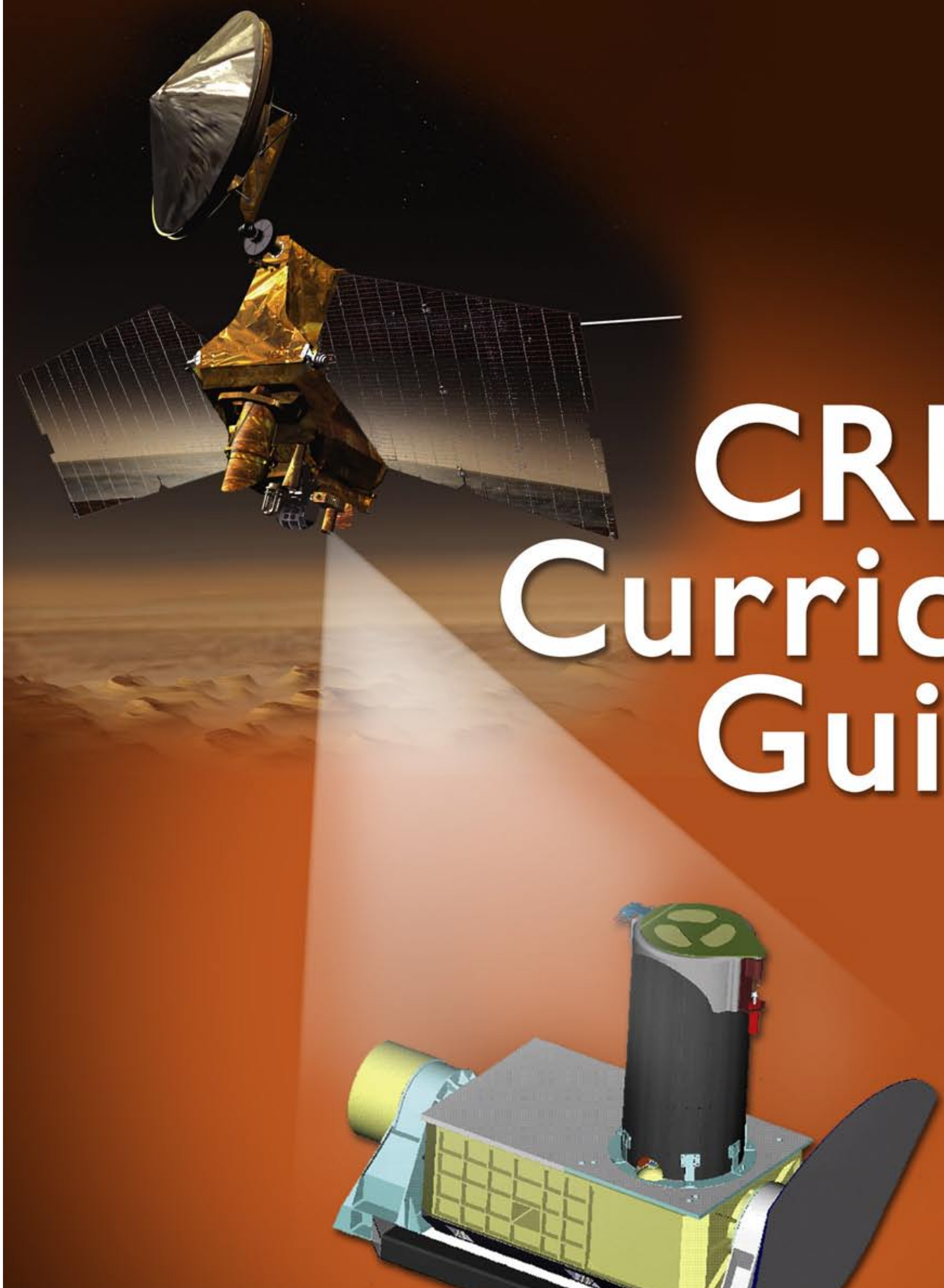
Compact Reconnaissance Imaging Spectrometer for Mars

CRISM Curriculum Guide



crism.jhuapl.edu

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Contents

How to Use this Guide

The activities in this guide are designed so that they can be used separately or together. They can also be used with materials and activities teachers have developed and are already using with students. You are encouraged to change the lessons in this guide to reflect your classroom goals or objectives. The lessons are written in a "5 E's" format (see below) to help facilitate student learning. Please feel free to share your feedback and comments about the lessons and activities.

A Note to Teachers Regarding the 5 E's Model

These lessons have been developed using a learning cycle model titled "The Five E's." This model was developed by the Biological Science Curriculum Study (BSCS) and follows a constructivist approach to teaching science. Below is a brief overview of this model.

- Engage: The activities in this section capture the student's attention, stimulate their thinking, and help them access prior knowledge.
- Explore: In this section, students are given time to think, plan, investigate, and organize collected information.
- Explain: Students now analyze their exploration. Their understanding is clarified and modified because of reflective activities.
- Extend or Elaborate: This section gives students the opportunity to expand and solidify their understanding of the concept and/or apply it to a real-world situation.
- Evaluate: Evaluation occurs throughout the lesson. Scoring tools developed by teachers and students target what students must know and do. Consistent use of scoring tools improves learning.

Note that not every lesson will follow each "E" in order. Teachers might find that after students complete the Explain portion of the learning cycle they will return to the Explore phase. This may be due to some new learning that has taken place during the explanation part of the lesson. The lessons contained in this module, however, take students and teachers through each of the E's. Teachers are encouraged to modify these lessons as they see fit.

The activities in this guide were developed by Bruce Booher, an eighth-grade teacher in Frederick County (Maryland) public schools, while he participated in the Maryland Space Grant Consortium's Johns Hopkins University Earth/Space Science Graduate Studies Program, summer 2004.

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.

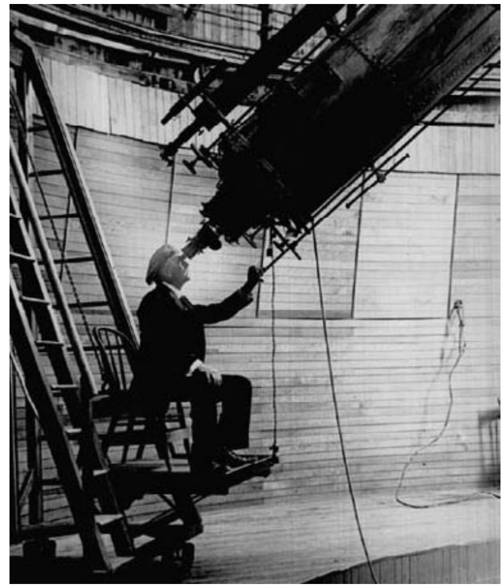
Evaluation:

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



Lowell Observatory Archives

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

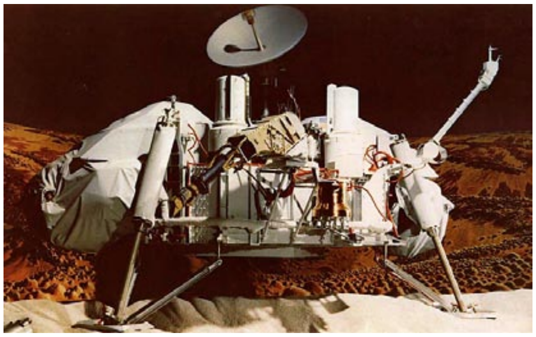
Mars has long held the fascination of scientists and the general public since the invention of the telescope. It wasn't until the late 1800s that Mars began to attract the attention of a number of astronomers. The wealthy astronomer Percival Lowell had an observatory built in Flagstaff, Arizona, for 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.

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.



NASA

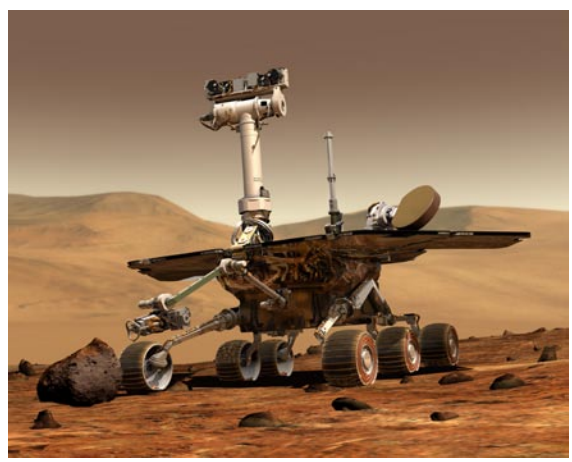
Mariner 9 paved the way for Mars landers such as this one – the Viking Lander, 1976.

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

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.



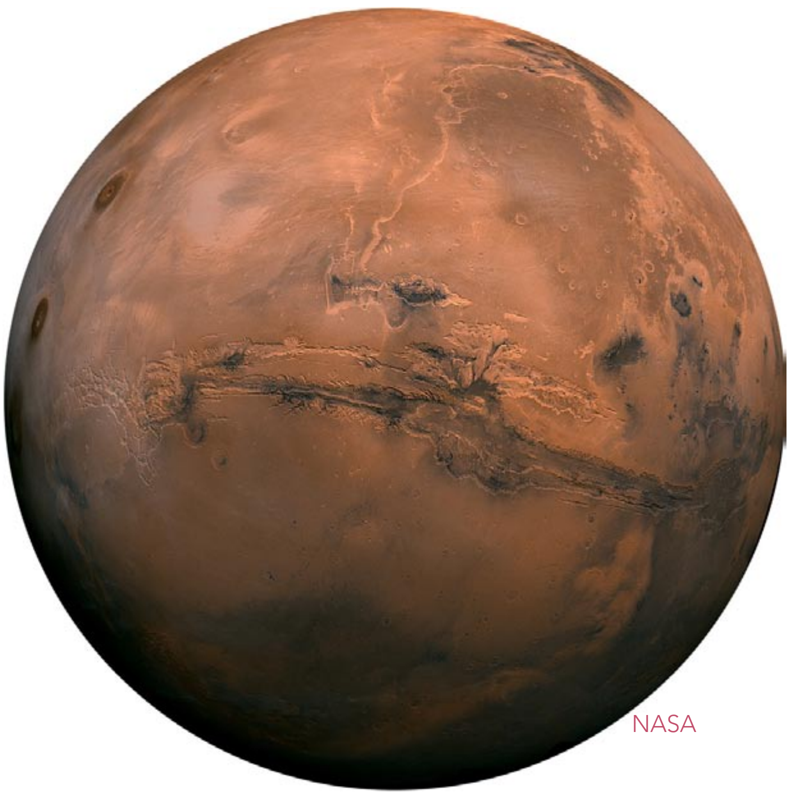
NASA

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)



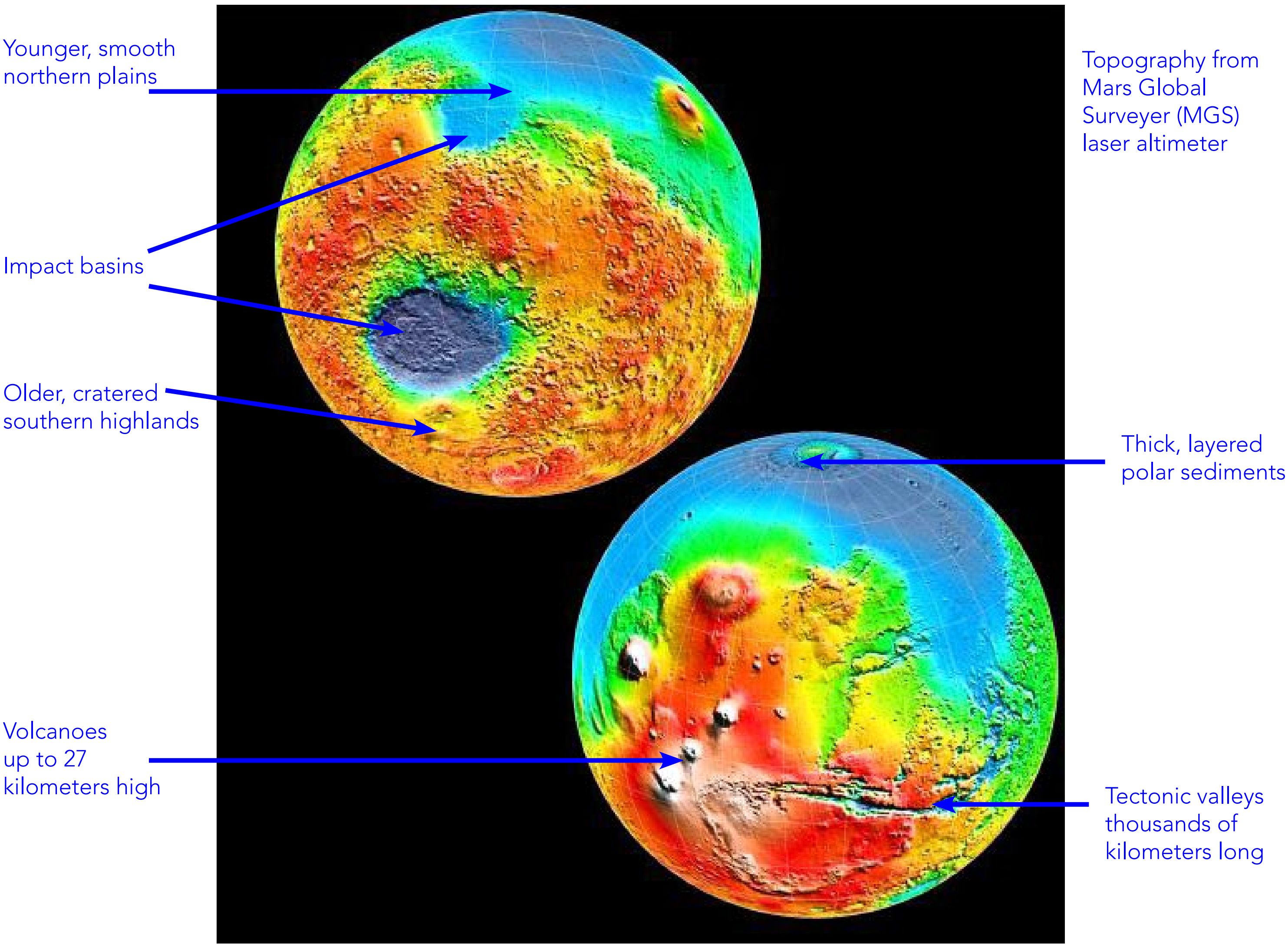
NASA

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.



