CRISM
Compact Reconnaissance Imaging Spectrometer for Mars on the Mars Reconnaissance Orbiter

Earth/Mars Comparison of Geological Features

Objective(s):

- Students will use satellite images to observe and compare various geological features between the planets Earth and Mars.
- Students will work in groups to simulate and reproduce one of the geological features that they observed in the satellite images.
- Students will use observational data from the experiment to conclude that some of the geological features on Mars could have been formed by flowing water.

National Science Education Standards:

- Content Standard D Grades 5 – 8: Earth's History
- Content Standard F Grades 5 – 8: Science and Technology in Society
- Content Standard G Grades 5 – 8: Science as a Human Endeavor and Nature of Science

Background:

In this lesson, students explore the landforms of both Earth and Mars by carefully examining satellite images. The role of the student is to compare these landforms and share their observations with the class. Noting the similarities and the differences, the teacher then has the students focus on particular landforms on Mars – the channels and valley features. After discussing possible explanations for these features, the teacher introduces the stream tray investigation and the students conduct the experiment. Afterward, the students compare their data to several more images taken of Mars and conclude that these landforms could be the result of water having once flowed across the planet's surface.

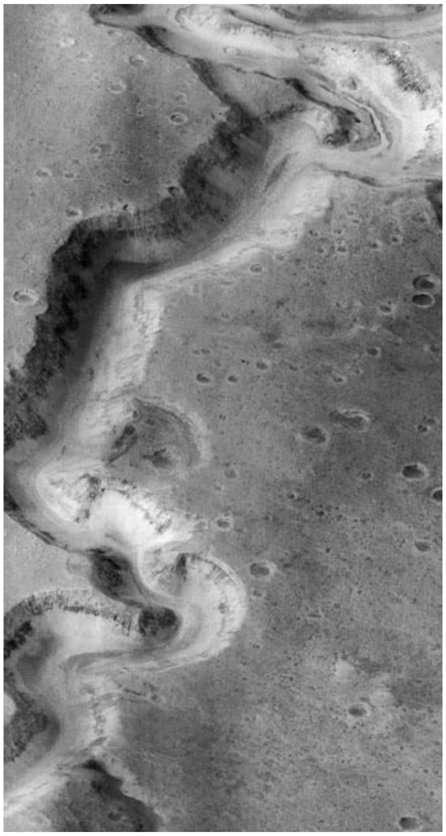

NASA

Figure 1. This image taken from the Mars Global Surveyor using the Mars Orbiter Camera reveals a 9.8 kilometer by 18.5 kilometer (6.1 mile by 11.5 mile) area of Nanedi Vallis. This feature looks very similar to a river valley on Earth, but lacks other features such as smaller channels surrounding the valley surface.

"Did water once flow across the surface of Mars?" is a question that scientists are still struggling to answer. A great deal of evidence leads many to believe that water did indeed exist on Mars. For how long and how much remain a mystery. However, current and future Mars missions plan to shed light on our understanding of the forces that shaped the planet. A role of CRISM is to look for traces of where water might have once existed. Such evidence could be used to determine a possible landing site for another Mars rover. For the time being, though, scientists have hundreds of thousands of Mars images to study. A number of these images reveal landforms very similar to those seen on Earth. Some, however, are very different from what we see on Earth. (Figure 1)

The Mars image in Figure 1 is just one of many that scientists are studying to better understand the planet's early geological history and learn whether water once flowed across its surface. They also study volcanoes and craters, adding to our overall understanding of the planet.

Like the scientists, students will also explore these images and, with the help of what they observe in the experiment, will make up their own minds about what caused these Earth-like features on Mars.

Materials:

- Stream tray with centimeter lines marked along both sides; use a plastic wallpaper tray about a meter long and 10 centimeters wide. (These can be purchased from a local hardware store or paint store.) 1 per group
- Playground sand; one 50-pound bag should be enough for 3 to 4 trays. 2 cupfuls per group
- Container for holding water (empty 2-liter soda bottle or 500 milliliter beaker), 1 per group
- Bricks, books or blocks to raise the stream tray at one end (keep in mind that books could get wet and damaged)
- Protractor, 1 per group
- Dice or similar 1-centimeter cubes, 1 per group
- Small (about 9-ounce) cups and large (about 16-ounce) cups, 1 each per group
- Shower curtain (optional) to use as a tablecloth for the activity, 1 per group
- Two or three large containers (5-gallon buckets work well) for collecting water once the students have completed each trial in the experiment
- Meter stick, 1 per group
- Permanent markers for students to measure and mark the stream tray
- Stream Tray Investigation Data Table and pencil, 1 per student
- Stream Tray Investigation Teacher's Copy
- Stream Tray Investigation Student Copy, 1 per student
- Earth LANDSAT Images, 1 set of each per group
- Mars Images, 1 set of each per group
- Mars Water Features Images, 1 set per group

Teacher Preparation:

- Measure and mark the stream tray in 10-centimeter increments along the sides. (Teachers may decide to let students do this activity. However, once done it will not need to be done again.) See the Stream Tray Investigation Teacher's Copy for more details.
- Make copies of the Stream Tray Investigation Data Table for each student.
- Make copies of the following for each group:
    - Earth Images
    - Mars Images
    - Mars Water Features Images

  All of these images can be reused with future classes.

Time:

- Two to three 45-minute class periods

Engagement Activity:

In this first activity, students are to share their ideas about how scientists might compare Earth and Mars. Included with the engagement activity is an Introduction to Mars. Teachers can have students read this if this is their first time learning about Mars.

1. What are some of the land features scientists might look at to help them compare Earth and Mars?

   List their ideas as they are shared. Examples might include mountains, craters, valleys or canyons.

2. How would it help scientists to compare these various land features? What are some things that the scientists might learn about each planet's geological history?

   Student responses might include that scientists can learn how the planets are similar or if the various land forms were created in the same way on both planets.

Exploration Activity I:

During the exploration phase, students will work in small groups to examine satellite images of both Earth and Mars. They will work together to identify various geological features as well as similarities and differences between the two planets.

1. Begin by asking students how scientists would obtain data about the various landforms on both planets. (Scientists could use remote sensing such as satellites, rovers, ground truthing here on Earth or even what can be observed from an aircraft.)
2. Working in groups of three or four, have the students carefully examine the Earth and Mars images and list on an organizer the similarities and differences.
3. After about 10 minutes (or more if students need the time), have students return their images and share with the class their comparisons.

   The teacher might want to display the images at the front of the room where students can refer to them as they share their comparisons.

   a. What land features were they able to identify in the images of Earth and Mars?
   b. How do these various landforms compare? How are they similar? How are they different?

4. Using the Mars images of the outflow channels and the valley networks, ask students for a list of possible causes for these landforms.

   Students might respond with the idea that water could have created these features. Whether they do or not, have the students reexamine the Earth images and discuss the similarities of the landforms. The intent of this discussion is for students to think critically about the causes for the landforms observed on Mars. Students will observe the effects of water as it flows across a surface in the next activity.

Exploration II:

In this activity students will use a stream tray to simulate water flowing across the surface of a planet. The students will conclude the activity by sharing their results and answering several follow-up questions. This particular activity has been adopted and modified from the NASA Mars Curriculum Module series and is titled The Great Martian Floods & The Pathfinder Landing Site. For more information or a detailed version of this lesson, visit http://marsprogram.jpl.nasa.gov/education/modules/gmfact1.pdf.

1. Have students work in groups of four to conduct the stream tray experiment. Refer to the teacher's copy of the procedure for a more detailed account of this activity. Each group of students will require a copy of the student procedure.
2. Each student will need a copy of the Stream Tray Investigation Data Table. (It is important to allow at least 45 minutes to complete this experiment. Remember to allow time for student clean up as well.)
3. Have the students answer the questions on the Stream Tray Investigation Data Table.

Explanation:

The students and teacher will conclude the series of activities by looking at the Mars Water Features Images. The students will apply their observations from the stream tray investigation as well as what they have discussed as a class in order to explain the geological features on Mars as seen in the images.

1. Begin by having the students share their results. Have the students discuss how the angle of the stream tray affected the channel and the bend in it.
2. Pass out the Mars Water Features Images to groups of students. Have the students compare their observations from the stream tray with the various land forms in the Mars images.
3. Have the students write down their comparisons by making two lists. On one list, have the students write down their ideas that support the concept that water once flowed across Mars' surface. On the other, have them list ways that these landforms could have been created without the help of water.
4. Allow as much time as needed for the students to create their lists and then have the groups share their thoughts with the class.

Students may have a difficult time coming up with ways that the landforms could have been created without the help of water. Encourage students to consider ways in which landforms on our planet have been created in the absence of water. For example, wind and uplifting have altered a great deal of the planet. Could similar processes have occurred on Mars?

Extension:

Teachers can have students visit the CRISM Web site to learn more about the instrument and its scientific overview as well as follow the links to the Mars Reconnaissance Orbiter. Included are links about Mars and other Mars missions.

Evaluation:

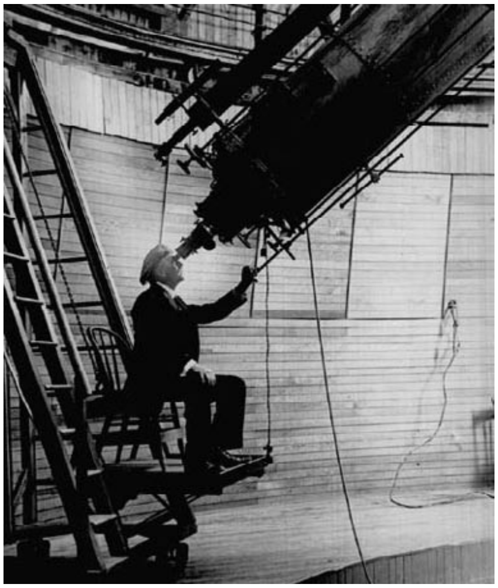
Assessing student understanding of the objectives can be done informally through questioning or formally by collecting their Stream Tray Investigation Table.

