Rocks and Minerals

I. OBJECTIVES

One of the many ways to study Earth is by examining the rocks that make up its surface. Earth is a dynamic planet, with plate tectonics, water, wind, volcanoes, and mountains. These processes create many different kinds of rocks. Geologists examine these rocks to try to infer the conditions under which they formed and thereby understand the history of Earth. This knowledge of rocks can then be extended to interpret the surfaces and histories of other planets.

In this lab, you will:

- examine several types of rocks and minerals;
- determine the formation and the history of each rock and mineral;
- infer conditions under which the rocks and minerals formed;
- compare conditions on Earth to those on other planets.

II. PRE-CLASS PREPARATION

This lab assumes that you have no prior knowledge of geology or rocks, but you are expected to familiarize yourself with the material covered in this lab before beginning the lab exercises. Understand the concepts to be studied in this lab. The methods and instruments will be introduced to you during the lab activities. Read the background section and focus on understanding different rock formation processes. Make sure you know the definitions of important terms so you can describe the types and characteristics of rocks.

III. BACKGROUND

A. MINERALS. Earth and the other planets are not just chaotic blobs of chemical elements; rather, the elements are combined into chemical compounds, and these chemical compounds arrange themselves into ordered crystal structures called ***minerals***. There are over 2000 known minerals. All gemstones, like diamonds, opals, and turquoise, are minerals.

Rocks are composed of minerals. Most rocks in the solar system are formed from the few basic minerals described below.

- ***Quartz*** is usually glassy and clear, white, or gray, but can be almost any color. Purple quartz is *amethyst*. Quartz is an important component of most rocks and sand.

- ***Feldspar*** is usually bright pink or chalky white. Feldspar is common in granitic rocks.

- ***Pyroxene, amphibole, and mica*** are usually small, black, rectangular crystals in igneous rocks.

- ***Olivine***, an olive-green mineral, is the most important mineral in Earth's mantle. Gem-quality olivine is called *peridot*.

When minerals form, they grow into ***crystals***. The sizes and shapes of crystals (see Figure 1) are indicative of the processes that formed them. If a crystal grows slowly, it tends to be large and euhedral. ***Euhedral*** crystals have good geometric shapes and angular edges (a rectangular box is euhedral but an egg is ***anhedral***). Small, fast-growing crystals can also have geometric forms, but they are usually not equidimensional. Instead, they usually grow in long needles or thin plates. If the ***melt*** (liquid from which minerals crystallize) is ***quenched*** (cooled extremely rapidly), then crystals do not have time to grow. A non-crystalline solid is called a ***glass***.

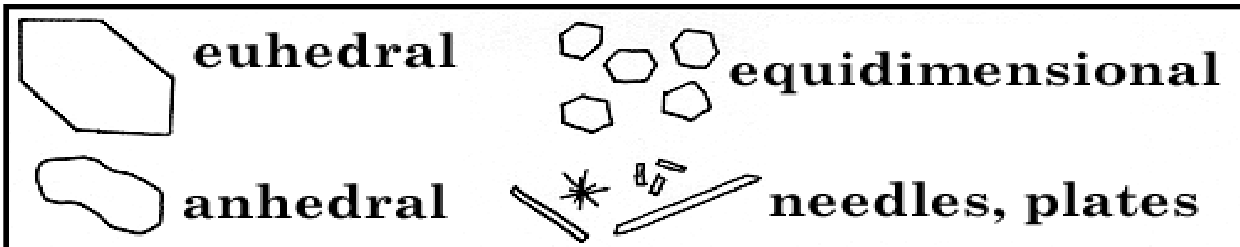

FIGURE 1: Rock crystals come in many different shapes and sizes.

B. ROCKS. ***Rocks*** are combinations of minerals that can be formed in many different ways. The textures and minerals that make up a rock can be used to determine the geologic processes that produced it. Traditionally, there are three types of rocks found on Earth: ***igneous***, ***sedimentary***, and ***metamorphic***. Each rock type can be formed from or made into every other type in a process called the ***rock cycle*** (see Figure 2).

