Surface Processes and Landforms

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Printed: September 26, 2014

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CHAPTER 1

Surface Processes and Landforms

CHAPTER OUTLINE

Introduction

How long will these footprints be on the Moon?

In a billion years, or even 5 billion years, these footprints will still be on the Moon. In that time Earth will undergo enormous changes due to plate tectonics but also to the processes of weathering and erosion that modify the landscape. Of course, if commercial flights to the Moon ever become a reality, the trash from new visitors could cover or erase the tracks left by the Apollo astronauts.

1.1 Weathering and Erosion

- Define weathering and erosion.

What is the history of this rock face?

Walnut Canyon, just outside Flagstaff, Arizona, is a high desert landscape displaying cliff dwellings built 700 years ago by a long gone people. On the opposite side from the trail around the mesa is this incredible rock. In this rock you can see that the rock has slumped, and also see signs of mechanical weathering (fractures) and chemical weathering (dissolution). If you get a chance, go see the rock (and the cliff dwellings) for yourself.

Weathering

Weathering is the process that changes solid rock into sediments. Sediments were described in the chapter "Materials of Earth's Crust." With weathering, rock is disintegrated. It breaks into pieces. Once these sediments are separated from the rocks, **erosion** is the process that moves the sediments.

While plate tectonics forces work to build huge mountains and other landscapes, the forces of weathering gradually wear those rocks and landscapes away. Together with erosion, tall mountains turn into hills and even plains. The Appalachian Mountains along the east coast of North America were once as tall as the Himalayas.

Weathering Takes Time

No human being can watch for millions of years as mountains are built, nor can anyone watch as those same mountains gradually are worn away. But imagine a new sidewalk or road. The new road is smooth and even. Over hundreds of years, it will completely disappear, but what happens over one year? What changes would you see? (**Figure** 1.1). What forces of weathering wear down that road, or rocks or mountains over time?

- Animations of different types of weathering processes can be found here: http://www.geography.ndo.co.uk/animationsweathering.htm# .

FIGURE 1.1
A once smooth road surface has cracks and fractures, plus a large pothole.

Summary

- Weathering breaks down Earth materials into smaller pieces.
- Erosion transports those pieces to other locations.
- Weathering and erosion modify Earth's surface landscapes over time.

Explore More

Use this resource to answer the questions that follow.

http://www.ux1.eiu.edu/~cfjps/1300/weathering.html

1. What is weathering?
2. What is mechanical weathering?
3. What is chemical weathering?
4. What is erosion?
5. Describe frost wedging.
6. What is abrasion?
7. List the types of chemical weathering.
8. What factors can influence chemical weathering?

Explore More Answers

1. Weathering is the disintegration and decomposition of rock at or near the surface.
2. Mechanical weathering is the physical disintegration of rock into smaller fragments.
3. Chemical weathering is when the internal structure of a mineral is altered by the addition or removal of elements.
4. Erosion is the incorporation and transport of weathering products by a mobile agent such as wind, water or ice.
5. Water that goes into a crack in rock expands when it freezes and pushes the rock on both sides a little bit. The water then warms and becomes liquid. This continues over time and can weather away a rock.
6. When rocks grind together they are undergoing abrasion.
7. dissolution, oxidation, hydrolysis
8. climate, life, time, mineral composition, chemical weathering products

Review

1. What is weathering?
2. How is weathering different from erosion?
3. Why does weathering take so much time?

Review Answers

1. Weathering is the process that changes solid rock into sediments.
2. Weathering separates the mineral from the rock, erosion moves the sediments to another place.
3. The amount accomplished at a time is not great compared to the amount of weathering it would take to decompose a rock so it must take place over a long time.

1.2 Mechanical Weathering

- Define mechanical weathering.
- Describe the various processes of mechanical weathering.

Who broke those rocks?

In extreme environments, where there is little moisture and soil development, it's possible to see rocks that have broken by mechanical weathering. This talus in Colorado's Indian Peaks broke from the jointed rock that is exposed.

Mechanical Weathering

Mechanical weathering (also called physical weathering) breaks rock into smaller pieces. These smaller pieces are just like the bigger rock, but smaller. That means the rock has changed physically without changing its composition. The smaller pieces have the same minerals, in just the same proportions as the original rock.

Ice Wedging

There are many ways that rocks can be broken apart into smaller pieces. **Ice wedging** is the main form of mechanical weathering in any climate that regularly cycles above and below the freezing point (**Figure** 1.2). Ice wedging works quickly, breaking apart rocks in areas with temperatures that cycle above and below freezing in the day and night, and also that cycle above and below freezing with the seasons.

Ice wedging breaks apart so much rock that large piles of broken rock are seen at the base of a hillside, as rock fragments separate and tumble down. Ice wedging is common in Earth's polar regions and mid latitudes, and also at higher elevations, such as in the mountains.

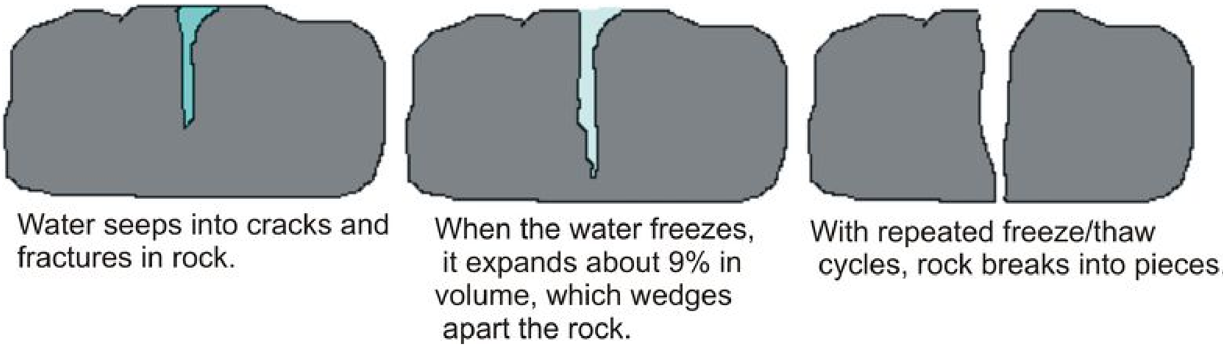


FIGURE 1.2
Ice wedging.

Abrasion

Abrasion is another form of mechanical weathering. In abrasion, one rock bumps against another rock.

- Gravity causes abrasion as a rock tumbles down a mountainside or cliff.
- Moving water causes abrasion as particles in the water collide and bump against one another.
- Strong winds carrying pieces of sand can sandblast surfaces.
- Ice in glaciers carries many bits and pieces of rock. Rocks embedded at the bottom of the glacier scrape against the rocks below.

Abrasion makes rocks with sharp or jagged edges smooth and round. If you have ever collected beach glass or cobbles from a stream, you have witnessed the work of abrasion (**Figure** 1.3).

FIGURE 1.3
Rocks on a beach are worn down by abrasion as passing waves cause them to strike each other.

Organisms

Now that you know what mechanical weathering is, can you think of other ways it could happen? Plants and animals can do the work of mechanical weathering (**Figure** 1.4). 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.

Humans

Human activities are responsible for enormous amounts of mechanical weathering, by digging or blasting into rock to build homes, roads, and subways, or to quarry stone.

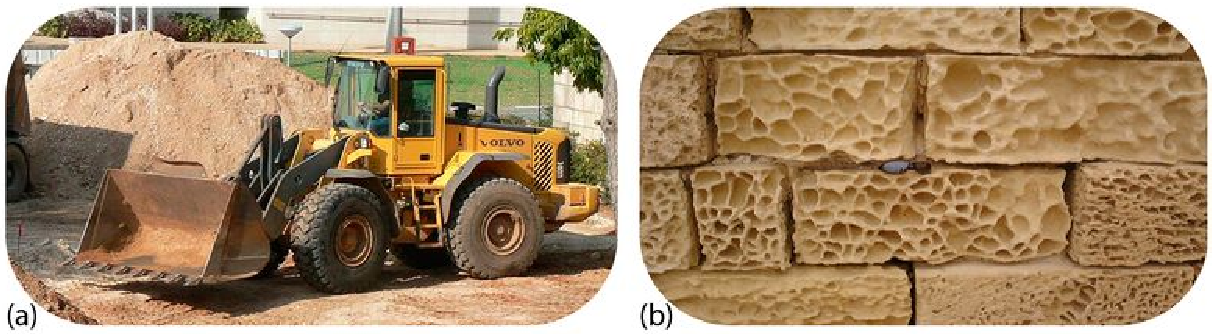


FIGURE 1.4

(a) Humans are tremendous agents of mechanical weathering. (b) Salt weathering of building stone on the island of Gozo, Malta.

Summary

- Mechanical weathering breaks down existing rocks and minerals without changing them chemically.
- Ice wedging, abrasion, and some actions of living organisms and humans are some of the agents of mechanical weathering.

Explore More

Use the resource below to answer the questions that follow.

- **Physical Weathering** at http://www.youtube.com/watch?v=u_WN2ICRb2M (7:10)

MEDIA

Click image to the left for use the URL below.

URL: http://gamma.ck12.org/flx/render/embeddedobject/1620

1. What is weathering?
2. What are the agents of weathering?
3. Will physical weathering increase or decrease if a rock is broken into smaller rocks and why?
4. What is mechanical weathering?
5. Explain frost wedging.
6. Explain root wedging.
7. What is abrasion?
8. Explain the two types of abrasion.
9. What is exfoliation? What is it unique to?
10. What is differential weathering? What can be created with differential weathering?
11. What role does climate play in physical weathering?

Explore More Answers

1. Weathering is the breakup of rocks into sediments.
2. Agents include water, wind, gravity, and glaciers.
3. The greater the surface area, the greater the chance of weathering. Thus, physical weathering will increase.
4. Mechanical weathering is the physical breakup of rock; there is no chemical change.
5. In frost wedging, water seeps into cracks in the rock and freezes. This causes it to expand, which makes the crack bigger and the rock more porous so that even more water can get into the crack and freeze.
6. Root wedging is similar to frost wedging. A plant's roots grow into a crack in rock; as the roots grow larger, they wedge open the crack. The larger the plant, the larger the crack will become.
7. In abrasion, rocks or sediments smash against other rocks or sediments.
8. Wind abrasion blasts sand against rock surfaces, as the wind carries sand particles. Water erosion rounds and smooths rock surfaces as it flows over it; the water may also carry rocks and sediment that abrade the surface.
9. Exfoliation only occurs in granite. Heat expands and cold cools the rock, which causes layers to break and peel away.
10. Differential weathering occurs when some rocks are harder and some are softer. The harder rocks are more resistant to erosion than the softer rocks. This can lead to overhanging ledges, created when a softer rock eroded more than a harder rock on top.
11. Climate plays an important role in physical weathering, particularly in ice wedging, since temperatures need to rise and fall for it to occur.

Review

1. Describe the process of ice wedging.
2. Describe the process of abrasion.
3. How do plants and animals cause mechanical weathering?

Review Answers

1. Water goes into a crack in rock and then expands when it freezes. When it thaws it can go deeper into the crack. Over time the crack expands until the rock breaks apart.

2. Rocks that bump against each other can wear each other down.
3. Roots can expand a crack. Animals can burrow into the ground. Both increase mechanical weathering.

1.3 Chemical Weathering

- Define chemical weathering.
- Describe the various processes of chemical weathering.

How do rocks turn red?

In the desert Southwest, red rocks are common. Tourists flock to Sedona, Arizona to see the beautiful red rocks, which are set off very nicely by the snow in this photo. What makes the rocks red? The same process that makes rust red!

Chemical Weathering

Chemical weathering is the other important type of weathering. Chemical weathering may change the size of pieces of rock materials, but definitely changes the composition. So one type of mineral changes into a different mineral. Chemical weathering works through chemical reactions that cause changes in the minerals.

No Longer Stable

Most minerals form at high pressure or high temperatures deep in the crust, or sometimes in the mantle. When these rocks are uplifed onto Earth's surface, they are at very low temperatures and pressures. This is a very different environment from the one in which they formed and the minerals are no longer stable. In chemical weathering, minerals that were stable inside the crust must change to minerals that are stable at Earth's surface.

Clay

Remember that the most common minerals in Earth's crust are the silicate minerals. Many silicate minerals form in igneous or metamorphic rocks. The minerals that form at the highest temperatures and pressures are the least stable at the surface. Clay is stable at the surface and chemical weathering converts many minerals to clay (**Figure** 1.5).

There are many types of chemical weathering because there are many agents of chemical weathering.

FIGURE 1.5
Deforestation in Brazil reveals the underlying clay-rich soil.

Chemical Weathering by Water

A water molecule has a very simple chemical formula, H_2O, two hydrogen atoms bonded to one oxygen atom. But water is pretty remarkable in terms of all the things it can do. Remember that water is a polar molecule. The positive side of the molecule attracts negative ions and the negative side attracts positive ions. So water molecules separate the ions from their compounds and surround them. Water can completely dissolve some minerals, such as salt.

