Highs and Lows, Floods and Flows
PLANETARY MAPPING

OVERVIEW —

Teams of students become familiar with the topography of Mars, its geologic features, and patterns of features using a color-coded topographic map. They discuss the geologic processes that have occurred, or are occurring, and assign relative ages to them. Based on their observations and interests, they propose a landing site for their exploration team.

Grades: 5 to 8

Duration: 45-60 minutes

OBJECTIVE —

Students will:

- Gain general knowledge about how to read a topographic map
- Identify elevation features on Mars
- Identify geologic features and patterns on Mars and relate these to geologic processes
- Draw conclusions regarding the events and relative ages of geologic features

MATERIALS —

For the class:

- A large color image of the Mars Orbiter Laser Altimeter (MOLA) map from http://mola.gsfc.nasa.gov/images/mercat.jpg, projected or displayed as a large poster

For each team of 2-4 students

- Investigator Package

ACTIVITY —

> **Facilitator's Note:** The question sets in the Investigator Packet start on a very basic level and become increasingly challenging. If students are already familiar with maps, you may wish to skip question set 1 or review it briefly as a class.

1. Divide the students into groups of planetary scientists. Explain that they are studying the geologic history of a planet. Ultimately they will propose future landing sites for exploration that will help to answer *their* interesting scientific questions.

- What scientific questions do they have?
- Where is the best place on the planet to address these questions?
- Where would the safest place be to land a rover or an astronaut to address these questions?

2. Invite each team to begin the challenge by projecting or displaying the MOLA map to determine what kind of picture it is and what features might be represented by the different colors.

- What particular type of picture do you think this is? **(a map)**
- What do you think is represented by the different colors? **(the answer to this question – elevation – will be determined by students as they progress through the exercise)**

3. Distribute to each group one copy of Investigator Package. Review the "Terms to Know" and encourage the students to use them throughout the activity.

4. Share your expectations: Give the students directions on which activities to complete and the amount of time you expect them to spend on each section. Have them work together to answer the questions in the package. You may wish to review the answers to each Question Set with the students before proceeding to the next.

IN CONCLUSION —

Ask the teams to share their questions and suggestions for a landing site, and to describe how they think Mars has changed over time. Invite the students to use their observations to justify their explanations, and to describe why they agree or disagree with the different explanations presented. Share that planetary scientists are still formulating models to explain some of the features we observe on Mars and that they do not agree on all of these explanations yet—more data is still needed.

