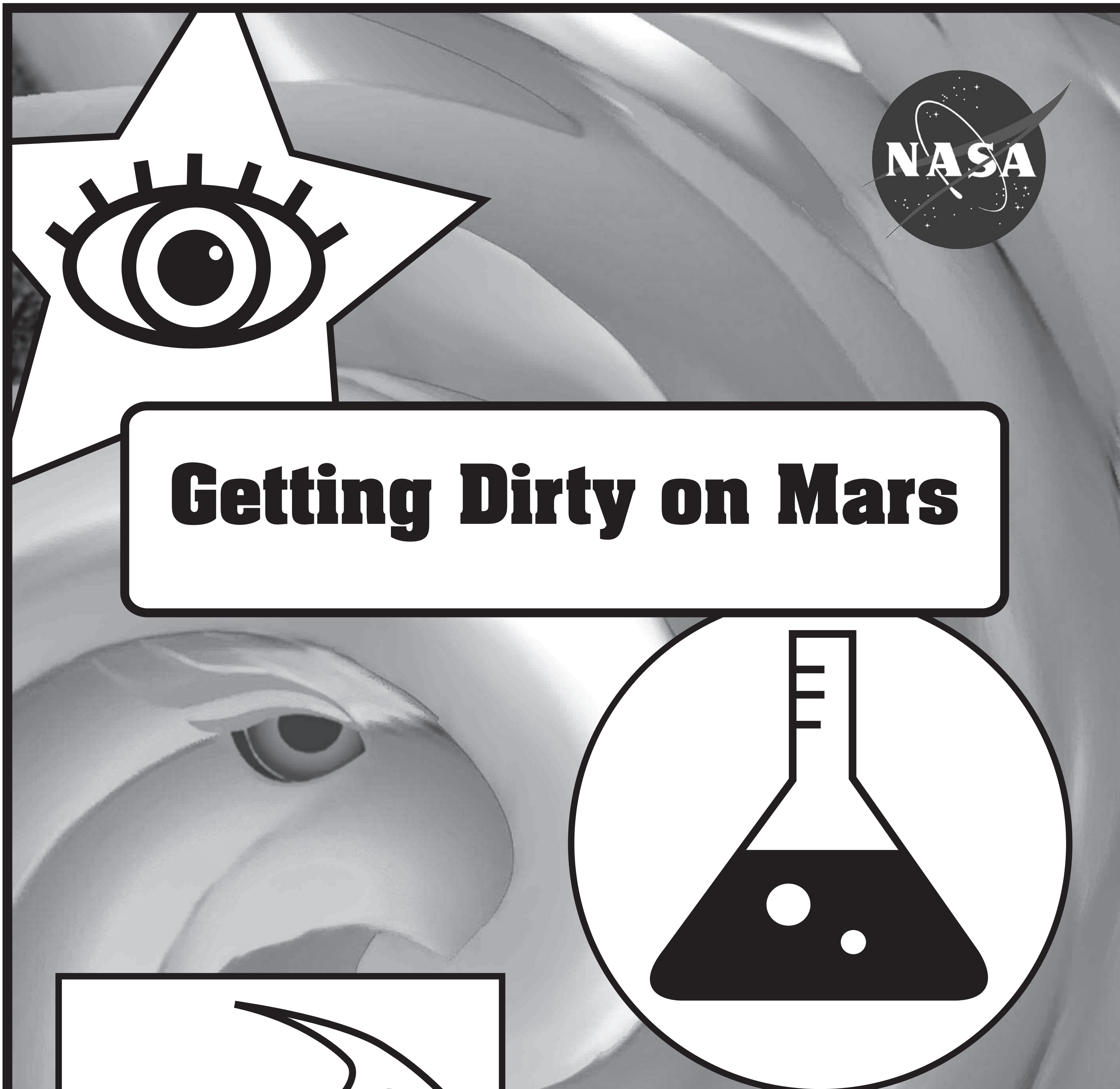
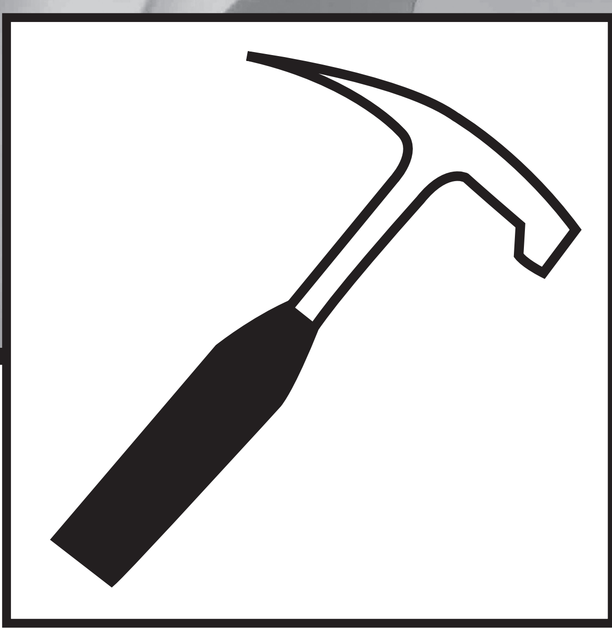


