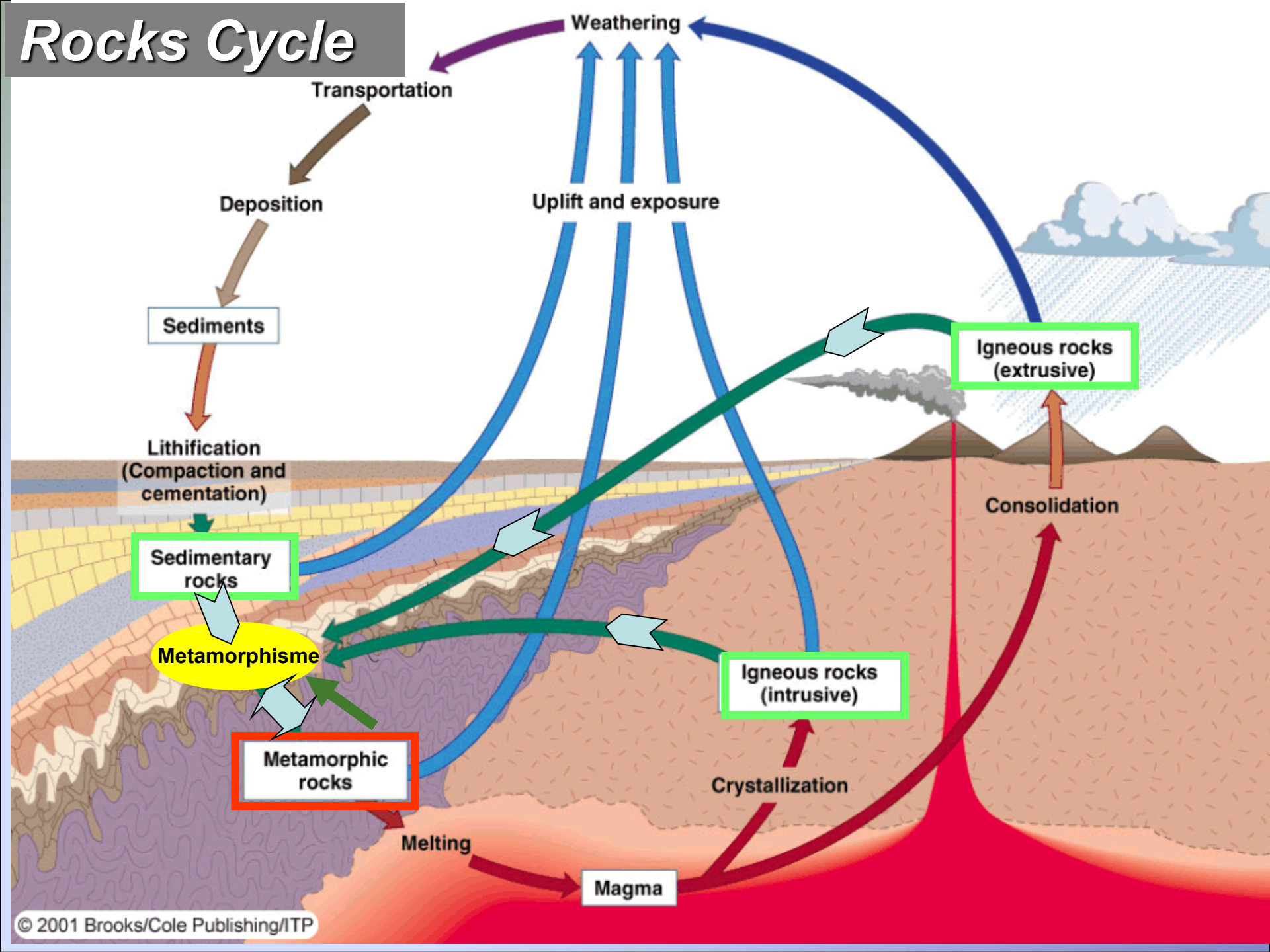


Module 8
Metamorphic Rocks

Rocks Cycle



METAMORPHIC ROCKS

- Metamorphic rocks are **changed rocks**
- They are ***formed in the solid state*** in response to the following ***principal agents of metamorphism***:
 - Change in ***pressure***
 - Change in ***temperature***
 - Change in ***pressure*** and ***temperature***

Metamorphic Rocks

- The protolith (the parent rock) is the preexisting rock from which the metamorphic rock was formed
- Metamorphism may cause a change in a rock's:
 - Composition
 - Mineral assemblage
 - Texture
 - All of the above

Factors That Control the Characteristics of Metamorphic Rocks

- 1. Protolith Composition**
- 2. Pressure**
- 3. Temperature**
- 4. Time**

Factors That Control the Characteristics of Metamorphic Rocks

1. Protolith Composition

- ❑ **Mafic protoliths** (basalt, diabase, and gabbro) yield a dark charcoal gray mafic metamorphic rock called *amphibolite*
- ❑ **Felsic protoliths** (granite, rhyolite, mudstone, sandstone, conglomerate, breccia) yield light colored tan, silver, light to medium gray, etc. **felsic metamorphic rocks**

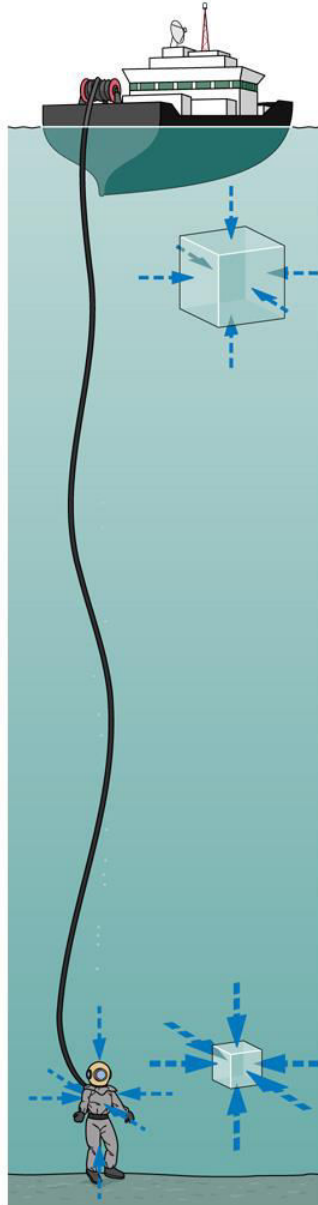
Factors That Control the Characteristics of Metamorphic Rocks

2. Pressure (stress)

- ❑ Increasing pressure flattens grains, crushes grains (reduces size), causes shearing
- ❑ **Confining pressure**, associated with depth of burial, is equal in all directions
- ❑ **Differential pressure** is not equal in all directions
 - Produces foliation (parallel alignment of grains)
 - **Pure shear = compression, flattens grains**
 - **Simple shear = skewing, stretches grains, produces lineation, aligns elongate grains in direction of transport**

Factors That Control the Characteristics of Metamorphic Rocks

Copyright © McGraw-Hill Companies, Inc. Permission required for reproduction or display.



