Craters of The Moon

David-Alexander Robinson[*]; Daniel Tanner; Jack Denning
08332461

12th November 2009

Contents

1 Abstract

In this experiment the shadow length of a crater wall and the Sun's zenith angle at the time of observation were used to calculate the depth of craters on the moon. We then calculated the impact energy of an asteroid to cause such craters. Finally we used these details to calculate an approximate range of the mass of asteroids hitting the moon. We also calculated an estimate for the total number of asteroids to hit the moon.

2 Introduction & Theory

It was originally thought that the craters on the moon were caused by volcanic activity, this however is now commonly known to be false. Astronomers now know that they arise from bodies impacting on the surface of the moon, such as asteroids and comets. Some of these bodies were very large and occurred millions of years ago. On the earth there is no evidence of these impact craters. This is precisely because there are none! The earth has a protective atmosphere surrounding it which protects us. When an asteroid enters the earth's atmosphere, it gets broken up due to friction with the tiny dust particles in the atmosphere. Also, most asteroids can be though of 'dirty snowballs' composed of ice. The friction creates heat which causes some of the asteroid to evaporate. There have been some very very large asteroids however which survived the entry to the atmosphere, for example that which is claimed to have wiped out the dinosaurs 65 million years ago. Furthermore, on the earth, the presence of the atmosphere causes geological events like soil deposition etc to cover up the traces of possibly many more averaged sized impact craters.

The equation describing such impacts on the moon is

$$D = 2.5 \left(\frac{E}{(\rho g_m)} \right)^{\frac{1}{4}}$$

where D is the depth, E is the impact energy, ρ is the mean density of the rock and g_m is the acceleration due to gravity at the surface of the moon. From this we can find E, where

$$E = \frac{1}{2} m v^2$$

which leads us to m, given a reasonable velocity range.

Figure 1: Barringer Crater, Arizona, US

The most widely-recognised theory on the evolution of the solar system and the formation of the sun is known as Nebular hypothesis and involves the collapse of a giant gas cloud of about 10-20 solar masses. This forms a young star and a gaseous protoplanetery disc around it. As it collapses, the system starts to spin due to the conservation of angular momentum. Eventually the disk may begin to form planets. A sun-like star can take around 100 million years to form, the planets can take anything from 100 million to a billion years.

3 Experimental Method

3.1 Depht of Craters

The shadow length of several different craters were measured and then from the following formula the depth of the craters were calculated

$$\tan\theta = \frac{\text{Depth}}{\text{Shadow Length}}$$

where θ is the elevation of the sun above the lunar horizon.

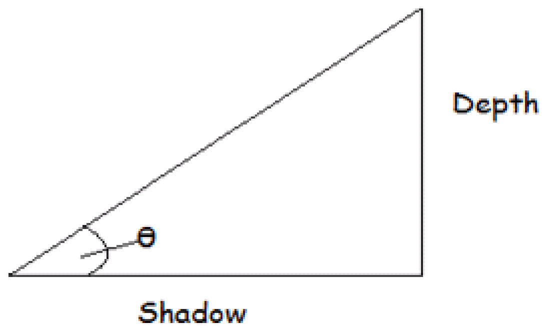

Figure 2:

3.2 Number of Craters On The Moon

Next, taking a random section of the moon of about 330000km^2 the number of craters of varying sizes were counted baised on three diameter ranges > 2.5km, > 5km and > 10km. Our findings were averaged and scaled up to the whole moon surface.

3.3 Mare Region

Some areas of the moon that look darker than the others. These are called *The Mare Region* due to their basalt composition from ancient volcanic activity. The amount of craters in the Mare regions were compared to those in the so-called *Highland Regions*.

4 Results & Analysis

4.1 Depht of Craters

The resultant crater depths were found to be

Height(m)	Diameter(m)
9864.333	86666.67
4932	33333.33
4438.667	64000
2962	14666.67
3357	16666.67
4344.333	18666.67
6399.667	32666.67
2666.333	13333.33
4533	11333.33

