Mars Image Analysis

Grades: 9-12 Prep Time: ~10 Minutes Lesson Time: 3 Hours

WHAT STUDENTS DO: Establish geologic sequences in a Mars image.

Students step into the shoes of real planetary scientists. Using large-format images of Mars, provided by Mars Education at Arizona State University, students reach conclusions about the geology of Mars. Students are tasked with identifying features on the surface of Mars, determining the surface history of the area, calculating the size of features, and developing research questions.

NRC FRAMEWORK/NGSS CORE & COMPONENT QUESTIONS

WHAT IS THE UNIVERSE, AND WHAT IS EARTH'S PLACE IN IT?

NRC Core Question: ESS1: Earth's Place in the Universe

How do people reconstruct and date events in Earth's planetary history?

NRC ESS1.C: The History of the Planet Earth

How do Earth's major systems interact?

NRC ESS2.A: Earth Materials and Systems

INSTRUCTIONAL OBJECTIVES (IO)

Students will be able to:

IO1: Reconstruct geologic events using empirical evidence while assuming the laws of nature on Mars are relatively similar to those laws on Earth.

IO2: Respectfully debate potential Mars geologic history research topics and questions to elicit relevant information, using quantitative and qualitative evidence and scientific reasoning based on personal observations and previous scientists work regarding patterns of change or possible relationships.

See Section 5.0 and Teacher Guide at the end of this lesson for details on Instructional Objective(s), Learning Outcomes, Standards, & and Rubrics.

1.0 Rationale

Students and teachers alike are often confused or mislead by the textbook version of the scientific method. The process of science is often portrayed as a linear process with a defined beginning and endpoint. For many very young students (K-4), the linear process is a good place to start as they are learning the scientific method; however, for older students, the focus on the iterative process of science begins to develop.

The intent of these lessons is to address the misconceptions of the scientific method and teach a much more accurate representation of the process as a whole. Each segment will provide a rationale section, similar to this one, explaining the intent of the lesson along with possible iterations.

Last edited: February 25, 2016

2.0 Material

Required Materials

Please supply:

- Wet erase marker - 1 per group
- Ruler - 1 per group
- Calculator - 1 per student
- Optional: Computer and Projection System

Materials Supplied from Mars Education:

- Feature ID Charts - 1 per group
- THEMIS image - 1 per group
- MOLA map - 1 per group
- Optional: Mars Image Analysis PowerPoint Presentation

Please Print:

From Student Guide:

(A) What Can You Tell from a Picture?	- 1 per group
(B) Background	- 1 per student
(C) Lesson Background	- 1 per student
(D) Student Data Log	- 1 per student
(K) Making Measurements Notes	- 1 per student
(L) Student Measurement Data Log	- 1 per student
(M) Establishing a Research Topic of Interest	- 1 per student
(N) Background Research	- 1 per student
(P) Example Observation Table	- 1 per student
(Q) Observation Table	- 1 per student
(R) Choosing a Topic for Research	- 1 per student
(T) Reflection	- 1 per student

NGSS Teacher Tip: Print the *(T) Reflection of Science and Engineering Practices* on blue paper and *(T) Reflection Crosscutting Concepts* on green paper to match the color-coded posters and standards.

From Supplemental Materials:

(E) Sunlight and Shadows	- 1 per group
(F) Determining the Relative Ages of Features	- 1 per group

(G) Crater Classification – Guide	- 1 per group
(H) Relative Age Dating Principles – Guide	- 1 per group
(O) Using THEMIS Website to Make Scientific Observations	- 1 per student
(S) Feature ID Charts	- 1 per group

Optional Materials:

Supplemental Materials:

(I) Classifying Craters	- 1 per student
(J) Relative Age Dating Principles	- 1 per student
(V) Classifying Craters – Sample Answers	
(W) Relative Age Dating Principles – Sample Answers	

Teacher Guide:

(U) Teacher Resource #1
(V) Teacher Resource #2
(W) Mars Image Analysis Rubrics
(X) Alignment of Instructional Objective, Standards, & Learning Outcomes

NGSS Materials:

"A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas" (NRC, 2012), also known as the Framework, articulates a vision of exemplary science instruction based upon current research. This vision centers on 3-dimensional learning in which Disciplinary Core Ideas, Science and Engineering Practices, and Crosscutting Concepts in science and engineering are coherently integrated in instructional design. It isn't enough, however, that students engage in the Practices as they develop a deep understanding of the Core Ideas. Students must also be cognitively aware of what they are doing and what the Practices are. The reflection assignment will engage students in thinking about the Practices, about what those Practices are, and how the Practices relate to doing science.

This lesson will assist you in integrating this activity and will suggest resources.

Please Print:

NGSS Practices Poster
NGSS Crosscutting Concepts Poster
NGSS Understanding about the Nature of Science Poster

Please Read:

Appendix F – Science and Engineering Practices in NGSS
Appendix G – Crosscutting Concepts
Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

3.0 Vocabulary

Analyze	consider data and results to look for patterns and to compare possible solutions
Classification	the assignment of objects to categories based on characteristics
Deposition	accumulation of material (such as sediment)
Erosion	the process where the surface of a planet is worn away by water, glaciers, winds, waves, etc.
Evaluate	check the scientific validity or soundness
Everyday Observation	the act of noting facts or occurrences that are common characteristics.
Explanations	logical descriptions applying scientific information
Geologic History	the history of geologic events (such as erosion, deposition, glaciers, volcanism, etc.) of an area
Inference	drawing a logical conclusion based on observations and data collection
Scientific Observation	the act of noting facts or occurrences that are unique or interesting and can lead to a scientific research question.
Qualitative Observation	the act of noting facts or occurrences that are based on physical characteristics or attributes, such as color or texture.
Quantitative Observation	the act of noting facts or occurrences that are based on numerical data, such a counting the number of a feature or making measurements of a feature.
Weathering	mechanical and chemical processes that cause exposed rock to decompose

4.0 Procedure

PREPARATION (~15 minutes)

A. Print materials
B. Organize 1 THEMIS image, 1 MOLA map, 1 set of (S) *Feature ID Charts*, and 1 wet erase marker for each group (face down on table).

