CORE CONCEPTS

Created by Mining Matters

Rocks & Minerals

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TABLE OF CONTENTS

1 MINERAL CHARACTERISTICS

MATERIALS

- Mineral samples: *Quartz, Magnetite, Barite, Gypsum, Calcite, Hematite, Amethyst, Chalcopyrite*
- Handout: Mineral Characteristics - Reference Chart
- Handout: *Mineral Characteristics Activity*
- Mohs Scale of Hardness
- Magnet
- Copper coin
- Nail
- Streak plate (unglazed porcelain tile)
- Magnifying glass
- Electronic balance or electronic balance
- Eye dropper
- Graduated cylinder or graduated beaker
- Safety goggles
- Rubber gloves
- Lab coat

Consumables:

- Dilute hydrochloric acid (10%)

SUMMARY OF TASK

Students will:

- Classify minerals, using their observations, according to their characteristics.
- Follow standard procedures for applying scientific tests.

EARTH SCIENCE LITERACY PRINCIPLE(S)

BIG IDEA 1 Earth scientists use repeatable observations and testable ideas to understand and explain our planet.

OBJECTIVES

1. Understand the concept that all minerals have characteristic properties.
2. Undertake 8 geological tests and use observations to identify minerals.
3. Develop skills in using scientific equipment and tests to make observations and draw conclusions.

INSTRUCTIONS

Engage

1. Review the concepts of physical and chemical properties.
2. Brainstorm ways in which to test these properties using standard scientific equipment.

Explore

3. Distribute the handout: *Mineral Characteristics Activity*. Read the instructions for each test with the students, demonstrating techniques if necessary. Have students conduct the 8 scientific testing methods (Density, Hardness, Streak, Cleavage, Conductivity, Magnetism, Lustre, Colour, Chemical Reaction), recording their observations on the activity sheet. Test 8 - Chemical Property of Minerals may be best performed as a teacher demonstration due to safety requirements for handling dilute hydrochloric acid.

Explain

4. Discuss characteristics of minerals and how they are used to determine mineral type.

Elaborate

5. Provide the handout: *Mineral Characteristics - Reference Chart*. In small groups or individually, have students take one specimen. Use the 8 scientific tests, their observations, and the reference chart to identify the mineral name.

Evaluate

6. Through observation or individual student conference, evaluate each student's mastery of applying the tests, making observations, and identifying minerals.

Rubric

The student:	Level 1	Level 2	Level 3	Level 4
used equipment safely and appropriately:	rarely	occasionally	frequently	consistently
identified the physical properties of the sample:	with many errors	with some errors	mostly correctly	correctly
Identified the name of the mineral using the reference chart based on their observations:	with limited reasoning	with some reasoning	with considerable reasoning	with highly effective reasoning

PREPARATION AND SET-UP

The following instructions will help to prepare the samples before conducting this activity.

1. Make an instructor copy of the Mineral Characteristics – Reference Chart. This will be the "Answer Key."
2. Number the mineral samples using correction fluid and a fine tip permanent marker. For durability paint over the dry number with clear nail polish. Make sure to randomize the numbers so that the order does not correspond to the reference chart, e.g. do not label amethyst #1, barite #2, etc.
3. Record each sample number beside the appropriate mineral name on the Answer Key.
4. For the Mineral Characteristic Activity, prepare labels for each mineral name. Collect the equipment needed for each test station as described below.

SUPPORTING INFORMATION

Key Words:

Basic Terms: density, specific gravity, Mohs Scale of Hardness, streak, cleavage, conductivity, lustre, minerals, magnetism, magnetic

Secondary Terms: pure substance, mixture

SAFETY

- Care should be taken with glassware in test one. Broken glassware should not be used and should be disposed of properly if it is found.
- Test eight calls for the use of dilute acid (10% HCl). Teachers and students need to be very careful with the acid. Rubber gloves, safety goggles and a lab coat should be worn.

Test One - Density and Relative Mass

Teaching Notes: Some minerals are heavier than other minerals, which allows geologists to distinguish between them. Geologists use Specific Gravity (S.G.). However, since Specific Gravity is a complex and difficult test, density and relative mass have been substituted here as a comparable test. **Specific Gravity** is the ratio of the mass (weight) of a substance to the mass (weight) of an equal volume of water at 4ºC. The average specific gravity of most minerals is between 2.65 and 2.75. Quartz is 2.65, Feldspar is 2.65, Magnetite is 5.18, Gold is 15.0.

Equipment: balance, graduated beaker or cylinder, water, mineral samples (Magnetite, Barite, Quartz)

Observation:

Lightest - - - Quartz	S.G. 2.65
Middle - - - Barite	S.G. 4.5
Heaviest - - - Magnetite	S.G. 5.18

Test Two - Physical Property of Hardness

Teaching Notes: Scratch tests allow geologists to test the hardness of minerals. The **Mohs Scale of Hardness** was developed as a standard to help identify minerals in relation to each other. The resistance that a smooth surface of a mineral offers to scratching is its hardness which is determined by the observed ease or difficulty with which one mineral is scratched by another, or by a copper coin, knife or file.

Equipment: Mohs Scale of Hardness, copper coin, nail, mineral samples (Quartz, Talc, Calcite)

Observation: Talc is the softest mineral and can be scratched by the fingernail. Calcite is in the middle and may be scratched with the copper coin. Quartz is the hardest of all minerals in the kit.

Test Three - Physical Property of Streak

Teaching Notes: The **streak** of a mineral is its colour when it is ground into a fine powder. To grind a mineral into a fine powder, rub it against a streak plate. Although the colour of a mineral may vary, the streak is usually constant and is useful in mineral identification.

Equipment: paper, streak plate, mineral samples (Magnetite, Calcite, Hematite)

Test Four - Physical Property of Cleavage

Teaching Notes: **Cleavage** is the tendency of minerals to break parallel to their atomic planes. Not all minerals show cleavage. Some minerals break along their planes of cleavage which appear as lines or flat surfaces on minerals. Usually they will break easily along these lines. Cleavage surfaces shine brightly such as those on a diamond. Diamonds are cut along their cleavage lines to produce their sparkling appearance. Cleavage may be well developed as in mica, or fairly obscure as in apatite, or absent as in quartz.

Equipment: magnifier, mineral samples (Mica, Halite)

Observation: Halite is cubic and has 3 lines of cleavage at right angles. Mica is layered and has only 1 line of cleavage, parallel.

Test Five - Physical Property of Conductivity

Teaching Notes: **Conductivity** determines how well a mineral carries electricity. Certain minerals are more conductive than others, while others are not conductive at all.

Equipment: conductivity tester, mineral samples (Quartz, Chalcopyrite)

Observation: Chalcopyrite is conductive and will set off the buzzer. Quartz is not conductive and will not set off the buzzer.

Test Six - Physical Property of Magnetism

Teaching Notes: The degree of **magnetism** of a mineral is determined by how well a mineral attracts a magnet. Some minerals are highly **magnetic** while others are not. Knowing the degree of magnetism helps geologists identify mineral samples.

Equipment: magnet, mineral samples (Quartz, Hematite, Magnetite)

Observation: Quartz is not magnetic and will not attract the magnet. Magnetite is magnetic and will attract the magnet. Hematite is weakly magnetic.

Test Seven - Physical Properties of Colour and Lustre

Teaching Notes: Two important physical properties that geologists use are colour and lustre. The colour of a mineral is one of the first things that we notice. **Lustre** is the way in which light is reflected and scattered off the surface of a mineral. Words such as vitreous, dull, waxy, earthy, metallic, greasy, silky and pearly describe the lustre of a mineral.

Equipment: mineral samples (Amethyst, Quartz, Talc, Chalcopyrite)

Observation: Amethyst is purplish in colour and has a vitreous lustre. Quartz is clear to white in colour and has a vitreous lustre. Talc is grey to white in colour and has a pearly or silky lustre. Chalcopyrite is yellow-gold in colour and has a metallic lustre.

Test Eight - Chemical Property of Minerals

Teaching Notes: Geologists use dilute hydrochloric acid - (HCl) to determine whether or not a mineral will effervesce (bubble) when the acid touches it. The bubbles show the release of the gas carbon dioxide (CO_2) that occurs during the chemical reaction:

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$$

Calcium carbonate + acid → calcium chloride + water + carbon dioxide

Note: quickly rinse with water and dry samples after the test. See the *Safety* section for precautions and First Aid when working with hydrochloric acid.

