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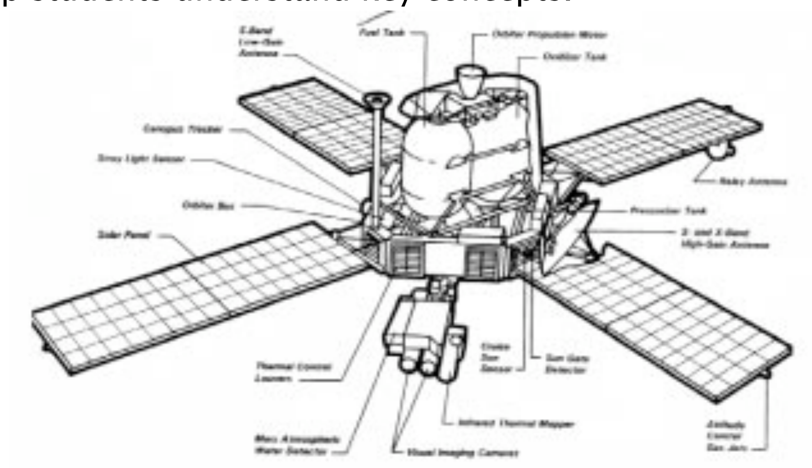
WHAT DO THESE IMAGES SHOW?

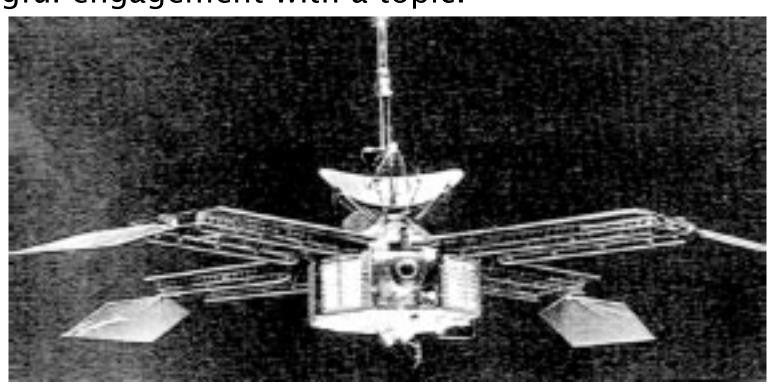
Background Information

The Mariner and Viking missions to Mars have taken thousands of pictures of Mars from orbit and from the surface, and new missions will provide many more images. These images are essential for scientists wanting to learn more about Mars. It is important for students to have the opportunity to work with images because of their central role in planetary research and because of their power to help students understand key concepts.



Starting in 1976 the Viking Orbiter returned thousands of images of Mars.

Students should consider the images as “mystery stories.” When you distribute the images, do not explain what they show. Instead, ask your students what they see in the images. Each image has some sample questions to help launch discussions. This early in the module, students may not know enough to give strong answers. Nonetheless, the thinking, problem-solving, and speculating engages students and inspires them to generate questions – the building blocks of meaningful engagement with a topic.



Mariner 4 was the first spacecraft to return images of Mars in 1965.

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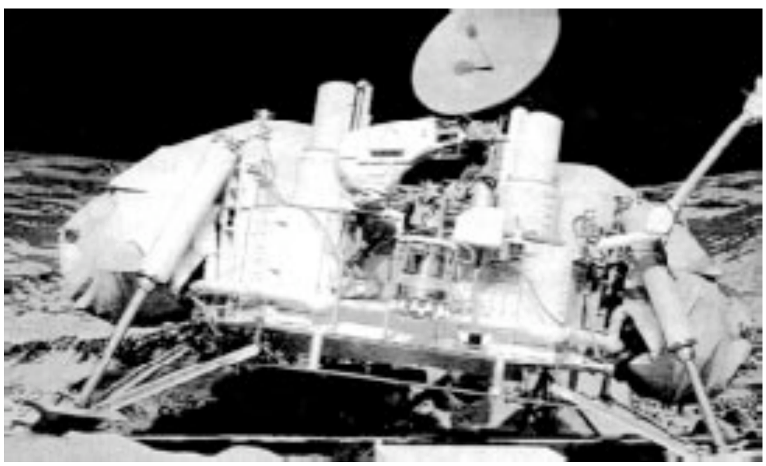
Objective
Upon completion of this activity, students will be able to:

- interpret images of the surface of Mars.
- hypothesize about what might have caused the features in the image.
- determine scale.