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

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.

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.

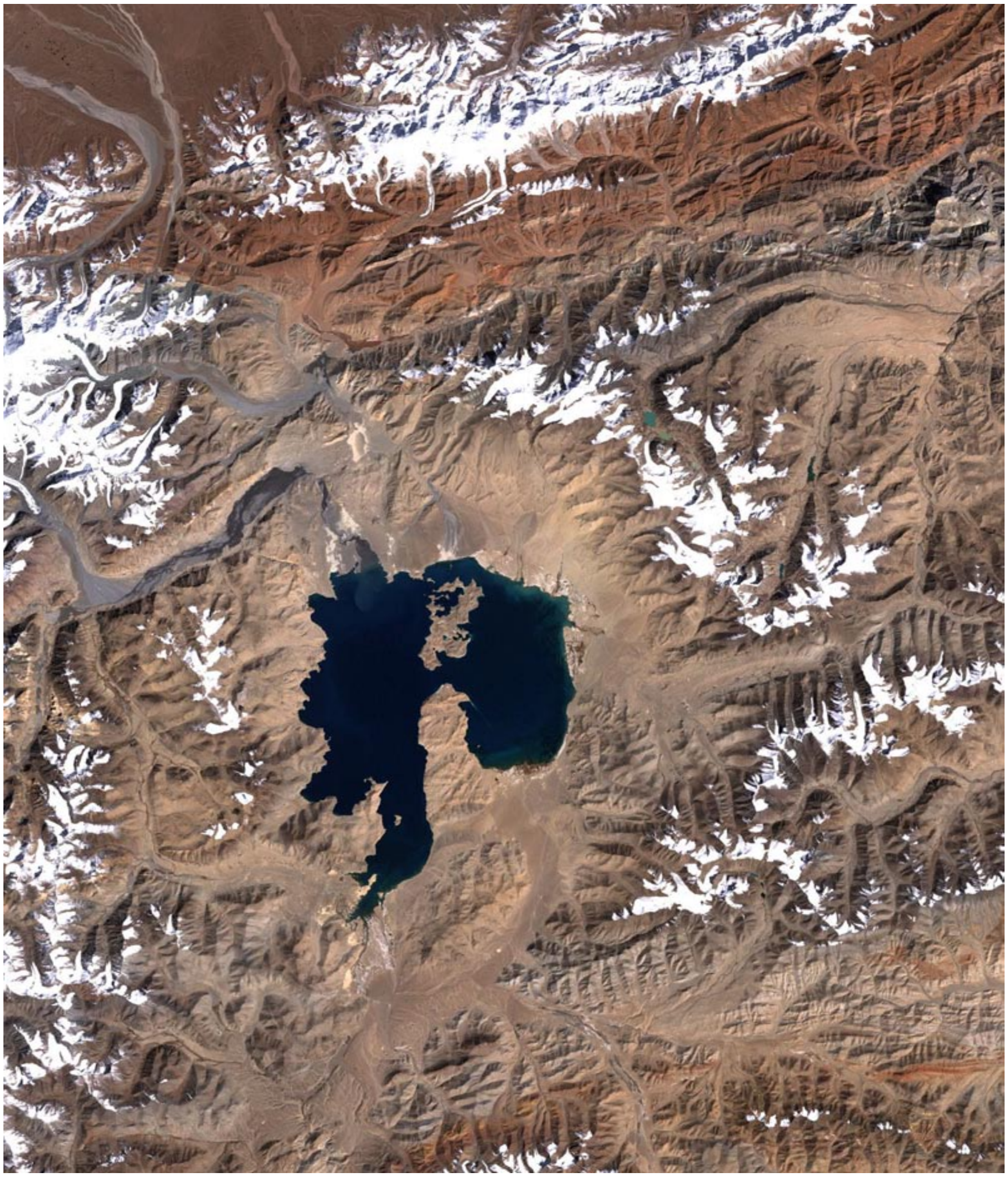
2. Compare your model to the features observed in the Earth LANDSAT images and the Mars images. How are they similar and how are they different?

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.

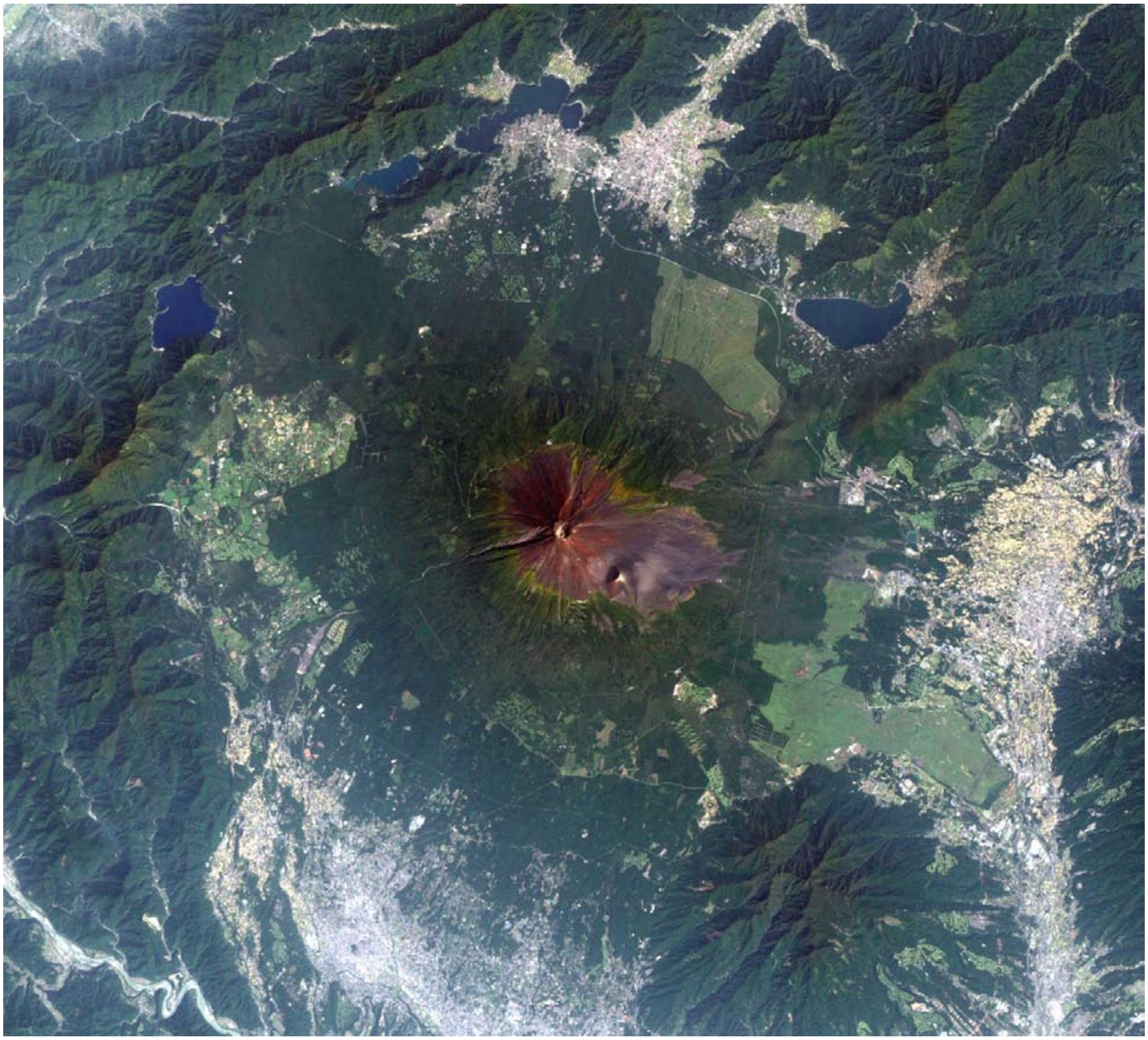
USGS

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.



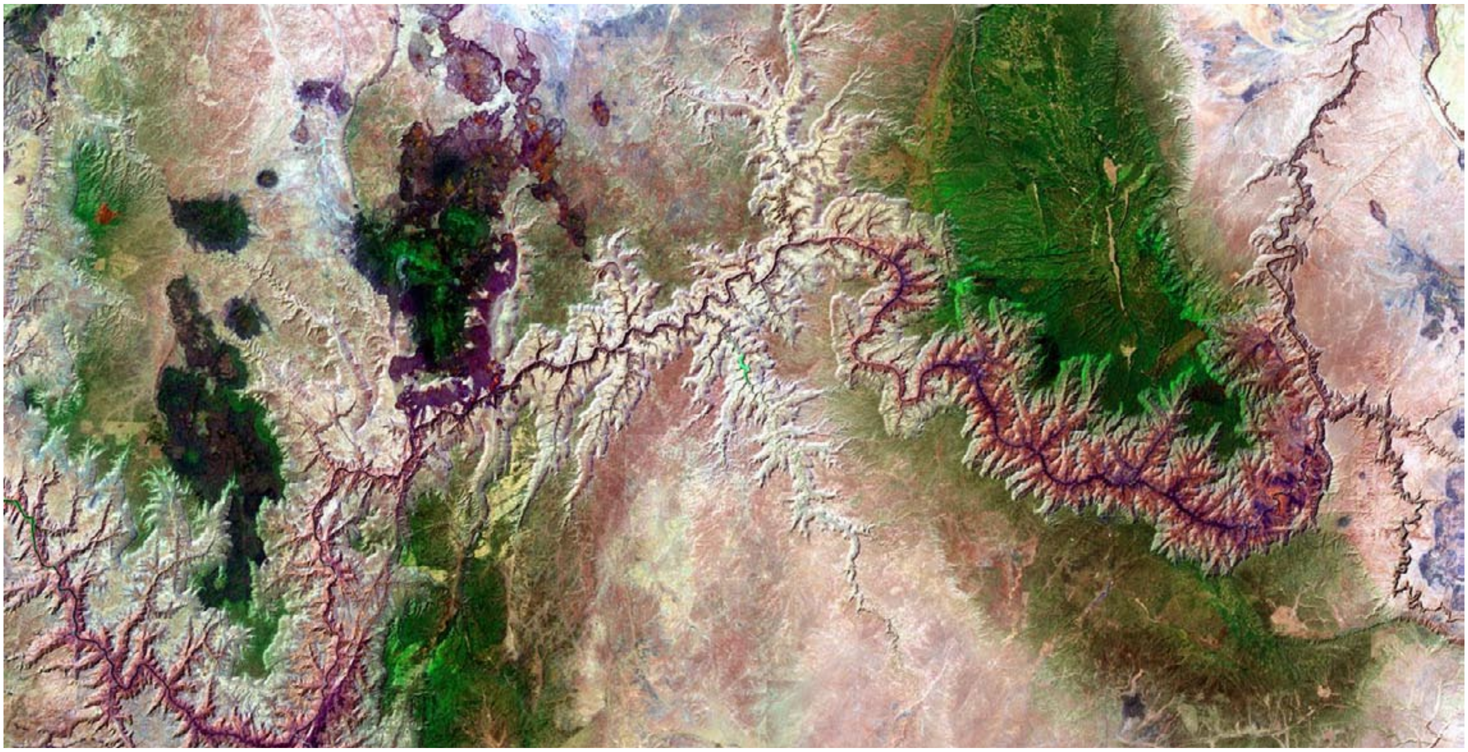
USGS

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.



