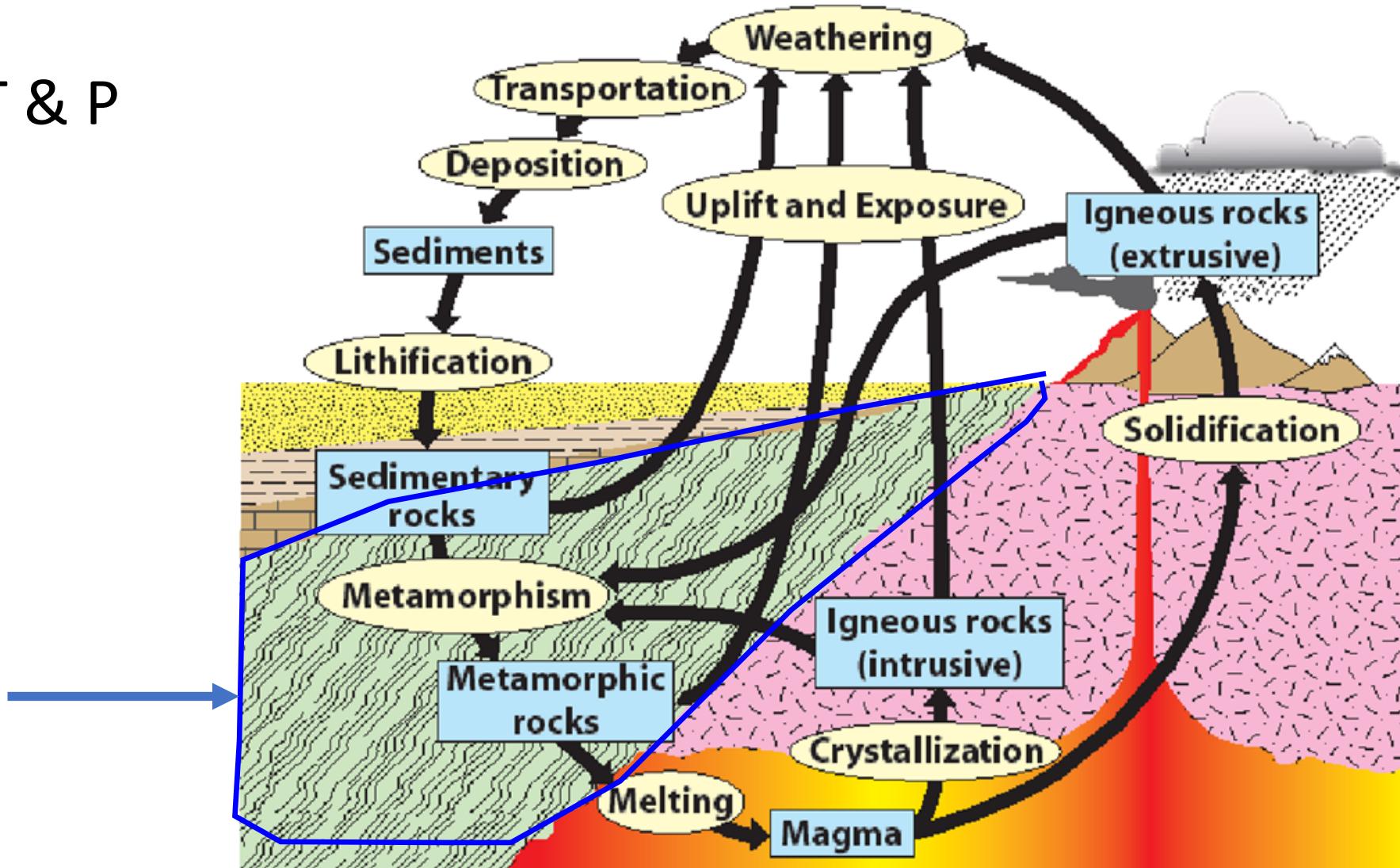


Metamorphism: The process that changes existing rocks into new rocks with new minerals and new textures *in solid state*.

Causes: Increases in T & P
and action of fluids.



Metamorphic rocks, from Greek, meta- meaning change and –morphos meaning form.

