Planetary Geology
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Lab5: Impact Cratering and Crater Counting

Section I

This section of the lab uses a very good online exercise developed by my colleagues at the Center for Lunar Science and Exploration at the Lunar and Planetary Institute. Go to the following website and follow the instructions:

http://www.lpi.usra.edu/nlsi/education/hsResearch/crateringLab/

There are two parts, each including a short reading and a set of activities. The activities use a software program called *ImageJ*. A cross-platform installer for this will be available from the class website.

Turn in your answers to the boldface questions.

Section II

This section of the lab is a simple introduction to planetary surface geochronology using the “crater counting” technique.

Objective

Making the assumption that the cratering rate on the Moon as measured by the Apollo missions is typical of the cratering rate for the entire inner solar system, you will extend the measurements of the lunar crater density (where we know the actual ages of the surfaces) to the surface of Mars. In doing so, we will estimate model ages for resurfacing on two specific regions on Mars.

Background

Impact craters are the dominant landforms on most of the solid surfaces in our solar system. These impact craters have accumulated on the surfaces over the 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). This is a common, qualitative use of relative, overall crater density. A more sophisticated, quantitative chronologic method further examines the density of craters of a range of sizes. The resulting size-density distribution can then be compared to calibrated size-density distributions to determine *absolute ages*. It is important to note, however, that such ages are estimates for the age of the surface, or, more precisely, the time since that surface was last devoid of craters. Such an event that erases the craters can be called a "resurfacing" event and examples include volcanic eruptions, episodes of weathering and erosion, or tectonic processes. Earth's surface has been largely resurfaced and continues to be, hence the dearth of impact craters and the very young crater counting age one would deduce for the Earth.

Another way to get an absolute age is to obtain a sample from and date it radiometrically. This can then be used to calibrate the crater counting method. Fortunately, the Apollo missions to the Moon brought back rocks from six sites on the lunar surface. By determining the ages of these rocks, and measuring the crater size-density distributions at the landing sites, we can determine how the crater density is related to the absolute age. We can then measure the crater size-density distribution of any part of the Moon (from images, for example) and compare it to the crater density at the Apollo sites to determine relative ages. Furthermore, since we now know the absolute ages of the rocks at the Apollo sites, we can also determine the absolute age of any part of the Moon.

We will make the simple (yet common) assumption that the cratering rate measured by Apollo on the Moon is typical of the cratering rate in the inner solar system. We can therefore extend our measurements of the crater size-density distribution (and relationship to absolute age) on the Moon to estimate the ages of various regions on the surfaces of Mercury, Mars, and Venus.

The materials we will use for this exercise are images of Mars taken by the Viking 1 and 2 orbiters (see attached). 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 Viking 1 and Viking 2 landers entered the Martian atmosphere and soft-landed in the summer of 1976. Both 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

1. On each of the Mars images you have are 5 white scale bars that represent 128, 64, 32, 16 and 8 km in size. Use these scale bars to create a measuring tool that is divided into several different size ranges (0-8 km, 8-16 km, 16-32 km, etc.). Your measuring tool should look like this:

   Now use your measuring tool (NOT the example one just above – it is not drawn at the right scale!) to determine how many craters are in each size range. You may not be able to use all the different size ranges because 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 Table (see attached page).

2. The data for the crater density at the Apollo sites was determined from images covering areas of about 1,000,000 km^2. The total area of the Mars images you have is shown at the bottom of the images. Using the numbers you record in the Crater Density 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 Crater Density Table.

$$\text{Number of craters per } 1{,}000{,}000\ \text{km}^2 = \text{Number of craters} \times \frac{1{,}000{,}000\left[\text{km}^2\right]}{(\text{Image size})\left[\text{km}^2\right]}$$

3. Plot your data points from the Crater Density Table on the Crater Density Graph (see attached). 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 4 km (half way between 0 and 8 km) on the x-axis. (Note: the y-axis of this graph has a logarithmic scale and the x-axis is linear).

4. Determine the age of your surface with the following procedure. 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 labeled 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 labeled age lines already on the graph.

