Name _____ Class _____ Date _____

CHAPTER 16 Groundwater

SECTION 1

Water Beneath the Surface

KEY IDEAS

As you read this section, keep these questions in mind:

- What are two properties of aquifers?
- How is the water table related to the land surface?
- How are wells, springs, and artesian formations related?
- What are two features formed by hot groundwater?

What Is Groundwater?

Some of Earth's fresh water is in streams and lakes, but much of it is found underground. Surface water seeps through the soil and into the upper layers of Earth's crust. It settles into the spaces between underground rocks. This water is called **groundwater**. A layer of rock or sediment that holds groundwater is called an **aquifer**.

READING TOOLBOX

Take Notes As you read this section, create combination notes that express information about groundwater in words and pictures or diagrams.

How Does Water Flow Through an Aquifer?

Groundwater flows downward because of gravity, but water flows through some aquifers more easily than others. Aquifers have two main properties that affect water flow: porosity and permeability. ☑

READING CHECK

1. Explain What are the two properties of an aquifer that affect water flow?

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Pores are open spaces between the particles in a rock or sediment. **Porosity** is the percentage of a rock or sediment that pores take up. A rock with high porosity is said to be more *porous* than one with low porosity. Three main factors affect porosity:

- sorting
- particle size
- particle shape

Well-sorted sediment contains particles that are all about the same size. Poorly sorted sediment contains particles of different sizes. In general, well-sorted sediments are more porous than poorly sorted sediments.

If you fill a jar with pebbles, there will be open spaces between the pebbles. If you pour sand into the jar, the sand fills the spaces between the pebbles. The mixture of sand and pebbles is less porous because it is poorly sorted.

LOOKING CLOSER

2. Identify Which of these pictures represents an aquifer with high porosity? Which represents an aquifer with low porosity?

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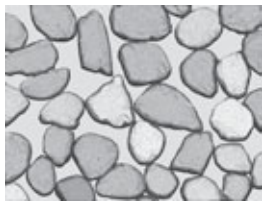
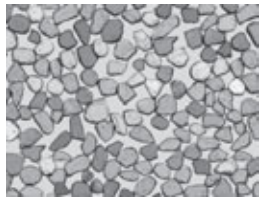
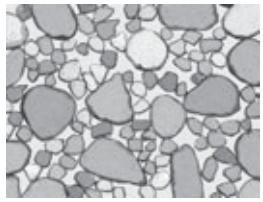


Well sorted



Well sorted



Poorly sorted

Particle packing also affects porosity. If the particles in an aquifer are packed together tightly, there are few spaces between them. Therefore, the aquifer is less porous. If the particles are loosely packed, the spaces between them are larger. Therefore, the aquifer is more porous.

The shape of the particles affects porosity as well. If the particles have an irregular shape, the aquifer will have a higher porosity.

PERMEABILITY

If the open spaces in the rock layer are connected, water can move through the rock. A rock's ability to let water pass through is called **permeability**. Rock that water cannot flow through is called *impermeable*.

The size and sorting of rock particles affects permeability. Rock made of large, well-sorted particles tends to have a high permeability. For example, sandstone is very permeable. Limestone may be permeable if it contains cracks that are connected to each other. Clay is made of flat, very small particles. The particles stick tightly together and prevent water from moving between them. Therefore, clay is impermeable.

Critical Thinking

3. Make Connections Can a material have a high porosity but a low permeability? Explain your answer.

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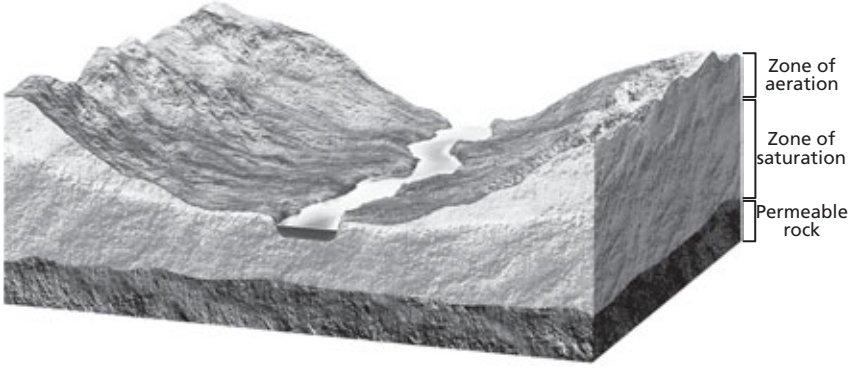
This rock is permeable because its pores are connected to each other. Therefore, water can flow easily between the pores.

