Lecture 7 – Metamorphic rocks

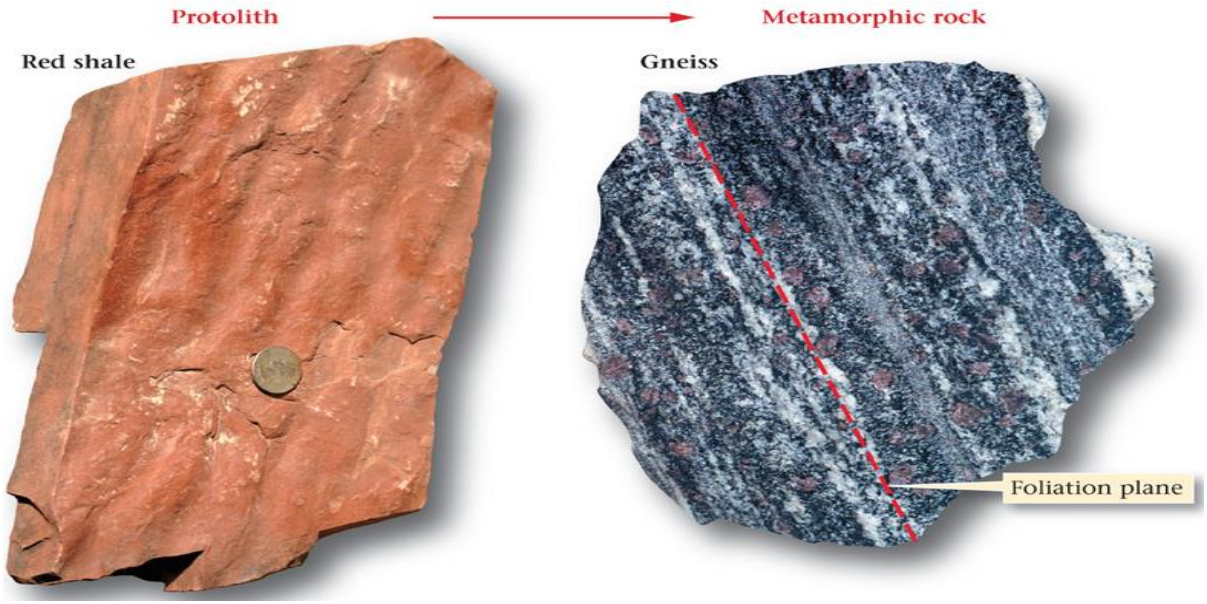
Metamorphism

- Process that leads to changes in:
  - Mineralogy
  - Texture
  - Sometimes chemical composition

- Metamorphic rocks are produced from parent rocks, called “protoliths”

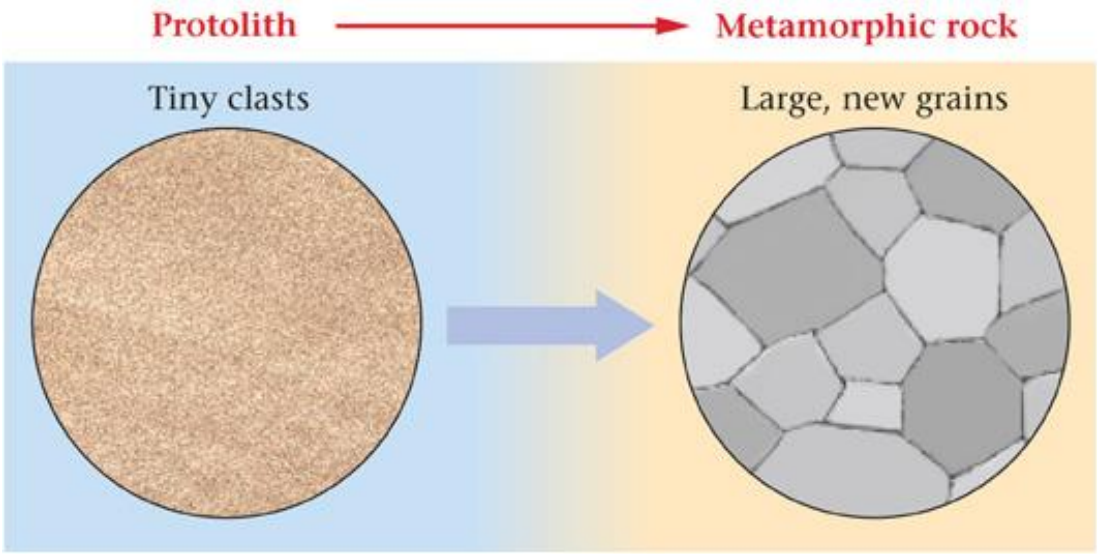
Metamorphic Character

- Metamorphic rocks have distinctive properties
  - Unique texture – intergrown and interlocking grains
  - Unique minerals – some minerals are only metamorphic
  - Unique foliation – a planar fabric from aligned minerals
- These transformations can change the rock completely



Metamorphic Processes

- Metamorphic change occurs slowly in the solid state
- Several processes are at work:
  1. **Recrystallization** – Minerals change size and shape



Metamorphic Processes

- Metamorphic change occurs slowly in the solid state
- Several processes are at work

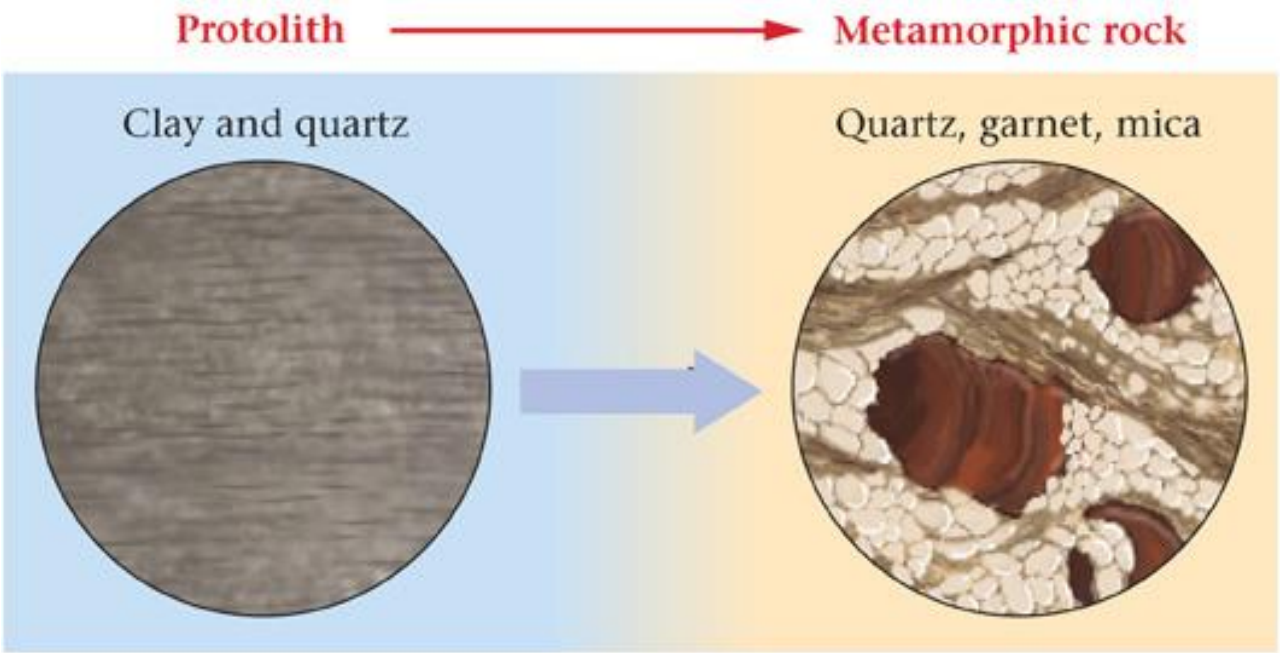
  2. **Phase change** – New minerals with different structure

  Example: Andalusite to kyanite

Metamorphic Processes

- Metamorphic change occurs slowly in the solid state
- Several processes are at work

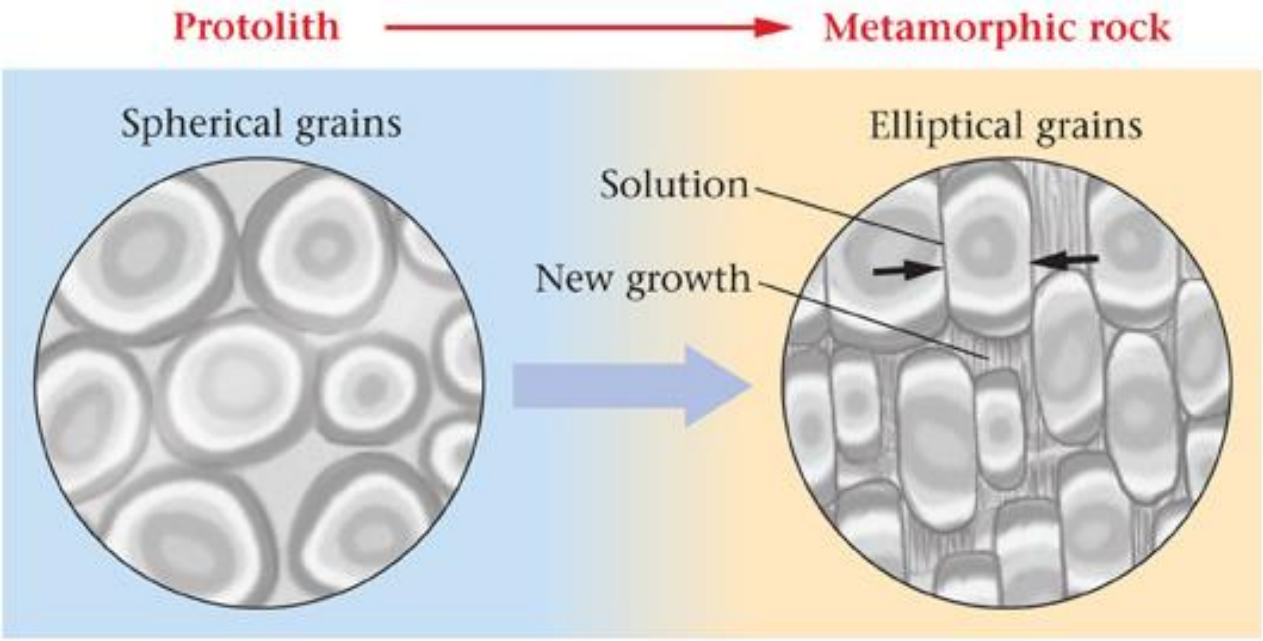
  3. **Neocrystallization** – New minerals of different composition