Further Investigation/Extenstion:

The following NASA Web page, http://science.nasa.gov/headlines/y2001/ast05jan_1.htm, offers an excellent summary of NASA's search for evidence of past water on Mars. Teachers could use this as an additional extension to what students did in this lesson or as an introduction to the lesson. Regardless of whether students read the article, it's highly recommended that teachers read it for background purposes!

Mars: Then and Now, A Brief History

Mars has long held the fascination of scientists and the general public since the invention of the telescope. It wasn't until the late 1800s that Mars began to attract the attention of a number of astronomers. The wealthy astronomer Percival Lowell had an observatory built in Flagstaff, Arizona, for the sole purpose of observing and gathering as much information as possible about the Red Planet. After careful observations and much reading about other astronomers' findings, Lowell came to the startling conclusion that Mars was inhabited by advanced life forms. He based his rather incredible theory on what he observed to be canals crisscrossing the surface of Mars. These canals, Lowell believed, were the work of intelligent life forms desperately trying to bring water from melting ice caps at the poles to the warmer regions at the equator. Lowell even wrote a book about his findings, titled <u>Mars as the Abode of Life</u>. Lowell had unknowingly set the world on edge with his remarkable ideas. Various artists shared their visions of what the planet must look like if it were visited by an Earthly being. In H.G. Wells' famous science fiction story <u>The War of the Worlds</u>, Martians leave their dying planet for the Earth's vast resources. Ruthless and uncaring, they destroy everything in their path. The alien invaders eventually die as a result of a common germ to which they have no immunity.



Lowell Observatory Archives

Percival Lowell sits at the eyepiece of his 24-inch telescope.

NASA

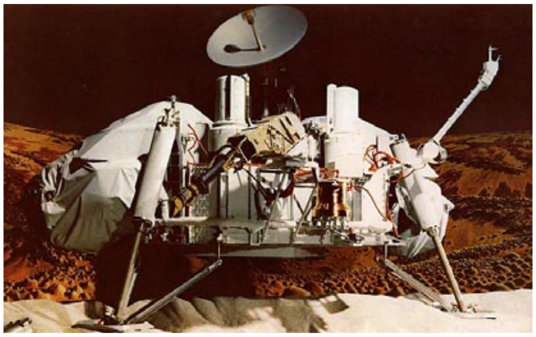
This drawing shows the canals that Percival Lowell believed to exist on Mars.

After much debate, advances in telescope making, and better observations it was decided that Mars was not likely populated with life as we know it. Still, speculation remained that vegetation growing in the Martian soil was responsible for what many observers identified as dark spots when looking at the planet.

By 1964, the United States began in earnest to explore Mars. A space probe named Mariner 4 sent back several close-up photographs. Based on the data sent back, scientists were fairly certain that Mars was devoid of any kind of life. In fact, it was compared to the Moon – geologically dead. Interest in the Red Planet began to wane. It wasn't until another space probe, Mariner 9, that scientists took a renewed interest in the planet. Mariner 9 was the first spacecraft to orbit Mars and sent back more than 7,000 images of the planet's surface. Scientists were surprised to find a canyon long enough to stretch from Washington, D.C., to Las Vegas, Nevada! The dark patches thought to be vegetation were in fact patches of windblown dust. Many more space probes followed the Mariner missions. In addition to the United States, other countries have sent space probes to inspect the planet. Together, the data collected has helped scientists to map the planet's surface. Scientists have also been able to date many of Mars' geological features. By 1976, the United States was landing space probes on the surface of the planet. We now have two large rovers searching the planet for signs that water once existed in abundance on its surface.

Mars continues to hold a great deal of interest to scientists. NASA now has four main goals for the exploration of Mars:

- Determine whether life ever arose on Mars
- Characterize the climate of Mars
- Characterize the geology of Mars
- Prepare for human exploration


NASA

Mariner 9 paved the way for Mars landers such as this one – the Viking Lander, 1976.

If only Percival Lowell could be alive today to witness the frenzy of activity taking place around the exploration of his favorite planet. Although he wouldn't be able to say, "I told you so," he could at least appreciate his pioneering efforts in our hope to someday send humans to the planet. Who knows, maybe you or your children will watch as the first humans set out on their maiden voyage to Mars. What will lay in store for them? What discoveries will be made? How will our view and understanding of Earth be changed?

Many instruments have accompanied the spacecraft that have orbited and landed on Mars. Each one was designed to carry out a very specific task, such as study the Mars atmosphere or map the planet's surface. The Compact Reconnaissance Imaging Spectrometer for Mars (better known as CRISM) is an instrument built by the Johns Hopkins Applied Physics Laboratory (APL). It is due to fly aboard the Mars Reconnaissance Orbiter in 2005. This advanced instrument will use super-cooled detectors to search the planet for signs of past water. CRISM will measure 560 colors reflected back to the instruments' two spectrometers, looking for these signs of past water. Such evidence would greatly help future missions to Mars. Data collected by CRISM also will help scientists to determine where to land the next Mars rover.


NASA

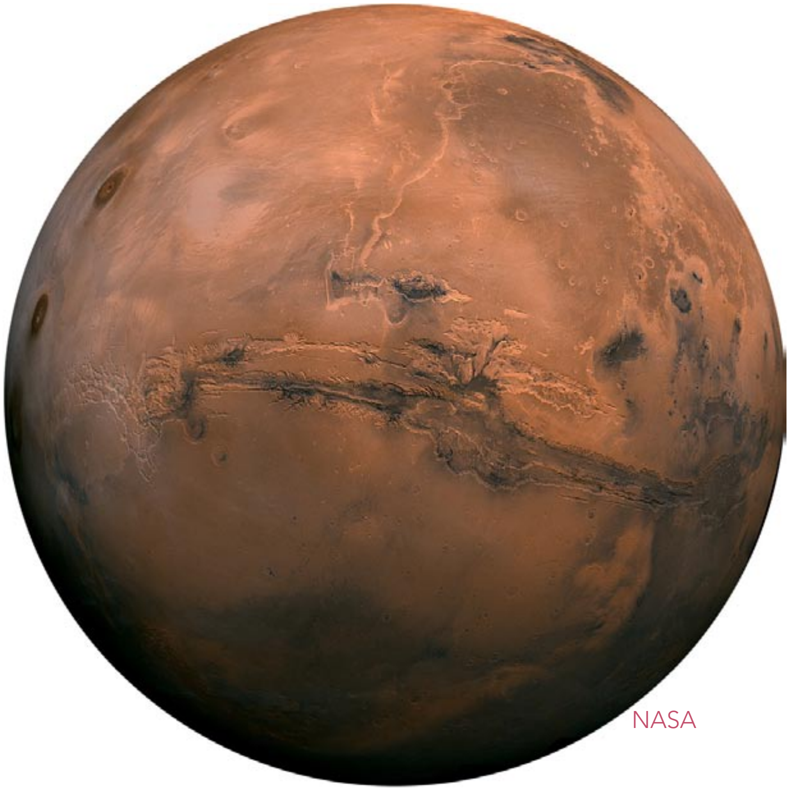
NASA's Mars Exploration Rover seeks out answers to our questions about the planet Mars.

If this is your introduction to Mars, take some time to read over the facts put together for you. Although Mars shares some features in common with Earth, it is also very different. It has several volcanoes like those on Earth. However, they are quite enormous and would dwarf even the largest ones here on Earth. Mars also has valleys and channels. Some scientists believe that these are the result of past water and geological activity.

About Mars

Bulk Properties

Radius – 3,390 kilometers (0.53 of Earth)
Density – 3.93 grams per cubic centimeter (71% of Earth)
Gravity – 0.38 of Earth
Mass – 0.1 of Earth
Two small moons – Phobos (Fear) and Deimos (Panic)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This true-color view of Mars is centered on the Valles Marineris chasma system. The Tharsis plateau, topped with 3 immense volcanoes, is at left.

