

HS Rocks

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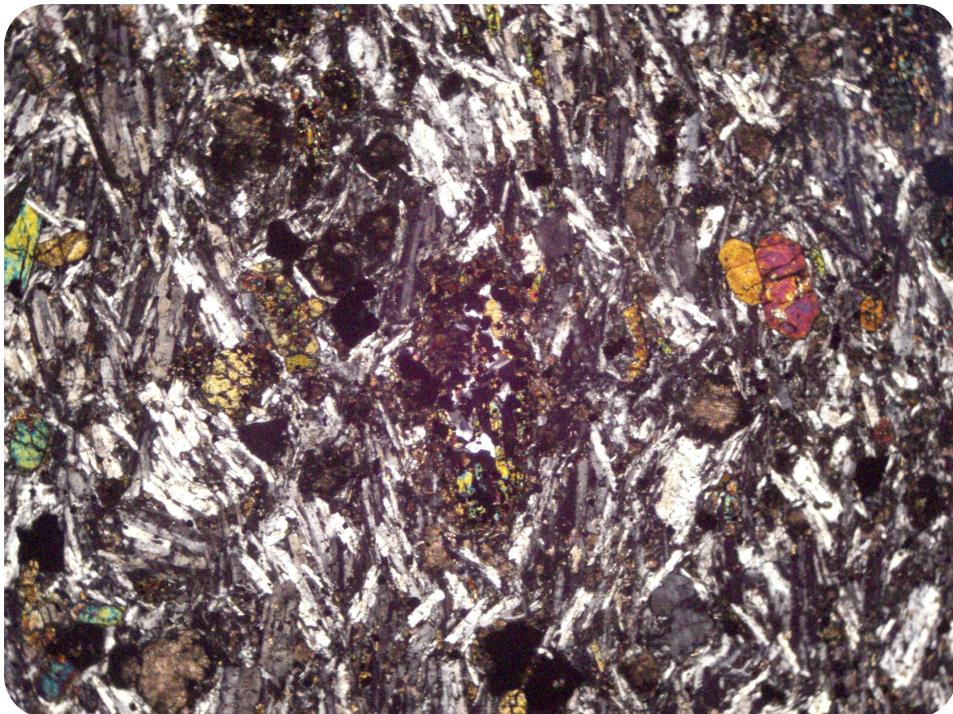
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CHAPTER**1****HS Rocks****CHAPTER OUTLINE**

- 1.1 Types of Rocks
- 1.2 Igneous Rocks
- 1.3 Sedimentary Rocks
- 1.4 Metamorphic Rocks
- 1.5 References



This image is of an igneous rock. The rock, called a trachyte, was sliced very thin, mounted on a slide and viewed in a polarizing light microscope. In a photomicrograph, different minerals have different colors and shapes. The long whitish crystals are feldspar and the colored rounded crystals are olivine. Geologists like to use photomicrographs because the minerals are more identifiable. The textures are also easier to recognize, which gives the scientists clues about the rock's formation. All this makes a rock easier to identify.

1.1 Types of Rocks

Lesson Objectives

- Define rock and describe what rocks are made of.
- Know how to classify and describe rocks.
- Explain how each of the three main rock types formed.
- Describe the rock cycle.

Vocabulary

- crystallization
- erosion
- igneous rock
- metamorphic rock
- metamorphism
- outcrop
- precipitate
- rock cycle
- sediment
- sedimentary rock
- sedimentation
- weathering

Introduction

There are three types of rocks: igneous, sedimentary and metamorphic. Each of these types is part of the rock cycle. Through changes in conditions one rock type can become another rock type. Or it can become a different rock of the same type.

What Are Rocks?

A rock is a naturally formed, non-living earth material. Rocks are made of collections of mineral grains that are held together in a firm, solid mass (**Figure 1.1**).

How is a rock different from a mineral? Rocks are made of minerals. The mineral grains in a rock may be so tiny that you can only see them with a microscope, or they may be as big as your fingernail or even your finger (**Figure 1.2**).

Rocks are identified primarily by the minerals they contain and by their texture. Each type of rock has a distinctive set of minerals. A rock may be made of grains of all one mineral type, such as quartzite. Much more commonly, rocks are made of a mixture of different minerals. Texture is a description of the size, shape, and arrangement of mineral grains. Are the two samples in **Figure 1.3** the same rock type? Do they have the same minerals? The same texture?

**FIGURE 1.1**

The different colors and textures seen in this rock are caused by the presence of different minerals.

**FIGURE 1.2**

A pegmatite from South Dakota with crystals of lepidolite, tourmaline, and quartz (1 cm scale on the upper left).

