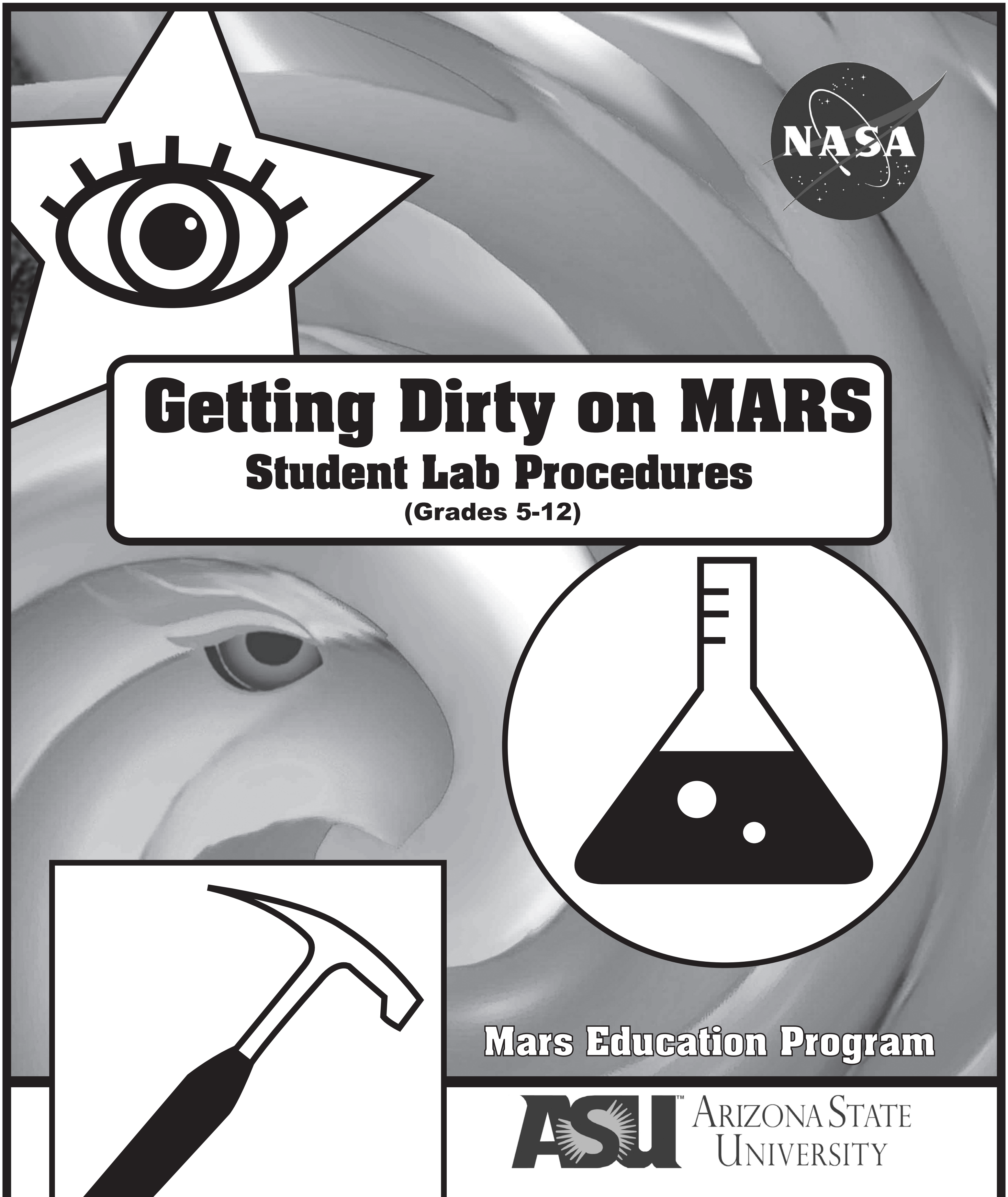

Getting Dirty on MARS

Student Lab Procedures

(Grades 5-12)

Mars Education Program

Arizona State University

The University of Arizona

Lunar and Planetary Laboratory

version 2.0

Getting Dirty on Mars
STUDENT LAB PROCEDURES

Getting Dirty on Mars

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Getting Dirty on Mars

STUDENT LAB PROCEDURES

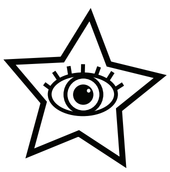
You could call Mars the Pigpen Planet. It has gone 4.6 billion years with almost no house-cleaning. It's about as dusty and dirty a place as you could imagine. For scientists, this is wonderful news, however, because it means that if Mars ever had life, there's a chance the Martian soil may still contain 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 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 these activities, you will collect a soil sample and measure most of the major properties that soil scientists study. (Unfortunately, unlike Phoenix, you'll have to work in your own neighborhood because NASA isn't yet ready to send you to Mars.) If you choose, in a separate activity, you can assess the ***habitability*** of your soil sample.

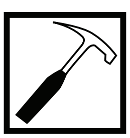
Your activities will fall into two parts: field work and lab work.

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.

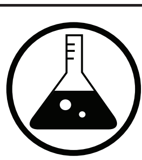


Collecting the sample:

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 contaminates 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 contamination, because 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 moisture content, biomarkers (traces of living things), grain size, pH, and **carbonates**. Finally, you will assess the habitability of your sample.

FIELD WORK

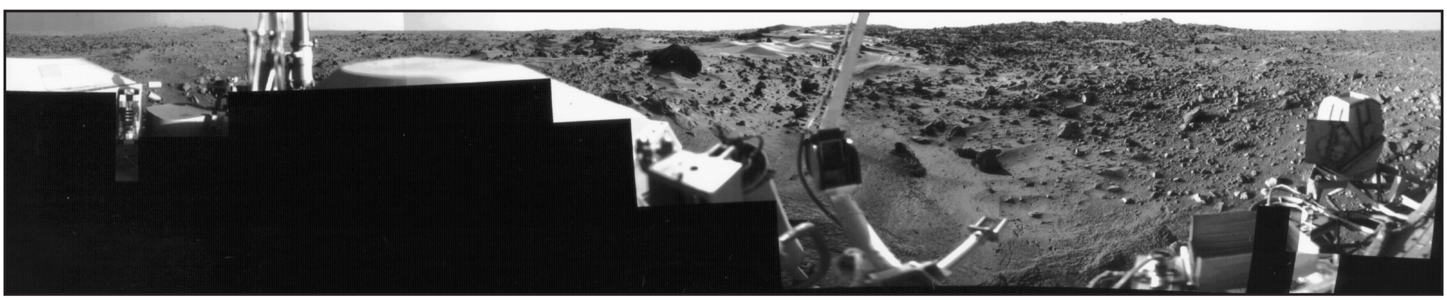
The **Viking 1 and 2** landers (1976), **Mars Pathfinder** (1997), and both **Mars Exploration Rovers** (2004) returned a wealth of data about the surface of Mars. The locations where they landed were carefully selected by scientists because of the promise the sites held for scientific discoveries.

After studying orbiter photos, the Viking team decided to send Viking 1 to Chryse Planitia and Viking 2 to Utopia Planitia. The Mars Pathfinder was sent to Ares Vallis. For the Mars Exploration Rovers, scientists chose Gusev Crater as the site for the rover Spirit and Meridiani Planum for Opportunity. Each location was chosen so scientists could study a wide variety of rocks and soils.