STEP 1: ENGAGE (~10 minutes)

What can you tell from a picture?

A. At the beginning of the lesson very briefly tell students that scientists and engineers engage in certain practices when they are doing science or engineering and certain fundamental ideas are applicable to all science and engineering, called crosscutting concepts.

B. Provide either wall posters (11 x 17 format) or individual handouts (8.5 by 11 format) briefly describing the Practices and Crosscutting Concepts (be sure to include the Nature of Science also).

C. Tell students that they will be asked to identify if they do any of these practices at the end of the activities.

 NGSS Teacher Tip: The descriptions of the Practices and Crosscutting Concepts on the poster or handout are brief; therefore, you may wish to become more familiar with the Crosscutting Concepts and the Understandings about the Nature of Science. You can get very good information from the Next Generation Science Standards (NGSS) web site. Recommended are *Appendix F – Science and Engineering Practices in NGSS, Appendix G – Crosscutting Concepts*, and *Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards*. These resources will help you to assist your students if they say that they don't understand the Practices, Crosscutting Concepts, or the Nature of Science. Also, in the Alignment document provided for this lesson the instructional designers have indicated the Crosscutting Concepts they have determined to be most appropriate.

A. Hand out THEMIS image, (A) *What can you tell from a picture?* Sheet.

D. Ask students to look at the top image on page 1 of *(A) What can you tell from a picture?* and ask where the arrow is pointing on the map. Ask the students to make observations and share their observations about this area on the image.

E. Next, ask the students to look at the second and third images on (*A) What can you tell from a picture?* (which are zoomed-in versions of this image) in both colorized elevation and black and white infrared imaging. Again, make observations and share them about this area on their image. Do they understand anything different about this area than they did before? Share out with the classroom.

F. Finally, ask the students to look at the final image on (*A) What can you tell from a picture?* - a black and white THEMIS image. This image is further zoomed in for even more detail. One last time, ask them to make observations and share their observations about this area. Do they understand anything different about this area than they did before? Share out with the classroom.

G. At this point, the students should have made many observations. Ask students what information is missing? If we were to attempt to explain why this crater looks so different from other craters, what else would we need to know, observe, or understand to do that? (Students should say they need more observations, find more distinguishing characteristics, possibly a closer image or other types of data.)

H. Point out that images provide the simplest means of exploring another world. We use images of Mars to make observations and identify what other information we need. We zoom in and zoom out to get better detail or more information about our image. We will look at some of these THEMIS images of Mars. Before we do, let's learn a little about THEMIS. Hand out *(B) Background sheet*.

STEP 2: EXPLORE (~60 minutes)

- Print B-L and S in Materials list

Image Analysis

Identify Surface Features

(See Teacher Resource #1 and #2 for an orientation of these materials)

A. Before distributing materials, have students brainstorm analogous features they know exist on Earth that may also exist on Mars. This will help students build knowledge and make connections to previous knowledge throughout the activity.

B. Have students read (*C) Lesson Background* to orient them to the purpose and intent of the lesson.

C. Familiarize and distribute Feature ID Charts, *(E) Sunlight and Shadows Sheet*, and THEMIS images to students.

D. Have students use erasable markers to identify features on laminated THEMIS images using *(S) Feature ID Charts*. Have students initially work with one image.

E. After ~10-15 minutes, have students exchange images they have analyzed so other students can make observations from each of the images.

    i. End this part of the activity with a discussion of features observed in images from either the PowerPoint slides or paper.

    ii. Ask students to record the identified features into the *(D) Data Log Sheet* and the geologic processes involved in their creation.

Teacher Tip

The observations students will make here are most likely considered “everyday observations.” This means they will be simplified to examples such as “There are 30 craters in the image.” While this is a true observation, it most likely will not lead to an experimental question. Providing extra time, even when the students appear to be done and off task will allow them to make better observations; however, students may need more content knowledge about the topic they choose before they can make scientific observations. This will be addressed later in the lesson.

Determine the Relative Ages of Features
(See Teacher Resource #2 for an orientation of these materials)

A. Before distributing materials, discuss with students how they may know when one feature is older or younger than another. This will again help students build knowledge and make connections to previous knowledge throughout the activity.

B. Familiarize and distribute *(H) Relative Age Dating Principles Guide* and **(***G) Crater Classification Guide* handout to students.

C. Have students use erasable markers to identify relative ages of features on the original image they were working with. Have students at least label the “oldest” and “youngest” feature. Students can then identify relative ages of other features with respect to the oldest/youngest feature.

D. After ~8-10 minutes, have students discuss the relative ages of features on their image with other groups. Students should discuss the geologic history (what has happened in their area of Mars) as part of their discussion.

E. Ask students to go back to their *(D) Student Data Log* and include the order of which the features have occurred in the Relative Age column and the evidence they used to determine this rank in the Evidence column.

Teacher Tip

Supplemental Materials *(I) Classifying Craters* and *(J) Relative Age Dating Principles* have been provided as additional practice sheets to strengthen their understanding of these principles that are often incorporated in National and State standards. Answer Keys can be found in *(V)* and *(W).*

Calculate the Size of Features

A. Using *(K) Student Measurement Notes* **sheet**, have students measure and simply label features using metric units.

B. Review the example of calculating the size of features in THEMIS images with students.

C. Have students determine the *scale factor* of their image.

D. Once students have determined the *scale factor* of their image, make sure they write this somewhere on their image.

E. Have students use the measurements (in centimeters) of the features labeled on their image and make the appropriate calculation (feature measurement X scale factor) to determine the size of each measured feature in kilometers on Mars.

F. Have students write these measurements for each feature into their *(L) Student Measurement Data Log* in the Measurement column.

Teacher Tip

This would be a good time to discuss scale. Have students estimate the size of the classroom in meters, measure the room, then figure out how many of their classroom would fit into one of their features. For example, in a 3-kilometer wide crater, your classroom may fit inside it 200 times!

