Lesson 17: Vast Deserts on Mars

Summary
Using a Sandbox experiment and Google Earth students will study the formation of dunes and relate their observations to Mars dune field imagery.

Learning Goals

Students will be able to:

- Identify wind current directions on Earth and Mars
- Explain the formation of certain dune morphologies.
- Use Google Earth to identify changing paleocurrent direction, bounding surfaces, and their potential to be observed/preserved on Mars.

Context for Use
This learning module is meant for integrating the Martian wind into terrestrial analysis. The *In-Class Activities* can be easily adapted for homework when desired.

Description and Teaching Materials
In-Class Activity

In-Class Activity 1: Sandbox Dunes
In-Class Activity 2: Martian Ventifacts

Homework/Lab

Homework 1: "Bounding" Through Dunes

Teaching Notes and Tips

1. For larger classes (>20 students) you can either create your own Sandbox Dune demonstration or use the Video demonstration (see Resources).
2. In Homework 1: students will need a clear understanding of how dunes and dune processes are recorded in the rock record (marching away from you, toward you, paleocurrent direction etc.).
3. You will often integrate the Explain and Explore sections of the In-Class Activities. Interact with the students as they "explore" and help them define terms/principles (Ex: Sandbox Dunes).

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

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References and Resources

1. Image file: Vast Deserts on Mars
2. Antarctica Ventifacts
3. Sand Box Dune Video: http://serc.carleton.edu/details/files/44290.html
4. Grotzinger, J.P. et al., 2005. Stratigraphy and sedimentology of a dry to wet eolian depositional system, Burns formation, Meridiani Planum, Mars. Earth & Planetary Science Letters, v. 240, p.11-72.
5. Burns Formation PanCam Sol 288 Image Source: http://marsrover.nasa.gov/gallery/all/1/p/288/1P153752565ESF37MIP2544L7M1.HTML

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In-Class Activity 1
Vast Deserts_MFE
Sand Box Dunes

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

Preparation:

1. Build your own Sandbox or download the video of MFE's sandbox demonstration from **References and Resources** of this module for use in the classroom.

Resources:

1. For full resolution images in this *In Class Activity* use the PowerPoint image file (.pptx) for this module located in **References and Resources**.
2. Sandbox video: http://serc.carleton.edu/details/files/44290.html
3. HiRISE Dune Image Source: http://hirise.lpl.arizona.edu/ESP_012202_1390
4. THEMIS Dune Image Source: http://themis.asu.edu/node/5758
5. Mars Global MOLA map: http://mola.gsfc.nasa.gov/images/mercat_med.jpg

Engage

Encourage discussion from students using the following questions:

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*

Explore

1. Take the students through a Sandbox demonstration (via video or http://serc.carleton.edu/details/files/44290.html from Mars for Earthlings website, or your own sandbox)
    a. Vary sediment input
    b. Vary wind speed

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   c. Vary surface area or focus of wind source
   d. If possible incorporate varying wind directions to achieve multi-directional dune morphologies
2. Watch the sandbox demonstration and answer the following
   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?
3. View Mars Images
   a. Present students the following Mars Images (see **Resources** in this activity). Indicate where these areas are found on Mars using Google Mars or the annotated image in the Image File for this module).
      i. HiRISE: ESP_012202_1390 Dunes in the Western Nereidum Montes (38.6S, 44W)
      ii. THEMIS: V43323004 Terra Sirenum (39.7S, 150W) is the location of this image. The unnamed crater has dunes on its floor (students will likely have to zoom-in on the image).
   b. Have students discuss the following
      i. What is the prevailing wind direction in each image?
      ii. Are the dunes multi-directional? If so, how can the students tell?
      iii. Is there more than one dune shape/morphology (barchans, transverse, longitudinal, parabolic etc.)? If so, what are they?

Explain

1. As students complete their observations in **Explore** discuss the following terminology in light of their sketches and observations *before they interpret Mars* images.
   a. Angle of Repose
   b. Slip face
   c. Saltation
   d. Deflation and Abrasion
   e. Dune Morphologies (barchans, transverse, longitudinal, parabolic etc.)
2. If possible, have students label these terms in their sketches after they are finished sketching.

Elaborate

Referring to the Mars Images utilized in **Explore**, encourage students to interpret the following about the eolian system:

1. What is the sediment supply like (abundant, sparse)? Have students explain their answer.

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2. According to your knowledge of the geography of Mars and its regions, what might be the source of the sediment (Supply students a copy of a Mars MOLA or project the global MOLA map)?

Evaluate

1. Peer evaluation
    a. In both the Exploration and Elaboration activities, try having students write their answers on cards and pass them to their neighbors
    b. Have their peers agree or disagree with their findings. Given time, have them discuss their findings.
2. The labeling activity in **Explain** will help instructors determine whether or not students comprehend the terms and their use.

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In-Class Activity 2
Vast Deserts_MFE
Martian Ventifacts

Purpose: Explore the existence and formation processes of ventifacts.

Preparation
Depending on your mode of delivery (in class versus a homework setting), load the Image File .ppt for the class and make sure you have an Internet connection to view the associated videos.