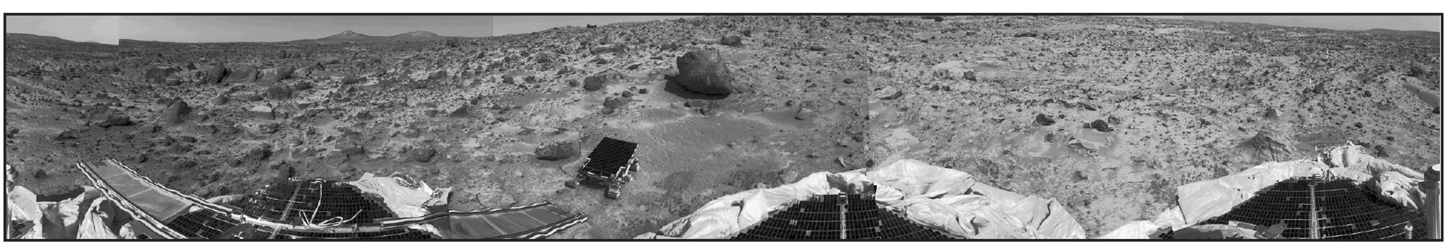
Working like field scientists, the landers and rovers surveyed their surroundings with scientific instruments and cameras. Scientists determined precisely the locations of the Viking landers, the Mars Pathfinder, and the Mars rovers, making note of the context in which each spacecraft landed.

By surveying the spacecraft's initial location from orbit and from the surface, scientists began to formulate ideas about the types of rocks at the sites, how they may have formed, and if water was once present.

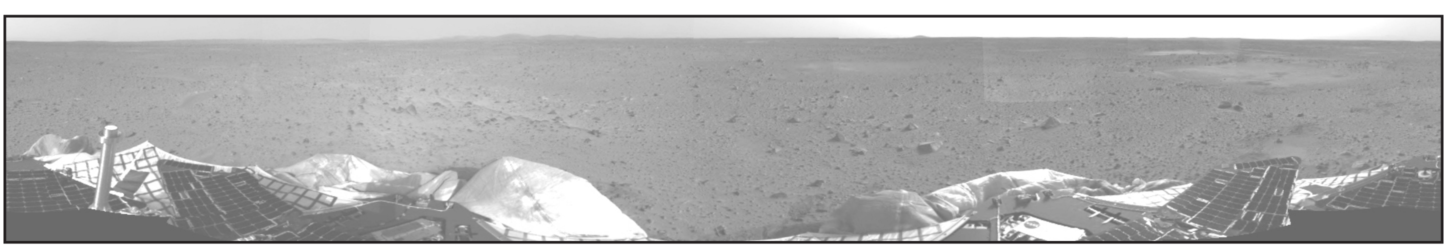
Like the mission planners and scientists, you will need to survey the location where you will collect soil samples. As you document this information, begin your initial observations about how the soil may have formed, and if it could harbor life.



Viking 2 Lander, Camera 1 - Utopia Planitia (1976)



Mars Pathfinder - Ares Vallis (1997)



Spirit - Gusev Crater (2004)

INTRODUCTION

Since our first close-up picture of Mars in 1965, spacecraft voyages to the Red Planet have revealed a world strangely familiar, yet challengingly different. Every time we feel close to understanding Mars, new discoveries send us straight back to the drawing board to revise existing theories.

You'd think Mars would be easier to understand. Like Earth, Mars has polar ice caps and clouds in its atmosphere, seasonal weather patterns, volcanoes, canyons, and other recognizable features. However, conditions on Mars differ greatly from what we know on our own planet.

Over the past three decades, spacecraft have shown us that Mars is rocky, cold, and sterile beneath its hazy, pink sky. We've also discovered that today's Martian wasteland hints at a onetime active world where volcanoes raged, meteorites plowed deep craters, and flash floods rushed over the land. And Mars continues to throw out new enticements with each landing or orbital pass made by our spacecraft.
After years of studying the Red Planet, NASA has developed a Mars exploration strategy: Follow the Water! Its goal is to discover the possibilities for Martian life — whether past, present, or even our own in the future.

Following the water begins with understanding the current environment on Mars. We want to explore features such as dry riverbeds, ice in the polar caps and rock types that form only when water is present. We want to look for hot springs, hydrothermal vents, or subsurface water reserves. We want to understand if ancient Mars once held a vast ocean in the northern hemisphere, as some scientists believe, and how Mars may have shifted from a wetter climate to the dry and dusty one it has now. Searching for these answers means delving into the planet's geologic and climatic history to find out how, when, and why Mars became the forbidding, yet promising, planet we observe today.

KWL Pre-Activity:

Currently, we can send only robotic spacecraft to orbit Mars and land on its surface. By studying the rocks, we can learn a lot about the surface of a planet such as Mars. To prepare you for studying soil samples in a way similar to the Phoenix Lander, we will do some inquiry activities that focus on what you already know about soil. Here is how you should prepare to ***<u>fill out the chart in your Data Log</u>*** called "**KWL**: (what I **K**now, what I **W**ant to know, and what I **L**earned):

1. Understanding what you already know will guide you as you progress through the soils activities in this module. Write what you know about soil in the section "What I know."

2. Once you have completed the section on what you know, set some goals by writing what you wish to know about soil by the end of the module. This might include whether or not some soils are better for organisms to grow. Or it could include information leading you to investigate data collected by the Viking, Mars Pathfinder, and the Mars Exploration Rovers. Put your goals in the section "What I want to know."

3. Finally, you will complete the **KWL** chart by describing what you have learned. This will guide you in preparing your report at the end of this module. Do not fill out the "What I learned" section until you have completed the module.

INTRODUCTION

4. For further investigation, make note of anything more you want to investigate by writing this in the last column called "What I want to explore further."

5. After doing the module and learning the material, go back to the K column and see if any of your prior knowledge was inaccurate. Check any entries that are inaccurate according to the text. Correct any inaccurate statements by rewriting them.

6. Then go to the W column and look for the questions that the text did not answer. Be prepared to bring these unanswered questions up in class, or tell how you will find answers to them and where you will look to get the answers.

Now, let's begin our soil study with an activity to help us understand what soil really is, and why it is important to study.

As you look at the following questions, fill in the appropriate spaces on the **KWL** chart.

What do you see in the pictures below?

PHOTO CREDIT: NASA/JPL/CORNELL/USGS

- *How are these pictures similar? How do they differ?*
- *Looking at both pictures, what do you think the soil in each is made of?*
- *Do you think all soil is alike?*
- *Share with the class what you know about soil from your own personal experiences and hands-on explorations.*

HANDS ON:
Pour the contents of the soil container from your teacher onto a sheet of white paper. As you examine the soil, ask yourself the following questions:

(1) Have you ever looked closely at a handful of soil?
(2) What did you notice?
(3) Is the soil at the beach the same as the soil in your back yard or on the playground?
(4) How are they different?
(5) How do you think the soil gets there?

FIELD WORK

Activity 1: Soil Context Description

Understanding where the soil comes from will help you to interpret accurately the soil property measurements. Scientists call this the soil context. This information will be noted on your Soil Context Card, as well as on your Data Log.

The data to collect and record are:

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.

Land Use:
What is the site used for? (Is it an industrial area? Farmland? Schoolyard? Backyard? Do you think it has been disturbed from its natural state by human or animal activity?)

