BAA Lunar Section
British Astronomical Association
Director: Bill Leatherbarrow

LUNAR SECTION CIRCULAR

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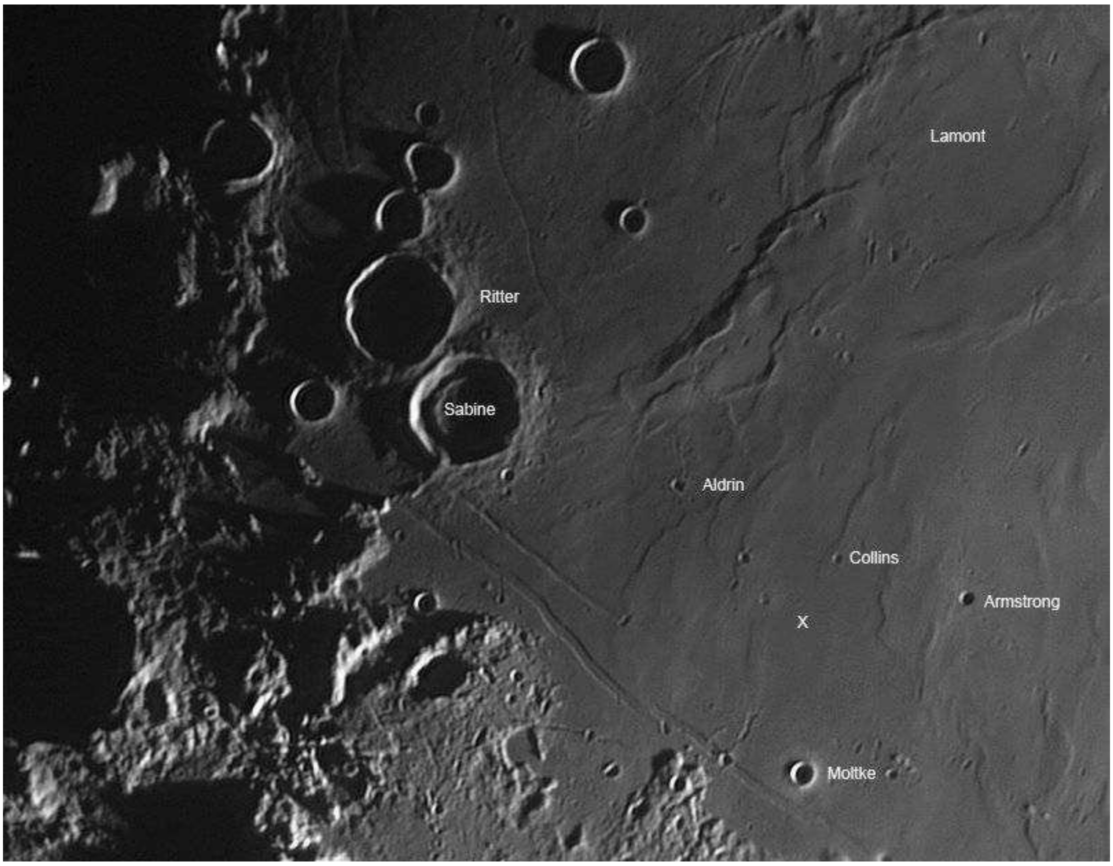
FROM THE DIRECTOR



Area of Apollo 11 landing site (image Bill Leatherbarrow)

16 July 2019 will mark the fiftieth anniversary of Apollo 11 and the first Moon landing. For those of us old enough to remember those halcyon days there will be mixed feelings. Memories of the excitement generated by humankind's greatest voyage of discovery will be tempered by disappointment at the fact that in the subsequent half century we have made no further progress in manned exploration of the Solar System. Yes, we have made huge strides forward in robotic probes to other

worlds, but our species has not ventured beyond low earth orbit since the early 1970s. Perhaps that is about to change.

At the time of the Apollo missions I participated in NASA's Lunar International Observers Network (LION), a group charged with monitoring the Moon's surface for transient phenomena while the Apollo astronauts were in orbit or on the surface. They were exciting times and, although I saw nothing unusual, it was a novel feeling to be observing the lunar surface knowing that men were upon it.

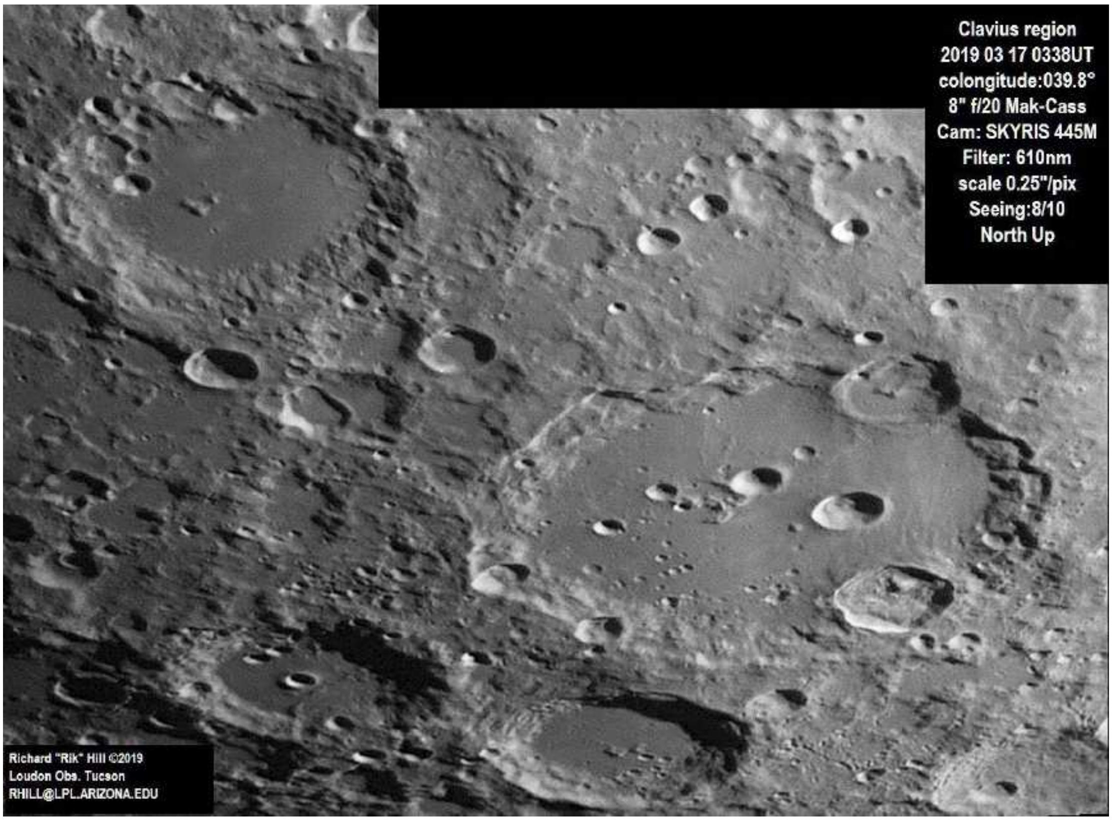
I have written a couple, of items for the BAA Journal and website to mark this summer's anniversary, but I thought it would be nice if any other Section members old enough to recall those distant days had memories of their own they would like to share. If so, please send them in to me. If there are enough we might use them in an issue of the Circular closer to the time.

Bill Leatherbarrow

OBSERVATIONS RECEIVED

Drawings and images have been received from the following observers: Paul Abel, Leo Aerts (Belgium), Dave Finnigan, Rik Hill (USA), Rod Lyon, Mark Radice, Dave Scanlan, Bob Stuart, Ivan Walton, and the Director.

Rik Hill has submitted several fine images, including one of the Clavius region.



Rik writes as follows:

‘Another one of those breathtaking scenes that sneak up on you on the terminator. Of course the huge crater just right of center is Clavius at a whopping 231km diameter. On the northeast wall (upper right) is Porter (54km) and on the southeast wall is Rutherfurd (56km), the youngest of the three craters as the ejecta splash might hint. The distinctive arc of craters on the floor of Clavius that starts with Rutherfurd, arcing to the left (west) are Clavius D, C, N and J. Between C and N notice the curious formation of mountains.

The crater below Clavius is Blancanus (109km) and to the west of it is slightly larger Scheiner (114km). Above and to the west of Clavius is another larger crater Longomontanus (150km). All three of these craters, like Clavius, are Nectarian (3.85-3.92 billion years old) or Pre-Nectarian (3.92 to 4.55 b.y.o.), or roughly 16 to 18 rotations of our galaxy ago! Notice the crater in the lower right corner, Gruemberger (97km). Between it and Blancanus is a wonder field of secondary cratering. Lots of great things to explore here!’

Clavius is, of course, a popular target for lunar imagers – and deservedly so. However, Rik has also submitted a study of the little-known formation Wolf, located near the crater Bullialdus. This is an unusual feature, probably the remains of one or more flooded craters. Its unusual nature ic captured both in Rik’s image and in a photograph taken from the Apollo 16 mission.

Rik writes the following:

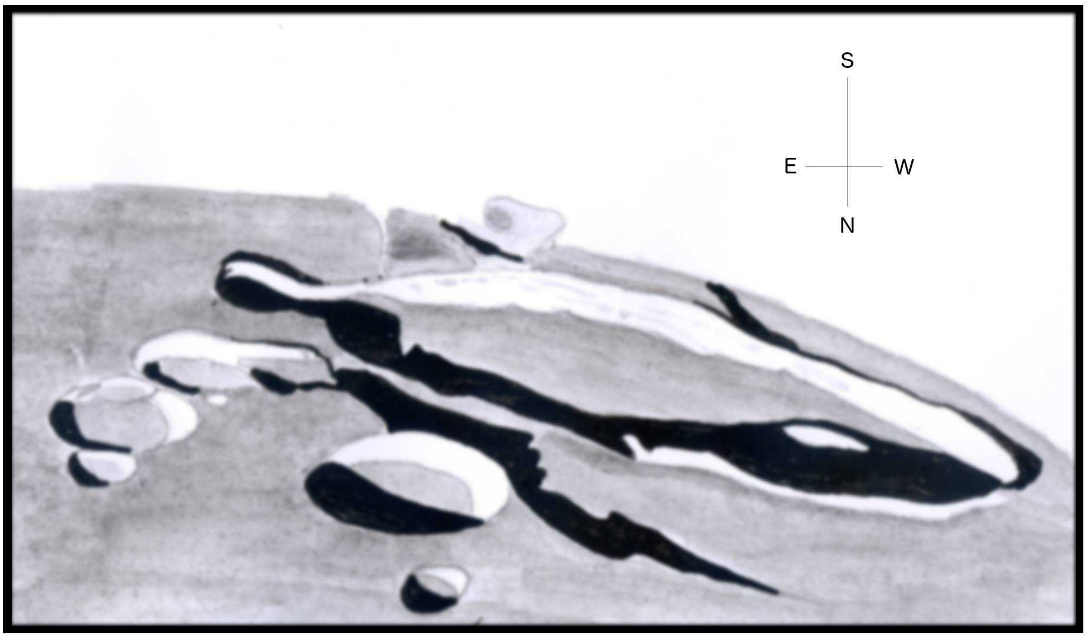
‘A little south of center in Mare Nubium lies a curious feature, the 26km diameter "crater" Wolf, sitting there like a lunar interior retainer snap ring. Now I'll pause a moment while you scramble to your search engines to see what *that* is. This crater is named after the astronomer with the unpretentious name Maximilian Franz Joseph Cornelius "Max" Wolf. It's a pre-Imbrium feature maybe as old as 4.5 billion years which was probably highly modified during the Nubium flooding event about the same time. The southern wall of this heart-shaped crater, was obviously breached making it *look like* the ejecta blanket was something that flowed out of the interior but, looks can be deceiving. This is really the remnants of two, possibly three, overlapped craters. The walls only rise to 700m above the surrounding plain. A low angle image taken with Apollo 16 shows how flat this feature is.

A few other features in my image are, in the upper left, the big crater Bullialdus (63km) with it's wonderful central peak reminiscent of the one in Theophilus. Just below Bullialdus is Bullialdus A (26km) and Bullialdus B (21km) a little farther out. To the left of these is König (24km). Directly above Wolf is an angled mountain that is the western wall of Gould (36km), Even at this sun angle you can still see the gash that cuts almost east-west through the south half of Gould. Due east or right of Wolf is Nicollet (15km) and lastly south west of Wolf is the ghost crater Kies (46km) and just west of that the beautiful Kies 1 dome also called Dome Kies. Unfortunately you cannot see the central pit in the dome as it is just below the 2km resolution of this image.'

It is always good to see that a few of our members are still keeping alive the traditions of visual observation and drawing. While it is true to say that the eye cannot match the resolution of the latest planetary cameras, visual work maintains an essential link with the past and allows us to understand the achievements of our predecessors. High-resolution lunar imaging is by no means straightforward, even with the benefits of modern technology, but we should not underestimate the skills required to depict the Moon's surface using eye and pencil.

Paul Abel is one of the BAA's best known and most experienced visual observers, but by his own admission he is a relative beginner in lunar observation. He has sent in the following sketch of the strange elongated crater Schiller, and I hope he will submit more of his work in future.

Schiller & Bayer Crater

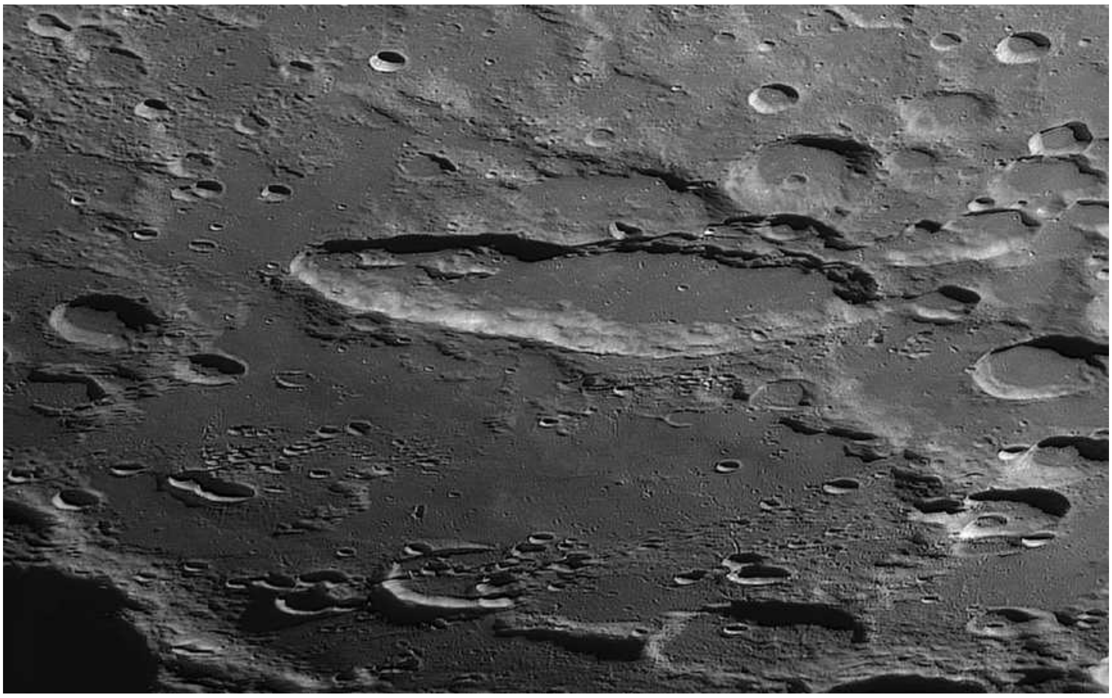


Date: 2019 March 17th Start: 2003UT Finish: 2024UT, Seeing: AIII, Transparency: Good
203mm Newtonian Reflector, x167. Filter(s): None- integrated light only.
Phase= 85.4%, Moon's age: 11.2d, Colongitude: 48.4° to 48.5°

Paul G. Abel, Leicester UK.

