ALTA Reflectance Spectrometer
Activity: Mars Mystery Rocks

What is this activity about?

Students learn to use the ALTA reflectance spectrometer to take reflectance measurements of "Mars" rocks at different wavelengths, and to graph a reflectance spectrum for each rock. Students compare their reflectance spectra graphs to graphs of Earth rocks, to identify some of the types of rocks found on the Mars.

Anticipated class time: 60 minutes

Learning Objectives for this Activity:

The student will be able to

- record measurements of the amount of light reflecting from a surface using an ALTA reflectance spectrometer.
- construct a graph from the reflectance spectrum data.
- compare reflectance spectra.
- predict that different objects have their own unique spectra.

Key Concepts:

- The data can be used to construct a graph of the reflectance spectrum for an object.
- Each object has its own unique reflectance spectrum.
- Scientific investigation includes observations, gathering, analyzing, and interpreting data, and using technology to gather data.

Activity Addresses National Science Education Standards (Gr 5-8):

- Use appropriate tools and techniques to gather, analyze, and interpret data.
- Mathematics is important in all aspects of scientific inquiry.
- Technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigations.
- Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection). To see an object, light from that object—emitted by or scattered from it—must enter the eye.
- Science and technology are reciprocal. Science helps drive technology, as it addresses questions that demand more sophisticated instruments and provides principles for better instrumentation and technique. Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable due to factors such as quantity, distance, location, size, and speed. Technology also provides tools for investigations, inquiry, and analysis.

- The sun is a major source of energy for changes on the earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the earth, transferring energy from the sun to the earth. The sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation.

Materials for the class:

- Handouts or projection of different spectra of Earth rocks
- 1-4 ink pads
- Hand wipes or access to a sink and soap

Materials for each group of 3-4 students:

- Copy of the Fingerprint Chart
- A large rock sample of one of these: specularite hematite, oxidized (red ochre) hematite, or basalt
- 2 sheets of white paper (copy paper will be fine)
- 1 ALTA reflectance spectrometers
- 1 Calculators
- 1 pencil with an eraser
- 1 copy of the *Reflectance Worksheet*
- 1 copy of the *Spectrum Graph on transparencies*

Teacher Preparation:

1. Plan to break your class into groups of 3-4 students each, with one ALTA spectrometer per group.

2. Check each ALTA reflectance spectrometer—make sure that it has a relatively new battery in it, and that numbers appear on the digital display when you turn it on.

3. The darker the classroom is, the better the measurements collected by the ALTAs will be; consider closing window blinds and turning off the overhead lights.

The Activity

1. Invite your students to describe how they can identify someone. Hold a brief class discussion on ways we use to identify people. (Discussion may include appearance, photo identification cards like driver's licenses, their knowledge of personal information, and fingerprints.)

2. Pass out a fingerprint card to each group of 3 to 8 students, and pass around 1-3 ink pads. Ask the students to each use an ink pad to ink either their thumbs and slowly press their thumb into one of the boxes on their fingerprint card.

3. Ask each group to hold a quick discussion.

   What are some of the similarities for some of their fingerprints? What are some of the differences? Can they identify at least two different characteristics for fingerprints? Can they group the fingerprints by characteristics?

4. Let your class know that minerals also have a type of fingerprint—each mineral has a characteristic reflectance spectrum. Scientists can use this information from a distance to identify rocks and minerals.

5. Tell your students that they are going to simulate a mission to understand and map out the rocks at the surface of Mars. There are orbiters and rovers that have gathered spectroscopic data from Mars rocks. When these missions measure a spectrum, they send the information back to Earth and the scientists have to determine the rock type by matching the spectrum of a known rock or mineral on Earth to the spectrum collected at Mars.

6. Divide your class into groups, and give each group of 3-4 students an ALTA spectrometer. Ask the students to turn on the ALTA spectrometer. [Some of the spectrometers may turn themselves off immediately; the students will need to play with the on/off button until it stays on. If there is no reading on the digital display, the spectrometer is off.]

   What is on the back of the spectrometer? [There is a circle of 11 little lights—led's—with another similar-looking object in the middle.]

7. Ask the students to experiment with pushing the different buttons on the front, and observing the led's on the back. If they are having difficulty pushing the buttons hard enough or holding down the buttons, recommend that they use a pencil eraser to push the buttons.

   What happens when you push the "blue" button after turning it on? [The blue led on the back lights up and remains lit while you hold the button down.]

   What happens when they push one of the "IR" buttons on the front? [Nothing noticeable—in fact, one of the infrared led's on the back "lights up" but at a frequency our eyes cannot see.]