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.

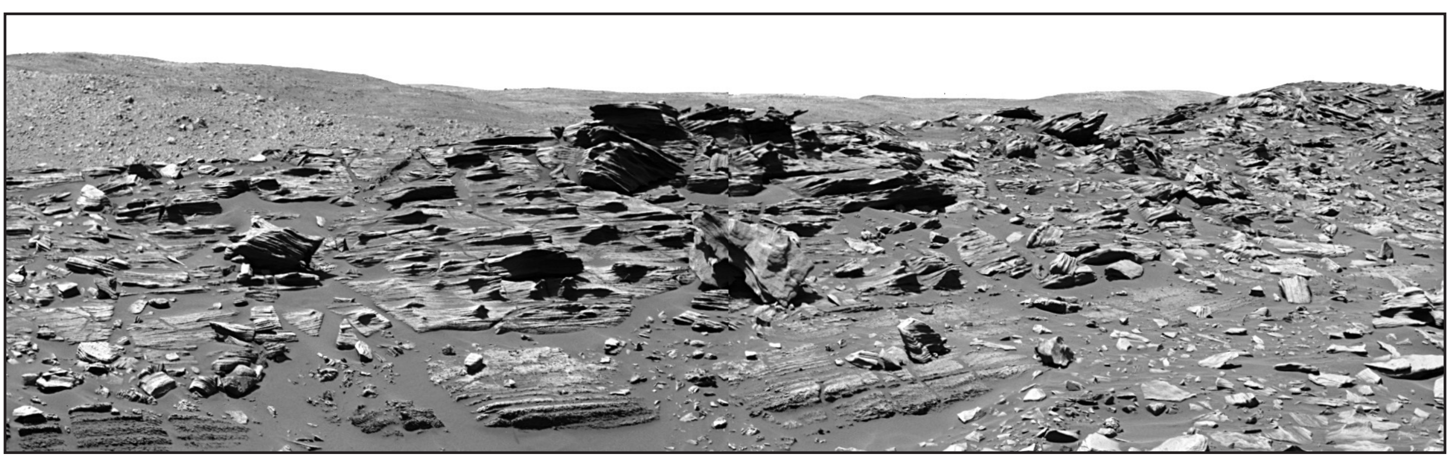
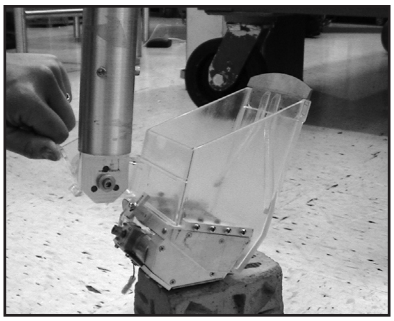
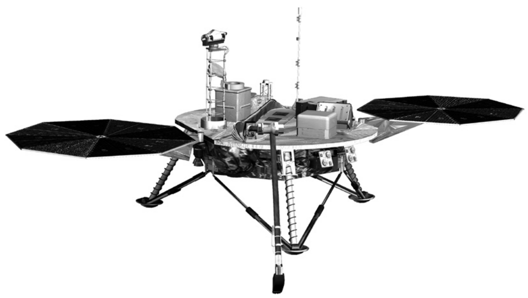


PHOTO CREDIT: NASA/JPL/CORNELL/USGS

FIELD WORK

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.





Close up of the scoop and other instruments at the end of the RA.
Photo courtesy of NASA, UA Phoenix website

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.

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

Activity 2: Sample Collection Procedures

The Phoenix 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: up and down, side to side, and rotation.

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

1. Take a powdered laundry detergent scoop (or similar sized instrument) to the sampling site you have observed. Also bring two ziplock sandwich bags, marking each with the name of your team or a team member's initials and class period.

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. If you choose to perform further tests on the soil with the ***Soil Habitability*** activity, then transfer approximately half the sample into a second bag, leaving half in the original bag.

4. Seal both so you don't lose any soil or moisture. With a marker, clearly label one bag with number 1 and the other with number 2.

5. If you are doing the ***Soil Habitability*** activity, then give the labeled sample bag number 2 to your teacher.

6. Before moving on to the lab work, wash your hands.

LAB WORK OVERVIEW

(Activities 3 through 9)

The following descriptions give a general outline of the remaining activities. This will allow you to plan your lab work efficiently. More detailed instructions are found on the specific activity pages.

Soil Moisture (Activity 3, part 1 and 3):

This and the soil color part of this activity must be done together as soon as you return to the classroom. Expect that it will take a couple of days for the soil to dry if left out in the room. ***Record your work in the Data Log.***

Soil Color (Activity 3, part 2):

Soil color must be studied before the soil dries. Using a magnifying glass, as well as your eyes, compare the soil color to the color chart and record the closest color on your Data Log. Moisture and organic material make soil appear darker. Based on the soil's darkness, record whether the soil is moist or dry, or contains much organic material. Then, going by the soil's color, estimate its parent material using the mineral chart in Appendix 3, and ***record your estimate in the Data Log***.

Soil Structure (Activity 4):

Structure refers to the shape of the individual soil particles. Place a small portion of the sample on white paper and examine it under a magnifying glass. Sketch what you see, and compare the structure to the soil structure pictures in the procedures. ***Record this information on the Soil Context Card and give reasons why you classified the soil the way you did on your Data Log.***

Soil Consistency (Activity 5):

This is a measure of how tightly soil particles hold together. Loose soil crumbles easily, while firm soil may require a shovel to break apart. Soil consistency is determined by the ***parent materials***, how much erosion the soil has experienced, whether it has been broken up by plant roots or digging, and how much pressure the soil has experienced.

Biomarkers (Activity 6):

Plants have a hard time growing in rocky soil, so it's important to know how many rocks are within your sample. Also, by measuring the amount of roots contained in your soil sample, you can get an estimate of the soil's fertility. This helps you assess the soil's ***habitability***.

Soil Texture (Activity 7):

Soil texture differs a bit from soil consistency. While soil consistency concerns how well the grains that make up a sample hold together, ***soil texture*** involves how large the individual grains are.

Chemical analysis and pH (Activities 8 and 9):

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. During this portion of the lab, you will test the sample for ***carbonates*** (CO_4) and measure the ***pH*** of the soil (how acidic or basic it is).

LAB WORK

During the Viking missions, scientists were able to view some images that showed a thin layer of frost on the ground. At the Viking I landing site, this frost proved to be carbon-dioxide frost (dry ice). But at the Viking II landing site, scientists now believe that the frost seen in photos is actually water ice that has condensed from the thin atmosphere. Later, measurements made by the rovers Spirit and Opportunity showed that in places their landing sites have pockets of sulfate-rich soil that could have developed by long exposure to very small amounts of moisture.

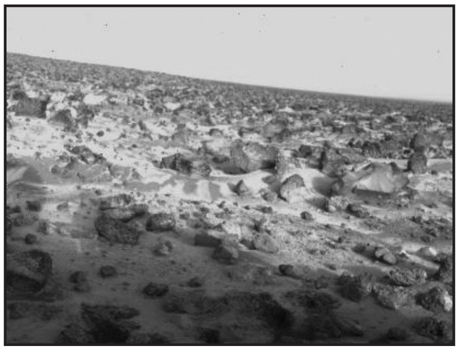


PHOTO CREDIT: VIKING-1979

Opportunity also found rock layers in Meridiani Planum that formed underwater long ago, but unfortunately, no liquid water exists today at the Martian surface.

