Chapter 10A: Mascons structures on the Moon

Abstract

Mascons appear as areas of increased gravitational attraction on the moon's surface at the centers of larger craters. As they have no equivalent structure in topographic maps, it suggesting their structure is subsurface and corresponds to areas of lifted mantel and thinner crust. On gravity maps they are recognized as red center in the larger craters with concentric red and blue gravity pattern continuing outwards like bullseye target patterns. There are several theories for their origin, but none satisfy the collected evidence. A new theory for their origin as proposed that connects mascons to annulus from distant cratering centers, which show up because of the thinned crust. This principle requires recognizing Concentric Global Ring Structures and the expanded effects of the shear center from an individual cratering event. The increasing numbers of ghost craters that can be recognized in gravity mapping reminds us that we are looking through much more confusion from succeeding impacts then has been previously recognized.

Keywords: Mascons, GRAIL, Moscoviense, Freundlich-Sharonov, Ghost Craters, CGRS, Mare Orientale, Mare Nectaris.

Introduction

As early as 1966-67, the Lunar Orbiter spacecraft was recognized to dip and speed up passing certain regions of the moon surface. This was recognized as a gravitational affect. Since 1687 Newton's Law of Universal Gravitation had explained gravity as a function of distance and the quantity of mass. The greater the mass the greater the gravitational pull in its vicinity. Therefore, these regions must contain greater mass and became known as mass concentrations or "mascons."

Between 2011 and 2012 the Gravity Recovery and Interior Laboratory (GRAIL), a two satellite system appropriately names "Ebb" and "Flow," orbited the moon providing a finely detailed gravity map of the lunar surface. The GRAIL map of a portion of the moon's farside is compared with the Red Relief map (Chiba 2019) in Figure 9.1B. Both maps emphasize the difference in structure of the moon's features. In Free Air Gravity Anomaly's visualization of gravity, GRAIL map, high gravity is shown in red while low gravity is shown in dark blue. Numerous spots of dark blue correlate with the flat center of smaller craters shown in Red Relief (Figure 9.1A). The Mendeleev crater, ~280 km diameter, has only a small mascon showing up as a spot of lighter blue at its center. While it is not red, the lighter blue would indicate it is higher gravity at the center than the general crater. The dark blue, low gravity, is repeated as rings around mostly red centers in the Moscoviense crater, ~380 km diameter, with a very distinct mascon; the Freundlich-Sharonov basin (not even previously recognized as a crater), ~550 km diameter, with a somewhat scattered mascon and several distinct small craters inside the mascon; and the Korolev crater, ~360 km diameter, with a medium sized yellow-green mascon.

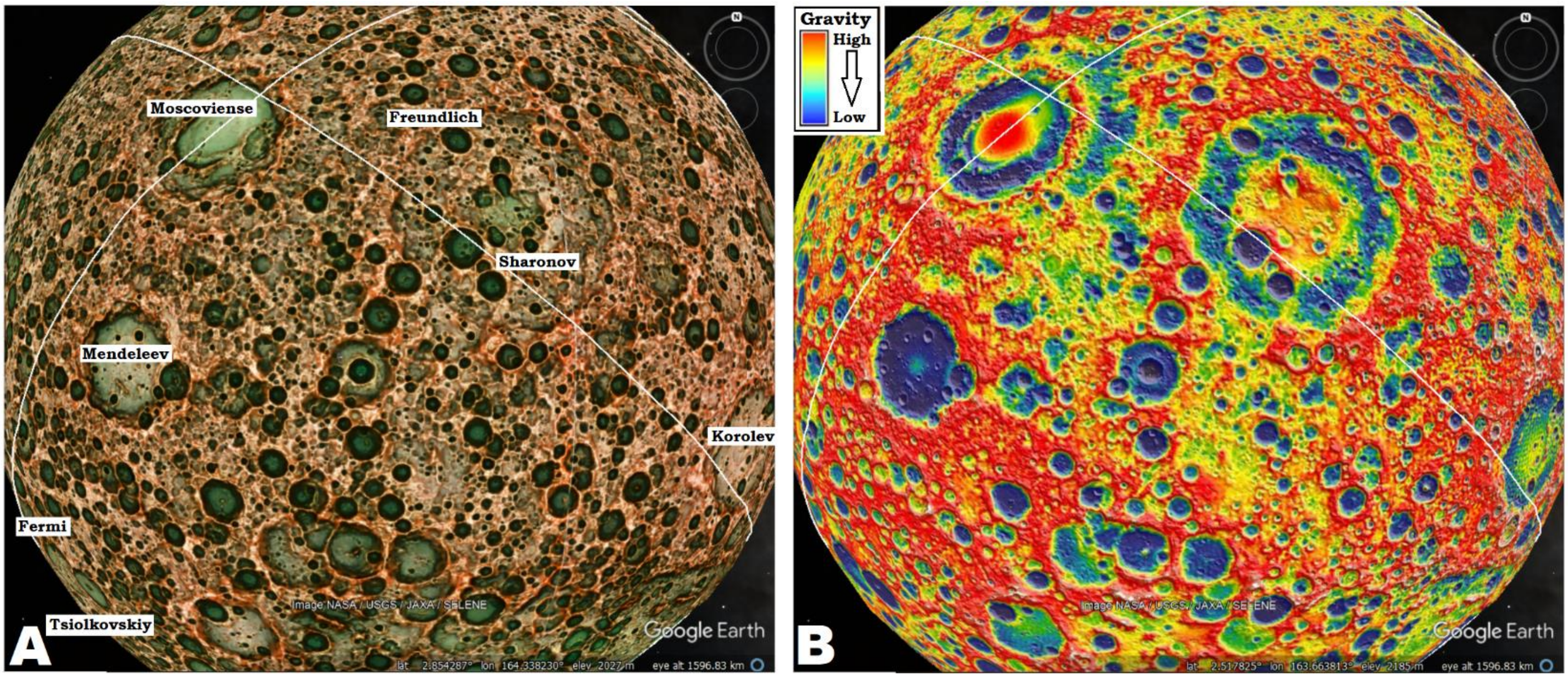


Figure 10.1: (A) Red Relief image of farside of the moon. (B) GRAIL image of same area showing gravity signature of typical craters. Note the ring of dark blue surrounding the red mascon within the center ring of Moscoviense crater, Freundlich-Sharonov basin, and Korolev crater, while Mendeleev and many smaller craters are almost completely filled with the dark blue of lower gravity.

