Name _____ Class _____ Date _____

CHAPTER 4 Rocks: Mineral Mixtures

SECTION 4

Metamorphic Rock

BEFORE YOU READ

After you read this section, you should be able to answer these questions:

- How do metamorphic rocks form?
- How do geologists classify metamorphic rocks?

National Science Education Standards

ES 1c

How Does Metamorphic Rock Form?

Metamorphic rock forms when the chemical composition of a rock changes because of heat and pressure. This change is called *metamorphism*. Metamorphism can happen to any kind of rock.

Most metamorphism happens at temperatures between 150°C and 1,000°C. Some metamorphism happens at even higher temperatures. Many people think that all rocks must melt at such high temperatures. However, these rocks are also under very high pressure, so they do not melt.

High pressure can keep a hot rock from melting. Even very hot rocks may not melt if the pressure is high. Instead of melting, the minerals in the rock react with each other to form new minerals. In this way, the composition of the rock can change, even though the rock remains solid. ☑

High pressure can also affect the minerals in a rock. It can cause minerals to react quickly. It can also cause minerals to move slowly through the rock. In this way, different minerals can separate into stripes in the rock. The figure below shows an example of these stripes.

The bands in this metamorphic rock formed as molecules of different minerals moved together.

STUDY TIP

Ask Questions Read this section quietly to yourself. As you read, write down any questions you have. When you finish reading, try to figure out the answer to your questions in a small group.

READING CHECK

1. Describe How does the composition of a rock change during metamorphism?

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TAKE A LOOK

2. Identify How did the bands in the rock in the figure form?

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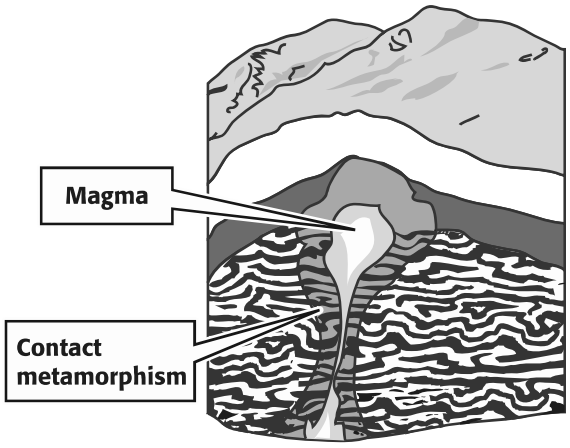
CONTACT METAMORPHISM

There are two main ways that rock can go through metamorphism—contact metamorphism and regional metamorphism. *Contact metamorphism* happens when rock is heated by nearby magma. As the magma moves through the crust, the rocks in the crust heat up. The minerals in those rocks can react to produce new minerals.



Contact metamorphism happens when magma heats nearby rock.

TAKE A LOOK

3. Define What is contact metamorphism?

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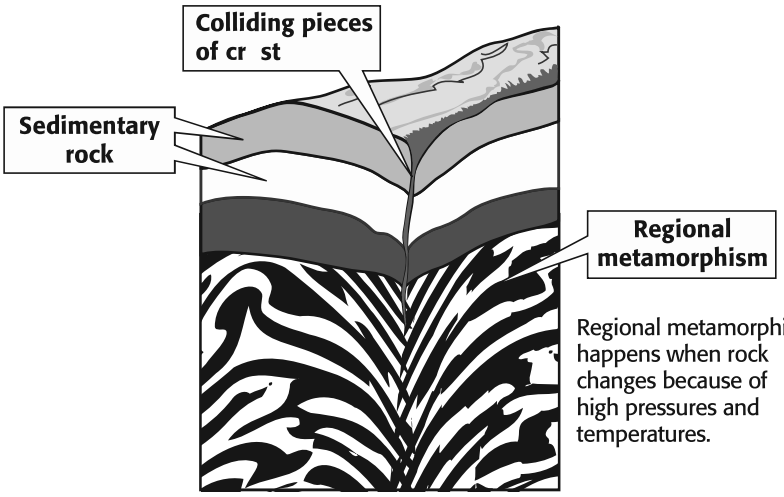
Rock that is very near the magma changes the most during contact metamorphism. The farther the rock is from the magma, the smaller the changes. This is because the temperature decreases with distance from the magma. Contact metamorphism usually only affects rock in a small area.

REGIONAL METAMORPHISM

During *regional metamorphism*, high pressures and temperatures cause the rock in a large area to change. Regional metamorphism can happen where rock is buried deep below the surface or where pieces of the Earth's crust collide.



Regional metamorphism happens when rock changes because of high pressures and temperatures.

TAKE A LOOK

4. Describe Give two places where regional metamorphism can happen.

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METAMORPHIC STRUCTURES

Both contact and regional metamorphism can cause deformation. *Deformation* is a change in the shape of a rock. When forces act on a rock, they may cause the rock to be squeezed or stretched.

