GreatHearts®

Earth Science 8

May 11 – May 15

Time Allotment:30 minutes per day

Student Name: ___________________________________

Teacher Name: ___________________________________

Packet Overview

Date	Objective(s)	Page Number
Monday, May 11	1. Students will be able to define mechanical and chemical weathering.	1
Tuesday, May 12	1.Students will be able to describe how surface rivers and streams produce erosion and describe the types of deposits left behind by rivers and streams.	5
Wednesday, May 13	1. Students will be able to explain how ocean waves produce erosion an describe the types of coastal features created by wave erosion.	8
Thursday, May 14	1. Students will be able to explain the ways particles are carried by wind and describe how sand dunes form.	10
Friday, May 15	1.Students will be able to explain the process of glacial erosion.	13

Academic Honesty

I certify that I completed this assignment independently in accordance with the GHNO Academy Honor Code.

Student signature:

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I certify that my student completed this assignment independently in accordance with the GHNO Academy Honor Code.

Parent signature:

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Lesson 1: Monday, May 11

Weathering

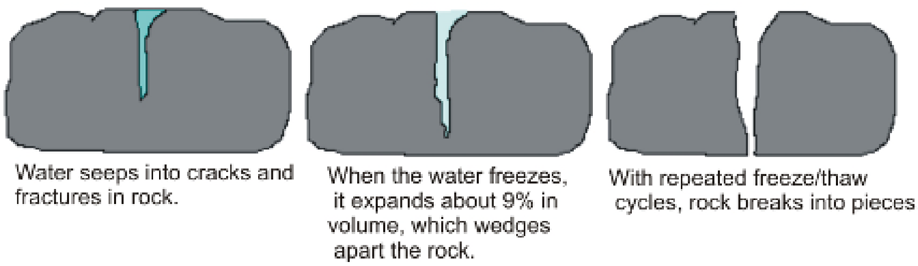
Weathering is the process that changes solid rock into **sediments**. Geologists use the word sediment to describe all different sizes of rock particles. Sediment includes really large pieces of rock, like boulders or gravel, but it also includes sand and much smaller particles, called silt and clay. In the process of weathering, rock is disintegrated and decomposed. The chemical composition breaks down, and the disintegration of rock happens as rock is broken into pieces. Once the pieces are separated from the rocks, **erosion** is the process that moves those pieces. Gravity is one way that pieces of rock move, as broken pieces of rock fall or tumble from high places to lower ones. Gravity causes large and small pieces to fall from cliffs, as well as moving water in rivers and streams from mountaintops to the ocean. Wind and glaciers also move pieces of rock from one place to another. Wind moves sand sized and smaller pieces of rock through the air. Glaciers can move all sizes of particles, from extremely large boulders to the tiniest fragments.

Weathering happens at the Earth's surface. When most rocks form, they are forming at very high temperatures and pressures. This is a very different environment than the low temperatures and pressures at Earth's surface. When rocks reach Earth's surface, weathering causes them to change form. The new form will include minerals that are stable at the low temperatures and pressures of Earth's surface. So while powerful forces on Earth, such as those resulting from plate tectonics, work to build huge mountains like the Himalayas or majestic volcanoes like Mt Fuji, the forces of weathering gradually wear away rocks, changing once tall mountains into hills and even plains. The Appalachian Mountains along the east coast of North America were once as tall as the Himalayas! So what happened?

Mechanical Weathering

Mechanical weathering (also called physical weathering) is the breaking of rock into smaller pieces. These smaller pieces will be just like the bigger rock, the pieces will just be smaller. That means the rock has been changed mechanically (or physically) without changing its composition. The smaller pieces will have the same minerals, in just the same proportions as the original rock. You could actually use the expression, 'A chip off the old block' to describe mechanical weathering! The main agents of mechanical weathering are water, wind, ice, and gravity. You will see how each of these works to break rock into smaller pieces.

There are two main ways that rocks can break apart into smaller pieces. The way that is most common in cold climates is called **ice wedging**. Ice wedging is the main form of mechanical weathering in any climate that regularly cycles above and below the freezing point. Some places where this happens include Earth's polar regions and mid latitudes. It also happens in the colder climates of higher elevations, like mountainous regions.