**FIGURE 1.3**

Rock samples

TABLE 1.1: (continued)

Sample	Minerals	Texture	Formation	Rock type
TABLE 1.1: Comparing properties of Sample 1 and Sample 2				
Sample	Minerals	Texture	Formation	Rock type
Sample 1	plagioclase, hornblende, pyroxene	Crystals, visible to naked eye	Magma cooled slowly	Diorite
Sample 2	plagioclase, hornblende, pyroxene	One type of crystal visible, rest microscopic	Magma erupted and cooled quickly	Andesite

As seen in **Table 1.1**, these two rocks have the same chemical composition and contain mostly the same minerals, but they do not have the same texture. Sample 1 has visible mineral grains, but Sample 2 has some visible grains in a fine matrix. The two different textures indicate different histories. Sample 1 is a diorite, a rock that cooled slowly from magma (molten rock) underground. Sample 2 is an andesite, a rock that cooled rapidly from a very similar magma that erupted onto Earth's surface.

Three Main Categories of Rocks

Rocks are classified into three major groups according to how they form. Rocks can be studied in hand samples that can be moved from their original location. Rocks can also be studied in **outcrop**, exposed rock formations that are attached to the ground, at the location where they are found.

Igneous Rocks

Igneous rocks form from cooling magma. Magma that erupts onto Earth's surface is lava, as seen in **Figure 1.4**. The chemical composition of the magma and the rate at which it cools determine what rock forms as the minerals cool and crystallize.

**FIGURE 1.4**

This flowing lava is molten rock that will harden into an igneous rock.

Sedimentary Rocks

Sedimentary rocks form by the compaction and cementing together of **sediments**, broken pieces of rock-like gravel, sand, silt, or clay (**Figure 1.5**). Those sediments can be formed from the weathering and erosion of preexisting rocks. Sedimentary rocks also include chemical **precipitates**, the solid materials left behind after a liquid evaporates.



FIGURE 1.5

This sedimentary rock is made of sand that is cemented together to form a sandstone.

Metamorphic Rocks

Metamorphic rocks form when the minerals in an existing rock are changed by heat or pressure within the Earth. See **Figure 1.6** for an example of a metamorphic rock.



FIGURE 1.6

Quartzite is a metamorphic rock formed when quartz sandstone is exposed to heat and pressure within the Earth.

A simple explanation of the three rock types and how to identify them can be seen in this video: <http://www.youtube.com/watch?v=tQUE9C40NEE&feature=fvw>.

This video discusses how to identify igneous rocks: <http://www.youtube.com/watch?v=Q0XtLjE3siE&feature=channel>.

This video discusses how to identify a metamorphic rocks: http://www.youtube.com/watch?v=qs9x_bTCiew&feature=related.

This *Science Made Fun* video discusses the conditions under which the three main rock types form (3c): <http://www.youtube.com/watch?v=G7AWGhQynTY&feature=related> (3:41).



MEDIA

Click image to the left for more content.

The way scientists measure earthquake intensity and the two most common scales, Richter and Moment Magnitude, are described along with a discussion of the 1906 San Francisco earthquake in *Measuring Earthquakes* video (3c):

http://www.youtube.com/watch?v=wtlu_aDteCA (2:54).



MEDIA

Click image to the left for more content.

The Rock Cycle

Rocks change as a result of natural processes that are taking place all the time. Most changes happen very slowly; many take place below the Earth's surface, so we may not even notice the changes. Although we may not see the changes, the physical and chemical properties of rocks are constantly changing in a natural, never-ending cycle called the **rock cycle**.

The concept of the rock cycle was first developed by James Hutton, an eighteenth century scientist often called the “Father of Geology” (shown in **Figure 1.7**). Hutton recognized that geologic processes have “no [sign] of a beginning, and no prospect of an end.” The processes involved in the rock cycle often take place over millions of years. So on the scale of a human lifetime, rocks appear to be “rock solid” and unchanging, but in the longer term, change is always taking place.



FIGURE 1.7

James Hutton is considered the Father of Geology.

In the rock cycle, illustrated in **Figure 1.8**, the three main rock types – igneous, sedimentary, and metamorphic – are shown. Arrows connecting the three rock types show the processes that change one rock type into another. The cycle has no beginning and no end. Rocks deep within the Earth are right now becoming other types of rocks. Rocks at the surface are lying in place before they are next exposed to a process that will change them.

Processes of the Rock Cycle

Several processes can turn one type of rock into another type of rock. The key processes of the rock cycle are crystallization, erosion and sedimentation, and metamorphism.

Crystallization

Magma cools either underground or on the surface and hardens into an igneous rock. As the magma cools, different crystals form at different temperatures, undergoing **crystallization**. For example, the mineral olivine crystallizes out

**FIGURE 1.8**

The Rock Cycle.

of magma at much higher temperatures than quartz. The rate of cooling determines how much time the crystals will have to form. Slow cooling produces larger crystals.

