Lecture 5 – Sedimentary rocks Recap+ continued

and Metamorphic rocks!

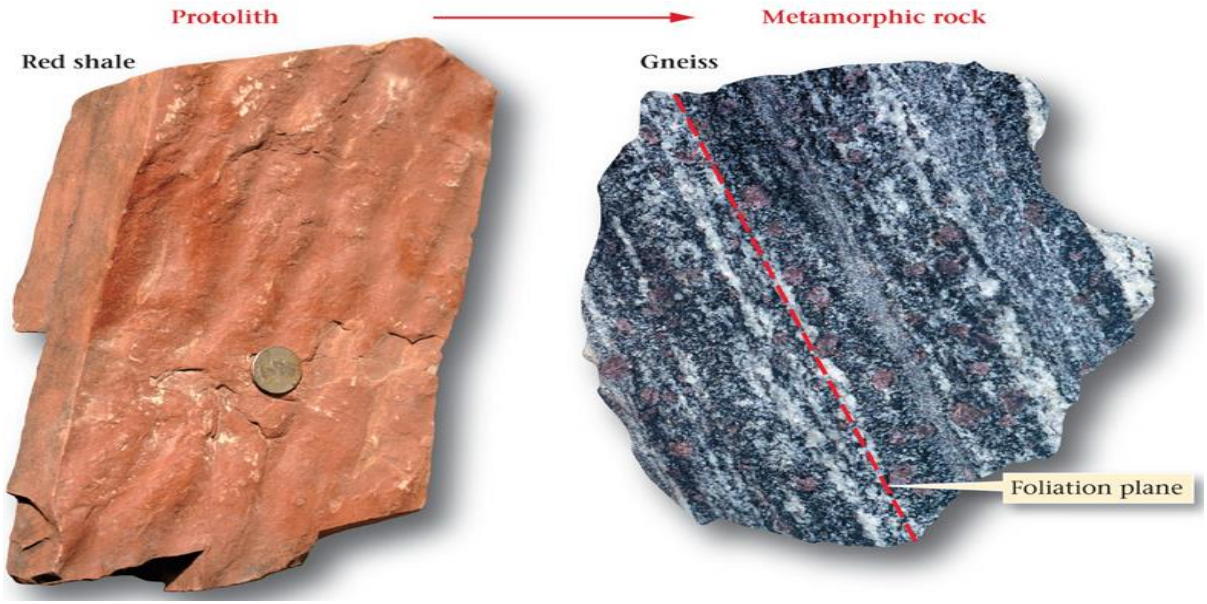
Metamorphism

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

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

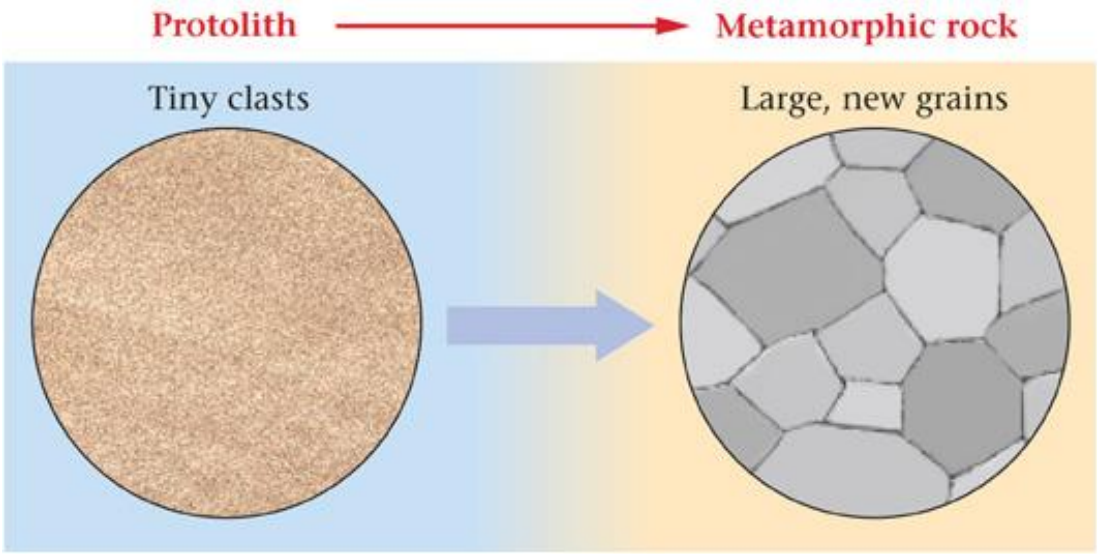
Metamorphic Character

- 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

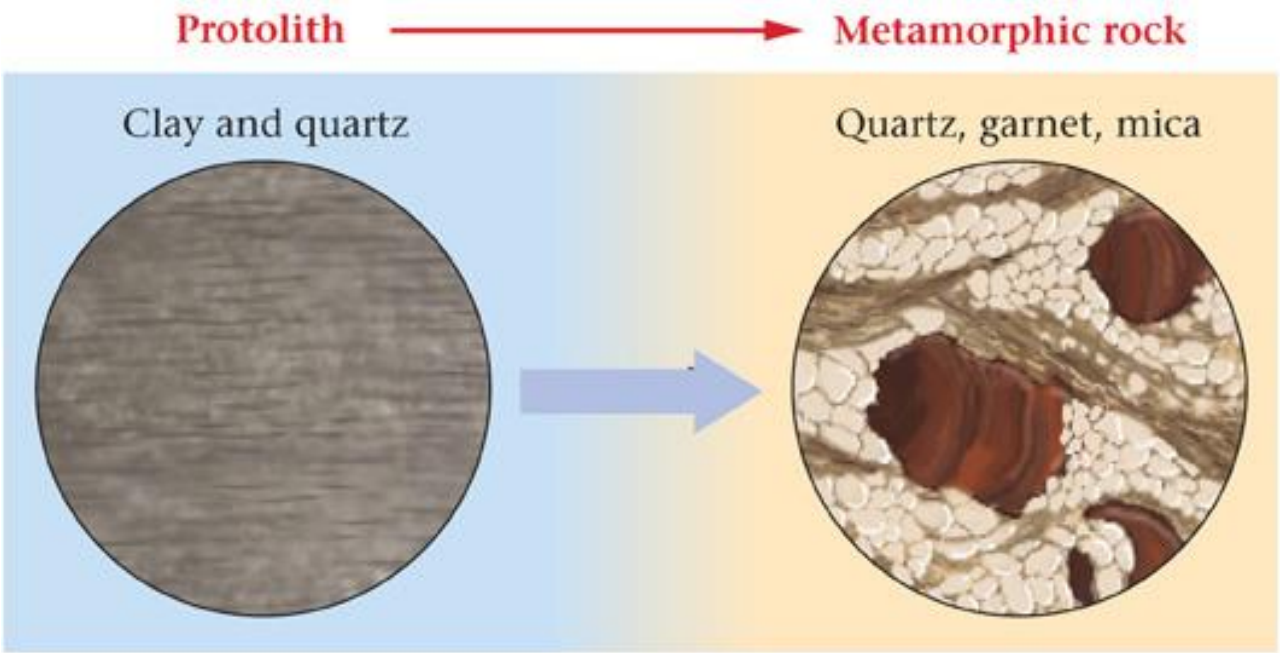
  2. **Phase change** – New minerals with different structure

  Example: Andalusite to kyanite

Metamorphic Processes

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

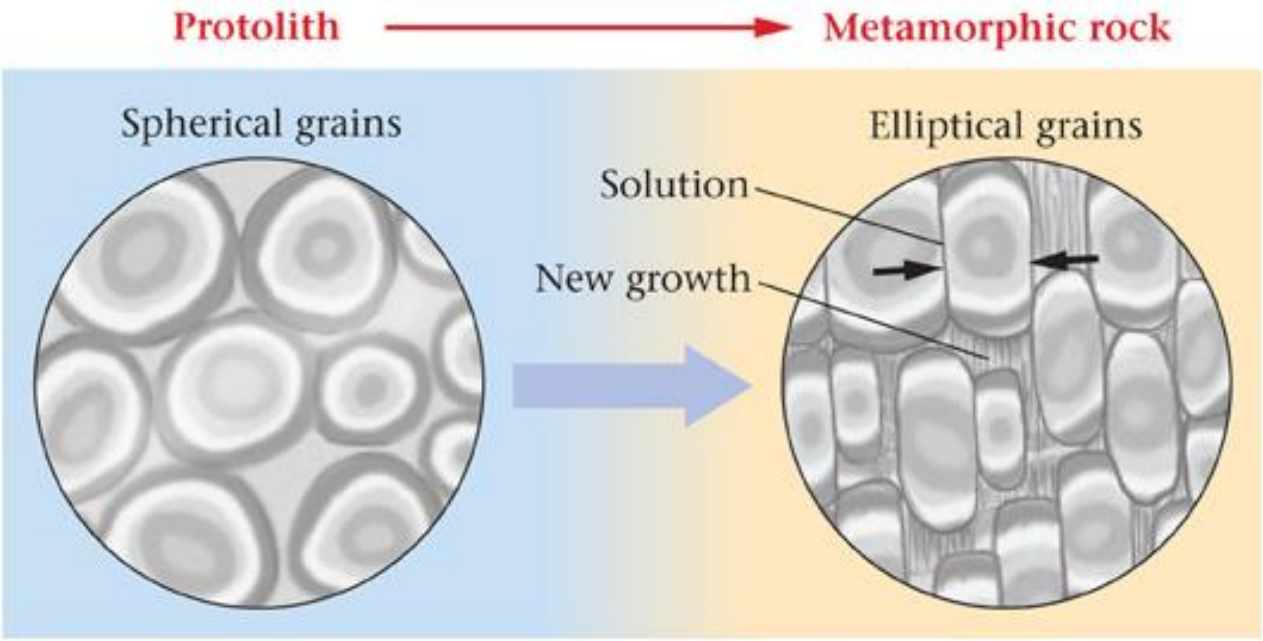
  3. **Neocrystallization** – New minerals of different composition