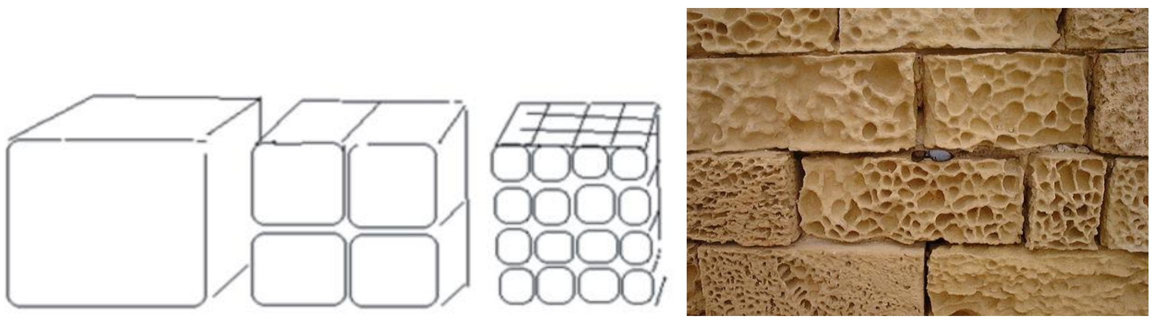
Water seeps into cracks and fractures in rock. As it freezes, it expands which wedges the rock apart.

This is how it works. When water changes from a liquid into a solid (ice), it increases in volume. This is a very unusual property. Most substances contract (get smaller) as they change from a liquid to a solid, but water does just the opposite. You may have already experienced this if you ever filled an ice cube tray all the way to the top with water and then put it into the freezer. The ice cubes will be much larger than the amount of water you first put in. You may have also made the mistake of putting your favorite soda into the freezer to cool it down quickly. If you leave your drink in the freezer too long, it will expand so much that it bends or pops the can. Ice wedging happens for the same reason. Water works its way into cracks and fractures in rock, and then expands as that water freezes. The ice takes up more space than the water did, which wedges the rock apart, physically breaking the rock into pieces. Ice wedging breaks apart so much rock that you will find large piles of broken rock at the base of a cliff or mountain, as broken pieces separate and tumble down its sides. Ice wedging will work quickly, breaking apart lots of rock in areas that go above and below the freezing point every night and day, and also in areas that cycle with the seasons.

Abrasion is another form of mechanical weathering. Abrasion can happen anywhere. All that is needed is one rock bumping against another rock. Gravity can cause abrasion as a rock tumbles down a mountainside or cliff. Moving water causes abrasion as particles carried in the water collide and bump against one another. Strong winds can pick up pieces of sand and blast surfaces with those sand grains. Finally, the ice in glaciers carries many bits and pieces of rock. As the glacier moves, pieces of rock embedded in the ice scrape against the rocks below. Broken pieces of rock tumbling down a mountain stream or tossed about by waves crashing onto the shore, will become smooth and rounded as abrasions smooth and round the sharp or jagged edges. If you have ever collected beach glass or cobbles from a stream, you have benefited from the work of abrasion.

Scientists talk about a few other types of mechanical weathering but ice wedging and abrasion are the two most important types. Without these two types of mechanical weathering, very little rock would break apart and that would slow down the rate of chemical weathering as well. Sometimes biological elements can do the work of mechanical weathering. This could happen slowly as a plant's roots grow into a crack or fracture in rock and gradually grow larger, wedging open the crack. Burrowing animals can also break apart rock as they dig for food or to make living spaces for themselves. Today, of course, human beings do quite a bit of mechanical weathering, whenever we dig or blast into rock to build homes, roads, subways, or to quarry stone for construction or other uses.

Actually whenever there is mechanical weathering, it increases the rate of chemical weathering. This happens because as rock breaks into smaller pieces, the surface area of the pieces increases. With more surfaces exposed, there are more places for chemical weathering to occur. Let’s say you wanted to make some hot chocolate on a cold day. You can imagine how hard it would be to get a big chunk of chocolate to dissolve in your milk or hot water. Maybe you could make hot chocolate from some smaller pieces like chocolate chips, but it is much easier to add a powder to your milk. This is because the smaller the pieces are, the more surface area they have and the easier it is to dissolve in the milk.



Left: *As rock breaks into smaller pieces, overall surface area increases.* ***Right:*** *Salt weathering of building stone.*

Chemical Weathering

Another important type of weathering that happens on the Earth's surface is **chemical weathering**. Chemical weathering is different than mechanical weathering because with this type of weathering, rock is changed, not just in size of pieces, but changed in composition. This means that one type of mineral changes into a different mineral. The reason chemical weathering happens is that most minerals form at high pressure or high temperatures, deep within the Earth. When rocks reach the Earth’s surface, they are now at very low temperatures and pressures. This is a very different environment from the one in which they formed. The environment at Earth's surface is so different that these minerals are no longer stable. That's where chemical weathering begins. Minerals formed deep within the Earth must change to minerals that are stable at Earth's surface. Chemical weathering is important because it starts the process of changing solid rock into the soil we need to grow food and for the plants we need for our clothing and medicine. The way that chemical weathering works is through chemical reactions that cause changes in the rock.