FIGURE 1.6
Weathered rock in Walnut Canyon near Flagstaff, Arizona.

- Check out this animation of how water dissolves salt: http://www.northland.cc.mn.us/biology/Biology1111/animations/dissolve.html .

Hydrolysis is the name of the chemical reaction between a chemical compound and water. When this reaction takes place, water dissolves ions from the mineral and carries them away. These elements have been **leached**. Through hydrolysis, a mineral such as potassium feldspar is leached of potassium and changed into a clay mineral. Clay minerals are more stable at the Earth's surface.

Chemical Weathering by Carbonic Acid

Carbon dioxide (CO_2) combines with water as raindrops fall through the atmosphere. This makes a weak acid, called carbonic acid. Carbonic acid is a very common in nature, where it works to dissolve rock. Pollutants, such as sulfur and nitrogen from fossil fuel burning, create sulfuric and nitric acid. Sulfuric and nitric acids are the two main components of **acid rain**, which accelerates chemical weathering (**Figure** 1.7). Acid rain is discussed in the chapter Human Impacts on Earth's Systems.

FIGURE 1.7
This statue at Washington Square Arch in New York City exhibits damage from acid rain.

Chemical Weathering by Oxygen

Oxidation is a chemical reaction that takes place when oxygen reacts with another element. Oxygen is very strongly chemically reactive. The most familiar type of oxidation is when iron reacts with oxygen to create rust (**Figure** 1.8). Minerals that are rich in iron break down as the iron oxidizes and forms new compounds. Iron oxide produces the red color in soils.

FIGURE 1.8
When iron-rich minerals oxidize, they produce the familiar red color found in rust.

Plants and Animals

Now that you know what chemical weathering is, can you think of some other ways chemical weathering might occur? 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.

Mechanical and Chemical Weathering

Mechanical weathering increases the rate of chemical weathering. As rock breaks into smaller pieces, the surface area of the pieces increases **Figure** 1.9. With more surfaces exposed, there are more surfaces on which chemical weathering can occur.

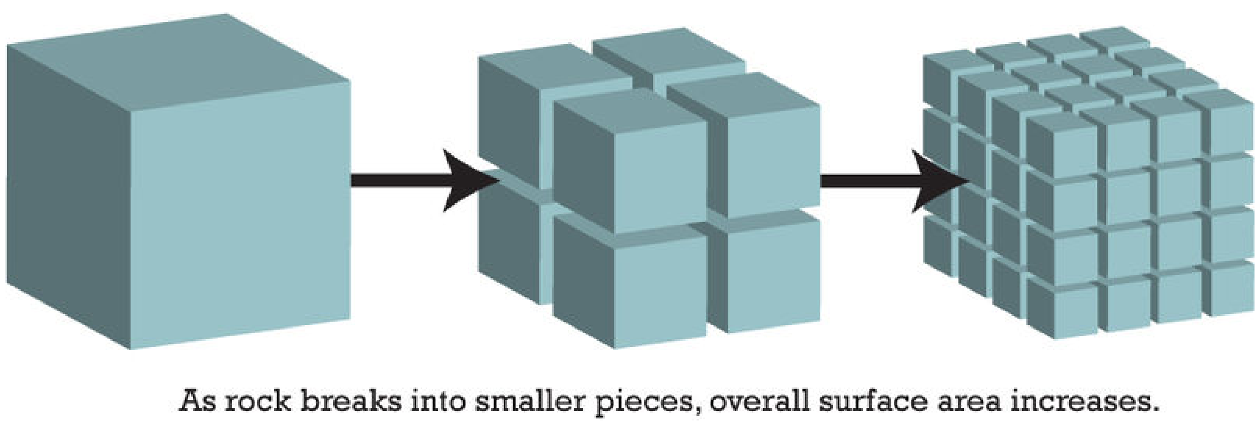


FIGURE 1.9
Mechanical weathering may increase the rate of chemical weathering.

Summary

- Chemical weathering changes the composition of a mineral to break it down.
- The agents of chemical weathering include water, carbon dioxide, and oxygen.
- Living organisms and humans can contribute to chemical weathering.

Explore More

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=P8oWj3PVK9E

1. What is hydrolysis? What is a common example in your kitchen?
2. What happens when water travels through soil?
3. What is oxidation? Why is Mars red?
4. What is carbonation?
5. How does carbonation work to create caves?

6. What are lichens?
7. What is acid precipitation?

Explore More Answers

1. The chemical reaction of anything with water. Coffee!
2. The water dissolves the minerals in the soil and chemically alters them.
3. When anything mixes with oxygen. It is made of mafic rocks that have oxidized.
4. When a rock is altered by carbonic acid.
5. Groundwater mixes with carbon dioxide and so a mild acid is created. This acid works through rock and dissolves it to create caves.
6. Lichens are a moss that eat rocks. Lichens are high in acid.
7. Pollutants mix with water vapor in the atmosphere and create mild acids that can rain, snow or create fog.

Review

1. How does the structure of the water molecule lead to chemical weathering?
2. How does carbon dioxide cause chemical weathering?
3. How does oxygen cause chemical weathering?
4. How does mechanical weathering increase the effectiveness of chemical weathering processes?

Review Answers

1. Water is a polar molecule so the negative side attracts positive ions and vice versa. The water molecules then separate these ions from the compounds they are in and takes them away.
2. Carbon dioxide combines with water to crate a weak acid. Acids dissolve some types of rock like limestone and marble.
3. Oxygen is strongly chemical reactive so it combines with other elements to create oxidized elements like iron oxide, which is rust.
4. Mechanical weathering breaks a rock into smaller pieces so the surface area increases and more surfaces are exposed to the agents of chemical weathering.

1.4 Influences on Weathering

- Identify and explain factors that influence the rate and intensity of weathering.

What circumstances allow for the most intense weathering?

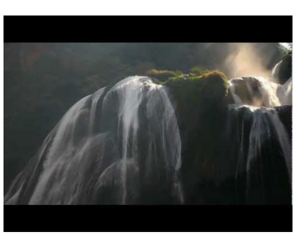
The rate and intensity of weathering depend on the climate of a region and the rocks materials that are being weathered. Material in Baraboo, Wisconsin weathers a lot more readily than similar material in Sedona, Arizona.

Rock and Mineral Type

Different rock types weather at different rates. Certain types of rock are very resistant to weathering. Igneous rocks, especially intrusive igneous rocks such as granite, weather slowly because it is hard for water to penetrate them. Other types of rock, such as limestone, are easily weathered because they dissolve in weak acids.

Rocks that resist weathering remain at the surface and form ridges or hills. Shiprock in New Mexico is the throat of a volcano that's left after the rest of the volcano eroded away. The rock that's left behind is magma that cooled relatively slowly and is harder than the rock that had surrounded it.

Different minerals also weather at different rates. Some minerals in a rock might completely dissolve in water, but the more resistant minerals remain. In this case, the rock's surface becomes pitted and rough. When a less resistant mineral dissolves, more resistant mineral grains are released from the rock. A beautiful example of this effect is the "Stone Forest" in China, see the video below:



MEDIA

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FIGURE 1.10
The Shiprock formation in northwest New Mexico is the central plug of resistant lava from which the surrounding rock weathered and eroded away.

Climate

A region's **climate** strongly influences weathering. Climate is determined by the temperature of a region plus the amount of precipitation it receives. Climate is weather averaged over a long period of time. Chemical weathering increases as:

- Temperature increases: Chemical reactions proceed more rapidly at higher temperatures. For each 10^{o}C increase in average temperature, the rate of chemical reactions doubles.
- Precipitation increases: More water allows more chemical reactions. Since water participates in both mechanical and chemical weathering, more water strongly increases weathering.

So how do different climates influence weathering? A cold, dry climate will produce the lowest rate of weathering. A warm, wet climate will produce the highest rate of weathering. The warmer a climate is, the more types of vegetation it will have and the greater the rate of biological weathering (**Figure** 1.11). This happens because plants and bacteria grow and multiply faster in warmer temperatures.

Resources from Weathering

Some resources are concentrated by weathering processes. In tropical climates, intense chemical weathering carries away all soluble minerals, leaving behind just the least soluble components. The aluminum oxide, bauxite, forms this way and is our main source of aluminum ore.

Summary

- Different materials weather at different rates and intensities under the same conditions.
- Different climate conditions cause the same materials to weather different intensities.

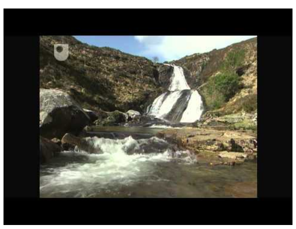
Explore More

Use this resource to answer the questions that follow.

FIGURE 1.11
Wet, warm tropical areas have the most weathering.

Rock types on the Isle of Sky - Geological Landforms

http://www.youtube.com/watch?v=l-Y6588DnQg



MEDIA
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URL: http://gamma.ck12.org/flx/render/embeddedobject/4780

1. What type of rocks make up most of the Isle of Skye?
2. What other types of rocks are found on the island?
3. Why do the dikes on the hillside stick out of the hill?
4. What two processes shape the landscape of the island?
5. What are the primary sources of weathering on Skye?
6. How is scree produced?
7. How does weathering affect granite?
8. What is responsible for the topography of the island?
9. Which rocks are more resistant to weathering? How does that affect the topography?

Explore More Answers

1. The largest amount are basalts erupted in the early Tertiary and second are igneous intrusive, granites.
2. older metamorphic and sedimentary
3. The dikes are made of harder material that does not weather as easily as the rest of the rock on the hill.
4. The landscape is created by the underlying geology shaped by weathering and erosion.
5. snow and ice
6. Scree is broken rocks produced by snow and ice.
7. Rounded mountains.
8. Different rates of weathering and erosion.

9. Igneous rocks are more resistant and form the high ground. Sedimentary rocks have higher rates of weathering and erosion and so produce the flatter ground.

Review

1. What types of rocks weather most readily? What types weather least readily?
2. What climate types cause more intense weathering? What climate types cause less intense weathering?
3. How does the aluminum resource bauxite form?

Review Answers

1. The easiest to weather rocks are the ones that dissolve in acid such as limestone. The hardest to weather are the more solid rocks that are harder for water to penetrate.
2. Chemical reactions proceed faster at higher temperatures and water increases both mechanical and chemical weathering so the most intense weathering is in warm, tropical areas. The least intense are cold, dry places like the polar regions.
3. Intense chemical weathering carries away the soluble minerals and so the aluminum oxide, bauxite, is left behind

1.5 Soil Characteristics

- Describe the characteristics of soil.

"Land, then, is not merely soil; it is a fountain of energy flowing through a circuit of soils, plants, and animals." —Aldo Leopold, *A Sand County Almanac*, 1949

Even though soil is only a very thin layer on Earth's surface over the solid rocks below, it is the where the atmosphere, hydrosphere, biosphere, and lithosphere meet. We should appreciate soil more.

Characteristics of Soil

Soil is a complex mixture of different materials.

- About half of most soils are **inorganic** materials, such as the products of weathered rock, including pebbles, sand, silt, and clay particles.
- About half of all soils are **organic** materials, formed from the partial breakdown and decomposition of plants and animals. The organic materials are necessary for a soil to be fertile. The organic portion provides the nutrients, such as nitrogen, needed for strong plant growth.
- In between the solid pieces, there are tiny spaces filled with air and water.

Within the soil layer, important reactions between solid rock, liquid water, air, and living things take place.

In some soils, the organic portion could be missing, as in desert sand. Or a soil could be completely organic, such as the materials that make up peat in a bog or swamp (**Figure** 1.12).

Soil Texture

The inorganic portion of soil is made of many different size particles, and these different size particles are present in different proportions. The combination of these two factors determines some of the properties of the soil.

FIGURE 1.12
Peat is so rich in organic material, it can be burned for energy.

- A **permeable** soil allows water to flow through it easily because the spaces between the inorganic particles are large and well connected. Sandy or silty soils are considered "light" soils because they are permeable, water-draining types of soils.
- Soils that have lots of very small spaces are water-holding soils. For example, when clay is present in a soil, the soil is heavier, holds together more tightly, and holds water.
- When a soil contains a mixture of grain sizes, the soil is called a **loam** (**Figure** 1.13).

FIGURE 1.13
A loam field.

Classification

When soil scientists want to precisely determine soil type, they measure the percentage of sand, silt, and clay. They plot this information on a triangular diagram, with each size particle at one corner (**Figure** 1.14). The soil type can then be determined from the location on the diagram. At the top, a soil would be clay; at the left corner, it would be sand; at the right corner, it would be silt. Soils in the lower middle with less than 50% clay are loams.

