Rocks & Minerals

Background Information for Teachers

INTRODUCTION

Washington is a state known for its geology. Step outside your school in western Washington, and look at the landscape. On the horizon, you can see our state's two mountain chains, the Olympics and Cascades, both formed less than 30 million ago. If you live on a steep hill, or boat on Puget Sound or Lake Washington, you are experiencing products of glaciation that occurred within the last 20,000 years. In eastern Washington, you might find evidence of great lava flows that covered the area 13 and 17 million years ago, and the Ice Age floods, one of the greatest geologic events on earth, which carved the landscape with unrivaled torrents of water. The northeast corner of Eastern Washington claims Wahington's most ancient rock, at over one billion years old. On a more intimate scale, rocks and minerals affect us on a daily basis. We sprinkle salt on French fries. We eat calcite-rich antacid tablets when we have stomach aches, or wear a watch that contains a tiny piece of quartz. We appreciate jewelry made from gold, silver or gemstones. We watch films featuring depicitons of the great animals that lived tens of millions of years ago. We visit, or live in, a building, made of brick (made from glacier-derived sediments), or granite (formed by subducting plates), or sandstone (made from eroded mountains). We use gravel that may have come from glacial deposits on our paths and driveways. We take vacations or field trips to see geological phenomenon, such as Mt. Rainier, the Republic fossil beds, the Grand Coulee, or the Columbia Plateau basalts. We read about how our use of rocks and minerals affect the modern world, from climate change and energy policy, to natural resources, and natural disasters.

This curricumum focuses on rocks and minerals of Washington State, what are they are, and how they affect our lives. The background section starts with an introduction to rocks and minerals and an exploration of the three rocks types, followed by a geologic history of the state, and ending with an overview of plate tectonics, which provides the basic theory of how all geology is set in motion.

MINERAL AND CRYSTAL FORMATION

People often use the terms rocks and minerals interchangeably. If we think there is a difference, we may associate minerals with being shinier or rarer or smaller than rocks, but many rocks defy these classifications. Instead, geologists have a much clearer way to define a rock and a mineral. Simply put rocks are made of minerals. Another way to think of this is that minerals are the ingredients of rocks. As when one makes cookies, if the recipe of ingredients differ, the final product, the cookie or the rock, differs.

Geologists define a mineral as a natural, inorganic solid, with a definite chemical composition and an ordered atomic arrangement. In practical terms, this means that any artificial, organic, or liquid substance is not a mineral, such as zirconium or oil. The definition also means that all minerals consist of crystals, although most crystals can only be seen with a microscope. The few minerals that generate large crystals, such as quartz and calcite, are exceptions.

Although geologists have described over 4,000 different minerals, only about 20 to 30 are common. Of these, just 10 make up more than 90% of the Earth's crust. These include quartz, feldspar, micas (muscovite and biotite), and hornblende. Other well-known, but less common minerals include pyrite (fool's gold), calcite, and halite (table salt).

Most minerals form from molten rock —either liquid magma or very hot solids— that has solidified. Crystal size usually relates to how long it takes to cool, with larger crystals forming more slowly.
Large crystals also need a space to grow, which is why some of the biggest crystals, up to 10 or 11 feet long, form in caves.

MINERAL IDENTIFICATION

Minerals are defined by their chemical composition and their crystal structure. But these characteristics are usually determined by large and expensive equipment such as x-ray defraction machines. However, several characteristics can be used to identify an unknown mineral in a hand sample.
The most useful physical characters are hardness, cleavage and fracture, luster, density, streak, effervescence, color, smell, taste, and magnetism. Some minerals have properties that are very distinct and immediately recognizable, such as the smell of sulfur, the hardness of diamond, or magnetism of magnetite, but many require more investigation.

Mohs Hardness Scale	
TALC	1
GYPSUM	2
CALCITE	3
FLUORITE	4
APATITE	5
ORTHOCLASE	6
QUARTZ	7
TOPAZ	8
CORUNDUM	9
DIAMOND	10

NON-MINERAL ITEMS RANK AS FOLLOWS ON THE SCALE:

fingernail: **H= 2.5**

pocket knife: **H= 5.5**
glass plate: **H= 5.5**

unglazed porcelain streak plate: **H= 6.5**

Hardness refers to a mineral's resistance to scratching or abrasion. It does not denote how readily a mineral will break (which is referred to as brittleness).
In the early 1800s a German mineralogist, Friedrich Mohs, assigned ten minerals a number of hardness on a scale from 1 to 10; the hardness of all minerals is determined relative to this scale (note that it is a relative scale, not linear, as diamonds are not "ten times as hard as talc"). Geologists call this rating system the Mohs Hardness Scale.