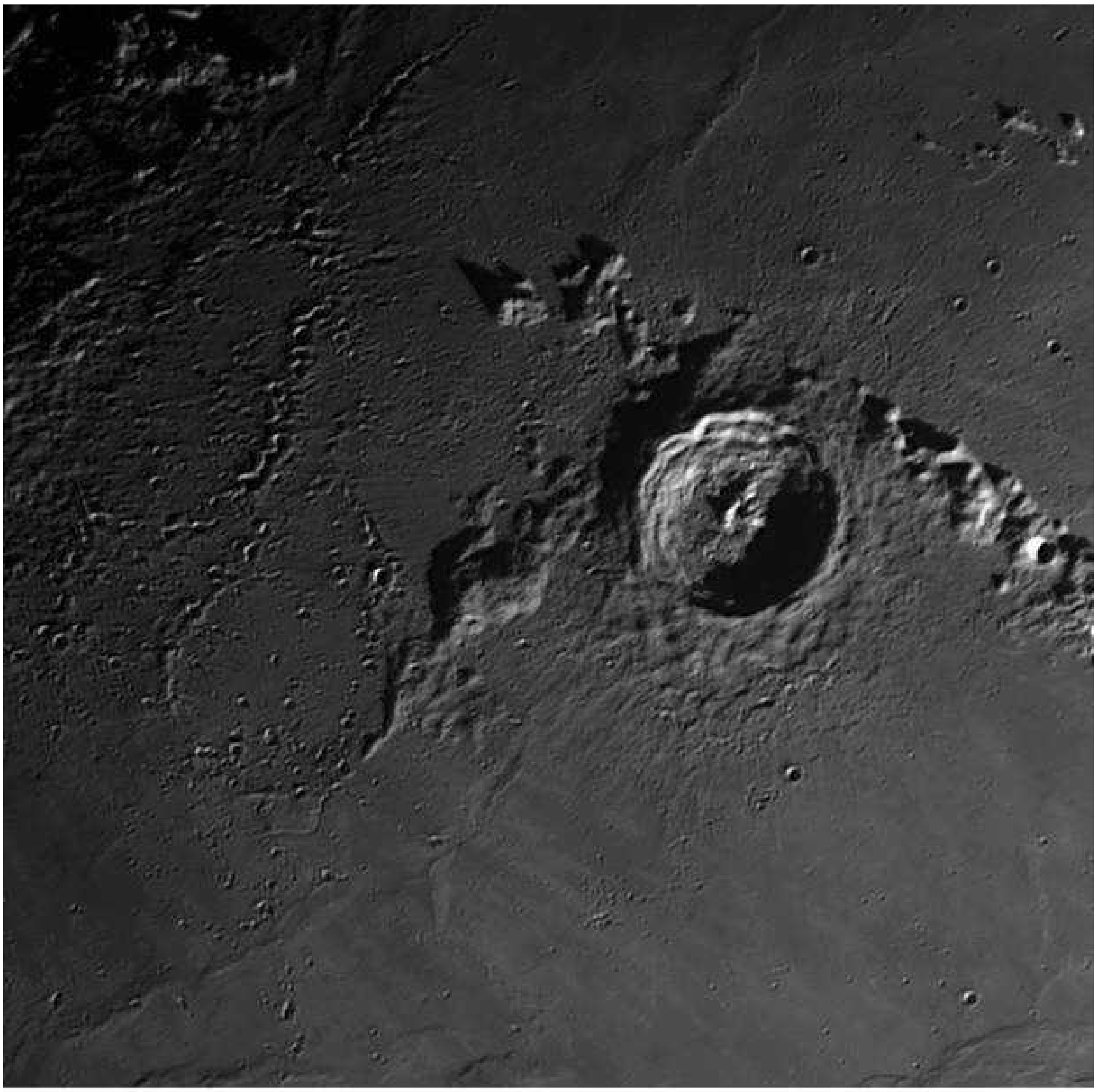
As space is tight in this month's issue I attach below, without commentary, a selection of images received, starting with Leo Aerts' stunningly detailed captures of Palus Putredinus (11 February 2019) and Schiller (16 February 2019), both made with a C14.

Palus Putredinus, 11 February 2019 (Leo Aerts)



Schiller, 16 February 2019 (Leo Aerts)

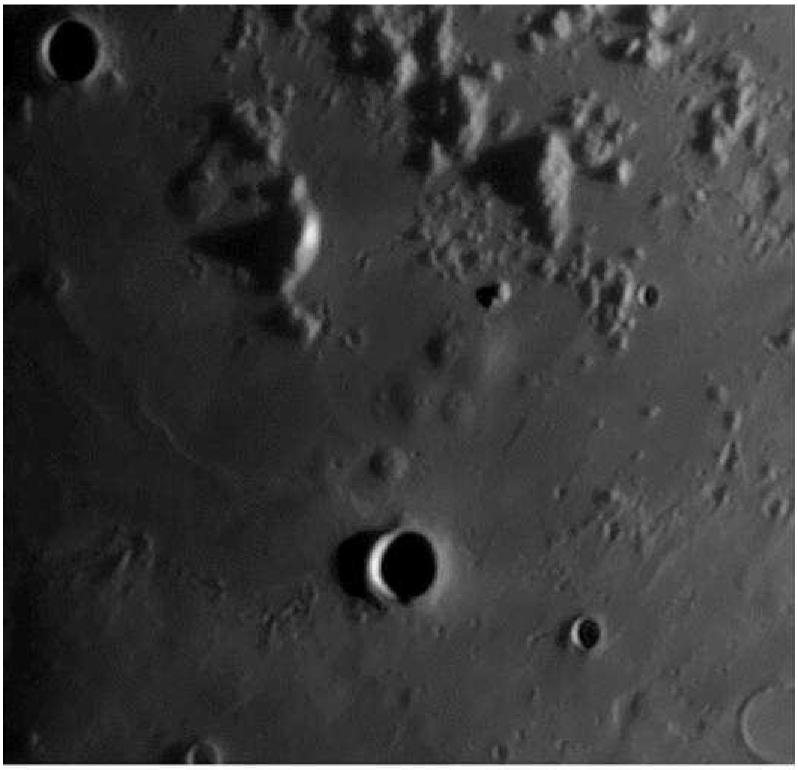
Rheita Valley, 21 February 2019, 23.20 UT, 250mm Newtonian (Bob Stuart)



Eratosthenes & Stadius 2019.02,13 - 21.21 UT
Meade 300mm LX90, ASI224 MC Camera,
Pro Planet 742nm I-R Pass Filter.
1050/3000 Frames. Seeing 8/10, with slight
turbulence

(Rod Lyon)

Anaxagoras to Philolaus 2019.02.15 19:18 UT, S Col. 43.1°, seeing 4/10, transparency good.
Libration: latitude +3°11', longitude -06°21'
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



Hortensius Domes
14 February 2019 2232Z
C11 f18 ASI224MC 685nm IR filter

Mark Radice RefreshingViews-com

NEW AND OLD CRATERS SIDE BY SIDE?

Barry Fitz-Gerald

The recent spectacular images returned by the NASA New Horizons probe of the KBO Ultima Thule illustrate quite graphically that the Solar System is probably full of small objects that are either contact binaries or binaries. Previous missions to asteroids have also identified the fact that many of these bodies have their own moons. These objects probably give us a good idea of what planets are made of, and what the early Solar System looked like. Of course you need not travel to the outer edges of the Solar System to work this out, as it is becoming quite apparent that many of the crater-forming bodies that have struck the Earth-Moon system in the past were not solitary travellers but gregarious creatures.

The Moon provides ample evidence of this, with many binary and multiple impact craters being present. There is even a possibility that the craters Copernicus and Pytheas were formed at the same time and represent the impact of a binary pair [1]. Research on simultaneous impacts has identified features produced during the crater-forming process that allow such pairs to be identified [2],[3]. The degree to which these features are developed depends on many factors such as the size and separation of the two (or more!) bodies, but overlapping or elongated craters are reasonably diagnostic. Even more so are the prominent radial lobes or more accurately combined ridge/crater chains formed by the collision of the ejecta curtains from each crater, the same process that produces the 'herringbone' pattern seen in secondary crater chains. As with everything there are exceptions to the rule, and a brief tour of some binary craters will illustrate that not all such pairs are obvious.

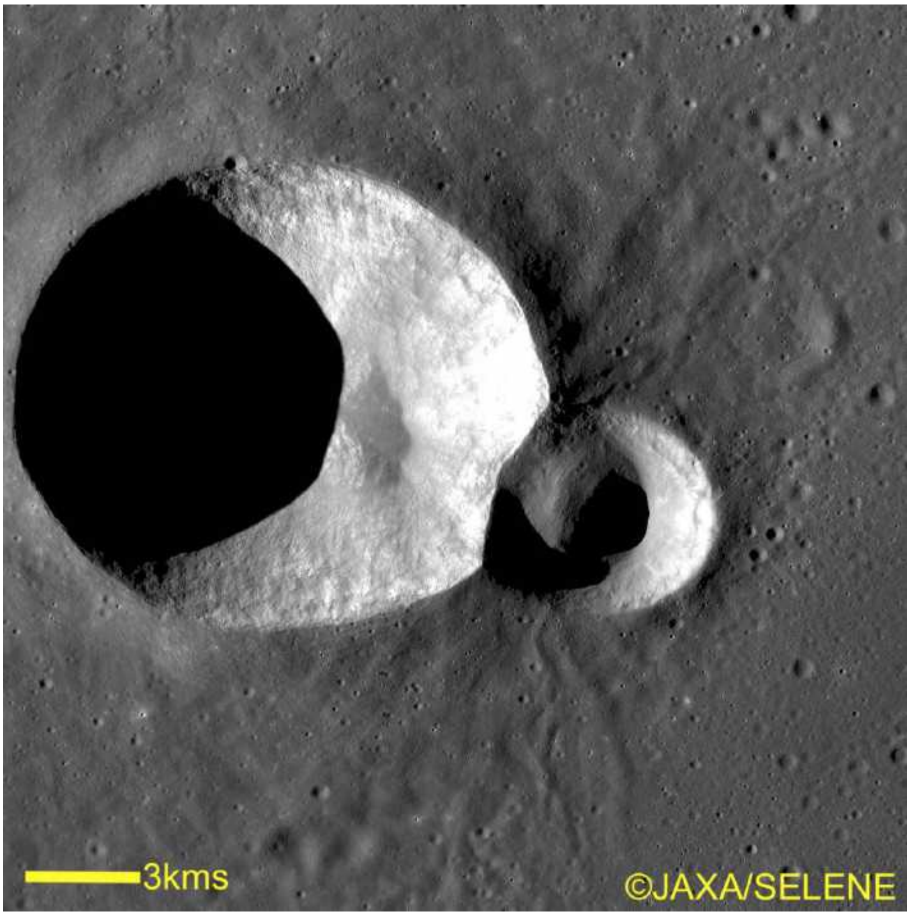


Fig.1 JAXA/SELENE image of Birt and Birt A showing the conspicuous ridges in the ejecta extending away to the north-east and south, and approximately the junction between the two craters.

A good place to start is with the craters Birt and Birt A. There has been some speculation about the nature of the Birt pair in the past but Fig. 1 clearly shows the ridge-like lobes extending out from the area where the two craters intersect. I use the word 'area' deliberately in this case because as you can see not all the ridges emerge from the 'neck' between the craters and this probably reflects the fact that the impact took place on the Moon's surface and not in a laboratory or computer where the ridges would have been nice and symmetrical. These ridges are pretty good evidence that the Birt pair represents the simultaneous impact of two bodies, one larger than the other possibly in the form of a binary or contact binary asteroid. I am always reminded of a water flea when I see these binary crater ridges, a quick search for images of this little creature on the internet will show you why.

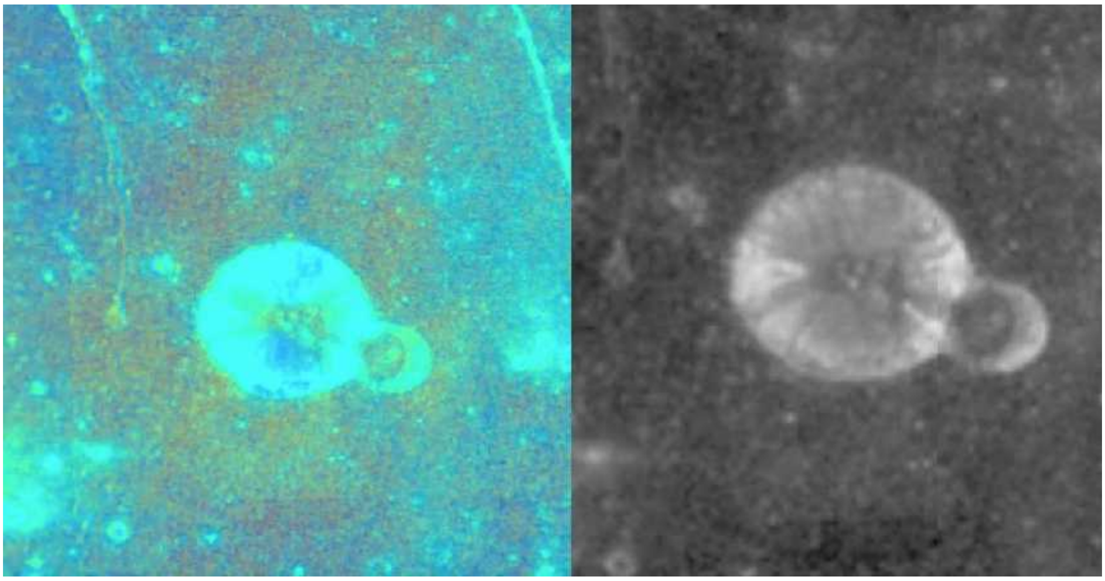


Fig. 2 Clementine UVVIS Colour Ratio (left) and UVVIS Optical Maturity (right) images. Note the orange 'wings' of ejecta around the craters, also the more optically mature (darker/older) appearance of Birt A in the Optical Maturity images.

We can tease out more information on the crater pair from the Clementine Colour Ratio and UVVIS Optical Maturity images shown in Fig. 2. The Colour Ratio image shows orange 'butterfly wings' of ejecta to the north and south. This shows that the Birt pair formed by a low-angle impact from the west-northwest which excavated older low titanium material which make up the wings from beneath the higher titanium mare surface. A look at the WAC-Nearside (big shadows) overlay in Quickmap also shows a clear zone-of-avoidance in the proximal ejecta to the west, just what we would expect in such a scenario. A look at the UVVIS Optical Maturity images shows that whilst Birt has a low optical maturity (bright - indicating 'fresh' material and therefore of a relatively young age) Birt A *appears* slightly more optically mature and therefore slightly older. This is particularly the case for the floor of Birt A, which appears to consist of material that has slumped off the septum separating the two craters. This could be explained if Birt A was already present when the impact that formed Birt occurred, with the rim of Birt A being pushed outwards by the larger crater. However the evidence from the radial ridges strongly suggest a simultaneous event, and some other explanation for the appearance of Birt A must be found.

A quick detour to the binary craters Fontenelle F and C (Fig. 3) and Bessarion B (Fig. 4) shows that this sort of post-impact modification by slumping off the septum separating the craters is quite common. Both of these crater pairs appear to have formed from impacts where the impacting bodies were slightly further apart than the case in Birt and Birt A.

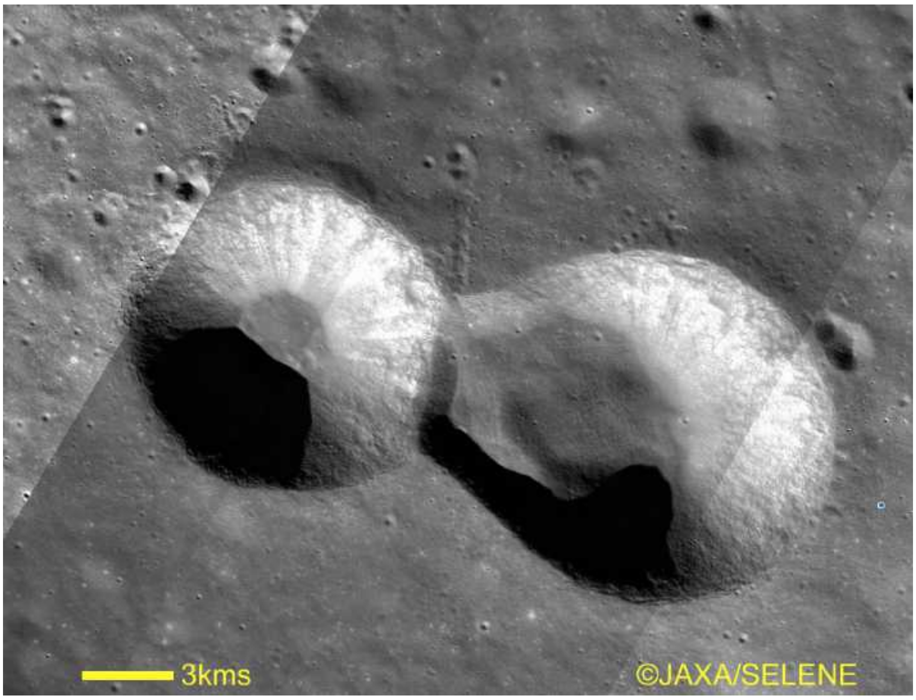


Fig. 3 JAXA/SELENE image of Fontenelle F and C showing the short crater chain extending northwards from the intersection of the two craters and the prominent slump on the floor of Fontenelle C.