Getting Dirty on Mars

Mars Education Program



Arizona State University

The University of Arizona
Lunar and Planetary Laboratory

Phoenix Mars Lander
Educator Conference
August 1 - 3, 2007

Getting Dirty on Mars

Phoenix Mars Lander
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Written and Developed by:

Brian Grigsby
Assistant Director
ASU Mars Education Program

Robert Burnham
ASU Mars Space Flight Facility
Arizona State University

Sheri Klug
Director
ASU Mars Education Program

Editing by:

Don Boonstra
NASA Explorer Schools
Content Developer

Debbie Grigsby
Educator, 5/6 grade
Edu-Prize Charter School

Graphic Design by:

Chris Capages
ASU Mars Space Flight Facility
Arizona State University

------------------ Contact info ------------------

Brian Grigsby
Mars Education Program
Mars Space Flight Facility
Arizona State University
Moeur Building, Room 131
P.O. Box 876305
Tempe, AZ 85287-6305
(480)-965-5514
brian.grigsby@asu.edu

To download additional curriculum, go to http://www.marsed.asu.edu

Getting Dirty on Mars

Introduction

You could call Mars the Pigpen Planet. It has gone 4.6 billion years with almost no house-cleaning. It's about as dusty and dirty a place as you could imagine. For scientists, this is wonderful news, however, because it means that if Mars ever had life, there's a chance the Martian soil may still contain traces of it.

Previous Mars lander missions — from Viking in the 1970s to the recent rovers Spirit and Opportunity — found inconclusive results. The mission of the Phoenix Mars Lander is to set down on Mars where water (in the form of ice) lies just under the soil surface. Mission scientists will scrape up soil and ice, analyzing them for chemical signs that point to life.

In this series of activities, your team will analyze soil that has been "collected" from a particular "landing site". In addition, your team will collect soil from an additional landing site to give you an idea as to how Phoenix will collect soil when it lands. You will be measuring physical and chemical properties of the soil sample.

Goals:

- Participants will understand the similarities and differences between soil properties on Earth and Mars.
- Upon completion of this activity, participants will gain a better understanding about habitability in relation to the exploration of Mars.

Objectives:

- Participants will list and describe importance of soil properties and be able to relate that information to students.
- Participants will work in cooperative groups to collect soil samples from the field (similar to NASA's robotic Phoenix Mars Mission).
- Participants will use a soil test kit to determine soil properties such as pH levels, and specific chemical levels.
- Participants will use Earth soil analogs to understand the kinds of tests being performed by spacecraft on Mars.

National Science Education Standards:

- **Standard A:** Science as Inquiry (grades 5-12)
- **Standard B:** Physical Science (grades 9-12)
- **Standard C:** Life Science (grades 5-12)
- **Standard D:** Earth and Space Science (grades 5-8)
- **Standard G:** History and Nature of Science (grades 5-8)

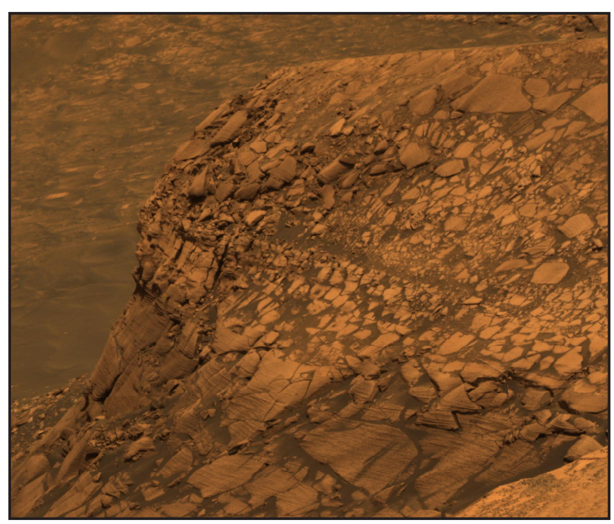
National Math Education Standards:

- **Measurement**
- **Data analysis and Probability**

Grade Levels: 5-12

Timeframe:

- Activity 1: 30 min
- Activity 2: 15 min
- Activity 3: 45 min



Victoria Crater wall, taken from Opportunity
Image credit: NASA/JPL-Caltech/Cornell

Getting Dirty on Mars

During this series of activities, your work will consist of two parts; Field Work and Lab Work

Field work consists of:

Making observations:

An important part of scientific research is recording your work. Other scientists may want to repeat your procedures or collect samples at the same location. Thus you need to give enough detail to identify your site. Before you sample anything, make observations about the area. The details of what to note are in the Soil Context Description procedures for Activity 1. The data will be collected and recorded on a Soil Context Card that will remain with your sample.

