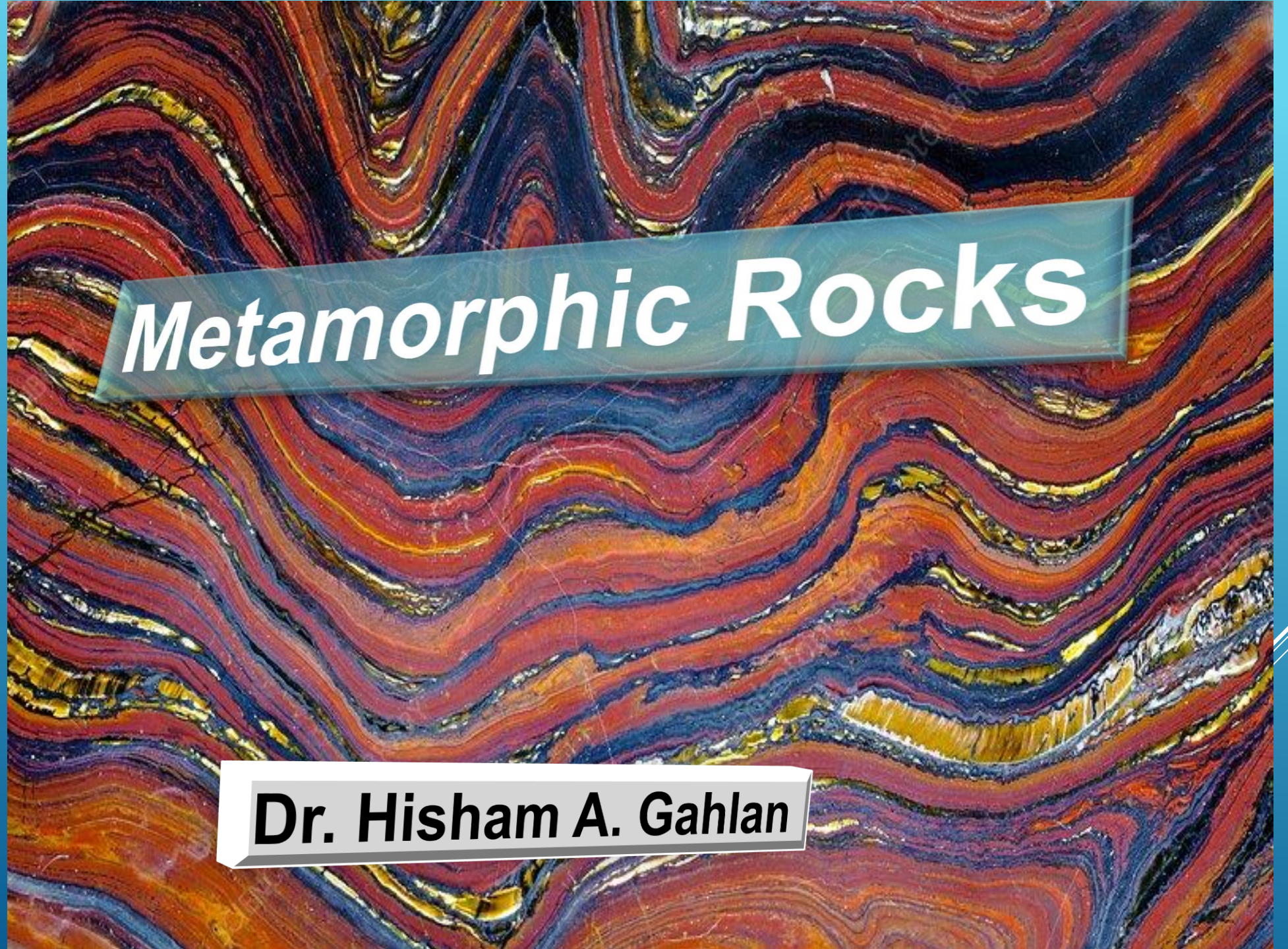

Metamorphic Rocks
Dr. Hisham A. Gahlan

Meeting Time:

Sun. 11:00 – 11:50

Tues. 11:00 – 11:50

Office Hours

Mon. 10:00 – 11:00

Credits:

3 hours (2+1)

Assessment method

1st Exam (Week 6, 15%)

2nd Exam (Week 11, 15%)

Lab Activities (10%)

Final Exam (40%)

Practical Exam (20%)

Reference Book:

Bucher, K. and Grapes, R. (2011) Petrogenesis of Metamorphic Rocks. Springer-Verlag, Heidelberg; 8 edition, 428 p.

Topics

- Definitions
- Agents and Types of Metamorphism
- Structure and Classification of Metamorphic Rocks
- Metamorphic Processes
- Metamorphic Grade
- Metamorphism of Specific Rock Types

Metamorphic Rock

- "Meta"= Change *(Grk)*
- "Morph"= form *(Grk)*

- **A rock that has been changed**

from its original form (parent) by heat , pressure , and fluid activity into a new rock (daughter).

WHAT IS METAMORPHISM?

- **Metamorphism is the transformation of a rock type to another due to change in pressure and temperature.**
- **Change in Mineralogy, Chemistry and Structure.**
- **The rock should be in the solid state during metamorphism.**
- **If the rocks melt at a certain point, then we enter the zone of igneous rock**

How did metamorphism take place?

- By changing in Temp. and Pressure.

What can cause change in Temp. and Pressure?

- Large scale geologic events,

  such as: global lithospheric plate movements, subduction, continent–continent collision and ocean floor spreading all have the consequence of moving rocks and transporting heat.

- The gray shales (diagenetic clay minerals + quartz) were transformed to hornfels by thermal metamorphism.
- The hornfels contains metamorphic minerals (biotite, cordierite, K-feldspar and sillimanite).
- At metamorphism limestone nodules (pure calcite, $CaCO3$) reacted and reaction produced concentrically zoned nodules consisting of the Ca-silicates (anorthite, wollastonite and diopside).
- All calcite has been used up in the reaction and all $CO2$ +$H2O$ has left the rock during the dehydration of the clay minerals.

