Metamorphic Rocks

any rock that has undergone changes in texture, mineralogical, or chemical composition in the solid state

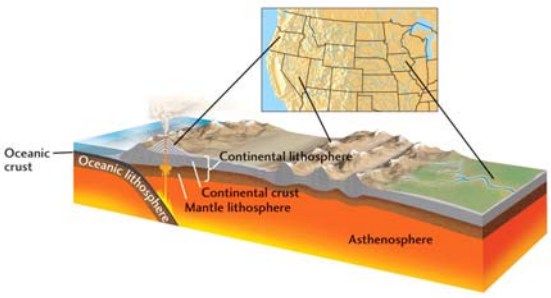
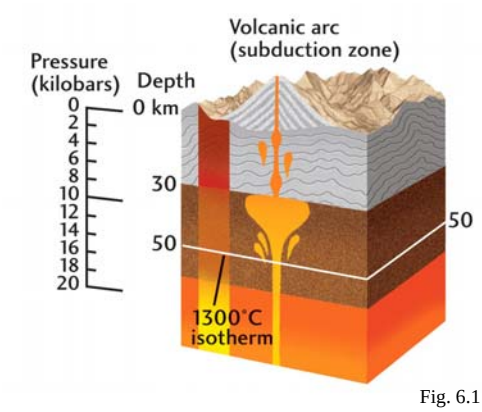


Fig. 6.1



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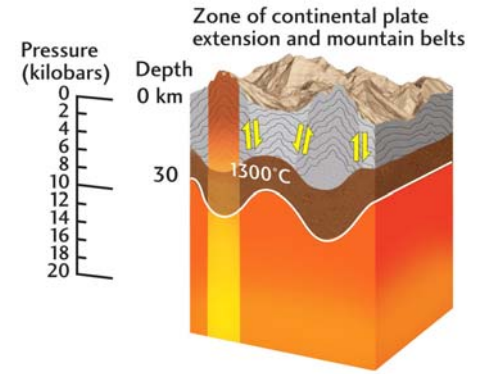

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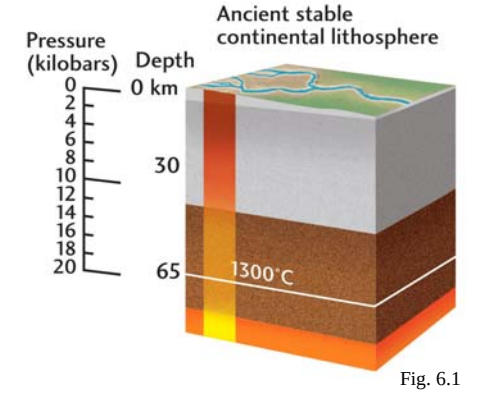

Fig. 6.1

How do rocks metamorphose?

- From the partial or complete recrystallization of minerals in the rocks over long periods of time
- Rocks remain essentially solid during metamorphism

Metamorphic Processes

PRESSURE: greater pressure tends to decrease space available for mineral growth, so metamorphic minerals tend to be more dense. Increased pressure can come from any directed stress (burial). Stress will bring about a preferred orientation of minerals.

Metamorphic processes

FLUIDS (H_2O): acts as a catalyst during metamorphism; aids the exchange of ions between growing crystals.

HEAT: stability region of mineral sensitive to temperature. With increased temperature, pore fluid decreases.

Metamorphic Grade

Refers to the intensity of metamorphism.

High grade: High temperature, and pressure

Low grade: Low temperature and pressure

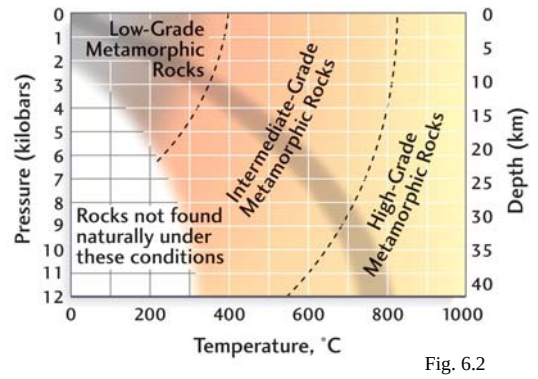

Fig. 6.2

Metamorphic Reactions

Prograde: mineral changes that take place during an *increase* in temperature

Retrograde: mineral changes that take place during an *decrease* in temperature

Types of Metamorphism

- Regional
- Contact
- Seafloor
- Burial
- Shock (impact)