Collecting the sample:

This is the most important step. Sample collection lets you do further testing back in the lab. It is important to maintain the sample's original condition. This means handling it as little as possible with your bare hands so you don't contaminate it (Yes, dirt can get dirty!). We want to keep the soil samples as close to their original condition when we collected them. Sometimes, the oils or other contaminants from your hands (lotion, other bacteria, etc) can cause different results when you analyze them in the lab with chemicals or other instruments. Scientists are very careful when building the Mars instruments. They wear protective suits from head to toe to protect the instruments they are working on from any Earth contamination. When the spacecraft arrives at Mars, we want to make measurements of the environment that are as accurate as possible.

When you have collected your sample and returned to the classroom to analyze it, wash your hands before working with the sample. Details on what and how to collect are in the procedures for Activity 2.

Lab work consists of:

Conducting experiments:

The bulk of scientific investigation is lab work. In these activities you will examine and measure pH, nitrogen, potassium, phosphorus, and habitability (Activity 3)

Field work, Licancabur Expedition 2003

Image credit: Brian Grigsby, ASU

Lab work, testing soil moisture content

Image credit: Earth Observatory (http://earthobservatory.nasa.gov/)

FIELD WORK

Activity 1: Soil Context Description of Collected Sample

Materials Needed (per landing site/table group):
- "Collection Site" image (located at your table)

Understanding where the soil comes from will help you to interpret accurately the soil property measurements. Scientists call this the soil context.

Procedures
1. Using the "Collection Site" image, locate the area where you will perform your soil collection.

2. Before you collect your soil, make sure you note the context in which you find the sample, and write this information in the spaces below.

Context descriptions:

Location:
What is the location where the soil is found? (This can tell you about the climate in which the soil formed.) What is the site's elevation?

Aspect:
Was the soil taken in a shaded area or a sunny location?

Ground Cover:
Ground cover is a description of the vegetation or other material (such as pavement or gravel) on the surface of the soil. If nothing is covering the soil, then it is described as bare soil. Otherwise, the material covering the soil can be described as rocks, grass, shrubs, trees, or other.

Parent Material:
This refers to the underlying ***bedrock*** from which soil forms. Soils typically get a great deal of structure and minerals from their parent material. Can you tell what rocks and minerals (parent material) are in the area? It's likely these were weathered or broken down to create the soil in the first place. Sometimes the soil could be from a different source. For instance, rivers can carry soil hundreds or even thousands of miles and deposit it where rocks and minerals are quite different from those in the original area.

Location:____

____

Aspect:____

Ground Cover:____

Parent Material (make an estimate based on the surrounding area)______________________

____

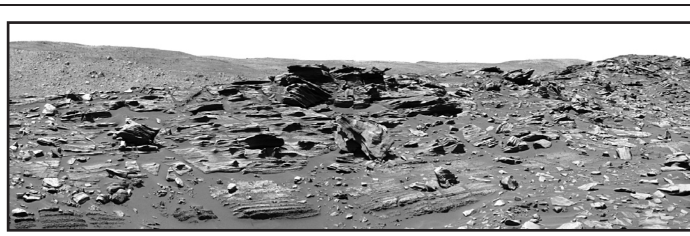


Image Credit: NASA/JPL/Cornell/USGS

FIELD WORK

Activity 2: Sample Collection Procedures

Both Viking landers, the Mars Pathfinder, and the Mars Exploration Rovers collected samples or measured soil using different instruments. Each Viking lander used a robotic arm to scoop up soil and place it into test chambers aboard the lander. The Mars Pathfinder used an instrument called APXS (Alpha Proton X-ray Spectrometer) to measure elements in the soil and rocks near its landing site. The Mars Exploration Rovers carry a robotic arm similar to yours, with a shoulder, elbow, wrist, etc. The arm allows the rover to use specialized instruments to drill into rocks, take close-up soil pictures, and make measurements of the soil chemistry.

Each of the landers used different tools to collect data on rocks and soils. Likewise, the Phoenix Mars Lander will use a specialized tool to dig below the surface called the Robotic Arm, or RA.

During this activity, you will simulate how the Phoenix Mars Lander collects soil samples

Materials Needed (per landing site/table group):

- scoop (or similar sized instrument)
- ziplock baggie

Procedures

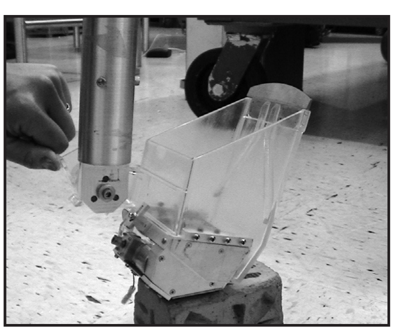
The Phoenix Mars Lander has a robotic arm designed to trench the ground at the landing site, scoop up soil and water ice samples, and deliver them to onboard instruments for chemical analysis.

