Lab 2

Cratering and the Lunar Surface

2.1 Relevant Lecture Chapters

This laboratory exercises draws upon the material in Chapter 12: The Terrestrial Planets. There are related materials in Chapter 6: The Origin of the Moon and Chapter 11: The Formation of the Planets.

2.2 Learning Objectives

After completing this laboratory exercise, the student should be able to do the following:

- Appreciate that cratering has been an important process in shaping the appearance of the Moon's surface, and in shaping planetary surfaces in general.

- Distinguish between the heavily cratered, older lunar highlands and the younger, smoother and darker lunar maria.

- Understand both relative and absolute dating techniques, and describe the types of data needed to apply either method to lunar features.

- Realize that the Moon's surface, unlike that of the Earth, has changed little in the last three billion years, and that the once-high cratering rate has decreased markedly.

- Describe first-hand the experience of creating impact craters, and using the resulting data to define a relationship between impact velocity and crater diameter.

- Recognize that studying cratering processes and lunar craters can increase our understanding of the Earth's impact history, and the likelihood of future impacts.

- Identify key factors that determine the environmental consequences of impacts here on Earth.

- Realize that a catastrophic impact due to a six-mile meteoroid 65 million years ago produced a large crater and quite probably led to the extinction of the dinosaurs.

- Connect the act of plotting two variables against each other to the process of studying their intrinsic relationship.

- Understand the relationship between a mathematical model and its representation as a curve or set of points on a plot of relevant variables.

2.3 Keywords

Absolute dating – Absolute dating refers to the process of assigning absolute ages to physical samples (such as rocks) or to geologic events. These ages are usually based on radioactive decay rates.

Central peak – A central mountain peak is produced when molten excavated material from an impact blast flows back towards the center of the excavation and creates an uplift. This typically occurs at the center of large craters, those which are 40 kilometers or more in diameter.

Crater – A crater is a generally circular surface depression, caused by an impact or an explosion, a volcano, or a geyser.

Crystalline rock – Crystalline, or igneous, rock forms as molten rock cools and crystallizes. It is generally harder and denser than sedimentary rock. Granite is an example of crystalline rock.

Density – The density of a three-dimensional object is equal to its mass divided by its volume (or the mass per unit volume), and is typically measured in units of grams per cubic centimeter, or kilograms per cubic meter. The density of water is one gm cm^{-3}, while rock is roughly three times more dense, and steel has a density of eight gm cm^{-3}. One could also refer to the surface density of features found on a planetary surface, for example, with units of counts (the number of features) per unit area.

Ejecta – Ejecta refers to a blanket of material surrounding a crater that was excavated during an impact event. The ejecta will become thinner at increasing distances from a crater.

Impact crater – An impact crater is one produced by the collision of an object with a planetary body's surface.

Kinetic energy – Kinetic energy is commonly referred to as energy of motion, and is equal to one-half of an object's mass times the square of its velocity.

Law of Cross-Cutting Relations – The law of cross-cutting relations states that any geological feature that cuts across another geological feature must be younger (must have formed later) than the feature it disturbed.

Maria – The lunar maria are the dark, smooth regions believed to represent ancient lava flows. They are generally younger than the heavily cratered highlands. They were immortalized in Bernstein and Sondheim's 1956 West Side Story.

Meteoroid – A meteoroid is a particle of rocky or metallic debris found in space. If a meteoroid enters the Earth's atmosphere it becomes a meteor, and upon landing any surviving remnant is called a meteorite.

Plate tectonics – Plate tectonics defines a theory of planetary surface dynamics in which a planet's outer skin (the lithosphere) is broken into plates. These plates are driven by internal heat, and shift and interact in various ways (including collisions).

Projectile – A projectile is an object that is launched or dropped into space, or into an atmosphere. It is sometimes called an impactor, once it has struck a surface.

Rays – Rays are bright linear streaks extending radially outward from certain craters, most notably young ones like Tycho and Copernicus on the Moon. They indicate the presence of thin deposits of lighter material.

Terraces – Terraces are stair-like levels in the sloped walls of craters.

Terrestrial – The term "terrestrial" means Earth-like or pertaining to the Earth's surface. Planets with rocky surfaces are sometimes called Terrestrial planets, in contrast to the Jovian gas giants.

Radioactive – An radioactive isotope of a particular element is unstable, and will decay into other elements and isotopes over time. We define the "half-life" of a radioactive sample as the amount of time in which half of its atoms will decay into another state. By comparing the relative amounts of various isotopes of key radioactive elements, we can often determine absolute ages for samples of various materials.

Relative dating – Relative dating refers to the process of placing an event along a time line relative to other events (before them or after them), without defining a specific time for any event.

Sedimentary rock – Sedimentary rock, such as limestone or sandstone, is rock that was originally laid down as horizontal sediment (deposited by water, air, or ice). Contrast it with igneous rock, which is formed by the cooling of molten rock.

Velocity – The velocity of an object is its speed in a particular direction. It has units of distance traveled per unit time, such as miles per hour, or centimeters per second.

2.4 References and Notes

1) The left-hand image in Figure 1is a mosaic of lunar images collected by the Clementine spacecraft in 1994 [NASA/USGS/ASU]. All three images shown in Figure 1 are shown courtesy of NASA.

2) Figure 2 is a portion of a larger lunar orbiter image [NASA].

3) Figure 3 is an adaptation of a figure taken from D.E. Gault's 1970 article in Radio Science, volume 5, #2, page 277, with permission being given by Dr. Shane Bryne of the Lunar and Planetary Lab of the University of Arizona.

4) Figure 4 is composed of two lunar orbiter images of the Apollo mission landing sites (photo IV-125-H3 of Apollo 12, and photo IV-089-H3 of Apollo 16) [NASA].

5) The primary and secondary images in Figure 5 are #C223 and #N5818 from the Consolidated Lunar Atlas, of the Lunar & Planetary Institute [NASA].

6) The basis for the account of the Giordano Bruno crater study is

www.psrd.hawaii.edu/Feb10/GiordanoBrunoCrater.html

which is partially based on the following Plescia, Robinson, & Paige 2010 conference proceeding

www.lpi.usra.edu/meetings/lpsc2010/pdf/2038.pdf.

7) Figure 6 is a portion of a larger Landsat satellite image [NASA].

8) The Earth Impacts Effect program is used courtesy of Robert Marcus, H. Jay Melosh, and Gareth Collins of Imperial College, London. Detailed information regarding the program can be found in Collins, Melosh & Marcus 2005 publication in Meteorics & Planetary Science, volume 40, #6, pages 817-840.

9) Certain physical measurements for the asteroid 99942 Apophis were taken from its Wikipedia entry.