

Mentor (Teacher) Guide to Moon 101

This **Mentor (Teacher) Guide to Moon 101** is broken down into three sections:

- 1) Formation of the Moon
- 2) Evolution of the Lunar Surface
- 3) Lunar Exploration and Surface Characterization

Each section includes a list of suggested readings along with questions students should be able to answer after going through the readings. By reading these articles and answering the questions, students will have obtained a new knowledge of lunar science that will be useful throughout the length of the research program. For now, students will use this knowledge to interpret and describe the geology seen in three images of the lunar surface.

Links to websites and documents necessary to complete Moon 101 can be found at:

http://www.lpi.usra.edu/exploration/education/hsResearch/moon_101/

A) Moon Formation

- 1) Students should read the following articles:

a) The Scientific Legacy of Apollo, Jeffrey Taylor, 1994, *Scientific American*, volume 271, number 1, pages 40-47. Rocks retrieved during the Apollo missions provided a new view of our Moon's, and Earth's, origin and evolution. **LPI cannot provide due to copyright issues. However, this article should be obtainable through your library.**

b) Origin of the Earth and Moon, G. Jeffrey Taylor, 1998, *Planetary Science Research Discoveries*,
<http://www.psrdr.hawaii.edu/Dec98/OriginEarthMoon.html>. First hand report of the December 1998 conference on the formation and very early history of the Earth and Moon.

c) Time to Solidify an Ocean of Magma, G. Jeffrey Taylor, 2009, *Planetary Science Research Discoveries*,
<http://www.psrdr.hawaii.edu/Mar09/magmaOceanSolidification.html>. A small mineral grain places limits on how long it took the lunar magma ocean to solidify.

d) The Oldest Moon Rocks, Marc Norman, 2004, *Planetary Science Research Discoveries*,
<http://www.psrdr.hawaii.edu/April04/lunarAnorthosites.html>. Rocks from the lunar crust provide new clues to the age and origin of the Moon and the terrestrial planets.

2) Questions to discuss with each other after reading:

- a) What is the prevalent scientific hypothesis for the formation of the Moon?
- b) What evidence supports this hypothesis?
- c) Create a table that compares and contrasts alternative ideas and lines of negating evidence for those ideas.
- d) How long after the Moon formed did the lunar highlands form?

3) Extension Questions (optional): Why are the maria smaller and fewer on the farside compared to the near side? Why is the crust thicker on the far side than the near side? How does the Moon's interior compare to Earth's? What evidence supports this?

B) Lunar Evolution

1) Students should examine the image “Global Moon” and discuss the following questions with the team:

- a) Describe the geologic features observed in the image.
- b) How did these features form?

2) Students should read the following:

a) Wandering Gas Giants and Lunar Bombardment, G. Jeffrey Taylor, 2006, *Planetary Science Research Discoveries*, <http://www.psr.d.hawaii.edu/Aug06/cataclysmDynamics.html>. Outward migration of Saturn might have triggered a dramatic increase in the bombardment rate on the Moon 3.9 billion years ago.

b) Lunar Meteorites and the Lunar Cataclysm, Barbara A. Cohen, 2001, *Planetary Science Research Discoveries*, <http://www.psr.d.hawaii.edu/Jan01/lunarCataclysm.html>. Dating of impact melts in lunar meteorites supports the idea that the Moon was intensely bombarded about 3.9 billion years ago.

c) Impact Cratering Notes (PDF) **Available at:**
http://www.lpi.usra.edu/exploration/education/hsResearch/moon_101/

d) Lunar Volcanism Notes (PDF) **Available at:**
http://www.lpi.usra.edu/exploration/education/hsResearch/moon_101/

e) Mare Materials, Don Wilhelms, 1987, *The Geologic History of the Moon: USGS Professional Paper 1348*, <http://ser.sese.asu.edu/GHM>. Summary of lunar volcanism. Read the sections: “Mapping Properties” (pgs. 86-93) and “Origin and Emplacement” (pgs. 102-103).

f) Read the following sections in “Relative Ages” from *The Geologic History of the Moon: USGS Professional Paper 1348* by Don Wilhelms:

- i) Superpositions: Mare-crater relations, Crater-crater relations, Basin-crater relations, pg. 125.
- ii) Structure, pg. 10

BE SURE TO READ THE CAPTIONS WITH THEIR CORRESPONDING IMAGES.

Both sections available online at
http://ser.sese.asu.edu/GHM/ghm_06txt.pdf.

3) Questions to discuss with the team after reading:

- a) Describe the evolution of the Moon’s surface beginning 4.5 billion years ago with ages of formation of the different types of features. Alternative: draw this as a cartoon that captures the details.
- b) What types of volcanoes are observed on the Moon? The Earth?
- c) What are the volcanic features on the Moon (volcanoes, maria) made of? What are Earth’s volcanic features made of?
- d) Why do we not observe the same diversity of volcanoes and volcanic rock types on the Moon as we observe on Earth?
- e) The youngest volcanic rock on the Moon is ~1 billion years old. How old are the youngest volcanic rocks on Earth? Why is there such a discrepancy in the ages? What does this tell us about the state of the interior of the Moon?
- f) Describe the shapes of three types of lunar rilles. Sketch each type to illustrate your description. How is the formation of lunar rilles explained?
- g) Sketch and describe how complex and simple impact craters form.
- h) Why is the idea of a lunar cataclysm ~3.9 billion years ago a hypothesis and not a theory?
- i) Why are there so many impact craters on the Moon compared to Earth?

4) Extension Questions (optional): Why do we only see the near side? Why are the Apollo landing sites concentrated on the near side and near the equator?

C) Lunar Exploration and Surface Characterization

1) Students should do some research on the spacecraft that have returned lunar data. This section is intended for students to conduct a *SURVEY* of available lunar data. It is important to determine what datasets and maps are available, and the advantages and limitations of each dataset. These include data from the following missions. Links to online data can be found on the Moon 101 webpage:

- a) Ranger missions (1962-66)
- b) Lunar Orbiter (1966-67)

- c) Apollo (1968-72)
- d) Lunar Prospector (1998) -
- e) Lunar Reconnaissance Orbiter (2009 – present)

2) After doing some research on lunar data sets, discuss the following questions:

- a) What types of data did each mission collect? At what scale?
- b) What challenges are presented by the different data sets if you were to choose any one of them (resolution, oblique angle of view, ease of access, etc.)?
- c) What data set(s) would be most appropriate for characterizing the geology of a larger region of the lunar surface?
- d) What data set(s) would be most appropriate for a detailed characterization of the floor of a crater?

3) Examine the three of the lunar surface (Moon 101 image 1, Moon 101 image 2, Moon 101 image 3) at

http://www.lpi.usra.edu/exploration/education/hsResearch/moon_101/

Using copies of the image, identify the different geologic features present. Next, create a key to these features and then carefully mark and label the surface features using the key. As a team, describe their characteristics (morphology, scale).

- a) What types of features are present on the image?
- b) Based on your reading about the formation and evolution of the Moon, how did the different types of features form? When did they form relative to each other?

D) Moon 101 Presentation

Create a PowerPoint summarizing the geologic history of the surface seen in each of the three Moon 101 images. What geologic features are present? How did they form? How old are they relative to each other and how do you know that?