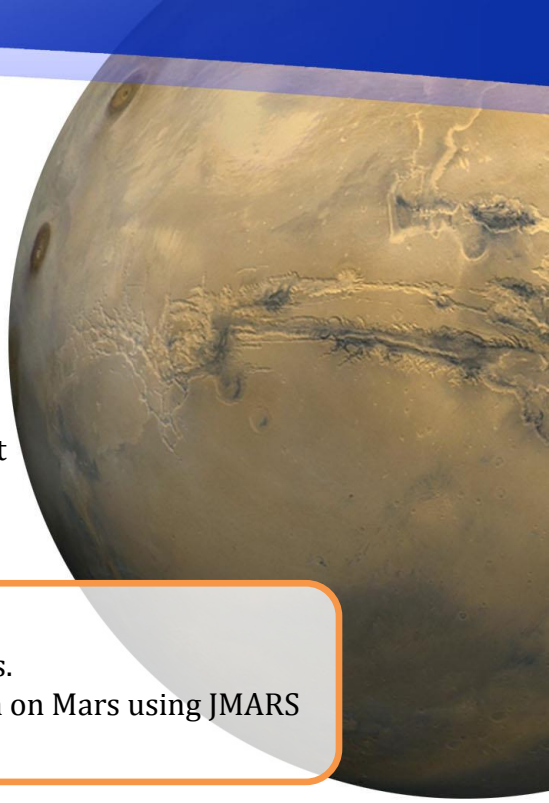
Lesson 10: Meteorites and Impact Craters



Summary
A learning module for incorporation in to Earth science courses that exposes students to the formation of impact craters and what differentiates a meteorite from other rocks on Earth.

Learning Goals

Students will be able to:

- Practice identifying meteorites vs. Earth rock specimens.
- Attempt crater counting and accurately age-date terrain on Mars using JMARS software.

Context for Use
Prior exposure to rock & mineral classification is advisable, although not necessary to be successful in these exercises. In addition discuss relative and absolute dating techniques on Earth prior to these activities.

Description and Teaching Materials
In-Class Activity
In-Class Activity 1: Is it a Meteorite?
Homework/Lab
Homework 1: Crater Counting

Teaching Notes and Tips

1. It will take at least an hour of prep time to become familiar with the crater count material in order to teach the crater counting method. It is recommended that during the class meeting when you assign Homework 1 that you provide a quick tutorial of crater counting and how to use the tools in JMARS.
2. For *In-Class Activity 1* you may provide samples of the required rocks/meteorites or use the images provided in the *Image File*.

Assessment
Methods of assessment are within each individual *In-Class Activity* and *Homework*.

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References and Resources

1. Image File: Meteorites and Impact Craters
2. Criteria to identify a meteorite via NASA/DAWN mission interactive: http://dawn.jpl.nasa.gov/meteorite/experiment.asp
3. Background on determining the age of surfaces on Mars: http://www.msss.com/http/ps/age2.html
4. JMARS crater counting tutorial: http://jmars.asu.edu/crater-counting-layer

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Homework 1
Ages and Times of Earth & Mars
Crater Counting

Background:
In reference to: http://www.msss.com/http/ps/age2.html (**NOTE: This map is centered at a different location than the map below in question 4, so you need to be sure to match up appropriate geographic locations).

1. We often use radiometric dating to determine the age of Earth's rocks. Is this technique applicable on Mars? What would be the challenges of preforming this technique on Mars?

