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SUPPLEMENTARY INFORMATION

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# Evidence for basaltic volcanism on the Moon within the past 100 million years

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**Table S1 | List of 75 Irregular Mare Patches (IMPs)**

| # | Informal Name | Max Length [m] | Lat [°] | Lon [°] | Host Mare | Previous Citation | Geologic Context | Grade |
|---|---|---|---|---|---|---|---|---|
| 1 | Sosigenes | 5000 | 8.335 | 19.071 | Tranquillitatis | Stooke, 2012 | within a topographic depression | A |
| 2 | Ina | 3000 | 18.650 | 5.300 | Lacus Felicitatis | Whitaker, 1972 | within a volcanic caldera | A |
| 3 | Cauchy-5 | 3000 | 7.169 | 37.592 | Tranquillitatis | | with a volcanic summit crater | A |
| 4 | Maskelyne | 3000 | 4.330 | 33.750 | Tranquillitatis | | mare | A |
| 5 | Nubium | 2000 | -25.724 | 332.319 | Nubium | | within a topographic depression | A |
| 6 | Ross-E-1 | 1200 | 10.460 | 23.547 | Tranquillitatis | | mare | A |
| 7 | Maclear-2 | 800 | 9.102 | 20.298 | Tranquillitatis | | mare | A |
| 8 | Aristarchus North | 800 | 25.044 | 313.233 | Oceanus Procellarum | | superposed on crater ejecta | A |
| 9 | Arago-5 | 750 | 9.230 | 20.824 | Tranquillitatis | | near a volcanic summit crater | A |
| 10 | Unnamed | 670 | 7.559 | 20.984 | Tranquillitatis | | mare | A |
| 11 | Jansen-1 | 600 | 11.669 | 32.659 | Tranquillitatis | | next to a semi-circular depression | A |
| 12 | Unnamed | 560 | 8.298 | 21.600 | Tranquillitatis | Stooke, 2012 | mare | A |
| 13 | Unnamed | 550 | 9.580 | 25.514 | Tranquillitatis | | mare | A |
| 14 | Unnamed | 500 | 7.348 | 20.897 | Tranquillitatis | | near an oblong topographic depression | A |
| 15 | Maclear-1 | 430 | 8.891 | 21.487 | Tranquillitatis | Stooke, 2012 | inside a shallow topographic depression | A |

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|---|---|---|---|---|---|---|---|---|
| 16 | Unnamed | 400 | 9.112 | 21.758 | Tranquillitatis | | mare | B |
| 17 | Unnamed | 400 | 10.310 | 21.360 | Tranquillitatis | Stooke, 2012 | mare | A |
| 18 | Unnamed | 350 | 8.670 | 17.510 | Tranquillitatis | Stooke, 2012 | inside basalt-flooded impact crater | A |
| 19 | Unnamed | 350 | 9.564 | 25.392 | Tranquillitatis | | mare | A |
| 20 | Unnamed | 350 | 9.432 | 26.287 | Tranquillitatis | | mare | A |
| 21 | Unnamed | 350 | 21.653 | 359.135 | Imbrium | | mare | B |
| 22 | Unnamed | 340 | 9.540 | 20.220 | Tranquillitatis | Stooke, 2012 | in a linear chain with other IMPs | A |
| 23 | GEM30 | 330 | 37.919 | 314.779 | Unnamed | | inside a basalt-flooded crater | A |
| 24 | Unnamed | 315 | 7.887 | 21.937 | Tranquillitatis | | mare | A |
| 25 | Jansen-2 | 300 | 11.235 | 32.806 | Tranquillitatis | | part of a circular depression | A |
| 26 | Unnamed | 300 | 10.163 | 19.228 | Tranquillitatis | | next to an impact crater | A |
| 27 | Unnamed | 300 | 14.440 | 326.344 | Insularum | | shallow IMP near a degraded crater | B |
| 28 | GEM1 | 300 | 38.152 | 315.400 | Unnamed | | mare | A |
| 29 | Unnamed | 280 | 10.045 | 25.247 | Tranquillitatis | | mare | A |
| 30 | Manilus-1 | 270 | 14.889 | 6.467 | Vaporum | | near a tectonic feature | A |
| 31 | Unnamed | 270 | 10.770 | 20.520 | Tranquillitatis | Stooke, 2012 | mare | A |
| 32 | Unnamed | 255 | 9.102 | 20.265 | Tranquillitatis | | mare | A |
| 33 | Unnamed | 250 | 9.894 | 24.851 | Tranquillitatis | | mare | A |
| 34 | Unnamed | 250 | 37.121 | 319.374 | Imbrium | | inside oblong, basalt-flooded depression | A |
| 35 | Unnamed | 230 | 8.279 | 9.319 | Vaporum | | near dark halo craters | A |
| 36 | Carrel-1 | 200 | 9.817 | 25.519 | Tranquillitatis | | IMP forms an oval outline | A |
| 37 | Manilus-2 | 200 | 14.628 | 6.821 | Vaporum | | inside topographic depression | A |
| 38 | Unnamed | 200 | 9.244 | 23.924 | Tranquillitatis | | mare | A |
| 39 | GEM24 | 200 | 37.428 | 316.457 | Unnamed | | inside a basalt-flooded crater | A |
| 40 | GEM4 | 190 | 38.090 | 315.416 | Unnamed | | mare | A |
| 41 | GEM28 | 175 | 37.304 | 316.372 | Unnamed | | on edge of circular depression | A |
| 42 | Unnamed | 170 | 4.096 | 21.218 | Tranquillitatis | Schultz, 1976 | mare | A |
| 43 | GEM3 | 170 | 38.115 | 315.323 | Unnamed | | mare | A |
| 44 | Unnamed | 160 | 8.844 | 21.762 | Tranquillitatis | | in a linear chain with other IMPs | A |
| 45 | Unnamed | 160 | 13.131 | 355.639 | Sinus Aestuum | | on edge of linear rille | B |
| 46 | Hyginus | 150 | 7.726 | 6.350 | Vaporum | Schultz, 1976 | within a circular volcanic crater | A |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 47 | Unnamed | 150 | 7.083 | 38.574 | Tranquillitatis | | mare | A |
| 48 | Unnamed | 150 | 8.714 | 19.383 | Tranquillitatis | Stooke, 2013, pers. comm. | inside semi-circular depression | A |
| 49 | Unnamed | 150 | 10.101 | 25.278 | Tranquillitatis | | mare | A |
| 50 | Unnamed | 150 | 12.931 | 356.194 | Sinus Aestuum | | part of a topographic depression | A |
| 51 | Unnamed | 150 | 14.597 | 326.021 | Insularum | Stooke, 2012 | partially destroyed by impact crater | A |
| 52 | GEM21 | 150 | 37.882 | 315.712 | Unnamed | | on the rim of a mare basalt flooded crater | A |
| 53 | GEM32 | 140 | 37.826 | 314.871 | Unnamed | | inside a basalt flooded topographic depression | A |
| 54 | GEM7 | 140 | 38.058 | 315.927 | Unnamed | | mare | A |
| 55 | Unnamed | 130 | 4.550 | 22.882 | Tranquillitatis | | IMPs follow a circular curve along a shallow deformation | A |
| 56 | Unnamed | 130 | 2.934 | 38.975 | Tranquillitatis | | mare | A |
| 57 | GEM11 | 130 | 37.941 | 315.782 | Unnamed | | mare | B |
| 58 | Unnamed | 125 | -2.008 | 43.333 | Fecunditatis | Schultz, 1976; Stooke, 2012 | along rim of partially flooded impact crater | B |
| 59 | GEM 31 | 120 | 38.018 | 315.887 | Unnamed | | mare | A |
| 60 | Unnamed | 100 | 9.012 | 22.248 | Tranquillitatis | | near a wrinkle ridge | A |
| 61 | Unnamed | 100 | 9.738 | 22.320 | Tranquillitatis | | near a wrinkle ridge | A |
| 62 | Unnamed | 100 | -2.113 | 43.512 | Fecunditatis | Schultz, 1976; Stooke, 2012 | inside shallow topographic depressions | B |
| 63 | Unnamed | 100 | 26.786 | 317.041 | Oceanus Procellarum | Stooke, 2012 | near a sinuous rille and source vent | A |
| 64 | Unnamed | 100 | 14.468 | 326.271 | Insularum | Stooke, 2012 | Semi-circular curve | A |
| 65 | GEM35 | 100 | 36.937 | 315.879 | Unnamed | | along rim of degraded crater | A |
| 66 | GEM29 | 100 | 37.904 | 314.920 | Unnamed | | inside a basalt-flooded topographic depression | A |
| 67 | GEM26 | 100 | 37.417 | 316.423 | Unnamed | | inside a basalt-flooded topographic depression | A |
| 68 | GEM17 | 100 | 37.974 | 315.715 | Unnamed | | on edge of circular depression | B |
| 69 | GEM12 | 100 | 37.995 | 315.841 | Unnamed | | mare | A |
| 70 | GEM6 | 100 | 37.864 | 315.522 | Unnamed | | on interior rim of basalt flooded crater, possibly where basalt flowed into the depression | A |