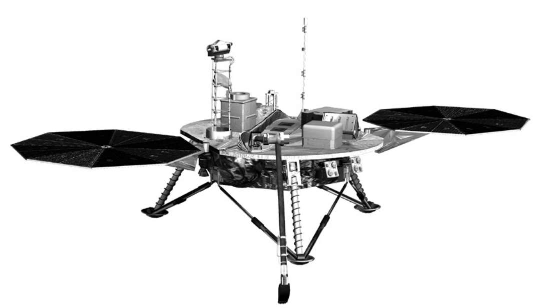
The Robotic Arm has four motions: (1) up, (2) down, (3) left to right and (4) rotation.

To simulate what the Phoenix Mars Lander does on Mars, you'll collect your sample in a similar way.

1. Take a provided powdered scoop (or similar sized instrument) to your selected sampling site. Also bring a ziplock sandwich bag to place the sample into.
2. Scrape the ground five times with the scoop and put the contents from each scrape into the bag. If the bag fills with less than five scrapes, stop.

   (Do you find that five scrapes collect only a small sample? Well, it's too bad, but you can't make any more scrapes. This is the kind of real-life limit planetary scientists often face.)
3. Seal the bag so you don't lose any soil or moisture.
4. Before moving on to the lab work, wash your hands.





Close up of the scoop and other instruments at the end of the RA (Robotic Arm).

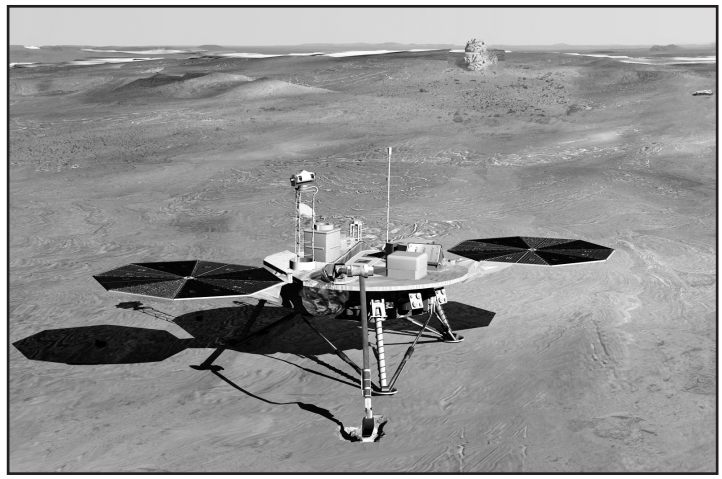
Image credit: NASA, UA Phoenix website

LAB WORK

Activity 3a: Habitability

Both Viking Landers housed specialized instruments to measure the chemistry of the soil, and to test for biological activity in it. While the experiments discovered chemical activity in the Martian soil, they provided no clear evidence for the presence of living microorganisms in the soil near the landing sites. In the decades since Viking, scientists have concluded that a combination of strong solar ultraviolet radiation, the soil's extreme dryness, and the oxidizing nature of the soil's chemistry make the Martian soil hostile to living organisms, especially microbes.

While the Phoenix Mars Lander will not be measuring biological activity in the soil, it will be measuring the soil's chemical composition. This will help us determine if the Martian soil can support life. One of the instruments is called the Microscopy, Electrochemistry, and Conductivity Analyzer (MECA). MECA characterizes the soil of Mars much like a gardener tests the soil in the backyard. By dissolving small amounts of soil in water, MECA determines the soil's pH and its abundance of minerals, as well as dissolved oxygen and carbon dioxide. Looking through its microscope, MECA examines soil grains to help determine their origin and mineralogy. Needles stuck into the soil determine its water and ice content, and the ability of both heat and water vapor to penetrate the soil.



Artist rendition of the Phoenix Mars Lander. Image credit: NASA/JPL

During activity 3a, you won't be measuring the chemical composition. Instead, you will assess the soil sample's ability to support life by experimenting with fast-growing seeds.

This portion of the activity is a part of a more in-depth curriculum called “Soil Habitability” that is found within you conference binder.

Soil Sample Testing

Materials:

- Soil sample (provided or collected)
- 3 ziplock baggies
- Seeds
- Water to moisten the soil
- Pen, marker, or masking tape to label the baggies

LAB WORK

Procedure

Using the soil sample you collected from the field or the sample supplied for you:

1. Label the 3 baggies (including date, time, etc.):

- **a.** Bag 1: Room temp (simulates equatorial location conditions on Mars)
- **b.** Bag 2: Refrigerator (simulates mid-latitude location conditions on Mars)
- **c.** Bag 3: Freezer (simulates Phoenix lander conditions near the north pole of Mars)

The control with this experiment will be 3 seeds placed between moist paper towels, and sealed in a baggie at room temperature.

