78	9.13N
-	3 15 0	54 32 15.8	4 2 11		18 86	3.15	16.6	355.81	9.11N
-	3 0 0	54 34 51.1	4 2 17		18 86	3.12	16.7	355.84	9.08N
-	2 45 0	54 37 25.0	4 2 23		18 86	3.09	16.7	355.87	9.05N
-	2 30 0	54 39 57.5	4 2 28		18 87	3.06	16.7	355.89	9.02N
-	2 15 0	54 42 28.6	4 2 34		18 87	3.03	16.8	355.92	8.99N
-	2 0 0	54 44 58.4	4 2 40		18 87	3.00	16.8	355.95	8.96N

This information should allow an observer to plan ahead. Contact the Lunar Occultation Coordinator to request full information from Occult4 software which I have already prepared (3 files).

# Occultation predictions for North Oxfordshire in 2021 August and September

Longitude 1 18 46 W , Latitude 51 55 41 N, Alt. 119m; Moon Alt>5 degrees

Some fainter predictions are omitted near Full Moon.

y	m	d	h	m	s	P	Star No	Sp	Mag v	Mag r	% ill	Elon Alt	Sun Alt	Moon Alt	Az	CA	Notes
21	Aug	1	0	5	57.3	R	93122	K2	8.8	8.3	45-	85		9	80	76S	
21	Aug	1	1	3	43.5	R	93135	K0	8.3*	7.6	45-	84		18	91	55N	
21	Aug	1	1	41	15.2	R	93145	K0	8.9	8.3	45-	84		23	98	77N	
21	Aug	2	1	54	46.8	R X	4678	A5	8.9	8.8	35-	73		22	89	85N	
21	Aug	3	2	1	17.4	R	76611	G5	8.6	8.2	27-	62		19	79	80N	
21	Aug	3	2	26	54.7	R	76624	K0	8.8	8.4	26-	62		22	84	32S	
21	Aug	3	3	16	51.4	R	76632	A0	8.6	8.5	26-	61	-10	30	93	37S	
21	Aug	5	2	9	46.0	R	78069	B9	8.6	8.7	12-	40		9	61	57N	Dbl*
78069 is double: AB 8.6 9.8 5.9" 358.1, dT = -9s, Observations are desired																	
21	Aug	5	2	34	3.0	R	78091	K0	8.8	8.1	12-	40		12	65	73S	
21	Aug	5	2	46	46.4	R	78100	K0	8.9	8.3	11-	40		14	67	60N	
21	Aug	5	3	14	55.1	R	78118	K0	8.5	7.8	11-	39	-11	18	72	47S	
21	Aug	6	2	37	14.6	R	79054	K8	6.9	6.1	6-	28		6	57	79S	
21	Aug	6	3	31	38.0	R	79098	K5	8.7	7.9	6-	28	-9	13	66	78N	
21	Aug	13	20	32	23.5	D	139538	K0	8.9	8.3	30+	66	-9	10	243	72N	
21	Aug	13	21	4	30.2	D	1975	G5	8.7	8.3	30+	67		5	249	60N	
21	Aug	16	20	8	14	D	2374	G8	8.5	7.9	64+	106	-7	14	197	13N	
21	Aug	20	23	7	19.9	D	189703	M2	7.9	7.0	97+	159		15	183	51S	
21	Aug	21	22	8	4.2	D	3178	A0	6.2	6.1	99+	171		15	156	89N	
21	Aug	23	22	26	37.3	R	3450	F0	8.5	8.3	97-	161		18	134	47S	
21	Aug	23	23	58	34	M	3458	K0	6.2	5.5	97-	161		26	156	25N	
21	Aug	24	2	35	8.2	R	146764	K0	8.0	7.5	97-	160		28	199	29S	
21	Aug	25	3	21	39	M	128707	K0	6.9*	6.4	92-	148		34	201	20N	
21	Aug	25	3	29	25.7	R	44	F8	7.4*	7.1	92-	148		33	203	61S	
21	Aug	25	3	33	2.2	R	128715	F8	8.9	8.6	92-	148		32	204	38S	
21	Aug	26	23	4	25.1	R	262	G0	8.8	8.5	80-	126		20	105	53S	
21	Aug	27	1	46	10.6	R	110154	G1	7.4*	7.1	79-	125		40	144	76S	
21	Aug	27	3	12	14.5	R	110180	A3	8.2	8.0	79-	125		46	172	85S	
21	Aug	27	4	9	40.9	R	281	K2	7.4	6.7	78-	124	-9	46	191	33S	
21	Aug	28	0	55	49.1	R	93004	G0	7.5	7.1	71-	114		34	116	55N	
21	Aug	28	2	45	43.8	R	384	F7	5.6*	5.4	70-	114		47	147	84N 31 Ari	
384 is double: AB 5.7 5.8 0.08" 144.5, dT = +0.1s, Observations are desired																	
21	Aug	28	2	53	59.9	R	93029	G5	7.6	7.1	70-	114		47	149	21S	
21	Aug	29	2	25	34.2	R	93407	K0	8.3	7.5	61-	103		44	125	54S	
21	Aug	29	2	29	18.2	R	488	K0	7.9	7.3	61-	103		44	126	45S	
21	Aug	29	3	2	33.4	R	93410	F5	8.5	8.3	61-	103		48	135	63S	
21	Aug	29	23	28	7.8	R	602	F5	8.3	8.1	53-	93		14	75	52N	
21	Aug	29	23	50	41.6	R	93759	F0	8.7	8.5	53-	93		17	80	88N	Dbl*
21	Aug	30	23	50	26.5	R	739	K0	7.2	6.5	43-	82		12	69	63S	
21	Aug	31	1	14	41.4	R	76871	K0	8.8	7.9	42-	81		25	84	49S	
76871 is double: 9.5 9.5 0.10" 227.0, dT = -0.24s, Observations are desired																	
21	Aug	31	2	37	10.5	R	749	K0	8.6	8.0	42-	81		37	100	90N	
21	Aug	31	3	45	7	D	76938	K5	7.6	6.7	42-	80		47	115	4N	
21	Aug	31	3	56	49	R	76938	K5	7.6	6.7	42-	80		49	118	23N	
21	Aug	31	4	3	35	D	76950	F5	8.9	8.6	42-	80	-11	50	120	1N	
21	Aug	31	4	19	31	R	76950	F5	8.9	8.6	41-	80	-9	52	125	25N	
21	Aug	31	23	47	16.0	R	880	K2	6.8*	6.0	34-	71		7	59	35N	
21	Aug	31	23	52	22.3	R	77571	K	7.6*	6.8	34-	71		8	59	47N	