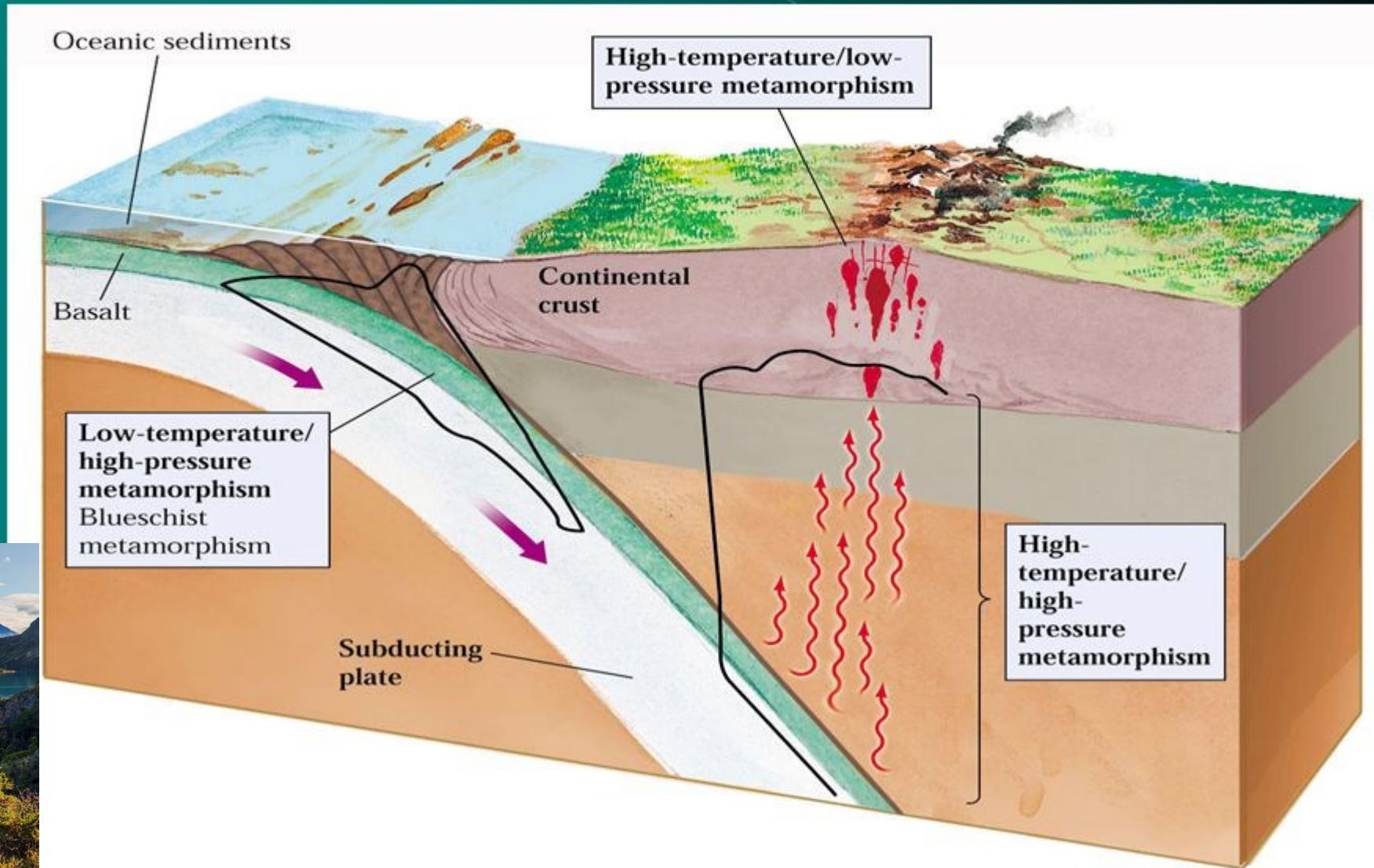
Metamorphism is caused by plate tectonic motion.

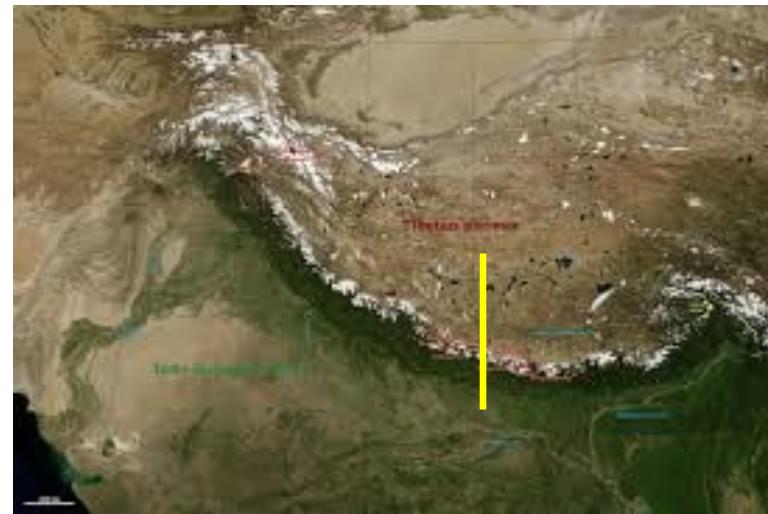
So, metamorphic rocks tells geologists how past tectonic processes shaped our planet.

