

### Objectives

- **Compare** and **contrast** the different types and causes of metamorphism.
- **Distinguish** among metamorphic textures.
- **Explain** how mineral and compositional changes occur during metamorphism.
- **Understand** how rocks continuously change from one type to another in the rock cycle.



### Vocabulary

- regional metamorphism
- contact metamorphism
- hydrothermal metamorphism
- foliated
- nonfoliated
- porphyroblast
- rock cycle



### Causes of Metamorphism

- Metamorphic rock forms when high temperature and pressure combine to alter the texture, mineralogy, or chemical composition of a rock without melting it.
- The high temperatures ultimately are derived from Earth's internal heat.
- The high pressures can be generated in two ways:
  - From vertical pressure caused by the weight of overlying rock
  - From the compressive forces generated as rocks are deformed during mountain building

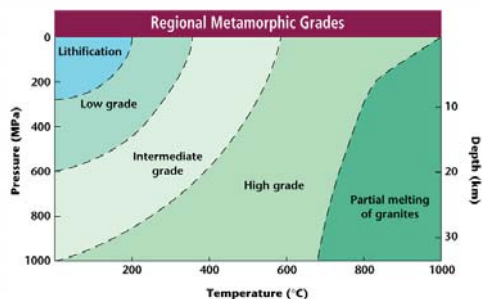


### Types of Metamorphism

- Different combinations of temperature and pressure result in different types of metamorphism.
- Large belts of **regional metamorphism** are produced when high temperature and pressure affect large regions of Earth's crust.
- Regional metamorphism can be low grade, intermediate grade, and high grade.
- The grade of regional metamorphism reflects the relative intensity of temperature and pressure.

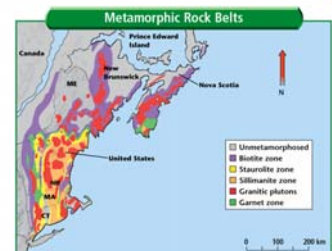


### Types of Metamorphism



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- Geologists have divided the regional metamorphic belt that has been mapped in the northeastern United States belt into zones based upon the mineral groups found in the rocks.



SECTION 6.3 Metamorphic Rocks

### Types of Metamorphism

- Knowing the temperatures that certain areas experienced when rocks were forming can help geologists locate economically valuable metamorphic minerals.

Metamorphic Rock Belts

SECTION 6.3 Metamorphic Rocks

### Types of Metamorphism

- Some key minerals are used to map metamorphic zones.

**Minerals in Metamorphosed Shale**

Lithification Low grade Intermediate grade High grade

Chlorite

White mica (mainly muscovite)

Biotite

Garnet

Staurolite

Kyanite

Sillimanite

Albite (sodium plagioclase feldspar)

**Minerals in Metamorphosed Basalt**

Lithification Low grade Intermediate grade High grade

Chlorite

Zeolites

Epidote

Amphibole

Garnet

Pyroxene

(Sodium-rich) Plagioclase feldspar (Calcium-rich)

SECTION 6.3 Metamorphic Rocks

### Types of Metamorphism

- A local effect called **contact metamorphism** occurs when molten rocks, such as those in an igneous intrusion, come in contact with solid rock.
- High temperature and moderate-to-low pressure form the mineral assemblages that are characteristic of contact metamorphism.

Chlorite, Muscovite, Biotite, Andalusite, High-temperature metamorphic rock, Granite batholith, Temperature decreasing, 1 km

SECTION 6.3 Metamorphic Rocks

### Types of Metamorphism

- Because temperature decreases with distance from an intrusion, metamorphic effects also decrease with distance.
- Contact metamorphism from extrusive igneous rocks is limited to thin zones.

Chlorite, Muscovite, Biotite, Andalusite, High-temperature metamorphic rock, Granite batholith, Temperature decreasing, 1 km

SECTION 6.3 Metamorphic Rocks

### Types of Metamorphism

- Hydrothermal metamorphism** occurs when very hot water reacts with rock and alters its chemistry and mineralogy.
- Hydrothermal fluids can dissolve some minerals, break down others, and deposit new minerals.
- Hydrothermal metamorphism is common around igneous intrusions and near active volcanoes.

SECTION 6.3 Metamorphic Rocks

### Metamorphic Textures

- Metamorphic rocks are classified into two textural groups: foliated and nonfoliated.
- Foliated** metamorphic rocks are characterized by wavy layers and bands of minerals.
  - High pressure during metamorphism causes minerals with flat or needlelike crystals to form with their long axes perpendicular to the pressure.

### Metamorphic Textures

- **Nonfoliated** metamorphic rocks lack mineral grains with long axes in one direction.
- Nonfoliated rocks are composed mainly of minerals that form with blocky crystal shapes.
- Quartzite and marble are two common examples of nonfoliated rocks.



### Metamorphic Textures

#### Porphyroblasts

- Under certain conditions, new metamorphic minerals can grow quite large while the surrounding minerals remain small.
- **Porphyroblasts** are large crystals, which can range in size from a few millimeters to a few centimeters.
- Porphyroblasts are found in areas of both contact and regional metamorphism.



### Mineral Changes

- Minerals are stable at certain temperatures and crystallize from magma at different temperatures.
- During metamorphism, the minerals in a rock change into new minerals that are stable under the new temperature and pressure conditions.
- Minerals that change in this way are said to undergo solid-state alterations.



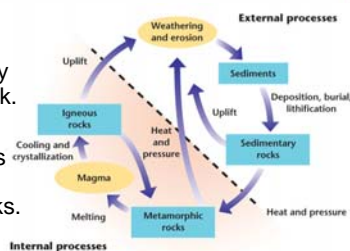
### Compositional Changes

- When hot fluids migrate in and out of the rock during metamorphism the original composition of the rock can change.
- Chemical changes are especially common during contact metamorphism near igneous intrusions.
- Valuable ore deposits of gold, copper, zinc, tungsten, and lead are formed through the invasion of hydrothermal fluids.



### The Rock Cycle

- Metamorphic rocks are formed by the changing of other rocks.
- Any rock can be changed into any other type of rock.
- The **rock cycle** is the continuous changing and remaking of rocks.



### Other Possible Paths

- There is more than one path in the rock cycle.
- The rocks of Earth's crust are constantly being recycled from one type to another.
- The processes that help shape Earth's landscapes are also part of the rock cycle.