## Occultation prediction for 2021 September

21 Sep	1	0 15 10.5 R	77581 A0	8.4	8.3	34-	71	11	64	87N	
21 Sep	1	0 26 14.3 R	882 G8	5.0*	4.4	34-	71	12	66	86N	132 Tau
21 Sep	1	1 36 51.8 R	77640 K0	9.0	8.3	33-	70	22	78	85N	
21 Sep	1	4 1 32.3 R	77746 K5	8.7	7.8	32-	69	-12	44	106	64N
21 Sep	1	4 28 25.4 R	77770 K0	8.4	7.8	32-	69	-8	47	112	35S
21 Sep	1	4 34 26.9 R	77772 B5	8.7	8.7	32-	69	-7	49	114	40N
21 Sep	2	1 2 39.6 R	1030 A3	3.1	2.3	25-	59	11	63	74S	epsilon Gem
21 Sep	2	3 31 11.6 R	78778 K0	6.8	6.0	24-	58	32	89	55N	Db1*
78778 is double: ** 7.7 8.4 0.25" 69.0, dT = +0.37sec, Observations are desired											
21 Sep	2	4 8 50.8 R	78791 K0	8.8	8.2	23-	58	-11	38	96	64S
21 Sep	3	1 15 20.9 R	79578 A0	8.8	8.8	16-	48	5	56	39S	
21 Sep	3	3 6 37.6 R	1168 A5	7.1	6.9	16-	47	20	76	11S	
21 Sep	3	3 35 36.7 R	1170 G8	3.6	3.1	16-	47	24	81	59S	Kappa Gem
21 Sep	3	3 44 15.1 R	79662 G0	8.6		16-	47	25	82	39S	
21 Sep	5	3 41 2.7 R	98640 K0	8.0	7.5	4-	23	6	67	1S	
21 Sep	13	19 2 28.7 D	2483 K1	7.1	6.5	49+	89	-7	11	196	72N
21 Sep	14	18 44 59.9 D	2650 K3	4.7	3.8	60+	102	-4	11	179	36S
21 Sep	14	19 34 36.4 R	2650 K3	4.7	3.8	61+	102	-12	11	190	-46S
21 Sep	15	21 48 21.9 D	188125 A0	7.8*	7.7	72+	116	8	206	63N	
21 Sep	16	21 48 41.6 D	189297 G0	8.5	8.3	81+	129	13	194	64N	
21 Sep	16	22 44 30.0 D	2984 G6	7.1	6.6	82+	129	10	206	37N	
2984 is double: AB 6.9 0.20" 231.0, dT = -0.6s Observations are highly desired											
21 Sep	17	22 35 44.3 D	190337 K0	7.2	6.6	89+	142	16	192	89S	
21 Sep	18	22 7 47.0 D	3276 G0	7.3	7.0	95+	154	21	173	83S	
21 Sep	19	20 36 29.2 D	3396 A8	7.7	7.5	98+	165	18	138	67N	
21 Sep	19	21 33 30.9 D	165509 F8	8.9	8.6	98+	165	23	152	40N	
21 Sep	20	1 38 10.5 D	3413 K5	6.1	5.3	99+	167	21	216	64N	
21 Sep	20	3 1 35.4 D	165603 G5	8.1	7.5	99+	168	13	235	76N	
21 Sep	22	2 32 59.8 R	109473 G0	8.2	7.8	99-	167	34	212	88S	
21 Sep	22	3 45 22.0 R	109496 K0	8.4	7.7	99-	166	27	231	47S	
21 Sep	22	4 32 31.4 R	110 G0	8.8*	8.5	99-	166	22	242	75N	
21 Sep	22	23 53 16.3 R	109931 G0	8.5	8.2	96-	156	40	148	59N	
21 Sep	23	1 19 45.7 R	109961 G5	8.9*	8.3	96-	156	44	176	35S	
21 Sep	24	0 51 0.0 R	92875 G0	8.7	8.4	91-	145	46	151	46S	
21 Sep	24	4 55 36.9 R	92910 G0	8.9	8.6	90-	144	-10	39	234	56N
21 Sep	24	5 27 34.5 R	92929 K5	7.9	7.1	90-	143	-5	34	241	7S