However, using measurements from orbit, scientists have found there may be water (as ice) a distance below the surface of Mars, and this is what Phoenix will hunt for. On any planet, soil tells of more recent environmental conditions than rocks do. This is why we need to study the color and moisture content of our collected samples.

Activity 3 — Part 1: Soil Moisture Content

Start measuring soil moisture as soon as possible after collecting your sample. It takes a couple of days to dry out a soil sample if you leave it exposed to the room air.

The amount of water in the soil not only gives an estimate of how well it could support life, it also tells us much about the ***hydrology*** of the land from which the sample came. ***Nutrients*** must be dissolved in water so that plants can take them up through their roots.

To measure your sample's soil-moisture content, take sample bag 1 and do as follows:

1. Using a balance or scale, measure the mass of a paper plate and 2 sheets of paper towels (or some other container) and ***record the value on your Data Log*** as M_1.

2. Put the soil sample onto the paper plate with one paper towel sheet under the soil sample and one towel sheet on top (to reduce contamination). Measure the mass of the sample again and ***record the value on your Data Log*** as M_2.

3. Subtract the mass of the empty paper plate and paper towels (M_1) from the weight of the paper plate and towels with dirt (M_2). The difference is the soil sample's wet mass. ***Record this on your Data Log*** as M_W.

4. Now, before the sample dries, you must record the soil color. (deleted)

LAB WORK

Activity 3 —Part 2: Soil Color

Soil color tells about the materials that make up the soil. Most color comes from chemicals that coat each particle of the soil, but the type of parent material also affects soil's color. With most soils, wetting them generally makes them darker, as does adding lots of ***organic material.***

When we talk about color, though, we often run into a problem. The names we use for colors — such as "red," "blue," and "green" — actually apply to a wide range of shades of those colors. Also, many colors don't have a particular name.

When scientists talk about soil color, they need to be sure they are talking about the same thing. If you were doing a detailed scientific experiment that needed exact measurements, then you would use the Munsell Color Code System, developed in 1905 by Albert Munsell.

The Munsell system contains thousands of standard colors, but the Soil Color Comparison Chart in Appendix 1 shows just the dozen most common. If you wish your descriptions to be more accurate, however, you can use a full Munsell color card set.

5. Using a magnifying glass, as well as your naked eye, compare the soil color to the chart and ***record the color on your Data Log***.

6. Organic material and moisture make soils appear darker. Based on the soil darkness, record whether you think the soil is moist or dry, or has a high amount of organic material.

7. Based on the sample's color, estimate the soil's parent material using the mineral chart in Appendix 2. ***Record your estimate in your Data Log.***

8. With the soil color determined, you must now dry the soil sample. There are a couple of ways to do this:

   (1) You can dry the soil by leaving it on the paper plate in the classroom for several days. With this method, make sure the second paper towel covers the sample to reduce contamination. Or —

   (2) You can carefully heat the sample in a fireproof container (with proper supervision) on a stove or over a Bunsen burner for about five minutes.

9. In either method, spread the soil as thinly as you can to help it dry faster. (But, do not crush the sample to a powder — in Activities 5, 6 and 8, you will be studying the soil sample's structure and texture.)

LAB WORK

Activity 3 —Part 3: Soil Moisture Content
After drying is complete:

10. Measure the mass of the dry sample on its paper plate and with its paper towels. ***Note this on your Data Log*** as M_3.

11. Subtract the mass of the clean paper plate and paper towels (M_1) from the mass of the paper plate and towels with dry dirt on it (M_3). The difference is the soil sample's dry mass. ***Record the value on your Data Log*** as M_D.

12. Subtract the dry mass (M_W) from the wet mass (M_D). This is the mass of water that was in your soil sample. ***Record it on your Data Log.***

13. Divide the sample's dry mass (M_D) by its wet mass (M_W) and multiply the result by 100. This number is the percentage of water that was in your soil sample. ***Record it on your Data Log.***

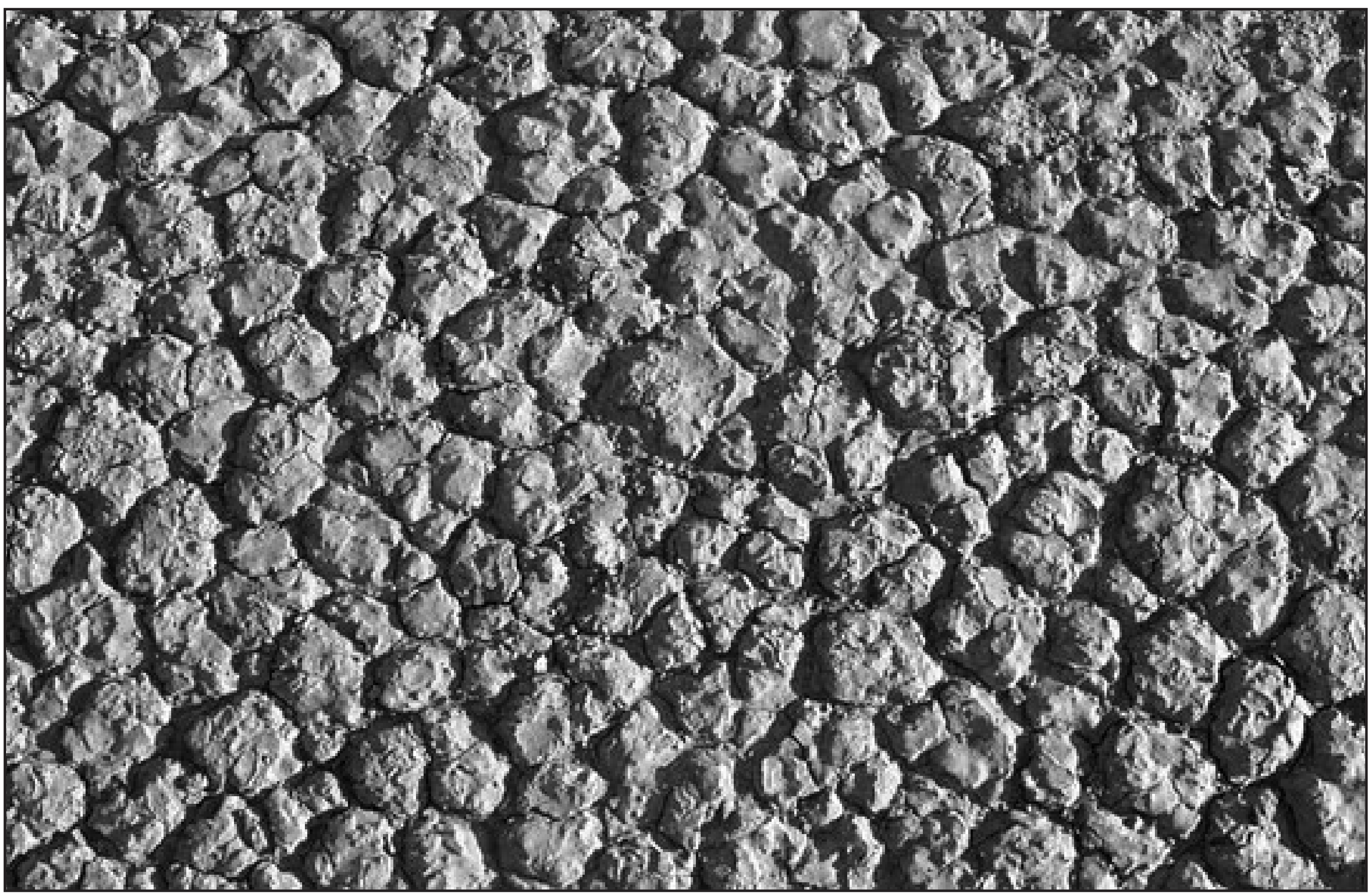


photo of dried up lake bed

LAB WORK

The Viking landers could photograph only the surrounding terrain — they were not equipped to take close-up images of the soil. With Mars Pathfinder, images taken by the Sojourner rover did not show the detailed soil structure.