Figures S1 and S2 contain images for each IMP in the Table (except Ina). The informal name "GEM" indicates that the IMP occurs in the region near the impact craters Gruithuisen E and M. Grade "A" indicates the feature is

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definitely an IMP. Grade "B" indicates uncertainty due to the small size of the feature and/or image viewing geometry. The accuracy of the NAC pointing is ±19 m. Previous mentions of IMPs noted in the table originate from Schultz, P. H. *Moon Morphology* (University of Texas Press, Austin, Texas, 1976) and Stooke, P. J. Lunar Meniscus Hollows. *Lunar Planet. Science* 43, abstract 1011 (2012).

**Table S2 | Parameters of the Digital Topographic Models (DTMs)**

| Informal Name | Lat [°] | Lon[°] | NACs | DTM scale [m/px] |
|---|---|---|---|---|
| Sosigenes | 8.335 | 19.071 | M177508146, M177514916 | 2 |
| Ina | 18.650 | 5.300 | M119808916, M119815703 | 2 |
| Cauchy-5 | 7.169 | 37.592 | M1108039362, M1108025067 | 5 |
| Hyginus | 7.730 | 6.350 | M1114121068, M1114135273 | 5 |
| Manilus-1 | 14.889 | 6.467 | M1121188383, M1121202582 | 5 |
| Maclear-1 | 8.891 | 21.487 | M144483945, M144490730 | 2 |

**Table S3 | Number of Craters Reported**

| IMP area | # impact craters D ≥ 10 m | # impact craters D ≥ 25 m | # impact craters D ≥ 50 m |
|---|---|---|---|
| Sosigenes smooth deposit | 286 | 29 | 3 |
| Ina smooth deposit | 232 | 8 | 1 |
| Cauchy-5 smooth deposit | 262 | 16 | 4 |
| Sosigenes uneven deposit | 9 | 2 | 0 |
| Ina uneven deposit | 28 | 4 | 0 |
| Cauchy-5 uneven deposit | 62 | 12 | 0 |

**Table S4 | Sample Areas for Spectral Ratio Comparisons**

| Region of interest | Type | Min Lat[°] | Max Lat[°] | Min Lon[°] | Max Lon[°] |
|---|---|---|---|---|---|
| Ina | IMP | 18.51 | 18.71 | 5.24 | 5.43 |
| Sosigenes | IMP | 8.26 | 8.46 | 18.97 | 19.17 |
| Cauchy-5 | IMP | 7.05 | 7.25 | 37.50 | 37.70 |
| Maskelyne | IMP | 4.26 | 4.46 | 33.61 | 33.80 |
| Nubium | IMP | -25.83 | -25.63 | -27.75 | -27.55 |
| Rima Bode | pyroclastic, high-Ti | 11.66 | 11.86 | -3.83 | -3.63 |
| Mare Vaporum | pyroclastic, high-Ti | 10.45 | 10.64 | 6.80 | 7.00 |
| Sinus Aestuum | pyroclastic, high-Ti | 6.16 | 6.35 | -7.55 | -7.36 |
| Sulpicius Gallus | pyroclastic | 22.39 | 22.59 | 8.16 | 8.36 |
| Aristarchus | pyroclastic, low-Ti | 26.93 | 27.13 | -52.00 | -52.80 |
| Harbinger | pyroclastic, low-Ti | 26.87 | 27.07 | -44.30 | -44.11 |
| Southwest Mare Humorum | pyroclastic, low-Ti | -26.70 | -26.50 | -44.62 | -44.42 |
| Laplace A | immature mare (crater ejecta) | 43.34 | 43.54 | -27.13 | -26.94 |
| Carlini G | immature mare (crater ejecta) | 32.51 | 32.71 | -24.93 | -24.74 |
| Linne B | immature mare (crater ejecta) | 30.68 | 30.88 | 14.12 | 14.32 |
| Jansen E | immature mare (crater ejecta) | 14.61 | 14.80 | 27.71 | 27.91 |
| Dawes (distal) | immature mare (crater ejecta) | 17.09 | 17.29 | 24.72 | 24.92 |
| Imbrium-1 (red) | mature mare | 46.97 | 47.17 | -18.03 | -17.83 |
| Imbrium-2 (red) | mature mare | 46.33 | 46.53 | -16.99 | -16.79 |
| Tranquillitatis-1 (red) | mature mare | 5.49 | 5.69 | 26.08 | 26.28 |
| Tranquillitatis-2 (red) | mature mare | 13.07 | 13.27 | 36.99 | 37.18 |
| Imbrium-1 (blue) | mature mare | 43.12 | 43.32 | -23.41 | -23.21 |
| Imbrium-2 (blue) | mature mare | 41.12 | 41.32 | -26.61 | -26.41 |
| Tranquillitatis-1 (blue) | mature mare | 10.72 | 10.92 | 30.67 | 30.87 |
| Tranquillitatis-2 (blue) | mature mare | 9.79 | 9.99 | 23.11 | 23.31 |
| Serenitatis-1 (red) | mature mare | 26.51 | 26.71 | 24.20 | 24.40 |
| Serenitatis-1 (blue) | mature mare | 26.80 | 27.00 | 27.05 | 27.25 |