2. Place 3 seeds into each baggie.

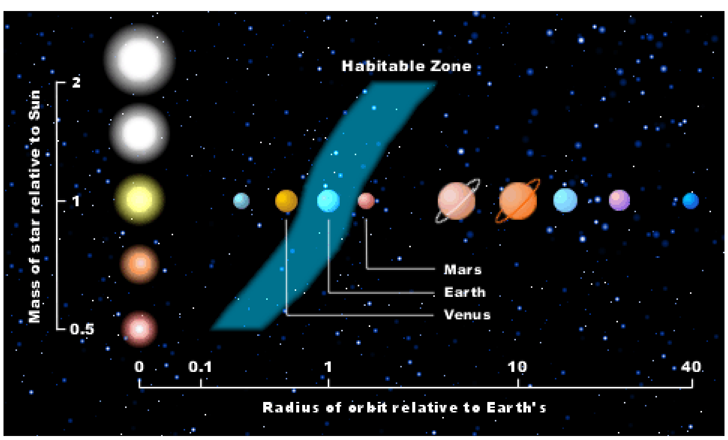
3. Moisten the soil in each baggie. Don't put in a lot of water…you don't want mud.

4. Seal the bags tightly, and place them in the simulation locations (refrigerator, freezer, etc.)

Note: you can use your room refrigerator to place the samples into the simulated locations.

5. Using the Soil Habitability Tracking Chart, make some initial observations about what the soil looks like. At first, all the samples will probably look the same, but noting this will help you when you make future observations.

6. Finish filling out the Soil Habitability Chart.



Habitable zone according to the size of the star

LAB WORK

Activity 3b: Sample Physical and Chemical Analysis

Why Is Soil Important?

We experience soil every day of our lives. Even the cleanest city street has some dust and dirt on it, but when we talk about soil, we are usually talking about the thick layer of dirt that covers the natural ground.

Soil is a critical component of Earth's ecosystem. It holds water and nutrients for plants, many of which are eaten by animals – and humans, too! Soil is important to farmers, as the properties of a particular kind of soil determine what crops will grow best in it. Much of our building materials, such as bricks, also come from certain kinds of soil.

Soil can change the chemistry of groundwater (e.g., acidity, saltiness) and the type of soil in a region will determine whether groundwater will collect in an area for use by its inhabitants or if it will run off downstream, eroding the landscape. Soil helps regulate Earth's temperature and its atmosphere, and soil affects the types of gases released into the atmosphere as well.

Microbes living in the soil break down organic material into nutrients that can be used by plants. Soil is critical to life on Earth, so it is important that we understand its properties. Soil is equally important on Mars. Just as on Earth, the pedosphere (the outermost layer of a planet's surface, primarily composed of soil) of Mars can tell us a great deal about the planet's history. The pedosphere can tell us if Mars was ever capable of supporting life or if it could support life in the future.

You will analyze the physical and chemical properties of both the collected sample and the provided sample.

Materials Needed (per landing site/table group):

- soil samples (provided and collected samples)
- craft sticks
- magnifying glass
- soil test kit
- squeeze bottle for water
- clear plastic containers
- distilled water
- metric ruler
- eye droppers
- latex gloves

Spirit digs a trench
Image credit: NASA/JPL

IMPORTANT NOTE:

In order for the N-P-K test to have time to work for this session follow these instructions:

1. Place 2-3 scoops of soil into the provided container.

2. Add 2-3 cm of water to the provided container.

3. Place the cap back on the container firmly and shake to mix the soil and water.

4. Set the samples aside to allow the soil to settle.

LAB WORK

Soil Structure--Physical Properties

This section will help in determining a physical property called Soil Structure. This is the shape of the individual particles, called ***peds***, which make up the soil. Early Mars missions found that Mars soil also tends to clump into particles.

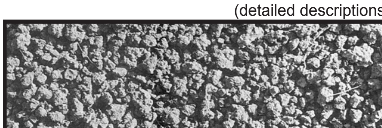
Soil Structure

The biological characteristics of a soil, the succession and activity of microbes, minute insects and worms, are directly affected by the physical and chemical conditions of that soil. In turn, the activity of life in the soil helps to improve its physical and chemical conditions. Together, these conditions determine whether the soil will produce a minimal harvest or a healthy bumper crop.

1. Separate a small portion of both samples and examine them under a magnifying glass.
2. Compare its structure to the diagrams below.
3. Record this information on the Soil Structure section below, and sketch what you see in the space provided. This can be an estimate, but a metric ruler has been provided for you to measure the grain size.

Soil Structure Comparison Chart

(detailed descriptions can be found at the end)

	**Granular** (less than .5 cm in diameter)
	**Blocky** (1.5-5 cm in diameter)
	**Prismatic** (35-45 mm)
	**Columnar** (like prismatic, but with a rounded "cap" on top, 45 mm)
	**Platy** (units are flat and platelike)

(Photos Courtesy of USDA Natural Resources Conservation)

Provided Soil Sample

Using a magnifying glass, sketch the soil structure:

Soil Structure Type

Collected Soil Sample

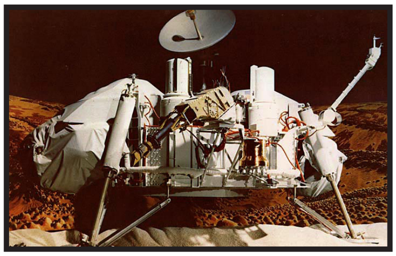
Using a magnifying glass, sketch the soil structure:

Soil Structure Type

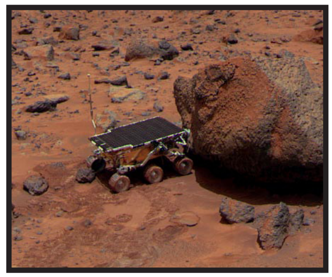
LAB WORK

Chemical Analysis--Chemical Properties

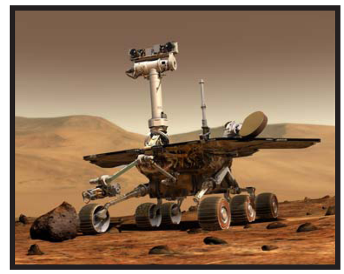
Observing the physical properties of a soil sample can tell us only so much about the soil. To understand more requires a chemical analysis of the sample. The Viking landers, Mars Pathfinder, and Mars Exploration Rovers all used instruments that helped analyze the chemical make-up of the soil. The Viking landers used an instrument called a gas chromatograph mass spectrometer to look for organic chemistry in the soil. The Mars Pathfinder used an instrument called an Alpha Proton X-ray Spectrometer (APXS) to determine the elements that make up the rocks and soils. And finally, the Mars Exploration Rovers use an updated version of the APXS, as well as an instrument called a Mössbauer Spectrometer to identify minerals that contain iron.



Viking Lander 1975-1982
Image credit: JPL/NASA



Mars Pathfinder 1997
Image credit: JPL/NASA

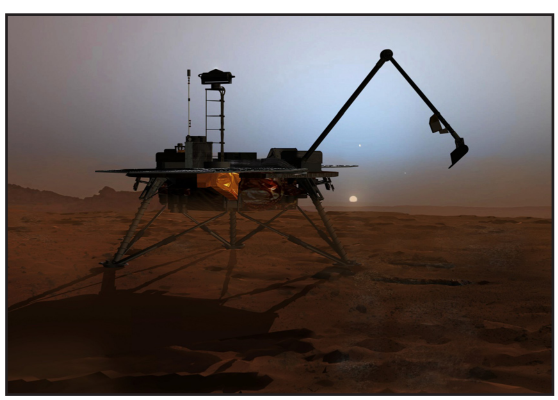


Mars Exploration Rovers 2004-present
Image credit: JPL/NASA

The Phoenix Mars lander will analyze soil chemistry as well. One of the instruments is called the Microscopy, Electrochemistry, and Conductivity Analyzer (MECA). MECA characterizes the soil of Mars much like a gardener would test the soil in the backyard. By dissolving small amounts of soil in water, MECA determines the soil's pH and its abundance of minerals, as well as dissolved oxygen and carbon dioxide. Looking through a microscope, MECA examines the soil grains to help determine their origin and mineralogy. Needles stuck into the soil determine the water and ice content, and the ability of both heat and water vapor to penetrate the soil.

Phoenix Mars Mission Lander
Image credit: U of A

Just like the Phoenix Mars Lander, you will also be using a soil test kit that will measure pH, nitrogen, phosphorus and potassium levels.



Artist rendition of the Phoenix Lander

LAB WORK

Measuring pH

The first thing to measure will be pH. The pH is a measure of how acidic or basic things are and is measured using a pH scale between 0 to 14, with acidic things having a pH between 0-7 and basic things having a pH from 7 to 14. For instance, lemon juice and battery acid are acidic and fall in the 0-7 range, whereas seawater and bleach are basic (also called "alkaline") and fall in the 7-14 pH range. Pure water is neutral, or 7 on the pH scale.

1. Using the craft stick as a scoop, place 2-3 scoops of soil into the provided container.

2. Holding the green capsule horizontally over the container, carefully separate the two halves of the green capsule and pour powder into the container.

3. Add 2-3 cm of distilled water to the container.

4. Fit the cap onto the test container, making sure it is properly secured, and shake thoroughly.

5. Allow the soil to settle and the color to develop for about a minute.

6. Compare the color of the solution against the provided pH chart.

pH of Soil Sample:

pH of Soil/Water Mixture: Collected________ Provided________

Put a "C" for collected or "P" for provided to indicated the pH of the sample:

Acidic ________ Neutral _________ Basic (Alkaline)_________

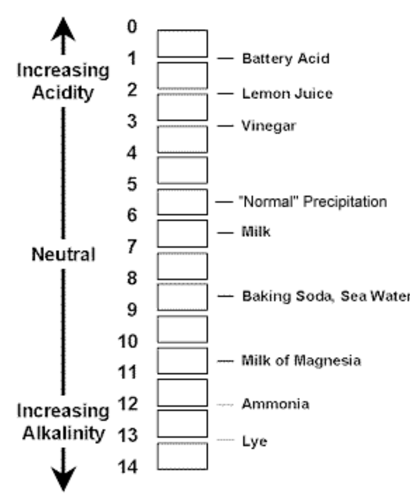
Based on pH alone, what would be the initial conclusion regarding the habitability of both soil samples?