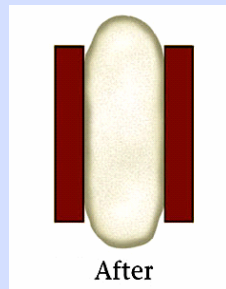
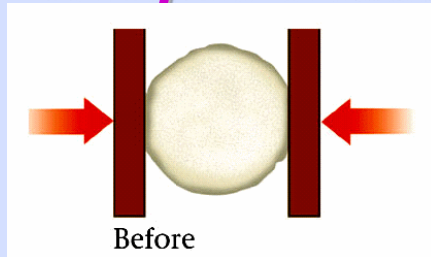
Confining Pressure

**Pressure is equal in
all directions**

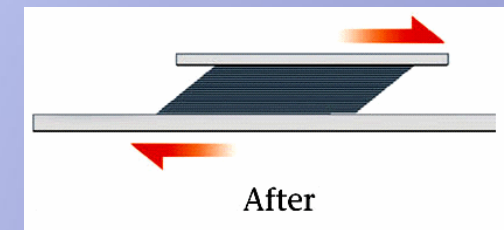
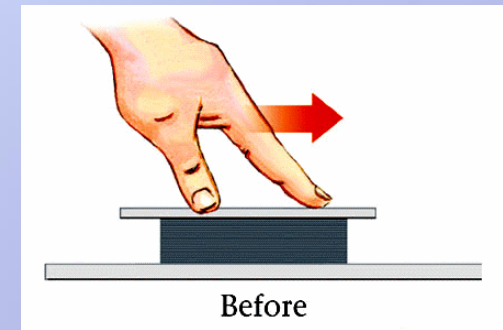
Factors That Control the Characteristics of Metamorphic Rocks

- Differential pressure
 - Is ***not*** equal in all directions
 - Leads to ***formation of foliation*** by either
 - ***Pure shear (flattening)***
 - ***Simple shear (skewing)***

Differential Pressure



Pure shear (flattening)



Simple shear (skewing)

Factors That Control the Characteristics of Metamorphic Rocks

Type of foliation

- ***Slaty Cleavage*** – Alignment of small mica flakes
- ***Schistosity*** – Alignment of large mica flakes
- ***Gneissic Banding*** – segregation of felsic and mafic minerals into alternating light and dark bands