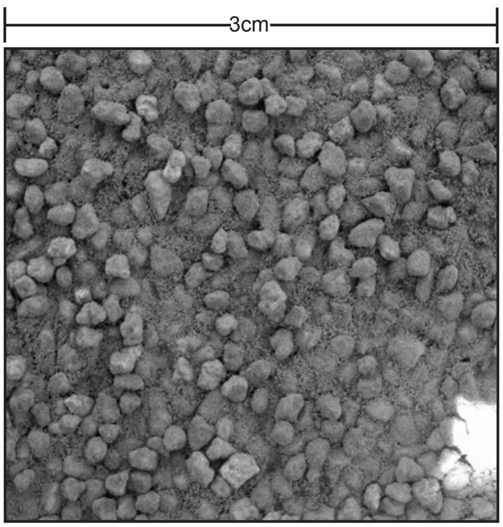
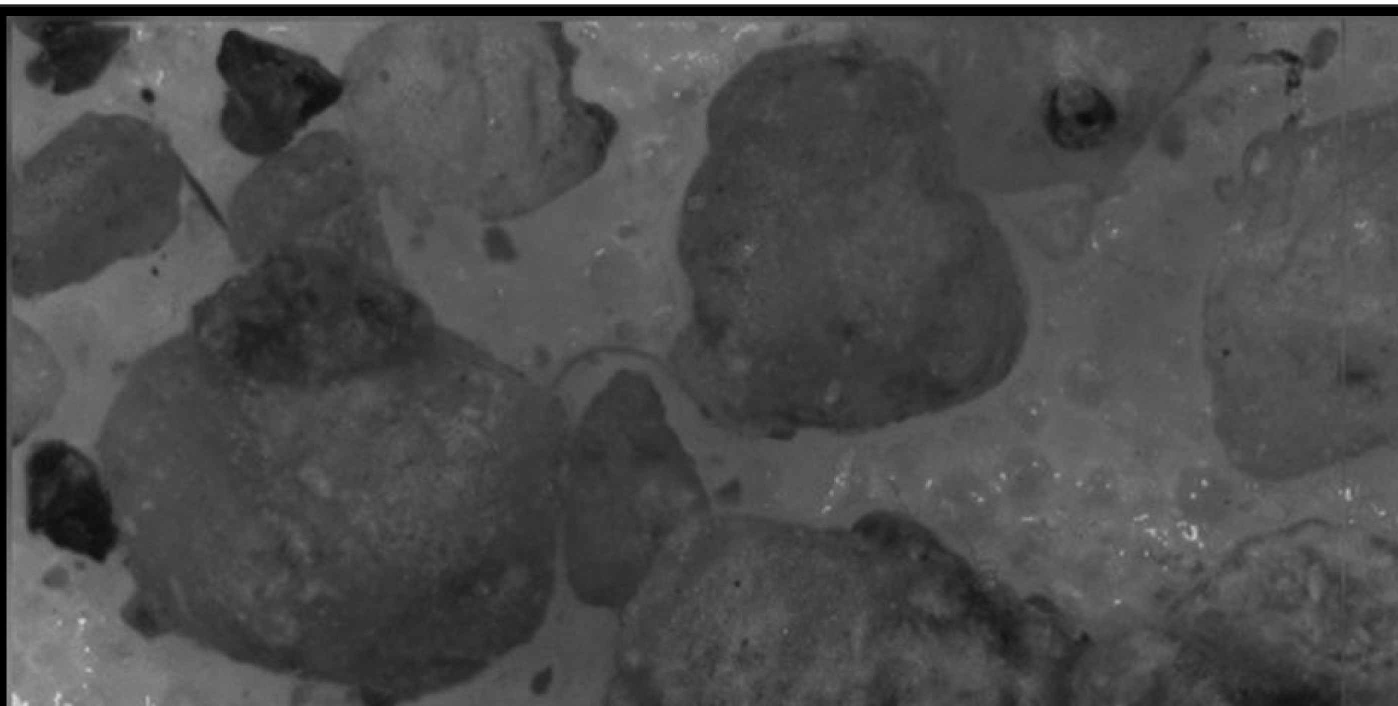


PHOTO CREDIT: NASA/JPL/CORNELL/USGS

Each Mars Exploration Rover, on the other hand, carries a camera called the Microscopic Imager on its robotic arm. The camera takes sharp pictures of the soil in an area just 31 millimeters on a side. Microscopic Imager pictures provide essential clues to how the rocks and soils were formed. For example, the size and angularity of the grains in water-deposited sediments reveal how they were transported and deposited at the site.

The Phoenix lander has two cameras on an instrument called MECA (Microscopy, Electrochemistry, and Conductivity Analyzer). The two cameras, the optical and atomic-force microscopes, complement MECA's wet chemistry experiments. With images from these microscopes, scientists will examine the fine detail structure of soil and water ice samples. The images taken by these two cameras will be at the finest resolution ever seen on Mars and their imaging of soil structure and ice crystals will be critical to our understanding of the Martian arctic.



Phoenix microscope image of beach sand, the largest grains are 500 μm in diameter.

LAB WORK

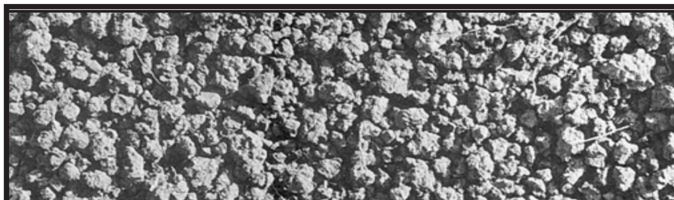
Activity 4: Soil Structure

The first soil property to determine is structure. This is the shape of the individual particles, called ***peds***, which make up the soil. Earlier missions found that Mars soil also tends to clump into particles.

Separate a small portion of your sample and examine it under a magnifying glass. Compare its structure to the diagrams below. Record this information on the Soil Structure Card, and sketch what you see in the space provided. ***On your Data Log, record reasons why you classified the soil as you did.***

Remember to handle the sample very gently so that you can preserve its original structure as much as possible. Take only as much of the sample as you need for the measurement you are making at that moment.