2. What is the general assumption of age relative to the overall appearance of craters?

3. How can we roughly divide the history of crater formation into three periods, from oldest to newest?

4. Using the map of Mars below, sketch the basic boundaries of the three Mars Epochs that are based on crater counts (Labels: Noachian, Hesperian, Amazonian)

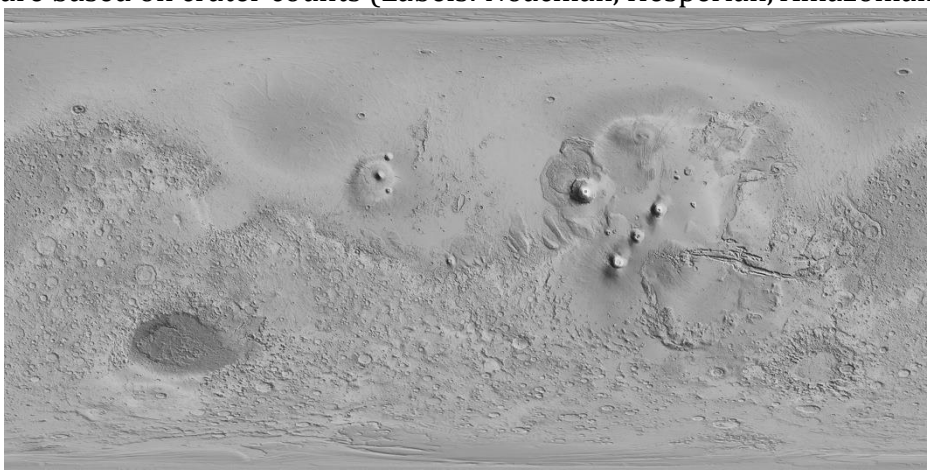

Figure 1 MOLA colorized elevation map in grayscale.

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Crater Counting:
Review this tutorial in order to use the Crater Counting layer in JMARS:
http://jmars.asu.edu/crater-counting-layer

5. Measure the diameter of as many craters you can using JMARS *Crater Counting* layer. Choose craters that are roughly the same size. Use a 128 zoom OR larger (to give you at least 30 or more craters) and fill in the average crater diameter and # of craters you measured. If the students can separate out sizes, do so. Use the measure tool located in the tool bar at the top of the window to measure the x and y dimensions of the area they're counting in, then calculate area by Area = x*y.

Region	**Size 1:**		**Size 2:**		**Size 3:**	
	Ave diameter *(X-axis)*, #	**#/ area = *plot on Y-axis***	**Ave diameter *(X-axis)*, #**	**#/ area = *plot on Y-axis***	**Ave diameter *(X-axis)*, #**	**#/ area = *plot on Y-axis***
Amenthes Rupes Area =	**Dia:** **X=**		**Dia:** **X=**		**Dia:** **X=**	
Vichada Valles Area=	**Dia:** **X=**		**Dia:** **X=**		**Dia:** **X=**	
Mawrth Valles **Area=**	**Dia:** **X=**		**Dia:** **X=**		**Dia:** **X=**	
Astapus Colles **Area=**	**Dia:** **X=**		**Dia:** **X=**		**Dia:** **X=**	

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6. Use the isochron diagram on the following page to determine the age of the terrain. Have students PLOT their points on Figure 2. To scale the Y-axis correctly: use proportions and be sure to square the area they investigated.
   Example: 20 counted craters, diameter 4km in a 200km by 200km counted area-
   $20/ (200)^2 = 0.0005$ which gives you a y-axis value of 10^{-5}
   Use the diameter of 4km that they measured for the x-axis and plot.
   Does their age coincide with the sketch they made in #4?

   Amenthes Rupes- Epoch: _____

   Vichada Valles- Epoch: _____

   Mawrth Valles- Epoch: _____

   Astapus Colles- Epoch: _____

7. What are the difficulties the students faced in crater counting on Mars? Do they feel like it is too "averaged" and some terrains are not accounted for? Why or why not?

