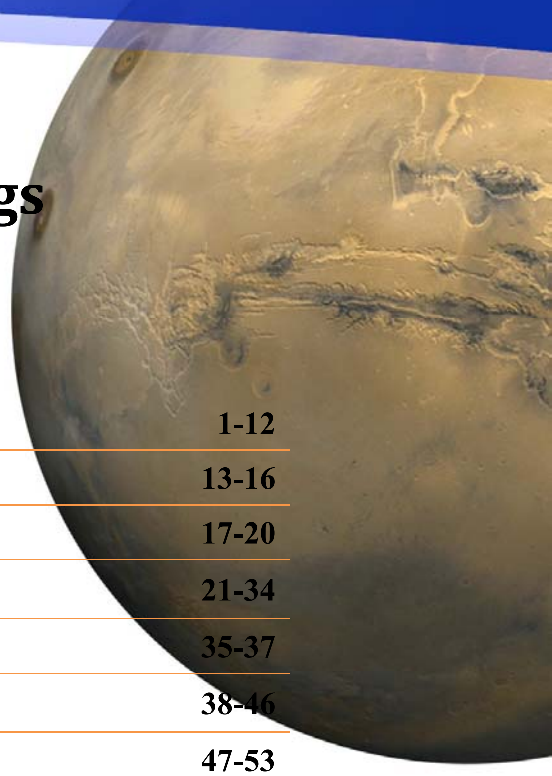
Dynamic Mars: Mars for Earthlings

Student Version



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These modules are arranged by lesson topics (#1-23). Under each lesson there are activities (for in class) as well as homework assignments (to work on at home).

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LESSON 1: Introduction

In-Class Activity 1
Mars Analogs

Purpose: Observe and rank potential Earth analogs for Mars planetary study.

Earth Analogs

1. What do you think scientists mean by an "earth analog" in the context of studying Mars?

2. As an example, why is the komodo dragon considered an "analog" for a dinosaur?

Analog Regions on Earth

For the following regions (may need to do a bit of internet searching) write in the most important similarities to Mars:

- Atacama Desert, South America
- Death Valley, CA
- John Day Formation, Oregon
- Southern Utah
- Antarctic Dry Valleys

NOW... Check off how important you think the following factors are in deciding whether this is a good analog to Mars (1-very important, 5-not important)

_________ Environment conditions, setting for deposits

_________ Geomorphic features (landscape expression)

_________ Type of water and its presence or absence

_________ Ambient temperature range

_________ Mineralogy

_________ Type of life, if present (extremophile or not)

_________ Rainfall

_________ Atmospheric composition

Note: it may be difficult for any Earth Analog to satisfy all the conditions of similarity to Mars

Mars for Earthlings

Homework 1
Intro to Mars_MFE
Google Mars

Objective: Observe important features and "divisions" of the surface of Mars.

Introduction: This brief introduction will hone your observation skills to notice features on the surface of Mars and some of the major natural landscape features.

Getting Started
Use the web version of Google Mars http://www.google.com/mars/
Notice that the map wraps (repeats), so you'll want to crop the window so it just shows 1.

Exploring Mars
This initial flat plane projection map has 3 viewing options (upper right). The standard default is ______________________________. Here, the colors represent the scale in units of __________________. The other 2 viewing options are ____________________ and __________________.

Click on Stories. What is the name of the Martian rift zone? _________________________
In the left column window, click on "glossary" and review the terms. A mountain is called ___________________________ and a low plain is called _____________________. A high plain is called __________________________.

Click on Spacecraft. Why do you think the spacecrafts were mainly in the "middle" of the planet?____

Overall
Just looking at the color patterns & textures, if you were dividing the planet into 2 parts, how would they be defined and what are their characteristics?

Location	Characteristics

1.

2.

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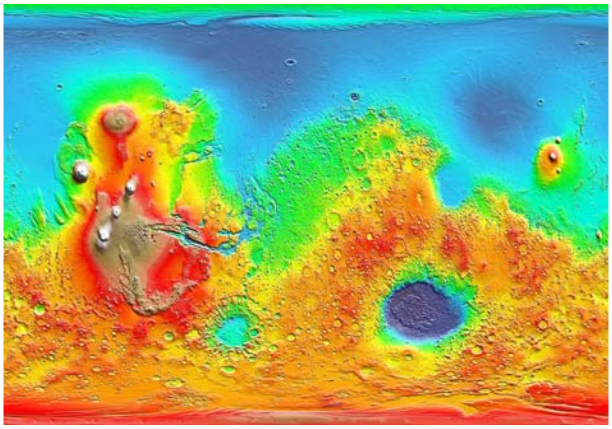
Draw the boundary line between your two parts and discuss your answers with one of your classmates (as assigned) and compare thoughts.



Mars for Earthlings

Homework 2
Intro to Mars_MFE
Exploring Gale Crater

Objective: To navigate, learn and utilize the tools offered within Google Mars.

Introduction: In order to accomplish this lab you will need to download Google Earth 6 (http://www.google.com/earth/index.html). This lab will completely utilize Mars; all answers to questions can found by using the layers provided in the program. Some questions will be straightforward; however others will require you to use your own judgment and intuition.

Intro to Google Mars
Open Google Earth. In the icon list across the top of the window, click on the planet with a single ring button with a small dropdown arrow. The dropdown menu will provide options for Sky, Mars, and Moon. Click on Mars.

Searching the Layers Bar on the left:

1. Click on the drop down arrow for Global Maps.
    a. What map is used (checked/dotted) when Google Mars loaded (consult the Global Maps Layer)?

       What do the colors refer to?

    b. View the other Global Map types. Is there another you prefer? (Why or why not?)

2. Click on the drop down arrow for Spacecraft Imagery.
    a. How many imaging devices are available?
    b. What are the image devices' names and what spacecraft are they aboard (click on each)?

    c. Which instrument/camera has the best resolution?

3. Make sure *Rovers and Landers* are checked before you proceed.

Exploring Curiosity's Landing Site

4. Type Gale Crater into the Search Box (Curiosity's landing site on August 5th, 2012).
    a. Is any imagery available right after it zooms in? Why or why not?

    b. Who is the crater named for and what is his/her nationality?
    c. What is the documented location of the crater?
        i. Center latitude
        ii. Center longitude
    d. What is the diameter size of the crater?

5. Zoom out (exit street view if necessary) until the MOLA colorized elevation map comes into better resolution. You should see a swath of "***i***'s" in the upper left corner of Gale Crater.
    a. Find the landing site of the Curiosity Rover. It is marked with a flag icon. What was the location of its landing site (use the Google GPS coordinates)?

    b. Click on the Flag icon. What other landing sites were considered for Curiosity?

    c. Why do you think that the majority of landing sites are crater locations?

6. Activate the HiRISE imagery in the Spacecraft Imagery Layer (red outlined rectangles should appear).
    HiRISE stands for ____
    a. Where are most of the HiRISE images taken?

    b. Why might the majority of images be in this location?

c. View the HiRISE image with the small *pink square box* labeled "Grand Canyon of Gale Crater" ESP_012195_1750 (located S of the landing site, where red line box appears as you hover the mouse). Can you see the canyon? To download the image:
   i. In the information pane click on *observation information page* in blue (link)
   ii. This will bring up the HiRISE webpage. Scroll down to "Image Products" purple bar
   iii. Choose JPEG→ Grayscale → Map Projected
   iv. Paste the image here as a .jpg or sketch the image. Use an arrow and point to the location of the canyon. Use the space below to explain why this might be of interest to scientists.

7. Go through other images and information provided by Google Mars for Gale Crater. Write a convincing argument in 3-5 sentences on why Gale Crater was chosen as the landing site for MSL Curiosity.

Mars for Earthlings

Homework 3
Intro to Mars_MFE
JMARS- Mawrth Vallis "Potential landing site"

Objective: To navigate, learn and utilize the tools offered within the software JMARS.

Introduction: In order to complete this lab you need to register and download JMARS:

1. Go to webpage: http://jmars.asu.edu/
2. Click: Create New Account
3. Enter desired account information
4. Click: Request New Account (page should prompt you to check your email for password and further instructions)
5. Check email and click on link (or enter the link into your browser)
6. Click login and change password. The account should last 6 months.
7. Click on "Download JMARS" tab
8. Under section "JMARS Public Downloads" click "Cross-platform Java Webstart Installer"
9. Open installer: When JMARS opens you will need to enter username and password.

For information about the software and great tutorial videos, go to https://jmars.mars.asu.edu/videotutorials. Make sure to watch Tutorial 1 to gain a brief introduction to the layout and use of the JMARS software. Alternatively, go to the JMARS homepage and explore the options under the "Tour of the JMARS user interface" and "Tour of the JMARS Layers" panels. Have fun exploring Mars and other planetary bodies.

Intro to JMARS
Open JMARS using your email/password. JMARS functions very much like the layers in Photoshop or GIS in order to view different image sets.

8. In the Layer Window, choose and press the button "Add New Layer" in the Main tab (other tabs at this point are: MOLA Shaded Relief NE, Lat/Lon Grid).
   a. Add the layer Nomenclature. With this layer open, you can navigate to any feature on Mars by name.
   b. Activate/Open the Nomenclature tab. Keep all default boxes checked. Select Vallis in the *Selected Landmarks Types* menu.
   c. In the *Navigation* Menu select Vallis for *Landmark Type* and Mawrth Vallis for *Landmark*.

d. Then press the *Go-To* button below. The software will automatically find and zoom to this location and label it.
e. What are the coordinates of Mawrth Vallis (place cursor/arrow over the red marker; the default color for the marker)?
f. Observe the terrain; explain why you think this area was considered as a landing site for MSL Curiosity (you may play around with the Zoom in the upper right of the viewing window, default is always 32).

9. Exploring Mawrth Vallis' relationship to other major Mars geologic/geographic features.

   Add a new layer: Choose by Instrument → MOLA → MOLA Shaded relief/Colorized Elevation → View Graphic data. **note, if you are having trouble seeing the labels, move the Nomenclature label to the top of the layer window.

   a. How does the colorized data help you?

   b. Where is Mawrth Vallis in relationship to Vallis Marineris (you may need to using the Nomenclature tab to find Vallis Marineris)?

      Do you think these features are the same? Why or why not?

   c. Where is Mawrth Vallis in relationship to the large expanse of "blue space" in the Martian Northern Hemisphere?

      How could you potentially interpret the 'blue space?' What about Mawrth Vallis?

10. Exploring the mineralogy of Mawrth Vallis.

    There are several methods to explore the mineralogy of the Martian surface in JMARS. We will only explore one. *Note: Make sure you can see the Mawrth Vallis label. If not, drag your Nomenclature layer to the top of the Layer Window.

    Using TES Mineral Maps: Add New Layer → Maps by Instrument → TES Mineral Map → Now select the following maps separately and explain their: spatial coverage, resolution and abundance of that mineral.

    a. TES Hematite

    b. TES Basalt Abundance

    c. TES Carbonate Abundance (Bandfield 2002*)

** tes.asu.edu/mineral_map/bandfield_minmap.pdf*

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Homework 4
Intro to Mars_MFE
Meet the Scientist-Who studies Mars?

Directions: Navigate to http://serc.carleton.edu/marsforearthlings/index.html and click on "Meet the Scientist". Answer the following questions:

Watch all the short clips (only 2 mins. each or less) and answer the following questions.

1. How is this group of profiled scientists DIVERSE?

2. Who are the scientists that study Mars? *Choose 5 scientists to profile.* List the scientists' last name and the institution each scientist is associated with. Describe the goals of their research.

	Name	Institution	Research
a.			
b.			
c.			
d.			
e.			

3. What is interesting and relevant? Choose two of your more favorite scientists from *Meet the Scientists*.

- What is the most interesting fact (or rumor) you can find when you Google their name?

	Name	Fact
a.		
b.		

- In your opinion, is their research relevant (use a scale from 1-10 with 10 being extremely relevant)? Give a brief statement to justify your answer.

	Name	Relevance
a.		
b.		

- Can their research be helpful in other fields? If so give example(s).

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Name	Helpful

a.

b.

- If you were an investor/ philanthropist/ government official would you fund the scientist's research? What would you change or applaud in their research?

Name	Fact

a.

b.

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Homework 5
Intro to Mars_MFE
Having fun with Mars programs

1. Directions: Navigate to NASA's Eyes on the Solar System http://eyes.nasa.gov/

Explore Mars, and click on the Spacecraft icon.

Name the 3 types/categories of Mars Missions and cite the newest (most recent/current) example of each:

Mars Mission TYPE Newest Example

a. ________________________________: ________________________________

b. ________________________________: ________________________________

c. ________________________________: ________________________________

Click on the Landing Sites icon (top bar on right). Which landing site was closest to the N Pole of Mars? ______________________

Explore several other planets. Which of the other Non-Mars planets did you personally find most interesting? ______________________

Explain why, what was interesting to you?:

____

Note: You can look at the planet in all kinds or orientations.

2. Directions: Navigate to NASA Spacecraft 3D (may work best on mobile, available in app store free download). You may want to use the Augmented Reality target.

Take a picture of you and the Curiosity rover and email to your instructor

LESSON 2: Birth of Planets

In-Class Activity 1

Differentiation and JELL-O 1-2-3

Purpose: Observe and understand the reasons for internal planetary differentiation.

JELL-O 1-2-3

Observe the JELL-O provided by your instructor and answer the following:

1. What has happened to the JELL-O?

2. Explain why the layers formed.

3. What is the difference between the layers?

The Earth's Interior

1. Describe the Earth's interior. What are the different layers?

2. How does the composition of the Earth change between the layers?

Planets and JELL-O

1. How similar/dissimilar is the internal differentiation of the planets from JELL-O 1-2-3 differentiation?

Changing Conditions

What physical and/or chemical conditions might change the behavior of the JELL-O and the differentiation of a planet?

Mar's Interior

1. Explore the information page on the future InSight mission (http://insight.jpl.nasa.gov/home.cfm). What is the primary goal of the mission? Why can understanding the planet's interior tell us about the history of Mars?

Homework 1
Birth of Planets_MFE
The Pluto Debate

Directions:
1. You will be asked to argue in the affirmative or negative for the retention of Pluto's classification as a planet. Utilize facts of Pluto and the IAU Planet Classification system (http://www.iau.org/public/pluto/).
2. Write a 1 page, 12pt font, double-spaced summary of your position regarding Pluto's classification as a planet.

Pluto Facts:
1. Pluto is the smallest planet in the Solar System, smaller than Earth's Moon, and half the width of Jupiter's moon, Ganymede.
2. Pluto's journey around the Sun takes 248 Earth years. This means that, since its discovery in 1930, it still has 177 years to go until it has made a complete orbit around the Sun.
3. Pluto's atmosphere is composed of a thin layer of gas containing carbon monoxide, methane, and nitrogen. Its atmospheric pressure has been estimated to be 1/700,000 compared with that of earth.
4. Pluto orbits the Sun on a different plane than the other 8 planets.
5. Pluto has three identified moons. Charon, the largest, is not much bigger than Pluto itself (Pluto is 2,280 kilometers wide, Charon is 1,212 kilometers wide).
6. A day on Pluto is equivalent to Earth's 6 days and 9 hours, meaning that it has the second slowest rotation in the Solar System (after Venus, which takes 243 days to turn on its axis).
7. Pluto's orbit is the more eccentric (more elliptical) than any planets' orbit. It can come closer to the Sun than Neptune, but then go almost two billion kilometers further away from Neptune's orbit.
8. Pluto maximum distance from the Sun – 7.38 billion km (4.6 billion miles).
9. Pluto's minimum distance from Earth – 4.28 billion km (2.7 billion miles).

Kuiper Belt and the Oort Cloud:
1. Familiarize yourself with the Kuiper Belt and the Oort Cloud: http://www.nasa.gov/sites/default/files/files/Kuiper_Belt_Lithograph.pdf

IAU Classification System:
1. A planet is a celestial body that
   a. is in orbit around the Sun,
   b. has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, and
   c. has cleared the neighborhood around its orbit.
2. A "dwarf planet" is a celestial body that
   a. is in orbit around the Sun,
   b. has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape,

c. has not cleared the neighborhood around its orbit, and
d. is not a satellite.

The New Horizons Probe:

1. Explore the mission page for the New Horizons Probe. (http://www.nasa.gov/mission_pages/newhorizons/main/)

2. What new information did you learn about Pluto from this mission? Does this information change your opinion about Pluto's classification? Why or why not?

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LESSON 3: Missions to Mars

In-Class Activity 1

Measuring "the tiny"

Purpose: Determine a method to detect elements of interest (water and/or life-indicating) on Mars and become familiar with mass spectrometer devices on Mars-bound missions.

The Periodic Table

1. Find the elements carbon, potassium, and oxygen on the periodic table provided by your instructor. How are they different, and how are they the same?

   What are the measureable attributes of these elements?

Measuring "the tiny"

1. With a few other students, devise a method to measure the amount of these elements in the rock provided.
   a. What exactly do you need to measure? The charge? The mass? The weight?
   b. Do you want the rock to remain a solid for measurement? Why or why not?
   c. List your method in at least (3) steps.

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2. Can you turn this method into an instrument? Describe your instrument and draw it below:

3. Watch the following NASA Mass Spectrometer Video: http://www.youtube.com/watch?v=_L4U6ImYSj0. How does your instrument compare to the one in the video?

4. Can you use your instrument to detect elements on Mars? Why or why not?

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Homework 1
Views & Missions in Space_MFE
A Mission Comparison

Objective
Explore past exploration of Mars and discuss the increase in sophistication and resolution of data over century and decadal scales.

Introduction
Space exploration is an iterative process; current exploration builds on the knowledge and technological breakthroughs of past missions, which allows for further improvements to spacecraft and instruments. This process is best illustrated by comparing two wildly successful missions: Viking launched in 1975, and MSL (Mars Science Laboratory) launched in 2011.

Part 1
Watch the following videos then answer the following questions:

- Viking Missions to Mars:
  http://www.youtube.com/watch?v=ggjD3i7efKU
- 7-Minutes of Terror:
  http://www.youtube.com/watch?v=h2I8AoB1xgU
- MSL Curiosity Entry, Descent, Landing:
  http://mars.jpl.nasa.gov/msl/mission/timeline/edl/

1. What are some of the complicating factors with landing spacecraft on the surface of Mars?
2. How is the entry and landing of Viking similar to Curiosity?
3. How does the entry and landing differ?
4. What is your favorite component to Curiosity's landing procedure (EDL)?
5. How were the landing sites for Viking 1 and 2 selected? How does this differ for the landing site selection for MSL?

Part 2
Discuss the increase in resolution and available data
As imaging/data collection capabilities increase, our ability to comprehend geologic features increases. Consider this through the next activity.

Mars for Earthlings

Exploration of historic maps available through google earth

1. Open Google Earth
2. Click on the planet icon in the toolbar and select Mars (alternatively, go to top tool bar and click "View" → "Explore" → "Mars") to switch to Google Mars.
3. In the "Layers" panel to the lower left, click on the arrow by "Historic Maps" to expand the layer options and check the circle next to "Giovanni Schiaparelli - 1890" (make sure that the global maps layer circle is unchecked).
   A. What are some general observations regarding this map?

   B. What are the prominent features?

4. Click on "Giovanni Schiaparelli" in the layer options to access information about this map.
   A. How and when did he make this map?

   B. What do you think the linear features are in this map?

5. Now click on the arrow by "Global Maps" to expand the layer options, and check the circle next to "Viking Color Imagery".
   A. What are the similarities between the historic maps and the global mosaic from spacecraft data?

