AS 101 – Planet Topography – Impact Craters

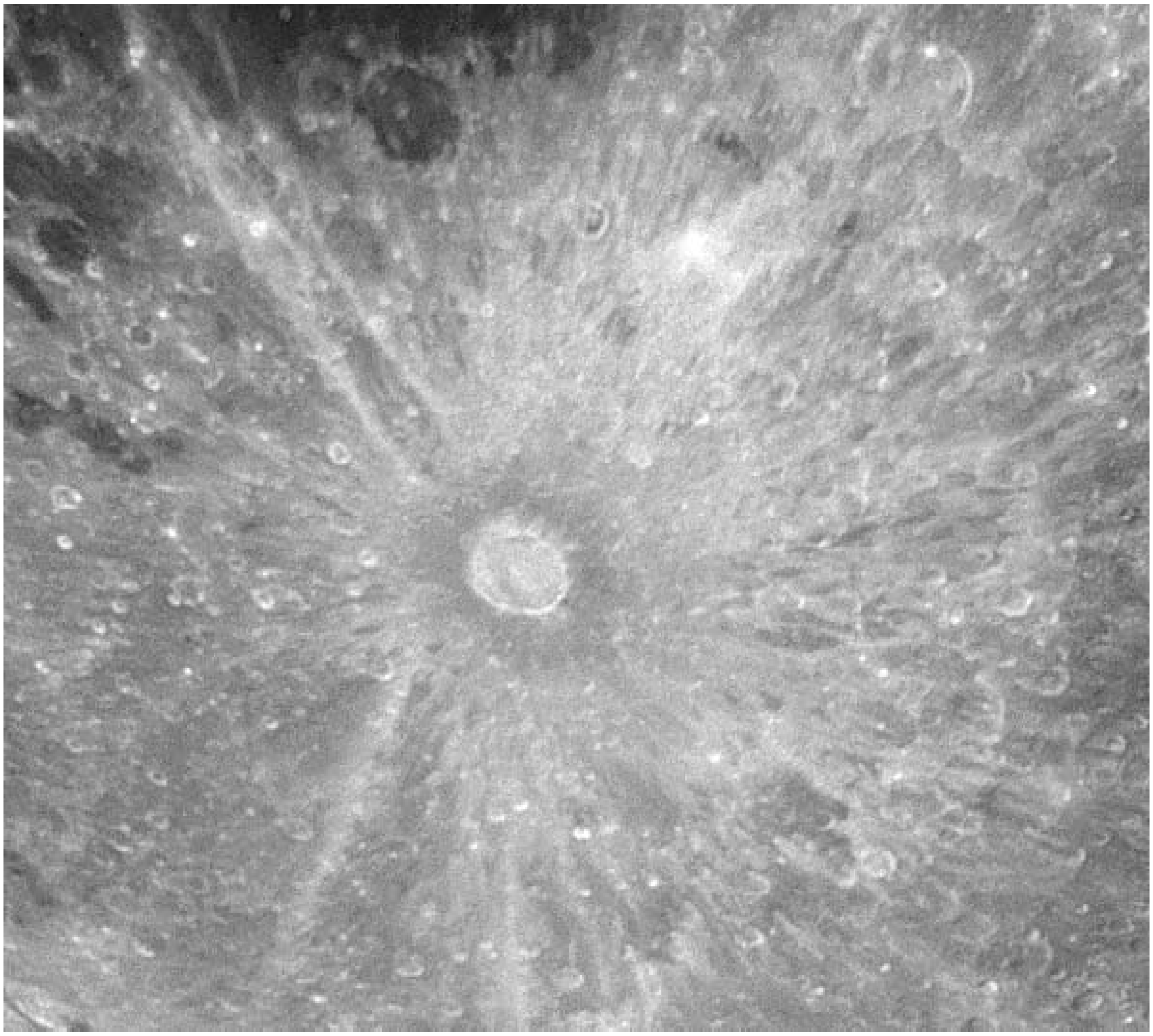

Figure 1– The lunar crater Tycho is a young impact crater (about 100 million years old), with a diameter of 85 km. It is the youngest large crater on the Moon. At the time of full moon an extensive series of rays is easily visible in a small telescope.