There are many types of chemical weathering because there are many agents of chemical weathering. You probably remember that mechanical weathering is caused by several agents, such as water, wind, ice, and gravity. Well, water is also an agent of chemical weathering, so that makes it a double agent! Two other important agents of chemical weathering are carbon dioxide and oxygen. We will talk about each of these one at a time.

The minerals that make up most of the Earth's crust are called silicate minerals. These minerals are mostly made of just eight elements; oxygen (O), silicon (Si), aluminum (Al), iron (Fe), magnesium

(Mg), calcium (Ca), potassium (K) and sodium (Na). When chemical weathering occurs, the elements that make up the minerals react to form new minerals. The minerals that form at the lowest temperatures and pressures (closest to the situation at the Earth's surface) are the most stable while minerals that form from very hot magmas or at very high pressures are the least stable. The elements sodium, calcium, potassium and magnesium actually dissolve easily in water. Iron reacts with oxygen, which leaves atoms of silicon, oxygen and aluminum to combine to form new minerals, like clay minerals.

Water is an amazing molecule. It has a very simple chemical formula, H_2O, which means it is made of just two hydrogen atoms bonded to one oxygen atom. Even though it is simple to remember, water is pretty remarkable in terms of all the things it can do. Water is an excellent solvent. The way that a water molecule joins together allows water to attract lots of other elements, separate them from their compounds and dissolve them. Water is such a good solvent that some types of rock can actually completely dissolve in water. Other minerals change by adding water into their structure.

Hydrolysis is a chemical reaction between a mineral and water. When this reaction takes place, water itself separates into ions. These ions grab onto other ions, dissolving them in water. As the dissolved elements are carried away, we say that these elements have been **leached**. Through hydrolysis, a mineral like potassium feldspar is changed into a clay mineral. Once clay minerals have formed, they are stable at the Earth's surface.

Carbon dioxide (CO_2) combines with water as raindrops fall through the air in our atmosphere. This makes a weak acid, called carbonic acid. This happens so often that carbonic acid is a very common, weak acid found in nature. This acid works to dissolve rock. It also slowly changes the paint on a new car or eats away at sculptures and monuments. The normal situation can be made worse when we add pollutants to the air. Any time we burn any fossil fuel, it adds nitrous oxide to the air. When we burn coal rich in sulfur, it adds sulfur dioxide to the air. As nitrous oxide and sulfur dioxide react with water, it forms nitric acid and sulfuric acid. These are the two main components of acid rain. Acid rain accelerates chemical weathering.

Oxidation is the type of chemical reaction that happens when oxygen reacts with elements at the Earth's surface. Oxygen is very strongly chemically reactive. The type of oxidation that you are probably most familiar with produces rust when iron reacts with oxygen. Many minerals are rich in iron. They break down as the iron oxidizes, forming new compounds. Iron oxide produces the red color in soils. Chemical weathering can also be contributed to by plants and animals. As plant roots take in soluble ions as nutrients, certain elements are exchanged. Plant roots and bacterial decay use carbon dioxide in the process of respiration.

Differential Weathering

Rates of weathering depend on several factors. Different types of rocks weather at different rates. Certain types of rock, like granite, are very resistant to weathering. Igneous rocks tend to weather slowly because it is hard for water to penetrate them. Other types of rock, like limestone and marble are easily weathered because they dissolve easily in weak acids. More resistant rocks remain at the surface and form ridges or hills. Devil's Tower in Wyoming is an interesting example of how different types of rock weather at different rates. As the softer materials of the surrounding rocks were worn away, the resistant center of the volcano remained behind. Different minerals also weather at different rates. Some minerals completely dissolve in water. As less resistant minerals dissolve away, a rock's surface becomes pitted and rough. When a less resistant mineral dissolves, more resistant mineral grains are released from the rock.

Devil's Tower is an amazing example of differential weathering. All that remains of the volcano today is this central plug of resistant lava that forms the tower.

Review Questions:

1. Name two types of mechanical weathering. Explain how each works to break apart rock.

2. What are three agents of chemical weathering? Give an example of each.

3. Would a smooth even surface weather faster than an uneven, broken surface? Why or why not?

<u>Lesson 2: Tuesday, May 12</u>

Water Erosion

As streams move over the ground, they transport weathered materials. Streams continually erode material away from their banks, especially along the outside curves of meanders.

