MARS STUDENT IMAGING PROJECT

ASU MARS EDUCATION PROGRAM

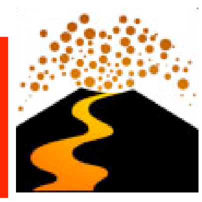
Name ___________________________ Date _________________________

Earth / Mars Comparisons and Introduction to MSIP and THEMIS Images

1. The Mars Student Imaging Project is sometimes called _______________________ for short.

2. The Science Process involves:

a. Idea / Topic ____________________

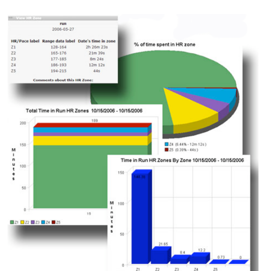


b. Preliminary ________________ and Hypothesis Development

c. Experiment ____________________

d. Proposal Development

e. Competition (for use of the _______________ camera)

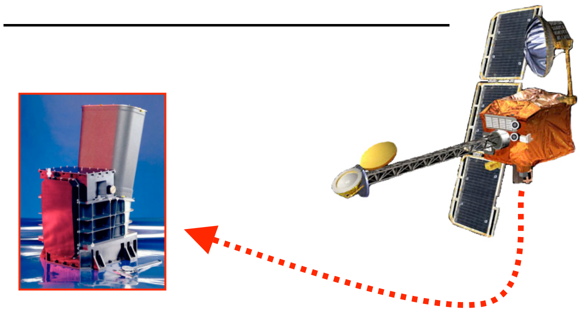


f. Gathering, Analyzing, and Interpreting _________

g. Write-up _________ report

h. ____________ Work

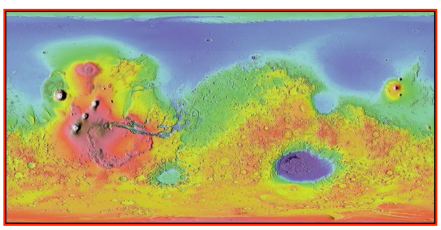
3. The name of the spacecraft the camera is on is the ___________________________ spacecraft.



4. The name of the camera MSIP student scientists can use is ___________________________.

5. This camera's full name is:

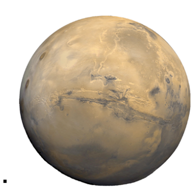
Th .... **Em** .... **Im** .... **Sy** ....



6. The ______________________ topography map uses color to show the different elevations on Mars. The colors blue and purple indicate ____________________ elevations and the colors red and white indicate ___________________ elevations.

7. Earth and Mars are **alike** in that they both: (list your observations):

8. Earth and Mars are **different** in that they: (list your observations):



9. In looking at the globe of Mars, list at least **three** geologic features or observations:
   a.

   b.

   c.

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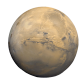
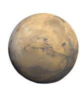
For the rest of the slides, take notes on the information and observations of topics and features discussed that are found on both Earth and Mars and are seen in THEMIS visible images.

General Topic: Mountains, Volcanoes and Volcanic Features

		**THEMIS Images**

General Topic: Canyons and Canyon Features

		**THEMIS Images**

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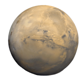
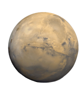
General Topic: Aeolian (Wind Related) Features

		**THEMIS Images**

General Topic: Craters and Crater Features

		**THEMIS Images**

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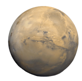
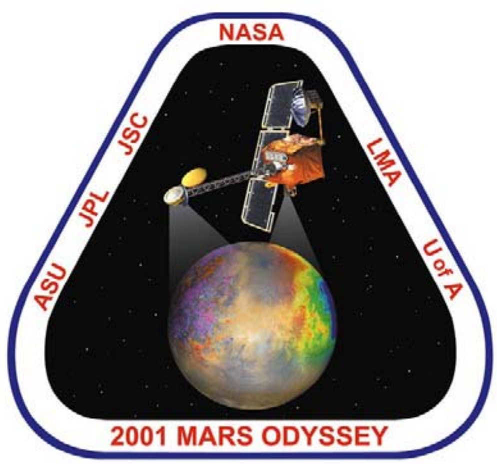
General Topic: Water Related Features

		**THEMIS Images**

MARS STUDENT IMAGING PROJECT

Resource Manual



ARIZONA STATE UNIVERSITY

Mars Education Program
Jet Propulsion Laboratory
Arizona State University

Version 2.00

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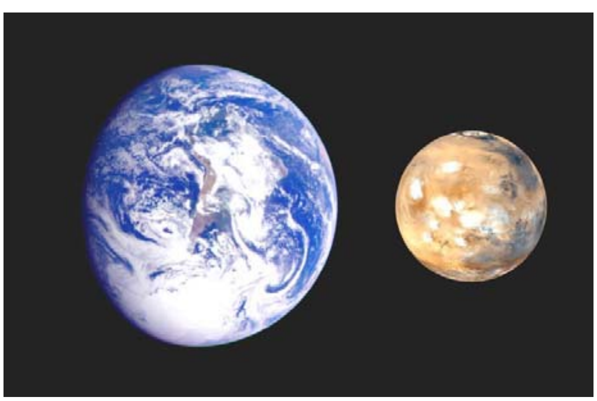
Chapter 3: Mars in the Solar System

Mars is a world of puzzles. It is both very similar to and very different from our own Earth. Mars is the fourth planet from the Sun and orbits at a distance one and a half times that of Earth's orbit. As a result, Mars receives much less light and heat from the Sun than the Earth does, so it is much colder. Also, unlike the Earth, Mars has a very thin low-pressure atmosphere which is unable to retain what heat it does receive. Because of the temperatures and pressures on the Martian surface today, water cannot exist in liquid form. Mars today is therefore a dry, frozen desert.

Similarities and Differences

Mars is similar to Earth in a number of important ways. It has an axial tilt of 23.98 degrees, very similiar to Earth's 23.44 degrees. Mars therefore has seasons, just like Earth, with cold winters and warmer summers. Mars' rotation period, its "day", is 24 hours, 37 minutes, again almost exactly the same as Earth's. Like Earth, Mars has ice caps at both poles. It has clouds, winds, weather, dust storms, volcanoes, and channels. For many years, Venus was considered the "twin" of Earth. Unlike Mars, Venus is very similar in size and mass as Earth and therefore has very similar gravity. But Venus is a hothouse, with temperatures soaring to hundreds of degrees centigrade and atmospheric pressures high enough to crush our toughest metals like tin cans. Mars, on the other hand, could one day conceivably be changed to be more like Earth through advanced engineering known as "terraforming". In many respects, Mars is a much more hospitable environment than Venus, making it an obvious target for our imaginations.



Earth/Mars Comparison
Credit: NASA/JPL

But Mars is very different from Earth as well. Surface temperatures on Mars range from hundreds of degrees centigrade below zero in the winter to nearly freezing (0º C) in the summer. Because Earth's orbit is nearly circular, our seasons are virtually the same in both hemispheres. Mars travels in a more elliptical orbit around the Sun than does the other planets, so it is 20% closer to the Sun during southern summer than it is in northern summer. This results in very long, relatively warm southern summers and very long, cold northern winters. Mars has an atmospheric pressure less than seven-tenths of one percent of Earth's, far too low to sustain most forms of life as we know it. The southern ice cap is made mostly of frozen carbon dioxide ("dry ice"), not water. Much of the surface of Mars is covered with craters much like the Moon. All of these differences make Mars a world unto itself, rather than a "twin" of Earth or another planet.

The northern and southern hemispheres of Mars are very different. In general, the south is very heavily cratered, while the north is made up mainly of smooth dark plains. There are many exceptions to this general rule, for example, Hellas Planitia (*planitia* are smooth, low plains or basins) lies in the southern hemisphere and, at 3 km below "datum", is the deepest basin on Mars. The word "datum" is used rather than "sea level", because, obviously, Mars currently has no seas! The datum is defined as the altitude at which the atmospheric pressure is 6.1 millibars (6.1 thousandths of the sea level pressure on Earth). The planet isn't spherical either. There is a very large bulge in the crust located at around 113º west longitude. This region, called the Tharsis Bulge, is home to the largest volcanoes on Mars – and in the entire Solar System. The southern hemisphere reveals the ancient cratering record of impacts early in the Solar System's history. On Earth, this record has been virtually erased by the effects of volcanoes, wind, and water. Planets such as Mercury died young, ceasing geological activity not long after the period of major impacts. Mars, however, was geologically active for most of the life of the Solar System – the great volcano Olympus Mons was probably active just thirty million years ago – so has examples of young terrain in the north right alongside the ancient cratered terrain in the south. In many ways, Mars uniquely records the history of the Solar System in its surface features.

Polar Caps

The polar caps of Mars change dramatically over the course of a Martian year (which is almost two Earth years). During each hemisphere's winter, carbon dioxide freezes out of the atmosphere at the poles to form "dry ice". This dry ice causes the polar cap in that hemisphere to grow by a substantial amount. As much as one-third of the atmosphere of Mars freezes into dry ice at each pole during winter in its hemisphere. Changes of this magnitude in the atmospheric pressure of the Earth would signal that a storm of

Mars South Polar Cap, Summer 2000
Credit: Malin Space Science Systems

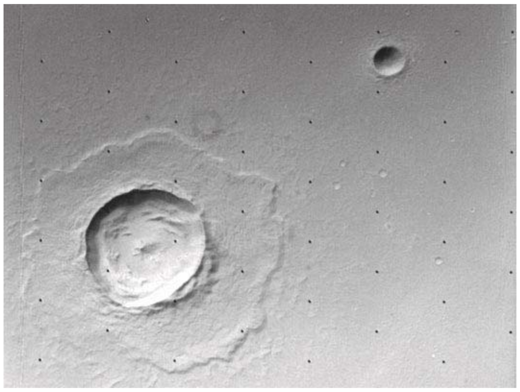
unprecedented power was forming, but on Mars it is just a part of the yearly cycle. In the summer, the temperature rises above the vapor point of carbon dioxide and therefore the dry ice sublimates back into the atmosphere. The polar cap then begins to shrink, though there is always some ice left at the poles. The two poles are not the same, however. The ice that remains at the north pole during the northern hemisphere's summer is mostly water ice, while the residual ice at the south pole is still mostly carbon dioxide ice. Scientists assume that there is water ice buried below the dry ice at the south pole. *Mars Polar Lander* was intended to resolve this particular question once and for all (but unfortunately did not).

Craters

As with Earth and the Moon, Mars was bombarded with debris left over from the formation of the Solar System. The craters left behind have many of the same properties as those on the Moon: a nearly circular raised rim, steep walls, and a smooth floor. If the debris hit with enough energy to liquefy the surface at impact, a central peak often formed in the center of the crater floor. Ejecta, material blasted into the air from the impact, fell in a blanket that extends outward from the crater. Unlike the Moon, however, ejecta blankets on Mars do not have a perfectly circular form. Many craters have irregular ejecta blankets that seem to indicate that some of the ejecta flowed across the surface outside of the crater rather than simply falling straight back to the surface. Craters of this type are called rampart craters because the ejecta is made up of sheets that have distinct outer ridges, or ramparts.

Another unique type of crater on Mars is the pedestal crater. This type of crater is found largely in the northern hemisphere. Craters of this type seem to sit upon a raised pedestal of ejecta. Some of these craters also show ridges like rampart craters, but in other cases the ridges have been eroded away by wind. In some cases the pedestal crater looks to be situated atop a flat, raised plateau which rises above the surrounding terrain.

Any of these types, including the more "standard" lunar-type crater can be made into an incomplete circle by lava flows covering part of the rim. These flooded craters are particularly common near the Tharsis Montes volcanoes.



Belz Crater, Chryse Planitia, Mars

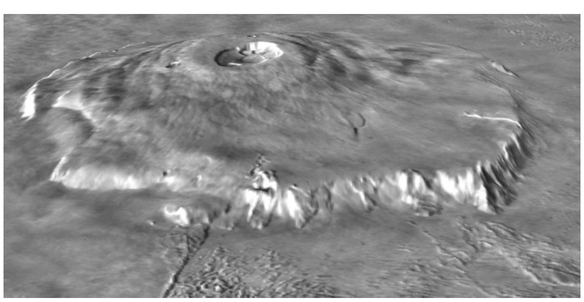
Credit: NASA

Wind Features

Although Mars has a very low atmospheric pressure, the surface winds are very fast. Wind effects are responsible for many of the features that are seen on Mars today. Sand dunes, very similar to those seen on Earth, are abundant in the northern hemisphere. These dunes form in broad lines that run perpendicular to the wind direction. By tracking these dunes, we gain some idea of how the Martian winds flow over time. The wind is also responsible for eroding the Martian landscape, often in strange and bizarre shapes. The wind is strong enough to blow the red dust away to expose darker-colored rock below, an effect which, as mentioned in Chapter 2, once convinced scientists that Mars was covered with vegetation.

Volcanoes

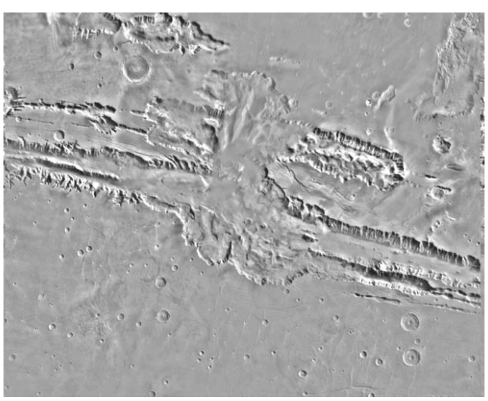
Mars has the largest volcanoes in the Solar System. One theory why this is true is that Mars seems to have a much thicker crust than Earth, and so it doesn't have floating, moving crustal plates. Instead of lots of comparatively small eruptions, as occurs with volcanoes on Earth, the pressure on Mars built up into major eruptions that always occurred in the same places – the weak points in Mars' stable crust. One of the most significant features influencing the development of volcanoes, however, is the Tharsis Montes bulge. The bulge is the site of Olympus Mons, the largest volcano in the Solar System, as well as the three Tharsis Montes volcanoes, each larger than any volcano on Earth. Olympus Mons is 22 km (13.75 miles) high and 550 km (343.75 miles) in diameter. If placed on the surface of the Earth, it would be two and a half times the height of the tallest mountain on Earth (Mt. Everest at 8.85 km or 5.5 miles) and would cover almost the entire state of Arizona! Numerous other volcanoes dot the region as well. These volcanoes were almost certainly formed from lava upwelling through vents in the fractures created by the bulge. No one really knows what formed the bulge. A number of theories have been proposed, but none have yet been proven. Mars has no magnetic field to speak of, so it probably has no molten, liquid core as the Earth does. Some rocks, however, do show "frozen-in" magnetic field lines, which could be evidence that Mars had a strong magnetic field – and therefore a liquid core – in the past. What happened to the core to cause it to solidify? What formed the Tharsis bulge? These are some of the puzzles that Mars presents to us today.