Erosion and Sedimentation

Weathering wears rocks at the Earth's surface down into smaller pieces. The small fragments are called sediments. Running water, ice, and gravity all transport these sediments from one place to another by **erosion**. During **sedimentation**, the sediments are laid down or deposited. In order to form a sedimentary rock, the accumulated sediment must become compacted and cemented together.

Metamorphism

When a rock is exposed to extreme heat and pressure within the Earth but does not melt, the rock becomes metamorphosed. **Metamorphism** may change the mineral composition and the texture of the rock. For that reason, a metamorphic rock may have a new mineral composition and/or texture.

Lesson Summary

- Rocks are collections of minerals of various sizes and types.
- The three main rock types are igneous, sedimentary, and metamorphic.
- Crystallization, erosion and sedimentation, and metamorphism transform one rock type into another or change sediments into rock.
- The rock cycle describes the transformations of one type of rock to another.

Review Questions

1. Describe the difference between a rock and a mineral.
2. Why can the minerals in a rock be a clue about how the rock formed?
3. What are the three main types of rocks and how does each form?
4. Describe how an igneous rock changes into a metamorphic rock.
5. Describe how an igneous rock changes into a sedimentary rock.
6. Explain how sediments form.
7. In which rock type do you think fossils, which are the remains of past living organisms, are most often found?

Further Reading / Supplemental Links

- An interactive, illustrated rock cycle diagram is seen here: <http://www.learner.org/interactives/rockcycle/diagram.html>.

Points to Consider

- If Earth's interior were no longer hot but all other processes on Earth continued unchanged, what would happen to the different rock types in the rock cycle?
- Stone tools were important to early humans. Are rocks still important to humans today?

1.2 Igneous Rocks

Lesson Objectives

- Describe how igneous rocks form.
- Describe the properties of some common types of igneous rocks.
- Relate some common uses of igneous rocks.

Vocabulary

- Bowen's Reaction Series
- extrusive
- felsic
- fractional crystallization
- intermediate
- intrusive
- mafic
- partial melting
- pluton
- porphyritic
- ultramafic
- vesicular
- volcanic rock

Introduction

Igneous rocks form from the cooling and hardening of molten magma in many different environments. These rocks are identified by their composition and texture. More than 700 different types of igneous rocks are known.

Magma Composition

The rock beneath the Earth's surface is sometimes heated to high enough temperatures that it melts to create magma. Different magmas have different composition and contain whatever elements were in the rock that melted. Magmas also contain gases. The main elements are the same as the elements found in the crust. **Table 1.2** lists the abundance of elements found in the Earth's crust and in magma. The remaining 1.5% is made up of many other elements that are present in tiny quantities.

TABLE 1.2: Elements in Earth's Crust and Magma

Element	Symbol	Percent
Oxygen	O	46.6%
Silicon	Si	27.7%
Aluminum	Al	8.1%
Iron	Fe	5.0%
Calcium	Ca	3.6%
Sodium	Na	2.8%

TABLE 1.2: (continued)

Element	Symbol	Percent
Potassium	K	2.6%
Magnesium	Mg	2.1%
Total		98.5%

(Source: http://en.wikipedia.org/wiki/Abundance_of_elements_in_Earth%27s_crust)

Whether rock melts to create magma depends on:

- Temperature: Temperature increases with depth, so melting is more likely to occur at greater depths.
- Pressure: Pressure increases with depth, but increased pressure raises the melting temperature, so melting is less likely to occur at higher pressures.
- Water: The addition of water changes the melting point of rock. As the amount of water increases, the melting point decreases.
- Rock composition: Minerals melt at different temperatures, so the temperature must be high enough to melt at least some minerals in the rock. The first mineral to melt from a rock will be quartz (if present) and the last will be olivine (if present).

The different geologic settings that produce varying conditions under which rocks melt will be discussed in the “Plate Tectonics” chapter.

As a rock heats up, the minerals that melt at the lowest temperatures will melt first. **Partial melting** occurs when the temperature on a rock is high enough to melt only some of the minerals in the rock. The minerals that will melt will be those that melt at lower temperatures. **Fractional crystallization** is the opposite of partial melting. This process describes the crystallization of different minerals as magma cools.

Bowen’s Reaction Series indicates the temperatures at which minerals melt or crystallize (**Figure 1.9**). An understanding of the way atoms join together to form minerals leads to an understanding of how different igneous rocks form. Bowen’s Reaction Series also explains why some minerals are always found together and some are never found together.

To see a diagram illustrating Bowen’s Reaction Series, visit this website: <http://csmres.jmu.edu/geollab/Fichter/RockMin/RockMin.html>.