8. Ask the students to observe the numbers on the front.

   What do the numbers do when you point the bottom of the ALTA towards your desk or a book? What do they do when you hold it up higher in the air? [The numbers change and increase with increased brightness, until they overload the detector—at which point the ALTA gives a "1".]

   What do the numbers do when you cover up the back? [They go down.]

9. Ask the students to place the ALTA down onto a surface (such as a dark piece of paper, a book, their coat…) and push two or three of the buttons (one at a time) and look at the numbers. Ask them to then place the ALTA onto a white piece of paper and repeat the same buttons and look at the numbers.

   How were the numbers different? [The numbers should be much higher for the white piece of paper. If they were not, ask the students to repeat their observations, making sure to lay the ALTA onto the flat surface of the object they are measuring, and to hold the buttons down firmly until the numbers stop changing.]]

What could the reflectance spectrometer be measuring? [Answers may include "color" or "brightness" or "light;" a better answer is the amount of light that is reflecting off of an object.]

Which part of the ALTA could be taking the measurements? [The object in the center of the led's on the back is a detector, measuring the amount of light that is entering it.]

10. Share with the students that the light detector measures the amount of light it receives, and displays that amount as a number on the front of the Alta, measured as voltage.

    Why are the numbers higher when the ALTA is held up in the air? [Light from the room is entering the detector.]

    Why are the numbers so low when the ALTA is completely covered up? [No light is getting into the detector. The number that each ALTA reads when it is receiving absolutely no light is called its "Dark Voltage".] *Do the ALTAs have the same numbers for the "Dark Voltage"?* [Each ALTA detector will be slightly different, so they will probably have different numbers.]

    Why are there different colors of light bulbs that turn on when you press the buttons on the front? [The different colors can emit certain frequencies of light, which will reflect off of a surface and into the detector, so that we can measure how well an object reflects that particular frequency of light.]

    *Why are the numbers higher for a white sheet of paper than a dark object, when you turn on one of the lights? [*More light is bouncing off of – reflecting from - the paper and into the detector.]

11. Tell the students they are going to make a graph of the different intensities / amounts of energy for different frequencies of light reflecting off of a rock. Ask them to stay in their groups (with one ALTA per group) and give each group one of the "Mars" rocks and a copy of the *Reflectance Worksheet* and the *Spectrum Graph* transparency*.*

12. Give the students some instructions on taking reflectance measurements of rocks: the **overhead lights need to be off**, the "dark voltage" measurement before each reading should be close to the number the students get when the ALTA is pressed against a flat surface like their desks, and the rock should be large enough to cover the hole at the back of the ALTA. They should avoid trying to fit a pointed part of the rock into the hole—they should only take measurements from a flat surface.
    Why is this important? [Rocks are not perfectly flat—we are trying to cut down on the amount of outside light reaching the ALTA's detectors, and to position the rock at the optimum distance from the LEDs and detector.]

13. As a group, the students should determine the maximum reflectance for their Alta. [Each ALTA is slightly different, due to variations in the electrical components,

lamps, and light sensors, so each ALTA has its own unique sensitivity to different frequencies of light. One way to measure how much light of each frequency is being reflected is to measure the <u>percentage</u> of light reflected, by comparing the light reflected from an object to the light reflected from a bright standard material, such as white paper. Students will use their measurements of white paper to calculate the percentage of light reflected from an object.] The students should place their ALTA flat down on several blank white sheets of paper and press the different frequencies (colors) one at a time, and record the number for each of the 11 frequencies on their *Reflectance Worksheets*.

14. Students should also record the "dark voltage"—the number displayed when none of the buttons are being pushed and the Alta's detector is completely covered.

15. Next, each student should place the ALTA directly onto a flat surface for the rock they are analyzing, and push the different frequencies (colors) one at a time, and record the number for each of the 11 frequencies on their *Reflectance Worksheets*. [If you are pressed for time, each group of students can take one set of readings that they can all share.]

16. Give each group of students a calculator. The students should determine what the percentage of reflectance is for their material for each of the 11 frequencies, by following the calculations on their *Reflectance Worksheet*.

17. The students should fill out their *Spectrum Graph* on transparencies, with the final numbers from their *Reflectance Worksheet*. Note: graphing is a skill that has not been mastered by even some high school students; you may wish to demonstrate how to fill out the graph by doing one as an example while projecting it for the class to view together.

    Where is the x-axis for this graph? What does it indicate? [The horizontal x-axis indicates different frequencies of light.]

    Where is the y-axis for this graph? What does it indicate? [The vertical y-axis indicates the percentage of light reflected off of their object.]

    Does your graph have any peaks or high points? If so, at which frequencies? What does that tell you about your object? [Objects reflect more of the light at those frequencies; red objects will reflect more red and orange light, for instance.]