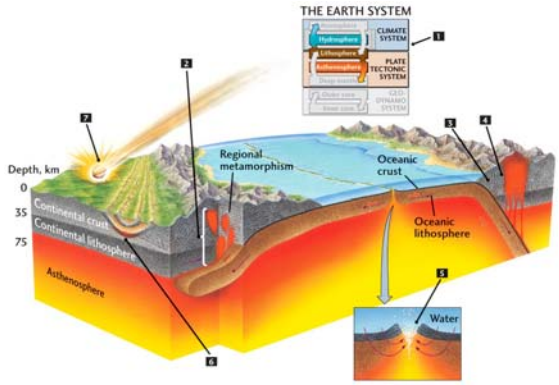

Fig. 6.3

Regional Metamorphism

Widespread changes in temperature and pressure due to tectonic forces.

Contact Metamorphism

Intrusion of magma against colder rocks. Local phenomenon.

Seafloor Metamorphism

Chemical reactions promoted by the infiltration of heated seawater at mid-ocean ridges

Deformational Metamorphism

Changes in rocks associated with faulting and folding (regional or local)

Burial Metamorphism

Changes in temperature and pressure due to successive burial (regional)

Impact Metamorphism

Changes due to rapid increase in pressure (localized only)

Metamorphic Reactions

Mineralogical changes (e.g., clay to mica): Series of complicated reactions that depends on pressure, temperature, and composition

Common metamorphic minerals include amphiboles, garnet, mica, staurolite, and kyanite.

Textural changes: recrystallization (grain boundaries become more compact) and foliation (preferred orientation of minerals)

How Much Can a Rock Change?

The amount of change during metamorphism depends on:

- **the grade of metamorphism**
- **the duration of metamorphism**
- **the composition of the rock**

Changes in Texture due to Recrystallization

- Grain **size** can increase or decrease
- **Shape** of grains can change
- Orientation/arrangement of mineral shifts

Directed stress will orient minerals in two ways:

- *Lineation*
- *Foliation*

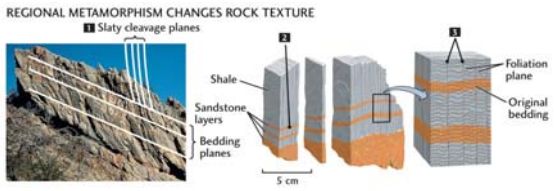

Fig. Story 6.4

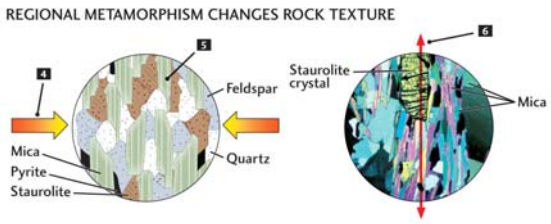

Fig. Story 6.4

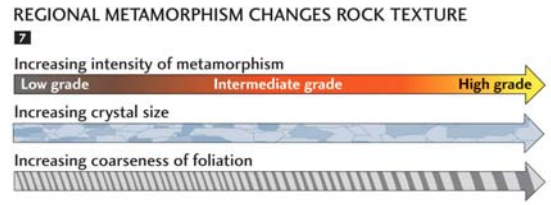

Fig. Story 6.4

Fig. Story 6.4

Classification of Metamorphic Rocks

Classification is based on the texture and composition of the rock:

Low grade	Slate
	Phyllite
	Schist
	Gneiss
High grade	Migmatite

Table 9.1 Classification of Metamorphic Rocks on Texture

Classification	Characteristics	Rock Name	Typical Parent Rock
Foliated	Distinguished by slaty cleavage, schistosity, or gneissic foliation; mineral grains show preferred orientation	Slate Phyllite Schist Gneiss	Shale, sandstone
Granoblastic (nonfoliated)	Granular, characterized by coarse or fine interlocking grains; little or no preferred orientation	Hornfels Quartzite Marble Argillite Greenstone Amphibolite[a] Granulite[b]	Shale, volcanics Quartz-rich sandstone Limestone, dolomite Shale Basalt Shale, basalt Shale, basalt
Porphyroblastic	Large crystals set in fine matrix	Slate to gneiss	Shale

[a]Typically contains much amphibole, which may show alignment of long, narrow crystals.
[b]High-temperature, high-pressure rock.

Table 6.1

Quartzite

Fig. 6.5

Marble

Fig. 6.5

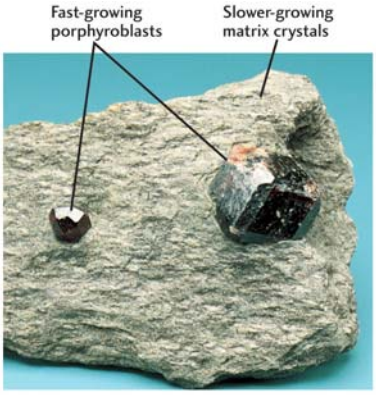

Fig. 6.6

Stability of Minerals

- Most minerals are stable over a relatively narrow range of pressure and temperature (*e.g.*, ice unstable above 0°C).
- The stability range of different minerals sometimes overlap and provide insights into the metamorphic history of rocks.

Metamorphic Facies

- a given set of metamorphic conditions
- each facies is characteristic of particular tectonic environments and will have certain minerals that are indicative of those conditions
- the minerals in a rock can therefore be clues to the (pressure and temperature) history of the rock