This excellent video that explains Bowen’s Reaction Series in detail: <http://www.youtube.com/watch?v=en6ihAM9f e8>.

If the liquid separates from the solids at any time in partial melting or fractional crystallization, the chemical composition of the liquid and solid will be different. When that liquid crystallizes, the resulting igneous rock will have a different composition from the parent rock.

Intrusive and Extrusive Igneous Rocks

Igneous rocks are called **intrusive** when they cool and solidify beneath the surface. Intrusive rocks form plutons and so are also called plutonic. A **pluton** is an igneous intrusive rock body that has cooled in the crust. When magma cools within the Earth, the cooling proceeds slowly. Slow cooling allows time for large crystals to form, so intrusive igneous rocks have visible crystals. Granite is the most common intrusive igneous rock (see **Figure 1.10** for an example).

Igneous rocks make up most of the rocks on Earth. Most igneous rocks are buried below the surface and covered with sedimentary rock, or are buried beneath the ocean water. In some places, geological processes have brought igneous rocks to the surface. **Figure 1.11** shows a landscape in California’s Sierra Nevada made of granite that has been raised to create mountains.

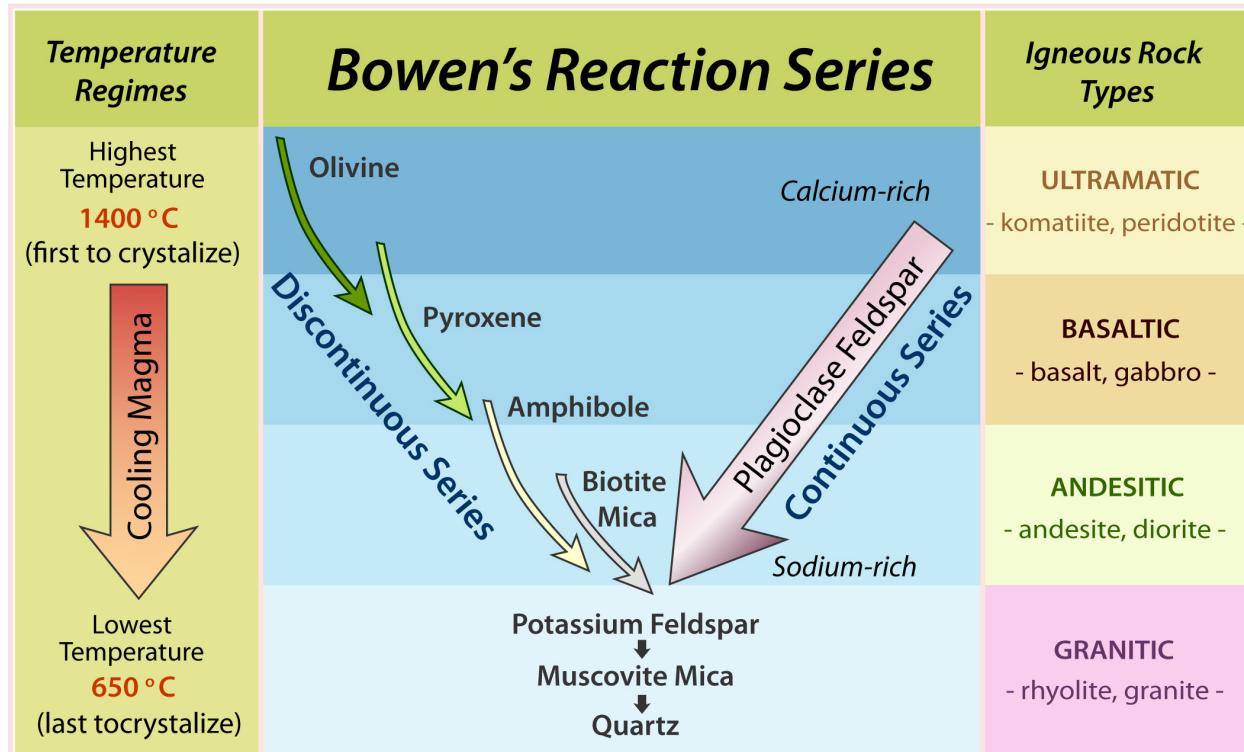


FIGURE 1.9

Bowen

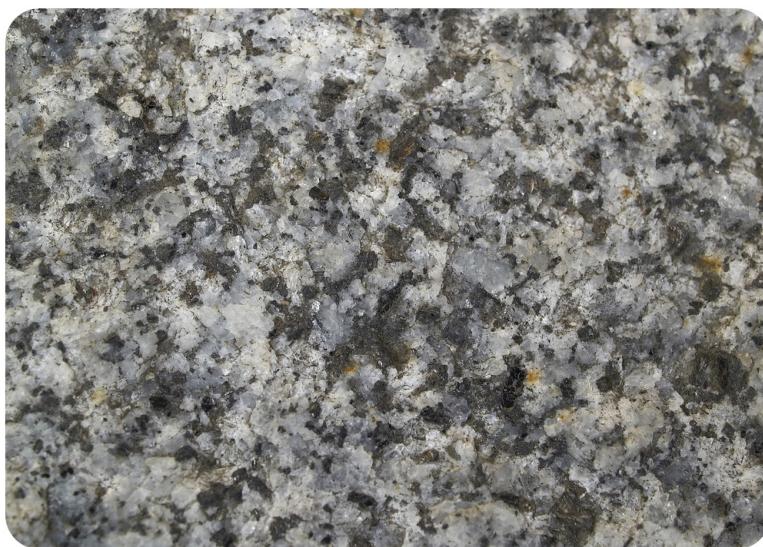


FIGURE 1.10

Granite is made of four minerals, all visible to the naked eye: feldspar (white), quartz (translucent), hornblende (black), and biotite (black, platy).



FIGURE 1.11

California

Igneous rocks are called **extrusive** when they cool and solidify above the surface. These rocks usually form from a volcano, so they are also called **volcanic rocks** ([Figure 1.12](#)).



FIGURE 1.12

Extrusive igneous rocks form after lava cools above the surface.

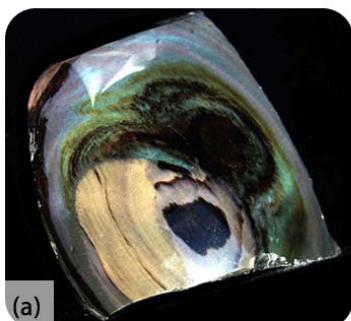
Extrusive igneous rocks cool much more rapidly than intrusive rocks. There is little time for crystals to form, so extrusive igneous rocks have tiny crystals ([Figure 1.13](#)).

What does the andesite photo in the lesson *Types of Rocks* indicate about how that magma cooled? The rock has large crystals set within a matrix of tiny crystals. In this case, the magma cooled enough to form some crystals before erupting. Once erupted, the rest of the lava cooled rapidly. This is called **porphyritic** texture.

