## 19.4 Metamorphic Rocks

Unlike an igneous or a sedimentary rock, a **metamorphic rock** is formed when another rock is changed by heat and pressure. In fact, the word *metamorphic* means "changed form." Where on Earth's surface might there be conditions for making a metamorphic rock? As you might imagine, high heat and pressure are created when lithospheric plates come together. Near plate boundaries you find the right conditions for making metamorphic rocks.

**VOCABULARY**

**metamorphic rock** - a rock formed when another rock is changed by heat and pressure.

### Making a metamorphic rock

**Where do you find heat and pressure?**

The boundaries between lithospheric plates are locations with many interesting features such as mountains, volcanic eruptions, and earthquakes. Metamorphic rocks are also formed at these locations. In particular, rocks at convergent plate boundaries are subjected to varying degrees of heat and pressure. If rocks at these boundaries melt, they will cool and crystallize as igneous rocks. However, rocks that are heated and squeezed, but remain intact, will change to become metamorphic rocks.

*Metamorphic rocks are formed by heat and pressure at convergent plate boundaries.*

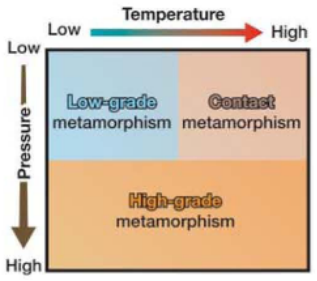



**Figure 19.16:** *Metamorphic rocks form under varying conditions of temperature and pressure.*

**Regional metamorphism**

Metamorphism is described by the size of the affected area. Large-scale metamorphic events, called *regional metamorphism,* occur when lithospheric plates subduct or collide. Metamorphic pressures and temperatures affect rocks for hundreds of kilometers along plate boundaries. Figure 19.16 provides the terms for smaller scale metamorphic events under varying conditions of heat and pressure.

**Contact metamorphism**

Magma rising toward Earth's surface heats surrounding rocks. Because this heating takes place near the point of contact, *contact metamorphism* is the result of high temperature but low pressure. Heat from a magma intrusion only penetrates the cool surrounding rock a few tens of meters, so contact metamorphism typically affects small areas. An example of contact metamorphism occurs when hot magma contacts limestone, a sedimentary rock and the limestone changes into marble (Figure 19.17).


**Figure 19.17:** *Limestone is metamorphosed into marble when it comes in contact with hot magma.*

**Metamorphic grade** Metamorphic grade is a continuous scale that describes the intensity of metamorphism as temperature and pressure increase (Figure 19.16, previous page). During metamorphism, solid minerals change into new solid minerals, without melting, through a process called recrystallization. *Low-grade metamorphism* occurs under conditions of low temperature and low pressure. Typically, clay minerals are recrystallized to form tiny mica flakes which grow perpendicularly to the direction of pressure. These flake-like minerals give the rock the tendency to split along one plane. Slate and phyllite are low-grade metamorphic rocks that form from mudstone. During *high-grade metamorphism*, minerals recrystallize into new minerals. Gneiss is a high-grade metamorphic rock that has light and dark bands of recrystallized minerals that lie across the direction of pressure (see sidebar).

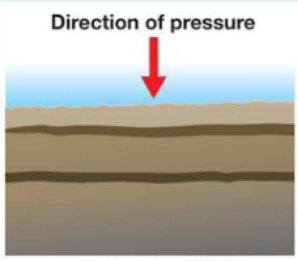
**Changing rocks** The differences between sedimentary and igneous rocks are clearly defined based on how and where they are formed. However, describing the difference between metamorphic rocks and sedimentary or igneous rocks is harder. The table below describes what happens to sediment that undergoes changes in pressure and temperature. Pressure compacts silt and clay into mudstone, a sedimentary rock. Increased pressure changes mudstone into slate and more pressure forms phyllite. Both slate and phyllite are metamorphic rocks. Similarly, increased temperature causes some minerals in gneiss, a metamorphic rock, to melt. But when the rest of the rock melts, it becomes magma that forms igneous rocks. It is important to note that it is difficult to tell the difference between rock types at these transition stages.

Increasing Pressure and Temperature

| Class | Material/Rock | Earth Process |
|---|---|---|
| Sedimentary Rock | Loose silt and clay | Sediments carried to low basins; grains in loose contact |
| | Compact silt and clay | Compaction due to weight of sediments presses grains together; excess water removed |
| | Mudstone | Lithification (rock formation); pressure causes grain points to fuse; pore spaces may fill with other minerals |
| Metamorphic Rock | Slate and phyllite | Clay minerals recrystallize to micas due to pressure; rock develops a tendency to split into sheets |
| | Schist | Minerals are recrystallized and micas increase in size |
| | Gneiss | New minerals form in alternating light and dark bands. |
| | Migmatite | Transition to igneous rock; some minerals in rock begin to melt |
| Igneous Rock | Any | Rock melts forming magma; magma cools and cystallizes to form igneous rocks |

**Pressure and Rocks**

When metamorphic rocks are formed, minerals in a rock change to form new minerals. For example, minerals in clay are altered to form mica. Increased pressure causes the new minerals to form in flat layers perpendicular to the direction of pressure. This is called *foliation*.