Martian Northern Hemisphere Surface: _________ billion years old

Martian Southern Hemisphere Surface: _________ billion years old

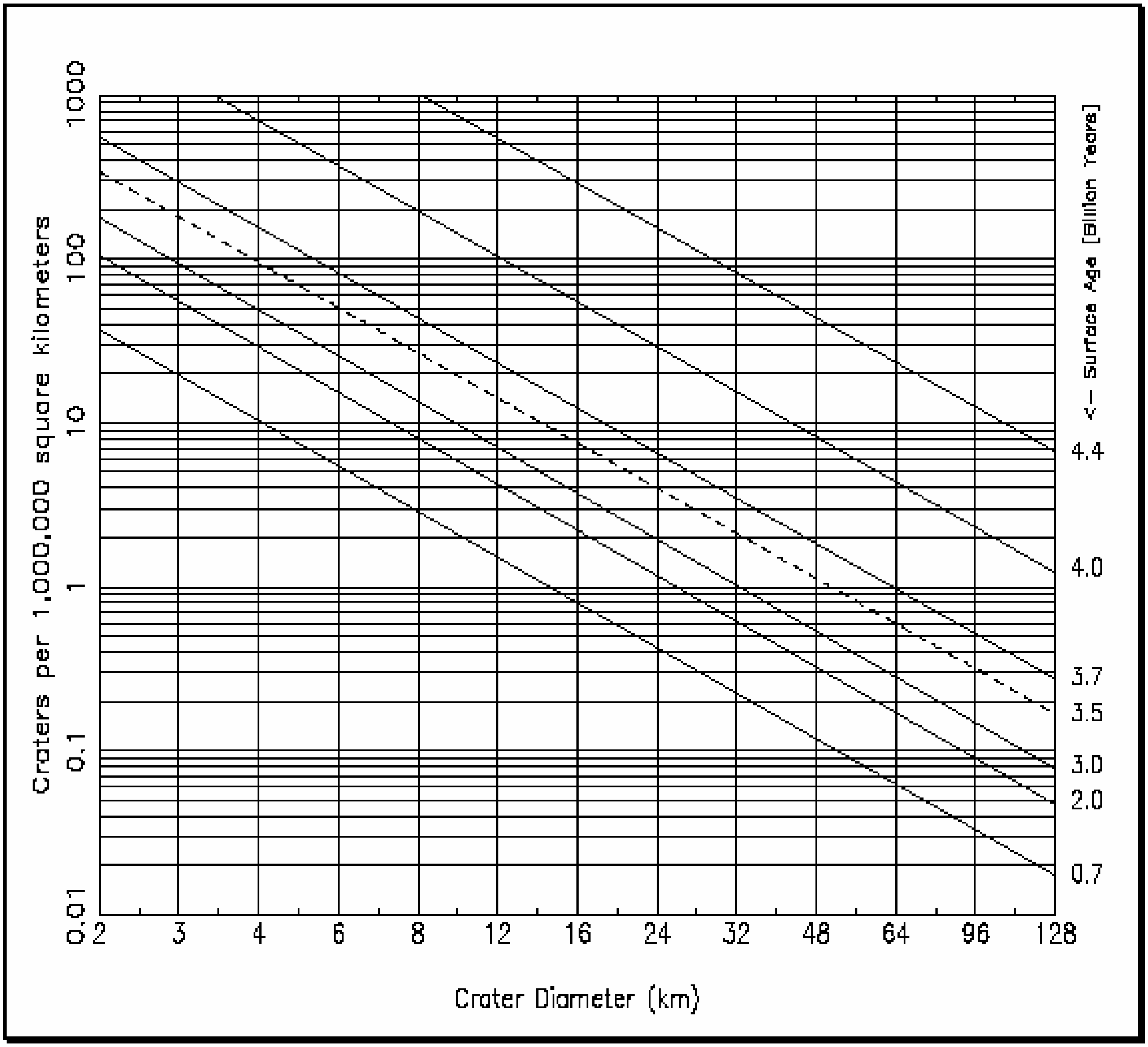
5. How accurate do you believe your estimates of the age of the surfaces are? That is, for each surface, what are the oldest and youngest ages that fit your data? Be quantitative (i.e. ± 1 billion years).