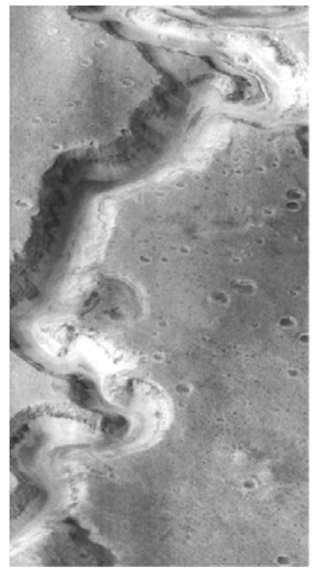
Olympus Mons
Credit: Goddard Space Flight Center

Canyons

Canyons exist in many places on Mars, but none are as famous as Valles Marineris ("The Valley of the Mariners", named for the American probes sent to Mars). The largest canyon in the Solar System, Valles Marineris is even visible from Earth. The canyon is not actually a single canyon, but is instead a system of interconnecting canyons. Valles Marineris varies in depth, but reaches a maximum over 7 km (4.37 miles). Individual canyons are as much as 200 km (125 miles) wide. The central section of Valles Marineris is made up of three nearly parallel canyons, having a total width of over 700 km (437.5 miles) and nearly 2,400 km (1,500 miles) in length. The total length of the Valles Marineris system is over 4,000 km (2,500 miles). The canyon is divided into three general parts. In addition to the central section, to the west, near the Tharsis Montes, is an extremely complex system of interlocking canyons called Noctis Labyrinthus. The eastern end of the canyon is a region of chaotic terrain that could be the result of huge floods flowing out of the canyon after it was formed. Unlike most canyons on Earth, Valles Marineris was not formed by flowing water. The canyon is another effect of the Tharsis bulge. One theory is that it was formed by a literal ripping apart of the Martian crust during the event that caused the Tharsis bulge. Another theory proposes that the canyon was formed when magma underneath it was drawn out in the eruptions of the Tharsis Montes. Once again, we have many puzzles, but very few answers.



Central Valles Marineris
Credit: NASA



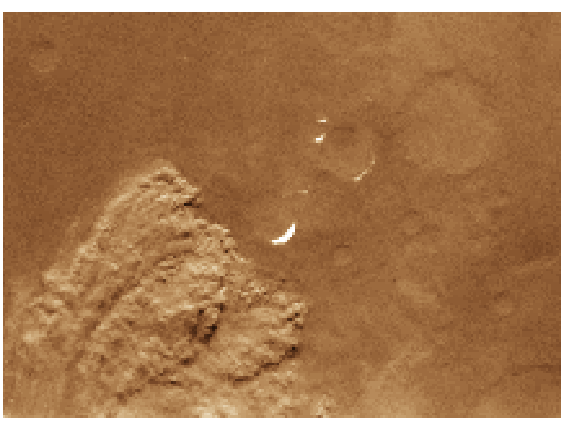
Nanedi Vallis
Credit: Malin Space Science Systems

Channels

As mentioned previously, Mars today cannot have liquid water present on its surface. We have ample evidence, however, that Mars did at one time have water flowing across its surface. Much of this evidence is in the form of channels that appear to be the result of water runoff and outflows from flooding. We know some channels were formed by flooding that resulted when large impact craters were formed on the surface. The force of the impact melted the permafrost (a layer of ice that scientists think lies frozen beneath the Martian surface) and caused the resulting water to flow violently away from the crater. This water eventually refroze or evaporated into the atmosphere. In addition to water-created channels, channels could also have been formed by flowing lava. Channels formed by water and channels formed by lava have very different appearances. The characteristics of the channel (its walls, its floors, whether or not it has tributaries, etc.) also tell us something about how much water was present and how fast it was flowing. The questions of what happened to the water on Mars and what the surface of Mars was like when water flowed across it are the central questions facing Mars scientists today. Our experience on Earth has been that where there is water, there is life. Is the same thing true on Mars?

Atmosphere

The atmosphere of Mars is very thin, but Mars still has weather! The atmosphere is composed of about 95% carbon dioxide, 2.5% nitrogen, and 1.5% argon. The remaining 1% is mostly oxygen, carbon monoxide, and water vapor. We believe that much of the water on Mars is frozen at the poles and under the ground in a layer called "permafrost", but some of it actually exists as ice-crystal clouds that float in the atmosphere. These clouds don't look like the fluffy cumulus clouds we see here on Earth, but they can resemble the thin, wispy cirrus clouds we often see high in our atmosphere. Where different air masses come together, cyclones can form on Mars, just as they do on Earth. The most striking features of the Martian atmosphere, however, are the dust storms, which can grow strong enough to cover the entire planet. In addition to the dust storm of 1971, which blocked *Mariner 9*'s view of the planet, in 1977 the *Viking* orbiters observed no fewer than 25 major dust storms, two of which grew to global proportions. In 2001, the *Mars Global Surveyor* spacecraft was fortunate to witness the formation and growth of the largest dust storm since the 1971 storm. We have learned a great deal about how the surface of Mars and its atmosphere interact as a result of seasonal heating. This is information that we can use here on Earth as we try to understand our weather and its interactions with the surface.



Local Dust Storm on the Surface of Mars

Credit: NASA

Arizona State University

National Aeronautics and Space Administration

Mars Uncovered

Revealing the Geologic History Through Mapping

An inquiry-based, critical thinking lesson about interpreting the geologic history of regions on Mars

STUDENT GUIDE

STUDENT WORKSHEET 1

Initial Observations and Strategies

Name(s) ________________________________

Date __________________________________

Look at the Thermal Emission Imaging System (THEMIS) Daytime Infrared (IR) image mosaic your teacher has given you. You will be investigating this image throughout this activity looking for clues about the geologic history of this region. Areas where no THEMIS data has been acquired yet are seen as vertical black lines on the image.

1. What is the name of your region on Mars: ______________________________________

2. What are the two main geologic features seen in your image? Explain the process of how these features form.

   A. Geologic Feature: ______________________________

   Formation:

   B. Geologic Feature: ______________________________

   Formation:

3. List two pairs of geologic features (two craters, or a crater and a channel) for which you can tell the relative ages (older/younger). Briefly describe where those features are on the image mosaic (NW part of image, center of image, etc.):

   A. Two Features:___________________________ Location:____________________

      Younger Feature:_____________________________________

      Older Feature:_______________________________________

   B. Two Features:___________________________ Location:____________________

      Younger Feature:_____________________________________

      Older Feature:_______________________________________

4. Describe two methods (strategies) you used to determine which features are younger/older.

   A.

   B.

Mars Uncovered

Revealing the Geologic History Through Mapping

OBJECTIVE:
Make a simple geologic map of a region on the surface of Mars and interpret the region's geologic history using relative age dating.

BACKGROUND INFORMATION:
Planetary scientists make geologic maps of Mars to understand the history of particular regions. The maps show present-day features along with evidence of past events that modified or changed the region. Scientists study these maps, looking for clues to determine what geologic events have occurred. An important technique is called **relative age dating**.

Relative age dating uses inference (which is often just common sense) to reveal the sequence of events that shaped a planetary surface. While exact dates in years can not be determined, noting which event occurred before or after a different event lets you reconstruct a relative-age geologic history. On Earth, geologic maps are made by scientists on foot in the field, plus photographs taken from airplanes or Earth-orbiting satellites. On Mars, maps are made using photographs (images) taken by orbiting spacecraft. (In very local areas, rovers have begun to act like scientists on foot.)

Over the past 30 years, cameras on spacecraft have taken lots of images from above the martian surface. Like puzzle pieces, individual images of specific areas can be put together to create what scientists call a mosaic. Image mosaics let you look at a large region, analyze it, and interpret its geologic history.

This activity will put you in the role of a scientist. You will use image mosaics taken with the Thermal Emission Imaging System (THEMIS). This camera system is onboard NASA's Mars Odyssey orbiter. THEMIS has taken hundreds of thousands of images of Mars that are available on the Internet at http://themis.asu.edu.

THEMIS (pictured on the left) 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

This activity will use mosaics of daytime infrared THEMIS images. Although infrared mosaics provide information on both the morphology (the shape of the surface) as well as the temperature of the surface, for this activity, you will focus only on the morphology, identifying features such as craters and channels. As you map a region, it is important for you to be able to:

- Distinguish between preserved, modified, and destroyed craters
- Understand different relative age dating principles

These are both relative age dating techniques. They will help you better interpret the sequence of events that made a surface look the way it does today.

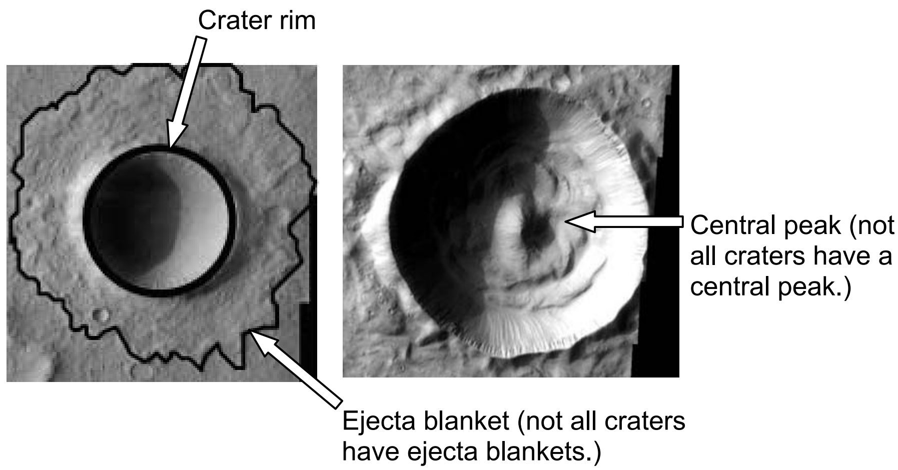
Mars Uncovered

Crater Classifications

We can classify impact craters into three general categories or classifications based on their appearance. These three categories give clues about the history (or relative age) of the crater. We cannot identify the exact age of a crater on Mars, but relative ages for different craters can help us develop a sequential history.

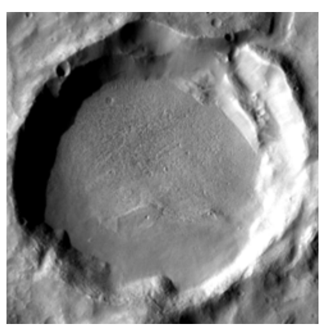
I. Preserved Craters:

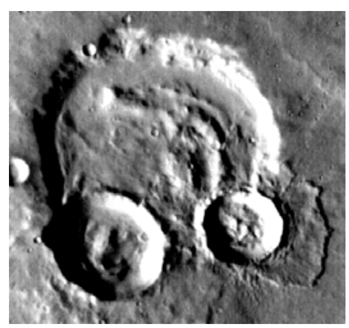
- Near perfect craters
- Raised rims
- Look new
- Can sometimes see ejecta blanket or central peak
- Young crater



II. Modified Craters:

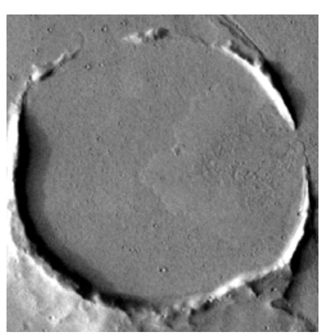
- Craters that have been changed or modified by:
  - o Erosion (wind, water or lava)
  - o Other impacts
- Sometimes crater ejecta is visible but looks eroded
- Crater may have smooth floor (partially filled in with material or sediment)
- Middle-aged craters

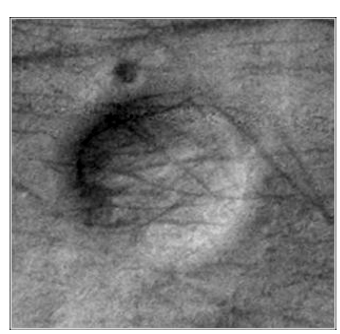




III. Destroyed Craters:

- Look very worn away
- Rims are broken
- Have been severely changed or modified
- Crater has been filled in almost completely by sediment
- Very old craters





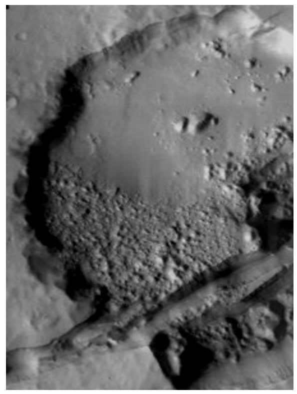
Mars Uncovered

Relative Age Dating Principles

Scientists use two basic rules or principles to help determine the relative age of craters or other features on a surface. They are as follows:

I. Cross-Cutting Relationships:

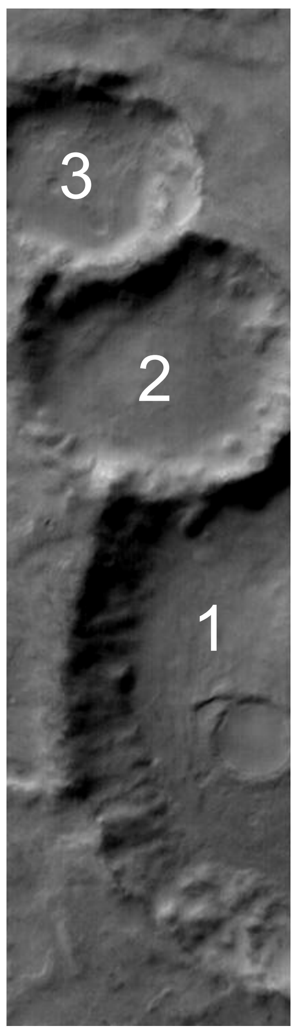
- A crater (or any other feature) can be cut by another feature.
- The feature cut is older than the feature that cut it.



Crater shown here is older than the fracture (crack) that cut through it.

II. Principle of Superposition

- When one feature is on top of another feature, the feature on top is younger.
- The feature on the bottom is the older feature.



Crater #1 is partly covered by crater #2, so crater #1 is older.

Crater #2 is partly covered by crater #3, which makes crater #2 older than #3.

By inference then, crater #1 is the oldest and crater #3 is the youngest.

Student Worksheet 2

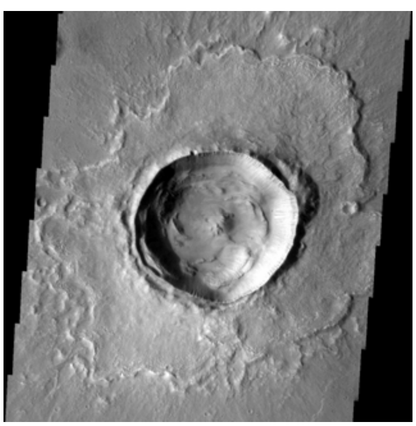
Classifying Craters

Name(s) ______________________________

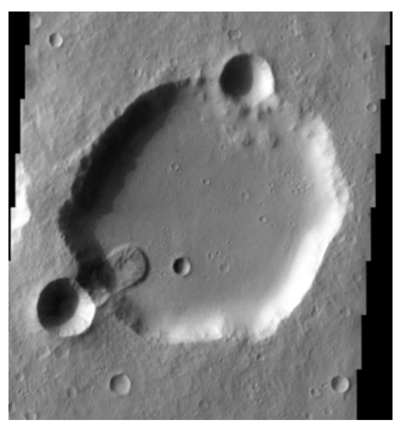
Date ________________________________

Based on the *Crater Classification* information sheet, classify the craters at the bottom of the page. Be sure to explain your reasoning for each classification.