Layers of minerals across direction of pressure

Phyllite and gneiss (pronounced as "nice") are two metamorphic rocks that are formed in this way. They have mica flakes that are layered (foliated) across the direction of pressure. Gneiss has light and dark bands of recrystallized minerals that lie across the direction of pressure.

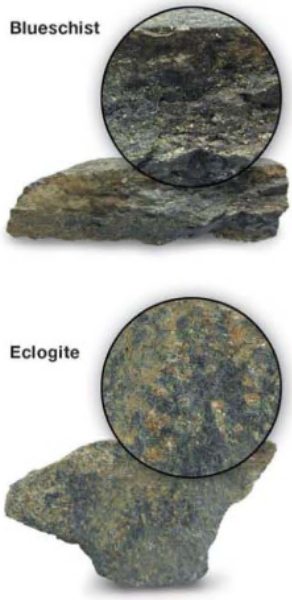
## Metamorphic rocks tell great stories

**Rock detectives** Geologists work like detectives. They use rocks as clues to understand the history of Earth. The only real difference is that detectives solve crimes that took place over days or weeks, but geologists study events that took place over hundreds of millions of years ago. Here are two examples of amazing events that are discovered using rock clues.

**Finding old subduction zones** High-grade metamorphism can occur at low temperature. Where do the conditions of high pressure and low temperature exist? An ocean floor plate encounters great pressure when it subducts into Earth's mantle. But it is cool because it was covered by ocean water. High-grade metamorphism changes the sediments on the ocean floor to the metamorphic rock called blueschist. It also changes the basalt of the ocean floor to the metamorphic rock eclogite (Figure 19.18). When geologists find these metamorphic rocks they know that they have found the remains of an ancient subduction zone!

**Finding places where ancient mountains once existed** Mountains are formed when converging plates cause one continent to collide with another. These continental collisions produce both tremendous heat and pressure. High-grade metamorphic rocks, like gneiss, form at the core of the growing mountains. Plate movements change direction, and after some time, these collisions stop. Then the mountains stop growing, and weathering and erosion begin to wear them down. Some of the remains of once great mountain ranges are now just rolling hills. The igneous rock, gneiss, formed at the core of growing mountain ranges, is a clue that these giants once existed.

**Gneiss**
A clue that a mountain range once existed




Clues that a subduction zone existed

**Figure 19.18:** *Blueschist and eclogite are formed by high-pressure metamorphism.*

## Section 19.4 Review

1. What does the term metamorphic mean?
2. What two conditions can cause metamorphic rocks to form?
3. What is regional metamorphism?
4. Describe the conditions for contact metamorphism and give an example of a rock formed by contact metamorphism.
5. Look at the rock images in Figure 19.19. Which image is most likely to be a metamorphic rock? Explain your answer.
6. Metamorphic rocks are commonly formed at what kind of plate boundary? Why?
7. Name one event that takes place at a convergent plate boundary that can cause a rock to be metamorphosed into another rock?
8. Compare and contrast phyllite and gneiss.
9. Schist is a metamorphic rock that contains mica flakes. What characteristic of these flakes allow geologists to be able to determine the direction of pressure that formed them?
10. Why is it sometimes hard to tell the difference between certain sedimentary rocks and metamorphic rocks?
11. Blueschist, eclogite, and gneiss are rocks that formed during certain types of events in Earth's geologic past. Identify the type of event that each of these rocks signifies.
12. Copy the table below on your own paper and fill in the blank spaces.

| Examples of Metamorphic Rocks | |
|---|---|
| Example | Type of Metamorphism |
| Slate | |
| Phyllite | |
| Marble | |
| Eclogite | |
| Gneiss | |

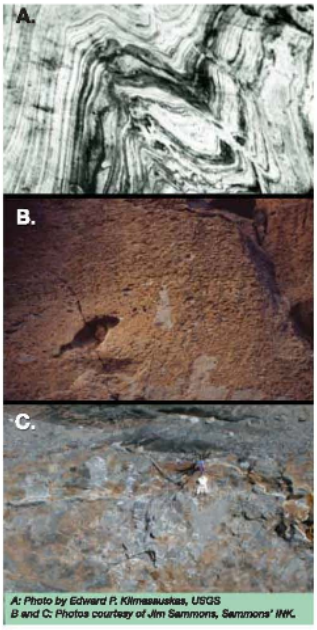



**Figure 19.19:** *Question 5.*