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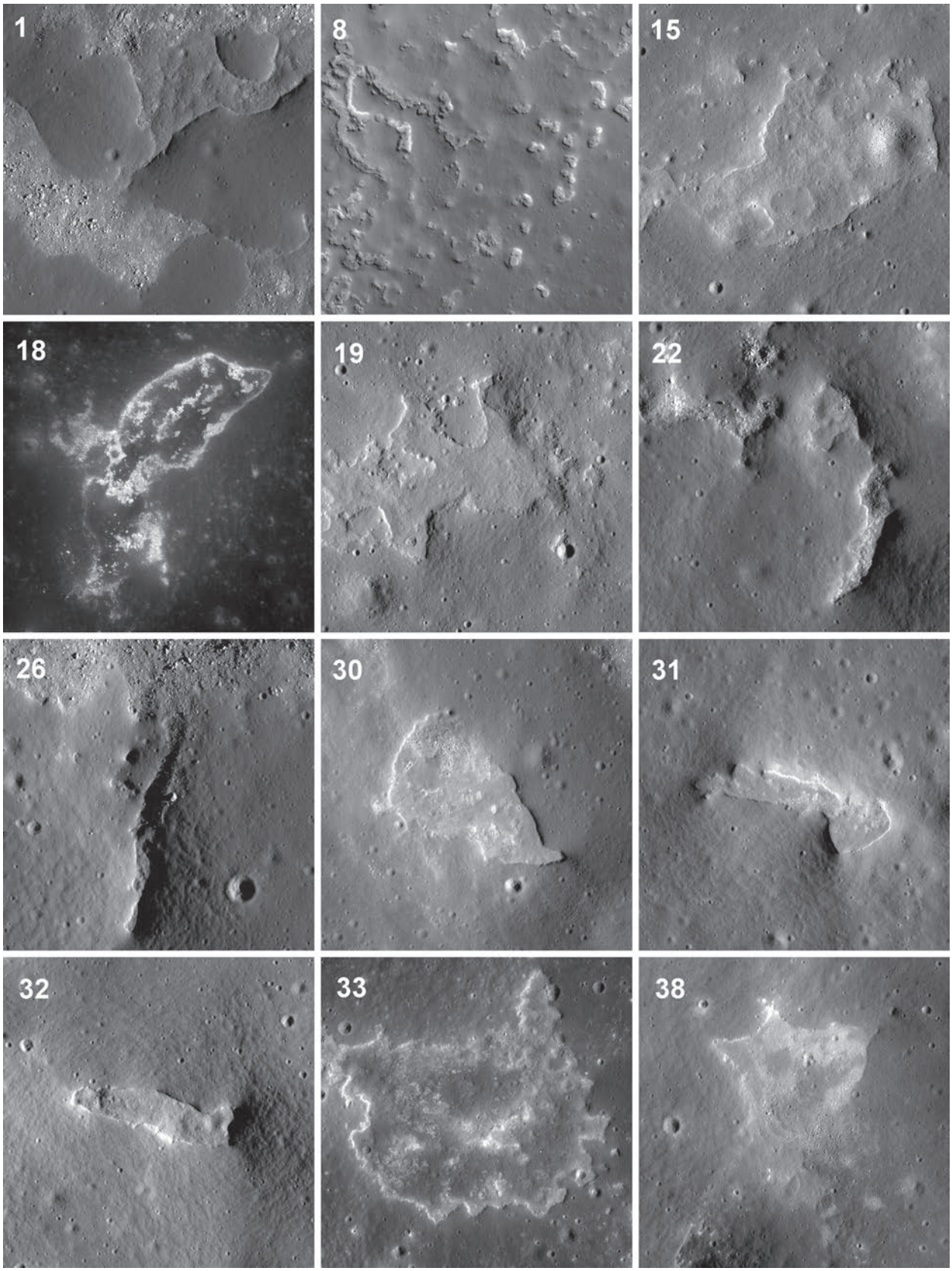

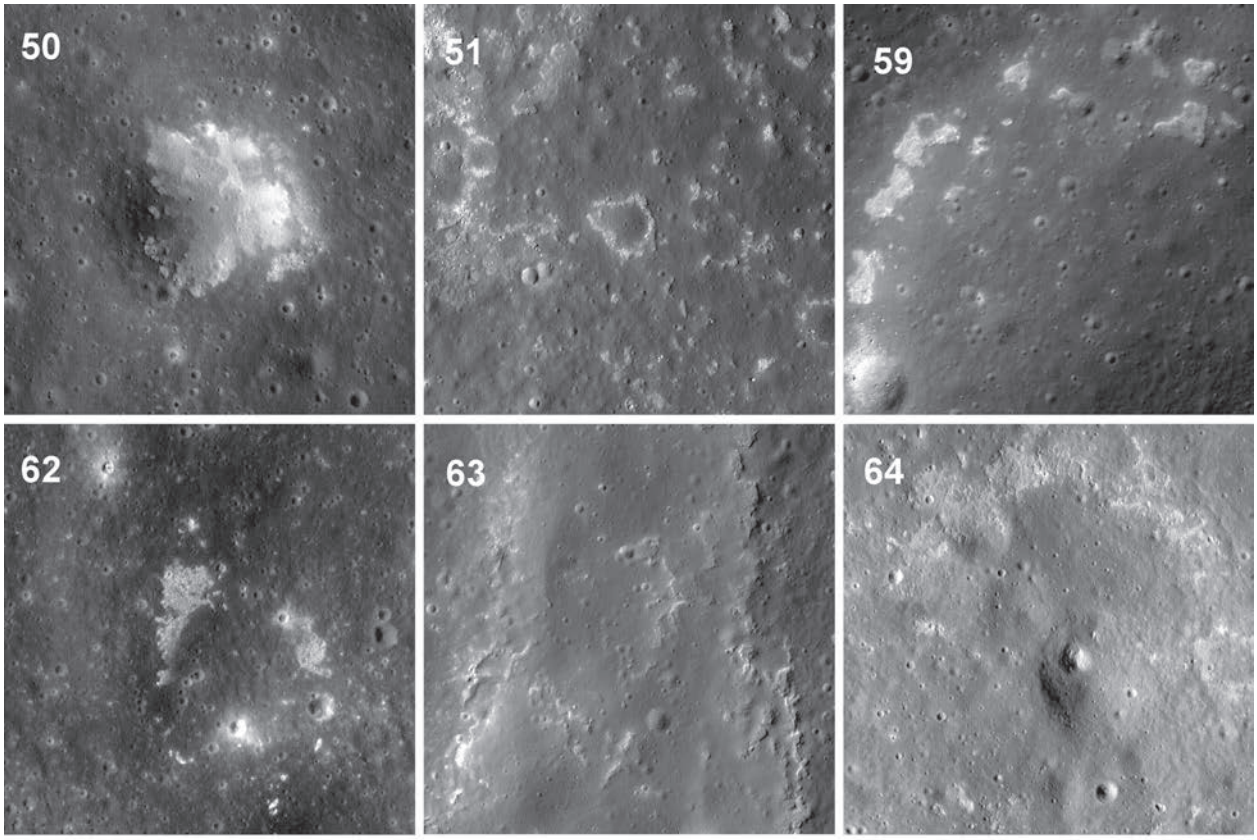


**Figure S1 | Images of IMPs in Table S1, Part 1**
The number of each image corresponds to an IMP in Table S1. Images are 450 m in width. Figure S2 continues Figure S1. In some images only a portion of the IMP is shown. In some cases the center of the image was shifted from the coordinates in Table S1 to focus on representative morphology.

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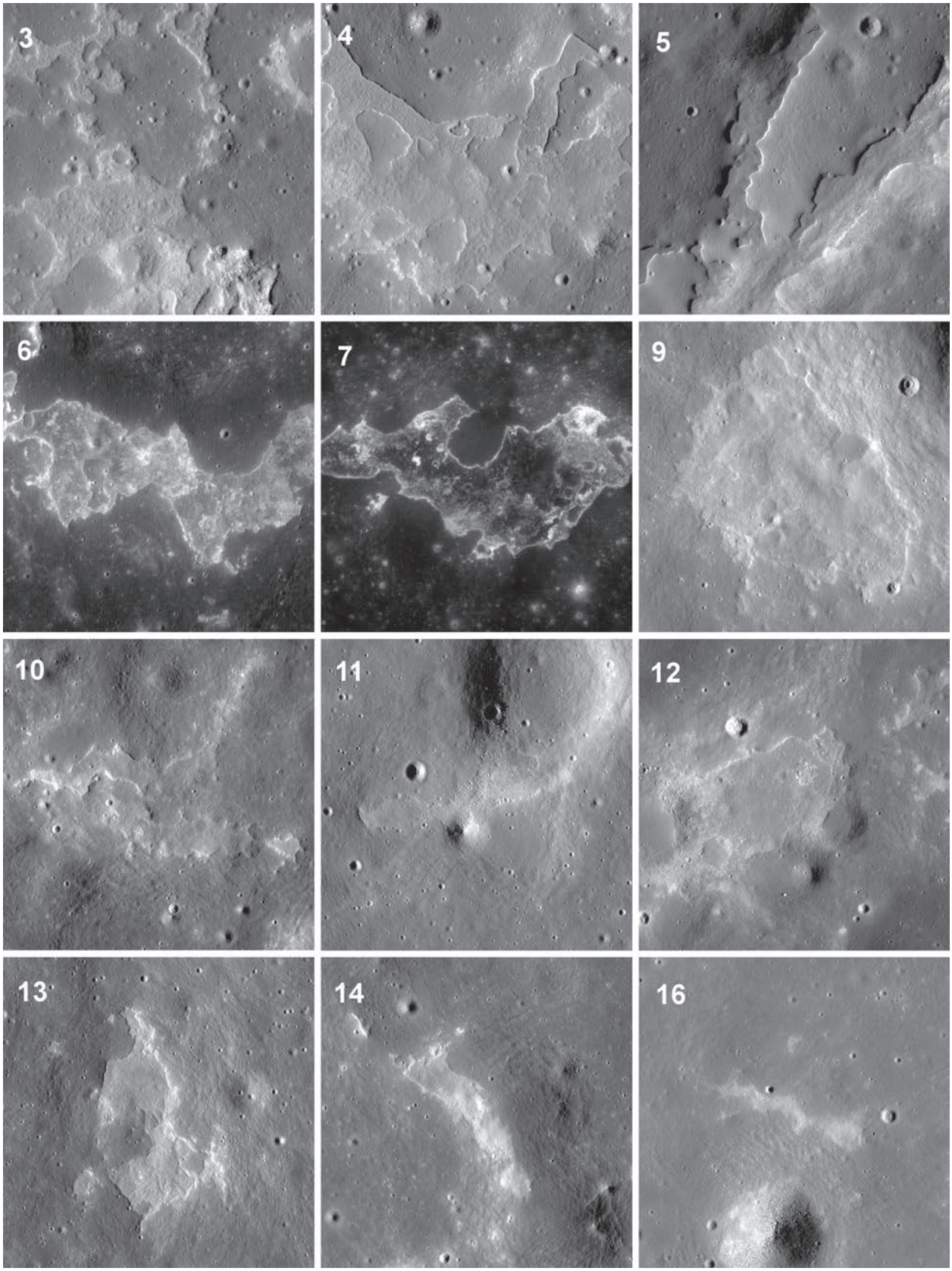