STEP 3: EXPLAIN (~50 minutes)

Discussion and Sharing

Identify Surface Features:

A. End this part of the activity with a discussion of features observed in images

Determine the Relative Ages of Features:

A. After ~8-10 minutes, have students discuss the relative ages of features on their image with other groups. Students should discuss the geologic history (what has happened in their area of Mars) as part of their discussion.

Calculate the Size of Features:

A. Have students use the measurements (in centimeters) of the features labeled on their image and make the appropriate calculation (feature measurement X scale factor) to determine the size of each measured feature in kilometers on Mars.

B. Have students write this measurement for each feature into their *(L) Student Measurement Data Log* in the Measurement column.

C. Organize students into groups of size and composition you know to be most effective.

D. Hand out (F) **Reflections.**

E. Allow discussion for 10 – 15 minutes.

F. Ask each group to share its best thinking about which Practices and Understanding of Nature of Science were done, when it was done, and what the group's reasoning was for this. Record the results from each group in columns on the board.

Teacher Tip: The most important part of these activities is to engage students' thinking about the Practices, Crosscutting Concepts and the Nature of Science. The emphasis is on the rationale the students provide rather than what Practices or Crosscutting Concepts were identified in the Alignment document. Be prepared to ask questions to elicit more complete reasoning for the group's decision. Allow discussion if groups do not initially agree. The discussions will help to develop deeper understandings.

STEP 4: ELABORATE (~15 minutes)

- Print (M-R)

Compare Mars to Earth

A. Have students take their list of geologic features they have identified on Mars and make a list of similar Earth geologic features and their locations.

B. Compare and contrast the geologic features on both planets.

C. Present a hypothesis as to why the geologic features might differ.

Establishing a Research Topic

Materials Needed:
- (N) Background Research
- (O) Using THEMIS Website to Make Scientific Observations
- (P) Example Observation Table
- (Q) Observation Table (2 sheets)
- Index cards (3"x5")
- Markers

A. Have each student find a partner and work together to fill in list #1 on the *(M) Establishing a Research Topic of Interest* sheet. They should spend about 3-5 minutes doing this and can come up with topics from any aspect of Mars exploration or geology that interests them.

B. As a class, the students will need to debate and establish their research topic of interest. Should the class be evenly split on a research topic, they could possibly combine their two top topics by establishing a relationship between the two topics to explore.

C. After the students have established a topic, they will need to do some research about it. The goal is to learn how the feature forms, where they are typically found, if there are similar features on Earth or other planetary bodies and how they are the same or different to feature on Earth or other planetary bodies. Students should become experts on their topic. Photocopy as many *(N) Background Research* sheets as they will need.

D. Students may need help getting started with their research. Here are a couple of sources they can use to learn more about their topic of interest:
   - http://themis.asu.edu/topic
   - http://redplanet.asu.edu/

Making Scientific Observations

A. Using background knowledge on their topic, students will make scientific observations about their selected topic as opposed to everyday observations.

B. Point out that the primary difference between these types of observations is the understanding of the topic. A scientist who understands how craters are formed will notice a crater(s) with a different pattern, shape or possibly different features that are interesting or unique to the crater. Simply observing that a crater exists is an everyday observation.

C. Their research will help the students make scientific observations. For example, their observations will improve from "There are 30 craters in the image." to "There are 5 Modified craters, 25 destroyed craters, 10 craters are less than 2km wide, 20 are greater than 2 km wide, all of the modified lack a central peak, etc."

D. Students will use *(O) Using THEMIS Website to Make Scientific Observations, (P) Example Observation Table,* and *(Q) Observation Table.*

Choosing a Final Research Topic

A. Students will complete *(R) Choosing a Topic for Research* and share their most interesting scientific observations from *(Q) Observation Table*. These observations will guide the potential discussion and will allow them to group topics or concepts.

B. It may be helpful to use index cards for topics and scientific observations. They may even find they can incorporate a couple of topics of interest for primary and secondary science. Allow the students to debate and come to a consensus on the final topic for research. This is an opportunity to experience authentic science and debate. Scientists typically do not work individually. They discuss ideas and interesting topics for research with other scientists in the field.

> "Critical thinking is required, whether in developing and refining an idea (an explanation or a design) or in conducting an investigation. The dominant activities in this sphere are argumentation and critique, which often lead to further experiments and observations or to changes in proposed models, explanation, or designs. Scientists and engineers use evidence-based argumentation to make the case for their ideas, whether involving new theories or designs, novel ways of collecting data, or interpretations of evidence. They and their peers then attempt to identify weaknesses and limitations in the argument, with the ultimate goal of refining and improving the explanation or design." (National Research Council Science Framework, pg. 46.)

STEP 5: EVALUATE (~20 minutes)

- Print Rubrics

Evaluate proposed solutions using criteria.

Identify Surface Features

A. Ask students to record the identified features into the *(D) Data Log Sheet* and the geologic processes involved in their creation.

Determine the Relative Ages of Features

A. Ask student to go back to their *(D) Student Data Log* and include the order of which the features have occurred in the Relative Age column and the evidence they used to determine this rank in the Evidence column.

Making Scientific Observations and Establishing a Research Topic

Last edited: February 25, 2016

A. For students to make scientific observations instead of everyday observations, they will need to understand a topic very well. To do that, they will need to establish a topic that interests them about Mars and do in-depth research on that topic. Scientific observations lead to testable research questions. A rubric has been provided to evaluate the student's ability to write scientific observations and to actively debate the qualities of a good research topic.

5.0 Extensions

CALCULATING HEIGHTS AND DEPTHS OF FEATURES:
Students can calculate depths and heights of features by dividing the length of a shadow by the tangent of the incidence angle (incidence angle information is provided).

To do this, students would use the following steps:
- Measure the width of the shadow in centimeters.
- Using the calculated scale factor (Part 3 of the *Mars Image Analysis* activity), convert the shadow measurement to kilometers.
- Divide that calculated measurement by the tangent of the incidence angle to compute the depth of the feature being observed.