Orbit and Rotation

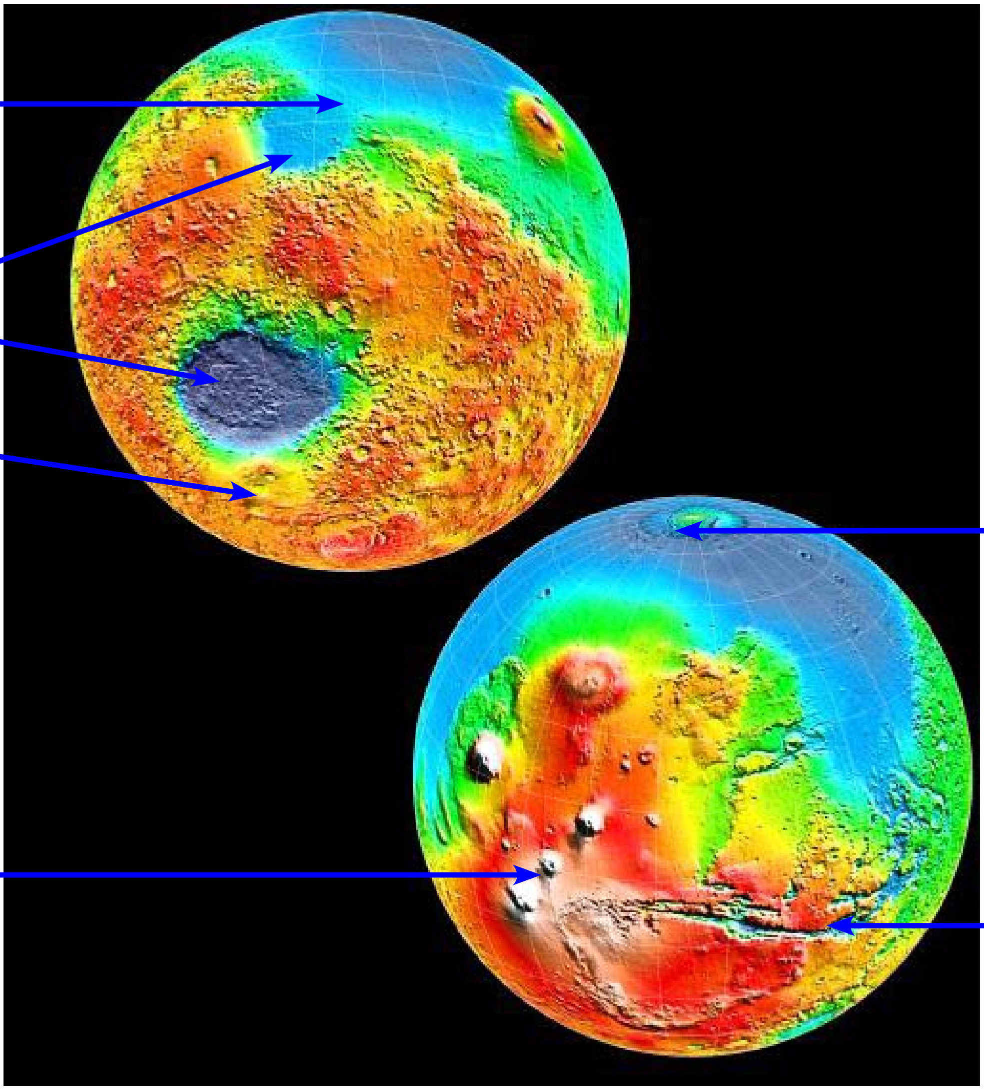
Elliptical Orbit 1.38 to 1.67 AU
(1 AU = Earth-Sun distance)
Mars Year – 687 days
Rotates – 24 hours, 37 minutes
Axis Inclined 25˚, has seasons

Climate

Surface Temperature: -129˚ C to 37˚ C (-199˚ F to 99˚ F)

Atmosphere 1% of Earth, primarily carbon dioxide; polar caps of water, ice and carbon dioxide ice; strong winds, driven by seasonal heating and cooling; great dust storms – near perihelion (southern summer)

This false color image of Mars shows its topography. Areas of blue indicate a low region. Red and white indicate elevated areas of the planet.



Younger, smooth northern plains

Impact basins

Older, cratered southern highlands

Volcanoes up to 27 kilometers high

Topography from Mars Global Surveyer (MGS) laser altimeter

Thick, layered polar sediments

Tectonic valleys thousands of kilometers long

NASA

Stream Tray Investigation

Teacher's Copy

Materials:

- Stream tray with centimeter lines marked along both sides (This can be done ahead of time or the teacher may allow students to do this themselves.)
- Meter stick for measuring centimeter lines if stream tray has not already been marked with centimeter lines
- Permanent marker for marking centimeter lines
- Playground sand (One idea is to have the sand already damp and in the trays or have a large [or several] containers with damp sand in it. Keep in mind that these containers of sand can get quite heavy once water has been added.)
- Approximately 1000 milliliters of water
- Blocks to raise the stream tray at one end (Books can be used as a substitute, but keep in mind that they could get wet!)
- Protractor
- Dice or similar 1-centimeter cubes
- One small cup and one large cup
- Stream Tray Investigation Data Table and pencil
- Each student will need a copy of the Stream Tray Investigation Procedure

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Procedure:

1. If your stream tray has not been marked with centimeter lines along the edges, you will need to do so now.
    a. Using the meter stick, measure along both sides of the tray and make a mark using the permanent marker for each centimeter.
    b. Go back and label the centimeter marks in 10-centimeter increments.
2. Now fill the stream tray with a layer of sand about 2 centimeters deep.
3. Add approximately 1,000 milliliters of water to the tray of sand. You may need to add more (or less) to make the sand damp all the way through to the bottom of the tray.
4. Smooth and level the sand with your hands. Be sure to make the sand in your stream tray flat and as level as possible.
5. Using a centimeter cube or similar cube, make a standard river bed.
    a. Beginning at the top of the tray and in the center of the sand, depress the cube to the depth of the cube.
    b. Make a straight channel by dragging the cube to the 25-centimeter mark. Move the excess sand to the edges of the tray.

c. Now add a bend (curved shape) to the 30-centimeter mark.
d. Continue to make the channel straight to the end of the tray and move the excess sand to the edges of the tray.

Your finished river bed should look similar to the illustration below. Now sketch your river bed on your copy of the Stream Tray Investigation Data Table.

It's important that the sand is damp. Otherwise, students will not be able to create a channel. When students have added sand to their stream tray, have them add just enough water so that sand is damp enough to hold its shape when the cube is pressed into the sand. Another option is for the teacher to prepare the stream trays ahead of time.

6. Place one end of the stream tray on a pile of books (or blocks). Using the protractor, adjust the stream tray so that it is at an angle of 5 degrees. Use the illustration below to help with where the protractor should be placed and how your set up should look.

7. Fill your empty bottle (or beaker) with 500 milliliters of water.

8. Before pouring the water into the stream tray predict the effect the running water will have on the channel. Write your prediction on the Stream Tray Investigation Data Table.
9. Holding the bottle (or beaker) of water approximately 8–10 centimeters above the top of the river bed, begin pouring a steady stream of water into the channel. Continue to pour until your bottle or beaker is empty.

   Have students fill a 2-liter soda bottle with approximately 500 milliliters of water and use it or a beaker to pour water into the river bed. It's important that the students pour the water out in an even manner in order to assure a gentle flow. Also, it may be necessary for the students to hold the bottle or beaker closer than 8–10 centimeters. Allow the students to practice if necessary or at least provide them with a demonstration.

10. Observe what happens to the bend as well as the channel and record your observations on your copy of the Stream Tray Investigation Data Table. Also, consider the following questions.

    Because of the steep angle of the stream tray, the water will create a mud flow. In fact, a mud flow will occur and destroy the bend in the river bed until the tray is at an angle of about 5 degrees or lower. However, this is the intent of this activity. The students will come to expect the mud flow until the tray is at 5 degrees, where they will observe the flowing water behave differently than before.

    a. Does the bend move? If so, how far?
    b. Does the flowing water move the bend upstream or downstream?

11. On the Stream Tray Investigation Data Table, record what happened to the bend. Be sure to note any shapes created, the amount of erosion, and any mud flows. Use the measurements on the side of the stream tray to help document where each feature occurred.
12. Use the large and small cups to scoop the water out of the tray. Be sure to empty the water into the collecting bucket. Finally, smooth the sand and make the river bed just as you did in step 5.

    It's important that the students put the water into collecting buckets. If it is poured down the drain, it will clog the sink! Dispose of the water by dumping it outside or in a toilet.

13. Repeat setps 1 through 12 two more times using 10 and 20 degrees as the stream tray angles.
14. Clean up your area and return materials. Be sure to dispense of the sand according to teacher directions.

    Teachers can have students leave the sand in the trays to dry out or have them dump the sand in several 5-gallon containers. Note that if the sand is given time to dry out, it can be used again in the future.

15. Answer the conclusion question on the Steam Tray Investigation Data Table.

NASA CRISM

Compact Reconnaissance Imaging Spectrometer for Mars on the Mars Reconnaissance Orbiter

Stream Tray Investigation

Student Copy

Materials:

- Stream tray with centimeter lines marked along both sides
- Meter stick for measuring cm lines if stream tray has not already been marked with cm lines
- Permanent marker for marking cm lines
- Playground sand
- Approximately 1,000 milliliters of water
- Blocks (or other items) to raise the stream tray at one end
- Protractor
- Dice or similar 1-centimeter cubes
- One small cup and one large cup
- Stream Tray Investigation Data Table and pencil

Procedure:

1. If your stream tray has not been marked with centimeter lines along the edges, you will need to do so now.
    a. Using the meter stick, measure along both sides of the tray and make a mark using the permanent marker for each centimeter.
    b. Go back and label the centimeter marks in 10-centimeter increments.
2. Fill the stream tray with a layer of sand about 2 centimeters deep.
3. Add approximately 1,000 milliliters of water to the tray of sand. You may need to add more (or less) to make the sand damp all the way through to the bottom of the tray.
4. Smooth and level the sand with your hands. Be sure to make the sand in your stream tray flat and as level as possible.
5. Using a centimeter cube or similar cube, make a standard river bed.
    a. Beginning at the top of the tray and in the center of the sand, depress the cube to the depth of the cube.
    b. Make a straight channel by dragging the cube to the 25-centimeter mark. Move the excess sand to the edges of the tray.
    c. Now add a bend (curved shape) to the 30-centimeter mark.

   d. Continue to make the channel straight to the end of the tray and move the excess sand to the edges of the tray.

Your finished river bed should look similar to the illustration below. Now sketch your river bed on your copy of the Stream Tray Investigation Data Table.