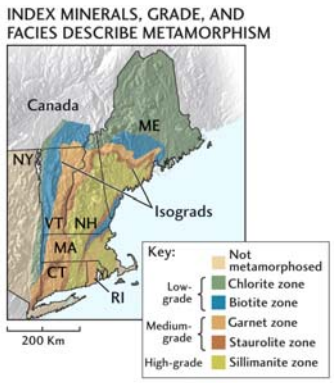

Fig. story 6.7a

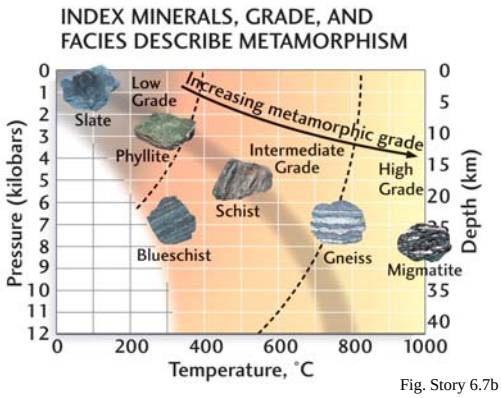

Fig. Story 6.7b

INDEX MINERALS, GRADE, AND FACIES DESCRIBE METAMORPHISM

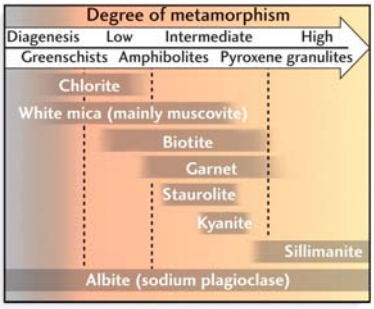

Fig. Story 6.7c

INDEX MINERALS, GRADE, AND FACIES DESCRIBE METAMORPHISM

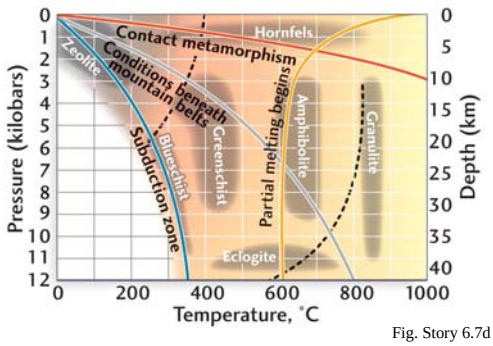

Fig. Story 6.7d

INDEX MINERALS, GRADE, AND FACIES DESCRIBE METAMORPHISM

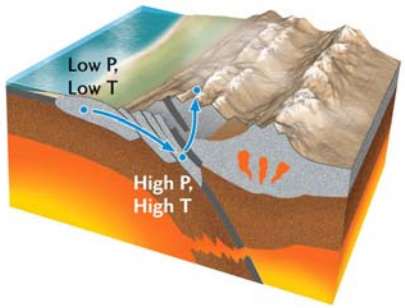

Fig. Story 6.7e

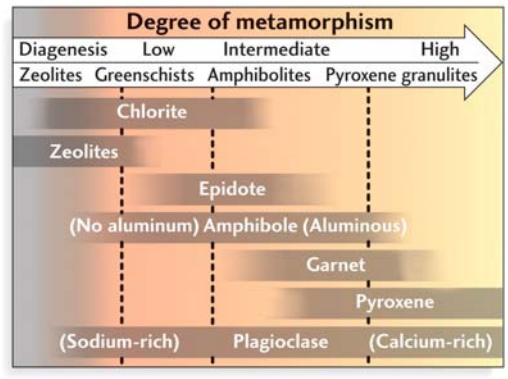

Fig. 6.8a

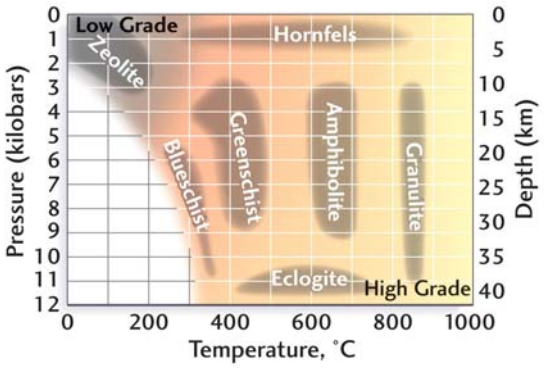

Fig. 6.7

Table 9.2 Major Minerals of Metamorphic Facies Produced from Parent Rocks of Different Composition

Facies	Minerals Produced from Shale Parent	Minerals Produced from Basalt Parent
Greenschist	Muscovite, chlorite, quartz, sodium-rich plagioclase feldspar	Albite, epidote, chlorite
Amphibolite	Muscovite, biotite, garnet, quartz, plagioclase feldspar	Amphibole, plagioclase feldspar
Granulite	Garnet, sillimanite, plagioclase feldspar, quartz	Calcium-rich pyroxene, calcium-rich plagioclase feldspar
Eclogite	Garnet, sodium-rich pyroxene, quartz	Sodium-rich pyroxene, garnet

Table 6.2

Plate Tectonics and Metamorphism

The pressure-temperature history of the rock can often be tied to tectonic setting

- Continent-ocean convergence
- Continent-continent collision

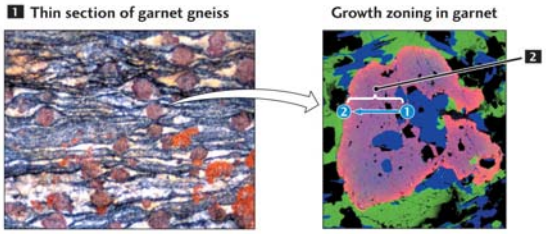

Fig. 6.9

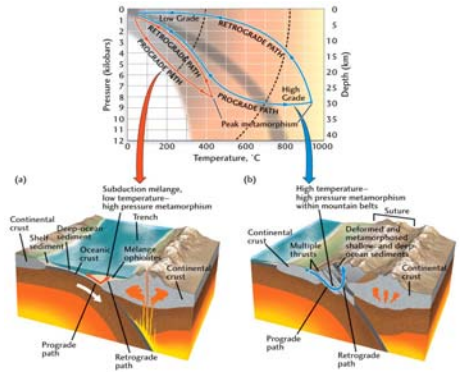

Fig. 6.10