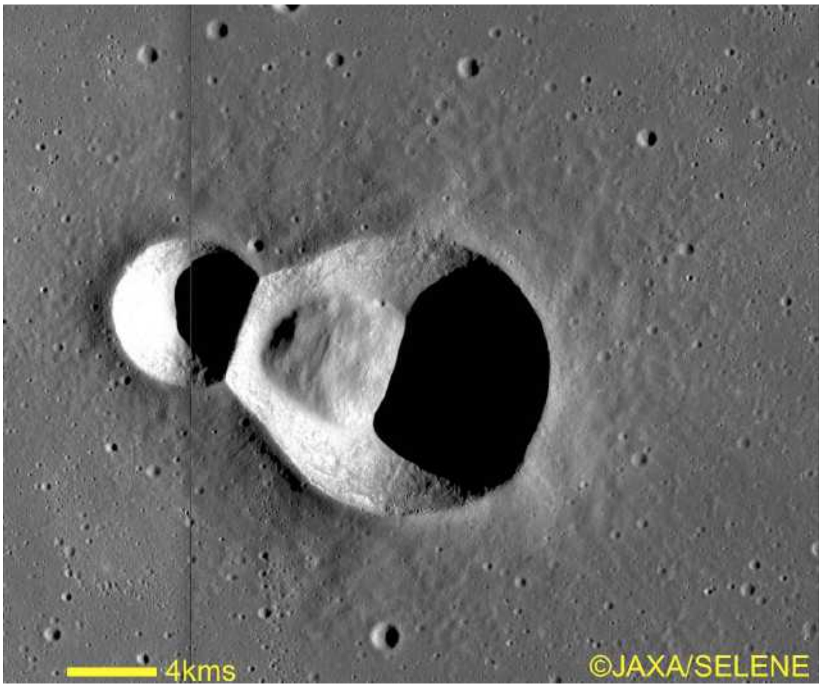


Fig. 4 JAXA/SELENE image of Bessarion B and unnamed companion crater to the north-west. Note the prominent slump away from the intervening septum and into the larger crater.

A short crater chain extends north from the junction of Fontenelle F and C which is evidence of a binary impact, but the strongly developed ridges seen in Birt are absent due the increased separation of the impactors, which reduced the interaction between individual ejecta curtains. Both the Fontanelle and Bessarion pairs have that straight, sharp septum between the craters which is another characteristic of binary impacts, and as can be seen part of the rim has slumped away from this septum into one of the pair (coincidentally eastwards in both cases) modifying the outline of that crater from circular and into a flask shape. So, these slumps off the intervening septum seem to be a feature of binary craters, possibly because the thin fillet of terrain left between two such craters is so unstable that once the impact process is over it quickly collapses.

A side by side comparison of the UVVIS Optical Maturity images Fontenelle F and C and Bessarion B (Fig. 5) shows that both crater pairs exhibit broadly similar optical maturity, the exception being slump features which appears darker and therefore more optically mature. Of course this cannot be an age effect as the craters, their floors and the slumps are all of the same age, and part of the explanation would be that the crater rims and walls are subject to ongoing erosion and exposure of fresh material as the loose regolith moves downslope under the effect of gravity.

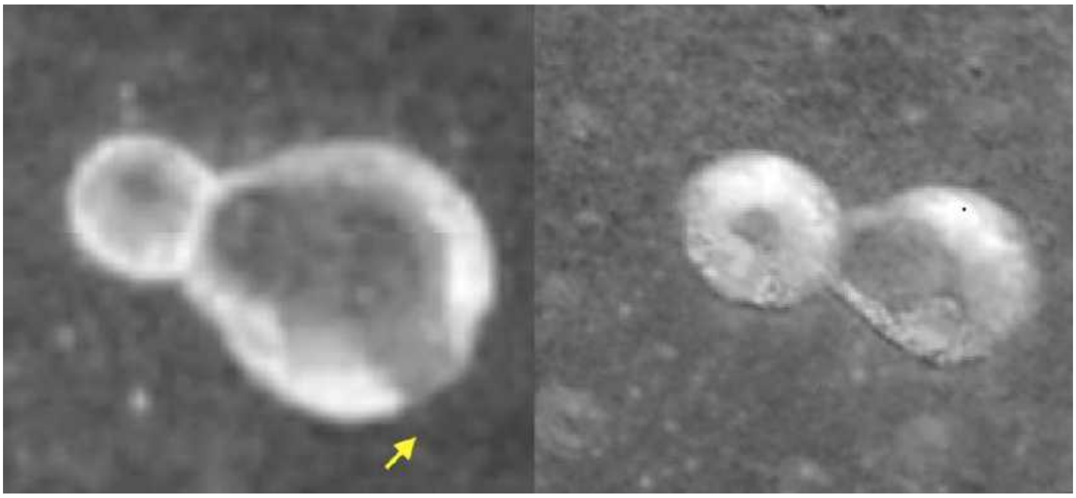


Fig. 5 Clementine UVVIS Optical Maturity images of Bessarion B (left) and Fontenelle F and C (right).
The yellow arrow shows impact melt thrown over the southeastern rim of Bessarion B onto the mare surface.

Another factor contributing to the darker appearance of the slumps is the fact that they are rich in impact melt as these slumps occurred during the crater modification stage, when the crater floor would have been awash in impact melt. Evidence of this can be seen in Bessarion B where the slump off the septum to the west pushed a large dollop of melt in the opposite direction, up the south-eastern crater wall and out onto the mare surface. So this type of process might well explain the slightly older appearance of Birt A compared to Birt in the optical maturity images, as impact melt can *appear* optically more mature (and therefore older) that fresh fragmented material of the same age.

Fig. 6 shows the intersection of the northern rims of Birt and Birt A, and as can be seen the rim of Birt A is smothered in extensive dark impact melt deposits. These deposits have concealed the sharp crater rim beneath, giving the false impression that the rim is older and more subdued due to space weathering, whilst the melt also looks optically more mature, enhancing the *apparent* age of Birt A. As we have already seen, the Birt pair were produced by an impact from the west-southwest, and such low-angle impacts tend to eject melt downrange, which would in this case be towards Birt A, so the rim being smothered with impact melt is no surprise. Melt is also concentrated at the interface between the two ejecta curtains during simultaneous impacts, so the extra helping of melt shown in Fig. 6 is again no surprise.

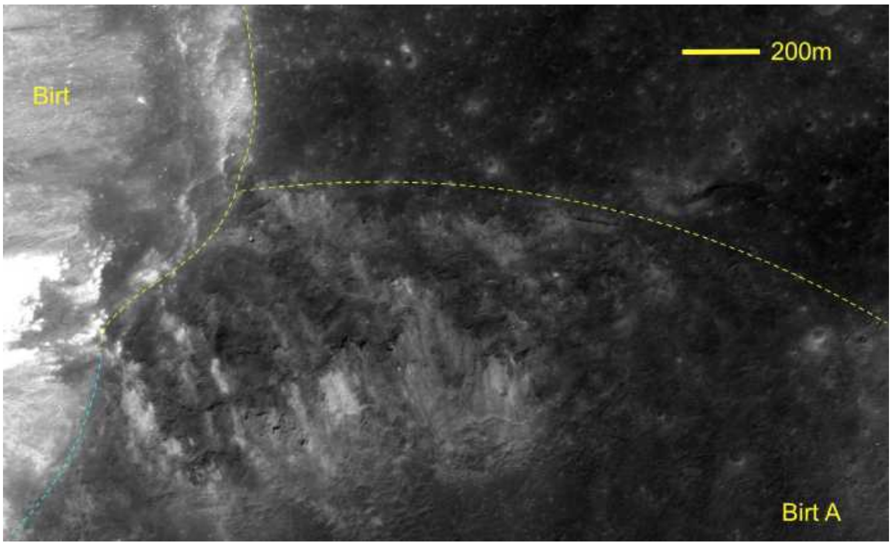


Fig. 6 NAC detail of northern rims of Birt and Birt A – the rims are marked by yellow dotted lines and the septum between them in blue. Note the dark impact melt deposits smothering the rim of Birt A.

Moving north-westwards into Mare Imbrium we find the fine binary pair of Heis and Heis A (Fig. 7). As with Birt and Birt A we can see the binary credentials in the form of ridges of ejecta extending outwards from the point where both craters intersect. The western filament is the most prominent, the eastern one harder to spot, but such irregularities are not unusual. As with Birt the Heis pair formed from an impactor arriving at a low angle, in this case from the south which is indicated by a prominent zone of avoidance in the ejecta in that direction. The floor of Heis has a curious configuration with sausage-shaped terraces to the east and west and a depressed floor between. These terraces are the result of the collapse of the eastern and western inner walls. An explanation for this odd disposition can be seen some 180kms to the east in the crater Gruithuisen which has a similar arrangement of terraces on the southern and northern side of the crater floor. Gruithuisen is another low-angle impact crater, elongated east-west and with an impactor having arrived from the west. So these sausage-shaped terraces are indicative of the collapse of the cross range walls of a low-angle impact crater – exactly what we see in Heis if the impactor came from the south.

If we look at the UVVIS Optical Maturity image of Heis we see something similar to, but more extreme than the Birt pair, in that Heis A *appears* to exhibit much greater optical maturity and therefore age than Heis, an impossibility as both craters are the same age (Fig. 8). As with Birt the reason for this is impact melt – liberally splashed downrange into and over Heis A. We get a good impression of this from the LROC-NAC image shown in Fig. 9, which shows a couple of interesting features resulting from the volume of melt that ended up in and on it. To the north, and running from the northern rim of Heis A for about 3.5kms downwards some 160m onto the mare surface is a ramp with lateral levees which was built up by flowing impact melt. The slope of the ramp is some 2°, so no steeper that your average lunar dome. A similar but more spectacular example can be seen extending from the south-eastern rim of the crater Arago, and both features were produced by a

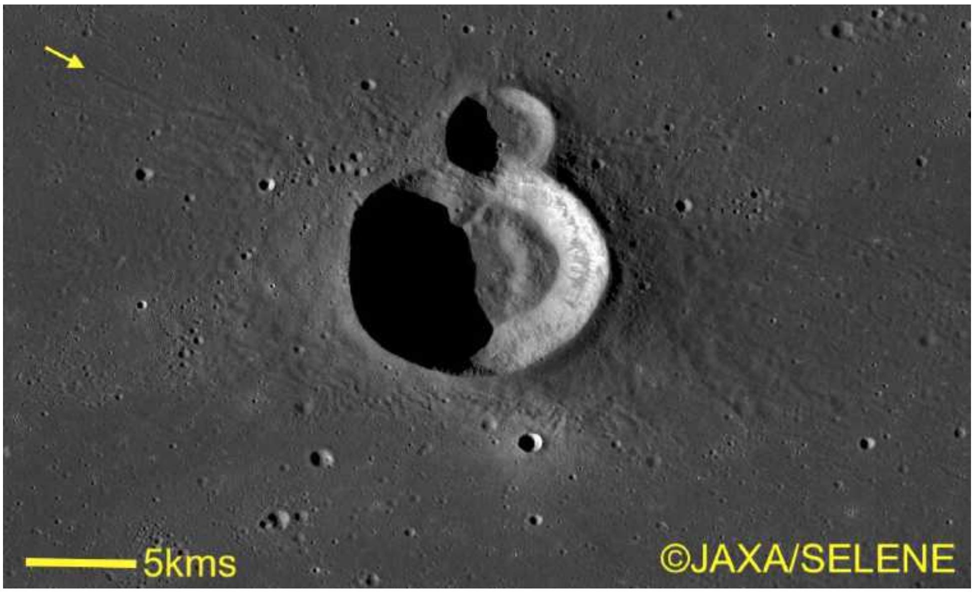
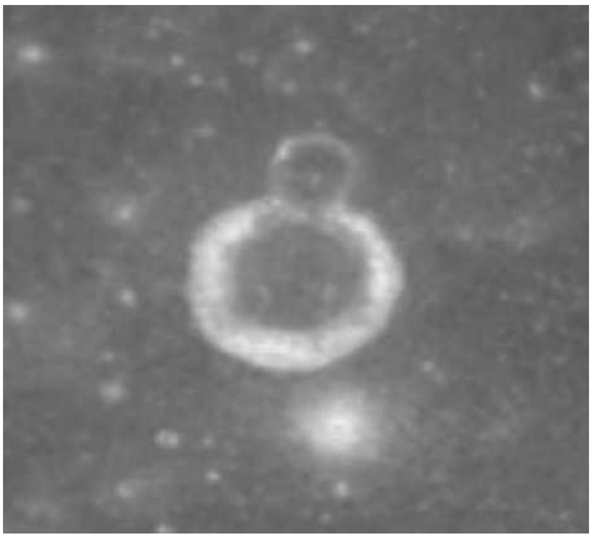


Fig. 7 SELENE image of Heis and Heis A. Note the ridge like filament of ejecta (arrow) extending to the north-west from the intersection of the two craters, as well as the zone of avoidance in the ejecta immediately outside the southern rim of Heis indicating a low angle impact from the south.

Fig. 8 Clementine UVVIS Optical Maturity images of Heis and Heis A



pulse or pulses of melt forced out of the crater and over the rim by material collapsing onto the opposite side of the crater floor. This would be consistent with the collapse of the intervening septum northwards into Heis A.

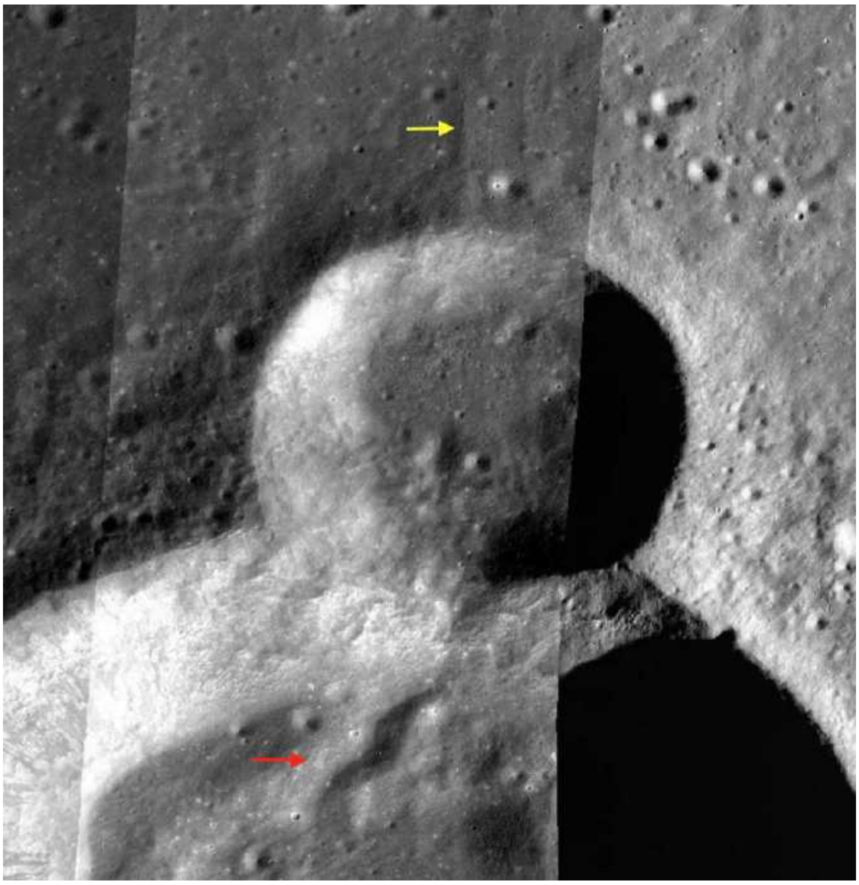


Fig. 9 Detail of Heis and Heis A showing the impact melt ramp from the northern rim of A (yellow arrow) and the channel carved in the northern terrace of Heis by impact melt draining southwards from A (red arrow).

