

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

2. For *In-Class Activity 1* you may provide samples of the required rocks/meteorites or use the images provided in the *Image File*.

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.

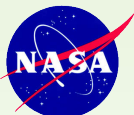
Assessment

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

Mars for Earthlings

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>



Mars for Earthlings

In Class Activity 1

Meteorite and Impact Craters_MFE

Is it a meteorite?

Purpose: Discover the criteria by which meteorites are identified.

Engage

Is it a Meteorite?

Have the students observe the rocks. Have them mark Yes or No for whether or not they think the rock is a meteorite. Also note if the rock is: igneous, metamorphic, or sedimentary.

	Yes	No	Lithology
Rock A			
Rock B			
Rock C			
Rock D			

What criterion/criteria do the students use to identify whether or not a rock is a meteorite? Have them explain below:

Explain

Criteria to identify a meteorite in hand sample (NASA DAWN Mission:

<http://dawn.jpl.nasa.gov/meteorite/experiment.asp>). Does the specimen have:

1. Presence of a fusion crust?
2. Presence of shiny metals?
3. Presence of regmaglyps (thumbprints)?
4. Attracted to a magnet?
5. Density greater than a typical Earth rock?
6. Presence of chondrules?

Go through these criteria as the discussion with the students would indicate in **Engage**. Ultimately, chemical analyses will be crucial to positive identification.

Explain

Read about meteorite vs. meteor-wrongs. Have students vote on what website they think gives the best presentation (and/or give some alternate sites). Possible websites to use are below.

<http://meteorite-identification.com/>

<http://www.littlewolf.us/meteoriteormeteorwrong.html>

<http://www.meteorites-for-sale.com/meteorite-identification/meteor-right-wrong.html>



Mars for Earthlings

Elaborate

Discuss how many meteorites are from Mars. Is the number single digits, tens, hundreds, or thousands? Have students guess, and then they can check their guess at this website.

<http://www2.jpl.nasa.gov/snc/>

What criteria do we use to tell if a meteorite is from Mars?

<http://www.imca.cc/mars/martian-meteorites.htm>

Evaluate

What happens when a meteorite hits a planetary surface? How big will the crater be?

Observe the below meteor crater in Arizona measuring: 0.737 mi (1.19 km) in diameter, 570 ft (170m) deep

1. Did scientists find any of the meteorite (students may need to do some outside research)?
2. What factors influence the size of the crater? List at least 5 below.



Figure 1: Photograph by David Roddy, United States Geological Survey.

Calculate your own crater size!

1. Using the below link, have the students calculate the size of 3 craters that will form when they change varying parameters. Record the parameters and results below. Have them consider #2 as they change their parameters.
http://www.jpl.arizona.edu/tekton/crater_c.html (*Note: Make sure they calculated at least 2 craters and varied the inputs.)

Mars for Earthlings

2. What parameter was the most influential in the size of a crater?

Google Mars & Craters

3. Using Google Earth find the region Mawrth Valles (22.43_N 343.03_E) in the Mars navigation. Using the ruler tool try and determine the average diameter of craters in the region. Write the average below.
4. What might this say about the ages of these craters compared to other regions? Is it more like the area to the South or to the North?

Testing your skills

Which image below is a meteorite, Figure 2 or Figure 3? List your criteria.

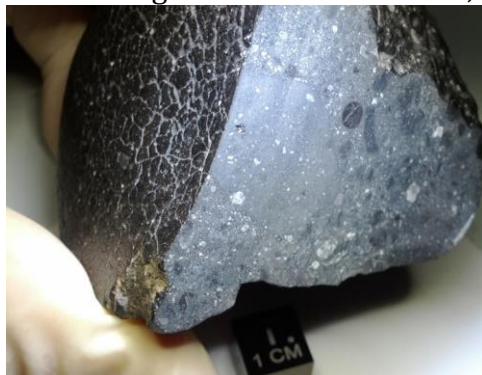


Figure 2. Image credit:
http://www.nasa.gov/mission_pages/mars/news/mars20130103.html



Figure 3. Image credit: Levi Huish, University of Utah

Mars for Earthlings

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 performing 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)