AGENTS OF METAMORPHISM

- **Heat**

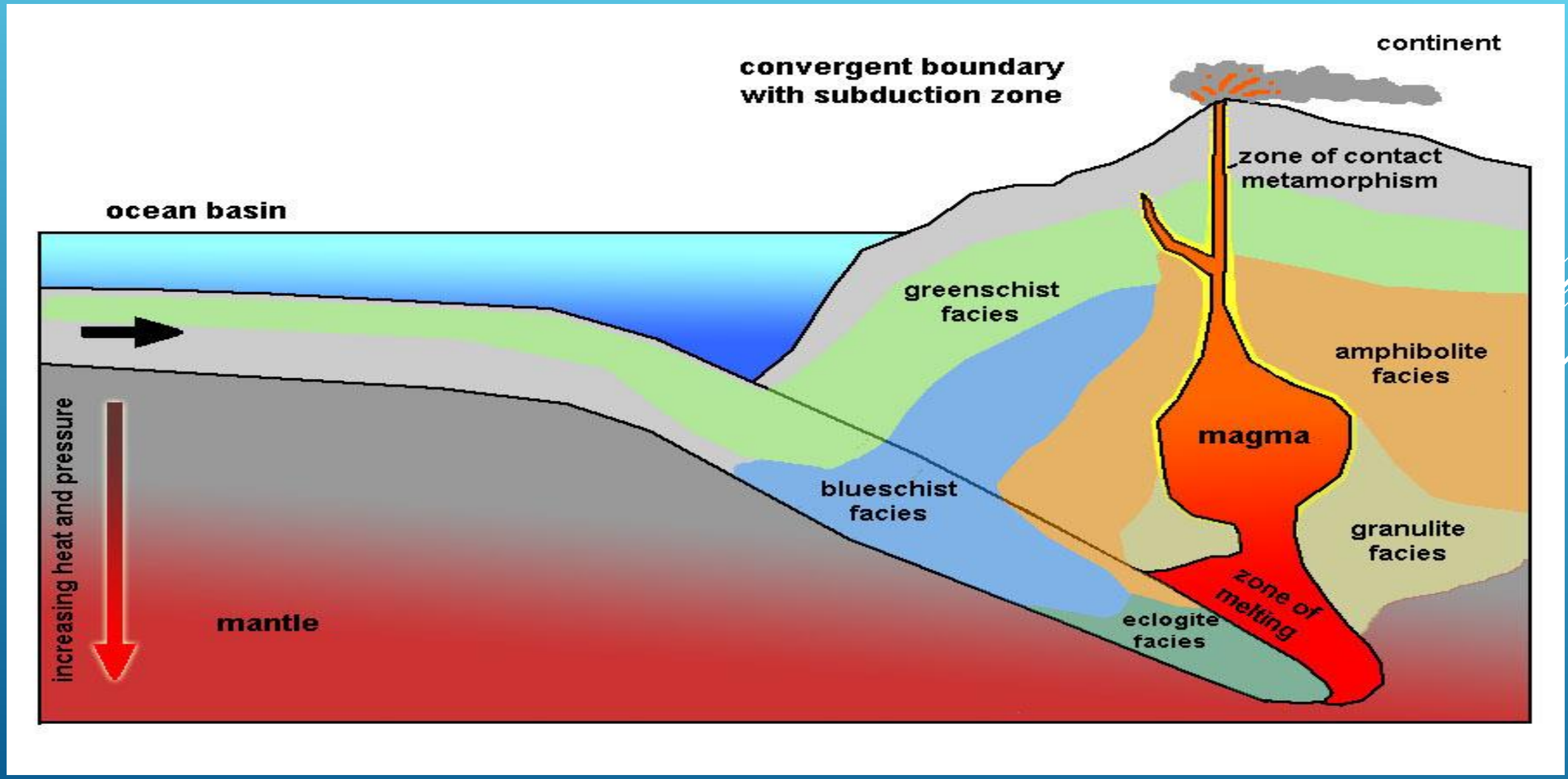
- **It makes all chemical reactions go faster.**

- **A mineral is stable at one temperature might become unstable at a higher (or lower) temperature.**

- **The lower-temp. limit of metamorphism is ≥ 200ºC.**

- **The high-temp. limit of metamorphism = the melting temperatures of rocks ≥ 600ºC (wet melting point of granite).**

The upper temperature limit of crustal metamorphism in the lower continental crust = 750-850ºC = Granulite rocks.