21 Sep	24	5 51 49.2 R	92923 F0	8.5	8.2	90-	143	-1	31	247	66S
21 Sep	24	23 0 48.7 R	445 F8	7.3	7.0	85-	134	32	107	56N	
21 Sep	24	23 17 47.3 R	93238 F2	7.8	7.4	85-	134	34	110	82N	
21 Sep	25	5 35 46.0 R	93318 A5	7.9	7.7	84-	132	-4	43	236	61S
21 Sep	26	0 14 6.2 R	93629 F0	8.5	8.3	77-	123	39	110	61N	
21 Sep	26	2 50 36.0 R	93672 G0	8.9	8.6	77-	122	56	158	9S	
21 Sep	26	22 0 14.0 R	76669 F5	8.2*	7.9	70-	113	14	73	14S	
21 Sep	26	22 6 47.2 R	76665 K0	8.2	7.6	70-	113	15	74	66N	
21 Sep	28	1 11 26.9 R	77245 F8	8.9	8.7	59-	101	37	97	46S	
21 Sep	28	1 37 5.9 R	835 B8	7.0	6.9	59-	101	41	103	79N	
21 Sep	28	22 6 40.6 R	78207 B8	7.8	7.8	51-	91	5	54	70N	
21 Sep	28	22 51 7.3 R	966 B9	7.1	7.1	51-	91	10	62	58S	
21 Sep	28	23 19 31 R	78281 B9	8.8	8.7	51-	91	14	67	21N	
21 Sep	29	0 12 44.9 R	78321 A5	8.9	8.8	50-	90	22	76	44S	
21 Sep	29	0 26 23.5 R	78322 B1	8.4	8.4	50-	90	24	79	82S	
21 Sep	29	1 25 58.3 R	78362 A2	8.6	8.6	50-	90	33	89	86S	
21 Sep	29	1 29 29.6 R	78365 G0	8.9	8.5	50-	90	33	90	83N	
21 Sep	29	2 49 30.7 R	78415 A0	8.6	8.6	49-	89	45	107	90S	
21 Sep	29	3 14 59 D	78451 G8	8.3	7.7	49-	89	49	112	0N	
21 Sep	29	3 28 52 R	78451 G8	8.3	7.7	49-	89	51	116	21N	
21 Sep	29	5 9 14.1 R	78477 K2	8.4	7.8	49-	88	-9	62	152	60N
21 Sep	30	1 35 20.9 R X	10934 N0	8.4	7.2	40-	78	26	82	16S	
21 Sep	30	2 12 59.3 DB	1117 G8	5.0	4.6	40-	78	31	89	-49S	57 Gem
R1117 = 57 Geminorum is double: ** 5.9 5.9 0.10" 90.0, dT = +0.23sec											
21 Sep	30	2 54 59.5 RD	1117 G8	5.0	4.6	40-	78	38	97	27S	57 Gem
21 Sep	30	5 26 11.8 R	79407 F0	8.5	8.3	39-	77	-7	58	138	21S
21 Sep	30	13 37 25.1 DB	1170 G8	3.6	3.1	36-	74	31	15	290	-63S kappa Gem
21 Sep	30	14 26 36.3 RD	1170 G8	3.6	3.1	36-	73	26	8	299	66S kappa Gem
21 Oct	1	0 7 45.5 R	80002 A0	8.6	8.6	31-	68	5	58	14S	
21 Oct	1	3 57 0.4 R	80105 A0	7.9	7.9	30-	66	38	100	36N	
21 Oct	2	1 25 3.7 R	80648 K0	8.7	8.2	22-	55	7	65	76N	
21 Oct	2	3 45 31.6 R	80693 G0	8.4	8.1	21-	54	27	90	74S	
21 Oct	2	5 42 44.7 R	80735 K0	8.7	8.1	20-	54	-5	44	116	69N
21 Oct	3	3 44 1.8 DB	1484 A0	3.5	3.5	13-	42	16	83	-23N	eta Leo
21 Oct	3	4 2 56 Gr	1484 A0	3.5	3.5	13-	42	20	**	GRAZE:	N England
21 Oct	3	4 15 47.1 RD	1484 A0	3.5	3.5	13-	42	21	89	41N	
21 Oct	3	4 44 2.2 R	98961 F8	8.6	8.3	13-	42	25	95	25S	