Subduction
Zone like
Andes

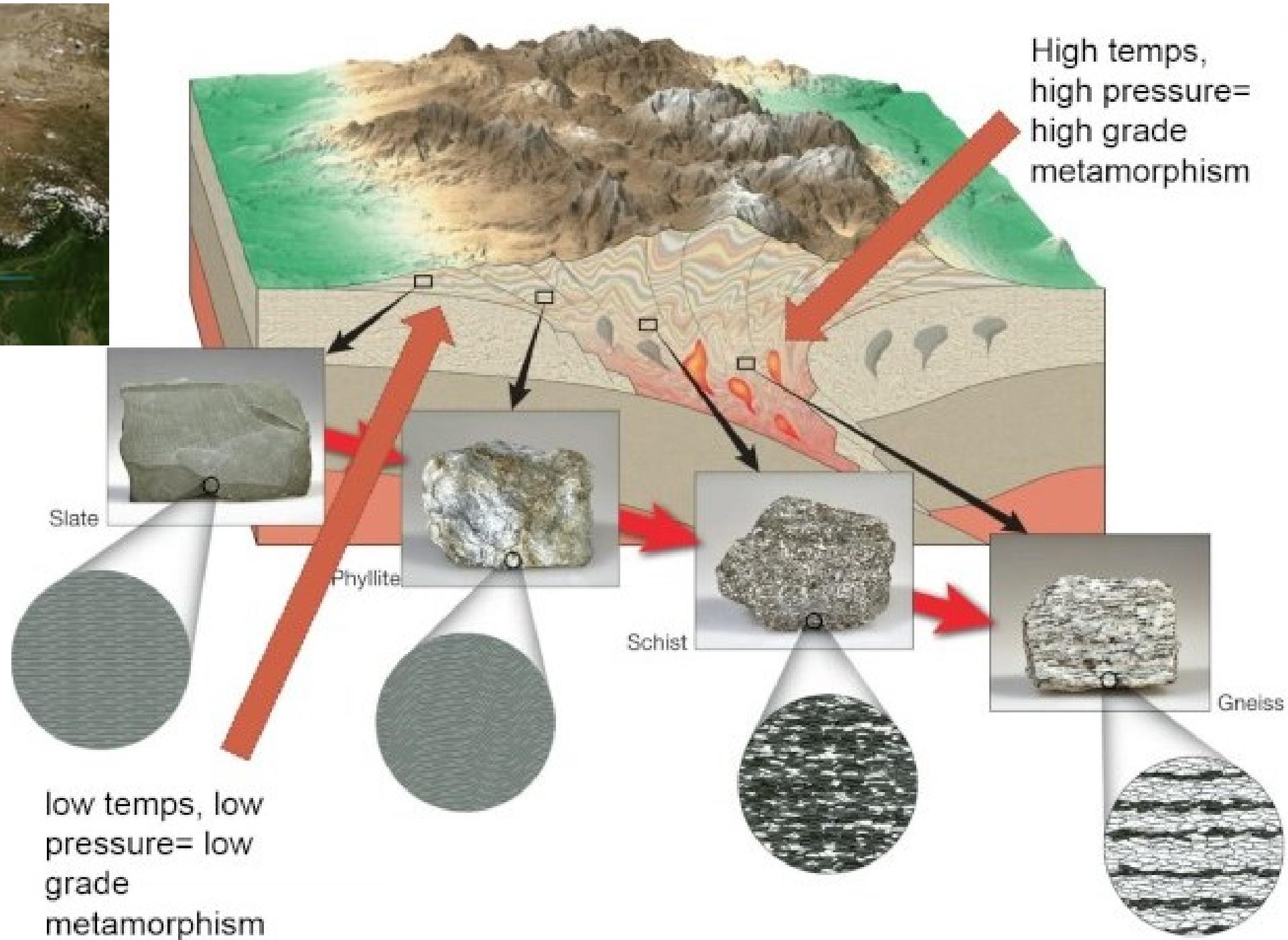


Three main metamorphic environments





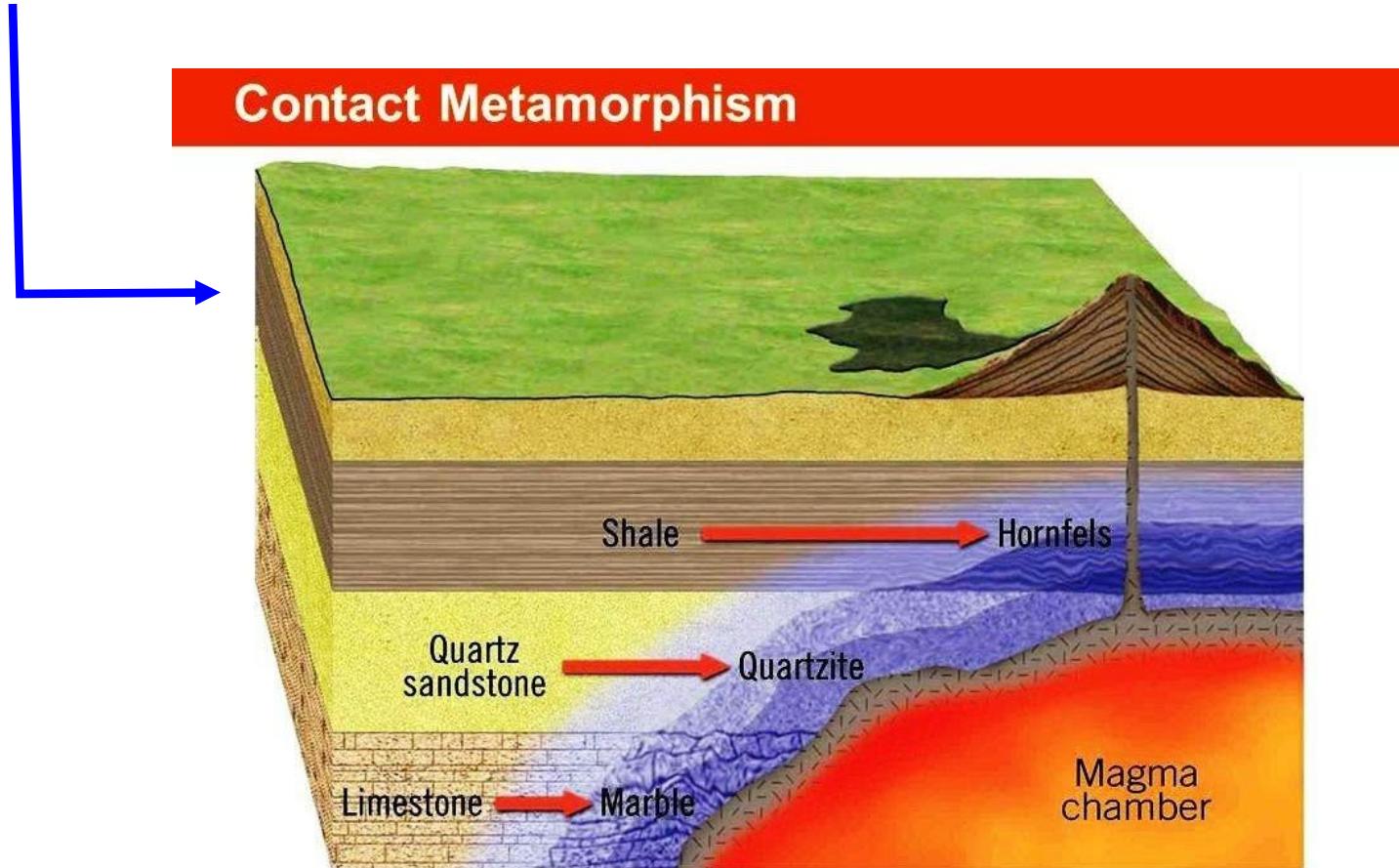
Collision Zone like Himalayas



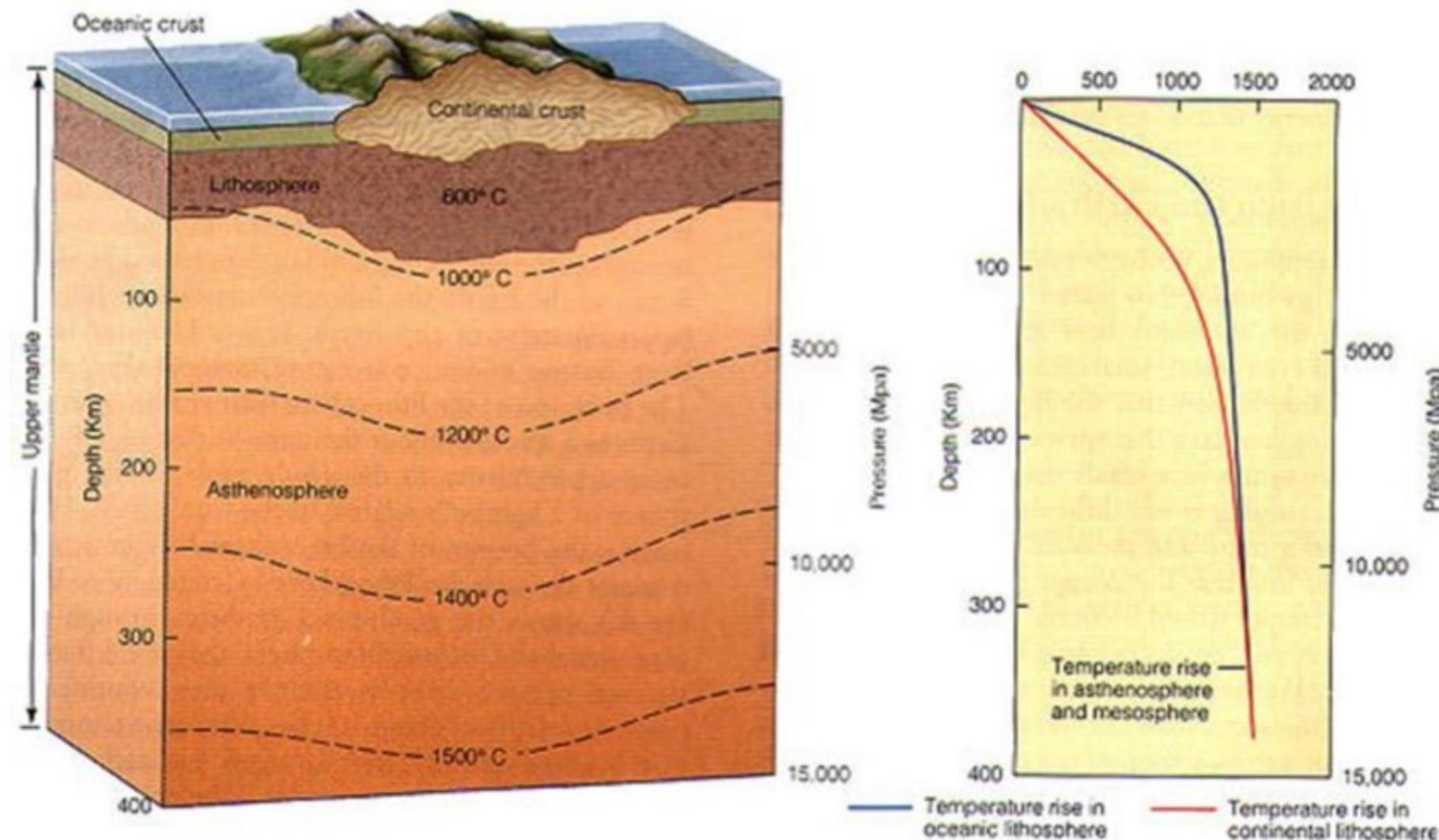
Agents of metamorphism: 1. Temperature