PARTICIPATING IN THE MARS STUDENT IMAGING PROJECT:
This activity can be used as an introduction to participation in the Mars Student Imaging Project (MSIP). The Mars Student Imaging Project allows students to conduct authentic research about Mars with the opportunity to target a new image from the THEMIS visible camera onboard the Mars Odyssey spacecraft. For more information on the Mars Student Imaging Project, go to http://marsed.asu.edu/msip-home.

ANALYZING OTHER THEMIS IMAGES:
Students can analyze other THEMIS visible images available on the THEMIS website: http://themis.asu.edu.

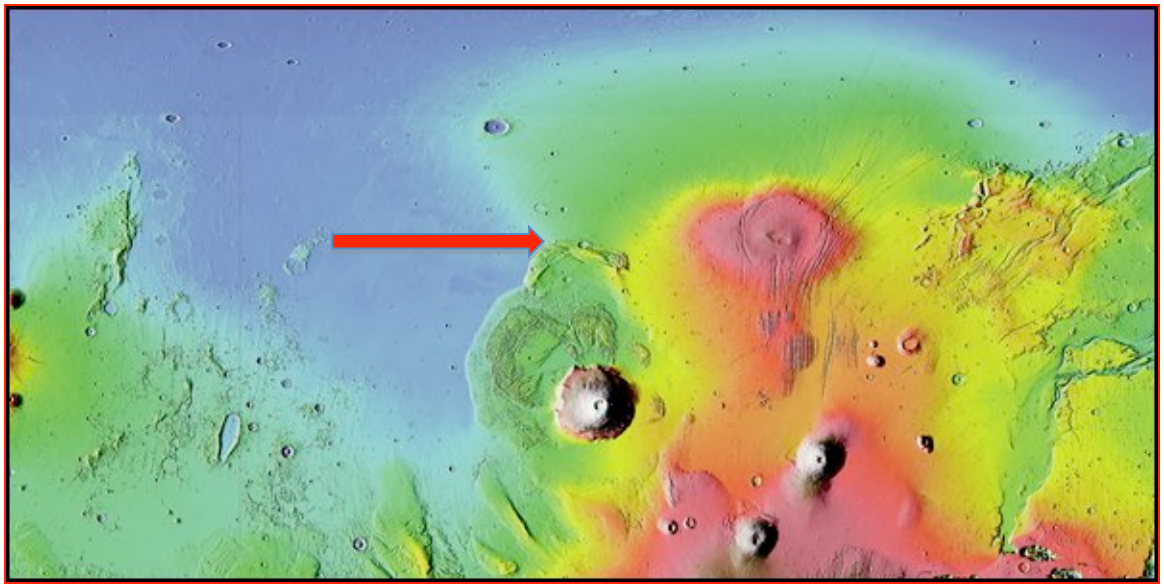
GETTING INVOLVED IN OTHER MARS-RELATED OPPORTUNITIES:
Students can get involved in activities available on NASA's Be A Martian website: http://beamartian.jpl.nasa.gov/welcome.

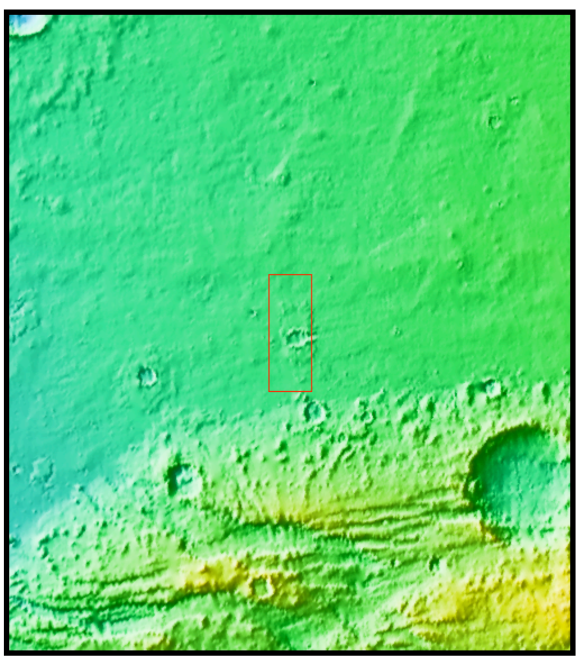
6.0 Evaluation/Assessment

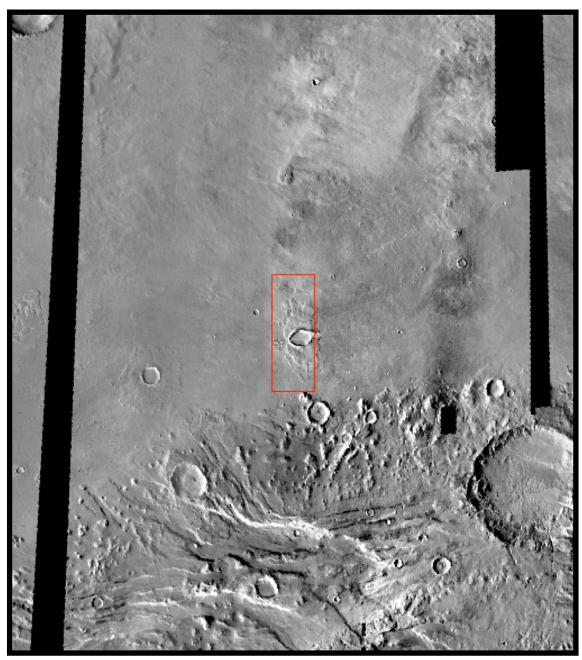
Use the *(X) Mars Image Analysis Rubric* as a formative and summative assessment, allowing students to improve their work and learn from mistakes during class. The rubric aligns with the NRC Framework, National Science Education Standards, and the instructional objective(s) and learning outcomes in this lesson.