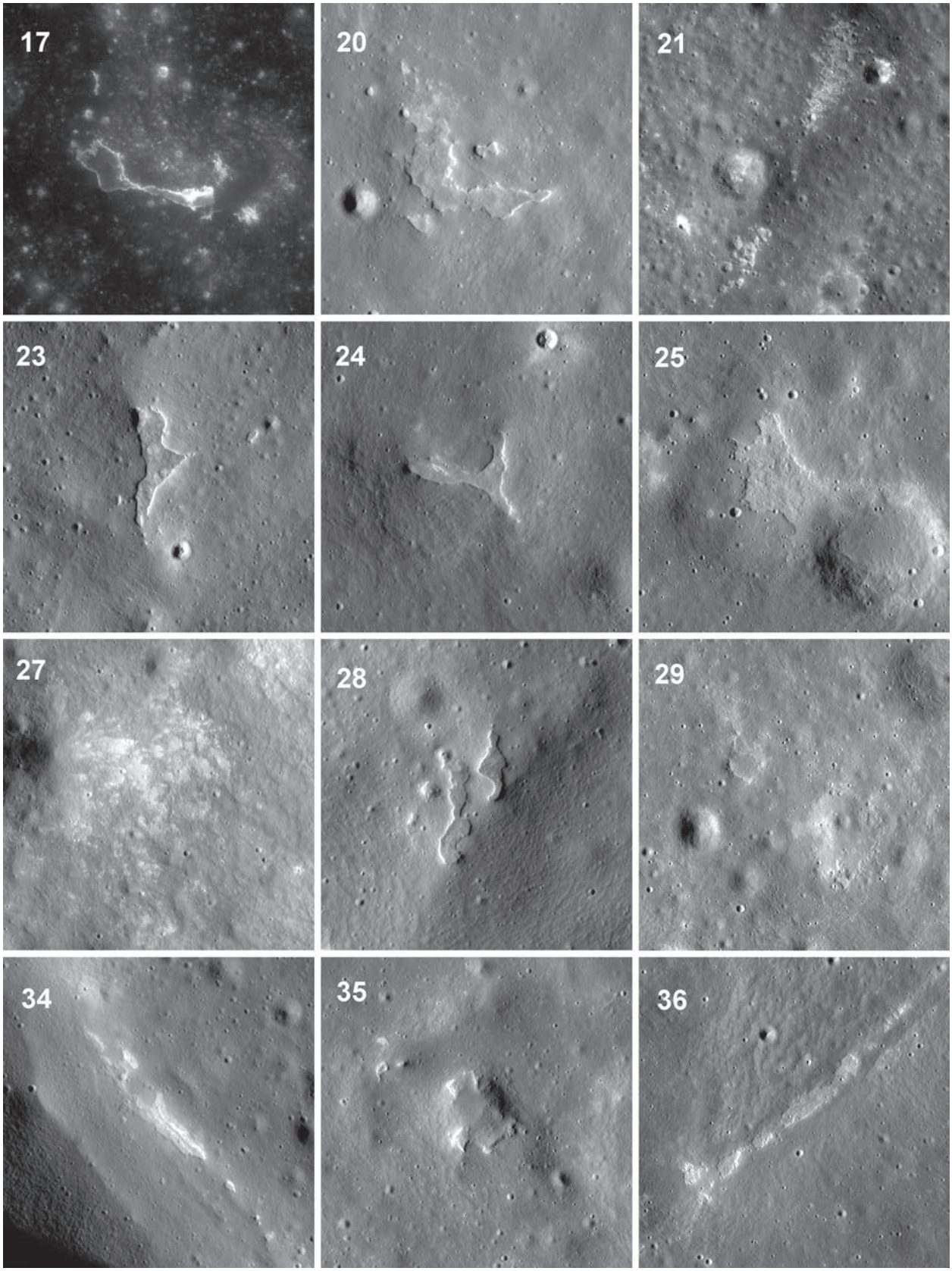
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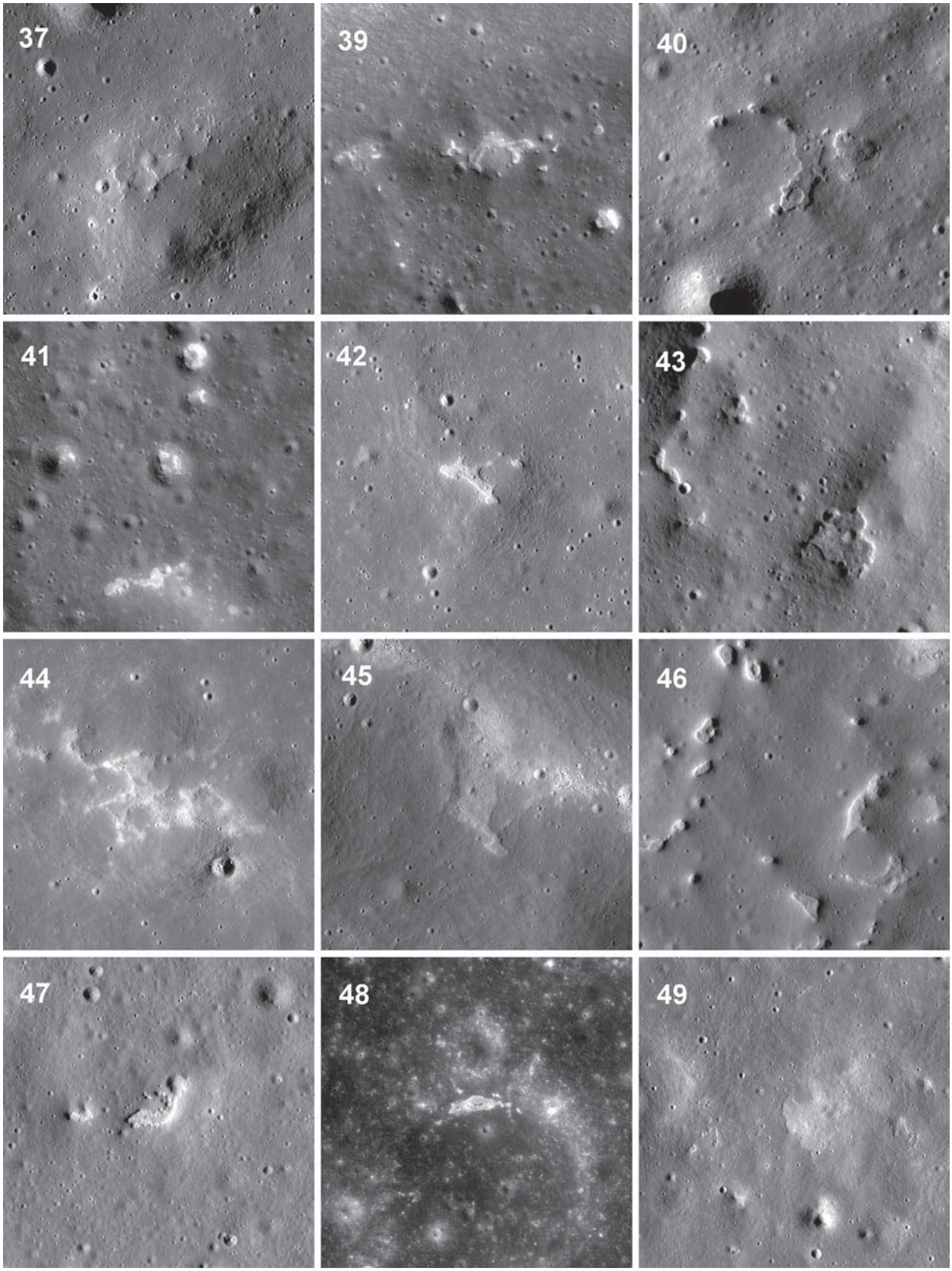

