Craters of the Moon

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Abstract

This experiment was conducted to measure the shadows cast by assorted craters using digitized images of the lunar surface, to calculate the heights of crater walls, to relate these data to the sizes of the craters, to calculate the energies of the impact that caused the craters and to derive some properties of bodies that impacted on the Moon and the Earth during the early phases of the Solar System. These measurements and calculations were used overall to extrapolate information about the moon.

Apparatus

Printed pictures of lunar surface with scale and incident angle of air included

Ruler

Theory

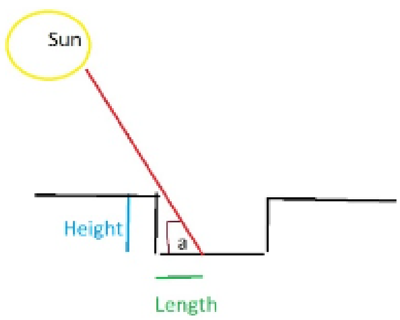
The pictures used to measure the shadows cast by the by the assorted craters were taken at times other than full moon as the sun is perpendicular (at a zenith of 90°) to the moon and no shadows will be cast at lateral angles. On earth this phenomenon is known as Lāhainā Noon.

The measurements taken were taken through printing the images given and applying the scale provided to the measurements taken with a ruler. The height calculation was performed using the following equation:

$$C_h = L_s \times \tan(a)$$

and

$$a\ (°) = 90° - \text{Incident Angle } (°)$$



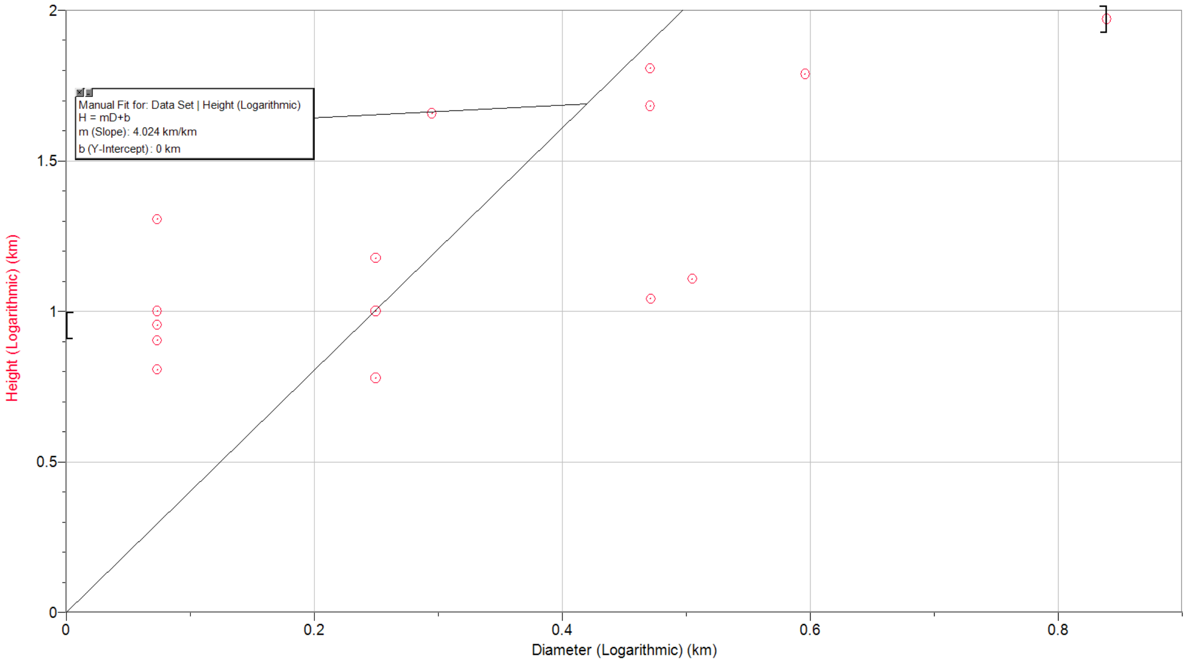
Where:

C_h: Crater Height

L_s: Length of Shadow

Incident Angle: Angle of incidence of the rays in relation to the normal

Fig 1: Crater Wall: Height (Logarithmic) Vs Diameter (Logarithmic)



This graph shows the relationship between the diameter and depth of the craters to be positive which can result in the conclusion that the larger the object colliding with the moon the deeper the crater.