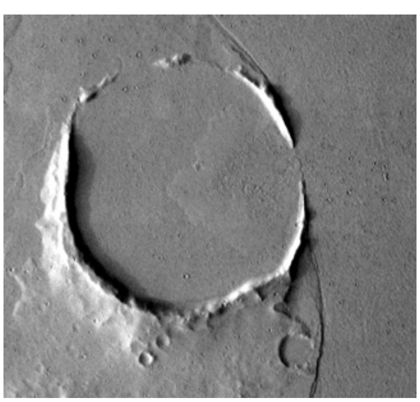
CRATER IMAGE	**CRATER CLASSIFICATION (Preserved, Modified or Destroyed)**	**REASONS**
Crater A		
Crater B		
Crater C		
Crater D		



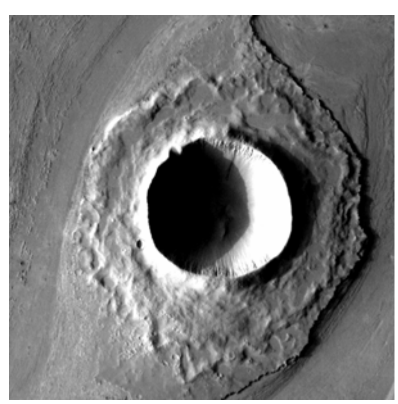
Crater A



Crater B



Crater C



Crater D

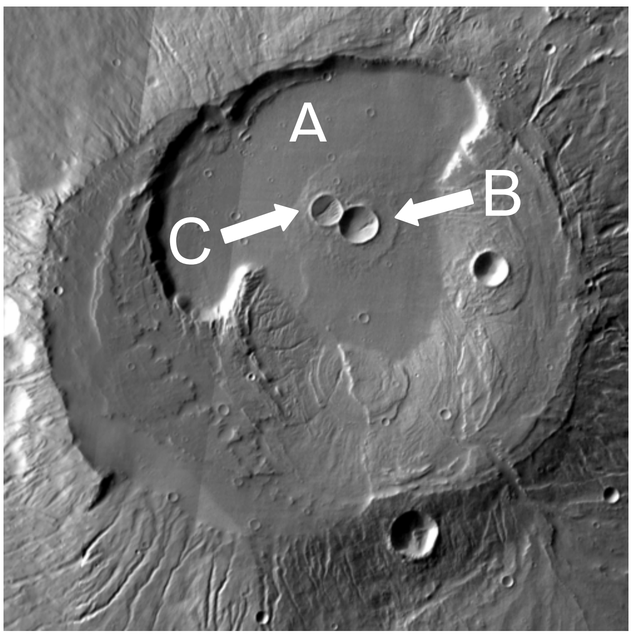
Student Worksheet 3

Relative Age Dating Principles

Name(s) ________________________________

Date ___________________________________

Based on the two relative age dating principles (cross-cutting relationships and superposition), write your interpretation of the relative ages of the features in the following images:



Oldest Feature: ________

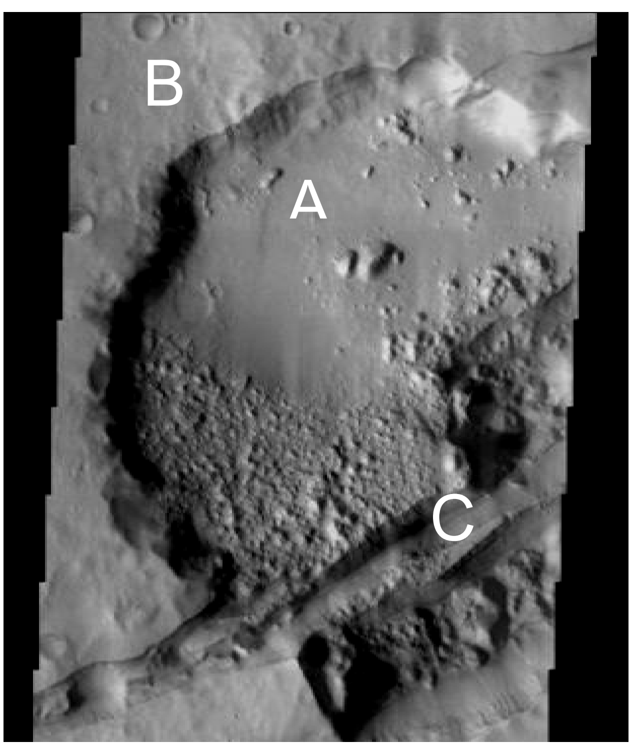
Younger Feature: ________

Youngest Feature: ________

Please explain your answers:

Which principle(s) did you use to choose your answer?

____



Oldest Feature: ________

Younger Feature: ________

Youngest Feature: ________

Please explain your answers:

Which principle(s) did you use to choose your answer?

____

Student Worksheet 4

Creating a Surface Feature Map

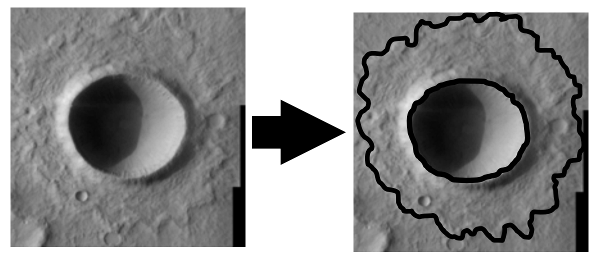
Now you know how to classify craters and are familiar with relative age dating principles. You can now create a feature map of your region of Mars that will help you interpret the geologic history.

In order to create your feature map, you will need to put a piece of transparency paper over your THEMIS mosaic image. Using paper clips, secure the THEMIS image and your paper together.

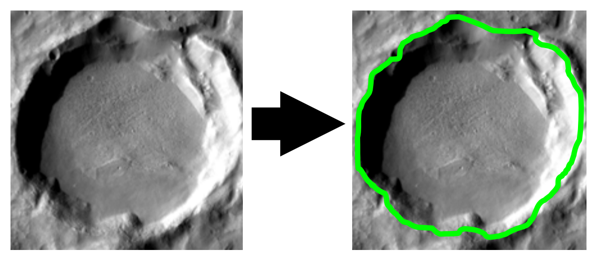
Using your observations and erasable markers, identify the features listed below to create your map. Keep in mind that some features may be too small to map. Use your best judgment to decide what may be too small to map and in determining how to the outline or color features. Outline or color the features as indicated below.

Feature | **Colored Feature**

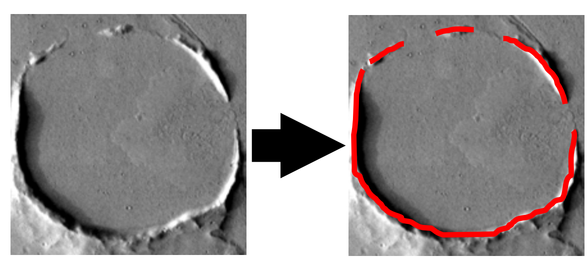
1. **Preserved Craters**: Carefully outline the rims and ejecta (if visible) of all preserved craters in **BLACK.**



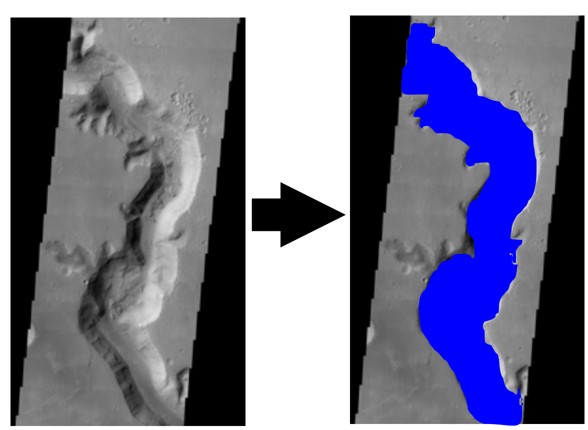
2. **Modified Craters**: Carefully outline the uneven, or eroded rims and ejecta (if visible) of the modified craters in **GREEN.**



3. **Destroyed Craters**: Carefully outline the very eroded crater rims in **RED.**



4. **Channels:** Color (not outline) all channels in **BLUE.**



STUDENT WORKSHEET 5

Interpreting the Geologic History

Name(s) ________________________________

Date ___________________________________

Once you have made your feature map, you are now able to answer some questions and interpret the geologic history of your region. Be sure to name the age dating technique you used for each answer.

REGION NAME: ______________________________________

1. Which is older – the channel(s) (blue) or the destroyed (red) craters? How do you know?

2. Which is older – the channel(s) (blue) or the modified (green) craters? How do you know?

3. Which is older – the channel(s) (blue) or preserved (black) craters? How do you know?

4. Which are older – most large craters or smaller craters? How do you know? Why do you think this is?

5. Which features are oldest, youngest, and of medium age?

Student Worksheet 5

Interpreting the Geologic History
(cont'd)

6. Scientists don't always agree, but they try to convince each other with logical reasons for their interpretations. Discuss and defend your answers to questions #1 through #5 with another group that is studying the **same region**. Change any of your answers to questions #1 through #5 if you feel it is necessary. Fill out the table below after your discussion.

Question #	Did you agree or disagree with the other groups answer	Did you change your answer (yes or no AND why) (Be specific and use 'geologic reasons')
1		
2		
3		
4		
5		

7. Write your interpretation of the geologic history (the sequence of events that made this area look the way it does today) of this region of Mars. You can use this sample starting sentence or create your own. Use additional paper as necessary.

In the ________________________ region of Mars, there was a lot of geologic activity that modified the surface. First, what happened was…..

Student Worksheet 6

Initial Strategies and Future Investigations

Name(s) ________________________________

Date ____________________________________

1. Look back at question #4 from *Student Worksheet 1*. List each of your initial strategies in the first column provided below. In column two, indicate if you feel it was a valid scientific strategy (method) to use. Use the knowledge you acquired after completing the lesson to make this decision. In the third column, state the common scientific name (if one exists) for the strategy you listed (crater classification or one of the relative age dating principles). If you feel your strategy is valid but there is no name for that strategy, create a name for that strategy that you feel is appropriate. If you feel the scientific strategy is not valid, leave the last column blank.

Initial Strategy Used	**Valid Scientific Strategy (Yes or No)**	**Common Scientific Name (if applicable)**

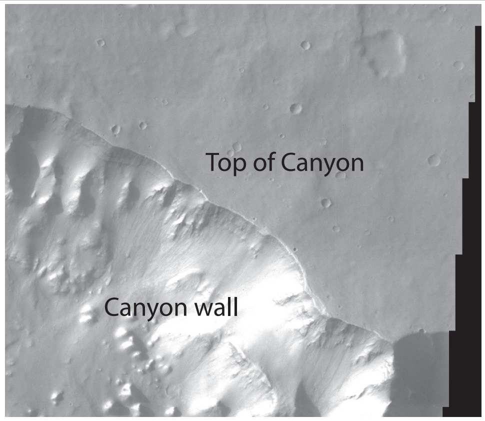
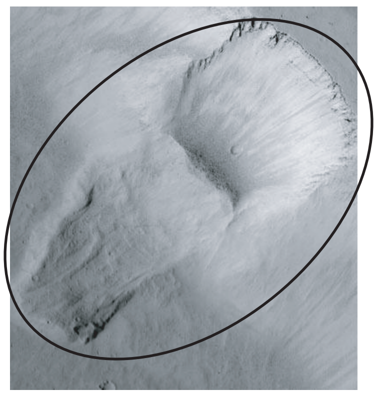
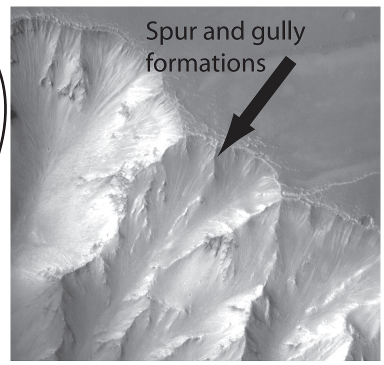
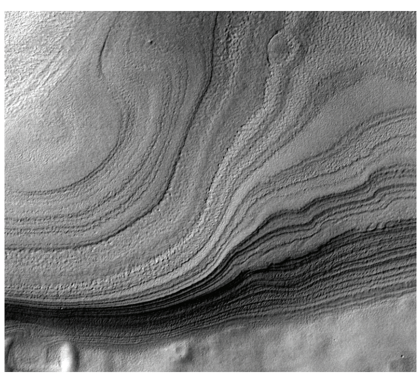
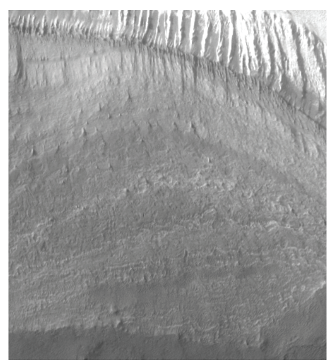
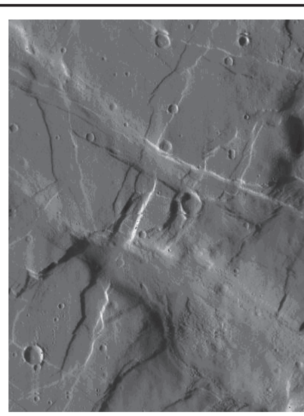
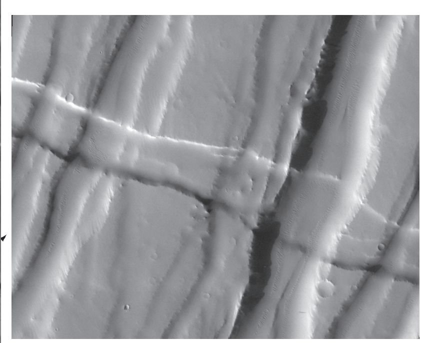
2. After creating, observing and interpreting your feature map, list at least two questions you have about channels or craters on Mars and how would you go about investigating each question?

Question about craters or channels on Mars	**How would go about investigating your question?**
1.	
2.	

NOTES

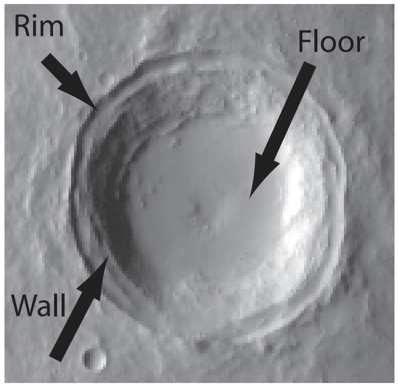
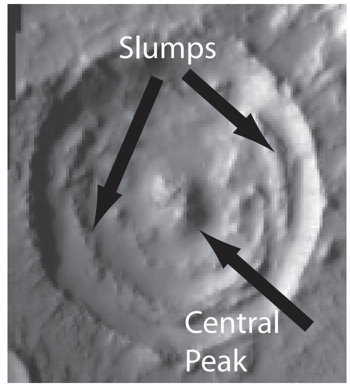
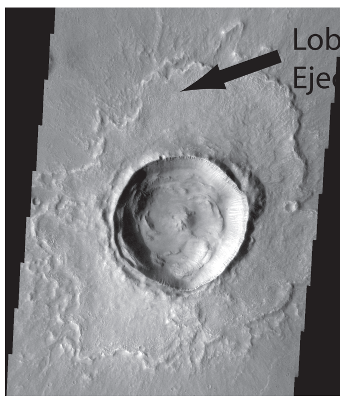
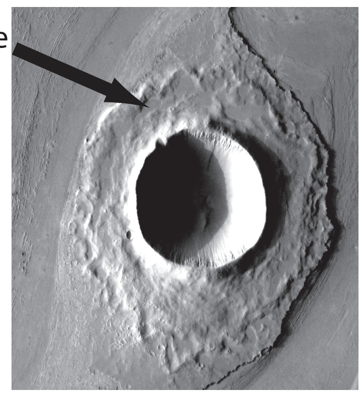
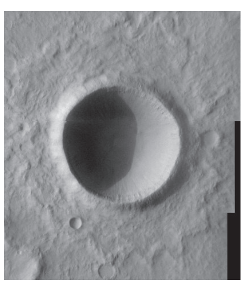
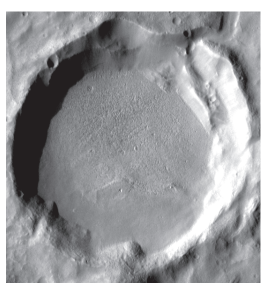
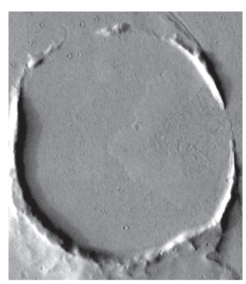
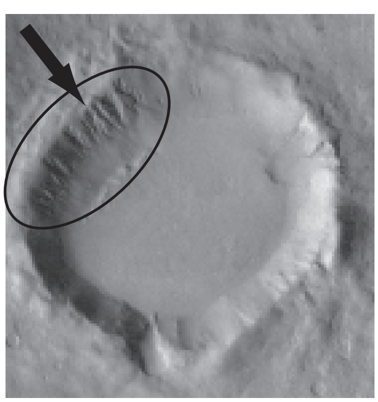
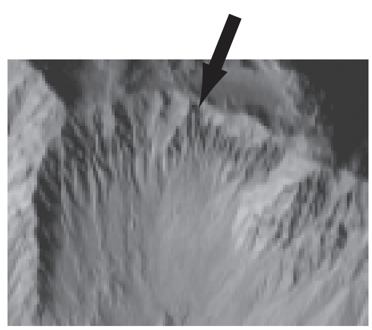
FEATURE IDENTIFICATION CHART

