Impact craters on the Moon, Mars, Mercury and Venus

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Abstract: The photographs of the lunar Aristarchus, martian Naar, mercurian Brahms and venusian Danilova impact craters were studied in order to find the differences in their morphological properties. The craters were compared in order to find how the planetary environments affect the end products of impact on different planets. It was found that the main environmental factors, which affect the impact processes are the presence of an atmosphere, surface gravitational field strength, and the presence of water in any state.

Introduction

The aim of this experiment was to understand, how the planetary environments affect the end products of impact on different planets. Four different planetary environments were chosen for the purpose of this experiment. The following craters were compared: lunar Aristarchus, martian Naar, mercurian Brahms and venusian Danilova. The inner Solar System objects are good examples of different environments, since they differ in many criteria: presence of atmosphere, surface gravity, water presence, and surface temperature. The Moon and Mercury have lost their atmospheres due to low gravity, but there are light airs on Mars and a very dense atmosphere on Venus. The highest gravity is on venusian surface, the attractive force on Mars and Mercury is the same, leaving the Moon behind other planets with its lowest gravitational field strength. Venus is very hot due to its dense atmosphere, therefore water vaporised from its surface. The lunar and martian environments are completely dehydrated. Mars is the only planet, which has some water on its surface in ice state, and there are also some vapours in the planet's atmosphere.

Procedure

The materials investigated are the pictures of the impact craters, taken during different space exploration missions. The pictures were reasonably big for a purpose of precise measurements. The distances were measured by a half-meter ruler. The first ten centimetres of the scale had a resolution of 0.5 mm, and the rest of the ruler had a resolution of 1 mm. Therefore, the distances within 100 mm were determined to an accuracy of $\pm$ 0.5 mm and the bigger distances were determined to an accuracy of $\pm$ 1 mm.

The mercurian impact crater Brahms was sketched and annotated in the observatory book and the rest of the craters were annotated on a hard-copy of the images. The annotations included the following features: central peak/pit, inner terraced walls, raised rim, continuous and discontinuous (where relevant) ejecta and secondary impact craters.

Three out of four craters were measured in order to determine their scales: Aristarchus, Brahms and Naar. The venusian Danilova was not to be measured. The size of the images was calculated using the following formula:

$$y = R \times \frac{x}{f}$$

where R - the distance between the spacecraft and the planetary surface,
x - the size of original frame,
f – focal length of the spacecraft camera lens.

The data was given on the experiment script [1].

Dividing the image size calculated according the above formula by the corresponding width of the image in millimetres measured by the ruler, the scale for each picture was determined in km/mm. These scales were then used to determine the actual sizes of the craters and the shadows cast by the crater rims and the central peak or pit. Knowing the Sun angle for each picture, the elevation of the craters' features above the flat surfaces was determined using the main trigonometric equations.

The outer slope of the wall of the lunar crater Aristarchus was in sunlight because it's low steepness. The width of the crater rim was visually estimated. Assuming that the Sun angle is equal to the rim's slope, the height of the feature was determined using trigonometry. After completing the determination of the craters' features dimensions, cross-sections of those three craters were drown on the same axis for a visual comparison. The venusian crater Danilova was not measured.

Measurements and results

The following parameters were used for the pictures sizes calculations:

	Aristarchus	***Brahms***	***Naar***
Range R (km)	127.4	22321	1641.4
Focal length f (mm)	80	1500	475
Frame size x (mm)	60	12.3	12.8
Sun angle α (°)	16	7.1	35.76

The following parameters were measured and calculated:

	Aristarchus	***Brahms***	***Naar***
Image size (mm)	95.55	183.03	44.23
Picture width (mm)	391 ± 1	258 ± 1	164 ± 1
Scale (km/mm)	0.2444	0.7094	0.2697
Crater width (mm)	175 ± 1	135 ± 1	45 ± 1
Crater real size (km)	42.77 ± 0.24	95.77 ± 0.71	12.14 ± 0.27

The following values were obtained after the shadow analysis of the craters:

	Aristarchus	***Brahms***	***Naar***
Inside (mm)	42.5 ± 0.5	31 ± 0.5	8.5 ± 0.05
Rim width (mm)	55.5 ± 0.5	N/A	N/A
Peak/pit (mm)	4.5 ± 0.5	30.5 ± 0.5	4.5 ± 0.5
External slope width (mm)	10 ± 0.5	N/A	N/A
Outside (mm)	N/A	19.5 ± 0.5	5.0 ± 0.5
Maximum depth (km)	3.0 ± 0.04	2.7 ± 0.04	1.6 ± 0.1
Peak/pit height (km)	0.3 ± 0.04	2.66 ± 0.04	0.9 ± 0.1
Rim height (km)	0.7 ± 0.04	1.7 ± 0.04	1.0 ± 0.1

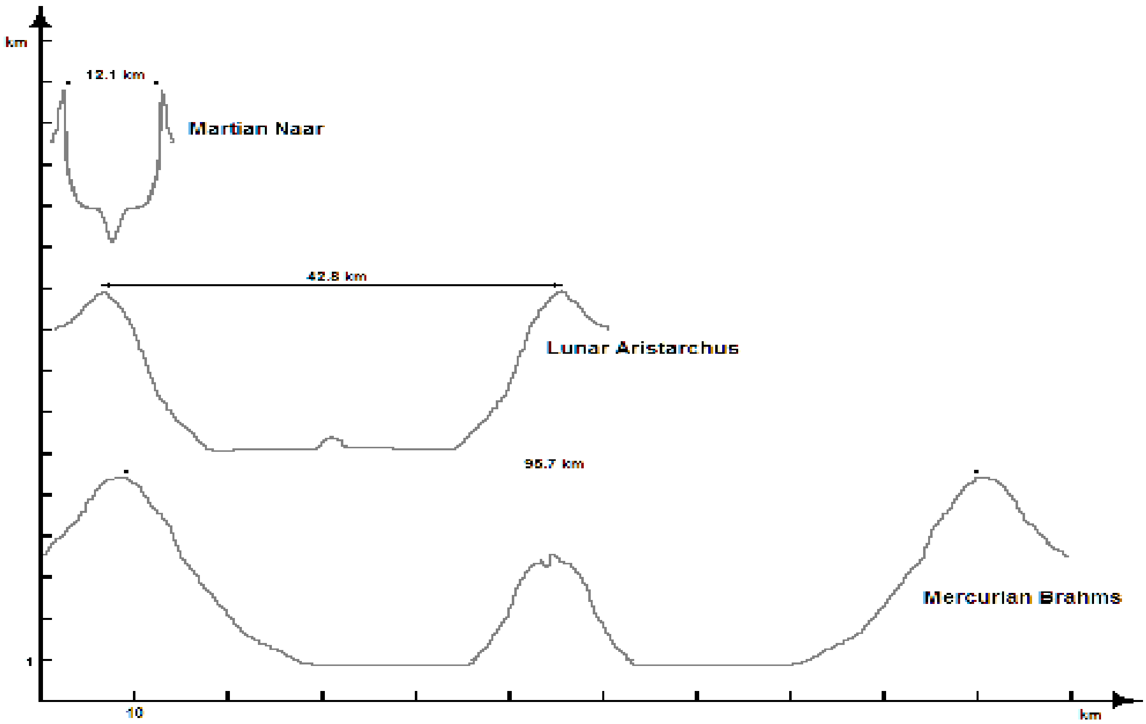

Figure 1: The cross-section of the craters Naar, Aristarchus and Brahms.

Figure 1 illustrates the comparative dimensions of three craters on the Moon, Mars and Mercury.

The discussion of the venusian crater, Danilova

Venusian craters are remarkable for the extensive outflow that extends far away from the crater rim. The conditions, which cause craters like Danilova to exhibit such outflows, are the high surface temperature of 700 K and the pressure of 92 bars [2]. The impacts between the venusian surface and bolides produce more melt than the collisions on other planets.

The crater's floor appears to be very smooth in colour. The radar backscatter images are showing objects in black and white colours, where the bright regions represent rough surfaces. Since the Danilova's floor is very dark on the image, it is very smooth and flat. This suggests that the crater floor is infilled with lava or impact melt, which are the only substances that could produce such an even surface.