The kinetic Energy was calculated using the following formula:

$$D = 2.5 \times (\frac{E}{\rho g_m})^{\frac{1}{4}} \therefore E = \frac{16}{625} D^4 \rho g_m$$

Where:

D: Crater Diameter

E: Kinetic Energy

P: Average Density of an Asteroid

g_m: Gravity of the moon

Dimensional Analysis of Emperical Equation:

$$[\mathrm{m}] = [1] \times \left(\frac{[\mathrm{J}]}{[\mathrm{kgm^{-3}}][\mathrm{ms^{-2}}]}\right)^{\frac{1}{4}}$$

$$[\mathrm{m}] = \left(\frac{[\mathrm{kgm^{2}s^{-2}}]}{[\mathrm{kgm^{-2}s^{-2}}]}\right)^{\frac{1}{4}}$$

$$[\mathrm{m}] = \left(\frac{[\mathrm{m^{2}}]}{[\mathrm{m^{-2}}]}\right)^{\frac{1}{4}}$$

$$[\mathrm{m}] = ([\mathrm{m^{4}}])^{\frac{1}{4}}$$

$$[\mathrm{m}] = [\mathrm{m}]$$

This dimensional analysis indicates that the metric for both sides of the equation of the empirical formula presented equate and it is only the constant factor which dictates its fidelity with reality.

Kinetic Energy [J] of Bodies by Empirical Formula Calculation $\pm 5 \times 10^{12}$ J
544×10^{14}
340×10^{14}
829×10^{14}
829×10^{14}
4200×10^{14}
340×10^{14}
1210×10^{14}
139×10^{14}
107×10^{14}
107×10^{14}
67.2×10^{14}
6290000×10^{14}
1170000×10^{14}
1390000×10^{14}
440000×10^{14}
350000×10^{14}
2230×10^{14}
61.4×10^{14}
61.4×10^{14}
1.71×10^{14}
1.07×10^{14}

1st Space Velocity: 7.9 km^{-s} (Velocity Required to Enter a Circular Orbit of Earth)

2nd Space Velocity: 11.2 km^{-s} (Velocity Required to Leave the Gravitational Influence of the Earth)

3rd Space Velocity: 42 km^{-s} (Velocity Required to Leave the Gravitational Influence of the Sun)

If bodies in the vicinity of the moon are travelling at a range between 10 and 100 km^{-s}. this means that the trajectory of these bodies is largely unaffected by the gravitational field of the Earth (>> 11.2 km^{-s}) and those found at the higher velocities (>> 42 km^{-s}) are largely unaffected by the gravitational field of the Sun. This suggests that bodies in the vicinity of the moon are traveling with trajectories that will largely not be altered by the gravitational field of the largest bodies in the solar system in the foreseeable future and thus their impact velocity if their trajectory coincides with the position of the moon at a simultaneous time will be almost equal to that of their velocities upon analysis before impact.

[5] The mass of the range of bodies was estimated using the following equation:

$$m = \frac{2E}{\bar{v}^2}$$

Where:

E: Kinetic Energy

$\bar{v}$: Average Velocity of a Body ($55 \times 10^3\ \mathrm{ms}^{-2}$)

This was found to be from $7.07 \times 10^5 kg$ to $4.16 \times 10^{11} kg$

This is a range which includes objects over 550 thousand times more massive than each other which is in line with the wide range of crater sizes observed on the moon.