Factors That Control the Characteristics of Metamorphic Rocks

Foliation: Development of Slaty Cleavage

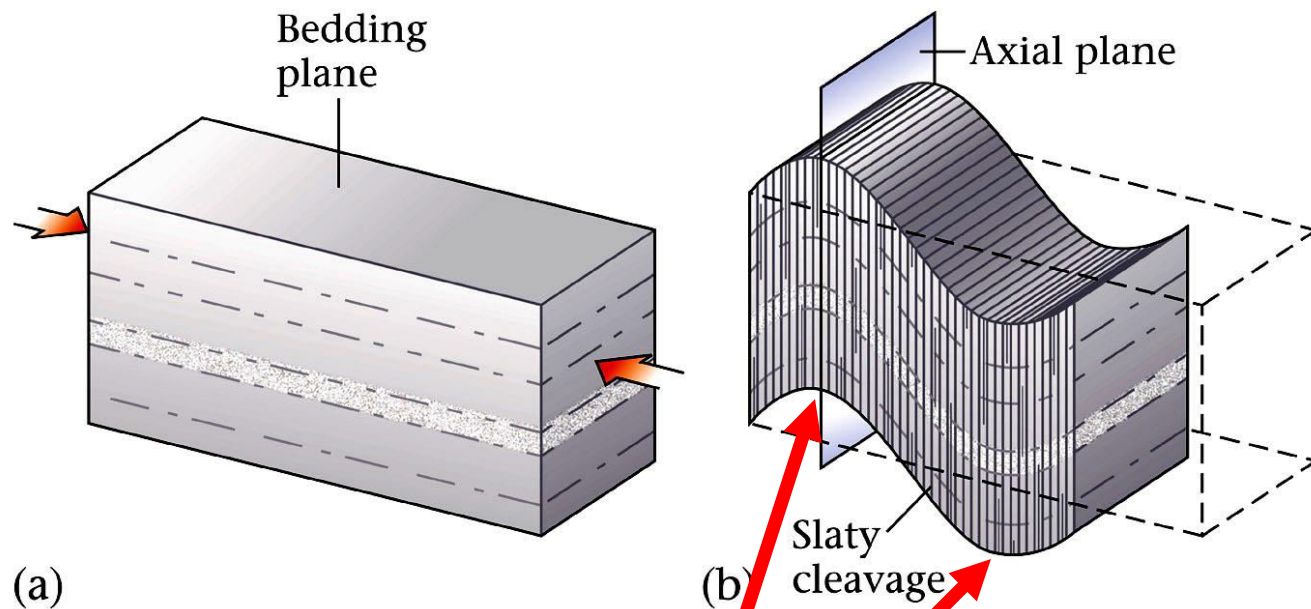


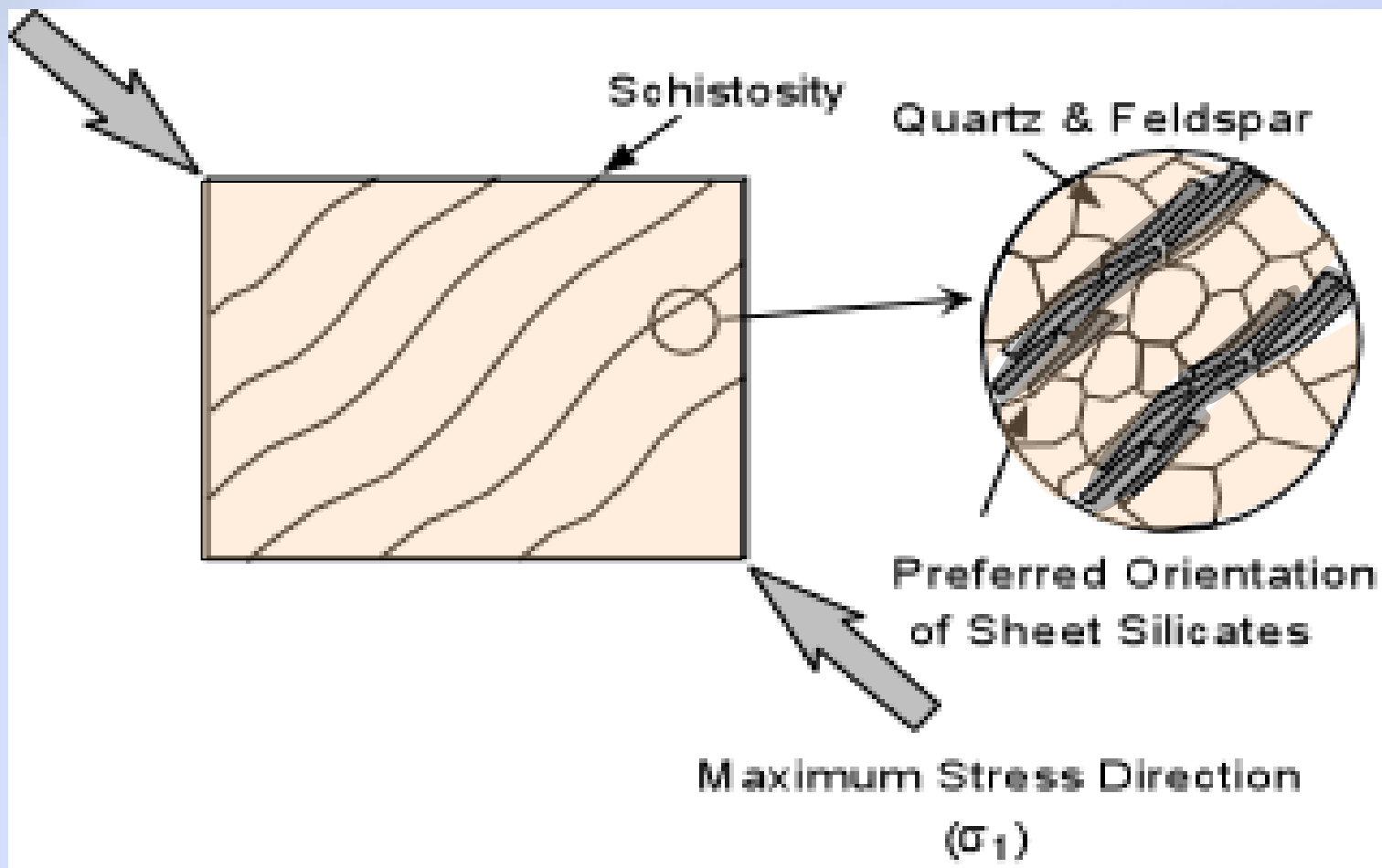
FIGURE 8.9

Earth: Portrait of a Planet, 2nd Edition
Copyright (c) W.W. Norton & Company

**Bedding is perpendicular to cleavage
at the top and bottom of the fold**

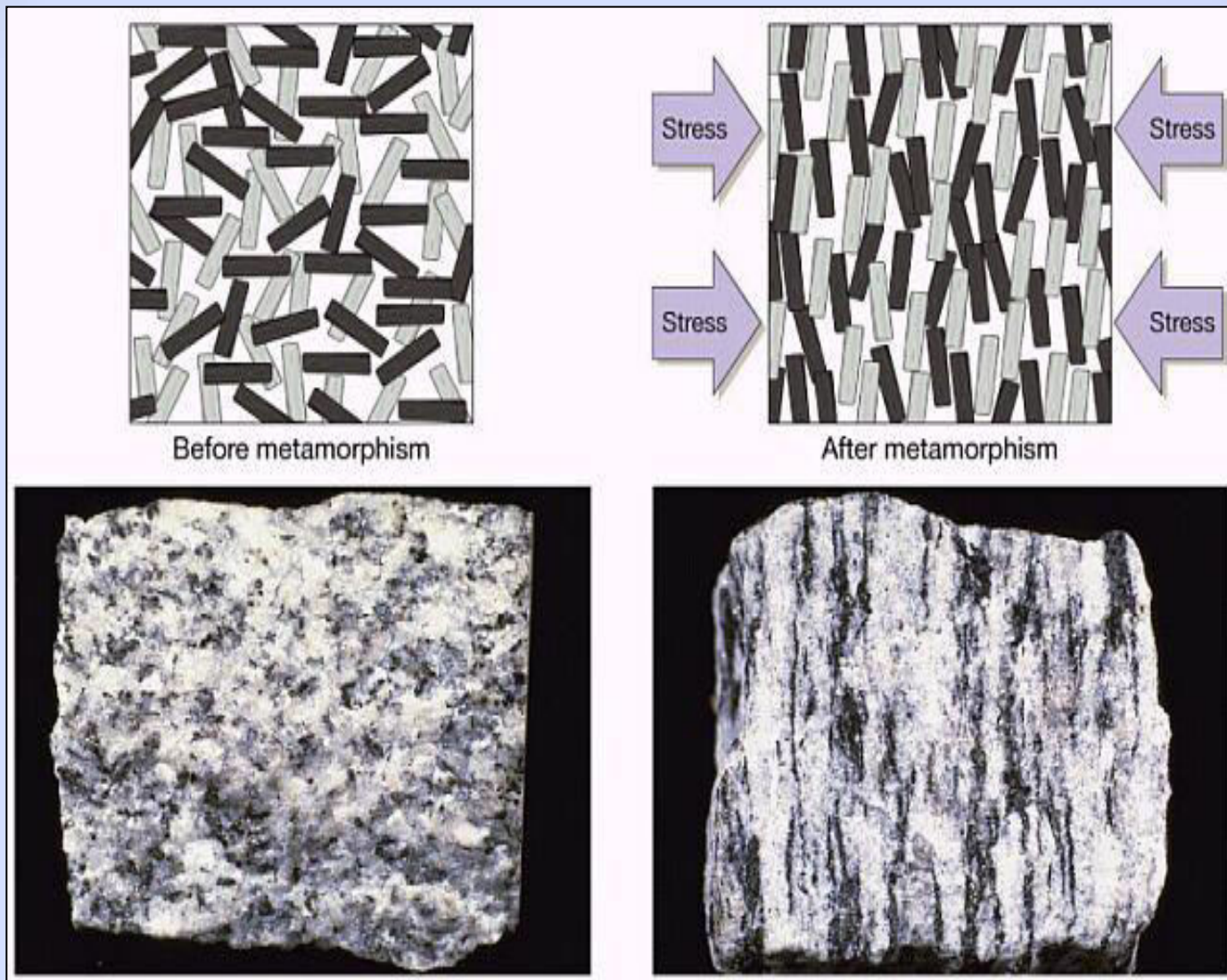
Factors That Control the Characteristics of Metamorphic Rocks