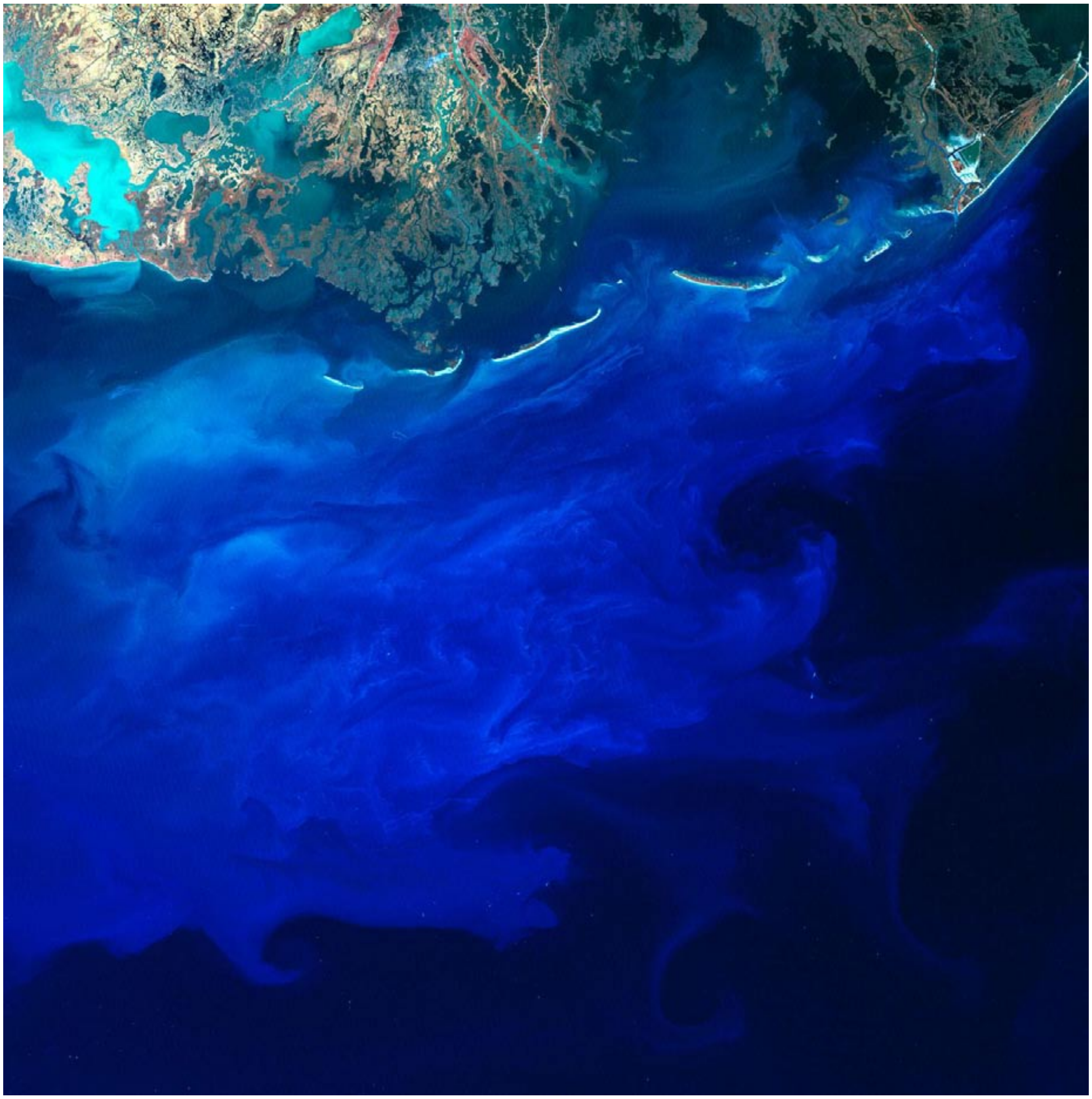
USGS

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

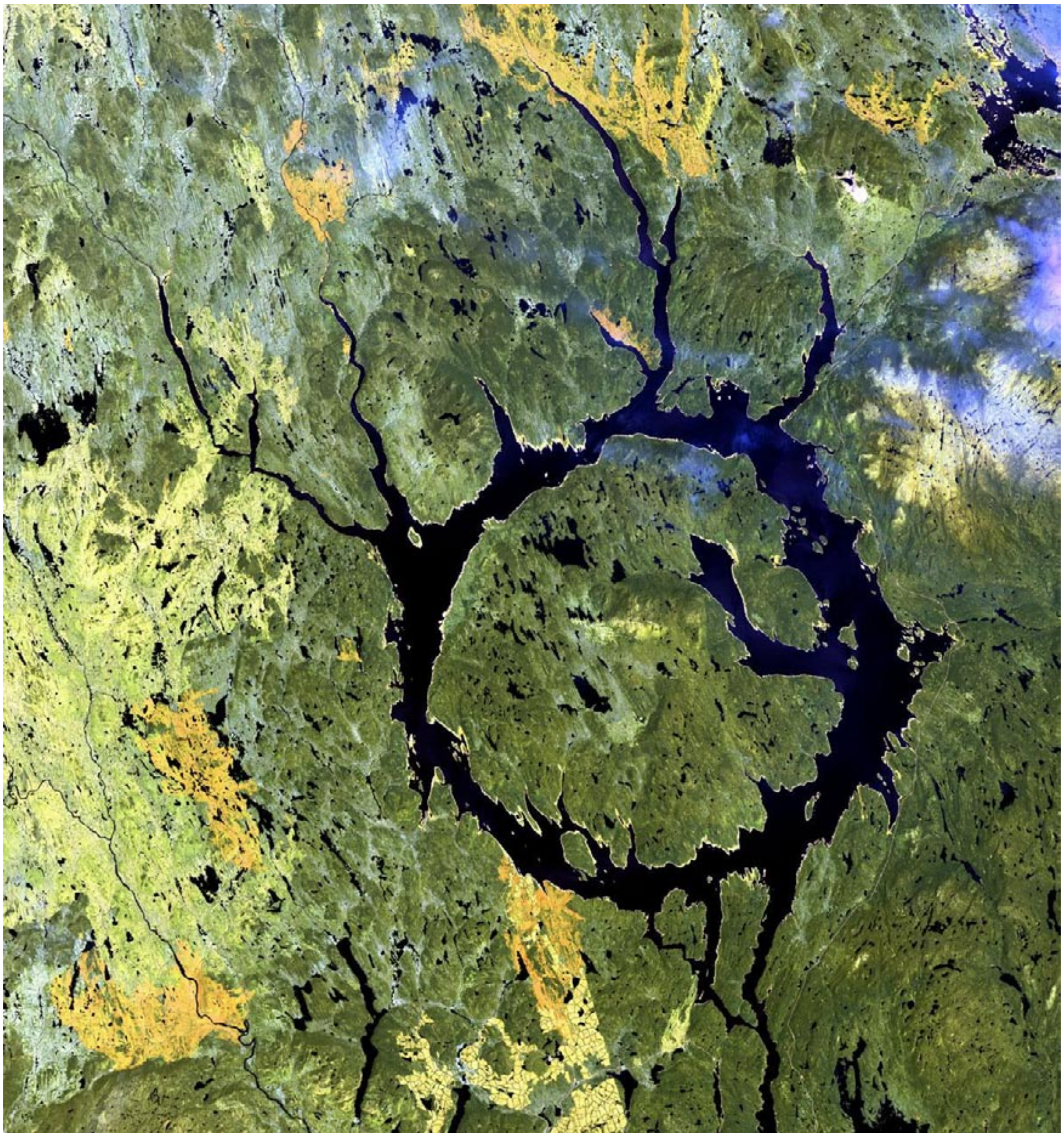


USGS

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

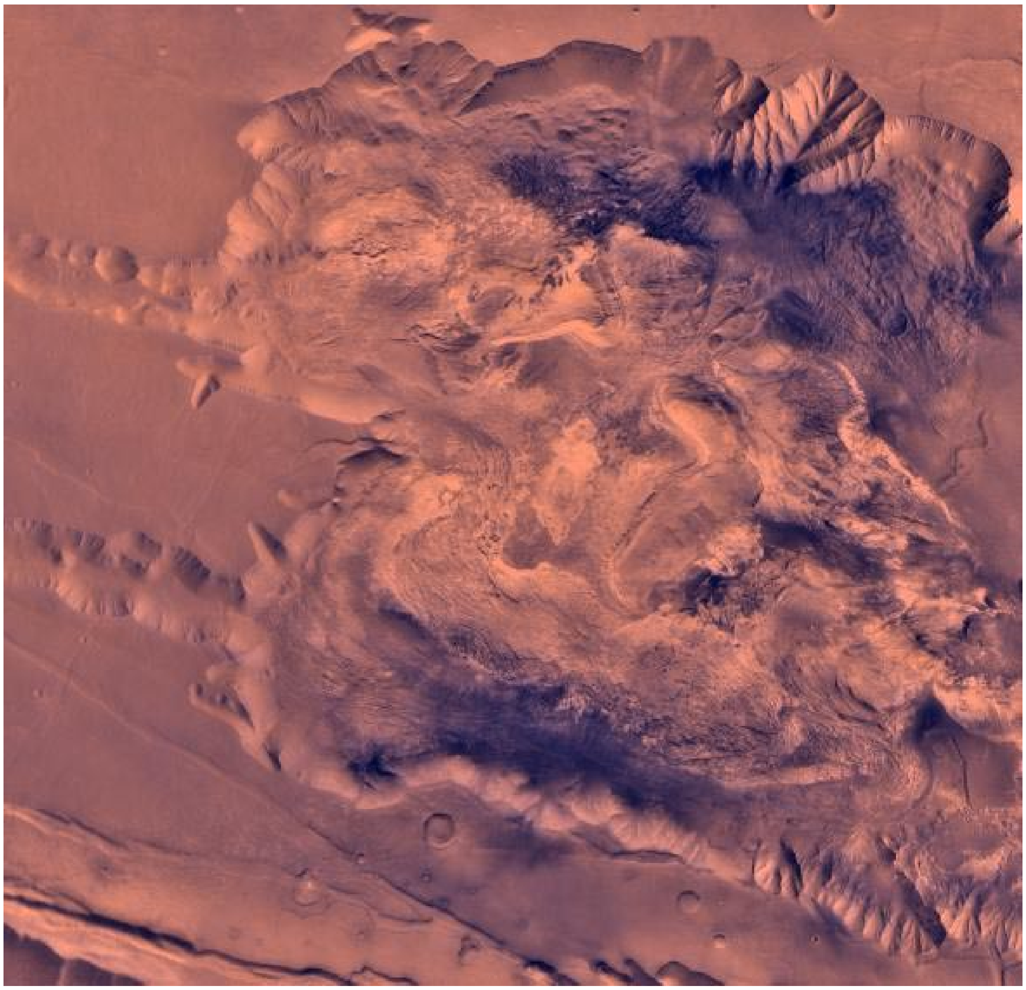
E. Silt from the Mississippi River can be seen suspended in the Gulf of Mexico just off the coast of Louisiana. The river enters the gulf at upper right, and silt is carried by currents to the left.



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

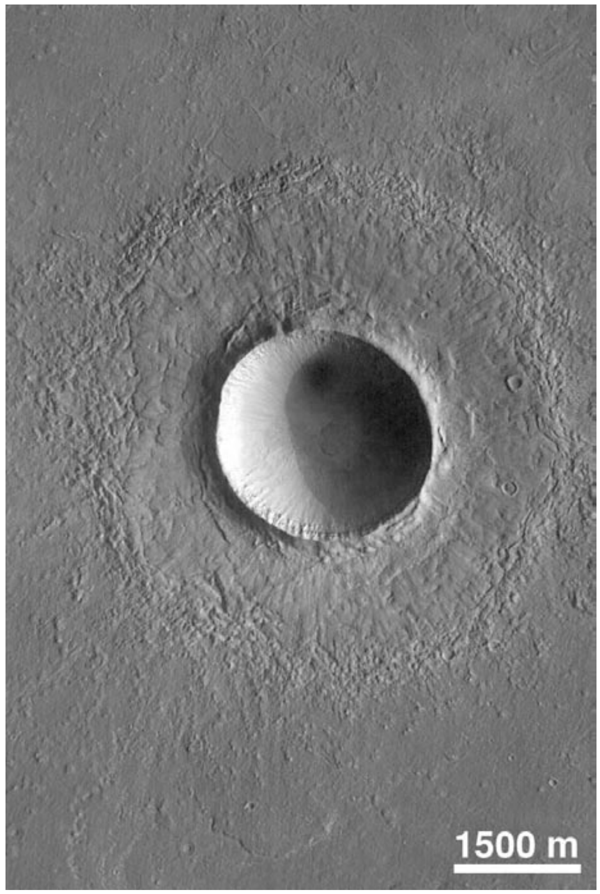
A. This Viking image of Mars shows the western part of Candor Chasma, which is about 100 kilometers (62 miles) across. The floor of the chasma is covered by eroded remnants of a thick stack of layered deposits. Candor Chasma is one branch of an immense connected system of chasmas and canyons called Valles 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.

