Probing Below the Surface of Mars

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In this activity, students will record and graph temperature data to learn about the search for water on Mars. Students will use a model of an ice-rich and ice-free near-surface on Mars to examine how the ice content of the martian soil will affect the rate at which a warm probe will cool. This activity is matched to both NAS National Science Education Standards and NCTM Principles and Standards for School Mathematics.

Time Requirements:

One 45-minute class period for the activity, plus an additional 45-minute class period if the students will make graphs in class.

National Science Education Standards:

Standard A: Abilities necessary to do scientific inquiry
Standard B: Properties and changes of properties in matter
Standard C: Earth in the Solar System

National Math Education Standards:

NM.5-8.1 Problem Solving
NM.5-8.3 Reasoning
NM.5-8.13 Measurement

National Technology Education Standards:

NT.K-12.6 Technology Problem-Solving and Decision-Making Tools

You will need:

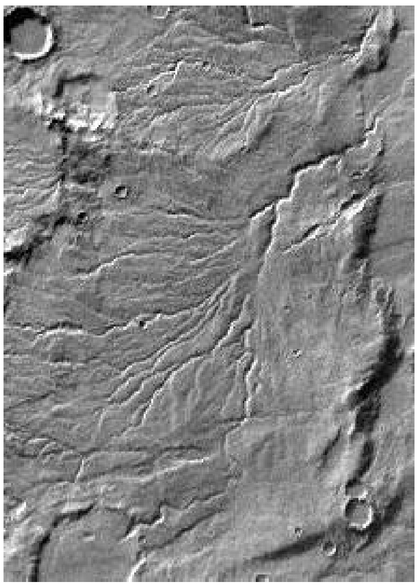
- 2 scientific classroom thermometers (The ideal thermometers are the large alcohol thermometers often found in school laboratories. Partial immersion thermometers are best. The thermometers should cover a range of at least 0 to 50 degrees C, or 32 to over 100 degrees F.)*
- 2 identical deep salad bar containers or disposable food storage containers (Inexpensive disposable food containers such as the deep Ziploc brand 32 ounce containers work well.)*
- 2 straws with a slightly larger diameter than the thermometers*
- 1 tray or plastic shoe box to hold the two food containers, cold water, and ice. (The walls of the tray should be at least a few inches high.)*
- cup to hold hot water*
- ice
- cold tap water
- hot tap water
- sand to fill each food container (Small bags of sand can be found in plant nurseries)
- access to a freezer the night before the activity
- wax paper
- transparent tape
- watch, clock, or stop watch
- data table for each student
- spoon (optional)
- masking tape (optional)
- permanent markers (optional)
- a cooler to transport the frozen materials (optional)
- graph paper (optional)
- two colors of colored pencils or pens (optional)
- petroleum jelly (optional)

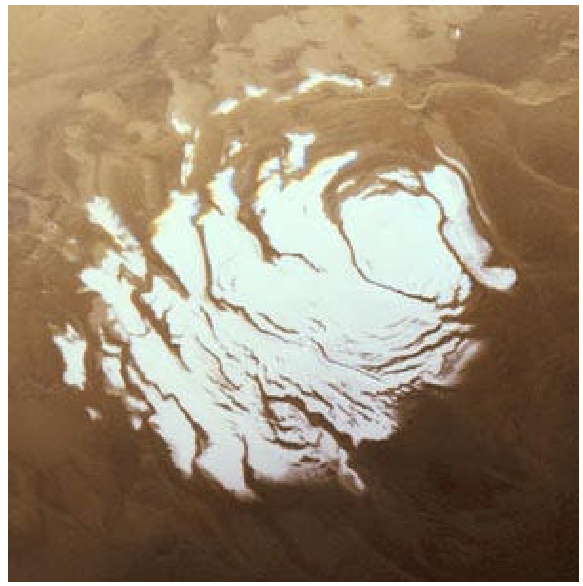
* you will need these supplies for each group of students doing the activity

Introduce the Activity:

Before the students begin the activity, spend a few minutes talking about how this activity is relevant to the ongoing search for water on Mars. The following paragraphs might help. I have also provided a student information sheet.

