Is There Liquid Water on Mars?

Purpose

To have students analyze actual data and images to assess whether there is liquid water on Mars

Overview

Groups analyze temperature and pressure graphs from the first 30 days of the Pathfinder mission and discuss whether liquid water could have existed under these conditions. The pressures make water theoretically possible although the temperatures are below water's freezing point. Next, students look at images of Mars. By interpreting the landforms and comparing a river-cut valley on Mars with Earth's Grand Canyon, they identify water as the agent that shaped the surface. They hypothesize about how water could have flowed across the Martian surface, even though current conditions make it virtually impossible for liquid water to exist. Finally, they consider how the considerable amount of water that seems to have flowed across the Martian surface could have disappeared.

Key Concepts

- Current climatic conditions make the existence of liquid water on Mars virtually impossible.
- Features on the Martian surface provide strong evidence for past flows of large amounts of water.

Context for This Activity

The Viking and Pathfinder missions have collected temperature and pressure data from the Martian surface. In this activity, students analyze some of these data and realize that the pressure at the Martian surface is so low that no liquid water can exist. Given this fact, they are then challenged to explain the existence of water-related features on Mars.

Skills

- *Analyzing* graphs
- *Interpreting* images
- *Measuring* distances using a map scale
- *Comparing* landforms on two planets
- *Developing* hypotheses to explain apparent contradictions
- *Drawing* conclusions and *communicating* them to others

Common Misconceptions

- Mars has liquid water (for example, the famous "canals").
- Liquid water can exist on Mars.
- Mars is dry and never had any water.
- Massive amounts of surface water cannot just disappear from view.

Materials

Pathfinder's temperature and pressure graphs, Images 1–15 in Appendix I, Notes on the Image Set in Appendix H

Preparation

- Plan how to conduct a discussion based on the Pathfinder data.
- Plan how you want students to proceed through the image set.

Time: 2 class periods

Background

After a 7-month, 300-million-kilometer journey, Mars Pathfinder landed on Mars July 4, 1997. The lander contained the radio link to Earth, most of the science instruments, and a rover named Sojourner (Figure 6.1). Sojourner was used to deploy two imagers and an instrument that could determine the composition of rocks and minerals on the surface.

Figure 6.1. An artist's rendition of the Mars Pathfinder and Sojourner on Mars.

Pathfinder also carried temperature, pressure, and wind sensors. Temperature was measured by thin-wire *thermocouples* mounted on a mast that was deployed after landing. The thermocouples monitored atmospheric temperatures 25, 50, and 100 centimeters above the surface. Atmospheric pressures were measured by a mechanical sensor (basically an aneroid barometer) similar to the one used by Viking in the mid-1970's. Visit the Jet Propulsion Laboratory (JPL) web site (*http://www.jpl.nasa.gov/*) for additional information on the instruments. With its instruments, the Pathfinder mission was able to investigate the structure of the Martian atmosphere, the weather and meteorology on the surface, the surface geology, and the form, structure, and composition of Martian rocks and soil.

The Martian atmosphere is made almost entirely of carbon dioxide (CO_2)—more than 95 percent. Because the weak Martian gravitational field has retained relatively few gas molecules, this tenuous atmosphere has a very low mass. On Earth, you would have to go about 13 kilometers above the surface to find an equivalent density and pressure. Keep the following points in mind when analyzing the temperature graph:

- The Mars Pathfinder landed at the height of summer in Mars' northern hemisphere (i.e., the Earth equivalent of mid-August) at a latitude of 19.3 degrees N, roughly the latitude of the Tropic of Cancer on Earth.
- The temperature never reached the melting point of ice, 273.16 kelvins.

  The Kelvin scale begins at absolute zero, and 1 kelvin equals 1 degree celsius. Ice melts ate 273.16 kelvins, and water boils at 373.16 kelvins.

- The steep slopes of the graph's temperature line show how quickly temperatures change in response to the available sunlight.
- The large daily temperature range suggests that the atmosphere is a poor insulator.
- The temperature spike on the first *sol* (a Martian day, 24.67 hours) occurred because the meteorological mast was not deployed until the afternoon of sol 1, so the thermocouples were positioned just above a solar panel. The dark panel absorbed sunlight and warmed the thermocouples.
- The gaps in data were caused by Pathfinder shutting itself down after sensing a problem. The problem turned out to be competition for memory. While the meteorological instruments were collecting data, the camera was panning the landing area, a memory-intensive task. Pathfinder sensed the overload, shut itself down, and reset itself. Each time, it took nearly 5 hours to resume data collection. Once engineers diagnosed the problem, they restricted meteorological data collection to 3:00–7:00 p.m. On sol 16, engineers sent a software "patch" that permitted data collection throughout the day.