    Does your graph have any valleys or low points? If so, what does that tell you about your object? [The object absorbs most of the light at those frequencies.]

18. Invite the groups to describe their spectra.
    Do they resemble any of the spectra of Earth rocks? Can they identify their Mars rock based on the spectra? What are some of the issues they face with comparing their individual spectrum to the spectra of the Earth rocks? [Each rock is different, and will have slightly different spectra.]

19. Ask all of the students with the red samples to meet together to compare their spectra in one part of the classroom. Similarly, ask the students with silver rocks and with dark grey/black rocks to meet at other parts of the classroom. Suggest that they overlay their transparencies with their spectra together, to look for common features.

20. Group Presentations: Ask everyone to return to their desks, then invite each group (one at a time) to present their results—.

    Together, can they identify the Mars rocks? What is the value of having scientists repeat experiments or having different teams of scientists testing the same materials?

21. Invite the students to reflect on the activity and analyze their results.

    What do the students think the point of this activity was? [Learning about gather data and analyzing it, taking and comparing reflectance spectra, using spectra to identify rocks on the Mars, and learning how scientists identify rocks on other planets and Mars.]

    *Which aspects of science did your students do today? [M*aking observations, analyzing data, sharing findings, recognizing patterns, devising explanations and evaluating each other's explanations.]

    How did the different groups' spectra compare to each other? [Different objects have different spectral "fingerprints" – each object had a unique spectral graph.]

    What does the ALTA record? How might this be useful? [The ALTA measures the amount of light that is reflected off of an object, for different frequencies of light. The second half of this question may be difficult for students; suggest that scientists could use the reflectance spectrum to identify a mysterious substance.]

    How is the ALTA similar to the human eye? [Both the human eye and the ALTA can measure the amount of light we see, at different frequencies or colors of light.]

    What colors do most humans see? How many different shades of color can people see? [People can detect differences between hundreds to thousands of different frequencies of light.]

    In what ways can the ALTA detect more than we can? [It can detect four different infrared wavelengths.]

    In what ways is the ALTA more limited? [The ALTA can only give us a spectrum with 11 data points.]

    How could the ALTA be improved to collect more data about the spectrum of an object? [More frequencies could be could be added, for more details within the visible and infrared range or to extend the range to include ultraviolet light, for instance.]

Do true scientific data contain errors? [Yes!!] *Do scientists have to account for errors?* [Yes; scientific studies examine potential sources of error.]

How can taking spectra help us to identify rocks on the Mars and other planets? [by comparing their spectra to Earth rocks]

How can scientists take better spectra to better identify rocks on the Mars and eliminate more errors? [By taking more detailed spectra, with a larger number of frequencies and at more infrared and ultraviolet wavelengths.]

Notes for the Teacher

Facilitator Background: the ALTA Reflectance Spectrometer

Each frequency or color of light has an associated wavelength. On the ALTA spectrometer, there are LEDs that emit specific wavelengths of light, which can reflect off of a surface. The shortest wavelength for the ALTA is emitted by a blue LED at 470 nanometers (nm) (4.7×10^{-7}m), and the longest wavelength is emitted by an infrared LED at 940 nanometers (9.4×10^{-7}m).

When measuring an object's reflectance using the ALTA, the students should hold down the ALTA and see if the dark voltage (the reading without any of the LED's turned on) is within one or two numbers as the dark voltage they have when the ALTA is pressed hard against a flat surface. If it is not, then outside light is getting in, and they should re-position the ALTA until the numbers are the same as the dark reading, before they begin to press other buttons.

Some of the buttons on the ALTA need to be pressed hard to turn on the LED; if students' data seem unusual (if multiple readings are around 20-30) ask them to try again. If students have difficulty pressing or holding the button down, have them use the eraser end of a pencil to push the buttons.

Facilitator Background on Purchasing Rocks

All rocks need to be at least 2"x2" wide (hand specimens), with a flat surface; can be purchased at Wards (http://wardsci.com/default.asp):

- basalt rocks (item# 47 V 1044)
- hematite - specular (item# 46 V 3879)
- hematite – red ochre (item# 46 V 0949)
- limestone (chalk) – (item# 47 V 4664)
- rhyolite (gray) - (item# 47 V 6909)

Facilitator Background on Rock Graphs:

There will be natural variations in each rock sample, and even different sides of the same sample may give slightly different spectra. Rocks and minerals can be better identified by scientists with more detailed spectra that extend further into the infrared than the ALTA or other reasonably-priced classroom spectrometers can reach.