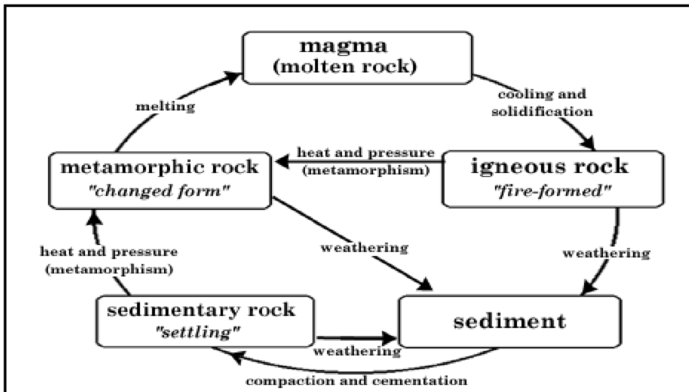

FIGURE 2: The rock cycle.

1. Igneous Rocks. Igneous rocks form from liquids that cool and crystallize. They are the most common rocks on planetary surfaces.

There are two major types of igneous rocks: extrusive and intrusive.

- ***Extrusive rocks*** are igneous rocks that cool on the surface. Liquid rock that is erupted onto the surface is called ***lava*** (see Figure 3). Rocks that form from lava cool quickly. Rapid cooling does not allow crystals in the lava to grow very large. If the rocks cool extremely rapidly, like in a fire fountain, they may be quenched to glass before any crystals can grow. Also, the lava on the surface is no longer under great pressure (that is, confined by overlying rock), so any gases originally trapped within it can come out of solution (like carbon dioxide bubbles in a newly opened can of soda). The gas bubbles escape, but they leave pits in the rock called ***vesicles*** (see Figure 3). The most common type of volcanic rock is ***basalt***.

- ***Intrusive rocks*** are igneous rocks that cool below the surface. Liquid rock below the surface is called ***magma*** (see Figure 3). Rocks that crystallize below the surface are well-insulated and cool slowly. Slow cooling gives the crystals time to grow large. The most common intrusive rock is ***granite***.

