Mars Image Analysis

Teacher Introduction:
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. This activity will provide a bridging context in which your students will experience a current and real-world application of how scientists think using authentic data and how the process of science evolves. By taking advantage of the inherent excitement of studying Mars, your students will be more motivated to better understand our own planet.

Planetary missions have to balance two critical areas – engineering and science. To have a successful mission, the engineers have to help to ensure the success of the spacecraft and mission success for landing by spacecraft design and landing site safety considerations. On the other hand, scientists want to argue for the area with the richest science return. These two groups don't always agree, but in real life must come to a compromise for a mission to go forward.

This activity will place students in the role of scientists as they analyze the geological processes that may have taken place using a visible image of the Martian surface taken with the Thermal Emission Imaging System (THEMIS). Your students will be able to make a recommendation as to whether or not they feel an area is scientifically interesting enough to be considered as a potential landing site. Students will also use NASA's four goals for the exploration of Mars to justify their decision. NASA's goals are as follows:

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.

As was done with the Mars Exploration Rover potential landing sites, those recommended areas would then be evaluated using a whole different set of criteria by the engineers.

As your students analyze their image(s) of Mars, the focus should be on the process being used rather than "correct" answers. Students should be able to justify the process they used to analyze and develop an understanding of their image. By using that process, they will be able to justify their decision as to whether or not they would recommend their area of Mars as a potential landing site, and have achieved the objective of this activity.

Objective:
Students will gain an understanding of the scientific inquiry process and the geological history of a terrestrial planet (*i.e.* Earth and Mars) by analyzing THEMIS visible images of Mars.

Suggested Grade Level: 5th – 12th grade

Time Frame:
1-2 class periods (~45 minutes each)

Materials Needed per Group (4 students per group):

- -1 laminated large THEMIS visible image (11" x 17" or larger)
- -1 context image (8.5" x 11") of the respective THEMIS visible image showing the surrounding area in which the image was taken (Sample images available at http://msip.asu.edu/sample.html or lendable images can be requested by contacting msip@asu.edu)
- -Mars Image Analysis Data Log Chart
- -Mars Image Analysis Surface Feature ID Charts (4 pages)
- -Water-soluble overhead transparency markers
- -2 Rulers
- -2 Calculators
- -Globe or map of Mars (For a map of Mars go to the download link at http://msip.asu.edu and access the MOLA map JPG.)

National Science Education Standards:
Content Standard A: As a result of their activities, all students should develop the abilities necessary to do scientific inquiry:

1. Identify questions that can be answered through scientific investigations.
2. Use appropriate tools to analyze and interpret data.
3. Develop descriptions and explanations using evidence.
4. Think critically and logically to make relationships between evidence and explanations.
5. Communicate scientific procedures and explanations.

Content Standard D: As a result of their activities, all students should develop an understanding of:

1. Structure of the Earth system.

Content Standard G: As a result of their activities, all students should develop an understanding of:

1. The nature of science.

National Council of Teachers of Mathematics *Principles and Standards:*
Numbers and Operations:

1. Work flexibly with decimals to solve problems.
2. Understand and use ratios and proportions to represent quantitative relationships.

Measurement:

1. Understand both metric and customary systems of measurement
2. Select and apply techniques and tools to accurately find length measures to appropriate levels of precision.
3. Solve problems involving scale factors, using ratio and proportion.

Background of Image Materials (to be shared with students by teacher):

Context Image

The context image shows a Mars Orbiter Laser Altimeter (MOLA) shaded relief map showing the area in which the THEMIS visible image was taken. The targeted THEMIS visible image is within the blue box shown in the center of the context image. Each context image provided also includes the THEMIS image identification number and the name of the region of Mars in which the image was taken. Also included is information that will be useful for this activity:

a. **Latitude:** Latitude (and longitude) is provided to identify (on a Mars globe or map) where the image was taken. Latitude is always provided here as north latitude. Students need to understand that 37.4 is 37.4 degrees North but –37.4 would indicate 37.4 degrees South.
b. **Longitude:** Longitude will always be provided as east longitude.
c. **Sun Angle:** This information provides the 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 angle. (Note: For all images in this activity, the sun is illuminating from the left.)