(A) What can you tell from a picture? (1 of 2)

NAME:_______________________________







(A) What can you tell from a picture? (2 of 2)

(B) Background

How do scientists understand and interpret the surface features of Mars from orbit and determine if a proposed landing site will meet the mission's science goals? The distance to Mars varies between 80 and 240 million kilometers (50 – 150 million miles). The planet is therefore studied using remote sensing techniques. As part of the science studies from the *Mars Global Surveyor* and *Mars Odyssey* missions, images from these spacecraft have provided valuable information that has been used to understand the surface of Mars in the context of finding and evaluating possible landing sites. The images from these orbiters have also given scientists a better understanding of the past geologic history and the present conditions on Mars. The geological processes that occur on Mars are similar to those that occur on Earth. Comparative planetology, especially between Earth and Mars, is widely used by scientists currently researching Mars. As you work through this activity, think about what you know about Earth to help you better understand the processes on Mars.

Photo Courtesy of NASA's Jet Propulsion Laboratory

For this activity, you will be using images taken with the Thermal Emission Imaging System (THEMIS) camera on-board Mars Odyssey Spacecraft orbiter (pictured above). THEMIS has taken hundreds of thousands of images of Mars that are available on the internet at http://themis.asu.edu.

THEMIS (pictured right) is a two-in-one camera system:

- Visible Imaging System
  - Shows the morphology or shape of the surface
- Infrared Imaging System
  - Can tell us the temperature of the surface (daytime and nighttime)
  - Provides information about what materials on the surface are made of
  - Daytime infrared images can also show the morphology or shape of the surface in much the same way visible images do.

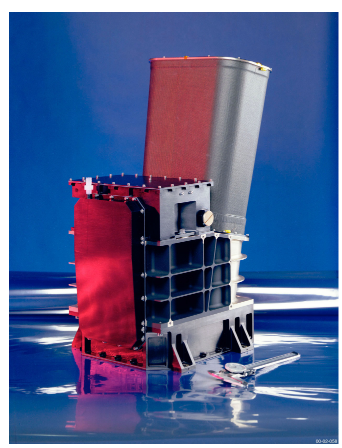


Photo Courtesy of NASA's Jet Propulsion Laboratory

(C) Lesson Background

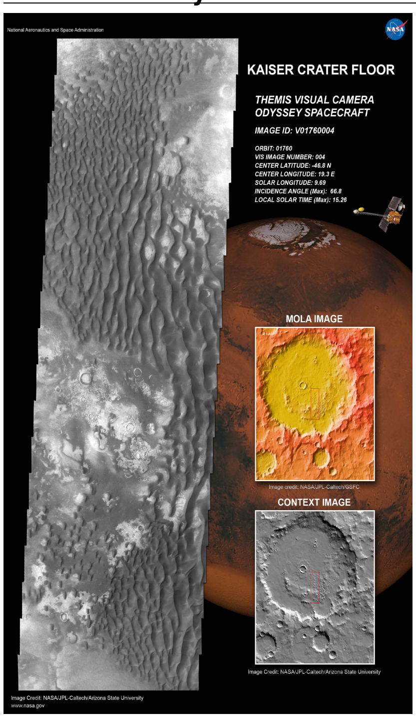
Essential Question: How do people reconstruct and date events in Earth's planetary history?

For this activity, you will be placed in the role of scientists. You will complete four different tasks as part of a guided investigation and introduction to the Mars Thermal Emission Imaging System (THEMIS) camera images. Your investigation will include:

1. Discovering what geologic features can be identified on the surface of Mars;
2. Determining the surface history of an area;
3. Calculating the size of observed features in images; and
4. Developing scientific observations.

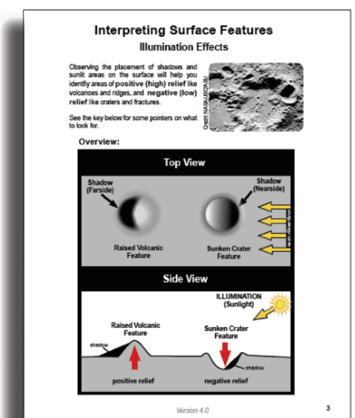
Throughout this activity, you will be completing a **Student Data Log**. A variety of tools are available to help you in this activity. Your teacher will help orient you to each of these throughout the activity.

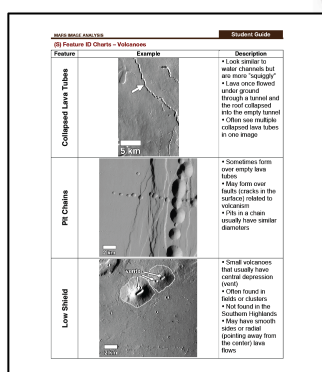
Part 1: Identify Surface Features:

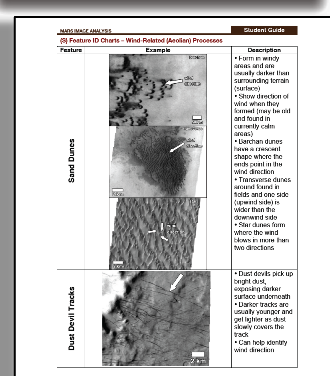


SAMPLE THEMIS IMAGE AND CONTEXT IMAGE

For this activity, you will analyze images of Mars provided by your teacher. As you observe images, be sure to use the **Feature ID Charts** to help you identify and label features with a wet erase marker. Your teacher will explain the materials and information you have available for this part of the activity and when to fill information into the **Student Data Log**. Here you will see a sample of the **THEMIS image** and **Feature ID Charts** you will be using.







(D) Student Data Log

NAME:______________________________

Use this table to order the major (most noticeable) features according to their relative ages. The oldest feature should be numbered 1, next oldest 2, 3, 4, 5, to the youngest number 6.

Feature Name	Oldest ↑ ↓ Youngest	Age Rank	Describe How Feature Formed

Write out a short "history" of the major events that took place in your area. Use the relative age of the features that you listed in your table.