Increase in T affects chemical equilibrium, new minerals form.

T increase either due to igneous intrusion



- T also increases with increasing depth along a geothermal gradient.
- Metamorphic rock records these depth-related T changes.
- Range of T: generally 200–1100 °C, higher T would create magma.



2. Pressure: (a) Confining or lithostatic pressure: Due to burial.

Equal pressure on all sides.

Causes chemical reactions & results in new minerals.

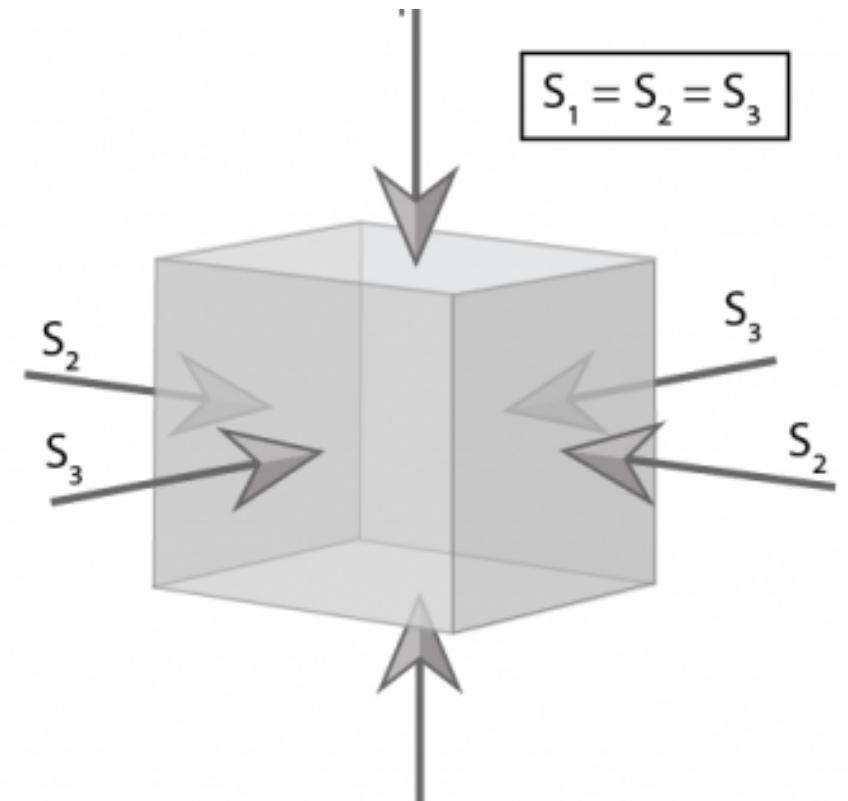
Generally, varies from 2 to 10 kbar (depth 5 to 35km) but at times 20 kb.

