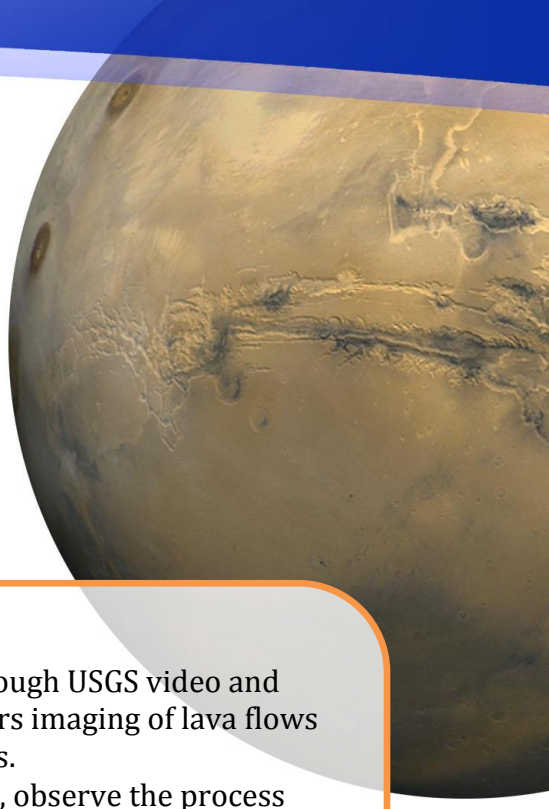
Lesson 6: Olympus Mons and Igneous Rocks



Summary
This learning module and related laboratory exercise exposes students to volcanic styles, eruptions, igneous rock textures and their evidence in the Martian landscape.

Learning Goals

Students will be able to:

- Differentiate between pahoehoe and a'a lava flows through USGS video and subsequent discussion. Students will then observe Mars imaging of lava flows and hypothesize which lava flow is more likely on Mars.
- Observe a columnar joint experiment using cornstarch, observe the process and discuss its potential formation on Mars. Students will observe columnar jointing on Mars using HiRISE imaging and compare the features to the Columbia River basalts on Earth as an analog.
- Use Google Mars and JMARS software, students will increase their literacy with the software packages as well as recognize and analyze different mineralogies on Mars and the nature of Olympus Mons in comparison to Earth analog volcanoes.

Context for Use
This learning module is meant for adaptation in an introductory earth science course and/or planetary science course. Before engaging in the In-Class Activities and/or Homework, students will need to be provided with an overview of igneous rocks (see Teaching Notes and Tips). All In-Class Activities can be adapted to a homework set if desired. Online access is essential for video viewing in association with the In-Class Activities.

Description and Teaching Materials
In-Class Activity
In-Class Activity 1: Lava flows
In-Class Activity 2: Cornstarch columnar joints
Homework/Lab
Homework 1: Google Olympus Mons
Homework 2: Basalt & JMARS

Teaching Notes and Tips
1. Provide students with a background in the rock cycle, igneous rock textures, volcanic styles, and rates of cooling for *In-Class Activity 1.*

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2. Instructors may choose to develop their own cornstarch experiment by the adaptation of the following published experiment and results: http://www.physics.utoronto.ca/~nonlin/papers_mud.html
3. Make sure students are familiar with both Google Mars and JMARS software. The introduction module "Introduction to Mars and Earth Analogs" provide homework and/or In-Class activities to expose and orient students to the software packages.

Assessment

- One of the goals of MFE is to have students become familiar with Mars imagery and navigating the mission online archives as well as software programs available to explore Mars imagery. The homework assignments, if completed, will provide students with increased competence in navigating both Google Mars and JMARS software.
- Through comparison of various Mars images students will be asked to identify common minerals on Mars, their abundance in terms of geographic location, as well as style of igneous rock formation.