Fingerprint Chart

Names of Scientists on Team

A ______________________________ B ______________________________

C ______________________________ D ______________________________

E ______________________________ F ______________________________

G ______________________________ H ______________________________

A **B** **C** **D**

E **F** **G** **H**

Descriptions of key characteristics of fingerprints:

____

____

____

____

Group by characteristics:

1st group: ______________________________

2nd group: ______________________________

3rd group: ______________________________

4th group: ______________________________

Names of Scientists on Team

______________________________ ______________________________

______________________________ ______________________________

Sample Description ______________________________

____

____

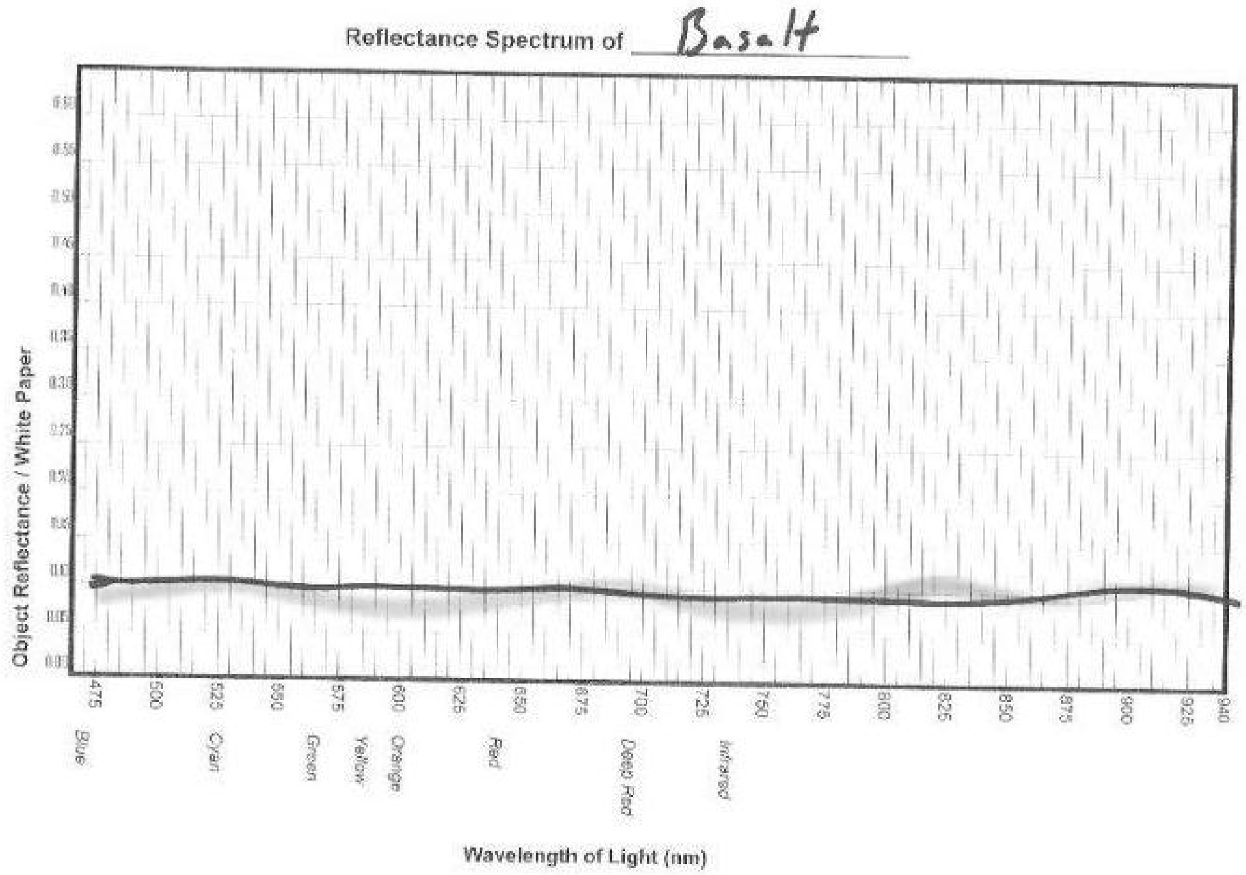
____

Dark Voltage Constant ______________________________

Color	Wavelength in Nanno-meters	White Paper Reading	Dark Voltage Constant	White Paper Reading - Dark Voltage (A)		Sample Reading	Dark Voltage Constant	Sample Reading -Dark Voltage (B)		B / A or (Sample – Dark V) / (White – Dark V)
Blue	470									
Cyan	525									
Green	560									
Yellow	585									
Orange	600									
Red	645									
Deep Red	700									
Infrared 1	735									
Infrared 2	810									
Infrared 3	880									
Infrared 4	940									

Basalt

Pattern remains fairly low with few ups and downs.



