

GEOLOGICAL SCIENCES 0050

I am aware of the Brown University Honor Code [see the Student Handbook, which can be accessed through the Geo0050 web site], understand that this exercise falls under that code, and know the penalties that exist for violating the code.

Signature: _____


Name: _____ Banner ID#: _____

EXERCISE 2 (17 POINTS): LUNAR EVOLUTION & APOLLO EXPLORATION

Due Friday, October 2, 2015

This exercise requires downloading Google Earth (you can use the copy you downloaded for the first lab exercise). Please make sure all your measurements and answers are in the metric system (kilometers, meters, or centimeters).

You will need the file “exercise2.kmz”, which is attached to the email and is available on the class website: <http://www.planetary.brown.edu/planetary/geo5/>.

All of the questions for this lab require looking at the Moon. To do this, use the  icon, and pull down the menu to select Moon.

Properties of Lunar Impact Structures

Load “exercise2.kmz” into Google Earth (Go to File-Open). Expand the tab for “Exercise 2” and turn on the Lunar Orbiter Mosaic layer under the Global Maps tab.

Impact structures are some of the most prevalent features on the lunar surface. The vast majority of large impact structures on the Moon are billions of years old and signify a time when the inner solar system was constantly bombarded by large bodies of rock, metal, and ice.

On the Moon, these structures can be separated into three distinct categories. Structures smaller than approximately 15 kilometers in diameter take the form of simple craters. These craters are the most common on any planetary body and have a traditional bowl-shape. Craters larger than 15 kilometers in diameter begin to form complex craters, which deviate from the traditional bowl-shape of simple craters. Complex craters typically have relatively flat floors, terraces on their inner walls, and central uplift features. These central uplift features can be separated into two distinct forms, again based on crater diameter. Complex craters smaller than approximately 175 kilometers in diameter typically have a single or small group of mountain peaks in the center of the crater. Complex craters greater than 175 kilometers in diameter, however, tend to have complex, ring-shaped uplift features that cover much more area than central peaks. Finally, impact structures larger than approximately 300 kilometers in diameter are referred to as impact basins. Impact basins have extremely flat floors and can have multiple central uplift features that form rings within the basin. More than 40 impact basins have been identified on the Moon. Many lunar impact basins have been filled with basaltic lavas since their formation. As a result, these basins are easily visible from the Earth as the darker regions surrounded by the lighter, older lunar crust.

Simple and Complex Craters

1. Heinrich Crater (1 point) *Double-click on the Heinrich Crater placemark.*

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Heinrich Crater, located in the Imbrium Basin, is an example of a simple lunar crater.

- a. Measure the diameter of Heinrich Crater using the ruler tool at the top of the screen.

- b. The latitude, longitude, and elevation at the location of your cursor should be displayed at the bottom of your screen. Using this information, calculate how deep the floor of Heinrich Crater is relative to the surrounding terrain.

- c. Many studies have been performed to calculate the "depth to diameter ratio" for craters on different planetary bodies. Using the information you just gathered, calculate the depth to diameter ratio for Heinrich Crater ($d/D = \text{crater depth} / \text{crater diameter}$)

2. Theophilus Crater (3 points) *Double-click on the Theophilus Crater placemark.*

Theophilus Crater is a complex lunar crater northwest of Nectaris Basin.

- a. Measure the diameter of Theophilus Crater using the ruler tool at the top of the screen.

- b. Calculate how deep the floor of Theophilus Crater is relative to the surrounding terrain (hint: The ejecta deposit of Theophilus Crater is relatively thin. Measure the elevation of the surrounding terrain to the southeast of Theophilus Crater).

- c. Calculate the depth to diameter ratio for Theophilus Crater.

d. Brown University Geological Sciences Professor Carle Pieters was the Principal Investigator on a NASA experiment, an imaging spectrometer named Moon Mineralogy Mapper (M^3) that flew on Chandrayaan-1, an Indian mission to the Moon. The results of her experiment revealed a wide range of discoveries and detection of minerals previously unknown on the Moon. One major discovery, by Deepak Dhingra, a student at Brown and colleagues, came from the central peaks of Theophilus. Go to

http://www.planetary.brown.edu/html_pages/publications.htm

publication 4176, or directly to

<http://www.planetary.brown.edu/pdfs/4176.pdf>.

What is the unusual mineral detected in the central peaks of Theophilus?

What additional minerals were detected in the central peaks?

What depth in the lunar crust (shallow or deep) was the new mineral interpreted to have formed?

Why is the new mineral thought to have been derived from this depth?

Impact Cratering and Depth/Diameter Relationships (2 points)

3. Studies have shown that the d/D ratios for simple and complex craters on the Moon are approximately $1/5$ and $1/50$, respectively. How do your calculations compare with these d/D ratios?

4. In fact, d/D ratios are somewhat variable from crater to crater. What factors do you think would influence a crater d/D ratio?

Stratigraphy, Age Relationships, and Geology

Mare Humorum (2 points) *Double-click on the Mare Humorum placemark.*

The Humorum Basin is one of the large impact basins on the near side of the Moon. It was formed when a large impactor struck the lunar surface more than 4 billion years ago. It was then filled with mare basal lavas.