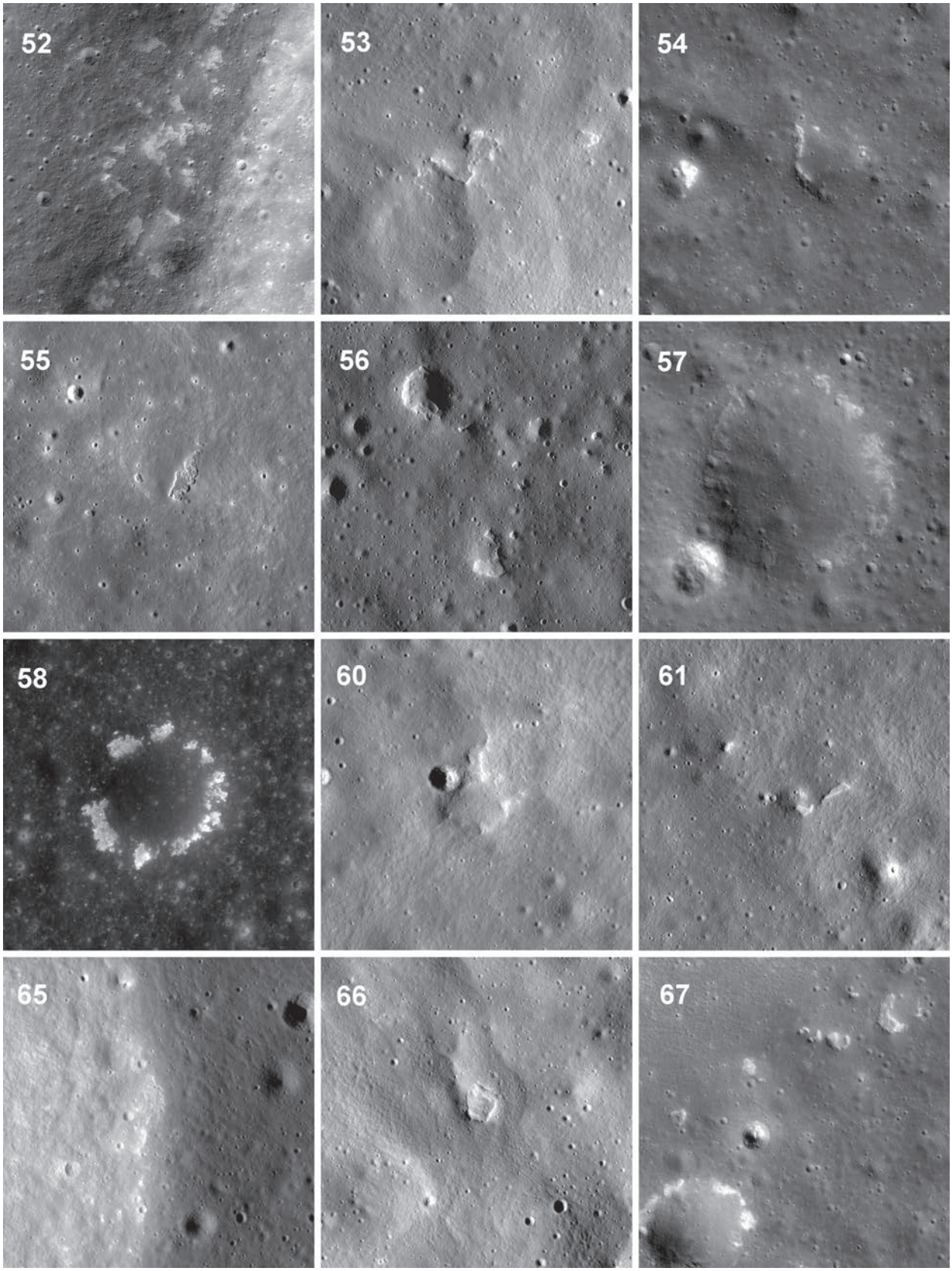
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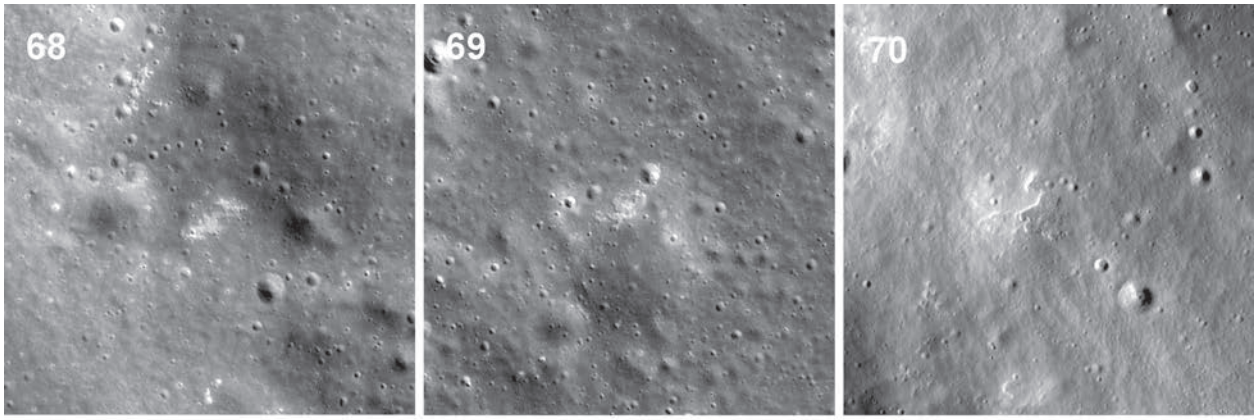


**Figure S2 | Images of IMPs in Table S1 Part 2**
The number of each image corresponds to an IMP in Table S1. Images are 900 m in width. In some images only a portion of the IMP is shown. In some cases the center of the image was shifted from the coordinates in Table S1 to focus on representative morphology.