Stream and River Erosion

As a stream moves water from high elevations, like mountains, towards low elevations, like the ocean, which is at sea level, the work of the stream changes. At high elevations, streams are just beginning streams that have small channels and steep gradients. This means that the stream will have a high velocity and will do lots of work eroding its stream bed. The higher the elevation, the farther the stream is from where it eventually meets the sea. **Base level** is the term for where a stream meets sea level or standing water, like a lake or the ocean. Streams will work to downcut their stream beds until they reach base level.

As a stream moves out of high mountainous areas into lower areas closer to sea level, the stream is closer to its base level and does more work eroding the edges of its banks than downcutting into its stream bed. At some point in most streams, there are curves or bends in the stream channel called **meanders.**

Left: *Here a stream can be seen actively eroding its outer banks along a meander.* ***Right****: This stream has deposited larger materials like gravel and pebbles along the inside curve of a meander.*

Stream and River Deposition

Once a stream nears the ocean, it is very close to its base level and now deposits more materials than it erodes. As you just learned, one place where a river deposits material is along the inside edges of meanders. If you ever decide to pan for gold or look for artifacts from an older town or civilization, you will sift through these deposits. Gold is one of the densest elements on Earth. Streams are lazy and never want to carry more materials than absolutely necessary. It will drop off the heaviest and largest particles first, that is why you might find gold in a stream deposit. Imagine that you had to carry all that you would need for a week as you walked many kilometers. At first you might not mind the weight of what you are carrying at all, but as you get tired, you will look to drop off the heaviest things you are carrying first!

When a river meets either standing water or nearly flat lying ground, it will deposit its load. If this happens in water, a river may form a **delta**. From its headwaters in the mountains, along a journey of many kilometers, rivers carry the eroded materials that form their stream load. Suddenly the river slows down tremendously in velocity, and drops the tremendous load of sediments it has been carrying. Deltas are relatively flat topped, often triangular shaped deposits of sediments that form where a large river meets the ocean. The name delta comes from the capital Greek letter delta, which is a triangle, even though not all deltas have this shape. A triangular shaped delta forms as the main stream channel splits into many smaller **distributaries**. As the channel shifts back and forth dropping off sediments and moving to a new channel location a wide triangular deposit forms.

If a river or stream suddenly reaches nearly flat ground, like a broad flat valley or plain, an **alluvial fan** develops at the base of the slope. An alluvial fan is a curved top, fan shaped deposit of coarse sediments that drop off as the stream suddenly loses velocity. The fan spreads out in a curve in the direction of the flat land as many stream channels move across the curved surface of the alluvial fan, forming and deforming many channels as sediments are deposited. Alluvial fans generally form in more arid regions.

Left: *This satellite photo of an alluvial fan in Iran shows the typical fan shape of these deposits. The stream forming the alluvial fan runs from the mountains in the southwest (lower left) corner of the photograph toward the flatter land to the northeast (upper right). The green rectangles are farm fields which utilize the distributed water.* ***Right:*** *Hamilton Pool in Austin is an example of a sinkhole.*

Groundwater Erosion and Deposition

Not all water that falls on the land flows through rivers and streams. When it rains, much of the water sinks into the ground and moves through pore spaces in soil and cracks and fractures in rock. This water necessarily moves slowly, mostly under the influence of gravity. Yet groundwater is still a strong erosional force, as this water works to dissolve away solid rock. If you have ever explored a cave or seen a sinkhole, you have some experience with the work of groundwater.

As groundwater moves through spaces between mineral grains, it works to dissolve and carry away different elements. Some types of minerals are easily dissolved by groundwater. Rainwater absorbs carbon dioxide (CO_2) as it falls through the air. The carbon dioxide combines with water to form carbonic acid. This naturally occurring weak acid readily dissolves many types of rock, including limestone. If you have ever watched an antacid tablet dissolve in water, you have seen an example of just how quickly this type of rock is eroded away. Caves are one of nature's most spectacular demonstrations of erosion. Working slowly over many years, groundwater dissolves and carries away elements of once solid rock in solution. First it travels along small cracks and fractures, gradually enlarging them. In time, caverns many football fields long and as high as many meters tall can form.