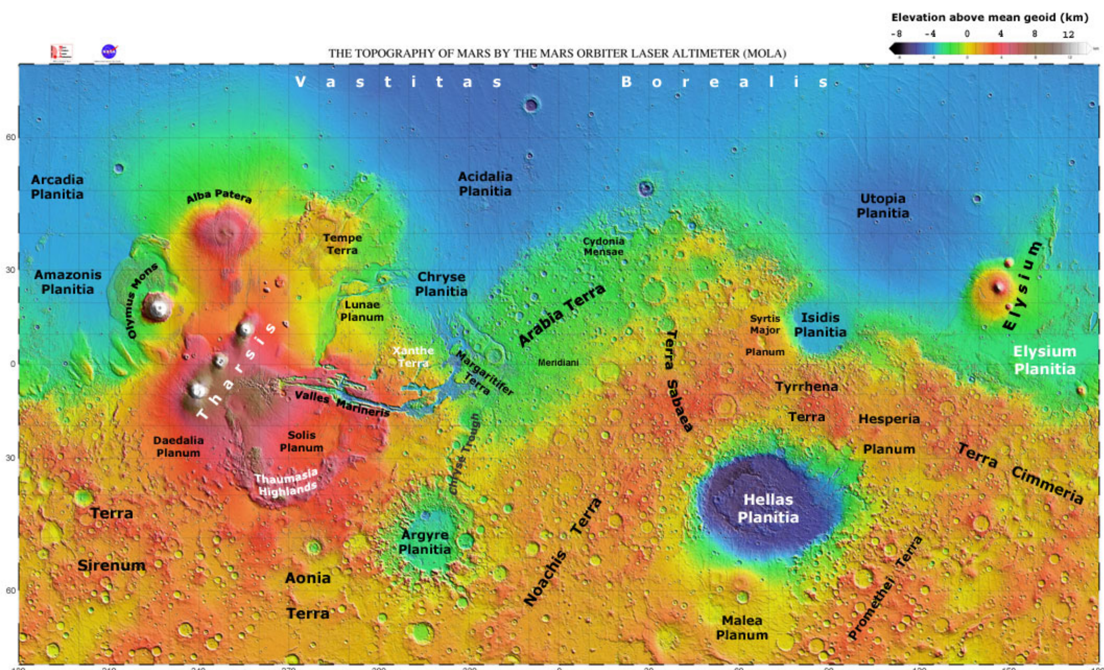
BACKGROUND INFORMATION

Planetary scientists can say a lot about a planet's history by looking at a map of its surface. They examine the features to understand the geologic activity that has occurred, look for patterns, determine the order in which events happened – and formulate questions for further exploration. They use maps to select locations on the planet's surface to investigate that may answer those questions. Maps are critical for identifying targets for rovers, human exploration, and future colonies.

This activity analyzes the Mars Orbiter Laser Altimeter (MOLA) map, a color-coded topographic map of Mars' surface obtained from laser altimeter measurements taken by the Mars Orbiter Laser Altimeter instrument on the Mars Global Surveyor, 1997-2000.

The format of the MOLA map in this activity is a Mercator projection, a rectangular map with lines of latitude and longitude intersecting at right angles, in which true compass directions are correct but the areas are distorted; features in the extreme north and south are stretched.

Mars' topography shows a variety of interesting features. The high elevations—volcanos—are primarily clustered in the Tharsis region near the equator on the left side of the map, probably the result of a hotspot which has caused this bulge in the crust. Just to the right of these volcanos is Mariner Valley (Valles Marineris); this very long straight canyon is a tectonic fault, likely formed when the surface of Mars thinned, stretched, and broke from the volcanic activity. The large very low circular region on the lower right side of the map (Hellas Planitia) is an extremely large impact crater. There are many other impact craters on the map as well.



place name labels, C.M. Rodrigue (2009)

The map also shows features that appear to have been formed by water, north and northeast of Mariner Valley (around the borders of Chryse Panitia). Occasional warm periods in Mars' history resulted in melting of the subsurface ice and gigantic floods. The floods are recorded by outflow channels that feed into the Northern Lowlands, formed from catastrophic floods of water.

A quick look at elevations on Mars shows that the northern hemisphere is relatively low or deep and the southern hemisphere is high; this has been called the "great dichotomy". The crust in the southern hemisphere is about 25 kilometers (15 miles) thicker than in the northern hemisphere, and this causes the southern highlands to be about 4 kilometers (2.5 miles) higher in elevation than the northern lowlands. This evidently happened in the first few hundred million years of Martian history. The interesting problem is understanding why the crust is thicker in the south than it is in the north. Some scientists suggest that the northern hemisphere low is a depression created either by one giant asteroid impact or by several big impacts. Others suggest that motions inside of the mantle of Mars, known as convection, may have concentrated crust into the southern hemisphere. It is important to note that planetary scientists today are debating this dichotomy.

In general, the southern latitudes of Mars are rougher, and the northern latitudes are smoother. Rougher regions on most planets and moons are older regions, with heavier amounts of cratering. Students may need help making this connection.

- Planetary geologists assume that any location on a planet has an equal chance of being hit by impactors. So they expect a planet to have an even distribution of impact craters.
- Old surfaces have lots of impact craters, young surfaces have few impact craters. Just like old faces have lots of wrinkles and young faces have few wrinkles. With time, a planet accumulates more and more impacts.
- When an area has few craters, they suspect that another event has occurred to smooth the surface, such as lava flowing across the surface, or erosion.