Features Often Associated with Canyons

Feature	An Example of this Feature	Description of Feature
Canyons		-Identified by a steep drop in elevation, similar to what we see with canyons on Earth -Canyon walls often show material that has fallen or slid down slope -Top of canyon is generally flat and smooth
Landslides	 	-Material that has fallen or slid down a steep slope -Landslide material piles up at the bottom of slope -Often seen on steep canyon walls -Spur and gully formations are landslides that look similar to gullies that can be seen on crater walls
Layers	 	-Layers of material can be seen in different areas of Mars, including canyon walls -May be formed by stacks of lava flows, ash from volcanoes, dust, or by sediments deposited in water
Fractures/Faults	 	-The result of a break in the surface -Thought to be a result of weaknesses in the crust -Generally straight features that scar the surface -Often run parallel in areas where multiple fractures occur

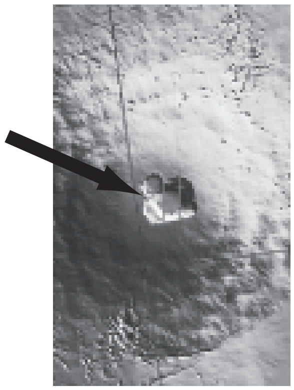
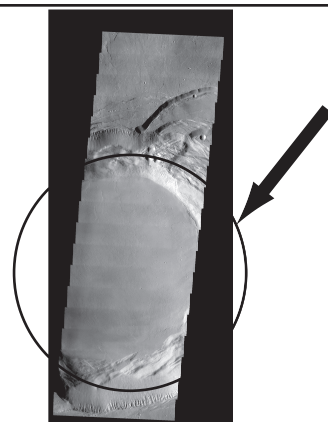
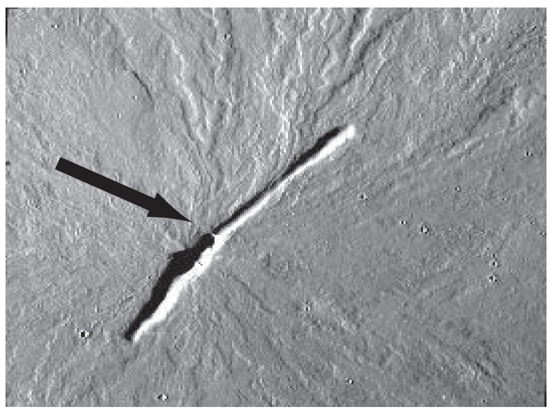
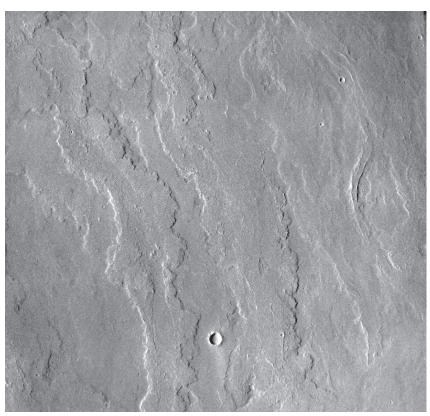
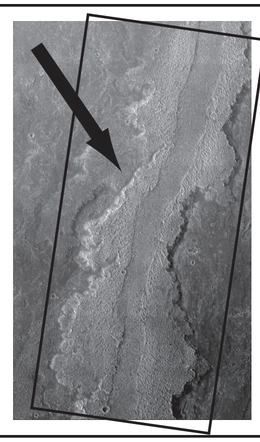
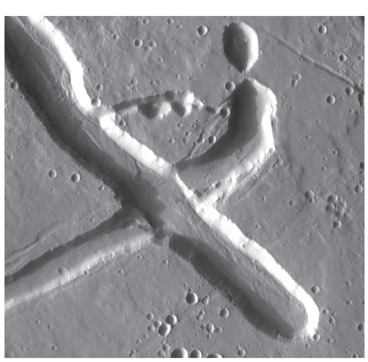
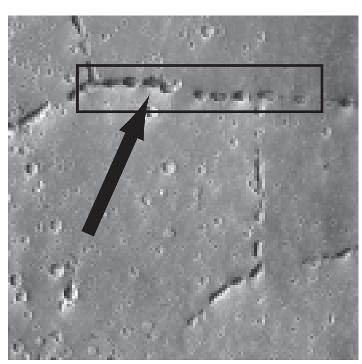
FEATURE IDENTIFICATION CHART

Features Often Associated with Craters

Feature	An Example of this Feature	Description of Feature
Crater	 	-Formed by meteorites striking the surface -Circular in shape -Have a rim, floor, and walls -Some have central peaks -Material can slump down to the bottom of the crater
Rampart Crater	 	-Have a special ejecta called lobate -Lobate ejecta looks like it flowed away from the crater (as if you dropped a ball into mud) -Are associated with liquid water or ice being below the surface at impact
Crater Classifications: Preserved Modified Destroyed	Preserved  Modified  Destroyed 	**Preserved Craters:** -Near perfect craters -Raised rims; look new **Modified Craters:** -Older craters -Changed by erosion or other impacts **Destroyed Craters:** -Very old -Look very worn away
Gullies	 	-Often found on crater walls or other slopes -Appear to be very young -Possibly associated with: 1. Past liquid water 2. Areas once covered with snow

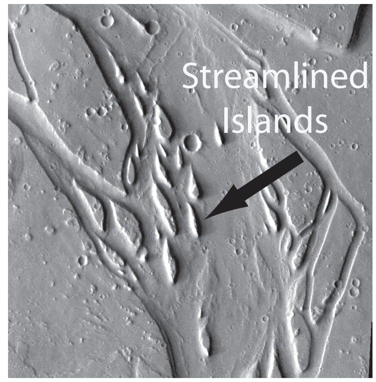
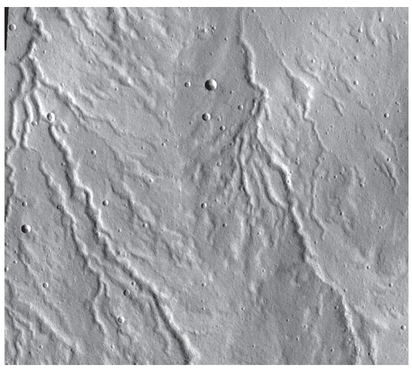
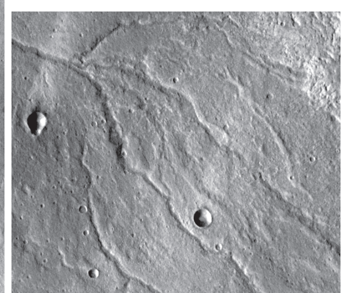
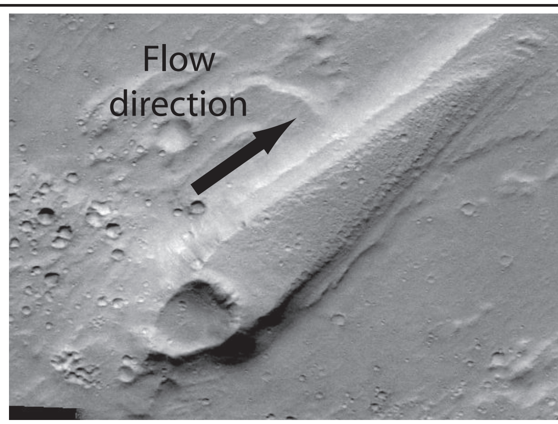
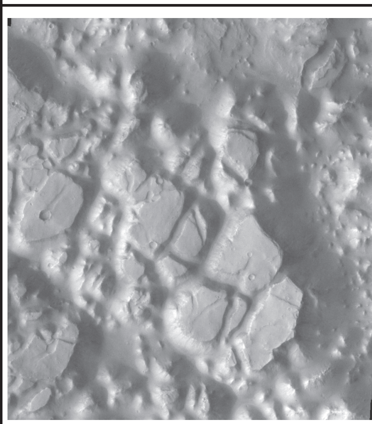
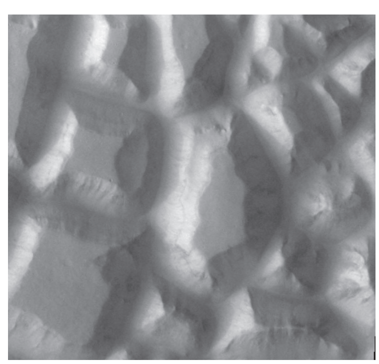
FEATURE IDENTIFICATION CHART

Features Often Associated with Volcanoes

Feature	An Example of this Feature	Description of Feature
Caldera	 	-A circular depression generally at the summit of a volcano -Considered a collapsed feature (magma comes up through a chamber and once the chamber is empty, collapse can occur) -Sometimes called a central vent
Fissures		-Cracks that are found sometimes on the sides of volcanoes -Lava flows can be seen trailing away from these cracks, indicating a fissure eruption
Lava Flows	 	-Formed by the eruption and flow of lava from a volcano -Flows can look "wavy" or “fingery” -You can often identify multiple lava flows in an image -Flows are raised features
Collapsed Lava Tubes	 	-Look similar to channels -Lava once flowed under ground through a “tunnel” and once the tunnel is empty these features often collapse -Some aren’t completely collapsed and look like a chain of small craters

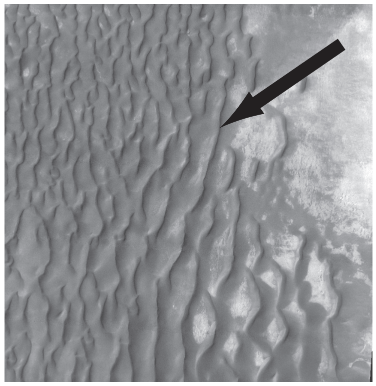
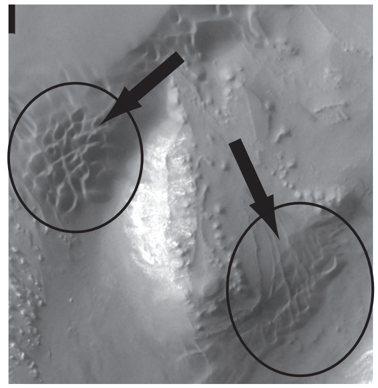
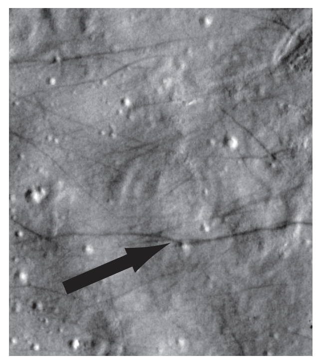
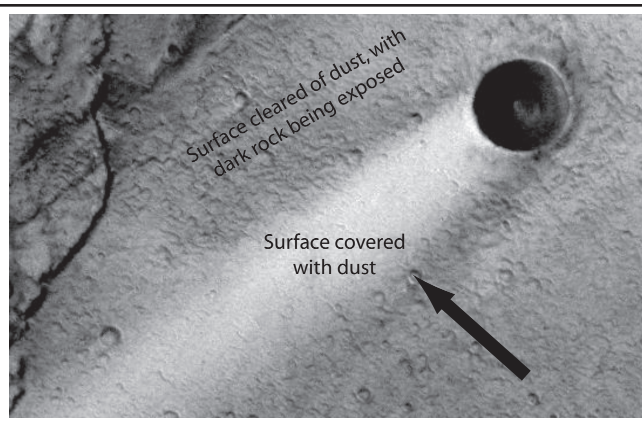
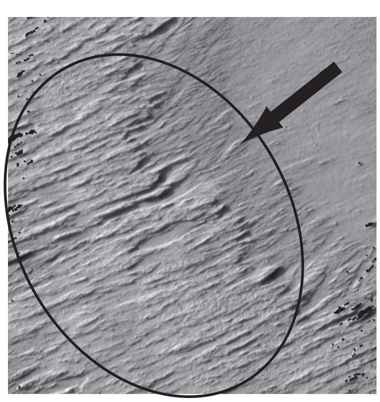
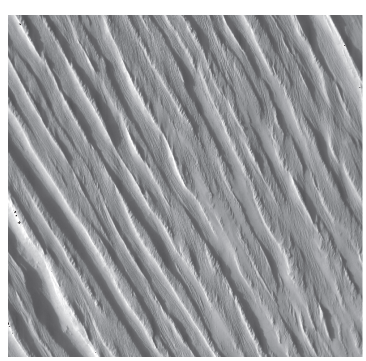
FEATURE IDENTIFICATION CHART

Features Often Associated with Water-Related (Fluvial) Processes

Feature	An Example of this Feature	Description of Feature
Channels	 Simple Channel  Outflow Channel	SIMPLE CHANNELS: -Formed by a consistent flow of water over a long period of time -Has a curvy or meandering shape OUTFLOW CHANNELS: -Huge channels formed by a catastrophic flood -May have streamlined islands
Valley Networks	 	-Small channels -Generally formed by small amounts of water -May have branching (dendritic) pattern starting with small branches and feeding into larger ones.
Streamlined Islands		-Thought to be associated with the past flow of water around a feature, such as a crater -Often found in outflow channels where large amounts of water flowed -Indicate flow direction -Also called teardrop islands
Chaotic Terrain	 	-Often found at the head or start of large channels -Thought to be areas where water burst out from the ground causing a chaotic collapse of the surface -Can look like jumbled terrain

FEATURE IDENTIFICATION CHART

Features Often Associated with Wind-Related (Aeolian) Processes

Feature	An Example of this Feature	Description of Feature
Sand Dunes	 	-Can form in many areas -Often seen in the bottom of craters or channels -Generally darker than the surrounding terrain -Can range in size and shape -Look like ripples of material
Dust Devil Tracks	 	-Left by dust devils (mini-tornadoes) moving through an area -Dust devils pick up dust uncovering the darker surface underneath -Darker tracks are newer -Lighter tracks tend to be older, as they could have been recovered by some dust
Wind Streaks		-Can be light or dark -Are often seen behind craters -Can give you an idea of wind direction
Yardangs	 	-Formed by sand-sized particles being blown against a surface wearing it away -Have a uniform direction -Are linear features -Found on surfaces that erode easily

Identify and sketch your favorite geologic features from the THEMIS images. Consider the importance of the context!

Instructions:

1. Observe the labeled image and materials at your table. Look at the approximate location of where the THEMIS image is located on the MOLA elevation map of Mars. Write down information you think is important about the surrounding area (the context) that may play a role in the formation of the geologic features you are observing in the THEMIS image.
2. Using the *Feature Identification Charts*, look at the labeled features identified on the THEMIS image. List two to three geologic features you find interesting from the image. You can choose to list features that may or may not have been labeled.
3. Sketch and label your favorite geologic feature or combination of features from each THEMIS image.