The impact involved in the formation of the Heis pair appears to have been at a shallower angle than that of Birt, and to have produced a much greater amount of impact melt, in fact the level of melt that ended up in Heis A was sufficiently high that when the septum between the two craters collapsed, some of it flowed back to the south into the larger crater. As it did so it carved a short sinuous channel through the terrace of slumped material inside the northern rim of Heis. The volume of melt produced during the impact event was sufficient large to effectively smother Heis A which is why it *appears* older and more subdued than Heis.

Having considered Birt and Heis, we are now ready to tackle the real subject of this article – the case of Thebit A and Thebit L (Fig. 10). Now, anybody in their right mind can quite clearly see that Thebit A is a 'fresh' looking crater with a sharp rim, whilst in Thebit L the rim is more subdued with all the indications of being much, much older. This conclusion is reinforced by the Optical Maturity image shown in Fig. 11, in which L is almost invisible against the mature soils of the surrounding terrain. But if we look more closely at the Thebit A/L pair (I am going to ignore Thebit itself, as it has little to add to this story), and bear in mind the observations made elsewhere we can come to a different conclusion, so the following comments will be made based on a low-angle binary impact model. For starters on the floor of Thebit L we see a substantial amount of impact melt forming a hummocky mass, thicker in the east and thinning towards the west, with an odd short curved ridge standing out which has been misidentified as a central peak (Fig. 12). To the east of this ridge is a blocky looking area coated in a veneer of melt which may represent the collapsed septum between A and L.

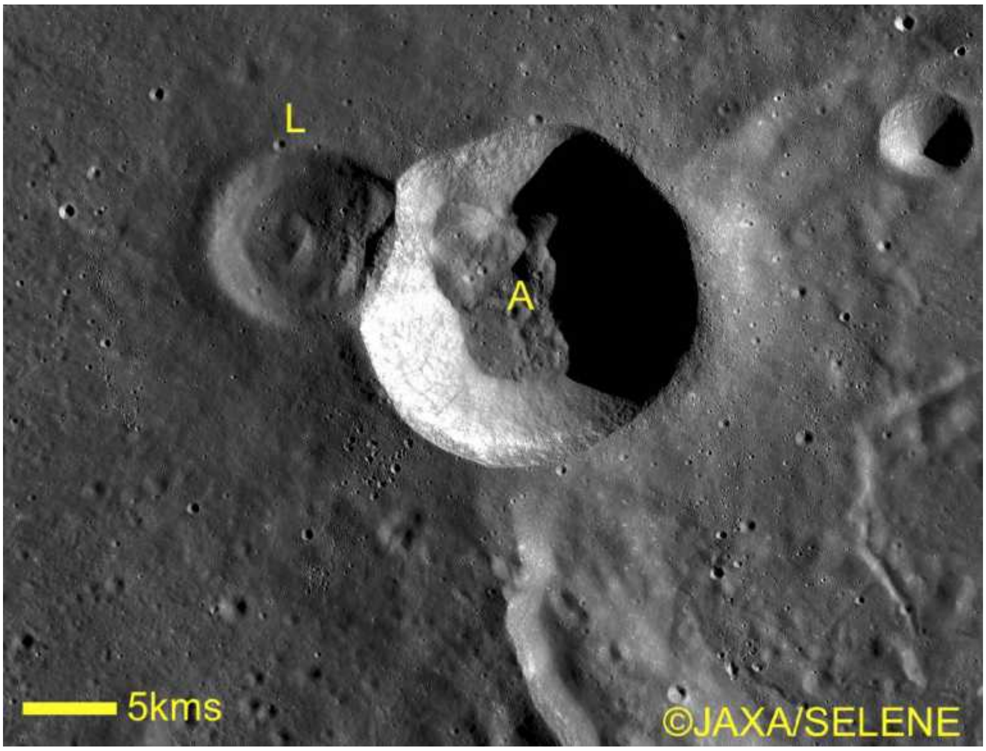


Fig. 10 SELENE image of Thebit A and Thebit L. Thebit is the large Floor Fracture crater lower right. Note the subdued rim and apparently greater age of L.

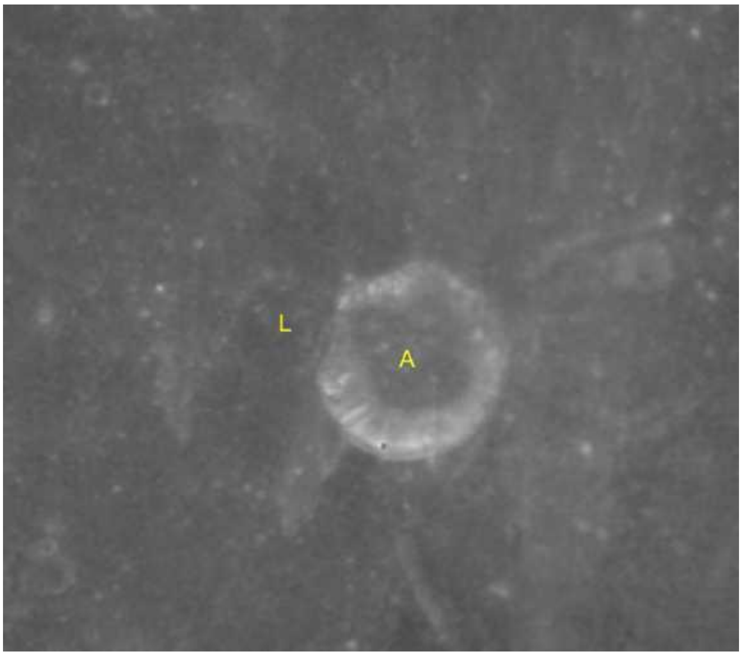


Fig. 11 Clementine UVVIS Optical Maturity images of Thebit A and L. Note how L is virtually undetectable against the background whilst the immature walls of A are conspicuous.

If this is the case the small curved ridge may represent a section of that septum which was detached bodily and shoved westwards by the collapse of the septum. It is also apparent that the impact melt deposited in L did not stay there as the remains of the septum now separating A and L is also coated in a thick veneer of melt, which has flowed over this ridge and down the onto the western floor of A where it is preserved as mound-like flows.

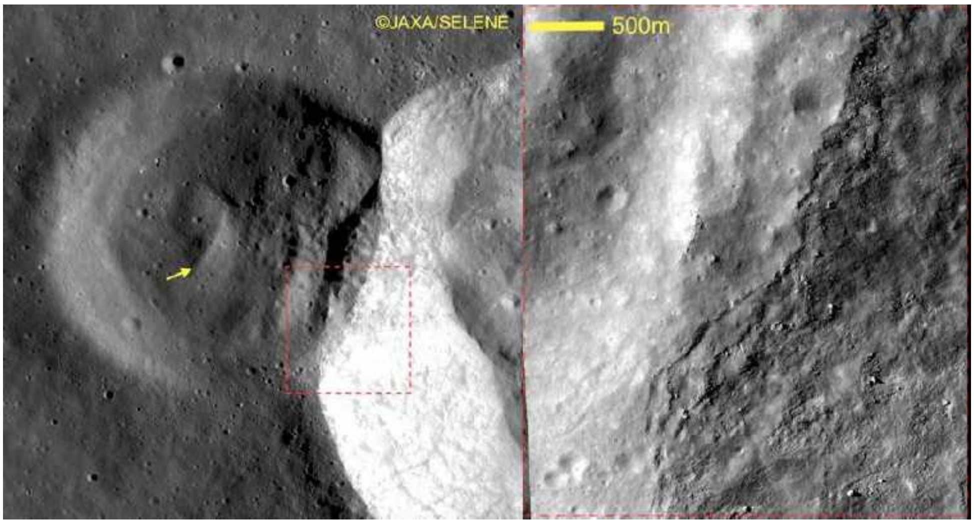


Fig. 12 Left - Detail of Thebit L and the septum between it and Thebit A. The yellow arrow indicates a curved ridge which may represent a section of that septum detached and forced into L during collapse of the septum into L. Area within the red box is shown enlarged on the right and shows the veneer of impact melt covering the remnants of the septum.

It appears therefore that Thebit A and L formed the same way as the Birt and Heis pairs, from a binary low-angle impact, with the anomalously old appearance of Birt A, Heis A and Thebit L being a result of their being smothered to varying degrees by impact melt expelled in the downrange direction during the impact. But is there any evidence that Thebit A and L were formed at the same time let alone by a low angle impact? Well, Fig. 10 gives some indication that the ejecta blanket that surrounds A also encompasses L – you can see that it is less heavily cratered than the surrounding terrain, and overlies some faintly preserved ejecta from Arzachel.

More evidence can be seen in the Clementine UVVIS Colour Ratio image (Fig. 13) showing that both A and L are both surrounded by a yellow 'halo' of ejecta which extends out some 30 to 40kms to the north, south and west, but only half that distance to the east. What is also visible is blue proximal ejecta immediately outside the rims of A and L, with conspicuous deposits at the junction between A and L. This blue colouration represents rocks with a highland component excavated during the later stages of the impact process from beneath the younger lavas of eastern Mare Nubium. The fact that the yellow distal and proximal blue ejecta surrounds both craters strongly suggests a contemporaneous origin.

The Kaguya Plagioclase Weight Percent images (Kaguya Multi band Imager, Plagioclase Weight Percent Colorized Global to use its full title) shows that both A and L are surrounded distally by a halo of material with a low plagioclase content, indicative of a basaltic mare composition, whilst immediately outside the rims a higher plagioclase signature is visible (Fig. 14). The plagioclase distribution is consistent with both craters forming during a simultaneous impact and the composition indicates an impact site with a surface of basaltic mare material underlain by material with a greater highland component and plagioclase content. The observations made using this data is pretty similar to the interpretation using the Clementine UVVIS Colour Ratio data in Fig. 13.

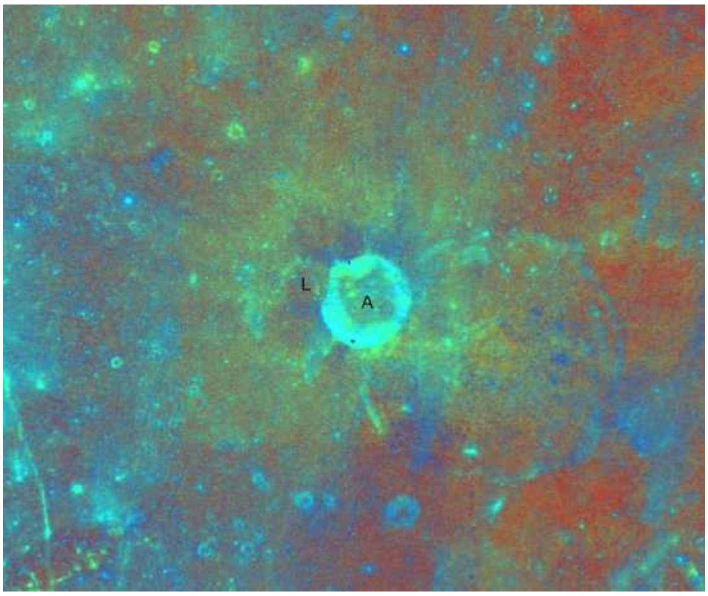


Fig. 13 Clementine UVVIS Colour Ratio image of Thebit A and L. Note the yellow 'halo' of ejecta distally, and smudges of blue ejecta proximally that surround both craters.

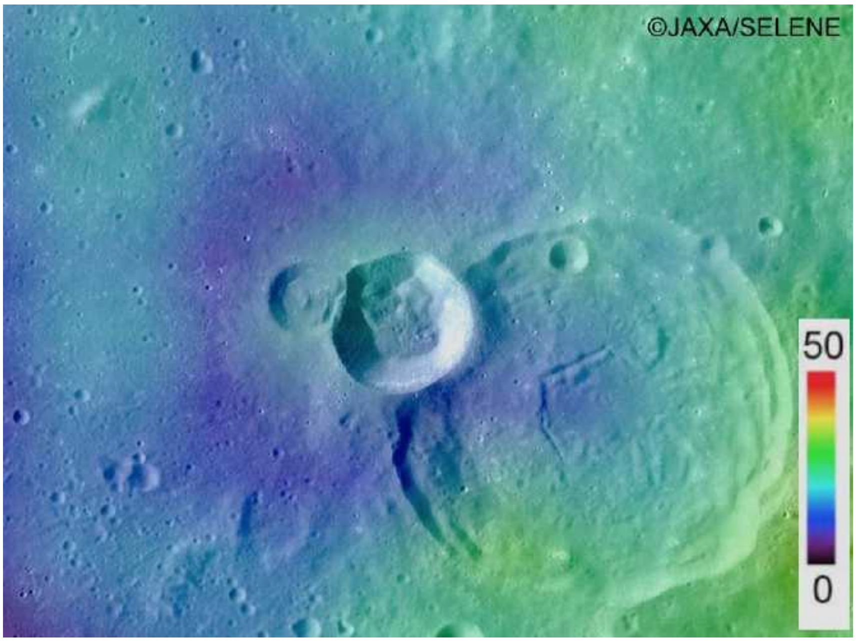


Fig. 14 Kaguya Multi band Imager, Plagioclase Weight Percent Colorized Global image of Thebit A and L. Note the distribution of low plagioclase material around both craters distally, with increased plagioclase content immediately outside the crater rims.

So what all these observations seem to be telling us is that in cases of binary impact, the component craters are separated by an unstable intervening septum that can collapse into one of the craters in the post-impact modification stage. This slump can incorporate and/or displace impact melt present on the floor of the crater into which it collapses, sending some over the crater rim and forming a veneer of melt which alters the optical maturity signal, and obscures the fresh rocky nature of the crater rim itself. The level of impact melt may be raised to such a degree that it drains over the collapsed septum into the other crater as has occurred in the Birt/Heis/Thebit pairs. The fact that the three pairs just mentioned seem to have been formed in low-angle impacts would explain why the bulk of the melt ended up travelling in the downrange direction, as low-angle impacts are known to produce copious amounts of melt which is preferentially ejected in that direction.

The mechanism described can adequately account for the anomalous nature of Messier A, where the ejection of copious amounts of impact melt in the downrange direction has smothered the westernmost component of the crater triplet (yes – triplet!). Fig. 15 shows two images of Messier A, the SELENE image shows three components to the crater, those labelled 1 and 2 form what is conventionally known Messier A. They are labelled 1 and 2 here because this crater is itself a close binary crater, the evidence for this being the shape of the rim. It looks a bit like a Remembrance Day poppy, with a 'pinched' northern rim and a corresponding low point on the southern rim. Filaments of impact melt extend away from these two points (these can be seen in other multispectral images such as the WAC Hapke-Normalized colour overlay in Quickmap) indication a simultaneous impact. Component 3 has been interpreted as an older pre-existing crater that just happened to be in the way, but the rather gaudy image on the right showing the Quickmap Global map of the H-parameter overlay clearly shows butterfly ejecta extending away from components 1 and 2 combined and also from component 3, a reasonably good indication that the entire Messier A complex formed at the same time in a triple impact event. Unfortunately for component 3 it was positioned furthest downrange and so got completely smothered in the impact melt produced when Messier A formed. As a consequence it *looks* much more subdued and with an optical maturity indicating a greater age than components 1 and 2 – exactly the situation seen in the craters considered above.