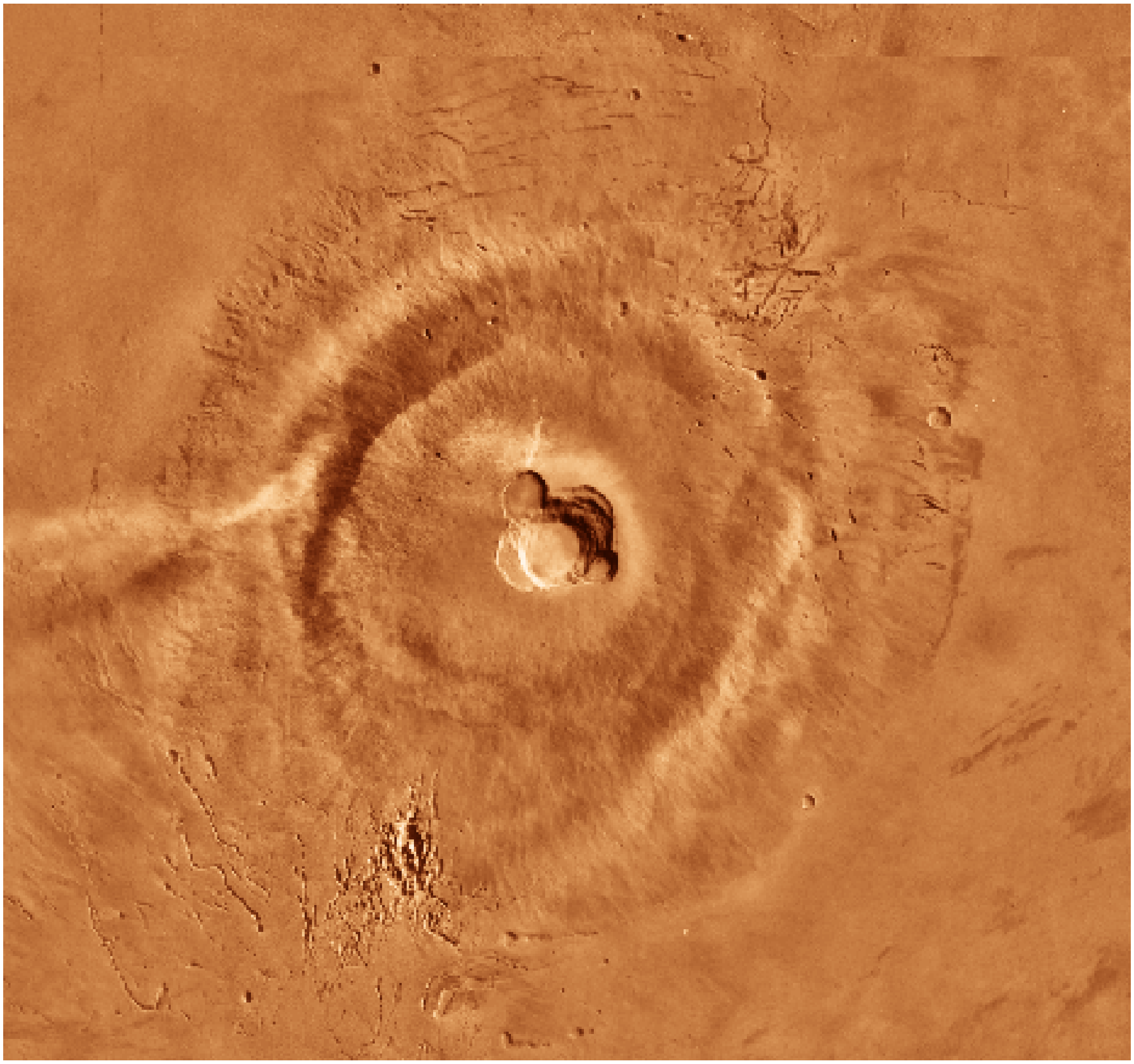
NASA

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.



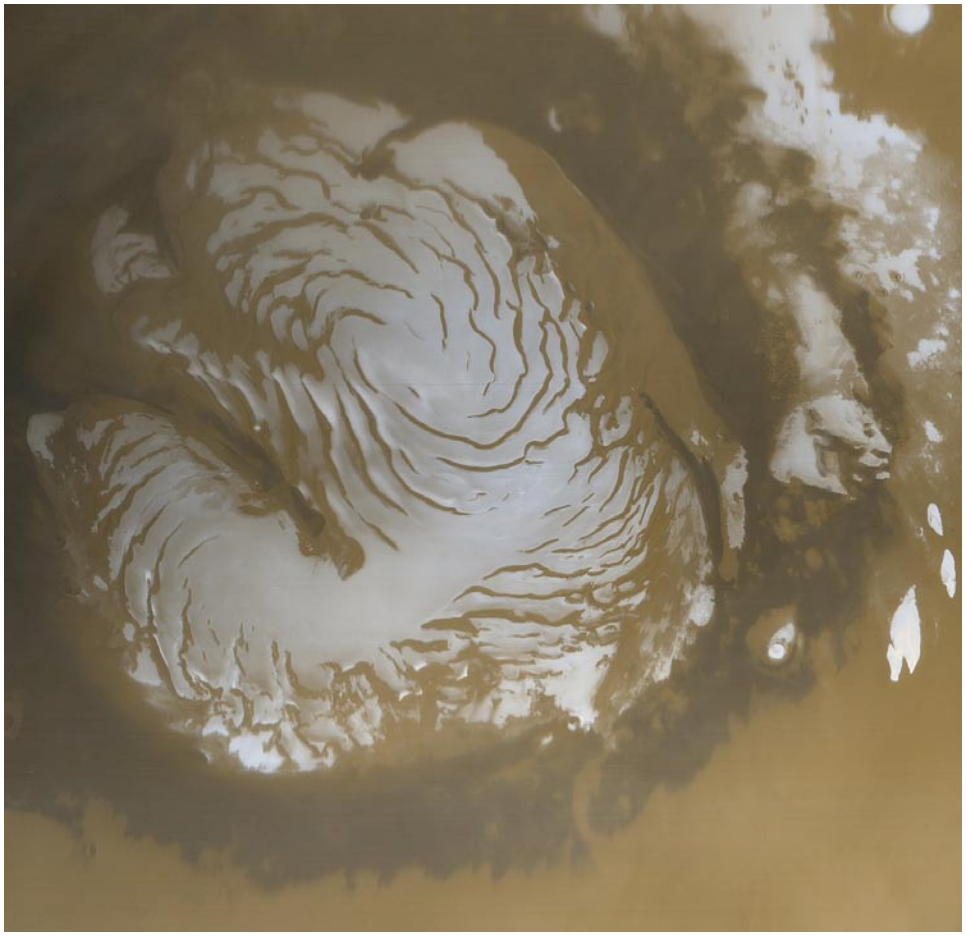
NASA

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.



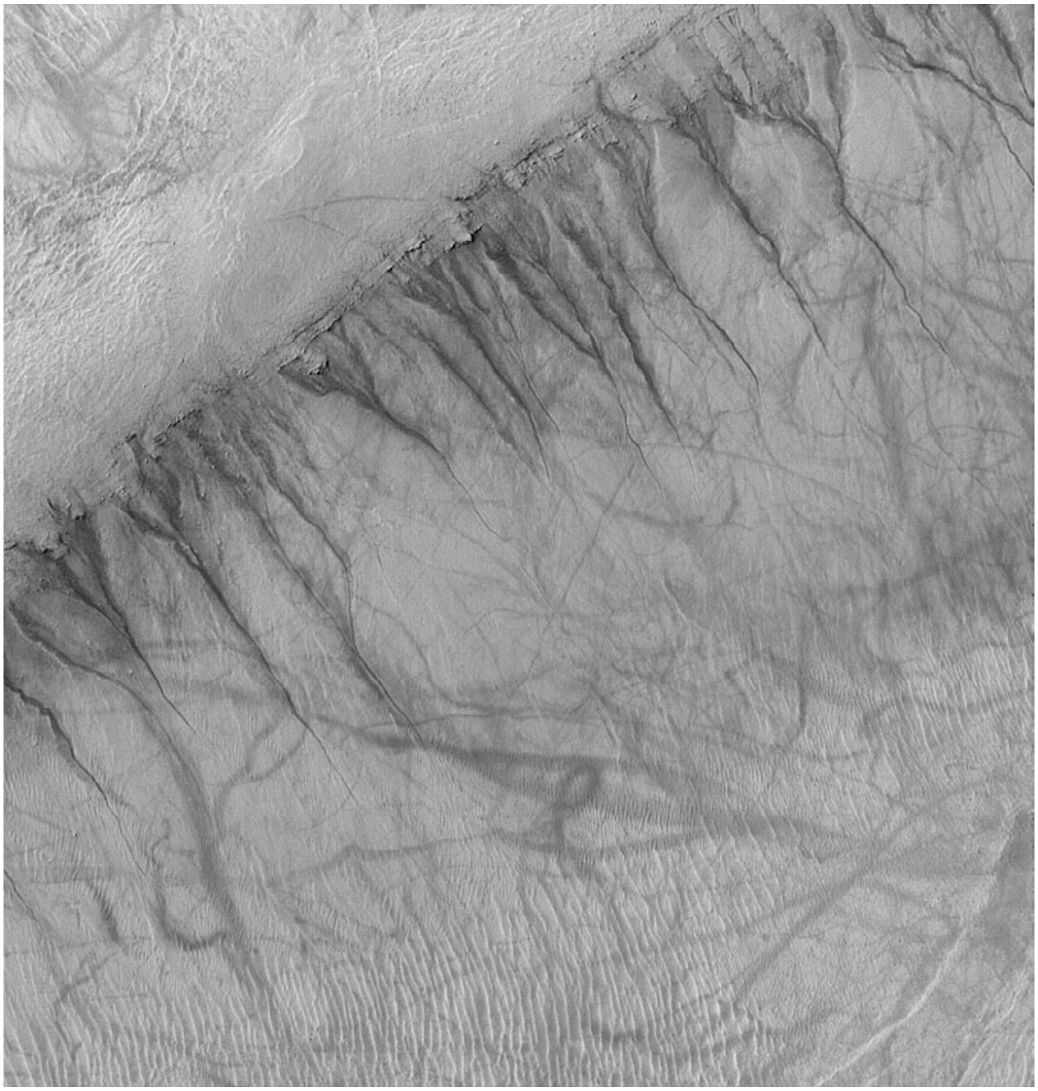
NASA

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.

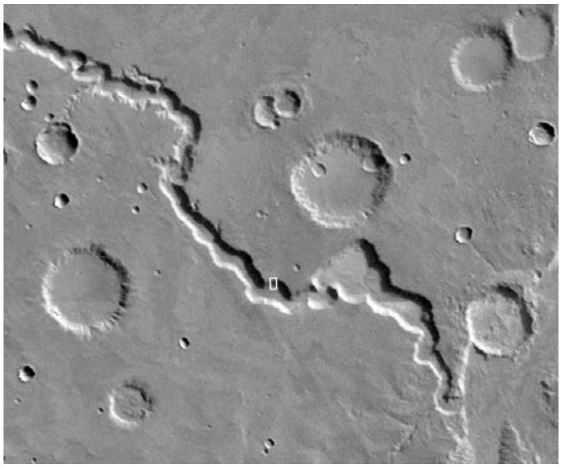
Mars Water Features Images

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.

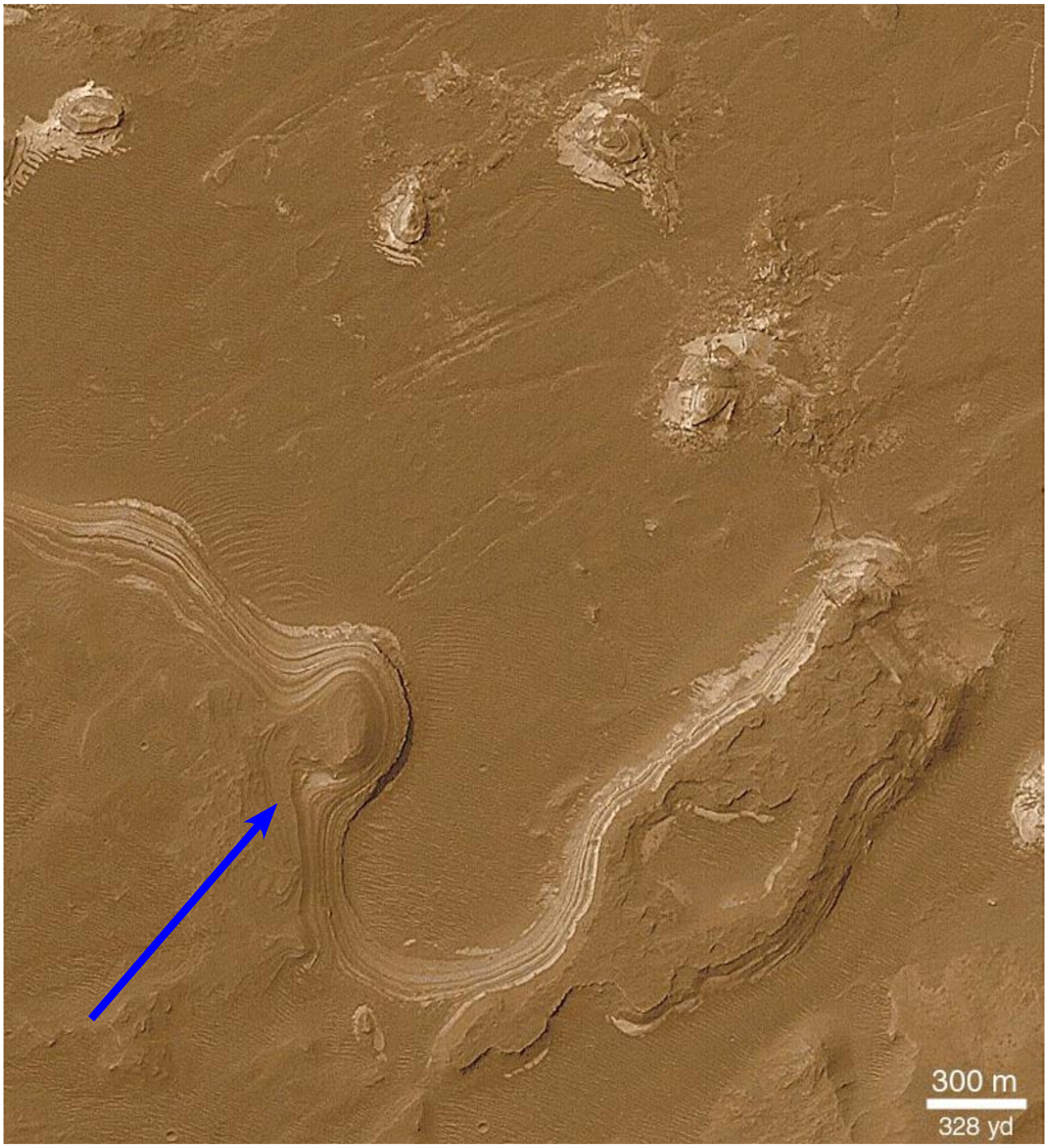

NASA

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).