Mars is a cold desert. Long ago, liquid water flowed on the surface of Mars. Today, water still exists on Mars, but what we can see is ice. The polar caps of Mars are at least part water ice, like those of the Earth. Telescopes and spacecraft can see a type of clouds made of tiny crystals of ice, called cirrus clouds, drifting in the atmosphere of Mars. Frost can even cover the surface of rocks and soil in the morning, much like it does on cold mornings in many places here on Earth. Scientists who study Mars see evidence that Mars had much more water in its past, at least on the surface. What happened to that water?





Water carved valleys billions of years old and the south polar cap of Mars. credit:Viking Orbiter, NASA

Some of the water is believed to be frozen in the martian soil. Many regions on our own world have water frozen in the ground, either during the winter or, in very cold places, all year long. Water frozen in soil is simply called ground ice. If the ground ice remains throughout the year without melting, it is called **permafrost.** Permafrost is common in places like Siberia, northern Canada, and near the peaks of high mountains.

Mars is as cold, or colder, than the coldest places here on Earth. Any ground ice on Mars should stay frozen all year, and will be permafrost. However, finding the ground ice on Mars isn't easy. A dry layer of soil is believed to be on top of the icy soil, making it difficult to detect at the surface. One way to find the ice is to send a probe below the surface of Mars. Mars scientists have thought of several ways to search for permafrost on Mars. Some look at images of the surface of Mars taken by orbiting spacecraft like Mars Global Surveyor, which is currently in orbit around Mars. In these images, the scientists hope to find features similar to those made by permafrost here on the Earth, including wedge-shaped cracks in the ground that meet to form multisided shapes and look a lot like giant mud cracks. In 2001, NASA plans to send another orbiter to Mars. The Mars Surveyor 2001 orbiter has a special instrument called a Gamma Ray Spectrometer that will search for ground ice on Mars over the entire planet. This instrument is designed to "see" ice below the dry soil at the surface.

Another way to find the ice is to send a probe below the surface of Mars. Close to the poles, many Mars scientists think the dry layer of soil will be very thin, and the icy ground will be close to the surface. The Mars Microprobes, two grapefruit-sized spacecraft, were supposed to have impacted Mars at just such a place near the south pole, and penetrate up to about 1 meter (or 3 feet) into the soil. Unfortunately, the probes were never heard from. If they had survived and sent information back to us here on Earth, scientists might have been able to find ground ice on Mars. The dusty or sandy soil near the south pole may be dry, or it may be contain ice. If the soil in the top meter is ice-rich, the probes were designed to detect the ice in three ways:

- by measuring how fast the probe decelerates. Ice will make soil harder, causing the probes to slow down more quickly than they would in ice-free soil.
- by collecting a soil sample and testing it for the presence of water.
- by measuring how quickly the probes cool off after impact.

Today's activity will focus on how ice in the soil would affect the temperature of the probe after impact. Initially, each probe would have been much warmer than the cold martian soil. Gradually, however, the probe would have lost its heat to its surroundings, and would cool down. For this experiment, thermometers will take the place of the Mars Microprobes.

<u>A question to ask the students before the activity</u>:

Do you think the temperature will cool down faster with ice in soil, or without it? Ask the students why they answered a particular way. They might say the icy soil will cool faster for the wrong reason; they think of ice as cold. But, both icy soil and dry soil can be at the same temperature. If the soil is as cold as the ice, how will the ice change how fast the probes can cool?

<u>The day before (with or without the students)</u>:

1. Wet half of the sand, either in a tray or another container.
2. Hold a straw upright in the center of each of the two identical food containers. Trim the straw so that it is slightly shorter than the top of the container. This will allow the students to more easily read the thermometers and will allow you to stack the lidded containers later.
3. Wrap the end of each straw in wax paper, and cover the seams with transparent tape, this will help prevent an. excess water in the wet sand from filling the straw. Be careful not to wrap the entire straw in several layers or wax paper. This will make the contact between the straw and the sand very poor. *Note: coating the straw and wax paper with petroleum jelly may improve contact between the straw and the sand, It may also prevent the wax paper from absorbing moisture in repeated uses of the containers. Do not apply petroleum jelly before using the transparent tape.*
4. While holding the straw, fill one container with dry sand. Be careful to make sure the sand level is below the top of the straw. One person can do this, but it will be easier if one person holds the straw and another fills the container with sand.
5. Once again, while holding the straw, fill the second container with wet sand (using a spoon may help). The sand will compress under the added weight of the water, so you will need more sand to fill the same volume. Filling the container with dry sand and then adding water may increase the likelihood of the straw filling with water as well.
6. Let go of the straws. They should remain upright on their own after the containers have been filled.
7. If the students made their own sand-filled containers, label each container with the masking tape and markers. This is especially necessary if more than one group of students filled containers.
8. Place each container in a freezer for a few hours or overnight. Be careful not to tip the containers, which may cause the straws to shift.