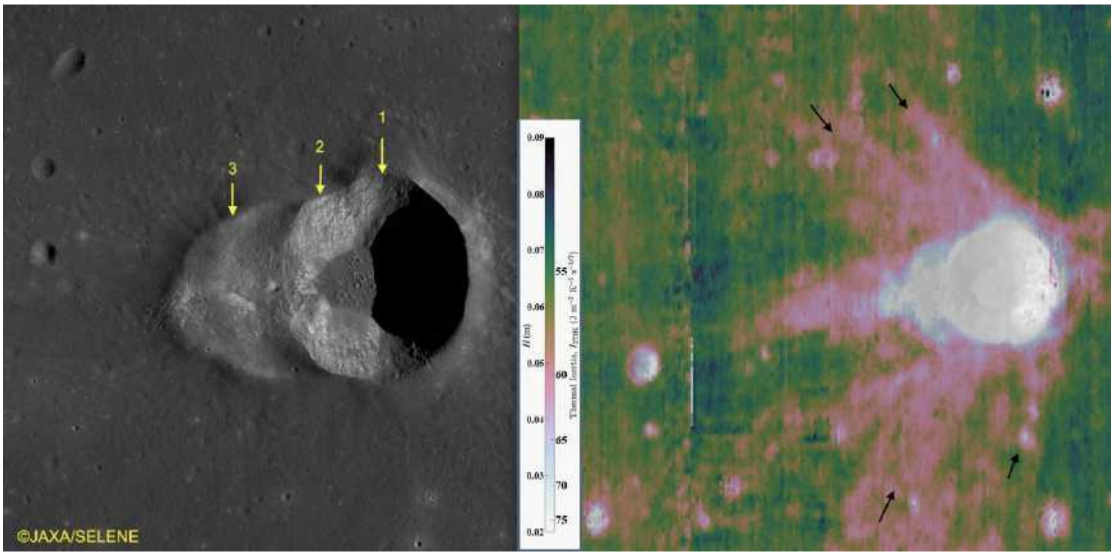


Fig. 15 SELENE image of Messier A on the left identifying the three components of the crater, and on the right the Global map of the H-parameter and equivalent regolith thermal inertia I (273K) image showing butterfly wing ejecta as pink (arrows) emerging from components 1, 2 and 3. The H-parameter correlates with the rockiness of the substrate, and compares with the Diviner Rock abundance overlay in LROC Quickmap.

The final example I want to discuss is that of Seneca F and an unnamed crater immediately to the north-west (Fig. 16).

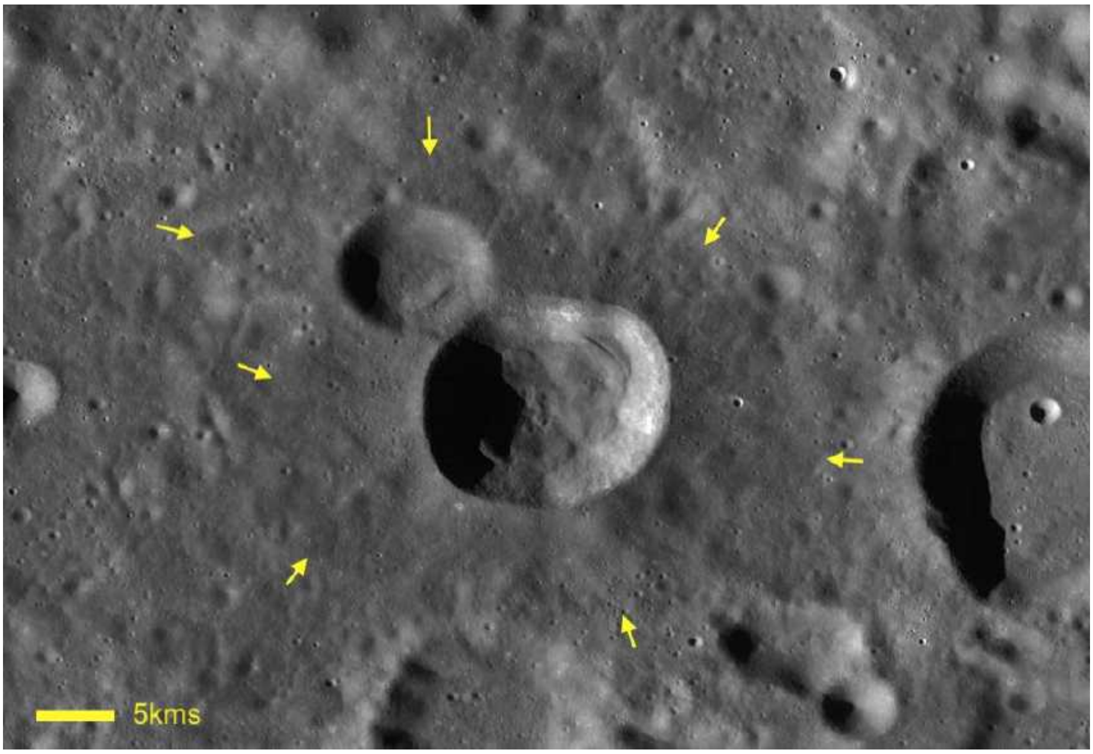


Fig. 16 LROC-WAC image of Seneca F and smaller companion crater to the north-west. Note the lower albedo ejecta appears to surround both craters (yellow arrows).

This pair appears to follow the same pattern as we have seen so far of a relatively fresh crater (Seneca F) adjacent to an *apparently* older crater (subdued rim, greater optical maturity) due to the smothering effects of impact melt from the larger crater during a simultaneous impact. The smaller crater in this pair even has a ridge-like structure, set in a mass of impact melt on its floor, a situation very similar to that in Thebit L, and possibly representing a section of the intervening septum which has collapsed towards the north-west. A Kaguya Plagioclase Weight Percent image (Fig. 17) reinforces the observation that ejecta, identified here as being of a lower plagioclase content than the surrounding terrain, envelops both craters. There is however little in the way of evidence in this pair of the features we have seen previously of a simultaneous impact, and also little indication that it was created in a low-angle impact. So, is it possible that Seneca F is in fact just a fresh crater that happened to impact next to an older crater and smothered it with ejecta, as it would anything else in the vicinity? I think this scenario cannot be categorically ruled out despite the strong evidence of a shared ejecta blanket suggesting a simultaneous event. Could the multispectral data be giving a false impression of a shared ejecta blanked due to some inhomogeneity in the distribution of the various target rock compositions? Of course if this is so, it could well undermine the interpretation given for Thebit A and L, which could also be just a couple of unrelated but adjacent impacts always been thought, and certainly *appears* to be the case. So, the simultaneous interpretation must come with a 'health warning' and I would be interested to hear what you think, one way or another.

Fig. 17 Kaguya Multi band Imager, Plagioclase Weight Percent Colorized Global image of Seneca F showing ejecta apparently surrounding both it and the companion crater to the north-west.

The interpretation of these crater pairs raises one issue that is worth addressing. *If* they were formed by low-angle binary impacts (or in the case of Messier A a triplet) then the two components of the impactor appear to have lined up with the direction of travel, with the smaller component travelling ahead of the larger, and impacting further downrange. Is this a likely scenario, produced by the dynamics of a gravitationally captured binary asteroid approaching the surface in a 'Shoemaker Levy 9' type of impact? This might seem unlikely given the relatively small mass of the Moon, and the likely small time interval during which the asteroid would be influenced by lunar gravity, but the configuration of the craters suggests that this was the case. An alternative hypothesis however is that these craters are not binary impacts at all, but the result of an low angle impactor being 'decapitated' by the shear forces acting on it's upper parts during the contact phase of impact. In this version of event, the impactor fragments on contact with the lunar surface due to these forces, with the upper portion shearing off and travelling further downrange to impact separately and form it's own crater. Numerical modelling to investigate this phenomenon indicates that the sheared-off part of the asteroid can travel along the surface to produce significant damage, but not necessarily a distinct separate crater and whilst this might well apply to Messier A, it is less applicable to the other cases considered [4]. However this sort of modelling might yet produce more information on this aspect of impact cratering and the apparently anomalous young/old crater pairs.

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1. Fitz-Gerald B (2017), ‘Pytheas and Copernicus’, BAA Lunar Section Circular, Vol. 54, Nos 8-9.

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3. Miljkovic´K, Collins, G.S, Mannick, P., and Bland, P.A. (2013), ‘Morphology and population of binary asteroid impact craters’, *Earth and Planetary Science Letters*, 363, 121–132.

4. Davidson, T.M, Collins, G.S, Elbeshausen,D Nnemann, K.W and Kearsley,A. (2011). ‘Numerical modeling of oblique hypervelocity impacts on strong ductile targets’, *Meteoritics & Planetary Science* 46, No. 10, 1510–1524.

Acknowledgements:

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http://l2db.selene.darts.isas.jaxa.jp

Selene/Clementine multispectral images courtesy of https://trek.nasa.gov/moon/

LUNAR DOMES (part XXVII): Domes near Lansberg D

Raffaello Lena

In this issue I will provide an analysis of three domes located near Lansberg D. The first dome, termed Lansberg 1 (La1), is located at 29.79° W and 3.54° S and has an elongated base area of 20x16km (Fig. 1). The second examined dome, termed Lansberg 2 (La2), is located to the south of La1 at 30.23° W and 4.02° S and has an elongated base area of 25x19km. It is clearly apparent in Fig. 1 that both domes are characterised by several straight rilles traversing their surfaces and by small non-volcanic hills. Another dome, Lansberg 3 (La3), is located at 30.09° W and 4.49° S, and has an elongated base area of 19x15 km. These flat domes are clearly detectable in the WAC imagery (Fig. 1c).

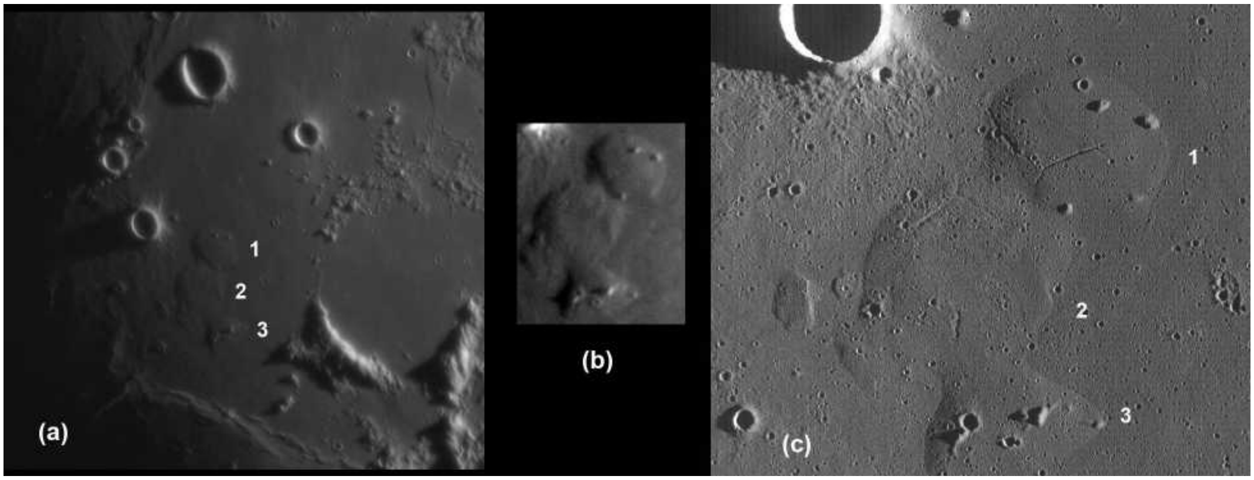

Figure 1: (a) Telescopic CCD image acquired on January 22, 2013 01:49 UT with a 400mm aperture Starmaster driven Dobsonian (Mike Wirths); (b) Rectified view of the telescopic CCD image; (c) Crop of the LRO WAC imagery M116507209ME.

It is unlikely that they are kipukas as no spectral contrast is apparent between them and the surrounding surface. Similar to previously examined lunar domes of presumably intrusive origin [1-2], the three domes near Lansberg D are of strongly elongated shape and La1 and La2 display straight rilles traversing their surfaces, which are likely of tensional origin, due to a possible intrusive origin [1-2].

Two recent images of these domes have been taken by Frank Schenck and Guy Leinen (Figs 2-3). Fig. 4 displays the domes in a CCD image taken by the author with a Mak Cassegrain 18cm.

Based on the telescopic CCD images, which were acquired under oblique solar illumination, I have determined DEMs of the examined domes by applying the combined photoclinometry and shape-from-shading method [3], (see also Figs 5 and 6). I have also have determined surface elevations from GLD100 dataset [4], which are in good agreement with our image-based photoclinometry and shape-from-shading analysis. The heights of La1-La3 correspond to 120m, 80m and 120m, respectively, resulting in average flank slopes of 0.68°, 0.40° and 0.77°.

The domes volumes were estimated by assuming a parabolic dome shape, resulting in edifice volumes of about 19km³, 17km³ and 15km³, respectively.

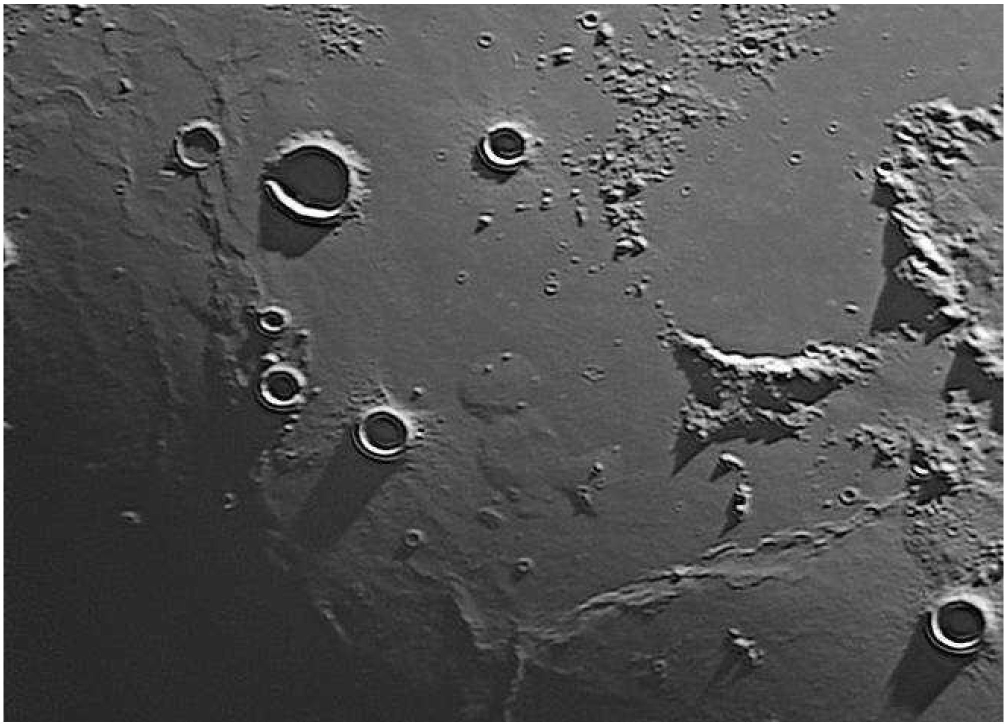

Figure 2: Telescopic CCD image taken by Frank Schenck with a Schmidt Cassegrain C-11, 2X Barlow, ASI290MM, IR-R filter.