   B. How do the historic maps differ from the global mosaics?

"Face on Mars"

Go to this website: http://www.msss.com/education/facepage/face.html

1. How does lighting direction influence the appearance of the "Face"?

2. How does the "Face" seem to change when viewed under higher-resolution imagery?

3. Does it still look like a face under higher resolution?

Questions

Based on the discussion of historic global maps and the "Face on Mars", answer the following questions:

1. How does the increase in resolution affect our understanding of geologic landforms?

2. How does this relate to the scientific process in general?

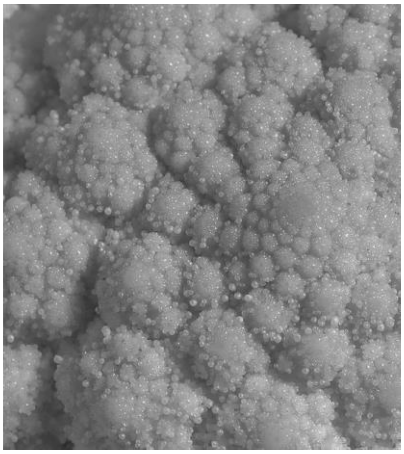
LESSON 4: Remote Sensing Mars

In-Class Activity 1

Scale and Context

Purpose: Recognize the purpose and need for understanding the scale and context of various remote sensing imaging techniques.

Study the following images: What observations can you make?



(Figs 1 & 2, Image credit: Petr Kratochvil (public domain)

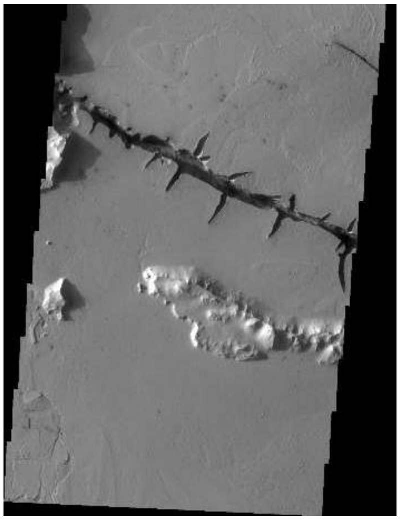


Figure 1: THEMIS Image #V13300013; Lat 7.3/Long 161.3. Image credit: NASA/JPL/ASU; Image Source: http://themis.asu.edu/zoom-20050225a

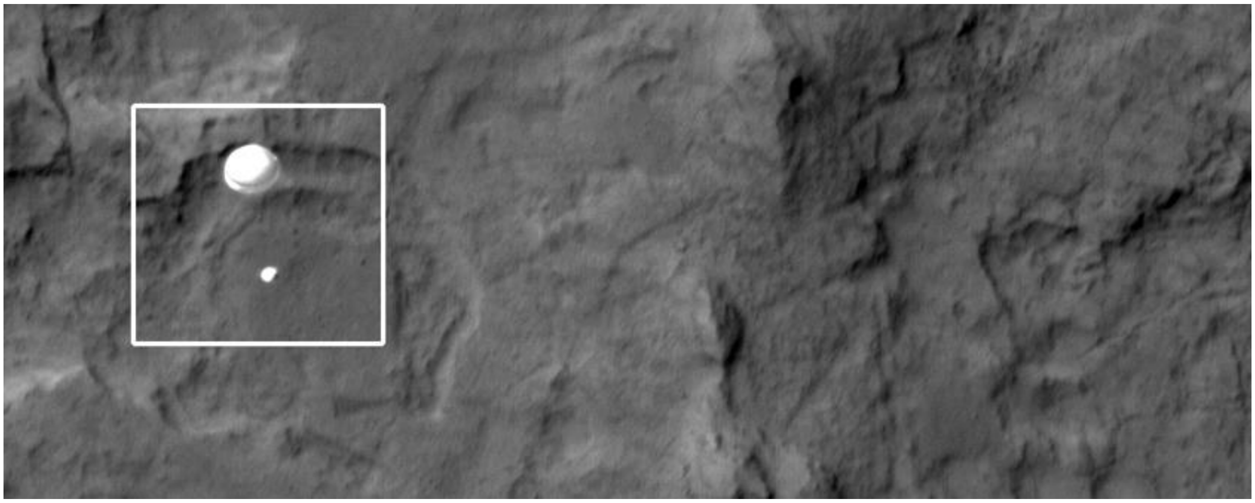


Figure 2 HiRISE image (ESP_028256_9022) of Curiosity descending to the Martian surface acquired August 5, 2012. Image Source: http://hirise.lpl.arizona.edu/releases/msl-descent.php

Seeing "scale" at work

Referring to Figure 1-2

1. Hypothesize what might be pictured in Figure 1 & 2.

2. Upon what evidence are you basing your hypothesis?

3. What other information could aid you in determining the identity of the image? List at least (4) ideas and explain your reasoning.

Does scale matter?

Come up with definitions for the following:

- Scale

- Context

In Figures 1 & 2, estimate a scale considering each image's context

1. Figure 1 Scale:

2. Figure 2 Scale:

What are you seeing on Mars?

1. What do you see in the Mars images, Figure 3-4? Anything familiar?

2. What would aid you in their interpretation?

THEMIS & HiRISE Imagery

Explore one of the following websites:
(http://themis.asu.edu) or HiRISE (http://hirise.lpl.arizona.edu)

1. Choose an image that interests you. What caught your interest? What features do you see?

2. Can you find the scale and context of the image? After knowing the scale and context, does your interpretation of the image change?

In-Class Activity 2
Remote Sensing_MFE
*MOLA Simulation**

Purpose:
Understand how we explore the surface of Mars via remote sensing techniques by performing a ping-pong experiment.

Materials:
Ping pong balls, removable color tape, stop watch, measuring tape, and wood blocks, bricks or stone/ ceramic tiles that can sit on top of books or boxes to create different heights from the floor.

Procedure:
You must have at least 2 people in your group, but 3 is preferable.

Step 1:

1. Place 2 strips of tape on the wall, one approximately 2 meters (200 cm) high and the other 45 cm high. Both should be at least 200 cm long and parallel; you will be using these as the points to start and stop the stopwatch.

2. One partner should hold the ping-pong ball between the first finger and thumb next to the higher piece of tape approximately one inch from the wall.

3. One partner, the "timer", should have a stopwatch and have his/her eyes level with the second piece of tape. A third partner, if available, should record the results of each ball drop using the attached data sheet. *Note: Use a spreadsheet for recording and calculating the data.

4. Drop the ball. Start the stop watch as soon as the ball begins to drop.

5. The timer will stop the watch when the ball rebounds and reaches the lower line, i.e. the clock starts when the ball drops and stops when the ball reaches the second piece of tape. Record the time on the data sheet. Repeat this step four more times.

6. Calculate the velocities (V=D/T). The distance (D) is the combination of the height of the high tape plus the height of the low tape. After finding the velocity for each of the trials, find the average velocity of the ping-pong ball. This average will be used later in this lab as your baseline for comparing data. For each trial are you measuring an average or instantaneous velocity?

7. Many spacecraft use lasers (light) to determine topography similar to how you are using a ping pong ball. However there is a potential over-simplification in using a ping pong ball as an analog to a laser. What are the issues? (Hint: Think about velocity vs. acceleration.)

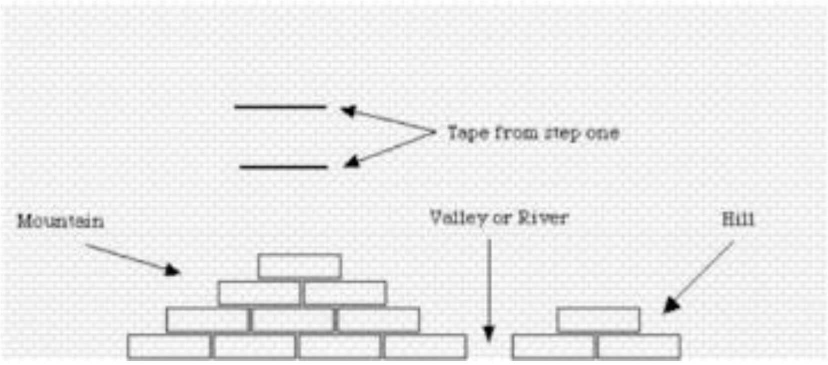
Data Table I (Baseline , datum)

Drop	Distance Ball Traveled	Time (Seconds)	Velocity (distance/time)
1			
2			
3			
4			
5			
		Average Velocity	

Step 2:

Now that you have found the velocity of the ping-pong ball, you will use this information to plot the topography of a transect along the surface of an imaginary asteroid. You will be creating your own asteroid terrain on the floor against the wall where you just did Step 1.

1. Create the topography model of *your* asteroid along the wall where you did Step One. In order to do this, you need to place wooden blocks *against* the wall in a line about 6 feet long. Be sure that you build some hills, mountains, valleys, etc. (see Figure below).



Ping-pong experiment layout diagram.©

2. Starting at the beginning of the top piece of tape, place a mark every 20cm. The bottom piece does not need to be marked. Measure and record your topography heights in the far right column of Table II as a check.

3. Again, starting at the 0 cm mark you made at the beginning of the tape, you will drop the ping-pong ball as you did in Step One, and record the time in Data Table II. Drop the ball every 20cm along the tape until you reach the end. Be sure to be as accurate as you can with the timing.

4. Find the average time for each of the intervals and record it in the data table.

5. Exchange your average time data with another student group (Table II) of just the cm interval, the average time. You will interpret each other's data to see if you can identify the topography of the other group's asteroid.

6. Next, fill in the distance traveled in Table II by multiplying the average velocity from Table I by the average time just calculated at each interval.

7. In Data Table III, take the original distance traveled (height of high tape plus height of low tape, which will be the same for every interval) and fill in the first column of the table.

8. In the second column, take the distance the ball traveled from the column in Table II (last column on right) and copy that information to the 2nd column of Table III. Now, for the last column, simply subtract the 1st column data from the 2nd column data (the difference between the two) to determine the altitude of your modeled topography.

9. Plot the data (with interval/distance on the x-axis and altitude on the y-axis). Connect the dots to create your transect. Does your image match the true topography? If not, explain why it is different.

Data Table II

Interval	Trial 1	Trial 2	Trial 3	Time Average	Distance Ball Traveled = (velocity*average time) (cm)	Known measured height of placed block topography (cm)
0 cm						
20 cm						
40 cm						
60 cm						
80 cm						
100 cm						
120 cm						
140 cm						
160 cm						
180 cm						
200 cm						

---------------- tear here to give Table III to blind student group ----------------
Check their altitude answers with your measured known values in far right column of your Table II.

Data Table III (share with other "blind" student group) Ave Vel. = ___________

*R Interval	Time Average of 3 Trials	Original Distance Ball Traveled (Baseline From Data Table I) {D1}	Distance Ball Traveled = (velocity*average time) (cm) {D2}	Altitude (cm) {D1-D2=Altitude}
0 cm				
20 cm				
40 cm				
60 cm				
80 cm				
100 cm				
120 cm				
140 cm				
160 cm				
180 cm				
200 cm				

Step 3: Optional Plotting and Graphing the Data (if time, check resolution)

Step 4: Expand your thought process

The Laser Rangefinder aboard NEAR sends out a laser beam and "catches" it as it returns from being reflected by the surface of 433 Eros. The instrument records how long it takes the beam to reach the surface and bounce back. The scientists know how *fast* the beam is traveling; therefore, they can calculate how *far* it traveled. By measuring this time and multiplying by the velocity of the beam, they calculate how far the laser has traveled. They must then divide the distance the beam traveled in half.

1. Why did you not divide in half to find the distance to the object in *your* topography model?

Next, the scientist must compare this distance to a "baseline" distance we will call zero. On Earth, we might use sea level as the baseline. Another way to set the baselines is to start at the center of the planetary body being studied and draw a perfect circle as close to the surface of the body as possible. Using this baseline, the altitude compared to zero can be calculated and graphed. (Here on Earth, we often say that some point is a certain number of feet above or below sea level).

1. Why do we not use the term "sea level" for Mars and other planets?

2. You will now calculate the altitude of the points along your model. To do this subtract the distance the ball traveled at each interval (from Data Table II) from the distance the ball traveled in Step 1 (column B, Data Table I). The number you come up with will be zero or greater. Use Data Table III to do your calculations. The number in column B in this table should be the same for every interval. Remember, it is the baseline altitude and does not change.

*This exercise was adapted from Goddard Space Flight Center:
http://mola.gsfc.nasa.gov/pingpong.html

In-Class Activity 2

Remote Sensing_ REVISED: *MOLA Simulation* (*Note: This is a shorter version of the previous activity. Instructors may choose either version depending on time constraints.)

Since we ran out of time, we're simplifying your ping pong exercise to just 3 "topographies"- 1) a base datum (floor), 2) a medium level, and 3) your highest level.

For each topography level, you should have had several timings to ensure that you have a consistent value. Just report the averages here. Transfer data in shade boxes to Data Table III for another group to calculate.

Data Table I (D1 Baseline , datum),

Level	Distance Ball Traveled	Ave. Time (Seconds)	Velocity (distance/time)
Base			

Data Table II

Level	Time Average (secs)	Calculated Distance Ball (cms) Traveled = (velocity*average time)	Your known measured height of placed block topography (cm) (keep as your "answer")
2- med			
3- high			

------------------------------- *tear here to give Table III to blind student group* -------------------------------

Transfer the data shown by the shade areas so they can make the calculations.

Data Table III (share with other "blind" student group)

Group _______

Give the {D1} Ave Vel. =

*R Interval	Time Average (secs) of "topographies"	Original Distance Ball Traveled (Baseline From Data Table I) {D1}	Distance Ball Traveled = (velocity*average time) (cm) {D2}	Calculated Altitude (cm) {D1-D2=Altitude}
2- med				
3- high				

After you calculate the altitude of the "unknown" topography heights 2 & 3, **check your calculated altitude answers with your measured known values the group had actually measured (their far right column of Table II**).

If the calculated doesn't match the measured values, explain why the results might be so different:

Part 4

The Laser Rangefinder aboard NEAR sends out a laser beam and "catches" it as it returns from being reflected by the surface of 433 Eros. The instrument records how long it takes the beam to reach the surface and bounce back. The scientists know how *fast* the beam is traveling; therefore, they can calculate how *far* it traveled. By measuring this time and multiplying by the velocity of the beam, they calculate how far the laser has traveled. They must then divide the distance the beam traveled in half.

1. Why did you not divide in half to find the distance to the object in *your* topography model?

Next, the scientist must compare this distance to a "baseline" distance we will call zero. On Earth, we might use sea level as the baseline. Another way to set the baselines is to start at the center of the planetary body being studied and draw a perfect circle as close to the surface of the body as possible. Using this baseline, the altitude compared to zero can be calculated and graphed. (Here on Earth, we often say that some point is a certain number of feet above or below sea level).

1. Why do we not use the term "sea level" for Mars and other planets?

2. You will now calculate the altitude of the points along your model. To do this subtract the distance the ball traveled at each interval (from Data Table II) from the distance the ball traveled in Step 1 (column B, Data Table I). The number you come up with will be zero or greater. Use Data Table III to do your calculations. The number in column B in this table should be the same for every interval. Remember, it is the baseline altitude and does not change.

*This exercise was adapted from NASA Goddard Space Flight Center (Education/Outreach): http://mola.gsfc.nasa.gov/pingpong.html

Homework 1
Remote Sensing_MFE
Google Mars-Following Opportunity

Objective: The purpose of this homework set is to get you familiar with different types of Mars remote sensing imagery and programs.

Google Mars-Following Opportunity

Directions/Questions:
Download Google Earth if you haven't already:
http://www.google.com/earth/download/ge/agree.html

In the icon list across the top of the window click on the planet with a single ring and a small dropdown arrow. You should see options for Sky, Mars, and Moon. Click on Mars.

1. Name the 5 types of spacecraft imagery available through Google Mars.
   What do the 5 acronyms stand for?
   a.
   b.
   c.
   d.
   e.

Find Olympus Mons (see if you can find it without typing the name in the "fly to" box).

2. What is the highest elevation according to Google (find the appropriate *Global Map Layer* in order to determine this information)?
3. In the *Global Maps Layer*, besides the *Visible Imagery*, which imagery gives you the highest resolution of the volcano? Why is this the case?

Go to the *Rovers* and *Landers layer*

4. What are the current coordinates of these 3 lander sites?
   Phoenix Lander
   Viking 2 Lander
   Mars 3 Lander

5. Where did MER Opportunity Rover land? (i.e. what crater?)

   What crater did it visit next?

Look at the Burns Cliff panorama photo (camera icon, you may have to click on a couple to figure out the right one).

6. List 2 observations you can make about the photo (colors, shapes, lineations, etc.)?

   Name 2 other craters the Opportunity rover explored.

   ________________________________, ________________________________

7. Write down two observations about what you see in the bottom/ centers of Victoria Crater. Can you name the features?

8. Using the Traverse Path layer of the MER Opportunity Rover, locate its position on Sol 1685 (sol= Mars day). What annotated feature (labeled named) is it nearest?

Homework 2
Remote Sensing_MFE
Mars Image Analysis

Directions: View the following THEMIS image and answer the questions about the image. As you view the image, think about how this image might support one or more of NASA's main exploration goals:

1. Determine if life ever existed on Mars
2. Characterize the climate of Mars
3. Characterize the geology of Mars
4. Prepare for future human exploration of Mars

Go to: http://themis.asu.edu/

Questions:
Getting to know THEMIS imagery (click on the "about")

1. In a few sentences explain what THEMIS detects and how it works.

2. Go to THEMIS image: http://themis.asu.edu/node/5765
   What is the title of the THEMIS image?

3. Study the THEMIS image. List at least two features you observe.
   a.

   b.

4. If the sun is illuminating from the left, are the features expressing positive (hill) or negative (valley) relief? If features differ from another (i.e. one has positive relief and the other negative) describe their relief separately.

5. What is the Lat/Long of the center of THEMIS image?
   Lat ______________________ Long ______________________

6. Explain how this image meets or does not meet NASA's exploration goals of Mars.

7. If you were to lead a lander mission to an area located within the image, where would you land and why?

More THEMIS Imagery

8. Go to the THEMIS image gallery by Topic: http://themis.asu.edu/gallery
   Choose an image you like and report the following:
   a. What is the image ID or the image url that you chose?

   b. Why did you choose this image?

   c. Where is the image located?

   d. Near what major Mars geographic region is it located (South/North pole, Victoria Crater, Endurance Crater, Merdiani Planum, Hellas Basin, etc.)? Use the *View this image on Map* link at the bottom of the image data column to see a map view of Mars.

   e. Why might this location be important to science?

HiRISE Imagery

9. Navigate to the HiRISE website: http://hirise.lpl.arizona.edu/
   a. Scroll to the bottom of the page (gray box) and click on the link "Science Themes". Click on the *Aeolian Processes* file of images. Under the main image click "View Images in this Theme." Find image titled "Dunes in the Western Nereidum Montes." If you cannot find the image type ESP_013046_1390 into the search box.

   b. Define the term *Aeolian*. (also known as eolian)

   c. Why might an image of *aeolian* processes on Mars be of interest to us on Earth?

   d. Sketch what you see below. Label appropriate parts (high and low areas). Can you identify the direction of the wind if North on Mars is up? If so, what direction (cardinal direction) is it?