Interpretations from literature

Melosh et al (2013) recounts that previous to GRAIL, mascons were ascribed "to mantle rebound during collapse of the transient crater cavity". Or, "flexural uplift of a thickened annulus of sub-isostatic [lowered gravity] crust surrounding the basin" and thickened crust around the basin. But using the GRAIL data they recognize, "Many mascons also exhibit an annulus of positive gravitational acceleration surrounding the annulus of negative gravity anomaly, so the gravity structure of most lunar basins resembles a bullseye target" (page 1553, brackets added). The distinctly higher gravity reading of the red ring surrounded by the dark blue they attribute to ejected material up to ~15 km thick on the rim and the high density central mascon to a solidified pool of hot melt.

Li et al (2018) studied mascons prior to China's landing "Chang'E4" satellite in Von Kármán crater in the South Pole-Aitkin Basin of the moon. They suppose that central peaks are "due to an overflow of [expelled] lunar material" (page 198, bracket added), and lava filled craters like Von Kármán may be only volcanic craters. This leads them to the conclusion that "[t]here may be an overflow of magma flow in areas of greater gravity anomalies" (page 199). That mascons are connected to the presence of lava is contrary to observation of both Von Kármán and Tsiolkovskiy craters (Figure 9.2) which both contain lava and no mascon, while Freundlich-Sharonov basin does not contain lava but does contain a mascon.

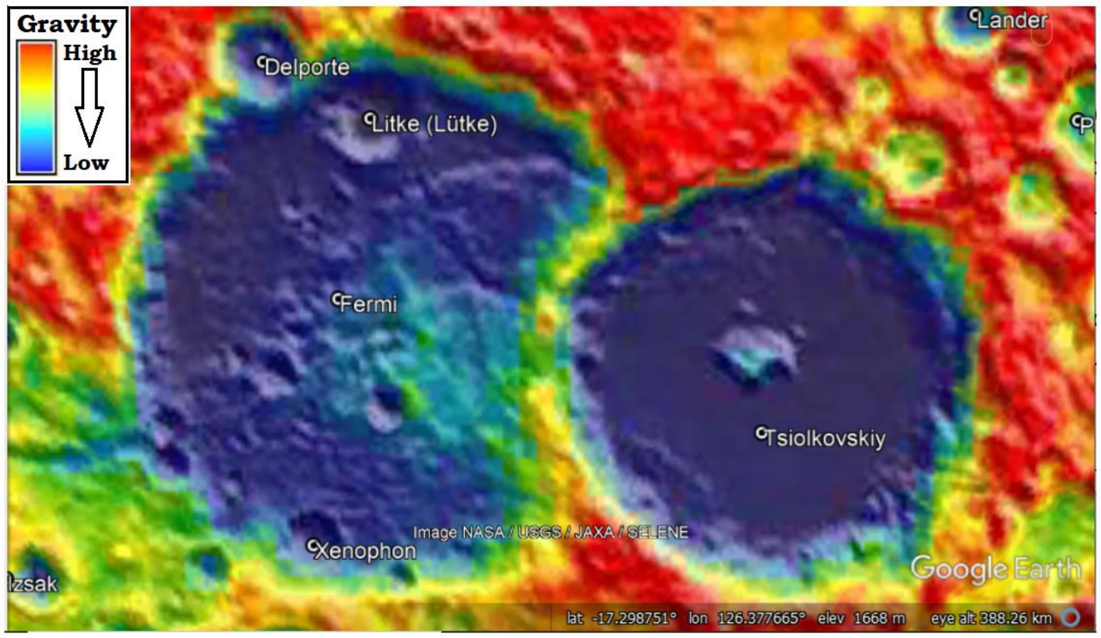


Figure 10.2: Fermi and Tsiolkovskiy craters, with no hint of a central mascon despite Tsiolkovskiy's basin being filled with lava.

Deutsch et al (2019) investigated four mascons, without obvious craters, in the area of the Aristarchus Plateau, south of Mare Imbrium Basin (Figure 10.3). They identify the three southern location as due to uplifted mantle material in the center of impact craters. They postulate intrusion of mantle material via a complex dyke system after the impact floor's rebound. The origin of the Southern Aristarchus Plateau, most northerly, spot they consider still ambiguous because of its smaller diameter <100 km and only semicircular shaped, so that they question an impact origin for mascons.

I will agree with this analysis as far as it goes, but due to their limited model of crater formation, they fail to take into account the underlying linear pattern of multiple Concentric Global Ring Structures (CGRSs) (black lines in Figure 10.3C) and the pervasiveness of ghost craters (yellow and red circles) which limit and crater's expressed shape. Is an explanation of mascons being associated with underlying CGRS consistent with other lunar mascons?