Cooling rate and gas content create other textures (see [Figures 1.14](#) for examples of different textures). Lavas that cool extremely rapidly may have a glassy texture. Those with many holes from gas bubbles have a **vesicular** texture.

**FIGURE 1.13**

Cooled lava forms basalt with no visible crystals. Why are there no visible crystals?



(a)



(b)



(c)

Obsidian is lava that cools so rapidly crystals do not form, creating natural glass.

Pumice contains holes where gas bubbles were trapped in the molten lava, creating vesicular texture. The holes make pumice so light that it can float on water.

The most common extrusive igneous rock is basalt because it makes up most of the seafloor. These are examples of basalt below the South Pacific Ocean.

FIGURE 1.14

Different cooling rate and gas content resulted in these different textures.

Igneous Rock Classification

Igneous rocks are classified by their composition, from felsic to ultramafic. The characteristics and example minerals in each type are included in **Table 1.3**.

TABLE 1.3: Properties of Igneous Rock Compositions.

Composition	Color	Density	Minerals
Felsic	Light	Low	Quartz, orthoclase feldspar
Intermediate	Intermediate	Intermediate	Plagioclase feldspar, biotite, amphibole
Mafic	Dark	High	Olivine, pyroxene
Ultramafic	Very dark	Very high	Olivine

TABLE 1.4: Silica Composition and Texture of Major Igneous Rocks.

Type	Amount of Silica	Extrusive	Intrusive	
Ultramafic	<45%	Komatiite	Peridotite	
Mafic	45-52%	Basalt	Gabbro	
Intermediate	52-63%	Andesite	Diorite	13
Intermediate-Felsic	63-69%	Dacite	Granodiorite	
Felsic	>69% SiO ₂	Rhyolite	Granite	

**FIGURE 1.16**

Granite is an igneous rock used commonly in statues and building materials.

around the house. When pumice is placed into giant washing machines with newly manufactured jeans and tumbled, the result is “stone-washed” jeans. Ground up pumice stone is sometimes added to toothpaste to act as an abrasive material to scrub teeth.

Peridotite is sometimes mined for peridot, a type of olivine that is used in jewelry. Diorite was used extensively by ancient civilizations for vases and other decorative artwork and is still used for art today ([Figure 1.17](#)).

**FIGURE 1.17**

This diorite vase was made by ancient Egyptians about 3600 BC.