Equipment: dilute hydrochloric acid, rubber gloves, safety goggles, mineral samples (Calcite, Chalcopyrite, Quartz)

Observation: Calcite effervesces strongly. Chalcopyrite does not effervesce. Quartz does not effervesce.

1 CHARACTERISTICS OF MINERALS

Amethyst ([Mn]SiO_2)
Manganese (Mn) + Silicon (Si) + Oxygen (O)

Colour: purple
Hardness: 7
Streak: white/colourless
Lustre: vitreous (glassy)
Cleavage: none
Fracture: conchoidal
A variety of quartz
Uses: Gemstones, mineral specimens

Barite ($BaSO_4$)
Barium (Ba) + Sulphur (S) + Oxygen (O)

Colour: white
Hardness: 3-3.5
Streak: white
Lustre: vitreous (glassy), pearly
Cleavage: perfect tabular crystals
Fracture: conchoidal
Special property: High specific gravity (very heavy)
Uses: carpets, barium ore

Calcite ($CaCO_3$)
Calcium (Ca) + Carbon (C) + Oxygen (O)

Colour: colourless/white, orange, blue, yellow, etc.
Hardness: 3
Streak: white
Lustre: vitreous (glassy)
Cleavage: rhombohedral
Fracture: conchoidal
Uses: cements, mortars, lime production, chemical uses

Chalcopyrite ($CuFeS_2$)
Copper (Cu) + Iron (Fe) + Sulphur (S)

Colour: brassy yellow/green
Hardness: 3.5-4
Streak: green-black
Lustre: metallic
Cleavage: rare
Fracture: conchoidal
Special property: Conductive
Uses: copper ore, electrical wires

Feldspar ($KAlSi_3O_8$)
Potassium (K) + Aluminum (Al) + Silicon (Si) + Oxygen (O)

Colour: pink
Hardness: 6
Streak: white/colourless
Lustre: vitreous (glassy)
Cleavage: 90°
Fracture: conchoidal, uneven
Uses: porcelain, mineral specimens

Halite (NaCl)
Sodium (Na) + Chlorine (Cl)

Colour: colourless/white, can be: blue, gray, red or brown
Hardness: 2
Streak: white
Lustre: vitreous (glassy)
Cleavage: cubic
Fracture: conchoidal
Special property: Tastes salty
Uses: road salt, table salt, glass, mineral specimens

Hematite (Fe_2O_3)
Iron (Fe) + Oxygen (O)

Colour: gray-black, red-brown
Hardness: 6-6.5
Streak: brick red
Lustre: metallic or dull
Cleavage: none
Fracture: conchoidal
Uses: iron ore, pigment, mineral specimens

Magnetite (Fe_3O_4)
Iron (Fe) + Oxygen (O)

Colour: black
Hardness: 5.5
Streak: black
Lustre: metallic, dull
Cleavage: imperfect cubes (rare)
Fracture: conchoidal
Special property: Magnetic
Uses: iron ore, mineral specimens

Mica ($KAl_3Si_3O_{10}[OH]_8$)
Potassium (K) + Aluminum (Al) + Silicon (Si) + Oxygen (O) + Hydrogen (H)

Colour: dark brown (biotite), colourless (muscovite)
Hardness: 2.5-3
Streak: white
Lustre: pearly, vitreous (glassy)
Cleavage: hexagonal
Fracture: laminar
Uses: industrial heat insulator, mineral specimens

Quartz (SiO_2)
Silicon (Si) + Oxygen (O)

Colour: clear, white or gray
Hardness: 7
Streak: white/colourless
Lustre: vitreous (glassy)
Cleavage: none
Fracture: conchoidal
Uses: glass, electrical components, optical lenses, abrasives

Talc ($Mg_3Si_4O_{10}[OH]_2$)
Magnesium (Mg) + Silicon (Si) + Oxygen (O) + Hydrogen (H)

Colour: colourless, white, greenish, yellowish
Hardness: 1
Streak: white
Lustre: pearly, greasy
Cleavage: monoclinic
Fracture: splintery, uneven
Uses: talcum powder, counter tops, carvings, heat, acid and electrically resistant stone (soapstone), an ingredient in paints, rubber, roofing materials, ceramics and insecticides

1 MINERAL IDENTIFICATION ACTIVITY

Test One: Density and Relative Mass ***Magnetite, Barite, Quartz***

Procedure:

- Pick up each mineral and estimate its weight.
- Use the scale to determine exact mass in grams.
- Partly fill graduated beaker with water. Record the level.
- Place each sample, one at a time, into the graduated beaker.
- Record the new water level and calculate the difference in mL (cm3).
- Dry samples and calculate the density of the sample (mass/volume).

Observations/Descriptions:

Densest		Least dense

Notes:

Test Two: Physical Property of Hardness ***Quartz, Talc, Calcite***

Procedure:

- Use your fingernail and scratch each of the minerals.
- Use the penny and scratch each of the minerals.
- Use the nail and scratch each of the minerals.
- Record your observations.

Observations - Mohs Scale Number

Fingernail	Penny	Nail

Notes:

Test Three: Physical Property of Streak ***Magnetite, Calcite, Hematite***

Procedure:

- Rub each mineral across the streak plate (gently).
- Record your observations.

Observations - Colour of powdered mineral

Magnetite	Calcite	Hematite

Notes:

Test Four: Physical Property of Cleavage — ***Mica, Halite***

Procedure:

- Pick up each mineral sample and observe how light is reflected off the surface of the mineral.
- Determine the number of lines of cleavage for each sample.
- Record your observations.

Observations: Planes of breakage

Mica	Halite

Notes:

Test Five: Physical Property of Conductivity — ***Quartz, Chalcopyrite***

Procedure:

- Check to ensure that conductivity tester is working.
- Test each sample for conductivity.
- Record your observations.

Observations:

Not Conductive	Conductive

Notes:

Test Six: Physical Property of Magnetism — ***Quartz, Hematite, Magnetite***

Procedure:

- Test each sample with the magnet.
- Record your observations.

Observations:

Non magnetic	Slightly magnetic	Magnetic

Notes:

Test Seven: Physical Properties of Colour and Lustre — *Amethyst, Quartz, Talc, Chalcopyrite*

Procedure:
- Observe the colour and lustre of each sample.
- Record your observations.

Observations:

Amethyst
Quartz
Talc
Chalcopyrite

Notes:

Test Eight: Chemical Property of Minerals — *Calcite, Chalcopyrite, Quartz*

Procedure:
- Slightly scratch the surface of each mineral sample with a penny.
- Using an eye dropper, place a drop 10% hydrochloric acid on each scratched mineral surface.
- Rinse and dry samples immediately.
- Record your observations.

Observations: reaction in presence of dilute hydrochloric acid

Calcite
Chalcopyrite
Quartz

Notes:

Questions:

Answer the following questions based on what you have learned about the physical and chemical properties/characteristics of minerals.

What is Mohs Scale of Hardness. When was it developed and by whom? (Clue: look at the information on the scale).

Why is colour not a reliable mineral identifier?

Name and describe four terms applied to minerals to describe their lustre.

2 MINERALS – THE BUILDING BLOCKS OF ROCKS

MATERIALS

- Rock sample: Granite
- Mineral samples: Mica (variety: *Biotite*), Quartz, Feldspar (variety: *Orthoclase*)
- Figure: *Minerals – The Building Blocks of Rocks* (Displayed on available classroom projection technology)
- Figure: *Compare and Contrast Chart* (copies for each student)

SUMMARY OF TASK

Students will:

- Distinguish between rocks and minerals and describe the differences in their composition (e.g. minerals, such as calcite, are components of rocks such as the sedimentary rock limestone).

EARTH SCIENCE LITERACY PRINCIPLE(S)

BIG IDEA 3 Earth is a complex system of interacting rock, water, air, and life.

BIG IDEA 7 Humans depend on Earth for resources.

OBJECTIVES

1. Understand that rocks are formed from a combination of different minerals.
2. Understand that minerals are substances that occur naturally.
3. Understand that minerals are naturally occurring, crystalline solid substances.
4. Make observations about rocks and minerals.

INSTRUCTIONS

Engage

1. Show students a sample of granite, and brainstorm words to describe the sample.

Explore

2. Have students draw a 2.5 cm border around the edge of a blank page and put a title at the top of "Rocks and Minerals – Granite and its Components".
3. Pass around samples of granite, mica, feldspar and quartz, and have students make a drawing of each of the four samples on their page and write a brief description of what they observe.

