LESSON **13**

Surface Features


NATIONAL AERONAUTICS AND SPACE ADMINISTRATION. IMAGE PROCESSING BY UNITED STATES GEOLOGICAL SURVEY

This image shows part of the Ophir Chasm in Valles Marineris, a huge 4000-kilometer-long canyon system on Mars. The Ophir Chasm is shaped by tectonics, wind, slumping, and perhaps by water and volcanism.

INTRODUCTION

The most spectacular feature on Mars is the great canyon system called Valles Marineris. It extends for about 4000 kilometers. That's nearly a quarter the way around the planet! The term canyon, however, is somewhat misleading. Why? On Earth, canyons generally are formed by running water. The canyons of Valles Marineris are basically cracks produced by tensions in the crust, although water is believed to have played a later role in shaping the canyons. After the cracks formed, deep springs seeped through the cliffs. This led to landslides, which were probably eroded by windstorms sweeping down the canyons. All of these processes combined make Valles Marineris and its Ophir Chasm a spectacular planetary feature!

In this lesson, you will examine a set of photographs showing surface features on Earth.

OBJECTIVES FOR THIS LESSON

Review photographs showing planetary surface features on Earth; then consider whether the processes that formed these features exist on other planets and moons.

Brainstorm what you know and want to learn about planetary processes on Earth and other planets.

Investigate wind erosion, water erosion, tectonics, and volcanism and their effects.

Analyze photographs of planetary surface features and determine how each was formed.

Summarize and organize information about Mars, and compare Mars to other planets.

You will investigate whether these features exist on other planets as well. Various groups in your class will model one of the different planetary processes that create these features—wind erosion, water erosion, fractures caused by tectonics and other stresses, or volcanism. You then will match each group's model with photographs of different planets' surface features. The lesson ends as you read about three NASA missions to Mars.

MATERIALS FOR LESSON 13

For you

- 1 copy of Student Sheet 13.1a: Planetary Process Observations (or your notebook)
- 1 copy of Student Sheet 13.1b: Matching Planetary Processes (or your notebook)
- 1 pair of goggles
- 1 pair of red and blue 3-D stereo glasses
- 1 working copy of Student Sheet 10.1c: Planetary Chart

For your group

- 1 large resealable plastic bag (from Lesson 12) filled with the following:
  - 2 hand lenses
  - 1 plastic spreader
  - 1 pack of 3 steel spheres
  - 1 metric measuring tape
  - 1 ring magnet
  - 1 flashlight
  - 2 D-cell batteries
  - 1 metric ruler, 30 cm (12″)
- Newspaper
- Paper towels
- 1 set of four Planetary Process Photo Cards
- 1 set of process materials from the following:

Wind erosion

- 1 plastic box filled with sand, flour, and cocoa (from Lesson 12)
- 1 sifter cup of all-purpose sand
- 1 sifter cup of flour
- 4 flexible straws

Water erosion

- 1 plastic box with drain hole and Velcro® filled halfway with dry sand
- 1 rubber stopper
- 1 cup with hole and Velcro®
- 1 bottle of clear tap water
- 1 bucket
- 1 large absorbent pad
- 1 small absorbent pad

Tectonics

- 1 plastic box filled with sand, flour, and cocoa (from Lesson 12)
- 1 sifter cup of sand
- 1 sifter cup of flour

Volcanism

- 1 plastic box filled with sand, flour, and cocoa (from Lesson 12)
- 1 piece of wide acrylic tubing
- 1 large plastic syringe
- 1 cup of flour, with lid
- 1 bottle of red water
- 1 plastic cup
- 1 plastic spoon

Getting Started

1. Within your group, review the photos of surface features shown in Figures 13.1–13.5 and discuss the following questions:

What observations can you make about each surface feature?

How do you think the surface features shown in the photos were formed?

Do you think the processes that created these features exist on other planets? Explain your answer.

2. Share your observations with the class.

3. Discuss what you already know about planetary surface features and what you want to learn about them. You may be asked to record your ideas in your science notebook.

R.L. SCHUSTER, UNITED STATES GEOLOGICAL SURVEY

Figure 13.1 *Debris flow in San Jacinto Mountains, California*

Figure 13.2 *Rippled sand dunes in Tibet*

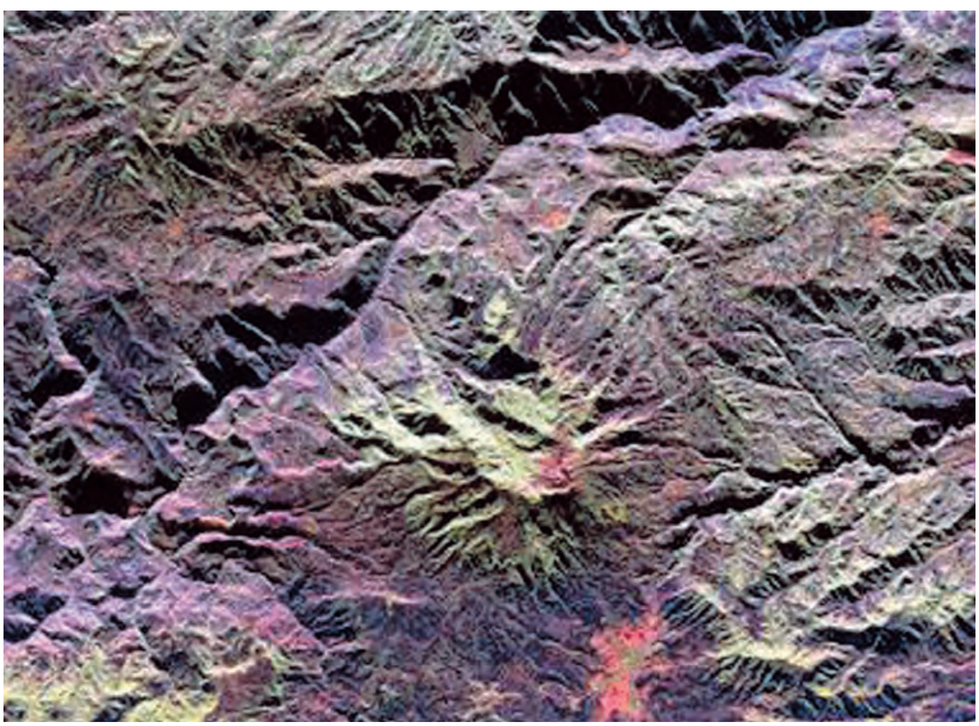


Figure 13.3 *Radar image of Galeras Volcano*

Figure 13.4 *The Colorado River cuts through limestone to create Marble Canyon, which is at the northeast end of the Grand Canyon in Arizona.*

R.E. WALLACE, UNITED STATES GEOLOGICAL SURVEY

Figure 13.5 *San Andreas Fault*

Inquiry 13.1
Investigating Planetary Processes

PROCEDURE

1. Look at the materials for this lesson. Which surface feature would your group like to model: wind erosion, water erosion, tectonics, or volcanism? Select one process, with your teacher's input.

2. Within your group, brainstorm ways that you might use the materials to model your selected process.

3. How will you record your observations? Discuss this with your teacher.

4. Review the Safety Tips with your teacher.

SAFETY TIPS

Work in a well-ventilated area to minimize the levels of dust in the air.

Wear indirectly vented goggles at all times during the investigation.

Do not throw or project the metal spheres.