Imagine a sheet of mud in a rainstorm. Early in the rainstorm, when only a few drops have fallen, there will be only a few raindrop patterns in the mud. With time, as the storm continues, more and more raindrops leave imprints in the mud. The longer (older) a planet's surface is, the more raindrops/impact craters it will have. After the storm, you have a mud sheet peppered with raindrop imprints. Now, imagine taking a bowl of mud and pouring it across half of the sheet. In the area where the new mud was poured, the imprints will be filled in / smoothed over by a newer surface. The mud represents a lava flow filling in and smoothing over the craters.

Correlation To Standards

Next Generation Science Standards

Assessment Standard:

- 4-ESS2-2. Analyze and interpret data from maps to describe patterns of Earth's features.
- MS-ESS2-2. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.

Disciplinary Core Ideas

- ESS1.C The history of planet Earth: 3-5. Certain features on Earth can be used to order events that have occurred in a landscape.
- ESS2.B Plate tectonics and large-scale system interactions: 3-5. Earth's physical features occur in patterns, as do earthquakes and volcanoes. Maps can be used to locate features and determine patterns in those events.

Science and Engineering Practices

- Asking Questions and Defining Problems: Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.
- Analyzing and Interpreting Data: Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.
- Analyzing and Interpreting Data: Analyze and interpret data to provide evidence for phenomena.

- Constructing Explanations and Designing Solutions: Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.
- Engaging in Argument from Evidence: Construct and/or support an argument with evidence, data, and/or a model.
- Engaging in Argument from Evidence: Respectfully provide and receive critiques from peers about a proposed procedure, explanation, or model by citing relevant evidence and posing specific questions.

Crosscutting Concepts

- Patterns: students identify patterns in rates of change and other numerical relationships that provide information about natural and human designed systems. They use patterns to identify cause and effect relationships, and use graphs and charts to identify patterns in data.
- Structure and Function: students observe the shape and stability of structures of natural and designed objects are related to their function(s).
- Stability and Change: students learn some systems appear stable, but over long periods of time they will eventually change.

ANSWER KEY

Question Set 1: Observing Patterns

1. This is a map of which planet? Mars

2a. What do the colors on the map key signify? Elevation

2b. Which physical features are represented by *all* topographic maps? Size, shape, and elevation are shown on all topographic maps.

3a. Where is north located on this map? Up, or at the top

3b. Where is south located on this map? Down, or at the bottom

4. Where do you think the equator is located? Horizontally across the middle at 0° latitude

5. Where are the red, orange & yellow colors located (in general)? Most of the red, orange, and yellow colors are in the southern hemisphere

6. Where are the greens and blues located (in general)? Most of the greens and blues are in the northern hemisphere

7. Where are the tans and whites? The tans and whites are clustered together

8a. Which colors represent higher terrain? The tans, whites, reds, and oranges are higher terrain

8b. Lower terrains? The greens, blues, and purples represent lower regions.

9. How do you know? You can tell by reading the elevation key on the map you have been given.

10. What patterns do you observe? Answers will vary and may include:
- "Most" of the blues and greens are located in the northern hemisphere
- "Most" of the reds, oranges and yellows are south of the equator
- Yellows and greens are found along the length of what looks like a shoreline
- The rough areas are almost exclusively reds, oranges, and yellows
- All the white areas are grouped together in close proximity to one another

Question Set 2: Analysis & Synthesis

1. What "type" of map is this? This is a topographic map; it provides elevation information

2. What color are the mountain tops? White

3a. Do any of the colors signify water? No

3b. If not, what does the color blue signify? Lower elevations

4. Refer to the "Terms to Know" and explain what feature is represented by the darkest blue area. The darkest blue area is a large impact crater basin.

5. What could have caused the *darkest* blue area to be in a location separate from the large *lighter* blue areas? That is where an impactor landed, creating a depression even deeper than the naturally occurring lowlands.