What Are the Parts of an Aquifer?

Gravity pulls rainwater down through the soil and into the spaces within an aquifer. Some aquifers lie just below the soil. Scientists divide these aquifers into two zones: the zone of saturation and the zone of aeration.

The *zone of saturation* is the area where most of the water collects. The spaces between particles in the zone of saturation are filled with only water. The top of the zone of saturation is called the **water table**. The *zone of aeration* is the area that rainwater passes through to reach the zone of saturation.



Groundwater soaks into the ground, passes through the zone of aeration, and collects in the zone of saturation.

The zone of aeration has three layers. The top layer of the zone of aeration is the soil moisture region. This layer is made of grains of topsoil. Each grain is surrounded by a thin layer of water.

The second layer takes up most of the zone of aeration. In this layer, the pores between particles contain both water and air.

The bottom layer of the zone of aeration is the *capillary fringe*. Small amounts of water move upward from the zone of saturation, through the capillary fringe, to the zone of aeration. The water moves upward because it is attracted to the particles in the capillary fringe. The pores in the capillary fringe contain both air and water. However, they contain more water than the pores in the main part of the zone of aeration. ☑

Talk About It

Infer Use a dictionary to look up the meaning of the word *saturated*. With a partner, discuss why the zone of saturation has that name.

LOOKING CLOSER

4. Identify Label the water table in the figure.

READING CHECK

5. Define What is the capillary fringe?

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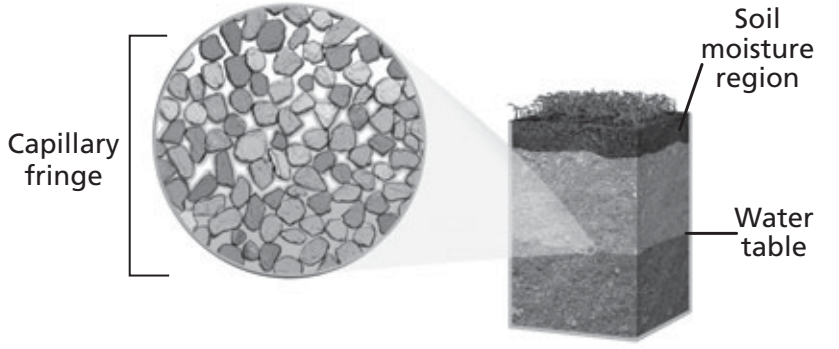

The top of the zone of saturation is the water table. The capillary fringe pulls water upward from the zone of saturation.

LOOKING CLOSER

6. Identify Circle the area in the figure that has the least amount of water per volume of rock.

The depth of the water table is not the same all the time or in all places. For example, the water table can rise closer to the surface during heavy rainfall. It can fall farther from the surface during a drought. In wet regions, the water table may be just below the surface. In dry regions, the water table may be hundreds of meters below the surface.

Critical Thinking

7. Predict If a region receives a lot of rainfall, will the water table in the region probably rise or fall?

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In most areas, there is only one water table. However, in some areas, the main water table is covered with a layer of impermeable rock. The rock layer blocks water from reaching the main zone of saturation. Therefore, water collects on top of the impermeable rock. This creates a second water table, called a *perched water table*.

MOVEMENT OF GROUNDWATER

Groundwater moves downhill, just as surface water does. If an aquifer is nearly flat, the groundwater moves slowly. If the aquifer has a steep slope, the groundwater moves more quickly. The steepness of the aquifer is called its *gradient*.

How Can People Protect Groundwater?

Although groundwater is renewable, it takes a long time for it to renew itself. Groundwater moves slowly. Therefore, the water that we take from aquifers may not renew itself for hundreds or thousands of years.

In many places, groundwater is the only source of fresh water. Therefore, some communities try to conserve groundwater. For example, they might monitor the level of the water table. They might clean and re-use wastewater. They might also prevent people from pumping too much water out of the aquifer.