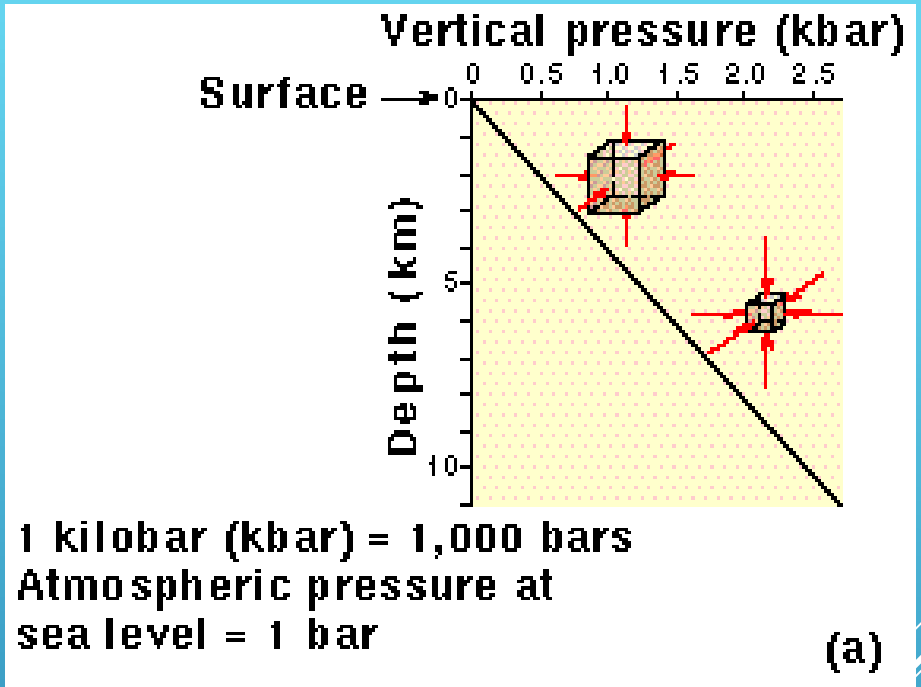
Heat

Sources Include……

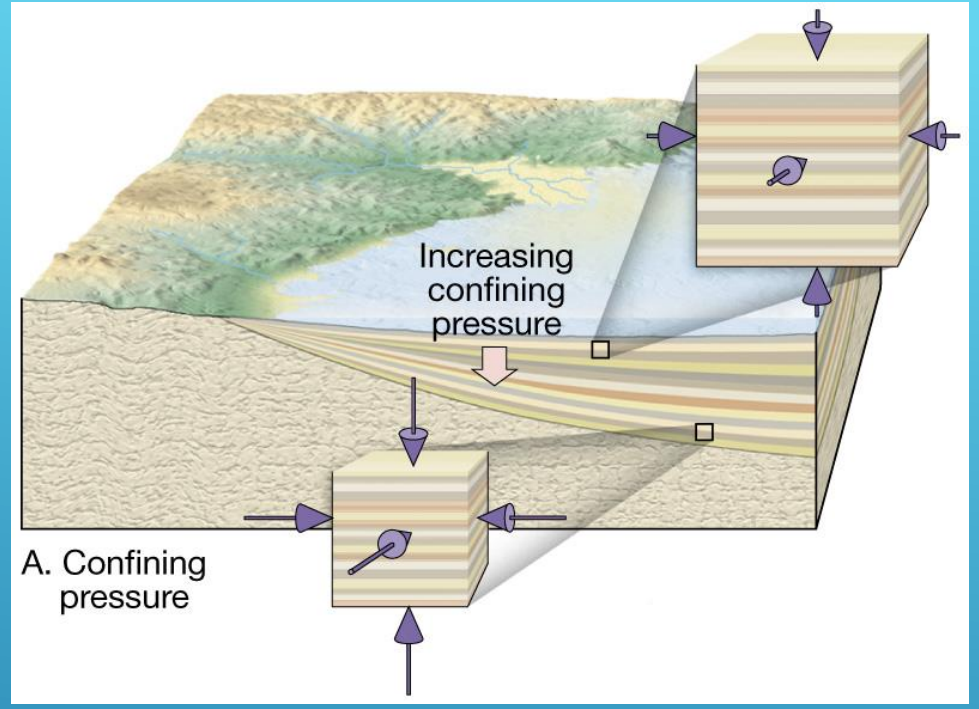
- Magma
  - temperature of magma
  - composition of magma
- Geothermal gradient
  - temperature increases with depth of burial
  - core of Earth is warmer than outer crust

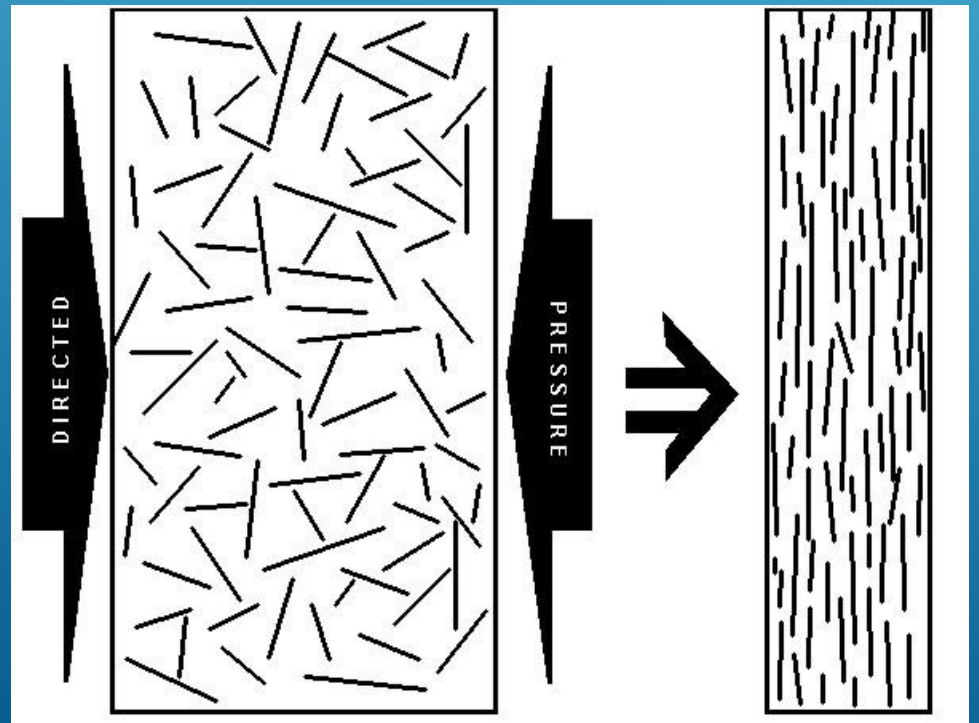
Pressure

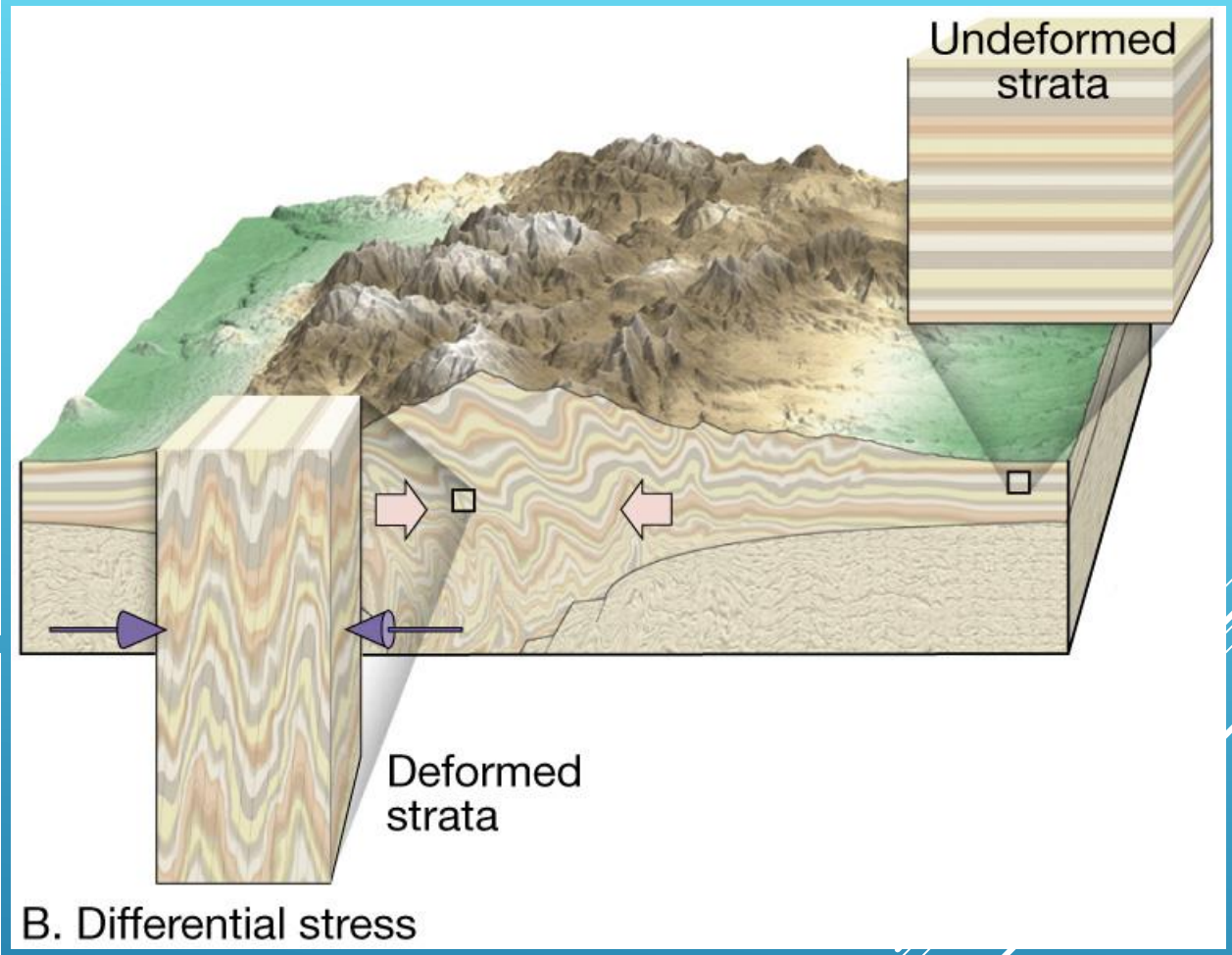
- Types of pressure: Confining and Directed
- It controls minerals' stability.
- Directed pressure only re-orient minerals.