Metamorphic Processes

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

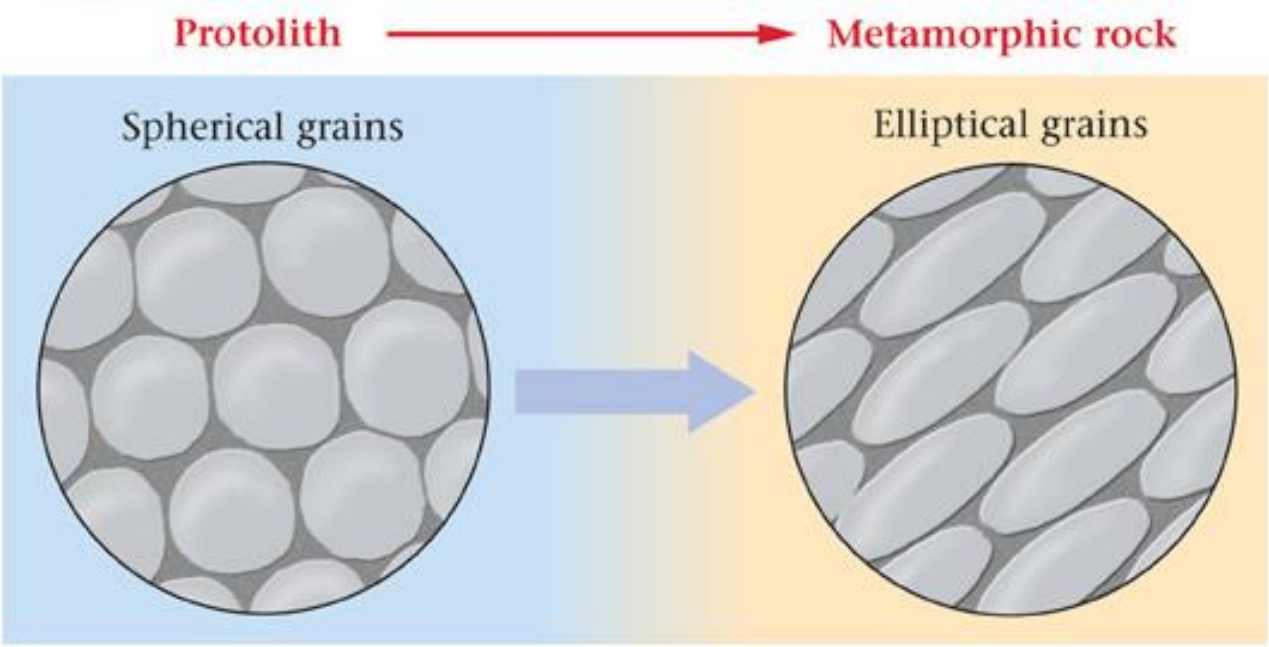
  4. **Pressure solution** – Mineral grains partially dissolve



Metamorphic Processes

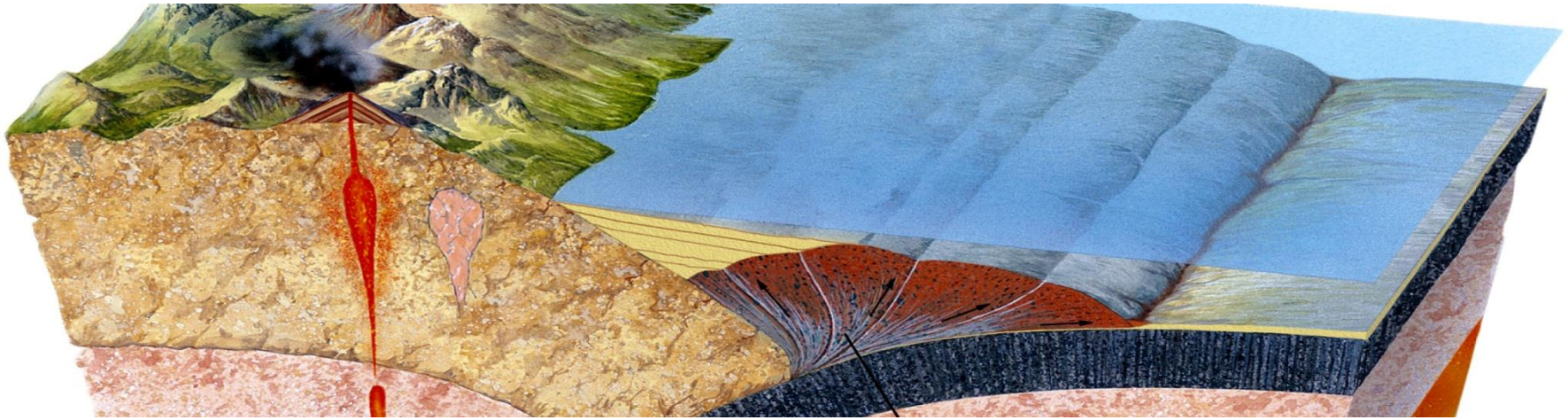
- Metamorphic change occurs slowly in the solid state
- Several processes are at work

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



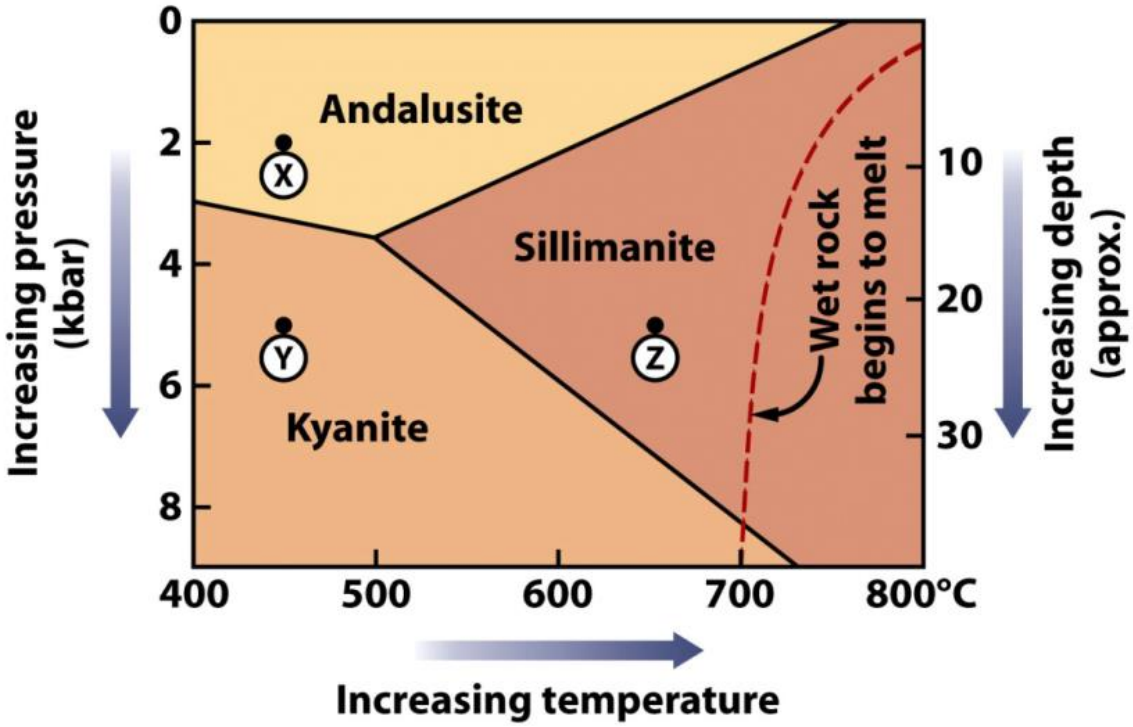
Causes of Metamorphism

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



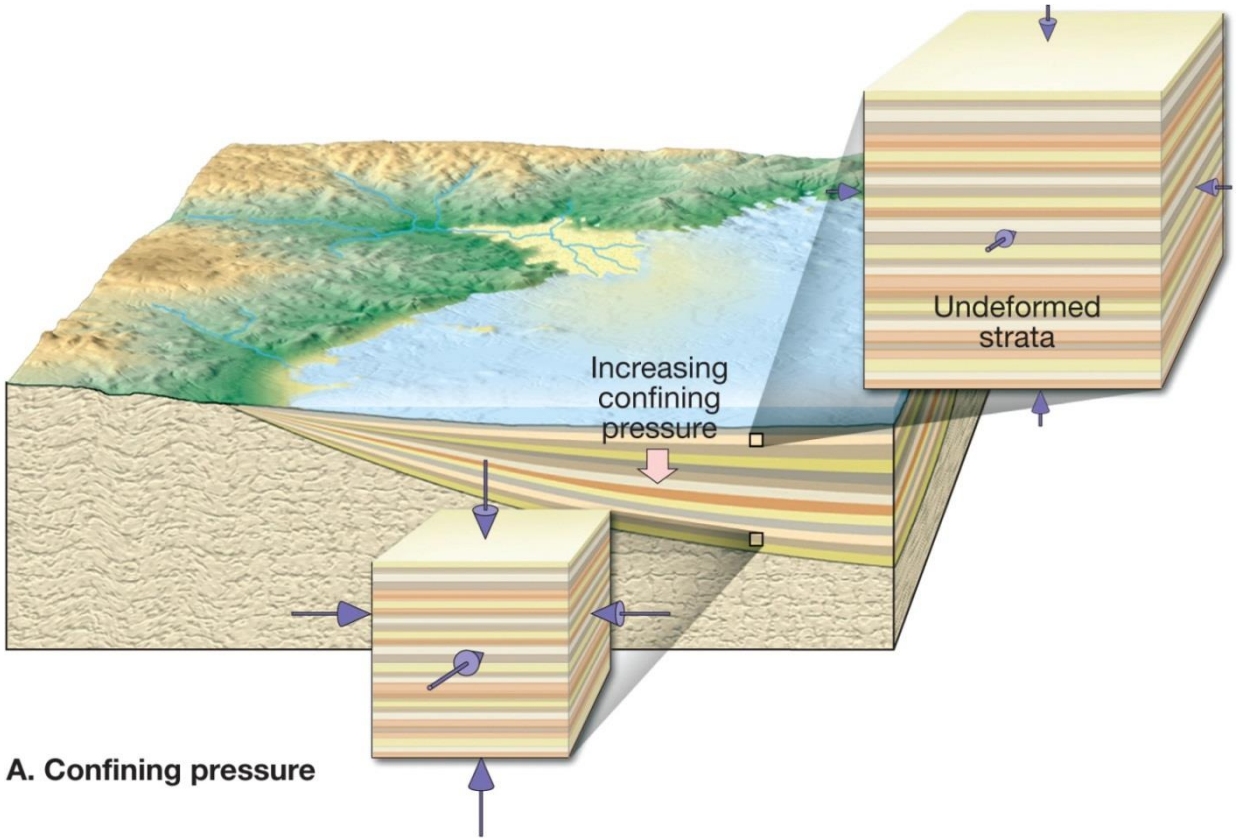
Causes of metamorphism: Temperature and pressure

