Craters of the Moon

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Abstract

The craters of the moon were examined. By measuring the diameter and shadow length of craters on the moon on printed photographs, the height of the craters could be found. It was found that the height and diameter of the craters showed a linear relationship. From the diameter of the craters, the energies of the asteroids that created the craters could be found. Using this, an estimate for the asteroids' mass was in the range $10^7 - 10^{14}$ kg. The number of craters on the moon larger than 4km was found to be ≈ 3600 by assuming uniform distribution of the craters.

⋆ Introduction

It is believed that the solar system started as a giant cloud of dust. Evidence suggests that a supernova produced shockwaves that disturbed the dust cloud such that high density regions formed. Since gravity is an attractive force, the dust can only collapse in on itself. Over a huge amount of time, the collapsing matter formed the Sun.

The remnants of mass that didn't become the Sun clumped up together. This formed the planets while the matter that did not become big enough formed the asteroids that orbit the Sun today. These asteroids travel through space and occasionally collide with other objects in space, including the Earth and the Moon. While the Earth has an atmosphere that protects itself, the Moon is vulnerable and the impacts form the craters of the moon.

Assuming the craters are ideal pits, it is simple to relate the Sun's zenith angle, ϕ, and the length of the shadow, l, to determine the height of the craters. Taking $\theta = 90 - \phi$, then from

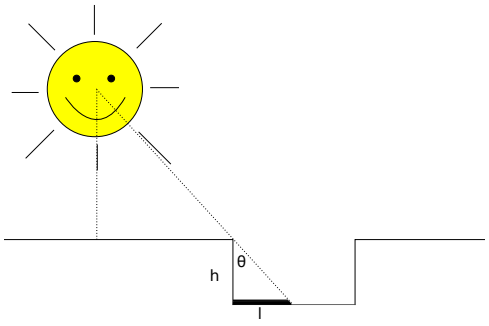

Figure 1: Diagram of Sun incident on Moon

basic trigonometry,

$$h = \frac{l}{\tan\theta} \tag{1}$$

Assume that the height of the craters, h, is proportional to the diameter of the crater, D. Then the volume, V is proportional to D^3. Hence,

$$m \propto \rho D^3$$

where m is the mass and ρ is the density of the moon. The kinetic energy, E, can be approximated as the potential energy required to lift the mass up to height h, ie,

$$E = mg_M h$$

Substituting in,

$$E \propto \rho g_M D^4$$

$$\Rightarrow E = k\rho g_M D^4$$

where k is a constant of proportionality. It is found from experiment that $k = 2.5$. Hence, to relate the diameter of the crater to the energy of the asteroid,

$$D = 2.5(\frac{E}{\rho g_M})^{\frac{1}{4}} \tag{2}$$

Values for the constants are $\rho = 2 \times 10^3$ kg m^{-3} and $g_M = 1.62$ m s^{-2}.

⋆ Experimental Method

Three different photographs of the moon were examined. The length scale and the Sun's zenith angle were taken into account for each. A crater was selected on a photograph and using a ruler, the diameter of the crater was found. The length of the shadow is also found. This was then repeated on many different craters on each of the three photographs. After converting the distances by the appropriate scale, the height of the craters were found.

Using equation (2), the energy of the asteroid that created the crater could be found and the range of the mass of the asteroids can then be inferred since it is known that an asteroids' velocity is in the range of $10 - 100$ m s^{-1}. The number of craters larger than 4, 8, 12, 16, 24 km were counted and the total surface area of the photographs was found. An estimate of the number of craters on the moon was found from this.

⋆ Results and Analysis

From figure 2, there is a linear relationship between the crater depth and diameter. This means there are few wide shallow or deep narrow craters. Intuitively, this makes sense since if an asteroid impacts the moon, the height and diameter of the crater will both depend on the energy of the asteroid.

After finding the energy for each asteroid that caused the crater, the masses of the asteroids were found for the range $v = 10 - 100$. The range that the masses fell in was found to be between $10^7 - 10^{14}$ kg.

Taking the diameter of the moon as 3476 km, it was found that the surface area of the photographs covered about 0.87% of the moon. Hence, the total number of craters could be deduced assuming uniform distribution. Figure 3 shows the relationship between the number of craters and the diameter. There appears to be a linear relationship although due to an insufficient amount of samples in the smaller and larger range, nothing definitive can be said. What is obvious though is that there have been more smaller asteroids impacting the moon than larger asteroids. It was found that there were ≈ 3600 craters on the moon over 4 km in diameter.

⋆ Conclusion

It was found that there was a linear relationship between the depth and diameter of lunar craters.

The masses of the asteroids that created the craters were estimated to be in the range $10^7 - 10^{14}$ kg.

The number of craters on the moon larger than 4km in diameter was found to be ≈ 3600.

It was noted that there were several contributions to the error. It was difficult at times to accurately judge when the shadow length ended or whether it was some natural formation in the crater. Due to percentage error, measuring the smaller craters was incredibly difficult. This could've been remedied with higher resolution pictures and a shorter scale. With this, a better sample distribution could be taken.

In conclusion, despite the errors, much was learnt about the moon. This experiment has been one small step for man, a giant leap for mankind.