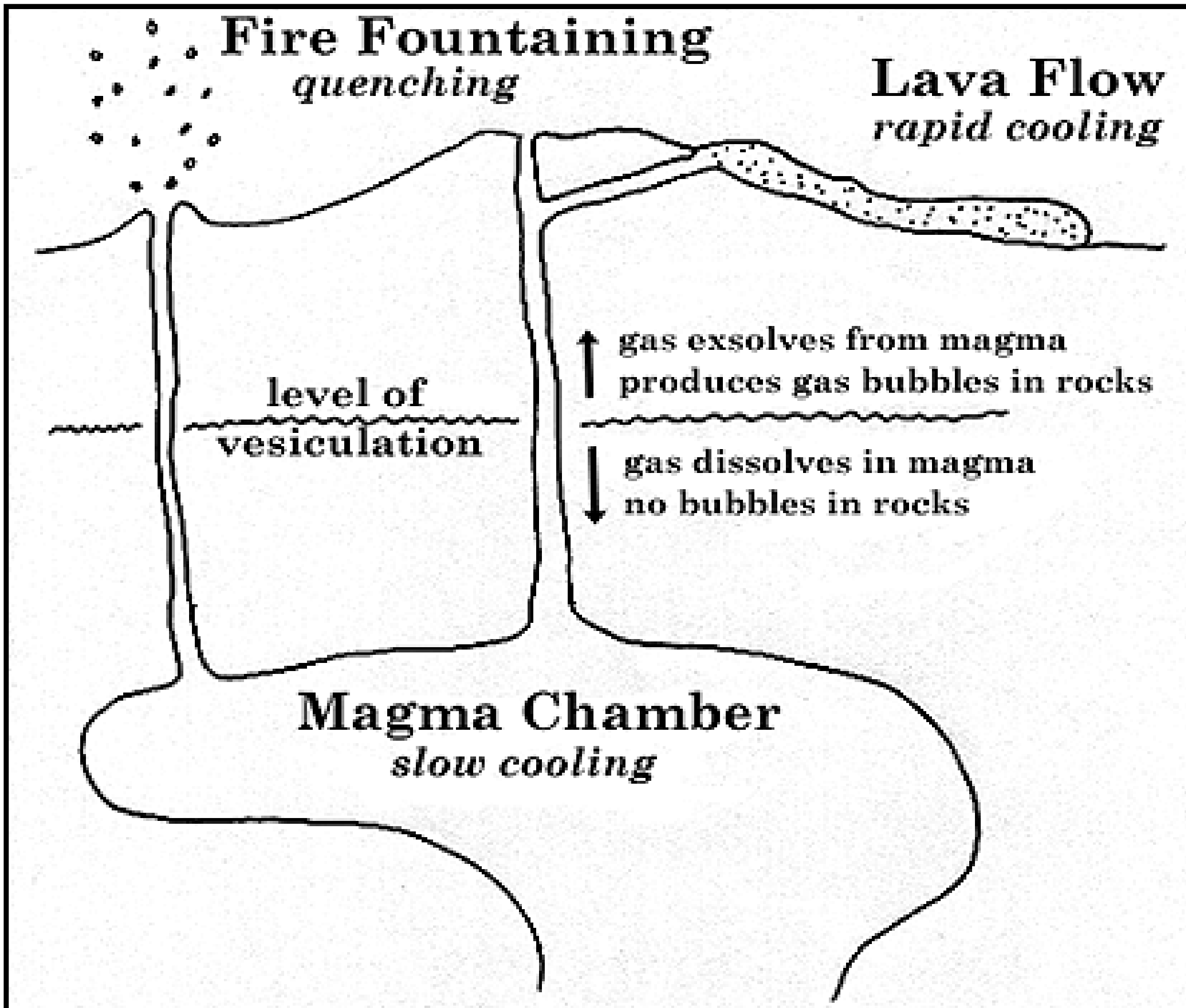

FIGURE 3: This diagram shows typical cooling time scales for igneous rock crystals. Notice that rapid cooling occurs at the surface where the surface and atmospheric temperatures are much lower than Earth's interior temperature. Extrusive rocks, therefore, tend to have small crystals because the faster cooling rate does not allow enough time for the crystals to grow large.

2. Sedimentary Rocks. Sedimentary rocks are accumulations of weathered bits of other rocks. Sandstone, limestone, and shale are good examples of sedimentary rocks. Often, sediments are laid down in layers, and sedimentary rocks preserve these layers. However, not all sedimentary rocks are layered, and layering can be present in other rocks as well. Water does not need to be present to weather rocks, but many sedimentary rocks form in water environments. Sedimentary rocks can also form from sand dunes, in rivers, and on the ocean floor. A good place to find a lot of sedimentary rocks is in the Grand Canyon.

3. Metamorphic Rocks. Metamorphic rocks are rocks which have been subjected to intense heat or pressure sufficient to alter their internal structure but not enough to melt them. For instance, slate is formed from shale that was exposed to high heat and pressure; and marble is a metamorphosed limestone. Metamorphic rocks form during deep burial under Earth's surface or in mountain-building events.

A common feature of metamorphic rocks is that minerals rearrange themselves to form plates perpendicular to the force that is applied. This is called ***foliation***. You can see foliation in gneiss (pronounced "nice"), which is a metamorphosed granite. The rocks on Mount Lemmon are mostly gneiss.