Soil Structure Comparison Chart

	**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**	

(Photos Courtesy of USDA Natural Resources Conservation Service)

LAB WORK

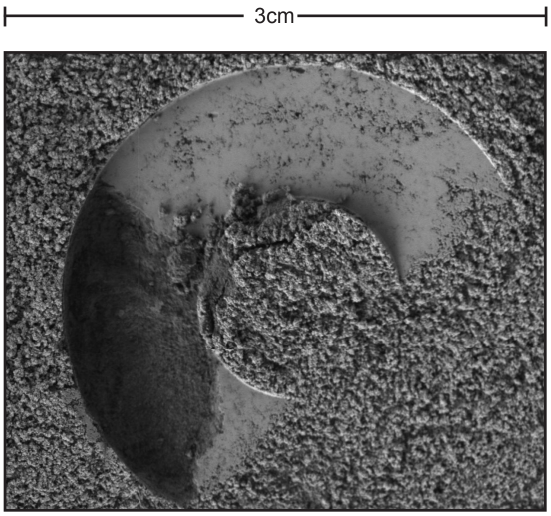


PHOTO CREDIT: NASA/JPL/CORNELL/USGS

While the Viking and Mars Pathfinder landers could not measure soil consistency, the Mars Exploration Rovers pressed the RAT (Rock Abrasion Tool) into the martian soil and photographed the impression. By studying how well the soil held together, scientists gathered valuable data on soil consistency. Scientists also used the rovers' wheels to dig trenches and compact the soil.

Similar to Mars scientists working with the rovers, you will gather soil consistency data on your sample by trying to deform it.

Activity 5: Soil Consistency

Consistency is a measure of how well soil particles hold together. Loose soil crumbles easily, while firm soil may require a shovel to break up.

Soil consistency is determined by the parent materials, how much erosion the soil has experienced, whether it has been disturbed by plant roots or digging, and how much pressure it has experienced.

Take a single ped (the smallest soil piece that holds together on its own) from the soil sample and squeeze it between your fingers.

Classify the sample's consistency using one of the following four categories below. ***Record the value, plus how you decided on it, on your Data Log:***

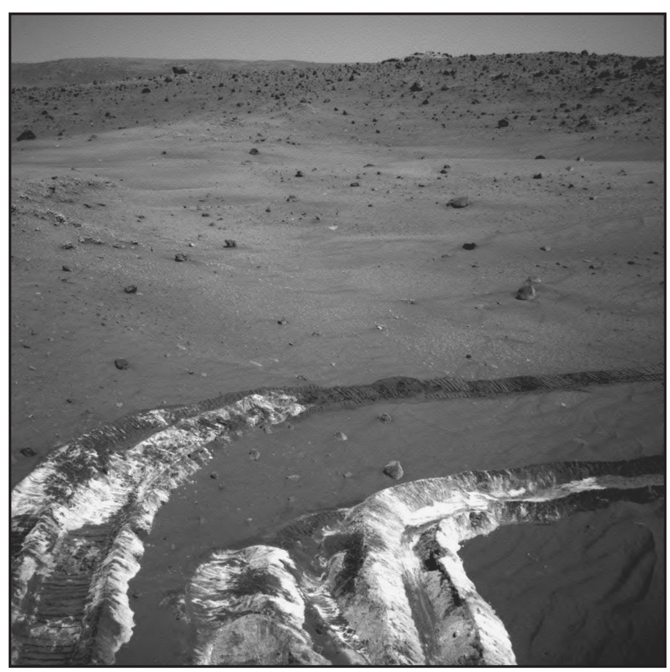
Loose: The ped falls apart extremely easily. (In fact, you may not be able to get a single ped to hold together at all.)

Friable: The ped breaks apart with just a small amount of force from your fingers.

Firm: Your fingers can break the ped apart, but you have to press hard to do so.

Extremely Firm: You can't break the ped apart at all.

PHOTO CREDIT: NASA/JPL/CORNELL/USGS



LAB WORK

To date, the Viking landers (1976) were the only spacecraft to conduct experiments looking for life in the Martian soil. The three biology experiments discovered unexpected and unexplained chemical activity in the Martian soil, but provided no clear evidence for the presence of living organisms in the soil. In the decades since Viking, scientists have concluded that a combination of strong solar ultraviolet radiation, the extreme dryness of the soil, and the oxidizing nature of the soil's chemistry prevent the formation of living organisms in the Martian soil.

In this activity, you will look for biological material, or ***biomarkers***, that will give you data on the ability of your soil sample to harbor living things.

Activity 6 —Part 1: Biomarkers (Roots, Organisms, and Rocks)

It would be wonderful if Mars soil had big, obvious signs of life that any lander could detect. But that hasn't happened. As a result, scientists say they need to examine Martian soil very closely to find any ***biomarkers***. This can happen here on Earth, too, where it can be hard to determine if samples of a particular soil are suitable for life.

For example, rocky soil is very difficult for plants to grow in, so it's important to know how many rocks are within your sample. Also, by measuring the amount of roots contained in your soil sample, you can get an estimate of the soil's ***fertility***. The fertility is one way to assess the soil's ***habitability***.

Another indication that your soil sample supports life can be in the form of a biomarker such as an ***organism*** (plants, bacteria or animals) that appears to be living in the sample.

Take approximately one cubic centimeter (2 pencil-eraser widths) of your soil sample and place it on a white piece of paper. Using tweezers or a ***sieve*** (a screen that allows some sizes of material through, but stops others and small animals), extract all the rocks bigger than 2 mm (about the thickness of a nickel) in diameter and all the roots in your sample.

Record the number of rocks, roots, and small animals (if any) per cubic centimeter for this soil sample on your Data Log.

Activity 6 —Part 2

Now that you have examined the soil sample for organic material, you can estimate the soil's suitability for plants to grow or animals to live. Determine if the sample's fertility is:

High: You can see several animals, plants or roots in your sample.
Medium: You can see only a few animals or plant roots in your sample.
None: This sample appears barren of any life.

Record the habitability of your sample on your Data Log.

LAB WORK

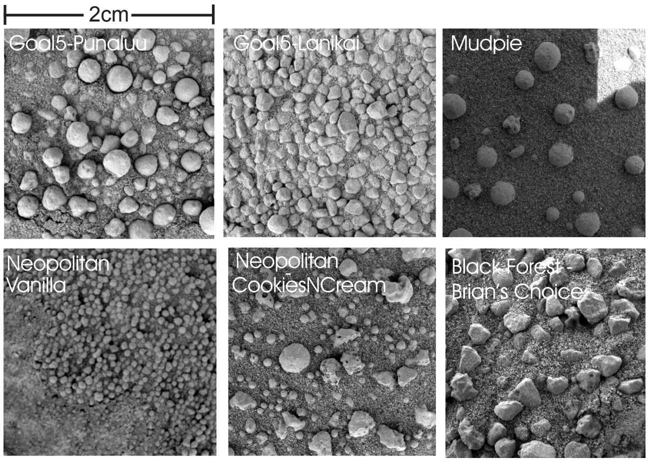


PHOTO CREDIT: NASA/JPL/CORNELL/USGS

The Mars Exploration Rovers use a special camera called the Microscopic Imager (MI) to look at small grains and details of rocks that scientists want to analyze more closely. This special camera is intended to produce images that simulate a geologist's view through a common hand lens.

Similarly, you will be looking at the sample you collected to determine how large or small the individual grains are.

Discuss: *Looking at the image at the left, why do these photos have interesting names?*

Activity 7: Soil Texture

Soil texture differs a bit from soil consistency. While soil consistency concerns how well the grains that make up a ped hold together, ***soil texture*** involves how large the individual grains are.

We classify soils into three general grain sizes:

Sand: Grains between 2.0mm and 0.05 mm in diameter.
Silt: Grains between 0.002mm and 0.05 mm in diameter.
Clay: Grains less 0.002 mm in diameter.