Prediction up to Oct 3rd

Notes on the Double Star selection.

Doubles are selected from Occult4, where the fainter companion is brighter than mag 9.0, and the time difference(dT) is between 0.1 and 10 seconds. **Please report double star phenomena.** Additional predictions are available from OccultWatcher software.

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. (-ve indicates bright limb)  
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.

H denotes the HIPparcus 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. Ask the*  
**Occultation Subsection Coordinator:** tvh dot observatory at btinternet dot com

## **LUNAR GEOLOGICAL CHANGE DETECTION PROGRAMME** Tony Cook

**Introduction:** In the set of observations received in the past month, these have been divided into three sections: Level 1 is a confirmation of observation received for the month in question. Every observer will have all the features observed listed here in one paragraph. Level 2 will be the display of the most relevant image/sketch, or a quote from a report, from each observer, but only if the date/UT corresponds to: similar illumination ( $\pm 0.5^\circ$ ), similar illumination and topocentric libration report ( $\pm 1.0^\circ$ ) for a past TLP report, or a Lunar Schedule website request. A brief description will be given of why the observation was made, but no assessment done – that will be up to the reader. Level 3 will highlight reports, using in-depth analysis, which specifically help to explain a past TLP, and may (when time permits) utilize archive repeat illumination material.

**TLP reports:** No TLP reports were received in June or July.

**News:** With the news that Bill Leatherbarrow is retiring as director of the BAA Lunar Section, I am working with Tim Haymes to keep the Lunar Section running, at least until a new director is confirmed. To be able to cope with this it will be necessary to streamline/shorten the LGC newsletter. More about this in the next newsletter, once I



have figured out how to abridge the writeup without detracting value from those who contribute. But please do keep on sending observations in – these all contribute to repeat illumination studies as you can see from some of the example Level 3 reports below, and in past editions of the newsletter.

June and July seem to have been a lean month for observations from around the world. I suspect that this is due to a combination of poor weather, and the low altitude of the Moon for the majority northern hemisphere observers.