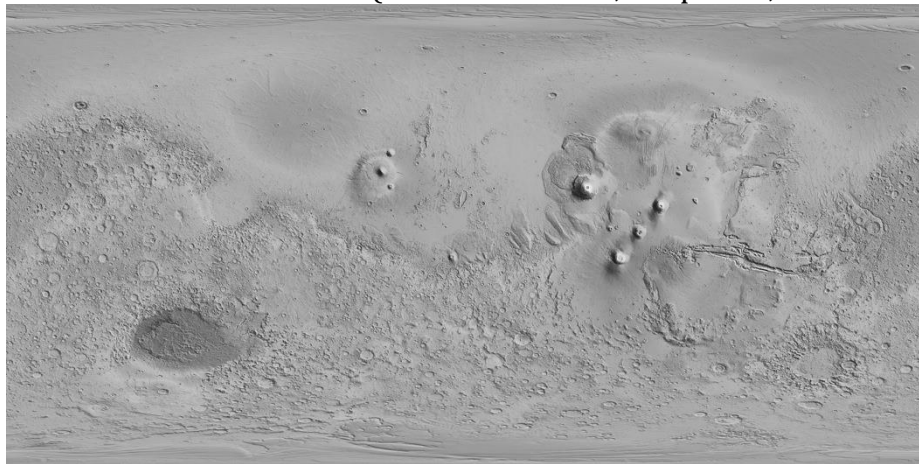


Figure 1 MOLA colorized elevation map in grayscale.

Mars for Earthlings

Crater Counting:

Review this tutorial in order to use the Crater Counting layer in JMARS:

<http://jmars.asu.edu/crater-counting-layer>

- 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 $\text{Area} = x \times y$.

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=	

Mars for Earthlings

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?



Mars for Earthlings

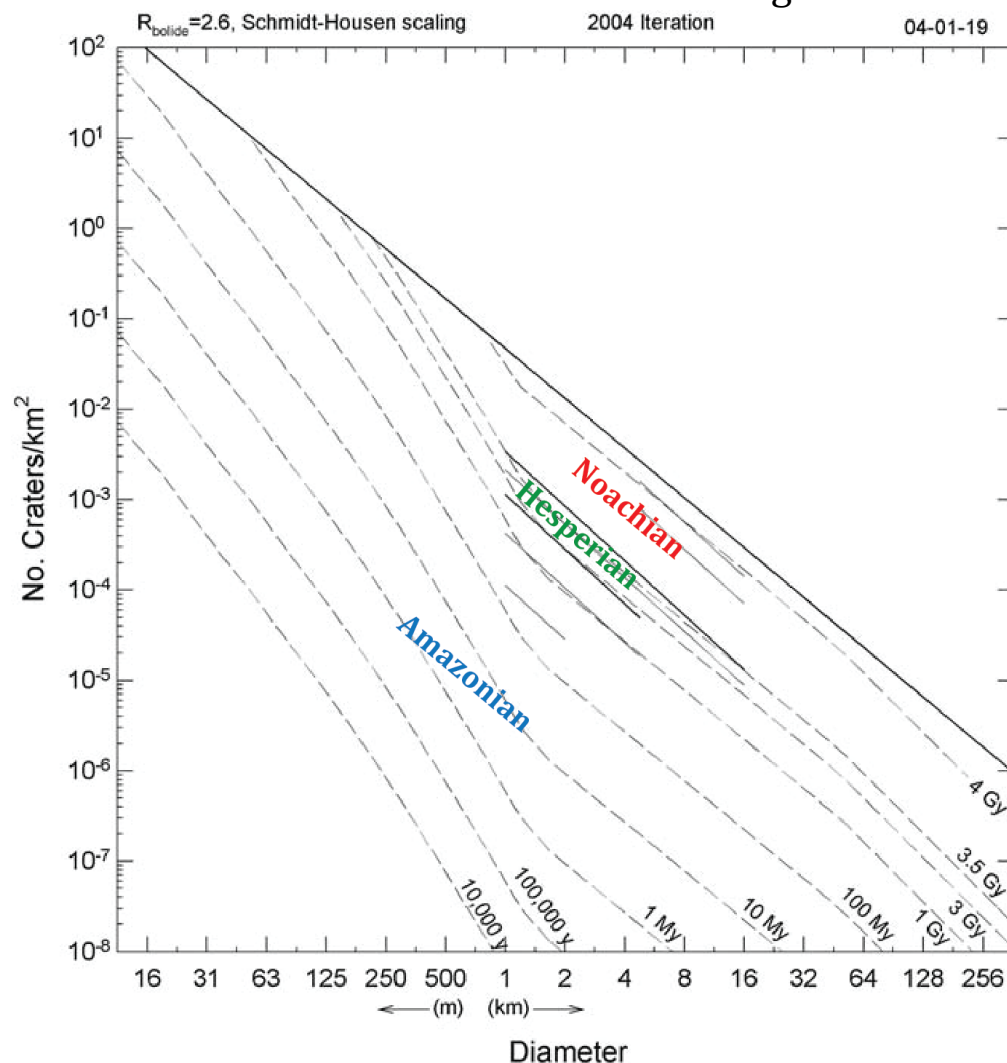


Figure 2. Final 2004 iteration of Martian crater-count isochron diagram. Upper solid line marks saturation equilibrium. Heavier short solid lines ($1 \text{ km} < D < 16 \text{ km}$) mark divisions of Amazonian, Hesperian, and Noachian eras; lighter nearby solid lines mark subdivisions of eras all based 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>