Instructional Time
45-90 Minutes

Materials
Image Set
Large sheets of paper to record ideas from the group discussions
Clear transparencies and water-soluble markers (optional)
Atlas of Earth (several copies for use in the class)



The Viking I Lander

Procedures

1. Set the tone for students by telling them that this activity recreates the experience many scientists had of seeing unfamiliar images for the first time.
   After Viking I and II reached Mars, scientists were inundated with many new views of the planet, and they often felt overwhelmed because most of the views raised more questions than they answered.
2. Have students work with their group and look through the image set with the goal of understanding what each image shows. They should examine them at two levels. The first level is to generally identify what is pictured in the image. The second level is to examine some of the details and

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speculate about what might have caused them. Also, how do the different features in the image relate to one another? In each group, one person should record the comments, speculations, and questions raised by the image.

Active involvement is a far more powerful learning experience than listening passively to someone else's discovery. Consequently, each person should examine each image. However, if time is a concern, you could assign a different image to each person and have them report on those images. If any person gets stuck, refer to the "Notes on the Images" below for questions and ideas to help prompt their thinking. To facilitate making comparisons and sketching features, students can mark on clear transparencies.

3. Ask a person to select one of the images and describe what he/she thinks it shows. Write their ideas on a large sheet of paper that everyone can see. Ask another person for another detail he/she noticed and what they think it is. Continue until each person has contributed something or no one has more observations to share. Ask students about their answers to the sample questions.

   Each image can be the beginning of an involved discussion. Many images are inter-related (see "Notes on the Images" below), and it can be more interesting and valuable to jump around and follow an idea rather than to fully document each image in order. The leaps of intuition, rather than completion, are what characterize success.
4. Proceed until all the images have been described.
5. Have your students pick a feature in one of the images and use the scale to calculate how big it is. Have them record this size. Then have them refer to an Earth atlas to find a region or feature about the same size. Relating a feature to something in a student's own experience and creating a "personal yardstick" helps a student to internalize and to better understand what a feature's size and scale really mean. For example, each crater in Image #2 is about 15 km in diameter, about the size of Manhattan Island.

   You may need to teach a lesson to help students understand scale.

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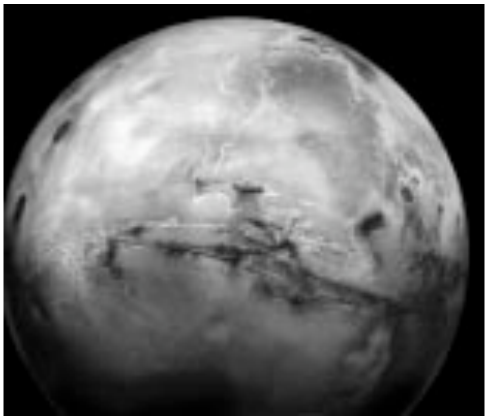
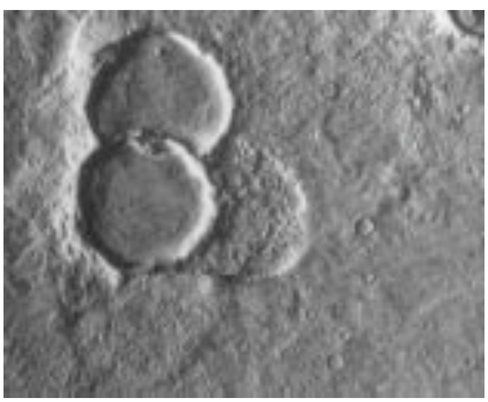


Image 1: Mars hemisphere

This photograph shows Mars as if you were viewing it from 2,500 km above the surface. It is a mosaic of 102 images taken by the Viking I spacecraft in 1976. This view shows some large impact craters, volcanoes (the three round spots on the left. Each volcano is 25 km tall and about 350 km in diameter.),and Valles Marineris, a huge 4,800 km canyon (across the middle of the photograph). In this view, the two Martian polar caps are not apparent.

Sample Questions:
- What is the feature across the middle?
- What do you think the circles on the left side are?

Image 2: Martian surface craters


Craters, formed when meteors strike a surface, cover much of Mars. These craters are located in the heavily cratered uplands about 5,500 km east of *Ares Vallis* (e.g., the Ares Valley). When one impact happens near another, the resulting craters overlap. Note that all crater walls and one crater in particular are severely degraded. Since the squiggles in the bottom of the two upper craters are dune fields, wind is a significant factor in this area and may have helped degrade the craters. The craters have two ejecta patterns – lobed (to the left) and striated (below). Lobed patterns suggest that water-rich material suchas mud flowed upon impact. Striated patterns are caused when an impact propels material across the surface at high speeds. (34.79N, 309.14W, Viking Orbiter frame 641A09)

Sample Questions:
- On Earth, what are some things about the size of these craters?
- Why do some of the craters overlap?
- In what order were the craters formed?
- What do the patterns around the craters reveal about the nature of the surface?
- Have you ever seen an impact crater? *(The "Man in the Moon" is a collection of impact craters.)*

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Image 3: Crater with a lobed ejecta pattern

In this image there is an "oozy" blanket around the crater. Scientists speculate that when the meteor causing these craters hit, the impact melted ice in the surface layers. The resulting water turned the surface to mud that flowed away from the impact. In Activity 3, your students will do their own crater experiments. (23S, 79W, Viking Orbiter frame 608A45)

Sample Questions

- What do you think caused the shape around the craters?
- Were these craters formed at the same or at different times?