- The lowest pressure limit of metamorphism is found around igneous intrusions (in contact metamorphism = 1 bar pressure).
- The highest pressure limit of metamorphism was formed in the deepest levels at~ 100-200km depth = 30-60 kbar pressure.







Confining Pressure and Directed Pressure

Fluids

- Chemical reactions require fluids, and most proceed much faster as the amount of fluids increase.
- Dissolved ions in fluids make chemical changes in minerals.

Types of Metamorphism

Regional Metamorphism (P + T)

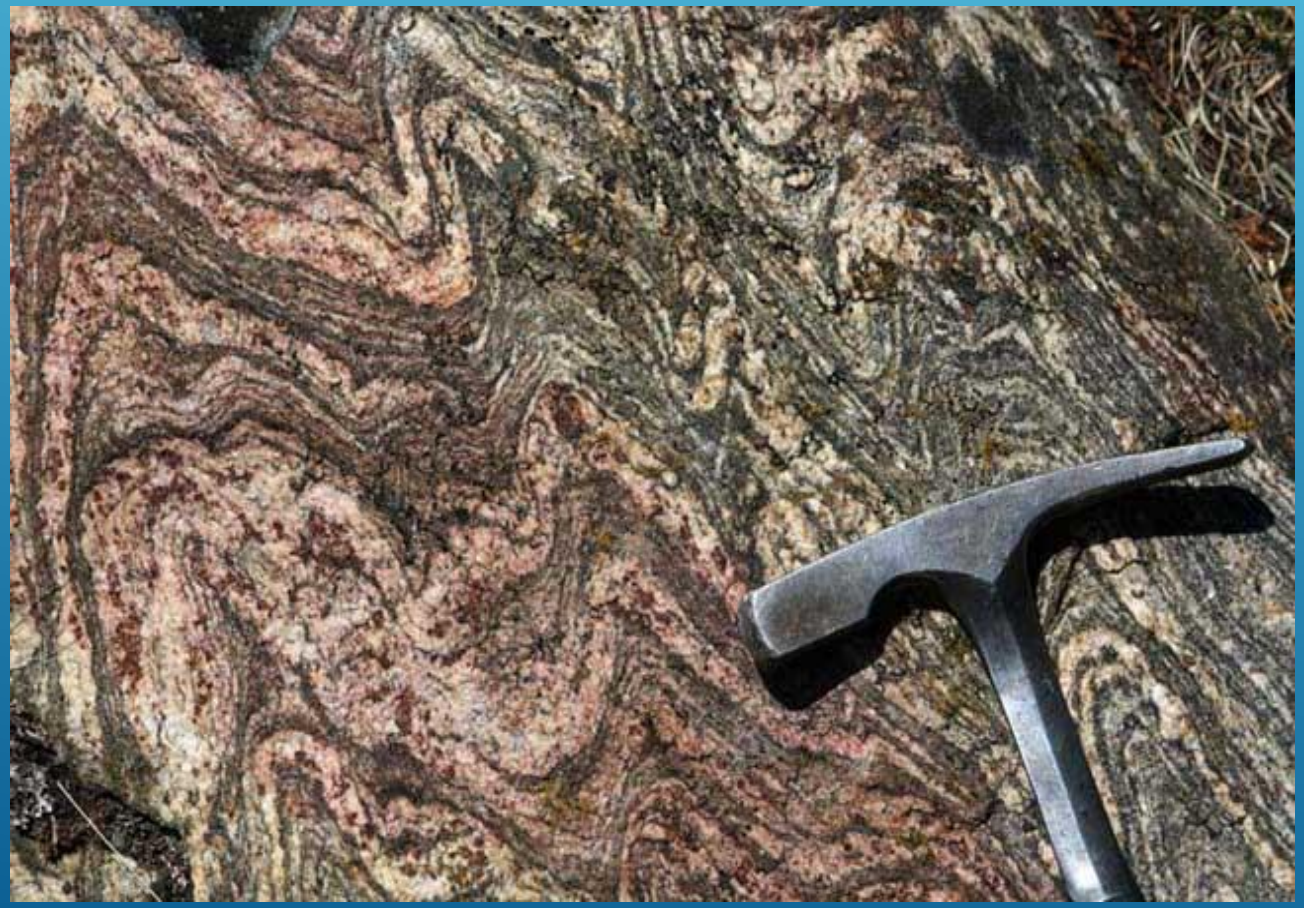
Thermal/Contact Metamorphism (T)