Lesson Summary

- Igneous rocks form either when they cool very slowly deep within the Earth (intrusive) or when magma cools rapidly at the Earth’s surface (extrusive).
- Rock may melt to create magma if temperature increases, pressure decreases, or water is added. Different minerals melt at different temperatures.
- Igneous rocks are classified on their composition and grain size, which indicates whether they are intrusive or extrusive.

Review Questions

1. What is the visible difference between an intrusive and an extrusive igneous rock?
2. How does the difference in the way intrusive and extrusive rocks form lead to the differences in how the rocks appear?

3. What causes solid rocks to melt?
4. How are partial melting and fractional crystallization the same and different from each other?
5. How are igneous rocks classified?
6. Describe two ways granite is different from basalt.
7. List three common uses of igneous rocks.
8. Occasionally, igneous rocks contain both large crystals and tiny mineral crystals. Propose a way that both sizes of crystals might have formed in the rock.
9. How do you imagine an igneous rock will cool on the seafloor, and what will be the size of its crystals?

Further Reading / Supplemental Links

- A way to learn about the three rock types and some of the rocks within each type: <http://geology.com/rocks/>

Points to Consider

- Are igneous rocks forming right now?
- Why don't all igneous rocks with the same composition have the same name?
- Could an igneous rock cool at two different rates? What would the crystals in such a rock look like?

1.3 Sedimentary Rocks

Lesson Objectives

- Describe how sedimentary rocks form.
- Describe the properties of some common sedimentary rocks.
- Relate some common uses of sedimentary rocks.

Vocabulary

- biochemical sedimentary rocks
- bioclastic
- cementation
- chemical sedimentary rocks
- clastic
- compaction
- lithification
- organic

Introduction



FIGURE 1.18

The White House of the USA is made of a sedimentary rock called sandstone.

The White House (shown in the **Figure 1.18**) is the official home and workplace of the President of the United States of America. Why do you think the White House is white? If you answered, “Because it is made of white rock,” you would be only partially correct. Construction for the White House began in 1792. Its outside walls are made of the sedimentary rock sandstone. This sandstone is very porous and is easily penetrated by rainwater. Water damage was common in the early days of construction for the building. To stop the water damage, workers covered the sandstone in a mixture of salt, rice, and glue, which help to give the White House its distinctive white color.

Sediments

Sandstone is one of the common types of sedimentary rocks that form from sediments. There are many other types. Sediments may include:

- fragments of other rocks that often have been worn down into small pieces, such as sand, silt, or clay.
- **organic** materials, or the remains of once-living organisms.
- chemical precipitates, which are materials that get left behind after the water evaporates from a solution.

Rocks at the surface undergo mechanical and chemical weathering. These physical and chemical processes break rock into smaller pieces. Physical weathering simply breaks the rocks apart. Chemical weathering dissolves the less stable minerals. These original elements of the minerals end up in solution and new minerals may form. Sediments are removed and transported by water, wind, ice, or gravity in a process called erosion (**Figure 1.19**). Much more information about weathering can be found in the “Weathering and Formation of Soil” chapter. Erosion is described in detail in the “Erosion and Deposition” chapter.



FIGURE 1.19

Water erodes the land surface in Alaska

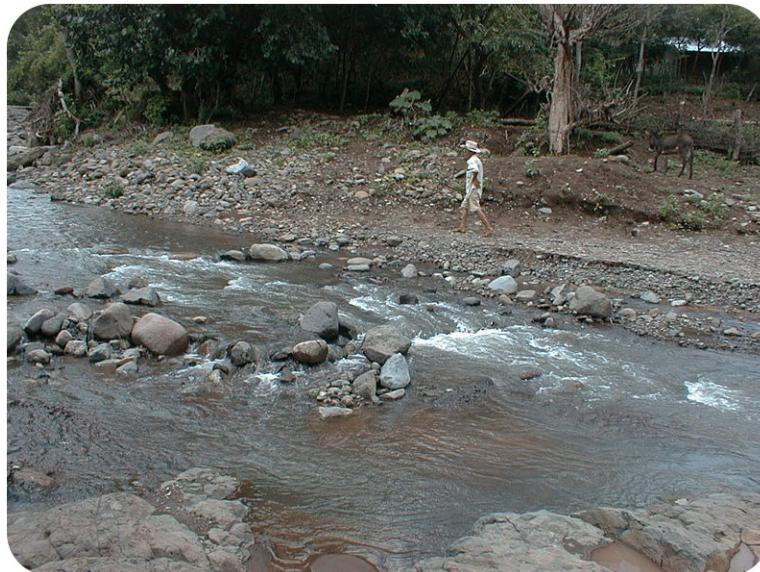
Streams carry huge amounts of sediment (**Figure 1.20**). The more energy the water has, the larger the particle it can carry. A rushing river on a steep slope might be able to carry boulders. As this stream slows down, it no longer has the energy to carry large sediments and will drop them. A slower moving stream will only carry smaller particles.