- 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



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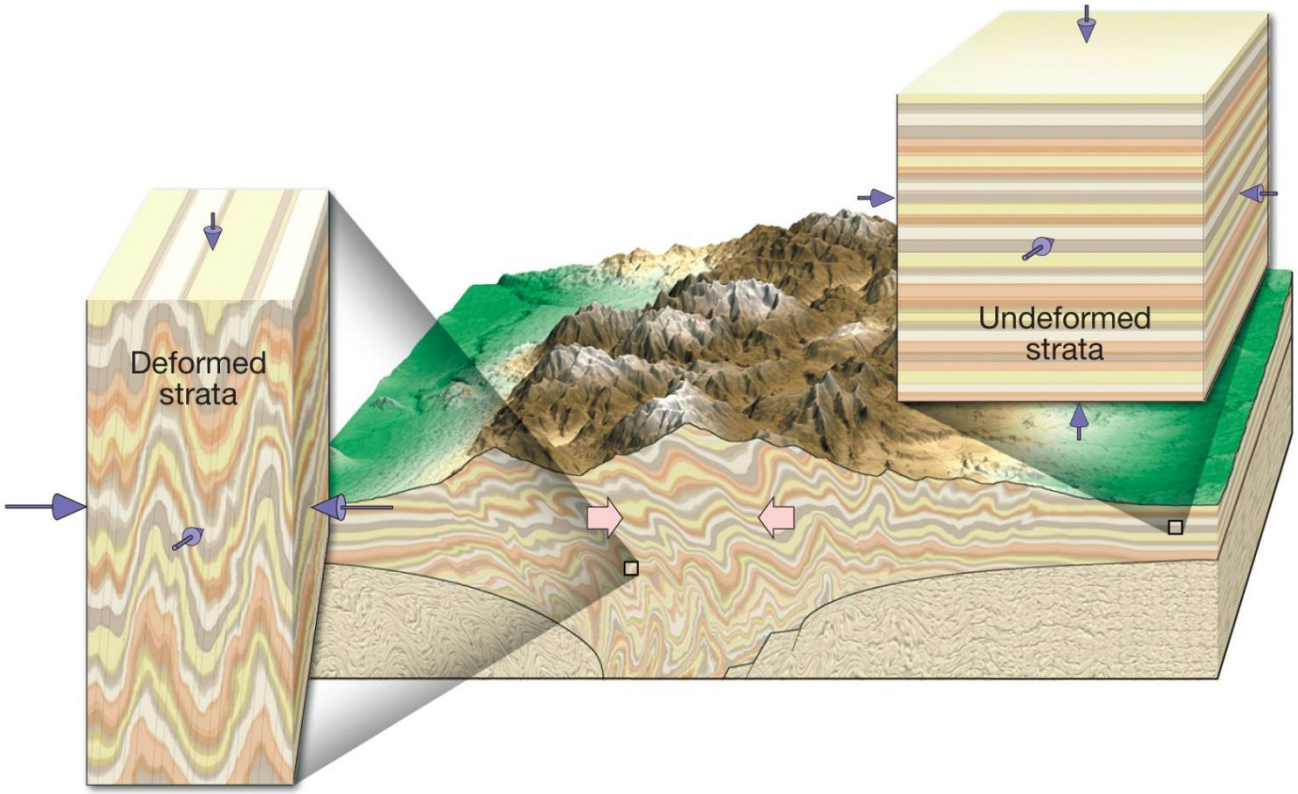
Causes of metamorphism: Differential stress

- 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

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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

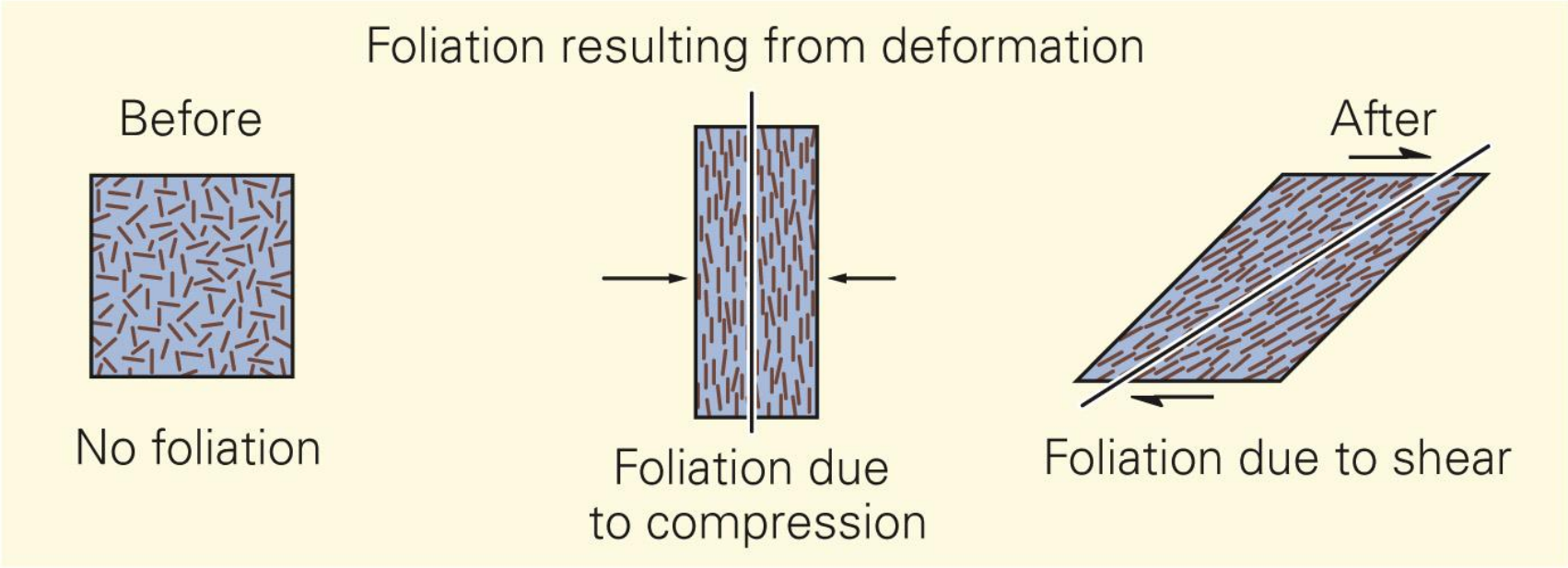
- Quartzite
  - Metamorphosed quartz sandstone
  - Mineralogy still is quartz
  - Quartz grains fuse together