<u>The day of the activity</u>:

1. Remove the containers from the freezer as soon to starting the activity as possible. The water in the sand should be frozen. If you need to remove them more than several minutes before the activity will begin, consider keeping them in a cooler. If you do use a cooler and ice, make sure that any water from melting ice doesn't enter the containers.
2. Just prior to beginning the activity, place the containers in the tray and put ice and cold water around them, being careful not to wet the sand, or displace the straw in the "dry" container.

<u>The activity begins</u>:

1. For a hands-on activity, divide the class into groups of 4 to 5 students. If this activity will be done as a demonstration, select 5 students to do this activity for the class.
2. Distribute the pre-made table (*see pg. 5*.), or make a 3-column table with time in the first column and two blank columns for the temperatures of the two probes. Make a place to record the starting temperature for each thermometer, the temperature every 15 seconds for the first minute, every 30 seconds for the next two minutes, and once every minute up to 6 minutes or so. If this activity will be done as a demonstration, have two of the student volunteers make separate tables on the board for the dry sand and the icy sand.
3. If you prepared the trays prior to the students arrival, give the students the tray with the containers and the ice water.
4. Fill the cup with hot tap water. Place the two thermometers into the hot water. Wait a few minutes until the thermometers have adjusted to the temperature of the water. Tell the students that heating the thermometers in hot water simulates the heating the probes will experience as they pass through the atmosphere and impact Mars's surface.
5. Record the temperatures of the thermometers as the starting temperatures.
6. Place one thermometer into each straw.
7. Record the temperature of each thermometer at the recommended intervals over a period of 6 minutes. In groups of 5 students, have one student keep track of time for the group, two students read the temperatures off of the thermometers (with one thermometer each), and two students record the temperatures in the table(s). For groups of 4, announce the time intervals to the class. A clock the entire class can see may help in both cases. If a group has an extra student, he or she can be responsible for making sure the data is recorded on schedule. Groups of 2 to 3 students will also work if the temperatures of the dry sand or the icy sand are measured one at a time. If you choose this option, obtain new hot water to heat the thermometer, preferably close to the previous starting temperature.
8. Have all of the students in each group complete their individual tables from the recorded data for the entire group.
9. Before putting away the trays, have each student test the hardness of the two samples with his or her fingers. This will simulate another way in which the probes will look for water ice. The icy sand will be much harder than the dry sand, making it more difficult for a finger to penetrate below the surface. On Mars, if ground ice is present, the probes will slow down more quickly, and will not go as deep as they will in ice-free soil.

For younger students who have not been introduced to graphing, or if time is very limited, you can end here with a qualitative discussion of the data. Which "probe" cooled faster? Was the result a surprise to the students, or was it expected?

<u>Graphing the data</u>:

1. Have the students plot the data for each of the probes on the same piece of paper, preferably using a different color for each probe. Time should be plotted on the horizontal axis, and temperature on the vertical axis. For students new to making graphs, this can be done in groups. For students who have been previously introduced to graphing, this should be done individually.
2. Compare the results from the class. Did one sample consistently cool the thermometer faster than the other?

<u>Follow up</u>:

Discuss the results of the experiment with the class.

<u>Why did the sample with the ice make the thermometer cool down faster</u>?

The icy-sand conducts (moves) heat away from the thermometer better than the dry soil. The dry sand has pockets of air around each of the tiny grains. These pockets of air, called pore space, act as insulation, and make it harder for the heat to be passed from one part of the container to another. Air spaces are often used as insulation in buildings. Double paned windows have a sheet of glass on either side of a pocket of air. Air space is also used in walls, and insulation usually has a high fraction of pore space.