____

____

____

____



Would you send a spacecraft to land at a location based upon this reading alone?

____

____

____

____

LAB WORK

Measuring N, P & K

For the other tests (nitrogen, phosphorus, and potassium (potash), follow the instructions below.

1. Using the plastic eye dropper, draw off some of the liquid from the container you set aside at the beginning of the activity.

2. Add 2-3 cm of liquid to the container to fill it to the line indicated.

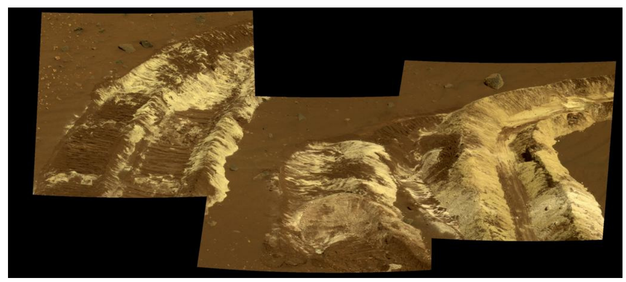
3. Holding the colored capsule (orange, blue or purple--be sure to keep track!) horizontally over the container, carefully separate the two halves of the capsule and pour powder into the appropriate test container.

5. Place the lid back on the container and shake thoroughly.

6. Allow color to develop in the container for a few minutes and compare the colors.

N, P & K levels:

	Collected	Provided
NItrogen (N) level:	____________________	
Phosphate (P) level:	____________________	
Potassium (K, Potash) level:	____________________	



Trench dug by Spirit's wheel
Image credit: NASA/JPL

Based on your results, what would be the initial conclusion regarding the habitability of the soils?

____

____

____

Based upon the information gained at the soil collection site, would this be a good or bad location to look for evidence of life?

____

____

Knowing that current technology can only allow spacecraft to dig a meter or so below the surface, would it be worth the effort to find ways to dig deeper? Why or why not?

____

____

SOIL HABITABILITY CHART

Using the chart below, briefly describe any growth in the soil that may have occurred since the last observation. Be as detailed as possible.

	Control	Refrigerator	Freezer	Room Temp
Initial Obs				
Final Obs				

Discussion

How would the following factors influence habitability?

Temperature____

____

____

Water____

____

____

Atmosphere____

____

____

Energy____

____

____

Nutrients____

____

____

For further discussion:

- What would happen to the habitability of the soil if you increased temperature, water, atmosphere, energy or nutrients?
- What would happen to the habitability if you decreased temperature, water, atmosphere, energy or nutrients?
- How would Earth and Mars compare with each of these factors?

ADDITIONAL INFORMATION

pH and N-P-K results

Similar to the tests you just conducted, scientists will use instruments on the Phoenix Mars Lander to analyze the soil for specific chemicals. Phoenix will land in the Martian arctic plains, where its Robotic Arm will dig through the dry soil to the ice layer. Samples of the soil and ice will then be brought to the Lander's platform and analyzed using special scientific instruments. These samples may hold the key to understanding whether the Martian arctic is a habitable environment.

Using the information below, you can make a theorhetical assesment about how easy it may or may not be for plants to grow in the samples provided.

Nitrogen: An over abundance of nitrogen can delay flowering while a deficiency can reduce yield.

Phosphorus: Necessary for almost all aspects of plant growth and is essential for flower and fruit formation.

Potassium: Necessary for the formation of sugars, starches, carbohydrates, protein synthesis and cell division in roots and other parts of the plant

Structures

There are five major classes of structure seen in soils: platy, prismatic, columnar, granular, and blocky. There are also structureless conditions. Some soils have simple structure, each unit being an entity without component smaller units. Others have compound structure, in which large units are composed of smaller units separated by persistent planes of weakness.

Granular (less than .5 cm in diameter)

In granular structure, the structural units are approximately spherical or polyhedral and are bounded by curved or very irregular faces that are not casts of adjoining peds. In other words, they look like cookie crumbs. Granular structure is common in the surface soils of rich grasslands and highly amended garden soils with high organic matter content. Soil mineral particles are both separated and bridged by organic matter breakdown products, and soil biota exudates, making the soil easy to work. Cultivation, earthworms, frost action and rodents mix the soil and decreases the size of the peds. This structure allows for good porosity and easy movement of air and water. This combination of ease in tillage, good moisture and air handling capabilities, and good structure for planting and germination, are definitive of the phrase good tilth.

Blocky (1.5-5 cm in diameter)

In blocky structure, the structural units are blocklike or polyhedral. They are bounded by flat or slightly rounded surfaces that are casts of the faces of surrounding peds. Typically, blocky structural units are nearly equidimensional but grade to prisms and to plates. Blocky structures are common in subsoil but also occur in surface soils that have a high clay content. The strongest blocky structure is formed as a result of swelling and shrinking of the clay minerals which produce cracks. Sometimes the surface of dried-up sloughs and ponds shows characteristic cracking and peeling due to clays.