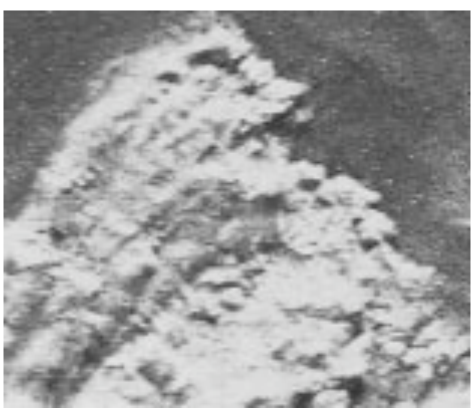

Image 4 : Dust storm on the Martian surface

This image shows craters and a 270 km-wide dust storm just at the edge of the South Pole. The winds, induced by great temperature contrasts between the ice cap and the land surface, can create such storms. Dust storms can obscure large areas of Mars, and Earth-based telescopes can even see some of these storms! (70S, 60W, Viking Orbiter frame 248B57)

Sample Questions:

- What could this feature be?
- How big is the feature in this image?
- In what direction is the storm moving?
- Why might there be strong winds over the land next to an ice cap?

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Image 5: View of the thin Martian atmosphere

From 18,000 km away and at an orbital height of about 1,500 km, the Viking I Orbiter took this image of the sky above the *Argyre Planitia* (i.e., the Argyre Plain). Of special interest are the light-colored bands above the horizon. Dust from a dust storm creates a haze in the atmosphere 25-30 km above the planet's surface. This view emphasizes the shallowness of the Martian atmosphere. (47S, 22W, Viking Orbiter Image 34A13)

Sample Questions:

- What is the line on the horizon above the Martian surface?
- How high above the surface is it?
- What causes it to be visible?

Image 6: Martian volcanoes and fault lines

The surface of Mars has volcanoes, none of which are active. These two shield volcanoes formed as low-viscosity basaltic lava flowed from a central vent. The larger one is 6 km tall, 90 x 130-km in diameter, and has a slope of 7 degrees. The smaller one is 3.5 km tall, 60-km in diameter, and has a slope of 5 degrees. They are among the steepest volcanoes on Mars. On both volcanoes, note the lava channels and the impact craters. The long, straight fractures on the left formed when the Martian surface in this region bulged upward. (25N, 95W, Viking Orbiter photomosaic 211-5593)

Sample Questions:

- Which came first, the volcano or the impact craters? How can you tell?
- What might have caused the channels on the sides of the volcanoes?
- What are the lines in this image? What might have caused them?

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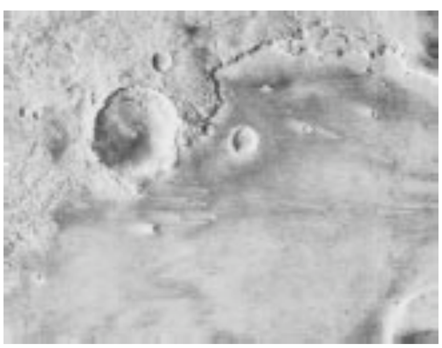
Mars has many canyons, and your students can learn more about them in other modules in the series. This image shows a 100 km-wide by 8 km-deep section of the Candor Chasm of Valles Marineris. Valles Marineris is a huge rift valley roughly as long as the US. Numerous landslides have eroded its edges and widened it. (25N, 95W, Viking Orbiter frame P40381)

Image 7: A section of the Candor Chasm in Valles Marineris

Sample Questions:
- What do you think caused the valley?
- What do you think shaped the cliffs on the edges of the canyon?
- How did this canyon get so wide?



This image shows a rich diversity of geological processes. There are fractured, ridged plains (top center), craters as big as 100 km (several have been severely degraded), lobed ejecta blankets, an enormous channel, and wind streaks (going in the opposite direction of the former water flow). (27N, 58W, courtesy of Arizona State University's Planetary Geology Group)

Image 8: Landforms at the mouth of Kasei Vallis

Sample Questions:
- Explain which came first, the fractures or the large crater in the center-left?
- Which came first, the crater in the bottom-center or the channel?
- Which direction did the fluid flow? Is any fluid apparent now?
- What caused the "tails" behind the small craters in the channel?
- What sequence of events and processes makes most sense in explaining all these features?