Image # A - Example

What is in the surrounding area (the context) of where this image was taken that may be important for understanding the geologic features that are in this image? *near other channels and in the northern hemisphere - low elevation*

Name two to three geologic features in this image:

- _____Channels_____________________
- ______Craters_____________________
- _______Streamlined islands______________

Sketch and label your favorite feature(s):

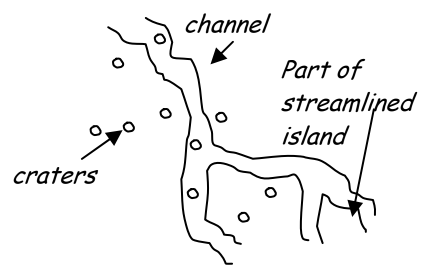


Image # 1

What is in the surrounding area (the context) of where this image was taken that may be important for understanding the geologic features that are in this image? ____

Name two to three geologic features in this image:

- ________________________________
- ________________________________
- ________________________________

Sketch and label your favorite feature(s):

Image # 2

What is in the surrounding area (the context) of where this image was taken that may be important for understanding the geologic features that are in this image? ______________________________________

Name two to three geologic features in this image: Sketch and label your favorite feature(s):

- ________________________________
- ________________________________
- ________________________________

Image # 3

What is in the surrounding area (the context) of where this image was taken that may be important for understanding the geologic features that are in this image? ______________________________________

Name two to three geologic features in this image: Sketch and label your favorite feature(s):

- ________________________________
- ________________________________
- ________________________________

Image # 4

What is in the surrounding area (the context) of where this image was taken that may be important for understanding the geologic features that are in this image? ______________________________________

Name two to three geologic features in this image: Sketch and label your favorite feature(s):

- ________________________________
- ________________________________
- ________________________________

Image # 5

What is in the surrounding area (the context) of where this image was taken that may be important for understanding the geologic features that are in this image? ______________________________________

Name two to three geologic features in this image: Sketch and label your favorite feature(s):

- ________________________________
- ________________________________
- ________________________________

Image # 6

What is in the surrounding area (the context) of where this image was taken that may be important for understanding the geologic features that are in this image? ____

Name two to three geologic features in this image:

- ________________________________
- ________________________________
- ________________________________

Sketch and label your favorite feature(s):

Image # 7

What is in the surrounding area (the context) of where this image was taken that may be important for understanding the geologic features that are in this image? ____

Name two to three geologic features in this image:

- ________________________________
- ________________________________
- ________________________________

Sketch and label your favorite feature(s):

Image # 8

What is in the surrounding area (the context) of where this image was taken that may be important for understanding the geologic features that are in this image? ____

Name two to three geologic features in this image:

- ________________________________
- ________________________________
- ________________________________

Sketch and label your favorite feature(s):

Image # 9

What is in the surrounding area (the context) of where this image was taken that may be important for understanding the geologic features that are in this image? ____

Name two to three geologic features in this image:

- ________________________________
- ________________________________
- ________________________________

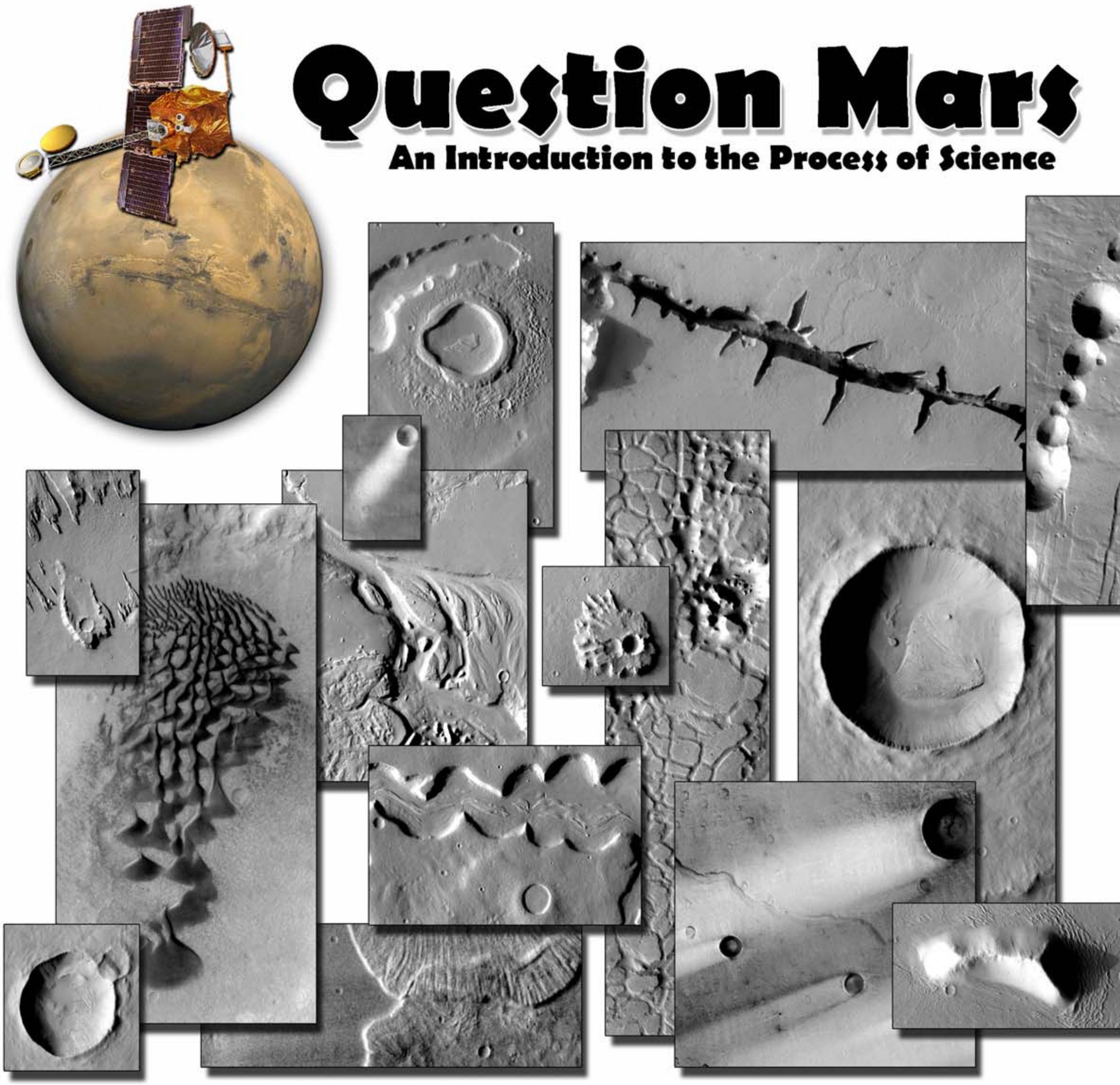
Sketch and label your favorite feature(s):

Arizona State University

National Aeronautics and Space Administration

Question Mars

An Introduction to the Process of Science



An inquiry-based, critical thinking lesson as an introduction to the process of science.

STUDENT GUIDE

Question Mars

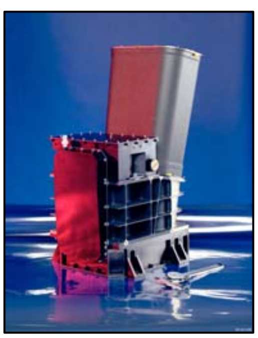
An Introduction to the Process of Science

Objective: Create a question about Mars that can be answered using images taken from orbit.

Student Introduction:
All science begins with a question. That is the foundation of this activity. The process of science begins with what some people refer to as the “scientific method”. We learn and practice this in our classrooms. This process can start from questions we create based on our curiosity. Professional scientists have questions about Mars they want to answer, and so will you as you start to investigate images from our neighboring planet. As you go through the process of science as it relates to this activity, it is important for you to:

- Think about what you are curious about related to Mars and create general questions
- Evaluate your questions making sure you have appropriate tools to answer those questions
- Realize that science is most often conducted in small bits and pieces. It’s understandable to have “big picture” questions, but scientists (and you) need a specific focus/question of study. This will contribute to a greater understanding about Mars through detailed research.

There are many images available of Mars. Over the past 30 years, NASA has sent landers, rovers and orbiters to image the surface of Mars. This activity will focus on images that have been taken from orbit. The Mars Odyssey spacecraft has been orbiting Mars since 2001. One of the tools it uses to take images of Mars is the Thermal Emission Imaging System (THEMIS). THEMIS has taken thousands of images of Mars that are available on the Internet (http://themis.asu.edu).



THEMIS (pictured on the left) 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 also show the morphology or shape of the surface in much the same way visible images do.

As you gather observations, you should try to focus on and examine visible images. If you do decide to examine infrared images, just be sure to focus on the shapes (morphology) of the surface features you see.

All science begins with a question and continues with observations and the development of possible hypotheses based on your initial observations. Keep in mind that it is a natural part of science to refine or even change your question as you research. The process of science continues with designing an experiment of how to answer that question and test your hypotheses. For this activity, the focus is on coming up with a question to research using the THEMIS camera as your primary tool or data set. This is not necessarily an easy task, but through making observations and looking for patterns, it should be fun!

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Student Worksheet 1

Establishing a Research Topic

Name(s) ___________________________________

Date _______________________________________

1. Within your group, brainstorm four general topics that can be studied about Mars:

________________________________ ________________________________

________________________________ ________________________________

2. After a class discussion, list six major categories of topics the class can choose to study about Mars:

________________________________ ________________________________

________________________________ ________________________________

________________________________ ________________________________

3. List the topic your group will research: ____

Brainstorming Questions

List five questions you are curious about based on your topic and how it may relate to Mars:

Question 1: ____

____

Question 2: ____

____

Question 3: ____

____

Question 4: ____

____

Question 5: ____

____

Student Worksheet 2

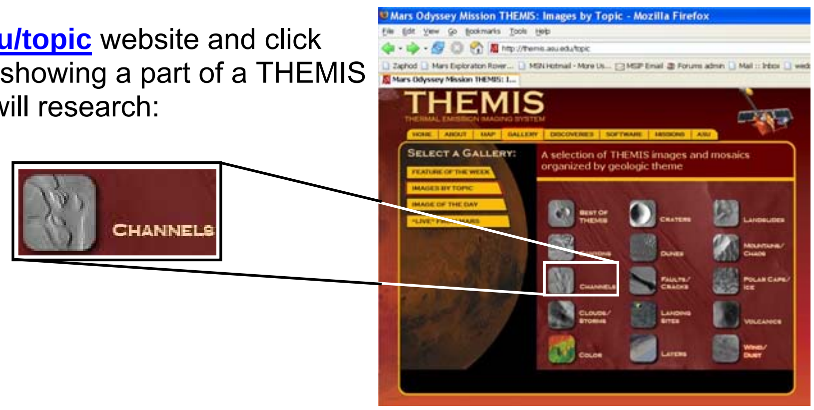
Making Observations of THEMIS Images

Name(s) ______________________________

Date ________________________________

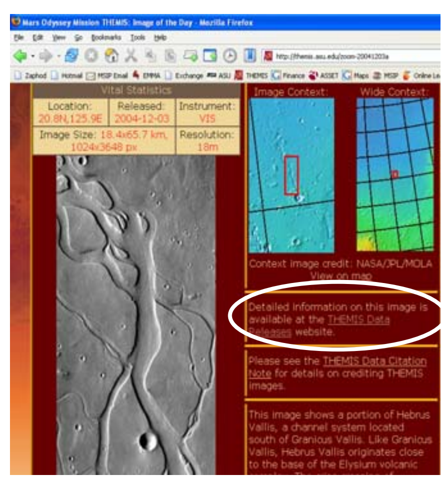
This activity will focus on images that have been taken from orbit by the Thermal Emission Imaging System (THEMIS) onboard the Mars Odyssey spacecraft. These images of Mars show great detail of many of the geologic features seen on the surface of Mars from orbit. In this exercise, you will look at THEMIS images and log specific information about each image you observe. Here's what to do:

1. Go to the http://themis.asu.edu/topic website and click on the thumbnail (small square showing a part of a THEMIS image) of the topic your group will research:



2. Click on any of the thumbnails to see a THEMIS image of Mars related to your topic:
   - There are six large thumbnails at the top of the page.
   - Below the top six thumbnails are more thumbnails of additional images.
   - There are generally multiple pages of image thumbnails to choose from.

3. Click on a thumbnail to see a specific THEMIS image, context images showing the area where the image is located on Mars, and general information about the image.
   - You can get an enlarged view of the THEMIS or context images by clicking on the image.
   - To get the Image Identification Number click on the THEMIS Data Releases link.
     - This will open a new window showing the Image ID # and image information
     - Images that are not yet released will not have this link.



Student Worksheet 2 (continued)

4. Log the information on the observation tables. Make observations of a minimum of four images. The more images you can observe, the more easily you can look for patterns. Log the following:

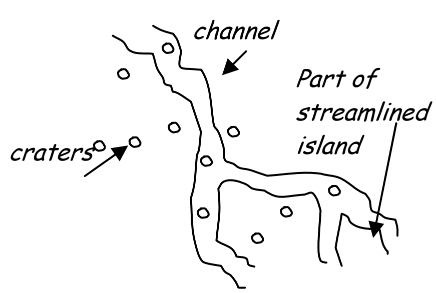
    a. Surface/Geologic Feature(s) Observed: Name the **specific** surface/geologic features you find interesting in each image. Look for patterns or for the same surface/geologic features in multiple images. Be sure to include those same features in your table multiple times. This will help you remember how a particular feature looks the same (or different) in multiple images – very valuable information! To help you correctly name surface/geologic features, use the **Feature Identification Charts**.

    b. Image ID Number: If the image has the THEMIS Data Releases link, click on it to find the image identification number. If not, write the title of this image and/or the page, column, and row number to possibly relocate it.

    c. Sketch the Geologic Feature(s): Make a sketch or drawing of the portion of the THEMIS image that shows the feature(s) you are observing. Do not sketch the entire image.

    d. Specific Observations of Geologic Feature(s): Write down specific observations of the feature(s) you sketched. Consider patterns you may look for with these features in other images.

Here's an example of how you can fill out the observation table:

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*

Student Worksheet 2

Making Observations of THEMIS Images

Surface/Geologic Feature(s) Observed & Image ID #	Sketch of Surface/Geologic Feature(s)	Specific Observations of Surface/Geologic Feature(s)
Image ID #:		
Image ID #:		
Image ID #:		
Image ID #:		

Student Worksheet 2

Making Observations of THEMIS Images

Surface/Geologic Feature(s) Observed & Image ID #	Sketch of Surface/Geologic Feature(s)	Specific Observations of Surface/Geologic Feature(s)
Image ID #:		
Image ID #:		
Image ID #:		
Image ID #:		

STUDENT WORKSHEET 3

Question Development – Refining Questions

Name(s) ___________________________________

Date ______________________________________

After making your observations of the different surface/geologic features, you should now have a better idea of what types of questions can be answered using THEMIS images. Keep in mind that ALL questions are good questions! Anything you are curious about is a valid question! For any science experiment, however, your question should be answerable by using the tools you have available. Your primary tool are images taken by the THEMIS camera.

In order to be sure you have the best question possible for your team to research, you will go through three steps.

- STEP ONE: Create three new questions, stating the geologic features that will be the focus of your question.
- STEP TWO: Evaluate each of your new questions with a set of criteria.
- STEP THREE: Discuss and debate with your teammates to finalize the science question you will focus your research on.

STEP ONE:
Create three new questions that focus on specific geologic feature(s) you have observed. Important points to think about are:

- Focus on Identified Surface/Geologic Features: Look at your *THEMIS Observation Tables*. Choose a **feature or combination of features** (sand dunes, lava flows, lava tubes, etc.) you were able to identify in one or more THEMIS image as the focus of your question.
- Try to focus on **size(s)** or **shape(s)** or **where a feature may form**.
- Key Question Words: Some suggested key words you may consider using are: evidence, size, shape, similarities, differences, relationships, patterns, distribution. Here are a few examples of possible questions:
    - Is there a relationship between ___________________ and ___________________?
    - What is the size range of ____?
    - Where do ____________________ occur on or around _______________________?

Here are two examples:

Example 1: Name of Surface Feature: Lava tubes

Sample Question: How wide are different lava tubes on Mars?

Example 2: Name of Surface Feature: Dunes and craters

Sample Question: Is there a relationship between crater size and evidence of sand dunes?

Create your new questions on the next page:

Student Worksheet 3 (continued)

Name of Surface Feature(s):________________________________

Question 1: ____

____

Name of Surface Feature(s):________________________________

Question 2: ____

____

Name of Surface Feature(s):________________________________

Question 3: ____

____

STEP TWO:
Look at the three new questions you just created. Evaluate your questions by using the checklist below. If you can check (√) most, or all of the red and blue boxes, your question should be good enough for your team to consider as the focus for your research.