A **sinkhole** could form if the roof of an underground cave collapses. Some sinkholes are large enough to swallow up a home or several homes in a neighborhood. As groundwater dissolves away solid rock, it carries those minerals in solution as it travels. As groundwater drips through openings, several interesting types of formations occur. **Stalactites** are icicle like deposits of calcium carbonate which form as layer on layer of calcite drips from the ceiling, coating the 'icicle'. As mineral rich material drips to the floor of a cave, **stalagmites** form rounded deposits of calcium carbonate on the floor of the cave. The word stalactite has a 'C', so you can remember it forms from the ceiling, while the 'G' in stalagmite reminds you it forms on the ground.

Review Questions:

1. When would a river form an alluvial fan and when will it form a delta? Describe the characteristics of each type of deposit.

2. What are two formations that form inside caves?

Lesson 3: Wednesday, May 13

Wave Erosion

Some beaches have large, strong rolling waves that rise up and collapse as they crash into the shore. All waves are *energy* traveling through some type of material. The waves that we are most familiar with travel through water. Most of these waves form from wind blowing over the water; sometimes steady winds that blow and sometimes from a storm that forms over the water. The energy of waves does the work of erosion when a wave reaches the shore. When you find a piece of frosted glass along a beach, you have found some evidence of the work of waves. What other evidence might you discover?

As wind blows over the surface of the water, it disturbs the water, producing the familiar shape of a wave. The highest part of a wave is called the **wave crest**. The lowest part is called the **wave trough**. The vertical distance from the highest part of a wave to the lowest is called the **wave height**. The horizontal distance between one wave crest and the next crest, is called the **wavelength**. Three things influence how big a wave might get. If the wind is very strong, and it blows steadily for a long time over a long distance, the very largest waves will form. The wind could be strong, but if it gusts for just a short time, large waves won't form. Bigger waves do more work of erosion which changes our shorelines. Each day that waves break along the shore, they steadily erode away a minute bit of the shoreline. When one day, a really big storm like a hurricane arrives, it will do a lot of damage in just a very short time.

As waves come into shore, they usually reach the shore at some angle. This means one part of the wave reaches shallow water sooner than the parts of the wave that are further out. As a wave comes into shore, the water 'feels' the bottom which slows down the wave. So the shallower parts of the wave slow down more than the parts that are further from the shore. This makes the wave 'bend', which is called **refraction**. The way that waves bend as they come into shore either concentrates wave energy or disperses it. In quiet water areas like bays, wave energy is dispersed and sand gets deposited. Areas like cliffs that stick out into the water, are eroded away by the strong wave energy that concentrates its power on the cliff.

***Left**: Cliffs are eroded by wave action that concentrates energy in these areas.* ***Right**: This large wave cut platform was formed by the cutting action of waves on the cliffs to the left.*

Wave-cut cliffs form where waves cut into the bottom part of the cliff, eroding away the soil and rocks there. First the waves cut a notch into the base of the cliff. If enough material is cut away, the cliff above can collapse into the water. Many years of this type of erosion can form a **wave-cut platform**.

***Left**: A sea stack forms if the upper layers of rock collapse, leaving an isolated pinnacle. **Right**: A sea arch can form if waves erode from opposite sides of a cliff.*

If waves erode a cliff from two sides, the erosion produced can form an open area in the cliff called an **arch**. If the material above the arch eventually erodes away, a piece of tall rock can remain in the water, which is called a **sea stack**.

Wave Deposition

Rivers carry the sand that comes from erosion of mountains and land areas of the continents to the shore. Soil and rock are also eroded from cliffs and shorelines by waves. That material is transported by waves and deposited in quieter water areas. As the waves come onto shore and break, water and particles move along the shore. When lots of sand accumulates in one place, it forms a beach. Beaches can be made of mineral grains, like quartz, but beaches can also be made of pieces of shell or coral or even bits of broken hardened lava.

__Left__: Quartz, rock fragments, and shell make up the sand along a beach. ***Right:*** *These sand dunes are part of Padre Island near Corpus Christi, which is a barrier island.*

Waves continually move sand grains along the shore. Smaller particles like silt and clay don't get deposited at the shore because the water here is too turbulent. The work of waves moves sand from the beaches on shore to bars of sand offshore as the seasons change. In the summer time, waves of lower energy bring sand up onto the beach and leave it there. That is good for the many people who enjoy sitting on soft sand when they visit the beach. In the wintertime, waves and storms of higher energy bring the sand from the beach back offshore. If you visit your favorite beach in the wintertime, you will find a steeper, rockier beach than the flat, sandy beach of summer. Some communities truck in sand to resupply sand to beaches. It is very important to study the energy of the waves and understand the types of sand particles that normally make up the beach before spending lots of money to do this. If the sand that is trucked in has pieces that are small enough to be carried away by the waves on that beach, the sand will be gone in a very short time.