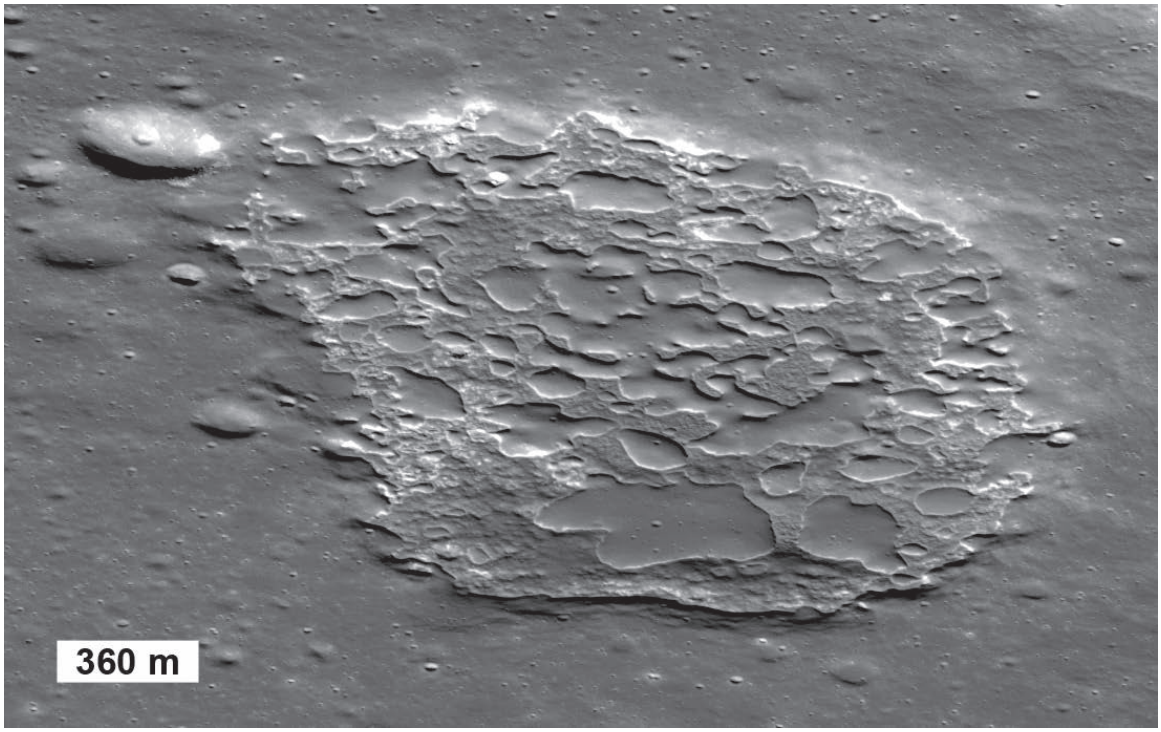


**Figure S3 | Oblique image of Ina**
Oblique NAC M1108203502 of Ina, an IMP located at 18.650°N, 5.300°E, in Lacus Felicitatis; north is to the right.

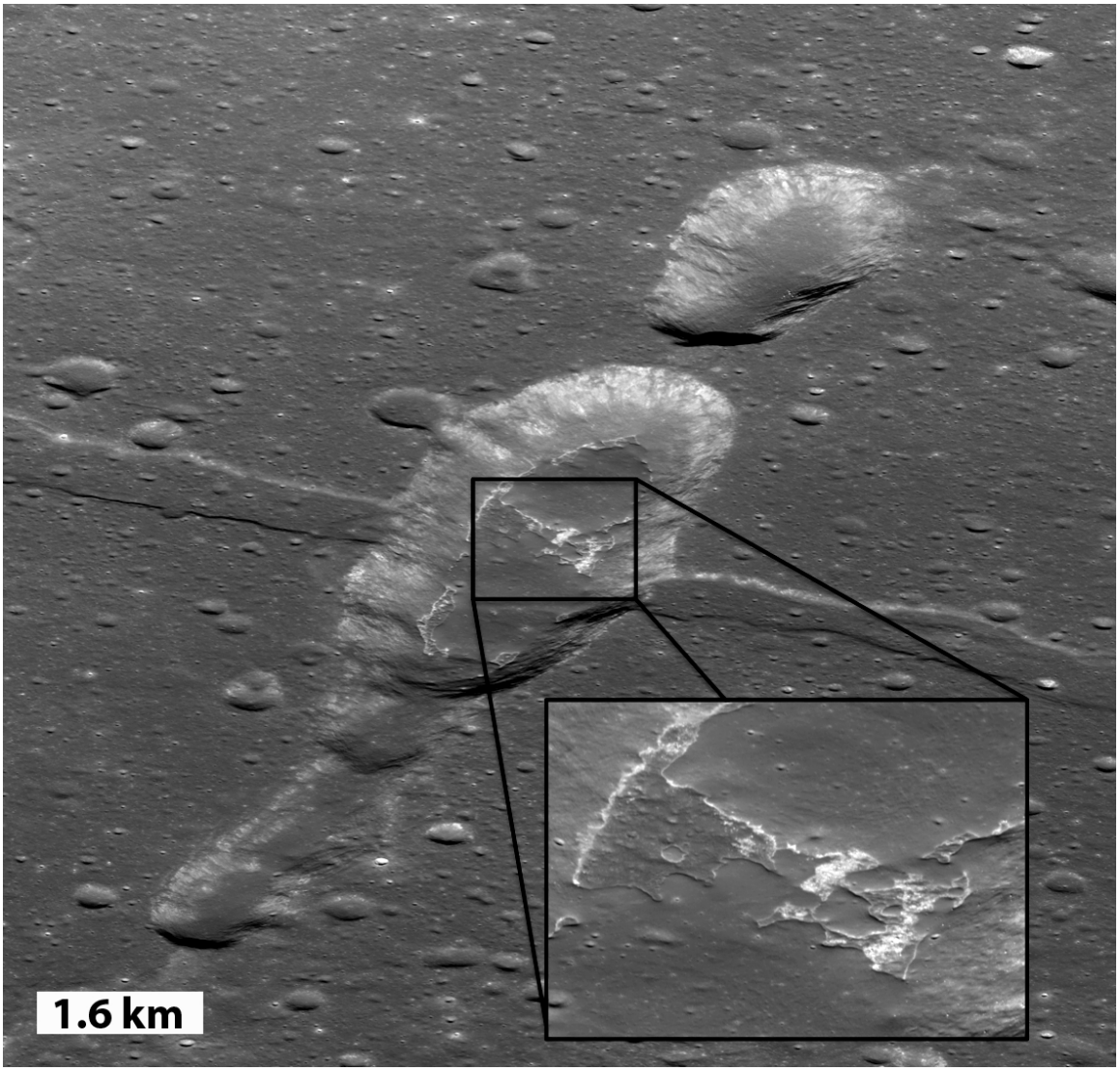


**Figure S4 | Oblique image of Sosigenes IMP**
Oblique NAC M1108117962 of the Sosigenes IMP (8.335°N, 19.071°E) in Mare Tranquillitatis; north is to the right.

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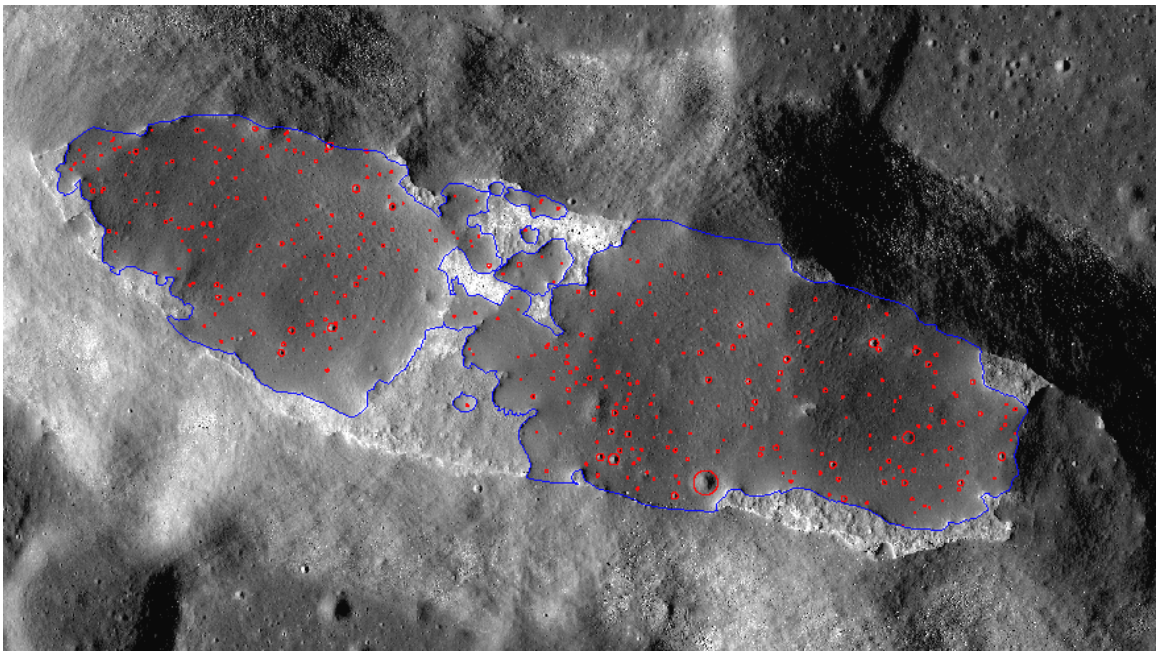