⋆ Appendix

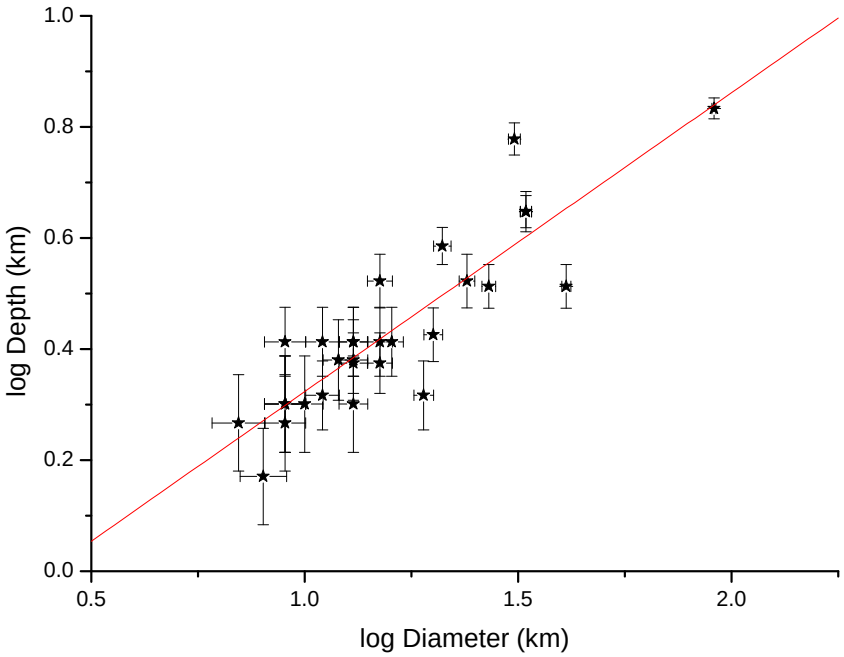

Figure 2: Graph of crater depth versus diameter on a log-log plot

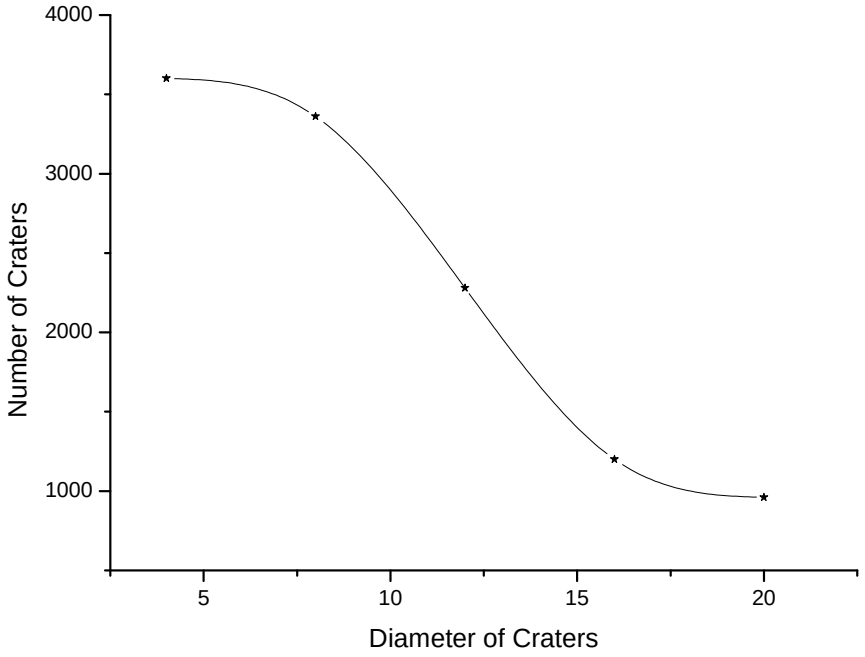

Figure 3: Graph of total number of craters on the moon versus diameter size

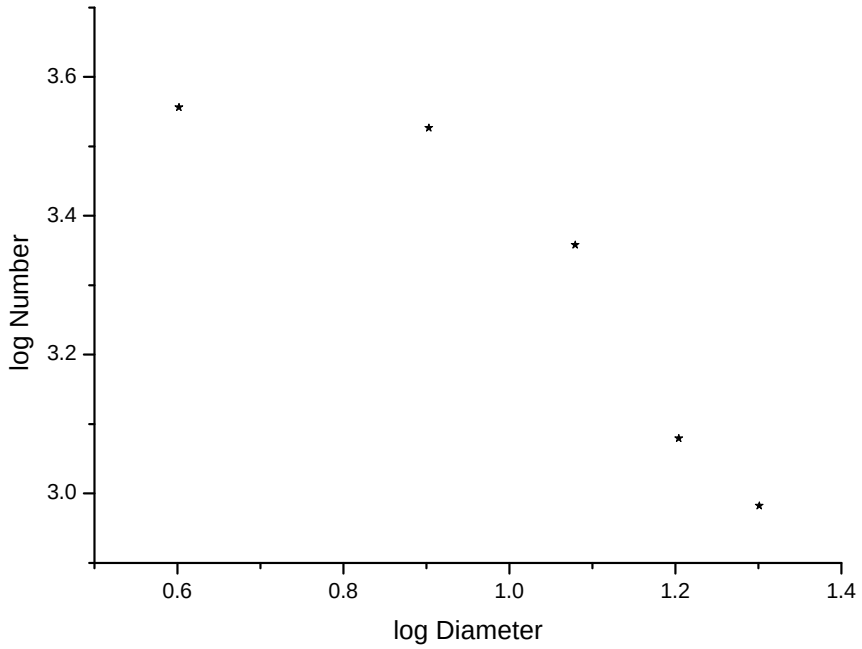

Figure 4: Graph of crater depth versus diameter on a log-log plot