As most scientists record as much information about their acquired image as possible, the following data is provided. This information is not required for this activity:

d. **Orbit:** The number of the orbit in which the image was acquired.
e. **VIS Start ET:** The number of seconds (in ephemeris time or ET) when the VIS (visible) image was taken. Ephemeris time is the number of seconds since this astronomical epoch began (12:00am on January 1, 2000, GMT).
f. **VIS Image ID:** Each THEMIS image has an identification number according to what number image it was in relation to all the other images taken during this orbit. (For example, VIS Image ID 005 means that this particular VIS image was the 5th image taken during its respective orbit.)
g. **Mars Local Time:** The time (on Mars) when the image was taken. The 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.

Note: In each context image the northernmost part of the image is at the top.

THEMIS Visible Image

The THEMIS visible image includes the name of the region in which the image was taken and also includes the image identification number in the lower right hand corner. This image identification number should match the image identification number on the context image. THEMIS visible images have a resolution of about 18 meters per pixel. The top portion of the image is the northernmost part of the image. Each complete THEMIS visible image consists of 19 framelets (almost seen as individual rectangles joined together). THEMIS visible images are approximately 18 km (~11 miles) across and 57 km (~35 miles) in length.

Other Handouts Provided

Included in this lesson is a **Data Log Chart** that will allow students to fill in the information they will obtain as they look at the THEMIS visible image. Also included are **Surface Feature ID Charts**. These four charts provide an example of what a particular surface feature may look like on Mars and has some written details about the feature in general and how it may form. The **MOLA map** will give your students an additional resource to examine the larger context in which their image was taken.

Procedure:

1. Students should be given an overview of the context image, the THEMIS visible image and the other materials they will be using for this activity (see above explanations).
2. Using the context image and/or a map or globe of Mars, students should answer the questions on the Student Worksheet Part I.
3. Using the Surface Feature ID Chart, students should identify the different features in their THEMIS visible image. Students can identify their features on the image itself as well as on the Data Log Chart provided. This part of the activity (Part II) also asks students to hypothesize as to how they think these features formed by using the written information provided in the Surface Feature ID Chart.
4. Using the information provided in Student Worksheet Part III, students should rank their labeled features according to age with one (1) being the oldest feature and subsequent numbers being younger features. Students should fill out this information on the Data Log Chart.
5. Using the information provided in Student Worksheet Part IV, students should measure the different features in their image and include the information in the Data Log Chart.
6. Using the information provided in Student Worksheet Part V, students should determine whether or not this area of Mars is scientifically interesting enough to be considered as a potential landing site.

Assessment:

Students will be assessed based on their written explanation of how they arrived at their decision to recommendation (or not recommend) the area of Mars they analyzed as a potential landing site. Their explanations should show evidence of an understanding of the analysis process they completed throughout the activity.

Extensions:

- You may consider having your students do the *Marsbound!* activity to actually design a future lander mission to Mars. Students can use the blank *Marsbound!* cards to help create their future lander that may include technology that is not included in the given *Marsbound!* card set.

- Students can calculate depths and heights of features by dividing the length of a shadow by the tangent of the sun angle (sun angle information is provided on the context image). To do this, students would use the following steps:
  - Measure the width of the shadow in centimeters.
  - Using the calculated scale factor (Part IV of the *Mars Image Analysis* activity), convert the shadow measurement to kilometers.
  - Divide that calculated measurement by the tangent of the sun angle (provided on context image) to compute the depth of the feature being observed.

- Students can analyze and label images using computer applications such as Adobe Photoshop.

Note: Consider having your students complete the *Mapping the Surface of a Planet* activity prior to the *Mars Image Analysis* activity. This activity provides great information allowing students to understand features found on Earth that we can compare to features found on Mars. It will also allow students to understand how you can determine the surface history of a planet or area of Mars (or Earth!). The *Mapping the Surface of a Planet* activity can be downloaded at http://marsed.asu.edu.