The pressure at the Pathfinder landing site ranged from roughly 6.4–6.85 millibars during the first 30 sols. The pressure is close to the minimum at which liquid water can exist—6.13 millibars. Students can use the phase diagram to discuss how water would behave at these pressures. To boil at 6.4 millibars, water would need to warm to above 0.6 degrees celsius. Between zero and 0.6 degrees celsius, it would evaporate in the desiccated Martian atmosphere. Keep the following points in mind when analyzing the pressure graph:

- Pressure is temperature related. The pressures are highest around 6 a.m., when the atmosphere is at its coolest and densest. The pressures are lowest around 6 p.m., when the atmosphere is at its warmest and least dense.

- The pressure spike on sol 1 is not yet understood.
- The blips in the middle of the day are caused by thermal tides. The side of a planet facing the Sun warms, while the side away from the Sun cools. Thus, the temperatures and, by extension, the pressures are constantly changing on a rotating planet. On-shore and off-shore breezes along a coast are analogs of how changing temperatures can affect air pressure and the movement of air. The continuous changes between the warm and cool sides of the planet set up thermal tides that travel a planet much the way our ocean tides sweep across Earth. However, rather than being based on gravity, thermal tides are based on heat. Earth has similar blips, but, because of our considerable atmospheric pressure of around 1,013 millibars, they are far less noticeable.
- Pathfinder landed at the height of winter in the southern hemisphere. Because of the elliptical orbit of Mars, the southern winter is colder than the northern winter. Consequently, more CO_2 sublimates out of the atmosphere and onto the southern pole as frost during this time. This buildup of frost deprives the atmosphere of gaseous CO_2 molecules and decreases the planet's pressure. The pressure minimums around sol 20 are also the annual pressure minimums for the planet. As the southern hemisphere warms, the CO_2 frost will sublimate back into the atmosphere and raise the pressure. The graph shows this pressure increase beginning to happen. Martian pressures reach their maximums just after the solstices.
- Pressure reflects planetary trends, while temperature is a function of local factors, such as the color and nature of the area within a few hundred meters of the sensor.
- The decreasing range of daily pressures during sols 20–30 is not yet understood.

The Viking missions collected atmospheric data from 1976 to 1978. If students want to analyze long-term trends, look at seasonal variations, or study the impact of dust storms, have them obtain the Viking data from the atmospheric node of NASA's Planetary Data System (*http://pds.jpl.nasa.gov/pds_home.html*). They can also find the complete Pathfinder data sets at this node.

The virtual impossibility of water on Mars poses a perplexing dilemma—how to explain all the surface features that were apparently produced by flowing water. While most scientists embrace the idea that water flowed across the Martian surface, how long it flowed, the amounts that flowed, and the climatic conditions under which it flowed are still being debated. Images of channels, meanders, and eroded landforms on Mars strongly suggest flowing water. Step 4 of the "Procedure" below reinforces the idea of sustained, long-term flows by comparing two river-cut valleys on Earth with what seems to be a meandering river valley on Mars (Figure 6.2). The "Notes on the Images" provide a more complete discussion of the evidence for water on Mars.

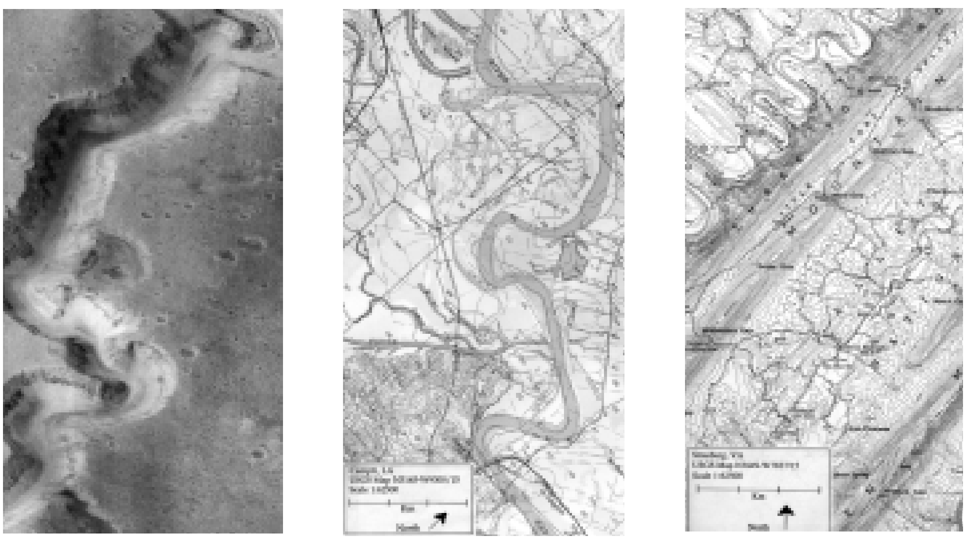


Figure 6.2. Nanedi Vallis on Mars shows similarities to river-cut valleys on Earth. See Images 11, 12, and 13 for a larger scaled view of these valleys.