Explain

4. Using the Figure: *Minerals – The Building Blocks of Rocks* that shows the picture of granite and the three minerals that form granite (mica – black, quartz – white, feldspar – pink) have students label their own diagrams according to the illustration to identify a few of the minerals that comprises granite.
5. Ask the students what they think the difference is between rocks and minerals. Make a list of their responses so that they can read and review them. Clarify misconceptions.

Elaborate

6. Granite is an extremely hard rock. Brainstorm uses of granite (tombstones, floors in commercial buildings, countertops in kitchens).

Evaluate

7. Hand out the *Compare and Contrast Chart*. Lead the students in the completion of the similarities and differences while explaining the comparison between rocks and minerals.
8. Compose a concluding statement together about rocks and minerals using the students' suggestions.

SUPPORTING INFORMATION

The difference between rocks and minerals

Minerals are naturally occurring, inorganic (non-living) substances, usually with a definite **crystal** structure. The crystal structure is formed due to the way the atoms are arranged in a regular geometric shape. Some minerals are made up entirely of one **element** (e.g. Gold - Au or Silver - Ag) and others are made up of a mixture of elements (e.g. Quartz – One third Silicon – Si and two thirds Oxygen – O = SiO_2). Minerals usually have a specific chemical composition (i.e. is always made up of the same elements – such as SiO_2) and a highly-ordered atomic structure.

Rocks are usually a mixture of two or more minerals. The differences between rocks are due to the different combinations of minerals that they contain and the different methods of formation. As an example, granite has crystals with about 20% quartz, 75% feldspar and 5% mica. However these amounts can vary and there can be minor amounts of other minerals included.

Additional Information:

A mineral has four characteristics:

1. Naturally occurring - it occurs naturally on earth and is not man-made. There are over 3,000 minerals on the earth, 100 of which are considered common.
2. Inorganic homogeneous solid - it is not the product of plants or animals and is made of the same molecules throughout.
3. Definite chemical composition - each mineral has its own chemical formula.
3. Highly-ordered atomic structure - the atoms and molecules that make up the mineral are arranged and repeated in a set order.

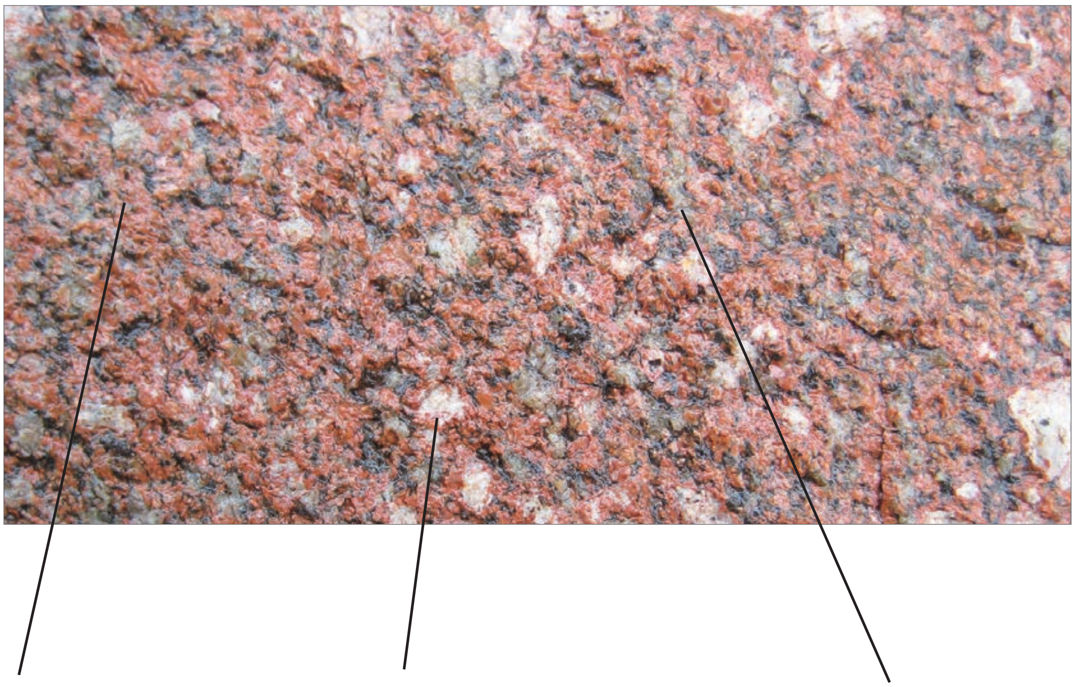
Over 100 chemical elements exist. These elements combine to make up all matter.

About eight of these elements make up most common minerals. These elements include: oxygen, silicon, aluminum, iron, calcium, magnesium, sodium, and potassium.

Key Words:
Basic Terms: mineral, crystal, element, rock

Granite

An igneous, coarse grained, intrusive rock composed of main minerals:
Feldspar (pink), Quartz, and Mica



Feldspar (pink)

A pink, hard mineral with a vitreous (glassy) lustre.

Quartz

A clear, white or gray, hard mineral with a vitreous (glassy) lustre.

Mica

A dark brown to black (may be colourless), soft, flaky mineral with a pearly, vitreous (glassy) lustre.

2 COMPARE AND CONTRAST CHART

Theme: ______________________ **Topic:** ______________________

COMPARE
How are ______ and ______ alike?

CONTRAST
How are ______ and ______ different?

Write a statement to compare and contrast two terms, concepts or events.

3 THE ROCK CYCLE AND THREE ROCK GROUPS

MATERIALS

- Samples: Granite, Rhyolite, Gabbro, Basalt, Limestone, Shale, Sandstone, Dolostone, Conglomerate, Quartzite, Gneiss, Marble, Slate
- Figure: *The Rock Cycle* (Displayed on available classroom projection technology)
- Handout: *The Rock Cycle Diagram*
- Handout: *The Rock Cycle and Three Rock Groups Information Bulletin*
- Handout: *The Rock Cycle and Three Rock Groups Activity*

SUMMARY OF TASK

Students will:

- Explain the Rock Cycle (e.g. formation, weathering and erosion, transportation, sedimentation and reformation)
- Use appropriate vocabulary, including correct science and technology terminology, to communicate ideas, procedures, and results (e.g., use terms such as magma, crystallization, igneous rock, weather, transportation, sediments, and sedimentary rock when describing the rock cycle).

EARTH SCIENCE LITERACY PRINCIPLE(S)

BIG IDEA 1 Earth scientists use repeatable observations and testable ideas to understand and explain our planet.

BIG IDEA 3 Earth is a complex system of interacting rock, water, air, and life.

BIG IDEA 4 Earth is continuously changing.

OBJECTIVES

1. Complete the rock cycle diagram and describe the key processes involved in rock formation.
2. Study the characteristics of the three rock groups and the interrelationships between them through the diagram and analysis questions.

INSTRUCTIONS

Engage

1. Review other natural cycles (e.g. the water cycle, biogeochemical cycles, etc) and explain to students that the rock cycle is a concept or a model that was developed by a scientist (James Hutton, 1727-1797) to help others understand the process of formation of rock.
2. Have students observe the rock samples and suggest ways they think those rocks could have formed. Record student hypotheses.

Explore

3. Display the Figure: *The Rock Cycle* and have students continue to suggest ways that rocks could form.

Explain

4. Distribute the handout: *The Rock Cycle and Three Rock Groups Information Bulletin* and the blank student version of *The Rock Cycle Diagram*
5. Explain that the rock cycle is like a giant recycling system. Nothing is created or destroyed. The same materials are transformed over time from one rock type to another due to surficial processes, melting, heat and pressure. Explain that you will examine this system using the diagram.

Elaborate

6. Have students fill in the blanks on their diagram as you go through the different processes that shape the formation of rock.
7. Have students read the information bulletin and answer the questions on the handout: *The Rock Cycle and Three Rock Groups Activity*

Evaluate

8. Have students demonstrate their understanding of the rock cycle by creating one of the following:
   a) written analogies from their everyday life for how each rock type is formed
   b) a diagram of their own design representing the rock cycle

   Share the following criteria for success with students prior to completing the task:
   - All three rocks groups included
   - Identifies each product of the rock cycle
   - Identifies the process by which each product is formed
   - Includes more than one pathway through the cycle

SUPPORTING INFORMATION

Explaining the Rock Cycle

Begin by explaining that the cooling of magma within the Earth forms **igneous** rocks which are called **intrusive** or *plutonic* (because they form inside the Earth). Explain that when magma reaches the surface of the Earth (e.g. through a volcano), it is called *lava*. Cooled lava also forms igneous rocks, however, these rocks are called **extrusive** or *volcanic* (because they are formed at the surface of the Earth). Extrusive lava cools more rapidly than intrusive magma (because it is exposed to the air), so the resulting rock contains finer-grained crystals.