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References and Resources

1. Image file: Igneous Rocks and Volcanics
2. Rock Cycle Background: http://www.classzone.com/books/earth_science/terc/content/investigations/es0602/es0602page02.cfm
3. Columnar Joint Experiment Video: www.youtube.com/watch?v=CJWfneKdv08
4. Columnar Joint Article: http://www.sciencedaily.com/releases/2008/12/081216104325.htm
5. Columnar Jointing in Columbia River Gorge Oregon: http://www.youtube.com/watch?v=WLGXmJZ_KIU
6. Mars columnar jointing discovery by HIRISE in Geology: http://geology.gsapubs.org/content/37/2/171/F1.expansion.html
7. HIRIES columnar jointing image: http://www.nasa.gov/mission_pages/MRO/multimedia/mro20090225.html
8. Pahoehoe lava flow video: http://www.youtube.com/watch?v=qTTLYx4Xo2k&feature=related
9. A'a lava flow video: http://www.youtube.com/watch?v=bWswq8PmRII
10. Basalt on Mars (Hawaii): http://www.psrd.hawaii.edu/May09/Mars.Basaltic.Crust.html
11. Athabasca Spiral lava flows: Discovery news article: http://www.space.com/15446-mars-lava-volcanoes.html
    Image source: http://www.space.com/15446-mars-lava-volcanoes.html
12. Mars Plagioclase mineralogy animation: http://www.youtube.com/watch?v=FRU0cHb31JM

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In-Class Activity 2
Olympus Mons_MFE
Columnar jointing on Mars

Purpose: Become familiar with the formation, the processes, of columnar jointing and its apparent formation on Mars.

Engage
Study Figure 1 (a) below. A. In a few sentences, have the students write down their hypotheses for how these features form. B. Are there any other features in their daily life or on Earth that have similar characteristics?