Sand transported by the work of waves breaking along the shore can form sand bars that stretch across a bay or ridges of sand that extend away from the shore, called **spits**. Sometimes the end of a spit hooks around towards the quieter waters of the bay as waves refract, causing the sand to curve around in the shape of a hook.

When the land that forms the shore is relatively flat and gently sloping, the shoreline may be lined with long narrow islands called **barrier islands**. Most barrier islands are just a few kilometers wide and tens of kilometers long. Many famous beaches, like Miami Beach, are barrier islands. In its natural state, a barrier island acts as the first line of defense against storms like hurricanes.

Instead of keeping barrier islands natural, these areas end up being some of the most built up, urbanized areas of our coastlines. That means storms, like hurricanes, damage houses and businesses rather than hitting soft, vegetated sandy areas. Some hurricanes have hit barrier islands so hard that they break right through the island, removing sand, houses and anything in the way.

Review Questions:

1. Name three natural landforms that are produced by wave erosion.

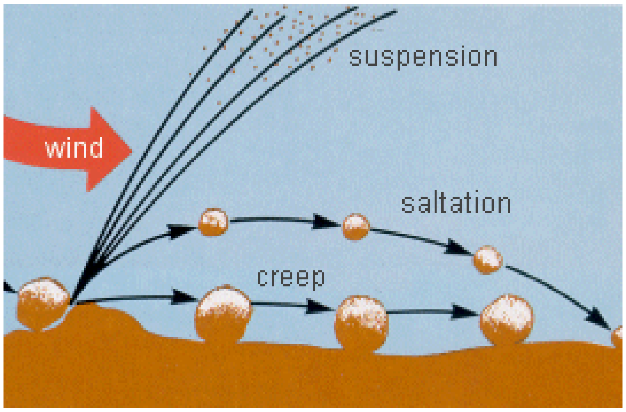
2. If you were to visit a beach in a tropical area with coral reefs, what would the beach there be made of?

<u>Lesson 4: Thursday, May 14</u>

Wind Erosion

Moving water does much of the work of erosion that shapes the land surface of our Earth. Wind also flows over the Earth's surface, sometimes carrying particles long distances before they are deposited. Wind blows from areas of high pressure to areas of lower pressure. The erosive power of wind varies with the strength of the winds that blow, but usually wind transports smaller particles like silt and clay.

Somewhat larger particles may be bumped or rolled along by the wind. Wind can carry particles across ocean basins and to great heights within our atmosphere. Wind is a stronger erosional force in arid regions than humid areas for two reasons. In arid regions, temperatures change greatly from night to day, which produces wind. Even strong winds in humid areas are less effective erosional agents because the ground is wet, so soil particles are heavier and less likely to be removed or transported by wind.



__Left__: Saltation moves sand-size particles along the desert floor or on sand dunes. __Right__: A dust storm approaches.

Wind is able to transport the smallest particles of sediment, like silt and clay, over great distances and areas. Once these particles become mixed into the air, wind can keep them suspended for hours or maybe even days at a time. If nothing disturbs these tiny particles, wind would have trouble picking them off the ground surface. This is because very close to the ground, there is very little motion due to wind. Look behind a car or truck as it drives over an unpaved road. You will see a big cloud of dust that wasn't there before the truck disturbed the ground surface. Once these fine particles are disturbed, wind easily picks them up and distributes them.

Just as water carries different size particles in various ways, wind also transports particles as both **bed load** and **suspended load**. For wind, sand sized particles make up the bed load. These sand grains are moved along by the wind in a bump, roll and jump kind of motion. First, a grain of sand gets knocked into the air. It is too heavy to have wind carry it for long in suspension, so it falls back to the ground, possibly knocking another sand grain into the air as it hits the ground. This starts the process all over again. This process is called **saltation**. The suspended load for wind will always be very small particles of silt and clay, which are still able to be carried suspended in the air by wind.

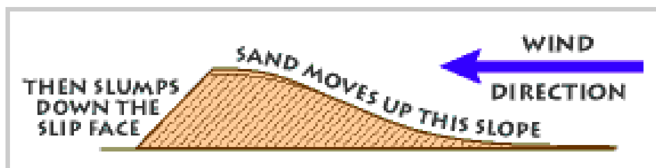
Erosion by Wind

As wind moves sand sized particles, they will remain close to the ground, usually less than a meter from the ground even in the strongest winds. In a sandstorm, about a quarter of the particles are sand which moves as bed load. In arid regions, a sandstorm actually moves much smaller particles than sand in the winds. Wind can carry these small particles high into the air and these particles can infiltrate cracks around windows and doors in a dust storm.