Cover any work surface with newspaper to absorb excess water and to avoid slippery surfaces.

5. Read the appropriate background selection ("Wind Erosion," "Water Erosion," "Tectonics," or "Volcanism") to learn more about the planetary process you have selected. You will need your red and blue glasses to view some of the images. (Put the red lens over your left eye.) Use the information in the reading selection to help you plan how to model that process.

6. Gather the materials you will need. Each set is labeled with the name of the process. Cover your workspace with newspaper before beginning. If you are testing wind erosion, volcanism, or tectonics, use the boxes of sand, flour, and cocoa from Lesson 12. If you are testing water erosion, use a stream table (a plastic box that has a drain hole and is filled halfway with sand).

7. Conduct your investigation using the background reading selection as your guide.

8. When you are finished with your investigation, hold a flashlight parallel to the table to observe the surface features in your box. Record your observations on Student Sheet 13.1a or in your notebook, as instructed. Write what you did, what you observed, and why you think it happened. Record which photograph of Earth (Figures 13.1–13.5) most resembles your results.

REFLECTING ON WHAT YOU'VE DONE

1. Share your group's results with the class. With the classroom lights dimmed, again use your flashlight at "sunset" (parallel to the table) to show off the features of your new surface to other groups.

2. Once all groups have reported, get one set of Planetary Process Photo Cards. Review the four photo cards with your group. Discuss what you see. How do you think each surface feature was formed? Where do you think each photo was taken? Read the caption on the back of each photo.

3. With your teacher's guidance, go around the classroom to see other groups' results. Use your photo cards and Student Sheet 13.1b (or your notebook) to match each photo card to the results in each group's plastic box. How do you think these features were formed? Which feature on Earth (Figures 13.1–13.5) matches the feature shown in each photo card? Record your observations.

4. Discuss your findings with the class. Then clean up.

5. Did you know that the relative positions of surface features can help scientists decide the relative age of the surface feature? (For example, a crater on the surface of a lava flow shows that the crater is younger than the lava. However, if lava fills the crater, then the crater is older.) Look again at the photos in this lesson and Lesson 12. (You may even be able to use the computer program *Explore the Planets* to view additional images.) Can you tell whether each crater shown is younger or older than the land around it?

6. With your class, return to the Question F folder for Lesson 1 and its photo card. What processes created each landform? Do these landforms exist on other planets or moons? Review your self-stick responses from Lesson 1. As a class, work together to remove any notes that now seem incorrect. Add any new ideas you have to the folder.

7. Read "Wet Like Earth?" Answer the following question in your science notebook.

   A. Does water exist on Mars? Explain.

8. Read "Mission: Mars." Add any new information about Mars to your working copy of Student Sheet 10.1c: Planetary Chart and to Student Sheet 10.1b: Planetary Brochure Outline if your Anchor Activity planet is Mars.

WIND EROSION

Planetary Winds

Wind is gas in motion. Wind can exist only on planets with atmospheres. Three of the terrestrial planets—Mars, Venus, and Earth—have atmospheres and therefore have winds. Mercury, the Moon, asteroids, and many of the moons of the gaseous planets do not have an atmosphere as we know it. This means they do not have winds.

The thinner (or less dense) the atmosphere, the faster the wind has to blow to make an impact on the planetary or lunar surface. It takes a powerful wind to move rock fragments on Mars, because its atmosphere is so thin. It takes very little wind to move rock fragments on Venus, which has a thick atmosphere. The density of Earth's atmosphere is somewhere between that of Mars and Venus. Streaks on a planet's surface caused by wind, like in the photo shown here, are evidence that wind moves smaller particles around. Wind erosion happens when gas molecules bounce against the rocks and other surfaces. A dense atmosphere has a lot of gas particles. This means that a dense atmosphere can erode a surface faster than a thin atmosphere in the same amount of time.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, VIKING ORBITER IMAGE

Wind streaks on Mars

Martian Winds

The Martian surface has been eroded by winds that swept away fine particles and left behind boulders. Boulder fields that were found at the *Viking 1* landing site on Mars resemble deserts on Earth.

You've seen sand dunes on Earth. But do sand dunes exist on Mars? Get out your red and blue glasses and examine this dramatic photo of dunes on Mars. This field of wavy dunes is found in Nili Patera, a volcanic depression in central Syrtis Major, the most noticeable dark feature on Mars—the "red planet."

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION/JET PROPULSION LABORATORY/MALIN SPACE SCIENCE SYSTEMS

3-D image of sand dunes on Mars. Two different images from the orbiting Mars Global Surveyor *spacecraft were combined to make this stereo picture. Notice the ripples along the sand dunes.*