PRESSURE

Pressure is a state where *all stresses* on a body are equal.

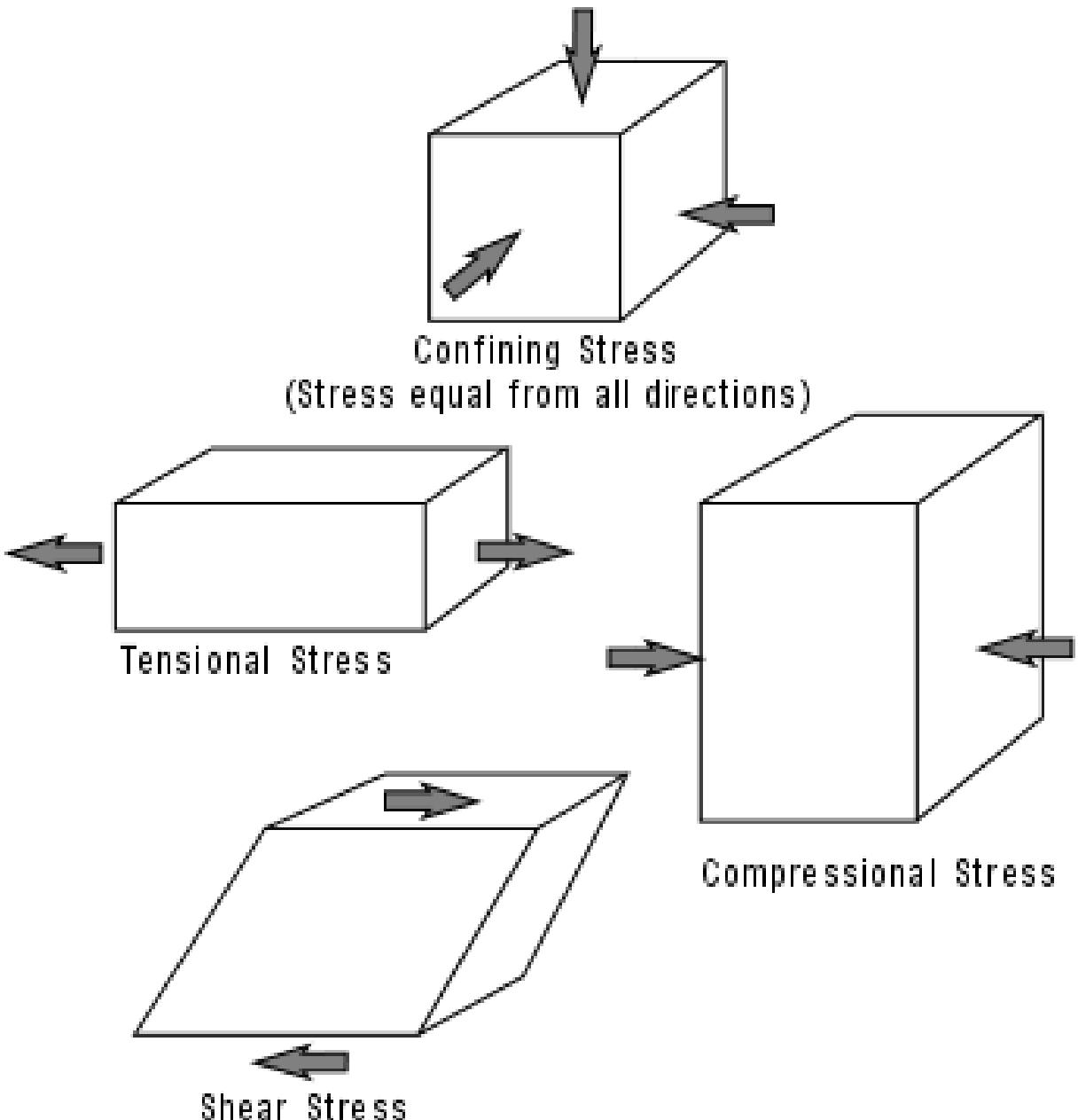
The magnitude of these balanced stresses increases with increasing depth within the earth. These stresses can not deform rocks other than to decrease their volume.

Pressure is the term used because the concept of pressure is used in chemistry, which is the discipline of science used to understand the mineral reactions that occur within the rock.