Venus shows no record of the heavy bombardment period, which suggests that the surface of the planet was re-emerged after the heavy bombardment period of about 400 million years ago. Most of the craters appear pristine, although they were formed after the venusian exterior was resurfaced. This proposes that the age of the craters is around 400 million years. There is a very little geological and weather activity to destroy most of the craters [3]. Venusian surface shows no small impacts, which is the consequence of its dense atmosphere, which burned and evaporated smaller bolides before they could reach the planet.

Discussion of environmental factors

Atmosphere

The atmospheres on the Moon and Mercury are very negligibly light with an average pressure of 10^{-15} bars. The most significant air is on Mars, which produces a pressure of 6.3 thousands of a bar. This low density can still create a significant resistance for the fast moving objects like incoming bolides. The friction between air molecules and a body heats the bolide up, starting to evaporate the substance. This burns small meteoroids completely and reduces the mass of bigger ones, thus lessen the collision quantity. Therefore, most of the martian impact craters are shallower than those on the Moon or Mercury.

Surface gravity

The gravitational filed strength is the smallest on the lunar surface and approximately the same on the exterior or Mars and Mercury. The attraction force affects the morphology of continuous ejecta. Generally speaking, the bigger the gravity, the shorter distance the ejected material can travel along. Therefore, the ejecta around the martian Naar and mercurian Brahms are similar in structure and thickness, and the outflow of the lunar crater Aristarchus is broader distributed. The continuous ejecta around the Naar has a distinctive outer boundary, and this feature not present on the other two craters. The reason will be explained later.

Secondary impact craters around martian crater are not detectable due to possible difference in ground composition; The derived impacts around Aristarchus are less deep and remarkable than those around Brahms as a consequence of gravity difference.

The rim of the mercurian crater seems to be more fractured than that of the lunar crater, which appears smoother and less terraced. This could happen due to gravity, as the rims are continuously pressed under gravitational force, which is again greater on Mercury.

Surface structure

The height of the central peak inside Brahms is higher than that of Aristarchus. This can be explained by the higher mercurian ground density. The lunar surface is more elastic and produces several floor vibrations, coming to rest at a lower point, while the mercurian central peak “freeze” after the first or second oscillation.

The water ice on the surface of Mars explains the existence of the central pit instead of more frequently occurring peak and the remarkable style of the ejecta. The pit is produced by a crushed ice between a colliding bolide and a planet, which melts after the impact leaving the central pit.

At a moment of impact, the water ice on Mars makes the ground viscous and the continuous ejecta forms its particular shape. While melted the surface material flows away from the impact crater, cooling down on its way. Then it crystallizes, creating the continuous ejecta with a defined outer boundary.

Conclusions

After completing the experiment and comparing the craters, different planetary environments of the Moon, Mars, Mercury and Venus were discussed. This enabled one to understand how these environments affect the morphology of impact craters. It was explained that the main factors which affect the impact end products are the presence of atmosphere, surface gravity and ground structure and composition.

The provisional aim of the experiment was to measure the dimensions of the craters and their shadows. This was completed to a certain degree of accuracy, because a ruler was used for distances determination. The comparative sizes of the Aristarchus, Brahms and Naar are 42.77 ± 0.24 km, 95.77 ± 0.71 km and 12.14 ± 0.27 km respectively. This correlates to the accepted values for these craters: Aristarchus is 40 km [4], Brahms is 98 km [5]. The deviations from the accepted values can be explained by the measurements precision. Craters did not have apparent borders between the rim peaks and the outer flat surface. The results could be improved by taking several measurements and finding the average.

References

[1] Experiment Observatory script, Department of Physics and Astronomy, UCL, ULO, course PHAS1130, (2009).
[2] N. McBride & I. Gilmour (eds), *An Introduction to the Solar System*, Table A1 in Appendix A.
[3] http://solarviews.net/eng/vencrate.htm
[4] http://en.wikipedia.org/wiki/Aristarchus_(crater)
[5] http://space.about.com/od/mercury/ig/Mercury-Pictures-Gallery/Brahms-Crater.htm