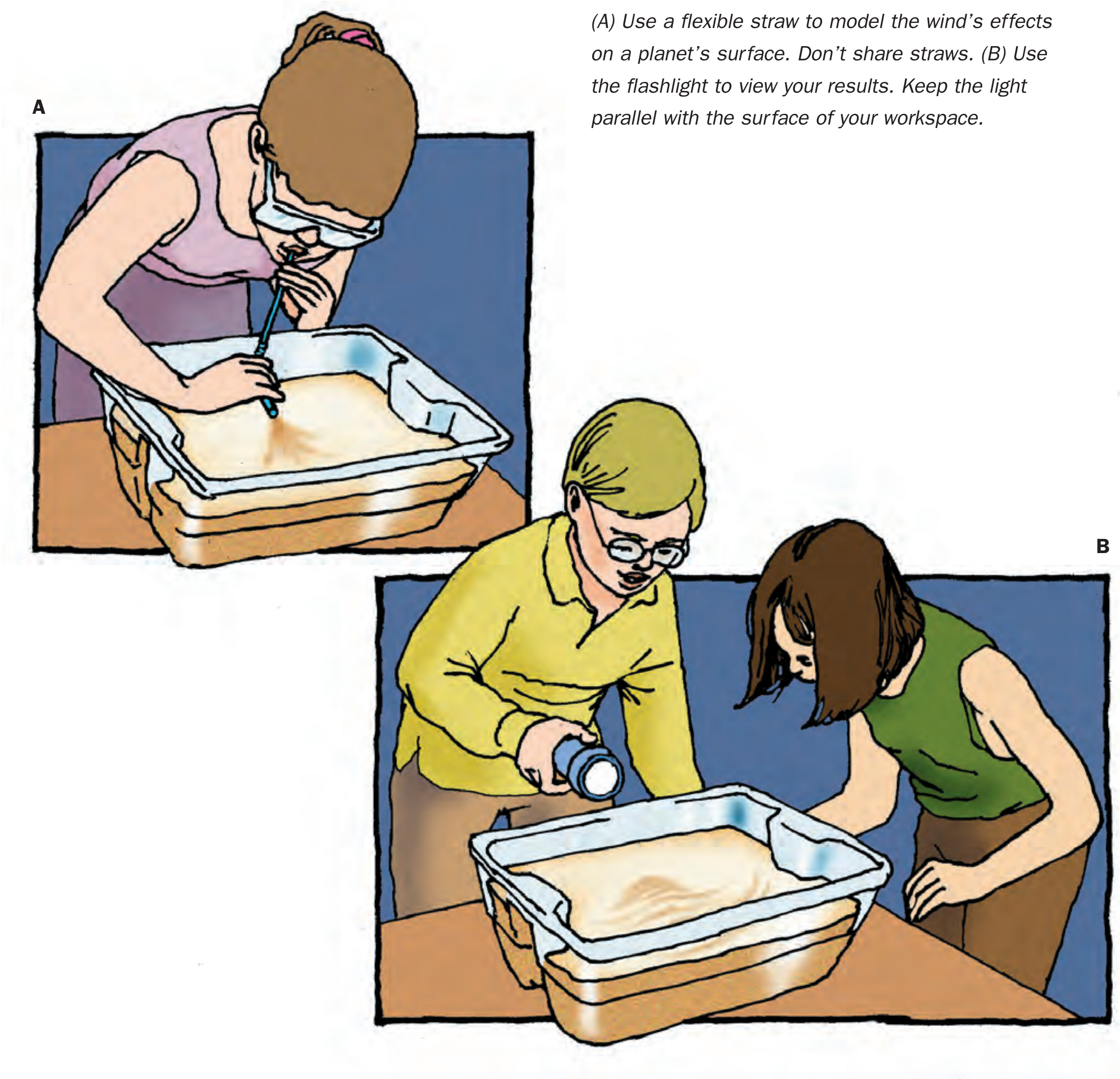
Winds on Venus

The upper atmosphere of Venus is very windy. The winds there reach speeds of up to 350 kilometers per hour. In the lower atmosphere, the wind speed decreases until it is nearly zero at the surface. The wind blows in the direction of the planet's rotation. Since Venus rotates very slowly, the Sun shines for a long time on the surface. As the Sun heats the surface of Venus, the warm surface also heats the air above it. The rising warm air may be responsible for Venus's winds.

Modeling Wind

You can use a straw and a box of sand, flour, and cocoa to model the effect of wind on a planet's surface (see the illustration on the next page). Do the following:

1. **With your plastic spreader, smooth the layers of sand, flour, and cocoa in your plastic box. Don't worry if they mix.**
2. **Sprinkle a layer of sand on top of your mixture.**
3. **Sprinkle a thin layer of flour on top of the sand.**
4. **Use your flexible straw and the illustration as your guide. Blow very gently onto the surface of your plastic box. (Do not share straws.) What happens when wind blows over a fine dust? In which direction does the dust move? How do large and small particles change the effects of wind? Can you create dunes and wind streaks like those shown in the photos?**
5. **Use your flashlight to examine the wind streaks and sand dunes you have created. Remember that the best time to view planetary surface features is when the Sun is setting (when your light is horizontal and parallel with the table), not when it is directly overhead.**



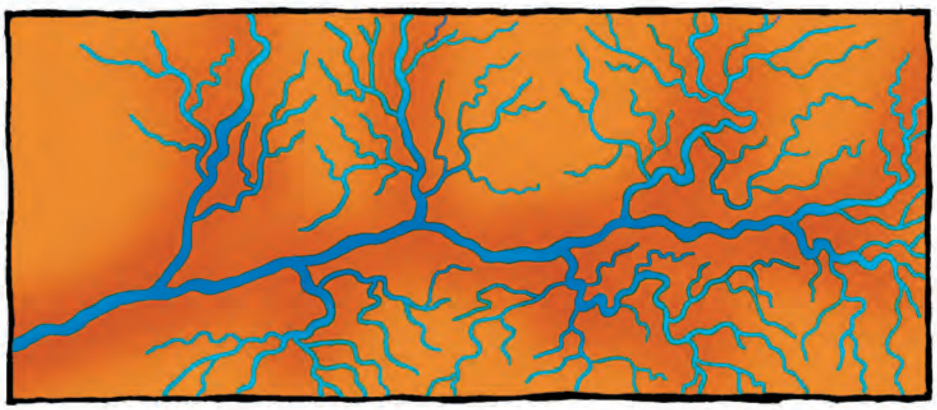
(A) Use a flexible straw to model the wind's effects on a planet's surface. Don't share straws. (B) Use the flashlight to view your results. Keep the light parallel with the surface of your workspace.

WATER EROSION

A high mountain or plateau forms when forces within a planet lift up a relatively flat area. Flowing water cuts deep canyons into the highlands. Water typically flows from highlands to lowlands. The source of that water can include underwater springs, melting snow or ice caps, or rain. The flowing water erodes rock and creates canyons, valleys, and stream networks. Large boulders and small rock fragments may move with the water and help further erode the rock. Complex stream patterns often look like networks of nerves in the human body (see the illustration). These patterns are common signs of water erosion on a planet or moon. A stream pattern depends on the slope, topography, soil type, and amount of water that flows across the surface.

Water on Mars

Running water formed the Grand Canyon on Earth, but Valles Marineris—a huge canyon on Mars—was formed by a combination of forces, mostly tectonics, although water is believed to have played a later role in shaping the canyons. After the cracks formed from tension in Mars's crust, deep springs seeped through the cliffs. This led to landslides. Valles Marineris is about as wide as the United States—some 4000 kilometers. The entire Grand Canyon could fit inside a small section of Valles Marineris.



Stream patterns such as the one shown here are common signs of water erosion.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION. IMAGE PROCESSING BY UNITED STATES GEOLOGICAL SURVEY

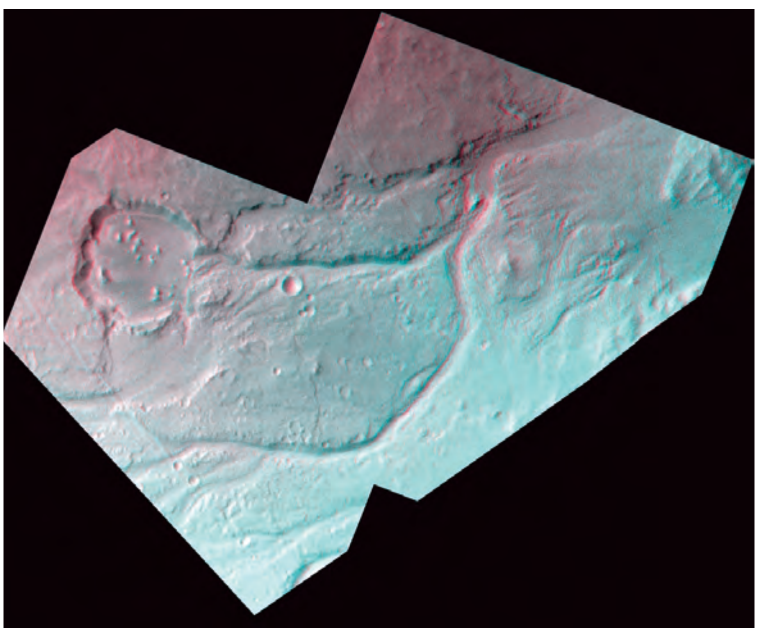
Valles Marineris

How does water erosion affect existing craters on a planet's surface? Get out your red and blue glasses and examine this dramatic view of water channels on Mars. The channels, which were carved by water, are probably 200–300 meters deep. Water from one set of channels broke through a 12–kilometer-wide impact crater (center left), and formed a large lake. The smooth floor may actually be lake sediment.