LESSON 5: Why Matter & Minerals Matter

In-Class Activity 1

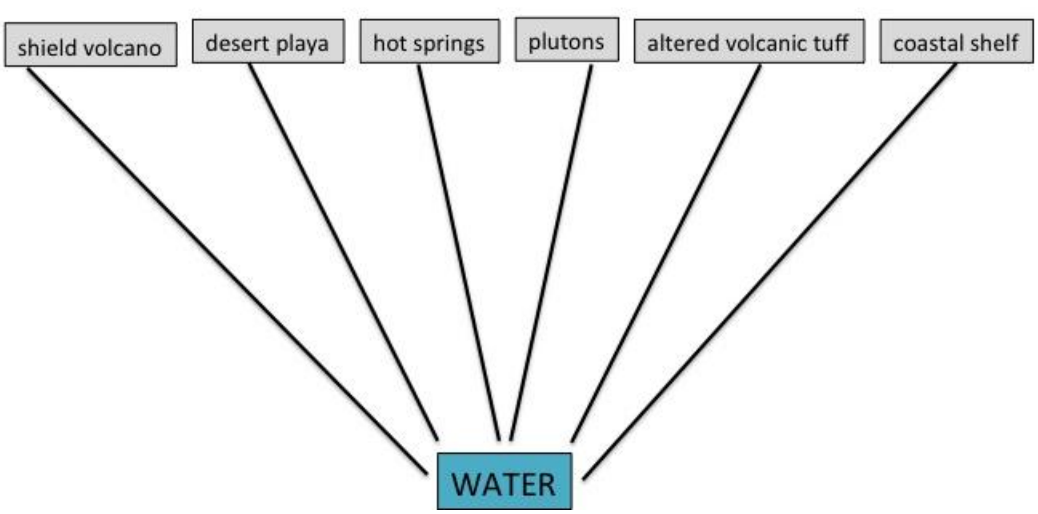
Follow the Water

Objective: Observe various minerals and identify their connection to water using their chemical formulas and depositional environments of formation. *Note: This lesson requires background knowledge of rocks and minerals and could require additional material and/or explanation.

Directions:

1. Connect the minerals/formula to their respective environments of formation with an arrow.
2. Identify how these minerals and environments are connected to liquid water. Write Yes/No on arrow from environment to WATER and a brief reason for your choice.

Fe_2O3 | $CaCO_3$ | $CaSO_4.H_2O$ | $(Mg,Fe)_2SiO4$ | $KAlSi_3O_8$ | $(Mg,Ca)O.Al_2O_3.5SiO_2.nH_2O$



3. Do you think some of the previous minerals have multiple environments of formation? If so, which ones?

4. Rank the minerals in terms of which are the most likely to infer an aqueous environment on Mars (1-highest, 6-lowest).

Homework 1
Matter and Minerals_MFE
Identifying the Clay: Endeavor Crater

Objective: To further utilize the tools offered within the software JMARS and investigate mineralogies observed at Endeavor Crater.

Introduction: In order to accomplish this lab you will need to register and download JMARS. By this point, you should be familiar with JMARS software and how to navigate to regions of interest on Mars.

1. Using the Nomenclature Layer, navigate to Endeavor Crater (approx. 354.7705°E, -2.2480°N).
    a. For best viewing results, Zoom to 1024 and center your main screen on the western rim of Endeavor Crater
    b. If you still have your nomenclature layer turned on, you will see the labeled "Endeavor" to the right of the rim we are exploring

2. Choosing HiRISE stamps to explore Endeavor Crater with the highest resolution possible.
    a. Using the stamps layer choose either HiRISE DTMS or HiRISE full stamps. Make sure you zoom in close so that when you search for HiRISE stamps hundreds do not try to load. Use the "main view" to limit the search of HiRISE stamps. Choose stamps rendered by ASU.
    b. Compare and contrast the HiRISE DTM images and the HiRISE Full stamps images. Which do you prefer and why?
    c. Consult the webpage: http://hirise.lpl.arizona.edu/dtm/about.php . After consulting the webpage, which set of imagery would you rather use, DTM or Full stamps? Did your choice change? Why or why not?
    d. Decide which HiRISE imagery you will choose to display and explore the western crater rim.

3. Exploring the mineralogy of Endeavor Crater using CRISM
    a. Add the CRISM stamps layer and use a different outline color to differentiate CRISM and HiRISE stamps. To display CRISM stamps, use the “Main View” to set the bounds of the image search.
    b. Provide a rough estimate of the number of CRISM stamps: ____________
    Do they outnumber the HiRISE DTM stamps or full stamps? Why do you think this is (think of current/past mission objectives)?
    c. Start exploring some of the CRISM stamps intersecting the HiRISE DTM stamps. Choose any stamp and the ASU-rendered images. When using ASU images, use the *color overlay*. ASU provides you with a number of options. List at least three below (i.e. Ferric Mineralogy):
    d. Find a CRISM stamp that is rendered for phyllosilicates. Where are the phyllosilicates located in the crater (the rim, the rim wall, or the bottom of the crater)? What does this tell you? *Note: the warmer the color the higher content of the respective mineral.
    e. Compare the sulfate CRISM overlays. Are sulfates found in the same region as the phyllosilicates? Why or why not?
    f. Select another crater on Mars that has CRISM stamps available. Compare and contrast the phyllosilicates abundance between the two craters below. Please name the crater and its coordinates for verification.

LESSON 6: Igneous Rocks & Volcanics

In-Class Activity 1

Lava Flows

Purpose: Recognize a pahoehoe vs. a'a lava flow through video, explain why the flows differ, and hypothesize which flow might be more common on Mars.

Resources:
Mars Lava Coils: Discovery news article: http://www.space.com/15446-mars-lava-volcanoes.html

Pahoehoe and A'a on Earth:
Watch the following YouTube videos:

Video 1: http://www.youtube.com/watch?v=qTTLYx4Xo2k&feature=related
Video 2: http://www.youtube.com/watch?v=bWswq8PmRII

- What are the differences between the two lava flows?

What is possible on Mars?

1. Consider both the pahoehoe and a'a lava flows. Which lava flow do you think is more common to Mars? Substantiate your answers.

2. Figure 1 is a volcanic feature on Mars. What type of lava flow formed this feature? Explain your reasoning?

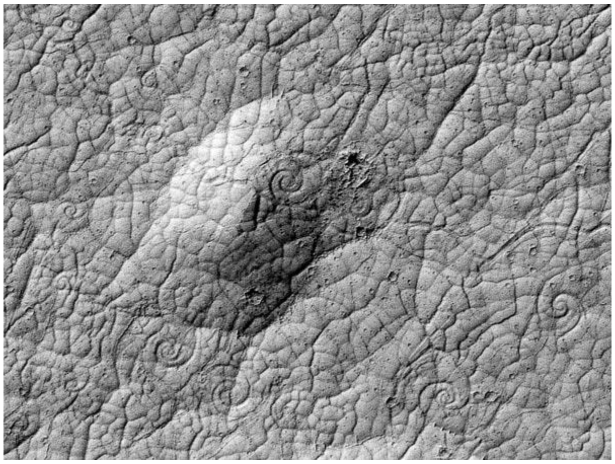


Figure 1: Spirals in Athabasca Valles, Credit: NASA/JPL/University of Arizona, Spirals are 16-98 ft wide. Image source: http://www.space.com/15446-mars-lava-volcanoes.html

Understanding volcanic rocks

Of the rocks pictured below in Figure 2:

1. Which rocks are more likely to have formed by igneous processes on Earth?

2. Which rocks are more likely to have formed by igneous processes on Mars? Explain your reasoning.

3. Is it likely that any of the rocks pictured below could be found in Athabasca Valles (Figure 1)? Why or why not?

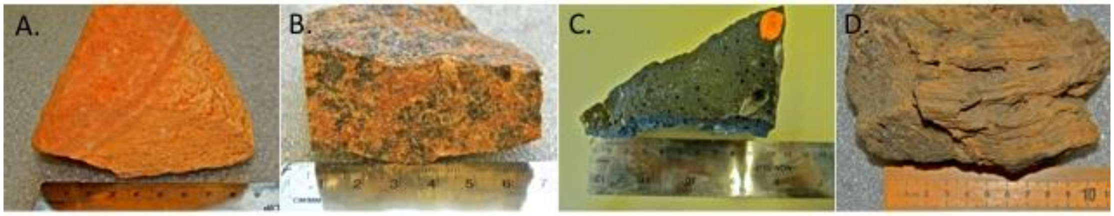


Figure 2

Image Credit: Levi Huish/University of Utah)

In-Class Activity 2
Igneous Rocks & Volcanics_MFE
Columnar Jointing on Mars

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

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

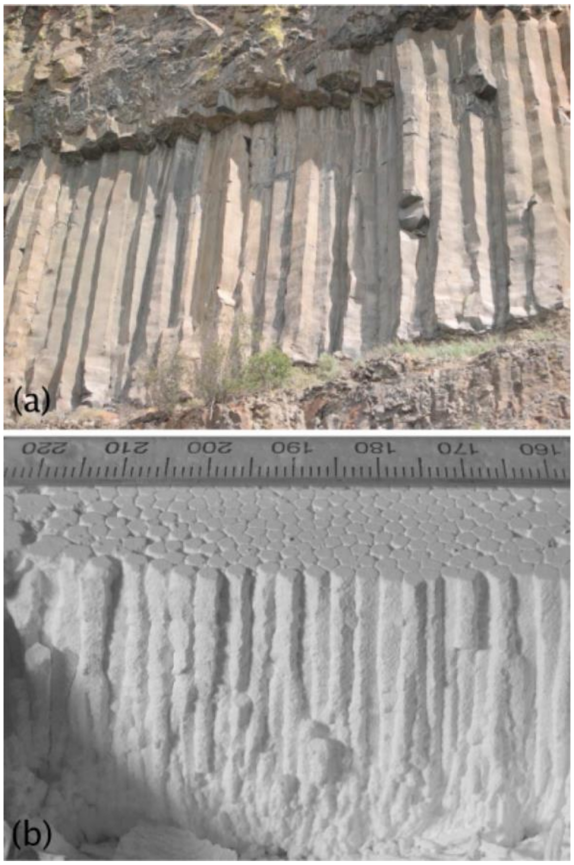


Figure 1 Columnar jointing in (a) basalt of the Columbia Plateau near Banks Lake ~95 cm average diameter, and (b) in desiccated corn starch. (Image Credit: Gohering L., Morris, S.W., and Lin, Z., 2006. Experimental investigation of the scaling of columnar joints. PHYSICAL REVIEW E 74, 036115, p. 1-12.)

Watching columnar jointing in action:
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 you foresee such features forming on Mars?

A Discovery!
View the following 2009 Mars discovery:

1. **Figure 2** (below) shows images of columnar jointing on Mars using the HiRISE camera (see original HiRISE link). Using arrows, point to where you think the columnar joints are exposed in this terrain.

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

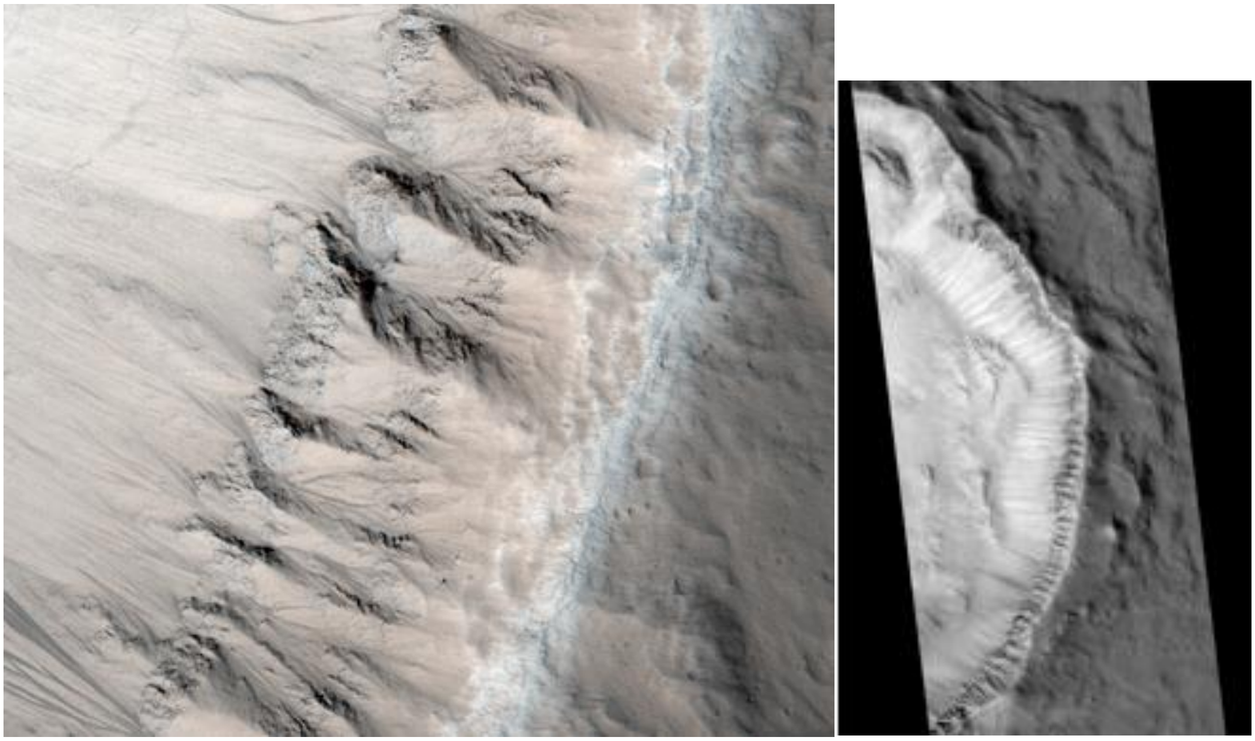


Figure 2 http://hirise.lpl.arizona.edu/PSP_005917_2020 **(Image Credit: NASA/HiRISE)**

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.

Homework 1
Igneous Rocks & Volcanics_MFE
Google Olympus Mons

Purpose: Explore Olympus Mons using the Google Mars platform through HiRISE imagery and Colorized Terrain maps.

Preparation: Download Google Earth 6
http://www.google.com/earth/download/ge/agree.html

Directions/Questions:

Navigate to Olympus Mons

1. Open Google Mars (click on the planet with a ring)
2. Turn on the Global Maps Layer *Colorized Terrain*
3. Navigate to Olympus Mons- the tallest point on Mars
    a. What is the elevation of Olympus Mons?
4. Activate the *HIRISE Image layer* under the Spacecraft Image Layer Folder

Analyze Olympus Mons Images

5. Zoom in to the top of the Olympus Mons Caldera
    a. Find image PSP_004821_1985 from HIRISE [near the Hiker icon]
    b. Sketch what you see in the image below.

    c. What might you be seeing? Consider the context image of the Colorized Terrain map and list your observations.

6. Find image PSP_004531_1990: NW flank of Olympus Mons (note the compass in the upper right ~ 15-18km elevation, 18.56N 224.28E)
    a. Sketch what you see in the image below.

b. Can you make some interpretations about what you are observing?

Comparing Olympus Mons and Earth Analogs

7. Of the volcanic styles (mafic vs. felsic), which volcanic type fits Olympus Mons the best in your opinion? Explain your choice and why Olympus Mons cannot be classified as the other choices.

8. If you wanted to be sure about your volcano classification, what additional data would you need to confirm your choice in #7?

9. What volcano on Earth serves as the best comparison to Olympus Mons (you may need to do some outside research to answer this question adequately)?

Homework 2
Igneous Rocks & Volcanics_MFE
Basalt & JMARS

Discussion/Questions

1. The following are common igneous/mafic rock forming minerals. For each mineral, list its chemical formula:
    a. Olivine

    b. Pyroxene

    c. Amphibole

    d. Biotite

    e. Plagioclase (anorthite)

2. Compare the chemical formulas and their elements to the element abundance list for Mars below. Which minerals do you think will be more common on Mars? Please explain your choices below next to the list.
    1. oxygen
    2. silicon
    3. iron
    4. magnesium
    5. calcium
    6. aluminium
    7. sodium
    8. potassium
    9. chloride

3. Open JMARS. Using the *Nomenclature* layer, zoom to Valles Marineris to gain your geographical bearing. Add and compare the following layers (Add New Layer → Maps by Instrument →TES Mineral Maps): Basalt Abundance, Plagioclase Abundance (Bandfield, 2002), any olivine abundance map, and Carbonate Abundance. Warmer colors denote greater abundance.
    a. Which map has the most coverage? Why might this be? What complications might arise from collecting this type of data? Could anything distort the data?

b. Where does the abundance of Plagioclase generally increase on the surface of Mars? Use geographical points of references or lat/long to explain.

c. Compare the following animation for plagioclase abundance on Mars to the JMARS mineral map. Which perspective do you prefer? http://www.youtube.com/watch?v=FRU0cHb31JM

d. Are you surprised about the abundance of plagioclase on Mars in comparison to other minerals? Why or why not?

LESSON 7: Life-Hosting Rocks

In-Class Activity 1

Swelling Rocks

Expanding Soil

Observe the class demonstration or video and answer the following questions.
http://www.youtube.com/watch?v=ACpuYED9WkU

1. According to the demo/video, why does the soil expand?

2. How does the bulk density change? What does this change indicate?

The Molecular Level

Observe the diagram below (Figure 1) and answer the following questions.

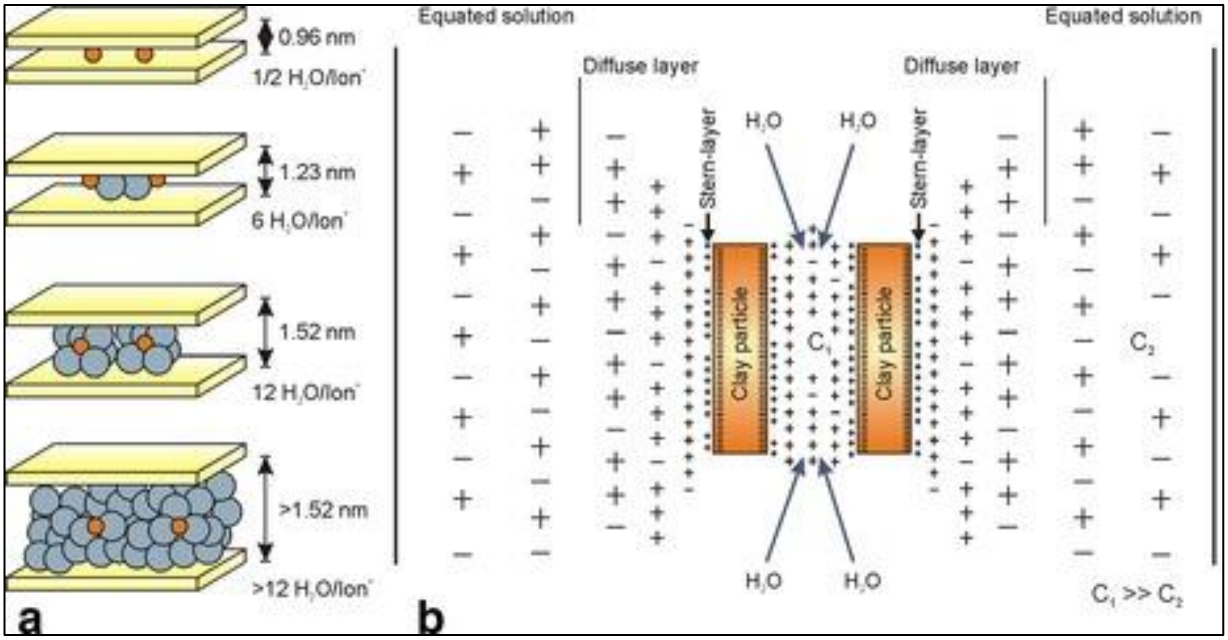


Figure 1 Butt et al., 2003

1. In Fig. 1a, how do the water molecules influence the structure?

2. Why does the water attract to the clay rather than the sand of the sandy loam (consult Fig. 1b)?

3. Given your understanding of clays now, if clays [$Na_{0.2}Ca_{0.1}Al_2Si_4O_{10}(OH)_2(H_2O)_{10}$] are observed on Mars….what does this mean?

4. Where might you find clays on Mars (what kind of features)? Hint: consider their environment of formation; do we have evidence for their presence on Mars?