5. Are the surfaces in the east and south of Mare Humorum older or younger than the surface in the west of Mare Humorum? How can you tell?

Double-click on the Doppelmayer Crater layer.

6. Is Doppelmayer Crater younger or older than the Humorum Basin? Is it younger or older than the surface of Mare Humorum? How can you tell? What about Vitello crater, to the southeast of Doppelmayer?

Hadley Rille (4 points)

Double-click on the folder entitled Hadley Rille. Turn on the Visible Imagery layer under the Global Maps tab.

Hadley Rille is located along the eastern rim of Mare Imbrium, which fills the Imbrium Basin, the largest impact basin on the near side of the Moon. The Apennine Mountains, which are located to the north, east, and south of Hadley Rille, are part of the rim of the Imbrium Basin. Astronauts Dave Scott and Jim Irwin landed the Apollo 15 spacecraft near Hadley Rille on July 30, 1971.

7. What may have formed Hadley Rille? [If you need a hint: See Chapter 4 of Exploring the Planets.]

*Load the Visible Imagery under the Global Maps tab. **Activate the Apollo 15 layer under the Moon Gallery -- Apollo Missions tab in the Primary Database.** Also activate the First Look: Falcon on the Plain layer under the Hadley Rille folder and double-click on the Apollo 15 Landing Site icon.*

Apollo 15 conducted three extra-vehicular activities (EVAs) during their 2 day, 19 hour stay on the lunar surface. The main objectives of Apollo 15 were to collect material that was created during the formation of the Imbrium basin in addition to studying the formation of Hadley Rille.

8. Approximately how far (in meters) is Site 6 (near the Apennine Front) from the Apollo 15 landing site? Hint: Use the ruler tool at the top of the screen.

9. Zoom in on Site 6 and read the information provided on the Apennine Front (bring this up by clicking on the red dot near Site 6). Why is understanding the Imbrium Basin significant to lunar science?

10. What important discovery was made at Site 7? What implications did this have for lunar science?

11. Zoom in on Site 3 and read the information provided. What is the geologic term for a rock with bubbles in it? How are these bubbles made? (Note: This is a very good sample to ask Dave Scott about on his visit!).

12. Zoom in on Site 4 and look at the surface panorama (click the camera symbol then click on the picture that pops up). What does Dune crater look like on the ground? Do you think this is a relatively old or relatively young crater? Why?

Taurus-Littrow Valley (5 points)

Double-click on the Taurus-Littrow Valley folder and load the Lunar Orbiter Mosaic background under the Global Maps tab.

Taurus-Littrow Valley is located along the eastern rim of the Serenitatis Basin. The valley floor is covered with regolith (impact generated fragments forming a soil layer) overlying dark mare material, while the nearby mountains and hills are portions of the rim of Serenitatis Basin. Apollo 17 landed in the Taurus-Littrow Valley on December 11, 1972 to further investigate the formation of some of the Moon's largest basins. Astronaut Harrison Schmitt, the Lunar Module Pilot on Apollo 17, was also the first and only geologist to land on the Moon.

Load the Visible Imagery under the Global Maps tab in addition to the Apollo 17 layer under the Moon Gallery, Apollo Missions tab. Double-click on the Taurus-Littrow Valley layer to zoom in.

13. Approximately how far east of the scarp (in meters) did the Apollo 17 Lunar Module land? Hint: Use the ruler tool at the top of the screen.

14. Zoom into site 2 and read the information on Nansen Crater. Here Eugene Cernan and Harrison Schmitt collected the oldest sample ever returned from the Moon, an olivine clast about 4.5 billion years old! What did this sample tell us about the composition of the Moon?

Activate the First Look: Challenger at Taurus-Littrow layer in the Taurus-Littrow Valley folder and double-click on the Apollo 17 Landing Site layer to zoom in.

At Site 6 of the third and final EVA of Apollo 17 (near LRV 10), Eugene Cernan and Harrison Schmitt studied a large boulder known as "Tracy's Rock". This boulder can be seen from orbit with the latest satellite imagery.

Zoom into Site 6 and find "Tracy's Rock" from orbit. Notice that "Tracy's Rock" (with diameter ~ 14 meters) rolled downhill and left a long track behind it. The fact that this rock rolled down the steep slope above it was a great benefit to the astronauts since it meant that they could get a sample of materials far above them on a slope that they could not traverse.

15. Place your mouse cursor over the rock. Notice the elevation at the bottom of the screen. Now, scroll to the top of the hill where the boulder track begins. How many vertical meters did "Tracy's Rock" fall based on its track? How long is its path (in meters)?

16. Read the information provided in Google Moon on "Tracy's Rock". What conclusion did Harrison Schmitt come to regarding the formation of this rock?

17. Observe the path taken between sites 1-9, and zoom in to observe some of the obstacles (read, craters) Eugene Cernan and Harrison Schmitt had to avoid. What is the largest distance between any two sites (#1-9) the Apollo 17 astronauts had to travel?

Apollo sample 78235, which you will get a chance to see during the next lab, was taken from Site 8 by the Apollo 17 astronauts. Read the additional information provided in Google Moon regarding the astronauts' time at Site 8. What were the astronauts hoping to find at Site 8? Keep this question in mind when you study sample 78235 next week!