Foliation: Development of Schistosity



Factors That Control the Characteristics of Metamorphic Rocks

Foliation: Formation of Gneissic Banding



Factors That Control the Characteristics of Metamorphic Rocks

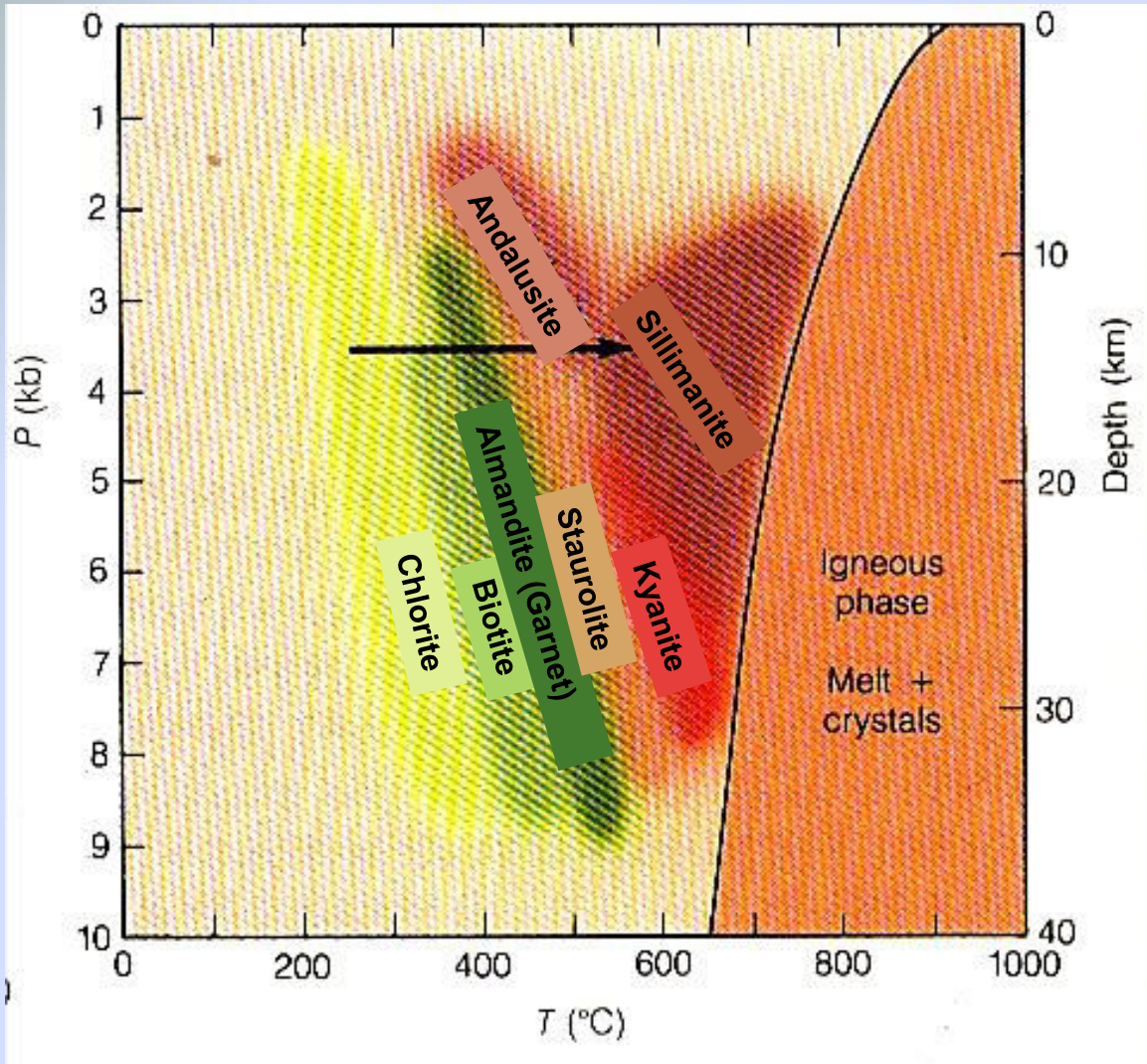
3. Temperature

- ❑ ***Increasing temperature*** causes increased movement of ions which in turn causes
 - Mineral grains to grow larger
 - Minerals to recrystallize
- ❑ The upper limit on T for metamorphism is partial melting

4. Time

- ❑ Metamorphic reactions and textural changes require millions of years to occur