Preassessment

(a) *Students Take a Position and Become Aware of Their Preconceptions:* Ask students:

- If a person visiting Mars gets hot in the noon sun and takes off his/her space suit, what will happen?
- What forms of water do you think might be found on Mars?
- What are some of the water-related features Mars Global Surveyor might see on Mars with its camera?

(b) *Students Expose Their Beliefs:* Have each student write down his or her prediction, sign his or her name, and hand it in to the teacher.

Procedure to Test Students' Preconceived Ideas

1. Distribute the temperature and pressure graphs based on data collected by Pathfinder. Have students consider questions such as:

- How many sols are represented on the graph?
- What is the temperature range? The pressure range?
- When are the temperatures and pressures at their highest? Lowest?
- How do the temperatures and pressures change over the course of the day?
- Do the patterns of temperature and pressure seem to be linked?
- What are the approximate maximum, minimum, and mean temperature and pressure levels?
- How do the maximum, minimum, and mean temperature and pressure levels on Earth and Mars compare?
- How does the variability of Martian temperature and pressure compare with the variability of temperature and pressures on Earth?
- At these pressures, what would the temperature have to be for liquid water to exist?
- At these temperatures, what would the pressure have to be for liquid water to exist?
- What would it take for liquid water to boil? Evaporate?
- Did Pathfinder ever measure temperatures or pressures that would enable liquid water to exist? If so, did the required temperatures and pressures occur at the same time? How long did these conditions last?

*To find temperature and pressure data for places on Earth, consult the National Climate Data Center (*http://www.ncdc.noaa.gov/ol/ncdc.html*) and (1) select "Products," (2) scroll down and select "CLIMVIS Global and US," (3) click on the map for desired region, (4) select graph type and state or location from menu, (5) click on boxes to select the parameters and time period for which you want data, and (6) select "Submit Graph Values."*

2. Have students look at images of Mars and describe what they see.

Features students might mention include:

- *Ice caps*
- *Canyons*
- *Craters*
- *Volcanoes*
- *Meanders*
- *Fractures*
- *A dry surface*
- *Runoff channels*

3. Have students examine Images 6 and 7 showing the area around Pathfinder's landing site. What processes have altered this region? Is there any evidence for water?

Scientists feel that vast floods flowed in this region. The evidence includes:

- *Runoff channels*
- *Rounded boulders*
- *A smooth floodplain*
- *Streamlined landforms*
- *Craters with mud-flow-like ejecta blankets*
- *Scour marks and grooves in the channels*

4. Have students compare Images 11, 12, and 13. How are the valleys on Mars and Earth alike and different? What conclusions can they draw about water on Mars based on this comparison?

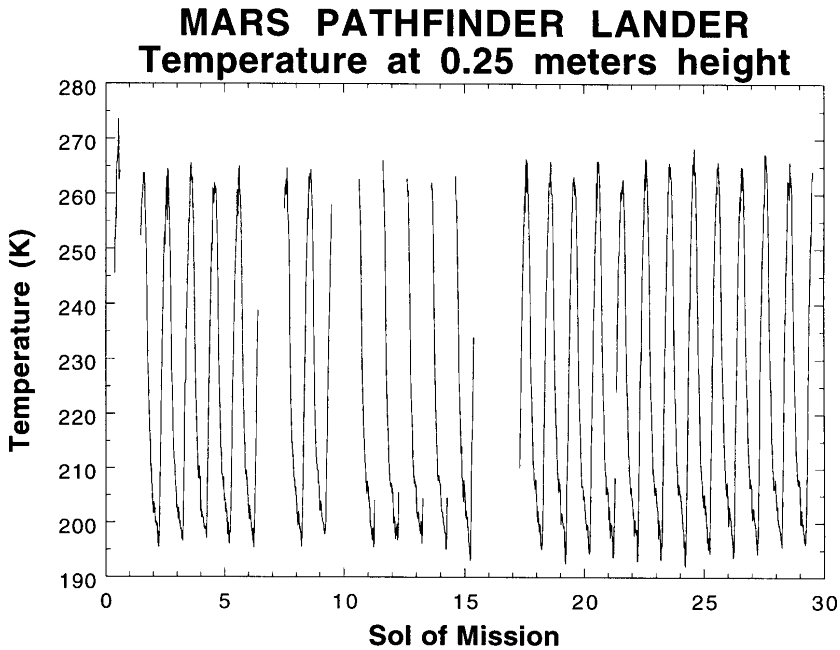
   Both canyons seem to show the effects of sustained water flow. For example:
   - *Because runoff channels tend to be straight and shallow, the meanders and canyon depths suggest water flowing over a long period of time.*
   - *The terraces and narrow channel suggest continual fluid flow and downcutting to produce such canyons.*
   - *The walls of both canyons reveal layers. The meanders suggest that some layers are more resistant to erosion than others.*
   - *As is typical with meandering rivers, there seem to be sediment deposits on the inside bends of the meanders. Such deposits are typical of continual, long-term flow. In addition, the channel seems to undercut the banks on the outer bends of the meanders. Undercutting is also typical of continual, long-term flow.*