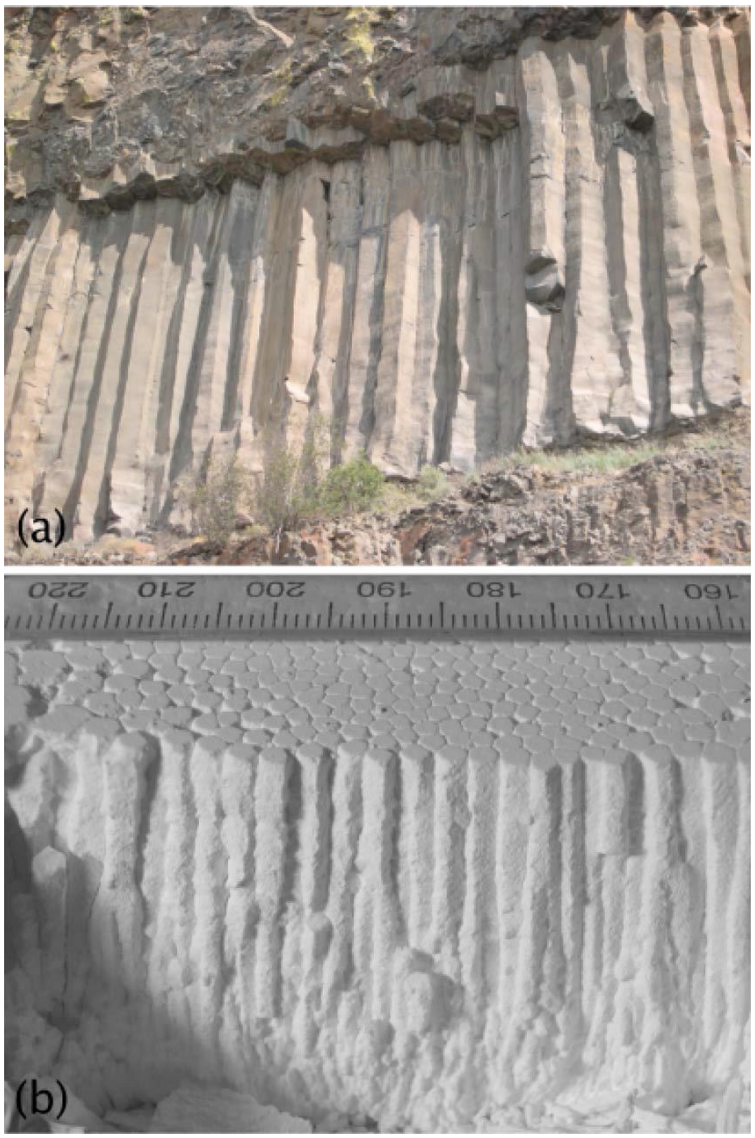

Figure 1: Columnar jointing in (a) basalt of the Columbia Plateau near Banks Lake ~95 cm average diameter, and (b) in desiccated corn starch. (Image Credit: Gohering L., Morris, S.W., and Lin, Z., 2006. Experimental investigation of the scaling of columnar joints. PHYSICAL REVIEW E 74, 036115, p. 1-12.)

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Explore

Read the following article or view the following cornstarch experiment video used to illustrate columnar jointing (Figure 1 (b) is a still from the experiment). Consult the explanation under the video window.

Video: www.youtube.com/watch?v=CJWfneKdv08

Article: http://www.sciencedaily.com/releases/2008/12/081216104325.htm

1. Is there perfect similarity between the "real" columnar joints of the Columbia River basalts and the experiment? Why or why not?

2. How do the fractures/cracks form? Are they widening, re-forming through time, or starting new fractures?

3. What might enhance the cracks?

4. How could the students foresee such features forming on Mars?

Explain

Columnar jointing forms in lava flows, sills, dikes, ignimbrites (ashflow tuffs), and shallow intrusions of all compositions. Most columns are straight with parallel sides (colonnade) and diameters from a few centimeters to 3 m. Some columns are curved and vary in width (entablature). Columns can reach heights of 30 m. The columns form due to stress as the lava cools (Mallet, 1875; Iddings, 1886, 1909; Spry, 1962). The lava contracts as it cools, forming cracks. Once the crack develops it continues to grow. The growth is perpendicular to the surface of the flow. Entablature is probably the result of cooling caused by fresh lava being covered by water. The flood basalts probably damned rivers. When the rivers returned the water seeped down the cracks in the cooling lava and caused rapid cooling from the surface downward (Long and Wood, 1986). The division of colonnade and entablature is the result of slow cooling from the base upward and rapid cooling from the top downward.

Website reference:
http://volcano.oregonstate.edu/education/facts/col_joint.html

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Elaborate

View the following discovery, in 2009, on Mars and have the students answer the following questions: http://geology.gsapubs.org/content/37/2/171/F1.expansion.html

1. Referring to the image, about how wide are the columns? (Pay attention to the horizontal scale bar)

2. What does this image tell you about igneous rocks and their history on Mars?

Evaluate

Students should understand how columnar joints form and should be able to identify columnar joints on Mars.

Figure 2 below is the original image of columnar jointing captured on Mars using the HiRISE camera for the above discovery. Using arrows, point to where you think the columnar joints are exposed in this terrain.