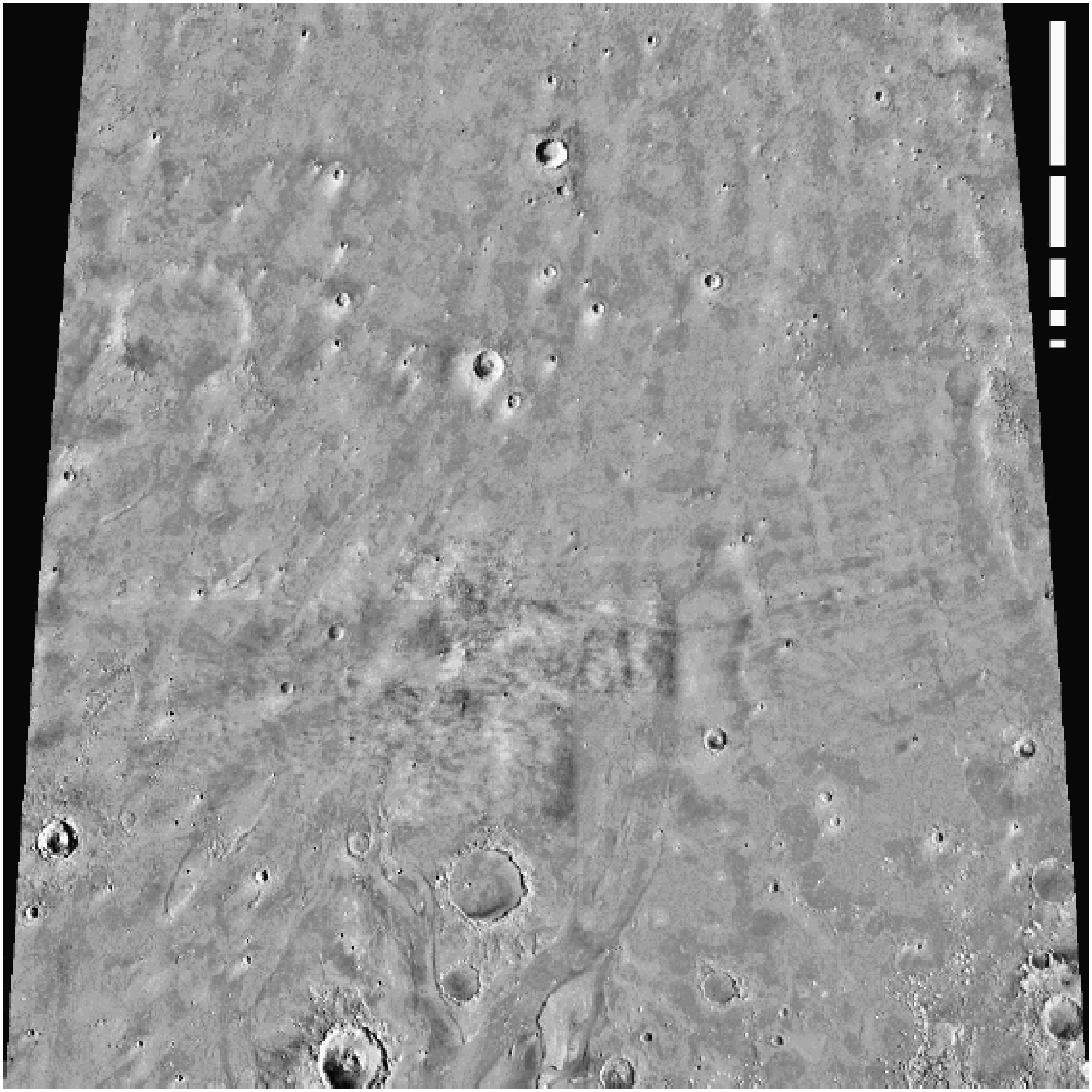
6. What do you believe was your greatest source(s) for the uncertainties in the ages? [Please be as specific and as quantitative as possible. Please note that the following are not adequate explanations: human error, bad eyesight, classmates talking, etc.]

7. Consider these two facts: (a) The Earth has been hit by as many impactors as the Moon and Mars. (b) The state of Texas has a total land area of about 696,241 km^2. Calculate how many 5-km-sized craters should have been formed in Texas over the last 4 billion years. [Show your work.]