In-Class Activity 2
Life Hosting Rocks_MFE
Understanding Albedo

Last Chance Canyon
Scenario: You are planning to hike Last Chance Canyon in the Guadalupe Mountains National Park. It is arid, no winds, and about 95^{o}F. If you had the following options for attire, which would you choose and why?

- Sleeveless cotton shirt
- White long-sleeve cotton shirt
- Black long-sleeve cotton shirt

Surface Albedo & Rocks
Observe the interactive Earth Surface Albedo Map (produced by NASA-CERES) provided by your instructor.

1. What do the colors indicate?

2. Why do some "surfaces" have a higher albedo than others (ocean, desert, forest cover etc.)?

3. Rank the hand samples according to their albedo effect provided by your instructor. How are you making your rankings?

4. Do you think an albedo map of the surface of Mars would be as variable as Earth? Overall, would Mars have a higher albedo than Earth? Why or why not?

Using JMARS to view Albedo
Explore TES imagery in JMARS.

1. Add the MOLA colorized elevation map for use as context if desired.
2. Add New Layer → Maps By Instrument → TES → TES-Albedo → View graphic data
3. Zoom to a window (2 or 4) that allows you to differentiate familiar terrain. You can change the transparency of the TES-Albedo map to see the underlying MOLA colorized map to find major geographic regions of interest.

4. Describe the albedo map of Mars? Does anything surprise you? What could distort the data?

5. Are albedo maps a good indicator of lithology? Would it depend on different circumstances or environmental conditions?

Using Light Grapher:

Directions (*Note: This section of the lesson requires a webcam):

1. Click “Run Light Grapher”
2. Select the appropriate camera and allow access
3. Click “capture data”

http://kepler.nasa.gov/education/ModelsandSimulations/lightgrapher/

6. Use the hand sample of basalt and sandstone provided by your instructor. Use Light Grapher to see the change in “light” as you pass the sample in front of your webcam. What is the result? How do they compare?

7. Try other objects with varying color and compare.

8. How is this activity an analogy for the albedo effect?

Homework 1
Life-Hosting Rocks_MFE
The Energy of Rocks

Purpose: Recognize the energy of the environment by its sedimentary structures.

Corn Syrup and Water Experiments
Watch the following videos:

- Flume Experiment: http://www.youtube.com/watch?v=zRGuMddjRGg&list=PL17AFB4B8AB3DCCF7
- Corn-Syrup Experiment: http://www.youtube.com/watch?v=W3YZ5veN_Bg

1. As you watch the videos, compare/contrast the following parameters:

Parameter	Corn Syrup	Water
Velocity of flow		
Type of structures formed		
High or low energy environment		

The dynamics of sedimentary environments

2. Compare the following environments of deposition according to the following parameters: [Write your answers a-c to the right of the image]
    a. Processes at work
    b. Strength of weathering and/or erosion
    c. Preservation potential of life

Figure 2: Cathedral Cove; Channel Islands National Park, CA. Image: nps.gov

Figure 3: White Sands National Monument, NM. Image: nps.gov

Sedimentary structures/textures on Mars

3. Similar to Question #3, annotate to the right of each image of Mars below:
    a. What structures do you see?
    b. What is a likely environment of formation?
    c. Was the environment high or low energy in your opinion?

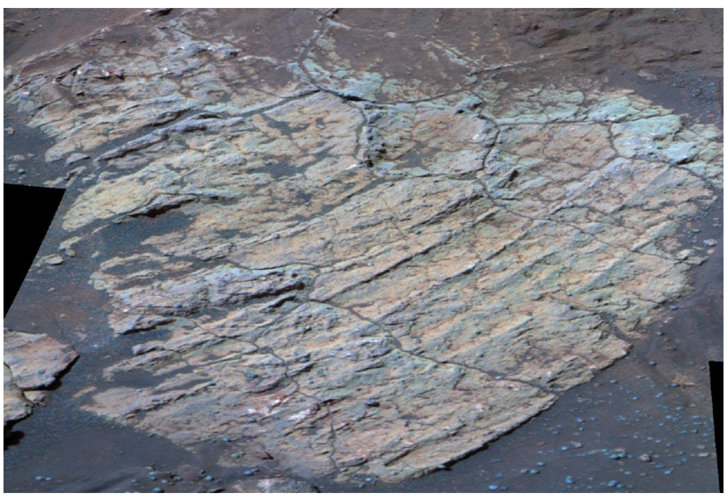


Figure 4: "Escher" rock in Endurance Crater investigated by Opportunity rover; Image Credit: NASA/JPL

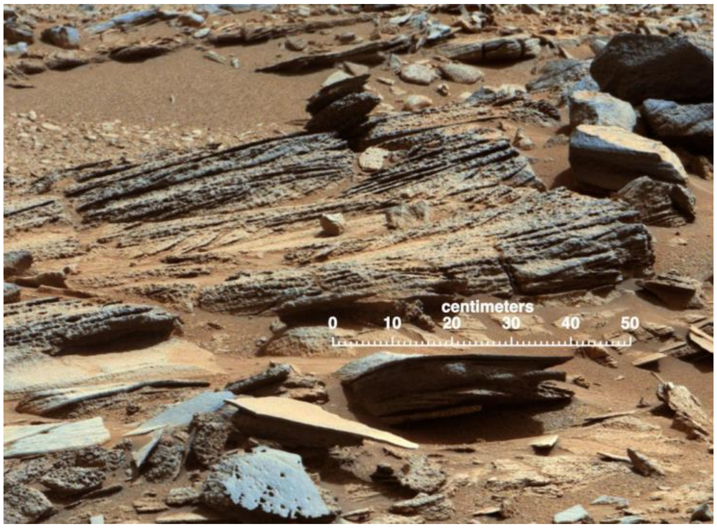


Figure 5: “Shaler” outcrop at Gale Crater investigated by MSL Curiosity rover; Image Credit: NASA/JPL-Caltech/MSSS

LESSON 8: Rock Evolution & Change

In-Class Activity 1

Cooking Rocks: Diagenesis

Objective: Observe and understand how iron oxide minerals are affected by diagenesis on Earth and apply this thinking to diagenesis and iron oxide minerals (e.g., hematite) on Mars.

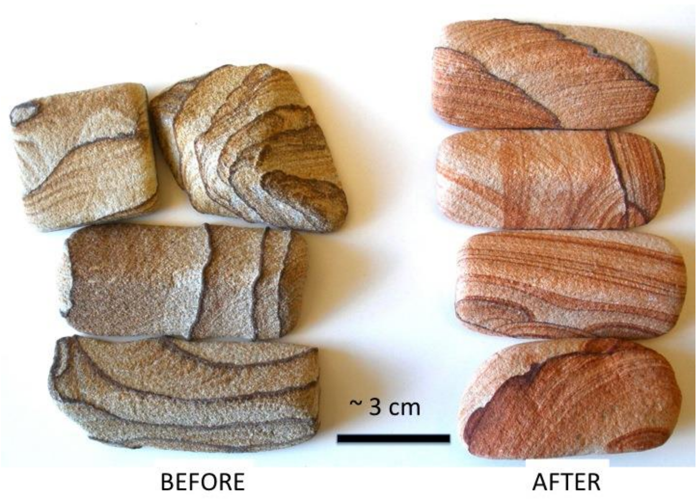
Materials Needed: Rock sample (your own pet rock picturestone), oven access, digital camera. *Note: This assignment may take up to a few hours.

Experiment Steps:

1. Read through all steps and the instructions for your report.
2. Get your piece of "Kanab Picturestone" rock. Make note of its color, size, and any other identifying features. Your rock is an ancient (Triassic) porous sandstone that has liesegang bands (iron –oxide mineral bands), a record of past fluids that moved through the rock during its burial history.
3. Carefully document all steps and experiment conditions.
4. Take a "before" picture with a ruler for scale.
5. Decide on an experiment to test how goethite (FeOOH) can transform to hematite (Fe_2O_3). In general the change can occur at temperatures of about 400 degrees F (~ 204 degrees C) in a normal oven for about an hour or more. Experiment with some different conditions (e.g., you may want to vary the time, and/or temperature). If you have access to a chemistry hotplate, you could try the experiment on it as well.
6. Be sure to use some aluminum foil or something underneath your sample as you heat your sample so sand grains don't get all over your oven, and/or it can protect your container if you are using one. ***<u>If using a microwave, do not use foil</u>***!
7. Leave the rock in the oven to cool before attempting to remove it!
8. Take an "after" picture with a ruler for scale (same position, conditions as step 4).

Safety:

Observe safety and caution at all steps (e.g., use safety goggles, and use insulated gloves/potholders). If your rock contains water, it is possible something could pop so it is advisable to have some aluminum foil around it loosely, and let it cool before trying to examine it. Be sure to keep track of your sample in the oven so you do not forget it and leave it unattended.



Sample from Triassic Chinle Formation (Shinarump Member), (samples available from www.westernhills.com), Kanab UT. Image: M. Chan, University of Utah.

Report your Experiment results

1. What was the purpose?

2. What was your Hypothesis?

3. State your Methods (conditions of the experiment). Make sure you document the actual conditions (temperature of oven, duration of time sample spent in oven, etc.) of your experiment and any other unusual circumstances.

4. **<u>Include a before and after picture of your sample in the same position and location with a consistent scale</u>** (show a ruler or similar measuring tool to indicate scale when taking photos). This can go on a separate page if you wish.

   Label your pictures and include appropriate explanatory photo captions.

Experiment Analysis & Follow-up:

1. What is the dominant change you observe (before vs. after experiment)?

2. Explain your reasoning for the dominant change you observe.

3. Explain the relevance of your experiment to understanding Earth processes and why this might help us understand similar mineralogies on Mars (e.g., hematite "blueberries" at Meridiani Planum, Mars).

4. What are the limitations of this experiment (scale, time) and why are Earth examples not perfect analogs to Mars (e.g., what are some of the differences between Earth and Mars sandstones or chemistry)?

5. If any failures or issues presented themselves, why did they occur? How could you mitigate them?

IN CLASS ACTIVITY (prep for Cooking Rocks)

What do you think?

1. What holds sand grains together in a sandstone?
2. How does the cementing mineral form?
3. Can some of these minerals change?
4. Do similar minerals occur on Mars?
5. What might happen when you "cook" a rock with minerals containing water?

A Mars correlation?

1. Are there diagenetic minerals on Mars? (more than one type?)
2. What is the origin of the hematite in the Thermal Emission Spectroscopy (TES) imagery?

Diagenesis

1. In your own words, define the term diagenesis:

2. How do goethite and hematite differ?

3. Would adding water into/onto the “after” sample change the mineralogy? Why or why not?

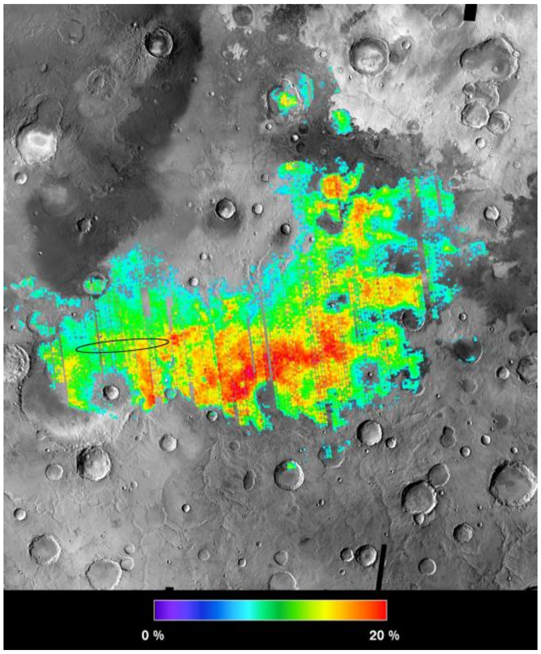


Figure 1: The distribution of hematite in Merdiani Planum; Image credit: NASA/JPL/Arizona State University

LESSON 9: The Active Interior and Crustal Change

In-Class Activity 1

Plate Tectonics & Magnetic Reversals

Why does the compass needle point North?

Use the link to help answer the following questions (http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/magearth.html):

1. What creates the Earth's magnetic field?

2. What is the dynamo effect?

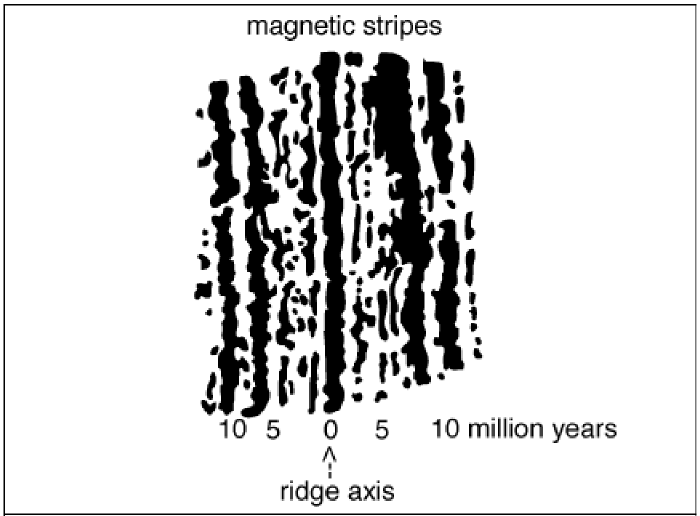
3. What benefits does a magnetic field provide?

The Mid-Atlantic Ridge-Earth and Polarity Reversals.

4. What is a polarity reversal (you may need to do some outside research)?

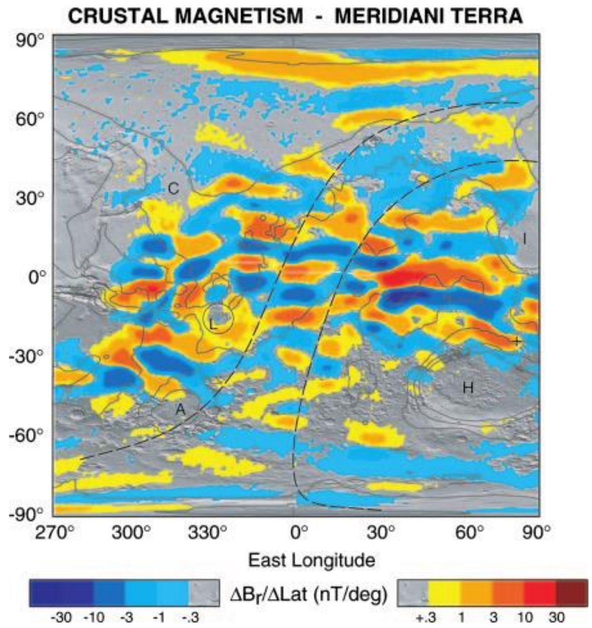
5. In Figure 1, note the "ridge axis of the Mid-Atlantic Ridge" in the image. How is this image proof that the Earth's crust is moving?

6. Why are the rocks recording a reversal/change in polarity?



Pattern created by magnetic stripes along the Mid-Atlantic Ridge south of Iceland.

Figure 1 Source: http://www.london-oratory.org/chemistry_folder/Revision/Earth&Rocks/New/student%20workbook%202.htm



7. Describe the crustal magnetism of Mars at Meridiani Terra (Figure 3). Do you see any banding? If so, what is the orientation?

Figure 2 Crustal magnetism at Meridiani Terra Mars. Warmer colors are positive anomalies (Connerney, 2005*).

* Connerney, J.E.P., et al., 2005 Tectonic implications of Mars crustal magnetism: PNAS v. 201, p. 14970-14975.

Recording changes in the EM field on Earth

Different stations on Earth are recording the changes in Earth's electromagnetic field. One such station is found in Sweden.

8. Navigate to the following website: http://www.irf.se/Observatory/?link[Magnetometers]=Data/
9. Note the legend and discuss the "description" tab. What do the X, Y, and Z data represent in the graphs?

10. Why is there activity in the data?

The Real Question

11. Does Mars have a magnetic field and what studies in the future could reveal new discoveries about the potential for Mars to have had a magnetic field in the past?

Homework 1
The Active Interior and Valles Marineris
Valles Marineris vs. The Grand Canyon

Preparation

- Have access to Google Earth and Google Mars

Comparing dimensions

Using Google Earth and Google Mars, compare the length of Valles Marineris (VM) to the Grand Canyon (GC) using the ruler tool [button with a ruler on it in top task bar].

1. Valles Marineris (take the longest axis measurement you can) _______________ mi

2. The Grand Canyon (start: Marble Falls, AZ; end: beginning of Lake Mead) __________ mi

3. How do their lengths compare? Find a comparable landmass on Earth that would be close to the length of Valles Marineris.

Depth of the Canyons

Using Google Mars, find Candor Chasma and make sure the colorized terrain map (layer in Global Maps) is visible.

4. What is the diameter of Candor Chasma (click on the dot/name)? ______________ mi

5. Is Candor Chasma longer or shorter than the Grand Canyon?

6. How deep is Candor Chasma (use the colorized terrain map and/or ruler tool)? Take 3 measurements trying to find the deepest points. Provide the average.

   a. _______________ mi

   b. _______________ mi

   c. _______________ mi

   d. _______________ average mi

7. Just west of Candor Chasma (orient N to be North) is a HiRISE image ESP_014286_1735. Go to the observation information page to view the image in greater detail. What kind of faults might be forming the ridges? Give your reasoning. (Hint: Basin and Range Province of the United States)

8. Sketch an image of how the fault you named in #7 works (Show the hanging wall and foot wall with relative motion. For help determining hanging wall and foot wall see: http://www.opensha.org/glossary-hangingFootWall):

Go back to Google Earth and find the Grand Canyon

9. How deep is the Grand Canyon? Take 3 measurements trying to find the deepest points. Provide the average. Use the ruler tool (you may need to adjust your viewpoint in Google Earth to see depth).

    a. _______________ mi

    b. _______________ mi

    c. _______________ mi

    d. _______________ average mi

10. Can you observe any evidence of faulting in the Grand Canyon (spend some time viewing the entire canyon in Google Earth)? If so, what do you observe?

11. Which canyon is deeper? Provide at least 2 reasons for why one canyon might be longer and deeper than the other.

LESSON 10: Meteorite and Impact Craters

In Class Activity 1

Is it a Meteorite?

Purpose: Discover the criteria used to identify meteorites.

Is it a Meteorite?

Observe the rocks provided by your instructor. Mark Yes or No for whether or not you 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 are you using to identify whether or not a rock is a meteorite? Explain below:

How big will the crater be?

Observe Meteor Crater in Arizona (pictured below) measuring: 0.737 mi in diameter, and 550 ft deep

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

1. Did scientists find any of the meteorite (you may need to do some outside research)?

2. What factors influence the size of the crater? List at least 5 below.

Calculate your own crater size!

1. Using the below link, calculate the size of 3 craters with varying parameters. Record the parameters and results below. http://www.lpl.arizona.edu/tekton/crater_c.html

2. What parameter do you find to be the most influential in the size of a crater?

Google Mars & Craters

3. Using Google Earth, find the Mawrth Valles region (22.43_N 343.03_E) in the Mars navigation. Using the ruler tool, 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.

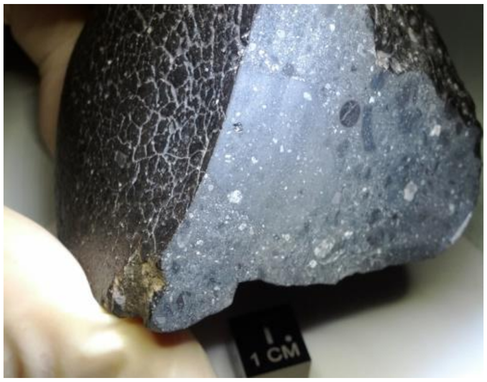


Figure 2 (Source: http://www.nasa.gov/mission_pages/mars/news/mars20130103.html)

Figure 3 (Source: Levi Huish, University of Utah)

Homework 1
Ages and Times of Earth & Mars
Crater Counting

The number of craters on a planetary surface has age implications. Let's explore how this works!