Index Minerals of Metamorphic Rocks



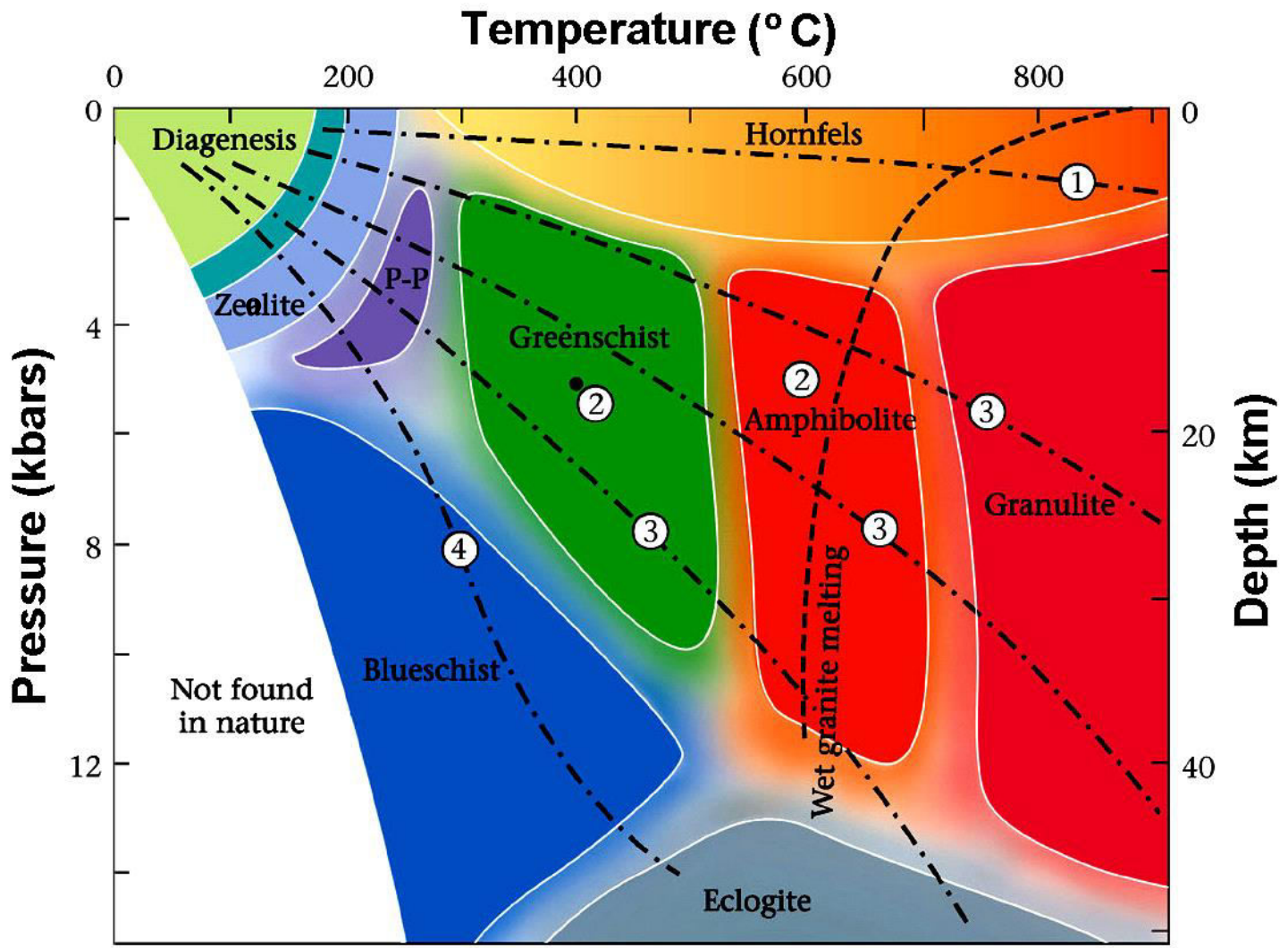
Index Minerals

- Chlorite
- Biotite
- Almandite (garnet)
- Staurolite
- Andalusite
- Kyanite
- Sillimanite

Not specific

- Quartz
- Plagioclase
- Orthoclase
- Biotite
- Muscovite
- Hornblende
- Calcite
- Dolomite

Metamorphic Facies



- ① Contact (thermal) metamorphism
- ② Volcanic arc
- ③ Collisional mountain belt
- ④ Accretionary prism

Classification of Metamorphic Rocks

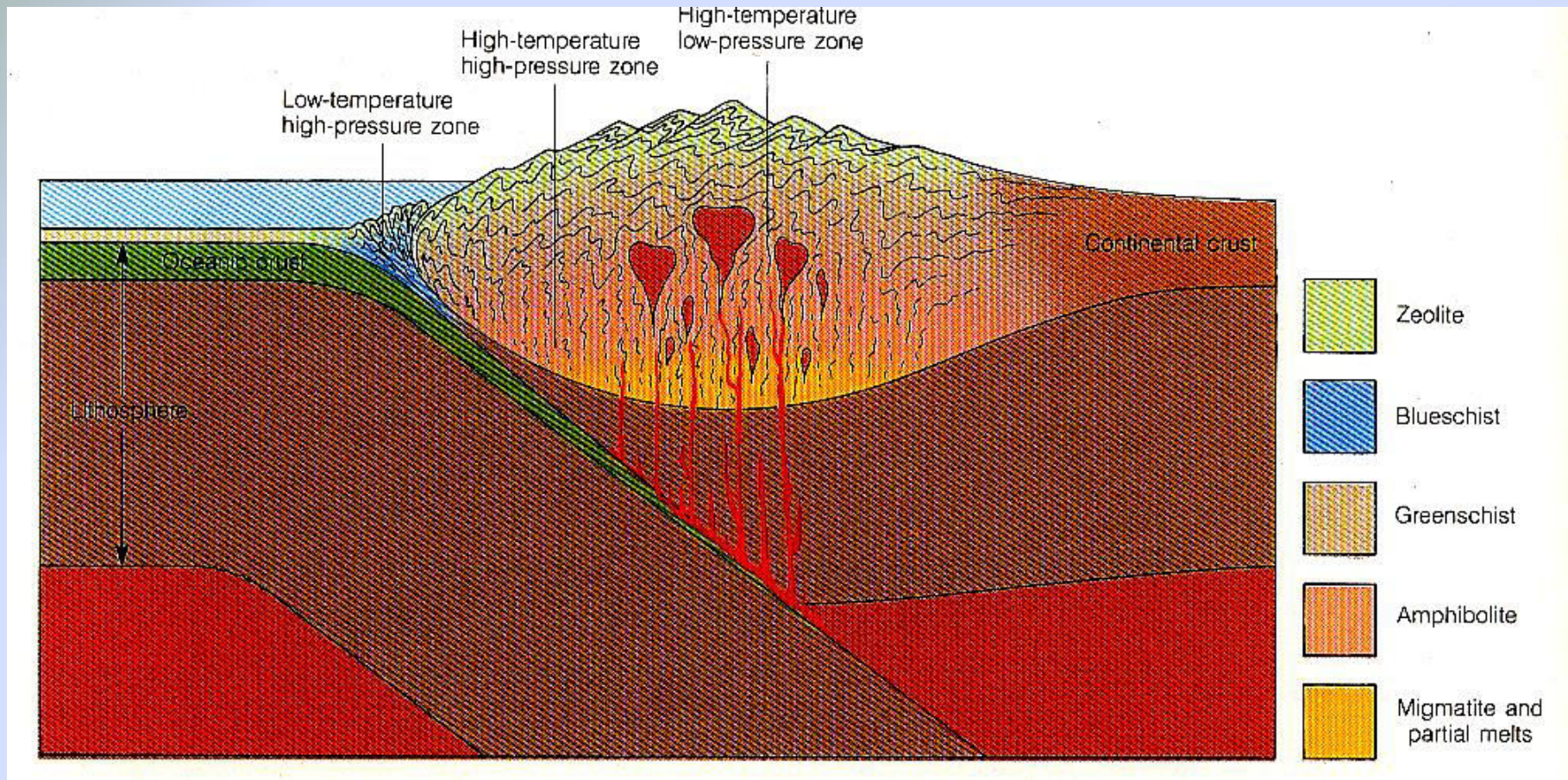
1. Regional metamorphic rocks

- **Form in response to increased temperature and directed pressure along plate boundaries**
- **Are foliated**
- **Were sheared by pure shear or simple shear**

