

## Instructor Guide to Moon 101

This **Instructor 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 characterize the geology seen in three images of the lunar surface

Links to websites and other readings/files necessary to complete Moon 101 can be found at:

<http://www.lpi.usra.edu/nlsi/education/hsResearch/resources/index.shtml>

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### PART 1 – FORMATION OF THE MOON

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.psr.d.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.psr.d.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.psr.d.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 address 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?

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## PART 2 - LUNAR EVOLUTION

1) Students should examine the image “Global Moon” and address the following questions:

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

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/nlsi/education/hsResearch/resources/index.shtml>**

d) Lunar Volcanism Notes (PDF) **Available at:**

**<http://www.lpi.usra.edu/nlsi/education/hsResearch/resources/index.shtml>**

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) Structure, Don Wilhelms, 1987, *The Geologic History of the Moon: USGS Professional Paper 1348*, pg. 107, [http://ser.sese.asu.edu/GHM/ghm\\_06txt.pdf](http://ser.sese.asu.edu/GHM/ghm_06txt.pdf). Summarizes lunar tectonic features and their possible formation mechanisms.

3) Questions to address after reading:

- a) Describe the evolution of the Moon’s surface beginning 4.5 billion years ago with ages of formation of 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 that 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 in proximity to the equator?
- 5) Read the following sections in Relative Ages from *The Geologic History of the Moon: USGS Professional Paper 1348* by Don Wilhelms:
- Superpositions: Mare-crater relations, Crater-crater relations, Basin-crater relations (pgs.125-127). [http://ser.sese.asu.edu/GHM/ghm\\_06txt.pdf](http://ser.sese.asu.edu/GHM/ghm_06txt.pdf). BE SURE TO READ THE CAPTIONS WITH THEIR CORRESPONDING IMAGES.
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## PART 3 - LUNAR EXPLORATION & 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 (with suggested websites):

- a) Ranger missions (1962-66) - <http://www.lpi.usra.edu/resources/ranger>
- b) Lunar Orbiter (1966-67) - <http://www.lpi.usra.edu/resources/lunarorbiter>
- c) Apollo (1968-72) - <http://www.lpi.usra.edu/resources/apollo>, (orbital images mixed-in with surface images taken by astronauts)
- d) Clementine (1994) - <http://www.nrl.navy.mil/clm>
- e) Lunar Prospector (1998) - <http://lunar.arc.nasa.gov/datavis/3ddata/multidata.htm>
- f) Lunar Reconnaissance Orbiter (2009 – present) - <http://lroc.sese.asu.edu>
- g) Google Moon - <http://www.google.com/moon/>

2) After doing some research on lunar missions, students should discuss the following questions with each other:

- 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 large area of the lunar surface?
- d) What data set(s) would be most appropriate for a characterization of the floor of a crater?

3) Examine the three images: Moon 101 image 1, Moon 101 image 2, and Moon 101 image 3 available at

<http://www.lpi.usra.edu/nlsi/education/hsResearch/resources/index.shtml>.

4) Questions to address in characterizing each image:

- a) Can you determine the scale of the image?
- b) If the image has horizontal lines, what causes these lines?
- c) Do you know which mission took this image?
- d) What types of features are seen in the image?
- e) How did the different types of features form? When did they form? Do you know their exact age?

## Moon 101

Create a PowerPoint summarizing the geologic history of the surface seen in the image in terms of relative ages of features and what you have learned in your previous reading about the geologic history of the Moon. What geologic features are present? How did they form? How old are they relative to each other and how do you know that?

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