STUDYING THE MOON WITH PHOTOGRAPHS

“That’s one small step for man; one giant leap for mankind”
- N. Armstrong, Apollo 11 Astronaut

“Whoopie! Man, that may have been a small one for Neil; but it’s a long one for me!”
- P. Conrad, Apollo 12 Astronaut

SYNOPSIS: In this lab you will explore the surface of the Moon using photographs. You will investigate some of the Moon’s physical properties, and learn about its history.

EQUIPMENT: Set of twelve lunar photographs, lunar map, Moon globe, ruler.

Please do not make any marks on the map or photographs!

The following photographs will be used in this exercise:

1. Full Moon
2. Composite Moon (1st & 3rd Quarters)
3. Lunar Farside (Mare Orientale)
4. Lunar Farside (Crater Tsiolkovsky)
5. Crater Copernicus (with Rays)
6. Crater Archimedes
7. Crater Tycho
8. Craters Letronne and Euclides
9. Lunar Rilles (Mare Vaporum)
10. Crater Thebit (Mare Nubium)
11. Crater Fracastorius
12. Crater Madler (Mare Nectaris)

Part I. The Faces of the Moon

The first step in exploring unfamiliar territory is to orient yourself using a map.

I.1 Using the lunar map, indicate on the drawing on the next page where the North and South poles of the Moon are located (check the orientation of the map carefully!). Indicate which are the East and West edges. These are known as the limbs.

The most obvious features on the lunar nearside (the half of the Moon that always faces the Earth) are the dark regions called maria (singular: mare). Samples brought back by the Apollo astronauts show that maria are lava flows that filled the low-lying areas of the Moon.

I.2 Use the lunar map or globe to identify and label the principal maria on your drawing.

Print #1 is a photograph of the full Moon, while Print #2 is a composite of two separate photographs of the Moon, one taken at first quarter phase, and the other at the third quarter phase.

I.3 Where was the Sun when each of the three pictures were taken? Where is the terminator (the line between sunlight and shadow) in each case?

Although both prints show the same face of the Moon, lunar rays (bright streaks of material ejected from impact craters) are predominant in one case, while the craters themselves show up best in the other.

I.4 What direction of lighting from the Sun is needed to see rays clearly?

I.5 What kind of lighting enhances the visibility of craters?
The lunar **farside** (which always faces away from the Earth) was first photographed in 1959 by a Soviet space probe. Not coincidentally most of the features on the farside have Russian names!

1.6 One of the most interesting features discovered was Mare Orientale, a giant impact crater lying just beyond visible limb of the Moon. Find Mare Orientale on the lunar globe, and identify it in *Print #3*. Note that the crater floor has been flooded with lava, and how the surrounding terrain was reshaped by this catastrophic event.

1.7 *Print #4* shows the crater Tsiolkovsky in the southern hemisphere of the lunar farside. Find the region on the globe, and identify Tsiolkovsky. Judging from the dark appearance of the crater floor, what would you assume it to be composed of?

1.8 The photographs and globe reveal that the nearside and farside of the Moon are extremely different in nature and appearance. Identify this remarkable difference. How might this phenomenon be related to the fact that the Moon always keeps one face pointed towards the Earth? (Feel free to consult your textbook or other sources.)
Part II. Details of the Lunar Surface

It is thought that both the Earth and the Moon formed by accretion of space debris about 4.6 billion years ago. Radioactive decay of elements has continued to heat the interiors of both bodies. This energy source maintains a molten core in the Earth, which in turn permits the plate tectonics that produce Earth's major geological features such as mountain ranges.

The Moon, being smaller, cooled more quickly and its interior has solidified. The last major internal activity on the Moon seems to have occurred about 3.5 billion years ago (as determined by Apollo samples), when the lava welled from the interior and spread out over the maria plains. As a result, lunar features including mountains are principally shaped by cataclysmic impact events.