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



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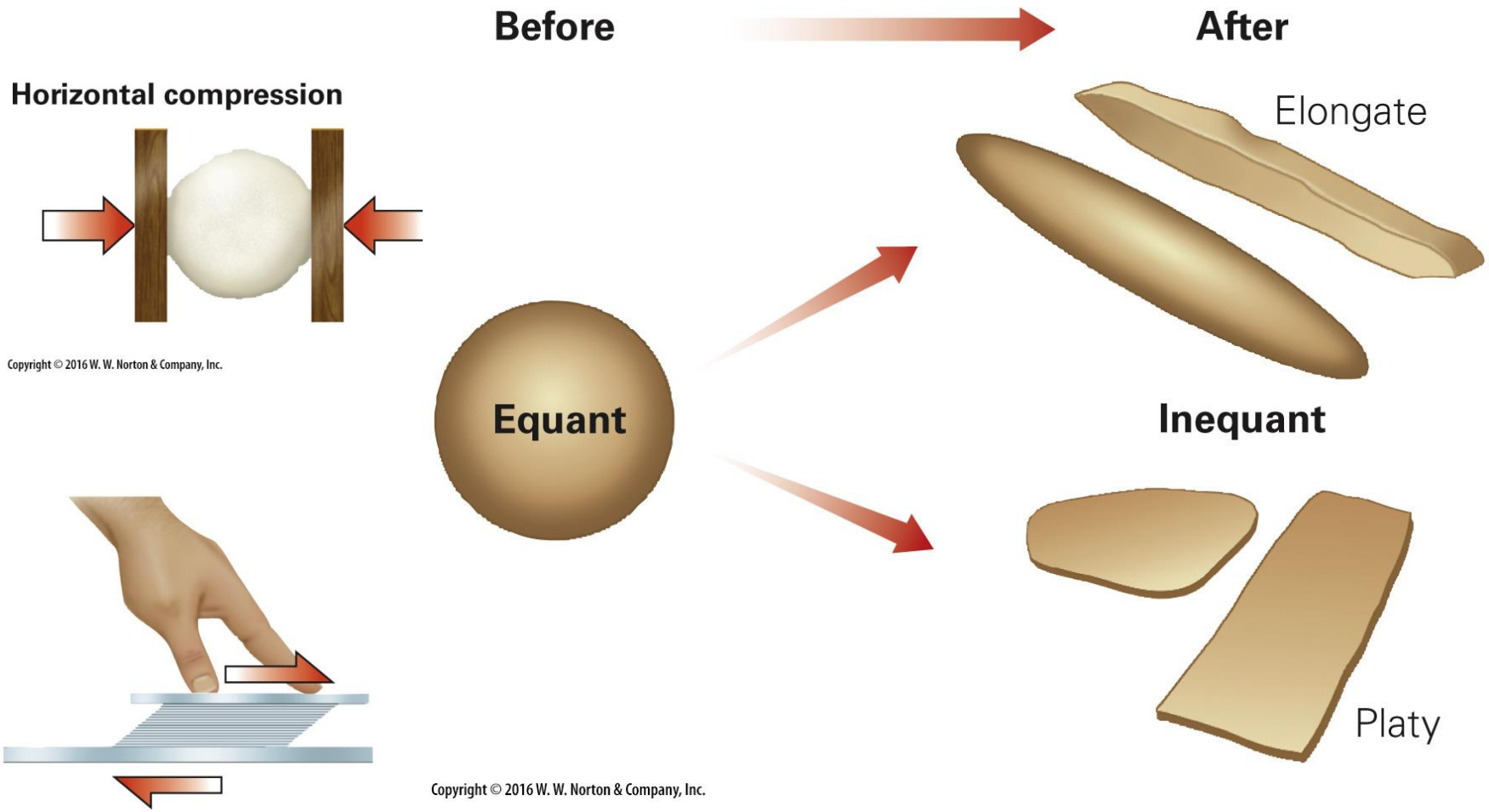
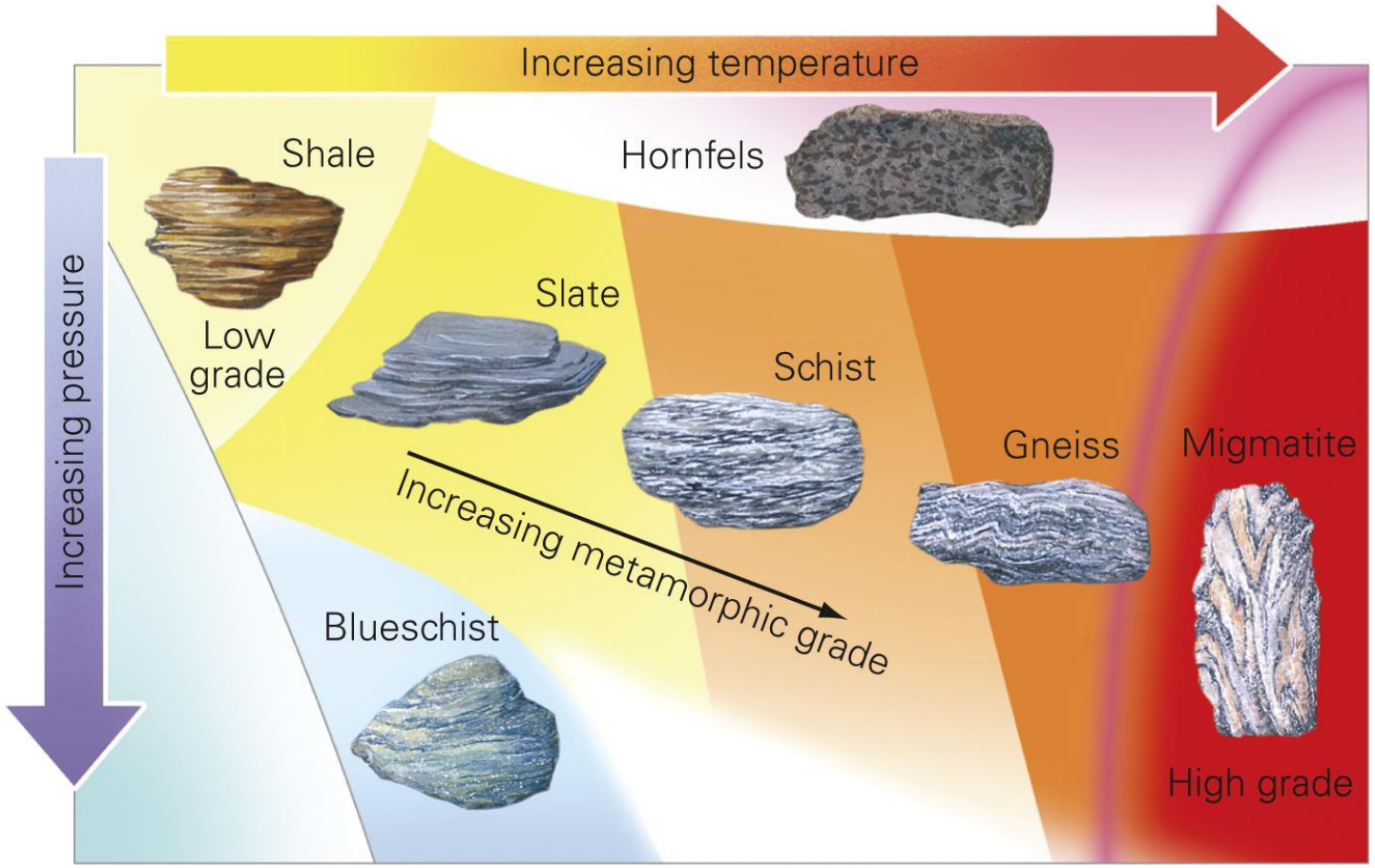
Foliated metamorphic rocks



Foliated metamorphic rocks



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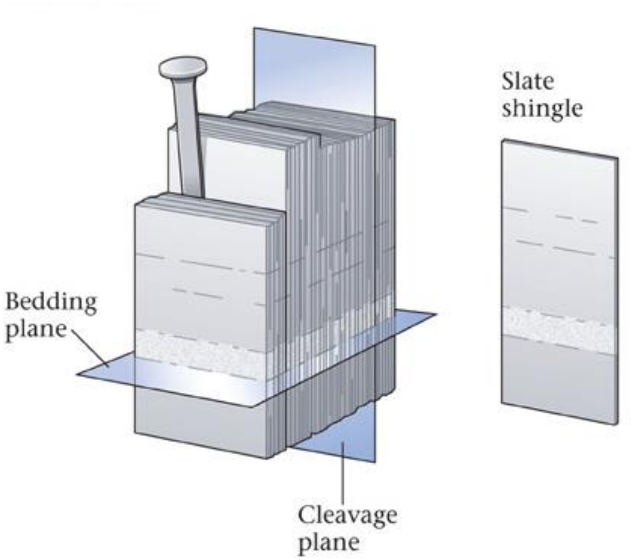
Foliated metamorphic rock: Slate