Modeling Water Erosion

You can use a stream table to model water erosion on planetary surfaces (see the illustration). Investigate water erosion by doing the following:

1. **Place the large absorbent pad on your table with the plastic side face down over your newspaper. Place the small absorbent pad on the floor.**
2. **Position your "stream table" on the large pad so the drain hole hangs over the edge of your workspace.**
3. **Using the plastic spreader, push the sand away from the drain hole. Make the sand have a slope.**
4. **Remove the rubber stopper from the drain hole.**
5. **Hold the bucket directly under the drain hole, over the pad on the floor.**
6. **Attach the Velcro® on the cup to the Velcro on the stream table. Rock the cup back and forth until the cup is secured to the box.**
7. **Pour the water slowly into the cup. Try to keep the water at the top of the cup at all times. Do not touch the sand once you start to pour. Observe your results.**



This Viking *3-D view shows Vedra Valles, a group of now-dry channels that once flowed eastward into the giant Chryse Basin on Mars. These channels were carved by running water when Mars had liquid water on its surface.*

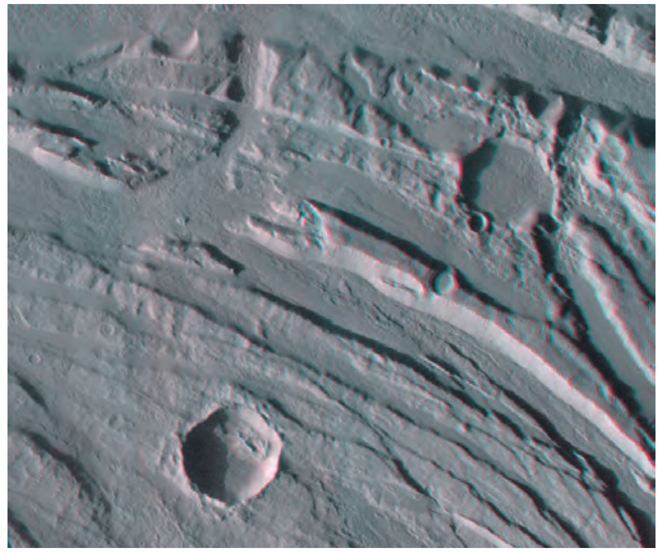
You can use a stream table to model water erosion on a planet's surface.

TECTONICS

Tectonics is the study of how the outer layer of a planet can shift and break. Faulting occurs when parts of that outer layer move past one another. Folding (compression) occurs when parts of the outer layer collide and bend. Thinning occurs when the outer layer stretches. Jupiter's moon Ganymede (see the photo below) and Saturn's moon Enceladus both exhibit examples of faulting. Tremendous stress was created when large parts of the outer layer moved past each another. This buildup of stress eventually caused the rock to break along fault lines.

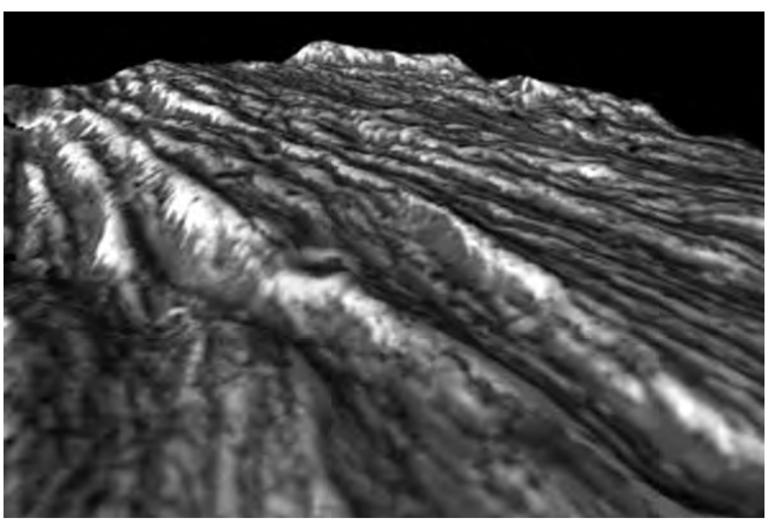
When the rocks on the outer layer of a planet collide, the rock folds. The compression stresses caused by those collisions can create wrinkle ridges in the surface of a planet or moon. Rock also can be stretched, which produces alternating large valleys and high standing blocks. These alternating blocks and valleys are evident on Mars and on Ganymede.

Earthquakes occur along faults on Earth. But what do faults look like on other planets? Get out your red and blue glasses and examine the dramatic view of faults on Mars. Acheron Fossae is a set of valleys on Mars formed when the crust stretched and fractured. When two parallel faults form, the block of crust between them may drop down, with a ridge forming between them.



Acheron Fossae is a set of valleys on Mars

If an asteroid or comet hits a planet or moon, it can fracture its surface. Strong seismic waves result from the energy of the impact and move through the planet's or moon's surface. Fracture lines might radiate outward from the crater. Extreme temperature changes from day to night also can cause fracturing. (Think of how an ice cube fractures when you place it in a cup of hot water.) Fracturing due to extreme temperature changes is especially common on planets or moons without an atmosphere. An atmosphere acts as a blanket that holds in heat at night and protects the surface from extreme high temperatures during the day.



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION/ IMAGE PROCESSING BY BROWN UNIVERSITY

The patterns of ridges and grooves indicate that pulling apart and horizontal sliding have both shaped the icy landscape of Jupiter's moon Ganymede.

Modeling Tectonics

You can model planetary tectonics by doing the following:

1. **Use your large steel sphere and your plastic box of sand, flour, and cocoa from Lesson 12 to investigate the effects of impact cratering on a surface. Do fractures form around the crater?**
2. **Extreme changes in temperature, planetary shrinking, and other internal forces in a planet may cause it to twist or pull. Examine the effects of pulling and twisting forces on the surface of your box (see the illustration at right). Can you see cracks and wrinkle ridges forming in the surface as you twist and pull the sides of the box?**
3. **Now use your plastic spreader to push (compress) the layers of sand and flour (see the illustration below). Were you able to shift the layers? Do you see evidence of faulting?**

You can use sand, flour, and cocoa in your model to test the effects of pushing, pulling, and twisting tectonic forces on a planet's surface.

Model faulting in your plastic box by pushing the layers of sand and flour with the plastic spreader.

VOLCANISM

Magma is made up of melted rock, crystals, and dissolved gases. It is found deep in a planet's interior. When magma erupts onto the planet's surface, it forms lava. This eruption creates distinctive landforms, such as lava plains and volcanoes.

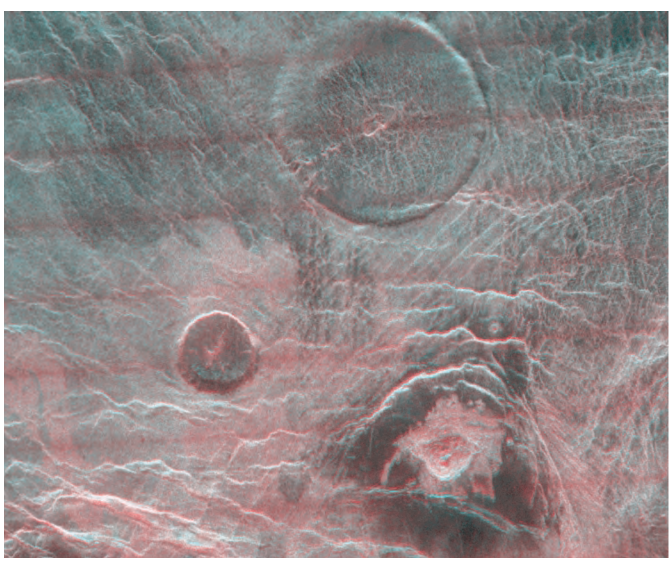
Volcanoes on Planets and Moons

Dark, flat lava plains cover about 17 percent of the Moon's total surface. These plains are called "maria," from the Latin word for "seas." You can see the maria on the surface of a full Moon on a clear night. The Moon's maria are made up of volcanic rock similar to the rock on Earth's ocean floor. The lava that formed the maria flowed long distances. Many maria were formed as lava flooded low-lying areas, such as the bottom of an impact crater. Older lava flows on the Moon have been covered by younger flows or have been pocked with impact craters.