6. Place one end of the stream tray on a pile of books (or blocks). Using the protractor, adjust the stream tray so that it is at an angle of 5 degrees.
7. Fill your empty bottle (or beaker) with 500 milliliters of water.
8. Before pouring the water into the stream tray predict the effect the running water will have on the channel. Write your prediction on your copy of the Stream Tray Investigation Data Table.
9. Holding the bottle (or beaker) of water approximately 8–10 centimeters above the top of the river bed, begin pouring a steady stream of water into the channel. Continue to pour until your bottle or beaker is empty.
10. Observe what happens to the bend as well as the channel and record your observations on your copy of the Stream Tray Investigation Data Table. Also, consider the following questions.
    a. Does the bend move? If so, how far?
    b. Does the flowing water move the bend upstream or downstream?
11. Record on your copy of the Stream Tray Investigation Data Table what happened to the bend. Be sure to note any shapes created, the amount of erosion, and any mud flows. Use the measurements on the side of the stream tray to help document where each feature occurred.
12. Use your large and small cups to scoop the water out of the tray. Be sure to empty the water into the collecting bucket. Finally, smooth the sand and make the river bed just as you did in step 5.
13. Repeat steps 1 through 12 two times using 10 and 20 degrees as the stream tray angles.
14. Clean up your area and return materials. Be sure to dispose of the sand according to teacher directions.
15. Answer the conclusion question on your Stream Tray Investigation Data Table.

Stream Tray Investigation Data Table

Student Name:

Tray Angle in Degrees	Predictions	Observations
5		
10		
20		

1. In the space below, illustrate and label your setup. Be sure to include measurements.

Illustrate here your setup as viewed from the side

Illustrate here the channel that you made in the stream tray

2. Next, illustrate and label your setup AFTER completing the trial with the tray at 5 degrees. Be sure to include measurements.

Illustrate here your setup as viewed from the side

Illustrate here channel after the water has been poured

3. Now illustrate and label your setup AFTER completing the trial with the tray at 10 degrees. Be sure to include measurements.

Illustrate here your setup as viewed from the side

Illustrate here channel after the water has been poured

4. Finally, illustrate and label your setup AFTER completing the trial with the tray at 20 degrees. Be sure to include measurements.

Illustrate here your setup as viewed from the side

Illustrate here channel after the water has been poured

Conclusion:

1. Based on your data, explain the relationship between the angle of the stream tray and its ability to erode the sand.

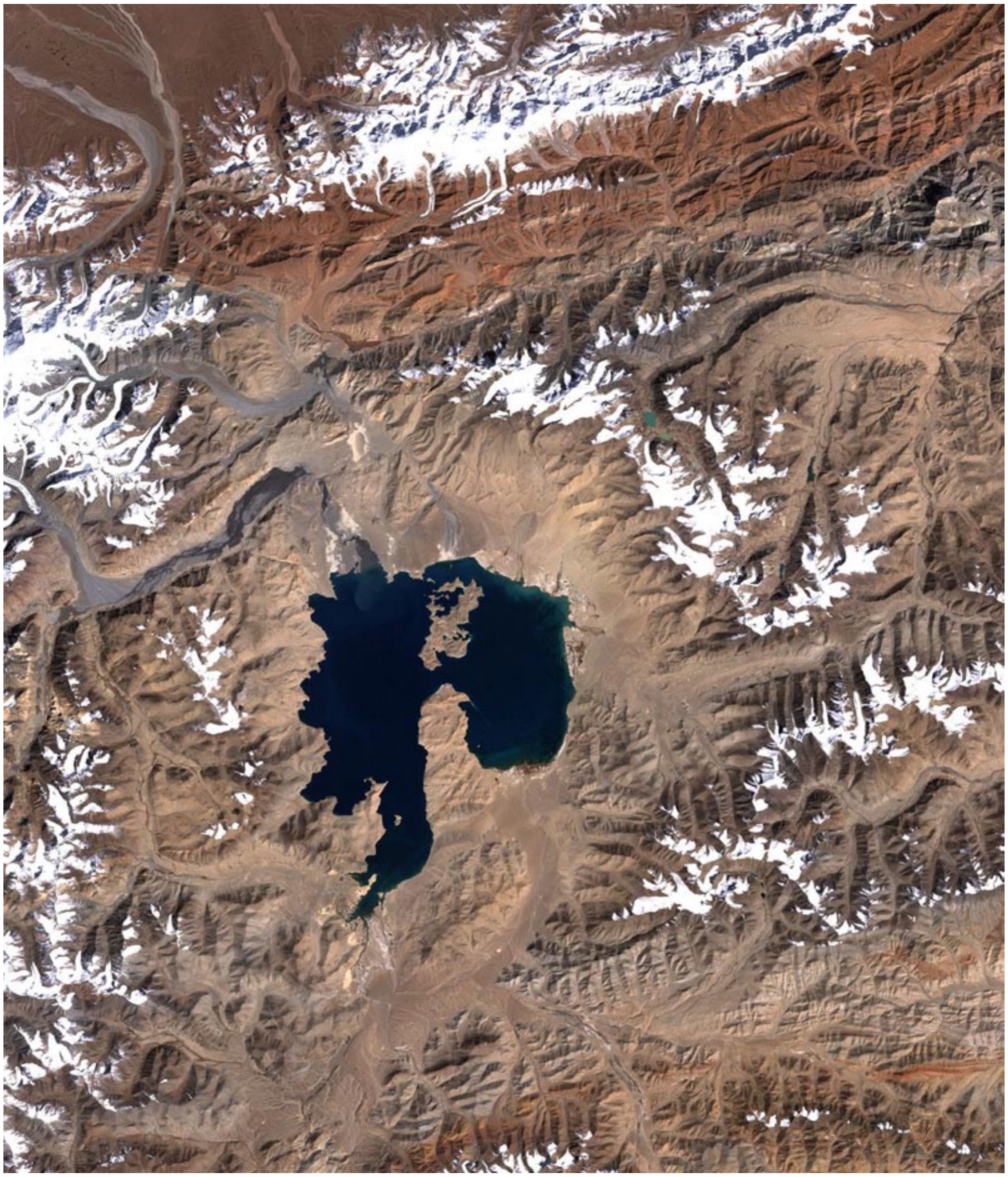
2. Compare your model to the features observed in the Earth LANDSAT images and the Mars images. How are they similar and how are they different?

Earth Images from LANDSAT

The surfaces of Earth, the Moon, and Mars are all bombarded by a constant rain of comets and asteroids. The effects of this bombardment are most evident on the surface of the Moon, as a dense population of impact craters. The differing densities - and appearances - of craters on the three bodies result from differences in the physical processes that modify them after formation. These images provide an overview of processes that modify and erase craters on Earth.

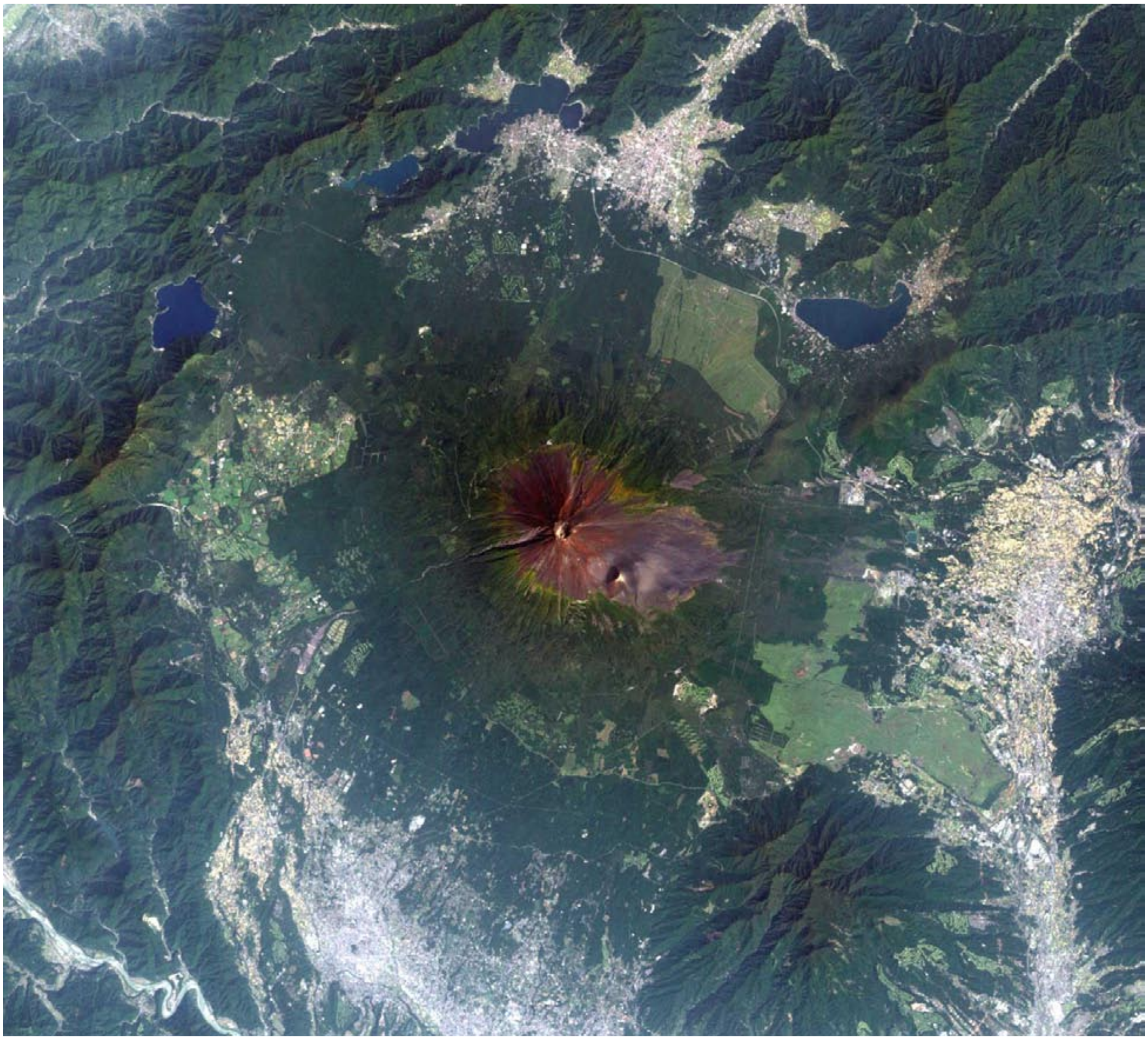
USGS

A. This image shows a 1.7 billion-year-old impact structure in the central part of Western Australia. It is approximately 30 kilometers (18 miles) in diameter and contains seasonal lakes. The colors of the lakes originate from algae growing in highly saline water.