____

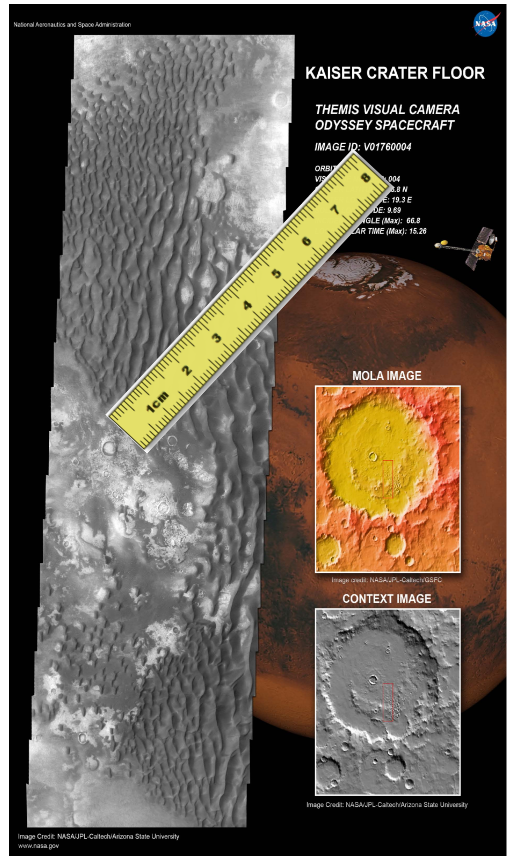
____

____

____

____

(K) Making Measurements Notes



Example:

1. **Determine the *scale factor* for your image:**
   A. Measure the distance across in centimeters: **21 cm**
   B. Divide to figure out the scale of your image:

   18 km = _**21**__cm

   18 km / _**21**__ cm = **0.86** km/cm)

   ***Scale Factor*: 1cm = 0.86 km**

2. **Multiply the size of any feature measured in centimeters by the scale factor:**

   Example: Width of channel = _**2**___cm

   _**2**__ cm X **0.86** km **=** _**1.72**_ **km**

   Width of channel = 1.72 km

**Use this page section to calculate the scale factor of your THEMIS image:
Determine the *scale factor* for ***your image***:

A. Measure the distance across in centimeters: __________cm

B. Divide to figure out the scale of your image:

18 km = __________cm

18 km / __________ cm = ____________km/cm)

***Scale Factor*: 1cm = ______________km** (Include this scale factor on your image)

**Remember, as you measure features on your image in centimeters, you will multiply that measurement by your *scale factor*. Be sure to list the *scale factor* on your image as well as the sizes of features you calculate.

Record the feature measurements into your Student Data Log sheet.

(L) Student Measurement Data Log

NAME:________________________________

Use this table to record your feature measurements.

Step 1: Measure the distance across in centimeters: _________cm

Step 2: Divide to figure out the scale of your image:

18 km = _________cm

18 km / _________ cm = ___________km/cm)

***Scale Factor*: 1cm =** ______________**km** (write this number in the column title "Scale Factor")

Feature Name	Feature Measurement X	Scale Factor	= Feature Actual Size

(M) Establishing a Research Topic of Interest

NAME:________________________________

Use the next page as a guide for completing your background research. Remember, your goal is to become an expert on your topic.

1. Within your group. brainstorm four general topics that can be studied about mars. For example; volcanism, cratering, water, human exploration, etc. These can be whatever interests you and your group.

____________________________________ ____________________________________

____________________________________ ____________________________________

2. As a class, vote on the topic that is most interesting for your research. Your class topic for research is: ____

Why Background Research?

Knowing a lot about your topic will help you make better observations. Better observations make better research questions.

Many of your THEMIS image observations are everyday observations. Everyday observations are very general. These observations are good, but we want to learn more about Mars. We need to look for features that are important to scientists.

Important observations make great research questions. Great research questions help scientists understand Mars and its history.

Examples:

<u>Everyday observation</u>:

There are many craters in the image.

<u>Scientific observation</u>:

There are 20 craters in the image that are over 10km wide.

25 craters are destroyed craters.

There are 34 craters in the rocky areas, but only 2 in the flat areas.

Not all of the craters with central peak have rough walls.

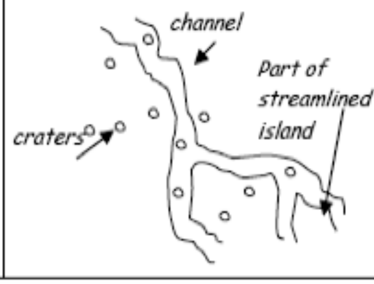
(N) Background Research

NAME:________________________________

Citation (Source):		
How was the feature formed?	Where are they typically found on Mars?	How are they similar or different from what can be found on Earth or other planetary bodies (planets/moons?)
Drawing	Drawing	Drawing

(P) Example Observation Table

Make scientific observations:

Surface/Geologic Feature(s) Observed & Image ID #	Sketch of Surface/Geologic Feature(s)	Specific Observations of Surface/Geologic Feature(s)
Channel with craters **Image ID #:** V11030007		*-Channel does not seem very wide* *-Can see streamlined islands* *-Small craters both on the outside and inside of channel* *-All craters in image seem to be about the same size*

1. Fill out the following two observation tables.
2. Be as detailed as possible as you enter the data in the tables. Remember, your goal is to make Scientific Observations, not Everyday Observations. Use your completed Background Research for details (such as usual features) on your topic.
3. Think about the surface features that you are observing - what interests you?
4. Work with people on your team to find other areas on Mars that have features you are interested in.

Credit: NASA

(Q) Observation Table (1 of 2)

NAME:__________________________________

Making Observations of THEMIS Images

Surface Geologic Features Observed & Image ID #	Sketch of Surface Geologic Features	Text Description of Surface Features (use bullets)
Image ID #:		
Image ID #:		
Image ID #:		
Image ID #:		

(Q) Observation Table (2 of 2)

NAME:________________________________

Making Observations of THEMIS Images

Surface Geologic Features Observed & Image ID #	Sketch of Surface Geologic Features	Text Description of Surface Features (use bullets)
Image ID #:		
Image ID #:		
Image ID #:		
Image ID #:		

(R) Choosing a Topic for Research

NAME:________________________________

1. Review your scientific observations from the Observation Table. Choose two observations you found most interesting during your online research. These are observations you would like to share with the class and could turn into an interesting research project. Record them below.