- 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

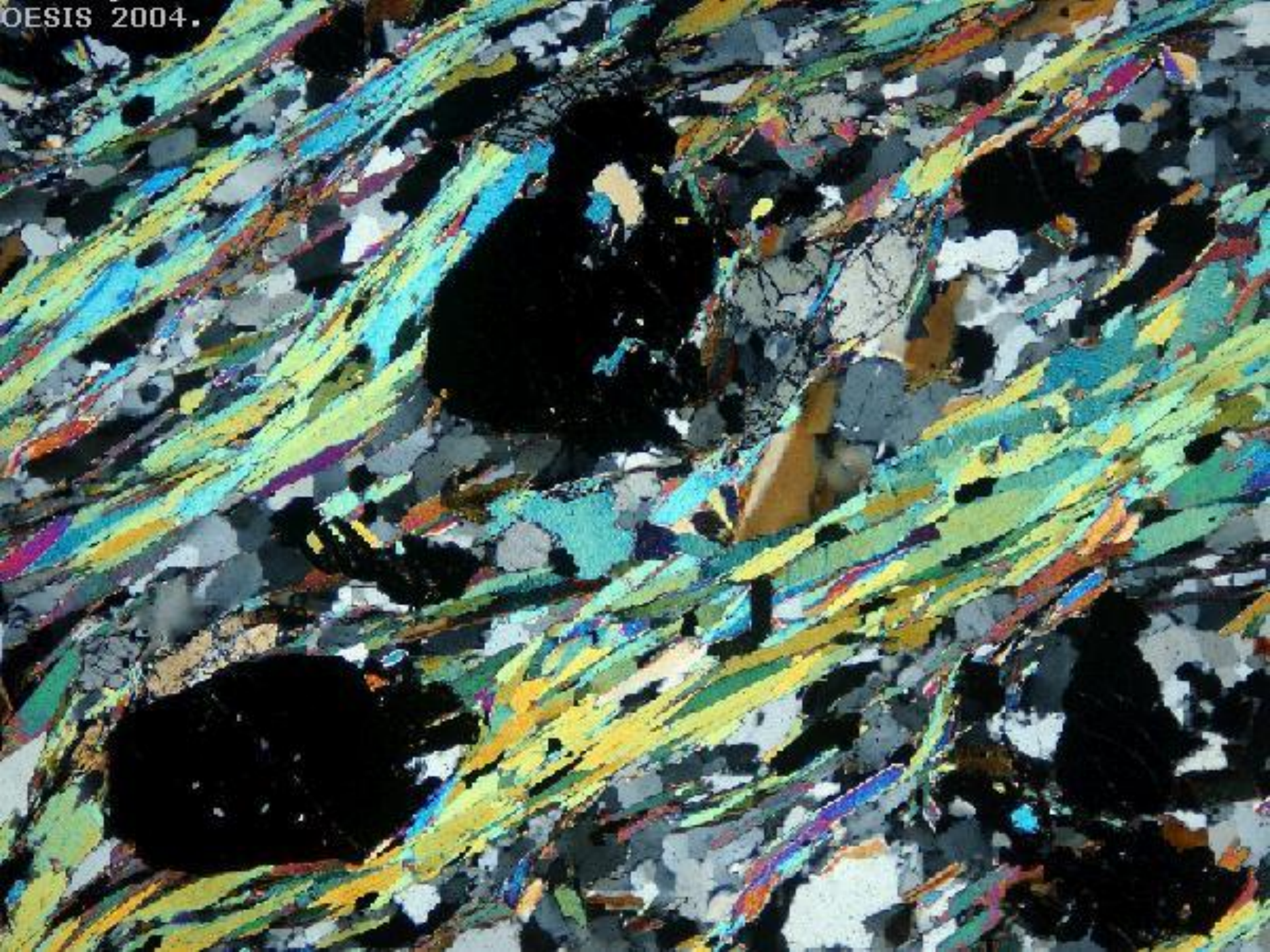


Foliated metamorphic rock: Phyllite

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

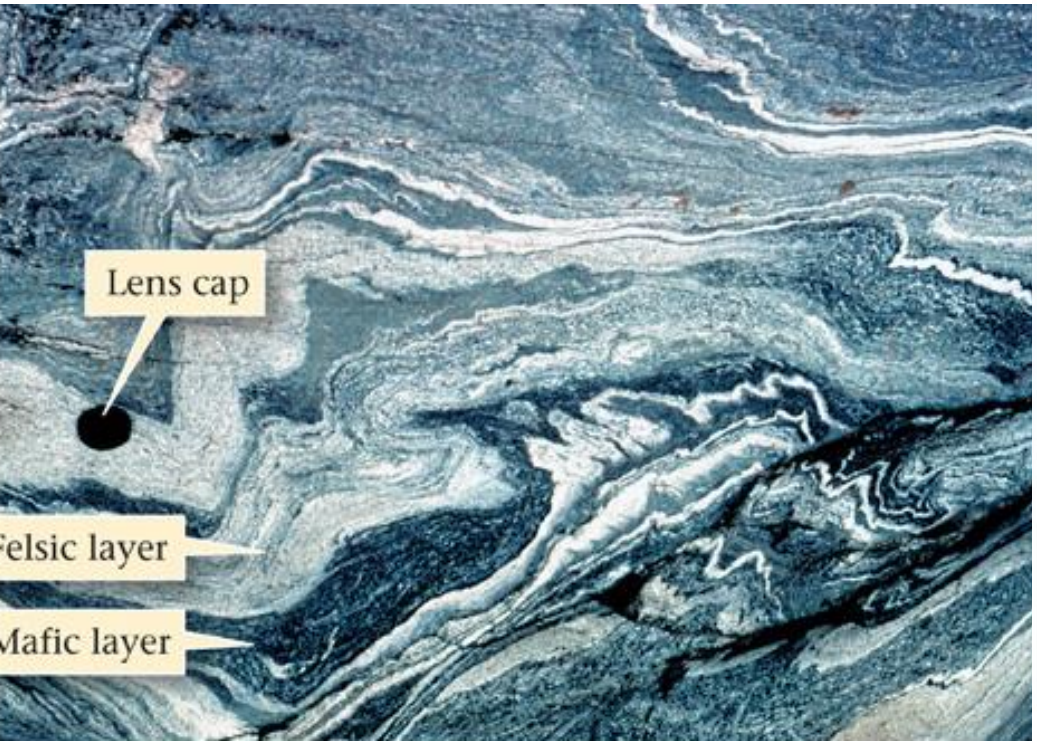
Foliated metamorphic rock: Schist

- 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



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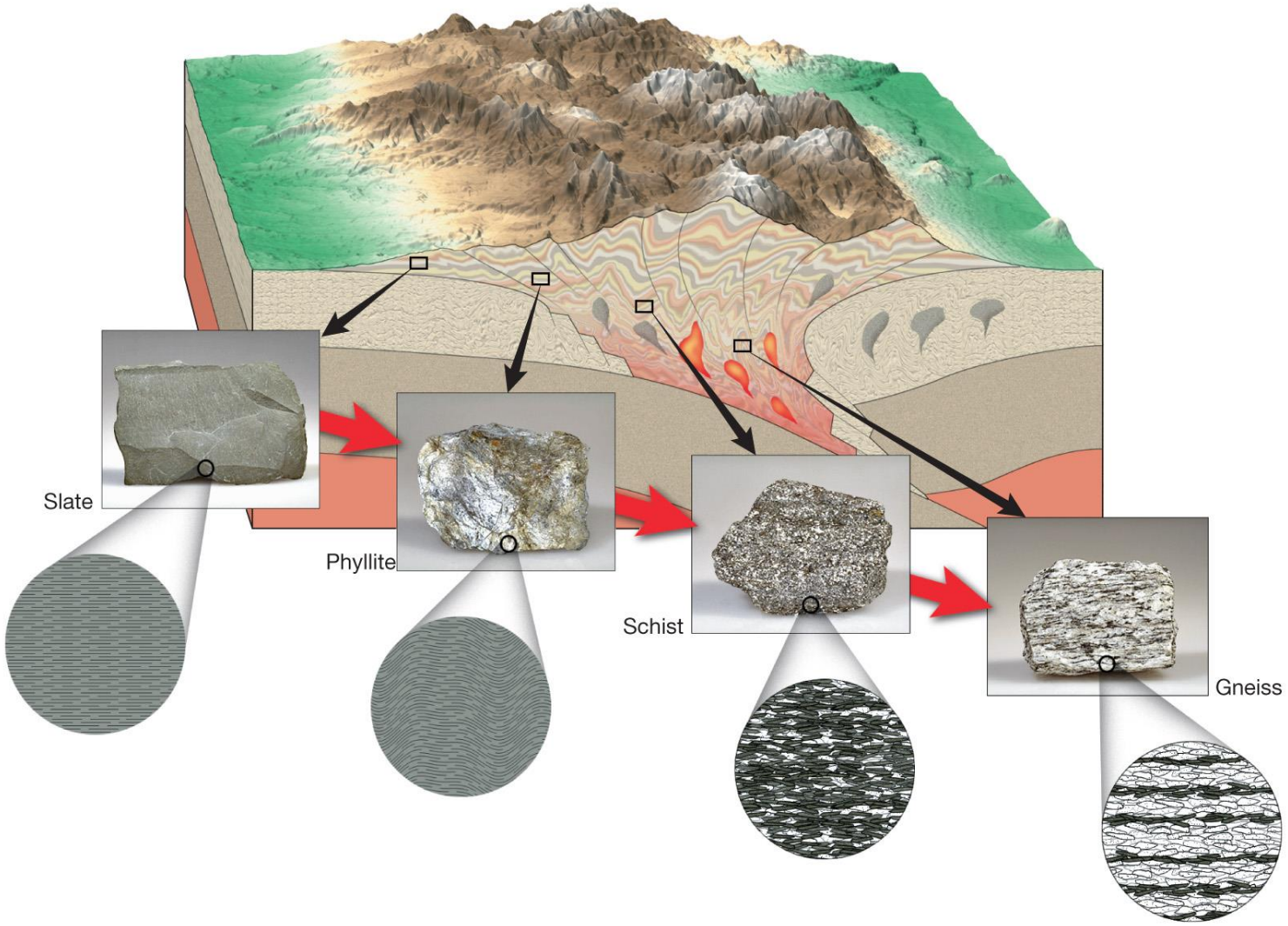
Metamorphic Grade: A measure of metamorphic intensity



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Main types of metamorphism

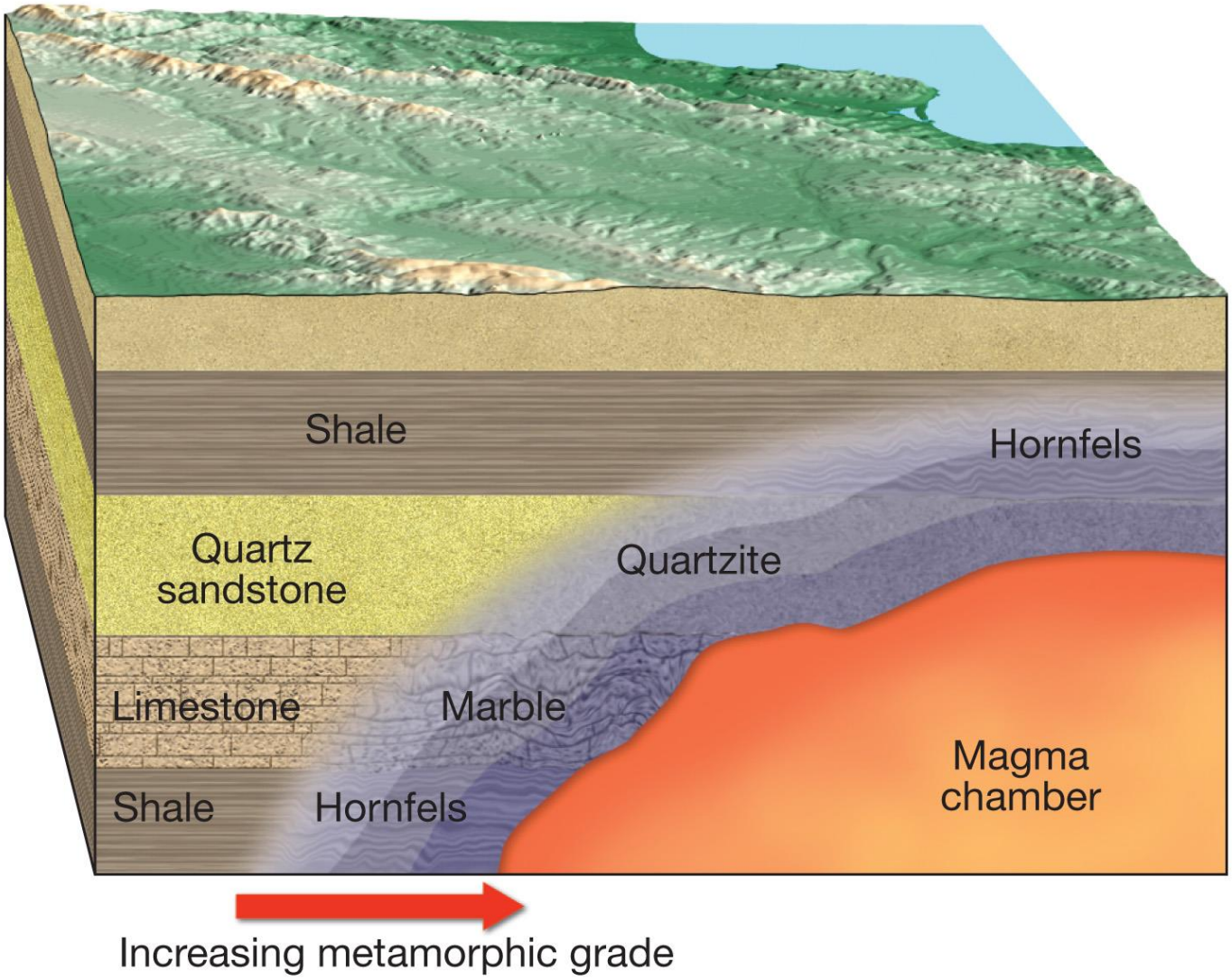
- **Contact metamorphism**
- **Regional metamorphism**
- **Burial metamorphism**
- **Hydrothermal metamorphism**