Remember, all questions are good questions! It is important, however to be sure you are asking a question that can be answered with the tools you have available – in this case, the THEMIS camera.

Questions

1	**2**	**3**	
			Question can be answered by images taken by the THEMIS camera.
			Question includes the name(s) of the surface geologic feature(s) you want to study.
			Question focuses on one or more of the following aspects of geologic features: Size(s) ☐ Shape(s) ☐ Where features form ☐ __________(other) ☐
			Question **does not** focus on **<u>HOW</u>** features form.
			Question includes one of the following words: evidence, size, shape, similarities, differences, relationships, patterns, or ____________________

Decide which one of your questions would be the best potential question for your team to research.

Potential Science Question: ____

____

STUDENT WORKSHEET 3 (continued)

STEP THREE:
After discussing and debating your potential questions within a group, now as a whole **TEAM**, decide which final question is the most interesting and answerable question using THEMIS images. Try not to feel "possessive" of your own created question. Your creation and participation in the team discussions and decisions will help your team select the best and most interesting question to focus on for your research.

Write your team's final science question in the box below.

Final Team Science Question: ____

____

Make sure your final question meets the criteria. If you can check (√) most, or all of the red and blue boxes, your question should be good enough for your team to use as the focus for your research.

- ☐ Question can be answered by images taken by the THEMIS camera.
- ☐ Question includes the name(s) of the surface geologic feature(s) you want to study.
- ☐ Question focuses on one or more of the following aspects of geologic features:
  Size(s) ☐ Shape(s) ☐ Where features form ☐ __________(other) ☐
- ☐ Question **does not** focus on **HOW** features form.
- ☐ Question includes one of the following words: evidence, size, shape, similarities, differences, relationships, patterns, or ______________________

STUDENT WORKSHEET 4

Experiment Design and Hypothesis Development

Name(s) ___________________________________

Date ______________________________________

For this exercise you will focus on one particular question that you refined in the last exercise. You will create a plan (an experiment design) of how you would go about answering that question using THEMIS images. Additionally, you will develop a set of working hypotheses (possible answers to your question) and consider how you would go about testing those hypotheses.

Science Question:____

____

1. What specific feature(s) do you need to have in a THEMIS image to answer this question?

2. What regions of Mars would you go to in order to find images that would help you answer this question? (You can either name regions of Mars or describe what type of regions you would look for.)

3. How many images of Mars do you think would be necessary to realistically and sufficiently answer your question?

   1   5 - 10   20 - 40   60 - 80   100+

   Please explain:

4. Do you need to make any measurements to answer your question? If yes, what measurements need to be made?

STUDENT WORKSHEET 4 (continued)

5. Based on your current observations, list at least one possible outcome to the answer to your question? (This will become your working hypothesis.) Include what observations you have already made that lead you to formulate your hypothesis.

   Hypothesis Example for the question "Is there a relationship between crater size and sand dunes?": *Craters larger than ~18 km will more likely have sand dunes than smaller craters.*

   Current observations that support this hypothesis: *Within our group we observed sand dunes in about five images that had craters wider than the THEMIS image width. There were no smaller craters that had sand dunes. Since THEMIS images are 18 km wide, we believe that we may find that craters larger than ~18 km will most often have sand dunes.*

   Look at the observations you and your group have made of images relating to your topic. Based on those preliminary observations, list your group's current working hypothesis below:

   Hypothesis:

   Current observations that support this hypothesis:

6. In science, experiments need to be designed so they are "repeatable". "Repeatable" means that other scientists could conduct the ***same*** experiment with the ***same*** images and follow the ***same*** step-by-step procedure and get the ***same*** results. This would validate your results.

   Let's pretend that you actually gathered the data from questions #1-4 in this section in order to answer your science question and test your hypothesis. That information would be:

   - Images that contain ____________________ (name the geologic feature you are looking for)
   - Images in regions of Mars such as ____
   - __________ # of images to answer the question and support or refute your hypothesis
   - Measurements of __________________________ (list what measurements, if any)

   Would this be enough information to have your experiment be repeatable? If yes, please explain. If no, what other information might you need to obtain to make your experiment repeatable by any scientist?

Student Worksheet 5

Experiment Design – Refining Your Experiment

Name(s) ___________________________________

Date ______________________________________

When designing an experiment to answer a question and support or refute a hypothesis, your experiment needs to be repeatable. If any scientist conducts your same experiment, they should be able to obtain the same results. This is what helps validate the science you have conducted. In order for your experiment to be repeatable, you need to be able to describe, in as much detail as possible, the step-by-step plan and the exact information you would gather from each and every image you observe.

To do this, think about specific information (including details from the previous questions) you would need to record from each image you observe, and what steps you would take to obtain data towards answering your question. It is important to think about why each step would be important in your process.

Here's how you may consider starting your list of steps:

1. First, I would go to the http://themis.asu.edu *topic page** website to find images to observe. For my project I would look at images relating to ______________________ (*list what topic/feature you are focusing on)*.
   (*Think about whether you would use the topic page or the map tool.)

2. For each image I observe, I would write down the **Image Identification number** (the V#) so that I (or other scientists) could reexamine those same images at any time.

3. For each image I observe, I would also write down whether it had (or didn't have) the specific feature/s in the image that I am looking for. Even if the image does not have the feature that I am looking for, that is still valuable data. The specific feature/s I would be looking for are: ____ *(list the specific geologic features you are looking for).*

4. Next, I would record the ___________________ **and** ____________________ of each image to look for any patterns in the observations I make and also to be able to plot that information on a map.

Continue this list or start a new list that describes how you would go about gathering data to test your hypotheses and help answer your question. (Use additional paper as necessary.)

NOTES

EXPERIMENT DESIGN
(DATA COLLECTION METHODS)

What, why and how do you plan to collect your data in order to answer you science question?

	WHAT data are you going to collect?	HOW/WHERE will you find this data?	WHY is this important for you to solve your problem/question?
LESS DETAIL	EXAMPLE: V # (Image ID)	This will be found by clicking on the *THEMIS Data Releases link* when looking at a THEMIS image.	Having the Image ID # will allow anyone to find and identify images. This helps make the experiment repeatable.
MORE DETAIL			

EXPERIMENT DESIGN
(DATA COLLECTION METHODS)

Continue your data collection methods on this page if necessary.

	WHAT data are you going to collect?	HOW/WHERE will you find this data?	WHY is this important for you to solve your problem/question?
LESS DETAIL			
MORE DETAIL			

THEMIS IMAGE DATA GATHERING

1. What is your science question? ____

2. List the website(s) you will use to gather your data: __http:// ________________________ __http:// ________________________

Note: You can go back to look at any THEMIS image by going to the http://themis-data.asu.edu website and typing in the Image ID.

Image ID (V #)	Latitude				
	Longitude				

Image ID (V #)	Latitude				
	Longitude				

Image ID (V #)	Latitude				
	Longitude				

Image ID (V #)	Latitude				
	Longitude				

Image ID (V #)	Latitude				
	Longitude				

Image ID (V #)	Latitude				
	Longitude				

Image ID (V #)	Latitude				
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Image ID (V #)	Latitude				
	Longitude				

Image ID (V #)	Latitude				
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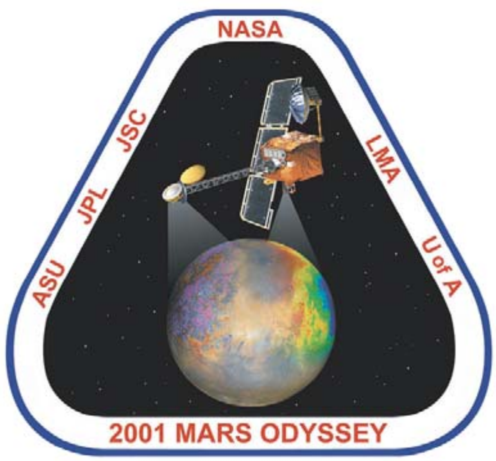
	Longitude				

Image ID (V #)	Latitude				
	Longitude				

MARS STUDENT IMAGING PROJECT

Data Analysis Practice Guide



Arizona State University

Mars Education Program
Arizona State University

Data Analysis Practice Guide

This set of activities is designed to help you organize data you collect so that you are able to graph and analyze it. The data table provided in this guide is a sample example only. Keep in mind that most data tables put together by researchers will have more data than what is shown on this sample table. For example, many data tables will include additional columns of information. This may include qualitative data written about observations of features being studied. There may also be a column for stating observations of the surrounding area (the context) of where an image was taken. A column for sketches can also be useful. These qualitative observations can be as important as the quantitative data represented in this sample. Additionally, five data points are too few to make valid conclusions of the data.

Goals of Activities: After completing these activities you will be able to:

- Use Excel to input any data you collect
- Use Excel to select and graph any pair of data you collect
- Make observations of data you graphed
- Make interpretations based on your observations

The four activities you will complete in this guide are as follows:

Activity 1: Using Excel to Create Graphs

Activity 2: Observations and Interpretations

Activity 3: Graphing Pairs of Data for Your Research Project

Activity 4: Graphing Latitude versus Longitude

Activity 1: Using Excel to Create Graphs

Presenting the information or data you gather from images can be done several different ways. Having your information in a data table is the first step and is extremely important. This will allow you to have an organized view of your data. This can also help you decide what to graph. Additionally, it will help you analyze your data. For this exercise, you will be asked to look at some sample data taken of channels. For this example, a number of channel widths and depths have been determined and are being compared. This information, along with other important information is presented in a data table. The information organized in a data table alone would make it difficult to make observations to analyze that data. It is important to illustrate your data in a way that makes it easier for you to interpret.

Below is a data table that shows channel data from five Thermal Emission Imaging System (THEMIS) images. Please note that the THEMIS Image ID's are not real. Follow the instructions given below to graph this data:

	A	B	C	D	E
1	**THEMIS Image ID#**	**Longitude (E)**	**Latitude (N)**	**Channel Width (meters)**	**Channel Depth (meters)**
2	V11111111	288.2	17.1	720	43
3	V22222222	177.6	-17.3	16952	926
4	V33333333	136	26.6	3626	301
5	V44444444	41.6	11.5	12836	658
6	V55555555	106.5	-41.4	4291	661

1. Open Excel by clicking on the green Excel icon on your computer. ( )

2. Choose a new Excel workbook.

3. Type in all the data from the table above into your new Excel workbook. Make sure to enter the data from **columns A through E** from the white boxes only.

4. Click and drag your mouse over all the cells below **columns D** and **E**, including their titles ("Channel Width" and "Channel Depth").

5. Choose **Insert** ▶ **Chart.**

6. Choose a **XY (Scatter)** chart in the left-hand menu and click **Next**.

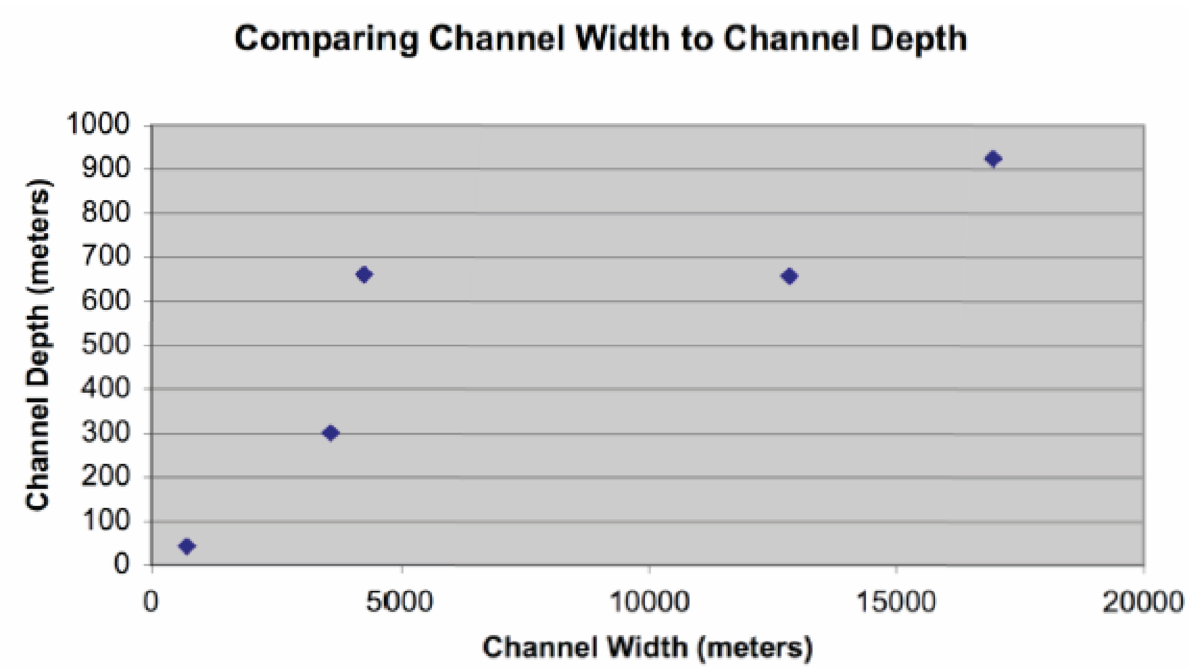
Activity 1: Using Excel to Create Graphs (cont.)

7. Make sure your chart looks alright in the preview box. Then click **Next**.

8. In the Chart Options dialog box click on the *Titles* tab and enter a title for your chart. Then enter the titles for each X and Y axes in the "Value" boxes. For example, the "Channel Width (meters)" would be the X-axis title. Also, be sure to include the correct channel dimension for your Y-axis. Each axis title should include the unit of measure being represented.

9. Under the *Legend* tab, uncheck **Show Legends**, then click **Next.**

10. Choose to place your chart "as new sheet" and click **Finish**. Your chart should look similar to the one below.



Activity 2: Observations and Interpretations

Now that you have graphed channel width versus channel depth from the data table, it's important to determine what these data mean scientifically. This can be done in two important steps: 1) making **observations** of your data, and 2) using these observations to make **interpretations**.

Observations are made by looking at data and stating their general characteristics, including any patterns or trends. Here are two examples:

> Observation #1: This graph shows that channels with greater widths are generally deeper.
>
> Observation #2: There is one point on the graph that doesn't seem to follow the same trend as the other data point (referred to as an outlier). There are two channels that are about 4000 meters wide (3626m and 4291m) but the channel that is 4291 meters seems to be a lot deeper. According to the trend, one would expect the width of a channel that is almost 700 meters deep to be somewhere between 5000 – 1000 meters.

Interpretations are made by taking observations and explaining what they may mean scientifically. Interpretations allow you to infer how a specific process(es) may work, in this case, on Mars. Here are two interpretations of the above observations:

> Interpretation of Observation #1: Since wider channels appear to be deeper, that probably means that the wider channels were formed by greater amounts of water. Channels that *don't* follow this trend may indicate that there are other processes at work on Mars that need to be considered.
>
> Interpretation of Observation #2: The deeper channel, the one that is 4291 meters wide, must have a greater amount of water that flowed through it. Another possibility is that this channel is not as long as the other channels. Therefore, the same amount of water flowed through the shorter channel with greater force.