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 (list size of crater and corresponding Mars Epoch with age constraints)?

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

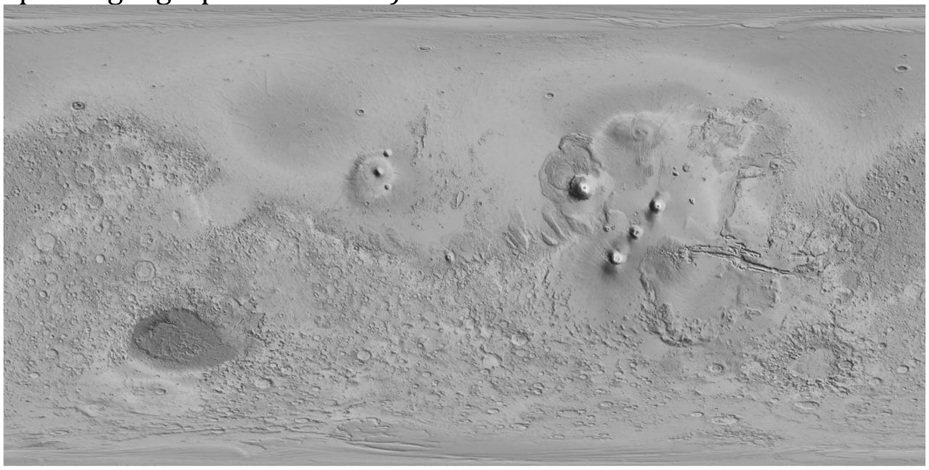


Figure 1 MOLA colorized elevation map in grayscale.

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 you 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 you'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=	

6. Use the isochron diagram on the following page to determine the age of the terrain. **PLOT your points on Figure 2.** To scale the Y-axis correctly: use proportions and be sure to square the area you 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 you measured for the x-axis and plot.
   Does your age coincide with the sketch you made in #4?

   Amenthes Rupes- Epoch: ______________________

   Vichada Valles- Epoch: ______________________

   Mawrth Valles- Epoch: ______________________

   Astapus Colles- Epoch: ______________________

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

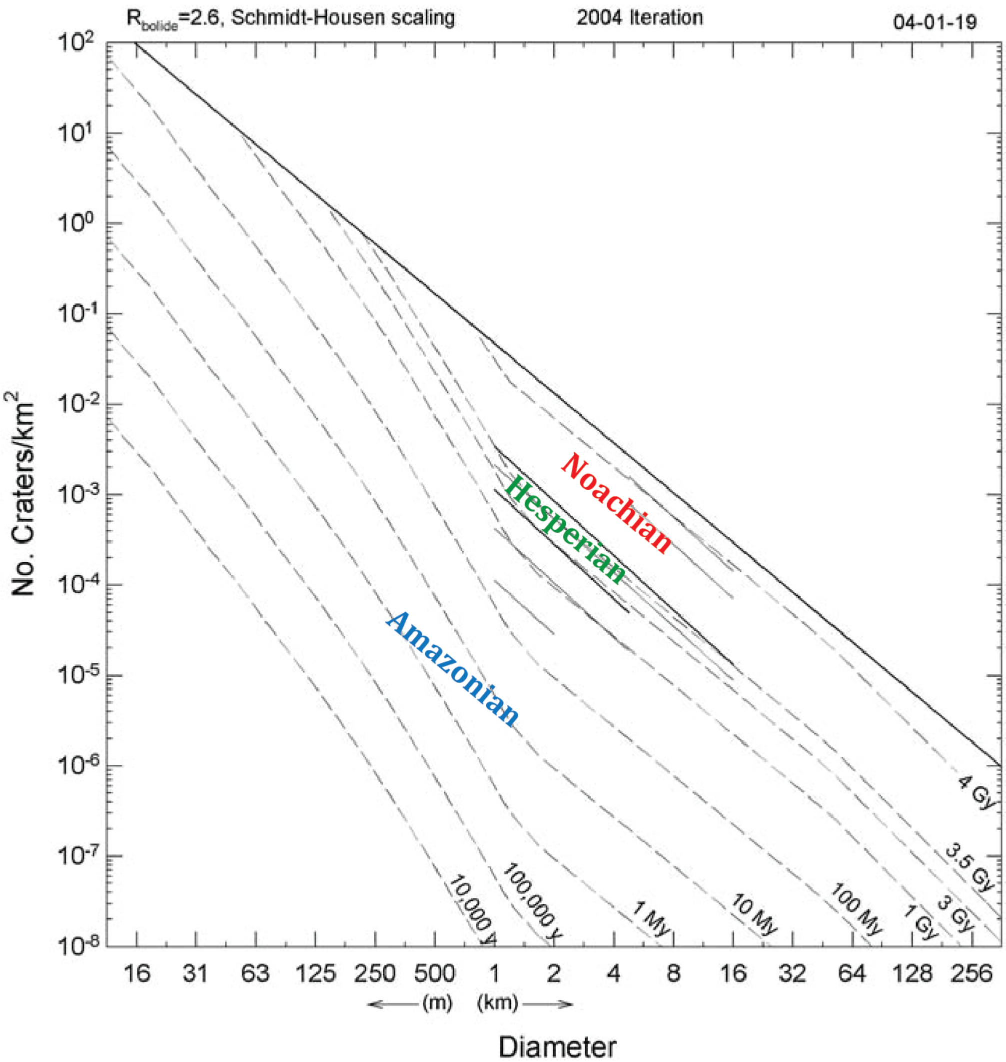


Figure 2. Final 2004 iteration of Martian crater-count isochron diagram. Upper solid line marks saturation equilibrium. Heavier short solid lines (1 km < *D* < 16 km) mark divisions of Amazonian, Hesperian, and Noachian eras; lighter nearby solid lines mark subdivisions of eras all based on definitions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

LESSON 11: Age & Times of Mars vs. Earth

In-Class Activity 1

A Timescale Comparison

Mars vs. Earth Time

Compare the geologic timescales of Earth vs. Mars and answer the following questions.

1. What differences do you observe in the timescales?

2. What do you think is responsible for those differences?

The Noachian

View the following YouTube video about the Noachian period of Mars (an artist's rendition/animation of the period): http://www.youtube.com/watch?v=JfYIvkTQ2pc

1. What do you notice about the early period of Mars?

2. How similar/dissimilar is it from Earth?

Geologic Map of Earth
View a geologic Map of the state of Utah.
http://geology.utah.gov/maps/geomap/postcards/pdf/utgeo_postcd.pdf
Note: this map is simplified

1. What is the scale of the map?

   How many degrees of latitude and longitude does the map cover?

2. Roughly how many colors are used on the map and what do they represent?

3. How old is the oldest terrain in Utah? (give "age name" and years)

   In your opinion why is there so little of this terrain?

Geologic Map of Mars
View a geologic Map of Mars:
http://www.lpi.usra.edu/resources/mars_maps/1083/index.html

1. What is the scale of the map (ratio)?

   How many degrees of latitude and longitude does the map cover?

2. What does the color scale indicate on the map and how does this differ from the Utah map?

3. How old is the oldest terrain according to the map? (give "age name")

   If this is hard to discern, why is this?

4. Now look at the latest map of Mars (click on map sheet) at:
http://pubs.usgs.gov/sim/3292/
Name 3 ways in which it is different from the earlier map of Mars that you looked at? (hint look at the abstract)

a.

b.

c.

Why the difference?

1. Consider the difference between Mars and Earth. Why was mainly only a geologic map of Utah (and then N. America) provided to you?

   What is the potential difficulty in providing you a geologic map of the entire Earth?

2. Notice how the shapes and geometries of colored units on Mars vs. colored units on Earth. Cite 3 ways in which the mapped geologic features of Mars are distinctive or different from Earth (comment on the implication of the processes that are different):

   a.

   b.

   c.

Homework 1
Age & Times of Mars vs. Earth_MFE
It's All Relative

Objective: Apply relative dating laws to interpret block diagrams, Earth road cuts, and Mars imagery.

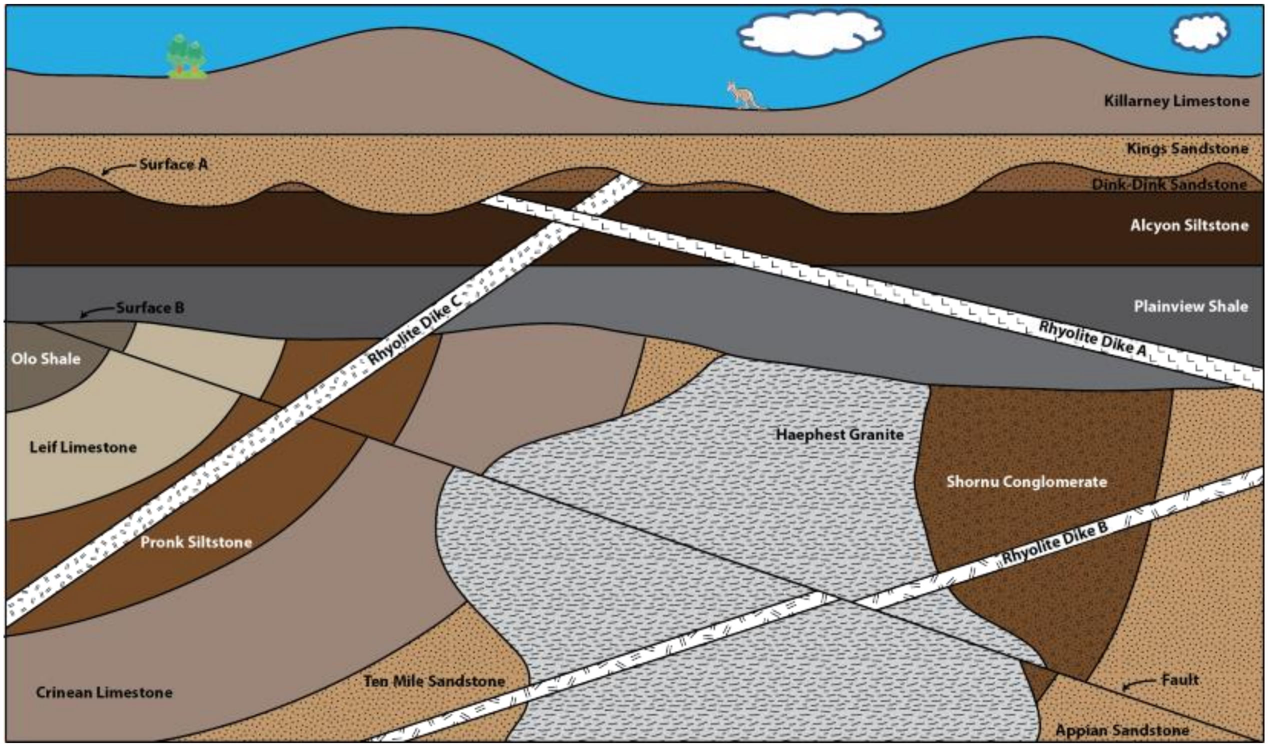


Figure 1 Block diagram. Source: http://fractalplanet.wordpress.com/2013/02/11/relative-dating-activity/

1. How many unconformities (erosional breaks) are present in the image? Name each kind and explain your reasoning.

2. What law did you use to determine the relative ages of the Ten Mile Sandstone and Appian Sandstone?

3. List the order of geologic events by name from *oldest to youngest* below (i.e. Surface A, Rhyolite Dike C, Ten Mile Sandstone etc.):

Road Cuts on Earth

Navigate to the website: http://www.gigapan.com/gigapans/104247 to view the Moab Fault Zone in Utah.

4. How many faults do you observe?
5. How many geologic units do you see? What criteria are you using to differentiate your geologic units?
6. What principle of relative dating is most useful for interpreting this image?
7. Are there any unconformities? If so, how many and what type?

Tractus Catena on the south of Alba Mons

Below (Figure 2) is an image taken by THEMIS of a fracture zone on Mars. Observe the image and answer the following questions:

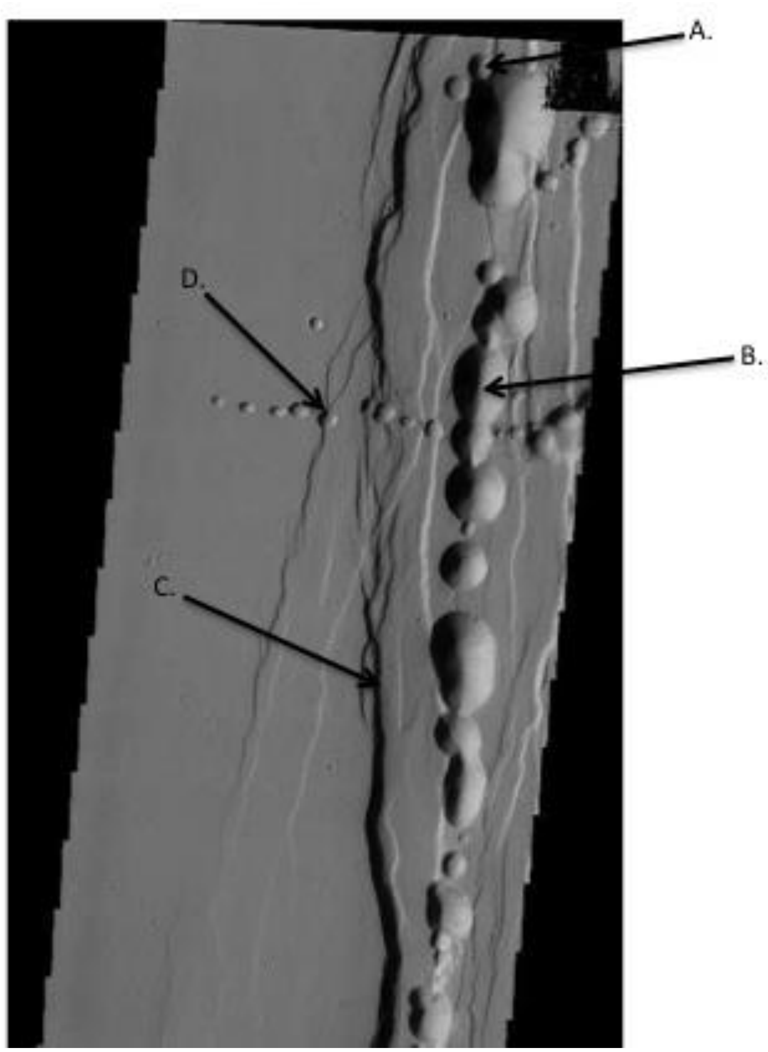


Figure 2 Tractus Catena on the south of Alba Mons, Mars. Themis image; Image Credit: NASA/JPL/ASU. Source: http://themis.asu.edu/node/5918

8. Order the geologic events (A-D) from *oldest to youngest*. Make sure you note the entire image as you make your decisions.

9. What makes this image difficult to interpret?

10. What law(s)/principles of relative dating did you use to interpret the image?

11. If you are already familiar with tectonics, are features B and D likely related to extension or compression? Justify your answer.

LESSON 12: Surface Water

In-Class Activity 1

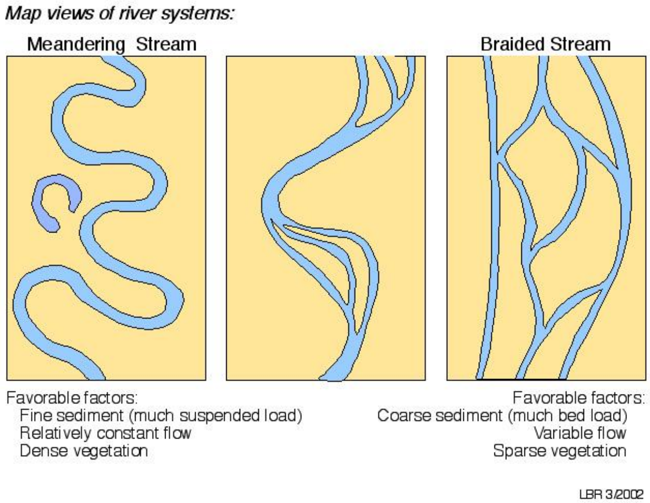
Carving Mars: Rivers

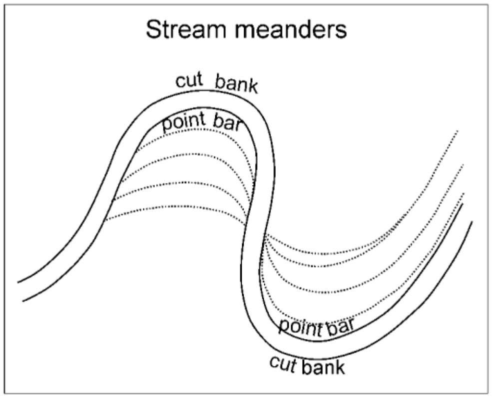
Purpose: Observe the formation of fluvial channels, the effects associated with varying water velocity and changing base-level/gradient, and the evidence for fluvial/alluvial environments on Mars.

Materials Needed: Internet connection and 3D glasses

Terms to understand:

- Cut bank
- Point Bar
- Meandering vs. braided (channel gradient, sediment input)





Source: http://www.gly.uga.edu/railsback/1121Lxr28.html, http://commons.wvc.edu/rdawes/G101OCL/Basics/streams.html

Why do waters "rage"?

Watch the following video: https://www.youtube.com/watch?v=E6sWiPAu708

As you watch the video, answer the following:

a. Where is the river fastest?

b. Where do sandbars form?

c. Why does the river form sinuous bends?

Watching a stream form:
Observe the Davidson Geology department's stream table experiment:
http://www.youtube.com/watch?v=YsQ7hW2fAEs&feature=related

1. Sketch each of the following as you observe it and list a time stamp for each. You may need to watch the video several times (use a separate sheet if necessary).
    a. Formation of a cut bank
    b. Formation of a point bar
    c. Stream avulsion
    d. Formation of multiple channels
2. For each of the sketches, describe why you think it occurred:
    a. Cut bank
    b. Point bar
    c. Stream avulsion
    d. Multiple channels

Seeing Mars stream in Red-Blue?
Explore the HiRISE anaglyph image of the Eberswalde region of Mars using red-blue glasses (blue filter over right eye):
http://hirise.lpl.arizona.edu/images/2007/details/cut/Eberswalde-delta-3x.jpg

1. Are any of your stream table sketches similar to what you observe on Mars? Which one(s), if any?

2. Explain how this surface geomorphology on Mars might have formed.

Mars Rivers?
Access the following Mars Global map produced by MOLA via Google:
http://www.google.com/mars/

1. Consider the landscape of Mars. In what regions could water have flowed as braided channels?

2. Would meandering or braided fluvial styles be more common on Mars? Does this differ from Earth? If so, how?

Just checking….

In reference to Figure 1, answer the following:

a. Where would it be safe to build a house (draw at least 2 arrows to areas in the photo where you would feel comfortable building a house)?
b. Where is deposition occurring? What about erosion?

With reference to the “scars”:

c. What does this tell you about the meanders?

d. Can you discern which meanders are older and which are younger?

e. Do you observe similar geomorphology on Mars?