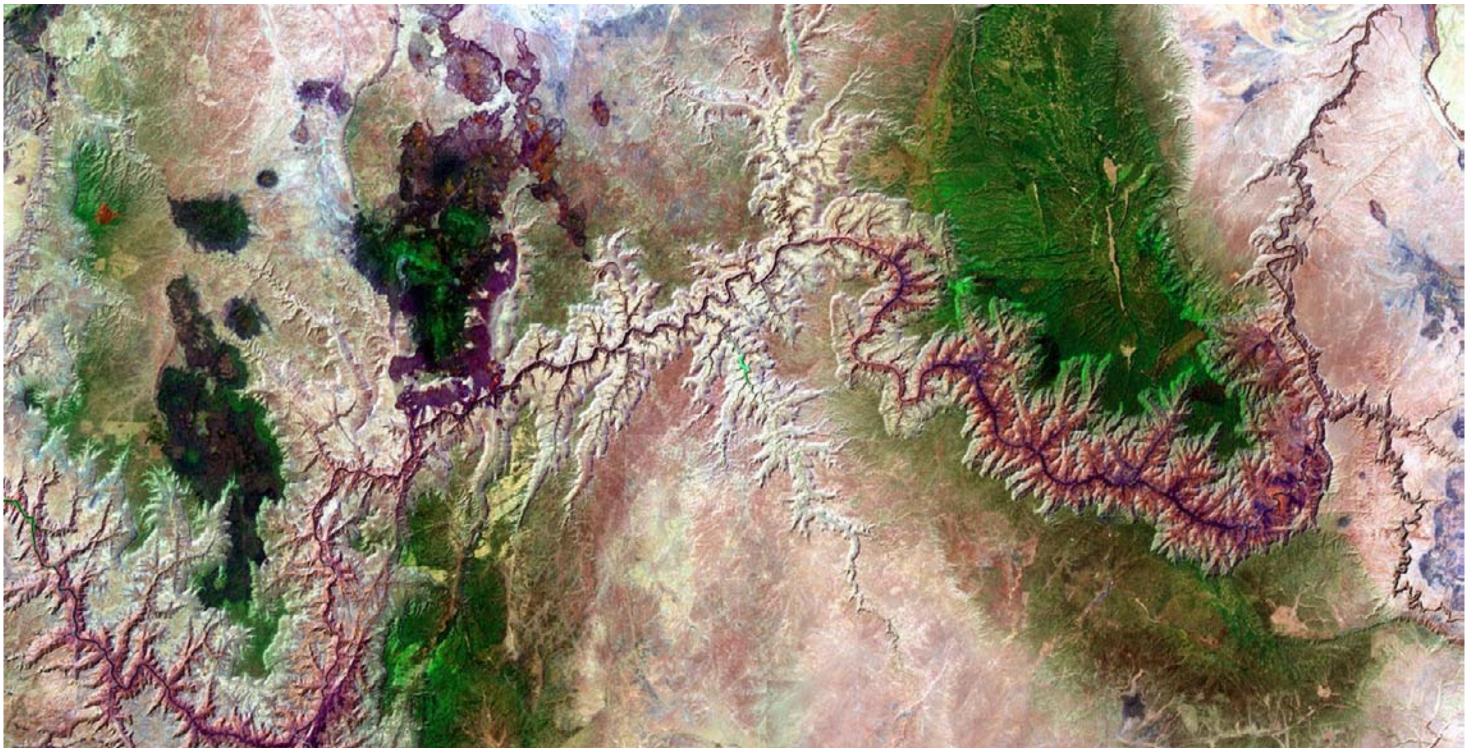
USGS

B. This image shows a mountain lake in Kara-Kul, Tajikistan. The lake occupies the low part of the floor of a highly eroded impact crater about 45 kilometers (28 miles) in diameter. The tip of the peninsula extending into the lake is the remnant of a central peak, and the quasi-circular band of mountains around the lake is the remnant of the rim. The impact occurred approximately 25 million years ago.