Compact Reconnaissance Imaging Spectrometer for Mars on the Mars Reconnaissance Orbiter

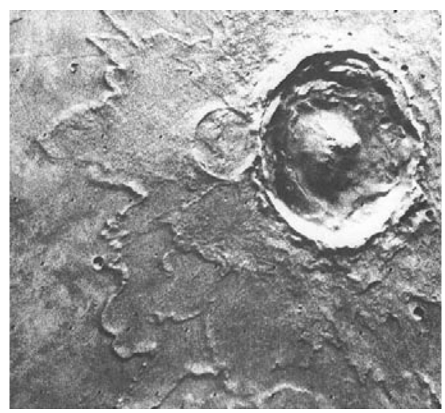
Splat Craters

Objective(s):

- Students will explore crater formation as it occurred on Mars by performing a hands-on experiment.
- Students will identify the distinctive features of impact craters.
- Students will explore the evidence used by scientists to hypothesize if water was once a feature of Mars.
- Students will study images of Mars' craters and compare these to data they collected during the hands-on portion of this lesson.

National Science Education Standards:

- Content Standard D Grades 5 – 8: Earth's History
- Content Standard F Grades 5 – 8: Natural Hazards
- Content Standard G Grades 5 – 8: Nature of Science



NASA

An example of a splat crater (Yuty Crater) on the surface of Mars.

Background:

This lesson expands on a lesson written by the Jet Propulsion Laboratory and Arizona State University titled, "Mud Splat Craters." A copy of this lesson can be found at http://mars.jpl.nasa.gov/classroom/pdfs/MSIP-MarsActivities.pdf. There are other Mars lessons as well that may be of great use to educators.

Splat craters (or rampart craters) are somewhat unique to Mars. Study the photograph at right and notice the unusual lobes that emanate from the center of the crater. This unique ejecta (the material thrown out from an impact crater when it is formed) is thought to be the result of subsurface water ice. Due to the energy released upon impact, this water ice is believed to have been melted, mixed with the surrounding Martian soil, and then turned to "mud."

Students will attempt to reproduce rampart craters by throwing marbles into a tray of mud. Keep in mind that this can become quite messy, so teachers may want to perform the hands-on portion of the lesson outside or use materials such as newspapers or shower curtains to cover tables and desks.

Materials:

- Aluminum pie pans, 2 per group
- Playground sand (two 50-pound bags should be more than enough)
- Flour (two 5-pound bags are enough for a class of 30)
- Cooking oil (optional; to be used only if the teacher mixes the flour and water ahead of time. The oil will keep it "fresh" until it is ready to be used by the students. Add about one tablespoon to each mixture.)
- Plastic 16-ounce cups for holding sand, 2 per group
- Containers for holding water (empty 2-liter soda bottles or 500-milliliter beakers work well)
- Plastic spoons or other utensils for stirring
- Marbles (approximately 25-millimeter diameter), 3 per group
- Metric rulers, 1 per group
- Lots of paper towels (for cleaning up afterwards)
- Copies of Splat Craters Investigation, 1 per student
- Copies of the article Impact Craters!, 1 per student
- Copies of Viking Images, 1 per group of students
- Copies of Water on Mars: Where is it All?

Time:

- Two 45-minute class periods

Engagement Activity:

In this first activity students will add to their background knowledge of craters by reading the article, Impact Craters!

1. Begin by asking students to share what they know about craters.

   Student responses might include that craters are formed as a result of a meteor or asteroid hitting a planet, that they can be seen on the moon, or that they can range in size from very small to very large.

2. Tell students that in the first part of this lesson they are going to read to be informed about craters. They will use this information to help them with the rest of the lesson as they model their own craters.
3. Pass out the article and allow time for students to read.
4. After students have completed the reading, use the following questions to either generate a discussion among the students or to check for understanding.
   a. What is an impact crater?
   b. What has happened to the impact craters here on Earth?

c. What are the parts of a crater?

d. Name the three types of craters and identify how they are different.

e. Explain how craters can be similar or different.

Exploration Activity:

During the exploration part of this lesson, students will carry out an experiment to simulate craters on the planet Mars. Students will add a layer of sand to the bottom of a clean pie pan, mix flour and water and pour this mixture on top of the sand, and then add another thin layer of sand. Standing above their simulated Mars surface, the students will carefully throw the marbles into the pie pan. Depending upon the students' accuracy and the marbles' velocity, they should be able to recreate a rampart crater.

1. Pass out the student procedure page and have students read over what they will do in this activity. The teacher may want to demonstrate how to mix the flour and water, layer the sand and water/flour mixture, and throw the marble into the pie pan.
2. Remind students that they probably will have only enough room to make three craters. Because of the layering of the sand and water/flour mixture they will be unable to smooth over their craters and produce more.
3. Go over with students the data they are to collect and remind them to use the article Impact Craters! to help with the parts of a crater.
4. Have the students gather their materials and work in groups of 2 or 4 to carry out the experiment.
5. Allow enough time for each student in each group to make at least three craters and then have them return their materials and clean up. (The contents of the pie pan can be disposed of and the pan recycled.)

Explanation:

Using their observations from the previous activity, students will compare their data to Mars images taken from the Viking spacecraft. With the help of the teacher, students will explore the possibility that the unique ejecta from the Mars craters are a result of water ice just below the planet's surface.

1. After students have had time to clean up or at the beginning of the next class, have students share with the class the data that they collected. Questions to ask students include:

   a. How do the properties of the craters you created compare to those that you read about in the article? (How do your craters compare to craters you've seen on the Moon or even Mercury?)

   b. What is different about the impactor (marble) you used to create your craters and the impactors that formed the craters on Mars?

   c. What are some possible explanations for the formation of the craters you created?

   d. Was there a relationship between the velocity of the marble and the appearance of the crater? If so, what is the relationship?

2. Pass out copies of the Viking Images and have students compare these images of Mars craters to the craters that they created. Have the students pay particular attention to the ejecta and how it compares to their results.
3. Have the students think about the properties of their simulated Martian surface and then ask for possible causes of the ejecta as observed in the Viking Images. (Students might think that the Mars surface is almost mud-ike or soft just below its surface. Tell students that this is not the case, but to consider what could possibly make the ground around a crater soft and mud-like.)
4. After some discussion, tell students that one possibility for the unique ejecta observed on Mars could be frozen water several hundred meters below its surface. With enough mass and velocity, an impactor could easily penetrate below the Mars surface, causing the frozen water to melt and then mix with the surrounding "soil." This mud-like substance simply would be tossed out of the newly formed crater flow away and then solidify into the patterns observed in the images.

Extension:

In this final activity, students will take what they have learned about the Mars cratering process and apply it to a reading from the Adler Planetarium and Museum. In this article, the authors specifically address rampart craters as evidence that water once existed on Mars.

1. Give each student a copy of the article Water on Mars: Where is it All? and have them read it.
2. When they have finished, ask students the following questions:
    a. Does water exist on Mars today? If so, where is the water?
    b. What do scientists call the type of crater that they created as well as those observed in the Viking images?
    c. Explain the process behind the creation of a rampart crater.
    d. How deep do scientists think an impactor must go before it reaches frozen water?
    e. Compare your model to a rampart crater. What do the various layers in your model represent?
    f. What other evidence exists that leads many scientists to believe that water once existed on Mars in a greater abundance than it does today?

Evaluation:

Teacher evaluation can be based on students' written responses as well as their discussion.

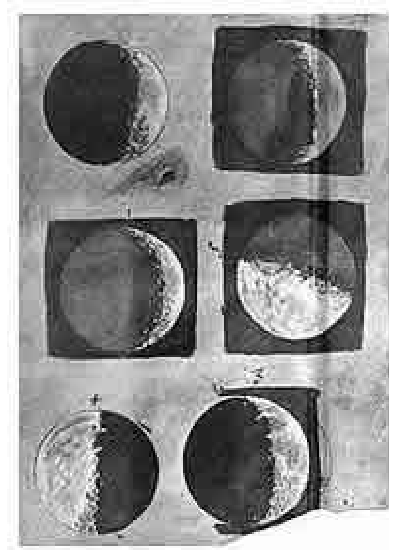
Further Investigation/Extenstion:

An excellent Web site that shows scientists creating impact craters here on Earth can be found at NASA's Deep Impact site, http://deepimpact.jpl.nasa.gov/gallery/mov3.html. This site contains video footage of scientists firing projectiles at high velocity into various substances. The resulting craters are very similar to those observed on the Moon.

Impact Craters!

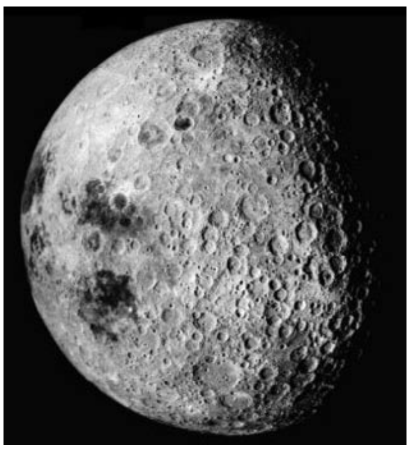
They're a Smash!

An impact crater is just what the term describes – a large depression on a planet's surface formed when an asteroid or meteoroid smashes into the surface at a very high velocity. Cratering, the term used by scientists to describe this phenomena, has occurred on every terrestrial planet in our solar system as well as on asteroids. Craters can be seen easily on the Moon using binoculars or a small telescope. In fact, it was thanks to Galileo that we learned that the Moon was not a smooth sphere. Instead, he discovered a heavily cratered surface (Figure 1). Had he been able to see the far side of the Moon (the side of the Moon we never see because it's facing away from us) he would have seen even more craters! (Figure 2)



NASA

Figure 1. Early sketches of the Moon made by Galileo



NASA

Figure 2. The far side of the Moon as seen from the Hubble Telescope.

Where are the Craters?

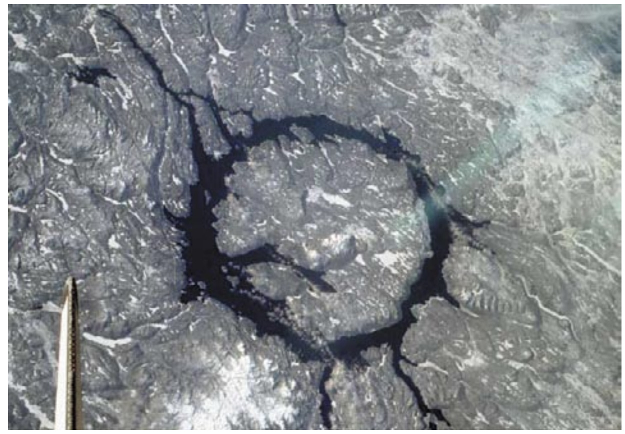
So, if craters exist on all the terrestrial planets, where are Earth's? Was Earth lucky enough to avoid being pelted by both large and small chunks of leftover solar system debris? No! As a matter of fact, the Earth has been hit nearly 10 times more than the Moon (Figure 3). Take another look at the Moon's far side and try to imagine Earth with more than 3 million impact craters! Some of these craters ranged in size from less than 1 mile (1.6 kilometers) in diameter to nearly 660 miles (1,060 kilometers) in diameter. However, due to the active geological processes constantly taking place on Earth, many of these craters have been erased over time.