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



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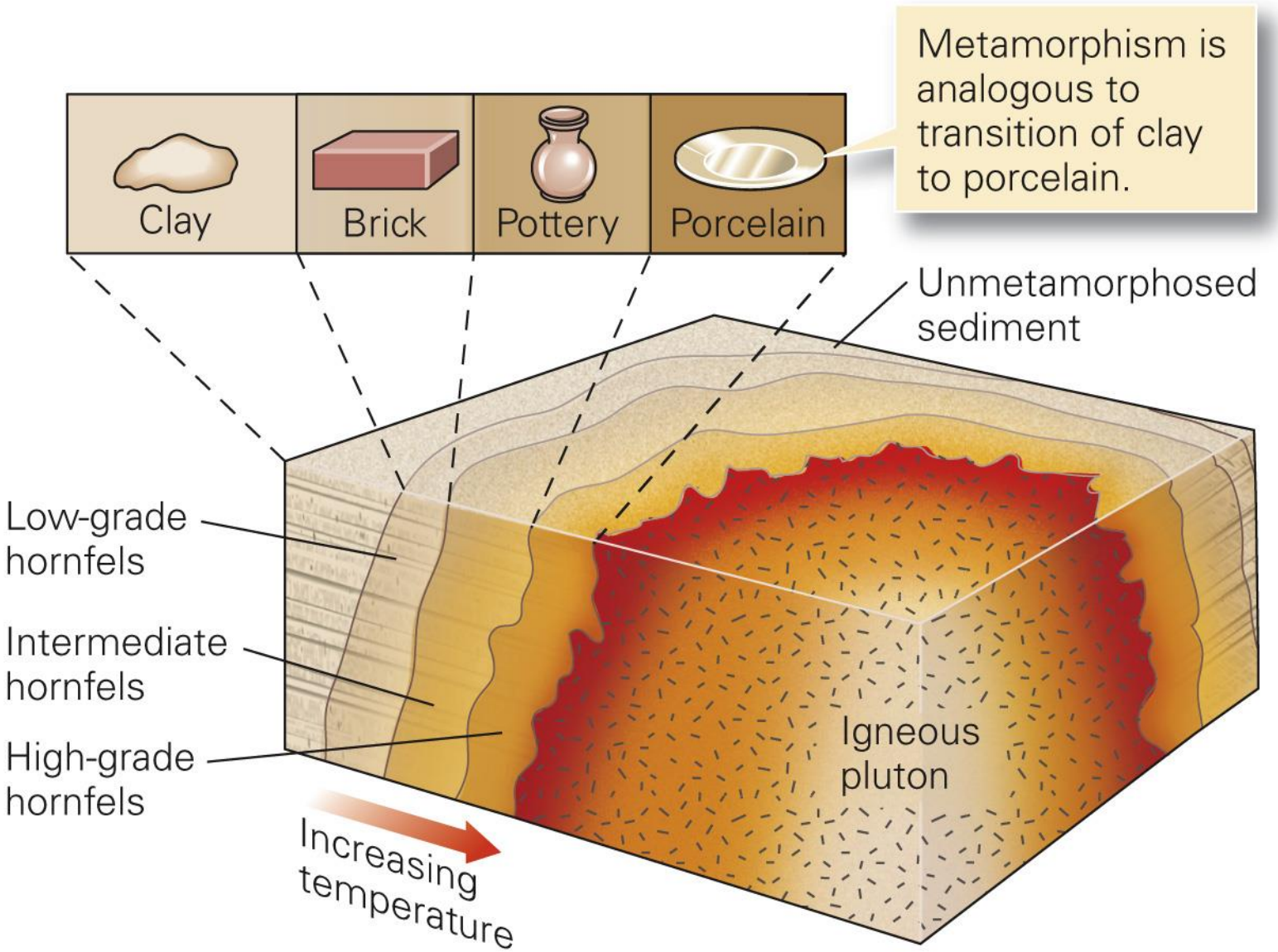
Contact metamorphism



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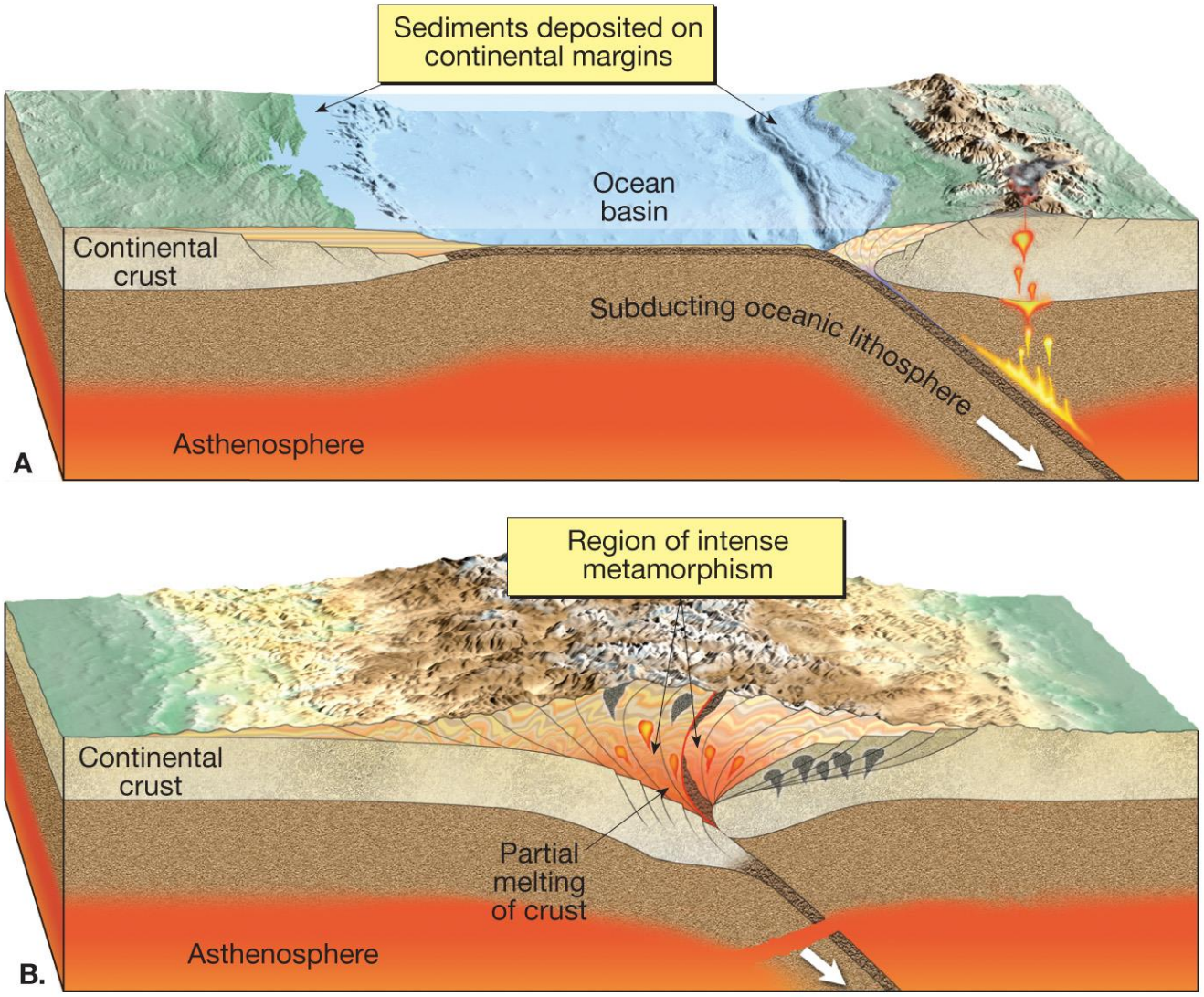
Regional metamorphism