Sometimes these small particles are deposited in areas relatively close to their original source, but often silts and clays have been carried halfway across a continent or from desert areas on one continent across an entire ocean basin. Wind is more effective at erosion in arid regions because in humid regions smaller particles are held together by the moisture in the soil and by plant roots from the vegetation. Where it is dry, plants don't grow as well, so both these factors increase the ability of wind to transport particles, eroding the landscape.

Eventually, most of the smaller particles will have been removed and the rockier surface left behind is called **desert pavement**. This surface is covered by pebbles and gravel sized particles that are not easily moved by wind. If no disturbance from vehicles or animals disrupts the surface, deflation will stop once this rocky surface has formed.

Deposition by Wind



Left: *This sand dune in Morocco shows secondary sand ripples along its slip face.* **Right**: Sand dunes have a gently sloping face in the upwind direction. Downwind, a steeper slip face forms.

When you think of a desert or perhaps even a beach, the image that comes to mind might include **sand dunes**. In coastal regions, you will find sand dunes in the landward direction of the beach. Sand dunes form here as sand is blown from the shore inland. The sand dunes along a beach are likely to be composed of individual grains of the mineral quartz, unless the beach is in a tropical area. In humid regions, other minerals break down readily to form clays, leaving behind only the more resistant quartz. In the tropics, sand dunes may be composed of calcium carbonate. In a desert, the sand dunes may be composed of a variety of minerals.

Just as water waves are very selective about the size particles they carry and deposit, so will the size of the sand grains in a dune be very uniform. The sand dunes are formed of a particular size particle which is too heavy for the wind to transport. This process is sometimes so selective that wind will transport and carry rounded grains of sand, which roll easily, more readily than angular grains.

So as wind erodes and transports sand grains along the gently sloped upwind side of a dune, it deposits sand along the downwind slip face. As each new layer of sand falls down the slip face of the dune, cross beds are formed. Cross beds are named for the way each layer is formed at an angle to the ground. Some of the most beautiful sandstones are crossbedded sandstones. These sandstones preserve sands originally deposited as sand dunes in deserts millions of years ago.

These beautiful rocks are crossbedded sandstones from the Canyons of the Escalante in Utah.

Sand is always moving up the gently sloped side of a dune, and depositing on the downwind side, which means that dunes themselves slowly migrate in the downwind direction. This means that over a period of years, sand dunes will move many meters downwind. This is something that beach house owners need to consider if they live near coastal sand dunes. Once a sand dune becomes stabilized by vegetation, such as sea grasses, its migration will stop. Beach goers need to be careful not to disturb these grasses when they go to and from the beach.

Review Questions:

1. Describe how desert pavement forms.

2. Why is wind erosion more important in arid regions than humid areas?

<u>Lesson 5: Friday, May 15</u>

Glacial Erosion

Today glaciers cover about 10% of the land surface on Earth, but there have been times in Earth's recent history when glaciers have covered as much as 30% of the land surface. Around eight to six hundred million years ago, geologists believe that almost all of the Earth was covered in snow and ice. So today, scientists do a kind of detective work to figure out where the ice once was. We can figure this out by observing the ways the land has been eroded and by looking at the deposits that have been left behind.

Formation and Movement of Glaciers

Today, we have glaciers near Earth's poles and at high altitudes in mountainous regions. The ice in a glacier erodes away the underlying rocks, just as rivers and streams shape the land they flow over. Like rivers and streams, glaciers tend to flow along existing valleys, but while the thick ice of glaciers is slowly moving over the land, it scours away the rocks below somewhat like a very slow and steady bulldozer. Especially up in the mountains, rivers cut 'V' shaped valleys as running water cuts deep into the rock. As a glacier flows through this same valley, it widens the valley and forms steeper sides to the valley walls, making a 'U' shape valley instead.

This valley in Glacier National Park shows the characteristic 'U' shape of a glacially carved valley.

In mountainous areas, often many smaller glaciers flow from higher elevations joining the main glacier as they move to lower places. Generally, these smaller glaciers carve shallower 'U' shaped valleys than the main glacier. A beautiful erosional feature, called a hanging valley, forms where the smaller 'U' shaped valley meets the deeper one of the main glacier. River water cascades down the steep valley walls forming breathtaking waterfalls.