NASA

Figure 3. Meteor Crater in Arizona, also known as Barringer Crater, was formed 50,000 years ago and is about 1 mile in diameter.

This includes processes such as weathering, erosion, mountain building, and volcanism (Figure 4). Still, scientists eagerly search the planet over for craters to learn about the Earth's geological past. There are currently 150 to 200 known craters on the Earth. Many of these craters are below water, such as the famous Chicxulub crater off the coast of Mexico (Figure 5).

Scientists believe that the event that created this crater was also responsible for the extinction of dinosaurs. Studying craters up-close allows scientists to learn about their formation as well as the object that made the crater. It would be very expensive and quite time consuming to go to another planet such as Mars to learn about craters.



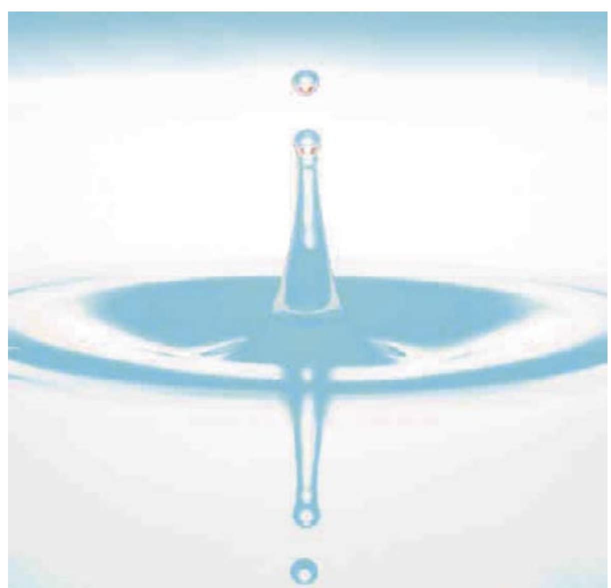
NASA

Figure 4. Manicouagan Crater in Quebec, Canada, as seen from the Space Shuttle. Over 210 million years of weathering has erased much of the crater.

Gail Christeson

Figure 5. Location and size of the Chicxulub crater. Note its size compared to the state of Texas.

In today's activity you will also become an expert in the study of craters, especially the ones on Mars. However, before getting started you need to learn more about the anatomy of a crater as well as the processes involved in making a crater.



Adam Hart Davis/DHD Multimedia Gallery

Figure 6. This drop of water looks very similar to an impact crater. Notice how the water rebounds, or bounces back, to form what scientists call a central peak in a crater.

Anatomy of a Crater

There are basically five parts to a crater that we will examine. They are the central peak, floor, wall, rim, and ejecta blanket. Use the photograph below to help you identify each of these parts of the crater (Figure 7).

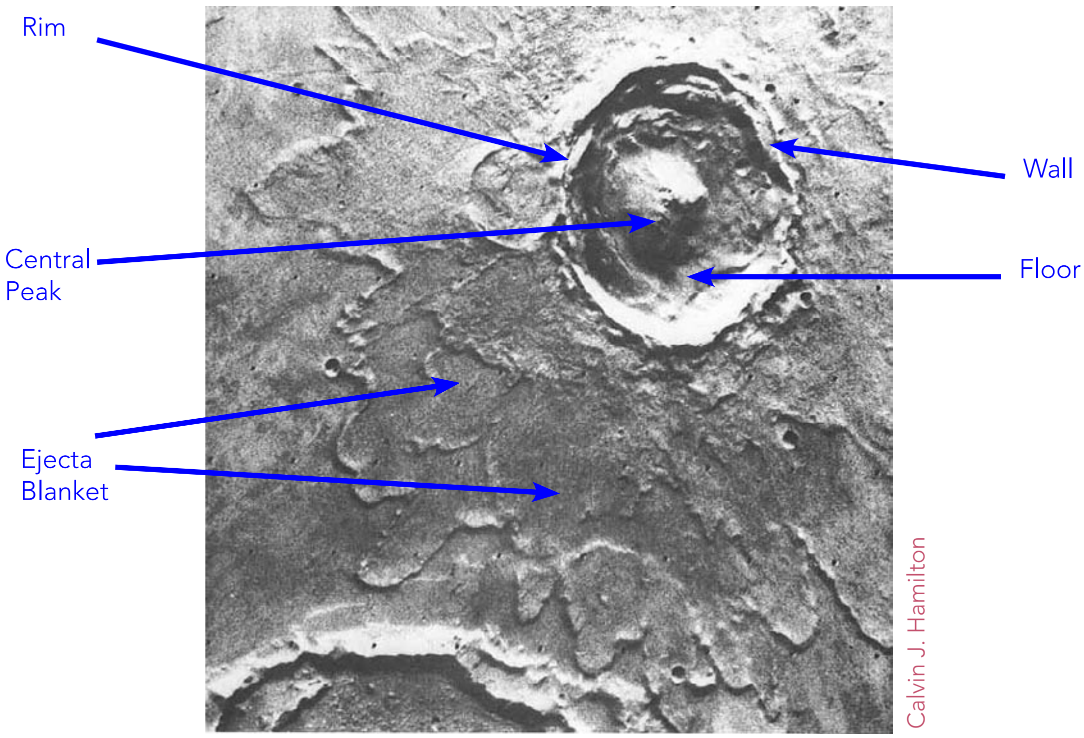
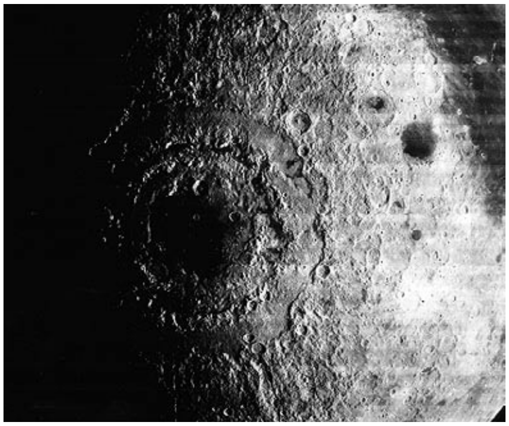


Figure 7. Parts of a complex crater from Yuty Crater, Mars.

Different Craters

Impact craters can be divided into three basic types: simple craters, complex craters, and multi-ring basins. The type of crater depends upon the size and speed of the object that makes the crater. Craters can range in size from extremely small to thousands of kilometers across. Simple craters are less than 3 miles (5 kilometers) in diameter and have a bowl-shaped depression. Meteor Crater is an example of a simple crater. Complex craters have a larger diameter of 3 to 31 miles (5 to 50 kilometers) and a central peak. The central peak is the result of the elastic rebound caused by the shock waves when the object impacts the planet (Figure 8). The force of the impact sends huge amounts of energy deep below the surface of the planet. This energy returns to the surface, bringing with it the rock that lies deep below (most often the oldest rock). The rock's strength keeps it from sinking back down and, as a result, a peak is formed. Multi-ring

Figure 8. Copernicus is an example of a complex lunar crater. Notice the central peak.

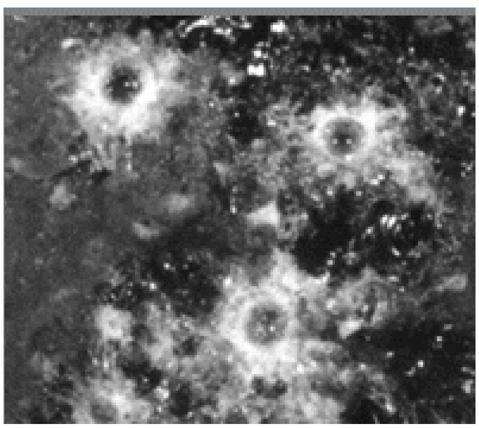


NASA

Figure 9. Orientale Basin on the Moon is an example of a multi-ring basin.

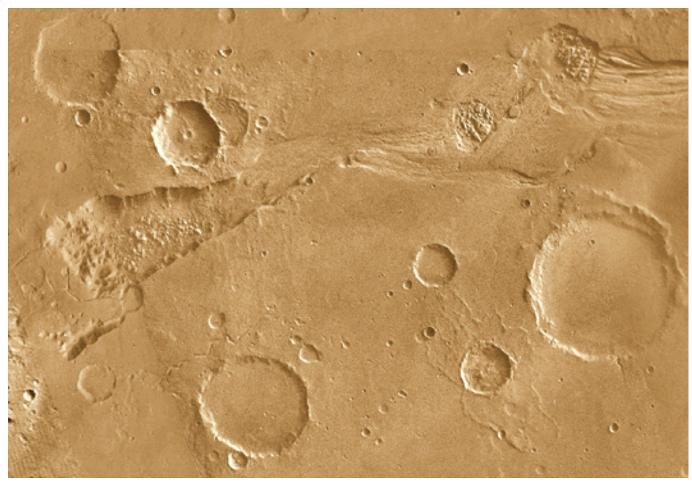
basins are the largest of the three craters. These impact features have diameters greater than 185 miles (300 kilometers). Inside the multi-ring basin are concentric rings. When viewed from above, these rings give the crater the appearance of having a bulls eye like target (Figure 9). The forces behind a crater this size are a bit more complicated than the other two.

At the opposite end of the size range is another crater. These craters, however, require the use of a microscope to see and are referred to as a zap pit crater. These were discovered by geologists while examining the lunar rocks returned to Earth by the Apollo astronauts. They are the result of small, high-velocity particles crashing into the Moon's surface. Zap pit craters have even been found on the Space Shuttle!



NASA

Figure 10. This image shows a close-up view of 1-millimeter diameter pits on a lunar sample from Apollo 16.



Calvin J. Hamilton

Figure 11. This Mars image of Ravi Vallis shows different size craters. The channel is 186 miles (300 kilometers) long.

Not All Craters are Alike!

Craters can vary from one to the next. One obvious example of this is the diameter of the craters. Some are very wide and some not so wide (Figure 11). Other craters have a central peak and some are missing this feature. It's not by chance that craters are different. How a crater looks depends on the size and mass of the object that made the crater in the first place as well as the material that makes up the planet's surface. A meteor crashing into a moist surface would appear different than one that collides with solid rock.

JHUAPL

Think Like a Scientist, Act Like a Scientist

Keeping in mind the parts of a crater as well as the variables involved in making a crater, you are going to make your own craters. Your craters, though, will be on a much smaller scale. Still, you will collect useful data that will help you identify specific craters on Mars as well as share your thinking about how these craters were formed.

Splat Craters Investigation

Teacher Copy

Teachers, please be aware that this is a somewhat messy activity. Consider using newspapers or shower curtains as drop cloths to make cleanup much easier. Another option would be to conduct the experiment outside.

Materials:

- Aluminum pie pans, 2 per group
- Playground sand (2 cupfuls)
- Flour (approximately 1 cup)
- Water (approximately 150 milliliters)
- Plastic spoon
- 3 marbles

  Medium-sized marbles seem to work best for this experiment. These are marbles that are about 25 millimeters in diameter.
- Metric ruler
- Paper towels for cleaning up spills

  Teachers may want to place newspaper or shower curtains over tables and desk to make cleanup a little easier.
- Copies of Splat Craters Investigation, one per student

Procedure:

1. You and your group will need to begin by making a Mars-like surface.
    a. Using one empty pie pan, add a layer of sand about 2 centimeters thick. Place this to the side.
    b. In the other pie pan add your cup of flour and 150 milliliters of water. Using the spoon, stir until the mixture is the consistency of pancake or cake batter. It should drip off of the spoon like thick paint.
    c. Carefully pour the flour/water mixture on top of the sand in the other pie pan. Use the spoon to carefully even out the mixture across the top of the sand.

    Caution students not to mix the sand and the flour/water mixture.

    d. Using the remaining sand, carefully sprinkle it over the top of the flour/water mixture. You don't need to add all of the sand, just enough to cover the surface.
    e. You now have a small piece of the Mars surface!
2. Place your Mars surface on the floor away from anything that might get splattered by the flour/water and sand mixture.

3. Holding the first marble, carefully stand over the Mars surface and throw the marble into the pie pan.

   This might take some practice on the part of the students. Keep in mind, however, that the small size of the pie pan won't allow for a lot of craters. The key is to transfer enough force to the marble so that it will cause the flour/water mixture to "splat" out and over the top layer of sand.

4. Carefully remove the marble and observe the crater and crater features. Record your observations below.
5. Repeat steps 3 and 4 with the remaining two marbles. However, add a little more force to the marbles when throwing them into the pie pan.
6. When you have finished making all three craters, use the paper towels to clean up and throw away the pie pan with the Mars surface.
7. Finally, complete the conclusion questions.

Observations and Data

1. In the space below, draw and label the parts of your "best" crater.

Using a ruler, measure the diameter (in centimeters) of each crater and record the data on the lines below.

First Crater _____   Second Crater_____ Third Crater_____

Conclusion

1. Briefly describe the features of the craters that you created. Consider how your craters compare to those you read about in the article Impact Craters!

   Responses should include details about the crater features as well as how they compare to the four types they read about in the article. (Simple, complex, multi-ring basin, and zap pit craters.)