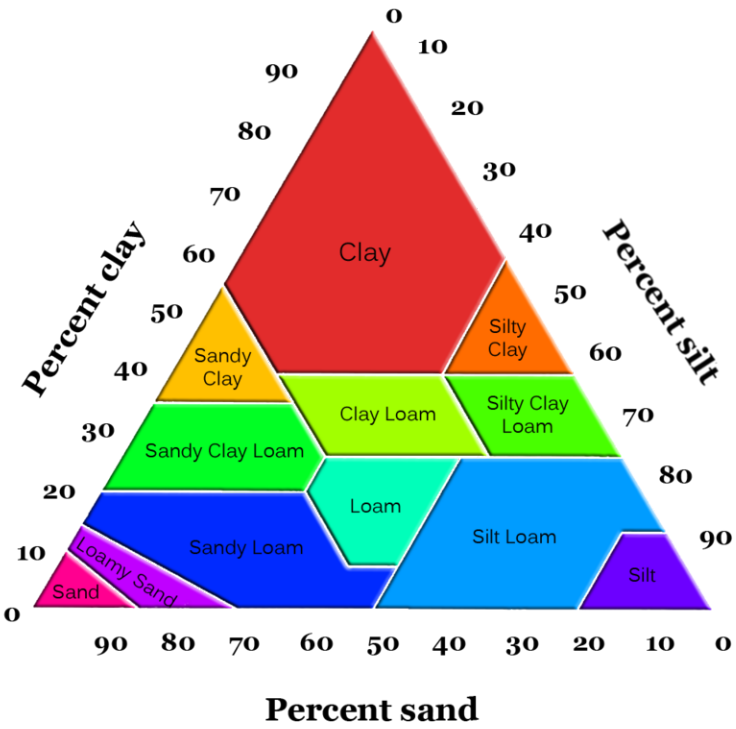

FIGURE 1.14
Soil types by particle size.

Soil, the Ecosystem

Soil is an ecosystem unto itself. In the spaces of soil, there are thousands or even millions of living organisms. Those organisms could include earthworms, ants, bacteria, or fungi (**Figure** 1.15).

FIGURE 1.15
Earthworms and insects are important residents of soils.

Summary

- Soil reflects the interactions between the lithosphere, atmosphere, hydrosphere and biosphere.

- Permeable soils allow water to flow through.
- The proportions of silt, clay, and sand allow scientists to classify soil type.

Explore More

Use this resource to answer the questions that follow. https://www.youtube.com/watch?v=-HKeaiKa3FE

1. What is soil? Does it contain organic or inorganic materials?
2. Why is soil a habitat?
3. What does soil do for water?
4. Where does the organic material in soil come from?
5. Where does the inorganic material come from?
6. What happens as a soil matures?
7. Why are mature soils best for plant growth?
8. What determines the characteristics that a soil will ultimately have?
9. What is the mnemonic device for the layers of soil: OAEBC?
10. What is in the O layer?'
11. What makes good topsoil?
12. Where is the E zone?
13. What does the E stand for? What happens in the E zone?
14. What is zone B?
15. What is zone C?
16. What important feature does particle size determine? What does that mean?
17. What makes up the most porous soil type? The middle soil type? The least porous soil type?
18. How is soil classified?
19. What about clay is important for plants?
20. What is 90% of the biological stuff in soil? What is the remaining 10%?
21. What happens when a soil is degraded?
22. Which soils are most vulnerable to erosion?

Explore More Answers

1. A connection between biological and geological world's. It is a combination of organic and inorganic materials.
2. It provides a place for plant growth and many organisms live in it.
3. Soil filters out a lot of chemicals as water seeps through it to head to groundwater.
4. Anything that lives, dies or decomposes on the soil surface.
5. The rock beneath the soil breaks down into the mineral component.
6. The soil goes from being dominantly inorganic to having much more organic material.
7. They have the best combination of minerals and organic material so that plants can thrive.
8. parent rock, climate, topography, organisms and time
9. Organic arthropods eat blind chickens.
10. Living or dead organisms
11. A lot of organic material is mixed with the sediment.
12. It can be between O and A or A and B or somewhere near the top of B.
13. It stands for eluvation; minerals get washed out by the water traveling through.
14. Zone B is subsoil that contains a lot of minerals, but not a lot of organic material.
15. Zone C is the parent rock.
16. Porosity, which is how easily water can flow through the material.
17. Sand, silt, clay in order of reduced porosity.

18. By the percentages of sand, silt and clay in the soil.
19. Clay is negatively charged so it attracts positively charged ions. Plants use these ions as nutrients.
20. The 90% is fungi, bacteria and protozoans; 10% are mixers such as burrowing organisms and detritivores, the things that break down living things.
21. The soil has lost fertility and/or productivity.
22. Soils that no longer are held together by plant roots.

Review

1. What is the inorganic material that makes up a soil?
2. What is the organic material that makes up a soil?
3. If a soil has equal amounts of silt, clay, and sand, what type of soil is it?

Review Answers

1. The inorganic material is mostly from the breakdown of the parent rock underlying the soil.
2. Living or formerly living things are the organic material.
3. The soil has 33.3% of each component so it is a clay loam.

1.6 Soil Formation

- Identify the factors that influence soil formation and explain how they work.

What do different types of soil feel like?

Did you ever plant a garden? Even if you live in an area with poor soil you can buy some dirt and put in some seeds. The type of soil that forms in an area depends on many factors. Some regions produce soil that are not good for crops, but may be good for something else, like cactus!

Soil Formation

How well soil forms and what type of soil forms depends on several different factors, which are described below.

- An animation of how weathering makes soil is found here: http://courses.soil.ncsu.edu/resources/soil_classification_genesis/mineral_weathering/mineral_weathering.swf .

Climate

Scientists know that climate is the most important factor determining soil type because, given enough time, different rock types in a given climate will produce a similar soil (**Figure** 1.16). Even the same rock type in different climates will not produce the same type of soil. This is true because most rocks on Earth are made of the same eight elements and when the rock breaks down to become soil, those elements dominate.

The same factors that lead to increased weathering also lead to greater soil formation.

- More rain equals more chemical reactions to weather minerals and rocks. Those reactions are most efficient in the top layers of the soil, where the water is fresh and has not yet reacted with other materials.

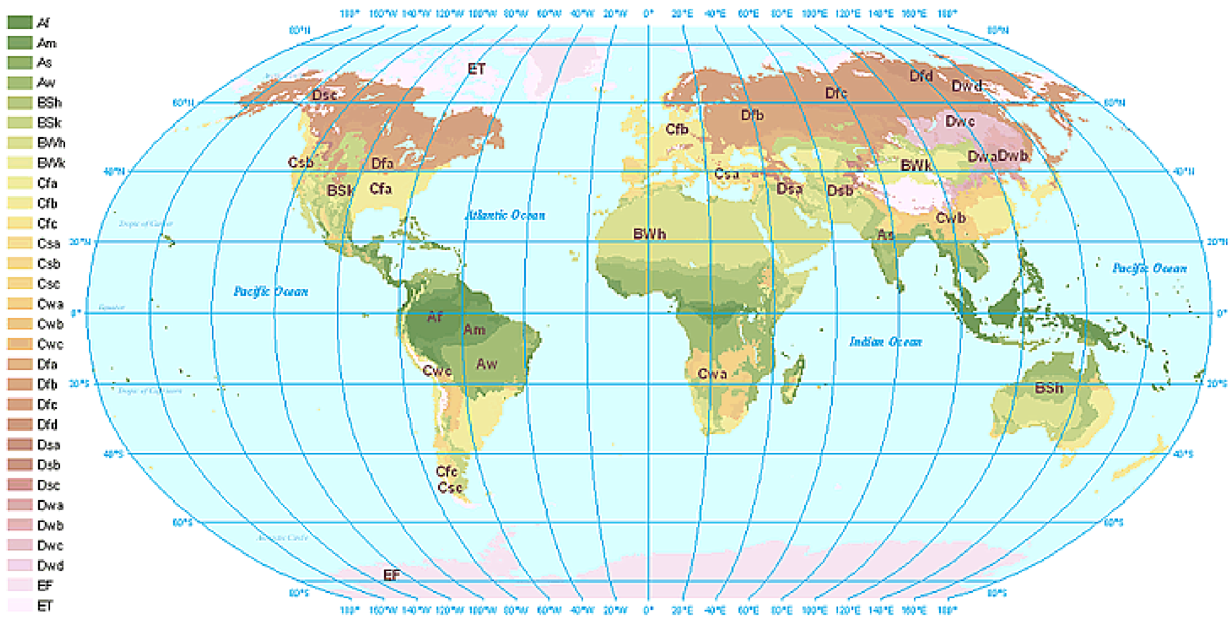

FIGURE 1.16

Climate is the most important factor in determining the type of soil that will form in a particular area.

- Increased rainfall increases the amount of rock that is dissolved as well as the amount of material that is carried away by moving water. As materials are carried away, new surfaces are exposed, which also increases the rate of weathering.
- Increased temperature increases the rate of chemical reactions, which also increases soil formation.
- In warmer regions, plants and bacteria grow faster, which helps to weather material and produce soils. In tropical regions, where temperature and precipitation are consistently high, thick soils form. Arid regions have thin soils.

Soil type also influences the type of vegetation that can grow in the region. We can identify climate types by the types of plants that grow there.

Rock Type

The original rock is the source of the inorganic portion of the soil. The minerals that are present in the rock determine the composition of the material that is available to make soil. Soils may form in place or from material that has been moved.

- **Residual soils** form in place. The underlying rock breaks down to form the layers of soil that reside above it. Only about one-third of the soils in the United States are residual.
- **Transported soils** have been transported in from somewhere else. Sediments can be transported into an area by glaciers, wind, water, or gravity. Soils form from the loose particles that have been transported to a new location and deposited.

Slope

The steeper the slope, the less likely material will be able to stay in place to form soil. Material on a steep slope is likely to go downhill. Materials will accumulate and soil will form where land areas are flat or gently undulating.

Time

Soils thicken as the amount of time available for weathering increases. The longer the amount of time that soil remains in a particular area, the greater the degree of alteration.

Biological Activity

The partial decay of plant material and animal remains produces the organic material and nutrients in soil. In soil, decomposing organisms breakdown the complex organic molecules of plant matter and animal remains to form simpler inorganic molecules that are soluble in water. Decomposing organisms also create organic acids that increase the rate of weathering and soil formation. Bacteria in the soil change atmospheric nitrogen into nitrates.

The decayed remains of plant and animal life are called **humus**, which is an extremely important part of the soil. Humus coats the mineral grains. It binds them together into clumps that then hold the soil together, creating its structure. Humus increases the soil's porosity and water-holding capacity and helps to buffer rapid changes in soil acidity. Humus also helps the soil to hold its nutrients, increasing its fertility. Fertile soils are rich in nitrogen, contain a high percentage of organic materials, and are usually black or dark brown in color. Soils that are nitrogen poor and low in organic material might be gray or yellow or even red in color. Fertile soils are more easily cultivated.

- An animation of how different types of weathering affect different minerals in soil: http://courses.soil.ncsu.edu/resources/soil_classification_genesis/mineral_weathering/elemental_change.swf .

Summary

- The factors that affect soil formation are climate, rock type, slope, time, and biological activity. Differences in these factors will produce different types of soil.
- Soil type determines what can grow in a region.
- Humus, the decayed remains of living organisms, is essential for soils to be fertile.

Explore More

Use the resource below to answer the questions that follow.

- **The Five Factors of Soil Formation** at http://www.youtube.com/watch?v=bTzslvAD1Es (9:28)

MEDIA

Click image to the left for use the URL below.

URL: http://gamma.ck12.org/flx/render/embeddedobject/1617

1. Which chemical property most contributes to soil formation and what effects does it have?

2. Which physical properties most contributes to soil formation and what effect does it have?
3. How does relief affect soil formation?
4. What do the scientists say is the succession that occurs in soil development?
5. How does the slope that has been deglaciated for 50 years differ from the nearby slope that has been glacier free for thousands of years?
6. How does agricultural development affect the timing of soil formation?
7. Why do scientists who study soils need a new set of terms to describe soils?

Explore More Answers

1. Soil pH, which changes over time, controls the types and rates of chemical properties in the soil.
2. Particle size, from coarse to fine, and their nature. These features affect the movement and retention of water. Size also determines how chemically reactive a soil can be; those with smaller surface area are more open to chemical changes.
3. Relief controls the distribution of water on a landscape. A convex slope sheds water; a concave slope collects water. The amount of time water spends on the slope controls soil development.
4. A new soil won't have many obvious living things; life is tiny and may be microscopic. Over time the soil will host more and larger plants; the organic matter will increase.
5. The newly exposed slope has less soil development; there are fewer plants but small trees are trying to establish themselves, especially those that are tolerant of the acidic soil. The older slope has a forest and much more soil.
6. An event that alters the soil will reset the soil development clock.
7. Human activities are affecting soils and so man-made soils need different classifications since they are not like naturally formed soils.