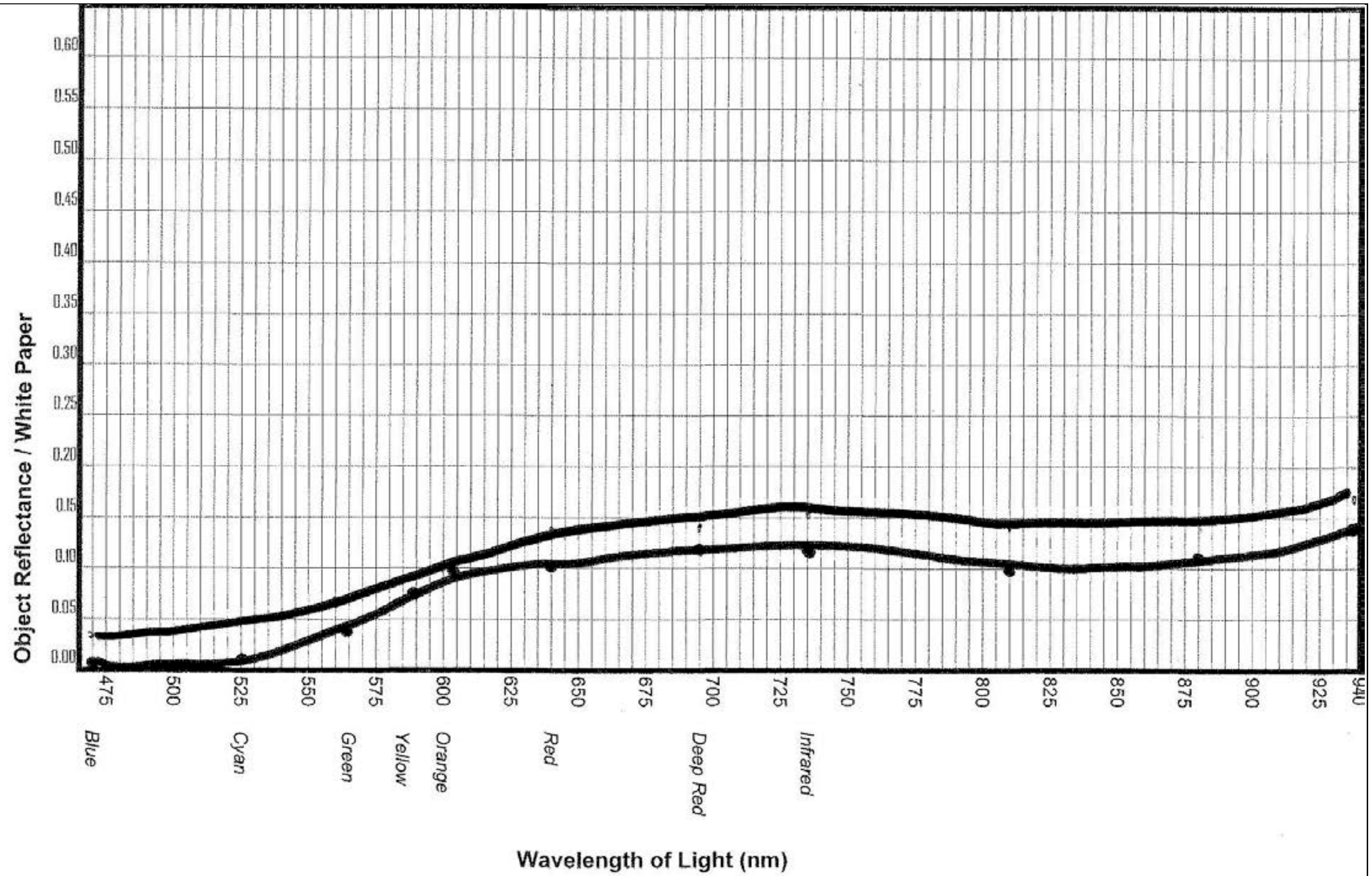
Description: Basalt is a dark grey volcanic rock with few or no visible crystals. It is heavier than most rocks. It has large amounts of the minerals plagioclase feldspar and pyroxene, and some olivine.

Locations on Earth: Basalt is found on the ocean floor and makes up the ocean crust. It is also found around shield volcanos like the Hawaiian Islands, and it can form huge, stacked sheets on land, such as the Deccan Traps in India and the Columbia River area of the United States.

Formation: Basalt is formed when magma from the Earth's mantle erupts onto the Earth's surface and cools quickly.

Red Hematite

Reflectance is low overall. Pattern begins extremely low for blue, then increases for orange through the near-infrared.