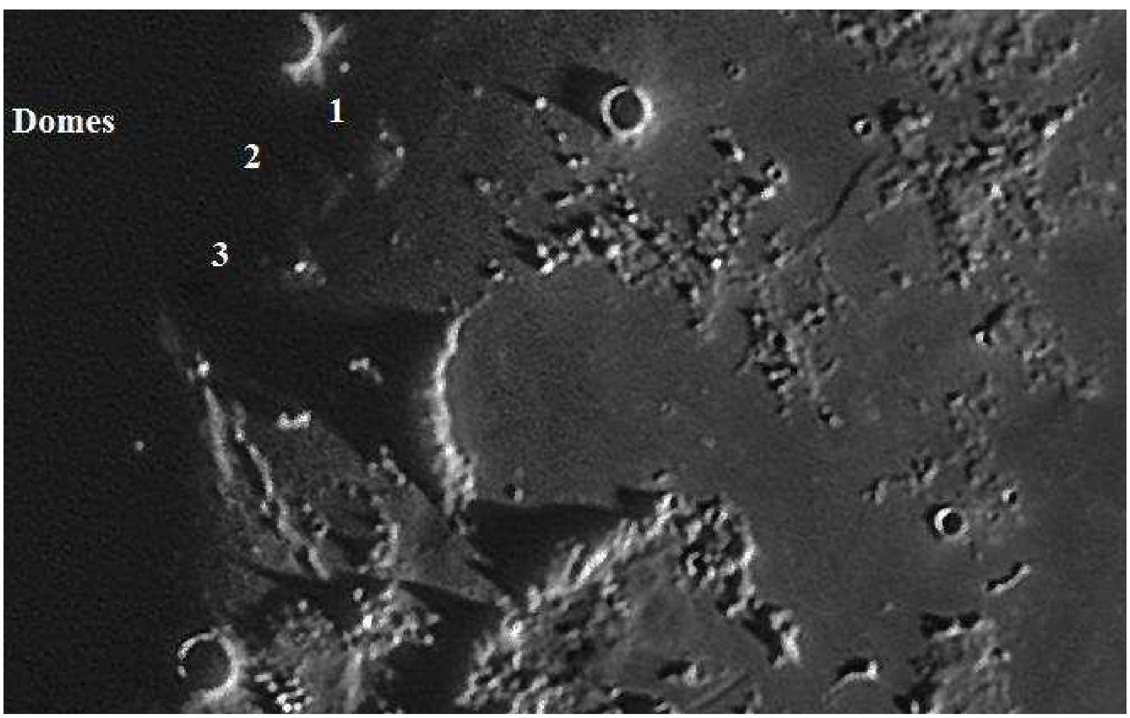

Figure 3: Telescopic CCD image taken by Guy Leinen February 1, 2019 18:03 UT.

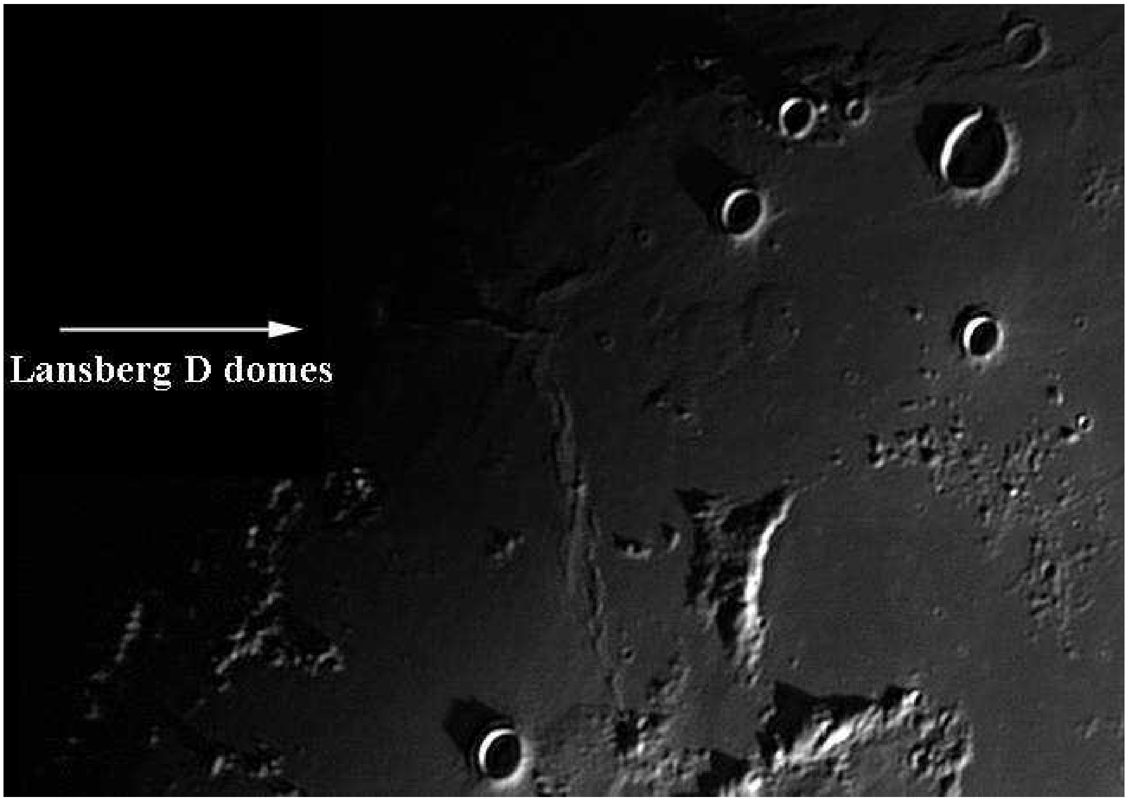

Figure 4: Telescopic CCD image taken by the author on March 18, 2016 at 22:02 UT with a Mak Cassegrain 18 cm from Rome Italy.

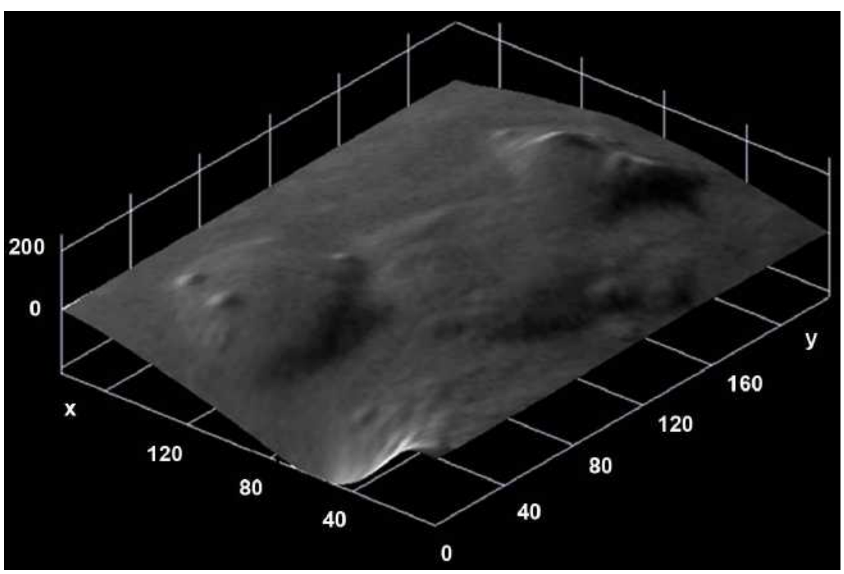

Figure 5: 3D reconstruction obtained from the DEM, with the original CCD telescopic image of Figure 1 superimposed on the elevation model. The region is seen from northwestern direction. The vertical axis is 10 times exaggerated.

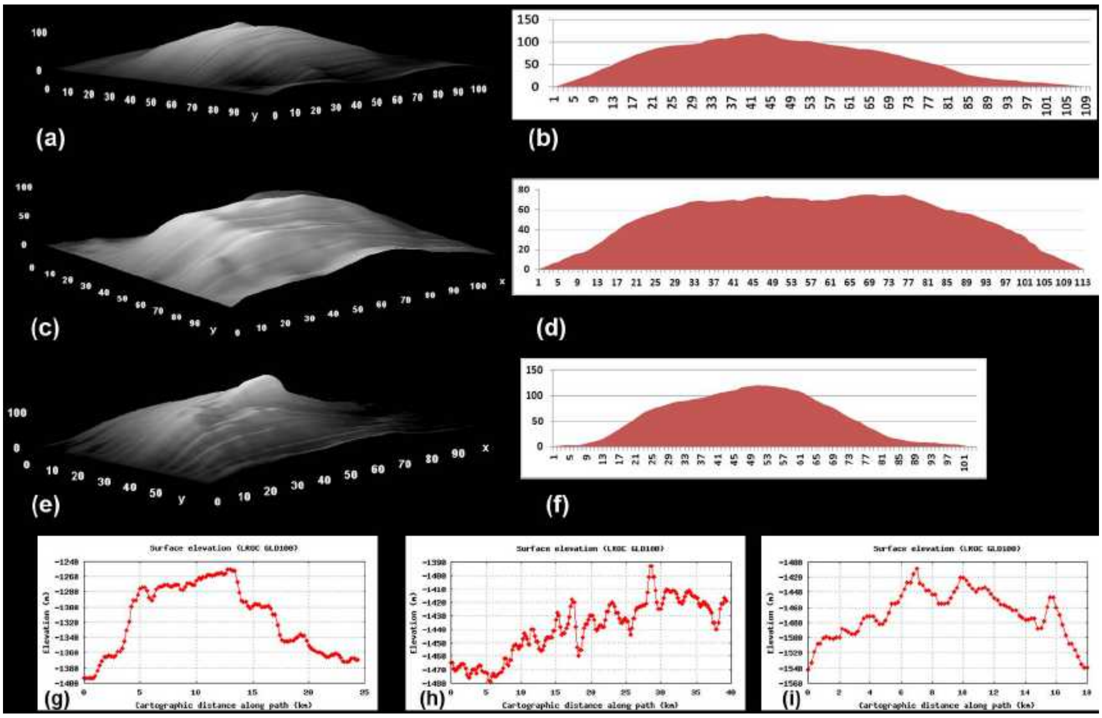

Figure 6: 3D reconstruction and cross-sectional profile in east-west direction derived for (a-b) La1 dome, (c-d) La2 and (e-f) La3. The vertical axis is 10 times exaggerated. (g-i) Cross-sectional profile in east-west direction based on GLD100 dataset for the examined domes La1-La3, respectively.

Both domes show the characteristic non-circularity of the outlines of candidate intrusive domes [1-2]. If we assume that the linear rilles on the surfaces of La1 and La2 are the result of tensional stress, the curvature radii of the dome surfaces inferred from our 3D analysis yield thicknesses of the uppermost mare basalt layer of at least 0.15 and 1.1km, respectively, assuming a typical value of the critical stress of basalt of 13MPa [5]. The laccolith model applied according to the numerical scheme suggested in [1] yields intrusion depths of 1.0km and 2.5km and maximum magma pressures in the laccolith of 7.9MPa and 20MPa, respectively.

The inferred intrusion depth and magma pressure of La3 amounts to 0.79km and 6.1MPa, while the thicknesses of the uppermost mare basalt layer corresponds to 0.12km. The intrusion depth and magma pressure obtained for La1 are lower than values inferred for other putative intrusive domes of class In1 introduced in [1-2]. According to the laccolith model, these lower values are mainly a result of the smaller size of La1.

Regarding the morphometric properties and modelling results La2 and La3 are typical representative of class In1 and In2, respectively [1]. The steeper dome La3 indicates that laccolith formation proceeded until the stage characterized by flexure of the overburden, while La2 and La1 are characterized by rilles likely due to tensional stresses, consistent with laccolith formation. Hence the magma accumulating beneath the surface produced not only an upbowing of the surface rock layers but also failures in the rock strata (fracturing).

The intrusion depth and magma pressure inferred for La1 is lower limit of the range of previously modelled values of class In1 domes [2] by factors of about 2–3.

References

[1] Wöhler & Lena (2009), *Icarus 204*, 381-398.
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[3] Wöhler, Lena et al. (2006) *Icarus 183*, 237-264.
[4] Scholten et al. (2012) *J. Geophys. Res.* 117 (E00H17), doi:10.1029/2011JE003926.
[5] Pollard and Fletcher (2005), *Fundamentals of Structural Geology*, Cambridge University Press.

OCCULTATION NEWS April 2019

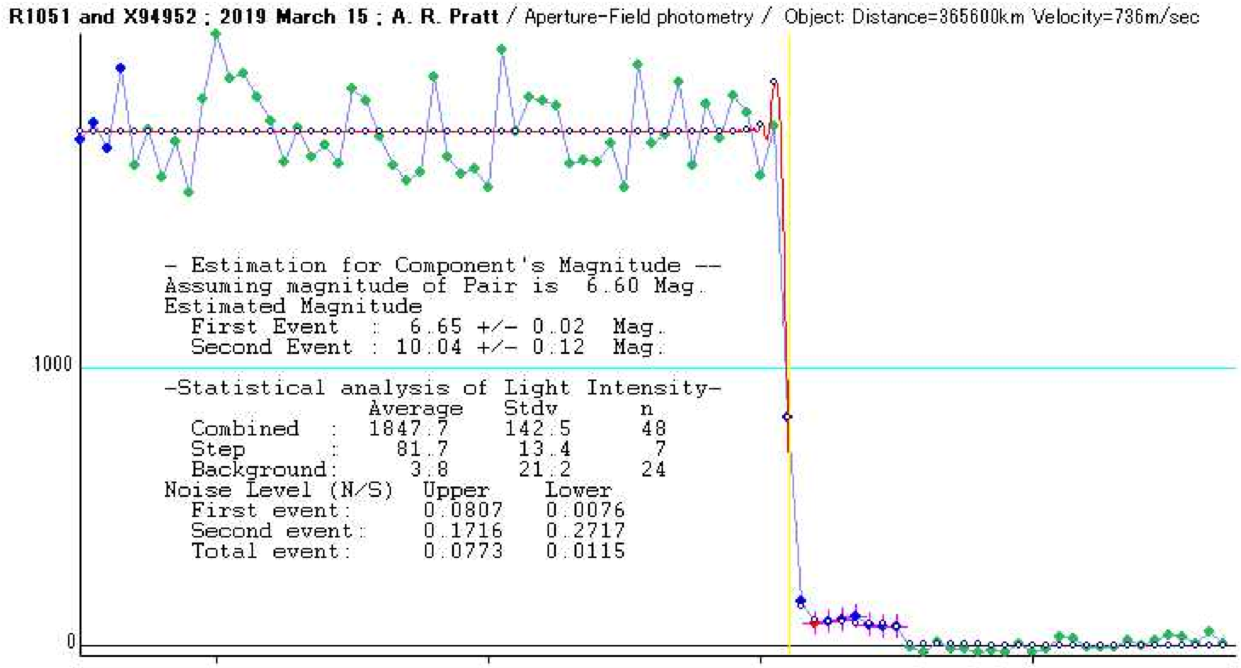
Tim Haymes

Observations

Alex Pratt (Leeds) reports R796 was recorded on 2019 Feb 14. There was no indication of a double. The light curve (instantaneous) was sent to Dave Herald. The procedure is to send light curves to Dave Herald using Occult4, but where there is a clear double, or known double, to send a Double Star light curve to Brian Loader in NZ as well.

Alex was also observing a known double, R1015 on 2019 Mar 15th. A brief but clear step was recorded with his C11 and WAT-910/HX. The step duration of 0.167s was about half the expected duration. Note that the magnitude of the faint companion was calculated as 10.04 +/-0.12.

The AVI recording was analysed by Limovie.