When water is added and is frozen into the soil, ice fills the pore spaces. The combined material is less insulating and can conduct heat away from the thermometer and into the sand more efficiently. On Mars, dry soil will be more insulating than dry soil here on Earth. The air in the pores still transports heat in the soil, even if not very efficiently. The denser the air is, the better it is at moving heat. On Mars, the air is much thinner than here on Earth, and therefore will be even more inefficient in conducting heat.

Note: *Poor contact between the straw/thermometer and the icy sand can cause the thermometer to cool off more slowly in the icy sand sample. You should be able to identify this problem by a visual inspection of the sample. The thermometer is then better insulated by the air pocket around the straw than it is in the dry sand sample. Also, if the samples are not kept frozen, the experiment will not work properly. If either problem happens, all is not lost. Discuss with the students that result was not as expected (by you), and use this as an opportunity to discuss experimental design. How might the students improve the design of the experiment?*

If the Mars Microprobe Mission had succeeded, but *didn't* find ice in the soil of Mars, would that mean that permafrost doesn't exist on Mars? No. The probes from the Mars Microprobe Mission would have only sampled one area on Mars, and would have told us about the ground very near the surface. **What other methods could be used to search for ground ice on Mars?**

Suggestions for materials:

Containers:

Inexpensive disposable food containers such as the deep Ziploc brand 32 ounce containers work well. They come in four packs for about $3.

Sand:

Several sources of sand are available. Fine to medium grained playground sand or clean construction can be purchased in 50 lb bags from many hardware stores. Small bags of sand, intended for the purpose of mixing with soil, can be found in plant nurseries. Masonry sand and aquarium sand may also work, however, the grains maybe courser than would be ideal. Of course, natural sources of sand such as a beach will also work just fine. Make sure the dry sand really is dry before beginning the experiment. Some types of sand, such as those for use with plants, may be packaged moist. You can dry sand quickly by spreading it in a thin layer in a tray, and then leaving it in the sun on a warm day or by baking it in your oven at about 225 degrees Fahrenheit for about an hour.

Straws:

Not all straws labeled "jumbo" really are. If you cannot find straws that are slightly larger than the diameter of your thermometers (probably about 6 to 7 mm, so an 8 mm straw would work well), try wrapping a small piece of wax paper around a pen that is just a bit larger in diameter than the thermometers. Make sure that the bottom of the pen is also covered in wax paper, and seal the seams in the wax paper with transparent tape. You may need to leave the pen in the wet sand until the water has frozen, and in the dry sand until you are ready to begin the experiment.

Thermometers:

The ideal thermometers are the large alcohol thermometers often found in school laboratories, and these are also relatively inexpensive. Partial immersion thermometers (which require insertion only to a specified depth to accurately measure the temperature of a material) are best. The thermometers should cover a range of at least 0 to 50 degrees C, or 32 to over 100 degrees F. One source for various types of inexpensive alcohol thermometers is Carolina Biological Supply Company at http://www.carolina.com. Other suppliers of scientific equipment for schools are also likely to have partial immersion alcohol thermometers.