The following relation was found from a log-log plot of the data

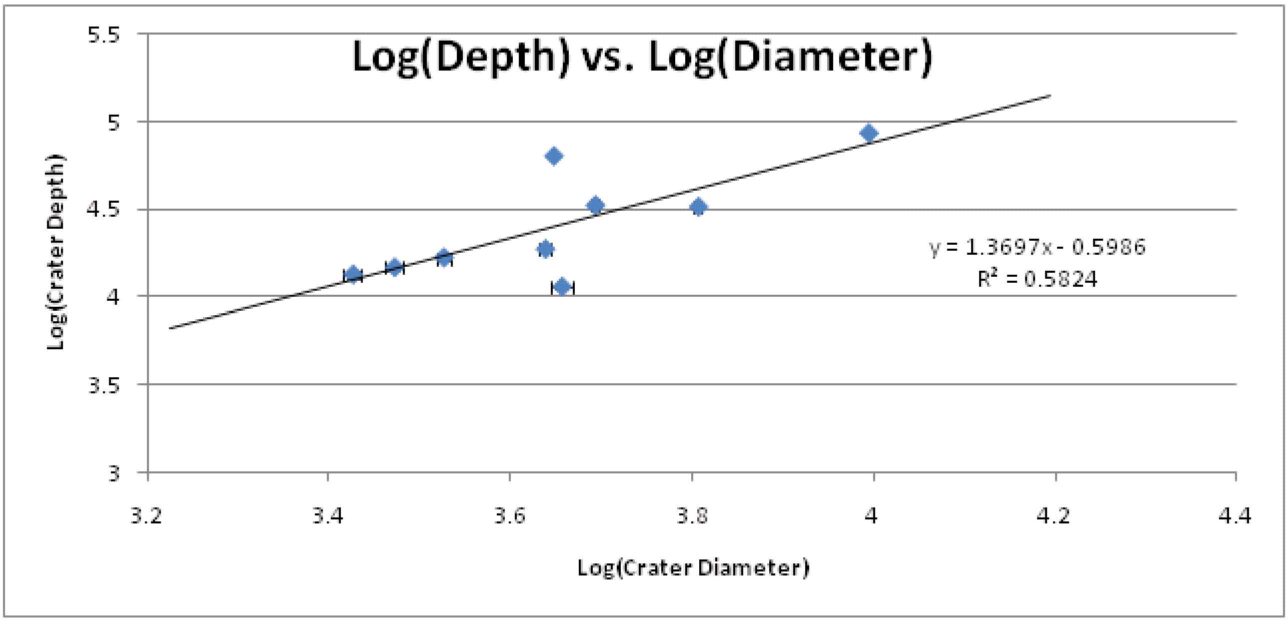

Figure 3: Graph of log(Depth) vs. log(Diameter)

This shows a clear increase in crater depth with diameter, something which would agree with what was expected. We found a range of Energy figures, and when using the velocity range of $10 - 100$km s^{-1} we found the range of masses impacting on the moon to be in the region of $9.35 \times 10^13 \pm 0.05$kg to $2.7 \times 10^8 \pm 0.1$kg. We used the above velocity range because anything with a lower velocity would have been pulled into the Sun by its gravitational field, and 100km s^{-1} is roughly about the escape velocity of the solar system at the moon. Therefore anything above this has very little chance of impacting with the moon.

4.2 Number of Craters On The Moon

We found the spread of craters to be roughly

2.5km	5km	10km
24.66667	5.33333	2
2808.934	607.337	227.7514

With the upper values being the average of each $330,000\text{km}^2$ square and the lower values an estimation of the total number of each on the moon.