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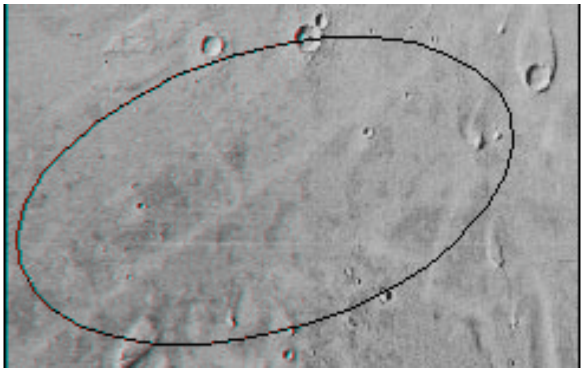
Image 9: Close-up view of the landing site



The 100 x 200 km ellipse, roughly the size of Massachusetts, delineates the expected landing area for Pathfinder at the mouth of Ares Vallis. It is an ellipse rather than a circle because Pathfinder sped in obliquely from the northeast and bounced to a stop rather than using rockets for a controlled, vertical landing. Pathfinder landed just northwest of center (19.35 N, 33.55 W). Note the landforms sculpted by flowing water (suggesting that large-scale floods swept this region), a smooth outwash plain (good for a safe landing and full of sediments from upstream), and impact craters with lobed ejecta blankets (suggesting water or ice-rich surface layers, an idea consistent with flooding). (Detail of USGS photomosaic I-2311)

Sample Questions:
- What is this ellipse?
- How would you describe this region?
- How might the teardrop-shaped landforms have formed?
- What might make this a desirable landing site?

Image 10: The Barringer Crater in Winslow, Arizona

Barringer Crater in Winslow, Arizona is about 50,000 years ago, 1.2 km in diameter, and 180 meters deep. While it takes billions of years to achieve this level of degradation on Mars, Earth's wind and water have severely eroded the crater walls and ejecta blanket in just thousands. The ejecta pattern suggests that Barringer Crater had a striated, not lobed, ejecta pattern. Thus, the surface layers were probably fairly dry at the time of the impact.

Sample Questions
- What planet is this crater on? How can you tell?
- Is this crater more like the one in Image 2 or the one in Image 3? Why?
- Is this a fresh or an aged crater?
- How does this crater compare in size to those in Images 2 and 3?

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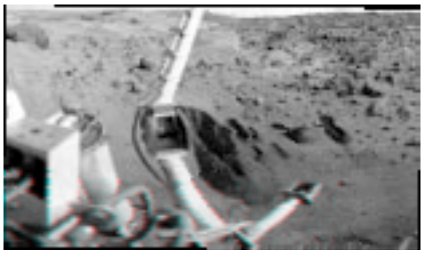
Image 11: Viking I's view of the Martian surface



On July 20, 1976, Viking I landed in the Chryse Planitia and was the first spacecraft to land successfully on Mars. Scientists think the Chryse Planitia is an outwash plain, and one reason Viking I landed here is that it is relatively flat, increasing the chances of a safe landing. Viking's robotic arm dug the trenches in the foreground to reveal the upper surface and to collect sediments for several experiments. Note the wind-deposited dust behind some of the rocks. As measured by Viking, temperatures typically ranged from -85oC to -30oC and wind speeds were around five meters per second, gusting to 25 meters per second. Pathfinder also landed in the Chryse Planitia, roughly 850 km east of this site. (22.4N, 48W)

Sample Questions

- How big are the largest rocks?
- Does this look like any place on Earth? If so, where?
- Can you tell if it is hot or cold?
- What might scientists learn from sampling in a place like this?
- How does this scene compare to the one around Pathfinder's landing site?

Image 12: Wide-area view of the landing site

Image 12 shows an expanded view of Pathfinder's landing site. Although there is currently no liquid water on Mars, the landforms strongly suggest that water flowed during an earlier time. There are more streamlined shapes evident in this image than in Image 9, as well as several apparent channels that may have carried water to the landing area. (33N, 20W, Detail from USGS photomosaic I-1345)

Sample Questions

- What information does this wide-area view add to your understanding of Image 9?
- Do you see anything that might make this an interesting area to explore?