Review

1. How does climate affect soil type? Why is climate the most important factor in developing the characteristics of a soil?
2. How does time affect soil formation in an arid environment versus in a warm, humid environment?
3. What is the role of partially decayed plant and animal remains in a soil?

Review Answers

1. Climate determines the rate of chemical reactions that produce soil. Chemical reactions occur more rapidly in warmer temperatures; they also are advanced by water.
2. Soils will form much more quickly in a warm, humid environment because chemical reactions are aided by increased temperature and the presence of water. Soils form slowly and do not get very developed in arid environments.
3. Partially decayed plant material produces adds organic material and nutrients to the soil. This increases the rate of soil formation and eventually will become part o the humus.

1.7 Soil Horizons and Profiles

- Define soil horizon and soil profile.
- Describe the characteristics of the three major types of soil horizon, and explain the relationship of each to weathering processes.

What conditions would create so much clay?

Soils are so different. In the desert there's a very thin layer and then bedrock. The quarry in the photo is of clay. A thick, thick layer of clay is found in this area. The area must be quite moist for so much rock material to have weathered to clays.

Soil Horizons and Profiles

A residual soil forms over many years, as mechanical and chemical weathering slowly change solid rock into soil. The development of a residual soil may go something like this.

1. The bedrock fractures because of weathering from ice wedging or another physical process.
2. Water, oxygen, and carbon dioxide seep into the cracks to cause chemical weathering.
3. Plants, such as lichens or grasses, become established and produce biological weathering.
4. Weathered material collects until there is soil.
5. The soil develops **soil horizons**, as each layer becomes progressively altered. The greatest degree of weathering is in the top layer. Each successive, lower layer is altered just a little bit less. This is because the first place where water and air come in contact with the soil is at the top.

A cut in the side of a hillside shows each of the different layers of soil. All together, these are called a **soil profile** (**Figure** 1.17).

The simplest soils have three horizons.

FIGURE 1.17
Soil is an important resource. Each soil horizon is distinctly visible in this photograph.

Topsoil

Called the **A-horizon**, the **topsoil** is usually the darkest layer of the soil because it has the highest proportion of organic material. The topsoil is the region of most intense biological activity: insects, worms, and other animals burrow through it and plants stretch their roots down into it. Plant roots help to hold this layer of soil in place.

In the topsoil, minerals may dissolve in the fresh water that moves through it to be carried to lower layers of the soil. Very small particles, such as clay, may also get carried to lower layers as water seeps down into the ground.

Subsoil

The **B-horizon** or **subsoil** is where soluble minerals and clays accumulate. This layer is lighter brown and holds more water than the topsoil because of the presence of iron and clay minerals. There is less organic material. **Figure** 1.18.

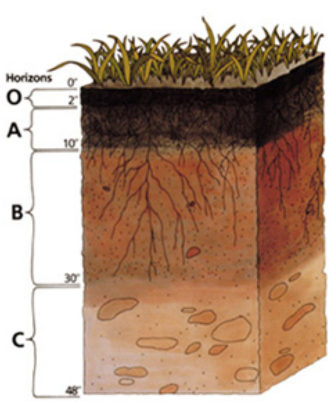

FIGURE 1.18
A soil profile is the complete set of soil layers. Each layer is called a horizon.

C horizon

The **C-horizon** is a layer of partially altered bedrock. There is some evidence of weathering in this layer, but pieces of the original rock are seen and can be identified.

Not all climate regions develop soils, and not all regions develop the same horizons. Some areas develop as many as five or six distinct layers, while others develop only very thin soils or perhaps no soils at all.

- An animation of soil profile development can be viewed here: http://courses.soil.ncsu.edu/resources/soil_classification_genesis/soil_formation/soil_transform.swf .

Summary

- Soil horizons are layers within a soil showing different amounts of alteration.
- Soil profiles show the layers of soil, which include topsoil, subsoil and the C horizon.
- Topsoil has the highest proportion of organic material and is very important for agriculture.

Explore More

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=YQhyMsisRD8

1. What creates soil horizons?
2. What is a soil profile?
3. What is the O horizon made of?
4. What are the characteristics of the A horizon?
5. What are the characteristics of the E horizon?
6. What are the characteristics of the B horizon?
7. What are the characteristics of the C horizon?

Explore More Answers

1. Changes in the soil over time through addition, loss, leaching or alteration.
2. A section of soil that can be viewed.
3. Decayed and decaying plant and animal debris, and humus.
4. Topsoil made of minerals with organic matter, zone of leaching.
5. The zone of eluviation, very leached so may minerals are gone.
6. The zone of accumulation where all the things that leached from above wind up.
7. Not too much soil formation goes on here.

Review

1. Describe topsoil. Why is loss of topsoil a very large problem when it happens?
2. Describe the weathering processes that go into producing soil.
3. What is the C horizon?

Review Answers

1. Topsoil contains the most organic material and so it is very rich and good for plant growth. When it is lost, plants do not grow as easily.

2. Mechanical and chemical weathering are needed to produce soil. Bedrock fractures due to mechanical weathering, making the route open for chemical weathering. Plants become established and continue to do mechanical and chemical weathering processes.
3. It is partially altered bedrock.

1.8 Types of Soils

- Describe the characteristics of types of soil and where each is found.

What makes soil good?

Some types of soils are good for growing crops and some are not. When good soils are found in good climates where water is available, a variety of crops will grow. If one of these things is missing, the possibilities are much more limited.

Types of Soils

Although soil scientists recognize thousands of types of soil –each with its own specific characteristics and name - let's consider just three soil types. This will help you to understand some of the basic ideas about how climate produces a certain type of soil, but there are many exceptions to what we will learn right now (**Figure** 1.19).

FIGURE 1.19
Just some of the thousands of soil types.

Pedalfer

Deciduous trees, the trees that lose their leaves each winter, need at least 65 cm of rain per year. These forests produce soils called **pedalfers**, which are common in many areas of the temperate, eastern part of the United States (**Figure** 1.20). The word pedalfer comes from some of the elements that are commonly found in the soil. The "Al" in ped **al**fer is the chemical symbol of the element aluminum, and the "Fe" in pedal **fe**r is the chemical symbol for iron. Pedalfers are usually a very fertile, dark brown or black soil. Not surprisingly, they are rich in aluminum clays and iron oxides. Because a great deal of rainfall is common in this climate, most of the soluble minerals dissolve and are carried away, leaving the less soluble clays and iron oxides behind.

Pedocal

Pedocal soils form in drier, temperate areas where grasslands and brush are the usual types of vegetation (**Figure** 1.21). The climates that form pedocals have less than 65 cm rainfall per year. Compared to pedalfers there is less chemical weathering and less water to dissolve away soluble minerals, so more soluble minerals are present and fewer clay minerals are produced. It is a drier region with less vegetation, so the soils have lower amounts of organic material and are less fertile.

A pedocal is named for the calcite enriched layer that forms. Water begins to move down through the soil layers, but before it gets very far, it begins to evaporate. Soluble minerals, like calcium carbonate, concentrate in a layer that marks the lowest place that water was able to reach. This layer is called caliche.

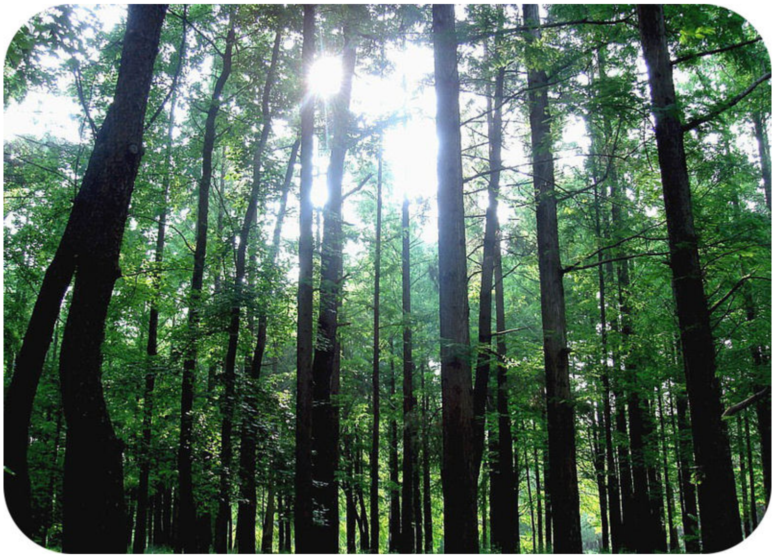

FIGURE 1.20
A pedalfer is the dark, fertile type of soil that will form in a forested region.

FIGURE 1.21
A lizard on soil typical of an arid region in Mexico.

Laterite

In tropical rainforests where it rains literally every day, **laterite** soils form (**Figure** 1.22). In these hot, wet, tropical regions, intense chemical weathering strips the soils of their nutrients. There is practically no humus. All soluble minerals are removed from the soil and all plant nutrients are carried away. All that is left behind are the least soluble materials, like aluminum and iron oxides. These soils are often red in color from the iron oxides. Laterite soils bake as hard as a brick if they are exposed to the Sun.

Many climate types have not been mentioned here. Each produces a distinctive soil type that forms in the particular circumstances found there. Where there is less weathering, soils are thinner but soluble minerals may be present. Where there is intense weathering, soils may be thick but nutrient-poor. Soil development takes a very long time, it may take hundreds or even thousands of years for a good fertile topsoil to form. Soil scientists estimate that in the very best soil-forming conditions, soil forms at a rate of about 1mm/year. In poor conditions, soil formation may take thousands of years!

Summary

- Pedalfer is the soil common in deciduous forests and is rich in aluminum and iron. Pedalfers are dark brown and fertile.

FIGURE 1.22
A laterite is the type of thick, nutrient-poor soil that forms in the rainforest.

- Pedocal is the soil common in grasslands where the climate is drier and is rich in calcium.
- Laterite forms in tropical rain forests. Chemical weathering strips the soils of their nutrients, so when the forest is removed the soil is not very fertile.

Explore More

Use these resources to answer the questions that follow.

https://www.youtube.com/watch?v=MQF5wlpvIfo Start at 3:52

1. What defines the two different soil types in the United States?
2. What are the characteristics of pedalfer? What is this due to?
3. What happens in the western half of the U.S. that inhibits soil development?

Explore More Answers

1. More and less than 30" of rain per year.
2. More aluminum and iron with thicker soils due to the amount of rain and the resultant biological activity.
3. There is much less rain. There are also more mountains and soils do not develop as well on steep slopes.

Review

1. What is pedocal and under what conditions does it form?
2. What is pedalfer and under what conditions does it form?
3. What is laterite and under what conditions does it form?

Review Answers

1. Pedocal forms in drier conditions such as grasslands. There is less chemical weathering and less biological activity so the soils are less well developed and they have less organic material. This soil is named for calcite that forms in it.

2. Pedalfer is the soil of deciduous forests and they are high in aluminum and iron. These soils are very fertile with lots of organic material. They form where there is a lot of rain so that the soluble minerals are taken away and the less soluble minerals remain.
3. Laterite is the soil of tropical rain forests. The intense amount of rain strips the soil of its nutrients. What remains is insoluble and not nutrient-rich for plants to grow.

1.9 Landforms from Stream Erosion and Deposition

- Describe how streams erode and deposit sediments.

What on Earth are 'goosenecks'?

In Southeastern Utah, stream meanders have been immortalized by erosion into the Goosenecks of the San Juan River. This satellite image shows the amazing path the river has cut. Even better is to stand at the edge and look into one of the meanders. Goosenecks State Park is in the southeastern corner of Utah.

Erosion by Streams

Flowing streams pick up and transport weathered materials by eroding sediments from their banks. Streams also carry ions and ionic compounds that dissolve easily in the water.

Sediment Transport

Sediments are carried as:

- **Dissolved load**: Dissolved load is composed of ions in solution. These ions are usually carried in the water all the way to the ocean.
- **Suspended load**: Sediments carried as solids as the stream flows are suspended load. The size of particles that can be carried is determined by the stream's velocity (**Figure** 1.23). Faster streams can carry larger particles. Slower streams can only carry smaller particles. Streams with a steep **gradient** (slope) have a faster velocity and can carry larger particles.

FIGURE 1.23
The Amazon River appears brown when carrying a large sediment load.

- **Bed load**: Some particles are too large to be carried as suspended load. These particles bumped and pushed along the stream bed as bed load. Bed load sediments do not move continuously. This intermittent movement is called **saltation**. Streams with high velocities and steep gradients cut down into the stream bed. This type of erosion is primarily by movement of particles that make up the bed load.

- An animation of saltation is found here: http://www.weru.ksu.edu/new_weru/multimedia/movies/dust003.mpg .
- A video of bedload transport is found here: http://faculty.gg.uwyo.edu/heller/SedMovs/Sed%20Movie%20files/bdld.mov .