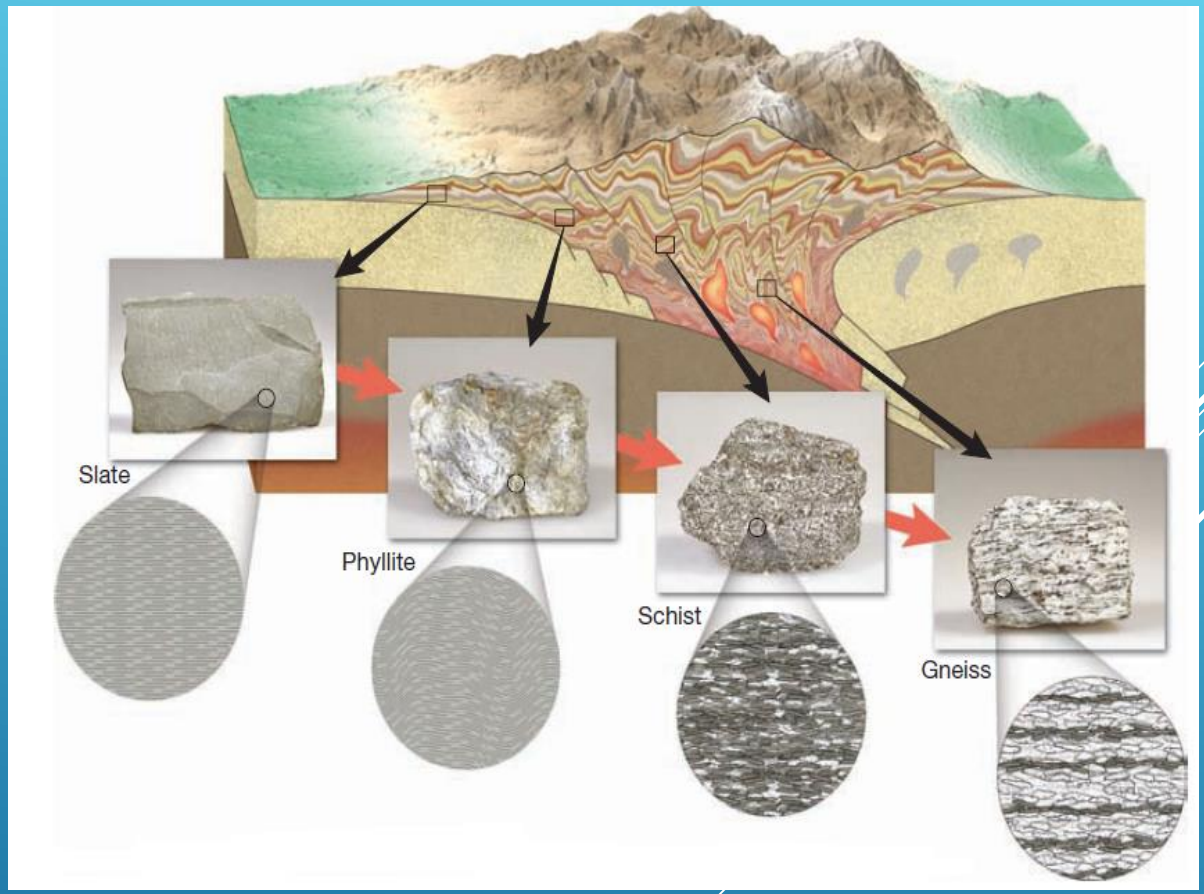
Cataclastic Metamorphism

Where do metamorphic rocks occur?

Regional/Orogenic metamorphism

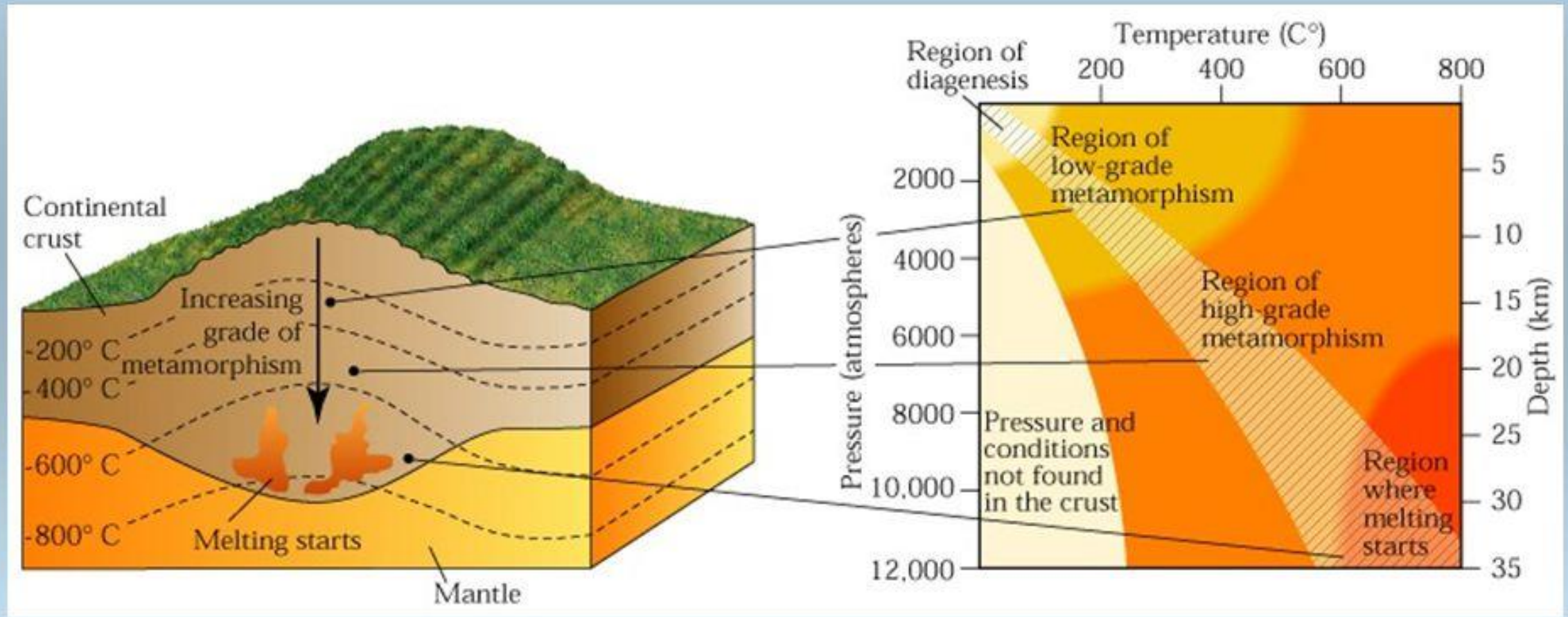
- occurs over large areas or scale, and resulted in foliated metamorphic rocks.
- Location: Mountain building areas.