A mineral's hardness (**H**) is determined by what it will scratch and what will scratch it. For instance, if you obtain an unknown mineral, and it will scratch a glass plate, but will not scratch quartz (quartz will scratch it), you can determine the hardness to be around 6.5.

Streak is the color of a mineral when powdered. In minerals that are softer than a ceramic streak plate, this can be determined by dragging the mineral across the streak plate. Unlike color, streak can be helpful in identification especially in metals. Although the color of a mineral can vary widely, its streak color will remain the same.

Cleavage refers to how a mineral breaks along a distinct plane. This happens because the bonds between atoms are weaker along that particular plane. How a mineral cleaves, or breaks, is different than what type of crystal it forms. For example, the mineral calcite cleaves into rhombohedra but its crystals are shaped more like an eight-sided dunce cap. Another way to think of cleavage is what would result if you hit the mineral

with a hammer. No matter what size or shape it is, if you hit a chunk of salt it will break into cubes.
Fracture also refers to how a mineral breaks, but with fracture, the breaks do not occur along distinct planes. This is what usually happens with very hard minerals – those with +7 on Mohs hardness scale. The best example of fracture is what happens when quartz breaks. The quartz break has the quality of broken glass; it breaks in smooth curve.

Luster refers to the way a mineral's surface reflects light. The most important distinction of luster is between metallic and non metallic. Other types of luster include earthy, waxy, greasy, pearly, and vitreous.

Density or specific gravity refers to the ratio of mass to volume, or in other words, how much a mineral weighs relative to its size. Density depends on what the mineral's ingredients are and how tightly they are packed together. The greater the density, the greater the weight. The simplest way to compare density is pick up two specimens, one in each hand, and see which one weighs more.

Effervescence refers to whether or not a mineral will react to acid (i.e. carbonate minerals). When a weak acid is placed on calcite ($CaCO_3$), it will fizz noticeably. Dolomite, which is a calcium-magnesium carbonate, will usually fizz only if it is first powdered.

Additional characteristics include **color, smell, feel, taste, magnetism**, and **crystal shape**. Color is usually the first thing that a person will notice, However, different specimens of the same mineral can vary widely in color due to impurities, making color an unreliable characteristic by which to identify a mineral. Smell can sometimes be helpful, as with sulfur, which smells like rotten eggs. Feel can be characteristic, as with talc and graphite, both of which have a greasy feel. It is generally not advised to taste a mineral (because you don't know where it's been), though some minerals, such as halite (salt) can be identified by their distinct taste. If you find a mineral that is magnetic you have found magnetite. Crystal shape can be a useful identifying characteristic, but since most minerals you encounter don't produce crystals large enough to see with the naked eye, crystal shape is not as straightforward as other characteristics.

ROCK IDENTIFICATION

Rocks are composed of minerals, usually many minerals like granite, but sometimes just one mineral like limestone. Geologists divide rocks into three categories. Igneous rocks, which occasionally generate news (i.e. Mt. St. Helens), form from molten rock. The most abundant rocks on the continents are sedimentary rocks, including sandstone, limestone, and shale. Perhaps best known for their use in art and architecture are metamorphic rocks, such as marble, formed by great pressure and temperature. Washington state contains all three types.

Igneous rocks solidify from molten rock which is called magma. **There are two types** of igneous rock based on the way the magma cools and solidifies to form rock.
1) Plutonic rocks, *also called intrusive rocks*, form from magma that cools within the crust of the Earth. Because it is a lot warmer within the crust than on the surface, the magma cools very slowly. Thus plutonic rocks, such as granite, generally have minerals that are visible to the naked eye. This is called a coarse-grained texture.
2) Volcanic rocks, ***also called extrusive rocks***, form from magma that is erupted

onto the surface of the Earth's crust. When it reaches the surface the molten rock is then called lava. Lava can flow in streams of molten rock until it cools and solidifies, or it can explode into the air and cool instantly, forming pumice or ash such as is found on Mt. St. Helens. Lava cools quickly at the earths' surface and its minerals are so small that they cannot be seen with the naked eye; such rocks have fine-grained texture.

In some rare case, lava cools so quickly there are no gases associated with the lava so no crystals are able to form at all. This rock is like glass and is called obsidian. In other cases the molten rock can sit in a magma chamber very close to the earth's surface, such as just below a volcano, like Mt. Rainier. This giant magma chamber begins to cool and one of the minerals will crystallize out of the liquid, often this is a feldspar or hornblende. Before the rest of the magma has time to cool and crystallize, the mountain erupts and the lava flows out. The resulting volcanic rock looks different as one crystal type is visible, but not the others. Andesite specimens found on Mt. Rainier and Mt Baker are typical examples of this type of rock.