Metamorphic Processes

- Metamorphic change occurs slowly in the solid state
- Several processes are at work

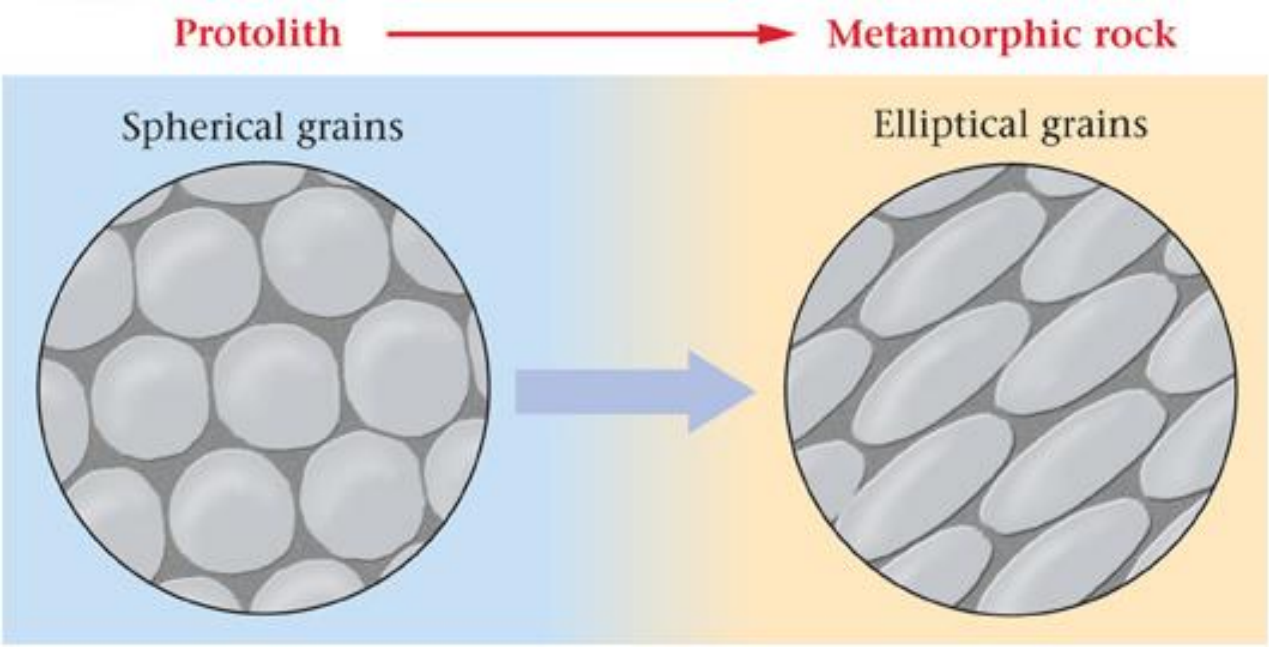
  4. **Pressure solution** – Mineral grains partially dissolve



Metamorphic Processes

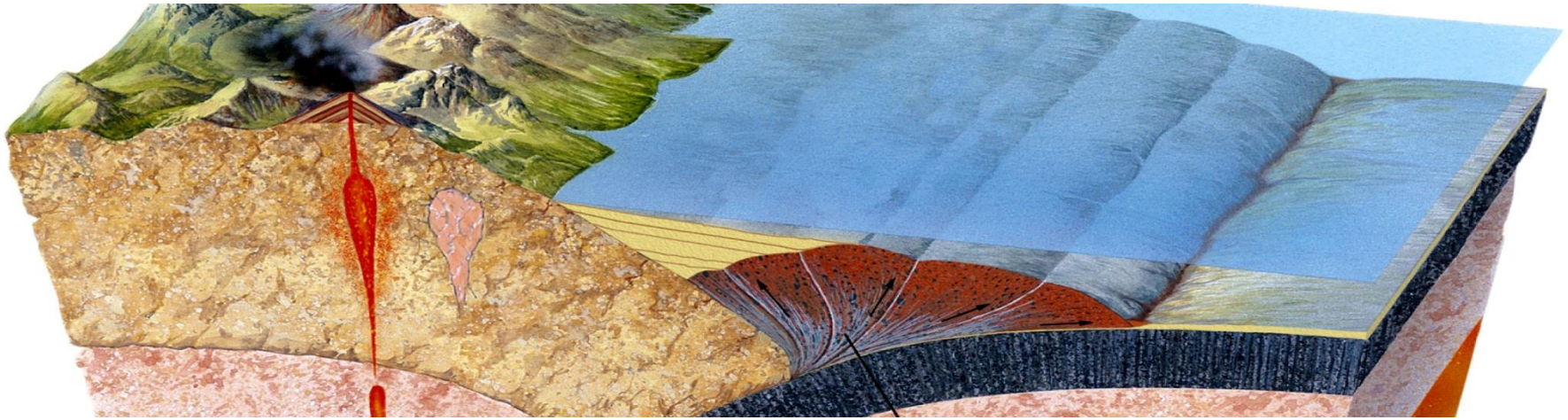
- Metamorphic change occurs slowly in the solid state
- Several processes are at work

  5. **Plastic deformation** – Mineral grains soften and deform



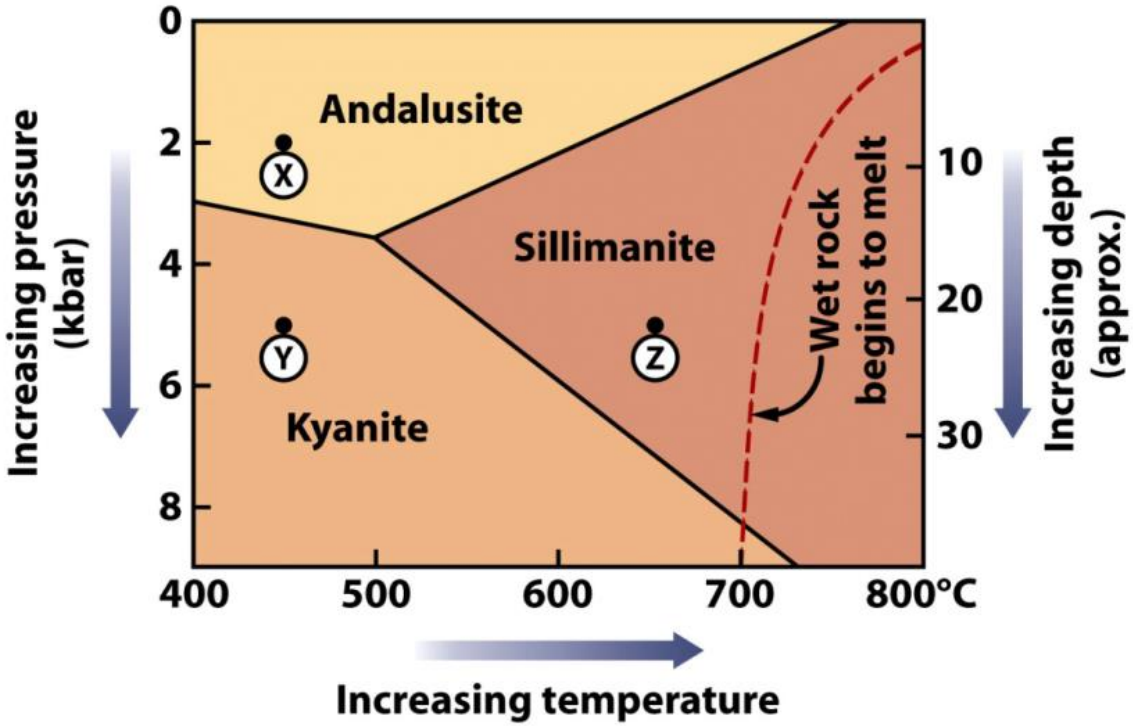
Causes of Metamorphism

- The agents of metamorphism are…
  - Heat (T)
  - Pressure (P)
  - Hot fluids (Chemical composition)
  - Differential stress