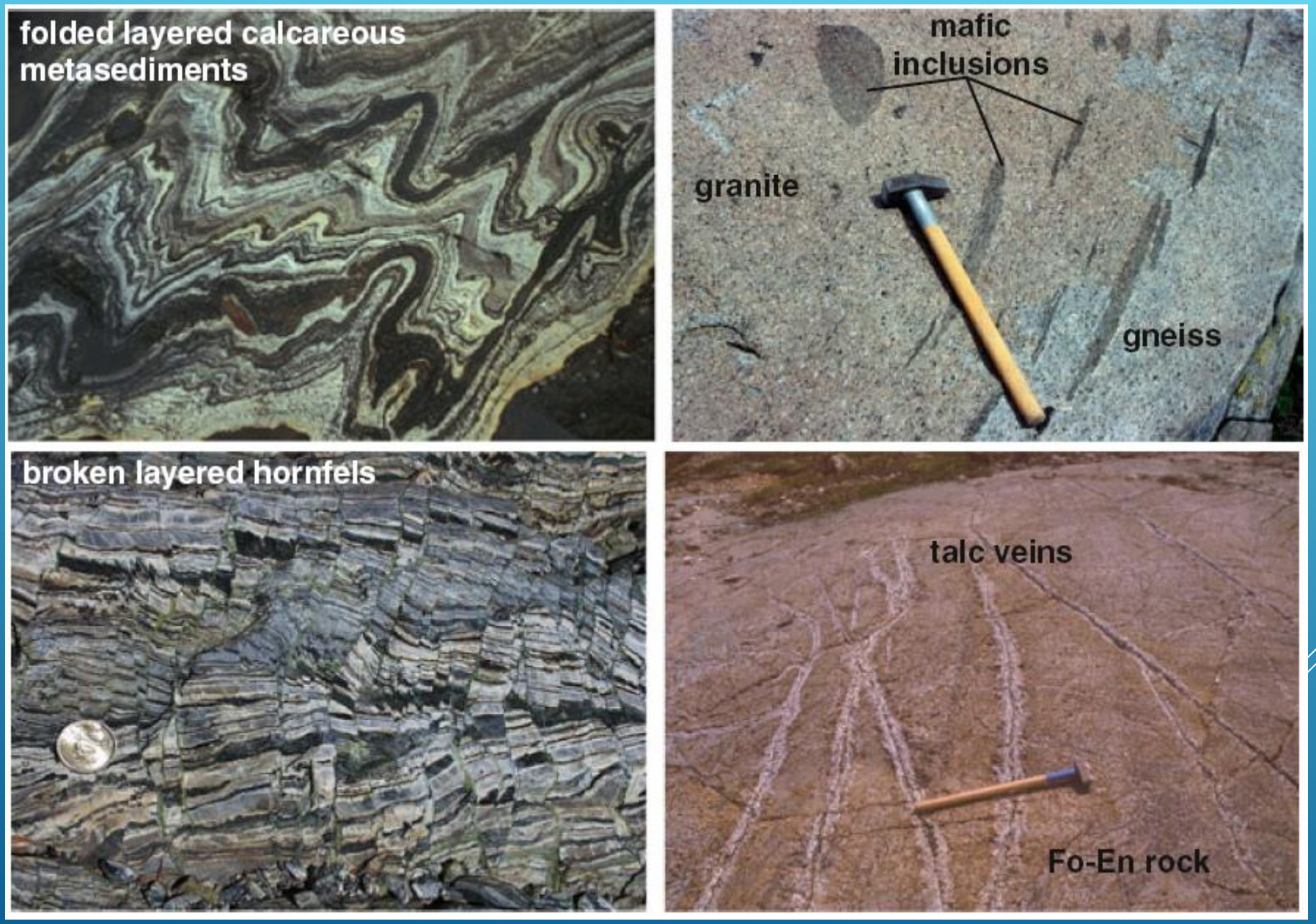


Regional metamorphism is a long-lasting process of millions or tens of millions of years duration.

Regional Metamorphism



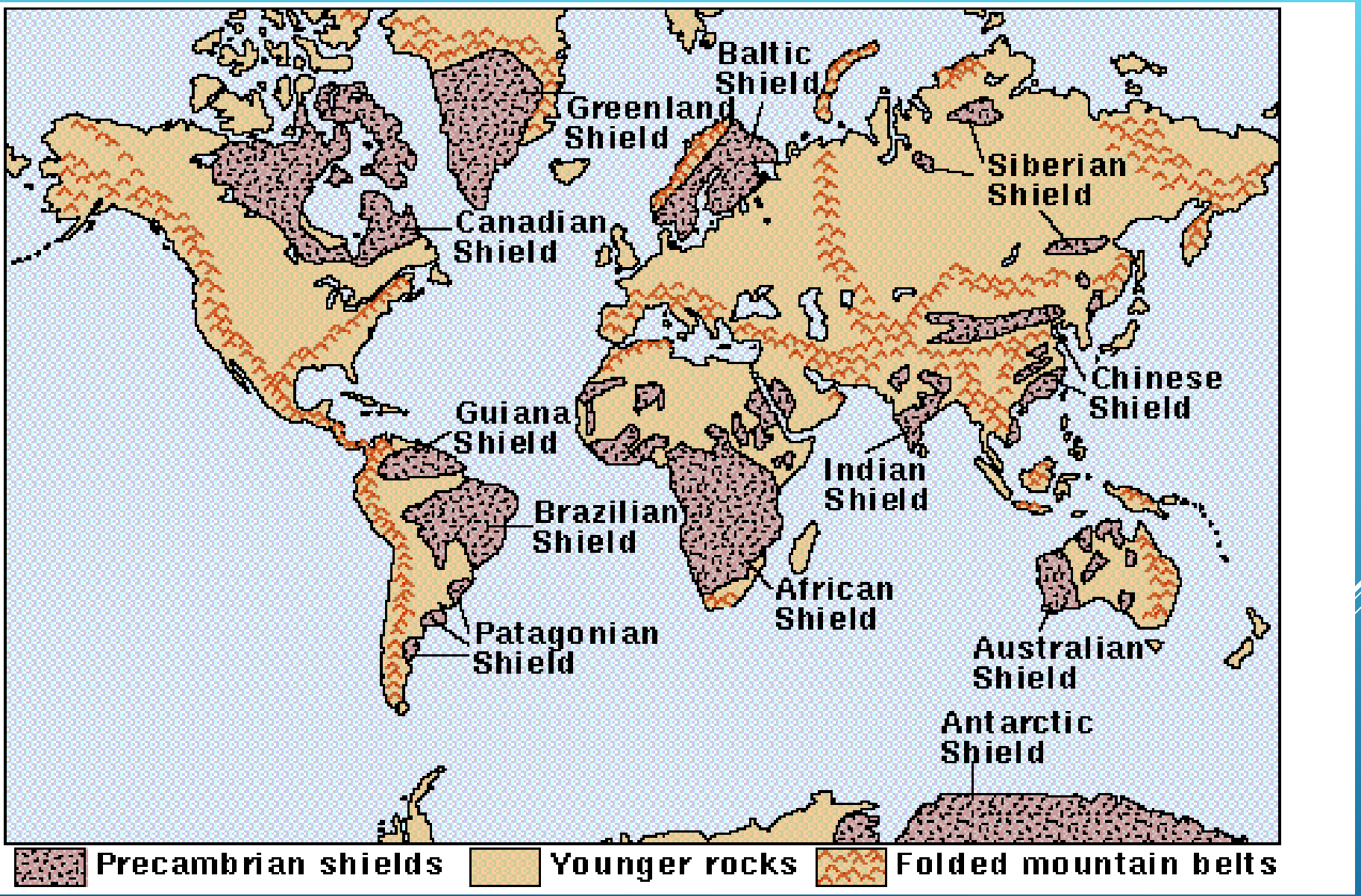
All metamorphic rocks show distinct features of ductile or brittle.