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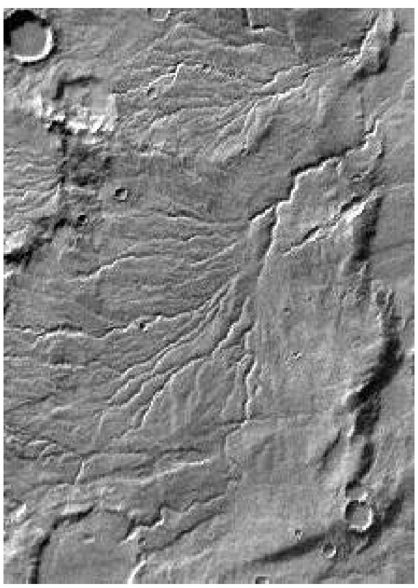
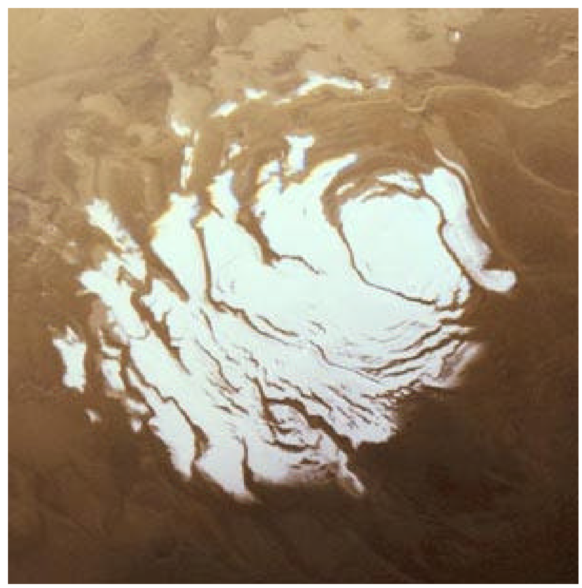
Probing Below the Surface of Mars
Student Information Sheet
Mars and the Search for Water

Mars is a cold desert. Long ago, liquid water flowed on the surface of Mars. Ancient water carved valleys were imaged by the Viking spacecraft, and more recently, by Mars Global Surveyor. The valleys are billions of years old, and look much like river valleys here on the Earth. Mars Pathfinder landed at a place on Mars that is the site giant flood, but no liquid water from that ancient flood remains on the surface.

Today, water still exists on the Red Planet, but what we can see is ice. Like the Earth, Mars has polar caps in both the north and the south. These ice caps are at least partly made of water ice. Telescopes and spacecraft can see a type of clouds made of tiny crystals of ice, called cirrus clouds, drifting in the atmosphere of Mars. Frost can even cover the surface of rocks and soil in the morning, much like it does on cold mornings in many places here on Earth. Scientists who study Mars see evidence that Mars had much more water in its past, at least on the surface. What happened to that water?

Water carved valleys billions of years old and the south polar cap of Mars. credit: Viking Orbiter, NASA

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Another way to find the ice is to send a probe below the surface of Mars. Close to the poles, many Mars scientists think the dry layer of soil will be very thin, and the icy ground will be close to the surface. The Mars Microprobes, two grapefruit-sized spacecraft, were supposed to impact the surface of Mars near the south pole in December 1999. Part of each tiny probe was designed to penetrate up to about 1 meter (or 3 feet) into the soil. Unfortunately, the probes were never heard from. If they had survived, scientists might have been able to find ground ice on Mars. The dusty or sandy soil near the south pole may be dry, or it may be contain ice. If the soil in the top meter is ice-rich, the probes were designed to detect the ice in three ways:

- by measuring how fast the probes slow down after impacting the surface. Ice will make soil harder, causing the probes to slow down more quickly than they would in ice-free soil.
- by collecting a soil sample and testing it for the presence of water using a heater and a tiny laser.
- by measuring how quickly the probes cool off after impact.

The Mars Polar Lander, also lost in December 1999, was also designed to search for ice. Instead of sending tiny probes into the soil, it would have used a robotic arm to dig a trench down into the surface to look for water ice and collect samples. In what other ways do you think scientists could search for ground ice on Mars?

Answering the question of what happened to the water on Mars is important to Mars scientists for many reasons. Water is related to the climate of Mars and finding ground ice could help scientists understand how the climate of Mars has changed over time. Did bacteria ever live on Mars? Does anything live underground on Mars today? Knowing how much water Mars had in the past and what has happened to that water will help us answer these questions. Someday, people may even go to Mars, and those people will need water.

Even though the Mars Microprobes and Mars Polar Lander were lost in December 1999, the search for ground ice on Mars goes on. Maybe someday new missions to Mars will probe the subsurface for water, just like the tiny Mars Microprobes were designed to. How might you design a mission to look for water on Mars?

Time	**Dry Sand**	**Icy sand**
Starting Temperature		
15 seconds		
30 seconds		
45 seconds		
1 minute		
1 minute 30 seconds		
2 minutes		
2 minutes 30 seconds		
3 minutes		
4 minutes		
5 minutes		
6 minutes		