This activity can be used as a part of the Mars Student Imaging Project (MSIP). It can be used to help students analyze images of Mars that may related to their project/research or can be used as the archived format of the program. For more information on the Mars Student Imaging Project, go to http://msip.asu.edu.

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

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Student Worksheet – Mars Image Analysis
Part I

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.

Planetary missions have to balance two critical areas – engineering and science. To have a successful mission, the engineers have to help to ensure the success of the spacecraft and mission success for landing by spacecraft design and landing site safety considerations. On the other hand, scientists want to argue for the area with the richest science return. These two groups don't always agree, but in real life must come to a compromise for a mission to go forward.

For this activity you will be placed in the role of scientists. You will complete five different tasks (parts of this lesson) to help you analyze an area of Mars and decide if you would recommend it as an area that is scientifically interesting enough to be considered as a potential landing site. To assist you with this recommendation, Part V of this activity discusses NASA's four goals for the exploration of Mars. You will need to consider if within the analysis of your image, any of these goals would be met. Recommended landing sites are then evaluated by a whole different set of criteria used by engineers. This was the process used with the landing site selection for the Mars Exploration Rovers.

Part I of this activity asks you to focus on the context image provided and a map of Mars. The context image shows you the larger area on Mars where your Thermal Emission Imaging System (THEMIS) image was taken. The THEMIS image is illustrated with the blue box in the center of the context image. Using a map of Mars you will see a more global view of where your image was taken. These resources will help you answer the questions below.

1. What is the latitude and longitude of your THEMIS visible image of Mars?

2. Looking at the title of your context image and THEMIS visible image, name the area/region in which your THEMIS visible image of Mars was taken?

3. Describe the type of area in which the THEMIS visible image was taken. Is your image in an area with lots of craters? Is it near a volcano? Is it near an area where it looks like there was once water?

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Student Worksheet – Mars Image Analysis
Part II – Identifying Surface Features

For this part of the activity, you will use erasable markers to label different features directly on your Thermal Emission Imaging System (THEMIS) visible image of Mars. To help you identify features, use the Surface Feature ID Charts and the descriptions provided. Keep in mind that some of the features in the Surface Feature ID Charts will not exactly match what you see in your THEMIS image.

If you have more than one example of the same feature, list those features with a number. For example, if there are three different craters in your image, identify them as Crater 1, Crater 2, Crater 3, etc.

What To Do:
On the Data Log Chart, list the features you found in your image. Write down your best hypothesis (scientific guess) as to how you think each of these features may have formed.

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Student Worksheet – Mars Image Analysis
Part III – Determining the Surface History

You now have identified features you see in your image. Next, think about the history of this area of Mars. What has happened to make this area of Mars look the way it does today? To determine the history of this area, you can use two geologic rules or principles. These rules will help you figure out the "relative ages" of features. Relative ages will not tell you the exact age of a feature. They will help you figure out what features are younger or older compared to one another. Two common rules you can use to determine relative ages of features are:

The Principle of Superposition: This rule says that if one feature looks like it is placed on top of another, the feature on top is younger. An example of this can be seen in the crater image on the Surface Feature ID Chart. The crater is on top of the surface around it. Because of this rule, we can say the crater is younger than the nearby area.

The Principle of Cross-Cutting Relationships: This rule says that if you have one feature that is cut by another feature, the feature that is cut is older. For example, look at the channel picture in the Surface Feature ID Chart. The channel looks like it cuts across the area. This means that the area is older. It also means the channel is younger. Another example of a cross-cutting relationship is Earth's Grand Canyon. In this case, you had rocks that were cut by the Colorado River. The result was the Grand Canyon itself. In this example, the rocks are the oldest because they were there first. The canyon itself is younger, since it was formed by the Colorado River that cut through the rocks that were there to begin with.

Sometimes you can also see how worn down a feature looks. This can also help you figure out the relative ages of features. Features that have been around longer are most likely more affected by erosion. A feature that is more worn down or eroded is most likely older.

What To Do:
In Part II, you identified features in your image on the Data Log Chart and included information as to how those features may have formed. In this part of the activity, rank the features listed on the Data Log Chart according to their relative ages. The oldest feature should be numbered one (1) and the younger features should be numbered two, three, four, etc.