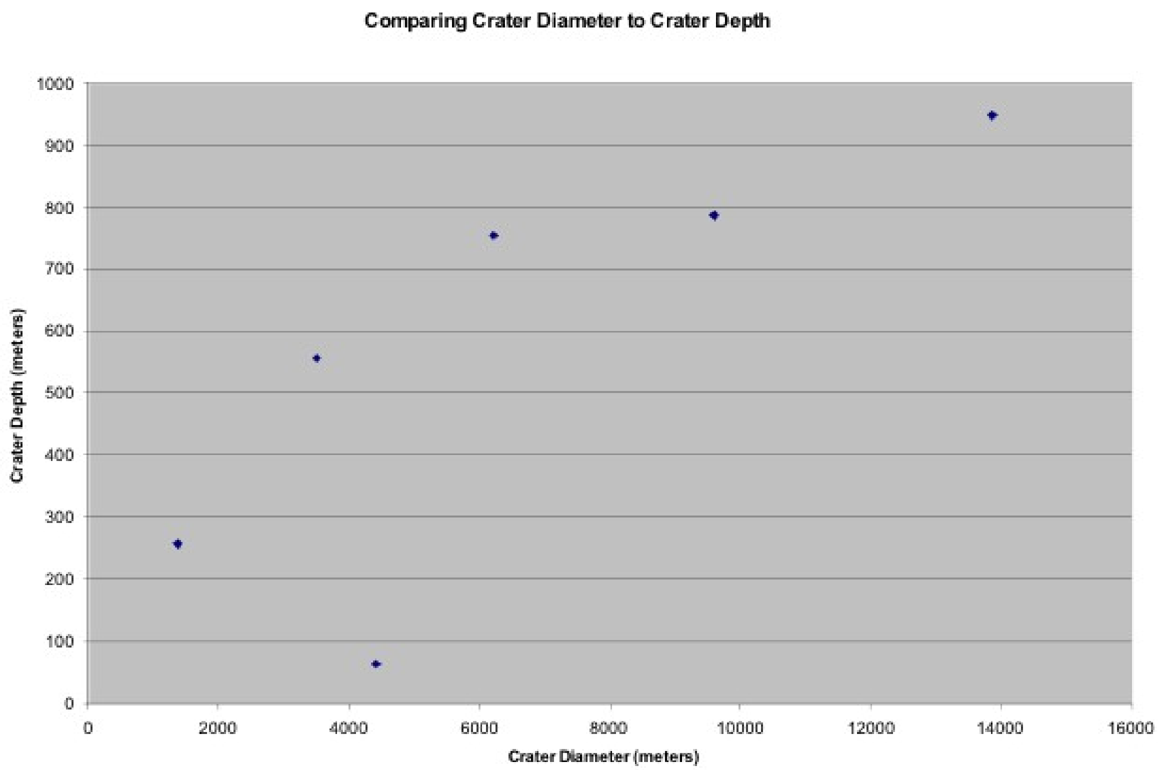
Keep in mind that you can make one interpretation (or multiple possible interpretations) of a single observation or your set of observations.

To review:

- Observations state general characteristics, trends, or patterns that you may notice about the data.
- Interpretations explain what those trends, patterns and observations may mean about how a particular process may be working.

Activity 2: Observations and Interpretations (cont.)

Now that you know the difference between observations and interpretations, let's give you some practice. Here is a different graph of another set of data. This graph is comparing the diameter of a crater to it's depth. Look at the graph and list at least one observation and one interpretation of the data.



A. List at least two <u>observations</u> of the crater data in the graph:

Observation #1: ____

____

Observation #2: ____

____

B. List your <u>interpretations</u> of what each individual or set of observations may mean:

____

____

____

____

Activity 3: Graphing Pairs of Data for Your Research Project

For <u>your science project and question</u>, you should organize your data in order to graph and analyze that data. Think about what data you will collect for your project and list three specific pairs of data you could graph. Include what the graph could tell you about these data. (For the first example it was channel width versus channel depth. This told us if there was a relationship between the width and depth of channels - which there was.)

1. ______________________________versus_________________________________

   Can tell you____

   ____

2. ______________________________versus_________________________________

   Can tell you____

   ____

3. ______________________________versus_________________________________

   Can tell you____

   ____

Only once you have made your graphs will you be able to make your observations and interpretations of your data. Keep in mind that you can make observations and interpretations of both **quantitative data** (measurements or latitude and longitude) <u>AND</u> **qualitative data** that you may have logged regarding visual observations you may have made. Qualitative data can be as equally important as the quantitative data but can not easily be display graphically.

Activity 4: Graphing Latitude versus Longitude

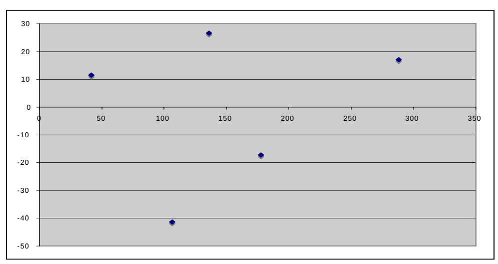
It may also be helpful when analyzing your data to plot the latitudes and longitudes of your THEMIS images on a map of Mars which will give you a different type of graph! One reason for doing this is to see where your channels (or whatever feature you are studying) are located on the planet, including where they are in relation to each other. You could also see other geologic features present in the region that may have a relationship to the channels you observed. These types of relationships are difficult to see in a data table!

1. Click on the "Sheet" tab at the bottom of your screen to see the table of data you entered in the previous exercise. Once you see your data table, click and drag your mouse over all the cells below columns B and C, including their titles ("Longitude" and "Latitude").

2. Choose **Insert** ▶ **Chart**.

3. Choose a **XY (Scatter)** chart in the left-hand menu and click **Next**.

4. In the preview box, your graph should look like the example below:



   Then click **Next**.

5. In the next **Chart Options** dialog box, do the following:
   a. Under the *Titles* tab, enter a title for this chart (it should not be "Latitude (N)") and label the X- and Y-axes. Note, the X-axis is Longitude (East), and the Y-axis is Latitude (North).
   b. Under the *Gridlines* tab, uncheck all grid line boxes.
   c. Under the *Legend* tab, uncheck "Show Legend".
   d. Then click **Next**.

6. In the Chart Location dialog box, choose to place your chart "as new sheet" and click **Finish**.

Activity 4: Graphing Latitude versus Longitude (cont.)

7. You're almost there! Now you will need to set up your graph to look like a map of Mars.
   a. For the lines of latitude (the Y-axis), put the mouse directly over the Y-axis and double-click. Then click on the *Scale* tab and enter the following in the Value (Y) axis scale boxes:
      - Minimum: -90
      - Maximum: 90
      - Major Unit: 30
      - Minor Unit: leave as is
      - Value (X) axis Crosses at: -90
      - Make sure that all boxes are <u>unchecked</u>.
      - Then click **Ok**.

   b. For the lines of longitude (the X-axis), double click on it also, and enter the following in the Value (X) axis scale boxes:
      - Minimum: 0
      - Maximum: 360
      - Major Unit: 90
      - Minor Unit: leave as is
      - Make sure that all boxes are <u>unchecked</u>.
      - Then click **Ok**.

   c. Look at the structure of your graph and check to see that the latitude and longitude data from your table are correctly displayed in the graph. The longitude should range from 0 to 360 degrees East, and the latitude should range from -90 to 90 North.

8. Now, for the final step, to add the color MOLA background map of Mars to your graph.
   a. Double-click on the gray area in your graph to open the **Format Plot Area** box.

   b. Underneath the "Fill" category, click on the **Color** drop down menu and then "Fill Effects". Note: if you are using a PC computer, click on the **Fill Effects** button.

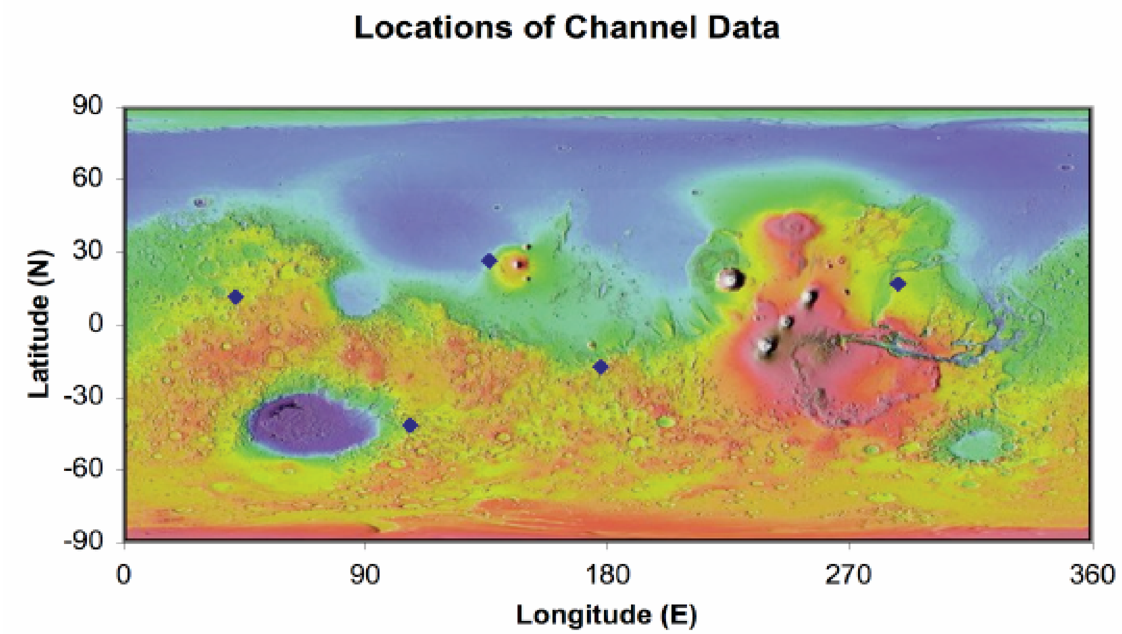
   c. Go to the *Picture* tab. Then click on the **Select Picture** button.

   d. Go to the desktop and click on the file "MOLA_Map_of_Mars.jpg" file. Click **OK** or **Insert**.

   e. Click **OK** on the **Fill Effects** window, and **OK** on the **Format Plot Area** window.

Activity 4: Graphing Latitude versus Longitude (cont.)

9. Your map of Mars should be underneath your data! Your map may be stretched too much. To adjust the shape of your map, click and drag the black square at the top or bottom center of the plot area. If a "legend" is present at the right side of your chart, you may want to select it (by clicking on it) and delete it. A legend is not necessary if you are plotting simply the location of your data on the map. You may want to change the color and size of your location points. Double click on the points to make changes. Your map should be complete as in the example below:



A. Now that you have plotted channel data on a map of Mars, list at least two observations of these data from the graph:

Observation #1: ____

____

Observation #2: ____

____

B. List your interpretations of what each individual or set of observations may mean:

____

____

____

____

MARS STUDENT IMAGING PROJECT

Data Analysis Practice Guide Summary

After completing these activities, you are now able to:

- **Create a Data Table in Excel**
  - Keep in mind that your data table will have your own data from your own particular research project. It's important that you include all your data on your table.

- **Create a Graph of any Pair of Data**
  - Remember that each graph needs to have a TITLE that indicates what the graph is illustrating.
  - You should also be careful to label your X and Y-axes correctly. Always be sure to include the appropriate units. For example: Channel Depth (meters).
  - Keep in mind that the first column that is selected in the Excel data table will always be the X-axis.
  - You can graph information based on measurements acquired or information such as latitude versus longitude.

- **Make Observations of Data you Graphed:**
  - Remember that observations state general characteristics, trends, or patterns. They do not attempt to explain <u>why</u> those trends may (or may not) exist.
  - You can make observations of quantitative data you graphed AND / OR qualitative data you have logged based on visual observations.

- **Make Interpretations of your Observations**
  - Keep in mind that interpretations attempt to explain what one or more observation may mean scientifically. Think about what those characteristics, trends, or patterns may tell you about how a process may be working.
  - You can make interpretations of quantitative data you graphed AND / OR qualitative data you have logged based on visual observations.

MSIP Proposal Outline

I. Introduction

The purpose of the introduction section is to introduce your project and science question. It should include the following information:

1. What is your science question?
   - This question should have a specific focus on a geologic feature(s) and you should be able to answer it by analyzing THEMIS images.

2. Why is your science question important and interesting?
   - Why is this question and topic interesting to your team?
   - How will answering this question be important in understanding Mars better?

3. List any hypothesis(es) you may have of what the answer(s) might be to your science question.
   - You may not formulate any hypotheses right away. It is best to look at images related to your question and formulate your hypothesis(es) based on the trends or patterns you have seen in those preliminary observations and data.
   - Hypotheses may change as you gather more data and make additional observations.

II. Background

The purpose of the background section is to provide background information about the specific feature you are studying.

- Any facts you mention should be followed by the source where you found that information. For example: *Mars has the largest volcanoes in the Solar System. One theory why this is true is that Mars seems to have a much thicker crust than Earth, and so it doesn't have floating, moving crustal plates (MSIP Resource Manual, p.16)*. It is important to cite your sources as it gives readers a way to verify your information.

- A few suggested resources you can use as you conduct your research are:
  -MSIP Resource Manual: http://msip.asu.edu/curriculum.html
  -Feature ID Charts: http://marsed.asu.edu/upload/FeatureIDCharts.pdf
  -THEMIS website: http://themis.asu.edu
  -Other reliable internet sources
  -Books, magazines or science journals

The background section should include the following information: (Don't forget to cite the source of piece of information including any image you include!)

1. List definitions of the geologic feature(s) on Mars you are studying as part of your science question.

2. Show **how** the geologic feature(s) you are studying are thought to form (the geologic process) on Mars in a sketch.

3. Describe how the geologic feature(s) you are studying are thought to form? If you created a sketch describe the process your sketch is illustrating.

4. Show what the geologic feature(s) you are studying **look like** on Mars.
   - Draw sketches.
   - Show THEMIS images that show good examples of your geologic feature(s).
   - Describe the defining characteristics or criteria for identifying the geologic feature(s) you are studying.
     (For example: Let's say you are studying the relationship between sand dunes in different types of craters. If this is the case, you should describe what criteria or defining characteristics let you know you are looking at the different types of craters (preserved, modified or destroyed) as well as what criteria or defining characteristics you look for to identify sand dunes.)
   - (Optional) Select an image that best illustrates each of the defining characteristics of the geologic feature(s) you are studying to use as a "control". (For example: If you described the criteria or defining characteristics of each type of crater and sand dunes, you could label those specific characteristics in a THEMIS image and use that as an exemplary example (a "control") to base your classifications throughout your project.)

5. List any hypotheses or information about the formation of the geologic feature(s) you are studying from other scientists.

6. **PRELIMINARY OBSERVATIONS:** All proposals should provide information about the preliminary observations or data you have already collected. During the initial stages of your research you should have looked at THEMIS visible images. To illustrate this, you should consider including the following in your proposal:

   a. How many images you have looked at up to the time you are putting together the proposal. (It is important for you to keep a log of all your data and observations.)
   b. Include a written description of what trends or patterns you are noticing with the images you have observed so far. (This is related to the hypothesis(es) you included in the Introduction section of the proposal. In this section of the background you would provide details and elaborate on the trends and patterns you are observing.)
   c. Plot points on a map of Mars that represent the location of each image you have observed. If you do this, you should consider:
      - Showing the map with the plotted data points.
      - Describing what geographic regions you observed these features on Mars? For example, "*During our preliminary research, as we have looked at THEMIS images on the http://themis.asu.edu website and plotted them on a map, we have noticed that most of the images of _______ seem to be found…(you would explain what you are noticing).*

III. Experiment Design

The purpose of the experiment design section is to show how you plan to design your experiment so that other scientists will be able to repeat it. This section includes a detailed step-by-step process explaining exactly **what** and **how** you will collect your data to answer your science question.

This section can include the following:
(Note: Some of this information may not apply to all projects.)

1. What specific spacecraft and camera will you use to collect data for your research?

2. What specific geologic features will you focus on for your study and why?

3. What geographic regions will you focus on for your study?
   - Examples of this may be as follows: certain latitude bands (*from 30N to 60N*), certain regions (*northern or southern hemisphere*).
   - It is not recommended to focus one small or specific geographic feature on Mars.

4. How many THEMIS images you will use to gather your data in order to answer your science question?

5. As part of your experiment design, **list** the specific data (information) you plan to record in a table from each image you observe, and why?