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Image 13: Sojourner, Barnacle Bill and Yogi

On its third day, Pathfinder made this image showing part of a deflated airbag and the area at the end of the lander's ramp. Note that some rocks are rounded and others are angular. Scientists think that the rounded rocks had their edges knocked off by the tumbling action of flood waters, and that the sharpedged rocks were ejected from nearby impact craters and/or volcanoes. Sojourner used its Alpha Proton X-ray Spectrometer (APXS) and cameras to examine the mineral composition of rocks and soil around the landing site. “Barnacle Bill” is the small rock on the left, and “Yogi” is the large rock at the upper right.

Sample Questions

- How many different general rock shapes can you see?
- What causes rocks to be different shapes? (*Hardness and their weathering history*)
- Is the surface of Mars dusty? How can you tell?

Image 14: Twin Peaks

Pathfinder made this image on the fourth day. "Twin Peaks,” the two hills about one kilometer away from the landing site, are of great interest to scientists. Sections of the hills look stratified, and white areas on the left hill, (nicknamed the "Ski Run”) may represent a high-water mark from one of the floods that swept this area. The jumbled boulders in the foreground probably were carried from upper portions of Ares Vallis by ice or water.

Sample Questions

- Does this look like any place on Earth?
- Why did the landing site look so smooth when it is really full of boulders?
- What are some ways a plain like this can become littered with rocks?

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Image 15: Regional view of the landing site

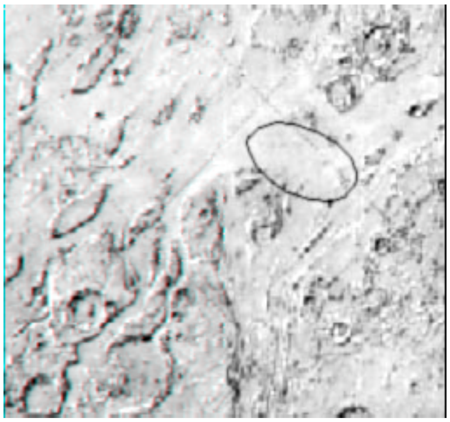

Image 15 shows the channel of Area Vallis extending 1,800 km southeast of Pathfinder's landing site. By tracing the channel upstream, you see depressions in the landscape - possible sources of water for Ares Vallis. These are *chaotic terrain*, a unique Martian feature that formed when large areas of permafrost melted (see Activity 4's Background section for a further discussion). The mouth of Ares Vallis is 2-3 km below the head of the channel. As the water flowed downhill, it crossed many different types of terrain and carried sediments from roughly a million-km2 area of the surface. This is why Pathfinder found sediments from many rock types at the mouth of this channel. The "one-stop-shopping" possibilities made Pathfinder's landing site exceptionally valuable to scientists wanting to learn more about the geology and hydrology of Mars. Activity 4 asks students to figure out why scientists chose Ares Vallis as Pathfinder's landing site. (Detail from USGS Map I-1551)

Sample Questions

- What information does this wide-area view add to your understanding of Image 12?
- How much water flowed in this region, a little or a lot?
- Do you see any sources for water?
- Why is the area at the end of the channel so smooth? (*It is a floodplain covered with sediment.*)

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Image 16: Regional map of Ares Vallis

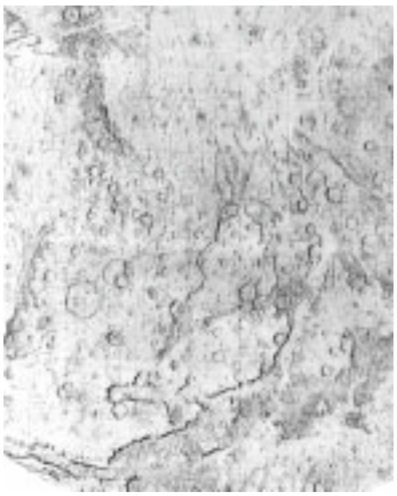

Image 16 highlights many of the region's interesting features. Channels descend 2-3 km from a plateau that surrounds most of the low-lying Chryse Planitia. The numerous areas of chaotic terrain and the many channels suggest that flowing water was a regional phenomenon. While there are many lobed ejecta blankets in the Chryse Planitia, there are none in the highlands. Since lobed ejecta blankets occur only in water or ice-rich areas, the highlands must have been drier than the plain at the times of impact. Also, the highlands are heavily cratered while the Chryse Planitia is relatively free of craters. Our solar system experienced a period of heavy bombardment by asteroids three-billion years ago. This bombardment created most of the craters on Mars, so the floods that obliterated the Chryse Planitia's craters must have occurred after that time. (Detail from USGS map I-1448)

Sample Questions

- How big is this area?
- Is Ares Vallis the only place where water flowed?
- What is the general topography of this region? Which direction is uphill?
- Where might the water that flowed in these channels have come from?
- Describe the distribution of craters in this region.
- What might explain this pattern of distribution?
- What are some differences between the craters on the plain and in the highlands?
- What might explain the differences between the craters in these two areas?
- What do you think the Chryse Planitia looked like when water flowed in the channels?