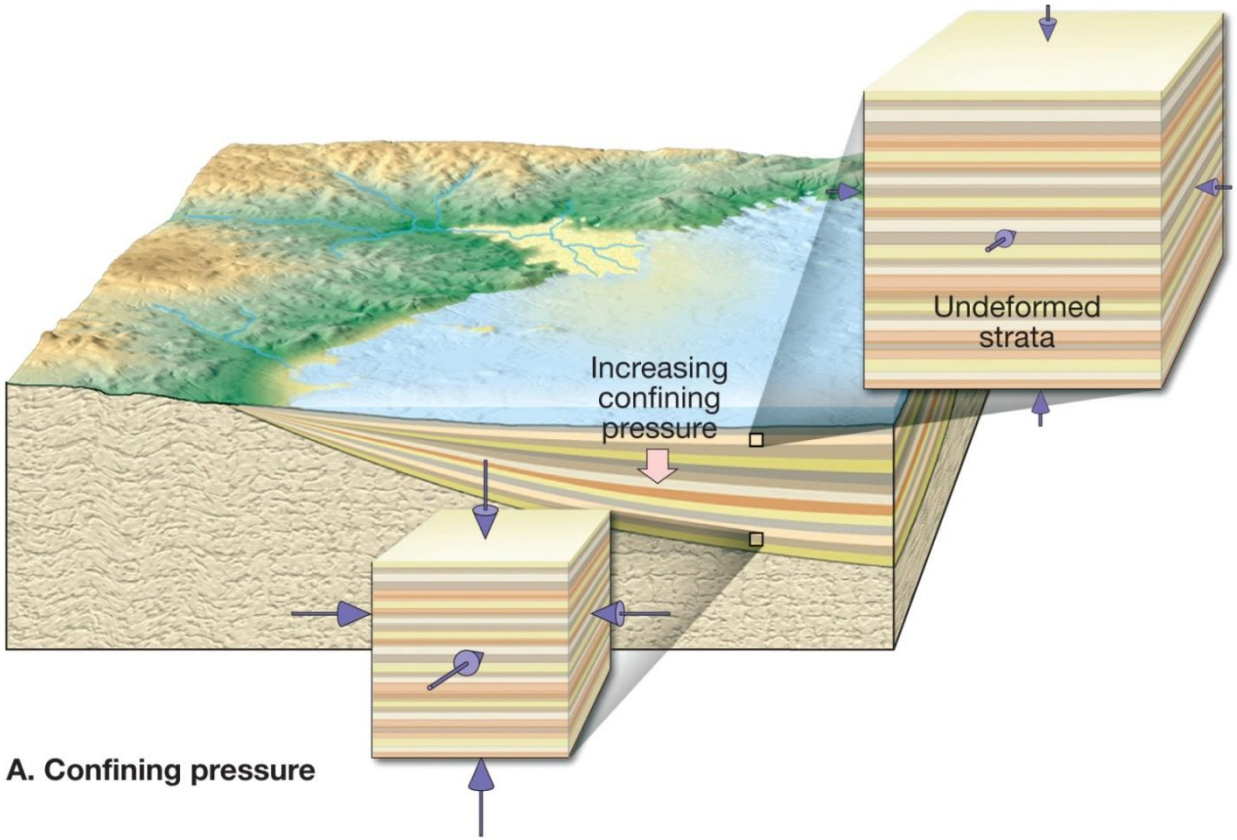
Causes of metamorphism: Temperature and pressure

- T and P <u>both</u> increase with depth
- Mineral stability is highly dependent upon T and P
- Mineral crystals grow larger
- Some minerals convert to new minerals



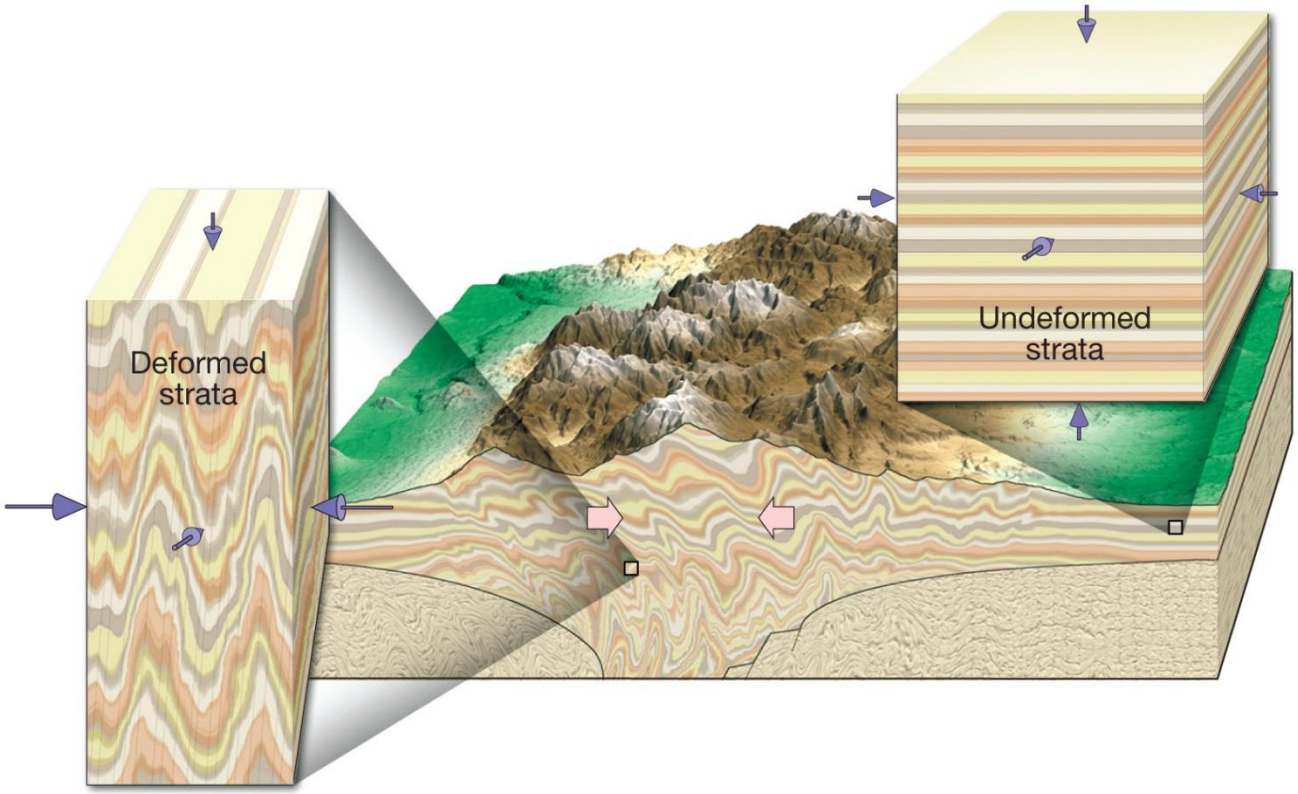
Causes of metamorphism: Confining pressure

- Caused by weight of overlying rocks, increases with depth
- Acts equally in all directions
- No deformation



Causes of metamorphism: Differential stress

- Caused by plate tectonic forces, like continental collisions
- Pressure that is greater in one direction than others
- Rocks can become highly deformed



B. Differential stress

Causes of metamorphism: Fluids

- Most rocks contain pore fluids

- These fluids enhance metamorphism, by:
  - Speeding up chemical reactions:
    - Recrystallization
    - Growth of new minerals
  - Influencing melting temperatures

Two subdivisions of metamorphic rocks

- Foliated – Has a through-going planar fabric
  - Subjected to differential stress
  - Has a significant component of platy minerals
  - Classified by composition, grain size, and foliation type
- Nonfoliated – No planar fabric evident
  - Crystallized without differential stress
  - Comprised of equant minerals only
  - Classified by mineral composition

Non-foliated metamorphic rocks

- Marble
  - Metamorphosed limestone
  - Mineralogy still is calcite
  - Larger, interlocking crystals

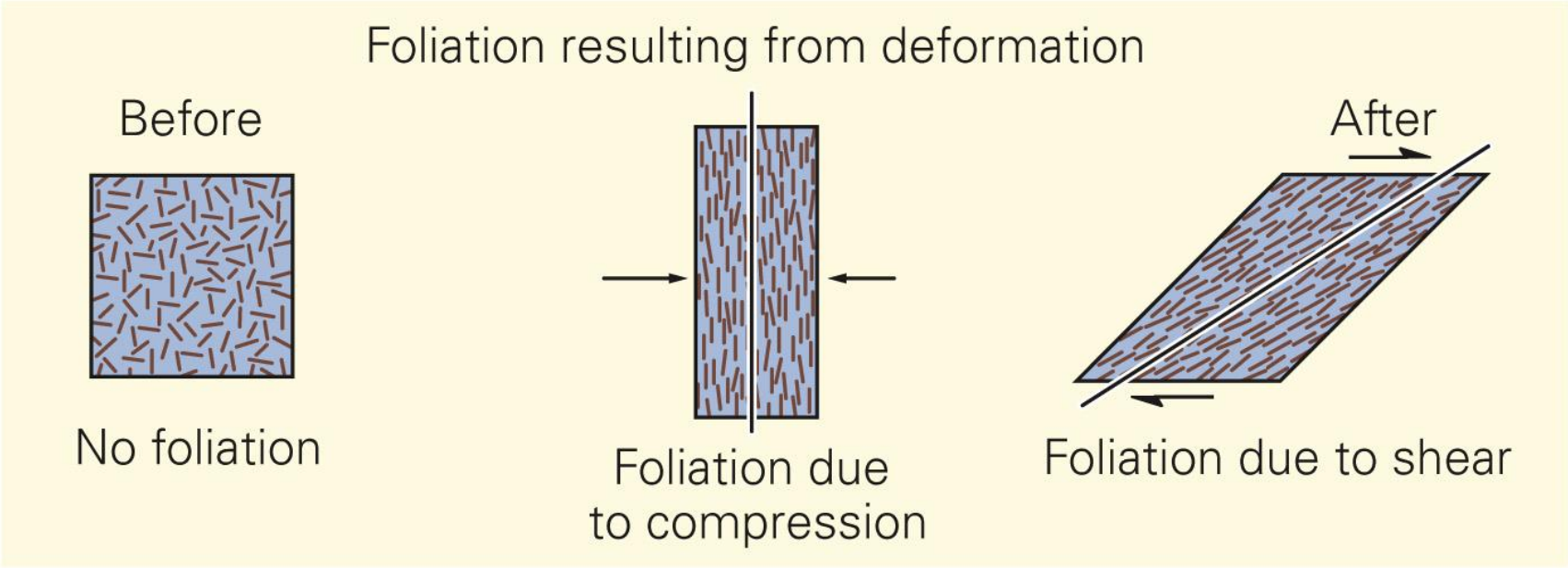
- Quartzite
  - Metamorphosed quartz sandstone
  - Mineralogy still is quartz
  - Quartz grains fuse together