6. What indications of past or present flowing water do you observe? Channels from the highlands to the lowlands occur east of the mountains

7. Which areas (colors) of the map look rough? Most of the red, orange, and yellow areas look rough

8a. What makes the area rough? Lots of circular patterns of different sizes.

8b. What do you think caused the roughness? Referring to the "Terms to Know", students may conclude that the rough areas are heavily cratered from meteorite impacts.

9a. How would you describe the surfaces downslope from the highest peaks (rough or smooth)? Smooth

9b. Do these surfaces have many craters on them? No

10. What might have caused the smoothness; why might this area not be cratered? Answers will vary: Something smoothed it out. It was eroded. There were not as many impacts. Water smoothed it out. Lava flows smoothed it out. Wind smoothed it out.

11a. What kind of geologic features are the highest mountains? Volcanos

11b. Why do you think that? They are the right shape and have lava flows around them.

12. What is the feature just to the east of the mountains that looks like an east-west gash in the surface of the planet? A large fault

Questions Set 3: Drawing Conclusions

1. How could smooth surfaces on Mars become rough? From meteorite impacts

2. There is a big difference in the characteristics of the northern part of Mars and the southern part. What could have caused the northern terrain to become smooth? Answers will vary: from flowing water (erosion), being covered up, being filled in by flowing lava, having a big ocean in the north….

3. Which do you think is older, the red rough terrain or the lighter blue smooth terrain? The red rough terrain

4. What are your reasons? The lowest (blue-colored) terrain has fewer craters. Something happened to fill them in.

5. Which do you think is older, the *rough* red terrain or the *smooth* red terrain (around the mountains)? The "rough" red terrain is older.

6. Why do you suspect is it older? The rough red terrain has more craters; the smooth red terrain is younger and has not been hit by as many impactors. The smooth terrain probably is formed by lava flows because they sit next to volcanos.

To Mars!

Decide as a team what scientific question you have about Mars. Based on your investigations, this could be a geologic question, but it could also be another question that can be answered by the scientific process.
To what location will you send a rover or astronaut to gather information that will address your question?
Why did you choose this site?

Answers will vary.:

Wrapping Up

Based on your study of the MOLA topographic map of Mars, describe its topographic features and the geologic processes you think may have caused them. Based on your observations, describe how the red planet has changed through time.

Answers will vary, but should include some of the following:

For topographic features:

- Volcanos (or volcanic mountains)
- a much lower, smoother northern hemisphere with few craters
- higher, rougher southern hemisphere with lots of craters
- a large depression, or impact basin in the southern area
- possibly a shoreline separating northern and southern areas
- smooth areas downslope of the mountains
- a large fault to the east of the mountainous area
- channels cutting from the highlands to the lowlands to the east of the volcanos.

For geologic processes:

- Volcanism with large lava flows
- cratering
- flowing water carving channels, faulting

For evolution of the planet:

- heavily cratered by impacts
- craters in low area were filled in or eroded
- flowing water carved channels between high southern area and low northern area
- volcanos erupted

Investigator Packet

Overview: Planetary scientists can say a lot about a planet's history by looking at a map of its surface. They examine the features to understand the geologic activity that has occurred, look for patterns, determine the order in which events happened – and formulate questions for further exploration. They use maps to select locations to investigate on that planet's surface that may answer those questions. Maps are critical for identify targets for rovers, human exploration, and future colonies.

Your Challenge: As a team, develop a good understanding of the features and geologic history of the planet by answering the questions presented in this Investigator's Packet. At the close of the project, your team will propose a scientific question that could be answered by a rover or astronaut expedition and will identify the best and safest place to go to answer that question.

Terms to Know

Topographic Map – a map that shows natural and human-made features of an area in a way that shows their relative positions and elevations. Topographic maps often show contour lines (lines of equal elevation).

Crater – large depressions in a planetary surface caused by impactors, such as asteroids or comets. Craters typically are circular in shape and have raised rims.

Channel - the bed where a natural stream of water (or lava) runs, or ran. Channels can be straight or sinuous (curvy).