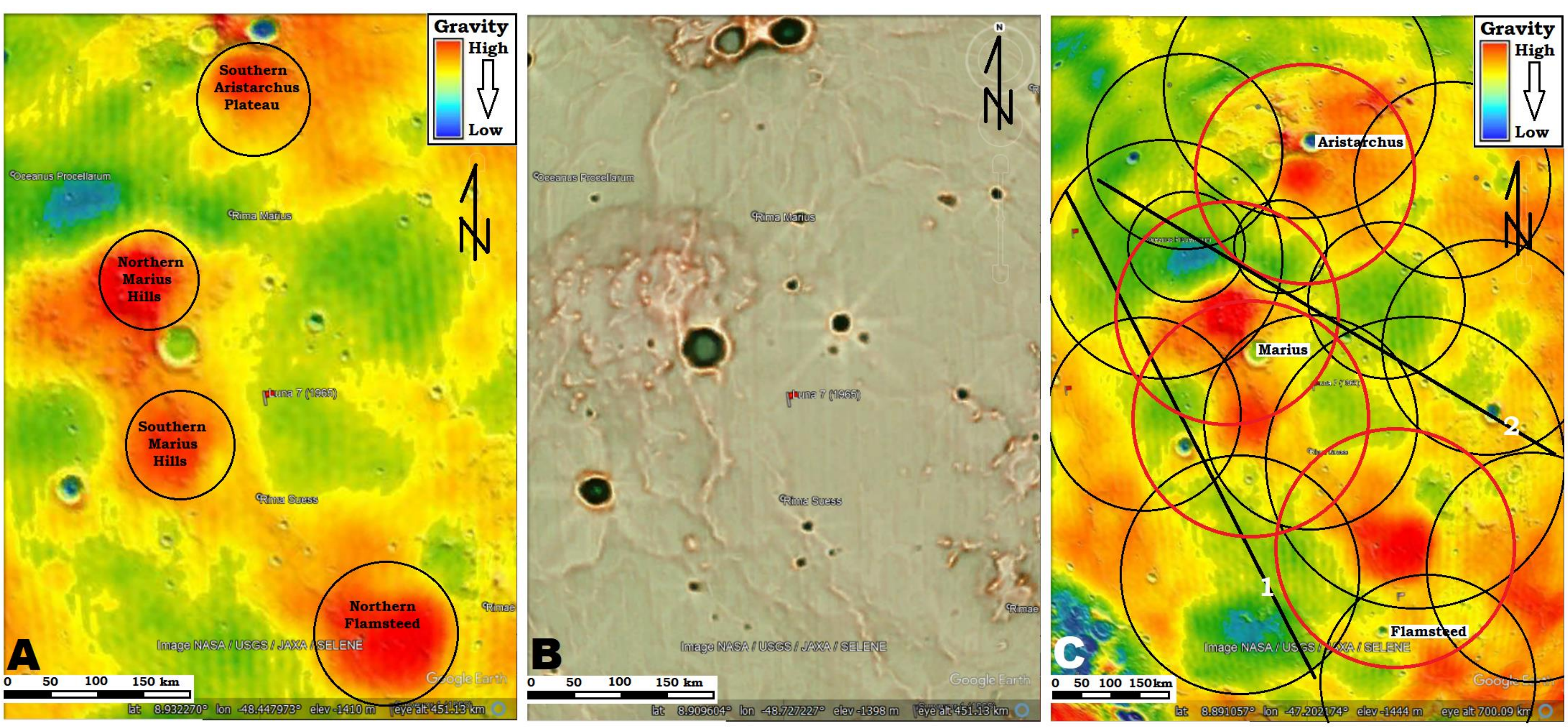


Figure 10.3: (A) Four positive Bouguer gravity anomalies (mascon) in Oceanus Procellarium, seen in GRAIL mission. (B) Surface elevation change of the same area in Red Relief. (C) Extended view of general area showing direction of prominent lineaments and rings of some ghost craters recognized in Red Relief map and gravity patterns. Craters in red associated with central mascons.

Melosh et al (2013) recognized the total crater as a result of the impact, and a pattern of a high density rim (red) encased a low density (dark blue) ring that was interrupted by the high density mascon. While Ishihara et al (2011) recognized the uplifted center of the crater, roughly equal to the size of the inner ring. This uplifted lunar disconformity leaving the thinnest crust and higher density of uplifted mantle within the crater. This produces the “target like” alternation of red and blue moving outwards from the center. With a careful look at the space between the Mousicovine and F-S basin. The many smaller blue craters, like Anderson (A), Sharonov (Sh), Spencer Jones (SJ), Freundlich (Fr), Dante (D), Morse (M), Trumpler (T), Shayn (Sy), Larmor (L), Fitzgerald (Fi) show the dark blue center with a ring of higher density but no hint of mascon. I will propose these smaller impactors did not penetrate far enough to draw up any portion of the mantle, so were left with the low gravity/expanded fill. Looking at the area where the M and F-S basins overlap, the alternation of high and low gravity can be discerned that looks like overlapping ripple patterns in a pond.

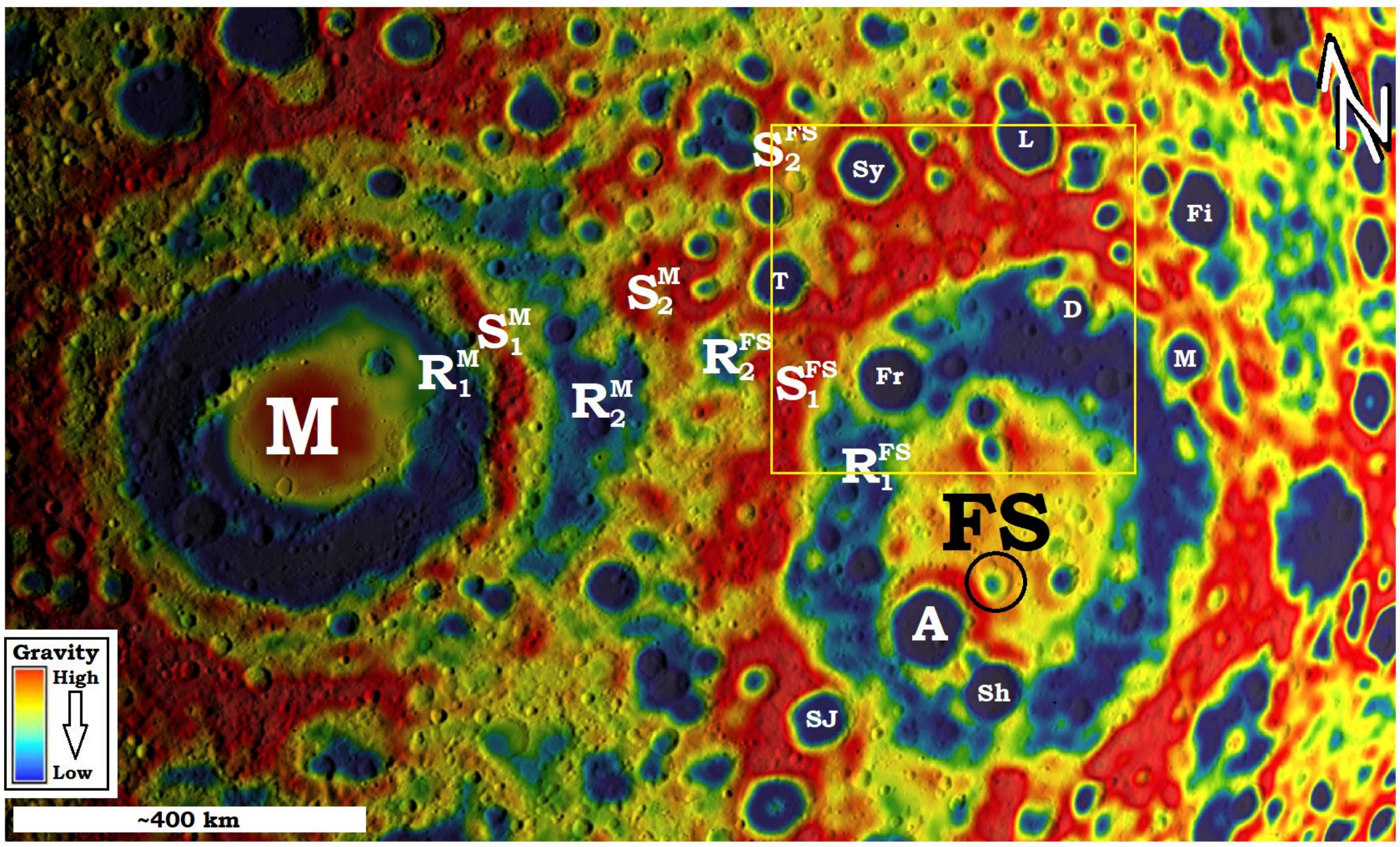


Figure 10.4: Moscoviense (M) and Freundlich-Sharonov (FS) Basins in Open-Air Gravity anomaly, with Anderson (A), Sharonov (Sh), Spencer Jones (SJ), Freundlich (Fr), Dante (D), Morse (M), Trumpler (T), Shayn (Sy), Larmor (L), and Fitzgerald (Fi) small craters are labeled. Density pattern of shock (S) and release (R) waves indicated. Subscript refers to the rings number and the super script refers to the basin origin for each rings.