Over time, all types of rock undergo transformations. On the surface of the Earth, rain, wind and snow break down (weather) the rock and small particles (or **sediments**) are transported to the river, lake or sea floor. These sediments form layers which eventually turn into rock under the weight of the overlying sediments. This process is called **lithification** and the result is **sedimentary** rock.

When either igneous or sedimentary rocks are exposed to extreme temperature and pressure due to being buried deep within the Earth over a period of millions of years, they are transformed into a new type called **metamorphic** rock. The extreme temperature and pressure change the appearance of the original rock.

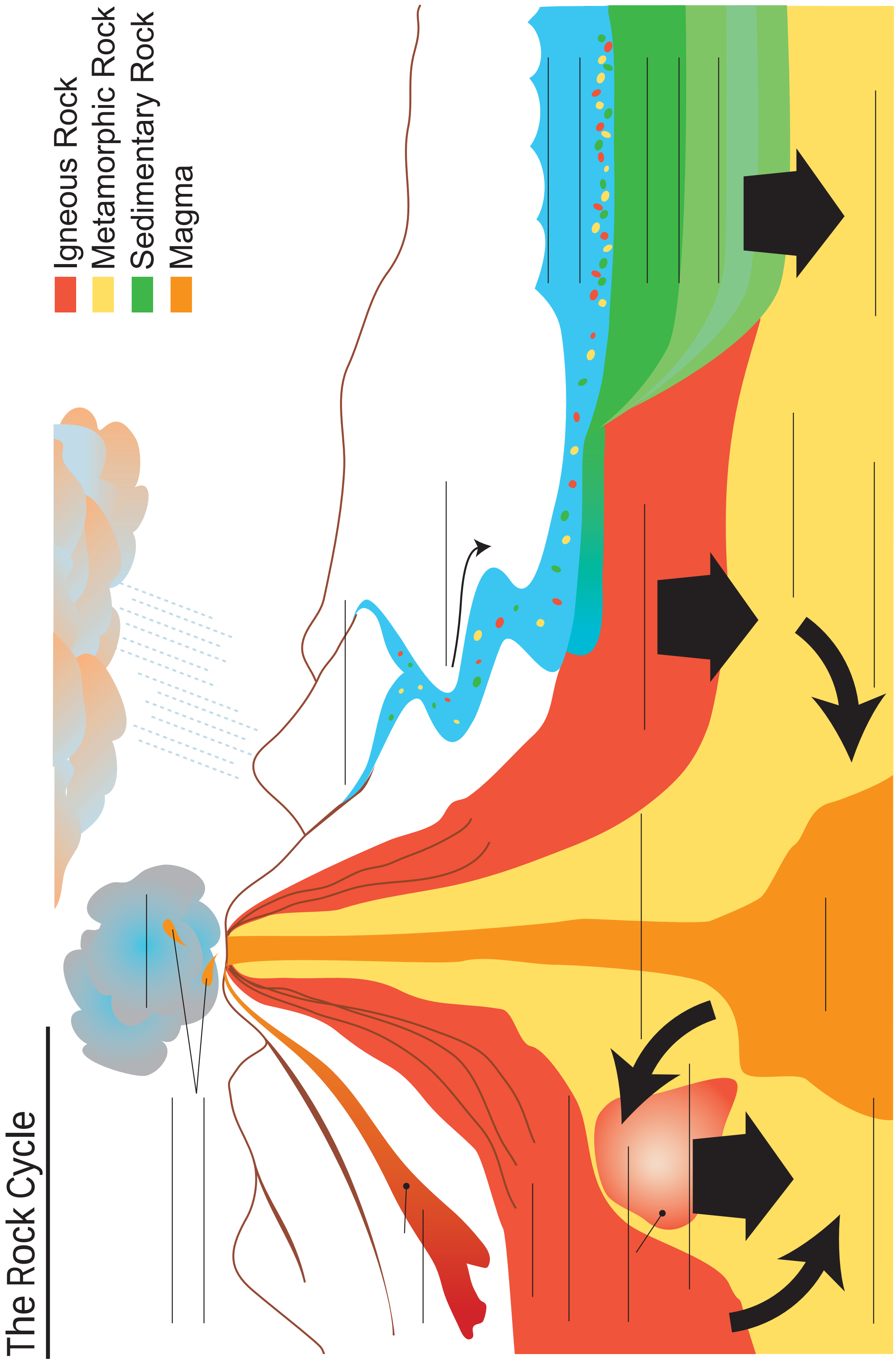
Key Words:

Basic Terms: igneous, rock cycle, intrusive, extrusive, eroded, sediments, lithification, sedimentary, fossils, metamorphic, metamorphism

Secondary Terms: plutonic, volcanic, granite, basalt, shale, sandstone, limestone, marble, slate, quartzite, gneiss

SAFETY

- Reinforce the need to handle the rock samples with care, as some are sharp while others are fragile.


The Rock Cycle
Igneous Rock
Metamorphic Rock
Sedimentary Rock
Magma

THE ROCK CYCLE AND THREE ROCK GROUPS

Geologists classify rocks into three groups according to the major Earth process that formed them. The three groups are **igneous, sedimentary,** and **metamorphic.**

Igneous Rock

Igneous rocks are formed from molten material called magma or lava that cools and solidifies to form a new rock. The term "igneous" comes from the Latin word meaning "fire." Igneous rocks are formed as magma cools either within the Earth or as it flows out of volcanoes on the Earth's surface. When magma cools deep within the Earth, it does so very slowly, allowing large crystals to form. This type of igneous rock is known as an **intrusive** igneous rock. *Granite* is a common intrusive igneous rock. Magma that reaches the Earth's surface is called lava. Lava cools very quickly because it is suddenly exposed to cool temperatures on the Earth's surface or in ocean water. Therefore, crystals do not have time to grow and are very small. This type of igneous rock is called an **extrusive** igneous rock, or volcanic rock. The most common type of extrusive igneous rock is *basalt.*

Igneous rock often contains metallic minerals that include valuable metals such as nickel, copper, gold and silver. The Canadian Shield is partially composed of igneous rock, and consequently, contains large amounts of these minerals. In fact, the Canadian Shield is often referred to as Canada's "storehouse of metallic minerals".

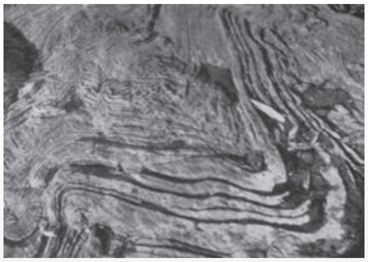
Sedimentary Rock

Sedimentary rocks form from existing rocks that have been **eroded** by wind, water or ice. Tiny pieces of rock and minerals (**sediments**) are eroded and carried by running water, ice or wind and deposited in seas, lakes and rivers. Over millions of years, these sediments are deposited in horizontal layers that can be thousands of metres thick. The weight of the sediments, compresses the layers into rock. If the sediments are composed of clay or mud, the resulting sedimentary rock is *shale*. If the sediments are sand, the resulting sedimentary rock is *sandstone.*

Under certain conditions coal, oil, natural gas, salt and potash may be found trapped in sedimentary rock layers. Over millions of years, dead plants and animals from the seas were deposited and compressed between layers of sediments. When the bodies of certain sea animals decayed and were compressed, oil and natural gas was formed. Wetland vegetation was compressed to form coal. The type of rock particles found today in sedimentary rocks depends on the type of sediments that were deposited millions of years ago. In other locations, the shells of marine animals form limestone or chalk. Sedimentary rocks can also include **fossils**, the remains and imprints of ancient life.

Metamorphic Rock

Sometimes igneous and sedimentary rocks, upon being deeply buried, are subjected to such very high pressures and temperatures that they are completely changed and become metamorphic rocks. The term metamorphic comes from the Greek word meaning "change of form". The process of **metamorphism** does not melt the rock, but instead transforms it into a denser, more compact and harder rock. Heat allows the chemical components of the rock to recombine to form new minerals. Pressure does the same, but only at great depths, typically greater than 10 kilometres. Metamorphism often occurs when hot magma is intruded into cracks and fractures in the surrounding igneous or sedimentary rocks. These surrounding rocks are changed to metamorphic rocks because of the high heat and pressure. *Marble* is metamorphosed limestone, *slate* is formed from metamorphosed shale, *quartzite* is metamorphosed sandstone. Some metamorphic rocks are strongly banded forming a rock called *gneiss* (pronounced "nice"). Metamorphosed granite commonly has a banded appearance.