Foliated metamorphic rocks

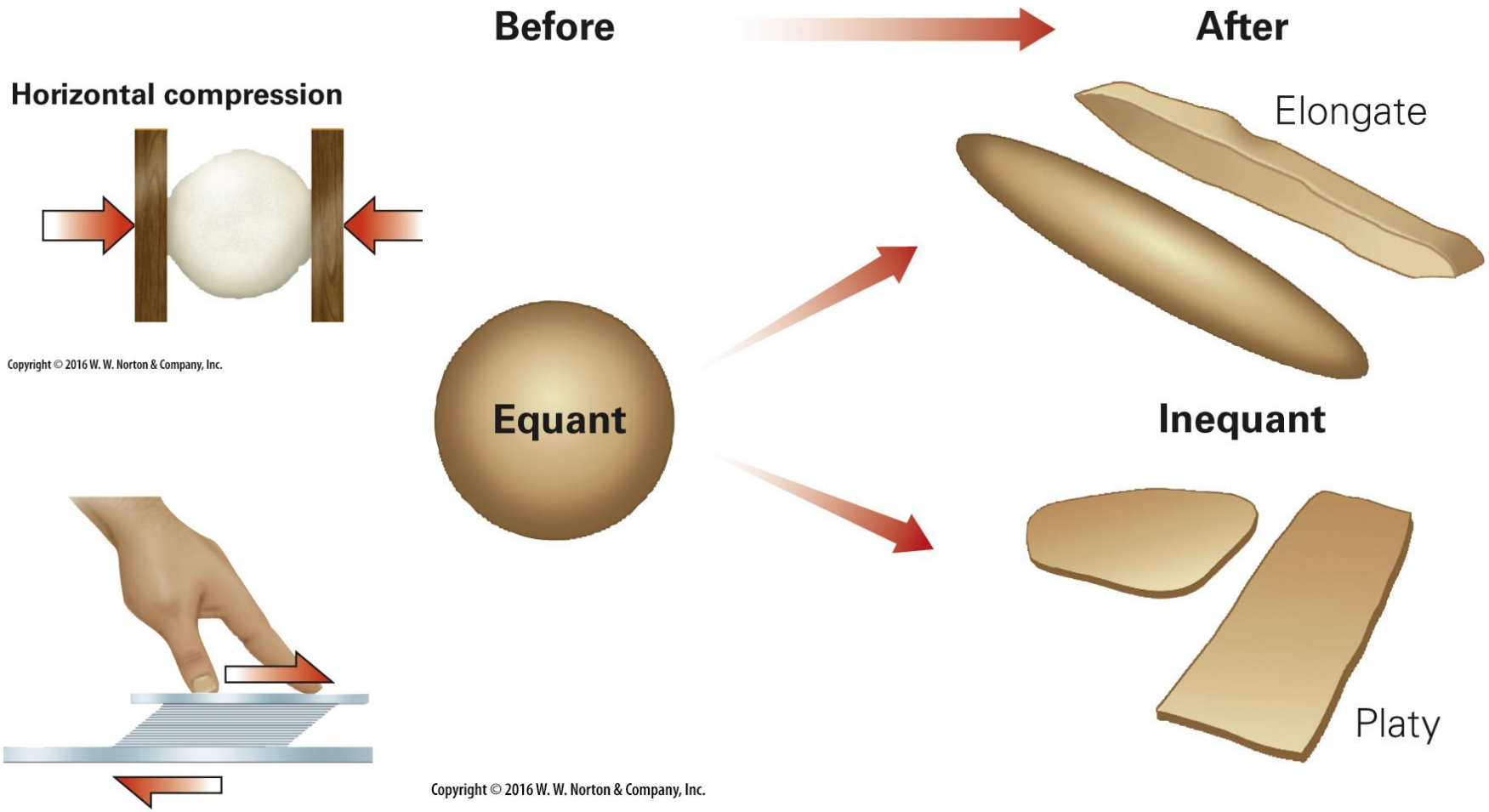
- Can be broadly classified by type of foliation and parent rock composition (less important)
- As metamorphic grade (T and P) increases, rock type will change:
  - Slate
  - Phyllite
  - Schist
  - Gneiss
- Parent rocks can vary (shale, siltstone, granite, etc...)

Increasing metamorphic grade

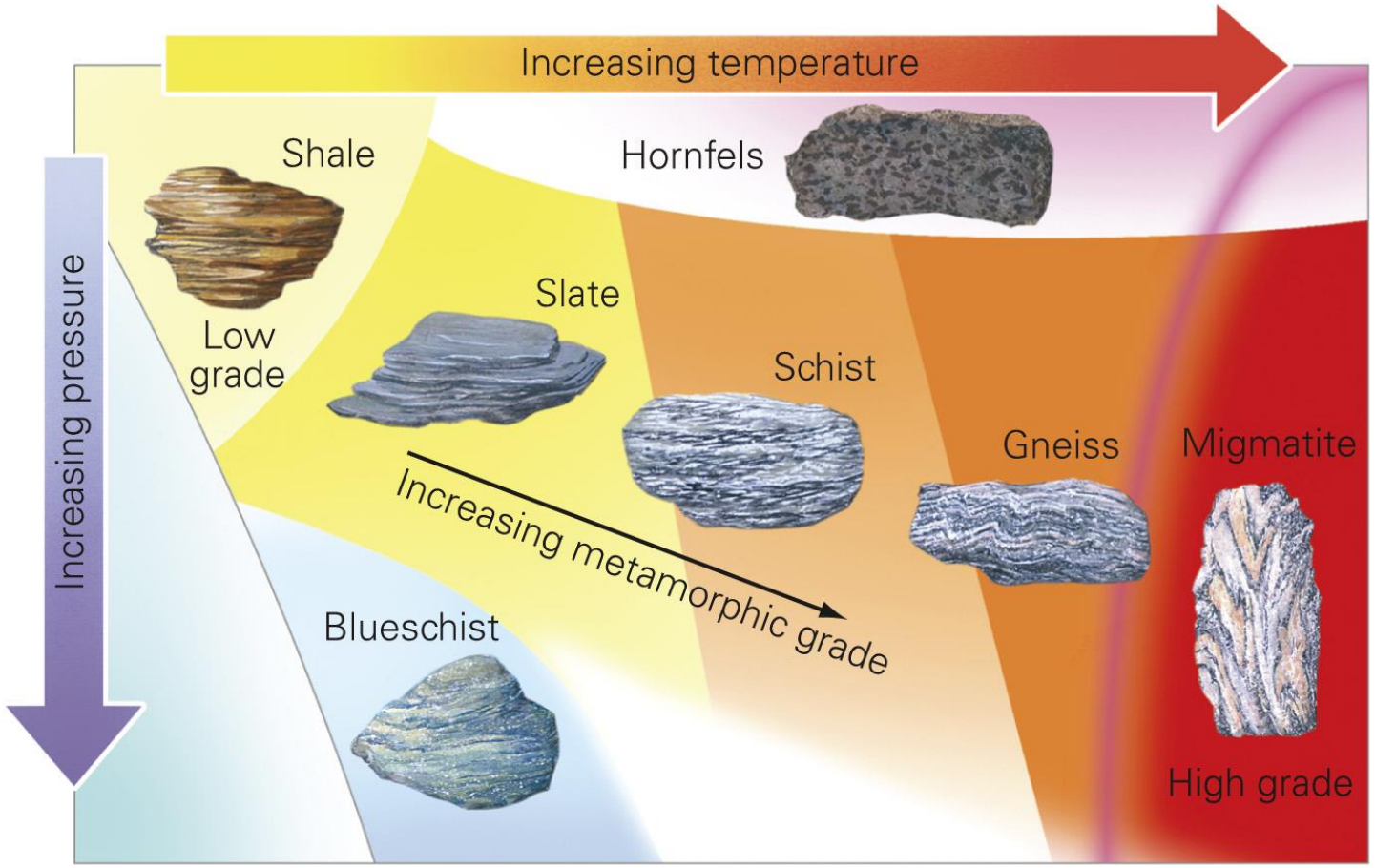
Foliated metamorphic rocks



Foliated metamorphic rocks

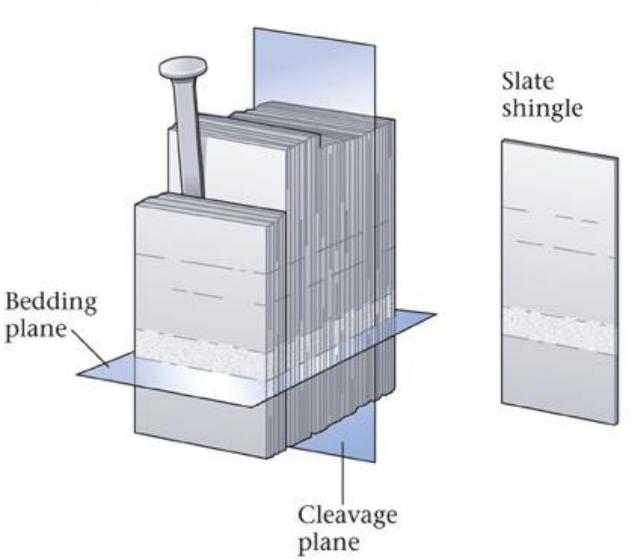


Foliated metamorphic rocks



Foliated metamorphic rock: Slate

- Fine clay, low-grade metamorphic shale
  - Has a distinct foliation called slaty cleavage
    - Develops by parallel alignment of platy clay minerals
    - Slaty cleavage oriented perpendicular to compression
    - Slate breaks along this foliation creating flat sheets