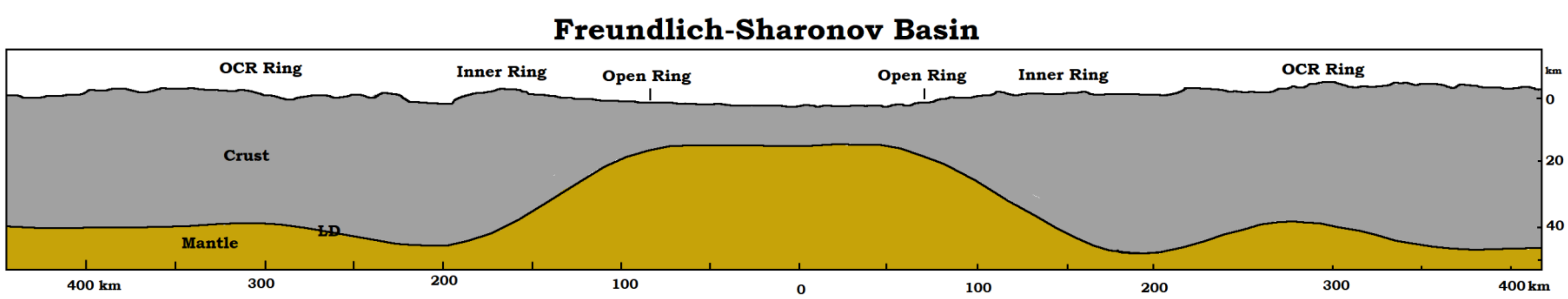
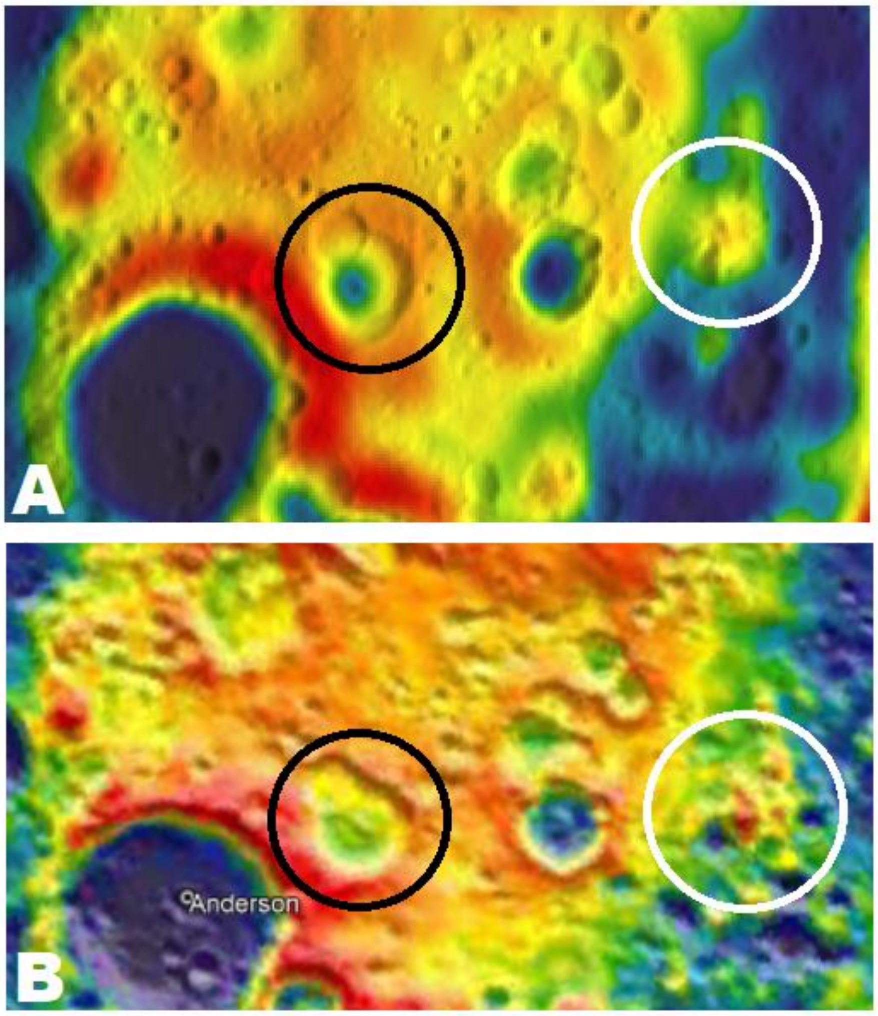


Figure 10.5: Section through the F-S Basin. Open Ring = 160 km (100 miles) diameter, Inner Ring = 280 km (174 miles) diameter. OCR Ring = 600 km (373 miles) diameter. (Image redrawn from Ishihara et al, 2011.)

Viewing the Moscoviense crater in Figure 9.4 we recognize the “bullseye” pattern that Melosh et al was describing, while the Fermi and Tsiolkovskiy (Figure 9.2) show only the single dark blue basin of the crater shading into the light blue, green, yellow and red of the crater rim. Comparing the color pattern of Fermi and Tsiolkovskiy craters to the smaller Anderson, Sharonov, Spencer Jones, Freundlich, Dante, Morse, Trumpler, Shayn, Larmor, and Fitzgerald craters of Figure 9.4, all of these smaller craters show the color shading going up to the red, so we can assume the dark blue, low gravity, floor of the crater always contrast with the red ring of elevated gravity rim around it.

If we assume this blue/low gravity rimmed with red/ high gravity is the simplest gravity pattern caused by the cratering process, we will have to assume a central mascon is not a direct result of the cratering process unless it is related exclusively to larger craters. I propose this is the situation based on a structure of the mantle that has a limited capacity to redistribute heat and limit the size of resultant uplift in the cratering process.

Searching for patterns of dark blue/low gravity surrounded by red/high gravity should prove instructive. Figure 9.5A shows a dark blue spot in the center of the unnamed crater in the black circle. In Figure 9.6B it appears as only a green bottomed crater. As this is in the center mascon of the Freud-Sharon basin, the green is a significantly lowered high gravity. This shows what we see is a constructive addition of the two gravity patterns. By comparison, the Anderson crater is significantly smaller than the F-S. We can assume its gravity over print was also significantly smaller, and yet, its low gravity center completely cancelled out the high gravity of the mascon. This suggest the gravity reading may only register the density in the first few kilometers of the crust.