   For example:
   - **Image identification # (V#)**: This will allow us and other scientists to reexamine the images we observed to check our data.
   - **Latitude and longitude:** This will allow us to map where each image we examine is located

- **Specific feature(s) (***You would name the specific features here*): We will look for _______ and ________ as those directly relate to our science question
- **Other?**

List what **you** will record from each image AND why it is important:

6. What measurements you will make, if any. Please describe **<u>how</u>** you will make these measurements and why they are important.

7. List and describe **<u>what</u>** website(s) and **<u>how</u>** you will use it/them to gather and record the data you listed above.
   - List each website.
   - Describe where you will look, once on that website, to find each piece of data you will record from each image. (This can be a step-by-step list. For example:
     - 1. Go to the http://themis.asu.edu/topic website;
     - 2. Click on the "craters" topic;
     - 3. To find the image ID #, click on the THEMIS Data Releases link
     - 4. To find the Latitude and Longitude look….

IV. Analysis Plan

The purpose of the analysis plan section is to plan how to list and display your data in order to analyze it. This section may include:

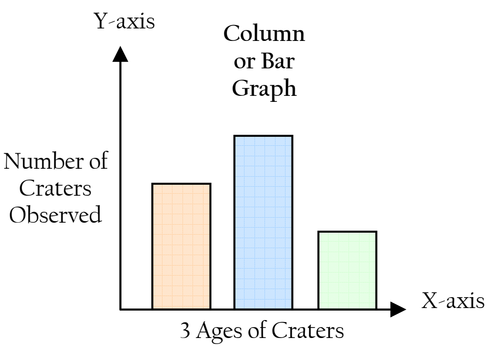
1. DATA TABLE: This table lists the specific information (Image ID#, latitude, longitude, specific feature(s), measurements, etc.) you listed in the experiment design that you will record from each image you observe. [For your proposal, you should show how your data table will be set up (showing the column headers) for you to display your data.]

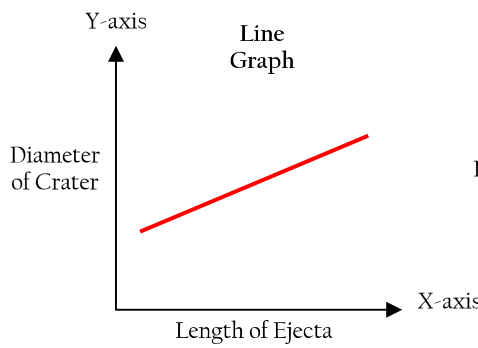
EXAMPLE

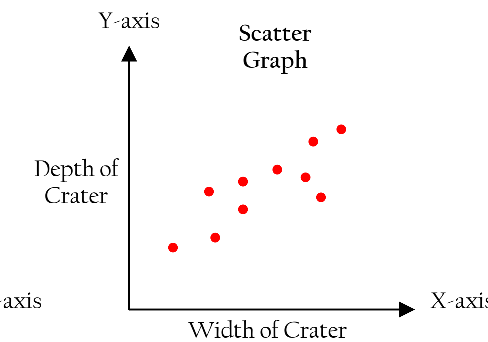
Image ID (V #)	Lat. (N)	Long. (E)			

- Show what will your table look like?

2. GRAPHS: Describe what specific pairs of information will you graph (including what type of graph you may use: bar, line, scatter, etc.; see examples shown below) and what will each graph tell you?



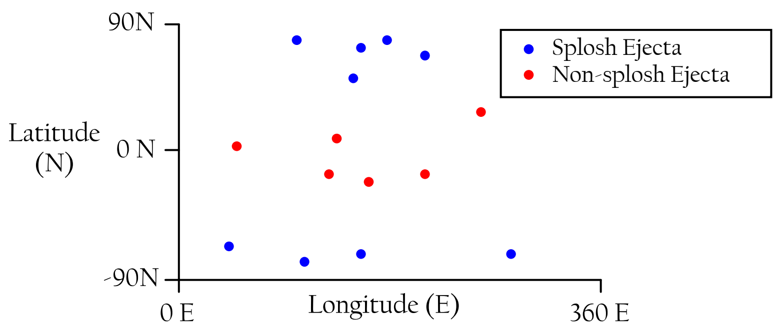


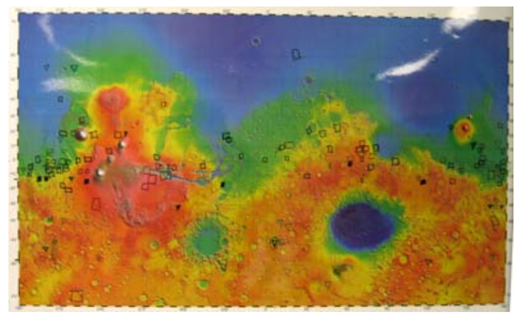


- Use the table below to list the details of what you plan to graph.

Pair of data you will graph ___________ vs. __________	Type of graph you will create	What that graph will tell you?
1.		
2.		
3.		

3. **MAP**: Scientists often plot their data on a map to look for patterns and trends. Here are two examples of data plotted. These graphs are looking at latitude versus longitude.





MOLA map with plotted dust devil data

- **Will you plot your images on a map? If yes, please explain what you will plot and why? (What will this map of data show you?)**

4. **OTHER**: Are there any other ways you will display your results?

- Labeled THEMIS images showing important descriptive or qualitative information about the geologic feature(s) you are studying.
- Context image sketches or images that provide descriptive or qualitative information important for understanding how the surrounding area (the context) may play a role in the process or formation of the geologic feature(s) you are studying.

V. Conclusion

The purpose of the conclusion section is to summarize what your team is proposing to study. You should:

1. Restate your science question.

2. Restate your hypotheses (if you had any).

3. Restate why it is important to answer your science question and why your proposal should be accepted for your team to use the THEMIS visible camera.

VI. References

The purpose of the references section is to list all sources of information used to create your science proposal. It includes a list of sources such as:

- Books
- Websites
- People
- Equipment

Note: Each reference you list in this section should be cited within the body of your proposal. There is a specific way to do this. For example:

- Within the body of your proposal after a written statement(s): (*MSIP Resource Manual, p. 16*)

- Listed in your reference section at the end of your proposal:

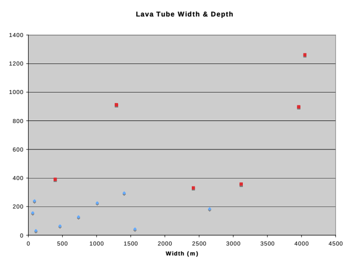
  Watt, K. (2002). *Mars Student Imaging Project: Resource Manuel*. Retrieved June 29, 2006, (the date you downloaded) from Arizona State University, Mars Student Imaging Project Web site: http://msip.asu.edu/curriculum.html.

You can go to www.apastyle.org for additional information.

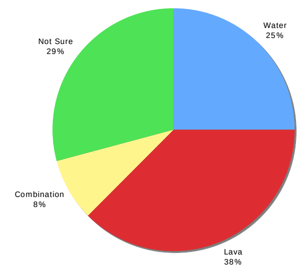
DATA ANALYSIS PLANNING

Use the structure provided in this handout to think about how you are going to graph your data in order to make observations and interpretations of your data as it relates to your question?

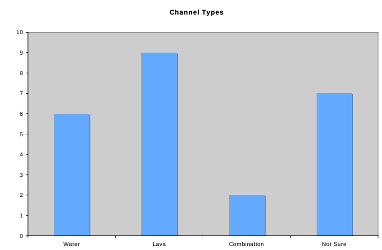
Graphs allow you to plot two variables and look for patterns or relationships between those variables. You can create many different types of graphs (bar, line, scatter plot, etc.) to help organize your data and make it easier to understand. You can even plot your data on a map as a type of graph.



Scatter Plot



Pie Graph



Bar Graph

List as many graphs that you feel would display your data in such a way that you could make observations and interpretations in order to answer your question.

1. Type of Graph: ____

   Graph of _____________________________ versus ______________________________

   What will this graph show you?

2. Type of Graph: ____

   Graph of _____________________________ versus ______________________________

   What will this graph show you?

DATA ANALYSIS PLANNING (CONT'D)

3. Type of Graph: ______________________________

   Graph of ______________________ versus ______________________

   What will this graph show you?

4. Type of Graph: ______________________________

   Graph of ______________________ versus ______________________

   What will this graph show you?

5. Type of Graph: ______________________________

   Graph of ______________________ versus ______________________

   What will this graph show you?

DATA ANALYSIS

For each graph, think about what these data are showing you (your observations). Based on these observations, think about what you can imply about what those observations mean (interpretations).

1. Type of Graph: ____

Graph of _____________________ versus ____________________

Observations	Interpretations

2. Type of Graph: ____

Graph of _____________________ versus ____________________

Observations	Interpretations

DATA ANALYSIS
CONT'D

3. Type of Graph: ____

Graph of _____________________ versus ____________________

Observations	Interpretations

4. Type of Graph: ____

Graph of _____________________ versus ____________________

Observations	Interpretations

DATA ANALYSIS
CONT'D

5. Type of Graph: ____

Graph of ____________________ versus ___________________

Observations	Interpretations

6. Type of Graph: ____

Graph of ____________________ versus ___________________

Observations	Interpretations

MSIP Final Report Outline

I. Introduction

The purpose of the introduction section is to introduce your project and science question. It should include the following information:

1. What is your science question?

2. Why is your science question important and interesting?

3. List any hypotheses you had of what the answer(s) might be to your science question.

II. Background

The purpose of the background section is to provide background information about the specific features you are studying.

- Any facts you mention should be followed by the source where you found that information. For example: *Mars has the largest volcano in the solar system (Watt, MSIP Resource Manual)*. It is important to cite your sources as it gives readers a way to verify your information.

The background section should include the following information: (Don't forget to cite the source of piece of information including any image you include!)

1. List definitions of the geologic feature(s) on Mars you are studying as part of your science question.

2. Show **how** the geologic features you are studying are thought to form (the geologic process) on Mars in a sketch.

3. Describe how the geologic features you are studying are thought to form? If you created a sketch describe the process your sketch is illustrating.

4. Show what the geologic features you are studying **look like** on Mars.
   - Draw sketches.
   - Show THEMIS images that show good examples of your geologic feature(s).
   - Describe the defining characteristics or criteria for identifying the geologic feature(s) you are studying.
     (For example: Let's say you are studying the relationship between sand dunes in different types of craters. If this is the case, you should describe what criteria or defining characteristics let you know you are looking at the different types of craters (preserved, modified or destroyed) as well as what criteria or defining characteristics you look for to identify sand dunes.)

5. List any hypotheses or information about the formation of the geologic feature(s) you are studying from other scientists.

III. Methods

The purpose of the methods section is to allow other scientists to repeat your experiment and to show the reliability of your data. The methods section includes the step-by-step process detailing exactly what you did to collect your data.

This section can include the following:
(Note: Some of this information may not apply to all projects):

1. What specific spacecraft and camera did you use to collect data for your research?

2. What specific geologic features did you focus on for your study and why?
   - Discuss how you used the defining characteristics to identify the feature(s) you were studying for your project.
   - (Optional) If you used a “control” (an exemplary example you used to based your classifications throughout your project), discuss how you used that control to identify the feature(s) you were studying.

3. What geographic region(s) and/or geologic features did you focus on during the process of collecting your data?

4. How many THEMIS images did you use to gather your data in order to answer your science question?

5. List the specific data you recorded from each image you observed, and why? For example:
   - **Image identification # (V#)**: This will allow us and other scientists to reexamine the images we observed to check our data.
   - **Latitude and longitude:** This will allow us to map where each image we examine is located
   - **Specific feature(s) (***You would name the specific features here***)**: We will look for _______ and _______ as those directly relate to our science question
   - **Other?**

   List what **you** recorded from each image AND why it was important:

6. If you made measurements, include **<u>what</u>** measurements you made and **<u>how</u>** you made them.

7. List and describe **<u>what</u>** website(s) you used to gather your data and **<u>how</u>** you used it (them). Be specific as to how you used the website(s) to gather your data.
   - List each website.
   - Describe where you looked, once on that website, to find each piece of data you recorded from each image. (This can be a step-by-step list. For example:
     - 1. Go to the http://themis.asu.edu/topic website;
     - 2. Click on the "craters" topic;
     - 3. To find the image ID #, click on the THEMIS Data Releases link
     - 4. To find the Latitude and Longitude look....

IV. Data

The purpose of the data section is to **list** and **display** the data you collected. It should explain what the data is showing and any patterns or trends you are noticing with the data. It only includes your observations. **It does not include any interpretations of those data.**

This section should include the following:

1. Display your data (attach any and all information you put together for this section):
    - Show your **data table** and explain what it is showing.
    - Show each of your **graphs** and explain what each graph is comparing and what observations, including patterns or trends you can observe with the data displayed on each graph.
    - Show your data on a **map** of Mars and explain what it is showing and what observations, including patterns or trends you can observe with the data displayed on the map.
    - Show any qualitative information (sketches and overall general observations) that are important for better understanding the feature(s) you are studying or how the surrounding areas (the context) that may play a role in the process or formation of the feature(s) you are studying.

V. Discussion

The purpose of the discussion section is to **show** the data you collected and **discuss and explain** the meaning or interpretations of your data as it relates to your science question. It should include the following information:

1. **Reshow each graph** individually (including your data on the map of Mars) and include the following:
   - A brief overview of what the graph is comparing and the trends, patterns, and observations of that graph.
   - Explain the interpretation of what those trends, patterns and observations tell you about how the specific process(es) you are studying may work on Mars. Include significant details that can be specifically linked to and back up your interpretations.
   - Apply those interpretations to your specific question and/or your hypothesis(es).

   (Attach any and all information you put together for this section)

2. Discuss the potential errors with the data you collected.
   - Could there be inaccuracies? If so, please explain.
   - Could there be misinterpretations? If so, please explain.

VI. Conclusions

The purpose of the conclusion section is to summarize and conclude your science project. It should include the following information:

1. Restate and answer your science question based on your interpretations from the discussion section.

2. Restate and support or refute any hypotheses based on your interpretations from the discussion section.

3. What future work could be done to expand your research project?

4. Who can you acknowledge for helping you complete your science project?

VII. References

The purpose of the references section is to list all sources of information used to create your science report. It includes a list of sources such as:

- Books
- Websites
- People
- Equipment

Note: Each reference you list in this section should be cited within the body of your final report. There is a specific way to do this. For example:

- Within the body of your proposal after a written statement(s): (*MSIP Resource Manual, p. 16*)
- Listed in your reference section at the end of your proposal:

> Watt, K. (2002). *Mars Student Imaging Project: Resource Manuel*. Retrieved June 29, 2006, (the date you downloaded) from Arizona State University, Mars Student Imaging Project Web site: http://msip.asu.edu/curriculum.html.

You can go to www.apastyle.org for additional information.

MARS STUDENT IMAGING PROJECT
ASU MARS EDUCATION PROGRAM

MSIP Team Results Outline Form

I. General Information:
School Name:

Teacher Name:

Grade Level:

City:

State:

Country:

II. Science Question:

III. Data Collection and Observations: (Summarize into three overall steps what you did to find your data and what observations you made. (What website did you go to and what specific feature(s) did you look for in THEMIS images to help you answer your question. Be specific as to what you were specifically looking for in each image.)

1)

2)

3)

IV. Main Results: (List three major conclusions you can make based on the data you collected and observed.)

1)

2)

3)

V. Extra Comments: (Three student quotes)

1)

2)

3)

Optional Pictures:

A) Team Image – a digital picture of your team.

If you provide a team picture, we would also need to have Image Release forms for each student in the picture. Image Release forms are available at:
http://marsed.asu.edu/upload/MarsEd_ImageReleaseFormv2.pdf

B) THEMIS Image – the image ID # (the V#) of a THEMIS visible image that best displays the specific feature(s) that is the focus of your question/research.

C) Extra Image – an additional digital image of your students working