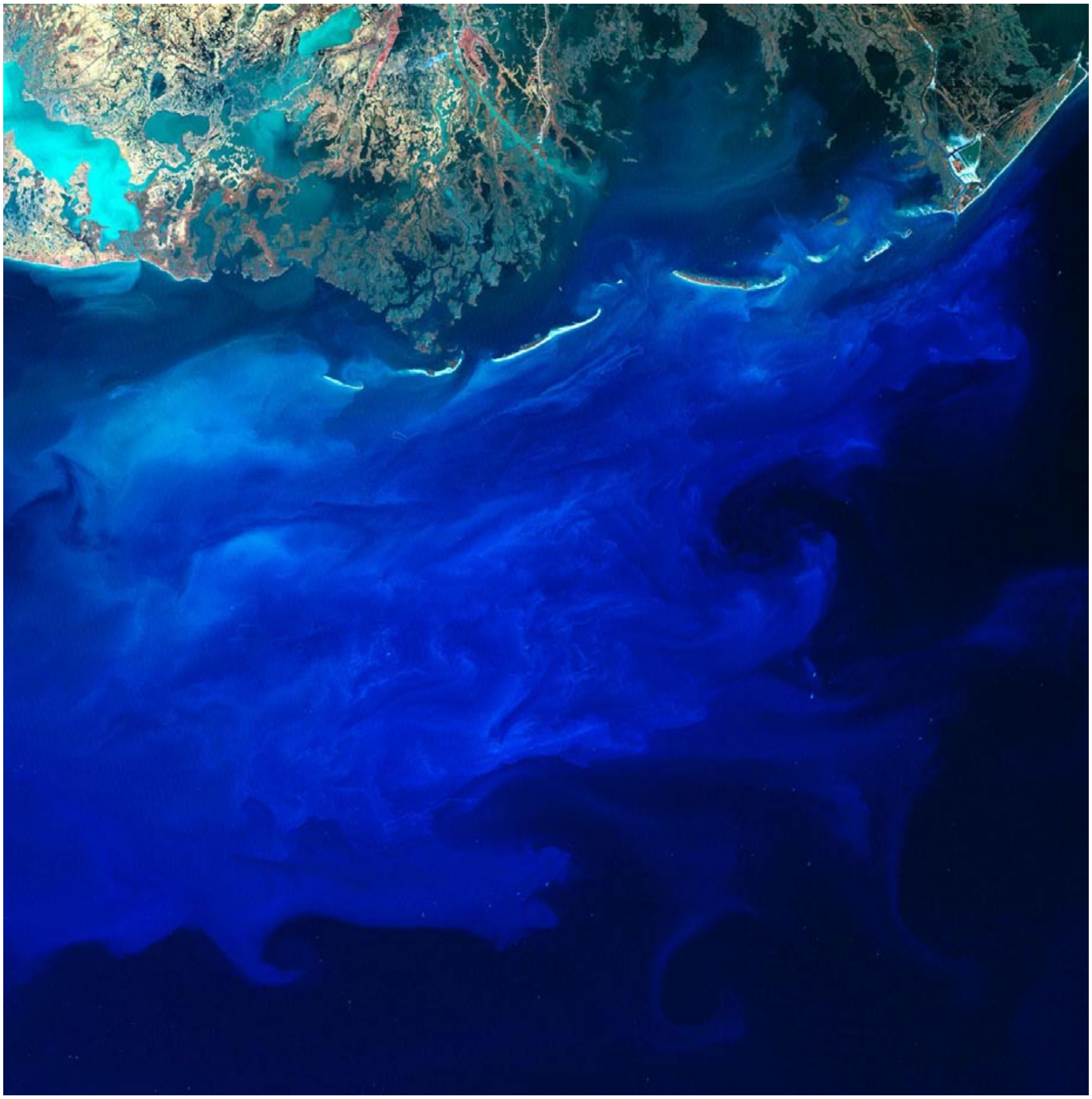
USGS

C. Japan’s Mt. Fuji rises to 3,776 meters (12,300 feet). It is a now-dormant volcano that last erupted in 1707.



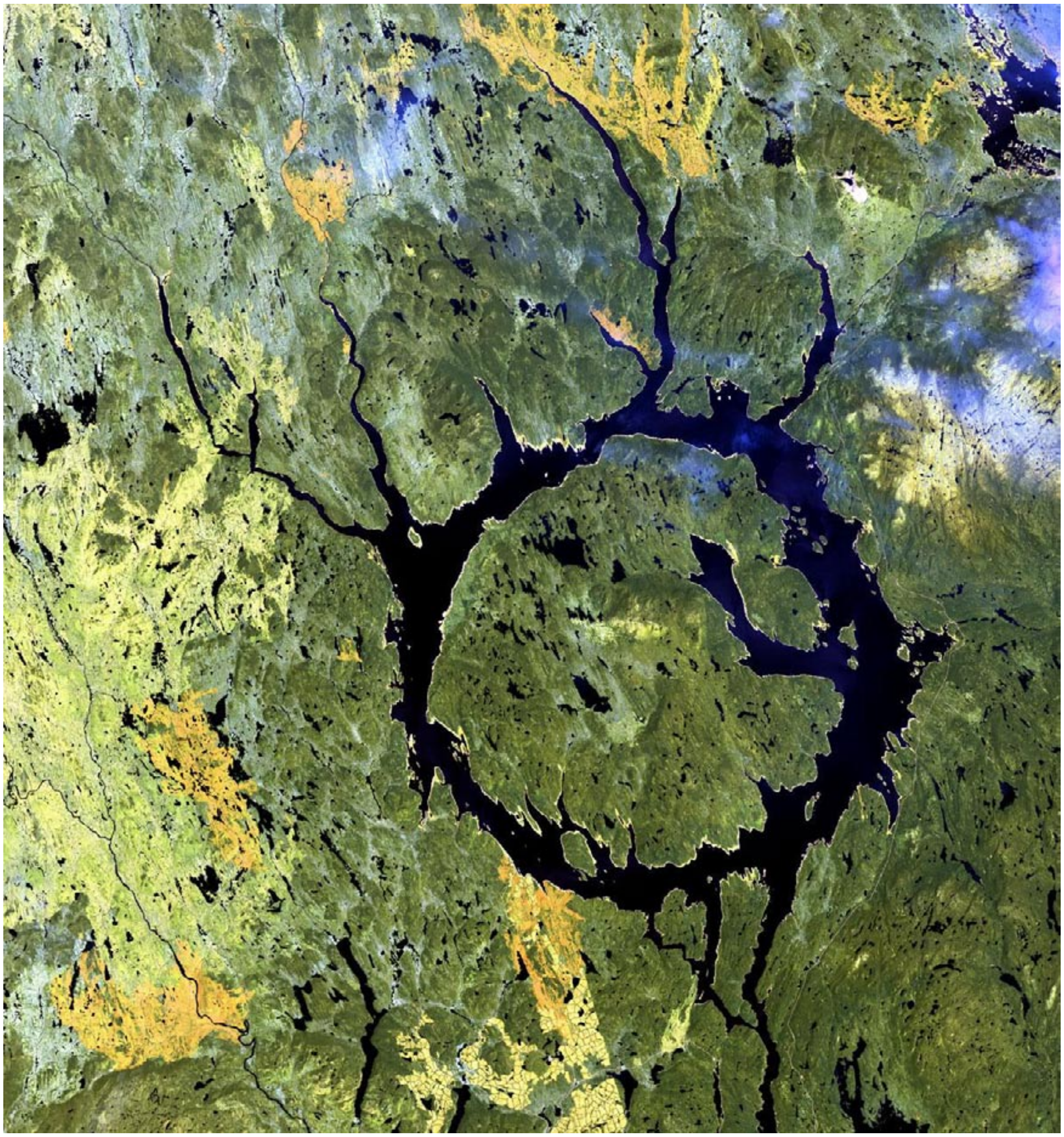
USGS

D. This view of the Grand Canyon shows the Colorado River cutting its way through many layers of sedimentary rock that were deposited hundreds of millions of years ago. That sedimentary rock was itself formed in shallow seas that advanced over billion-year-old mountain ranges that had been eroded flat.



USGS

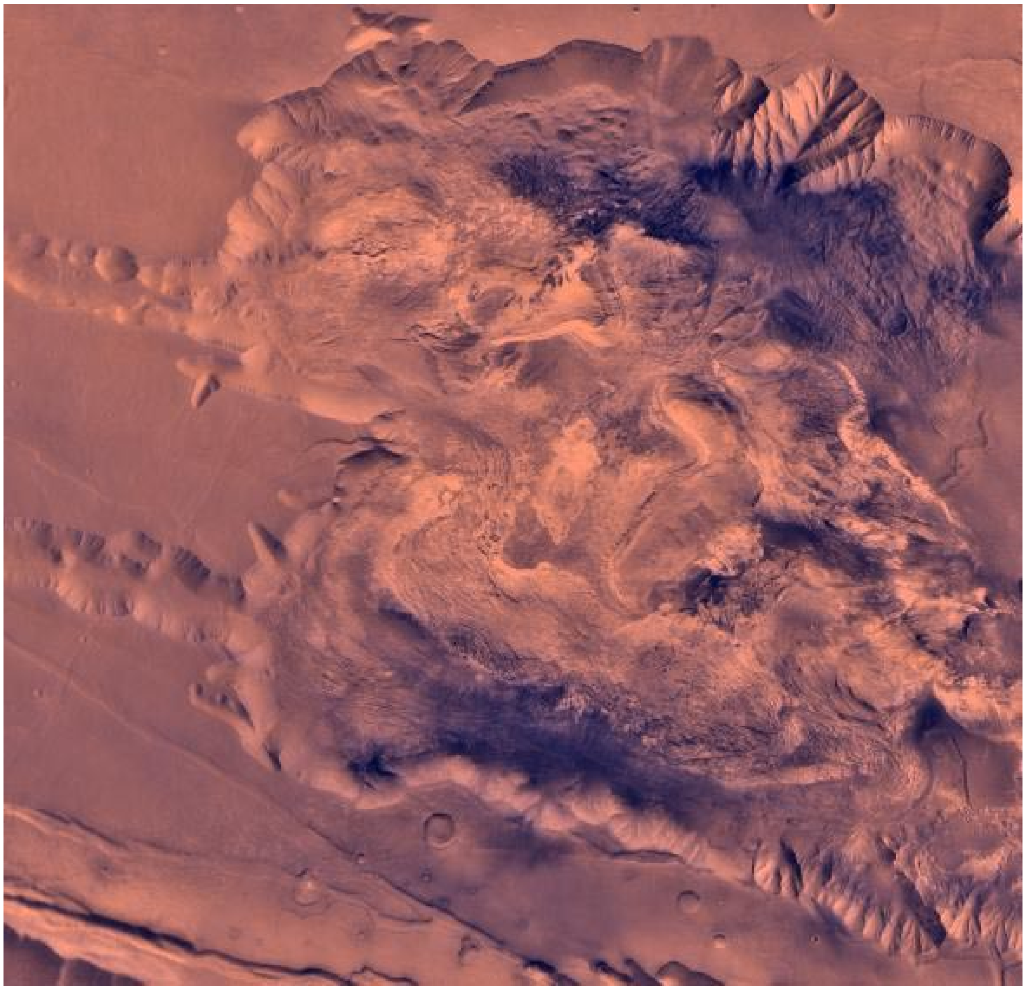
E. Silt from the Mississippi River can be seen suspended in the Gulf of Mexico just off the coast of Louisiana. The river enters the gulf at upper right, and silt is carried by currents to the left.



USGS

F. This image shows the Manicouagan impact structure in Quebec, Canada. The lake occupies the low part of the structure, which prior to being deeply eroded was 100 kilometers (62 miles) across. It has been dated at 214 million years.

Mars Images



NASA

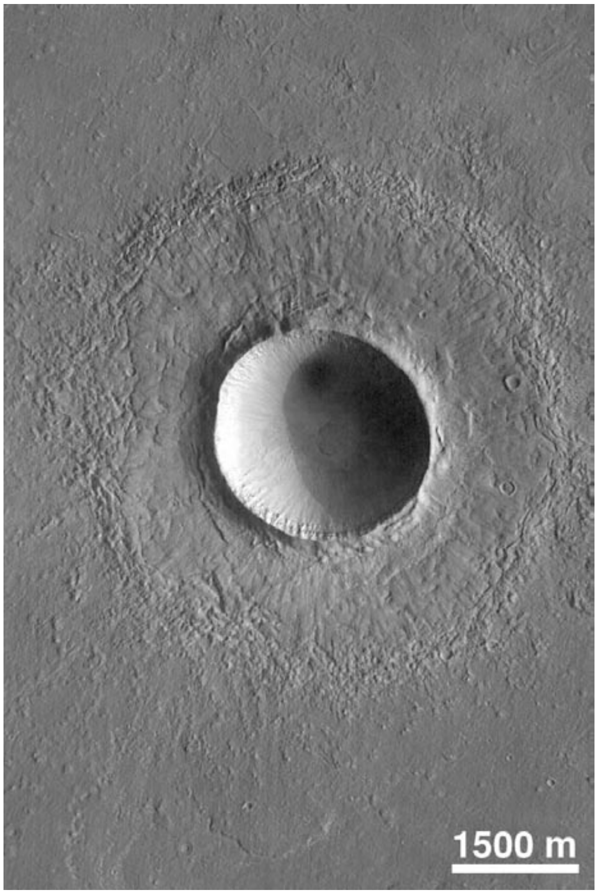
A. This Viking image of Mars shows the western part of Candor Chasma, which is about 100 kilometers (62 miles) across. The floor of the chasma is covered by eroded remnants of a thick stack of layered deposits. Candor Chasma is one branch of an immense connected system of chasmas and canyons called Valles Marineris (at the arrow in Mars image B, next page) that stretches for a distance equal to that from Washington, D.C., to Las Vegas, Nevada.

NASA

B. This Mars Global Surveyor image shows Nanedi Vallis, a long sinuous valley in the ancient southern highlands of Mars. The valley is about 5 kilometers (3 miles) wide. In parts of the valley (arrow) a much narrower channel is found in the center of the valley floor; in other parts of the valley the narrower channel is covered by sand dunes and debris from the valley wall.