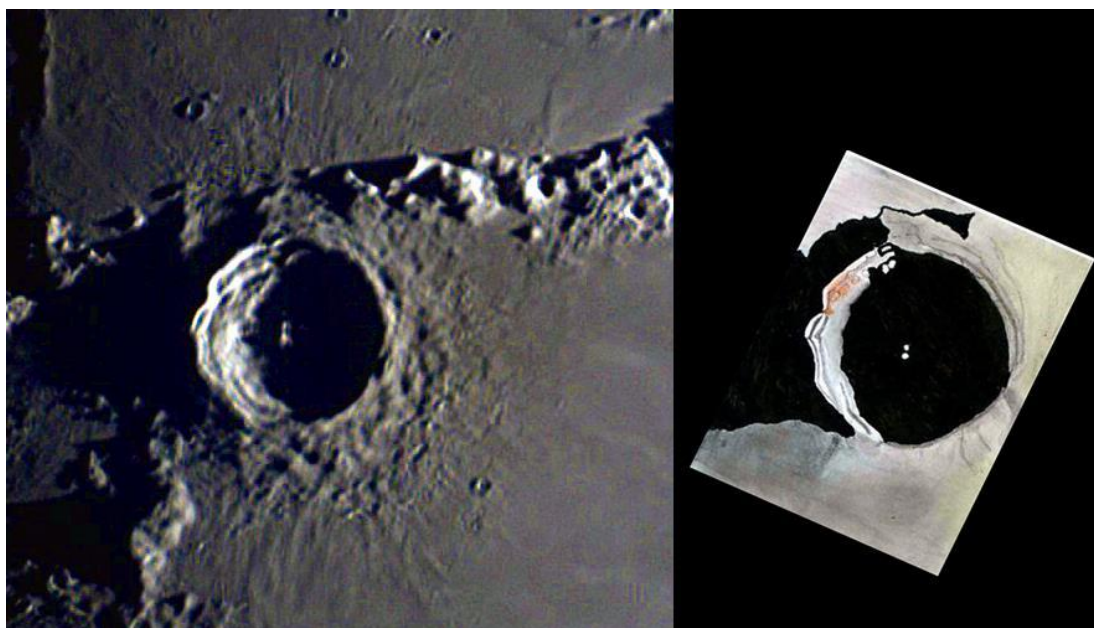
**Level 1 – Reports received for June included:** Jay Albert (Lake Worth, FL, USA - ALPO) observed: Alphonsus Kies and Plato. Alberto Anunziato (Argentina – SLA) observed: Agrippa, Plato, Swift and several features. Anthony Cook (Newtown, UK – ALPO/BAA) obtained video of earthshine in monochrome, colour images of several features, and the lunar surface in thermal IR. Rik Hill (Tucson, AZ, USA – ALPO/BAA) imaged: Clavius, Moretus, Rupes Recta and Tycho. Trevor Smith (Codnor, UK – BAA) observed: Archimedes, Aristarchus, Bullialdus, Plato, Tycho and several features. Aldo Tonon (Italy – UAI) imaged: Eratosthenes.

**Reports received for July included:** Jay Albert (Lake Worth, FL, USA - ALPO) observed: Birt, Copernicus, Hevelius, Plato, Posidonius, and Proclus. Anthony Cook (Newtown, UK – ALPO/BAA) imaged several features in the colour, and the lunar surface in thermal IR. Les Fry (West Wales – NAS) imaged: Babbage, Blancanus, Capuanus, Longomontanus, Moretus, Promontorium Kelvin, Schickard, T. Mayer and Vieta. Leandro Sid (Argentina – AEA) imaged: Cassini, Mare Anguis, Plato and several features.

## **Level 2 – Example Observations Received:**

**Eratosthenes:** On 2021 Jun 18 UT 20:48-21:15 Aldo Tonon (UAI) imaged this crater for the following lunar schedule request:

*ALPO Request: This request comes about because of two observations. Firstly, on 2009 Nov 25 Paul Abel and others detected some colour on the inner west illuminated slopes of this crater. No similar colour existed elsewhere. On 2012 Aug 25 Charles Galdies imaged this crater and detected a similar colour, approximately in the same location, though he also imaged colour elsewhere. It is important to replicate this observation to see if it was natural surface colour, atmospheric spectral dispersion, or some effect in the camera that Charles was using, namely a Philips SPC 900NC camera. The minimum sized telescope to be used would ideally be an 8" reflector. Please send any high resolution images, detailed sketches, or visual descriptions to: a t c @ a b e r . a c . u k .*



**Figure 1.** *Eratosthenes* orientated with north towards the top. **(Left)** An image by Aldo Tonon (UAI) take on 2021 Jun 18 UT 20:48. The image has been colour normalized and had its colour saturation increased to 65%. **(Right)** A sketch by Paul Abel (BAA) made on 2009 Nov 25 between 18:42 and 20:18UT. Colours have been exaggerated slightly.