Rock Type: Red Ochre Hematite

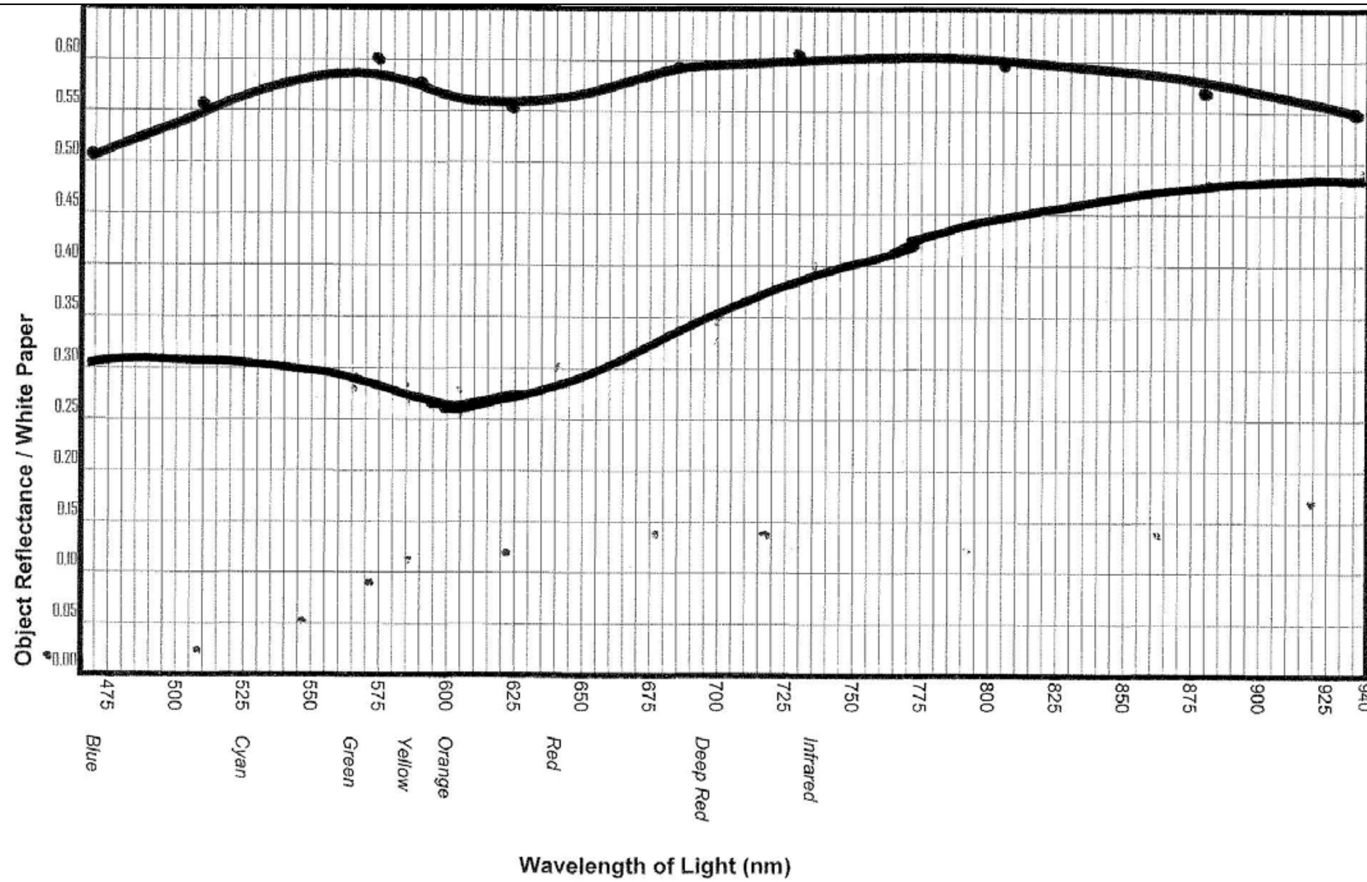
Description: Hematite is a mineral, colored black to steel or silver-gray, brown to reddish brown, or red. It is mined as the main ore of iron.

Location: Huge deposits of hematite are found in banded iron formations. Grey hematite is typically found in places where there has been standing water or mineral hot springs. Hematite is often the red cementing material in sandstones, and is found to a lesser extent in red clays and shales.

Formation: The mineral can precipitate out of water and collect in layers at the bottom of a lake, spring, or other standing water. Hematite can also occur without water, however, usually as the result of volcanic activity.

Chalk

Overall reflectance is very high. Pattern dips for green, bottoming-out around yellow-orange, then climbs sharply to higher reflections for red and continues to climb in the infrared.