Folds are features of a rock that show that the rock has been deformed. Some folds are so small that they can only be seen with a microscope. Other folds, like the ones below, are visible to the naked eye.

These folds formed during metamorphism. The rocks in this picture are found in Labrador, Canada.

TAKE A LOOK

5. Infer Were these folds probably caused by squeezing the rock or by stretching it?

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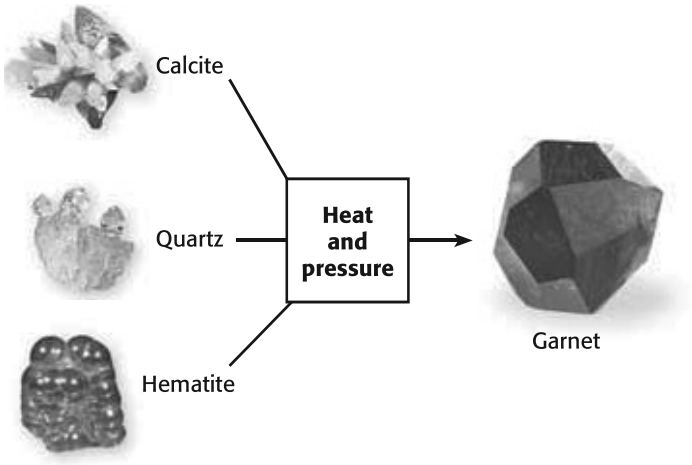
What Are Metamorphic Rocks Made Of?

Remember that different minerals form under different conditions. Minerals that form near the Earth's surface, such as calcite, may not be stable under higher temperatures and pressures. During metamorphism, these minerals are likely to react and produce new minerals. The new minerals are stable under high temperatures and pressures. The figure below shows how new minerals can form from unstable minerals.



Calcite, quartz, and hematite are not stable under high temperatures and pressures. They react to form garnet in metamorphic rocks.

Critical Thinking

6. Predict The mineral gypsum forms at low temperatures and pressures. The mineral sillimanite forms at high temperatures and pressures. Which mineral would most likely be found in a metamorphic rock? Explain your answer.

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INDEX MINERALS

Some minerals, such as quartz, can form at many different temperatures and pressures. Other minerals, such as garnet, form only at certain temperatures and pressures. Therefore, rocks that contain minerals like garnet probably also formed at those temperatures and pressures. Geologists can use such minerals as index minerals.

Index minerals can indicate the temperature and pressure or depth at which a rock formed. These minerals help geologists learn the temperature and pressure at which a rock formed. Chlorite, muscovite, and garnet are index minerals for metamorphic rocks.

Critical Thinking

7. Infer Why can't geologists use minerals like quartz to determine the temperature and pressure that a rock formed at?

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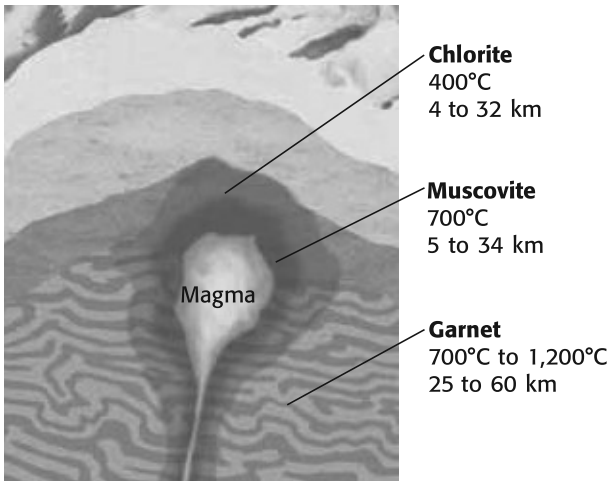

Geologists can use some minerals as index minerals. These minerals help geologists learn the temperature and pressure at which a rock formed. For example, a rock containing garnet most likely formed at a higher temperature and pressure than a rock containing chlorite.

TAKE A LOOK

8. Identify Which index mineral in the figure forms at the lowest temperature?

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How Do Geologists Classify Metamorphic Rocks?

Texture is an important feature that is used in classifying metamorphic rock. The texture of a metamorphic rock refers to the arrangement of the minerals in the rock. All metamorphic rocks have one of two textures—foliated or nonfoliated.