**Figure S5 | Craters on the smooth deposit of the Sosigenes IMP**
The red circles are impact craters superposed on the smooth deposit of the Sosigenes IMP, delineated by the blue line; image width is ~5 km; north is up.

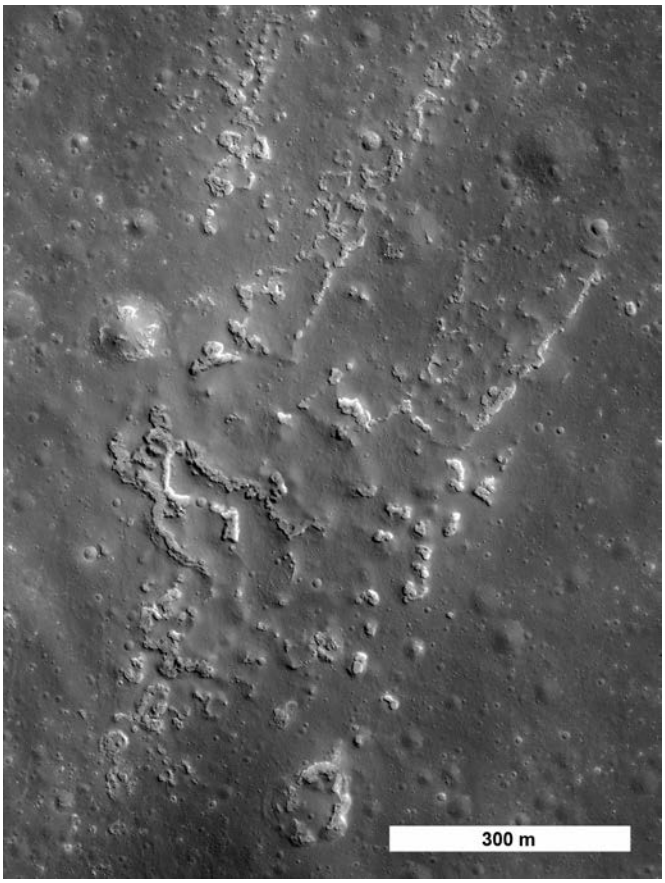


**Figure S6 | IMP north of the impact crater Aristarchus**
LROC NAC M168509312R of the IMP north of Aristarchus crater (25.044°N, 313.233°E); incidence angle is 43°; north is up.

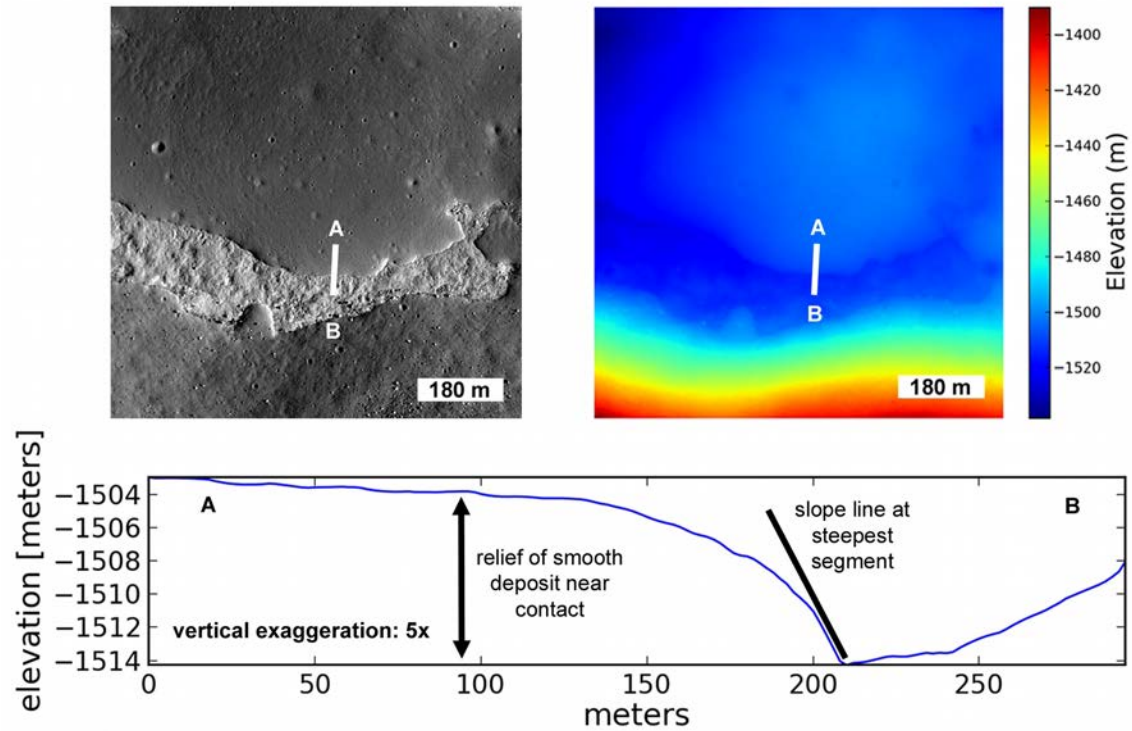


**Figure S7 | Example profile from the Sosigenes IMP**
Profile across a contact between smooth and uneven deposits. The relief of the smooth deposit is measured as the difference in elevation between the average flat surface of the smooth deposit (here -1504 meters elevation) and the base of the uneven deposit at the contact (here -1514 meters elevation). For this particular profile the smooth depositis 10 meters thick. Note the lobate margin of the smooth deposit at the contact.

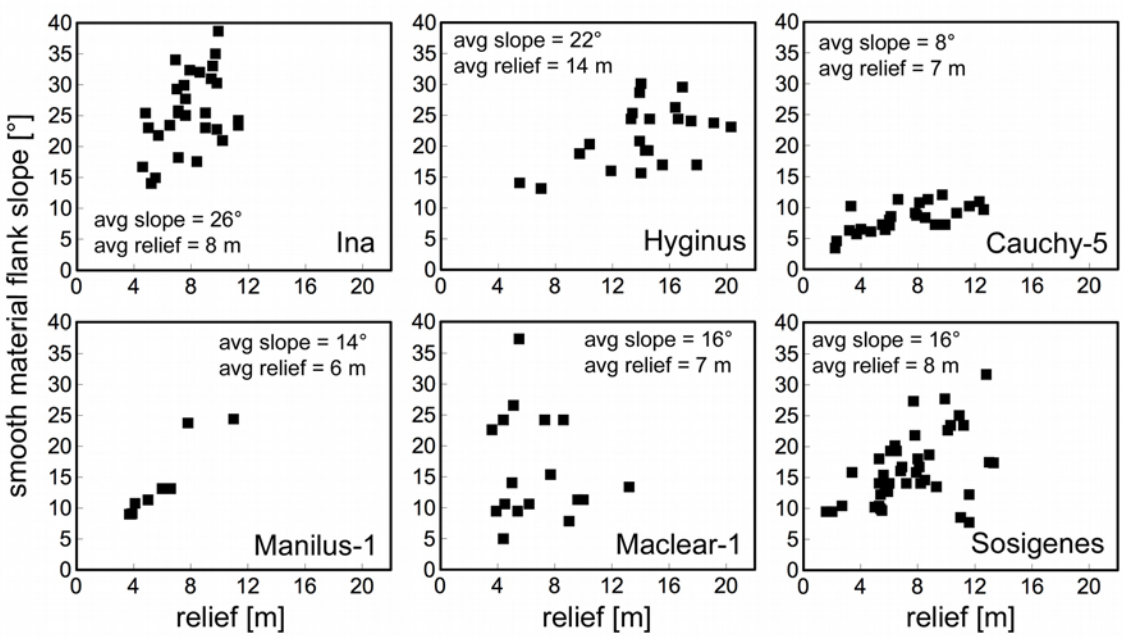


**Figure S8 | Smooth deposit relief and margin slopes**
Scatter plots of the relief, as elevation difference of the smooth deposit surface (height of flow) above the stratigraphically lower uneven deposit (x-axis), and the margin slope of the edge of the smooth deposit (y-axis).