2. Using your observations and data, compare crater sizes. How are they alike and how are they different?

   Responses should include numbers with labels as well as how they compare to one another.

3. Based on the various sizes of the craters and their features, give several reasons for their similarities and differences.

   Responses should include reasons for similarities and differences supported with details (e.g., observations) from the experiment.

Splat Craters Investigation

Student Copy

Materials:

- Aluminum pie pans, 2 per group
- Playground sand (2 cupfuls)
- Flour (approximately 1 cup)
- Water (approximately 150 milliliters)
- Plastic spoon
- 3 marbles
- Metric ruler
- Paper towels for cleaning up spills
- Copies of Splat Craters Investigation, one per student

Procedure:

1. You and your group will need to begin by making a Mars-like surface.
    a. Using one empty pie pan, add a layer of sand about 2 centimeters thick. Place this to the side.
    b. In the other pie pan add your cup of flour and 150 milliliters of water. Using the spoon, stir until the mixture is the consistency of pancake or cake batter. It should drip off of the spoon like thick paint.
    c. Carefully pour the flour/water mixture on top of the sand in the other pie pan. Use the spoon to carefully even out the mixture across the top of the sand.
    d. Using the remaining sand, carefully sprinkle it over the top of the flour/water mixture. You don't need to add all of the sand, just enough to cover the surface.
    e. You now have a small piece of the Mars surface!
2. Place your Mars surface on the floor away from anything that might get splattered by the flour/water and sand mixture.
3. Holding the first marble, carefully stand over the Mars surface and throw the marble into the pie pan.

4. Carefully remove the marble and observe the crater and crater features. Record your observations below.
5. Repeat steps 3 and 4 with the remaining two marbles. However, add a little more force to the marbles when throwing them into the pie pan.
6. When you have finished making all three craters, use the paper towels to clean up and throw away the contents of the pie pan.
7. Finally, complete the conclusion questions.

Observations and Data

1. In the space below, draw and label the parts of your "best" crater.

Using a ruler, measure the diameter (in centimeters) of each crater and record the data on the lines below.

First Crater _____ Second Crater_____ Third Crater_____

Conclusion

1. Briefly describe the features of the craters that you created. Consider how your craters compare to those you read about in the article Impact Craters!

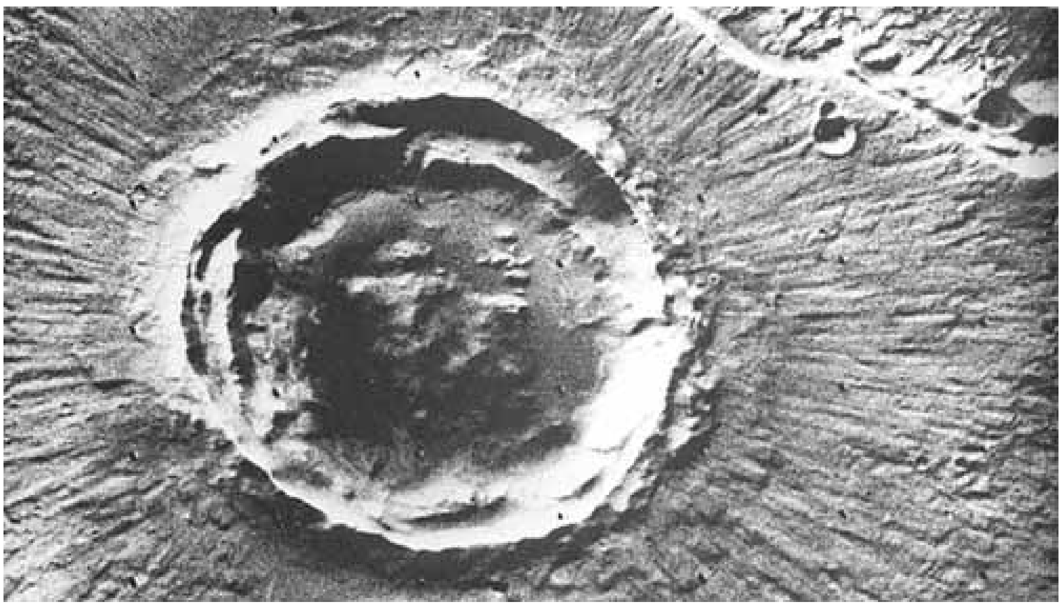
2. Using your observations and data, compare crater sizes. How are they alike and how are they different?

3. Based on the various sizes of the craters and their features, give several reasons for their similarities and differences.

Viking Images

NASA's Viking mission consisted of two spacecraft – Viking 1 and Viking 2 – each containing an orbiter and a lander. The mission is best known for the images it returned of the Martian surface and the landers' search for life. Although life was not detected, Viking returned a wealth of information about the planet's surface, temperature, atmospheric composition and meteorology.

Below is a series of Viking images of various Mars craters. Compare the craters in these images to the observations you recorded in the Splat activity.



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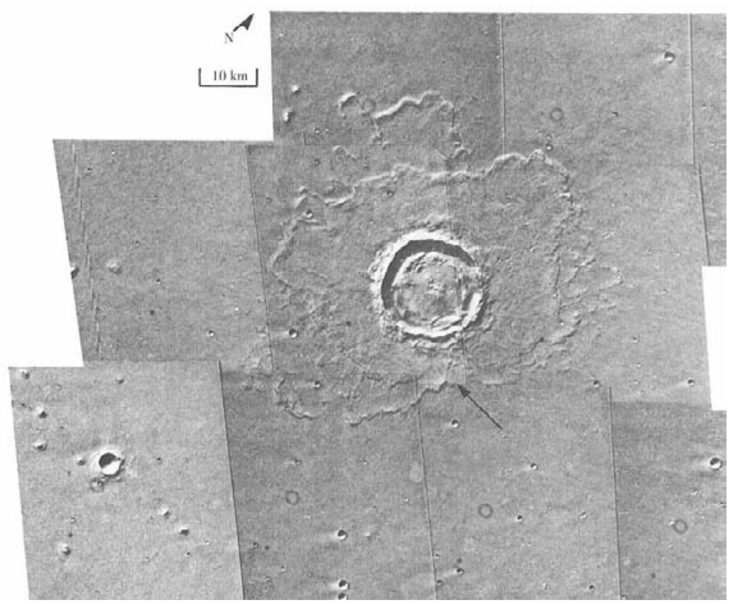
Complex crater on Mars



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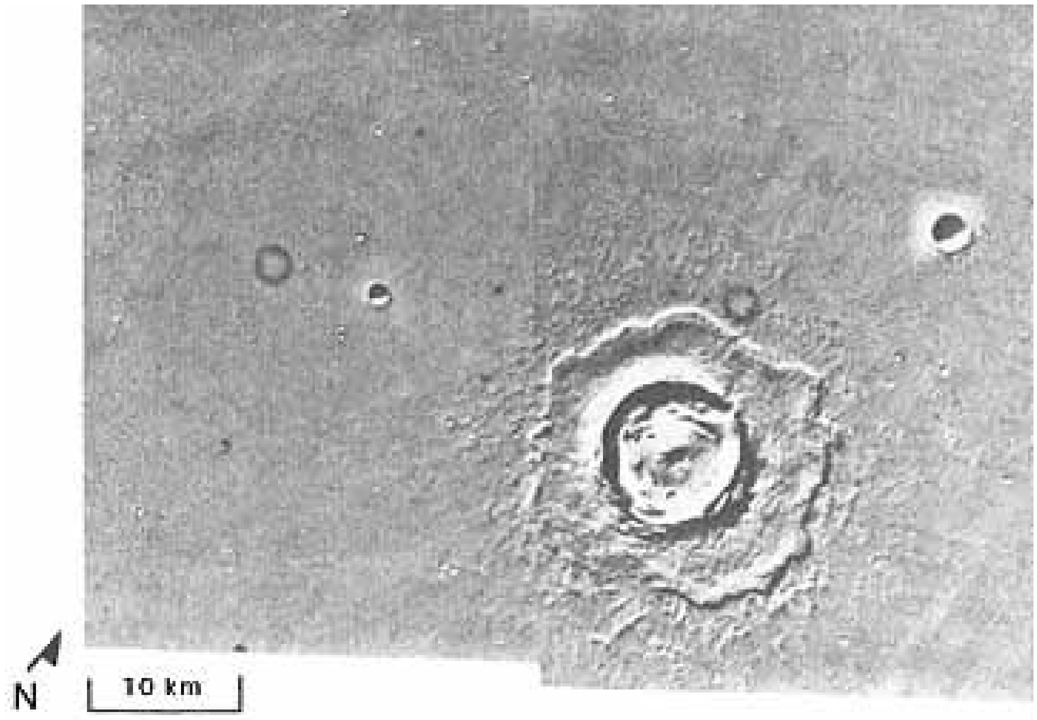
Crater Tarsus



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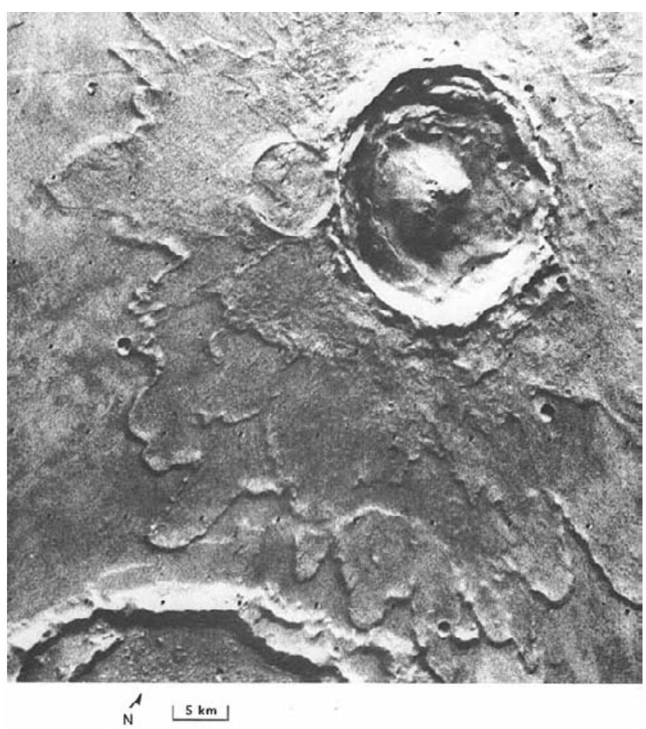
Crater in Chryse Planitia



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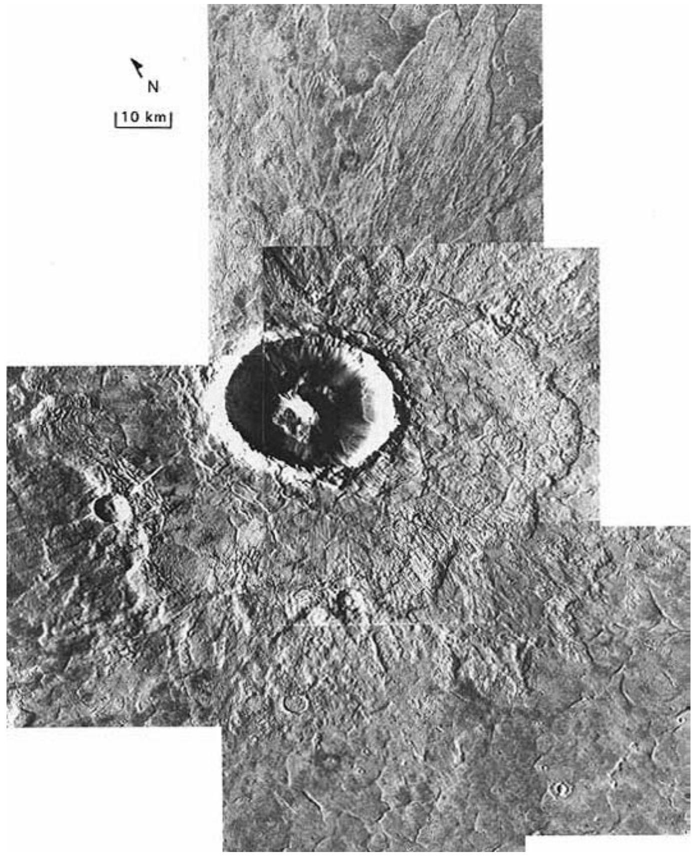
Yuty Crater



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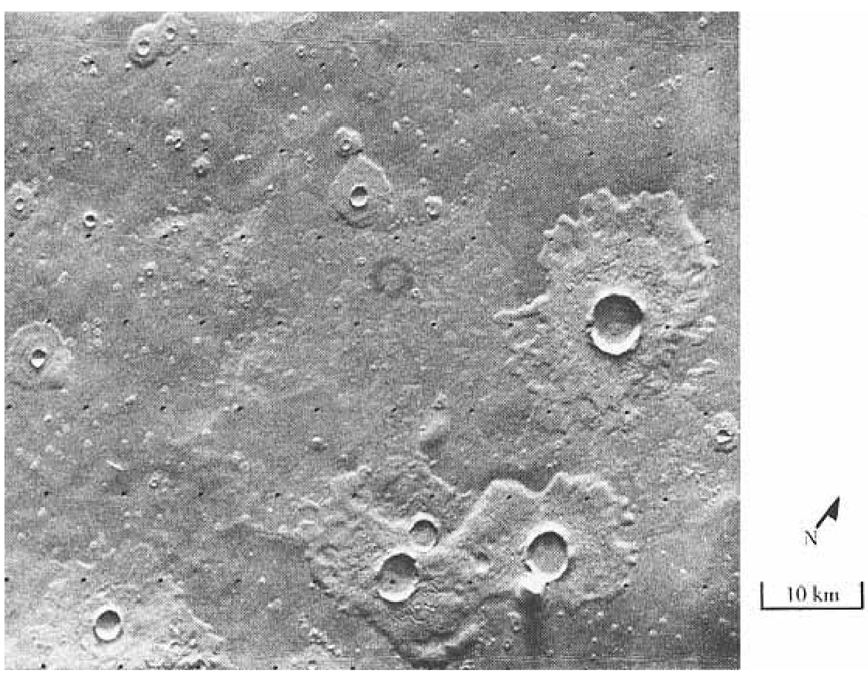
Arandas Crater



Calvin J. Hamilton

Pedestal Craters

Water on Mars: Where is it All?