Igneous rocks are all composed of at least 45% silica bound into different minerals. Silica is a combination of the elements silicon (Si) and oxygen (O) and has the composition SiO_2 . Silica on its own is the mineral quartz, but it also bonds with different elements, like iron or aluminum, to make other minerals. Granite and rhylolite are composted of more than 65% silica within its mineral components. Others igneous rocks have less silica and more iron and magnesium within their minerals and these give the rocks dark colors and greater density. For example the andesite of Mt Rainier has about 55% silica component and the basalt lava flows of western Washington about 50% silica content.

Sedimentary rocks form from the accumulation of any kind of rock that has been broken down on the surface of the Earth. They are the most common type of rock on continents. The three main varieties are derived from mechanical (physical), chemical, and organic processes. Mechanically derived sedimentary rocks are called clastics as they are composed of tiny bits broken (eroded) off other rocks. These little eroded bits are then transported and deposited by water, wind, or ice. Some minerals from eroded rocks will dissolve in water and are then carried in solution. When the water evaporates, chemically precipitated sediments form, such as halite (table salt) or gypsum. Organic sediments rocks form when plants or animals accumulate over time and compact to form a rock, such as coal (from compressed plants) and diatomite (from tiny, photosynthesizing, single-celled organisms called diatoms). Almost all limestone is made from the tiny calcite crystals that formed the hard parts of animals like corals, and some tropical algae, or are chemically precipitated as calcium carbonate is left after evaporation. Fossils are preserved in sedimentary rocks, including the great plant and insect fossils of Republic, the petrified wood near Vantage, and the whale fossils of the Olympic Peninsula.

Metamorphic rocks form when rocks are subjected to great pressure and temperature. Under these conditions (which only occur as the rocks are buried within the crust of the earth) the elements can become rearranged to form new minerals. This change or rearrangement of mineral components is known as metamorphism. Unlike igneous rocks that form from molten rock, metamorphic rocks never melt. They can become very hot and this allows the change, but always remains solid. Metamorphic rocks are classified based on the grade, or degree of metamorphism. For example, a shale becomes a slate and with progressively more heat and pressure (deeper burial) becomes a schist and then gneiss; basalt become a green schist and then amphibolites.

WASHINGTON GEOLOGY

The Pacific Northwest and the state of Washington have a very complex and exciting geologic history. For a fuller and more detailed account of this history, please visit the Burke Museum's website, at:

http://www.washington.edu/burkemuseum/geo_history_wa/index.htm

Click on *Research and Collections*, then *Geology*, then *Northwest Origins*. Written by Catherine L. Townsend and John T. Figge, this section provides a thorough introduction to the state's geologic past.

BUILDING THE PACIFIC NORTHWEST

An understanding of plate tectonics is where an understanding of Washington state history begins. The principle of plate tectonics states that the solid, brittle, outer crust of the earth is composed of a dozen or so large masses and a few smaller ones. Because of continuous motion of materials inside the Earth, the plates also constantly move. On a geologic timescale, they move between two and five centimeters a year, on average.

Sometimes small plates collide with and attach themselves along the edge of big plates. This is basically what has happened to Washington State over the past several hundred million years. Plate movement has added several masses, called accreted terranes, to the state, growing it westward. Most of western North America, as we now know it, didn't exist before 200 million years ago. The entire west coast, from California to Alaska, is made from a series of these terranes that were attached, or accreted, to the western edge of the continent.

About 500 million years ago, the western edge of the North American continent ended at roughly the Idaho/Washington border. Warm tropical seas washed against the shores and huge tidal flat areas extended deep into Montana. You can see this environment preserved in the red and green rocks along the freeway roadcuts, as you cross from Washington to Idaho. Some of these beach and sea-deposited sedimentary rocks contain fossils, including one of the most intriguing creatures of the time, trilobites, which superficially look like a potato bug. The rocks date back to between 530 and 430 million years ago and make up about 1/6th of the state, all in the northeastern corner.