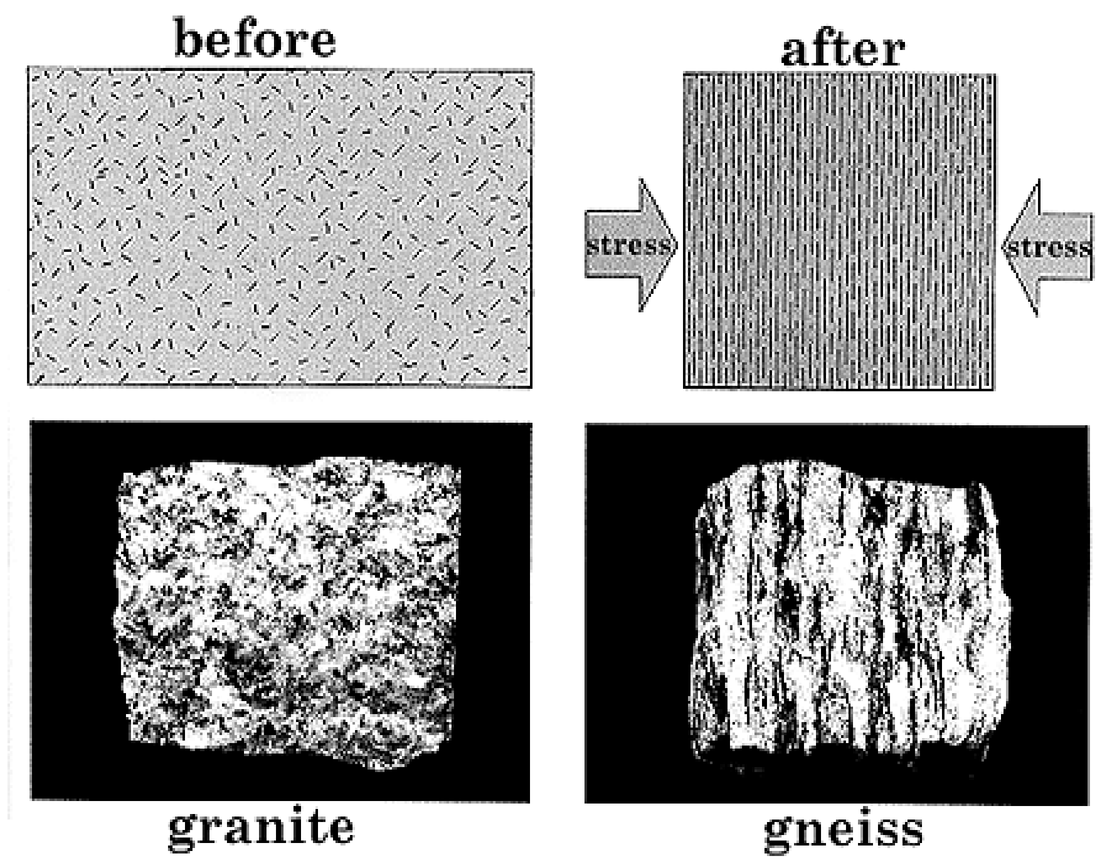

FIGURE 4: The transformation of granite to gneiss.

IV. THE APPARATUS

• rocks and thin sections • hand lens • microscope

A. ROCKS AND THIN SECTIONS. You will be provided with several rock samples to examine. You will also examine at least one thin section. ***Thin sections*** are slices of a rock that are so thin that light can shine through them. The thin sections will be mounted in glass slides. Be careful not to break them or get them dirty.

Please be careful when handling all samples. Some samples will break in your hands if you are not gentle with them. Other samples will break your foot if you lose your grip and drop them. Pay attention to the sample you are handling to avoid damage and injuries!

B. THE HAND LENS. You will find a geologist's hand lens in a leather case in the plastic container with the thin sections. To use the hand lens, place it close to your eye and ***move the rock*** until it comes into focus. Tip your head back slightly so as not to block the light.

C. THE PRECISION MICROSCOPE. In this lab, you will use a ***microscope*** for some observations. The microscope has a number of settings to help you make the best observations possible. To begin, notice that there are two disks that can be placed on the microscope platform for viewing. The first is a transparent disk used ***only*** for viewing thin sections. Placing rocks on the transparent disk will scratch or otherwise damage it. The second disk is a plastic disk with a black side and a white side. This is the disk you will use for viewing rocks. You may use either side.

Once you have placed the proper disk in position, turn on the light. For viewing thin sections, pull the toggle switch *toward* you. This turns on a light underneath the transparent disk that will shine through the thin section. For viewing rocks, push the toggle switch *away* from you. This turns on an overhead lamp that will shine on the sample for easy viewing.

Look through the lenses to see the rock. You may need to adjust either the position of the rock or the microscope's ***focus***. To adjust the focus, slowly turn the knobs at the side of the top portion of the microscope. Continue to turn them, in either direction, until the meteorite comes into focus. If you can no longer turn the knob and the object is still not in focus, ***don't force the knob***! If you try to force the focus knob, you may strip the screws and damage the microscope. Instead, you will need to move the whole top portion of the assemblage up or down. ***Ask your instructor for help doing this.***

You can change the ***magnification*** of the microscope. If you turn the microscope so that the eye-pieces point away from you, you will notice writing on the black cylinder above the rock. On one side you will see a 2x, and when you rotate it you will see a 4x. When the 2x is facing outward, the view you will get in the microscope is a magnification factor of 2. When the 4x is facing outward, the view you will get in the microscope is a magnification factor of 4.

Remember to turn the light off when you are finished with the microscope! Leaving the light on for long periods of time will burn out the bulb.

V. THE LAB SESSION

Your data for this lab will consist of detailed descriptions and sketches of each rock that you examine. Your description should include details like color, particle size, particle shape, number of different mineral components (***phases***), etc. Use the following outline for each sample. You cannot make any interpretations without detailed descriptions to justify your answers!

Rock Type:

Color:
Phases:

Description:

Interpretation/Questions:

Many steps in the lab have questions associated with them. These questions are designed to aid in your interpretations of the histories of the rocks. ***You should answer these questions while you have the rocks in front of you!*** The answers to these questions will form the basis of the discussion section of your lab report.