Jupiter's moon Io has numerous low, flat volcanoes called "shield volcanoes." Most shield volcanoes have dark peaks with long lava flows streaming from them. The lava ran gently down the sides of the volcano. On Venus, the shield volcano Sif Mons resembles many of the shield volcanoes on Earth. The volcano Olympus Mons on Mars is the largest shield volcano in the solar system. It measures 600 kilometers across.

The volcanoes on Venus have unusual circular, flat-topped domes called pancake domes. Wearing the red and blue glasses, examine the view of pancake domes on Venus. The largest dome in this scene is 65 kilometers across and roughly 1 kilometer high. This group of pancake domes is called Carmenta Farra. A small crater near the center of each dome may be the source for that dome's lava flow.

Why are shield volcanoes on other planets so large? Scientists believe that the crust of other planets, unlike Earth's crust, is not made of moving plates. Without plate tectonics, the volcanic vents on other planets may remain undisturbed for a long time. As a result, other planets have huge shield volcanoes many times larger than those on Earth.



3-D view of volcanic pancake domes on Venus

Volcanism (continued)

Volcanism (continued)

Modeling Volcanism

You can model volcanism on other planets by doing the following:

1. **Lava is often viscous (which means that it sometimes will flow slowly). Mix red water and a small amount of flour in a cup to create a viscous model "lava." Don't make it too thick, or it will not flow through your tube.**
2. **Bury one end of your 90-cm tubing beneath the sand. Turn the end so it faces up.**
3. **Attach the unburied end of the tubing to the syringe (see the illustration).**
4. **Pour lava into the syringe. Cap the syringe.**
5. ***Very slowly* compress your syringe to model lava eruption on your planetary surface. What do you observe? What happens when lava nears your craters?**

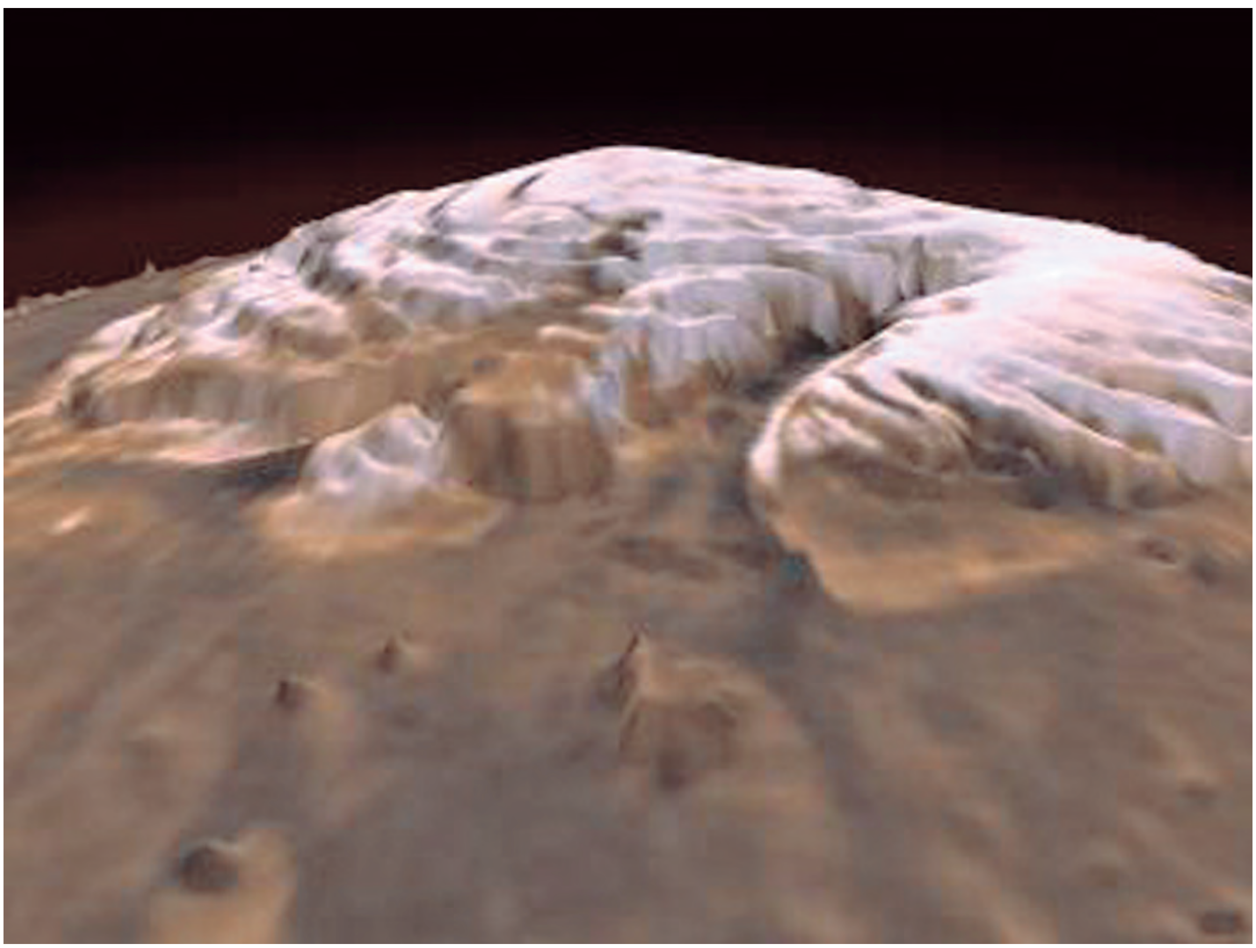
You can use a syringe and long tubing beneath the sand to model the eruption of lava onto a planet's surface. To create your lava, thicken your red water with flour. What would a lava flow do to the craters on the planet's surface?

Wet Like Earth?

Scientists have long known Mars has plenty of water in the form of ice. Its large polar ice caps have been visible to people looking through telescopes here on Earth for many years. Scientists also have observed channels and valleys on Mars that indicate that water might have flowed across its surface long ago.

But scientists did not believe that Mars had *liquid* water. How could it? Mars is colder than Antarctica and far dryer than any place on Earth.

However, in June 2000, scientists at the NASA announced an amazing discovery. New images transmitted from the Mars *Global Surveyor* spacecraft showed what looked like gullies on the surface of that planet. Gullies are ravine-like features on a planet's surface that have been carved out by flash floods. If NASA scientists were correct, then there is evidence Mars has had flowing, liquid water in its very recent past.



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION/JET PROPULSION LABORATORY/GODDARD SPACE FLIGHT CENTER

These polar ice caps prove that Mars has plenty of water in the form of ice.

Strong Evidence

The gullies in the NASA images are found on the sides of large craters or valley walls. Large pools of water, either from the surface of the planet or from beneath the surface, have flowed from them. Areas of accumulated rocks and other debris at the lower ends of the gullies are evidence that the water flow probably had great force.