Regional Metamorphism

- Most common form of metamorphism
- caused by large scale forces
  - lithospheric plate collision
- covers very large areas
  - metamorphic belts or zones
  - Zones are characterized by *Index Minerals*
    - form under specific temperatures and pressures
    - metamorphic facies
- commonly associated with
  - Shields and Mountains: areas of crystalline rocks

Shields of the World

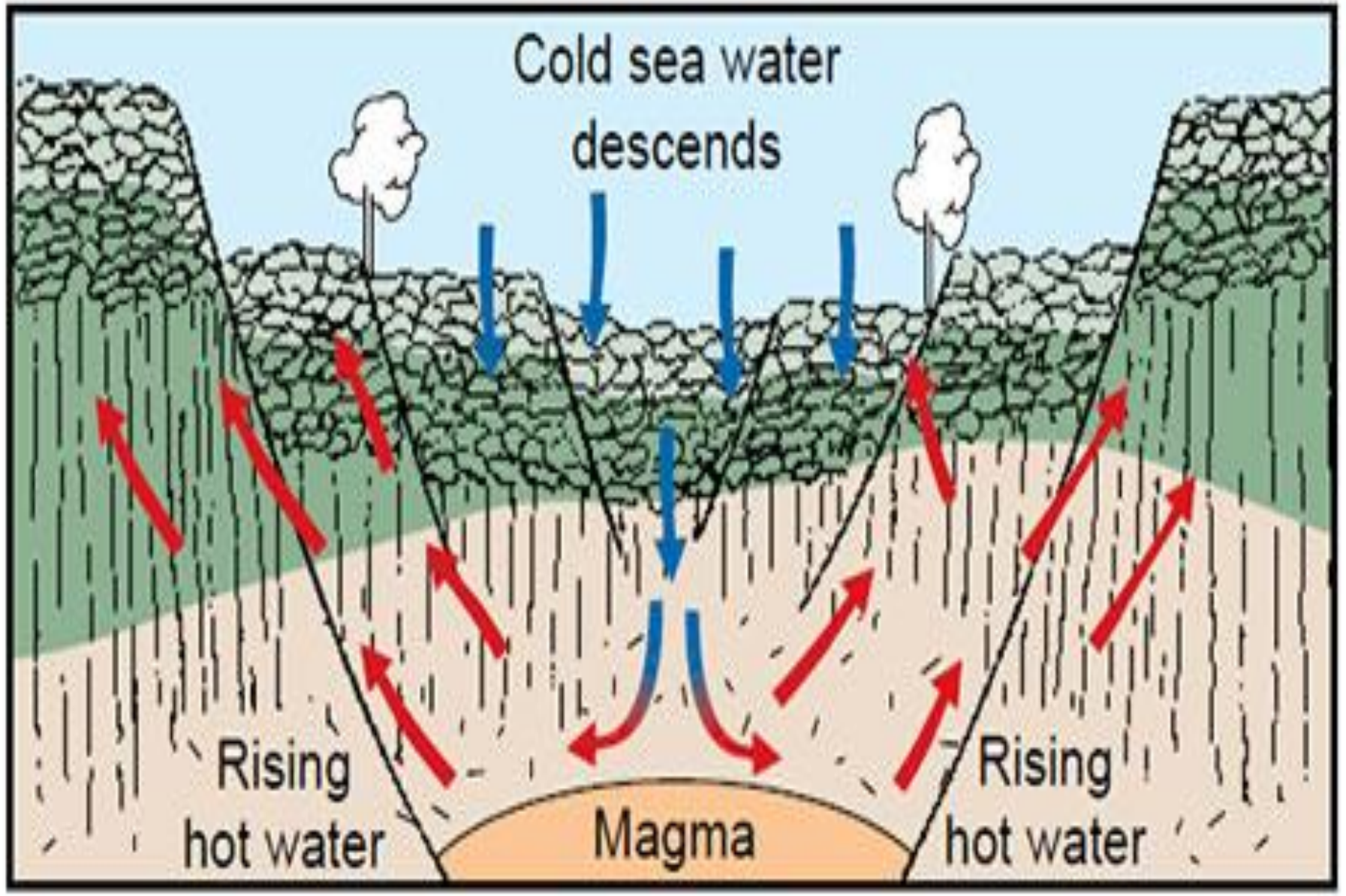


Types of Regional Metamorphism

1- Ocean-Floor Metamorphism (Miyashiro, 1971)

- Large scale metamorphism of mafic and ultramafic rocks in the ocean floor (static regime).
- Chemical reaction between seawater and ocean-floor rocks = hydrothermal metamorphism = metasomatism.
- Characterized by massive/non-foliated textures, extensive veining and metasomatism.
- Temp. 150 – 500°C, Pressure ≤ 3 kbar.
- Geologic setting = oceanic curst and upper mantle.

Seafloor metamorphism (Low P/T)