Soils that are a mixture of these types are called ***loams***. So, a soil might be referred to as a "loamy sand" or a "loamy clay." For our purposes, we will stay with sand, silt, or clay, but if your sample falls between the types, feel free to call it a kind of loam (loamy silt, loamy sand, loamy clay, etc.).

As you might imagine, it's difficult to measure something smaller than a single millimeter. Fortunately, there's an easy way to estimate the size of grains contained in the soil.

Take a small amount of soil (about 2.5 cm diameter) and wet it slightly with a spray bottle. The more the grains of soil stick together, the smaller those grains are.

1. Try to form a ball with the small amount of soil that you sprayed with water. If you can't form a ball that will hold together, the soil is mostly sand.

2. If you can form a ball with the soil, try squeezing it into a flat ribbon. If you can make a very long ribbon (more than 5 cm), the soil is mostly clay.

3. If you can form a ball with the soil, but the ribbon is only very short, then the soil is mostly silt.

Record the texture of your soil sample on the Data Log.

Once you have determined the texture, pour the separated sample materials back into sample bag 1, and shake it up to re-mix.

LAB WORK

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.

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.

You will also be analyzing your soil sample for the presence of carbonates, and measuring the pH of the soil.

Activity 8: Chemical analysis

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. During this portion of the lab, you will test the sample for carbonates ($(CO_3)^{2-}$) and measure the pH of the soil (how acidic or basic it is).

Divide the contents of sample bag number 1 into two parts, one for the carbonate test, and one for the pH test. Follow the instructions on how to perform the experiment.

Any Free Carbonates?

Carbonates are minerals that contain 1 carbon atom, and 3 oxygen atoms ($(CO_3)^{2-}$ ion) as part of their structure. Calcium carbonate ($CaCO_3$) is a very common carbonate, but there are many others.

Carbonates naturally form in the presence of carbon dioxide and liquid water, and could therefore provide important evidence for the presence of liquid water—and possibly life—in the Martian past. Although researchers have already detected carbonates in some meteorites from Mars, they have never yet found them on the surface of the planet.

These carbonates can form a white, extremely hard layer that is difficult for plant roots to break through. Because plant growth is limited, these types of soils are often much less fertile than others. This type of soil is often called ***caliche***, or hardpan.

Testing for carbonates is very easy. Put a small amount of vinegar into a foam cup. Take approximately one cubic centimeter of the soil sample and, using a spoon, put a few drops of vinegar onto the soil. If the soil contains carbonates, the vinegar's acid will release carbon dioxide gas, the same thing that puts the fizz in soda. This will bubble, or ***effervesce***. The more bubbling action you see, the more carbonate minerals the sample contains.

Record on your Data Log whether the soil sample contains a lot of free carbonates, some free carbonates, or no free carbonates at all.

LAB WORK

Activity 9: Measuring pH

NOTE: for this activity, you will need the other half of sample bag number 1 you separated in activity 8.

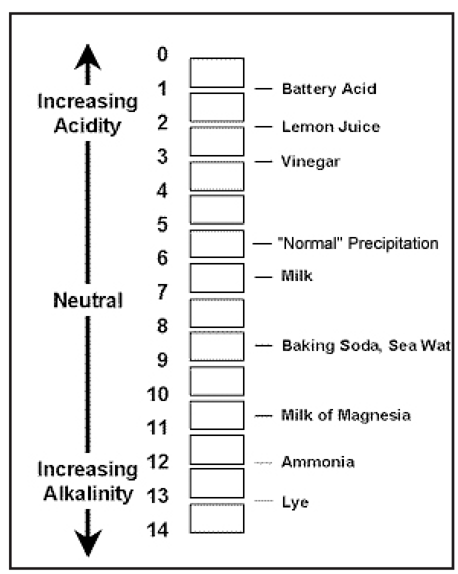
pH is a measure of how acidic or how basic a solution is. The pH scale ranges from 1 to 14, with a pH of 1 being highly acidic and a pH of 14 being highly basic. A pH of 7 is considered neutral.

pH is important in determining the kind of organisms that can live in the soil. For example, farmers plant crops that grow well in the pH of the soil on their farms. They may also adjust the pH of their soil by adding chemicals. Bacteria have adapted to live in environments that are close to a neutral pH.

There are some organisms that have been found in very extreme environments. Scientists call these organisms Extremophiles and scientists have found these organisms surviving in almost every imaginable environment. From the deepest parts of the ocean, to the highest mountains and everywhere in between, these organisms have found a way to survive. Generally though, if the soil is too acidic or too basic, most organisms will have a tough time surviving.

Determining the pH of your soil sample is an important step in describing it. Follow these steps with the other half of the contents of sample bag number 1:

1. Use a pencil to mark 2 cm on a popsicle stick.
2. Pour approximately 2 cm (measure the depth with the popsicle stick) of distilled water into a foam cup.
3. Using a pH test strip or a pH meter, measure the pH of the distilled water (it should have a pH of approximately 7). ***<u>Record the actual pH of your distilled water on your Data Log.</u>***
4. Add the soil sample to the distilled water in the cup and stir it with the popsicle stick until it is thoroughly mixed.
5. Using a new pH test strip or a cleaned pH meter probe, measure the pH of the soil/water solution and ***<u>record the value on your Data Log.</u>***
6. ***<u>Record on your Data Log whether the sample is acidic, neutral, or basic.</u>***



Keywords

Aspect: The direction towards which a slope faces. Aspect is important in hilly or mountainous terrain and affects site quality and what the soil is made of.

Bedrock: The solid rock that underlies all soil, sand, clay, gravel and loose material on the earth's surface.

Biomarker: material that indicates living organisms (plant, animal, bacteria, etc.) are currently living in a soil sample, or once lived in a soil sample.

Carbonate: A compound containing carbon and oxygen; an example is calcium carbonate. Carbonates naturally form in the presence of carbon dioxide and liquid water, and could therefore provide important evidence for the presence of liquid water – and possibly life - in the Martian past. Although researchers have already detected carbonates in some meteorites from Mars, they have never yet found them on the surface of the planet.

Caliche: $CaCO_3$, calcium carbonate; often seen as a white crust on stones. It may form subsurface nodules, or coalesce into layers, causing hardpans.

Effervescence: The bubbling action that occurs as a gas comes out of a liquid such as when carbon-dioxide gas is produced by the reaction of carbonate coatings on soil being treated with an acid like vinegar.

Extremophile: An organism that grows optimally in extreme conditions, including extreme temperature, pressure, pH, ionic concentration, and pressure.

Fertility: The ability of a soil to supply the elements and compounds needed for plant growth.

Friable: A type of soil consistency in which the soil ped breaks easily when squeezed between the thumb and fore finger with a small amount of pressure.

Habitability: a measure of an environment's potential to develop and sustain life.

Hardpan: a hard, compacted, often clayey layer of soil through which roots cannot grow.

Humus: The brown or black organic part of the soil resulting from the partial decay of leaves and other matter.

Hydrology: Scientific study of the properties, distribution, and effects of water on the Earth's surface, in the soil and underlying rocks, and in the atmosphere.

Loam: Soil that contains an approximately equal amount of sand, silt, and clay particles.

Mars Pathfinder Mission (July 1997-Sept 1997): Mars Pathfinder was originally designed as a technology demonstration of a way to deliver an instrumented lander and a free-ranging robotic rover to the surface of the red planet. Mars Pathfinder not only accomplished this goal but also returned an unprecedented amount of data and outlived its primary design life. You can find out more at http://mars.jpl.nasa.gov/missions/.