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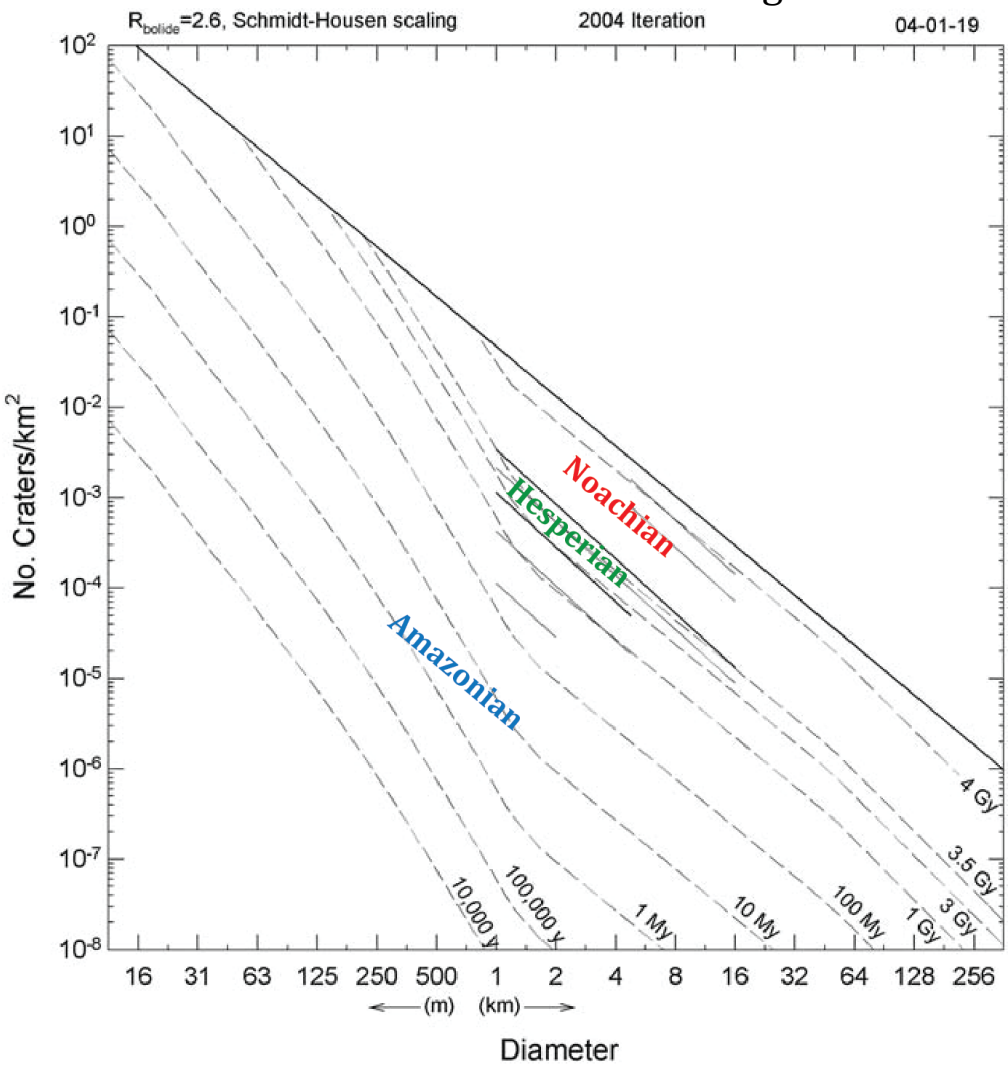

Figure 2. Final 2004 iteration of Martian crater-count isochron diagram. Upper solid line marks saturation equilibrium. Heavier short solid lines (1 km < *D* < 16 km) mark divisions of Amazonian, Hesperian, and Noachian eras; lighter nearby solid lines mark subdivisions of eras all based on definitions by Tanaka (1986). Uncertainties on isochron positions are estimated at a factor ~ 2, larger at the smallest *D*. 100 m (total uncertainties in final model ages, derived from fits at a wide range in *D*, including uncertainties in counts, are estimated a factor ~ 3).

Figure source: http://www.psi.edu/sites/default/files/imported/research/isochrons/mc8/fig6.jpg

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