These gullies are important evidence that liquid water existed in the recent past on Mars. The gullies have not been disturbed by wind erosion, asteroid impact, or volcanic activity. Scientists conclude that this means the gullies are extremely young.

During the first two decades of this century, NASA will send at least six missions to Mars to explore the planet's surface. The spacecraft will include orbiters with powerful telescopes and other sensors, a roving robot laboratory, and even a vehicle that will scoop up Martian soil and return it to Earth. These Mars missions will be looking for liquid water.

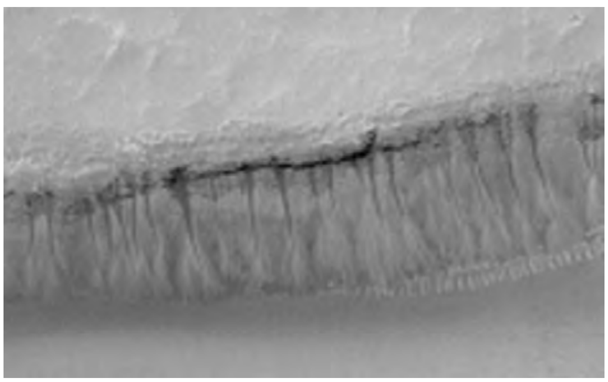
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION/JET PROPULSION LABORATORY/MALIN SPACE SCIENCE SYSTEMS

Small gullies on the walls of this valley system were created when a liquid—probably water—trickled through the walls until it reached the cliff, where it ran downhill to form the channels and fan-shaped aprons at the bottom of the slope.

The Martian Riddle

A long time ago, conditions on Mars may have been similar to those on Earth today. The channels tell us that mighty Martian rivers may have once flowed into oceans. The atmosphere then may have been more dense and full of oxygen. Temperatures may have been much warmer. If so, life may have existed there—and may exist there still. □

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION/JET PROPULSION LABORATORY/MALIN SPACE SCIENCE SYSTEMS



Evidence of liquid water in a crater on Mars, as taken by the Mars Global Surveyor *Orbiter*

Colonizing Mars

If scientists detect liquid water on Mars, will humans try to live on the planet? Even though the Martian atmosphere is too thin to breathe, humans can make oxygen from water. They also could generate hydrogen for rocket fuel from water. Water also means that humans could grow their own food.

When humans do reach Mars, they will begin to try to answer an important question—what happened to Mars? We need to know what caused the dramatic change in the Martian climate, which used to be so like our own. If we can find out, we might be better able to protect Earth. Martian water will help us learn such lessons.

Mission: Mars

Mars's reddish color can be seen from Earth. So can its white polar caps. Some astronomers in the late 1800s saw dark lines running across the surface of the planet. Percival Lowell and other U.S. scientists believed these lines were canals, built by Martians to transport water!

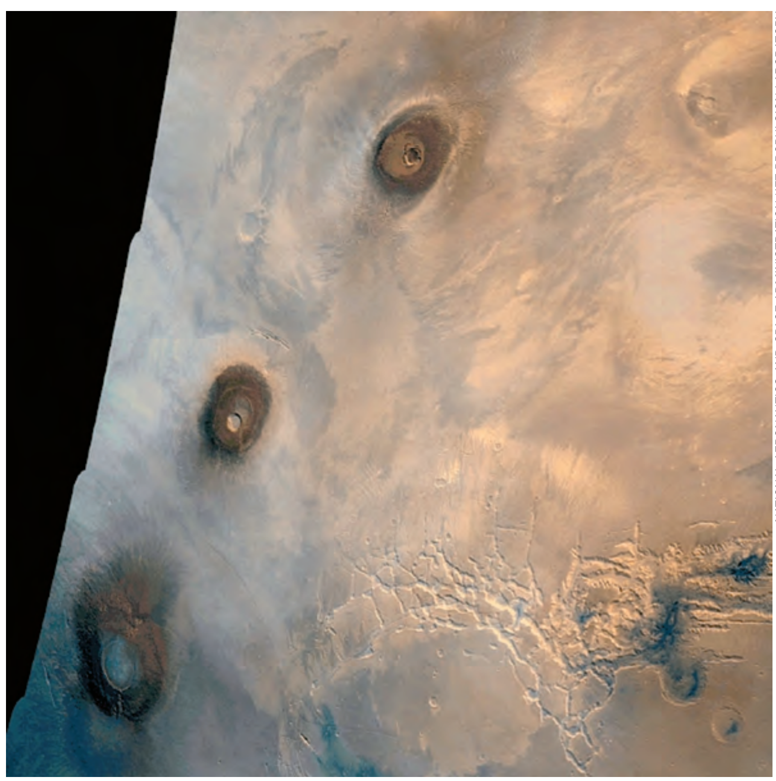
Not until 1965 would people know for sure what those lines were. In that year, *Mariner 4* flew by Mars and found a moonlike landscape, but no signs of life. Four years later, two other Mariner flyby missions confirmed these findings. Still, scientists believed that more time was needed to understand the red planet. That meant going into orbit.

Mariner 9 was the first spacecraft to orbit another planet. It arrived at Mars in November 1971, and orbited the planet for nearly a year. During that time, it witnessed a month-long dust storm. It also found canyons, floodplains, and other signs of ancient water. Before the century was over, other spacecraft—including *Viking 1* and *2,* the Mars *Pathfinder,* and the Mars *Global Surveyor*—would visit Mars.

Viking 1 and *2*

Both *Viking 1* and *2* arrived at Mars in 1976. Each spacecraft was made up of an orbiter and a lander. The orbiter was designed to find a landing site for the lander, and to relay information from the lander to scientists on Earth. *Viking 1* and *2* were designed to study Mars for several months—instead, they provided scientists with data for several years.