Fig 2: Frequency in the Data Set Vs Diameter of Crater

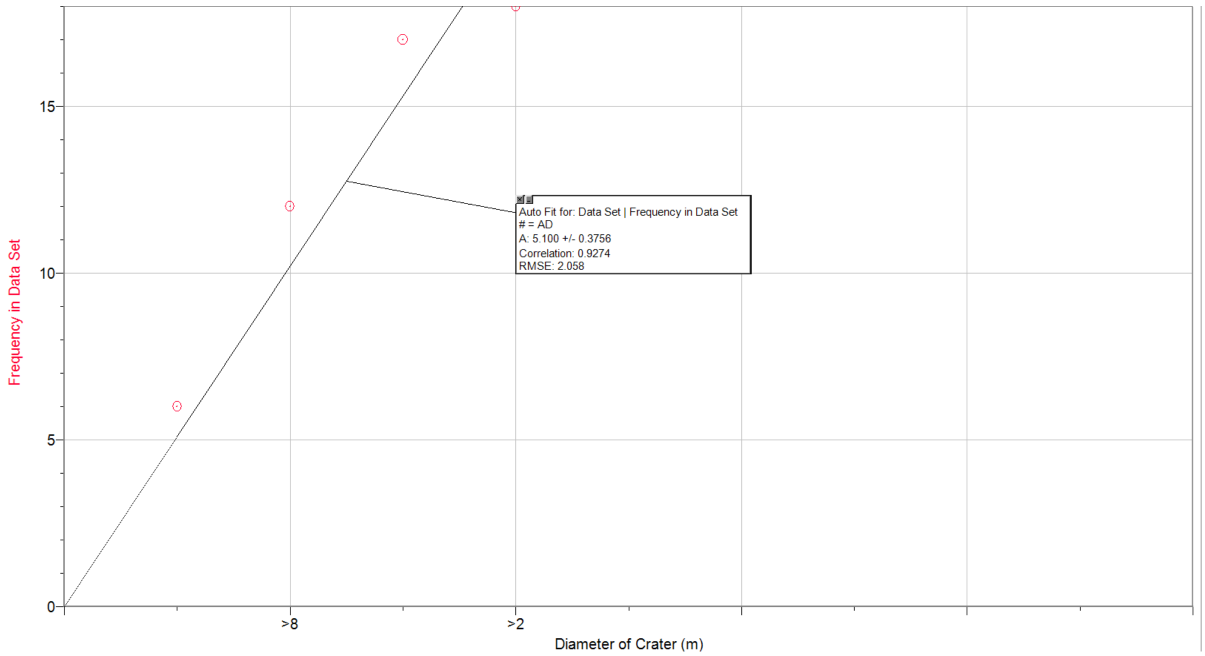
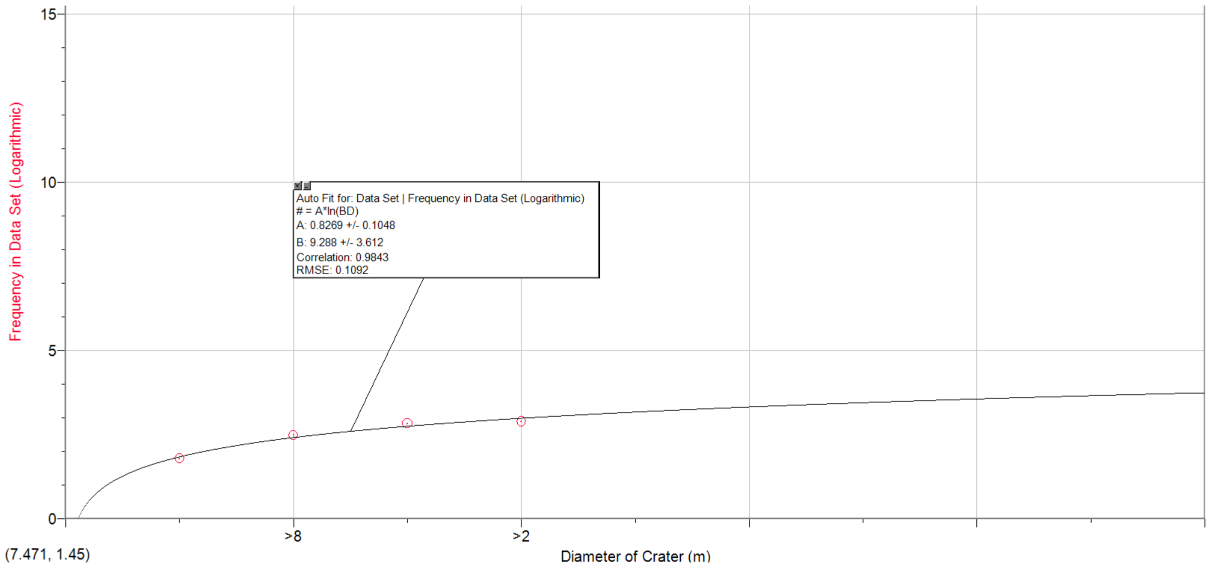