Stream Deposition

A stream is at its **base level** where it meets a large body of water. As a stream gets closer to base level, its gradient lowers. The stream deposits more material than it erodes. On flatter ground, streams deposit material on the inside of meanders. Meanders are bends in the stream's path. Placer mineral deposits are often deposited on the inside of meanders.

A stream's **floodplain** is much broader and shallower than its channel. When a stream flows onto its floodplain, its velocity slows. The stream deposits much of its load. Stream sediments are rich in nutrients and make excellent farmland. The Mississippi River floodplain is heavily farmed. Flooding can wipe out farms and towns, but the stream also deposits nutrient-rich sediments that enrich the floodplain (**Figure** 1.24).

A stream at flood stage carries lots of sediments. When its gradient decreases, the stream overflows its banks and broadens its channel. The decrease in gradient causes the stream to deposit its sediments. The largest sediments are deposited first. These large sediments build a higher area around the edges of the stream channel. This creates a **natural levee**.

When a river enters standing water, its velocity slows to a stop. The stream moves back and forth across the region. The stream drops its sediments in a wide triangular-shaped deposit called a **delta** (**Figure** 1.25).

If a stream falls down a steep slope onto a broad flat valley, an **alluvial fan** develops (**Figure** 1.26). Alluvial fans generally form in arid regions.

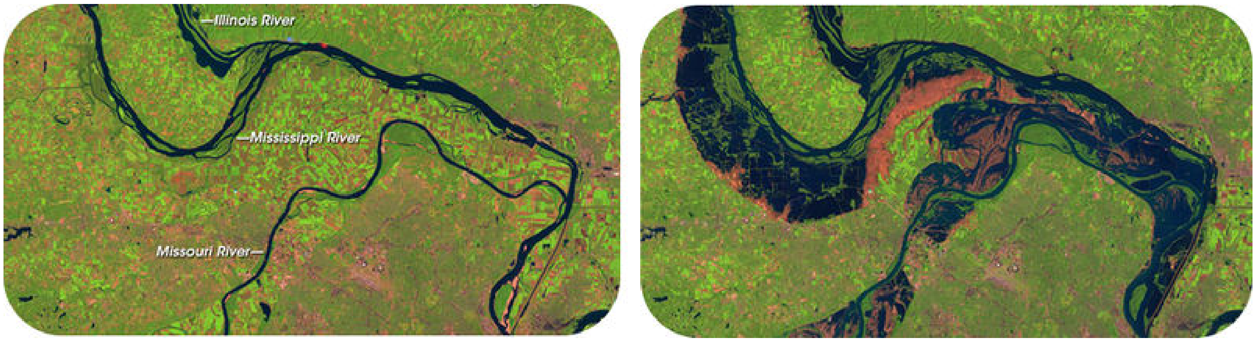

FIGURE 1.24
The Mississippi River floodplain at normal flow and during flood.

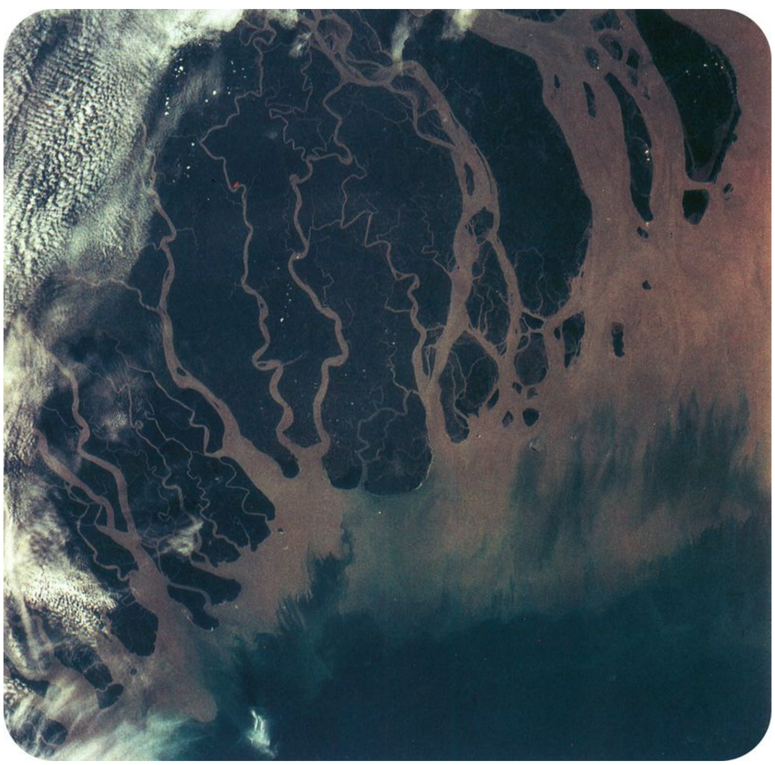

FIGURE 1.25
The Ganges River forms an enormous delta in Bangladesh.

Summary

- Streams carry dissolved ions and sediments. The sizes of the sediments a stream can carry depend on the stream's velocity.
- Particles that are too large to be suspended move along the stream bed by saltation.
- Rivers deposit sediments on levees, floodplains, and in deltas and alluvial fans.

FIGURE 1.26
A series of alluvial fans spread out from mountains along the Badwater Basin in Death Valley, California.

Explore More

Use the resource below to answer the questions that follow.

- **Running Water: How It Erodes and Deposits** at http://www.youtube.com/watch?v=_HFmxRicX4o (2:56)

MEDIA
Click image to the left for use the URL below.
URL: http://gamma.ck12.org/flx/render/embeddedobject/4784

1. What is laminar flow?
2. What is turbulent flow?
3. Where along the river in Yellowstone is there laminar flow and where is there turbulent flow? Why?
4. What is jet flow? Where does jet flow occur?
5. What is water velocity?
6. What factors can influence the stream velocity?

Explore More Answers

1. Laminar flow is smooth flow through a channel, mostly the water moves in straight line paths.'
2. Turbulent flow occurs in rough channels where there are obstructions that disrupt the smooth, streamlined flow that would occur without them.
3. Higher in the mountains there are more rocks, the stream is narrower and the land is steep flow is turbulent. Further down stream where the river can widen out and there are fewer rocks flow is laminar.
4. Jet flow is when the water is moving so fast it's like jets of water; this happens over waterfalls.
5. Velocity is the speed the water is moving: how far in a given period of time.

6. Stream velocity is influenced by the nature of the stream bank, the amount of water passing over a point and the slope of the stream bed.

Review

1. If flood waters decrease, what will happen to the size of particle the stream can carry? What will be deposited and where?
2. Under what conditions do streams cut down into their beds? Under what conditions do they erode their banks?
3. Deserts are extremely dry, yet alluvial fans are said to be deposited by stream flow. Describe how this occurs.

Review Answers

1. A stream in flood carries lots of sediments and relatively large particles. As the water slows, the stream will drop the larger sediments. These large sediments will be closest to the stream where flood waters are highest and the smaller particles will be further out where the water isn't moving as fast.
2. Streams cut into their beds when they have a lot of energy. Streams erode when they have a lot of energy. Both of these occur when the water is high.
3. Alluvial fans form during the rare times when there is a lot of water in the desert.

1.10 Landforms from Groundwater Erosion and Deposition

- Describe how groundwater erodes and deposits sediments.

How would you find an undiscovered cave?

Caves may be beneath your feet, especially if your feet are on limestone. In 1974 two amateur cavers found warm, moist air coming out of a crack in the ground in southern Arizona. They managed to find a way in and discovered the amazing Kartchner Caverns, 2.5 miles of pristine caves. You can see these spectacular caverns on a guided tour.

Groundwater Erosion

Rainwater absorbs carbon dioxide (CO_2) as it falls. The CO_2 combines with water to form carbonic acid. The slightly acidic water sinks into the ground and moves through pore spaces in soil and cracks and fractures in rock. The flow of water underground is **groundwater**. Groundwater is described further in the chapter Water on Earth.

Groundwater is a strong erosional force, as it works to dissolve away solid rock (**Figure** 1.27). Carbonic acid is especially good at dissolving the rock limestone.

Cave Formation

Working slowly over many years, groundwater travels along small cracks. The water dissolves and carries away the solid rock, gradually enlarging the cracks. Eventually, a cave may form (**Figure** 1.28).

You can explore a fantastic cave, Kartchner Caverns, in Arizona, by watching this video: http://video.nationalgeographic.com/video/player/science/earth-sci/exploring-kartchner-sci.html .

Sinkholes

If the roof of a cave collapses, a **sinkhole** could form. Some sinkholes are large enough to swallow up a home or several homes in a neighborhood (**Figure** 1.29).

FIGURE 1.27
When water sinks into the ground, it becomes groundwater.

FIGURE 1.28
Water flows through Russell Cave National Monument in Alabama.

Groundwater Deposition

Groundwater carries dissolved minerals in solution. The minerals may then be deposited, for example, as **stalagmites** or **stalactites** (**Figure** 1.30). Stalactites form as calcium carbonate drips from the ceiling of a cave, forming beautiful icicle-like formations. The word stalactite has a c, and it forms from the ceiling. Stalagmites form as calcium carbonate drips from the ceiling to the floor of a cave and then grow upwards. The g in stalagmite means it forms on the ground.

If a stalactite and stalagmite join together, they form a **column**. One of the wonders of visiting a cave is to witness the beauty of these amazing and strangely captivating structures. Some of the largest, and most beautiful, natural crystals can be found in the Naica mine, in Mexico. These gypsum crystals were formed over thousands of years as groundwater, rich in calcium and sulfur flowed through an underground cave. Check it out:

FIGURE 1.29
A relatively small sinkhole in a Georgia parking lot.

FIGURE 1.30
Stalactites hang from the ceiling and stalagmites rise from the floor of Carlsbad Caverns in New Mexico. The large stalagmite on the right is almost tall enough to reach the ceiling (or a stalactite) and form a column.

MEDIA
Click image to the left for use the URL below.
URL: http://gamma.ck12.org/flx/render/embeddedobject/4786

Summary

- Groundwater dissolves minerals, carries the ions in solution, and then deposits them.
- Groundwater erodes rock beneath the ground surface, especially carbonate rock.
- Groundwater deposits material in caves to create stalactites, stalagmites, and columns.

Explore More

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=rwb8KyvaFqQ

1. What rock type is the cave system formed in?
2. What was the source of the acid in the water that carved the cave?
3. Why are the rooms large at Carlsbad compared to most other caves?
4. What cave formations can be seen at Carlsbad? How do they form?
5. How does water form in and out of the caves?
6. What biological wonders are found at Carlsbad?

Explore More Answers

1. An ancient limestone reef.
2. Hydrogen sulfide from nearby petroleum deposits created sulfuric acid.
3. Sulfuric acid is stronger than the carbonic acid that creates most other caves. Also there are many fractures for caves to form along.
4. Stalactites, stalagmites and columns. Calcium carbonate dissolves in acidic water and flows through cracks and drips so the calcite forms on the ceiling.
5. Through fractures in the uplifted area.
6. Bats roost there and are found seasonally.

Review

1. How does groundwater erode rock material?
2. Describe how groundwater deposits stalactites and stalagmites.
3. Why is groundwater acidic?

Review Answers

1. Rainwater absorbs carbon dioxide to create the mild acid, carbonic acid. As this moves through cracks in limestone rock, it dissolves the rock.
2. Groundwater that has dissolved calcium carbonate enters the cave and as the water evaporates it precipitates out the calcium carbonate. If the mineral stays up at the ceiling, it forms a stalactite. if it drips to the ground, it forms a stalagmite.
3. Rain is mildly acidic because water mixes with carbon dioxide in the atmosphere to form carbonic acid.

1.11 Landforms from Wave Erosion and Deposition

- Describe how waves erode and deposit sediments.

How is surfing like erosion?

Have you ever surfed or even body surfed? Have you felt a wave crash onto your body and then try to drag you offshore? Surfers use the power of waves for a wild ride. But that power can also be used to create landforms along a shoreline.

Wave Erosion

Wave energy does the work of erosion at the shore. Waves approach the shore at some angle so the inshore part of the wave reaches shallow water sooner than the part that is further out. The shallow part of the wave "feels" the bottom first. This slows down the inshore part of the wave and makes the wave "bend." This bending is called **refraction**.

- In this animation, notice how the wave refracts as it comes into the beach. http://www.grossmont.edu/garyjacobson/Oceanography%20112/Wave%20Model.htm

Wave refraction either concentrates wave energy or disperses it. In quiet water areas, such as bays, wave energy is dispersed, so sand is deposited. Areas that stick out into the water are eroded by the strong wave energy that concentrates its power on the **wave-cut cliff** (**Figure** 1.31).

Other features of wave erosion are pictured and named in **Figure** 1.32. A **wave-cut platform** is the level area formed by wave erosion as the waves undercut a cliff. An **arch** is produced when waves erode through a cliff. When a sea arch collapses, the isolated towers of rocks that remain are known as **sea stacks**.