Keywords

Mars Exploration Rover (MER) mission (2004-present): This mission consists of two rovers (nicknamed Spirit and Opportunity). Primary among the mission's scientific goals is to search for and characterize a wide range of rocks and soils that hold clues to past water activity on Mars. The spacecraft are targeted to sites on opposite sides of Mars that appear to have been affected by liquid water in the past. The landing sites are at Gusev Crater, a possible former lake in a giant impact crater, and Meridiani Planum, where mineral deposits (hematite) suggest Mars had a wet past. You can find out more at http://mars.jpl.nasa.gov/missions/.

Viking I, II missions (1975-1982): NASA's Viking Project found a place in history when it became the first mission to land a spacecraft safely on the surface of Mars. Two identical spacecraft, each consisting of a lander and an orbiter, were built. Each orbiter-lander pair flew together and entered Mars orbit; the landers then separated and descended to the planet's surface. You can find out more at http://mars.jpl.nasa.gov/missions/.

Nutrients: Substances, such as nitrogen and phosphorus, required by organisms in order to grow and survive.

Organic material: Decomposed animal or plant material that is added to the soil and becomes a part of the soil profile. When it is fully decomposed and incorporated into the soil, organic matter becomes a dark, moist, nutrient-rich substance called humus and the plant and animal material from which it formed can no longer be recognized.

Organism: Any living thing including plants, animals, bacteria and other microbes.

Parent material: Refers to the primary material from which the soil is formed. The type of soil that forms depends on the type of rocks available, the minerals in rocks, and how minerals react to temperature, pressure, and erosive forces. Soil parent material could be bedrock, organic material, an old soil surface, or a deposit from water, wind, glaciers, volcanoes, or material moving down a slope.

Peds: An individual unit of natural soil structure or aggregation (such as granular, blocky, columnar, prismatic, or platy).

pH: A measure of acidity, ranging from 1 (acid) to 14 (base).

Sieve: An apparatus with openings for separating sizes of materials.

Soil consistency: How easy or hard it is for a soil ped to break apart when it is squeezed.

Soil structure: The arrangement of soil particles into larger particles or clumps.

Soil texture: The way soil "feels" when it is squeezed between the fingers or in the hand. The texture depends on the amount of sand, silt, and clay in the sample (particle size distribution), as well as other factors (how wet it is, how much organic matter is in the sample, the kind of clay, etc.).

Additional Resources

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 March 2007)

Name:______________________________

Data Log: Soil Properties

Soil Sample Number: ______________________________

1. Soil Context Description for this Sample:

Location: ______________________________

Aspect: ______________________________

Ground Cover: ______________________________

Land Use: ______________________________

Parent Material: ______________________________

2. Soil Moisture Content (part 1)

Weight of plate and towels (M_1): ________ g

Weight of plate, towels, and wet sample (M_2): ________ g

Wet mass of sample (M_W): ________ g
($M_W = M_1 – M_2$)

3. Soil Color: ______________________________

Moist? Y / N Dry? Y / N Organic Materials? Y / N

4. Soil Moisture Content (part 2)

Weight of plate, towel, and dry sample (M_3): ________ g

Dry Mass of Sample (M_D): ________ g
($M_D = M_3 – M_1$)

Mass of Water in Sample: ________ g
(Water mass = $M_W – M_D$)

Soil water percentage: _______ % water
(Water percentage = 100 x M_D ÷ M_W)

Data Log: Soil Properties

4. Soil Structure: ____

5. Soil Consistency: ____

6. Biomarkers

Rocks: ___________________ per cm^3

Roots: ___________________ per cm^3

Organisms: ___________________ per cm^3

7. Habitability: (Circle one)

High Medium None

8. Soil Texture: ____

9. Free Carbonates:

None ______ Some _______ A Lot _________

10. pH of Soil Sample:

pH of Distilled Water (should be near 7): ________

pH of Soil/Water Mixture: ________

Acidic ______ Neutral _______ Basic _______

KWL: what I Know, what I Want to know, and what I Learned

KWL chart about Soil
(Fill in the first 2 columns before you begin your research. Complete the last 2 columns after you have completed your research)

What I **K**now	What I **W**ant to Know	What I **L**earned	**+** What I want to explore further
1.	*1.*	*1.*	*1.*
2.	*2.*	*2.*	*2.*
3.	*3.*	*3.*	*3.*
4.	*4.*	*4.*	*4.*
5.	*5.*	*5.*	*5.*
6.	*6.*	*6.*	*6.*
7.	*7.*	*7.*	*7.*
8.	*8.*	*8.*	*8.*
9.	*9.*	*9.*	*9.*
10.	*10.*	*10.*	*10.*
11.	*11.*	*11.*	*11.*

Additional questions to consider:

- What type of life needs dirt to survive?
- What's in the dirt that life needs to survive?
- How do we find out what's in the dirt?
- Why is it important to understand the properties of dirt?
- Who is interested in dirt properties besides scientists?
- How do scientists help these other folks that are interested in dirt?

Soil Properties Report

Congratulations! You have now completed measuring the properties of this soil sample. To complete your analysis, write a one-page description of the soil, making sure that your report includes the values of all of the properties you measured. (You do not need to mention the calculations made to figure out those properties).

Knowing what you do about the missions that have already landed on Mars, how might you use their scientific data to design a new instrument to study the soil in greater detail? You just might be the next scientist or engineer to send a future spacecraft to Mars!

Appendix 1: Soil Color Comparison Chart

Color	Munsell Code	Color	Munsell Code	Color	Munsell Code
	2.5YR 3/6		5Y 6/4		10YR 2/1
	2.5YR 4/6		5YR 6/8		10YR 8/2
	5R 3/6		7.5YR 5/6		10YR 8/3
	5Y 5/1		10R 4/8		10YR 8/6

Appendix 2: Soil Structure Comparison Chart

	**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**	

(Photos Courtesy of USDA Natural Resources Conservation Service)

Laminate, and cut to use for assessment of soil color and structure

Appendix 3: Soil Parent Material Identification Chart

Mineral	Munsell Code	Color
Goethite (FeOOH)	10YR 8/6 7.5YR 5/6	yellow strong brown
Hematite (Fe_2O_3)	5R 3/6 10R 4/8	red red
Lepidocrocite (FeOOH)	5YR 6/8 2.5YR 4/6	reddish-yellow red
Ferrihydrite (Fe (OH)3)	2.5YR 3/6	dark red
Glauconite ($K(Si_xAl_{4-x})(Al,Fe,Mg)O_{10}(OH)_2$)	5Y 5/1	dark gray
Iron Sulfide (FeS)	10YR 2/1	black
Pyrite (FeS_2)	10YR 2/1	black (metallic)
Jarosite ($K\ Fe_3\ (OH)_6\ (SO_4)_2$)	5Y 6/4	pale yellow
Todorokite (MnO_4)	10YR 2/1	black
Humus	10YR 2/1	black
Calcite ($CaCO_3$)	10YR 8/2	white
Dolomite ($CaMg\ (CO_3)_2$)	10YR 8/2	white
Gypsum ($CaSO_{4X}\ 2H_2O$)	10YR 8/3	very pale brown
Quartz (SiO_2)	10YR 6/1	light gray