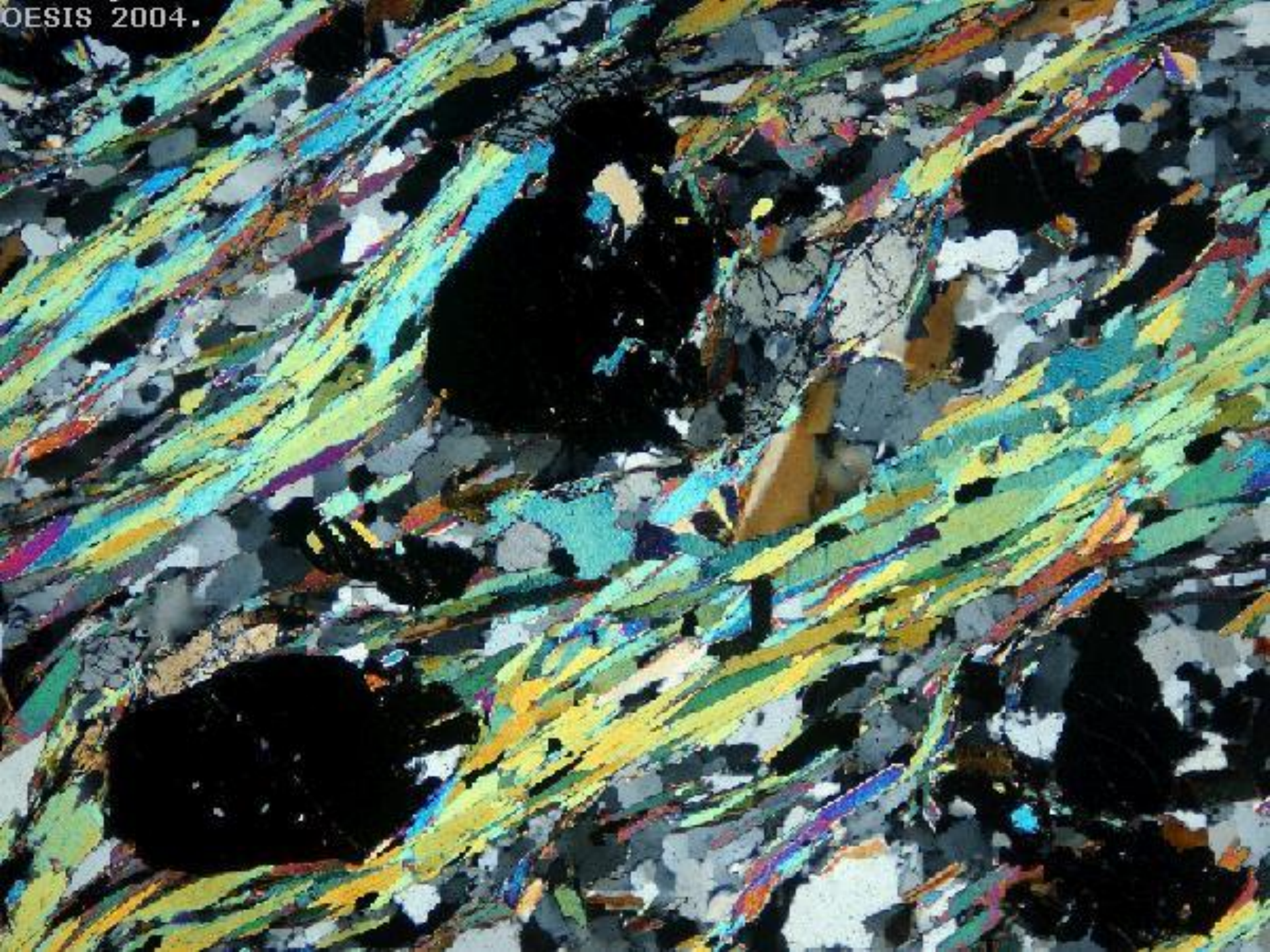


Foliated metamorphic rock: Phyllite

- Fine mica-rich rock
  - Formed by low- to medium-grade alteration of slate
  - Clay minerals neocrystallize into tiny micas
  - Micas reflect a satiny luster

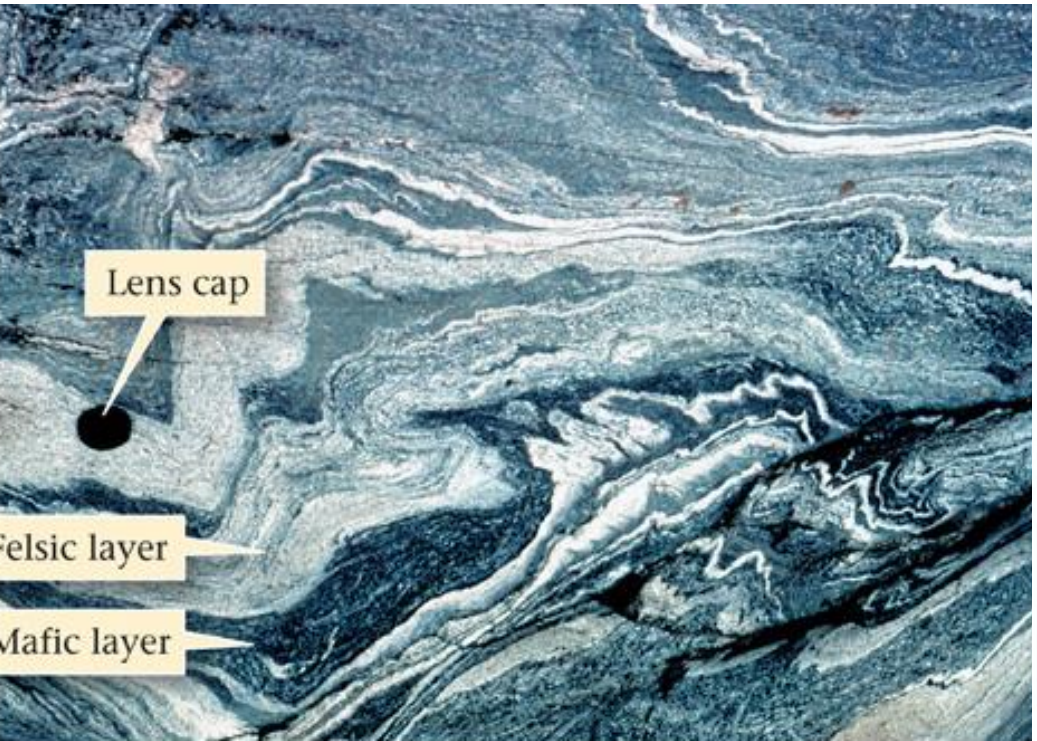
Foliated metamorphic rock: Schist

- Fine or coarse rock with larger micas
  - Medium- to high-grade metamorphism
  - Has a distinct foliation called schistosity
    - Parallel alignment of large mica crystals
    - Micas are visible because they have grown at higher T
  - Schist often has other minerals due to neocrystallization. e.g. garnet

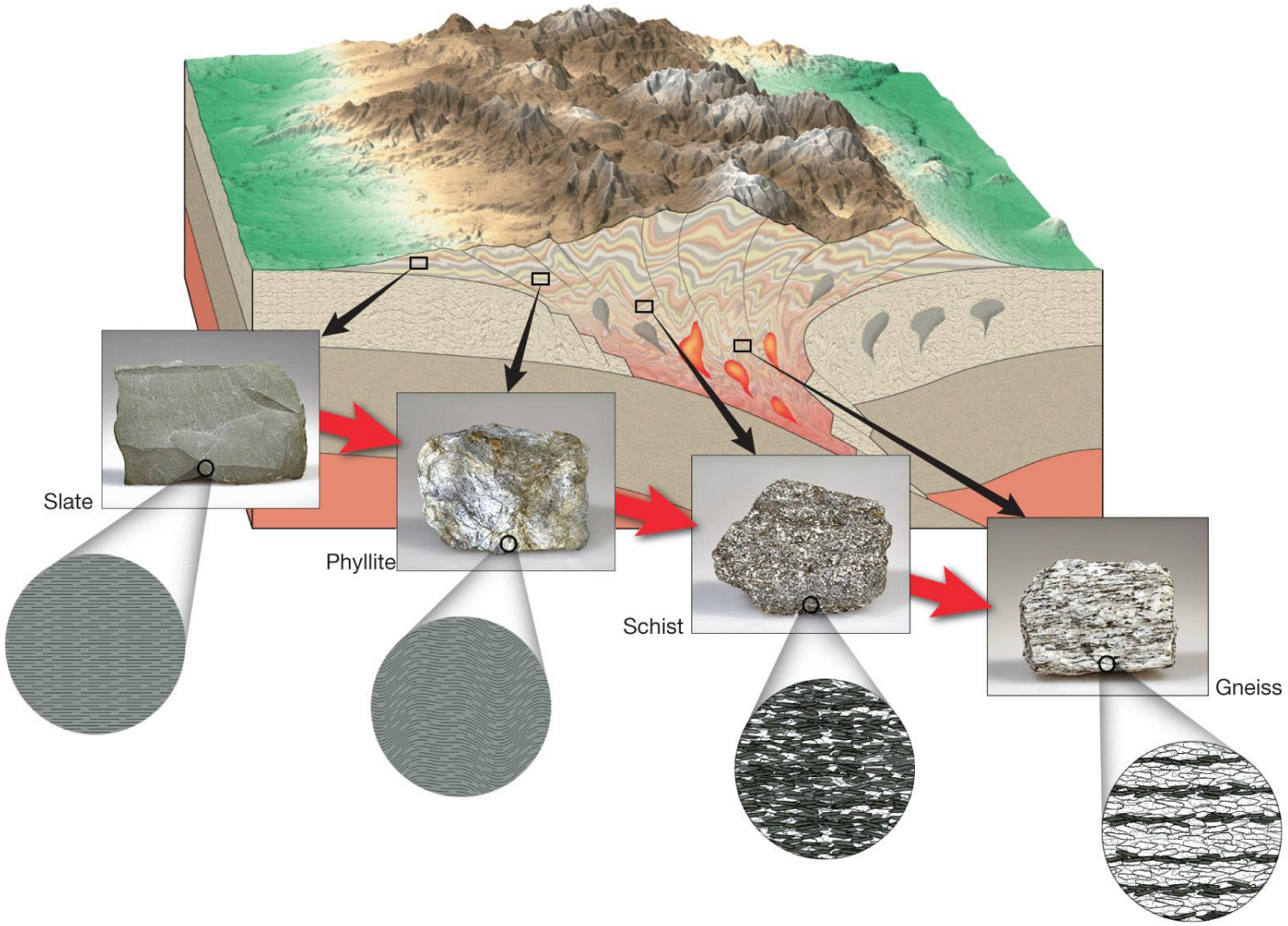

OESIS 2004.