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Student Worksheet – Mars Image Analysis
Part IV – Measuring Features

In this part of the activity, you will measure features. This information will help you understand this area of Mars better. It may also help you decide if you would recommend this area as a potential landing site. In order to measure features in your image, you need to figure out the scale of your image.

Scale:
Thermal Emission Imaging System (THEMIS) visible images are 18 km in width. You need to know the scale of the image you are working with to correctly measure features.
To figure out the **scale factor** of your image, complete the following steps:

1. Use a ruler to measure the width of your image. Measure this in centimeters. This measurement should be taken to the nearest tenth of a centimeter (example: 35.3 cm).

   The width of your image is: __________cm

2. Divide 18 km (the actual width of this area on Mars) by that measurement.

   18 km / _______ cm = _____________ km/cm

3. This answer gives you the scale factor of your image in km per cm.

You can now figure out actual measurements of features on Mars in your image. To do this, complete the following steps:

1. Measure a feature in centimeters.
2. Multiply that measurement by the scale factor you figured out.
3. The answer you get will give you the measurement of that feature on Mars in kilometers.

What to do:
After you have figured out the scale factor of your image, measure all the features you identified in your THEMIS visible image with your ruler. Figure out how the measurement of those features on Mars in kilometers. Fill in the information on the Data Log Chart.

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Student Worksheet – Mars Image Analysis
Part V – Landing Site Evaluation

You have now identified, measured and determined the relatives ages for the different features in your image. It is now your job to decide if you would recommend this area as a potential landing site for a future Mars lander mission. As a scientist, you need to decide if this area of Mars is geologically interesting and also if it would meet any of NASA's main goals for all mission to Mars. Those goals are as follows:

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.

The overall strategy that corresponds to each of these goals is the "follow the water" theme. On Earth, wherever we find water, we find life. Was that the same for Mars? With future missions, we hope to find out.

What to do:
Look over all the information you have completed for this activity and answer the following questions:

1. Write a brief geological "story" of this image. What happened to make this area of Mars appear the way it does today?

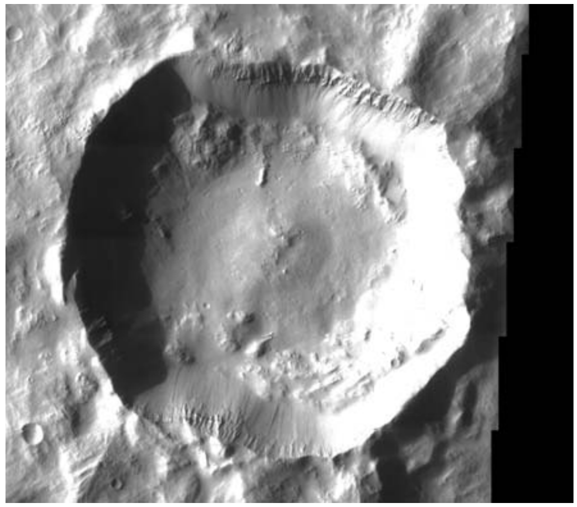
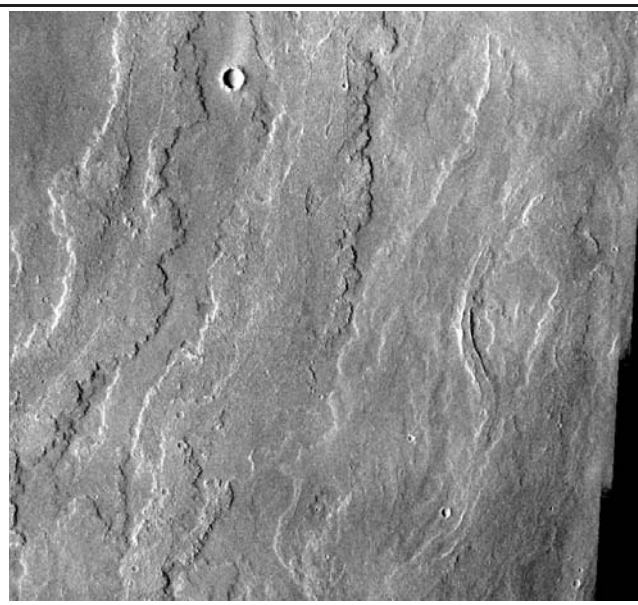
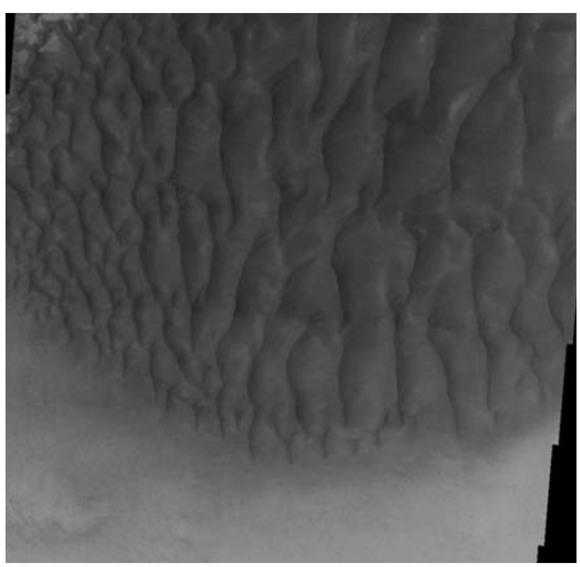
2. Considering NASA's four main goals for mission to Mars, which goal(s) does this area of Mars meet? Please explain.