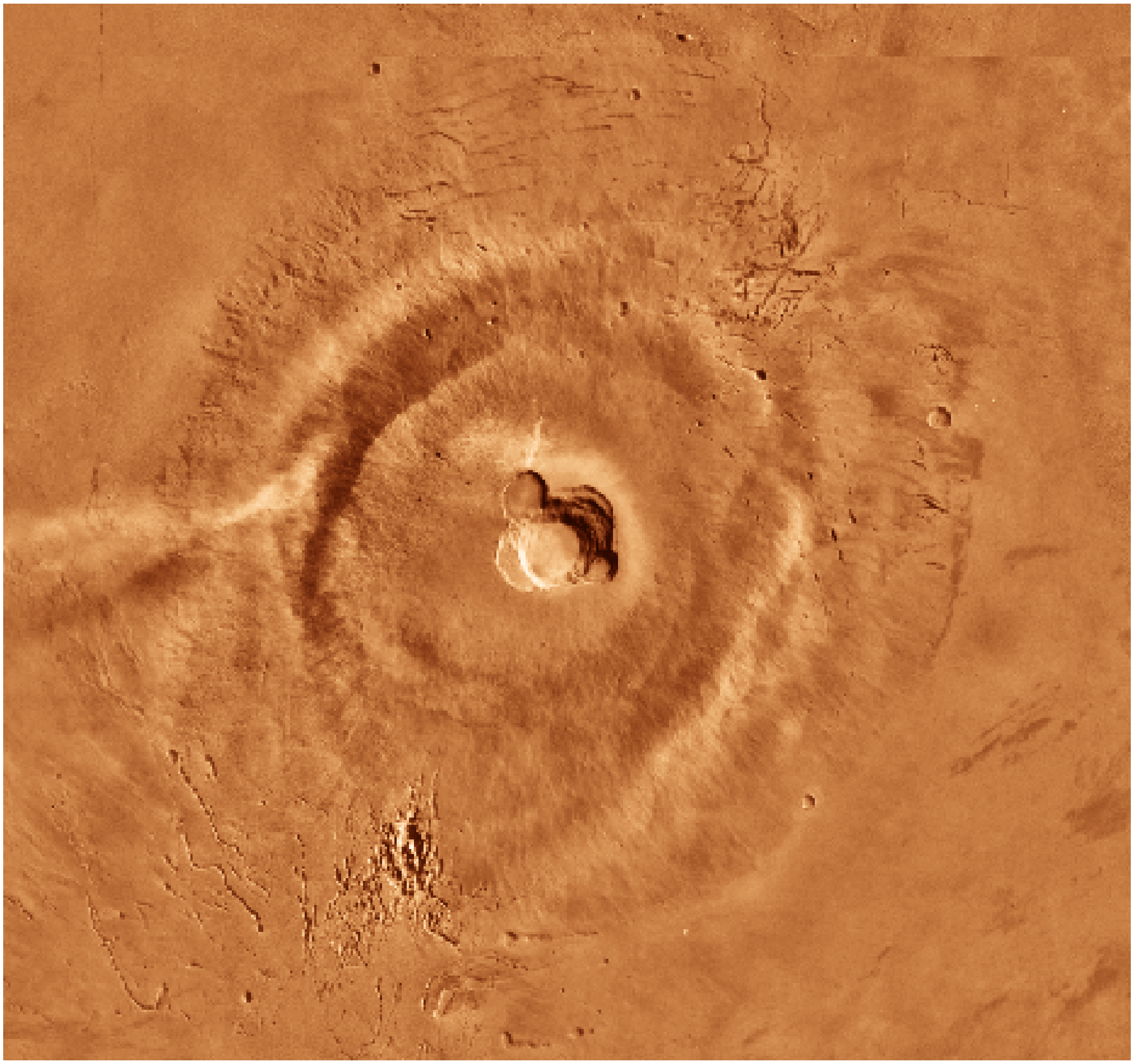
NASA

C. The northern Martian plains are lowlands with fewer impact craters exposed at the surface than the heavily cratered southern highlands. Normally, surfaces with fewer craters are considered younger (i.e., they have had less time to accumulate craters). This low-resolution view, covering an area 168 kilometers (104 miles) by 124 kilometers (77 miles), shows a few craters at the surface (such as the one at the center of the image), and several circular features that represent craters mostly buried beneath the plains.



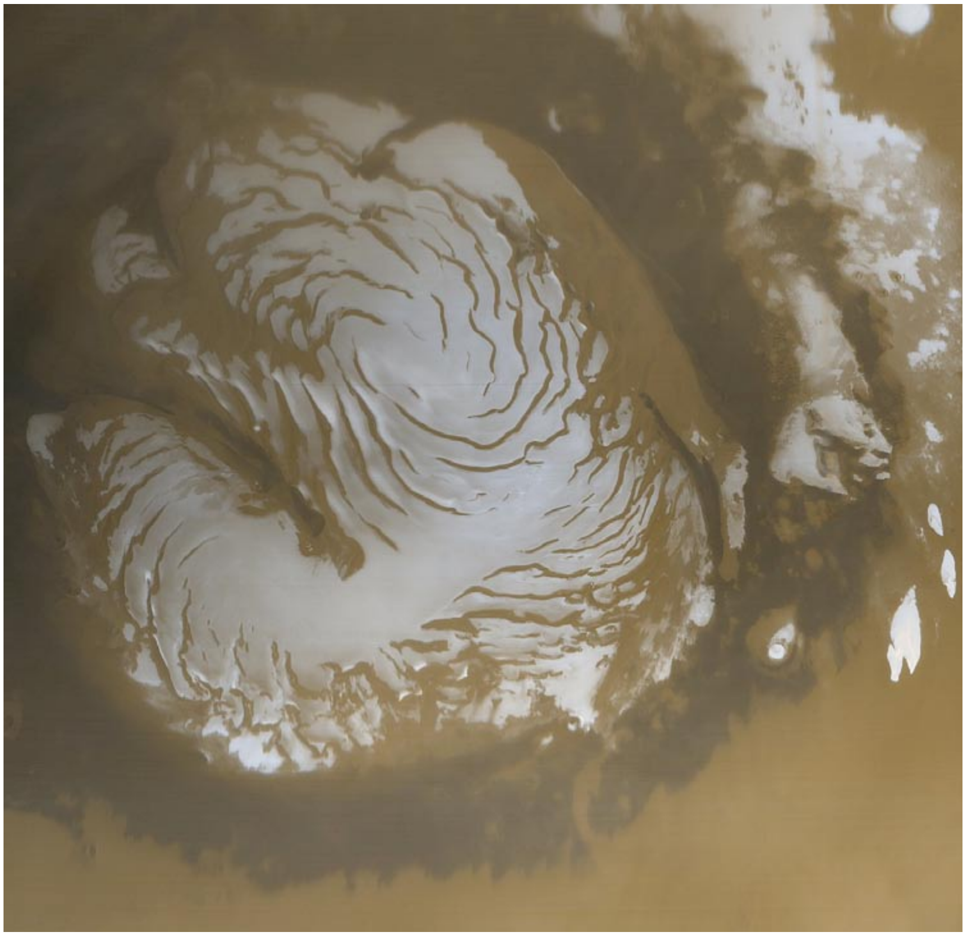
NASA

D. The Mars crater in this image is on northern Elysium Planitia. It shows the principal parts of smaller craters: the floor, wall, rim, and ejecta thrown from the inside of the crater during the formative impact.



NASA

E. The Ascraeus Mons volcano (center) rises 16,000 meters (about 52,500 feet) above the Tharsis plateau. This image covers an area 370 kilometers (230 miles) across.