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

Engage
Have students observe the large ventifact in Death Valley (see Image File, Photo by Marjorie Chan)

1. What formation seems odd to the students? Have they seen anything like it? Why is there only one?
2. Ask students to hypothesize how this might have formed.

Figure 1: Death Valley Photo, credit: Marjorie Chan

Explore
Ask students to view the following video and answer the following questions. Start a discussion with your students.
http://www.youtube.com/watch?v=OOqOm3KgGMw&feature=endscreen

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1. What do the students look for in order to determine if a rock or feature is a ventifact?

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

3. What causes the reddish-orange coloration?

Explain

Definition: Ventifact- A rock that has been shaped or polished by the sandblasting effect of wind-blown sand

Elaborate

Here are what might be considered ventifacts on Mars:
http://www.psi.edu/sites/default/files/imported/pgwg/images/VentFig4.jpg

1. Bring up images on the screen or provide laminated copies upon which students can make annotations
2. Ask students to label the wind direction on each: A thru G.
3. Discuss with students the preservation potential of these eolian reworked deposits.
    a. Is the preservation potential higher on Mars or Earth? Have the students explain their reasoning via images where possible.

Evaluate

1. Do the students believe that these are indeed ventifacts? Why or why not? Which images are the best examples of true ventifacts? Which images are more dubious?
2. Discuss student ideas and their understanding of ventifact formation and their indicators for wind current direction.

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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 the students have Google Earth downloaded on their 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 the viewing window.

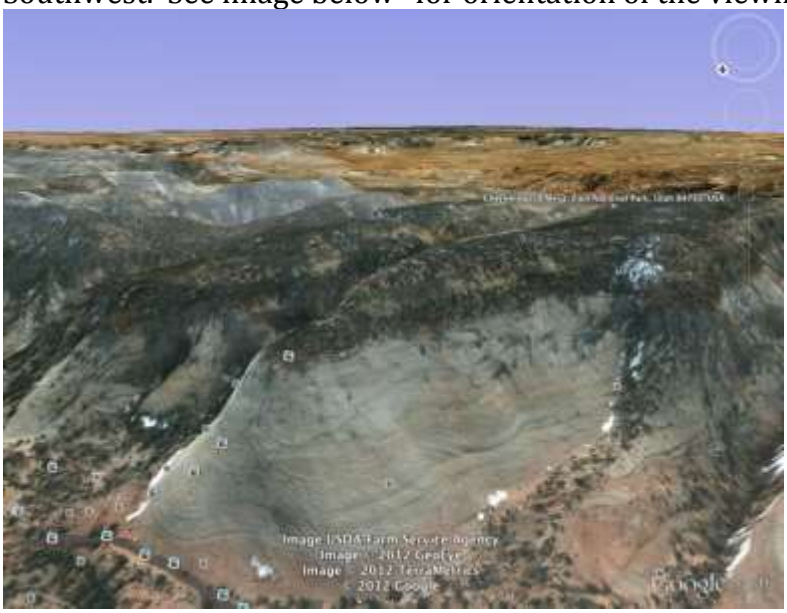

Figure 1 Image captured through Google Earth

Have the students capture their own .jpg and insert their image into a PowerPoint file.
*the image in this exercise is not zoomed in or large enough for their PowerPoint slide

3. In PowerPoint, have students annotate their 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

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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 the students 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 they observe in Image C of Figure 3? Why do some layers "look different"?

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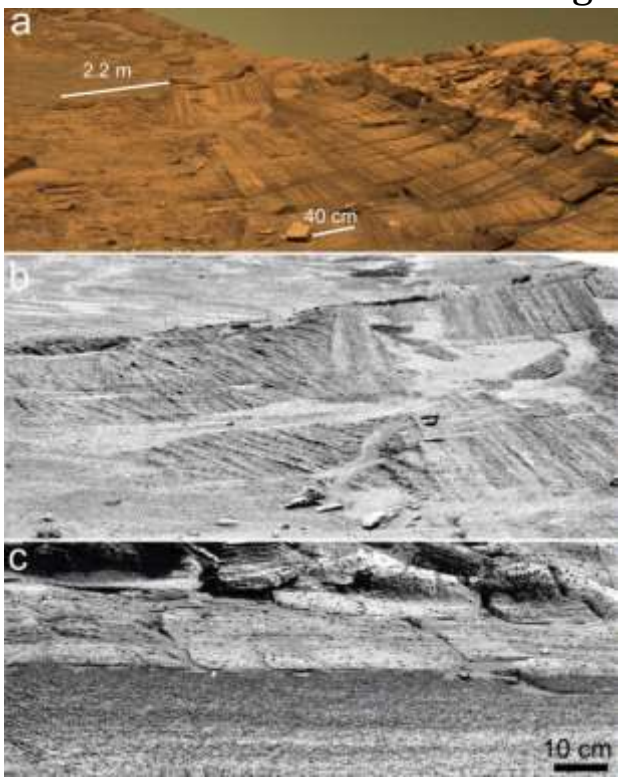

Figure 3: Burns Formation stratigraphy (Grotzinger et al., 2005).