The Problem:

Impact craters are ubiquitous throughout the solar system – but how are they made? What is the distribution of their sizes, and how do their numbers change from place to place? What determines the size and shape of a crater? The focus of this exercise will be to understand how craters are produced; what the relationship is between the size and energy of the impacting body and the resulting crater and what the numbers of craters on a planetary surface tells us about the surface. The hypothesis is the impact theory – that as the name suggests, impact craters are produced when high-speed objects strike the surface of a planet.

Introduction:

One of the best ways to learn how the surfaces of planets got to their present state is to compare one planet with another. How have the surfaces of planets been modified – was it through impact cratering, volcanism, weathering or tectonic activity? On the Earth, we can find examples of all of these processes; the surface of the Earth has been and continues to be modified (sometimes dramatically and catastrophically) by all of these processes. But the most ubiquitous features on planetary surfaces are impact craters. The primary goal of this exercise is to test the hypothesis that impacts do produce craters with the right sort of properties to explain what we see throughout the Solar System.

The idea of impact cratering is a simple one; any small body that impacts a surface has to dissipate its kinetic energy virtually instantaneously. The kinetic energy is dissipated either by heating both the incoming body and the surrounding surface, or at lower energies (such as you will have in the lab) the energy will be dissipated as random motions of the surface material – that is stuff will be knocked out in all directions by the impact, leaving a crater with a characteristic profile and circular shape.

The goals of this exercise will be to make several tests of the impact crater hypothesis.

1. Does the size of a crater depend on the kinetic energy of the impacting object alone, or does the diameter of the object play a role as well?
2. Do craters have circular shapes, regardless of the angle at which the impacting body approaches?
3. Explore the surfaces of various planetary bodies in the Solar System and date the relative ages of their surfaces by counting the numbers of craters.
4. What is the size distribution of impact craters? How does this relate to the size distribution of impacting objects in the solar system?

Available equipment:

1. Impact Equipment: steel balls, buckets of fine glass bead material, digital scale, iron filings, small ruler, meter stick.
2. Images and maps of planetary bodies.
3. Plaster “meteorite”.

Part I: Impact Experiment

You will need to devise an experiment to test the mechanism behind cratering with respect to two variables: the kinetic energy of the impacting body and the diameter of the impacting body. **We want to know if the size of a crater is dependent solely upon the kinetic energy of the impacting body, or if the diameter of the object plays a role as well.**

Definitions:

Size of crater:

Width = w
Depth = d

Energy:

Energy is measured in units of Joules. It comes in many different forms, but we will deal with mechanical energy. There are two types of mechanical energy: kinetic and potential.

If a mass ***m*** moves with a velocity ***v*** it has kinetic energy:

$$T(v) = \frac{1}{2}mv^2$$

A mass dropped from a distance ***h*** above the surface of the Earth with have some final velocity ***vf*** when it hits the surface, it will have a corresponding kinetic energy ***T(vf)*** as well. Thus, if the mass is held stationary at the height ***h*** above the surface, you could say it has the potential to achieve a kinetic energy ***T(vf)*** if you drop it. When the mass is held at height ***h*** it has a Potential energy:

$$U(h) = mgh$$

Where ***g*** is the gravitational acceleration **9.8 m/s^2**.

Thus if you drop a mass m from a height h above the sand, it will have a kinetic energy equal to ***mgh*** when it lands. All of its potential energy becomes kinetic energy.

T(v) = U(h) = mgh

Energy:

1. Choose 2 metal balls of different diameter to drop.
2. Measure the mass and diameter of each.
3. Ball 1 and ball 2 can be dropped from different heights such that they will have the same kinetic energy when they land.
4. Calculate these heights for three different energies. Pick energies such that your heights do not go above 2 meters.
5. For each energy, drop the balls from their respective heights and measure the size of the craters. Do 3 drops per ball.

Shape:

1. Sprinkle iron filings on the surface of the sand.
2. Drop one ball from straight above. Sketch the shape of the crater and the ejecta blanket.
3. Resurface with iron filings
4. Roll a ball off of the lab table into the bucket such that it impacts at an angle. This is called an oblique impact. Sketch the shape of the crater and the ejecta blanket.

Part II: Planetary Surfaces

- The class will determine the crater number density of several planetary surfaces.
- These densities will be used to rank the surfaces by age. The number density is proportional to the age of the surface.
- The class will also determine the size distribution of craters on the planetary surfaces.

Part III: Meteorite Size Distribution

A plaster “meteorite” will be destroyed to simulate the breakup of cosmic debris in the solar system. The size distribution of the fragments will show a possible explanation for the distribution seen during Part II.