The white circle in Figure 9.6 is a high gravity spot but it is formed between smaller craters; a small bit of the original mascon showing through. Using the concept of high gravity surrounding low gravity and high gravity spots occurring between craters, Figure 9.5 shows a sketch of the probable craters in this section across the Freundlich – Sharonov basin. Figures 9.7-9.9 showing increased identification of ghost craters visibility with increased detail.

Figure 10.6: (A) Lower resolution GRAIL image of the center of F-S crater, (B) Higher resolution GRAIL image with LOLA topography image superimposed over it. (Both images NASA) White circle 70 km diameter with >25 craters visible in it. Can you find more than that?

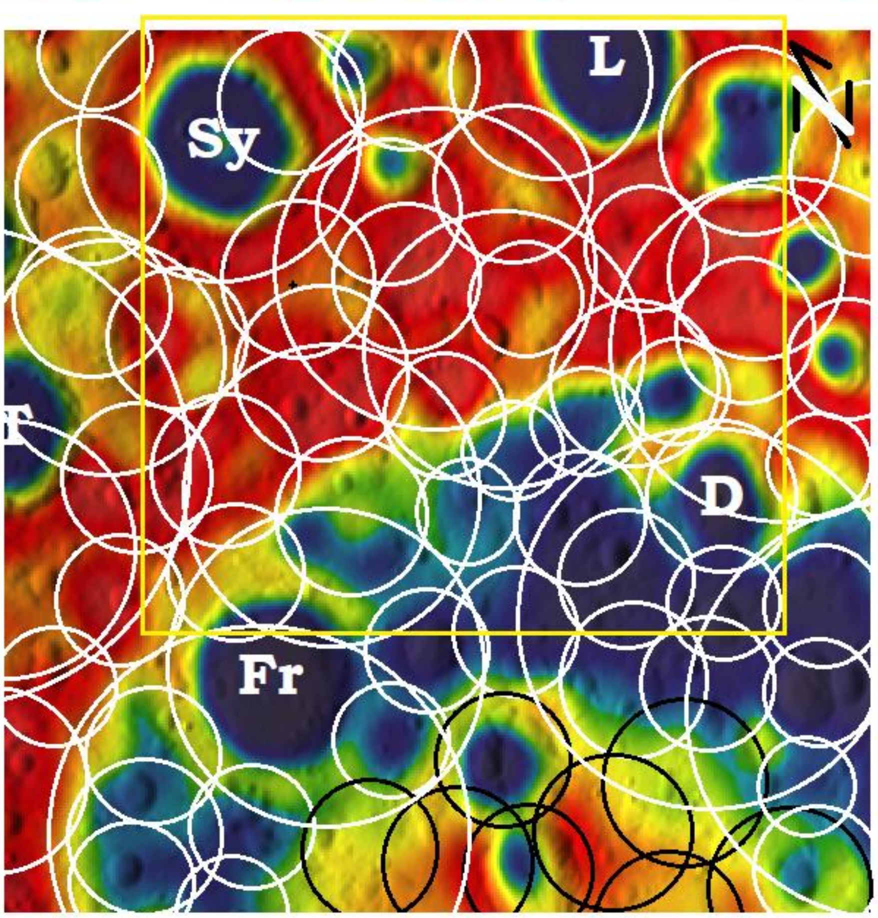


Figure 10.7: Detail of the Freundlich -Sharonov basin (See Figure 9.4 for location.) with some craters sketched based on the pattern of high and low gravity readings. Yellow box detail in Figure 9.8 showing ghost craters in the area of the Trumpler (T), Shayn (Sy), Larmor (L), Frieundlich (Fr) and Dante (D) craters showing their occurrence is roughly the same in both the high gravity and low gravity areas.

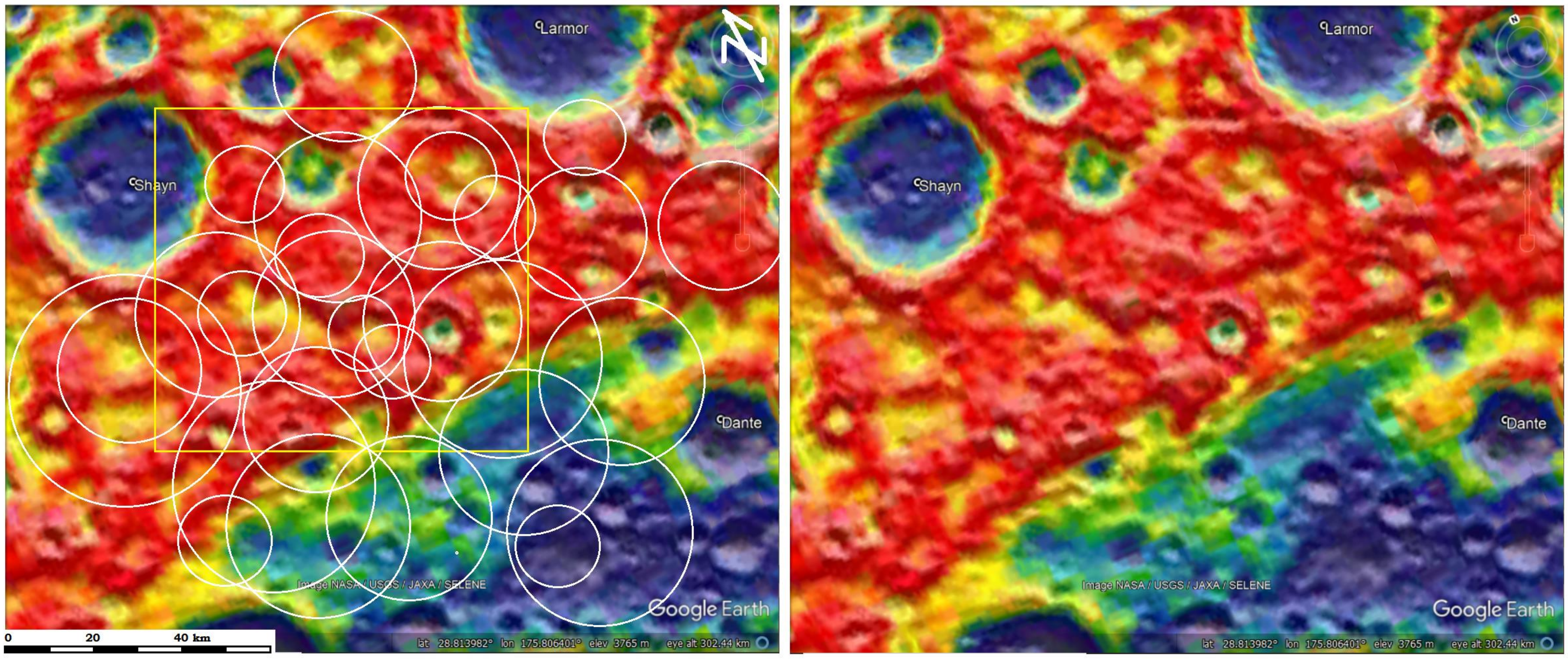


Figure 10.8: Detail of the F-S basin (see Figure 10.7 for location) with some craters sketched based on the pattern of high and low gravity readings. Blank copy of image included so reader can see clues for crater identification at this resolution. Yellow box is detail.