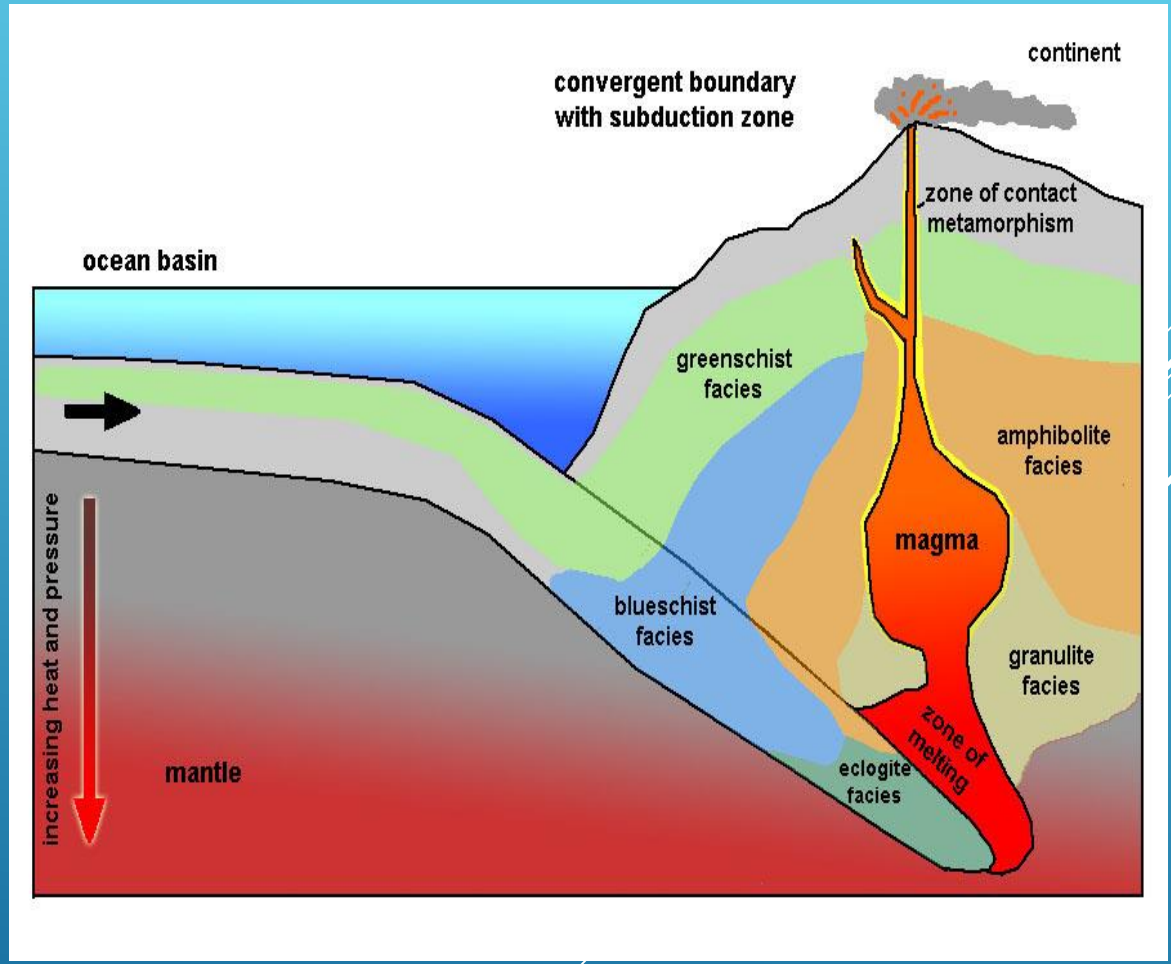
Metamorphic Facies

- Zeolite
- Greenschist
- Amphibolite

2- Orogenic metamorphism

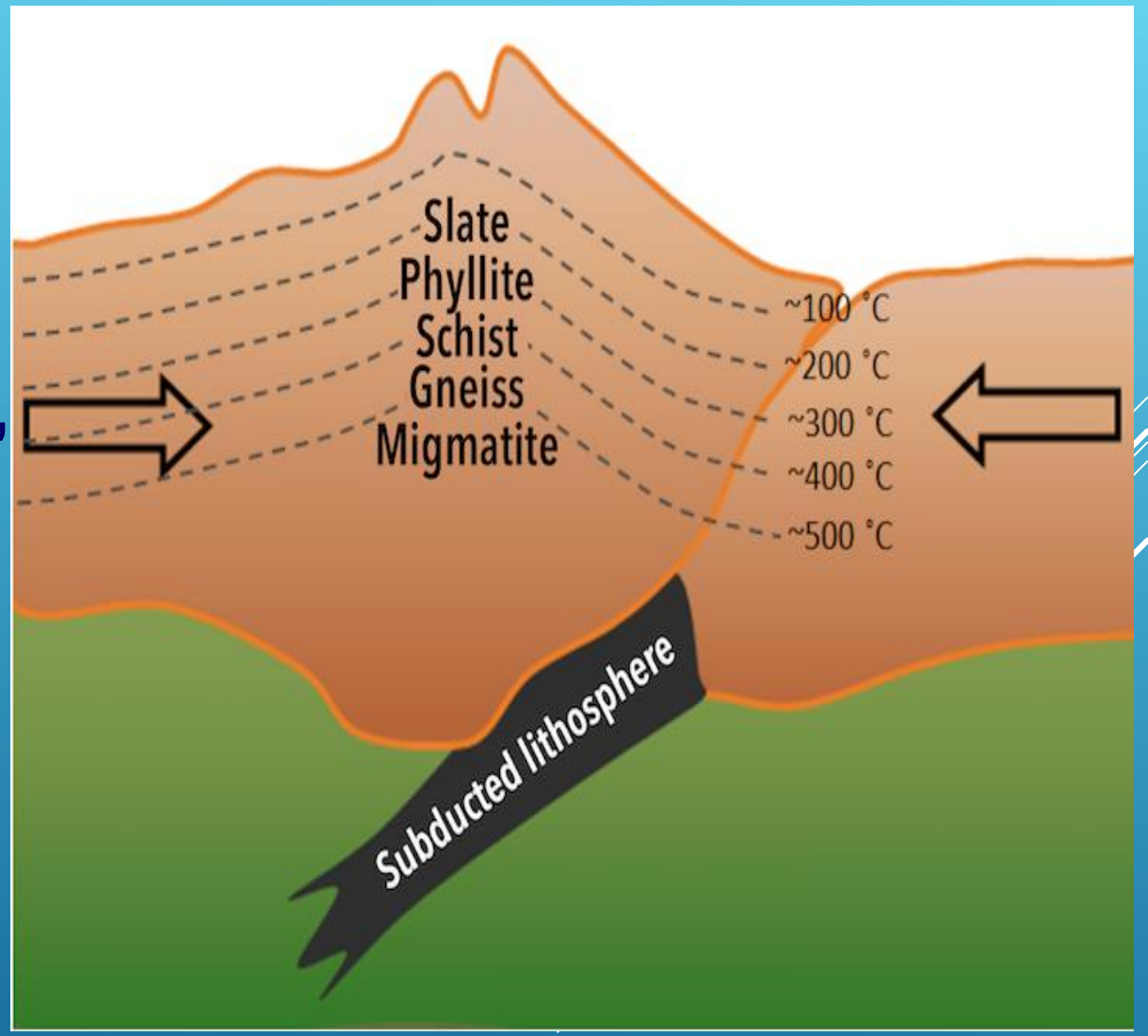
I- Subduction related metamorphism

- Early phase orogenic metamorphism.
- Related to subduction and thrusting of lithospheric plates (dynamic regime).
- Temp. = 200–700°C.
- Pressure = 2–30 Kbar, up to 90 Km depth.
- Vertical temp. gradient depends on subduction velocity (5-12°C/km) (generally low).



II- Collision related metamorphism

- Late phase orogenic metamorphism.
- Related to continent-continent collision (dynamic regime)
- Associated with polyphase deformation, folding and foliation.
- Temp. = 200-850°C.
- Pressure = 2 – 10 kbar, and 14 kbar in double crustal thickness.
- Vertical temp. gradient (12-60°C/km).



3- Burial metamorphism (Coombs, 1961)

- Low-temperature regional metamorphism affecting sediments and interlayered volcanic rocks (very close to the deep-seated diagenesis processes) (static regime).
- No magmatic influence = No orogenesis.
- Non-foliated texture with preserved fabrics.
- Mineralogical changes are incomplete
  = New minerals + Relict minerals.
- Pressure increase due to sediments weight (start ≥5 km depth ~ 2 kbar).
- Temp. increase due to geothermal gradient.