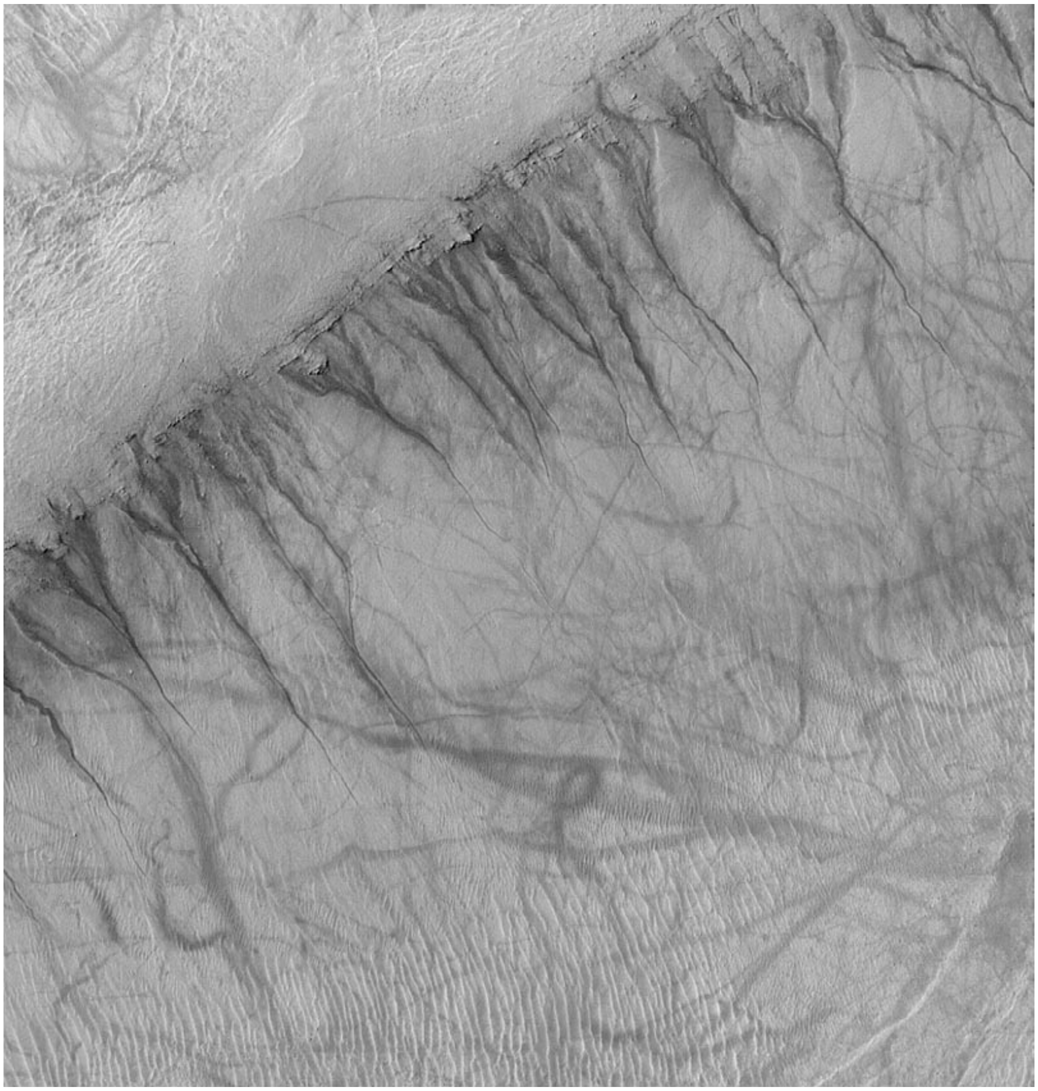
NASA

H. This Mars Global Surveyor image shows the north polar cap as it appears in early northern summer. The ice-rich north polar cap is about 1,100 kilometers (680 miles) across. The dark band surrounding it is a vast field of sand dunes.

Mars Water Features Images

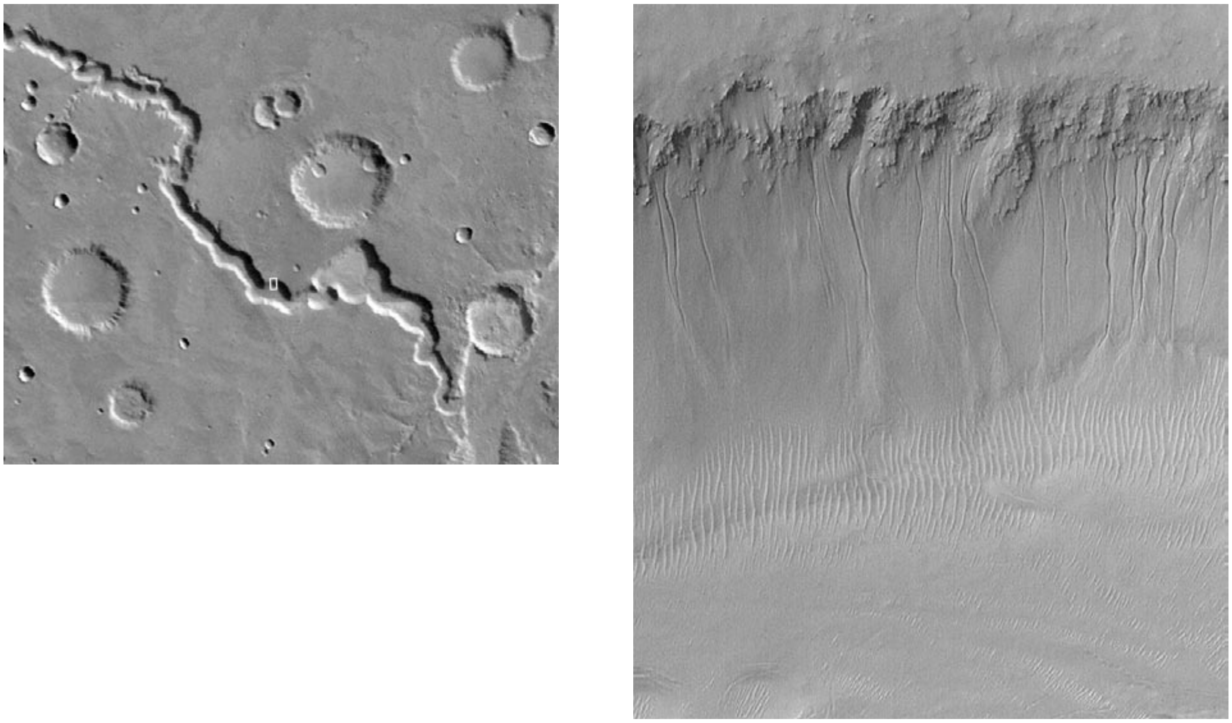
NASA

A. This image taken with the Mars Orbiter Camera on Mars Global Surveyor shows gullies and meandering channels on part of the inner wall of Newton Crater. It covers an area 3 kilometers (1.9 miles) across.



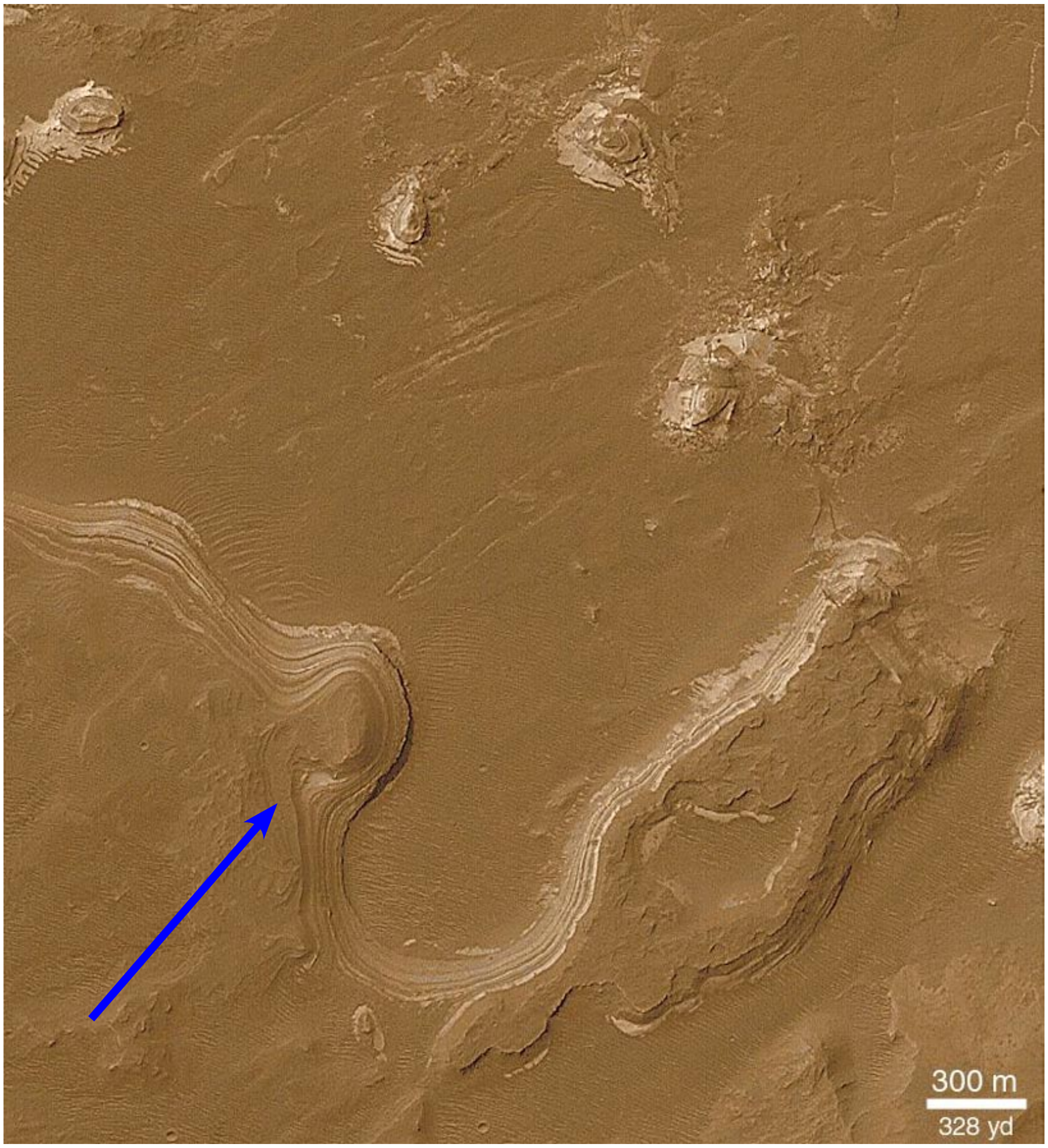
NASA

B. This Mars Global Surveyor image shows gullies along the wall of an ancient crater within a much larger crater named Kaiser. Ripples at the bottom of the image are sand dunes. The dark streaks are where dust has been lifted off the surface by dust devils, revealing darker soil just under the surface. The image covers an area 3 kilometers (1.9 miles) across.



NASA

C. This close up view of Nirgal Vallis, an ancient valley in the southern highlands, shows small, younger gullies on the wall of the valley. The Mars Global Surveyor image at right covers an area approximately 2.3 kilometers (1.4 miles) wide by 2.8 kilometers (1.7 miles) long. The image at left is part of a global mosaic of Viking orbiter images.



NASA

D. This image of the floor of Holden Crater shows remnants of a vast deposit of sedimentary material that has been eroded away, leaving cliffs that expose layers within the deposit. The crater has a diameter of 141 kilometers (88 miles).


NASA

This Mars Global Surveyor image shows tear-shaped landforms in Athabasca Vallis. The area in this image covers 11.9 kilometers (7.4 miles) by 13 kilometers (8.1 miles).