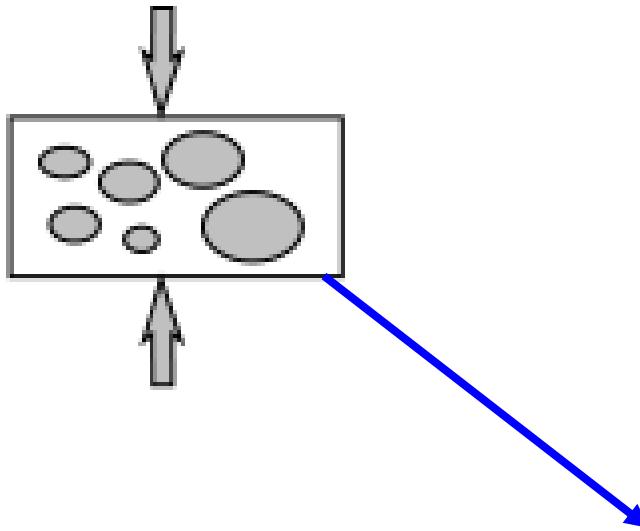
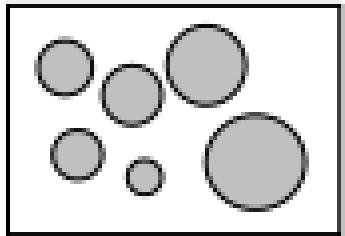


Directed Stress/differential or tectonic stress: unequal balance of forces on a rock in one or more

Generated by the movement of lithospheric plates.

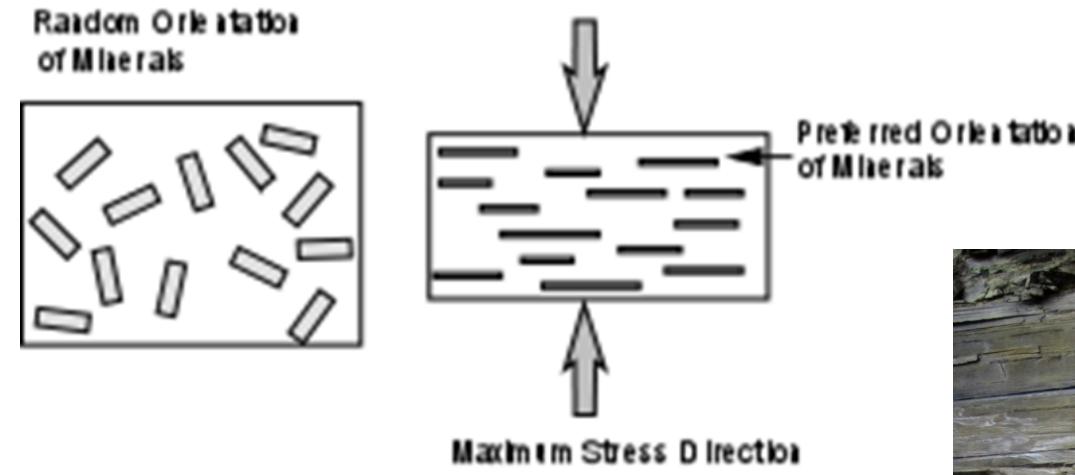


Directed stress causes changes in arrangement (rotation), size (increase or decrease), and/or shape of the mineral crystals – *new texture is created.*