POLLUTION

People can also have an effect on whether pollution enters an aquifer. For example, people can be careful not to pollute water in a recharge zone. A *recharge zone* is an area where water travels through permeable rock to reach an aquifer. Pollution in a recharge zone can enter an aquifer. A recharge zone can become polluted by fertilizers, chemicals in underground tanks, or leaking sewage systems. ☑

READING CHECK

8. Explain Why is it important to keep a recharge zone clean?

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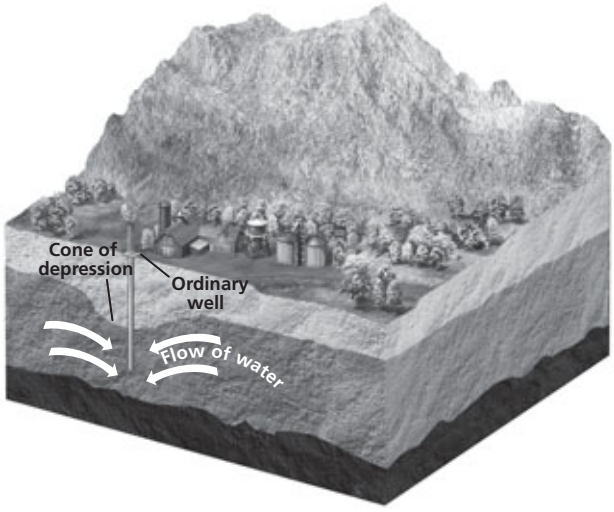
How Are Wells and Springs Different?

Groundwater reaches Earth's surface through wells and springs. A *well* is a hole that people dig that reaches below the level of the water table. A *spring* is a natural flow of groundwater to Earth's surface. Wells and springs are classified into two groups: ordinary and artesian.

ORDINARY WELLS

People dig wells to bring groundwater to Earth's surface. Ordinary wells work only if they reach permeable rock below the water table. If the rock is not permeable enough, it will take a long time for the groundwater to be replaced.

When water is pumped from a well, a *cone of depression* forms. At a cone of depression, the water table becomes much lower. If too much water is removed, the cone of depression may drop below the well. If that happens, the well will dry up. The cone of depression may also cause nearby wells to dry up.



A cone of depression forms in the water table around an ordinary well.

LOOKING CLOSER

9. Predict What would happen if the cone of depression dropped below the bottom of the well?

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ORDINARY SPRINGS

Ordinary springs are generally found in areas with uneven ground. In one spot, the ground is lower than the water table. Groundwater flows along the slope of the water table. When the water table meets Earth's surface, water flows out and forms a spring.

Ordinary springs may not flow continuously. If the water table drops below the level of the spring, the spring will dry up. For example, many springs go dry during a drought. ☑

READING CHECK

10. Describe What would happen to an ordinary spring if the water table dropped below the level of the spring?

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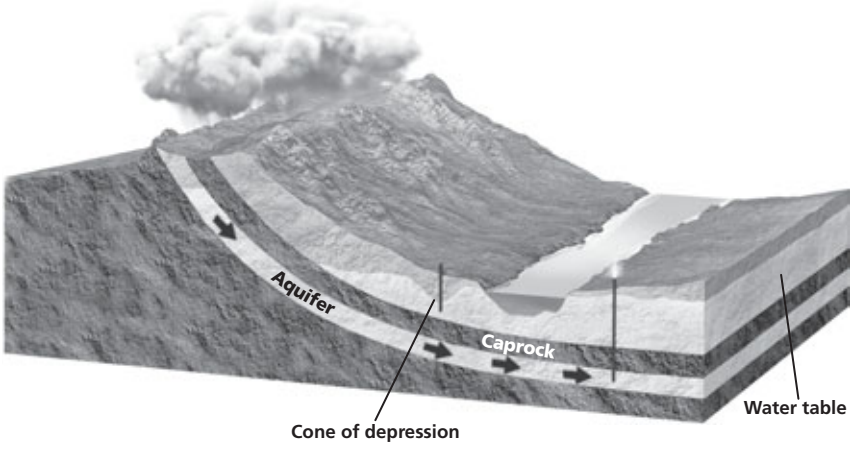
ARTESIAN WELLS AND SPRINGS

In some places, a layer of permeable rock is found between two sloping layers of impermeable rock. This arrangement of rock is called an **artesian formation**. The permeable rock is an aquifer. The top layer of impermeable rock is called the *caprock*.