As well as igneous rocks, The Canadian Shield contains many metamorphic rocks. These rocks contain a variety of deposits of metallic minerals e.g. nickel, copper, zinc, gold, and rare metals such as tantalum and niobium.

The three rock types can each be changed into another through the process known as the **rock cycle**. For example, magma when it cools forms igneous rocks. Igneous, sedimentary and metamorphic rocks exposed to water, wind and other erosional processes on the Earth's surface break down to form sediments. These sediments get transported, deposited and eventually buried forming sedimentary rocks. Sedimentary and igneous rocks that are exposed to high heat and pressure can form metamorphic rocks. If the heat becomes very high the metamorphic rocks can melt and become magma again.

Sources:

http://pubs.usgs.gov/gip/collect1/collectgip.html
Simple definitions of the three rock types.

http://www.cotf.edu/ETE/MODULES/MSESE/earthsysflr/rock.html
Diagram for the rock cycle and simple explanation.

3 ACTIVITY QUESTIONS

Use the Information Bulletin to answer the following questions:

1. Why is the rock cycle called a cycle?

2. What are the three rock groups?

3. How do igneous rocks become sedimentary rocks?

4. What forces are involved in the formation of metamorphic rocks?

5. How is lava different from magma?

4 ROCK STRATA AND FOSSILS

MATERIALS
- Sample(s): Dolostone
- Hand lens
- Common Fossils Cards
- Figure: *Rock Strata and Fossils – Geologic Time Scale* (Displayed on available classroom projection technology)
- Handout: *Rock Strata and Fossils Information Bulletin*
- Handout: *Canada's Tropical History Activity A*
- Handout: *Canada's Fossils Activity B*
- Handout: *Rock Strata and Fossils: Keys to our Geological Past diagram*

SUMMARY OF TASK
Students will:
- Analyze, through observation, evidence of geological change (e.g. fossils, strata)

EARTH SCIENCE LITERACY PRINCIPLE(S)
BIG IDEA 1 Earth scientists use repeatable observations and testable ideas to understand and explain our planet.

BIG IDEA 2 Earth is 4.6 billion years old.

BIG IDEA 3 Earth is a complex system of interacting rock, water, air, and life.

BIG IDEA 6 Life evolves on a dynamic Earth and continuously modifies Earth.

OBJECTIVES
1. Understand how, where and why fossils are preserved and their value.
2. Become familiar with the terms absolute and relative ages.

INSTRUCTIONS

Engage
1. Review how sedimentary rocks are formed and generally how fossils are preserved within the rock layers.
2. Set out the dolostone rock and hand lens for the class to examine the samples for evidence of fossils.

Explore
3. Conduct a class-wide discussion to answer the question: "How do geologists determine the relative age or absolute age of sedimentary rocks?" To explain absolute dating, compare dating methods to the use of batteries (i.e. we can determine how long a flashlight has been on by counting the number of used batteries.)

Explain
4. Have students read the handout: *Rock Strata and Fossils Information Bulletin.*
5. Distribute handout: *Rock Strata and Fossils Activity A*, and have students read the passage and fill in the blanks. This can be done independently.

Elaborate
6. In groups of 2 or 3, have students work with the *Common Fossil Card* and the handout: *Rock Strata and Fossils: Keys to our Geological Past diagram* by sketching the fossil in the appropriate box and writing the relevant information and the fossil's relative time in the geologic past.
7. Using the diagram *Geological Time Scale*, students complete the questions on the handout *Rock Strata and Fossils Activity B*.

Evaluate
8. In small groups, have each student make a one minute report to discuss what evidence we have that the Earth has changed through time.

SUPPORTING INFORMATION

What are Fossils?

Fossils are any remains, traces (evidence of), or imprints of a plant or animal that has been preserved in the Earth's crust since some past geologic or prehistoric time.

Fossils range in size from huge dinosaur skeletons to tiny plants and animals that can be seen only under a microscope. Most fossils are formed from the hard parts of animals and plants, such as shells, bones, teeth, or wood. They may be virtually unchanged from their original state, but more commonly occur as a mineral replacement or simple impression in the surrounding rock. An impression is called a *trace fossil.*

The study of fossils, called *paleontology*, shows us that life originated on Earth at least 3,600 million years ago. Since then there has been a succession of animal and plant species. Most are now extinct, and only a tiny number have survived as fossils due to a lack of the correct environmental conditions for preservation. By studying these survivors, we can get a fascinating glimpse of ancient life on Earth. This is called the *fossil record.*

The oldest fossils known represent simple, microscopic bacteria-like organisms that were single-celled. In rocks of around 545 million years in age, the fossil record explodes with evidence of a diversity and abundance of life.

Key Words:
Basic Terms: fossil, mammoth, amber, trilobites
Secondary Terms: paleontology, trace fossil, fossil record, paleontologist

SAFETY

- Reinforce the need to handle the rock samples with care, as some are sharp while others are fragile.

4 ACTIVITY A: CANADA'S TROPICAL HISTORY

Read the following passage and fill in the blanks with the appropriate word from the list at the end of the passage.

Imagine stepping out the back door of your house and being transported back in time 570 million years ago… It would be some 200 to 400 million years BEFORE ________________ roamed the Earth! You would be visiting young Canada where the south (e.g Ontario, Manitoba, etc.), beheld a landscape of shallow, warm ______________________ much like the Caribbean we see today. At that time the land beneath the cities of Windsor, Goderich, and Winnipeg, were in fact under shallow saltwater lagoons that were full of tropical organisms like corals, and shelled critters. How do we know these areas were covered with water so long ago? The rocks and fossils tell the story, and over time geologists have learned how to read their story.

Many answers to the Earth's geological past lie within _________________________. As we have seen in the study of the ________________, sedimentary rocks form in bodies of water when the surrounding land is eroded by rain, wind and glaciers. These ________________ settle on the floor of the lake or sea forming a sedimentary rock layer. Southern Canada is formed largely of sedimentary rock, telling us that it was under water when those layers were deposited. The life forms and salt deposits that we find within the sedimentary rocks tell us that it was once a warm, tropical environment covered by salty sea water.

Geologists can determine the relative (approximate) age of rocks by studying the sedimentary formations. As studied in earlier sections, each layer of sedimentary rock is _______________ than the layer lying beneath it. Within the different layers of sedimentary rock (called strata) we may find a number of different ______________ (remains of organisms that lived long ago and that have been cemented and preserved in the layers of rock). Geologists carefully study the fossils in the different ______________ to help them determine the relative age of the rock.

With new technology, __________________ can now determine the absolute age of rocks. They use a sophisticated scientific test that __________________ radioactive elements in the rock. Radioactive elements take a specific amount of time to release radiation. Knowing how long it takes for radioactive elements to give off radiation and by carefully studying the radioactive elements in a rock, geologists can determine its _______________ age.

Word Bank - Each word may only be used once

younger	**absolute**	**measures**	**tropical seas**
layers	**fossils**	**sediments**	**geologists**
sedimentary rocks	**rock cycle**	**dinosaurs**	

4 ACTIVITY B: CANADA'S FOSSILS

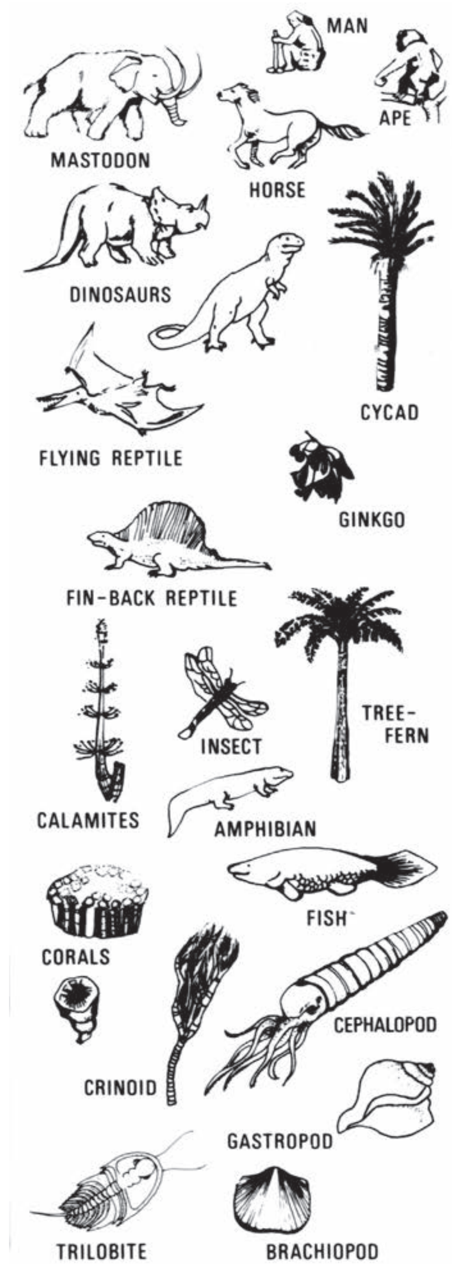
Using the *Rock Strata and Fossils diagram – Geologic Time Scale*, answer the following questions:

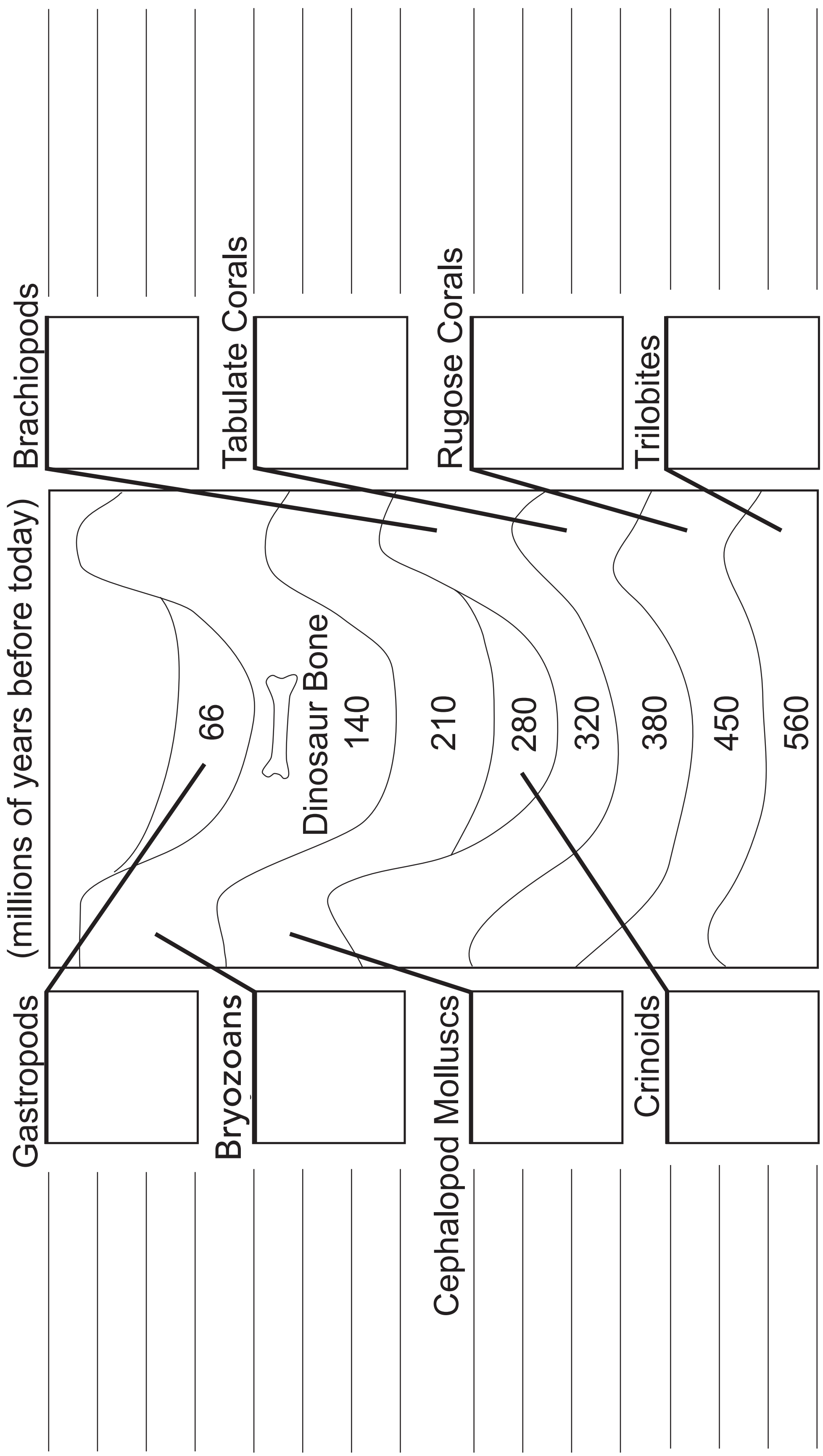
1. What is the name of the geologic time period when flying reptiles existed on Earth.

2. Insects are often considered "the most successful organism on Earth". How long have insects been present on Earth according to the geologic time scale?

3. During what geologic time period do you suspect the horses first roamed the Earth?

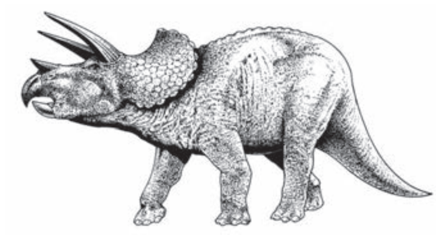
4. Referring to your Geologic Time Scale, what is the age of the oldest rock on Earth?

<table>
<tr><th>PERIOD</th><th>DATE IN YEARS</th><th>SUCCESSION OF DOMINANT LIFE FORMS</th></tr>
<tr><td>QUATERNARY</td><td></td><td rowspan="13">
</td></tr>
<tr><td>TERTIARY</td><td>1.8 MILLION</td></tr>
<tr><td>CRETACEOUS</td><td>65 MILLION</td></tr>
<tr><td>JURASSIC</td><td>135 MILLION</td></tr>
<tr><td>TRIASSIC</td><td>195 MILLION</td></tr>
<tr><td>PERMIAN</td><td>245 MILLION</td></tr>
<tr><td>PENNSYLVANIAN</td><td>280 MILLION</td></tr>
<tr><td>MISSISSIPPIAN</td><td>310</td></tr>
<tr><td>DEVONIAN</td><td>360 MILLION</td></tr>
<tr><td>SILURIAN</td><td>400 MILLION</td></tr>
<tr><td>ORDOVICIAN</td><td>440 MILLION</td></tr>
<tr><td>CAMBRIAN</td><td>500 MILLION</td></tr>
<tr><td></td><td></td></tr>
<tr><td>PRECAMBRIAN</td><td>545 to 4,500 MILLION</td><td>LIFE HAD ITS EARLY BEGINNINGS IN THE LATE PRECAMBRIAM SEAS</td></tr>
</table>

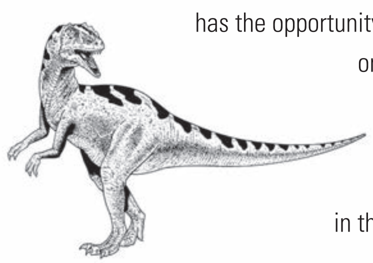

Age of Rock
(millions of years before today)
66
Dinosaur Bone
140
210
280
320
380
450
560
Brachiopods
Tabulate Corals
Rugose Corals
Trilobites
Gastropods
Bryozoans
Cephalopod Molluscs
Crinoids

A GLIMPSE AT THE HISTORY OF OUR EARTH

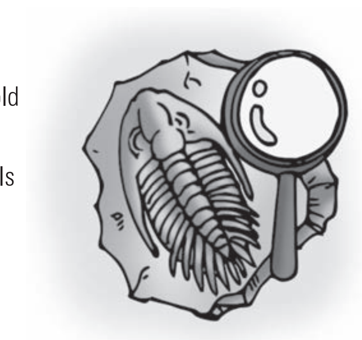
Fossils are the remains or traces of animals and plants that have been preserved in sedimentary rocks. Geologists that study fossils to determine the biology of these organisms and the environment and time in which they lived, are called **paleontologists**. These specialized geologists study fossils and fossil remains that may be billions of years old, ranging in size from microscopic one-celled organisms to huge dinosaur bones. Most fossils are formed from the hard parts of animals and plants, such as shells, bones, or teeth while the soft tissue of the organisms are commonly lost to scavengers or decomposed.