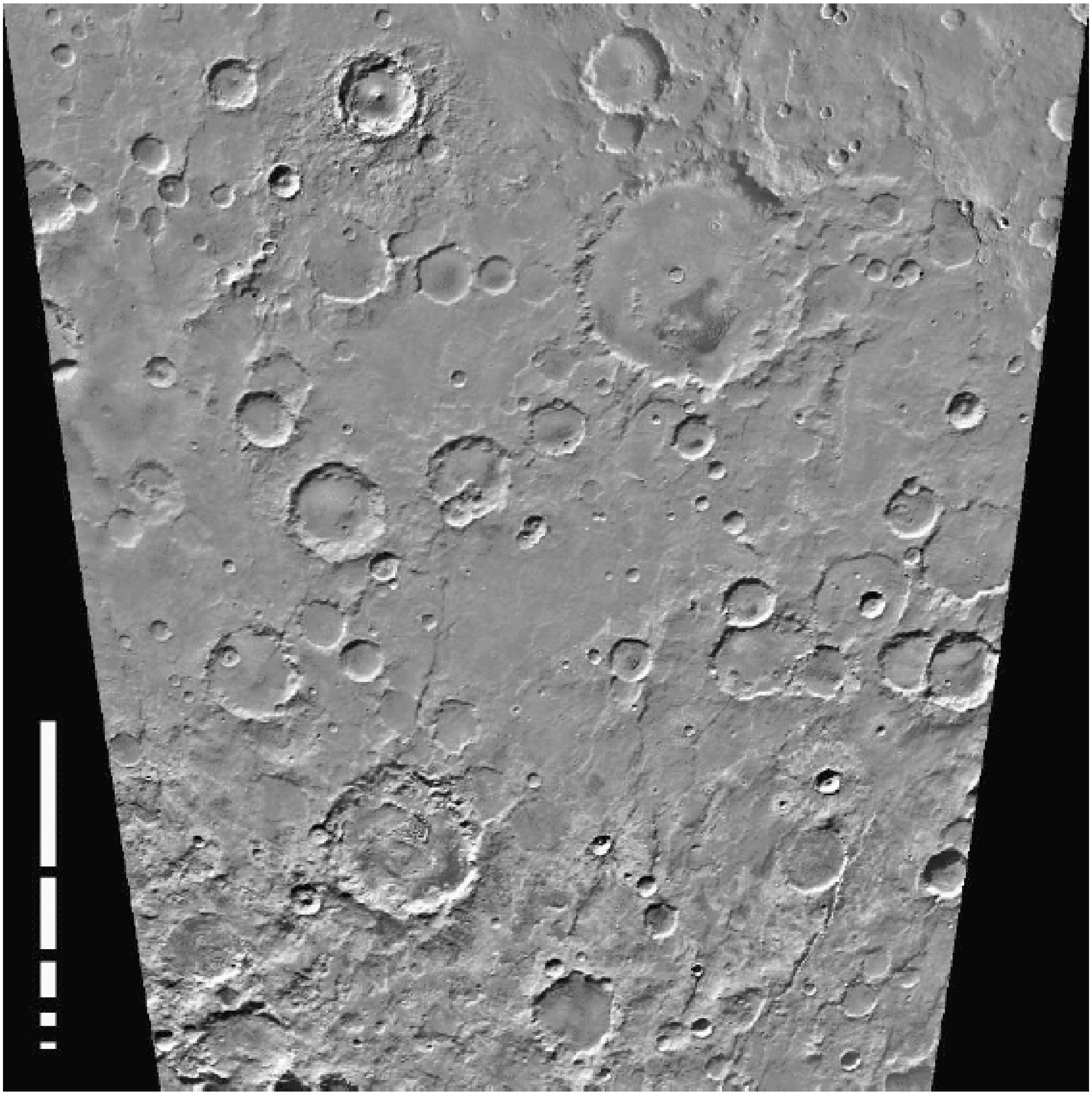
8. An online database of known terrestrial impact craters is the Earth Impact Database (http://www.unb.ca/passc/ImpactDatabase/). Use this to find the known impact craters in Texas. How does this compare with your calculated predictions? Come up with a hypothesis to explain the results.

Martian Crater Density Data Table				
	Northern Hemisphere		Southern Hemisphere	
Crater size range (km)	Number of Craters in Image	Number of Craters in 1,000,000 km^2	Number of Craters in Image	Number of Craters in 1,000,000 km^2
< 8				
8 - 16				
16 - 32				
32 - 64				
64 - 128				





Martian Northern Hemisphere - Image Size = 812,250 km^2



Martian Southern Hemisphere - Image Size = 774,250 km^2