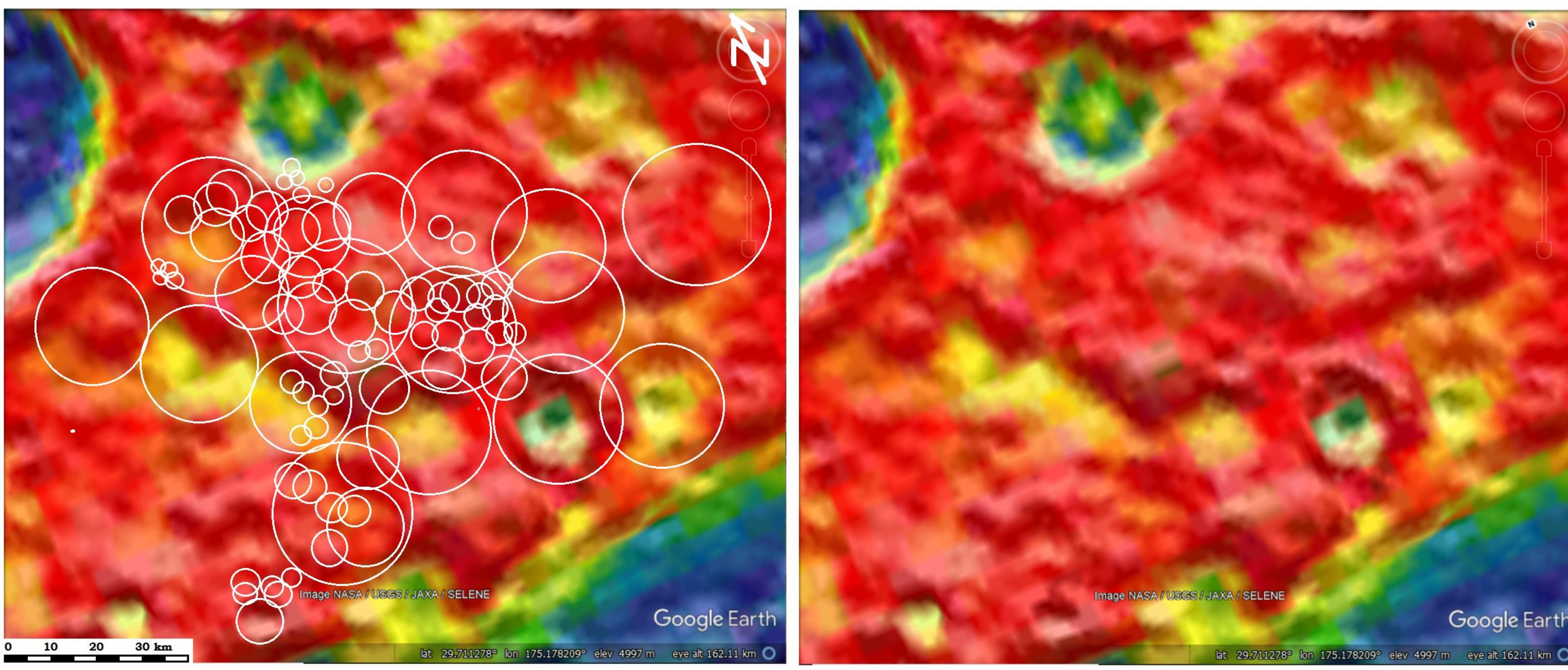


Figure 10.9: Detail of the F-S basin (see Figure 10.8 for location) with some craters sketched based on the pattern of high and low gravity readings. Blank copy of image included so reader can see clues for crater identification at this resolution.

Mascons of Mares Orientale and Nectaris

If a crater can be recognized by low gravity readings ringed by high gravity reading, such as in Figure 10.10A for Mare Orientale and Figure 10.11 for Mare Nectaris. The figures show they share five structures. One is the mascons/high gravity center, two is the inner/high gravity ring immediately above the outer edge of the mascon, three is the wide circular low gravity between high gravity rings, four and five are additional high gravity rings, with an almost indistinct low gravity ring separating them. The most obvious difference is in the expression of the number 3, low gravity ring. In Mare Orientale it is a distinct release valley that is very prominent, but with many green areas of intrusions from ring 4. The most pronounced of these intrusions is numbered 6. That these intrusions are higher gravity not higher topographic is indicated by the green color, which results from a high gravity over printing the low gravity ring. This indicates that the visible gravity reading is a cumulative sum of all the crater induced gravity expressions at that point.

I will define the 2-ring as the Open-ring, as it appears to have “opened up” and let the mascon in from the mantle, and the 4-ring as the original cratering rim (OCR) ring, the limits of the original bowl formed by the impact

While there are several linears that cross Mare Orientale indicated in Figure 10.10A, the north-south one is the most prominent as it dominates the entire center of the crater, even into rings 4 and 5. Straight lineaments like these have already been associated with

CGRS and have shear centers in other large impactor locations. These lineaments may center on Korolev crater, but that determination will require more research.

The superimposed gravity from other cratering events still shows in the ghost craters of Figure 10.10B. Circle 1 includes area 6, the green area in the otherwise dark blue of the lower gravity in Figure 10.10A. The green was produced by the higher gravity from crater 1. If that crater had a mascon, it blended with rings 4 and 5 accounting for a poor showing of the low gravity ring between them. The other two mascon are labeled Grimaldi and Cruger. Grimaldi is a recognized crater, but Cruger is a small craters visible south of the name. The south mascon is not associated with any recognized crater. Assuming mascons are only associated with once visible craters confirms the extensive number of earlier large craters completely obliterated in the now visible topography. Since the Grimaldi and Crugar craters produced mascons, it is logical that the larger circle 1 did also.