Since the Moon has no atmosphere, the normal erosion processes from wind and rain that occur on Earth are not present on the Moon. “Weathering” is primarily due to the ongoing bombardment of the surface by micrometeorites, which eventually pulverizes the exposed material: sharp ridges become rounded, and the dust settles into low-lying regions. Day/night temperature extremes also contribute to deterioration: eventually, areas crack and slump from the effects of thermal stress and lunar gravity. Large meteorite impacts aid the process by producing “moonquakes,” and by spraying ejecta over pre-existing features.

Print #5 is a photograph of the crater Copernicus, located on the southern edge of Mare Imbrium. Copernicus is known to be a relatively young crater, because the rays of ejecta from the impact have not yet been obliterated by micrometeorite erosion.

II.1 Note that crater rims cast shadows on the lunar surface. Do the rays cast any shadows? What does that suggest about their nature?

II.2 Examine the dense peppering of craterlets on the ejecta shield just east of Copernicus. How do we know that these did not occur before the crater formed? Speculate on their origin, using the photograph as evidence.

All of the remaining photographs in this set (#6 through #12) were reproduced from the Photographic Lunar Atlas using a photographic scale of 27.4 kilometers/cm. That is, one centimeter on the prints represents 27.4 km, or about 17 miles, on the actual lunar surface.

Print #6 shows the crater Archimedes near the east edge of Mare Imbrium.

II.3 Measure the diameter of Archimedes. What is its actual size?

II.4 What is the actual physical size the smallest object you can pick out in the photograph?

II.5 What crater is responsible for the rays crossing the mare? (Hint: refer to the previous photograph).

Print 7 shows heavily cratered terrain, with the crater Tycho located near the center of the picture. Tycho also exhibits a central peak, which is formed by a rebound shock wave from the impact that caused the crater. Most of the rays of ejecta seen at full Moon originate from this crater; they do not show in this photograph because the solar elevation angle $\alpha$ (the angle of the Sun above the lunar horizon) is only $5^\circ$.

II.6 What can you say about the age of Tycho? Contrast its appearance with the crater Maginus to its upper left.
If we know the elevation angle of the Sun, we can determine the height $H$ of a lunar feature by measuring the length $L$ of the shadow cast by it:

\[ H = L \tan \alpha. \]

II.7 Measure the lengths of the shadows cast by the central peak of the crater Tycho, and use the scale factor to convert to linear distances on the Moon. Then use the trigonometric equation to determine the heights of these features.

II.8 Compare the peak and rim heights to the overall size of the crater. Contrast the view from Tycho's floor with our own view of the Rocky Mountains from the plains.

*Print #8* shows the portion of Oceanus Procellarum centered on about -8° (south) latitude and -33° (west) longitude on the Moon.

II.9 Identify the craters Letronne and Euclides. Which crater is at least 3.5 billion years old? Which is much younger? How do you know?

Lunar maria are often crossed by narrow linear depressions called *rilles*, such as those found in *Print #9* of Mare Vaporum. Many are assumed to be collapsed lava tubes.

II.10 How can you tell that these features are actually depressions rather than ridges? (Hint: Consider the direction of sunlight.)

*Print #10* shows Crater Thebit at the edge of the Mare Nubium region.

II.11 The bright line crossing Crater Thebit is a *fault*, named the Straight Wall, where one side of the surface has moved up higher than the other. How can you tell that this is not a depression like the rilles? Which side of the fault is higher than the other?

II.12 Ten objects from *Print #10* have been labeled A through J in the drawing on the next page. Identify which of these features are older and which are younger than other features, and what criteria you used to decide. Also indicate which features *might* be older or younger than others, and which have no basis for correlation. Include your reasoning!
As a final challenge of your ability as a selenographer (lunar analyst), inspect photographic Prints #11 and #12, which are adjoining views of the south and north portions, respectively, of the Mare Nectaris region.

II.13 Note the bright ray crossing Crater Fractorius in Print #11. Would you estimate that the two small fresh-looking craters in line with the ray are younger or older than the crater that caused the ejecta? Why?

II.14 Using the lunar globe or map, trace the ray back (towards the upper right of the photograph) to determine its point of origin (a glance at Print #1 may help). What crater is responsible for the ray?

II.15 Identify the curious-looking crater in Print #12 named Madler. Try to develop a geological scenario that would explain its appearance.