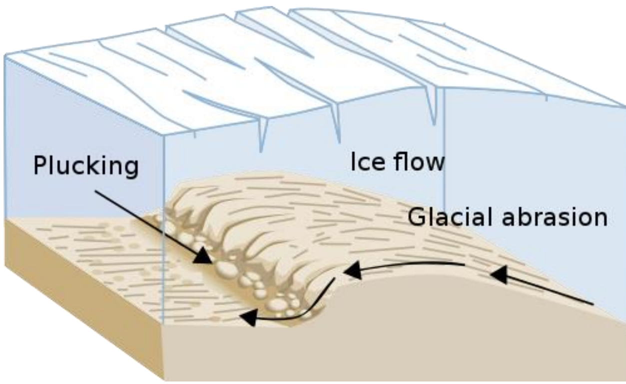
Glacial Erosion

The two main ways that glaciers erode the underlying rock are **abrasion** and **plucking**. As the thick layer of ice pushes against the underlying rock, it scrapes and polishes the rock surface. As glaciers flow, they scratch the underlying bedrock with all the rocky material they are carrying. These scratches make long, parallel grooves in the bedrock, called **glacial striations**, which show the direction the glacier moved. Also as the glacier slowly moves over the rock, glacial meltwater seeps into cracks and fractures of the underlying rock. As the water freezes, it pushes pieces of rock out of the underlying rock surface. These pieces of rock get plucked out and carried away by the flowing ice of the moving glacier.


***Left**: Iceberg Cirque in Glacier National Park was carved by glaciers. **Right:** The Matterhorn in Switzerland is a classic example of a horn.*

There are several erosional features that form as a glacier both scours the rock and pulls pieces away. As rocks are pulled away from valley walls, a steep sided, bowl shaped depression forms at the top of a mountain, called a **cirque**. The word comes from the French word for circle. Once the ice melts away, a high altitude lake, called a **tarn** often forms from meltwater trapped in the cirque. If several glaciers flow down in different directions from a central mountain peak, these steep walled depressions can leave behind an angular, sharp sided peak called a **horn**. The Matterhorn in Switzerland is the most famous example of this type of erosion.

As glaciers flow down a mountainside, the ice may also sculpt and shape the underlying bedrock as it flows. When a knob of bedrock is carved into an asymmetrical hill, it is called a **roche moutonnée**. In French, it means 'sheep rock'. Perhaps the villagers below the mountain thought these hills looked like sheep grazing in the valley. A roche moutonnée has a gently sloping side in the uphill direction of ice flow, with a steep side facing the downslope direction.



***Left**: A roche moutonée forms where glaciers smooth the uphill side of the bedrock and pluck away rock from the downslope side.* ***Right:** These long, dark lines on the Aletsch glacier in Switzerland are examples of medial and lateral moraines.*

Depositional Features of Glaciers

As glaciers flow over many years, all sorts of debris falls onto the glacier through mechanical weathering of the valley walls. Glaciers are solid ice, so unlike water, they can carry pieces of rock of any size. Glaciers move boulders as large as a house as easily as the smallest particles of sand and silt. These pieces of rock are carried by the glacier for many kilometers and are only deposited as the ice melts. When you think of a glacier, you may think of white ice and snow, but actually glaciers have lots of rocky bits all over them. Each of these different deposits has its own name based on where it forms, but as a group they are called **moraines**. A long pile of rocky material at the edge of a glacier is called a lateral moraine and one in the middle of the glacier is called a medial moraine. Lateral moraines form at the edges of the glacier as material drops onto the glacier from erosion of the valley walls. Medial moraines form where two glaciers join together. In this case, the lateral moraines from the edges of each glacier meet in the middle to form the medial moraine.

Wherever a glacier is located, it is always slowly flowing downhill. Sometimes the rate at which it is flowing downhill is faster than the rate at which it melts. In this situation, you will see the glacier advancing down the valley, with more and more ice with each successive year. More likely what you will see today if you get the chance to visit a glacier, is that the glacier is retreating. This means that is there is less ice in the glacier this year than there was the year before.

1938 1981 1998 2005

These photographs of the Grinnell Glacier in Glacier National Park were taken over an almost 70 year period. The glacier is clearly visible and well developed in 1938. From 1981 through 2005, the amount of glacial ice has decreased and the meltwater forming the lake has increased. In 2005, icebergs are further evidence of glacial melting.

Minor Assessment:

Of the four types of erosion we have studied, which do you think has made the largest impact on San Antonio and the Texas hill country? Explain your reasoning. Note at least one feature of each type of erosion that distinguishes it from each other type. (4-6 sentences)