Regional metamorphism



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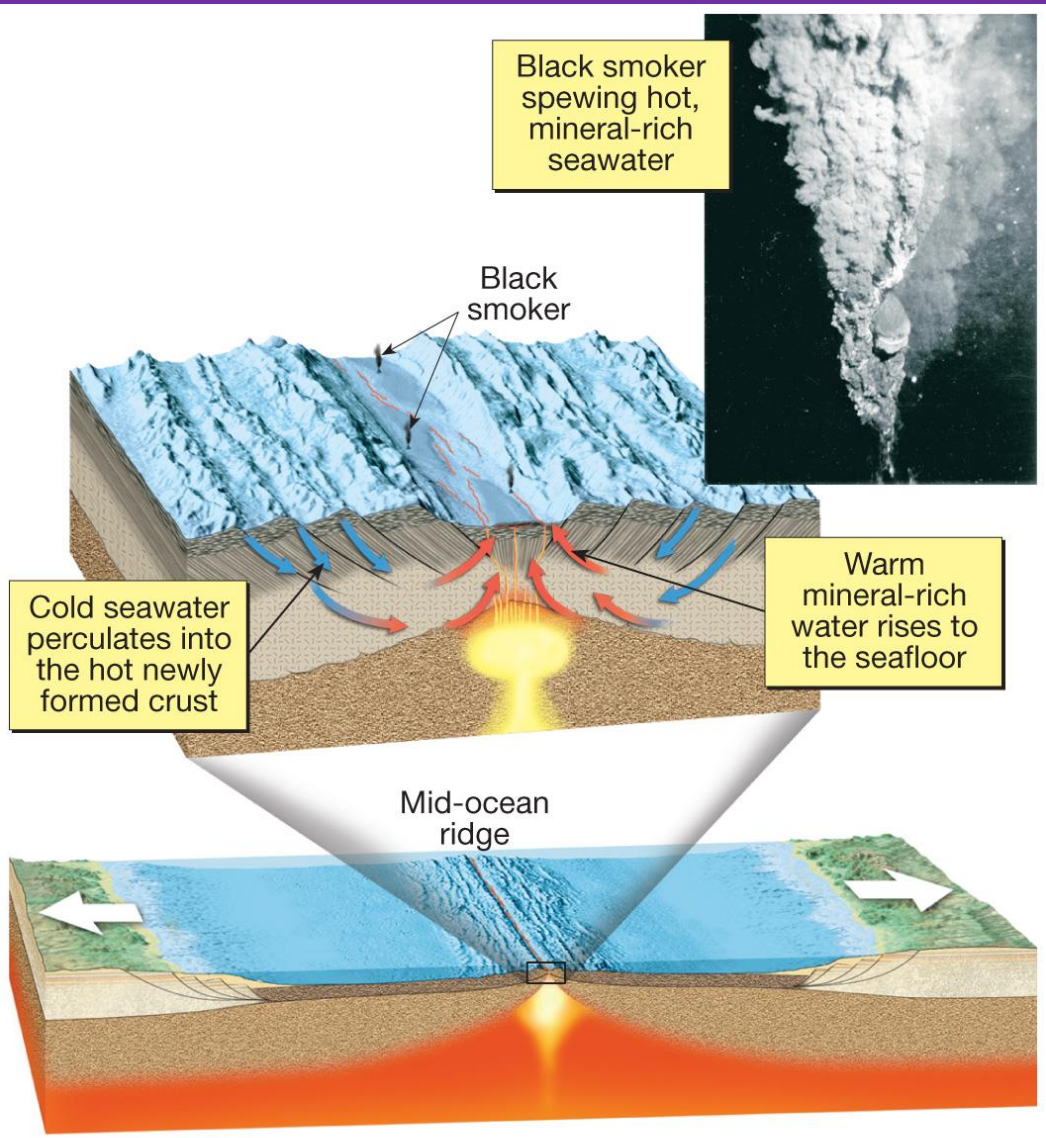
Hydrothermal metamorphism

Hydrothermal metamorphism



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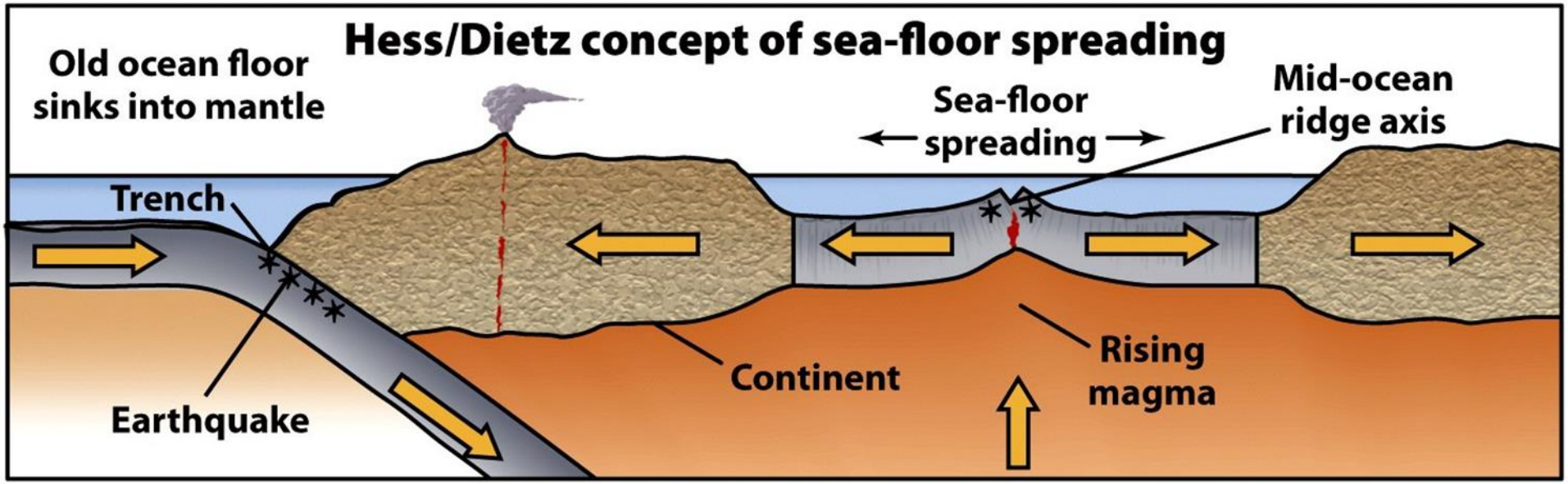
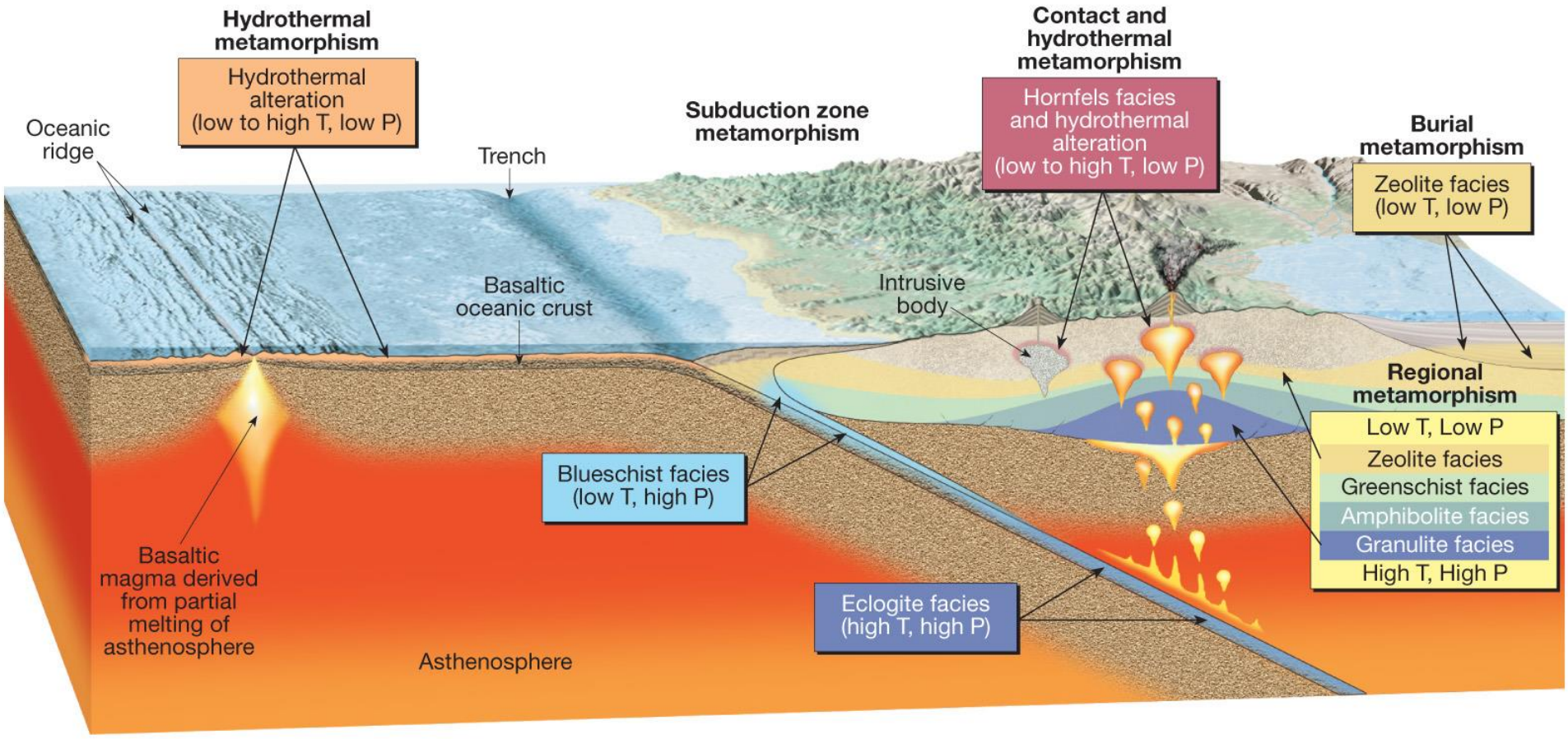
Metamorphic rocks reflect plate tectonic setting