2. Local metamorphic rocks

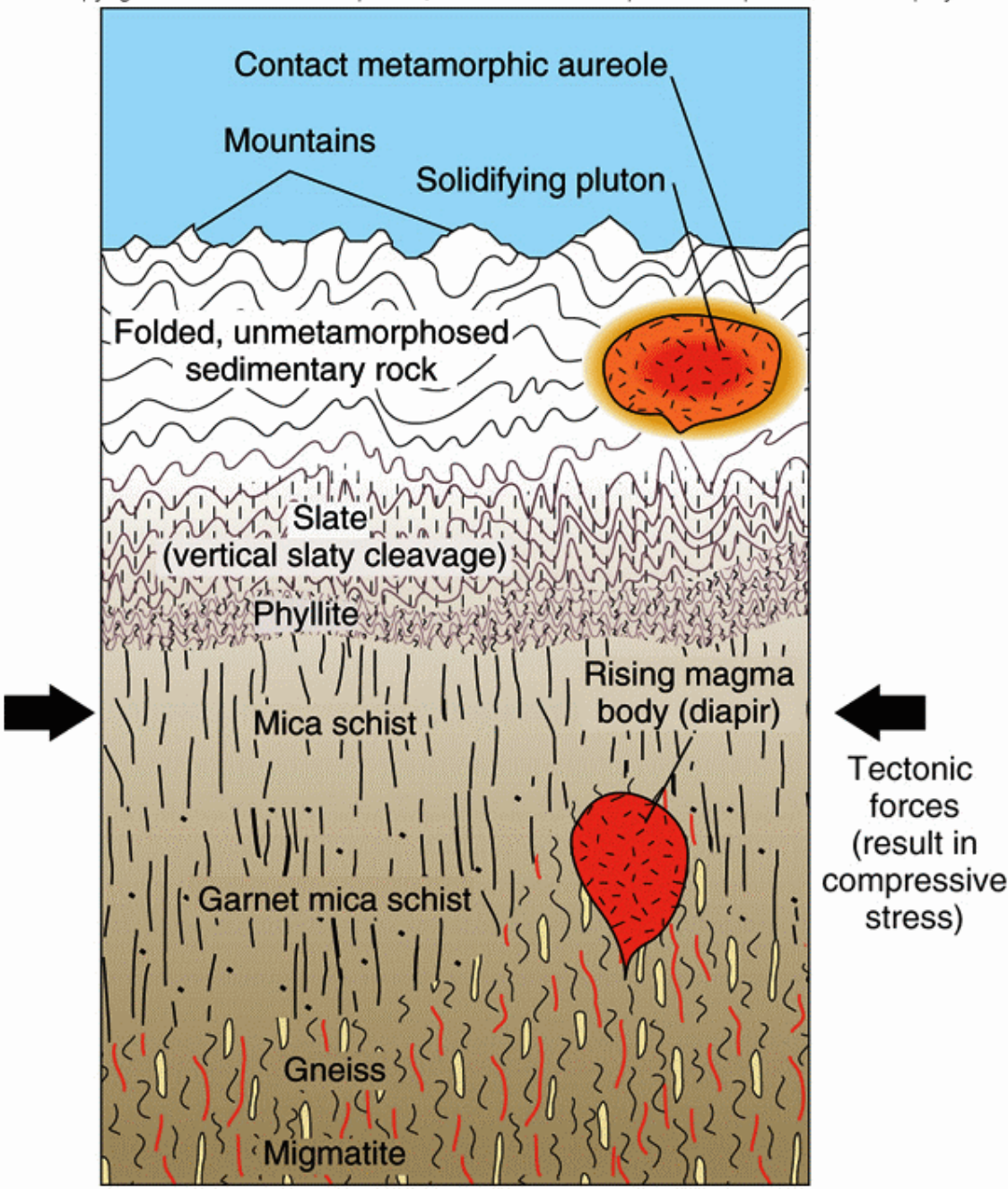
- **Form in response to contact with magma at high T and /or high confining P**
- **Found adjacent to igneous intrusions**
- **Are usually unfoliated**

Where do the metamorphic rocks form?



Classification of Metamorphic Rocks

Copyright © McGraw-Hill Companies, Inc. Permission required for reproduction or display.