Around 250 million years ago, these moving plates forced all of the continents of the world to came together into a supercontinent called Pangaea. But like many good things, it didn't last long. By 200 million years ago, Pangaea was breaking up with North America moving westwards, but the floor of the Pacific Ocean was moving in the opposite direction, eastwards. One of the plates had to give, and because the ocean floor consists of much denser rock that the continental crust, it dove under, or subducted beneath North America. This started to generate a chain of volcanoes along the edge of the continent. Riding on top of the ocean floor were a series of small continents and islands made up of much less dense rock. When they reached the margin of the North American continent, however, they did not subduct. Instead, they attached, or accreted themselves to the larger landmass. In the Washington-Oregon-British Columbia region, the first terrane to accrete onto North America is called the Intermontane Terrane. It attached around 160 million years ago during the Jurassic Period. As Hollywood has made clear, dinosaurs thrived during the Jurassic and they could have been living on this new land, but no dinosaur fossils have been found in Washington yet. Either they didn't live here, they weren't preserved, or paleontologists haven't found their remains in the few Jurassic period rocks in the state.

After this collision the edge of the continent in the Pacific Northwest was now further to the west, was at about the present day Methow Valley. At this time along the coastal region ammonites (shelled squids), clams and snails flourished and occasional marine reptiles swam past. We have fossils to show this.

The Insular Terrane collided around 130 million years ago, consisting of a set of islands with marine sedimentary rocks and volcanic rocks all squashed together. Concurrent with the collisions of each accreted terranes, huge amounts of rock were also thrust underground and subjected to intense pressure and heat. Later these were uplifted and the tops eroded off, revealing that much of the rocks of these accreted terranes are metamorphic rocks. Again, dinosaurs may have roamed over the new land that is Washington, but we have not record of them. Now much of the land that makes up the Pacific Northwest was formed, except for the westernmost edge.

After about 100 million years the new land of Washington was eroded flat by huge rivers coming out of the mountains in Idaho and eastern British Columbia. At this time, the whole world was warmer, and Washington's climate resembled those of modern subtropical countries. The river banks, swamps and deltas were home to a wide variety of plants and animals such as palms, relatives of magnolia and banana. The beautiful fossil plants from Republic, southern Puget Sound and the Bellingham area all date to this time.

Around 40 million years ago geology at the edge of Washington changed again. Subduction of the ocean plate began in earnest again, generating the first Cascade volcanic mountain chain. Since that first pulse of volcanism, hundreds of different volcanoes have grown, become extinct and been weathered away. All our current volcanoes – Mt. St. Helens, Mt. Rainier, Mt. Adams, Glacier Peak, and Mt. Baker – are less than 1 million years old, so we know that there must have been many, many generations of Cascade Mountains. Sometimes the volcanoes erupted violently. Sometimes they were more like today, quietly waiting to become active again. During this time, the sedimentary rocks that make up all of western Washington, including the Olympic Mountains, accumulated in the sea, just off the coast Gradually these rocks were lifted out of the water. The current coastline came into position about 5 million years ago and Washington as we know it was made.

But there were three more major events that shaped Washington. From 14-17 million years ago huge volumes of fluid, basalt lava erupted out of fissures along the Washington-Idaho-Oregon border. These are the Columbia River basalts, which flowed downhill to fill up the Columbia plateau. Some of the largest flows reached the sea about 650 kilometers (~400 miles) away. After millions of years of erosion these volcanic flows still cover 36% of the entire state. During the long periods between volcanic eruptions, when soils and lakes formed on the old flow tops, plants and animals inhabited the area. They are preserved as petrified wood, diatomite, and one unlucky, upside down rhinoceros, whose body formed the well-known "cave" and is reproduced in the Burke Museum exhibit.

At around the same time the Olympic Mountains began uplifting. They are composed only of well cemented sedimentary rocks, the same as the ones that cover the rest of western Washington. However beneath the northern Olympic Peninsula the subducting ocean plate has to squeeze down at a 'corner' where the continental coastline Washington meets the west coast of Vancouver Island. This squeezing causes the underlying plate to 'bump up' forcing the mountains to grow. The tops of the mountains are eroded rapidly by rain and ice, but the mountains continue to get taller.

Finally northern Washington was covered by the southern edge of the vast continental glaciers that covered the northern hemisphere during the Ice Ages, 2 million to 10,000 years ago). These glaciers waxed and waned during this time period with their greatest extent during the last cold phase, about 20,000 years ago. During this time, alpine glaciers covered the Cascades, too. Glaciation also generated one of the greatest events ever recorded on Earth.

In the northern panhandle of Idaho, ice repeatedly dammed the very large Clark Fork River and formed an immense lake. Periodically the dam would break, releasing a volume of water equal to ten times the flow of all rivers on the planet today. The waters ripped through the Columbia Plateau with enough power to carry house-sized boulders hundreds of miles from their sources. The waters carved out the deep coulees of the "channeled scablands" that we see today, and eventually emptied into the Pacific Ocean (see video).