Fig 3: Frequency in the Data Set (Logarithmic) Vs Diameter of Crater



According to the data obtained, the proportion of large impacts (craters > 16km) that the moon has suffered is roughly 28.57% which is a biased proportion as the craters chosen to investigate were those visible which sways towards larger craters. The relationship between the frequency as the range of crater diameters towards including smaller craters is widened has a positive relationship according to **Fig 2**. This relationship is more accurately displayed on log plot in **Fig 3** as it has a correlation >

98% which is a better fit than the correlation of < 93% present in the linear plot. This data suggests the frequency of larger bodies striking the lunar surface drops off logarithmically and thus areas of the moon with the presence of larger craters would suggest the part of the moon formed longer ago than areas with less large craters. This makes sense as the Lunar Highlands have more large impact craters (> 16 km) than those on Lunar Maria as the Highland regions formed before the formation of the Mare regions. This can be seen as all the craters in the data set that have been larger than 40 km have been taken from the Tycho region of the moon which is in the Lunar Highlands the mare regions of the moon were the ones that were more likely to include smaller craters.

The solar system likely began to form after the supernova of a star. This explosion likely resulted in a large disc of ice, rock and dust can be labelled the solar nebula. The Solar nebula swirled and the elements with larger mass likely concentrated in the centre. A proton-proton chain reaction involves the collision of protons under great pressure which has two protons reacting to create a positron, neutrino and dihydrogen and dihydrogen and a proton reacting to create helium and gamma radiation and two helium reacting to produce protons and a higher isotope of helium and so on. These reactions continued and caused the formation of the Sun as more material swirled into the centre of the solar nebula. While this process occurred, clumps of matter accreted together to form smaller bodies which were not large enough to accommodate proton-proton chain reactions. Some of these clumps eventually formed into planetesimals and then proto planets, this process likely took between 100-200 million years. The collisions involved in this planetary accretion likely resulted in radioactive isotope decay which increased temperatures enough to allow meltdown at the core. The planets that formed closer to the sun contain heavier elements in higher proportions as during formation, those present closer to the sun formed in areas of the solar nebula with heavier elements and the opposite was true form those in the further reaches of the solar system. This is what gives the divide between the terrestrial planets and the gas giants. It is likely that the moon formed when a large asteroid hit the earth and the debris formed from earth's material formed the moon.

Method

- Pictures of Lunar surface were measured with a ruler.
- Measurements of crater diameter and length of shadow were taken and adjusted to scale provided.
- Trigonometric relations using length of shadow and magnitude and direction of incident solar light were used to calculate height of craters.
- Graphical analysis and calculations were applied to the data in order to make inferences about the formation of the moon and solar system

Experimental Data

Diameter of Craters (Km) $\pm 0.05\ Km$
9.00
8.00
20.2
10.0
10.0
15.0
8.00
11.0
6.40
6.00
6.00
3.00
93.4
61.4
64.0
48.0
45.4
12.8
2.93
1.20
1.07

Accuracy

Accuracy:

Some bias was present when selecting craters for analysis as larger craters were selected for ease and accuracy of measurement which sways the data towards analysis of larger craters and thus statistics derived from this analysis is swayed towards larger craters.

References

GSU11005 Geology Slides

Appendices

Fig 1: Crater Wall: Height (Logarithmic) Vs Diameter (Logarithmic)

Fig 2: Frequency in the Data Set Vs Diameter of Crater

Fig 3: Frequency in the Data Set (Logarithmic) Vs Diameter of Crater

Results and Conclusion

Measurements of the shadows cast by assorted craters using digitized images of the lunar surface were taken to calculate the heights of crater walls, to relate these data to the sizes of the craters and to calculate the energies of the impact that caused the craters and to derive some properties of bodies that impacted on the Moon and the Earth during the early phases of the Solar System. These measurements colourised current theories of the formation of the moon and wider solar system and inferences made spoke to the relative accuracy of data gathered and calculations performed.