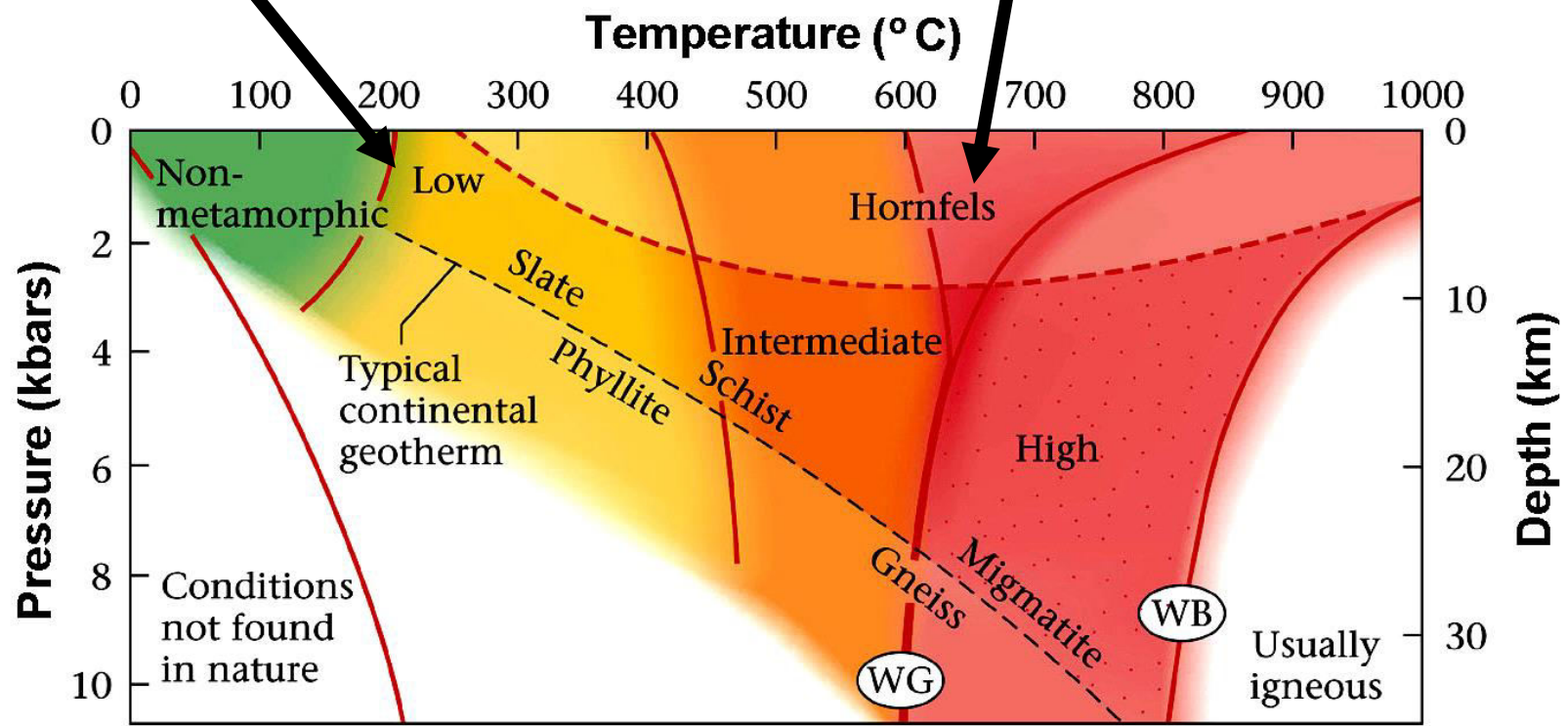
Formation of Contact Metamorphic Rocks

Formation of Regional Metamorphic Rocks

Classification of Metamorphic Rocks

Regional metamorphic rocks

Contact metamorphic rocks



(WG) Melting curve for wet granite

(WB) Melting curve for wet basalt

Classification of Metamorphic Rocks

Formation of Contact Metamorphic Rocks

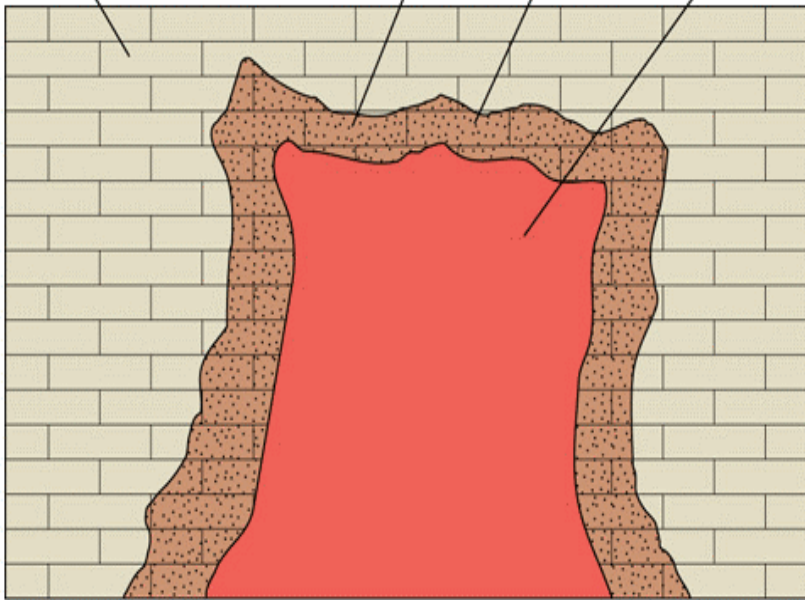
Copyright © McGraw-Hill Companies, Inc. Permission required for reproduction or display.

Zone of contact metamorphism (aureole)

Limestone

Marble

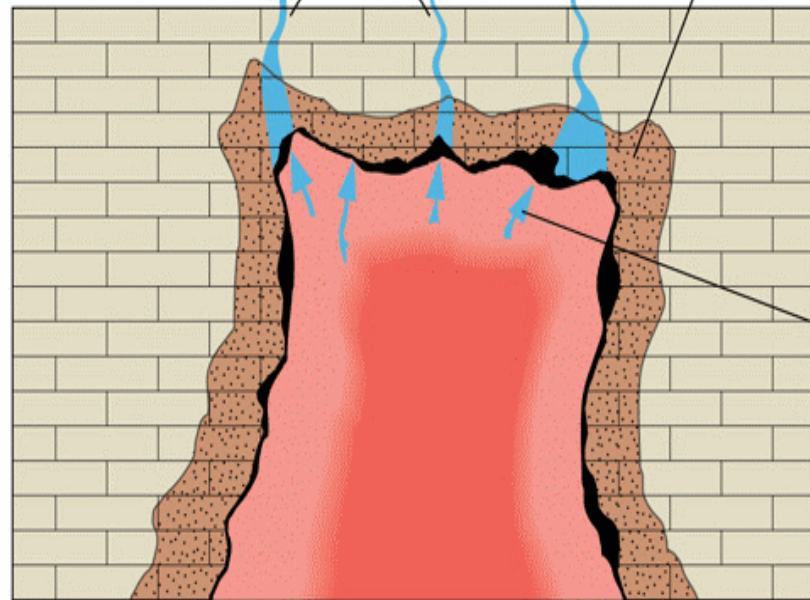
Magma



A

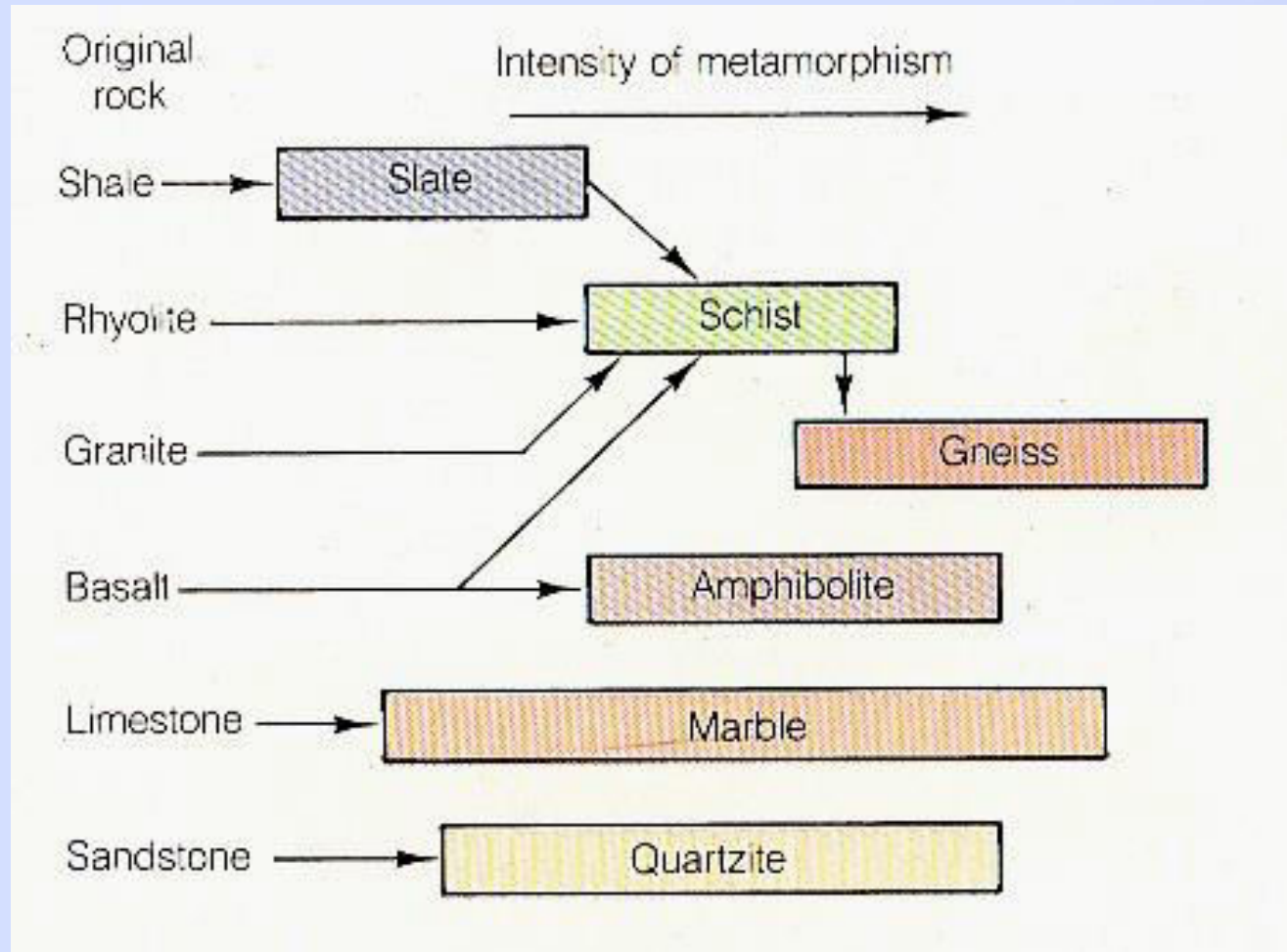
Water with Ca^{+2} (CO_3) $^{-2}$

Magnetite



B

Protolith and Metamorphic Rocks



Types of Metamorphic Rocks

A. Foliated Metamorphic Rocks

Are formed by differential pressure (pure shear, simple shear)