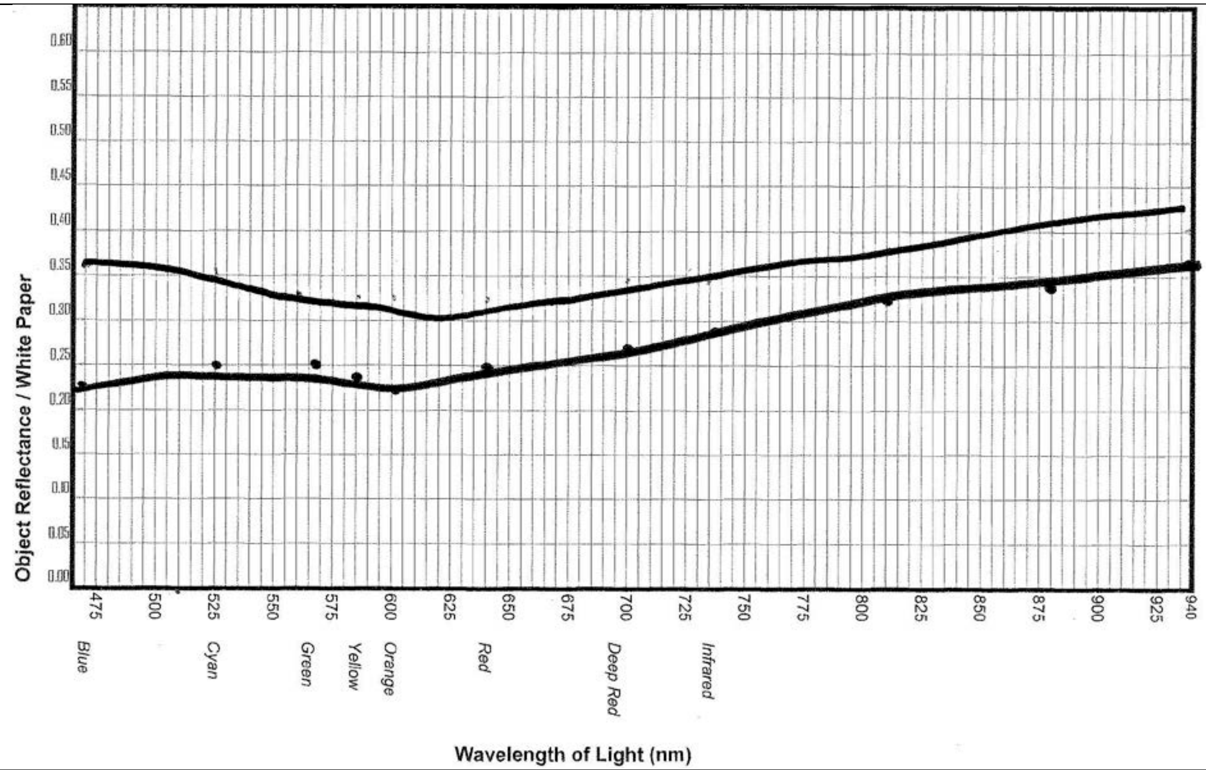


Rock Type: Limestone Chalk

Description: Limestone chalk is white sedimentary rock. It is lighter than the average rock on Earth. It has large amounts of calcite, also known as calcium carbonate, which fizzes when an acid, like vinegar, is dropped on it.

Locations on Earth: Chalk is found in rock deposits on land and in water.

Formation: Chalk is formed in deep seas and oceans from the shells or outer coatings of micro-organisms.

Rhyolite Overall reflectance is fairly high. Pattern gently slopes down for yellow-orange, then climbs to higher reflections for red and continues to climb in the infrared.	