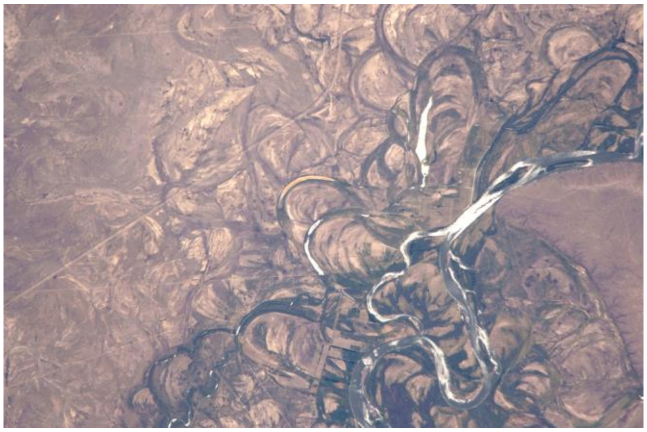


Figure 1 RIO NEGRO, COLONEL JOSEFA AREA, FLOOD PLAIN
Center Point Latitude: -39.8 Center Point Longitude: -65.4
(Image Source: ftp://eol.jsc.nasa.gov/EFS_highres_ISS022_ISS022-E-19513.JPG. ISS/NASA)

In-Class Activity 2
Surface Water_MFE
Eberswalde Delta Mars

Purpose: Become acquainted with deltas on Earth and apply the principles of delta-formation to Mars images.

Do you know what a delta is?
Compare and contrast the images provided by your instructor (or see the *Image File* for the Surface Water module online). Which image is of a delta? Why?

Delta Search on Earth

1. Explore other deltas on Earth via Google Image search or a similar method (Hint: search major coastal river systems). Which delta on Earth is most similar to Eberswalde Delta on Mars? Are any a good match? Why or why not?

Deltas on Mars?
View the following video from NASA.gov- click on the "+ View Video" link in blue:
http://www.nasa.gov/multimedia/imagegallery/image_feature_98.html

1. List the evidence cited by scientists that this is a delta on Mars.

2. Using the below grid, compare and contrast the Martian delta and Earth's Mississippi River delta.

Delta	Overall Geometry	Into what body of water/fluid does/did it empty? Evidence?
Eberswalde Delta, Mars		
Mississippi River, Earth		

Homework 1
Surface Water_MFE
Mars Fluvial Channels: Contour Maps

Purpose: Become familiar with contour maps and learn how to read them. Observe fluvial incised-channels on a contour map of Earth and compare to a contour map of Mars, and make predictions of potential fluvial activity on Mars.

Preparation:

1. If not uploaded to your Google Earth application, load the USGS topographic maps layer to Google Earth using the following website and link: http://www.gelib.com/ng-topo.htm
2. Open the Mars contour map found here: http://pubs.usgs.gov/imap/i2782/i2782_sh2.pdf

Directions/Questions:
Earth Fluvial Channels

1. Open Google Earth:
   a. To get your bearings on Earth, center your map/viewer on the following coordinates:38°27'N, 109°41'W, near Pyramid Butte, UT.

   b. What is the major river in the area?

   c. Find Dripping Spring (southeast of Pyramid Butte). What is the flow direction from Dripping Spring to the nearby major river?

      How do the contour lines indicate the flow direction? Sketch an example below of what the contour lines look like in relationship to the stream:

   d. If you were to hike from Pyramid Butte to the nearby campground in the northeast, would you be hiking uphill or downhill? Explain your reasoning.

e. Follow the meanders of the major river channel. How are the contours drawn near the river? Do they follow the river? Cross the river? Explain the reason why the contours are drawn that way.

f. Using the ruler tool, estimate the distance in miles from Pyramid Butte to Musselman Arch to the southwest.

g. Zoom in on the Goosenecks of the major river. Zoom in enough to see the annotated hand-drawn sand bars of the river. Explain the origin of the sand bars and whether or not you could hike out of the Goosenecks easily.

h. Is the white area where the words "Goosenecks" are written an area of relief or a depression? Explain your reasoning.

Mars Fluvial Channels

2. Using the Mars contour map, find Valles Marineris. Look northeast of Valles Marineris, around the 330E/30W longitude line and the Martian equator.
   a. What features stand out/are enhanced by the contour data (mountains, rivers, craters etc.)?

   b. Are there any areas that are similar to a fluvial channel? If so, screen capture an image and paste here or sketch what you see as evidence of a fluvial channel.

LESSON 13: The Water Underneath, Mars Groundwater

In-Class Activity 1

Catastrophic Flow Experiment

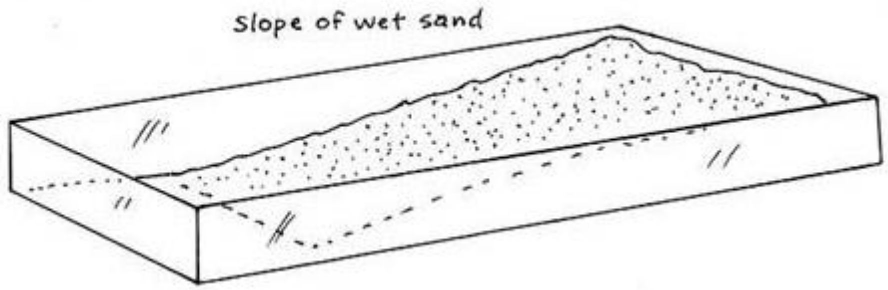
Adapted from J. Weller Cochise College, AZ (2008)

Purpose: To conduct a small benchtop experiment to understand the surface expressions of groundwater springs, sapping, and gullies.

Materials: A sandbox (could be a plastic bin filled about ½ way with sand), small plastic bag(s) proportional to your sandbox and sand supply, scissors.

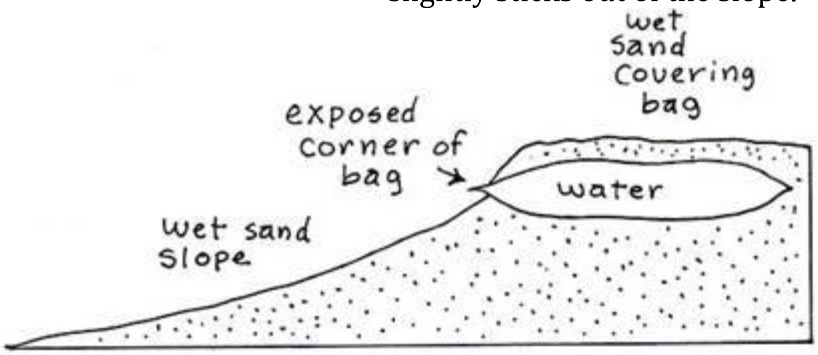
Directions: Using a sandbox, let's try to see if we can duplicate some of the features seen in the Martian photographs.

1. First, fill a zip-lock plastic bag with water. Try not to leave any air in the bag. Next, create a long, low angle slope of wet sand in the sandbox.



Credit: J. Weller Cochise College, AZ (2008)

2. At the top of the slope, bury the plastic bag of water so that one corner of the bag slightly sticks out of the slope.



Same as above: J. Weller Cochise College, AZ (2008)

3. Cover the bag with about one inch of wet sand. The water in the bag will slosh around, so smooth the surface above the bag so that there are no cracks at the surface.
4. If available, dust the slope with a very thin layer of dark dirt (although this may make sand less usable in future). This will help show the flow channel better.

5. With a pair of good scissors, quickly cut a small nip in the exposed corner of the water-filled plastic bag, setting off the flood and collapse.

Discussion:

1. Would the rate of water outflow change the surface expression? Why or why not?

2. Consider a liquid with higher viscosity then water (e.g. molasses), that might be used in the bag. Would the surface expression change?

3. This hypothesis is considered by many Mars researchers to be the cause of extensive deep channels and canyons present on the surface of Mars. Does groundwater sapping seem plausible as a formation mechanism for channels on Mars? Can it account for channeling as large and deep as Valles Marineris? Why or why not?

LESSON 14: Water World

In-Class Activity 1

Spits on Mars

Purpose:

- Understand the concept of longshore drift and the geomorphic features it creates.
- Search for and identify sand spits/tombolos on Mars

How do sand spits form?

View the following video of Spit Formation in the UK and consider the following questions (You may need to use some of your knowledge about Earth science in addition to the information in the video to answer the questions):
http://www.youtube.com/watch?v=Fe9YBuK_qEo&feature=endscreen&NR=1

1. Where would the coarsest grain sizes be deposited on a beach?

2. What determines the location of particular grain sizes?

3. What governs the growth of a spit?

Finding sand spits on Mars

Using a MOLA colorized elevation map, complete the following:

1. Mark or point to areas on Mars where spits could be present.
2. How did you make your choices?

3. If longshore drift was present in your chosen regions, what direction is the longshore drift heading? (Hint: You might want to look for elongate spit development.)

Looking into sand spits

1. What do you think deposits of longshore drift look like in cross-section? Draw/sketch your ideas below.

2. What determines the size of grains that are deposited?

In-Class Activity 2
Water World_MFE
Where is the Carbonate on Mars?

Purpose: Become acquainted with the carbon cycle on Earth and how carbonate rocks are formed. Develop a line of evidence or explanation for the reasons why carbonate rocks are not abundant on Mars.

What is a carbonate rock?
Observe the rocks provided by your instructor

1. What are the similarities between these rocks?

2. Where might these rocks have been deposited/formed? What is your evidence?

Forming carbonate rocks on Earth

1. Hypothesize how carbonate rocks form in an aqueous environment.

2. Watch the following NASA video entitled "Keeping up with Carbon": http://www.youtube.com/watch?v=FgEZpX3n5mo
    a. How does your hypothesis compare to what NASA shares?

    b. Could the carbon cycle work on Mars? Why or why not?

Carbonate rocks on Mars

1. Open up JMARS and view maps of carbonate rocks.
2. Where are the carbonate minerals most common?

3. What would you need to change about Mars today for Mars to be conducive to carbonate development?

Nili Fossae, Mars

1. Where might you find carbonates in Figure 1? Draw arrows to the region.

2. What is the basis for your decision?

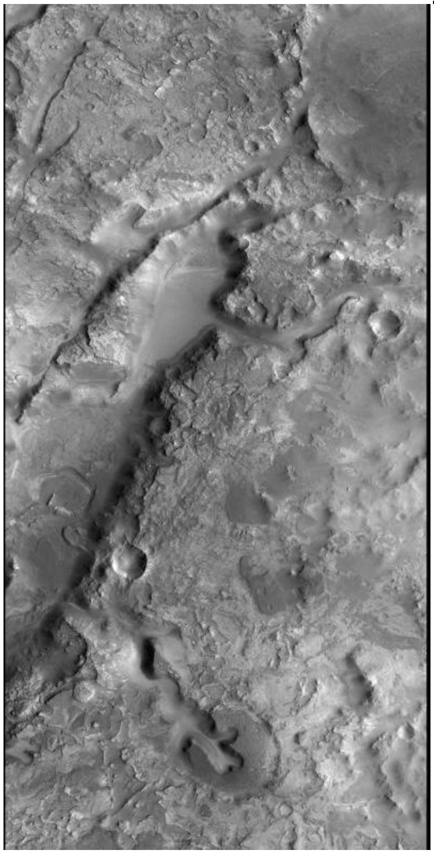


Figure 1: Nili Fossae Region Imaged by CTX
Image Credit: ASU/Malin Space Science Systems

Homework 1
Water World_MFE
Mars Ocean Press Release

Purpose:
Critically assess the validity of media-released discoveries of Mars; in this case, a Mars ocean.

Directions/Questions:
Navigate to the following press release by CU-Boulder in June 2010:
http://www.colorado.edu/news/releases/2010/06/13/new-cu-boulder-study-indicates-ancient-ocean-may-have-covered-one-third

1. What evidence does the article use to support an ancient Mars ocean?
2. In what geologic age of Mars' history would oceans most likely have existed? (Noachian, Hesperian or Amazonian) *Note: You may need to do some outside research to answer this question.
3. What evidence would convince you that an ocean existed on Mars that this press release did not address?
4. How would you improve the press release overall?
5. Contrast the Science Daily press-release with CU-Boulder's press release. Do they differ? If so, how?http://www.sciencedaily.com/releases/2010/06/100613181245.htm
6. Find a more recent article on the potential Mars Ocean. Summarize the major points. Has scientists' thinking on the topic changed?

Be prepared to discuss your opinions in class!

Mars for Earthlings

LESSON 15: Ice Ages

In-Class Activity 1

Ice Ages Through Time

Purpose:
Come to understand climate changes over time, hypothesize the causes of ice ages on Earth, and extrapolate those causes to Mars

I. Ice Ages on Earth:
Watch Earth's Paleogeography through time.
http://www.youtube.com/watch?v=Q2dAmLnR3tA

After watching the video, answer the following questions:

1. At what Earth age (ages) was there the greatest extent of ice cover towards the South/Southern Pole?

   At what Earth age (ages) was there the greatest extent of ice cover towards the North/Northern Pole?

II. Extreme Ice Survey on Earth
Watch this 21 min. Ted Talk 2009 movie on James Balog: Time-lapse proof of extreme ice loss: https://www.youtube.com/watch?v=DjeIpjhAqsM

What is he trying to do and show?

How does he power his equipment?

What is his photography showing?

1. Why do glaciers matter? See extremeicesurvey.org/why-do-glaciers-matter/
   Give 3 reasons:
   a.
   b.
   c.

Mars for Earthlings

III. Milankovitch Cycles and Glaciation

1. What are Milankovitch cycles and how do they affect glaciation? (For help use: http://www.indiana.edu/~geol105/images/gaia_chapter_4/milankovitch.htm)

2. What are some major differences between the Milankovitch cycles of both Mars and Earth? (For help use: http://phoenix.lpl.arizona.edu/mars172.php#1)

3. How might those differences affect climate changes on Mars compared to Earth especially related to ice ages?

IV. Mars and Ice Ages

1. Would you hypothesize that Mars experiences ice ages as well? Explain your reasoning.

2. Why or how would the orbital parameter of Mars affect potential ice ages?

Mars for Earthlings

Homework 1
Ice Ages_MFE
Ice on Mars

Objective: Find and understand terrains on Mars that contain or harbor ice.

Activity/Assignment:

1. Research regions on Mars that have been identified to have fretted terrain.

Hint: Fretted terrain is most common in northern Arabia, between latitudes 30°N and 50°N and longitudes 270°W and 360°W. Two good examples of fretted terrain are Deuteronilus Mensae and Protonilus Mensae.

2. Using JMARS, search for and capture images of the following:
    a. Fretted terrain
    b. Softened terrain
    c. Lobate morphologies
    d. Make note of the following for each captured image:
        i. Lat/Long,
        ii. Zoom increment
        iii. Map used for each image captured (THEMIS, MOLA etc.)

What you turn in:

3. Compile your findings into a .ppt presentation (print out your slide presentation with speaker notes where you've indicated any important info)
    a. Label all features.
    b. For JMARS images, label the feature, Lat/Long, Zoom increment, and Map on each slide (with the image).
    c. Use the "speaker notes" to further elaborate on your findings.
    d. You should have at least 3 slides
        i. Slide 1: fretted terrain
        ii. Slide 2: softened terrain
        iii. Slide 3: lobate morphology

Mars for Earthlings

LESSON 16: Weathering & Patterned Ground

In-Class Activity 1

Break a Rock!

Purpose:
Determine how the physical breakdown of rocks leads to increased rates of weathering and erosion.

Break a Rock!
Use the rock hammer and rock provided by your instructor. Break the rock in such a manner that you can see "the middle" of the rock.

Outside vs. Inside
Make a sketch in each circle below of the outside vs. inside of the rock. Note color changes, sizes of crystals, any mottling, etc. Be as observant as possible. Provide some sort of scale to understand the relative sizes of your sketches.

Outside
Scale:

Inside
Scale:

Mechanical vs. Chemical Weathering
List any evidence for mechanical weathering and/or chemical weathering.

Mars for Earthlings

The smaller the better?

1. Do you think smaller features will experience higher rates of weathering? Why or why not? What determines the "rate"?
2. Considering Figure 1, would the concept "the smaller the better" apply here? Why or why not? Note the scale in the caption.

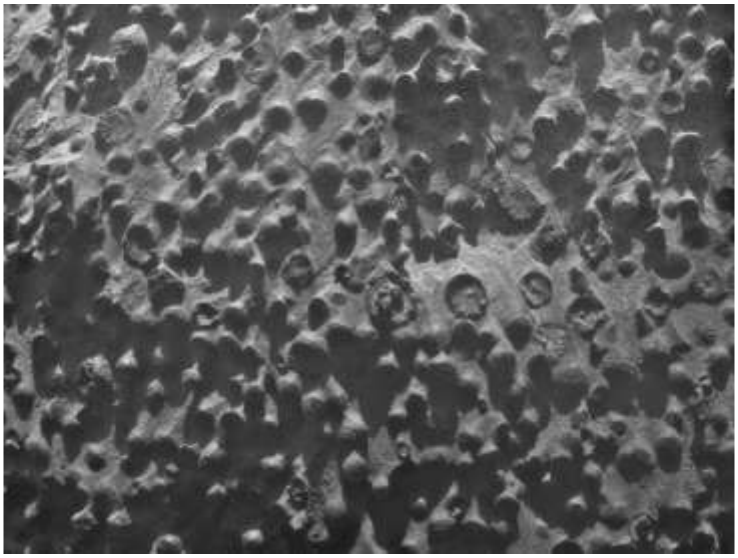


Figure 1: Image taken by rover Odyssey at Endeavor Crater: The view covers an area about 2.4 inches (6 centimeters) across, at an outcrop called "Kirkwood" in the Cape York segment of the western rim of Endeavour Crater. The individual spherules are up to about one-eighth inch (3 millimeters) in diameter. Image Credit: NASA/JPL-Caltech/Cornell Univ./ USGS/Modesto Junior College

To sum it all up…

List the three most important factors that determine the rate of weathering.

Mars for Earthlings

In-Class Activity 2
Weathering & Soils_MFE
Soils on Mars?

Purpose: Identify Earth soil horizons and extrapolate what characteristics of soil would be observable on Mars.

Is it a soil?
Study Figure 1 below (or the image provided by your instructor).

1. Does this picture represent a complete soil profile? If not, what horizons are present?

2. What criterion are you using to define a soil?

Figure 1: A Russian Chernozem (Mollisols in most cases) and the landscape NW of Kursk, in the Kursk Oblast, Russia.
Source: http://web.utk.edu/~ammonst/research.html

Mars for Earthlings

What makes a soil?

1. Brainstorm at least 4 factors that would create a soil.
    a. Factor 1:
    b. Factor 2:
    c. Factor 3:
    d. Factor 4:

2. Which factor is the most influential?

3. After discussing the 5 soil forming factors with your instructor, determine which factors exist and/or have the greatest influence on Mars. List and describe below.

Identifying Soil Horizons

In Figure 2, draw lines and/or labels at horizon boundaries. Are any horizons absent?

- Horizon- thick organic-rich layer
- A Horizon- relatively thin organic layer with rooting
- E Horizon- leached layer (not always present)
- B Horizon- mineral layer
- C Horizon- parent material

Figure 2: Image Credit: NRCS Soils

4. What characteristics of this profile might you observe on Mars? Can you observe it remotely? What do you think gives the yellow layer its color?