Slate

Dull, microscopic grains, strong slaty cleavage, any color, mudstone protolith

Phyllite

Shiny, strongly micaceous with microscopic grains, strong schistosity, cleavage, can be mafic or felsic, any rock-type protolith

Schist

Shiny, strongly micaceous, fine to medium grained, strong schistosity, cleavage, any color, any rock-type protolith

Gneiss

Dull, weakly micaceous, fine to coarse grained, banded, weak cleavage, any rock-type protolith, but most often sheared coarse grained protolith such as granite, conglomerate, breccia

Migmatite

Dull, weakly micaceous, fine to coarse grained, folded banded texture, weak cleavage, almost melted, any rock-type protolith

Types of Metamorphic Rocks

Slate

Protolith: Fine grained rock like shale, mudstone, or siltstone

Appearance: Dull, microscopic grains, strong slaty cleavage, any color



Types of Metamorphic Rocks

Phyllite

Protolith: Can be any rock-type

Appearance: Shiny, strongly micaceous with *microscopic grains*, has strong schistose cleavage, can be felsic (muscovite-rich, silvery) or Mafic (biotite-rich, shiny medium to dark gray)

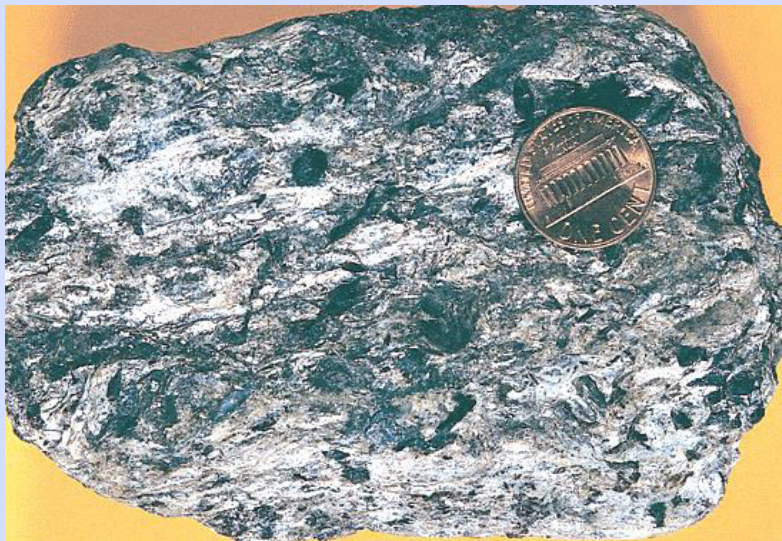


Types of Metamorphic Rocks

Schist



Protolith: Can be any rock-type



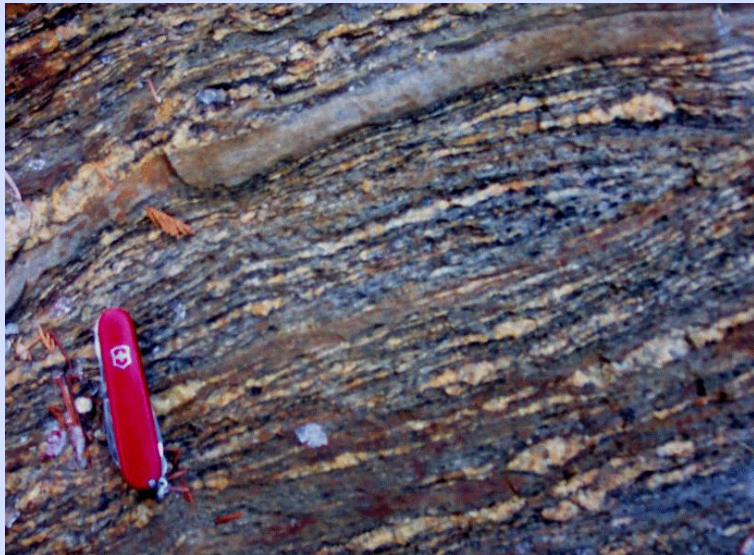
Appearance: Shiny, strongly micaceous, fine to medium grained has strong schistose cleavage, can be felsic (muscovite-rich, silvery) or mafic (biotite-rich, shiny medium to dark gray)

Types of Metamorphic Rocks

Gneiss



Protolith: Can be any rock-type, but most often formed from a sheared coarse grained protolith such as granite, conglomerate, breccia



Appearance: Dull, weakly micaceous, fine to coarse grained, **banded**, weak cleavage

Types of Metamorphic Rocks

Migmatite



Protolith: Can be any rock-type



Appearance: Dull, weakly micaceous, fine to coarse grained, folded banded texture, weak cleavage, almost melted, a folded gneiss

Types of Metamorphic Rocks

B. Special Types of Metamorphic Rocks

May be foliated or unfoliated

- **Quartzite**
 - Metamorphosed sandstone
 - Harder than marble
 - Will not fizz (release CO₂) in the presence of acid



Types of Metamorphic Rocks

B. Special Types of Metamorphic Rocks

May be foliated or unfoliated

- **Marble**
 - Metamorphosed limestone
 - Contains calcium carbonate
 - Will fizz (release CO_2) in the presence of acid
 - Softer than quartzite



Types of Metamorphic Rocks

B. Special Types of Metamorphic Rocks

May be foliated or unfoliated

- **Anthracite**
 - Metamorphosed bituminous coal
 - Low density
 - Very shiny black



Types of Metamorphic Rocks

B. Special Types of Metamorphic Rocks

May be foliated or unfoliated

- Amphibolite
 - Dull black, fine to coarse grained, weak cleavage if sheared (gneissic)
 - Metamorphosed gabbro, basalt, or diorite



Dark rock composed mostly of amphibole and Ca-Na plagioclase, may be either foliated or unfoliated, often with large (visible) elongated crystals of amphibole



How to determine the kind of rock?

- Structure: massive, vesicular, foliation, bedded, etc
- Texture: crystalline, granular, clastic, non clastic, etc
- Mineral Composition: rock forming minerals, others