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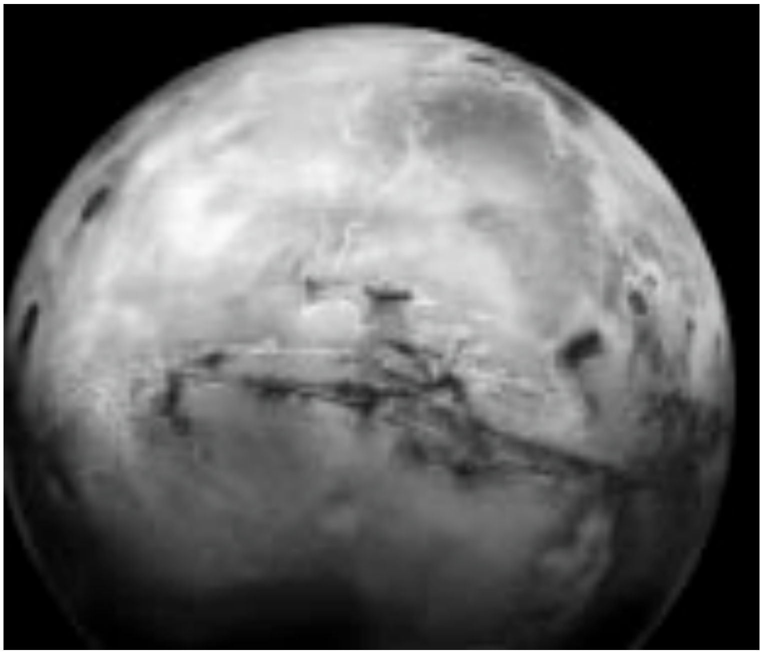

Image 1: Mars hemisphere

Image 2: Martian surface craters

Image 3: Crater with a lobed ejecta pattern

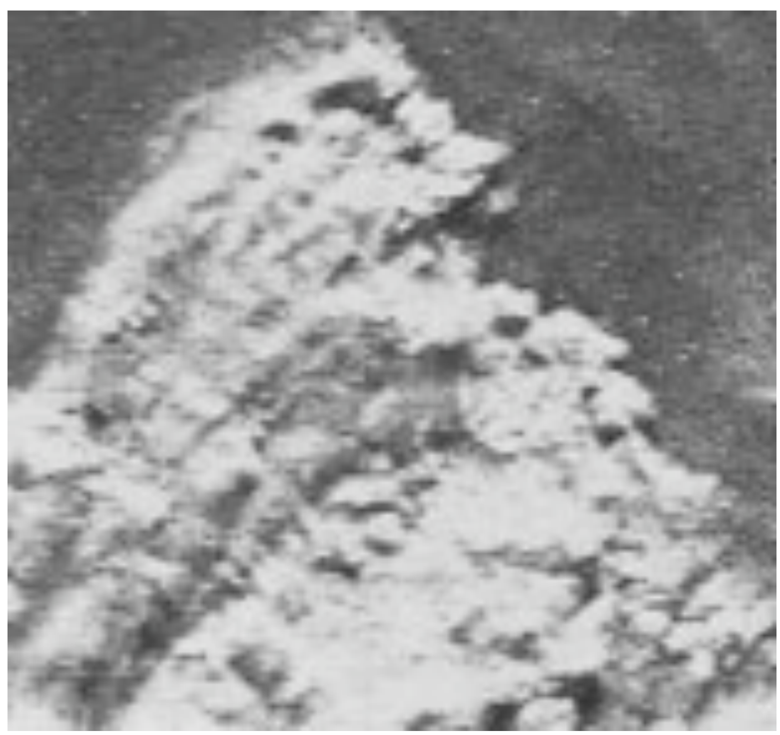

Image 4 : Dust storm on the Martian surface

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Image 5: View of the thin Martian atmosphere