Water enters the aquifer from a recharge zone, where the permeable rock is not covered by impermeable rock. It then flows downhill through the aquifer. As the water flows downhill, the weight of the water above it puts pressure on it. When a well is drilled in the caprock, the pressure forces the water up through the well. Therefore, people do not need to pump water out of an artesian well. It flows upward on its own.

Talk About It

Evaluate What are the advantages and disadvantages of ordinary wells and artesian wells? Discuss your answers with a partner.



In an artesian formation, the aquifer is covered by caprock. When a well is drilled through the caprock, pressure forces the groundwater upward.

LOOKING CLOSER

11. Identify Label the ordinary and artesian wells in the diagram.

In some places, there are natural cracks in the caprock. Water from the aquifer flows through the cracks. When it reaches the surface, it forms *artesian springs*.

How Do Hot Springs Form?

The water from most springs is cool. However, rock below Earth's surface can be very hot. Therefore, water that flows through deep aquifers may be very hot. When this water reaches the surface, it can form a *hot spring*. ☑

In some areas, chemically weathered rock mixes with hot water from the springs. When this happens, a *mud pot* forms. Mud pots look like puddles of bubbling clay.

READING CHECK

12. Explain What heats the water in a hot spring?

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How Do Geysers Form?

A *geyser* is a type of hot spring that erupts from time to time. A geyser has one or more underground chambers. It also has a vent that connects the chambers to Earth's surface.

Hot rocks surround the underground chambers, so the water in them gets very hot. However, the water does not boil. Its boiling point is very high because it is under a lot of pressure. When the water near the vent finally begins to boil, it produces steam. The steam pushes the water to the surface, where it explodes out of the vent. ☑

READING CHECK

13. Explain Why does the water in a geyser take so long to boil?

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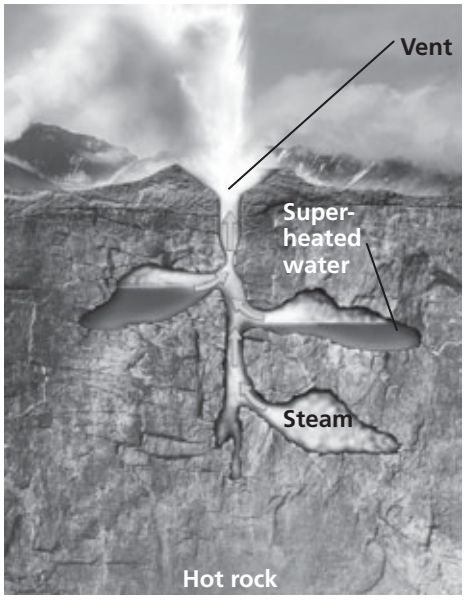
That water is no longer pushing down on the water in the chambers. Therefore, the water in the chambers is under less pressure. The water's boiling point goes down, so it begins to boil. It turns to steam and explodes through the vent. After the eruption, the groundwater begins to collect and the process begins again.



The water in a geyser's chambers gets superheated. When the pressure decreases, the water turns to steam and erupts to the surface.

LOOKING CLOSER

14. Describe What caused the water in the bottom chamber to turn to steam?

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Section 1 Review

SECTION VOCABULARY

aquifer a body of rock or sediment that stores groundwater and allows the flow of groundwater	**permeability** the ability of a rock or sediment to let fluids pass through its open spaces, or pores
artesian formation a sloping layer of permeable rock sandwiched between two layers of impermeable rock and exposed at the surface	**porosity** the percentage of the total volume of a rock or sediment that consists of open spaces
groundwater the water that is beneath Earth's surface	**water table** the upper surface of underground water; the upper boundary of the zone of saturation

1. **Compare** How are the rock layers in an artesian formation different from the rock layers in an ordinary aquifer?

2. **Identify** What are the two properties of an aquifer that affect the flow of groundwater?

3. **Describe** Name the two zones of groundwater, and describe their characteristics.

4. **Apply Concepts** During a hot summer, an ordinary spring in an area dries up. What most likely happened to cause the spring to dry up?

5. **Infer** A person must use a pump to get water out of a certain well. Is the well an ordinary well or an artesian well? Explain your answer.

6. **Identify** What are two land features caused by hot groundwater?