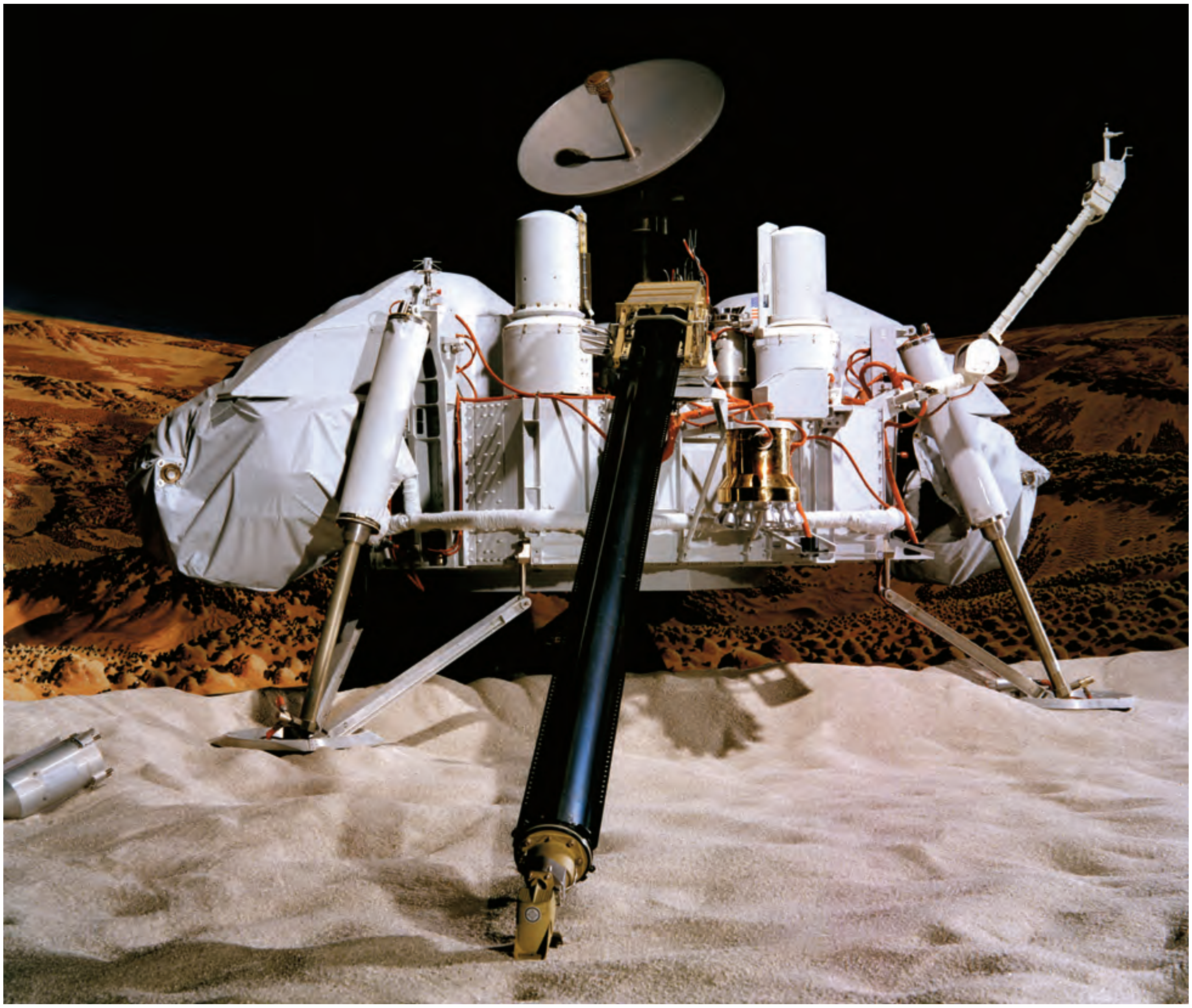
Images from the orbiters showed volcanoes, lava plains, canyons, and craters. They also showed dry valleys and channels. As expected,



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION/JET PROPULSION LABORATORY

A color mosaic of images taken by the Viking 1 *orbiter shows the eastern Tharsis region on Mars. Notice the three volcanoes on the left and the canyon in the lower right-hand corner.*

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION/JET PROPULSION LABORATORY



Viking *lander*

much of the landscape looked as if it had been carved by running water. The images also showed that Mars is divided into two main regions: northern low plains and southern cratered highlands.

With the orbiters flying overhead, the *Viking* landers descended through the thin Martian atmosphere. Their instruments revealed that carbon dioxide is the major gas surrounding Mars. They landed safely on opposite sides of the planet in iron-rich soil—it is this iron that gives Mars its reddish color.

The landers' cameras searched the landscape for large forms of life, but they didn't find any. Instruments on the landers conducted experiments to determine if the Martian soil at those sites contained microscopic life. They didn't find any.

The *Viking* landers did find a crusty surface that resembles Earth's crust. Tests also showed that Mars is extremely stable. There were no tremors, quakes, or volcanic eruptions.

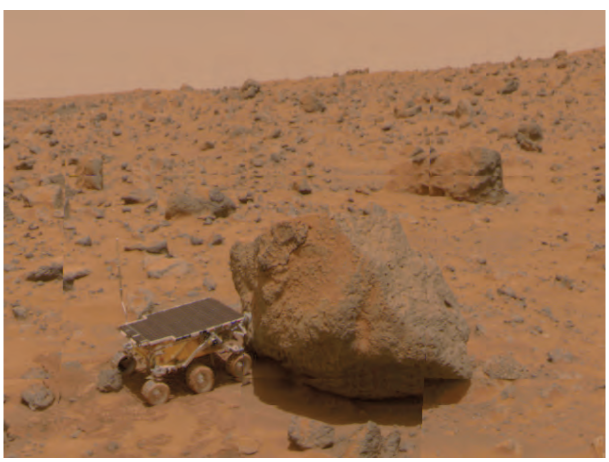
As of this writing, the *Viking* landers and orbiters were the longest-lived laboratories on another world, and they have provided the most complete view of Mars.

Mars *Pathfinder*

On July 4, 1997, the Mars *Pathfinder,* surrounded by huge air bags, bounced to a stop on the Martian surface. It had landed in an ancient plain where scientists believe a catastrophic flood left behind loads of rocks. Inside the *Pathfinder* spacecraft was a rover named *Sojourner.* It would become the first rover to operate on another planet. *Sojourner's* job was to analyze rocks and soils.

Data also showed that Mars is drier and dustier than any desert on Earth. The dust often spins in gusts, called "dust devils." Clouds that cover parts of Mars consist of water ice condensed on the reddish dust.

Pathfinder's lander operated nearly three times longer than its expected lifetime of 30 days. *Sojourner* operated 12 times its expected lifetime of seven days. Together, they sent back 2.3 billion bits of information, including more than 16,500 images.



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION/JET PROPULSION LABORATORY

Sojourner *is taking a measurement. Notice the two-toned surface of the large rock. Windblown dust may have collected on the surface (the rock is leaning into the wind). Or this rock may have broken off from a larger boulder as it was deposited in the ancient flood that scoured this area.*

Name This Roving Robot!

Imagine what it would be like to name the rover for the Mars Pathfinder mission. Valerie Ambrose, a 12-year-old student from Bridgeport, Connecticut, didn't have to imagine. In 1995, she won a contest held by the Planetary Society, a nonprofit organization dedicated to the exploration of the solar system.

Kids between the ages of 5 and 18 could enter the contest. The Society said that the rover had to be named for a heroine from mythology, fiction, or history (no longer living). Entrants had to submit a fully researched, 300-word essay explaining their choice of a name for the rover.

Entries came from around the world. Valerie suggested that the rover be named after Sojourner Truth, the African-American activist who wanted slavery abolished and who promoted women's rights. Sojourner Truth lived in the Civil War era, and she traveled around the United States speaking for the rights of all people to be free and for women to fully participate in society.