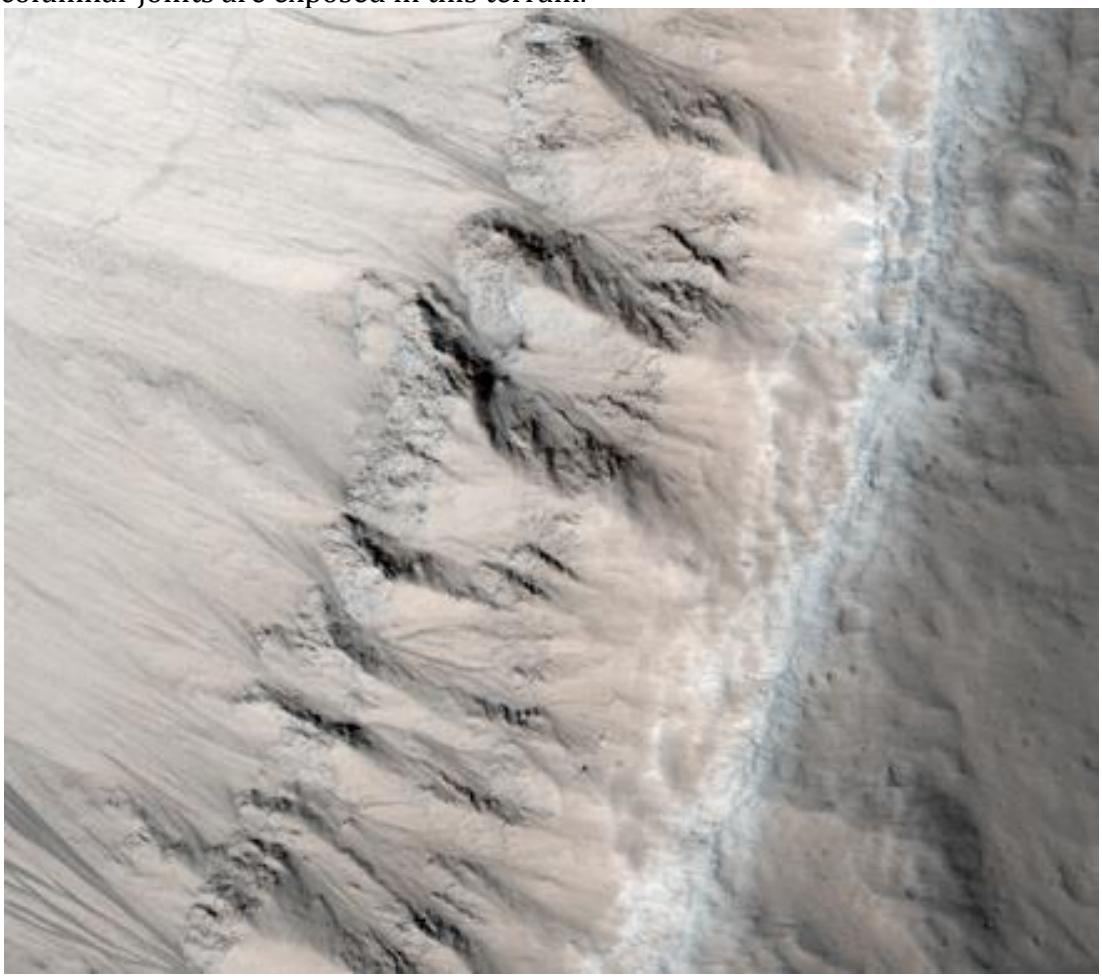

Figure 2: http://hirise.lpl.arizona.edu/PSP_005917_2020 (Image Credit: NASA/HiRISE)

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References:

Goehring, L., et al., 2008, Nonequilibrium scale selection mechanism for columnar jointing, PNAS, V. 106, p. 387

Goehring, L. and Morris, S.W., 2008, Scaling of columnar joints in basalt, JGR-Solid Earth, v. 113, pp. B10203

Iddings, J.P., 1886, Columnar structure in the igneous rocks of orange Mtn., N.J.: American Journal of Science, v. 131, p. 321-330.

Iddings, J.P., 1909, Igneous Rocks: Wiley, New York.

Long, P.E., and Wood, B.J., 1986, Structures, textures, and cooling histories of Columbia River basalt flows: Geol. Soc. America Bull., v. 97, p. 1144-1155.

Mallet, R., 1875, Origin and mechanism of production of prismatic (or Columnar) structure in basalt: Phil. Mag. v. 4, p. 122-135 and 201-226.

Milazzo et al., 2009 Discovery of Columnar Jointing on Mars; *Geology* 2009;37;171-174 doi:10.1130/G25187A.1

Spry, A., 1962, The origin of columnar jointing, particularly in basalt flows: Journal of the Australian Geological Society, v. 8, p. 192-216.