You should use a blue book to record your data and discussion. Turn it in at the end of class.

A. Learning How to Study Rocks. The starting point for describing and analyzing a rock is to determine what basic things you can say about the rock just from observation. Your instructor will walk you through a few examples of how to examine a rock, what to look for in the rock, and how to use this information to infer a history from the rock. Follow this general method when studying rocks:

1. ***Examine and describe the rock.***
2. ***Interpret what you see.***
3. ***Apply this knowledge to other rocks.***

STEP 1: Examine and describe the rock. From basic observations, we will identify a sedimentary rock (**conglomerate**) and an igneous rock (**granite**). There are four ways to examine each rock. When you make each observation, be sure to write down the descriptions!

Basic description: Without any prior knowledge, you can already describe rocks in a geologically useful way. Describe the whole rock--its color, texture, hardness, and weight. Identify some important sub-rock features. How many different minerals or components (phases) are there? Is the rock composed of separate grains or interlocking crystals? What are the shapes, sizes, and colors of the component grains or crystals?

Hand Lens: A typical geologist's tool, especially in the field, is a hand lens. The hand lens is powerful enough to be useful in examining the small details in rocks, and it is a lot more convenient than dragging microscopes across mountaintops! Examine the rock under the hand lens. Observe the fine details of the crystals and grains. Add these observations to your rock description.

Microscope: Examine the rock underneath the microscope (be sure you have read **section IV. C.** on how to use the microscope!). Observe the relationships between the crystals and the grains. Add to your description of the rock. Do the crystals border and interweave with each other, or are they resting on top of each other? Does there seem to be any stuff (***matrix***) between the crystals or grains?

Sketch: A sketch is helpful in describing what you see and for remembering it later. Sketch the rock as seen with the tool (eye, hand lens, or microscope) that gives you the most information. It is okay for the sketch to be rough and quick, as long as it conveys the information clearly. Each sketch MUST include a scale (use a ruler) and MUST be clearly labeled.

STEP 2: Interpret Your Observations. Now that you have examined some rocks, you will try to understand what you saw.

Sedimentary rocks are rocks whose components were originally other rocks that got broken apart and put back together. In the conglomerate, you should be able to see large, rounded grains. Each of these grains is made of individual quartz crystals. The grains come from quartzite (a metamorphic rock) which was broken apart. The pieces were then tumbled and rounded, probably in a stream bed. There is a cement between the round grains which, under a microscope, looks like it is made of smaller grains. This matrix was probably composed of the sand and mud in the stream bed. You should be able to identify this as a sedimentary rock and you should be able to justify your interpretation with your sketch and your description.

Igneous rocks cooled from a liquid state to a solid state. There are no gaps left in a liquid, so all the space is filled by crystals. You should see that the granite is made up entirely of crystals. The crystals have flat edges, angular ends, are all about the same size, and entirely border each other. However, the crystals are not all the same color or shape. You should be able to identify this as an igneous rock and you should be able to justify your interpretation with your sketch and your description.

- What differences would you expect in crystal or grain structure between sedimentary and igneous rocks based on their formation mechanisms? Do your observations show these differences?

- Can you think of an environment where sedimentary or depositional processes might occur? Where would you find liquid rock cooling to form solid rock?

STEP 3: **Apply Your Knowledge.** Applying what you learn from known samples to unknown samples is a particularly useful skill in planetary science. You can apply your knowledge of rocks on Earth to rocks from other planets. In this step, you apply the techniques and information learned by studying known rocks to understand unknown rocks.

Examine the unknown rocks with your instructor. Using the same methods and tools discussed above, describe and sketch these rocks. Mention the bulk rock characteristics and the sub-rock details.

With the class and your instructor, interpret your observations by answering the following questions:

- Is this rock sedimentary or igneous? How do you know?

- How did this rock form?

B. Reading Histories from Rocks. In this section, you will use the method established above to determine what other information can be gleaned from rocks. Not only can rocks record their formation processes, but they can also record events that happened to them after they were formed. The formation and evolutionary histories of rocks are good indicators of the formation and evolutionary history of the planetary bodies on which the rocks originated.

STEP 4: You can tell how quickly or slowly an igneous rock cooled by the relative sizes of its crystals. Look again at the igneous rock you examined in **STEP 3**. It is an igneous rock called ***pyroxenite***. You should have already described and sketched it. Measure the crystals and describe their shapes. This will give you a basis for comparison with the next rocks.