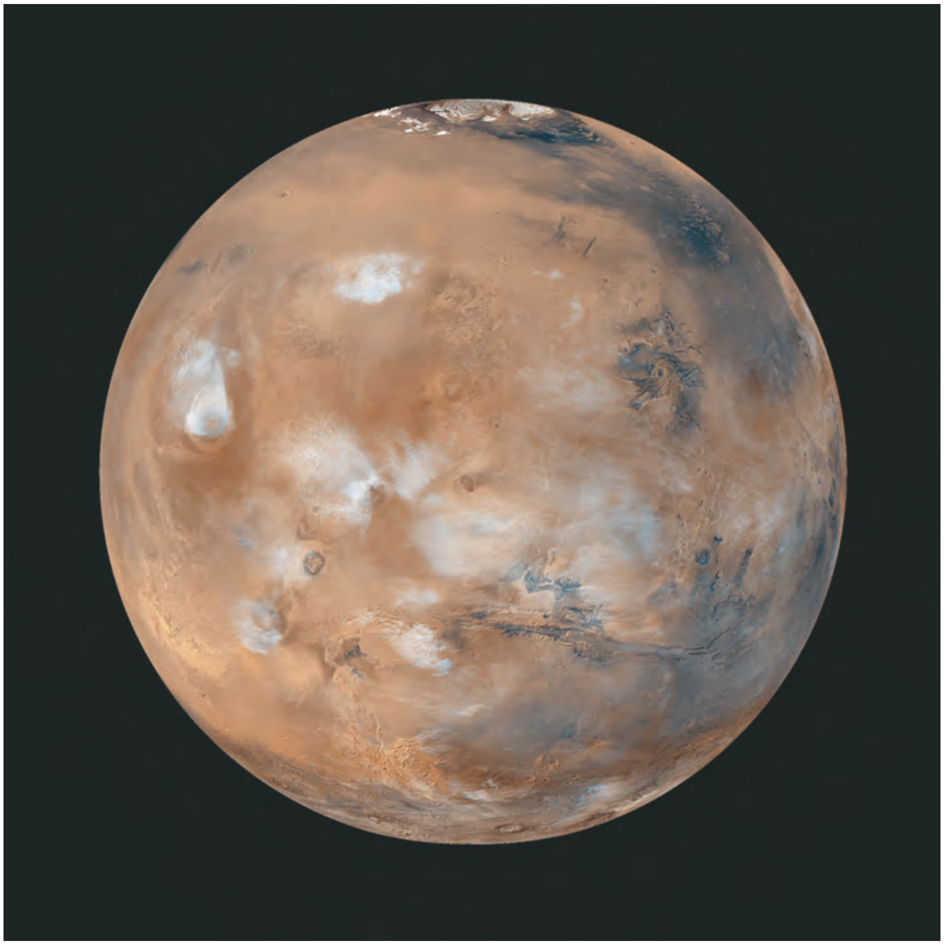
Finally, the day to name the winner arrived. Valerie won! NASA chose the name *Sojourner* for its Mars *Pathfinder* rover. The name honors Sojourner Truth. It is also appropriate because "sojourner" means traveler.

Another student's entry was also a winner. Second-place winner Deepti Rohatgi suggested Marie Curie, after the Polish-born chemist who won the Nobel Prize in 1911 for her discovery of the elements radium and polonium. NASA used Marie Curie as the name for its second Mars rover.

It's exciting to think that students just like you named these famous rovers. Who knows, maybe one day you may name a rover, a comet, an asteroid, or even the next planet in space!

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION/JET PROPULSION LABORATORY

This image shows the Global Surveyor *above Mars. Olympus Mons is in the background.*



Twelve orbits a day provide wide-angle cameras a global "snapshot" of weather patterns across Mars. Here, bluish-white water ice clouds hang above the Tharsis volcanoes.

Global Surveyor

The Mars *Global Surveyor,* launched in November 1996, was equipped to fly at a low altitude in a nearly pole-to-pole orbit. This speedy spacecraft orbited Mars 12 times a day.

Surveyor has returned images of clouds hanging over gigantic volcanoes, dust storms that blow around the entire planet, and polar caps that enlarge in the winter and shrink in the summer.

Surveyor confirmed that these polar caps consist of layers of dust and frozen carbon dioxide. Scientists believe that such layers hold secrets to seasonal changes on Mars. They also may be one of the best places to search for evidence of past life on the planet.

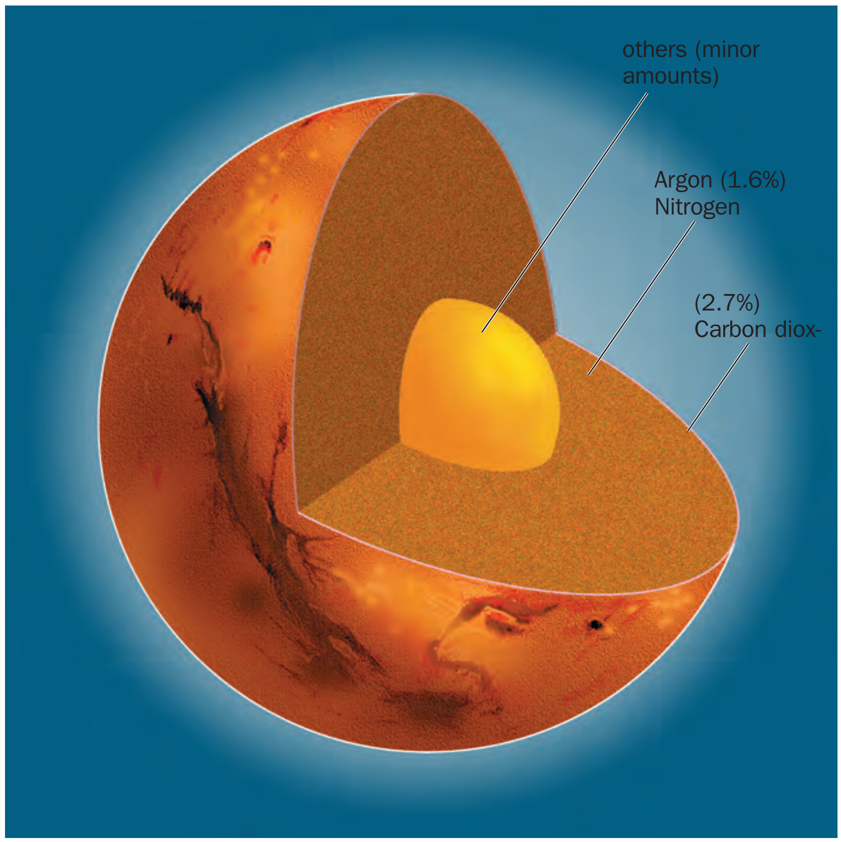
Surveyor made another discovery that increases the chances of finding traces of past life. Mars, it turns out, once had a magnetic field, much as Earth does today. This is significant because magnetic fields shield planets from harmful radiation.

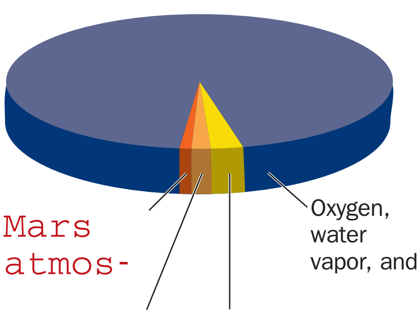
Only Earth and Mars have just the right temperature—neither too hot nor too cold—to support life as we know it. Scientists don't yet know if Mars ever developed life. But this rocky world is the only other planet in our solar system where it is possible for humans to walk around and explore. It may even one day be a place to live. ☐

PLANETARY FACTS: Mars

Mars: Quick Facts			
Diameter	6792 km	Average temperature	–55 °C
Average distance from the Sun	228,000,000 km	Length of sidereal day	24.62 hours
Mass	64×10^{22} kg	Length of year	687 Earth days
Surface gravity (Earth = 1)	0.38	Number of observed moons	2

ide (95.3%)





Mars atmos-
phere

Did You Know?

- Mars was named after the Roman god of war because the red color of Mars looks like spilled blood.
- Olympus Mons, a volcano on Mars, is 24 kilometers high—more than twice as high as the tallest volcano on Earth, and three times as high as Mount Everest.