Chips Off of the Old Block

Overview:

To familiarize students with spectra as a means of identifying minerals.

National Science Education Standards:

5th - 7th: Standard D: Earth in the Solar System

8th - 12th: Unifying concepts and processes in science

- Systems, order, and organization
- Evidence, models, and explanations
- Constancy, change, and measurement

Science as inquiry

- Abilities necessary to do scientific inquiry

Science and technology

- Abilities of technological design
- Understandings of science and technology

Time Frame:

45 minutes

Grade Levels:

9th - 12th Grade

5th - 8th Grade: This activity can serve as an introduction to the process by which scientists study minerals using remote sensing. Have the students concentrate on matching similar spectral features (in the lines) rather than concentrating on the mineralogy.

Materials:

- Copies of Figures 1 - 5 per group of students
- Student Pages

Procedure:

In each figure there will be spectra to analyze for similarities. Have the students compare and contrast the spectra to see if they can find similarities between the Earth minerals and those from Mars.

Figure1:

These are the middle infrared spectra of the four Martian meteorites named Nakhla, ALH77005, Zagami, and EET79001. These four meteorites represent three different types of rocks. Make observations of the spectra and group two together that look similar.

A. The grouping is the result of composition; Zagami and EET79001 are the two of the same type of rock. Both contain large amounts of two pyroxenes, augite and pigeonite, plus plagioclase feldspar and no olivine. Nakhla has abundant augite and olivine and there is also unshocked plagioclase. ALH77005 is dominated by olivine with augite being abundant.

This meteorite also has shocked plagioclase. The shock effect is probably induced by the impact on the Mars surface that ejected the meteorite.

<u>Figure 2</u>:

Fayalite, a variety of olivine, is the same form as forsterite and occurs chiefly in iron-rich igneous rocks. Forsterite occurs in basalts and rocks called peridotites (mostly made of magnesium-rich olivine). Look at the meteorite spectrum and compare it to the olivines.

A. Of the two olivines, fayalite is the dominant type in the ALH77005 meteorite.

<u>Figure 3</u>:

Nakhla is plotted with five pyroxenes. Even within the pyroxenes there is considerable variety. Which of the pyroxenes provides the best match with the spectrum of Nakhla?

A. Augite is the dominant pyroxene in the meteorite.

<u>Figure 4</u>:

In this figure, the meteorite Zagami is plotted with several different types of silicate minerals. Which of the silicates provides the best match with the Zagami spectrum?

A. When analyzing the possible composition of the Zagami, the quartz and labradorite (a feldspar) have little in common with the Zagami spectrum. Structures of quartz and feldspar are similar to each other, but they are very different from the mafic minerals such as pyroxene and olivine. The augite, amphibole, and forsterite have much better matches to the meteorite spectrum.

<u>Figure 5</u>:

The meteorite Zagami is compared to the same pyroxene minerals as in Figure 3. These pyroxenes are either low in calcium (enstatite and bronzite) or high in calcium (diopside, augite, and hedenburgite).

A. In this example, there are characteristics apparent of both types of pyroxenes in the meteorite.

<u>Assessment</u>:

After examining the different figures for spectral similarities and differences and discussing their patterns, students will investigate the different Earth minerals for composition and conditions for their formation. References such as the *Dictionary of Geological Terms* prepared by AGI, Internet sources, or a geology textbook may provide the necessary background information. Individual students reporting to their group or having groups report to the whole class about their findings will share the work and resources.

<u>Conclusions</u>:

What do we know about Earth's minerals that will help us to understand Mars' minerals? That is the primary question to keep in mind. Students need to use the information researched to begin to answer that question.

Credits:

Dr. Vicky Hamilton
Department of Geology
Arizona State University
P.O. Box 871404
Tempe, AZ 85287-1404
Hamilton@oliva.la.asu.edu

Jo Dodds
O'Leary Junior High School
2350 Elizabeth Blvd.
Twin Falls, ID 83301
jdodds@micron.net

Resources:

- *Dictionary of Geological Terms*, by Robert L. Bates and Julia A. Jackson, Doubleday, NY, NY, 1984. (ISBN # 0-385-18101-9)
- "Mars Meteorites Give TES Geologists a Preview of the (Infra) Red Planet," by Vicky Hamilton, *TES News*, March 1997.
- "MGS/TES Will Investigate Martian Minerals," by P. R. Christensen and others, *Arizona Mars K - 12 Education Program 1995 - 1996 Education Supplement and Guide*, August, 1995.