Foliated metamorphic rock: Gneiss

- Has a distinct banded foliation
  - Light bands of felsic minerals (quartz and feldspars)
  - Dark bands of mafic minerals (biotite or amphibole)
- During higher grades of metamorphism, ion migration results in the segregation of minerals



Metamorphic Grade: A measure of metamorphic intensity



Main types of metamorphism

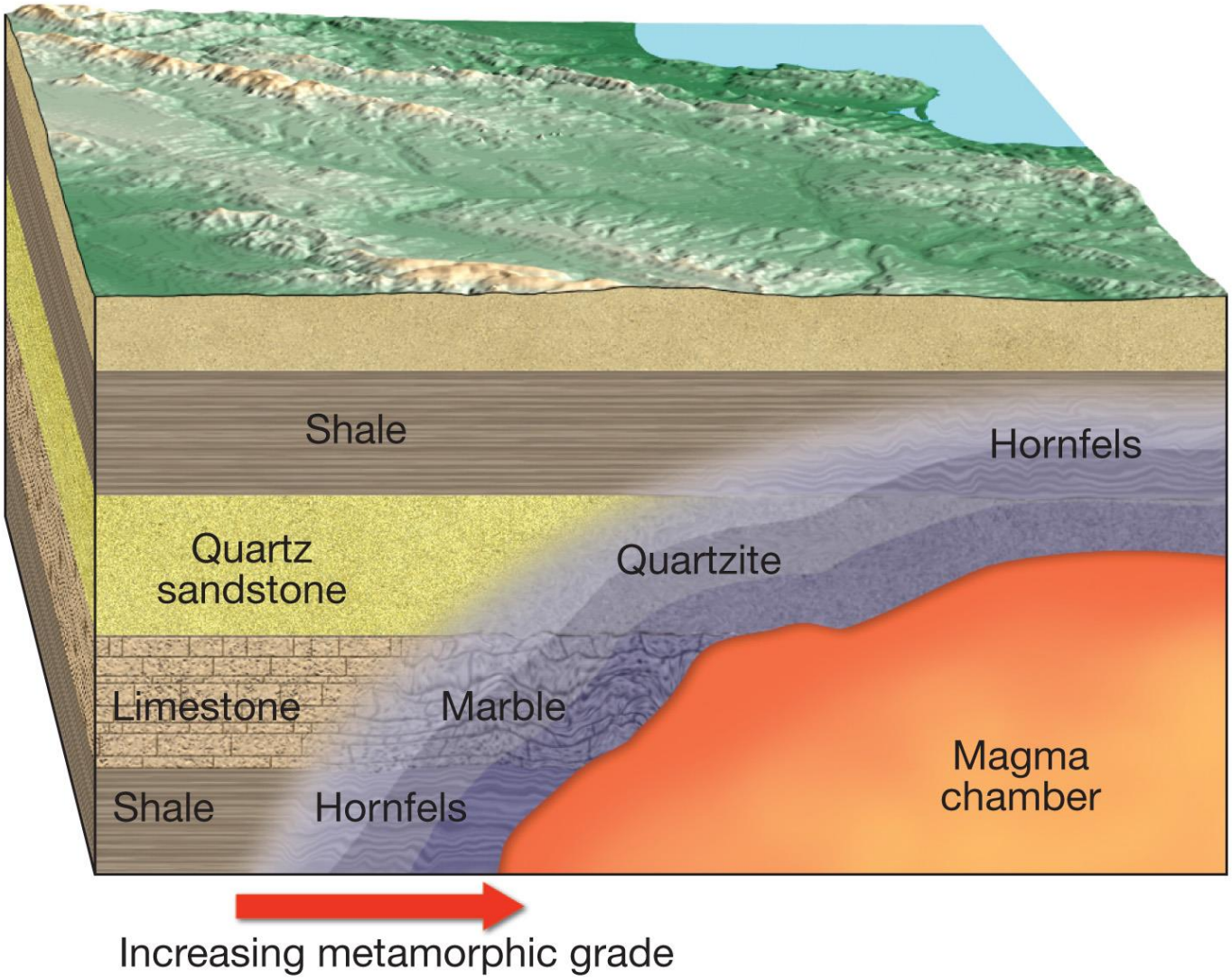
- **Contact metamorphism**
- **Regional metamorphism**
- **Burial metamorphism**
- **Hydrothermal metamorphism**

Main types of metamorphism

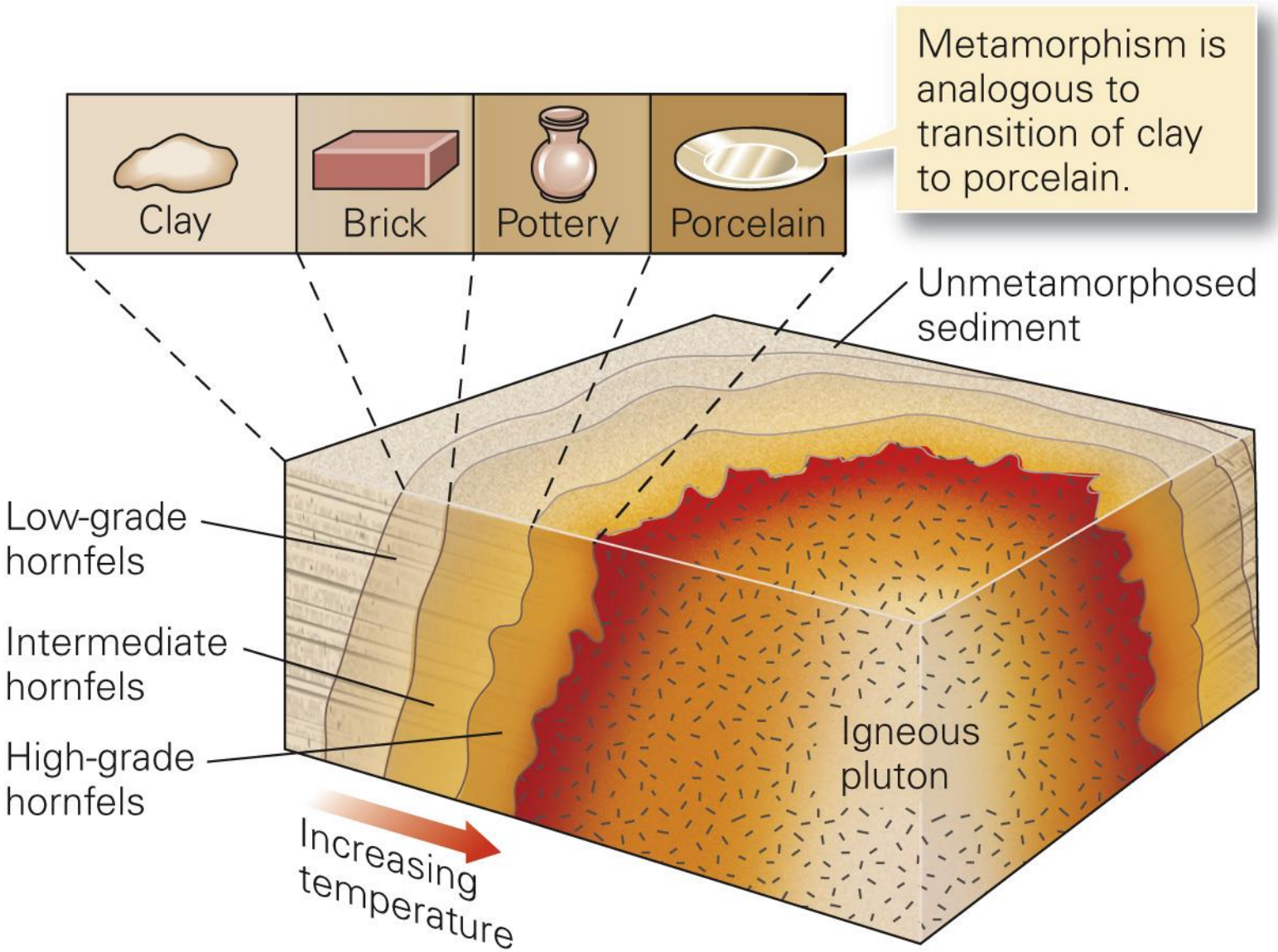
- **Contact metamorphism**
  - High temperatures caused by igneous intrusions (magma) "bake" surrounding rocks
- **Regional metamorphism**
  - Metamorphism of an extensive area of the crust, associated with high temperatures and pressures at convergent plate boundaries (subduction zones & continental collisions)
- **Burial metamorphism**
  - Burial of rocks by thick accumulations of sediment increase the temperature & pressure and cause low-grade metamorphism
- **Hydrothermal metamorphism**
  - Chemical alteration by hot, metal rich fluids associated with igneous activity (most commonly at mid-ocean ridges)