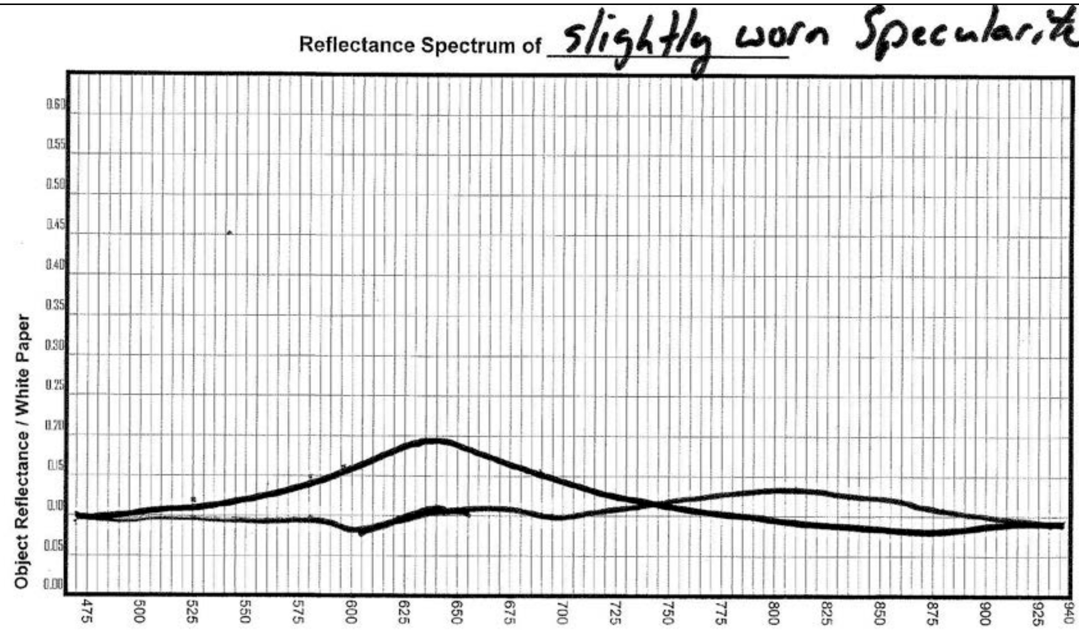
Rock Type: Rhyolite
Description: Rhyolite is a volcanic rock with few or no visible crystals. Rhyolite ranges in color from light grey to pink. It feels lighter than many other volcanic rocks. It may have layers that mimic sedimentary rocks. It has large amounts of the minerals quartz and potassium feldspar; it has varying amounts of plagioclase feldspar.

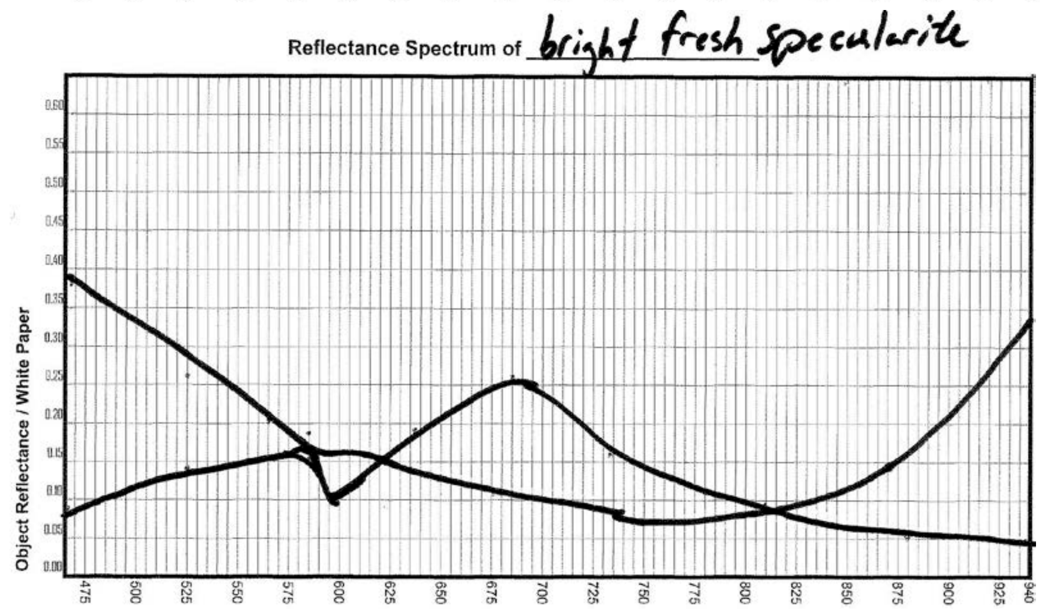
Locations on Earth: Rhyolite is found in continental crust, near explosive composite volcanos.

Formation: Rhyolite comes from lava formed by melting the Earth’s crust, such as melted continental crust or a combination of melted ocean and continental crust. Rhyolite often forms when volcanic ash from an explosive eruption settles in layers.

Specularite
This spectrum is highly reflective and changes depending on the angle and the weathering of the crystals.

Rock Type: Specularite
Specularite is a form of hematite, a mineral, colored black to steel or silver-gray, brown to reddish brown, or red.
Location: Huge deposits of hematite are found in banded iron formations. Grey hematite is typically found in places where there has been standing water or mineral hot springs.
Formation: The mineral can precipitate out of water and collect in layers at the bottom of a lake, spring, or other standing water. Hematite can also occur without water, however, usually as the result of volcanic activity.





Reflectance Spectrum of ______________________