FOLIATED METAMORPHIC ROCK

In a **foliated** metamorphic rock, the minerals are arranged in stripes or bands. Most foliated rocks contain crystals of flat minerals, such as mica. These crystals are lined up with each other and form the bands in the rock. ☑

READING CHECK

9. Define What is a foliated metamorphic rock?

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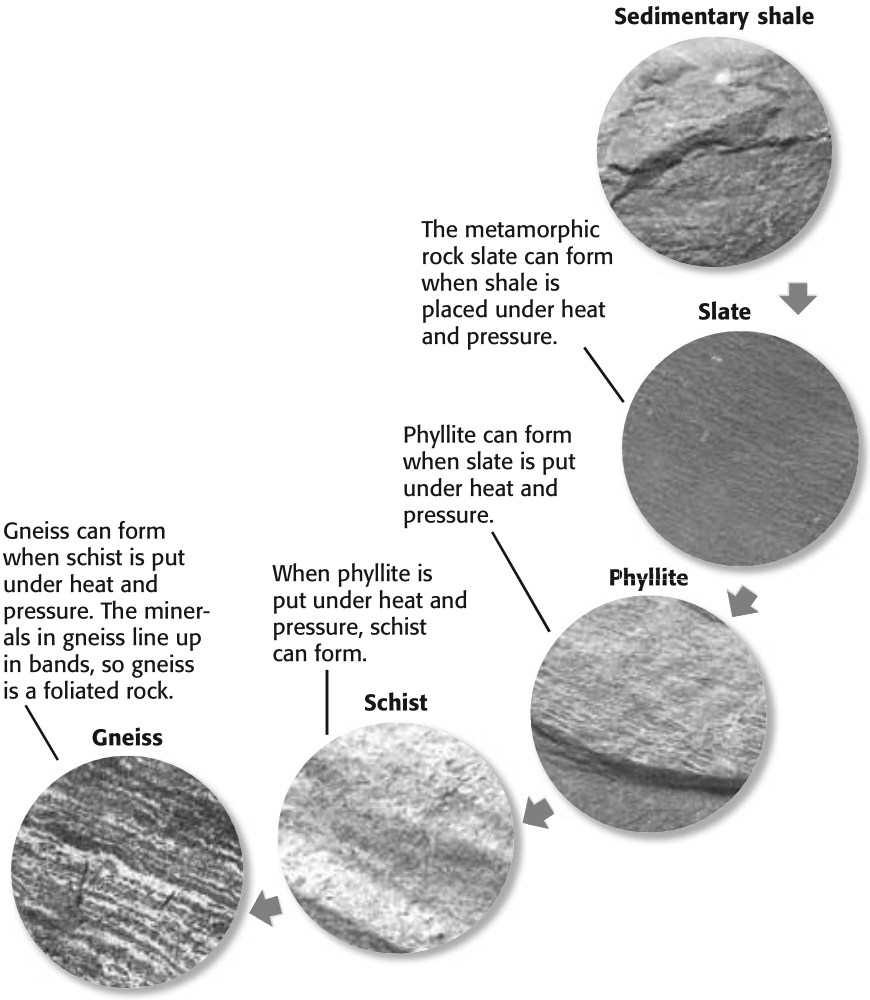
The figure on the next page shows how one kind of foliated rock, gneiss, can form. Gneiss may start out as the sedimentary rock shale. Heat and pressure can change shale to slate, phyllite, schist, or gneiss.



TAKE A LOOK

10. Infer Which rock in the figure has been put under the most heat and pressure?

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UNFOLIATED METAMORPHIC ROCK

In a **nonfoliated** metamorphic rock, the mineral crystals are not arranged in bands or stripes. Most nonfoliated rocks are made of only a few minerals. Metamorphism can cause the mineral crystals in a rock to get bigger. ☑

Quartzite is an example of a nonfoliated metamorphic rock. Quartzite can form from the sedimentary rock quartz sandstone. Quartz sandstone is made of grains of quartz sand that have been cemented together. The quartz crystals in these grains can grow larger during metamorphism. The quartz crystals in quartzite can be much larger than those in quartz sandstone.

READING CHECK

11. Describe What can happen to the sizes of mineral crystals during metamorphism?

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Type of Metamorphic Rock	Description	Example
Foliated		gneiss
Nonfoliated		quartzite

TAKE A LOOK

12. Define Fill in the blank spaces in the table.

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Section 4 Review

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SECTION VOCABULARY

foliated describes the texture of metamorphic rock in which the mineral grains are arranged in planes or bands	**nonfoliated** describes the texture of metamorphic rock in which the mineral grains are not arranged in planes or bands

1. **Compare** How are foliated metamorphic rocks different from nonfoliated metamorphic rocks?

2. **Define** What is regional metamorphism?

3. **Describe** What is an index mineral? Give two examples of index minerals for metamorphic rocks.

4. **Explain** How do index minerals help geologists?

5. **Describe** How does quartzite form?

6. **Apply Concepts** A geologist finds two metamorphic rocks. One contains chlorite. The other contains garnet. Which rock probably formed at the greatest depth? Explain your answer.