Mawrth Vallis

Observe Figure 3 of Mars at Mawrth Vallis, one of the landing site considerations of MSL Curiosity (captured via JMARS):

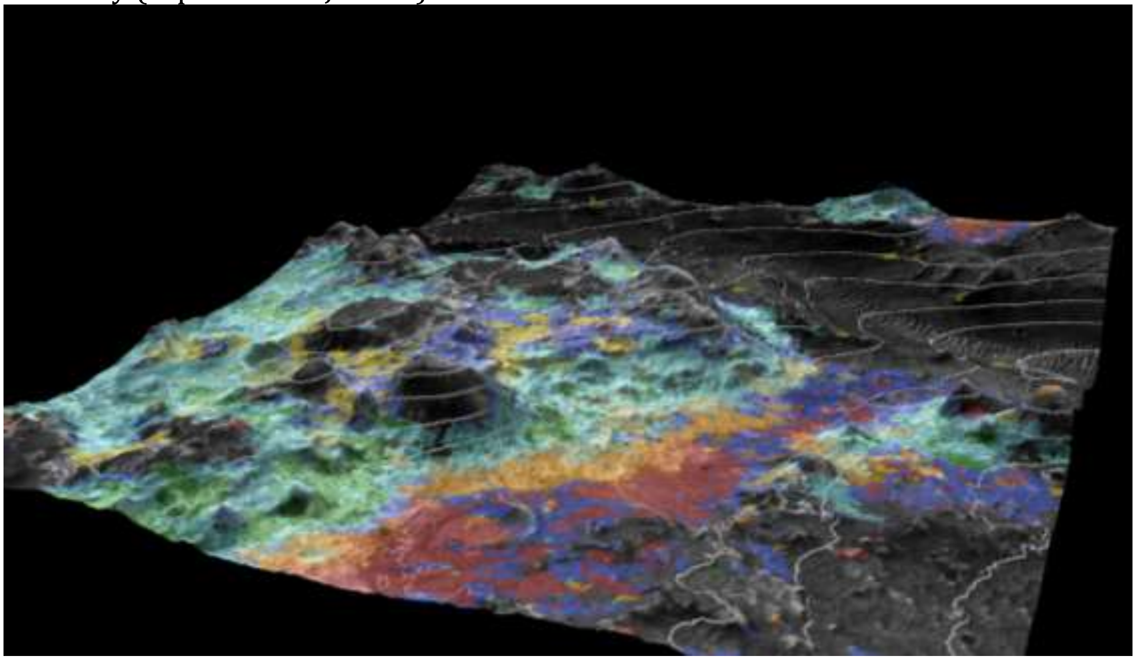


Figure 3: Mawrth Vallis CRISM image overlain on HiRISE imagery. Image Courtesy of Briony Horgan, ASU.

5. What do you observe in this image?

6. Do changes in color follow any other discernable pattern?

7. How would you recognize soils on Mars? What would be your criteria?

Mars for Earthlings

Homework 1
Weathering and Soils_MFE
Chemical vs. Mechanical

Introduction: This exercise will focus on your ability to identify weathering processes/features on Earth and on Mars. The last part of this exercise will involve using Google Mars to recognize weathering features through high-resolution images.

PART I—Weathering of Earth

For the following 4 images, determine whether they are the result of mechanical or chemical weathering, and identify the specific process that formed the weathering feature.

Sandstone
Australia
Humid continental

Image 1 (Image Source: http://commons.wikimedia.org/wiki/File:Cracked_boulder_DMCR.jpg, "Devil's Marbles" Author: Prince Roy)

Mars for Earthlings

Sandstone
Oregon,
Coastal/temperate

Image 2 (Image Source: http://www.earthscienceworld.org/images/search/results.html?Category=&Continent=&ImageID=hhrhsr#null Photographer: Marli Miller, University of Oregon)

Image 3 (Image Credit: Michael Szoenyi/Science Photo Library; http://www.sciencephoto.com/media/173681/enlarge)

Sandstone
Anza-Borrego Desert State Park,
California,
Semi-arid/rain shadow

Mars for Earthlings

Granite
Enchanted Rock,
Texas
Humid Subtropical

Image 4 (Image Source http://en.wikipedia.org/wiki/File:GeologicalExfoliationOfGraniteRock.jpg)

PART II—Weathering of Mars

For the following images, identify whether the features are caused by mechanical or chemical weathering and answer the additional questions for each image.

Image 5

1. What are 3 likely processes causing the pits in the rock in the image below?
2. What does that mean for the type of environment that could have existed on Mars?
3. Name 3 geographic areas on Earth that would work as an analog to this rock.

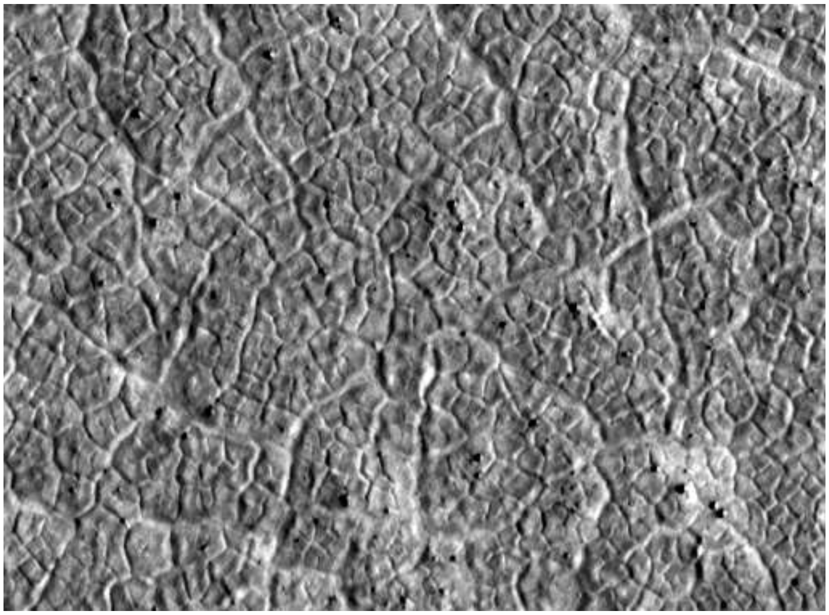
Volcanic rock
Ares Valles region,
Pathfinder landing site

Image 5 (Image Source: http://science.ksc.nasa.gov/mars/mpf/stereo-arc.html)

Mars for Earthlings

Image 6

1. What feature is shown below?
2. What are 3 processes/influences that can cause these features?



Likely sand-siltstone
Near North Pole

Image 6 (Image Source: http://web.pdx.edu/~pdx06058/Planetary_Research.html)

Image 7

1. This is a false-color image of the surrounding area around the Sojourner Rover. What is the red tone on the Martian surface and what does that mean?

2. Which direction is the wind coming from (This does not have to do with weathering)?

Volcanic rock (Yogi rock)
Ares Valles region
Pathfinder Lander location

Image 7 (Image Source: http://nssdc.gsfc.nasa.gov/planetary/marspath_images_2.html)

Image 8

1. What is the nickname given to the little balls scattered in the image below?
2. What are they? How are they formed and what does that mean for surface processes in the Martian past?
3. What weathers faster: the host rock or the little balls scattered on the surface? Give some reasons to support your answer.

Photo by MER Opportunity Rover At rock outcrop "Shoemaker's Patio"

Image 8 (Image Credit: NASA/JPL; Source: http://photojournal.jpl.nasa.gov/catalog/PIA05584)

PART III—Google Mars

1) The images in questions 1 and 3 were taken by the Mars Pathfinder Lander.
   a. Where is the lander located (lat/long)?
   b. Go into the "presidential" panorama and describe the image and features that you see.
   c. It landed in Ares Valles. Describe the area in terms of the geomorphic features and why it presently looks this way.

2) The image in question 2 was taken by the HiRISE camera aboard the Mars Reconnaissance Orbiter. The coordinates are approximately 71° 38' N and 145° 20' E.
   a. What kind of environment would create a surface like this? Is this process continuing today on Mars? Is it continuing on Earth?

Mars for Earthlings

3) The MER Opportunity rover took the image 8. Go to the following website:
   http://mars.nasa.gov/mer/home/
   Click on Multimedia
   - Click on images
   - Go to All Raw images for the Opportunity Rover
   - Next go down to Science Cameras/Panoramic Camera and scroll down to Sol 109, Click "View Selected Images"
   - Scroll down and explore images 8-20 under Sub-Frame EDR (not numbered)

   a. Determine why it took so many images of the same spot on the surface.
   b. Record the Sol from the latest image (go back one page). How does this Sol compare to the expected life of the mission?

   c. Go back to Google Mars and determine approximately where the rover was when it took these pictures, both geographically and lat/long.

   d. Go to the panoramic, "Crater of Clues" and briefly describe what you see, both around the rim of the crater as well as within the crater.

Mars for Earthlings

LESSON 17: Vast Deserts

In-Class Activity 1

Sand Box Dunes

Purpose: Understand the processes that form sand dunes on Mars and Earth.

Resources:

1. HiRISE Dune Image Source: http://hirise.lpl.arizona.edu/ESP_012202_1390
2. THEMIS Dune Image Source: http://themis.asu.edu/node/5758
3. Mars Global MOLA map: http://mola.gsfc.nasa.gov/images/mercat_med.jpg

Desert Pavement:

1. If you were to travel into a valley and see the rocks shown in Figure 1:
    a. What processes are at work in the valley?

    b. What grain sizes are left?

    c. What happened to the rest of the grains?

Figure 1: Death Valley ventifacts; *Photo by Marjorie Chan*

Mars for Earthlings

Sand Box

1. Watch the sandbox demonstration and answer the following (http://serc.carleton.edu/details/files/44290.html):

    a. How does the surface change?

    b. Which side of the dunes are the steepest? Why?

    c. What happens when the angle becomes too steep? What do we call that angle?

    d. What is the steep side of the dune called?

    e. How does the slip face change through time?

Mars Image Analysis

2. View the following Mars Images

    HiRISE: ESP_012202_1390 Dunes in the Western Nereidum Montes (38.6S, 44W)

    THEMIS: V43323004 Terra Sirenum (39.7S, 150W)

    a. Answer the following:

        i. What is the prevailing wind direction in each image?

        ii. Are the dunes multi-directional? If so, how can you tell?

        iii. Is there more than one dune shape/morphology (barchans, transverse, longitudinal, parabolic etc.)? If so, what are they?

Mars for Earthlings

Sediment Source Determination

Referring to the Mars Images, answer the following:

1. What is the sediment supply like (abundant, sparse)? Explain your answer.

2. According to your knowledge of the geography of Mars and its regions, what might be the source of the sediment (refer to the MOLA map your Instructor has posted)?

Mars for Earthlings

In-Class Activity 2
Vast Deserts_MFE
Martian Ventifacts

Purpose: Explore the existence and formation processes of ventifacts.

Resources:
1. Mojave Desert Ventifact Video: http://www.youtube.com/watch?v=OOqOm3KgGMw&feature=endscreen
2. Mars ventifact images: http://www.psi.edu/pgwg/images/jul09image.html

Ventifacts: For an explanation on ventifacts use the following link (http://www.psi.edu/pgwg/images/jul09image.html)

Death Valley
Observe the Death Valley photo below and answer the following questions:

Figure 1: Death Valley Photo, credit: Marjorie Chan

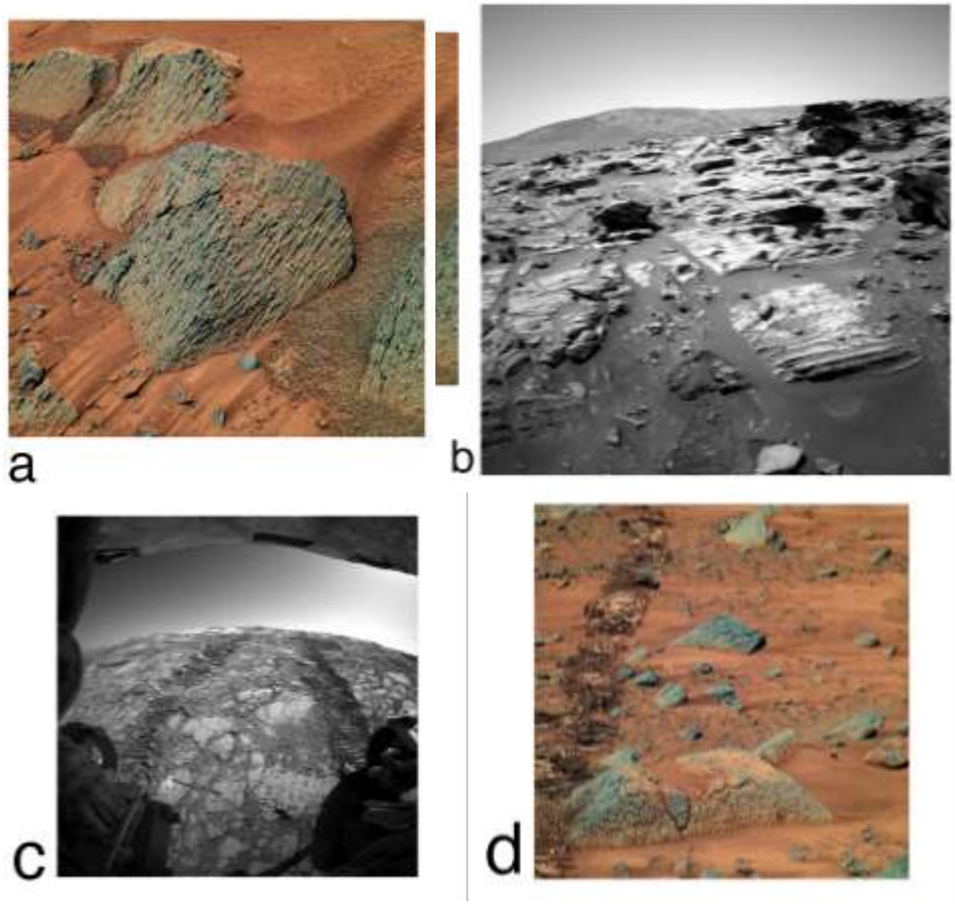
1. What formation seems odd to you? Have you seen anything like it? Why is there only one?
2. Hypothesize how this might have formed.

Understanding Ventifact Formation
View the following video and answer the following questions.
http://www.youtube.com/watch?v=OOqOm3KgGMw&feature=endscreen
1. What do you look for in order to determine if a rock or feature is a ventifact?

2. How can you discern which direction the wind was/is blowing?

3. What causes the reddish-orange coloration?

Martian Ventifacts?
Here is what might be considered ventifacts on Mars:
Image Source:
http://www.psi.edu/sites/default/files/imported/pgwg/images/VentFig4.jpg



Mars for Earthlings

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f

g

1. Label the wind direction on each image above with a colored pencil or colored pen.

2. Is the preservation potential higher on Mars or Earth? Explain your reasoning via images where possible.

3. Do you believe that these are indeed ventifacts? Why or why not? Which images are the best examples of true ventifacts? Explain your reasoning. Which images are more dubious? Explain your reasoning.

Mars for Earthlings

Homework 1
Vast Deserts_MFE
"Bounding" through Dunes

Purpose:
- Recognize bounding surfaces in Google Earth imagery and their meaning in the geologic record.
- Understand why bounding surfaces are or are not recognized on Mars.

Preparation:
Make sure you have Google Earth downloaded on your computer to accomplish this exercise. http://www.google.com/earth/download/ge/agree.html

Questions:
Checkerboard Mesa, Zion National Park UT
1. Open Google Earth (load the free program if necessary).
2. Navigate to 37°13'30.75"N 112°52'54.13"W and orient the window looking Southwest. See image below* for orientation of your viewing window.

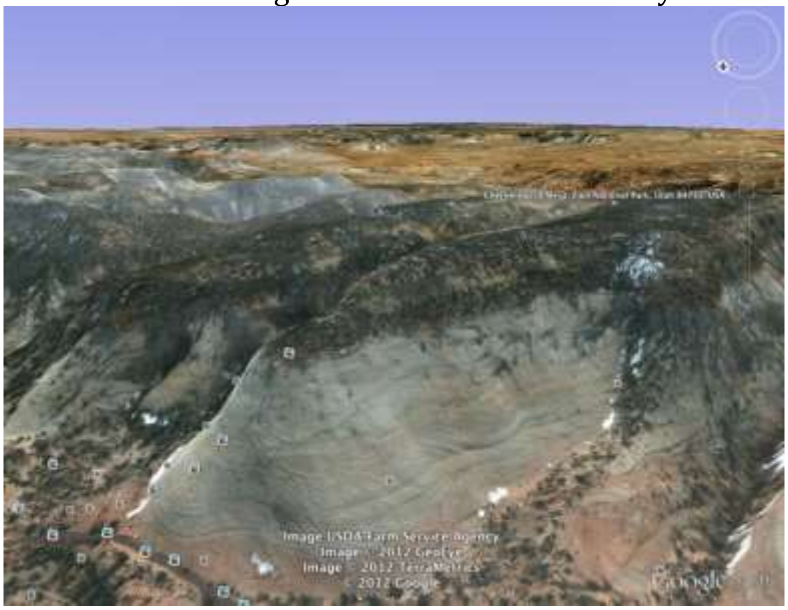

Figure 1 Image captured through Google Earth

Capture your own .jpg and insert your image into a PowerPoint file.
*the image in this exercise is not zoomed in or large enough for your PowerPoint slide

3. In PowerPoint, annotate your image with the following:
    a. Paleocurrent direction- red arrows
    b. Bounding surfaces- green lines
    c. Dunes are "marching towards you" – blue triangles
    d. Dune are "marching away from you"…in any direction – orange triangles

Mars for Earthlings

4. On another slide, answer the following questions
   a. What do the bounding surfaces represent?
   b. What created the sinusoid (sine wave) morphology of the beds?

Burns formation, Meridiani Planum Mars

5. Insert the following Burns formation image into a slide and do the following:

Figure 2 Left Panoramic Camera Non-linearized Sub-frame EDR acquired on Sol 288 of Opportunity's mission to Meridiani Planum at approximately 13:10:16 Mars local solar time, camera commanded to use Filter 7 (432 nm). NASA/JPL/Cornell

   a. Follow the same instructions for labeling as for Checkerboard Mesa above (answers to the following questions should be given in a separate slide).
   b. What are the main differences between Checkerboard Mesa and the Burns Formation outcrop? Cite at least 3.
   c. Do you think the Burns Formation was formed in an eolian environment? Why or why not?
   d. In the below photos, how is the colorized imagery helpful? What do you observe in Image C of Figure 3? Why do some layers “look different”?

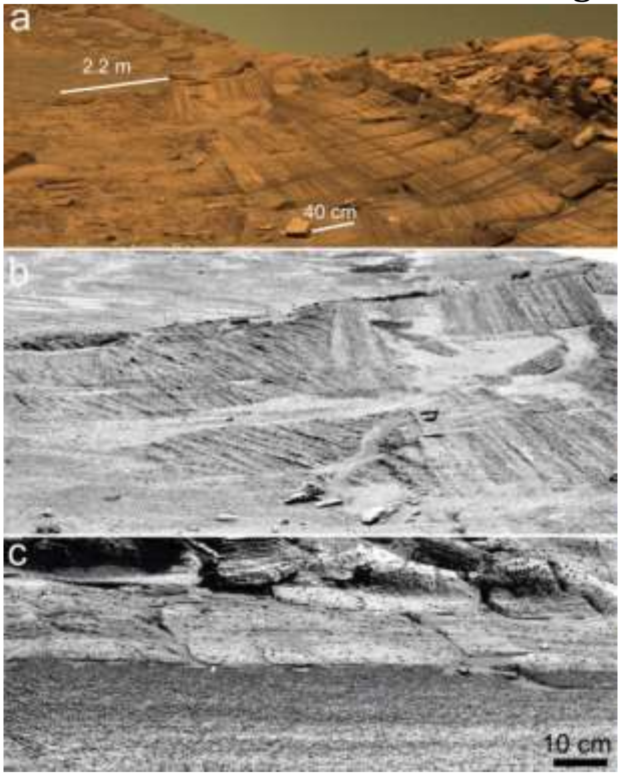

Figure 3: Burns Formation stratigraphy (Grotzinger et al., 2005).

6. Turn your .ppt presentation/slides into your instructor.

Mars for Earthlings

LESSON 18: The Origin of Life

In-Class Activity 1

Miller-Urey Experiment

What is life?