We have had several repeat illumination observations of this crater, mentioned in the following news letters: [2012 Oct](#) (p15-16), [2016 Feb](#) (p18-19), [2017 Sep](#) (p19-20), [2017 Dec](#) (p23), [2021 Apr](#) (p56-57), [2021 Jun](#) (p37). Aldo's image (Fig 1 Left) is very sharp, but it also most notably lacks colour from atmospheric spectral dispersion and chromatic aberration. Clearly there is no natural surface colour in the location (Fig 1 – Right) where Paul Abel, and others, saw a TLP back in 2009. What was interesting about the 2009 report was that the observers at Selsey, England did definitely check for false colour elsewhere on the Moon but couldn't see any till much later, however atmospheric spectral dispersion was seen by Bill Leatherbarrow up in Sheffield at the same location as Paul saw, but also elsewhere on the Moon. Richard McKim over in Peterborough, and Marie Cook in Mundesley, were unable to detect any colour. I wasn't able to observe till later that night, by which time 20:43UT atmospheric spectral dispersion was present on several craters, causing brown on the east exterior rim of Eratosthenes, and red on the emerging central peak. We need to keep on observing this crater under a variety of lunar altitudes to see if the effect repeats - where it was seen by Paul in 2009, and whether atmospheric spectral dispersion can be proven definitely to be the cause.

**Kies:** On 2021 Jun 20 UT 02:30-02:55 Jay Albert observed this area under similar illumination to the following report:

*On 1984 Jun 09 at UT 04:55-05:14 P. Jean (Outremont, Canada) detected in the dark side of the Moon, a few km east of Kies crater, a bright point that should not be poking out of the shadow (according to Foley). The Cameron 2006 catalog ID=244 and the weight=3. The ALPO/BAA weight=2.*



**Figure 2.** A colour image of the region around Kies taken by Jay Albert (ALPO) on 2021 Jun 20 UT 02:47. Captured with a cell phone through his Celestron NexStar Evolution 8" SCT using a 7mm Ortho eyepiece and a Celestron NexYZ adapter. North is towards the top. The image has been colour normalized and then had its colour saturation increased to 65%.

We have covered this repeat illumination event before in the [2017 Nov](#) (p25) newsletter. Jay used his Celestron NexStar Evolution 8" SCT with x290 magnification. The Moon was quite high up in the sky but transparency was poor. Seeing was mostly stable at 6-7/10 but deteriorated sharply at times when thin clouds passed by. Upon observing this region Jay was immediately struck by the fact that the terminator was well west of Kies and hence there was no bright point... poking out of the shadow on the dark side of the Moon. A cell phone image was taken (See Fig 2) and shows indeed that the terminator was even beyond the craters Campanus and Mercator. Perhaps Jean meant 1984 Jun 08 instead of 1984 Jun 09? It's probably worth lowering the ALPO/BAA database weight from 2 to 1, and trying out this scenario for illumination in the lunar schedule website.

**Plato:** On 2021 Jun 20 UT 21:37-21:55 Trevor Smith (BAA) Observed this crater under similar illumination to the following report:

*Plato 1967 May 20 UT 01:13 K.Simmons (Jacksonville, FL, USA, 10" reflector) observed a large bright (intensity 6.5) oval area on near the central floor. According to Ricker and Kelsey (ALPO selected area coordinators) this is unusual. ALPO/BAA weight=1.*

Trevor was using a 16" f/6 Newtonian with a 9.5mm Plossl eyepiece at x247. The seeing was Antoniadi IV. Trevor noted that the crater looked normal to him in white light, red (Wratten 25) and blue/green (Wratten 44a) filters. There was no oval at the centre of the crater, just the central craterlet and nothing else visible on the floor under the poor observing conditions. Looking back at the original 1967 report, in JALPO Vol 31, p163, it mentions that out of the craterlets on the floor of Plato, only the central one was visible; however, the oval was slightly to the west (IAU) of this. So, what Trevor reports in 2021 is the normal appearance and the offset oval seen in 1967 was abnormal. We shall leave the weight of this report as 1 for now.

### Level 3 - In Depth Analysis:

**Agrippa:** On 2021 Jun 19 UT 22:35-22:45 Alberto Anunziato (SLA) observed this crater under similar illumination to the following report:

*Agrippa 1966 Oct 24 UT 01:48-02:12 Observed by Bartlett (Baltimore, MD, USA, 5" reflector, x283, S=6, T=3-2) "Shadow of c.p. light & grayish, scarcely distinguishable from floor. (Sun is quite high (39deg) so shadow ought to be nearly gone)."NASA catalog weight=4 (good). NASA catalog ID #985. ALPO/BAA weight=2.*



**Figure 3.** *Agrippa orientated with north towards the top. (Left) A virtual view, under similar illumination to Alberto's sketch courtesy of NASA's [Dial a Moon](#). (Right) A sketch by Alberto Anunziato, at the date and UT stated in the sketch. Note that the labels have been re-orientated and the image mirror flipped to put north at the top and east on the left.*

Alberto was using a Meade EX 105 scope at a magnification of x154. He noted a (Fig 3 - Right) tiny grey shadow of the central peak seemed similar to the description by Bartlett.? The similarity in illumination to Alberto's sketch (Fig 3 – Right) and the Dial a Moon image (Fig 1 – Left) is in agreement too. Therefore, I think we can remove the Bartlett TLP report from the ALPO/BAA database by assigning a weight of 0.