Graze of SAO74910 on May 9th (BAAH #9)

The writer plans to observe this from a campsite near Fishguard (Wales). The star is magnitude 7.2 [r6.7], and the Moon 26% illuminated. Although the cusp angle is 0.6, it is hoped that contacts on the un-illuminated side will be recorded. The most recent version of GRAZPREP (4.25) uses the GAIA ZC positions, and this has moved the path 200m south of the earlier software version – Tim Haymes

2019 April predictions for Manchester (Occult 4.6.1.0 by D Herald).

W. Longitude 002d 15', Latitude +53 25', Alt. 50m;

y	m	day d	Time h	m	s	Ph	Star No	Sp	Mag v	Mag r	% ill	Elon	Sun Alt	Moon Alt	Az	CA	Notes
19	Apr	8	19	38	23.9	d	558	A0	8.2	8.1	12+	40	-7	23	265	45N	
19	Apr	8	19	57	7.5	d	93614		8.6	7.5	12+	40	-9	21	269	22N	
19	Apr	9	21	31	27.7	D	718	K4	6.0	5.4	20+	53		17	279	38N	
19	Apr	9	21	40	43.7	D	94119	K0	7.8	7.2	20+	53		15	280	77S	
19	Apr	9	22	25	25.9	D	726	G2	7.0	6.6	20+	53		9	289	62N	
19	Apr	9	22	30	56.8	d	94143	F5	9.0	8.6	20+	54		9	290	79N	
19	Apr	10	20	3	31.1	d	77368	K7	8.8*	7.9	29+	65	-10	39	251	78S	
19	Apr	10	20	56	37.3	D	77417	A5	8.7*	8.5	29+	65		31	263	78S	
19	Apr	10	21	10	29.0	D	77433	A0	7.9*	7.9	29+	65		29	266	78N	
19	Apr	10	21	43	23.9	d	77463	A0	8.9*	8.9	29+	65		24	272	78S	
19	Apr	10	22	13	13.1	D	77493	B9	8.2*	8.2	29+	66		20	278	84S	
19	Apr	10	22	33	54.2	D	77515	K0	8.2*	7.7	30+	66		17	281	77S	
19	Apr	10	22	38	56.5	D	77516	*5	6.9*	5.3	30+	66		17	282	61N	
19	Apr	11	19	45	40.9	D	78560	G5	8.1	7.4	39+	77	-7	49	233	21N	
19	Apr	11	19	50	46.6	d	78575	K7	8.6	7.8	39+	77	-8	48	234	66N	
19	Apr	11	20	23	22.3	d	78587	K0	8.6	8.1	39+	78	-12	44	243	54S	
19	Apr	11	22	24	30.6	d	78674	A2	8.9	8.8	40+	78		27	270	40N	
19	Apr	12	20	27	38.4	d	79587	K0	9.0	8.4	50+	91		50	227	57S	
19	Apr	12	21	43	19.6	D	79623	K1	7.9	7.3	51+	91		41	248	68N	
19	Apr	12	23	8	6.8	d	79670	A0	8.2	8.2	52+	92		29	266	61N	
19	Apr	13	0	41	4.1	d	79710	K0	7.8	7.2	52+	93		16	284	38N	
19	Apr	13	20	4	28.5	d	97994	A5	8.9	8.8	62+	104	-9	55	198	14N	
19	Apr	13	20	16	41.0	D	98009	A7	7.6	7.6	62+	104	-11	54	202	67N	
19	Apr	13	20	26	33.4	d	98003	F0	8.8	8.6	62+	104	-12	53	206	27S	
19	Apr	13	20	42	11.8	d	98026	F0	8.6*	8.5	62+	104		53	212	74N	
19	Apr	13	20	42	29.3	D	1297	A9	6.8	6.6	62+	104		53	212	39N	Dbl*

19	Apr	13	20	46	6.7	D		98027	A8	7.8	7.7	62+	104		52	213	65N	
19	Apr	13	21	10	45.3	D	X	13184	A3	8.0	7.9	62+	104		50	221	46N	
19	Apr	13	21	38	15.2	D		98054	A7	7.9*	7.8	62+	104		47	230	75S	
19	Apr	13	22	28	17.2	d		98075	A0	8.3	8.3	63+	105		41	243	58N	
19	Apr	13	23	7	39.0	d		98094	F0	8.4	8.3	63+	105		36	253	71N	
19	Apr	13	23	12	0.3	D		1312	F2	6.8*	6.6	63+	105		35	254	81N	
19	Apr	14	21	44	30.7	d		1430	K0	8.0*	7.4	73+	118		49	212	76S	
19	Apr	16	2	34	29.5	D		1576	A2	5.3*	5.3	85+	134		16	267	86N	53 Leo
19	Apr	16	21	22	48.8	d		118938	K0	8.2	7.6	91+	145		43	165	59N	
19	Apr	16	22	30	19.9	D		118952	A2	7.1	7.0	91+	146		43	188	59S	
19	Apr	16	23	29	7.3	d		118971	G5	7.6	7.2	91+	146		40	206	62S	
19	Apr	17	0	11	7.0	d		118979	K0	8.5	7.9	92+	146		37	218	55S	
19	Apr	17	21	22	46.9	d		1796	A5	7.6*	7.5	97+	159		34	151	54N	
19	Apr	17	22	30	34.0	d		119462	G5	8.1	7.7	97+	159		37	171	58N	
19	Apr	18	20	53	50.6	d		1923	K0	7.0*		99+	171		22	132	86S	
19	Apr	20	22	23	47.3	r		2180	M2	6.8	5.9s	97-	160		12	134	84N	
19	Apr	21	1	55	23.7	r		159185	K0	7.4*	6.7	96-	158		22	185	54N	
19	Apr	21	3	30	39.7	R		2196	K4	6.5	5.6S	96-	158	-12	17	209	88N	30 Lib
19	Apr	22	1	24	11.2	R		2331	K1	6.3	5.8	91-	146		17	165	76S	

Predictions up to May 5th

Notes on the Double Star selection.

Doubles are selected from Occult 4, where the magnitudes of the pair are not more than 2 magnitudes different, the fainter companion is brighter than mag 9, and the time difference(dT) is between 0.1 and 5 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. Negative CA = bright limb
Dbl* = This is a double star worth monitoring.
Mag(v)* = asterisk indicates a light curve is available in Occult-4

Star No:

2/3/4 digits = Zodiacal catalogue (ZC) but referred to as the Robertson catalogue (R)
5/6 digits = Smithsonian Astrophysical Observatory catalogue (SAO)
X denotes a star in the eXtended ZC catalogue

Detailed predictions at your location for 1 year are available upon request.
Occultation Subsection Coordinator: Tim Haymes occultations@stargazer.me.uk

LUNAR GEOLOGICAL CHANGE DETECTION PROGRAMME 2019 Apr

Tony Cook

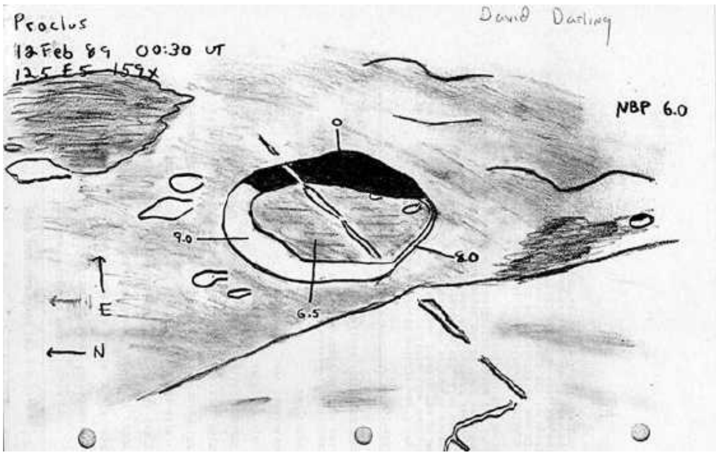
Reports have been received from the following observers for February: Jay Albert (Lake Worth, FL, USA - ALPO) observed: Aristarchus, Copernicus, earthshine, Fracastorius, Mare Crisium, Picard, Proclus, the lunar south pole area, and Tycho. Francisco Alsina Cardinali (Argentina – SLA) imaged Aristarchus, Copernicus, La Condamine, Mare Serenitatis, and Plato. Maurizio and Francesca Cecchini (Italy – UAI) imaged Herodotus and Vallis Schröteri. Jairo Andres Chavez (Columbia – LIADA) imaged: Eudoxus, Mare Serenitatis, Sinus Iridum, and several features. Maurice Collins (New Zealand – ALPO/BAA/RASNZ) imaged several features. Marie Cook (Mundesley, UK – BAA) observed Aristarchus, Proclus and Ptolemaeus.

Walter Ricardo Elias (Argentina – AEA) imaged Alphonsus, Chacornac, Plato, Theaetetus, and Plato. Valerio Fontani (Italy – UAI) imaged Herodotus and Tycho. Trevor Smith (Codnor, UK -BAA) observed Aristarchus, Campanus, Hecataeus, Hevelius, Santbach, Mare Fecunditatis, Mare Crisium, Proclus, and Kant. Rob Stuart (Mid Wales, UK – BAA) imaged Alphonsus. Archimedes, Arzachel, Biela, Boussingault, Bullialdus, Cichus, Clavius, Copernicus, Fabricius, Franklin, Fraunhofer, Goldschmidt, Langrenus, Longomontanus, Mare Crisium, Mare Insularum, Maurolycus, Messier, Montes Riphaeus, Petavius, Plato, Ptolemaeus, Reinhold, Rima Birt, Rosenberger, Snellius, Stadius, Stevinus, Tycho, Vallis Alpes, and several features. Franco Taccogna (Italy – UAI) imaged Herodotus, Vallis Schröteri and several features. Also Tonon Aldo Tonon (Italy-UAI) imaged several features. Luigi Zanatta (Italy – UAI) imaged Vallis Schröteri and several features.

TLP reports: No TLP were observed in February.

January's Reports: Due to pressure of work, I am delaying reporting the extra observations and analysis until the May newsletter. Apologies to those observers affected by this delay.

Routine Reports: Below are a selection of reports received for February 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.



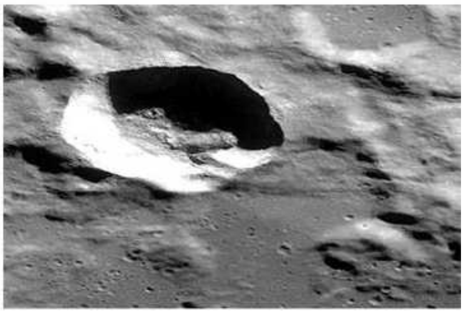


Figure 1. *Proclus, orientated with north to the left. (**(Left)** A sketch by David Darling (ALPO) from 1989 Feb 12 UT 00:30. **(Right)** From a NASA LROC WAC mosaic from Quickmap.*

Proclus: On 2019 Feb 10 UT 18:00-20:00 Trevor Smith (BAA) observed several features on the Moon, one of which was Proclus and this matched the illumination, to within ±0.5°, of the following report:

On 1989 Feb 11 at UT23:30-01:39 D. Darling (Sun Praire, WI, USA, 12.5" reflector, x159, seeing=7/10) observed a linear east to west feature in Proclus. D. Weier (WI, USA, 11" reflector, x378) found the NNW part of the crater to be brighter than expected and confirmed the presence of the east to west feature - this crossed the shadow on the east floor and over into Mare Crisium. R. Manske (WI, USA) detected another "streak" parallel to this. All observers suspect that the linear features were due to raised topography on the floor of Proclus - however Cameron comments that there does not seem to be any linear features on the floor of Proclus to cause these effects. The Cameron 2006 catalog ID=351 and the weight=5. The ALPO/BAA weight=2.

Trevor comments that: *'Proclus is very bright as usual but not unusually so. There is a darkish linear feature roughly situated east to west. It is not central but offset to the east. This linear feature could only be seen at times due to the poor seeing of around ant IV.'*. Just out of interest I managed to find a copy of David Darling's sketch from 1989 and replicate this in Fig. 1 (Left) in comparison with a modern day LROC image in Fig. 1 (Right). Although David's image and the LROC image differ in terms of illumination, they do show a fair agreement in terms of detail (allowing for the difference in resolution) and also the diagonal lineament running across the floor of Proclus. However, the LROC Quickmap view shows this to be slightly NW of the centre, unlike in David's sketch, and not to the east as Trevor mentions. We shall keep the weight at 2 for now as we have left ourselves with a bit of a mystery – perhaps there are more than one diagonal lineaments visible – depending upon the illumination?

Plato: On 2019 Feb 13 UT 00:13 Walter Ricardo Elias (AEA) imaged this crater under similar illumination to the following ALPO report:

Plato 1949 Mar 09 UT 02:00-03:00 E.J. Reese (6" reflector x240) and one hour later T.R. Hake (5" refractor x300) both unable to see any detail on the floor of Plato, despite both being able to see a "difficult to see" cleft near to the crater Connon. Reese was able to see detail under similar illumination back in 1948 and 1947 and saw the floor craterlets in Plato clearly then. ALPO/BAA weight=1.

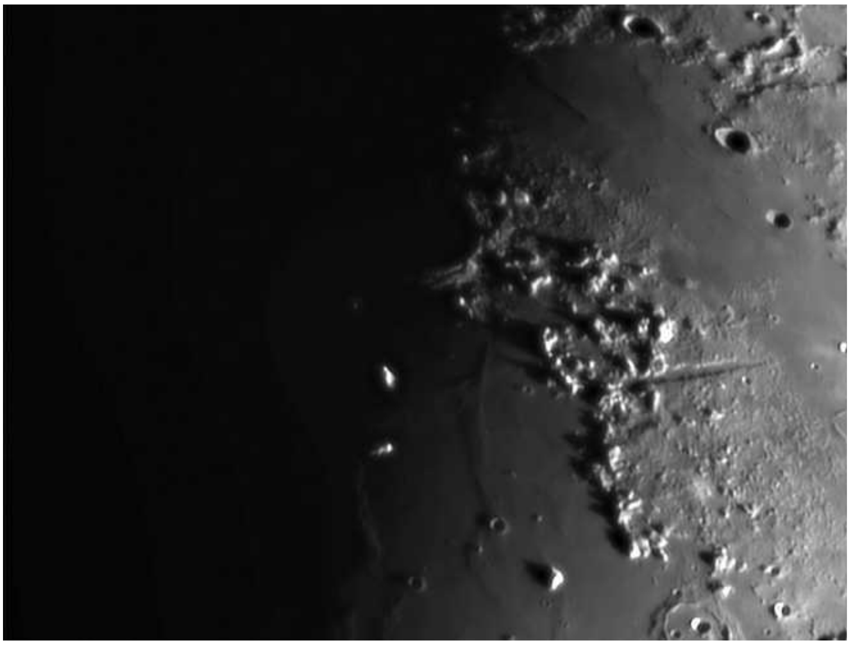


Figure 2. *Plato as imaged by Walter Elias (AEA) on 2019 Feb 14 UT 00:13 and orientated with north towards the top.*

Walter's image (Fig. 2) shows the crater floor to be completely in shadow, so clearly there is a timing discrepancy here. I will look into this. It maybe that the 1949 report UT is correct, but that the date needs to be shifted forwards by one day.

Alphonsus: On 2019 Feb 13 UT 08:04 Maurice Collins took a whole Moon image which covered similar illumination, to within ±0.5° of the following report:

Alphonsus 1966 Apr 28 UT 21:58 Observed by Smith (England, 10" reflector) and Corralitos Observatory (Organ Pass, NM, USA, 24" reflector+Moon Blink) "Reddish patches, (not confirmed at Corralitos with MB tho they give feature as Gassendi in their report)." NASA catalog weight=2. NASA catalog ID #930. ALPO/BAA weight=1.

Figure 3. *Alphonsus by Maurice Collins (ALPO/BAA/RASNZ) taken on 2019 Feb 13 UT 08:04 and orientated with north towards the top. Colour saturation increased to 70%.*

No sign of red patches can be seen (Fig. 3) in the floor of Alphonsus, so we shall leave the weight at the already low value of 1.

Carlini D: On 2019 Feb 14 UT 16:59 Bob Stuart (BAA) imaged the Mare Imbrium and captured this crater within ±0.5° similar illumination to a report of a flash seen on the Moon:

2004 Jan 02 UT 09:05 (approx) M. Collins (Palmerston North, New Zealand, ETX 90, seeing 3, clear) saw a possible(?) flash north of Carlini D at about 16W, 35N in adverted vision. It lasted only a split second. The ALPO/BAA weight=1.