Where do we find fossils? Fossils are most commonly found in sedimentary rocks such as shale, sandstone and limestone. They are very difficult to recognize in metamorphic rocks, and are non-existent in igneous rocks (they would melt at the high temperature that forms magma). Anyone who finds layers of unaltered sedimentary rock has the opportunity to discover fossils hundreds of millions years old. In order for fossils to be preserved, the organisms have to be buried quickly by layers of sediment so that their skeletons can remain undisturbed through the ages, until uncovered by man or erosion (by rain, wind, or ice). Some fossils are relatively unchanged from when the organisms were alive, such as **mammoths** frozen in ice, and insects preserved in **amber**, such as the mosquitoes shown in the Jurassic Park film.



Fossils are important to us today because they help explain the evolution of many different types of species over time. The oldest known fossils are simple single-celled microscopic bacteria-like organisms. They are found in rocks approximately 545 million years old and they mark the beginning of life on Earth. From that time onwards the number of fossilized organisms increased as organisms evolved into more complicated forms. Organisms grew shells for protection allowing them to live longer and adapt to their surroundings.



Many fossils have the general shape of modern animals and plants. A fossil snail (gastropod) looks very similar to the snails we see today except the fossil is only the shell and not the soft bodied animal inside. Many groups of fossils such as **trilobites** and dinosaurs no longer exist and are now only known as fossils.

Paleontologists have determined, through years of study, exactly when certain organisms lived on the Earth. This is valuable for us because we can identify the relative age of a rock layer by identifying the fossils within it. This is particularly useful in the search for fossil fuels such as oil and gas. Using the fossils found in sedimentary rocks, paleontologists can date the rocks that contain the fossils and determine what the past environment was like at that time and whether oil or gas are likely to be buried in the area.

5 ROCK CLASSIFICATION CHALLENGE

MATERIALS

- Samples: Granite, Rhyolite, Gabbro, Basalt, Limestone, Shale, Sandstone, Dolostone, Conglomerate, Quartzite, Gneiss, Marble, Slate (Use the Preparation and Set-up document to label the samples)
- Figure: *The Rock Cycle* (Displayed on available classroom projection technology)
- Handout: *Rock Classification Challenge Activity A - Observations*
- Handout: *Rock Classification Challenge Activity B - Analysis of Observations*
- Handout: *Rock Classification Challenge, Rock Description Chart*
- Hand lens
- Correction fluid
- Fine tip permanent marker

Consumables:
- Dilute 10% hydrochloric acid

Online reference:
- Rocks: Igneous, Metamorphic and Sedimentary **www.geology.com/rocks**

SUMMARY OF TASK

Students will:
- Classify rocks, using their observations, according to their characteristics and methods of formation

EARTH SCIENCE LITERACY PRINCIPLE(S)

BIG IDEA 1 Earth scientists use repeatable observations and testable ideas to understand and explain our planet.

BIG IDEA 3 Earth is a complex system of interacting rock, water, air, and life.

BIG IDEA 4 Earth is continuously changing.

OBJECTIVES

1. Make observations on the characteristics of 13 different unidentified rock samples using an observation table.
2. Answer questions based on their observations.

INSTRUCTIONS

Engage

1. Briefly review the rock cycle and characteristics of the three rock groups using the figure: *The Rock Cycle* (Displayed on available classroom projection technology).

Explore

2. Explain to the students that they will observe the characteristics of 13 different rock samples that have been set out.
3. Distribute the handout: *Rock Classification Challenge Activity A - Observations table*. Read the table headings together and stress the importance of complete observations, being concise and using scientific vocabulary where appropriate. Suitable words are included in the column headers of the chart. At this point, they leave the last column, *Rock Type blank*. Students must also understand that the sample numbers correspond to the table (i.e. if the first sample they observe is #5, they must record their observations in the #5 row).
4. Model the study of one rock sample to reinforce the use of the correct row and to introduce the type of observations to make and possible terminology to use.
5. Conduct the hydrochloric acid test on the limestone. Indicate to the students which sample number you are testing and while the students watch; place a drop or two of 10% HCl on the limestone. Have the students record the result in the appropriate row on their charts. Repeat the test for dolostone and marble, and students should observe and note that the reaction is not as strong.
6. Divide your class into 3 groups in order to allow all students to work with the rock samples. Distribute a set of the 13 rocks to each group (one rock going to each student). Students are to quickly make observations on their rock sample, and then carefully pass it to the next student in their group, following a rotation until all samples have circulated through the group. They will need about 2 minutes with each sample.

Explain

7. Once all the observations have been noted, have students complete handout: Rock Classification Challenge Activity B - Analysis of Observations.
8. After activity B has been completed, students are to complete the Rock Type column on the observation chart: Rock Classification Challenge Activity A - Observations.

Elaborate

9. After students have successfully identified the rock type (sedimentary, igneous or metamorphic) for each sample, provide them with the handout: Rock Classification Challenge - Rock Description Chart. Based on their rock type classification and observations and reference characteristics, have them attempt to give a name each rock sample.

Evaluate

10. Have each student design an instruction card for someone to identify whether a rock is sedimentary, metamorphic, or igneous.

PREPARATION AND SET-UP

The following instructions will help to prepare the samples before conducting this activity.

1. Make an instructor copy of the Rock Description Chart. This will be the 'Answer Key'.
2. Number the rock samples from 1 to 13. Make sure to randomize the numbers so that they don't correspond to the list on the Rock Description Chart (e.g. don't label granite #1, rhyolite #2…). Ensure that rocks of the same type have the same number.
3. To label the rocks, dab each sample with correction fluid and write the number in permanent marker on top of the correction fluid (ensure the correction fluid is completely dry). For durability, paint over the dry number with clear nail polish.
4. As you give each sample a number, record that number beside the appropriate rock name on the 'Answer Key'.

SUPPORTING INFORMATION

Hydrochloric acid test

The acid will react with the calcium in the limestone and will bubble (*effervesce*) strongly. The bubbles show the release of the gas carbon dioxide (CO_2) that occurs during the chemical reaction:

$CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2$ calcium carbonate + acid → calcium chloride (salt) + water + carbon dioxide

If no reaction occurs, scratch the surface with a tack or paper clip and place an additional drop or two of acid on the rock. This should produce slight bubbling. Immediately rinse with water and dry off the test rocks and place them back in the set they came from.

Key Words:

Basic Terms: sample, coarse-grained, fine-grained, igneous, sedimentary, metamorphic, plutonic rock, volcanic rock, vesicles

Secondary Terms: clast, effervesce, foliated

SAFETY

- Care should be taken with glassware in test one. Broken glassware should not be used and should be disposed of properly if it is found.
- This activity has the teacher use dilute hydrochloric acid (10% HCl). Rubber gloves, safety goggles and a lab coat should be worn.

5 ROCK DESCRIPTION CHART

Igneous	**Formed from cooling magma under the Earth's surface (plutonic) or lava at the Earth's surface (volcanic).**
Granite	• **Coarse** (1-10mm) interlocking **grains** show that this is a **plutonic rock**. • The three main minerals are orthoclase (pink feldspar), quartz (clear, white or-gray, glassy) and mica (black and flaky). • Sometimes the mineral hornblende (black and hard, not provided in this kit) is also present.
Rhyolite	• **Fine grains** (less than 1mm) show that it is a **volcanic rock**. • Based on mineral composition this is the extrusive equivalent of granite. • The samples provided are dull, red and are very hard with sharp edges.
Gabbro	• Coarse (1-10mm) interlocking grains show that this is a plutonic rock. • It is composed of dark minerals such as plagioclase (white, calcium-rich feldspar), pyroxene, olivine and amphibole.
Basalt	• Fine grains (less than 1mm) and **vesicles** show that this is a volcanic rock. • Crystals (green or beige) have formed in some of the vesicles. • Basalt is the extrusive equivalent of gabbro. • The samples in the kit are a deep brown-red colour.
Sedimentary	**Formed by erosion of existing rock by water, wind or ice and the transportation, deposition and lithification of rock particles.**
Limestone	• Composed mainly of calcium carbonate (calcite). • Typically a dull gray to beige colour. • Limestone can be fine-grained or coarse-grained. • *Effervesces* (bubbles) strongly in the presence of dilute HCl.
Shale	• Composed of clay-sized particles and as a result looks like hardened clay. • Samples range in colour from brick red to gray-green. • In some samples layers can be seen.
Sandstone	• Composed of sand-sized particles of quartz, feldspar and rock fragments. • The samples in the kit are beige colour. In some samples bedding (layers) can be observed.
Dolostone	• Composed of calcium magnesium carbonate (dolomite). • Limestone samples are turned into dolostone when rain or groundwater adds magnesium. • Dolostone samples effervesce (bubble) slightly in the presence of dilute HCl (make sure the sample is clean, sometimes carbonate dust will react with the HCl). • Samples are dull and can be beige or gray. They may look identical to limestone.
Conglomerate	• Rounded rock fragments of varying size (clasts) held together by a silica or calcium carbonate cement (matrix). • *Clast* size ranges from 1mm to several cm. • Fine grained and a magnifier is necessary to see individual grains. • Some of the clasts can be identified as feldspar, quartz and granite. Be on the lookout for smooth indentations where the clast has been 'plucked out'.