3. Is there any evidence that water was present in this area on Mars? (Yes or No?) ________ What evidence can you provide for your answer?

4. Would you recommend this area of Mars as a potential landing site? Explain how you arrived at your decision.

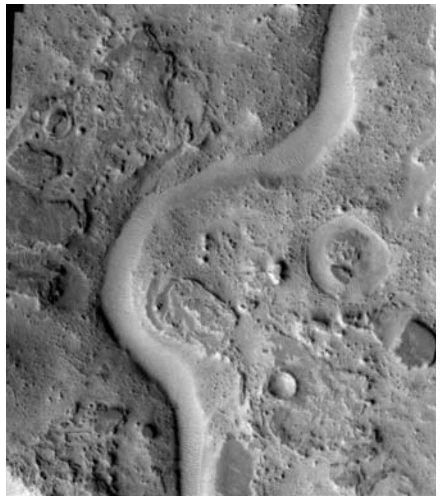
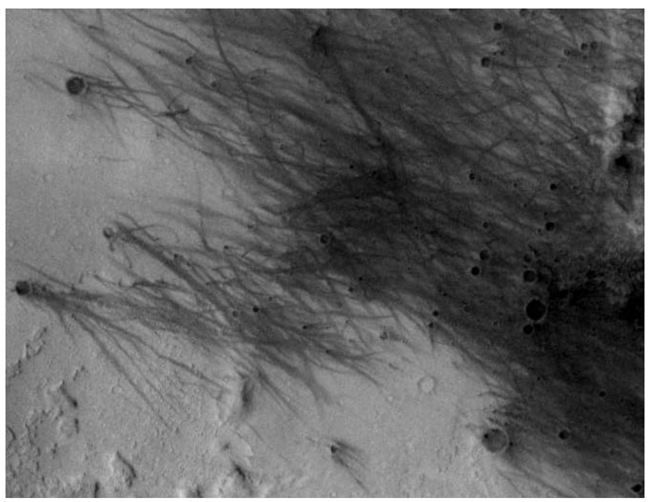
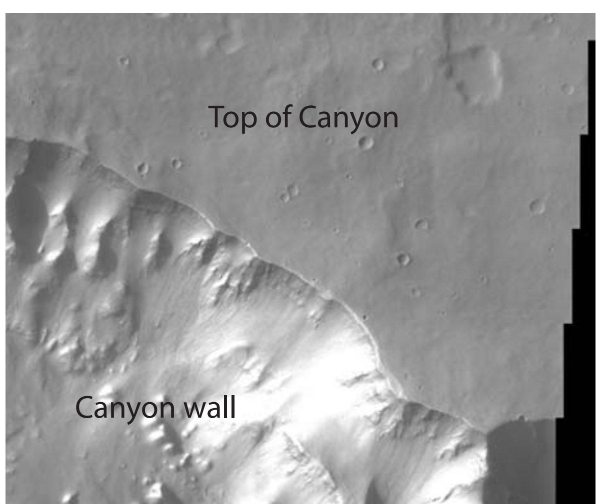
MARS IMAGE ANALYSIS