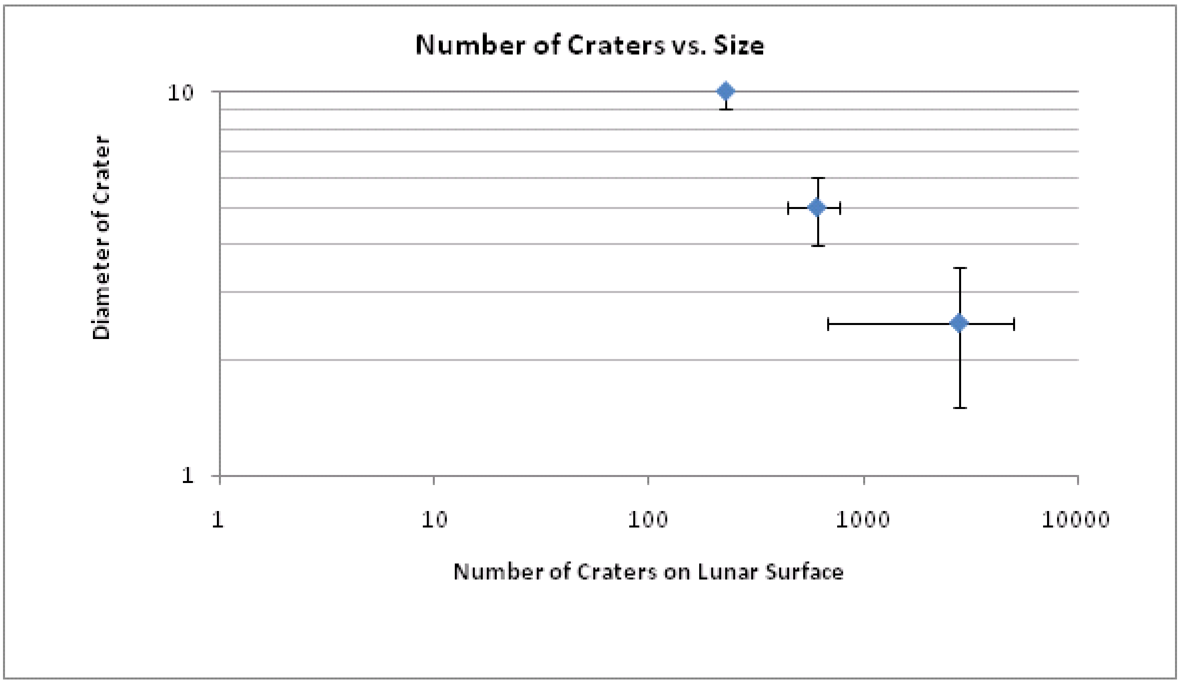

Figure 4: Upper estimate of number of craters on the moon

This clearly shows the relationship between size and occurrence, with smaller impacts occurring much more often than larger ones. The large error refers to the difficulty in identifying craters that small, causing quite a large deviation between each of our estimates.

4.3 Mare Region

There were much fewer impact craters visible in the Mare regions. Though an accurate relation was difficult to calculate, an estimated around 3:1 or 4:1 was found.

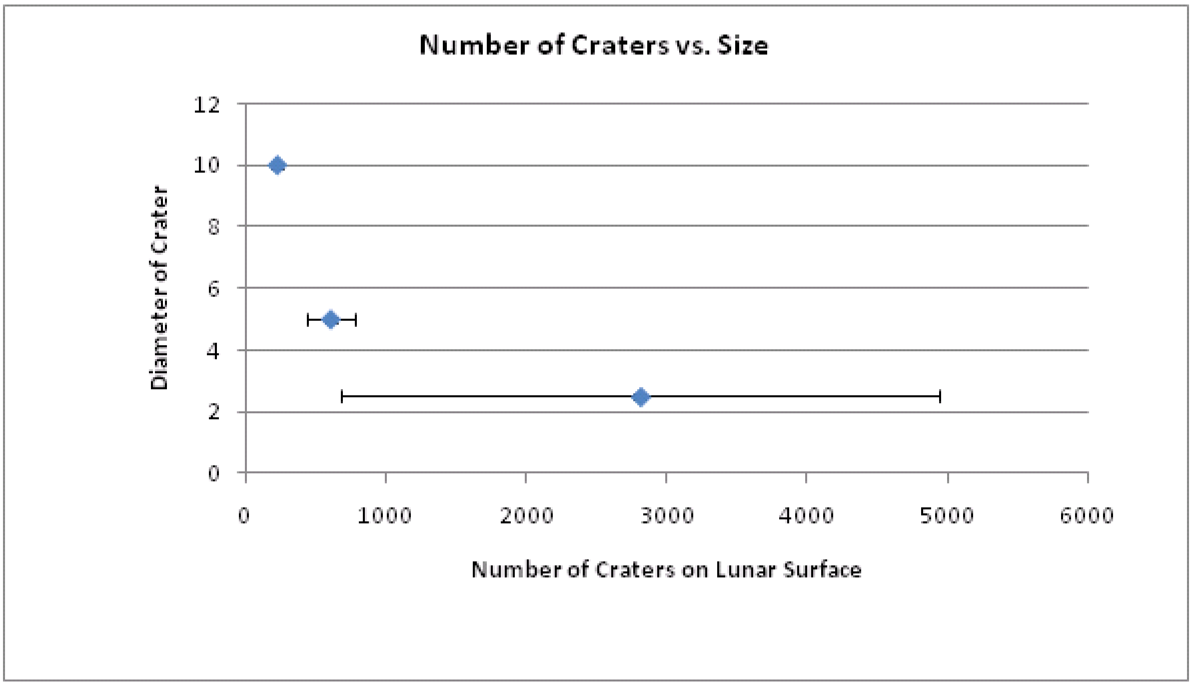

Figure 5: Lower estimate of number of craters on the moon

5 Error Analysis

The original error in taking the measurements was the smallest markings on the ruler, or ± 0.05cm, but since there was a certain amount of guesswork in finding where the crater began and the shadow ended, the estimated total error, including human contribution, was ± 0.1cm.

$$\frac{40 \times 10^3}{3} \times \Delta\text{Measurement} = \Delta\text{Actual Length}$$

$$\Delta\text{Shadow Length} \times \tan(\theta) = \Delta\text{Crater Depth}$$

$$\Delta E = \Delta\text{Depth} \times \frac{4\rho g_m}{2.5^4} \times \text{Depth}^3$$

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

$$\Delta \log(\text{Height}) = \frac{\Delta\text{Height}}{\text{Height}}$$

$$\Delta\text{Average} = \frac{\sigma}{\sqrt{3}}$$

6 Conclusions

We found a reasonable mass range of the impact bodies causing the moon craters of $9.35 \times 10^{13} \pm 0.05$kg to $2.7 \times 10^{8} \pm 0.1$kg. Also, a rough estimate of the total number of impact craters of various sizes on the moon was found as above.