5. By this point in the module, we know that we will not see evidence of liquid water on Mars, but we do! What must this mean? Ask student groups to develop two hypotheses that might explain the fact that water seems to have flowed across the Martian surface in the past, even though current conditions make it virtually impossible for liquid water to exist. Have them present their best idea to the class. Create a list of possible explanations on the board.

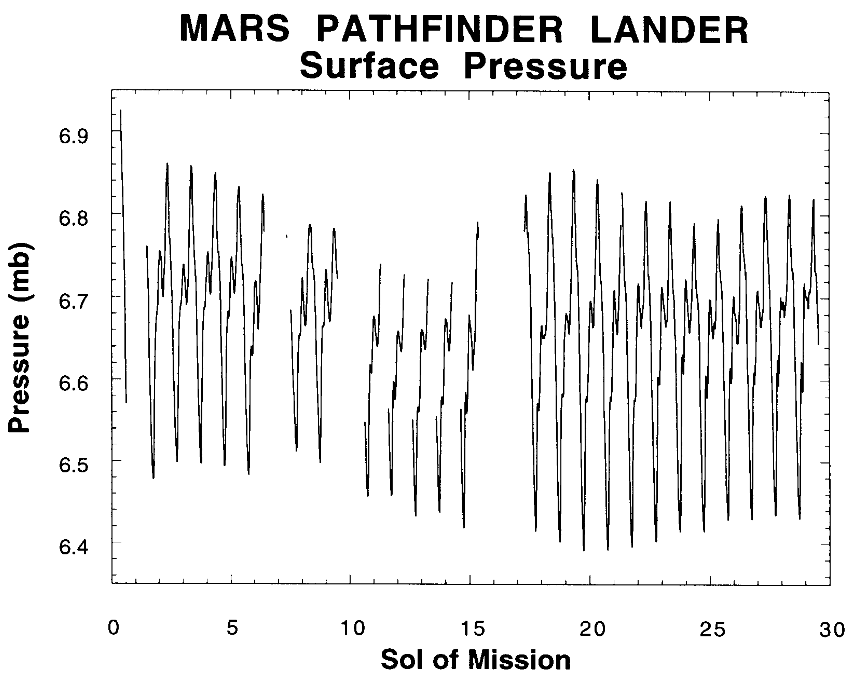
   Below are several hypotheses scientists have developed to explain the apparent contradictions:
   - *The atmosphere may have been denser at one time, making the pressure considerably higher.*
   - *The temperature may have been considerably higher at one point.*
   - *Massive amounts of water burst through the crust, and this water flow was enough to erode the surface before boiling off.*
   - *The top of the flowing water froze in the cold Martian temperatures, forming a protective ice sheet that greatly slowed the boiling off of the water. The temporarily encapsulated water eroded the surface before it eventually boiled off or percolated into the surface.*

6. As a class, discuss how a planet's surface water could disappear. Ask what kinds of information students would like to have to be more sure of their answers.

   Water can percolate into the ground, become chemically incorporated in minerals, exist as vapor in the atmosphere, become frozen in an ice cap, or be lost to space. Students might like to know whether the temperatures and pressures measured by Pathfinder were typical, what the surface is like, whether there is a lot of ice on Mars, how much water vapor is in the Martian atmosphere, and the past climate history of Mars. Activity 7 suggests a number of ways for students to gather additional information and to investigate their hypotheses. Question 6 could be assigned as homework.



Courtesy of Dr. Jim Murphy, Mars Pathfinder ASI/MET Team



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