Contact metamorphism

Contact metamorphism

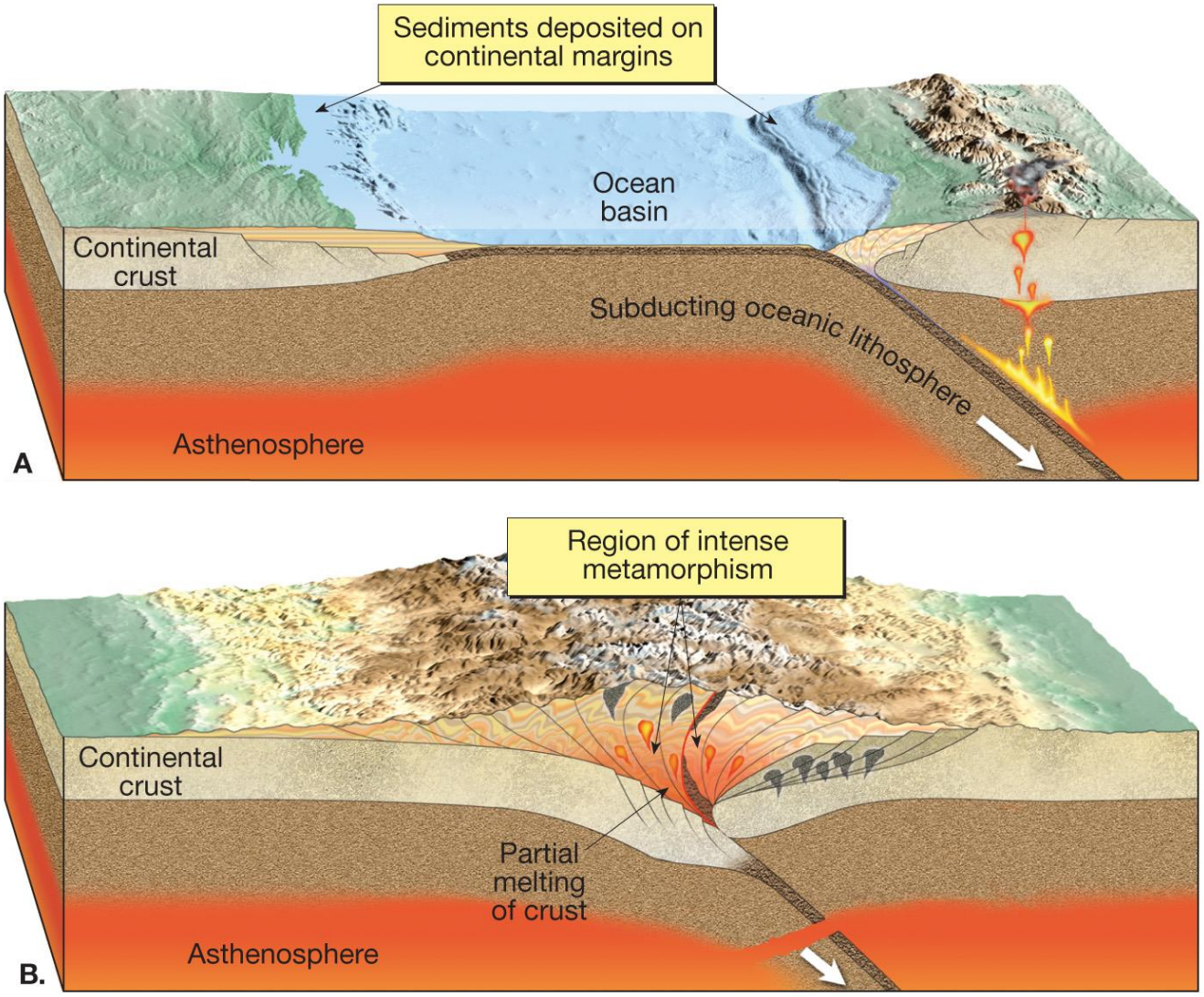


Contact metamorphism



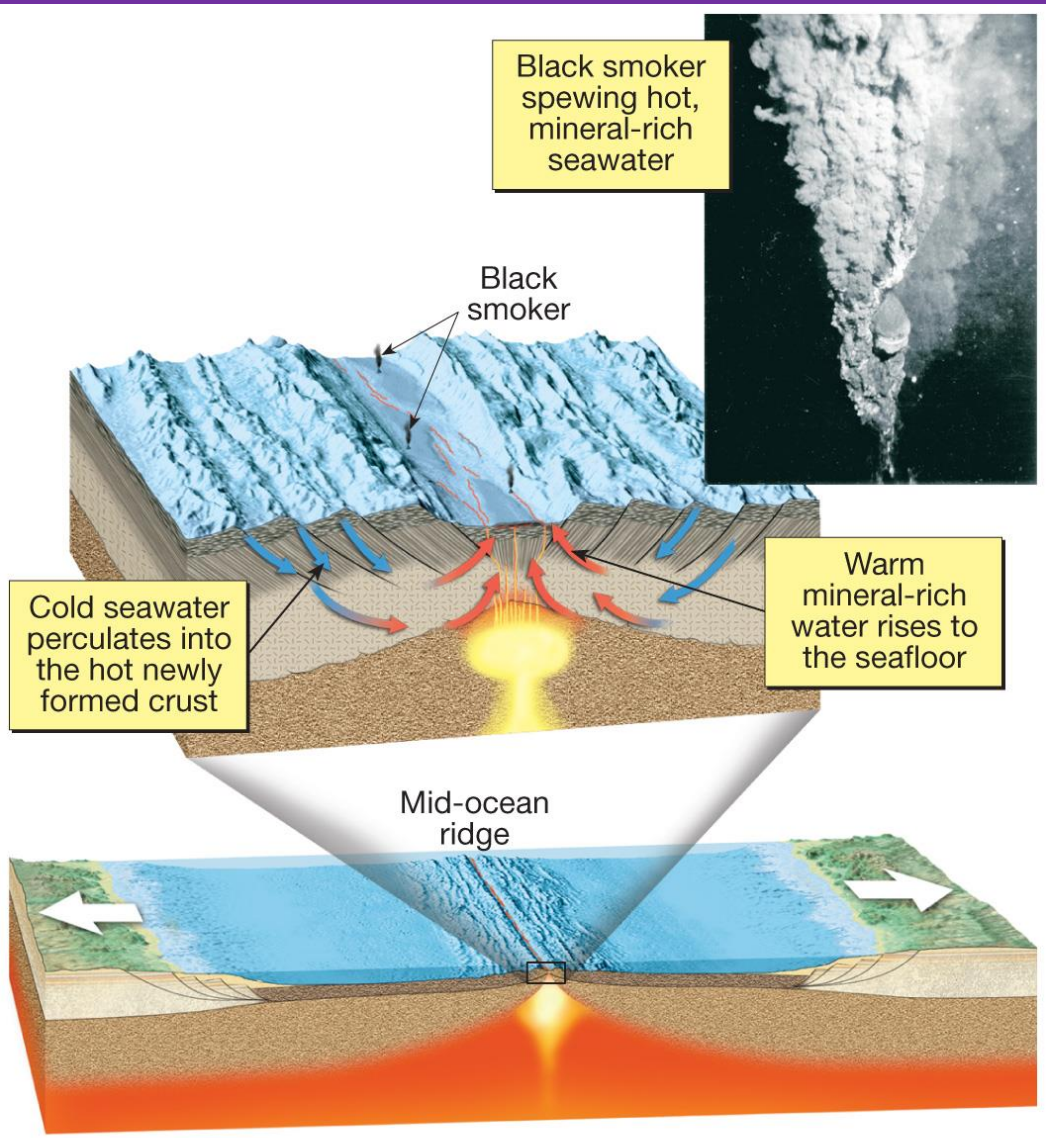
Regional metamorphism

Regional metamorphism

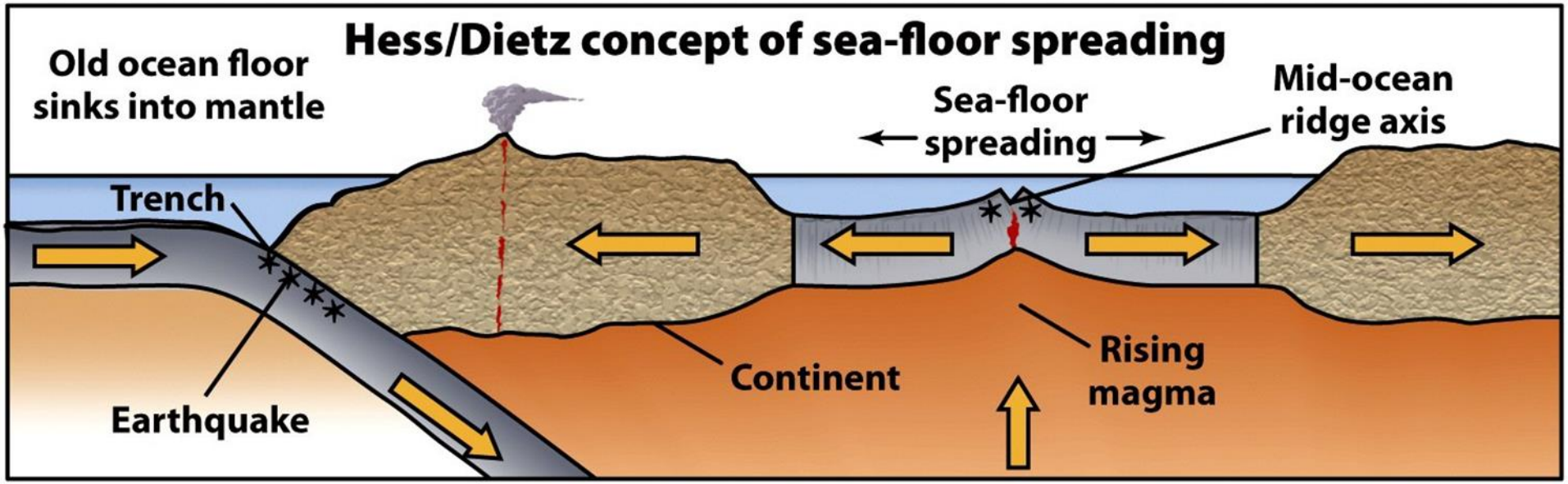


Hydrothermal metamorphism

Hydrothermal metamorphism

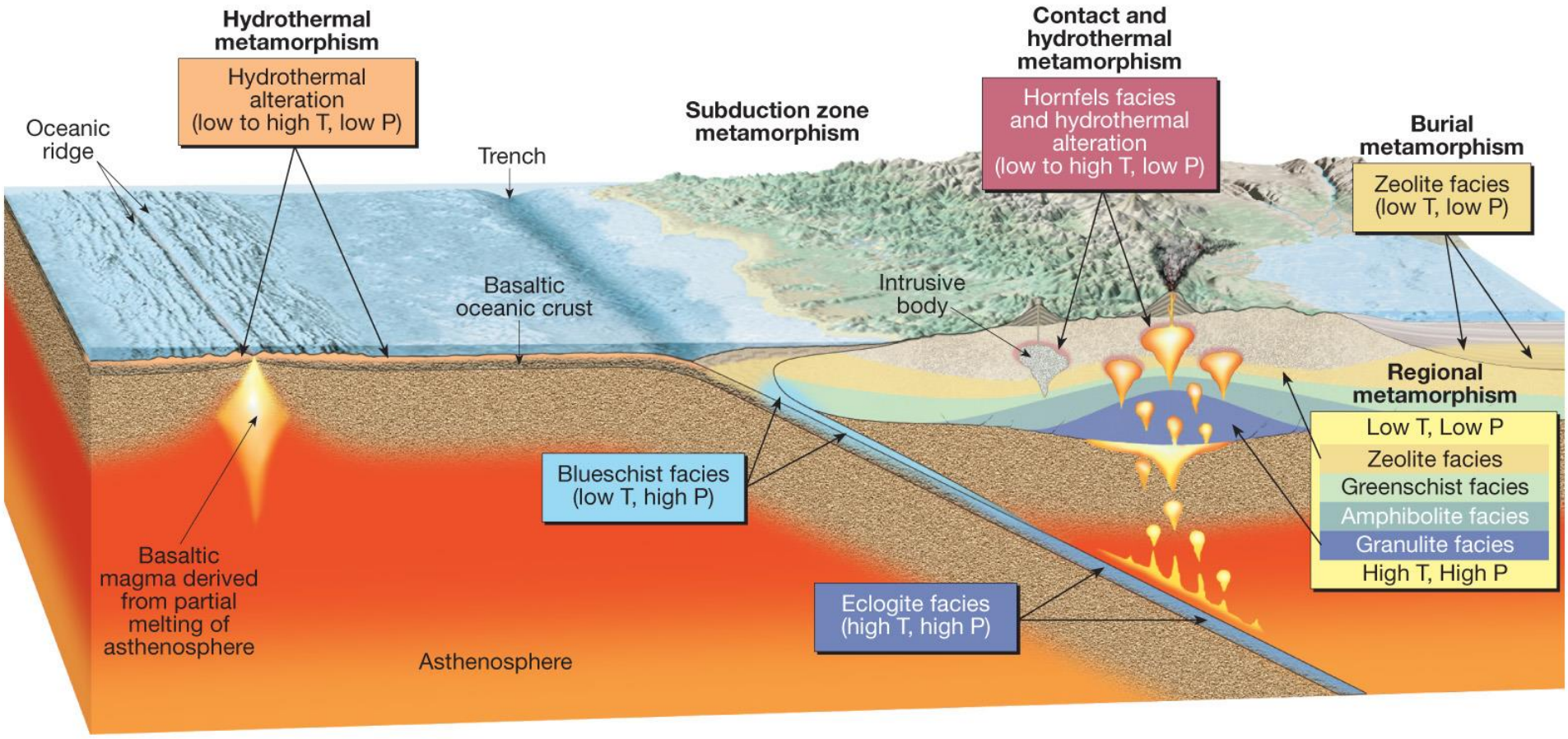


Metamorphic rocks reflect plate tectonic setting

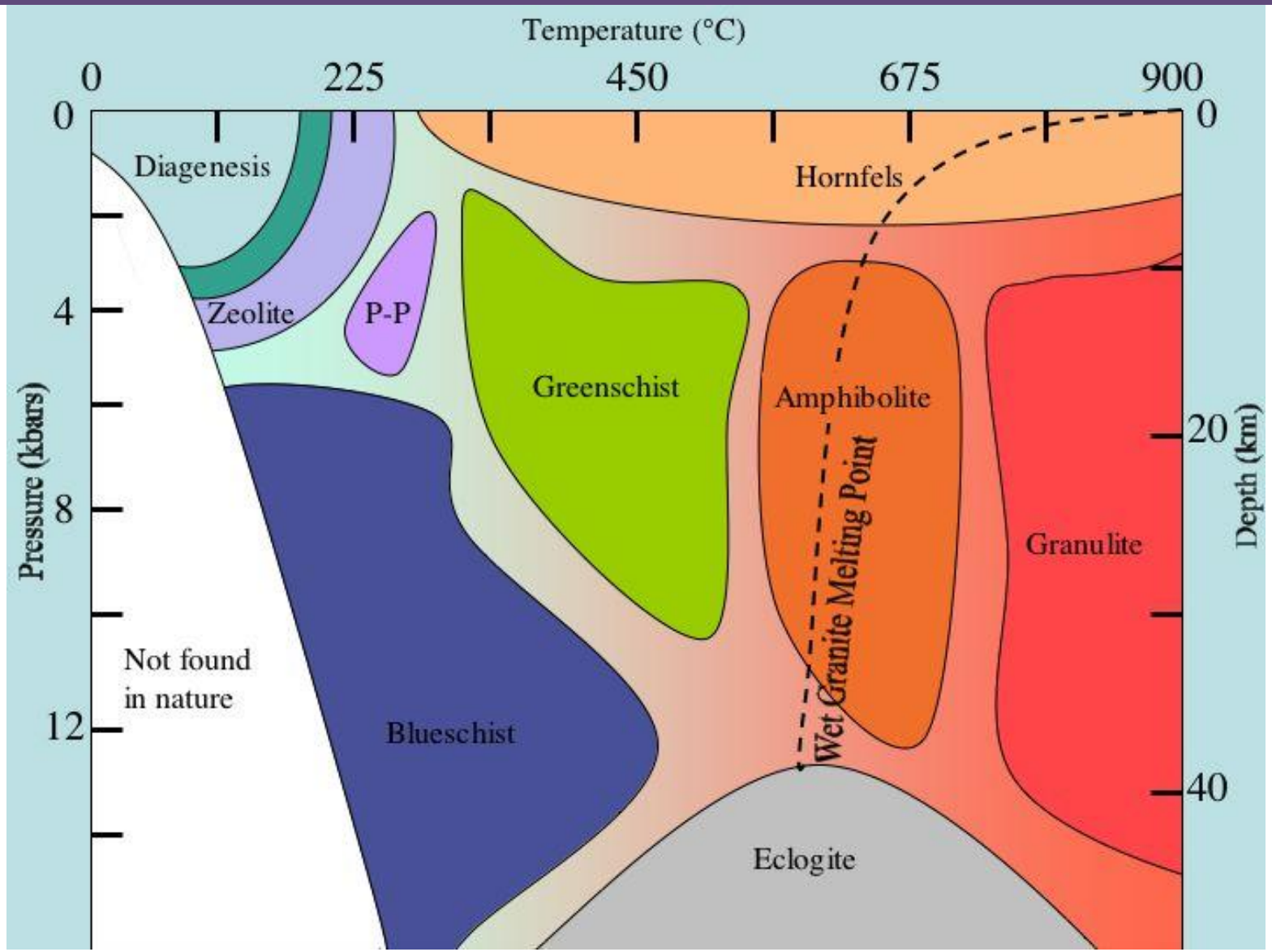


Where will you get metamorphic rock forming?