ADDTIONAL INFORMATION

Prismatic (35-45 mm)

In prismatic structure, the individual units are bounded by flat to rounded vertical faces. Units are distinctly longer vertically, and the faces are typically casts or molds of adjoining units. Vertices are angular or subrounded; the tops of the prisms are somewhat indistinct and normally flat. Prismatic structures are characteristic of the B horizons or subsoils. The vertical cracks result from freezing and thawing and wetting and drying as well as the downward movement of water and roots.

Columnar (like prismatic, but with a rounded “cap” on top, 45 mm)

In columnar structure, the units are similar to prisms and are bounded by flat or slightly rounded vertical faces. The tops of columns, in contrast to those of prisms, are very distinct and normally rounded. Columnar structure is common in the subsoil of sodium affected soils. Columnar structure is very dense and it is very difficult for plant roots to penetrate these layers. Techniques such as deep plowing have helped to restore some degree of fertility to these soils.

Platy

In platy structure, the units are flat and platelike. They are generally oriented horizontally. A special form, lenticular platy structure, is recognized for plates that are thickest in the middle and thin toward the edges. Platy structure is usually found in subsurface soils that have been subject to leaching or compaction by animals or machinery. The plates can be separated with a little effort by prying the horizontal layers with a pen knife. Platy structure tends to impede the downward movement of water and plant roots through the soil.

The Importance of Soil pH:

The pH of soil or more precisely the pH of the soil solution is very important because soil solution carries in it nutrients such as nitrogen (N), potassium (K), and phosphorus (P) that plants need in specific amounts to grow, thrive, and fight off diseases.

If the pH of the soil solution is increased above 5.5, nitrogen (in the form of nitrate) is made available to plants.

Phosphorus, on the other hand, is available to plants when soil pH is between 6.0 and 7.0.

Certain bacteria help plants obtain nitrogen by converting atmospheric nitrogen into a form that plants can use. These bacteria live in root nodules of legumes (like alfalfa and soybeans) and function best when the pH of the plant they live in is growing in soil within an acceptable pH range.

For instance, alfalfa grows best in soils having a pH of 6.2 - 7.8, while soybean grows best in soils with a pH between 6.0 and 7.0. Peanuts grow best in soils that have a pH of 5.3 to 6.6. Many other crops, vegetables, flowers and shrubs, trees, weeds and fruit are pH dependent and rely on the soil solution to obtain nutrients.
If the soil solution is too acidic plants cannot utilize N, P, K and other nutrients they need. In acidic soils, plants are more likely to take up toxic metals and some plants eventually die of toxicity (poisoning).

HELPFUL LINKS

Mars isn't the only planet that scientists are studying to gain an understanding of soils and how that relates to the search for life. The following resources are provided to help with your understanding of not only Mars, but additional planetary studies that are going on today.

Mars Websites

- ***http://phoenix.lpl.arizona.edu/*** The Phoenix Mars Mission official website
- ***http://mars.jpl.nasa.gov/*** This site focuses on the exploration that is being conducted not only in orbit around Mars, but on the surface as well, analyzing the composition of the soils on the surface.

Soil resources

- ***http://soils.usda.gov/*** This is the main website of the USDA's (United States Department of Agriculture) Natural Resources Conservation Service (NRCS). This site holds a wealth of information from printed publications, to online tools used to view soil survey maps and reports.
- ***http://visibleearth.nasa.gov/*** This is a collection of images and animations of Earth. It has a searchable index that will allow you to find images and animations of specific topics, such as soils.
- ***http://www.jpl.nasa.gov/solar_system/*** This site, through NASA's Jet Propulsion Lab, highlights missions that focus on exploration of the solar system.
- ***http://www.fs.fed.us/*** The main website for the USDA Forest Service

Biology resources

Habitability is an important factor when studying soils. Scientists today are studying locations on Earth that are very similar to Mars (called planetary analogs) to understand how life can survive in extreme environments. The following resources describe some of these environments, and what scientists are doing to study extreme life.

- ***http://nai.arc.nasa.gov/*** NASA Astrobiology Institute's (NAI) website. How does life begin and evolve? Is there life elsewhere in the Universe? What is the future of life on Earth and beyond? NAI carries out collaborative research and education in astrobiology, the interdisciplinary science that seeks answers to these fundamental questions. It supports investigation of these issues on Earth and serves as a portal to space for the scientific community.
- ***http://science.nasa.gov/PhysicalScience.htm*** The Science@NASA Web sites' stories feature such topics as astronomy, astrophysics, Earth science, physical science, biology, and living in space. From microscopic to astronomical scale, NASA science covers them all.
- **http://astroventure.arc.nasa.gov/** At this interactive site, students in grades 5-8 role-play NASA occupations as they search for and build a planet for human habitation.

Additional resources

- ***http://www.dlese.org/library/index.jsp*** DLESE is the Digital Library for Earth System Education, a geoscience community resource that supports teaching and learning about the Earth system. It is funded by the National Science Foundation and is being built by a community of educators, students, and scientists to support Earth system education at all levels and in both formal and informal settings.

(Each of the links above are active as of July 2007)