Sediments are deposited on beaches and deserts, at the bottom of oceans, and in lakes, ponds, rivers, marshes, and swamps. Avalanches drop large piles of sediment. Glaciers leave large piles of sediments, too. Wind can only transport sand and smaller particles. The type of sediment that is deposited will determine the type of sedimentary rock that can form. Different colors of sedimentary rock are determined by the environment where they are deposited. Red rocks form where oxygen is present. Darker sediments form when the environment is oxygen poor.

Sedimentary Rock Formation

Accumulated sediments harden into rock by **lithification**, as illustrated in the **Figure 1.21**. Two important steps are needed for sediments to lithify.

1. Sediments are squeezed together by the weight of overlying sediments on top of them. This is called **compaction**. Cemented, non-organic sediments become **clastic** rocks. If organic material is included, they are **bioclastic** rocks.

**FIGURE 1.20**

A river dumps sediments along its bed and on its banks.

- Fluids fill in the spaces between the loose particles of sediment and crystallize to create a rock by **cementation**.

The sediment size in clastic sedimentary rocks varies greatly (see **Table 1.5**).

**FIGURE 1.21**

This cliff is made of sandstone. Sands were deposited and then lithified.

TABLE 1.5: Sedimentary rock sizes and features.

Rock	Sediment Size	Other Features
Conglomerate	Large	Rounded
Breccia	Large	Angular
Sandstone	Sand-sized	
Siltstone	Silt-sized, smaller than sand	
Shale	Clay-sized, smallest	

¹⁸When sediments settle out of calmer water, they form horizontal layers. One layer is deposited first, and another layer is deposited on top of it. So each layer is younger than the layer beneath it. When the sediments harden, the

Biochemical sedimentary rocks form in the ocean or a salt lake. Living creatures remove ions, such as calcium, magnesium, and potassium, from the water to make shells or soft tissue. When the organism dies, it sinks to the ocean floor to become a biochemical sediment, which may then become compacted and cemented into solid rock ([Figure 1.23](#)).



FIGURE 1.23

Fossils in a biochemical rock, limestone, in the Carmel Formation in Utah.

[Table 1.6](#) shows some common types of sedimentary rocks.

TABLE 1.6: Common Sedimentary Rocks

Picture	Rock Name	Type of Sedimentary Rock
	Conglomerate	Clastic (fragments of non-organic sediments)
	Breccia	Clastic

TABLE 1.6: (continued)

Picture	Rock Name	Type of Sedimentary Rock
	Sandstone	Clastic
	Siltstone	Clastic
	Shale	Clastic
	Rock Salt	Chemical precipitate
	Rock Gypsum	Chemical precipitate
	Dolostone	Chemical precipitate
		

TABLE 1.6: (continued)

Picture	Rock Name	Type of Sedimentary Rock
	Limestone	Bioclastic (sediments from organic materials, or plant or animal remains)
	Coal	Organic

Uses of Sedimentary Rocks

Sedimentary rocks are used as building stones, although they are not as hard as igneous or metamorphic rocks. Sedimentary rocks are used in construction. Sand and gravel are used to make concrete; they are also used in asphalt. Many economically valuable resources come from sedimentary rocks. Iron ore and aluminum are two examples.

Lesson Summary

- Weathering and erosion produce sediments. Sediments are transported by water, wind, ice, or gravity.
- After sediments are deposited, they undergo compaction and/or cementation to become sedimentary rocks.
- Biochemical sedimentary rocks form when living creatures use ions in water to create shells, bones, or soft tissue die and fall to the bottom as sediments.

Review Questions

1. What are three categories of things that might be part of the sediments in sedimentary rock?
2. If you see a sedimentary rock outcrop with layers of red sandstone on top of layers of tan sandstone, what do you know about the ages of the two layers?
3. Why do sedimentary rocks sometimes have layers of different colors?
4. Describe the two processes necessary for sediments to lithify into sedimentary rock.
5. How are bioclastic rocks different from clastic rocks? Give an example of a bioclastic rock.
6. What type of sedimentary rock is coal?
7. In what environment do you think chemical sedimentary rocks are most likely to form?

Further Reading / Supplemental Links

- A way to learn about the three rock types and some of the rocks within each type: <http://geology.com/rocks/>

Points to Consider

- Is a rock always made of minerals? Do the requirements for something to be a mineral need to be met for something to be a rock?
- Which type of rocks do you think yield the most information about Earth's past?
- Could a younger layer of sedimentary rock ever be found under an older layer? How do you think this could happen?
- Could a sedimentary rock form only by compaction from intense pressure?

1.4 Metamorphic Rocks

Lesson Objectives

- Describe how metamorphic rocks form.
- Describe the properties of some common metamorphic rocks.
- Relate some common uses of metamorphic rocks.