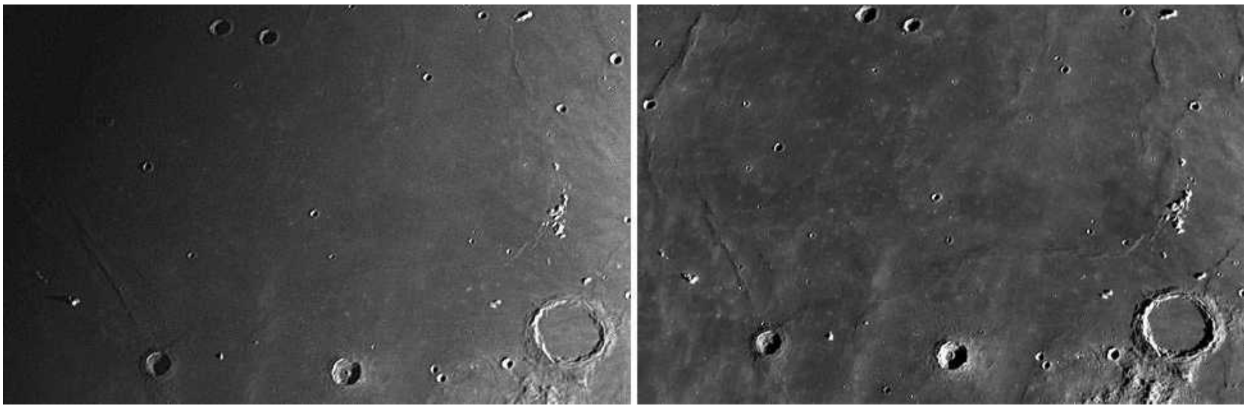


Figure 4. *The northern part of Mare Imbrium, centred on the 8 km diameter crater Carlini D and orientated with north towards the top.* ***(Left)*** *An image by Rob Stuart, taken on 2019 Feb 14 UT 16:59.* ***(Right)*** *For comparison a LROC ACT Quickmap mosaic of the same area, albeit at a different illumination.*

The reason why we are asking people to reimage this region is that there is a chance that the flash that Maurice saw might have been caused by a bright, but very small ray craterlet, that was only visible during a brief moment of excellent atmospheric seeing conditions. However as you can quite clearly see from Bob Stewart's image (Fig. 4 - Left) tor the NASA LROC WAC mosaic (Fig. 4 – Right) here is no obvious bright ray crater just to the north of Carline D. Alas nobody else was observing at the same time as Maurice. We are left to conclude that either Maurice saw a cosmic ray air shower flash of light in his eye, or he witnessed something on the Moon, such as an impact flash. Given that cosmic ray air shower events are considerably more frequent than impact flashes, this seems the most likely cause. We shall leave the weight at 1.

Alphonsus: On 2019 Feb 15 UT 01:50 Jario Andres Chavez (LIADA) imaged the Moon within about 20 minutes after the ±0.5° similar illumination window for the following report:

Alphonsus 1966 Apr 01 UT(?) 03:00-03:20 Observed by Jenning, Harris (Coral Estates, CA, USA, 12" reflector) "Red patch from c.p. to W. wall (no confirm. from Corralitos obs. moon blink device & obs. at that time)" NASA catalog weight=3. NASA catalog ID #924. ALPO/BAA weight=2.

Figure 5. *Alphonsus located at the centre of the image from a whole Moon image obtained by Jario Andres Chavez (LIADA) on 2019 Feb 09 UT 01:50. Image orientated with north towards the top and colour saturation increased to 50%.*

You can see from Fig. 5 that there is clearly no red patch between the central peak and the west wall. There is a dark spot, one of the usual three on the floor, and in higher resolution colour images these can have slightly red or brown hues, but the necessary detail is not visible in Jario's image. We shall therefore leave the weight at 2 for now.

Herodotus: On 2019 Feb 16 UT 16:53 Valerio Fontani (UAI) imaged this crater when the illumination and topocentric libration were both similar (to within ±1.0°) to the following report:

1954 Aug 11 UT 02:18-02:39 Observed by Haas (Las Cruces, NM, USA) "Temporary greyness seen in interior shadow. However, by 05:09-05:18 the grey shadow of Herodotus, was now black". ALPO/BAA weight=3.

Figure 6. *The Aristarchus area orientated with north towards the bottom.* ***(Left)*** *A colour image by Valerio Fontani (UAI) taken on 2019 Feb 16 UT 16:53.* ***(Right)*** *A sketch by Walter Haas (ALPO) with annotated Pickering scale intensity values – made on 1954 Aug 11 UT 02:18-02:39.*

Concerning the 1954 Herodotus observation of a transient grey shadow inside the crater, the image by Valerio is not only inside the ±1.0° similar illumination and topocentric libration window, but the colongitude was even close in precision to the 1954 colongitude. Fig. 6 (Left) shows the shadow in Aristarchus appearing quite black, but the shadow inside Herodotus, by comparison looks slightly greyish, and its shape agrees very well with the Haas sketch (Fig. 6 - Right). However, when I measure, using Adobe Photoshop, the intensity of the shadow in Aristarchus with that in Herodotus, I get respectively 34.4±2.3 and 30.3±1.5 (A big No. is bright and a small No. dark). This suggests a possible illusion effect caused by the contrast with the bright western rim of Aristarchus. As Walter Haas was a highly experienced observer, I have some doubt if he would have been tricked by this, and approximately 3 hours later said that the shadow of Herodotus was as dark as that in Aristarchus. Just for comparison Fig. 7 (Bottom), taken approximately 3 hours after Fig. 6 (Left), has the shadow of Herodotus again looking slightly lighter than that of Aristarchus, but intensity measurements show that Aristarchus has a slightly lighter shadow. We shall leave the weight at 3 for now.

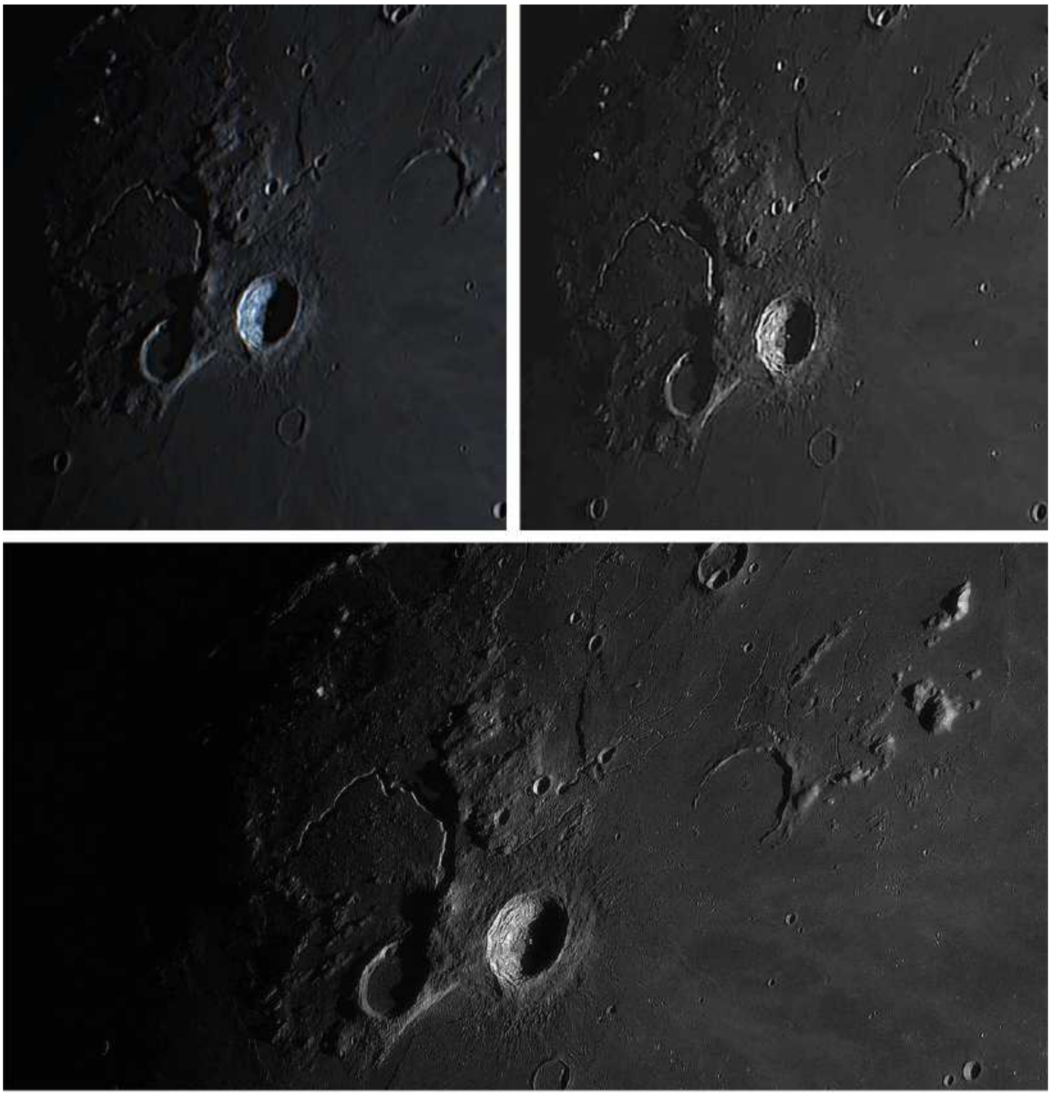


Figure** 7*. *Aristarchus on 2019 Feb 16 and orientated with north towards the top.* ***(Top Left) *19:13-19:14 UT two colour image by Franco Taccogna with colour saturation increased to 70%. Red filter in red channel, blue filter in blue channel, and an average of red and blue in the green channel.* ***(Top Right)*** *19:42UT UT image by Luigi Zanatta (UAI).* ***(Bottom)*** *UT 1946 monochrome image by Maurizio and Francesca Cecchini (UAI), taken in red light.*

Vallis Schröteri: On 2019 Feb 16, between UT 19:07-19:58 observers: Maurizio and Francesca Cecchini (UAI), Franco Taccogna (UAI), and Luigi Zanatta (UAI), observed this area when the selenographic colongitude matched that of the following TLP report:

"Aristarchus Area 2004 Nov 22 UT 04:58-05:49 Observed by Gray (Winemucca, NV, USA, 152mm f/9 refractor, seeing 4-5, transparency 4-5, x114, x228) "Blinked Herodotus with Wratten filters Blue 38A and Red 25. The illuminated west crater wall stood out brilliantly in blue light, much more so than in white light. This was true also of Aristarchus. Red light did not increase contrasts in Herodotus any more than they were in white light. Shadows in Herodotus appeared as black as the night west of the terminator and remained that way throughout the observing period. No TLP seen in Herodotus tonight. A possible TLP was seen to the west of Herodotus near the terminus of Schroter's Valley. It was noted at the beginning of the observing period that there were four very bright spots of light, one near the end of Schroter's Valley, the other three grouped together a little farther north. Although not far from the terminator they were definitely east of it. It was noted that all of them nearly vanished in the Blue 38A filter while

Aristarchus and the rim of Herodotus gleamed brilliantly. At 5:19UT it was noted that the most brilliant of the four lights, the one near the terminus of Schroter's Valley, had faded almost to invisibility in white light. When first seen it had been brighter than Aristarchus. It remained very dim after this through the remainder of the observing period, and was unchanged at 7:35-7:49UT when I again examined the area. The other three bright spots remained brilliant and unchanged."

Franco's image (Fig. 7 - Top Left) shows that Aristarchus' west illuminated rim had a slight bluish cast, as one would expect, and so agrees with the Robin Gray's report though no colour can be seen in Herodotus. Concerning the four bright spots, the one west of Herodotus cannot be seen, or at least is not obvious. There is nothing here that is as bright as Aristarchus. Indeed, even if we check earlier in Fig. 6 (Left), there is no bright spot here! The three bright spots to the north of Herodotus are clearly visible, but as you see in Fig. 7 (Top Left, Top Right & Bottom), there is no apparent sign of variation in brightness. Clearly, we should leave Robin Gray's report at a weight of 3.

Figure 8. *A monochrome image of Plato by Francisco Alsina Cardinali (AEA) taken on 2019 Feb 17 UT 02:42 and orientated with north towards the top.*

Plato: On 2019 Feb 17 UT 02:42 Francisco Alsina Cardinali (AEA) imaged the crater under similar illumination (to within ±1.0°) to the following report:

Plato 1906 Mar 07 UT 22:00? Observed by Fauth (Germany? 6" refractor)"Color (brightness?) greatly enhanced as on the previous nite" NASA catalog weight=3. NASA catalog ID #324. ALPO/BAA weight=2.

Francisco's image (Fig. 8) shows nothing unusual with Plato, so it's a bit of a mystery what Fauth saw back in 1906. We shall keep the weight at 2 for now.

Aristarchus: On 2019 Feb 22 UT 00:20-00:45 Marie Cook (BAA) observed the crater under similar illumination (to within ±0.5°) to the following report:

On 1990 Jan 13 at UT 22:15-23:05 J. Pedler (Bristol, UK, seeing=III and transparency=excellent, no spurious colour) detected a blue region on the north of Aristarchus, varying in sharpness/diffuseness. The crater rim in this region could not be discerned. Elsewhere the crater rim was normal as too were other features. When a Moon blink device was used, no colour blink was detected, however through the blue filter the suspected area was bright and the crater rim indistinct. Whereas through the red filter the area looked perfectly normal. At 22:30UT the effect had vanished and everywhere *was normal. The Cameron 2006 catalog ID=388 and the weight=5. The ALPO/BAA weight=3.*

Marie comments that without any filters, no blue region could be seen on the north of the crater, and when using red/blue colour filters, no blink could be seen. However, the crater was sharper in blue light than in red, but this applied to the whole crater. No variance was detected. Everything looked normal. We shall therefore leave the weight at 3.

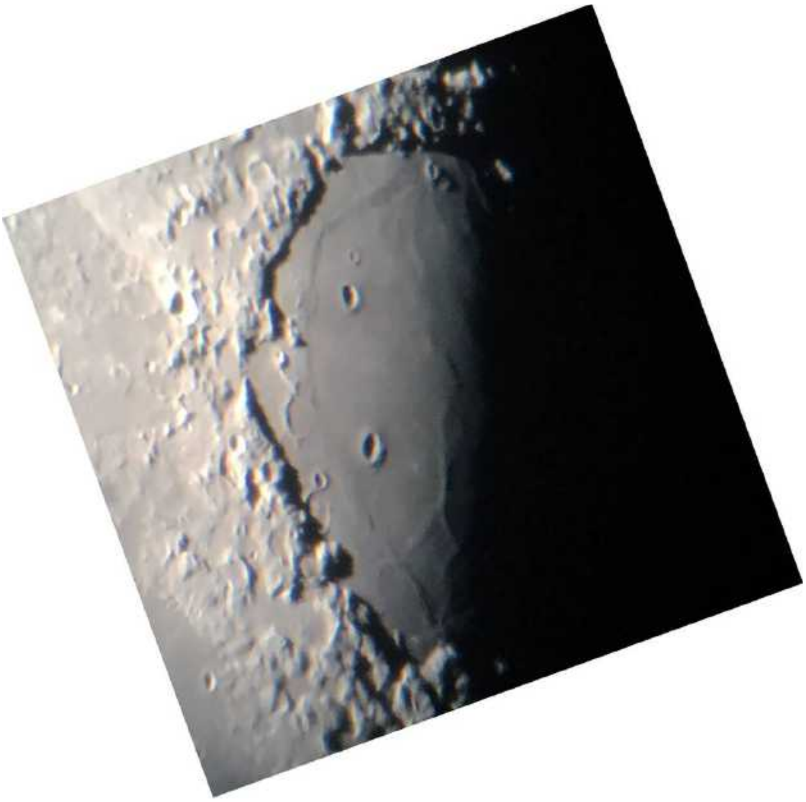


Figure 9. *A colour iPhone image of Mare Crisium obtained by Jay Albert (ALPO) on 2019 Deb 22 UT 04:35, orientated with north towards the top.*

Mare Crisium: On 2019 Feb 22 UT 03:55-04:10 Jay Albert (ALPO) observed this area under similar illumination (to within ±0.5°) to the following report:

1774 Jul 25 Eysenhard (France & a pupil of Lambert) observed: "4 bright spots intersected term. On dayside only. 2 identified. Reciprocating motion of term. In 5 or 6 min. between pairs-touching in turn. The term. In M. Fecund. Was still. Similar phen. Seen on Jup. Satellite once. (Date 1774 in MBMW wrong?". Source: Middlehurst 1968 catalog TLP ID=16. Ref Web 1962 p62-76. & Cameron NASA catalog : weight=2. The ALPO/BAA weight=1.

Jay, using a Celestron NexStar Evolution 8" SCT at x226 (Transparency magnitude 2 and 3-4/10 seeing) noted visually that *'roughly the eastern third of Crisium was in shadow. A few bright peaks and ridges were lit just beyond the terminator, but no bright spots on the sunlit mare floor'*. Although outside the repeat illumination window, he also took an iPhone image (Fig. 9). Although Cameron suspects that the year that Middlehurst gives, 1774, is wrong, at least we can see that the terminator is on Mare Crisium, and as Jay states, no bright spots were visible. The Eysenhard description of motion of the terminator sounds like an atmospheric seeing effect, though it's a puzzle why this was not visible in Mare Fecunditatis. We shall keep the ALPO/BAA weight at a low value of 1 for now.

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 .

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