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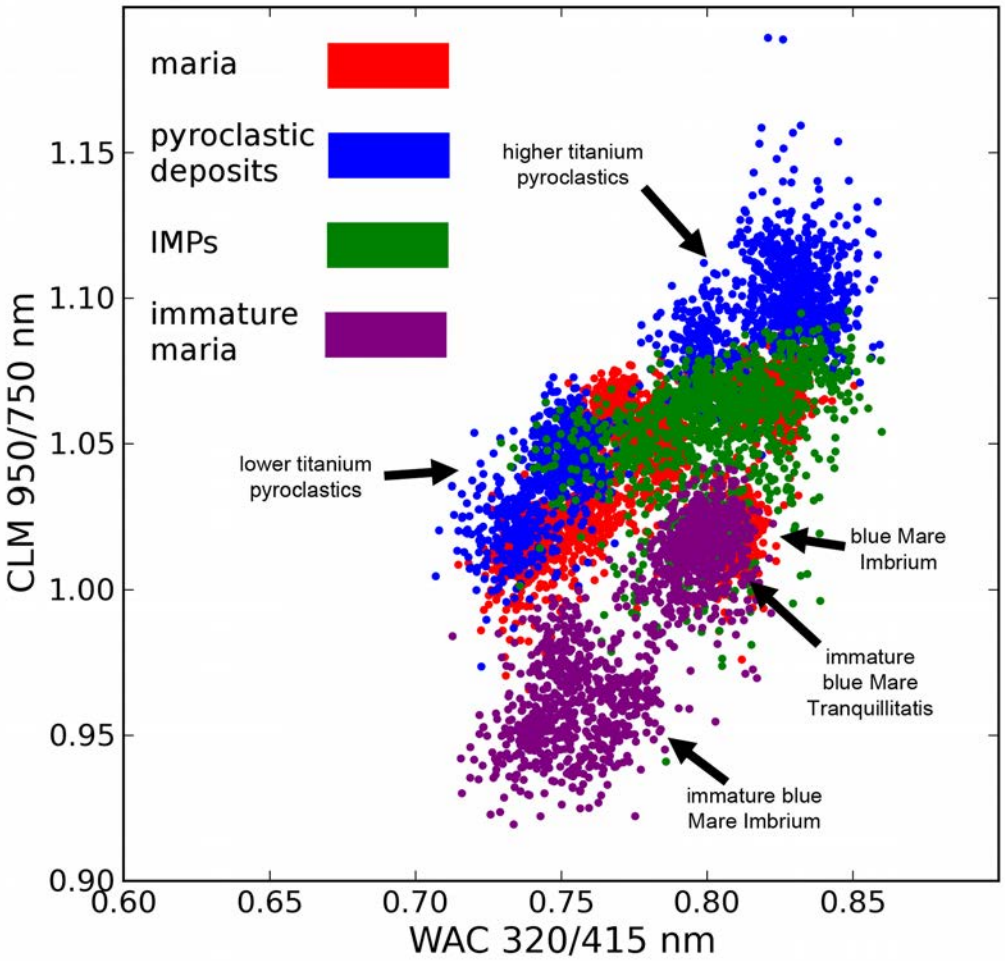


**Figure S9 | Spectral observations of IMPs and other lunar deposits**
Color ratios of deposits within and immediately surrounding a subset of five IMPs compared with color ratios of other lunar terrains: large pyroclastic deposits, mature mare basalt, and immature mare basalt. The horizontal axis is the 320/415 nm WAC ratio and the vertical axis is the 950/750 nm Clementine ratio. The IMPs and the deposits immediately surrounding the IMPs (green dots) have color ratios consistent with basaltic deposits. A higher 320/415 nm ratio indicates higher opaque content.

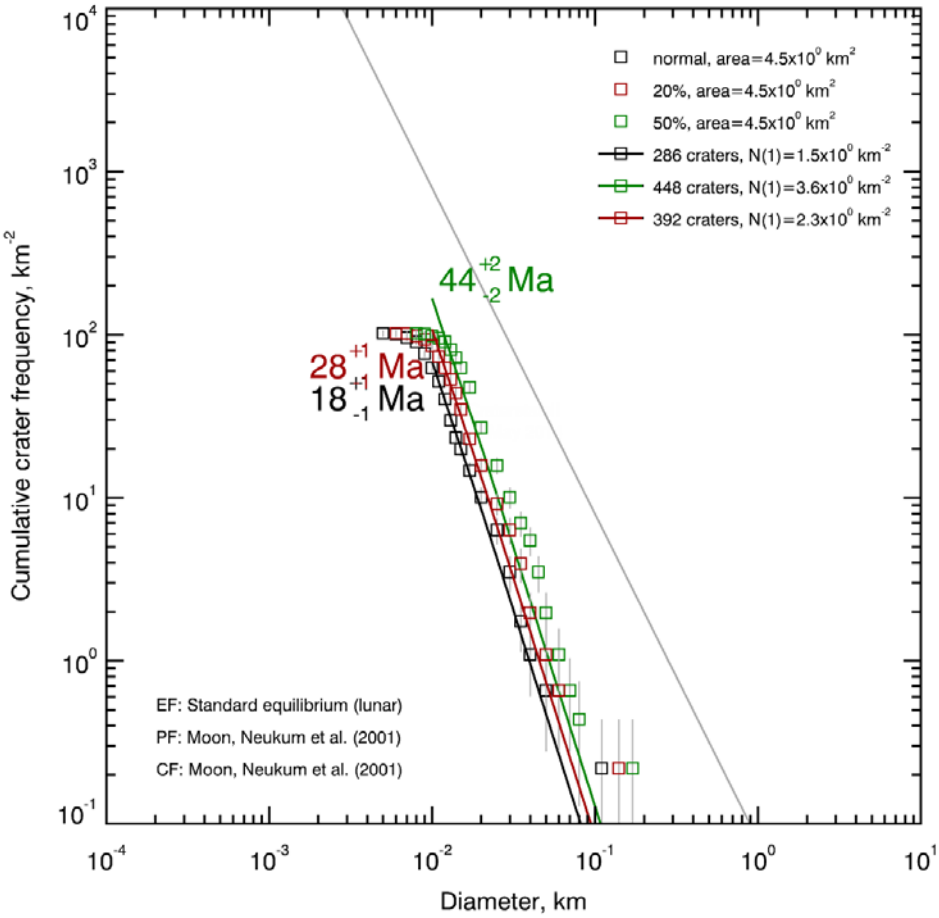


**Figure S10 | Simulated effect of different target properties**
A change in impact crater size due to different target properties increases the absolute model age for the surface, however the age is still late Copernican. The CSFD from the Sosigenes IMP (black line) with CSFDs where the size of the impact craters has been increased by 20% (red line) and 50% (green line). The original crater sizes give an absolute model age of 18 Ma, while the increase of crater sizes by 50% yields an age of 44 Ma.