Pick up the rocks labeled ***rhyolite porphyry***, ***vesicular basalt***, and ***obsidian***. Describe and sketch each rock. Pay particular attention to how they are different from each other and from the pyroxenite. Interpret the histories of these rocks with the guidance of the following questions:

- Did these rocks cool faster or slower than the pyroxenite? How can you tell?

- Which one of these rocks cooled the fastest? Which one cooled the slowest? Explain your reasoning.

- Where did the rhyolite form? Where did the obsidian form? Explain your reasoning.

- How did the holes in the vesicular basalt form? Where did this rock likely solidify? Was the cooling time for this rock closer to that of the obsidian or of the rhyolite porphyry?

STEP 5: Most rocks have a complex history. Igneous rocks can experience multiple cooling events, where the liquid begins to cool slowly, and then later cools rapidly. Look again at the rock labeled ***rhyolite porphyry***. You should have already described and sketched it. Did you notice the two different phases? You should have seen that the crystals of one phase are large, and the others are small.

Examine the rock labeled ***diabase porphyry***. Describe and sketch it, paying particular attention to the different phases in the rock. Interpret its cooling history, using the following questions as a guide:

- How many phases are present? How are they similar to or different from each other?

- What can you say about the cooling history of this rock based on your description of the crystals?

- Can a rock cool slowly and quickly simultaneously? Could a rock be in one environment, and then another?

STEP 6: Apply your knowledge of igneous cooling histories. Examine the rock labeled ***San Carlos***. Describe and sketch it. Interpret the formation and cooling history of this rock.

There is a thin section of a basalt, which is the grey part of San Carlos. Examine the thin section under the microscope. The green crystals are nodules from Earth's mantle. How does this help you interpret the rock? This rock is special because there are very few samples of the Earth's mantle and none of its core!

STEP 7: After igneous and sedimentary rocks form, they may undergo further processing called metamorphism. Compare the ***granite*** with the rock labeled ***gneiss***. A gneiss is a metamorphosed granite. Examine the pair of rocks labeled shale and slate. ***Shale*** is a sedimentary rock, made when layers of mud settle to the bottom of quiet water. ***Slate*** is a metamorphosed shale. Describe and sketch both pairs of rocks, paying particular attention to the similarities and differences between them. Interpret the history of the gneiss and slate using the following questions as a guide:

- How many different minerals are in the granite? The gneiss? Are the crystals oriented or randomly distributed?

- Why is the shale flaky? Is the slate flaky? Explain.

- The slate and the gneiss show foliation. Did you discuss foliation in your description of the rocks? From the foliation, you can determine the direction of maximum pressure on each rock. Indicate this direction on your sketches.

- Explain the history and evolution of the slate and the gneiss.

Rocks are metamorphosed by a combination of heat and pressure, which is often achieved by burying the rocks deep in Earth's crust. The combination of heat and pressure over many millions of years can change an igneous or sedimentary rock into a metamorphic rock, or re-metamorphose a metamorphic rock. If you could tunnel deep into Earth's surface, you would notice that the temperature increases by about 50° F per kilometer (the ***geothermal gradient***). Earth's average surface temperature is about 50° F but the gneisses that you see along Catalina Highway formed at a temperature of around 700° F. They must have been 13 km deep in Earth's crust at one time (and under a LOT of pressure!). Planetary scientists estimate that the geothermal gradient for Venus is 45° F/km, and they estimate that the geothermal gradient for Mars is 25° F/km (though these are highly uncertain numbers based on little data).

- If you had a gneiss from Venus that formed at a temperature of 1000° F, how deep in the crust of Venus did it form? The average surface temperature of Venus is 900° F. Show your calculation.

- How deep in the Martian crust would a similar rock form? The average surface temperature of Mars is about -50° F. Show your calculation.

5. Rock Identification.

STEP 8: Now that you have seen several rock samples, you can begin to identify the rocks around you! Examine, describe, and sketch the rock you brought to class. Determine its formation and history.

- Is this rock sedimentary, igneous, or metamorphic?

- How did this rock form?

- What processes formed this rock? What processes did not form this rock?

- What part of a planetary body is it from? Where can it not be from?

These are the questions planetary scientists ask when looking at rock samples. You may not be able to answer all of these questions for all of the rocks, however, you can still learn a lot about their histories and the histories of their parent planetary bodies.