Wave Deposition

Rivers carry sediments from the land to the sea. If wave action is high, a delta will not form. Waves will spread the sediments along the coastline to create a **beach**. Waves also erode sediments from cliffs and shorelines and transport

FIGURE 1.31
These colorful cliffs on Martha's Vineyard are eroded by wave action. Note that the topsoil and vegetation at the top of the cliff are undercut by the falling sand and clay beneath.

FIGURE 1.32
(a) The high ground is a large wave-cut platform formed from years of wave erosion. (b) A cliff eroded from two sides produces an arch. (c) The top of an arch erodes away, leaving behind a tall sea stack.

them onto beaches. Beaches can be made of mineral grains like quartz, rock fragments, and also pieces of shell or coral (**Figure** 1.33).

Waves continually move sand along the shore. Waves also move sand from the beaches on shore to bars of sand offshore as the seasons change. In the summer, waves have lower energy so they bring sand up onto the beach. In the winter, higher energy waves bring the sand back offshore.

Some of the features formed by wave-deposited sand are in **Figure** 1.34. These features include barrier islands and spits. A **spit** is sand connected to land and extending into the water. A spit may hook to form a tombolo.

Shores that are relatively flat and gently sloping may be lined with long, narrow **barrier islands** (**Figure** 1.35). Most barrier islands are a few kilometers wide and tens of kilometers long.

In its natural state, a barrier island acts as the first line of defense against storms such as hurricanes. When barrier islands are urbanized, hurricanes damage houses and businesses rather than vegetated sandy areas in which sand can move. A large hurricane brings massive problems to the urbanized area.

FIGURE 1.33
Quartz, rock fragments, and shell make up the sand along a beach.

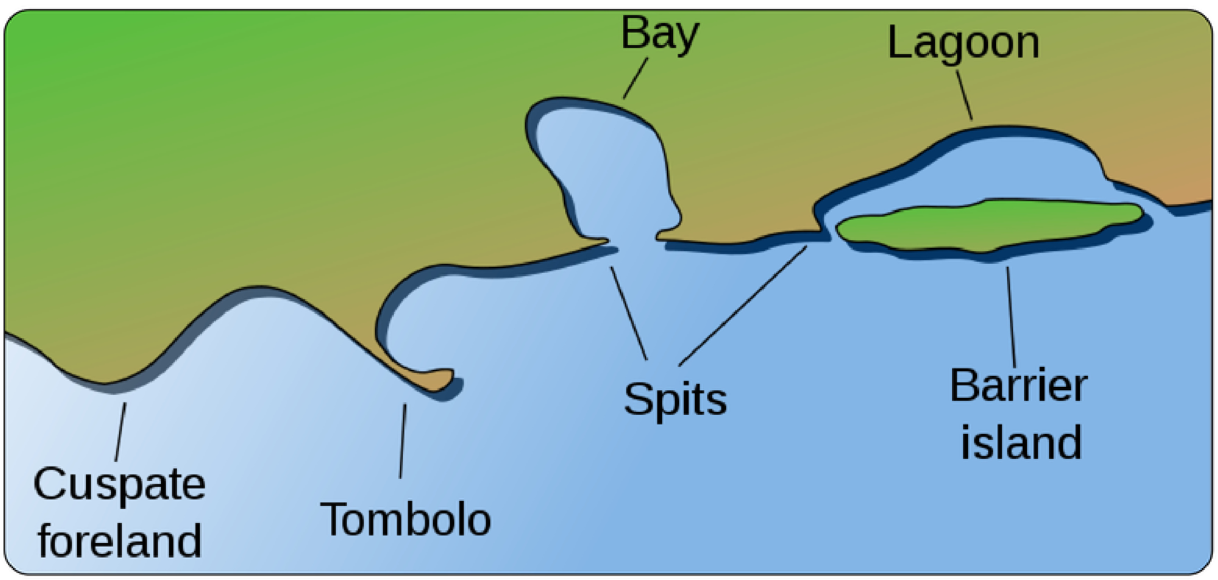

FIGURE 1.34
Examples of features formed by wave-deposited sand.

Protecting Shorelines

Intact shore areas protect inland areas from storms that come off the ocean. Where the natural landscape is altered or the amount of development makes damage from a storm too costly to consider, people use several types of structures to attempt to slow down wave erosion. A few are pictured below (**Figure** 1.36). A **groin** is a long, narrow pile of rocks built perpendicular to the shoreline to keep sand at that beach. A **breakwater** is a structure built in the water

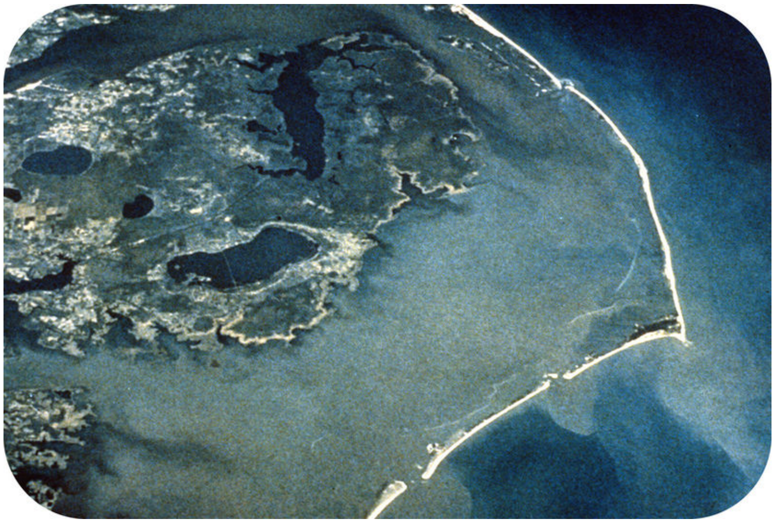

FIGURE 1.35
Much of North Carolina's coast is protected by barrier islands that enclose Pamlico Sound. The thin white strips on the outer edges of the islands are beach sand.

parallel to the shore in order to protect the shore from strong incoming waves. A **seawall** is also parallel to the shore, but it is built onshore.

FIGURE 1.36
(a) Groins trap sand on the up-current side so then people down current build groins to trap sand too. (b) Breakwaters are visible in this satellite image parallel to the shoreline. (c) Seawalls are similar to breakwaters except built onshore. Extremely large storm waves may destroy the sea wall, leaving the area unprotected.

People do not always want to choose safe building practices, and instead choose to build a beach house right on the beach. Protecting development from wave erosion is difficult and expensive.

Protection does not always work. The northeastern coast of Japan was protected by anti-tsunami seawalls. Yet waves from the 2011 tsunami that resulted from the Tohoku earthquake washed over the top of some seawalls and caused others to collapse. Japan is now planning to build even higher seawalls to prepare for any future (and inevitable) tsunami.

Summary

- Ocean waves have a tremendous amount of energy and so they may do a great deal of erosion. Some landforms created by erosion are platforms, arches, and sea stacks.

- Transported sand will eventually be deposited on beaches, spits, or barrier islands.
- People love the shore, so they develop these regions and then must build groins, breakwaters, and seawalls to protect them.

Explore More

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=m4bHsa1w0yI

1. What is the main agent of erosion at shorelines? How does more erosion take place?
2. What is differential erosion? What is the result?
3. When does the most erosion take place?
4. What is hydraulic action?
5. What causes abrasion?
6. How does cliff retreat happen?
7. How does a wave-cut platform form?
8. How do caves form?
9. How does a stack form?

Explore More Answers

1. Waves are the main agent; large waves cause more erosion and small waves cause less.
2. Soft rocks erode more than hard rocks so the amount of erosion in an area is not the same. Harder rocks create headlands, softer rocks create bays.
3. During storms or by waves that were generated in storms elsewhere.
4. Waves smash against cracks and joints in rocks compress the air in the cracks. The pressure created causes fragments of rock to break off.
5. Rocks smashing into each other. Waves can cause this.
6. Waves erode the base of a cliff so that eventually the cliff collapses. This causes the cliff to retreat.
7. The forces of waves only erodes the rock between the high and low water mark.
8. Weaknesses such as soft rock or a crack is made to expand by hydraulic action.
9. A cave forms through a headland. Eventually the roof of the cave collapses and leaves behind a stack.

Review

1. Describe how refraction concentrates wave energy so that some parts of a beach erode more.
2. What processes cause spits and barrier islands to form?
3. How do barrier islands protect beaches? What happens when these natural barriers are destroyed?

Review Answers

1. Most waves come in at an angle. The shallow end feels the bottom first and the wave bends, called refraction. This can concentrate wave energy and cause an area to erode more.
2. Waves deposit sand that is stretched out by currents.
3. Barrier islands absorb the highest energy waves away from the shoreline so that the beaches inland of the barrier island do not receive as much energy. if barrier islands are destroyed the shoreline is much more vulnerable to high energy events like hurricanes.

1.12 Landforms from Wind Erosion and Deposition

- Describe how wind erodes and deposits sediments.

What are the effects of sandblasting?

If you've ever been in a sand storm, you've felt the power of the wind carrying sand particles and blasting at your skin. Over time, this natural sand blasting can be a tremendous erosional force on rocks or buildings. Hopefully, you won't stay out long enough to experience permanent damage.

Transport of Particles by Wind

Wind transports small particles, such as silt and clay, over great distances, even halfway across a continent or an entire ocean basin. Particles may be suspended for days. Wind more easily picks up particles on ground that has been disturbed, such as a construction site or a sand dune. Just like flowing water, wind transports particles as both bed load and suspended load. For wind, bed load is made of sand-sized particles, many of which move by saltation (**Figure** 1.37). The suspended load is very small particles of silt and clay.

Wind Erosion

Wind is a stronger erosional force in arid regions than it is in humid regions because winds are stronger. In humid areas, water and vegetation bind the soil so it is harder to pick up. In arid regions, small particles are selectively picked up and transported.

Deflation

As small particles are removed, the ground surface gets lower and rockier, causing **deflation**. What is left is **desert pavement** (**Figure** 1.38), a surface covered by gravel-sized particles that are not easily moved by wind.

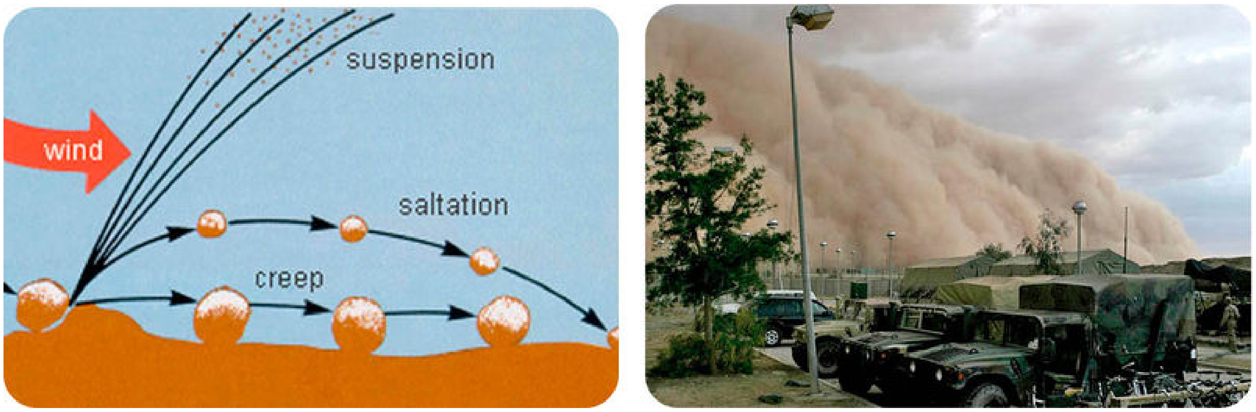

FIGURE 1.37

(a) Wind transport is by suspension, saltation, and creep (bed load). (b) In a sandstorm, sand is usually within a meter of the ground. A dust storm's smaller particles can travel higher. A dust storm as it approaches Al Asad, Iraq.

FIGURE 1.38

This desert pavement formed in the Mojave Desert as a result of deflation.

Abrasion

Particles moved by wind do the work of abrasion. As a grain strikes another grain or surface it erodes that surface. Abrasion by wind may polish natural or human-made surfaces, such as buildings. Stones that have become polished and faceted due to abrasion by sand particles are called **ventifacts** (**Figure** 1.39).

