Problem Set 3: Crater Counting

Introduction

Impact craters are the dominant landforms on most of the solid surfaces in our solar system. These impact craters have formed on the surfaces over the 4.6 billion year age of our solar system. The number of craters on a surface increases with the length of time that surface has been exposed to space. These rather simple ideas are the basis for a very powerful tool, called crater counting, that planetary scientists use to unravel the history of a planetary surface. The basic idea is that an old surface will have more impact craters than a younger surface.

By counting the number of craters in some defined area on a world (determining its crater density) and comparing it to the number of craters on a same-sized area on another part of that world, you can determine the relative ages of the two surfaces (e.g. one area is twice as old as another).

If you want to find out the absolute age of the surface you are studying, you need a sample from that surface. Fortunately for us, the Apollo mission brought back lots of rocks from six sites on the Moon. By measuring the ages of rocks from these six sites, and measuring the crater density at these sites, we can determine how the crater density is related to the absolute age at these sites. Now, at least for the Moon, if we can measure the crater density of any part of the Moon, we can compare it to the crater density at the Apollo sites to determine their relative ages. Since we now know the absolute ages of the rocks at the Apollo sites, we can determine the absolute age of any part of the Moon.

In this class, we make the assumption that the cratering rate measured by Apollo on the Moon is typical of the cratering rate in the inner solar system. (This is an important assumption. Do you think it is valid?) We can now extend our measurements of the crater density on the Moon to estimate the ages of various regions on the surface of Mars.

Images

The materials we will use for this lab are images taken by the Viking 1 and 2 orbiters. The Viking project consisted of launches of two separate spacecraft to Mars. Viking 1, launched on 20 August 1975, and Viking 2 launched on 9 September 1975. Each spacecraft consisted of an orbiter and a lander. After orbiting Mars and returning images used for landing site selection, the orbiter and lander detached. The lander entered the Martian atmosphere and landed at the selected site in the summer of 1976. The orbiters continued imaging and conducting other scientific operations from orbit, while the landers deployed instruments on the surface. The Viking 1 orbiter was turned off on 17 August 1980, after returning more than 30,000 images in 1485 orbits around Mars. The Viking 2 orbiter was turned off on 25 July 1978, after returning almost 16,000 images in 706 orbits around Mars.
Procedure

a) Determine the crater density. Use the scale bar below to determine how many craters are in each size range (it helps if you transfer the scale bar to the edge of a piece of paper). You may not be able to use all the different size ranges. There may be no craters in some of the larger ranges or too many craters in the smallest ranges. Try to fill in as many of the size ranges as you can. Record the numbers in the Crater Density Data Table.

![Scale bar with size ranges](image)

b) The data for the crater density of the Apollo sites was determined over 1,000,000 km$^2$. The total area of the images you used are shown at the bottom of the image. Using your numbers from the table and the formula below, determine how many craters of each size range are found in 1,000,000 km$^2$. Record this number in the table.

$$\text{Number of craters per 1,000,000 km}^2 = \text{Number of craters} \times \frac{1,000,000 \text{ km}^2}{\text{Image Size}[\text{km}^2]}$$

c) Plot your data points from the table on the Crater Density Graph. Put your points on the graph in the middle of your size range. For example, if you had 200 craters in the 0-8 km size range, you should put your point at the intersection of 200 on the y-axis, and 6 on the x-axis. (Note: the y-axis of this graph has a logarithmic scale.)

d) Determine the age of your surface. Once you have your points plotted, fit a straight line through the points, or as close to them as you can. Your line should be roughly parallel to the age lines on the graph. The line you have drawn represents the average age of the cratered surface you have been examining. Estimate the age by interpolating the location of the line you have drawn with the age lines already on the graph.

Martian Northern Hemisphere Surface Age = ________ billion years old

Martian Southern Hemisphere Surface Age = ________ billion years old
# Martian Crater Density Data Table

<table>
<thead>
<tr>
<th>Crater size range (km)</th>
<th>Northern Hemisphere</th>
<th>Southern Hemisphere</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of Craters in Image</td>
<td>Number of Craters in 1,000,000 km²</td>
</tr>
<tr>
<td>&lt; 8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 - 16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 - 32</td>
<td></td>
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<tr>
<td>32 - 64</td>
<td></td>
<td></td>
</tr>
<tr>
<td>64 - 128</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Crater diameter diagram](image)
Questions
1) How accurate do you believe your estimate of the age of the surfaces are for each surface, what are the oldest and youngest ages that fit your data? Be quantitative (i.e. ± 1 billion years).

2) Describe one way that you could increase the accuracy of your age determination.

3) Consider these two facts: (a) The Earth has been hit by as many impactors as the Moon and Mars. (b) The state of Washington has a total land area of about 177,000 km$^2$. Calculate how many 5-km-sized craters have been formed in Washington state over the last 4 billion years. [Show your work.]

4) Currently the state of Washington has zero 5 km impact craters. What happened to them?