**Cassini:** On 2021 Jul 17 UT at 21:49-21:50 Anthony Cook (ALPO/BAA) and at 22:25UT Leandro Sid (AEA) imaged this crater under similar illumination to the following report:

*Knopp of Paysandú, Uruguay on 1885 Feb 22 at 23:00-23:30? UT saw a definite light, looking like Saturn in Cassini? The previous night he had seen red patches in the crater. Cameron's 1978 catalog ID=348 and weight=4. ALPO/BAA weight=3.*



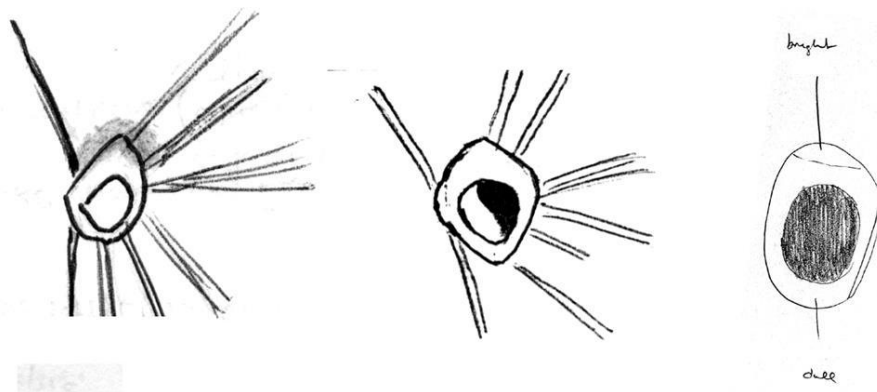


**Figure 4.** Cassini on 2021 Jul 17 and orientated with north towards the top. **(Left)** Image by Anthony Cook (ALPO/BAA) taken at 21:49-21:50UT. **(Right)** Image by Leandro Sid (SLA) taken at 22:25UT.

Now the Cameron catalog has a “?” for the UT given. There were actually two events observed. On 1885 Feb 21 red spots were seen. The following night a Saturn-like feature in Cassini crater. Now take a look at the images by myself and Leandro – both were made under poor observing conditions. Take a look at Cassini A, the larger of the two craterlets inside Cassini in Fig 4 – can you see a light diagonal area coming off the SE of Cassini A? With a bit of seeing flare (image ghosting) and imagination there is potentially a more stubby/shorter lighter projection coming off the NW of Cassini A. Taken together, with Cassini A slightly offset from the centre, it could be argued that these look like a blurry view of a nearly edge-on ring aspect of Saturn. This is perhaps more clearly visible in Fig 4 (Right). We cannot be too sure over this, but it is certainly plausible. I will therefore lower the ALPO/BAA weight from 3 to 2.

**Proclus:** On 2021 Jul 20 UT 01:10-01:50 Jay Albert observed crater under similar illumination to the following report:

*Proclus 1989 Jul 13 UT 21:04-21:13 Observed by M.Cook (Frimley, UK, 90mm Questar Cat., Seeing III, transparency hazy) and by Moore (Selsey, England) "Following an alert call by Miles concerning the crater Proclus looking different, Cook observed a circular dark patch that filled about half of the eastern half of the crater floor. To cut down the glare a blue filter was then used and a slightly less dark area was seen extending from this in a southerly direction. 8 rays were seen. The dark patch was confirmed by Patrick Moore. However, David Darling (USA) who observed a few hours later on 1989 Jul 14 at 03:28 UT could not see this dark patch." BAA Lunar Section observation. The Cameron 2006 catalog ID=370 and weight=? The ALPO/BAA weight=2*



**Figure 5.** Sketches of Proclus, orientated with north towards the top and west on the left. **(Left)** A sketch by Marie Cook (BAA) made on 1984 Nov 03 UT 23:06 with a 12" Newtonian. **(Centre)** A sketch by Marie Cook (BAA) on 1989 Jul 13 UT 21:04-21:17 with a 90mm Questar. **(Right)** A sketch by Jeremy Cook (BAA) on 1989 Jul 13 UT 22:31 with a 90mm Questar.