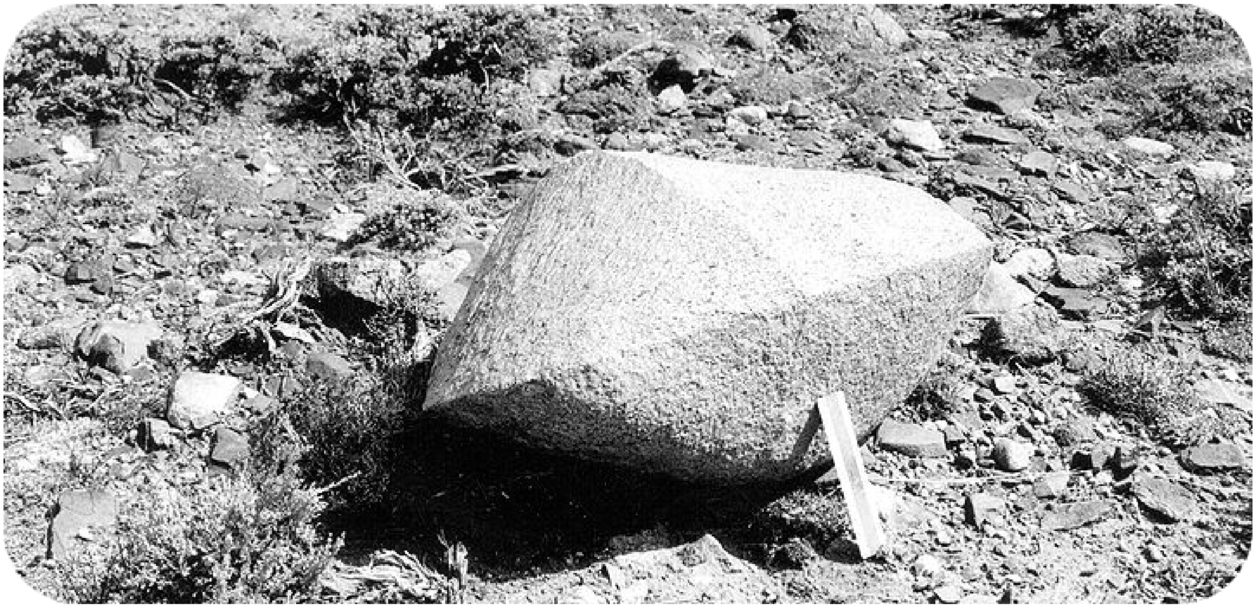

FIGURE 1.39
As wind blows from different direction, polished flat surfaces create a ventifact.

Desert Varnish

Exposed rocks in desert areas often develop a dark brown or black coating called **desert varnish**. Wind transports clay-sized particles that chemically react with other substances at high temperatures. The coating is formed of iron and manganese oxides (**Figure** 1.40).

FIGURE 1.40
Ancient people carved these petroglyphs into desert varnish near Canyonlands National Park in Utah.

Wind Deposition

The main features deposited by wind are sand dunes. Loess are wind deposits of finer sediments.

Sand Dunes

Deserts and seashores sometimes have **sand dunes** (**Figure** 1.41). Beach dunes are usually made of quartz because quartz is what's left in humid areas as other minerals weather into clays. Sand dunes may be composed of calcium carbonate in tropical areas. But in deserts, sand dunes are composed of a variety of minerals because there is little weathering.

Dune sands are usually very uniform in size and shape. Larger particles are too heavy for the wind to transport by suspension and smaller particles can't be picked up. Particles are rounded, since rounded grains roll more easily than angular grains.

FIGURE 1.41
This sand dune in Death Valley, California shows secondary sand ripples along its slip face.

For sand dunes to form there must be an abundant supply of sand and steady winds. A strong wind slows down, often over some type of obstacle, such as a rock or some vegetation, and drops its sand. As the wind moves up and over the obstacle, it increases in speed. It carries the sand grains up the gently sloping, upwind side of the dune by saltation. As the wind passes over the dune, its speed decreases. Sand cascades down the crest, forming the **slip face** of the dune. The slip face is steep because it is at the angle of repose for dry sand, about 34^o (**Figure** 1.42).

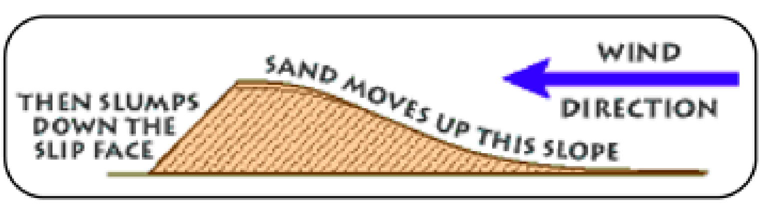

FIGURE 1.42
Sand dunes slope gently in the upwind direction. Downwind, a steeper slip face forms.

Wind deposits dune sands layer by layer. If the wind changes directions, cross beds form. Cross beds are named for the way each layer is formed at an angle to the ground (**Figure** 1.43).

The type of sand dune that forms depends on the amount of sand available, the character and direction of the wind,

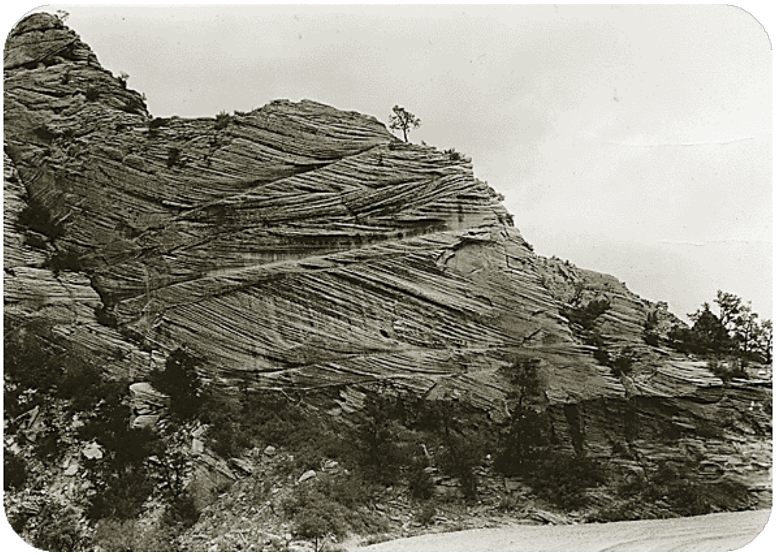

FIGURE 1.43
This sandstone in Zion National Park, Utah, shows crossbedding.

and the type of ground the sand is moving over. Dunes may be crescent-shaped, star-shaped, parabolic, linear, or barchan.

- An animation of the formation of the dunes at Great Sand Dunes National Park is seen on this website: http://www.nps.gov/grsa/naturescience/sanddunes.htm .

Loess

Windblown silt and clay deposited layer on layer over a large area form **loess** (**Figure** 1.44). Loess deposits form downwind of glacial outwash or desert, where fine particles are available. Loess deposits make very fertile soils in many regions of the world.

FIGURE 1.44
Loess deposits form nearly vertical cliffs, without grains sliding down the face.

Seafloor Mud

Fine-grained mud in the deep ocean is formed from silts and clays brought from the land by wind. The particles are deposited on the sea surface, and along with the shells of tiny surface ocean creatures, slowly settle to the deep ocean floor, forming brown, greenish, or reddish clays. Volcanic ash may also settle on the seafloor.

Summary

- In deserts, wind picks up small particles and leaves behind larger rocks to form desert pavement.
- Moving sand may sand blast rocks and other features to create ventifacts.
- The sand is transported until it is deposited in a sand dune.

Explore More

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=l8q1ss5M7ts

1. What size particles can wind move in a humid region? What size can wind move in an arid region? Why?
2. What is deflation?
3. How does desert pavement form?
4. What is a blowout?
5. How does sand move?
6. What sand makes up most of a sand dune and why?
7. How does a sand dune move?
8. What does cross bedding indicate?
9. Where is loess and what is it made of?

Explore More Answers

1. In a humid region wind can move sand but in a dry region wind may also be able to move silt and clay. If the small sediments are wet they stick together and can't be picked up by wind.
2. The removal of sand and silt so that the land surface goes down.
3. Small particles like sand and silt are blow away leaving behind a layer of residual pebbles that can't be blown away.
4. Wind blows sand away from sparse plants. The wind lowers the land surface and the plants are left on their roots that hold together the soil beneath them.
5. By saltation, so that it hops a few inches then it knocks another grain into the air.
6. It is mostly quartz because it is the most resistant.
7. It is blown up the top o the windward side and then falls down the back of the leeward side, which moves the sand dune in the leeward side.
8. That a sandstone formed at a sand dune.
9. Loess is found downwind of deserts and it is made of very fine sediments like silts.

Review

1. How does desert varnish form?
2. Describe how sand dunes form and move.
3. Why is loess a non-renewable resource?

Review Answers

1. Exposed rock reacts chemically with clay sized particles at high temperatures.
2. Sand dunes form when large particles are dropped near an obstacle like a rock or plant. The wind moves up the obstacle and when its speed decreases it drops its sand. The sand slips down the front of the dune.
3. Loess mostly came from glacial outwash so no more of it will be forming until the ice ages return.

1.13 Landforms from Glacial Erosion and Deposition

- Describe how glaciers erode rock and deposit sediments.

How is a geologist like a detective?

A geologist uses evidence left by events to reconstruct a geological history. Where should we go to study the tracks glaciers have left behind but Glacier National Park in Montana? The glaciers in the park have melted back a great deal in the past century, continuing a trend that began at the end of the ice ages. The features left behind by the glaciers are visible for everyone to see.

Glacial Erosion

Glaciers erode the underlying rock by abrasion and **plucking**. Glacial meltwater seeps into cracks of the underlying rock. When the water freezes, it pushes pieces of rock outward. The rock is then plucked out and carried away by the flowing ice of the moving glacier (**Figure** 1.45). With the weight of the ice over them, these rocks can scratch deeply into the underlying bedrock, making long, parallel grooves in the bedrock, called **glacial striations**.

Mountain glaciers leave behind unique erosional features. When a glacier cuts through a V-shaped river valley, the glacier plucks rocks from the sides and bottom. This widens the valley and steepens the walls, making a U-shaped valley (**Figure** 1.46).

Smaller tributary glaciers, like tributary streams, flow into the main glacier in their own shallower U-shaped valleys. A **hanging valley** forms where the main glacier cuts off a tributary glacier and creates a cliff. Streams plunge over the cliff to create waterfalls (**Figure** 1.47).

Up high on a mountain, where a glacier originates, rocks are pulled away from valley walls. Some of the resulting erosional features are shown in **Figure** 1.48 and **Figure** 1.49.

FIGURE 1.45
Glacial striations point the direction a glacier has gone.

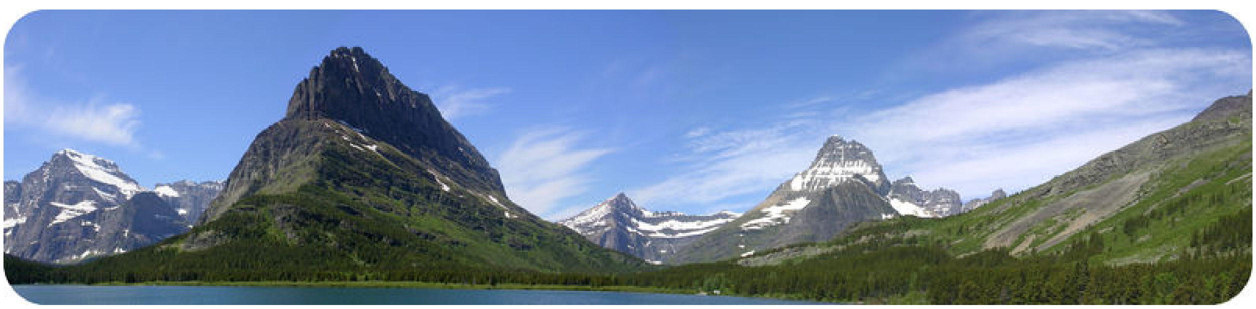

FIGURE 1.46
A U-shaped valley in Glacier National Park.

Depositional Features of Glaciers

As glaciers flow, mechanical weathering loosens rock on the valley walls, which falls as debris on the glacier. Glaciers can carry rock of any size, from giant boulders to silt (**Figure** 1.50). These rocks can be carried for many kilometers for many years.

Erratics

Rocks carried by a glacier are eventually dropped. These **glacial erratics** are noticeable because they are a different rock type from the surrounding bedrock.

FIGURE 1.47
Yosemite Valley is known for waterfalls that plunge from hanging valleys.

FIGURE 1.48
(a) A bowl-shaped cirque in Glacier National Park was carved by glaciers. (b) A high altitude lake, called a tarn, forms from meltwater trapped in the cirque. (c) Several cirques from glaciers flowing in different directions from a mountain peak, leave behind a sharp sided horn, like the Matterhorn in Switzerland. (d) When glaciers move down opposite sides of a mountain, a sharp edged ridge, called an arête, forms between them.

FIGURE 1.49
Snowmelt and melting glaciers combine to create a fast moving stream at Glacier National Park.

FIGURE 1.50
A large boulder dropped by a glacier is a glacial erratic.