Volcano – usually a large cone-shaped structure forming at a vent in the surface of a planet through which magma and gases erupt. The cone-shaped feature builds up from the ejected material.

Lava – molten rock that flows on the surface of a planet (*magma* is molten rock that is still inside the planet).

Early bombardment – a period early in the history of the Solar System during which asteroid impacts were very frequent. Very large craters were created on the planets at this time, caused by large impactors. While impacts still occur today, they are less frequent and smaller.

Fault – a break in a planet's surface, along which blocks of the surface move relative to one another. Faults are long straight features.

Question Set 1 - Observing Patterns & Mapping

1. This is a map of which planet?______________________________________

2a. What do the colors on the map key signify?___________________________

2b. Which physical features are represented by *all* topographic maps? ________

____

3a. Where is north located on this map? ________________________________

3b. Where is south located on this map? ________________________________

4. Where is the equator is located? ____________________________________

5. Where are red, orange & yellow colors located (in general)? ______________

____

6. Where are the greens and blues located (in general)? ___________________

____

7. The tans and whites? ____

____

8a. Which colors represent higher terrain? ______________________________

8b. Lower terrain? ____

9. How do you know? ____

____

10. What patterns do you observe? ____________________________________

____

____

Check your answers with your teacher!

Question Set 2 – Analysis & Synthesis

1. What “type” of map is this?____

2. What color are the mountain tops?__________________________________

3a. Do any of the colors signify water?_________________________________

3b. If not, what does the color blue signify?_____________________________

____

4. Refer to the “Terms to Know” and explain what feature is represented by the *darkest* blue area.

____

5. What would have caused the *darkest* blue area to be in a location separate from the large *light* blue areas?

____

____

____

6. What indications of past or present flowing water do you observe?

____

____

Use your writing utensil to mark the possible directions of the flows.

7. Which areas (colors) of the map look rough?___________________________

8a. What makes the area rough?_______________________________________

8b. What do you think caused the roughness?

____

____

9a. How would you describe the surfaces downslope from the highest peaks (rough or smooth)?____

9b. Do these surfaces have many craters on them?______________________

10. What might have caused the smoothness; why might this area not be cratered?____

____

____

____

____

11a. What kind of geologic features are the highest mountains?_____________

11b. Why do you think that?

____

____

____

12. What is the feature just to the east of the mountains that looks like an east-west gash in the surface of the planet?

____

____

Check your answers with your teacher!

Questions Set 3 - Drawing Conclusions

1. How could smooth surfaces on Mars become rough?____________________

____

2. How could rough surfaces on Mars have been smoothed out?_____________

____

3. There is a big difference in the character of the northern part of Mars and the southern part. What could have caused the northern terrain to become smooth?

____

____

____

4. Which do you think is older, the **red rough** terrain or the **blue smooth** terrain?

____

5. What are your reasons?

____

____

____

____

6. Which do you think is older, the ***rough* red** terrain or the ***smooth* red** terrain (around the mountains)?

____

____

7. What are your reasons?

____

____

____

Check your answers with your teacher!

To Mars!

Decide as a team what scientific question you have about Mars. Based on your investigations, this could be a geologic question, but it could also be another question that can be answered by the scientific process.

____

____

____

____

To what location will you send the rover or astronaut to gather information that will address your question?

Latitude: ____________________________________

Longitude: ____________________________________

Why did you choose this site?

____

____

____

____

Wrapping Up

The MOLA map you just used to determine your landing site was one of the same maps used by NASA scientists and engineers to determine the landing sites of the rovers, Spirit and Opportunity in the Mars Exploration Rover Mission. Spirit landed in Gusev Crater, located at 14.57° South and 184.53° West. Opportunity landed on Meridiani Planum, located at 1.95°South and 5.53° West.

Based on your study of the MOLA topographic map of Mars, describe its topographic features and the geologic processes you think may have caused them. Based on your observations, describe how the red planet has changed through time.

Color-coded Elevations on Mars, MOLA Altimeter, MGS Mission