1. In your own words, define "life":

2. What are some requirements for life?

The Miller-Urey Experiment

View the following YouTube animation of the Miller-Urey Experiment:
http://www.youtube.com/watch?v=iahBQolXQH8

3. Describe at least 4 conditions of the experiment.

4. What was "applied" after the gases travelled through the horizontal tube?

5. Was O2 gas an important component of the experiment? Why or why not?

6. Did the experiment accurately represent a scale model of early Earth? Did they set up the conditions of early Earth properly?

The Experiment on Mars

7. Would this experiment be applicable to early Mars?

8. How would you modify the experiment to represent what might have occurred on Mars? Would you modify the experiment?

NASA NAI-Astrobiology

9. Visit NASA's NAI-Astrobiology website and explore the various "headlines." https://astrobiology.nasa.gov/nai/ List at least 2 ongoing investigations that have applicability to researching the "origin of life."

10. Read "About NAI" on the website. Are investigations into the origin of life a NAI focus? Why or why not?

11. When you consider the present and/or past environment of Mars, could you find all the requirements for life?

Mars for Earthlings

In-Class Activity 2
Origin of Life
Mars Life: Through the Lens of Curiosity

Purpose: Students will become familiar with the Curiosity's mission as it pertains to finding life on other planets.

The Mission of Curiosity
View the following video from NASA regarding the mission of MSL Curiosity and answer the following questions:
http://www.youtube.com/watch?v=oHLbXTOaw7w&feature=relmfu

1. What type of "life" are scientists looking for?
2. Can instruments on the MSL Rover Curiosity detect life?
3. What compound is associated with all life?
4. What element is necessary for life?
5. Why would the layering of rocks at Gale Crater be of interest? What might that layering imply?

Looking for Life

1. Does Curiosity have any instruments that can directly test for life?
2. What are some of the challenges related to directly testing for life?

Mars for Earthlings

LESSON 19: Extremophiles

In-Class Activity 1

Tardigrades: Living Extremely

Purpose: Become acquainted with the Tardigrade ("water bear") extremophile, its living conditions, and importance of its scientific study.

Introducing the Tardigrade:
Watch the following You Tube Tardigrade video from the SciShow:
http://www.youtube.com/watch?v=6H0E77TdYnY&continue_action=r7OE3bLJMHT8fAwevwnX9Oh_0zzl6Ajt2P3129QN588gcYR6MkEN_obkOAtaq5MUvFV4Yiq09ljbJDp8wedzPE1U417RionrJuPdT2CAALc=

As you watch the video answer the following questions:

1. What is the *Tardigrade*?

2. What type of environments can the *Tardigrade* live in?

3. What is its importance to science?

Extremophiles

- Acidophile- high pH
- Alkaliphile- low pH
- Anaerobe- no need for oxygen
- Endolith- lives inside rocks
- Halophile- requires salt
- Piezophile/Barophile- requires high pressures
- Thermophile- lives in 40°C or higher
- Xerophile- limited water supply
- Psychrophile- lives in 15°C or lower

Consider the above list. What classification does the *Tardigrade* belong to and why?

Mars for Earthlings

Where could the *Tardigrade* live on Mars?

1. Observe a global Map of Mars. Where could the *Tardigrade* potentially live on Mars? Explain your reasoning.

2. Is studying the *Tardigrade* and other organisms like it useful to space research? Why or why not?

3. What other Extremophiles classifications (see above) could be present on Mars?

Mars for Earthlings

Homework 1
Extremophiles_MFE
Sea Monkey Experiment

Starting thinking: What is an extremophile?

Resources:
On brine shrimp (see materials needed on these sites)

- http://wildlife.utah.gov/gsl/
- http://www.youtube.com/watch?v=kUN61qJtp6s (tutorial on raising brine shrimp)

On extremophiles

- http://www.spiritus-temporis.com/extremophile/types-of-extremophiles.html
- http://www.daviddarling.info/encyclopedia/E/extremophile.html
- Example: Deinococcus radiodurans can withstand 1,500,000 "rads". 500 rads can kill humans!

Introduction:
Sea monkey eggs (like Great Salt Lake brine shrimp) reportedly can survive dormant for > 20,000 years without water. They breathe through their feet and are born with 1 eye but develop 2 more. They are ideal for testing life's response to extreme conditions since they can survive (or remain dormant) in a wide variety of conditions (pH of 2-10, high salinity, various radiation environs, range of temperatures, etc.).

Experiment - Project Assignment:

1. Design a scientific experiment to examine some kind of extreme conditions (without destruction) on the revival and/or survival of dormant life forms (your brine shrimp eggs). You might bake the eggs, drown them in your favorite soda, soak them in acidic lemon juice, or subject them to other extreme conditions or combinations!
2. Carry out a scientific experiment following the scientific method. Record all condition information of time, methods, amounts, solutions etc.
3. After this we will do a "blind test" and your sea monkey eggs will be given to someone else to raise (so you are not tempted to bias the experiment).
4. Meet with the group that attempted to hatch your eggs. Discuss the results in terms of your hypothesis.
5. In a clear and concise write up of your experiment, discuss the results in the broader terms of astrobiology.

In-Class Discussion
Discuss the design of your experiment and outcomes with the class following the submission of your assignment.

Limits of the Brine Shrimp
Were there any conditions too extreme for the brine shrimp?

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Homework 2
Extremophiles_MFE
The Color of Temperature

Objective: Identify why an environment is considered "extreme" and draw inferences about life based upon the attributes/characteristics of these environments.

Extremophiles in Hot Water
Watch the following YouTube video created by GNC Science and answer the following questions: http://www.youtube.com/watch?v=VU-A6Sx7k-U

1. Why is this environment extreme? List characteristics of the environment that would classify this environment as extreme.

2. Given the list of characteristics you provided in #1, name the types of extremophiles that could exist there [refer to the list of extremophiles provided by your instructor].

3. The colors of the hot spring have meaning. What do the colors represent? Which colors represent warmer water and, conversely, cooler water?

Yellowstone: An Earth case study
The photograph (Figure 1), taken in Yellowstone National Park, is a hot spring with outflow channels (hydrothermal environment, similar to above).

4. Determine how many colors you observe and assign a hypothetical temperature range to each color.

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5. Using your temperature ranges, outline the area of each temperature range (at least three but no more than six) to create a temperature map of the photograph provided (this will look similar to a contour map). You may use trace paper over the image to represent the changes you see in color.

Figure 1: A hot spring in Yellowstone National Park (Image Credit: nps.gov Source: http://earthobservatory.nasa.gov/Features/Zircon/zircon3.php)

Draw your map below (be sure to annotate your outlines):

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Holden Crater, Mars

Holden Crater, a potential landing site for MSL Curiosity, is thought to have hydrothermal deposits similar to the Earth environments above. Below in Figure 2 is an example of the terrain provided by HiRISE.

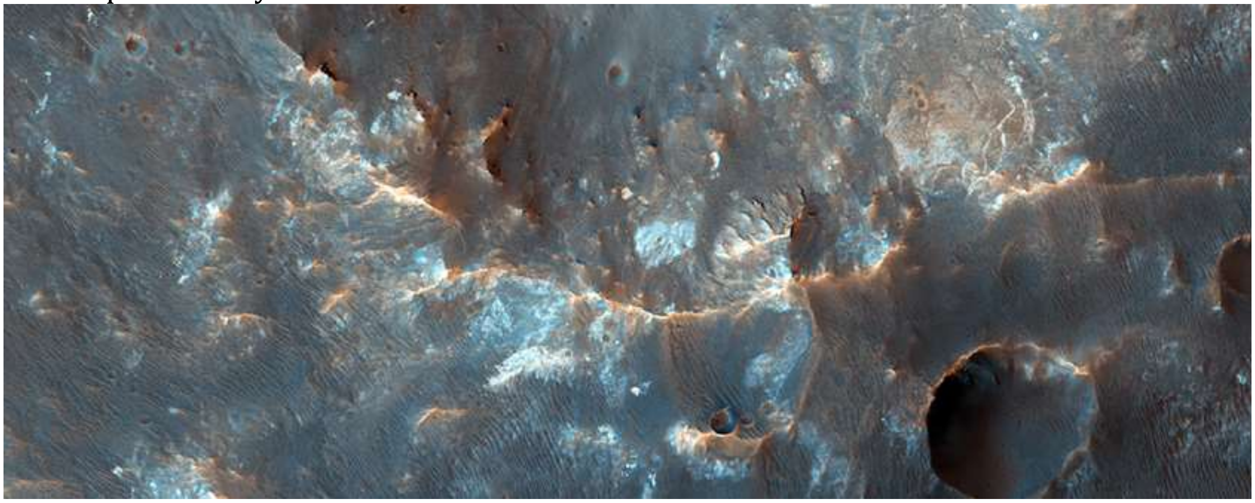

Figure 1: The Western Wall of Holden Crater, HiRISE Image ESP_021946_1535; (Image Credit: NASA/JPL/Univ of Arizona)

1. What do you think the colors represent in the HiRISE image?

2. Using JMARS, capture one CRISM image that would infer a hydrothermal environment and paste below. Hints: (1) Review navigation in JMARS if necessary and investigate the crater walls/rims. (2) Think about what mineral assemblages would suggest a hydrothermal environment.

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LESSON 20: ET in the Universe

In-Class Activity 1

Calling Earth

Purpose: Learn the mission of SETI (Search for Extraterrestrial Intelligence) and their protocols.

If you made first contact…

You are an astrophysicist. If you hear what you think to be communication from outside our solar system, what protocol would you follow to make a conclusive determination? Come up with at least 5 steps.

1. ____
2. ____
3. ____
4. ____
5. ____

Telling the World…

1. After you have determined a conclusive ET signal, what steps would you take to inform the world (list them in order of what you would do first)?

2. Compare your above steps to what SETI has published as their protocol for ET detection (http://www.seti.org/post-detection.html). How do they differ?

3. What ethical implications are involved if such an occurrence were to happen?

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LESSON 21: Kepler

In-Class Activity 1

Seeing like Kepler

Purpose: Understand how Kepler locates planets outside our solar system.

Searching for Exoplanets

Observe the orrery demonstration by your instructor

1. You need to detect a planet, thousands of light years away, orbiting its star. What problems inhibit this detection? List at least 3.

2. How might you overcome these issues?

Determine a Detection Method

Utilizing the help of a few students around you, develop a detection method for observing and studying exoplanets. Explain your detection method and the instruments you will use below (you may do some outside research or consult your instructor to help guide your ideas).

Finding Exoplanets in the Habitable Zone.

1. Navigate to the following link: http://kepler.nasa.gov/multimedia/Interactives/keplerFlashAdvDiscovery/?CFID=9187896&CFTOKEN=28729865 . Follow simulation instructions and record the following:
    a. Choose and record the star system you are observing.

    b. Manually record and make calculations throughout the simulation below:

c. At the end of the simulation, what kind of planet did you find? The programs offers an "artist's rendition" of the planet surface. What does it look like?

d. Determine if your star system has a planet in the habitable zone. Explain the reasoning for why the planet is or is not in the habitable zone.

2. From your experience in the Kepler simulation, what is the habitable zone and how does it relate to Earth? What criterion makes a zone "habitable"?

3. Explain the "transit method" of detecting planets below.

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Homework 1
Detecting Planets_MFE
Light Grapher

Directions

1. Go to: http://kepler.nasa.gov/education/ModelsandSimulations/lightgrapher/

2. Read over the webpage for context.

3. Briefly describe the principle(s) being used in order to locate planets.

4. Read through the directions and hints.

5. Run the program at least 3 different times. For each iteration, change the parameters by trying different methods of interaction with the camera, objects, sizes of objects, spacing of objects from camera, light source, etc. Report each iteration as follows as in the example below.

   Ex:
   Iteration #1
   Parameters Used:
   Outcomes (describe the graph and cut/paste images you capture)**:**

6. From your different iterations, what did you learn about the objects? Did the size, color, transparency, or opacity matter?

7. Consider the planet Mars (typically red-tones) and a planet like Neptune (lighter blue colors). If you were to pass it in front of the webcam which planet would yield a greater change in light? Explain your reasoning.

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Homework 2
Missions Outside our Solar System_MFE
Planet Hunters

Join Planet Hunters

1. Navigate to: http://www.planethunters.org. Register, and begin planet hunting by following the online tutorial.
2. What method is *PlanetHunters* using to detect planets?

3. What role do you play? Will people use your findings? Why or why not?

Classifying the star

4. What types of stars might you encounter? How do you discern the differences with the data provided? Draw examples of each star and the data they provide.

5. Draw below what a planet transit looks like below. From your observations, have most of the stars had a planet transiting? What does this tell you? Would it be possible for a star to have a planet but have an apparent transit?

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LESSON 22: Space Issues

In-Class Activity 1

Manned Space-Flight: Is it needed?

Purpose: Discuss the issues surrounding manned-space flight and the future of space flight.

Resources:

- News Article: http://www.science20.com/brinstorming/near_future_manned_spaceflight-93648
- NASA Human Space Flight Goals: http://www.nasa.gov/pdf/626738main_HEOMD2012Goals.pdf
- NASA roadmap for Astrobiology: https://astrobiology.nasa.gov/roadmap/
- Space-X CEO Interview: *http://www.youtube.com/watch?v=IiPJsI8pl8Q&feature=related*

Manned-Space Flight Discussion in the News:

Listen to "The Near Future of Manned Space Flight."
http://www.science20.com/brinstorming/near_future_manned_spaceflight-93648

1. What is your reaction to the article?

2. What do you think should be the future of space flight?

Review NASA Human Space Flight Goals and the NASA roadmap for Astrobiology.
http://www.nasa.gov/pdf/626738main_HEOMD2012Goals.pdf
https://astrobiology.nasa.gov/roadmap/

1. What points do you believe are important?

2. What aspects did you not expect?

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Space X Plans to put man on Mars in 10 years

Watch the interview with the CEO of Space-X (start interview at Time- 13:00-15:30)
http://www.youtube.com/watch?v=IiPJsI8pl8Q&feature=related

1. What do you think of this venture?

Statement to a Congressman/woman:

Prepare a 2-page statement to a Congressman/woman recommending or not recommending funding for space flight using NASA published goals and/or other publicly announced space flight goals.

a. Identify a real and acting member of Congress and write letter/statement accordingly.
b. Cite publications that support your recommendation

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In-Class Activity 2
Space Issues_MFE
Space Flight going Private

Purpose: Become aware of private companies pursuing space flight and their role outside of NASA's Mission directorate (government vs. private funding).

Dragon docking with the ISS
Watch the following video of Space X's Dragon spacecraft docking with the ISS:
http://www.youtube.com/watch?v=QwDCWTqNceQ&feature=player_embedded

a. What is significant about this event?

b. What are your reactions to this venture?

Government vs. Privatization

1. Make a list of the pros and cons of private companies taking over the space program:
   Pros Cons

2. Space X is awarded the manned-space flight contract.
   Video: http://www.youtube.com/watch?v=MZJk4CrxctQ&feature=youtu.be
   If you had the money, would you buy a seat? Why or why not?

3. Why is the Space X craft remarkable?
   Video: http://www.youtube.com/watch?v=sSF81yjVbJE&feature=related

4. What do you think of *Space X's* Mars Business Model?
   Video: http://www.youtube.com/watch?v=4fS1FxBq64A&feature=relmfu

Final Verdict
As a class, come to a final verdict "as congress" on whether or not NASA should privatize. Compromise is likely necessary.

Mars for Earthlings

Homework 1
Future Mars Missions & Societal Issues_MFE
Cut a Budget: An ethical debate?

Objective: Critique the viewpoint of a proponent of increased NASA funding and cut a theoretical mission budget to fit NASA cut backs.

A Viewpoint on NASA funding
Watch the following YouTube video, narrated by Neil deGrasse Tyson, concerning the national budget and NASA. Neil deGrasse Tyson is an astrophysicist and director of the Hayden Planetarium.
Video: http://www.youtube.com/watch?v=Fl07UfRkPas&feature=youtu.be

1. Do you agree with any of Neil deGrasse Tyson's points?

2. Similarly, do you disagree with any of his points?

3. Do you find Dr. Tyson's line of argument flawed? If so, why?

A Proposed Budget
Below is a proposed hypothetical NASA budget with all budget elements compliant with NASA documentation:
http://www.hq.nasa.gov/office/procurement/nraguidebook/proposer2013.pdf

4. Scrutinize the budget and make a 30% cut to your budget. NASA will approve this mission if you can cut your budget by 30%. For reference on what each budget item means see the above .pdf url link. (1) Show and justify all changes you make to achieve the 30% cut. (2) Attach an extra sheet of paper for justification if necessary. (3) Add items you think are necessary.

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Proposed Budget
(Sample, direct costs)

Mission: Orbit Europa

Duration: 4 years

Category	**Sub-Category (#)**	**Cost per Unit**	**Cost Total (4 years)**
Direct Labor	PI- Scientist (1) (1FTE)	$112,000	$448,000
	Co-I Scientist (3) (1/2 FTE))	$55,000	$660,000
	Co-I Engineer (5) (1FTE)	$95,000	$1,900,000
	Co-I Educator (1) (1/2 FTE)	$40,000	$160,000
	Post-Docs (3)	$48,000	$576,000
	Graduate Students (7)	$24,000	$672,000
	Undergraduate Students (3)	$3,000	$36,000
Other Labor	Consultant- Science (2)	$15,000	$120,000
	Consultant- Education (1)	$10,000	$40,000
Equipment	Orbiter (includes thermal, power, navigation, launch vehicle, etc)	$425,000,000	$425,000,000
	Cameras (1)	$31,000,000	$31,000,000
	Spectrometer (1)	$17,600,000	$17,600,000
	Website development	$40,000	$80,000
Supplies	Publications	$2,000	$10,000
	Software	$20,000	$20,000
	Computer Stations	$50,000	$50,000
Travel	LPSC Meeting Registration	$100	$800
	AGU Meeting Registration	$350	$2,800
	AAAS Meeting Registration	$400	$3,200
	Per Diems ($40/day /person)	$320	$10,240
	Airfare (roundtrip/person)	$600	$4,800
	Lodging (night/person)	$140	$4,480
	Transportation (trip/person)	$40	$960
Facilities/Administration	Imaging lab (yearly)	$15,000	$60,000
	Imaging rendering lab (yearly)	$15,000	$60,000
		Mission Total	$478,519,280

Mars for Earthlings

LESSON 23: Project Mission to Mars

Final Project

For a final class project, you will have the opportunity to put together your own **mission to explore the red planet**! Here is a chance to put all your creativity to work. What do you think is scientifically relevant and deserves a closer look, based on what you've learned in the class? Where will you go? How will you get there? What are the potential obstacles? What is new and novel? What is the major science question you are addressing? What kind of data will you generate? What will it cost? What will be the outcomes and benefits? How will your mission proposal stack up against others?

In this project you will:
1. Work in teams, capitalizing on different classmate strengths.
2. Define a mission project complete with science goals, background research, engineering, and technology designs for exploration.
3. At the end of the term, you will give an oral 15-minute team presentation of your project to be peer reviewed and evaluated with recommendations for funding or not.

In order to make sure you progress on the project throughout the semester, you will be give specific milestone deadlines so that you don't wait till the last minute. This includes an outline of your basic project, assignment of roles for each team member, and verbal consultation with the instructor on feasibility plans.

See if you can be successful in convincing a review panel that your project is worthy of funding. A typical evaluation that your classmates will fill out for each presentation is below:

PANEL EVALUATION (Class Peer Evaluation)

Team roles (defined)	____________
Presentation clarity	____________
Presentation Delivery	____________
Mission Objectives	____________
Background	____________
Merit	____________
Budget	____________
EPO (Education Public Outreach)	____________
Citations	____________

RECOMMEND YES NO

You will be asked to self-evaluate your effort and that of your team members to ensure that the final project grade also reflects each person's input.