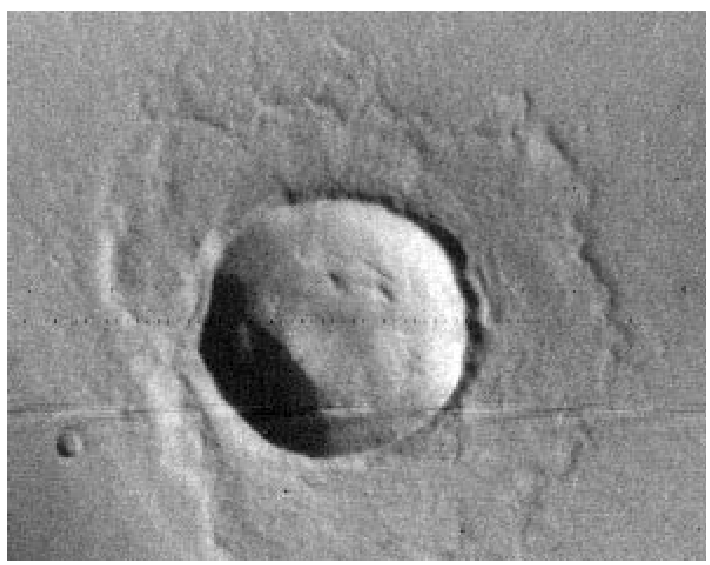
By Diana Challis and Jim Mikoda

Figure 1. Pathfinder took this picture of clouds on Mars.

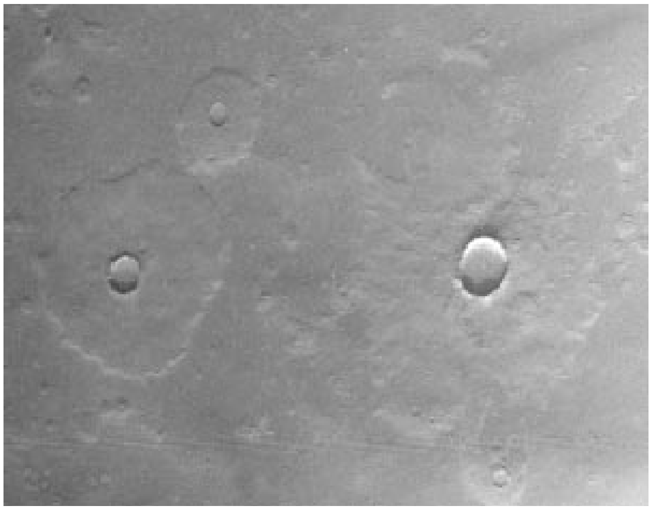
Unlike our Earth, where water is the most plentiful substance on the planet, Mars contains no liquid water. The temperature on Mars is so low and the atmosphere is so thin and dry that liquid water is very unstable. If you were standing on the Martian surface and emptied a bottle of water onto the ground, it would all instantaneously evaporate into gas! So, how can there be any water on Mars if liquid isn't stable for even a second?

Water exists on Mars in the form of ice. The Viking Orbiter has observed carbon dioxide ice at the north pole, which partially evaporates and exposes a water cap in the summer. In May 2002 the Mars Odyssey spacecraft detected massive amounts of water ice mixed in with the surface dirt around the pole. The ice wasn't found earlier because it wasn't visible. However, Odyssey has a water-detecting instrument on board which picked up this large deposit right away. Lastly, both the Viking and Pathfinder landers have observed hazy clouds of fine water ice crystals in the atmosphere. Figure 1 is a picture Pathfinder took of the clouds.

There are also signs that water ice exists below the surface of Mars in underground deposits. These signs include rampart craters, also called moat craters. Rampart craters are impact holes surrounded by ejecta material. They have a strong ridge around the far edge of the ejecta, suggesting that the material in the crater flowed out instead of being shot out. This means, when the impacting meteorite hit the surface, it may have liquefied underground ice. The ejecta would then be a water/dirt mixture flowing out from the center of the crater. The result is craters that tend to look like mud pies!



Single Lobe Ejecta: Patterns around this crater are formed by ejecta material.



Pancake Ejecta: These craters have a definite halo-like ring around the ejecta edge.

Pancake Ejecta: These craters have a definite halo-like ring around the ejecta edge.

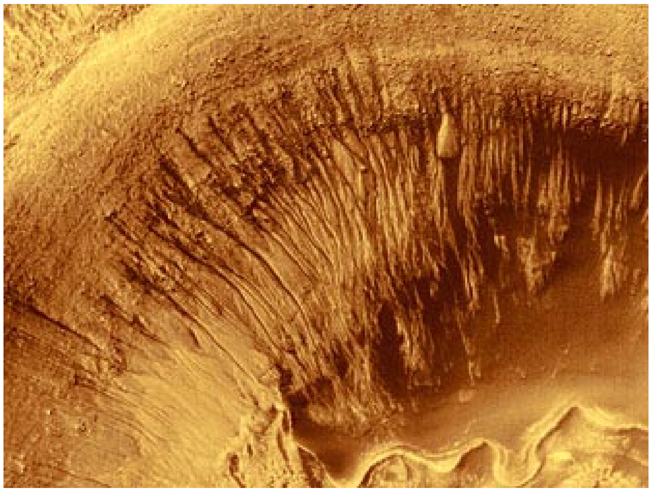


Figure 2. Could water be responsible for these long channels and gullies?

Note that only the deep-penetrating craters have this moat-like ridge around them, small shallow craters do not. This implies that there is a certain depth one must pass before any ice can be found. Scientists' best guess is that the depth to ice is about 100 meters near the poles, and about 400 meters near the hotter equator. Any ice above this depth has evaporated away.

Gullies and channels (figure 2) are cliff edges and crater walls with long channels coming out of a cut in the cliff. The channels look like they were formed by water, being that they are very long with aprons and fingers of material extending far onto the flatlands.

Again, this suggests that the ground contains a flowing water or ice-rich layer. It is believed that if the soil did not contain any ice-like material, it would not behave this way.

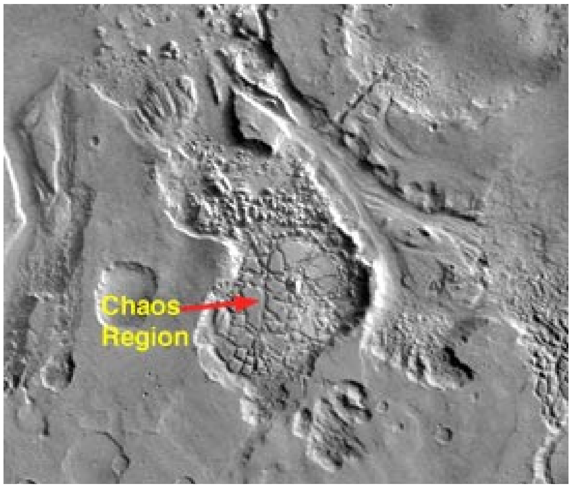


Figure 3. Images like the one above suggest to scientists that water once flowed across the surface of Mars.

Chaotic terrain (figure 3) is a jumble of cracked and collapsed blocks. It is often associated with the outflow channels. These broken up regions are thought to be created by the melting of underground ice. The new water flows downhill, which causes the ground directly above it, at the surface, to crack and slump in a disordered fashion.

Rampart craters, gullies and channels, and chaotic terrain are all similar to glacial features found on Earth. This suggests that there is ice present on or inside Mars today. Knowing where critical resources like water can be found is essential if humans are going to send astronauts to Mars someday.

Compact Reconnaissance Imaging Spectrometer for Mars

The Search for Water: If water once flowed on Mars, did it leave any clues? In 2005, aboard the Mars Reconnaissance Orbiter, the **CRISM** instrument will join NASA's set of high-tech detectives seeking evidence of past water on the Martian surface.

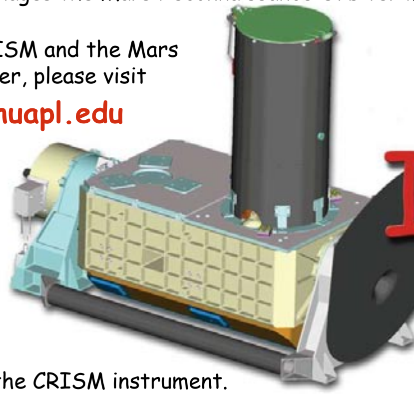
Disappearing with a Trace: Even when water evaporates, it doesn't really disappear. Traces of iron oxides, sulfates, clays, carbonates and other minerals stay behind like fingerprints, and scientists have embarked on an international effort to find these aqueous clues on Mars.

'Dusting' for Fingerprints: Circling 186 miles (300 kilometers) above Mars, CRISM will track regions on the dusty surface and map them at scales as small as 60 feet (18 meters) across. By looking at hundreds of visible and invisible (infrared) colors of sunlight reflected off the surface, CRISM can identify a range of minerals and help researchers find those that water may have left behind.

An Expert Expedition: Led by The Johns Hopkins University Applied Physics Laboratory, the CRISM team includes experts from universities, government agencies and small businesses in the United States and abroad. NASA's Jet Propulsion Laboratory manages the Mars Reconnaissance Orbiter mission.

To learn more about CRISM and the Mars Reconnaissance Orbiter, please visit

http://crism.jhuapl.edu



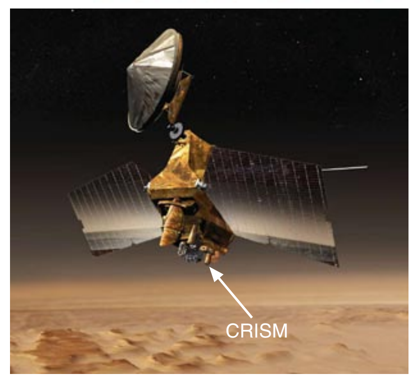
CRISM Instrument Model

OBJECTIVES

- Create a model of the CRISM instrument.
- Write a summary of the CRISM instrument and its importance to the scientific community.

MATERIALS NEEDED

Scissors Tape



INSTRUCTIONS

Adult supervision is suggested. Please read all the instructions before starting.
Estimated time: 1 hour.
Photocopy the model before cutting it to follow the instructions more easily.
Cut out all pieces of the model and fold all yellow flaps down except for **B** CRISM Telescope Tube and **D** CRISM Scan Motor.
Note: everything in yellow is hidden by folding under or folding inside.

A CRISM INSTRUMENT BODY

- Cut out the dotted white circles and throw them away.
- Fold and crease all inside black lines. Fold all flaps down.
- Assemble the **B** CRISM Telescope Tube (see below) and insert this, from the underside, into the larger hole and secure with tape.
- Assemble the **D** CRISM Scan Motor (see below) and insert this, also from the underside, into the smaller hole and secure the flaps with tape.
- Join **A-1** with **A-2** and secure with tape, with the flap under **A-1**. Fold flaps down on **A-3** and **A-4** and tape to make a box.

B CRISM TELESCOPE TUBE

- Join **B-1** and **B-2** and secure with tape. Fold the remaining 5 flaps up.

C CRISM TELESCOPE COVER

- Fold flap down and tape this to the top of the **B** CRISM Telescope Tube at **B-3** (covering the yellow rectangle).
- Point cover toward the **D** CRISM Scan Motor.

D CRISM SCAN MOTOR

- Fold flap down on **D-3**. Do not fold flap down on **D-1**. Fold the remaining flaps up on the other side of the rectangle.
- Join **D-1** with **D-2** and secure with tape, with the flap under **D-2**.
- Fold circle down and tape tab down on outside.

E CRISM PLATFORM & RADIATOR

- Fold at all lines. Bring **E-1** and **E-2** together and tape flap under **E-2**.
- Fold all flaps down on **E-4** and tape this end of the platform closed.
- Fold **E-3** (Radiator) up.
- Tape the platform to the **A** CRISM Instrument Body.
- Tape the Radiator to the **A** CRISM Instrument Body at **A-3**.

04-03456