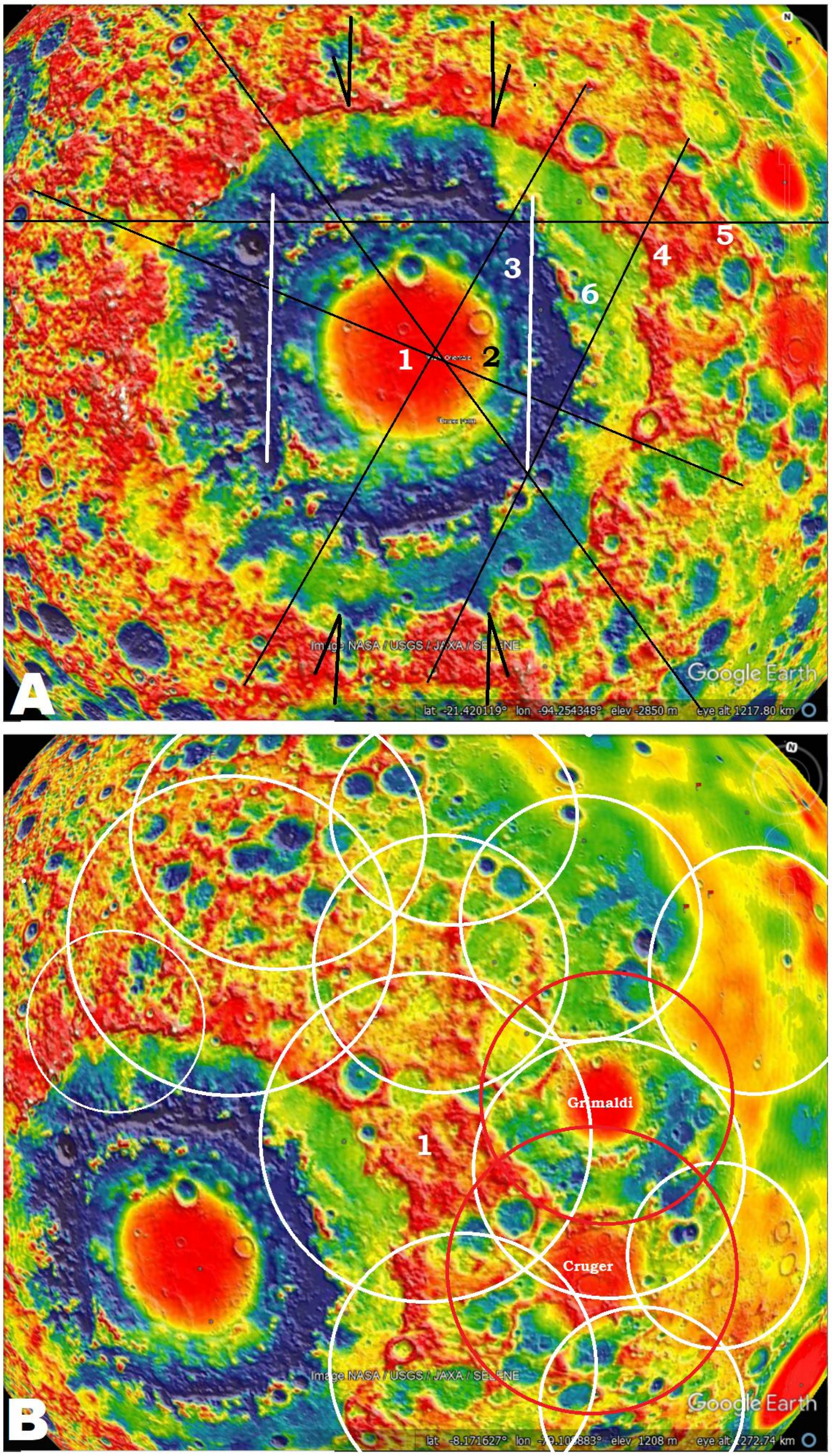


Figure 10.10: Mare Orientale in GRAIL image. (A) Showing the details of the first few rings. (B) Showing a few of the larger ghost craters found in the area, including the original crater rings for the Grimaldi and Cruger mascons. Since Mare Orientale is the clearest of these ring, all of the large ghost craters probably predate it.

Mare Nectaris (Figure 10.11) is really a double crater, with Sinus Asperitatis having a previous separate mascon which was merged with the later mascon of Mare Nectaris. A distinct lineament trend exist running down a central axis of the two mascons. This CGRS might center in the area of the Harkhebi and Fabry craters, or an early crater that existed in that area, although not much evidence of an early crater is seen in their location.

The green of ring 3 suggest a history of a higher gravity event in this area, but it seems to have occurred in the form of several separate craters. Figure 9.11B shows several CGRS that additionally have left their distinct mark, and three distinct large ghost craters. Smaller circles 1, 2 and 3 may define their originally separate mascons, but the intermixing of the high and low gravity rings have considerably confused the bullseye target patterns.

If high gravity, red areas, are due to cratering events such as the rim or mascons, is that their only source?