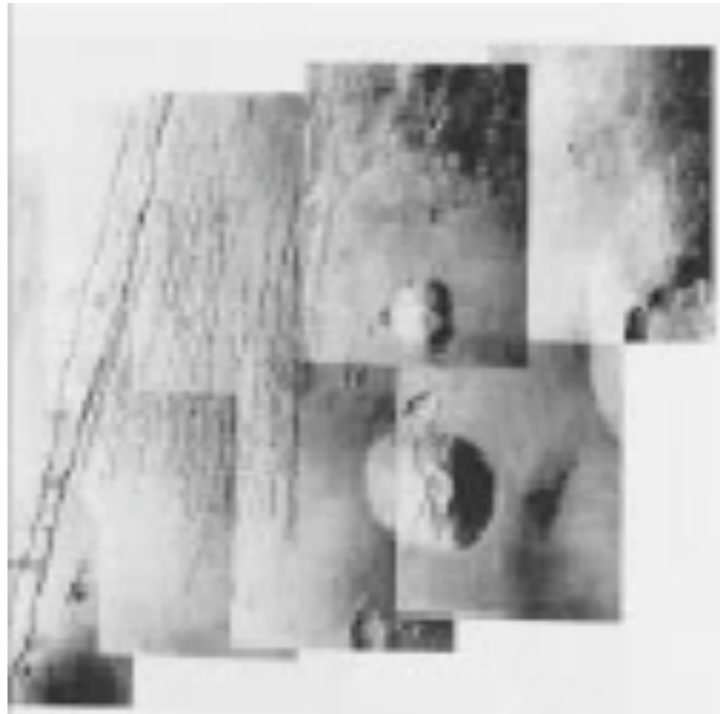

Image 6: Martian volcanoes and fault lines

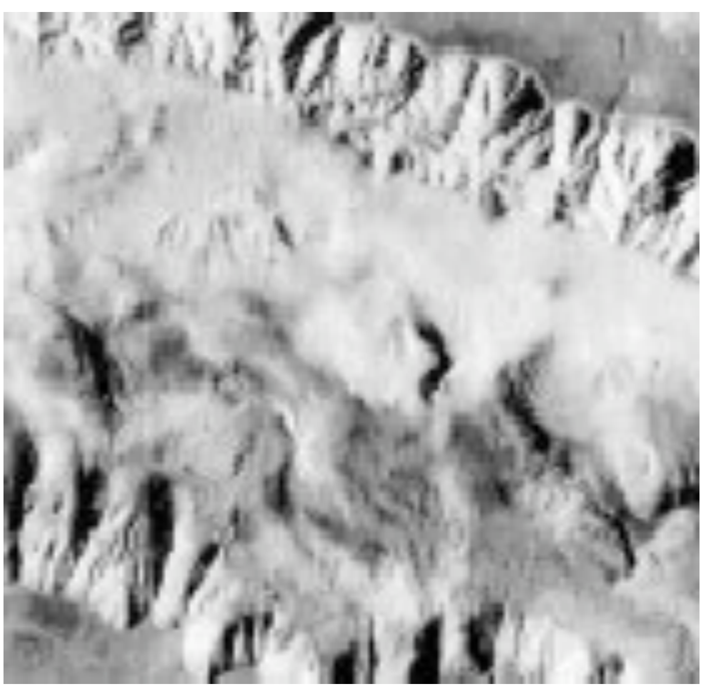

Image 7: A section of the Candor Chasm in Valles Marineris

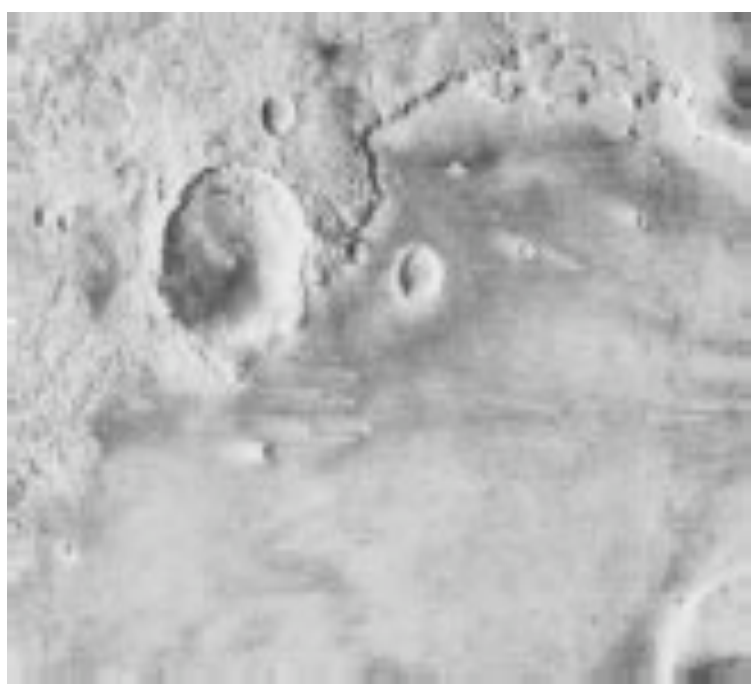

Image 8: Landforms at the mouth of Kasei Vallis

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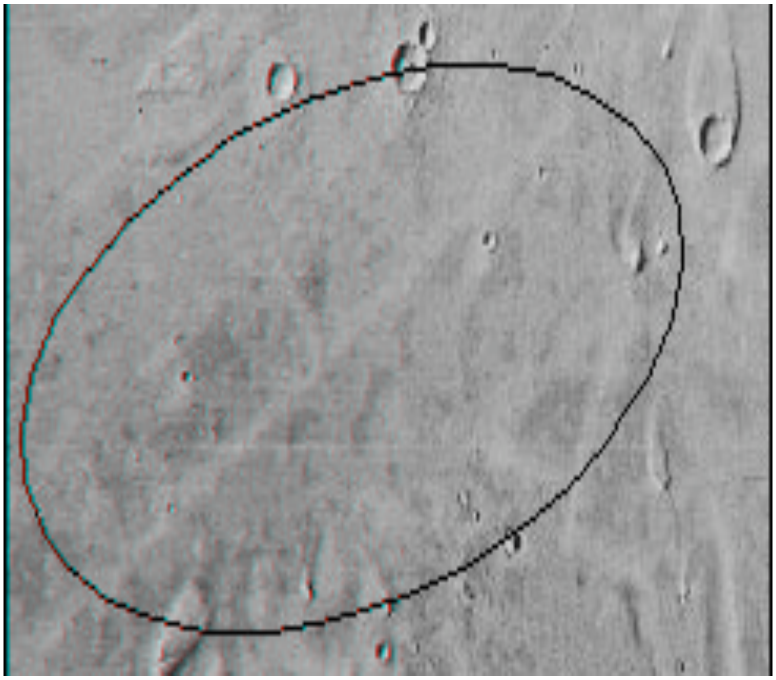

Image 9: Close-up view of the landing site

Image 10: The Barringer Crater in Winslow, Arizona

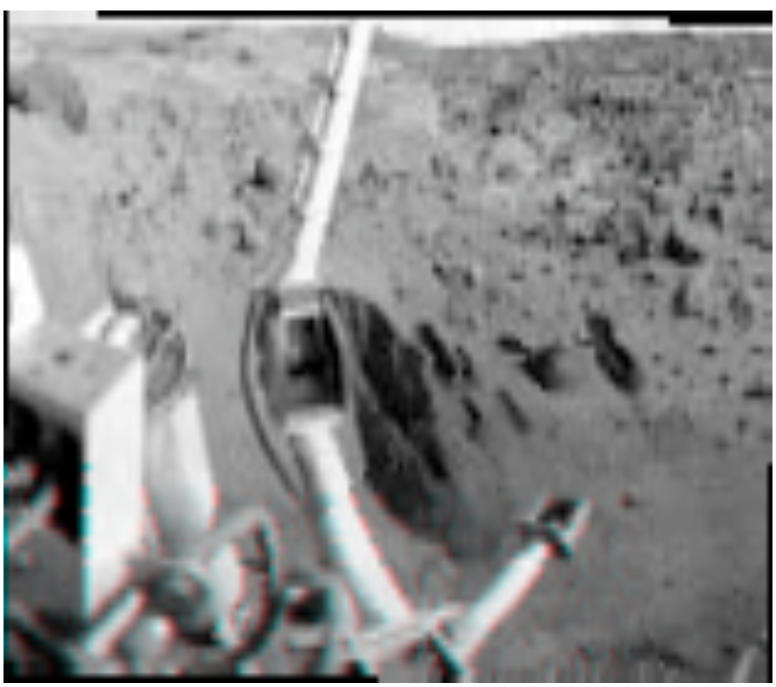

Image 11: Viking I's view of the Martian surface

Image 12: Wide-area view of the landing site

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Image 13: Sojourner, Barnacle Bill and Yogi

Image 14: Twin Peaks

Image 15: Regional view of the landing site

Image 16: Regional map of Ares Vallis

Student Name ______________________________________ Date _________________

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Directions. Use the Image Set to answer the following questions. There are several images that relate to each question, so build the strongest case possible for you answers by finding several examples of supporting evidence.

QUESTION	Y/N	EVIDENCE THAT MAKES YOU THINK SO	IMAGE #
Does Mars have an atmosphere?			
Is there evidence for water on Mars?			
Does Mars have volcanoes?			
Does Mars have strong winds?			
Is the surface of Mars dry?			
Does Mars have many craters?			
Is the surface hot by Earth standards?			
Does Mars have landslides?			
Did the surface of Mars ever crack?			
Does Mars have dust on the surface?			
Is Mars an easy planet on which to land a spacecraft?			