Vocabulary

- contact metamorphism
- foliation
- regional metamorphism

Introduction

In the large outcrop of metamorphic rocks in **Figure 1.24**, the rocks' platy appearance is a result of the process metamorphism. Metamorphism is the addition of heat and/or pressure to existing rocks, which causes them to change physically and/or chemically so that they become a new rock. Metamorphic rocks may change so much that they may not resemble the original rock.



FIGURE 1.24

The platy layers in this large outcrop of metamorphic rock show the effects of pressure on rocks during metamorphism.

Metamorphism

Any type of rock – igneous, sedimentary, or metamorphic - can become a metamorphic rock. All that is needed is enough heat and/or pressure to alter the existing rock's physical or chemical makeup without melting the rock entirely. Rocks change during metamorphism because the minerals need to be stable under the new temperature and pressure conditions. The need for stability may cause the structure of minerals to rearrange and form new minerals.

Ions may move between minerals to create minerals of different chemical composition. Hornfels, with its alternating bands of dark and light crystals, is a good example of how minerals rearrange themselves during metamorphism. Hornfels is shown in **Table 1.7**.

Extreme pressure may also lead to **foliation**, the flat layers that form in rocks as the rocks are squeezed by pressure (**Figure 1.25**). Foliation normally forms when pressure is exerted in only one direction. Metamorphic rocks may also be non-foliated. Quartzite and limestone, shown in **Table 1.7**, are nonfoliated.



FIGURE 1.25

A foliated metamorphic rock.

The two main types of metamorphism are both related to heat within Earth:

1. **Regional metamorphism:** Changes in enormous quantities of rock over a wide area caused by the extreme pressure from overlying rock or from compression caused by geologic processes. Deep burial exposes the rock to high temperatures.
2. **Contact metamorphism:** Changes in a rock that is in contact with magma because of the magma's extreme heat.

Table 1.7 shows some common metamorphic rocks and their original parent rock.

TABLE 1.7: Common Metamorphic Rocks

Picture	Rock Name	Type of Metamorphic Rock	Comments
	Slate	Foliated	Metamorphism of shale

TABLE 1.7: (continued)

Picture	Rock Name	Type of Metamorphic Rock	Comments
	Phyllite	Foliated	Metamorphism of slate, but under greater heat and pressure than slate
	Schist	Foliated	Often derived from metamorphism of claystone or shale; metamorphosed under more heat and pressure than phyllite
	Gneiss	Foliated	Metamorphism of various different rocks, under extreme conditions of heat and pressure
	Hornfels	Non-foliated	Contact metamorphism of various different rock types
	Quartzite	Non-foliated	Metamorphism of sandstone
	Marble	Non-foliated	Metamorphism of limestone

TABLE 1.7: (continued)

Picture	Rock Name	Type of Metamorphic Rock	Comments
	Metaconglomerate	Non-foliated	Metamorphism of conglomerate

Uses of Metamorphic Rocks

Quartzite and marble are commonly used for building materials and artwork. Marble is beautiful for statues and decorative items such as vases (see an example in [Figure 1.26](#)). Ground up marble is also a component of toothpaste, plastics, and paper.

**FIGURE 1.26**

Marble is used for decorative items and in art.

Quartzite is very hard and is often crushed and used in building railroad tracks (see [Figure 1.27](#)). Schist and slate are sometimes used as building and landscape materials. Graphite, the “lead” in pencils, is a mineral commonly found in metamorphic rocks.

Lesson Summary

- Metamorphic rocks form when heat and pressure transform an existing rock into a new rock.
- Contact metamorphism occurs when hot magma transforms the rock that it contacts.
- Regional metamorphism transforms large areas of existing rocks under the tremendous heat and pressure created by geologic processes.

Review Questions

1. Why do minerals change composition as they undergo metamorphism?
2. Describe the process by which minerals in a rock rearrange to become different minerals when exposed to heat or pressure.
3. Describe the conditions that lead to foliated versus non-foliated metamorphic rocks.

**FIGURE 1.27**

Crushed quartzite is sometimes placed under railroad tracks because it is very hard and durable.

4. List and describe the two main types of metamorphism.
5. What can geologists look at in a metamorphic rock to understand that rock's history?
6. Suppose a phyllite sample was metamorphosed again. How might it look different after this second round of metamorphism?

Further Reading / Supplemental Links

- Film: The Living Rock: Earth's Continental Crust http://media.wr.usgs.gov/movies/index.html?id=living_rock.

Points to Consider

- What type of rock forms if an existing rock heats up so much that it melts completely and then forms a different rock?
- What clues can a rock give about its history if it was so altered by metamorphism that it is unrecognizable?

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