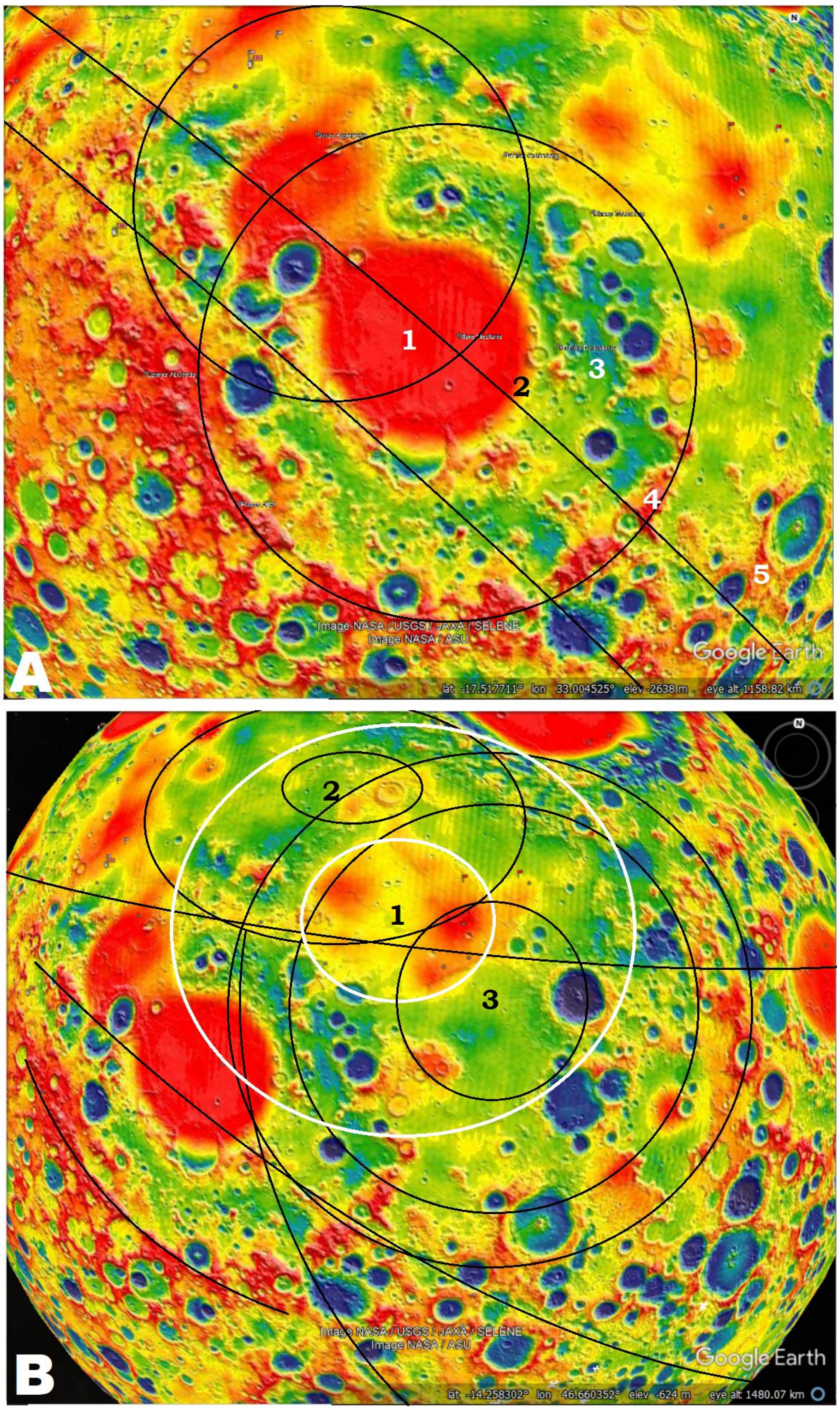


Figure 10.11: Mare Nectaris in GRAIL imagery. (A) Showing the probable location of original rings for the Asperitatis and Mare Nectaris when each originally formed. Two linears are shown that probably partially produced the common mascon in the center. (B) Three of the ghost craters which probably predated the Mare Nectaris crater. All of them may have had significant mascons in their centers.

Mascons in Moscoviense and Freundlich-Sharonov basin

Once again viewing the Moscoviense and Freundlich-Sharonov Basins in gravity, Figure 10.12, at least two significant sets of linears pass through these basins. These will account for the mascons now visible in their centers.

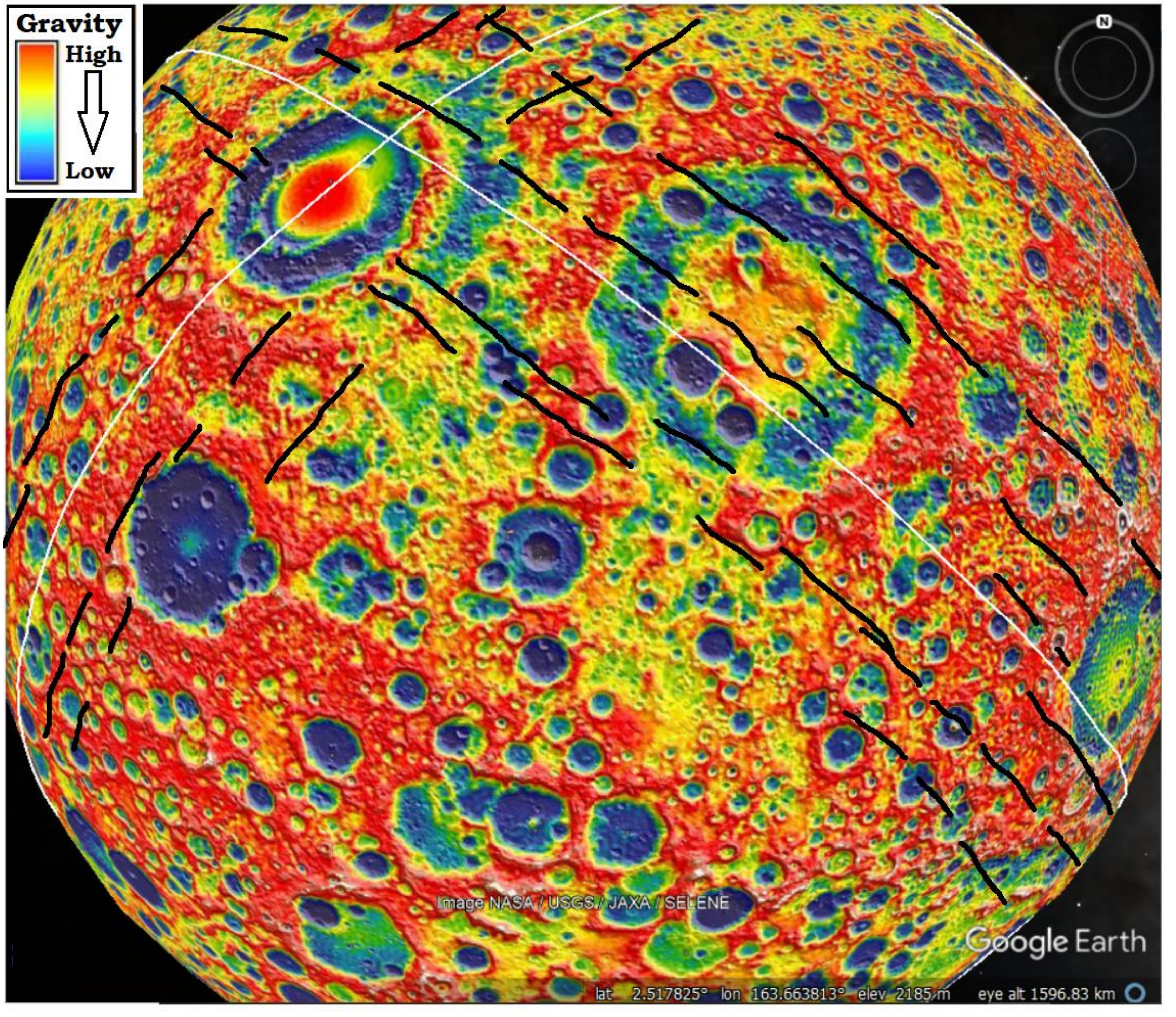


Figure 10.12: GRAIL image of the farside of the moon with two sets of crossing linears.

Conclusions

Gravity mapping of the lunar surface has confirmed the occurrence of at least three structures that had previously been unrecognized under ambient light. The occurrence of straight lineament having small circle relationships to the cratering center, CGRS. Mascons recognized in larger cratering structure's centers with the size and distinctness of the mascon dependent on the size of the cratering event. The occurrence of many more ghost craters then had previously been recognized becomes highly visible in gravity mapping where they leave a distinct "bullseye" target pattern.

Acknowledgements

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