Observation #1	Observation #2

2. After a class discussion about interesting scientific observations, list six major relevant categories within your topic – or features that the class can choose to study about Mars. For example, with volcanism think about related surface features such as lava flows, eruptions, volcanoes, ash and rock deposits. Once you have created the list, as a team debate and select your topic and relevant category.

______________________________ ______________________________

______________________________ ______________________________

______________________________ ______________________________

3. List the topic your group will research: ______________________________

Last edited: February 25, 2016

(T) Reflection – Science and Engineering Practices (1 of 6)

When scientists study phenomena to better understand how the natural world works or when engineers design solutions to a problem, they engage in certain processes called practices. These practices are, essentially, how science or engineering is done.

These Practices are:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Furthermore, there are 4 understandings about the Nature of Science that scientists have that are a foundation for the practices.

These Understandings about the Nature of Science are:

1. Scientific investigations use a variety of methods.
2. Scientific knowledge is based on empirical evidence (knowledge obtained by observation and experimentation).
3. Scientific knowledge is open to revision in light of new evidence.
4. Science models, laws, mechanisms, and theories explain natural phenomena.

(T) Reflection – Crosscutting Concepts (2 of 6)

Some concepts are important to all studies in science and engineering. Seven of these ***Crosscutting Concepts*** – ideas that are important to any science (biology, physics, chemistry, ecology, astronomy, geology, etc.) and to all engineering – have been identified.

1. ***Patterns.*** Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

2. ***Cause and effect:*** *Mechanism and explanation*. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

3. ***Scale, proportion, and quantity.*** In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.

4. ***Systems and system models.*** Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.

5. ***Energy and matter: Flows, cycles, and conservation.*** Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.

6. ***Structure and function.*** The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

7. ***Stability and change.*** For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

Furthermore, there are 4 understandings about the Nature of Science that are closely related to the Crosscutting Concepts.

These Understandings about the Nature of Science are:

1. Science is a way of knowing.
2. Scientific knowledge assumes an order and consistency in natural systems.
3. Science is a human endeavor.
4. Science addresses questions about the natural and material world.

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(T) Reflection – Science and Engineering Practices (3 of 6)

Name: ___________________________

In your group, reflect carefully on the activities you have just completed and answer the following questions using the table on the next page.

a. What Science and/or Engineering Practices did you do and which of the understandings about the Nature of Science were important to what you did? (There is probably more than one.)
b. When? During which activities?
c. Explain your reasoning.
d. Be prepared to explain your best thinking about what Practices you used and when you were doing them in a full class discussion.

Nature of Science	When?	What is your reasoning?
Scientific investigations use a variety of methods.		
Scientific knowledge is based on empirical evidence (knowledge obtained by observation and experimentation).		
Scientific knowledge is open to revision in light of new evidence.		
Science models, laws, mechanisms, and theories explain natural phenomena.		

(T) Reflection – Science and Engineering Practices (4 of 6)

Practice	When?	What is your reasoning?
Asking questions (for science) and defining problems (for engineering)		
Developing and using models		
Planning and carrying out investigations		
Analyzing and interpreting data		
Using mathematics and computational thinking		
Constructing explanations (for science) and designing solutions (for engineering)		
Engaging in argument from evidence		
Obtaining, evaluating, and communicating information		

(T) Reflection – Crosscutting Concepts (5 of 6)

Name: ___________________________________

In your group, reflect carefully on the activities you have just completed and answer the following questions using the table on the next page.

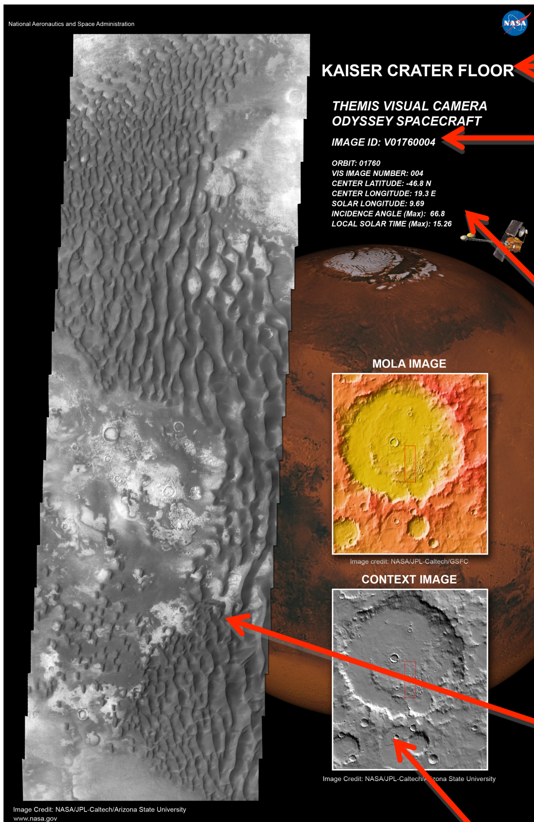
a. What Crosscutting Concepts did you do and which of the understandings about the Nature of Science were important to what you did? (There is probably more than one.)
b. When? During which activities?
c. Explain your reasoning.
d. Be prepared to explain your best thinking about what Crosscutting Concepts you used and when you were doing them in a full class discussion.

Nature of Science	When?	What is your reasoning?
Science is a way of knowing.		
Scientific knowledge assumes an order and consistency in natural systems.		
Science is a human endeavor.		
Science addresses questions about the natural and material world.		

(T) Reflection – Crosscutting Concepts (6 of 6)

Crosscutting Concepts	When?	What is your reasoning?
Patterns		
Cause and effect: Mechanism and explanation		
Scale, proportion, and quantity		
Systems and system models		
Energy and matter: Flows, cycles, and conservation		
Structure and function		
Stability and change		

(U) Teacher Resource #1 (1 of 2)



THEMIS visible images are ~18 km wide.

Title: Names the general region where the image is located on Mars.

Image ID: Includes the orbit # in which the image was taken (first 5 digits) followed by a 3 digit number that indicates the count of the visible images that were taken during that orbit.