Label the areas where you will have different mineral assemblages due to:
Low T, low P (where you might get thick sequences of sediment)
Low T, high P
High T, low P
High T, high P

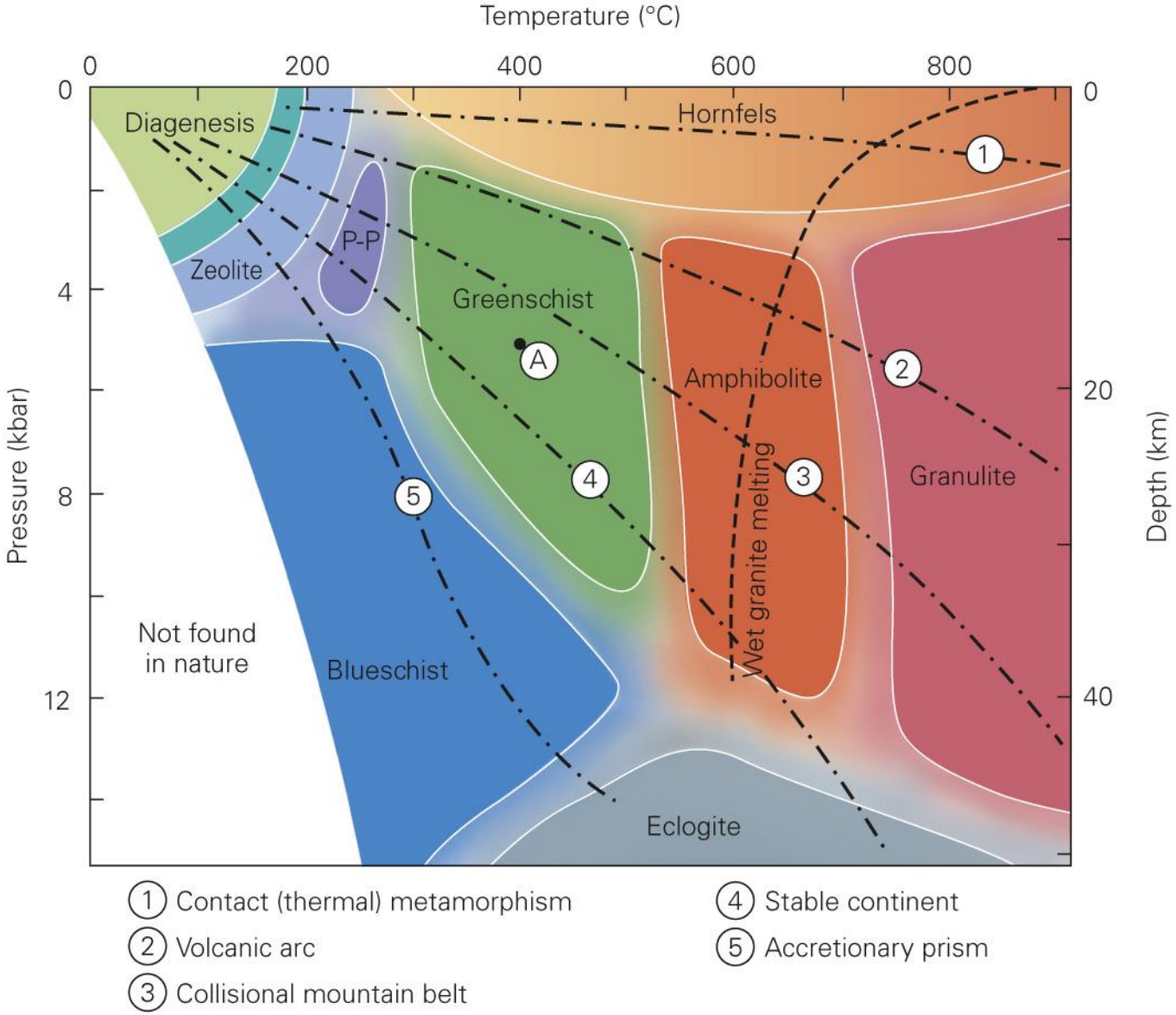
Metamorphic rocks reflect plate tectonic setting



Metamorphic facies



Metamorphic facies



Continental Shields

Much of the “continental basement” consists of metamorphic rock “shields” – the core of ancient mountain chains!