Surface Feature ID Chart

Feature	An Example of this Feature	Description of Feature
Craters		Craters are generally formed by meteorites striking the surface of a planet. The majority of craters are circular in shape and come in a variety of sizes.
Lava Flows		Lava flows are formed by the eruption of lava from a volcano. Lava flows can look "wavy" and are somewhat uniform in the direction they flow. You can often identify different lava flows from different volcanic eruptions.
Sand Dunes		Sand dunes can form in many different areas on Mars. They are often seen in the bottom of craters or channels or around the poles. These features are generally darker than the nearby terrain. Sand dunes can range in size and shape.

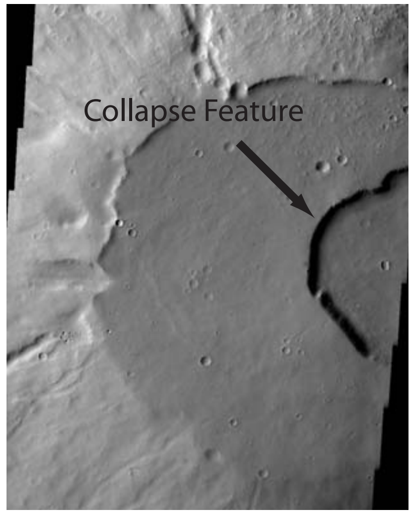
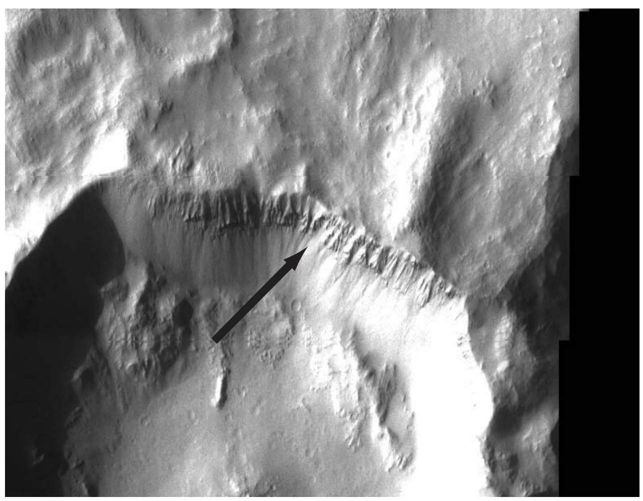
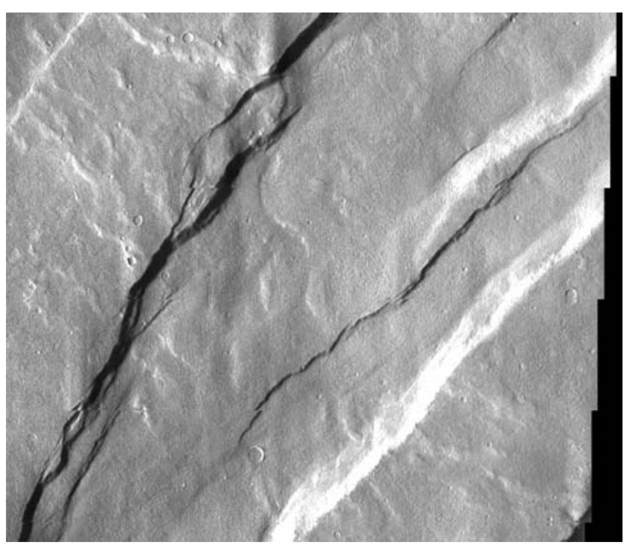
MARS IMAGE ANALYSIS