***Center Latitude and Center Longitude*:** Exact location of this image on a map of Mars.

Incidence Angle: Angle of the Sun when the image was taken. This would be used if the students wanted to measure depth or heights of features using the sun or incidence angle.

Orbit: Orbit in which the image was acquired.

Mars Solar Time: Time (on Mars) when the image was taken.

THEMIS Image: The long, rectangular image consisting of 18-19 framelets. Framelets are angled due to the rotation of the planet beneath the camera as it takes photos.

Context Image: Shows the surrounding area where the THEMIS image was taken. The THEMIS image "stamp" is the rectangular box in the center of the context image.

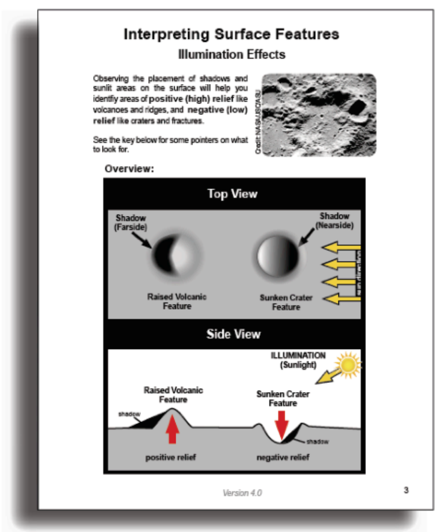
NOTE: With THEMIS visible images, the sunlight is coming from the left. A feature with a shadow on the left is carved into the surface. (Example: an impact crater will have the shadow on the left.)

(U) Teacher Resource #1 (2 of 2)

Additional Details:

- **Image ID #:** Allows you to view this image on the THEMIS viewer website (http://viewer.mars.asu.edu/#start)
- **Mars Solar Time:** Time is based on a 24-hour clock and uses percentages of hours rather than minutes. For example, if an image was taken at 15.75, it would be 3pm and 75% of an hour, or 3:45pm. If an image was taken at 16.2, the time would be 4pm and 20% of an hour or 4:12pm.
- **Context Image:** Shows a Mars Orbiter Laser Altimeter (MOLA) shaded relief map. This is not a photograph but is considered an "artificial image" that uses data acquired by the MOLA instrument to provide a black and white context showing elevation differences.

SUNLIGHT AND SHADOWS


Interpreting Surface Features

Illumination Effects

Observing the placement of shadows and sunlit areas on the surface will help you identify areas of **positive (high) relief** like volcanoes and ridges, and **negative (low) relief** like craters and fractures.

See the key below for some pointers on what to look for.

Overview:

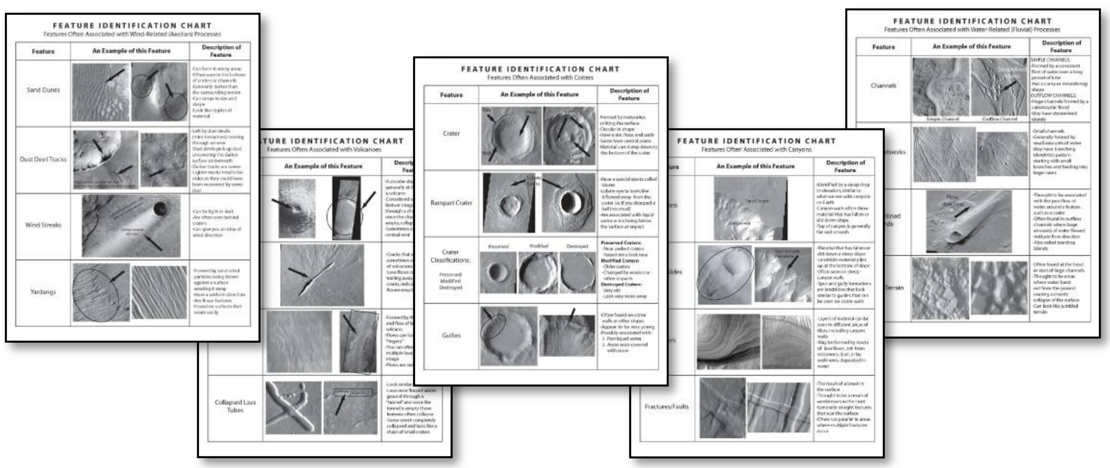
Version 4.0

3

The Sunlight and Shadows sheet will help students to identify features in their THEMIS image by orienting them to how shadowing is used to identify a raised or carved feature. Some students may need additional practice with this concept using concrete materials such as a cup and flashlight. Have students discover how the lighting works with the cup turned right-side up and up-side down.

(V) Teacher Resource #2

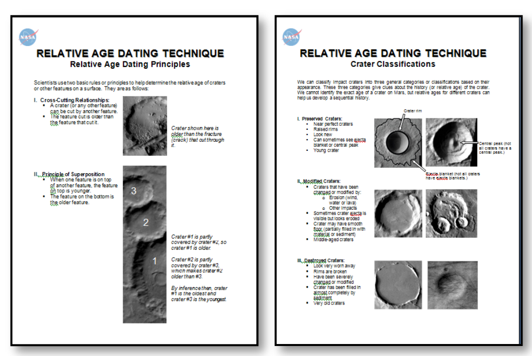
FEATURE IDENTIFICATION CHARTS



The Feature ID Charts will help students learn the names of different geologic features on Mars. They also provide information on how features form. The information at the top of each chart indicates what geologic process the listed features are associated with. There are 5 total charts that focus on features associated with *canyons*, *craters*, *wind*, *water*, and *volcanoes*. There are many other features students may observe in images that are not included on these charts. Encourage students to share other features they may know.

RELATIVE AGE DATING TECHNIQUE HANDOUTS

One additional tool students will use for this activity are the **Relative Age Dating Technique** handouts. These two pages will help students identify what features are older or younger, which will help them better understand the geologic history of the surface.



RELATIVE AGE DATING TECHNIQUE
Relative Age Dating Principles

RELATIVE AGE DATING TECHNIQUE
Crater Classifications