Jay was using a Celestron NexStar Evolution 8" SCT at 226x and 290x. The Moon high in altitude (compared to the 1989 observation. Transparency was poor though with only 1<sup>st</sup> magnitude stars visible and seeing was 7-8/10. He saw the dark gray, roughly circular dark patch taking up half of the E floor of the crater. The patch appeared to be somewhat elongated N-S. He tried an 80A blue filter which slightly improved the contrast and a 23A red filter which improved the contrast slightly more. The filters didn't change the overall appearance of the crater though. Jay noticed the usual prominent ejecta rays extending NW and SW from the crater, plus a few faint ejecta rays extending E over Mare Crisium.

Checking back through the archives I came across sketches by Marie and Jeremy Cook (Fig 5 – Centre and Right) showing the dark appearance to the floor. Then in Fig 5 (Left) we see a sketch by Marie Cook, from about five years earlier, but taken under the same illumination, which shows a very similar number of rays, but doesn't indicate a dark floor. Although no sketch was made by Patrick Moore during the TLP in 1989, he did make a comment that Proclus had a bright patch on its north wall (agreeing with Jeremy's sketch – Fig 5 Right) and the floor was unusually dark – similar to the darkness of Mare Crisium.

Jay's 2021 observation agrees with the appearance of the dark interior seen by Marie in 1989, but not with the appearance in 1984. I suppose by the time that Jeremy and Patrick were observing in 1989 the Moon must have been much lower and so definition must have been worse. At least Patrick and Jeremy agreed that the floor of the crater was dark and the north rim was bright. Perhaps it was the 1984 observation that was unusual and the 1989 appearance was normal? Now in view of some slight differences in descriptions between the 1989 observations, small aperture instruments were being used, and the fact that the Moon was only 13° to 11° above the horizon when Marie observed the TLP, I will lower the weight from 2 to 1. But we do need to keep it on the system as images are needed to verify the darkness of the floor of Proclus in comparison to Mare Crisium.

**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](http://users.aber.ac.uk/atc/lunar_schedule.htm) . By re-observing and submitting your observations, only this way 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? If you would like your observations to be considered for mention in the next newsletter, then they should be submitted by 17:00UT on the 24<sup>th</sup> of July, covering observations for June. Please send observations in, even if older than this as they are still very useful for future repeat illumination studies. This can be found on: [http://users.aber.ac.uk/atc/tlp/spot\\_the\\_difference.htm](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/ltip.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

### **THEOPHILUS, CYRILLUS AND CATHARINA**

Sketch by Tor Schofield



The above is of a well-known trio of craters that you would see when the Moon was just over 6 days old. Theophilus is 100 km in diameter – a handy scale comparison for judging the sizes of other craters! You can tell that Theophilus is the younger of the three as it overlies Cyrillus, and has the less degraded central peak of these three complex craters. Catharina is the considerably more eroded of the three, and so

probably the eldest. Tor sketched this area from an observation made at Maria Alm, close to the Hochkönig Massif in the Austrian Alps. He used a Bresslar 70/900 scope and rendered the sketch using 2H and B pencils. The date and UT given for the observation was 2021 Jul 15 UT 19:00-19:58. – Tony Cook

## **APOLLO 11 LANDING SITE**

Image by Paul Brierley





I can't remember what I was doing on this day in 1969, as Apollo 11 with its crew of three brave ambassadors from Earth onboard. I was only 5 and just a wee boy, wet behind the ears. But on 2021 Jul 16 UT 19:55, I was able to image the Mare Tranquillitatis area and the Apollo 11 landing site. Details: Altair GPCAM3 290M, William Optics Megrez II 80mm EDT with a 2x ED Barlow and Baader IR Proplanet filter. The Moon was veiled behind a film of high-altitude cirrus which made it appear soft and lacking in contrast. But despite this, using my processing skills, I have been able to pull out a lot of visible detail. North is towards the bottom left. - Paul Brierley

## **BAA LUNAR SECTION CONTACTS**

### **Acting Circulars Editor/Assistant Ditector**

Tony Cook (atc @ aber.ac.uk)

### **Website Manager**

Stuart Morris [contact link via the Section website at [https://britastro.org/section\\_front/16](https://britastro.org/section_front/16)]

### **Committee members**

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