Metamorphic	Previous rock changed by heat and/or pressure into a different rock.
Quartzite	• Metamorphosed sandstone. • Most of the samples in the kit are gray although the occasional sample might be pink-red. • Fine granular texture, looks as though it is wet.
Gneiss	• Metamorphosed granite. • Banding is characteristic with orthoclase (pink feldspar) and quartz forming together and mica and hornblende forming together. • Some samples have fine-grained crystals while others have coarse-grained crystals.
Marble	• Metamorphosed limestone that has been exposed to low levels of metamorphism will have small (calcite) crystals. The crystals become larger as the level of metamorphism progresses. • The samples in this kit are white or pink and coarsely granular. • Sparkly • Will effervesce (bubble) in the presence of dilute HCl.
Slate	• The alteration of shale by low-grade regional metamorphism. • Fine-grained *foliated* appearance. • The colour (dull black, grey, red, and/or green) is often determined by the amount and type of iron and organic material present in the rock. • Some pieces can be broken easily.

5 ACTIVITY A – OBSERVATIONS

Sample #	**Shape** (massive, lumpy, thin, layered, banded, etc)	**Surface Texture** (smooth, rough, granular, flaky, etc)	**Grain Size** (very fine like powder, fine, medium like sand, coarse like gravel)	**Scratch Test** (Can you scratch the surface with your fingernail?)	**Sketch** (use colours to sketch the sample)	**HCl Test** (Bubbles Y/N Weak/Strong)	**Rock Type** (Igneous, Sedimentary, Metamorphic)
1							
2							
3							
4							

Sample #	Shape	Surface Texture	Grain Size	Scratch Test	Sketch	HCl Test	Rock Type
5							
6							
7							
8							
9							

Sample #	Shape	Surface Texture	Grain Size	Scratch Test	Sketch	HCl Test	Rock Type
10							
11							
12							
13							

Notes:

5 ACTIVITY B – ANALYSIS OF OBSERVATIONS

The following questions will help you analyze your observations. While answering the questions, try to predict the rock type for each of the samples in your table. Record your answers in pencil in the Rock Type column on the observation table. Do your best to provide an answer for each of the 13 samples.

1. According to the characteristics of each of the three rock groups, which type is made up of layers of compressed sand or clay?

2. Which samples from your observation table had a layered structure?

3. Sedimentary rocks are the softest of the three rock groups. Which samples from your chart were you able to scratch with your fingernail?

4. Which sample numbers were repeated in your last 2 answers (soft and layered)?

5. Igneous rocks that are intrusive or plutonic (formed when magma cools under the Earth's surface) are characterized by coarse, interlocking grains and are very hard. Which sample number(s) correspond to this description?

6. Igneous rocks that are extrusive or volcanic (formed when lava reaches the Earth's surface, cools and solidifies) are often characterized by very fine-grained crystals that are difficult to see with the naked eye. There are two extrusive rocks out of the 13 that you identified. Which two could they be?

7. As you know, heat and pressure inside the Earth can cause igneous and sedimentary rocks to change, creating metamorphic rocks. Rocks that have a layered structure for example, but that are much harder could be metamorphic rocks. Igneous rock that has been affected by heat and/or pressure is often characterized by bands or stripes. Which samples do you think could be metamorphic rocks?

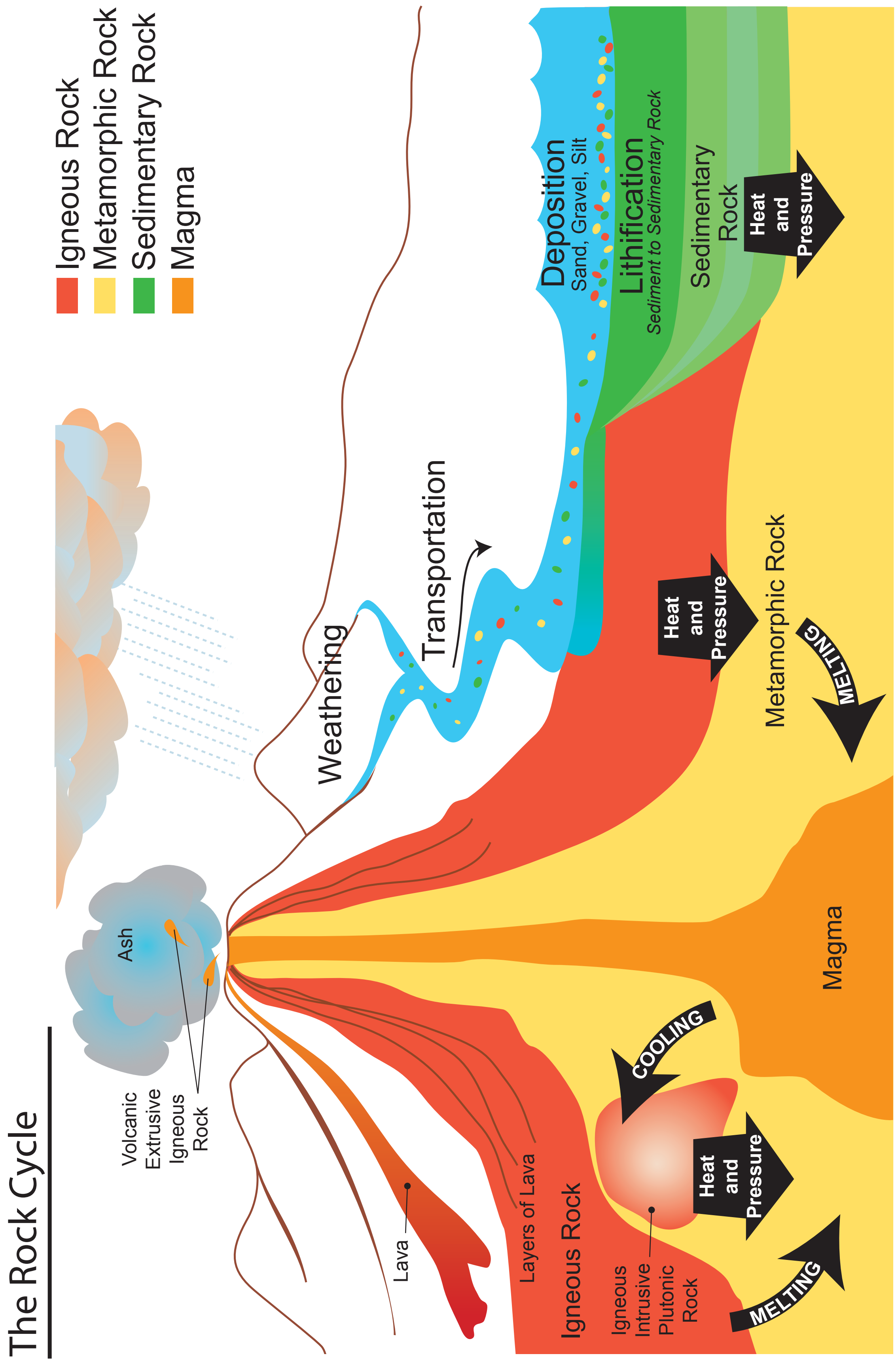
8. Which rock type(s) do you think is/are the easiest to identify? Why?

9. Which sample numbers were the most difficult to identify?

10. Choose one of rock samples that you believe is an igneous rock. Using descriptions from your observation table, explain why you believe that it is an igneous rock.

11. Choose one of your sedimentary choices, and explain why you believe it is a sedimentary rock using descriptions from your table.

12. Finally, choose one of your metamorphic choices and justify your choice using descriptions from your table.


The Rock Cycle
Igneous Rock
Metamorphic Rock
Sedimentary Rock
Magma
Volcanic Extrusive Igneous Rock
Ash
Lava
Layers of Lava
Igneous Rock
Igneous Intrusive Plutonic Rock
Weathering
Transportation
Deposition
Sand, Gravel, Silt
Lithification
Sediment to Sedimentary Rock
Sedimentary Rock
Heat and Pressure
Heat and Pressure
Heat and Pressure
Metamorphic Rock
MELTING
MELTING
COOLING
Magma