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



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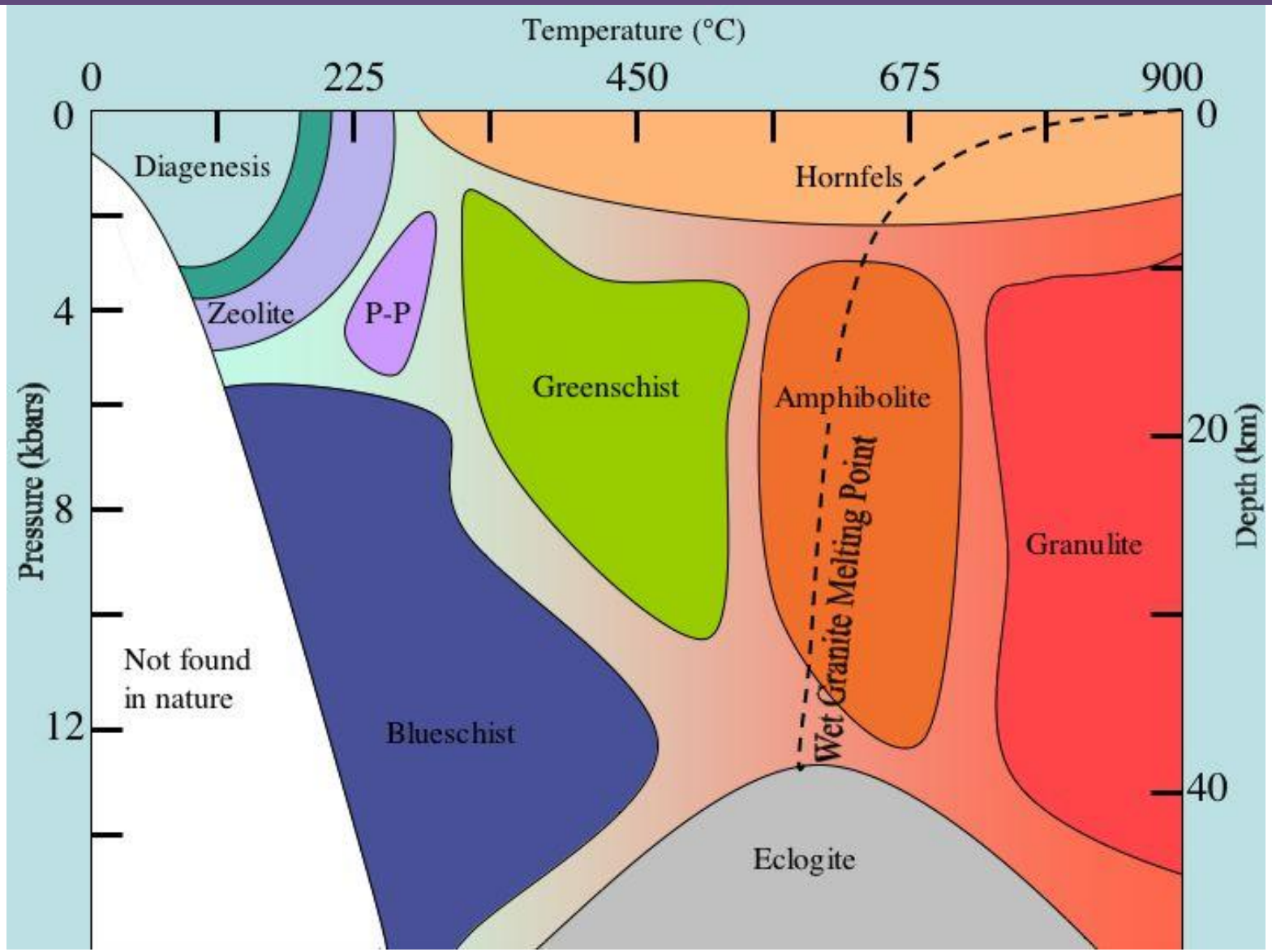
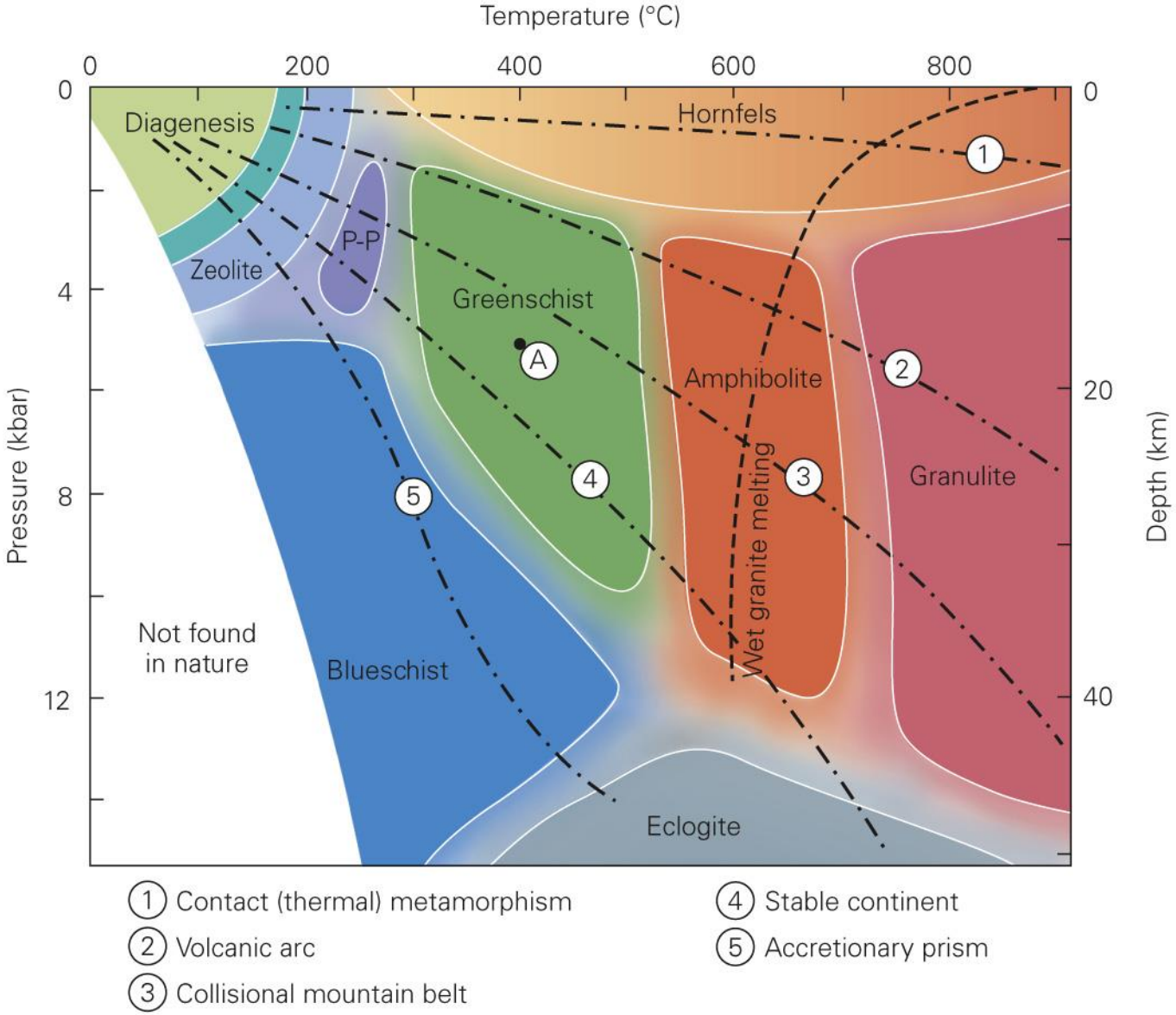
Metamorphic facies



Metamorphic facies



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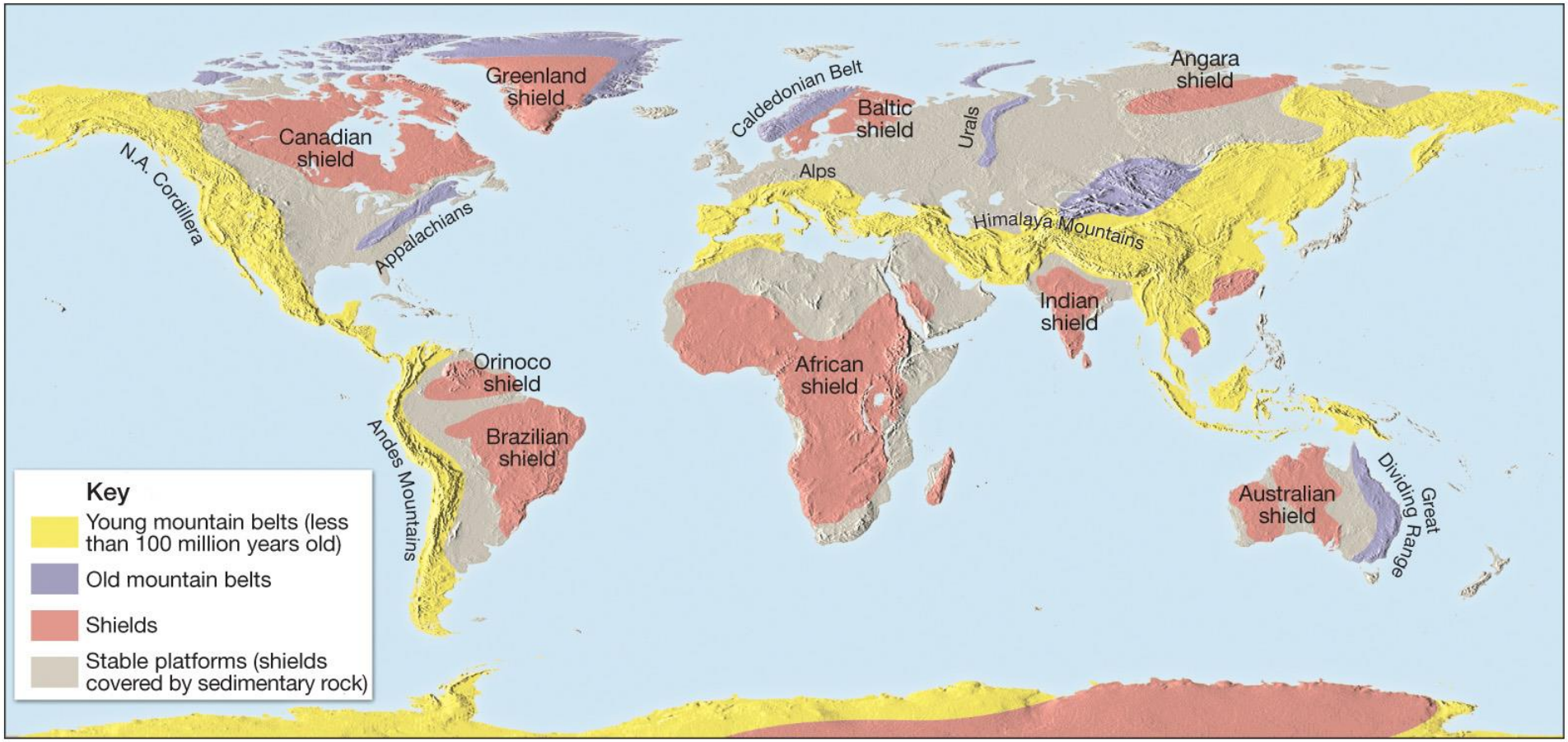
Continental Shields

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



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