Glacial Till

Melting glaciers deposit all the big and small bits of rocky material they are carrying in a pile. These unsorted deposits of rock are called **glacial till**. Glacial till is found in different types of deposits. Linear rock deposits are called **moraines**. Geologists study moraines to figure out how far glaciers extended and how long it took them to melt away.

Moraines are named by their location relative to the glacier:

- 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 the lateral moraines of two tributary glaciers join together in the middle of a larger glacier (**Figure** 1.51).

- Ground moraines forms from sediments that were beneath the glacier and left behind after the glacier melts. Ground moraine sediments contribute to the fertile transported soils in many regions.

FIGURE 1.51
The long, dark lines on a glacier in Alaska are medial and lateral moraines.

- Terminal moraines are long ridges of till left at the furthest point the glacier reached.
- End moraines are deposited where the glacier stopped for a long enough period to create a rocky ridge as it retreated. Long Island in New York is formed by two end moraines.

FIGURE 1.52
(a) An esker is a winding ridge of sand and gravel deposited under a glacier by a stream of meltwater. (b) A drumlin is an asymmetrical hill made of sediments that points in the direction the ice moved. Usually drumlins are found in groups called drumlin fields.

- Try to pick out some of the glacial features seen in this Glacier National Park video: http://www.visitmt.com/national_parks/glacier/video_series/part_3.htm .

Varves

Several types of stratified deposits form in glacial regions but are not formed directly by the ice. **Varves** form where lakes are covered by ice in the winter. Dark, fine-grained clays sink to the bottom in winter, but melting ice in spring brings running water that deposits lighter colored sands. Each alternating dark/light layer represents one year of deposits.

Summary

- Glaciers have more force than any of the other erosional agents because of their incredible mass. As a result, they can erode the landscape. Glacial features in alpine areas are beautiful.
- Glaciers dump material, leaving clues for scientists as to where the glacier went. Glacial moraines outline a glacier's extent.
- Varves form in lakes covered by ice. Varves are useful to scientists for understanding climate.

Explore More

Use this resource to answer the questions that follow.

https://www.youtube.com/watch?v=FYZtIVZmzlo

1. What is the main erosive process of a glacier and how does it erode material?
2. How does abrasion happen in a glacier?
3. What causes striations?
4. How does freezing and thawing promote erosion?
5. How does a glacier carry material so far?

Explore More Answers

1. Plucking, which is when a glacier moves around a rock melting a bit and then refreezing. The rock is ripped out of the ground as the glacier moves.
2. Rocks at the bottom of the glacier grind against the rocks on the ground and wears away the ground rocks.
3. Debris frozen into the bottom of a glacier makes a large, deep scratch on the bedrock it travels over.
4. Water enters cracks in the rock in the day, it freezes at night, expanding and placing pressure on the surrounding rock. Ovr time the pressure causes the rock to crack and split.
5. Glaciers travel far.

Review

1. How can glacial striations be used to indicate the direction a glacier moved? What is the process that creates striations?
2. How do glaciers modify mountain terrain? What are some of the features they create?
3. What information can scientists get from varves and how do they get it?

Review Answers

1. Rocks get caught up in the base of a glacier. As they are moved they scratch the bedrock below then. They scratch in the direction that they are moving, which is the direction the glacier is moving.
2. Glaciers pluck rocks from bedrock and create U-shaped valleys, hanging valleys, cirques, tarns, horns and aretes, among other features. They can also deposit features made from piles of sediment like moraines.

3. Varves indicate ice cover in winter and open water in summer. One dark (winter) and one light (summer) layer indicates passage of a year.

1.14 Landforms from Erosion and Deposition by Gravity

- Describe how gravity erodes and deposits sediments.

Would you live here?

La Conchita, California is in a beautiful location, nestled between a Southern California beach and a hillside. That hillside, though, is prone to landslides, and the town has lost several homes, a banana plantation, and 10 residents to landslides in 1995 and 2005. Despite these problems people stay in the community. Would you?

Landforms and Gravity

Gravity shapes the Earth's surface by moving weathered material from a higher place to a lower one. This occurs in a variety of ways and at a variety of rates, including sudden, dramatic events as well as slow, steady movements that happen over long periods of time. The force of gravity is constant and it is changing the Earth's surface right now.

Downslope Movement by Gravity

Erosion by gravity is called **mass wasting**. Mass wasting can be slow and virtually imperceptible, or rapid, massive, and deadly.

Weathered material may fall away from a cliff because there is nothing to keep it in place. Rocks that fall to the base of a cliff make a **talus slope**. Sometimes as one rock falls, it hits another rock, which hits another rock, and begins a landslide.

Landslides

Landslides are the most dramatic, sudden, and dangerous examples of Earth materials moved by gravity. Landslides are sudden falls of rock; by contrast, avalanches are sudden falls of snow.

When large amounts of rock suddenly break loose from a cliff or mountainside, they move quickly and with tremendous force (**Figure** 1.53). Air trapped under the falling rocks acts as a cushion that keeps the rock from slowing down. Landslides can move as fast as 200 to 300 km/hour.

FIGURE 1.53
This landslide in California in 2008 blocked Highway 140.

Landslides are exceptionally destructive. Homes may be destroyed as hillsides collapse. Landslides can even bury entire villages. Landslides may create lakes when the rocky material dams a stream. If a landslide flows into a lake or bay, they can trigger a tsunami.

Landslides often occur on steep slopes in dry or semi-arid climates. The California coastline, with its steep cliffs and years of drought punctuated by seasons of abundant rainfall, is prone to landslides.

- Rapid downslope movement of material is seen in this video: http://faculty.gg.uwyo.edu/heller/SedMovs/Sed%20Movie%20files/dflows.mov .

Mudflows and Lahars

Added water creates natural hazards produced by gravity (**Figure** 1.54). On hillsides with soils rich in clay, little rain, and not much vegetation to hold the soil in place, a time of high precipitation will create a **mudflow**. Mudflows follow river channels, washing out bridges, trees, and homes that are in their path.

- A debris flow is seen in this video: http://faculty.gg.uwyo.edu/heller/SedMovs/Sed%20Movie%20files/Moscardo.mov .

A lahar is mudflow that flows down a composite volcano (**Figure** 1.55). Ash mixes with snow and ice melted by the eruption to produce hot, fast-moving flows. The lahar caused by the eruption of Nevado del Ruiz in Columbia in 1985 killed more than 23,000 people.

FIGURE 1.54
Mudflows are common in southern California.

FIGURE 1.55
A lahar is a mudflow that forms from volcanic ash and debris.

Slump and Creep

Less dramatic types of downslope movement move Earth materials slowly down a hillside. **Slump** moves materials as a large block along a curved surface (**Figure** 1.56). Slumps often happen when a slope is undercut, with no support for the overlying materials, or when too much weight is added to an unstable slope.

Creep is the extremely gradual movement of soil downhill. Curves in tree trunks indicate creep because the base of the tree is moving downslope while the top is trying to grow straight up (**Figure** 1.57). Tilted telephone or power company poles are also signs of creep.

Contributing Factors

There are several factors that increase the chance that a landslide will occur. Some of these we can prevent and some we cannot.

FIGURE 1.56
Slump material moves as a whole unit, leaving behind a crescent shaped scar.

FIGURE 1.57
The trunks of these trees near Mineral King, California, were bent by snow creeping downhill when the trees were saplings.

Water

A little bit of water helps to hold grains of sand or soil together. For example, you can build a larger sand castle with slightly wet sand than with dry sand. However, too much water causes the sand to flow quickly away. Rapid snow melt or rainfall adds extra water to the soil, which increases the weight of the slope and makes sediment grains lose contact with each other, allowing flow.

Rock Type

Layers of weak rock, such as clay, also allow more landslides. Wet clay is very slippery, which provides an easy surface for materials to slide over.

Undercutting

If people dig into the base of a slope to create a road or a homesite, the slope may become unstable and move downhill. This is particularly dangerous when the underlying rock layers slope towards the area.

- Ocean waves undercut cliffs and cause landslides on beaches, as in this video: http://faculty.gg.uwyo.edu/heller/SedMovs/Sed%20Movie%20files/Cliff_retreat.mov .

When construction workers cut into slopes for homes or roads, they must stabilize the slope to help prevent a landslide (**Figure** 1.58). Tree roots or even grasses can bind soil together. It is also a good idea to provide drainage so that the slope does not become saturated with water.

FIGURE 1.58
A rock wall stabilizes a slope that has been cut away to make a road.

Ground Shaking

An earthquake, volcanic eruption, or even just a truck going by can shake unstable ground loose and cause a slide. Skiers and hikers may disturb the snow they travel over and set off an avalanche.

A very good introduction to the topic, "Landslide 101," is a video seen on National Geographic Videos, Environment Video, Natural Disasters, Landslides, and more: http://video.nationalgeographic.com/video/player/environment/ .

Prevention and Awareness

Landslides cause $1 billion to $2 billion damage in the United States each year and are responsible for traumatic and sudden loss of life and homes in many areas of the world.

Some at-risk communities have developed landslide warning systems. Around San Francisco Bay, the National Weather Service and the U.S. Geological Survey use rain gauges to monitor soil moisture. If soil becomes saturated, the weather service issues a warning. Earthquakes, which may occur on California's abundant faults, can also trigger landslides.

To be safe from landslides:

- Be aware of your surroundings and notice changes in the natural world.
- Look for cracks or bulges in hillsides, tilting of decks or patios, or leaning poles or fences when rainfall is heavy. Sticking windows and doors can indicate ground movement as soil pushes slowly against a house and knocks windows and doors out of alignment.
- Look for landslide scars because landslides are most likely to happen where they have occurred before.
- Plant vegetation and trees on the hillside around your home to help hold soil in place.
- Help to keep a slope stable by building retaining walls. Installing good drainage in a hillside may keep the soil from getting saturated.

Hillside properties in the San Francisco Bay Area and elsewhere may be prone to damage from landslides. Geologists are studying the warning signs and progress of local landslides to help reduce risks and give people adequate warnings of these looming threats.

See more at http://science.kqed.org/quest/video/landslide-detectives/.

Adobe Flash

MEDIA

Click image to the left for use the URL below.

URL: http://gamma.ck12.org/flx/render/embeddedobject/59198

Summary

- Landslides are sudden and massive falls of rock down a slope that may be very destructive or even deadly. Mudflows or lahars, which are volcanic mudflows, are mass movements that contain a lot of water. Slump and creep are slower types of mass wasting.
- Mass movements are more likely to occur on slopes that are wet, have weak rock, or are undercut. An earthquake or other ground shaking can trigger a landslide.
- To avoid being in a landslide, be aware of signs in a hillside, such as cracks or bulges and old landslide scars.
- To keep a slope stable, install good drainage or build retaining walls.

Explore More

Use these resources to answer the questions that follow.

https://www.youtube.com/watch?v=HoNzXauK63I

1. What is usually involved in starting a landslide?
2. What must be sitting on the slope waiting? What creates this material?
3. What starts the landslide?
4. In dry Arizona, how could a landslide happen?
5. What else can trigger landslides?

"Which slopes are at risk of failure?

Explore More Answers

1. water
2. There must be loose material that is ready to be sent down slope. Precipitation fractures, joints, ice wedging and other weathering will create loose material on the slope.

3. water or a vibration
4. A monsoon storm could bring 2 to 3 inches of rain in an hour, which could lubricate a bunch of rock that is waiting on a slope.
5. heliocopters
6. Slopes with a lot of water or a lot of loose material.

Review

1. How would installing drainage pipes in a slope change that slope's chance of a landslide?
2. If you look at a hillside, how can you tell that it's vulnerable to landslides? How can you tell that it's vulnerable to creep?
3. What is the scenario that creates a mudflow that kills 23,000 people?

Review Answers

1. Drainage pipes would rid a slope of water so that the chance of a landslide would be reduced.
2. A slope that is vulnerable to landslides will have evidence of prior landslides. There might be cracks or bulges in the slope; a time of excess rain or snowmelt might make it more vulnerable. Creep is indicated by belt trees that show the slope is moving downhill.
3. A lahar occurs when a volcanic eruption melts snow or glaciers and the meltwater mixes with ash. the whole mess moves fast down a river valley and wipes out a town or two.

Summary

Earth materials weather by mechanical or chemical processes; mechanical processes change the size of a substance but not its composition and chemical processes change its composition. Different types of weathering can work together on the same material. Soil forms on top of rock, the type depending on the environmental conditions in the region. A soil profile exhibits horizons, the nature of which depend on the type of soil. Topsoil is extremely important since it is in good topsoil that crops can grow. Water, ice, wind, and gravity create or modify landforms on Earth's surface. These agents can erode or deposit features that indicate their presence. Coastlines are modified by waves and currents along shore; groundwater carves caves and deposits cave features; wind abrades features and deposits sands in dunes; glaciers carve mountains into characteristic features and deposits massive amounts of debris; and gravity causes mass wasting, such as landslides.

1.15 References

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