Name ___________________________

Chip's Off Of The Old Block

Background:

Mars Global Surveyor was launched in Septmeber, 1997, on a Delta II rocket from Kennedy Space Center, Florida. It reached Mars and after a period of aerobraking, obtained it's circular orbit in March, 1999. The mapping phase lasted 2 Earth years. (You may want to figure out how many Earth years equal one Martian year.) Dr. Phil Christensen and his science team at Arizona State University operate an instrument called the Thermal Emission Spectrometer (TES). TES is one of seven experiments launched with the Mars Observer.

The TES will look at the infrared radiation emitted from the Martian surface. In a broad sense, TES will enhance the global understanding of the geology and climate of Mars. Specifically, the science team will be able to determine and map minerals on the surface, take the temperature of the surface, observe temperature and pressure of the atmosphere, see how the polar ice caps grow and shrink with the seasons, determine the composition and thickness of Martian clouds, and use temperature data to estimate the size of particles in the soil.

The *Mars Global Surveyor* TES can detect the part of the electromagnetic spectrum known as the thermal infrared. You detect thermal infrared energy by feeling it as heat. TES can separate thermal infrared energy that makes a spectrum with wavelengths from 6 to 50 micrometers (1000 micrometers = 1 mm). (You may want to review the electromagnetic spectrum.)

Rocks can absorb or emit infrared energy. The unique crystalline structure in a mineral allows it to have its own signature spectrum (mineral fingerprint) where there is a definite pattern of absorption or emissivity of infrared energy. Using Earth minerals and a spectrometer, a database has been created of six mineral spectra from Martian meteorites. These are used to compare and analyze the data from TES as the *Mars Global Surveyor* passes over the Martian surface.

In the 2001 mission, a thermal instrument is on board the orbiter - Thermal Emission Imaging System (THEMIS). This instrument also collects data about the surface rocks and minerals on Mars. Other Mars mission thermal instruments include a Mini-TES for future long-range rover mission.

We have thirteen Martian Meteorites that have been collected here on Earth and can give us a close up view of the Martian minerals. By studying the infrared spectra of these meteorites in the lab, the TES science team should be able to identify the minerals, identify similar rocks on the surface of Mars, develop an understanding of how they were formed and even find where on Mars the meteorites came from.

Procedure/Observations:

In each figure there will be spectra to analyze for similarities.

Figure1:

These are the middle infrared spectra of the four Martian meteorites named Nakhla, ALH77005, Zagami, and EET79001. These four meteorites represent three different types of rocks. Make observations of the spectra and group two together that look similar.

1. Which two Martian meteorites are the most similar?
   1. ________________________
   2. ________________________

2. Describe how did you arrived at this conclusion.

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Figure 2:

Fayalite, a variety of olivine, is the same form as forsterite and occurs chiefly in iron-rich igneous rocks. Forsterite occurs in basalts and rocks called peridotites (mostly made of magnesium-rich olivine).

Look at ALH77005 and determine which variety of olivine, forsterite or peridotite, is the dominant type.

1. Which olivine is most abundant in ALH77005?

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2. Why do you think it's the most abundant?

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Figure 3:

Nakhla is plotted with five pyroxenes. Even within the pyroxenes there is considerable variety in the spectra.

1. Which of the pyroxenes provides the best match with the spectrum of Nakhla?

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2. Why do you think that this pyroxene provides the best match?

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Figure 4: In this figure, the meteorite Zagami is plotted with several different types of silicate minerals.

1. Which of the silicates provides the best match with the spectrum of Nakhla?

2. How did you come to your answer?

Figure 5:

The meteorite Zagami is compared to the same pyroxene minerals as in Figure 3. These pyroxenes are either low in calcium (enstatite and bronzite) or high in calcium(diopside, augite, and hedenburgite).

1. Which pyroxenes are low in calcium?

2. Which are high in calcium?

Conclusions:

Now observe some Earth minerals and try to determine the composition and the conditions needed for their formation.

1. Why do you think that it is important for scientists to study Martian minerals?

2. What do we know about Earth's minerals that will help us to understand Martian minerals?