Surface Feature ID Chart

Feature	An Example of this Feature	Description of Feature
Channels		Channels on Mars are thought to have formed by liquid water flowing across the surface. Many of these features seem to form curvy river-like features along the surface.
Dust Devil Tracks		Dust devil tracks are formed by dust devils (mini-tornadoes). Dust devils swirl across the surface leaving a thin dark trail behind. This is a result of the dust devils picking up the thin surface dust, exposing the darker surface underneath as they move across the surface.
Canyons		Canyon systems on Mars can be identified by the steep drop in elevation, similar to what we see in our own Earth's canyons. Landslides of material that have fallen from the sides of the canyon walls are often visible.

MARS IMAGE ANALYSIS

Surface Feature ID Chart

Feature	An Example of this Feature	Description of Feature
Volcanoes		Volcanoes can be identified by their rise above the surface. Many volcanoes have collapse features near their top. Mars has some of the largest volcanoes in the solar system. Many of them are too large to fit in one image.
Gullies		Gullies are found on some crater walls or other slopes. Most gullies appear to be fresh or recently formed features. Gullies are thought to have an association with either past liquid water or areas that were once covered with snow.
Fractures		Fractures are a result of a break in the surface. They are thought to be a result of weaknesses in the crust, and are generally straight features that scar the surface. Fractures often run parallel in areas where multiple fractures occur.

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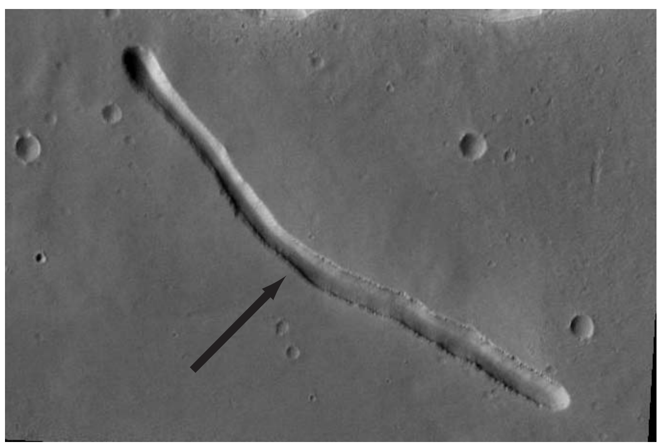
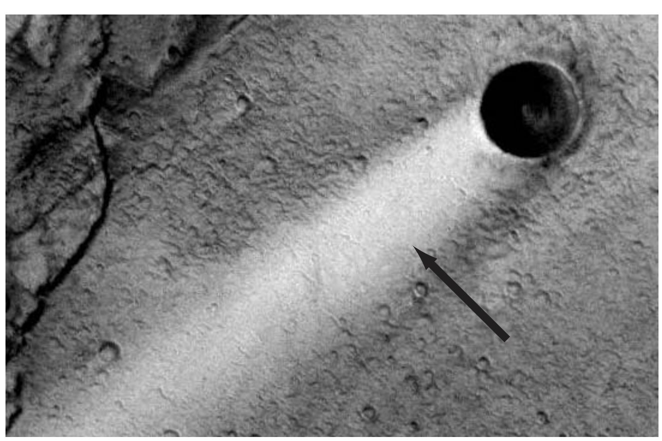
Surface Feature ID Chart

Feature	An Example of this Feature	Description of Feature
Streamlined Islands		Streamlined islands are thought to be associated with the past flow of water around a feature on the surface, such as a crater. These features are often found in large channels where there was probably large amounts of water flowing (floods).
Lava Tubes		Lava tubes are associated with areas where lava once flowed underground. After the lava stopped flowing the tubes often collapse. The result is often a worm or a tube-like feature on the surface similar to what is shown here.
Wind Streaks		Wind streaks can be seen on the surface of Mars as light or dark patches (or streaks) on the surface. These wind streaks can give you an idea of the direction the wind was or is currently blowing.

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MARS IMAGE ANALYSIS

Data Log Chart

THEMIS Image ID# ______________________________

Region of Mars ______________________________

Feature	How Feature May Have Formed	Age Rank	Measurement