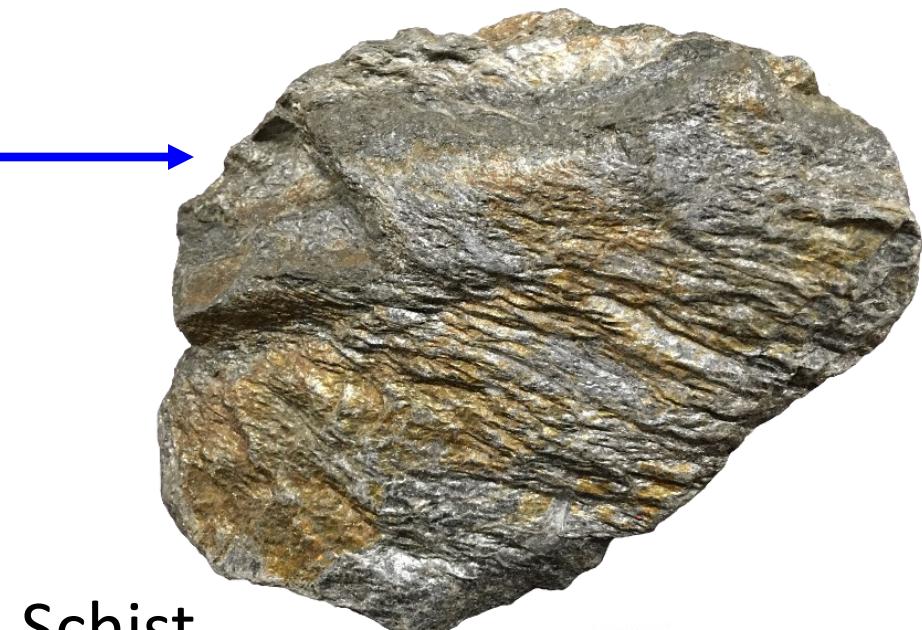


Pebbles (that used to be spherical in quartzite deformed by directed stress

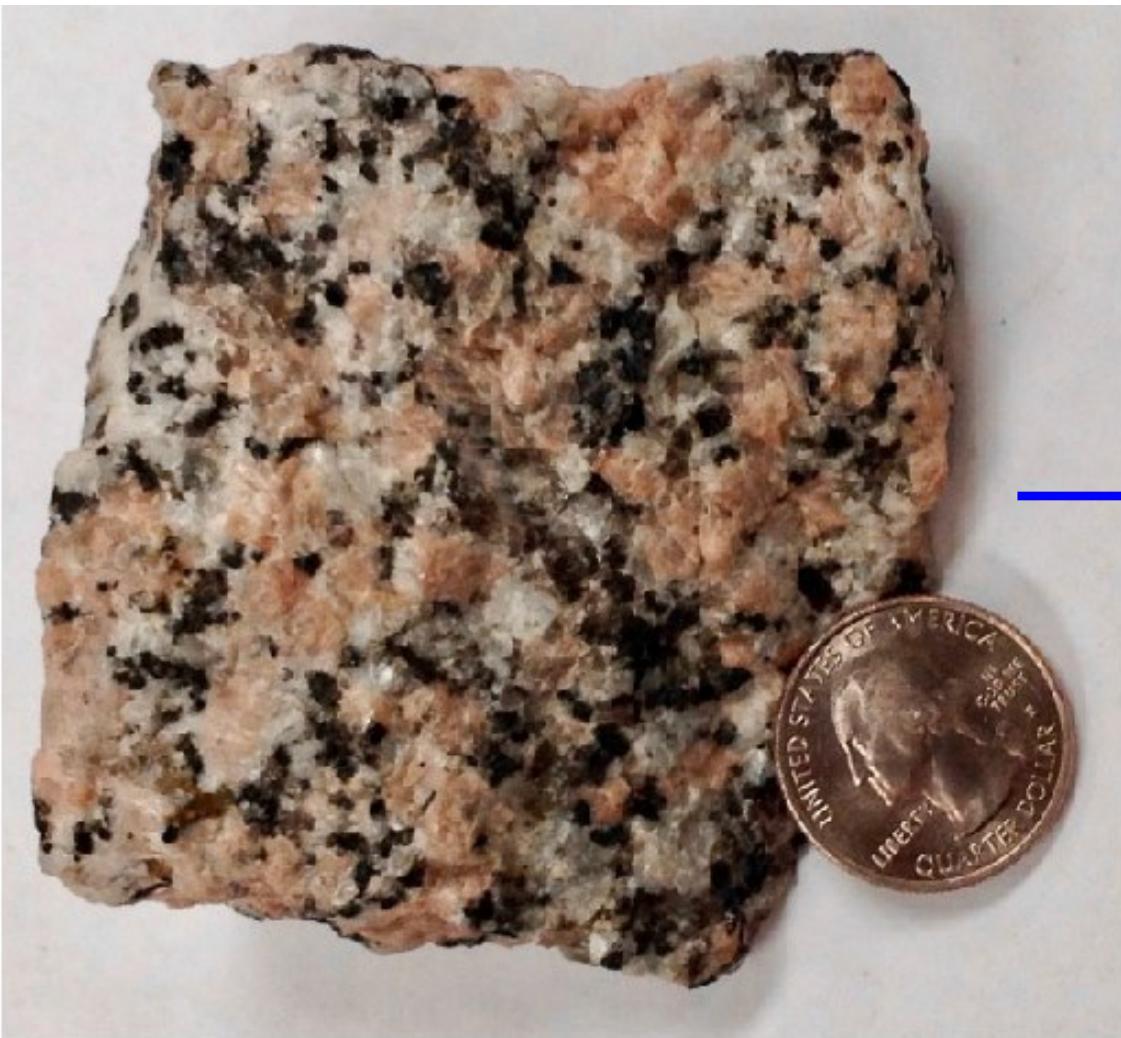
Minerals (especially sheet silicates like micas) that crystallize or grow in the differential stress field can have a preferred orientation.



Shale or
mudrock



Schist



Granite (igneous rock)



Foliated metamorphic rock (gneiss)

3. Fluids – chemically reactive

Expelled by crystallizing magma or created by metamorphic reactions.

Mostly water (H_2O) and carbon dioxide (CO_2) with dissolved ions.

React with minerals in the protolith, creates new minerals.

4. Time – tens of millions of years

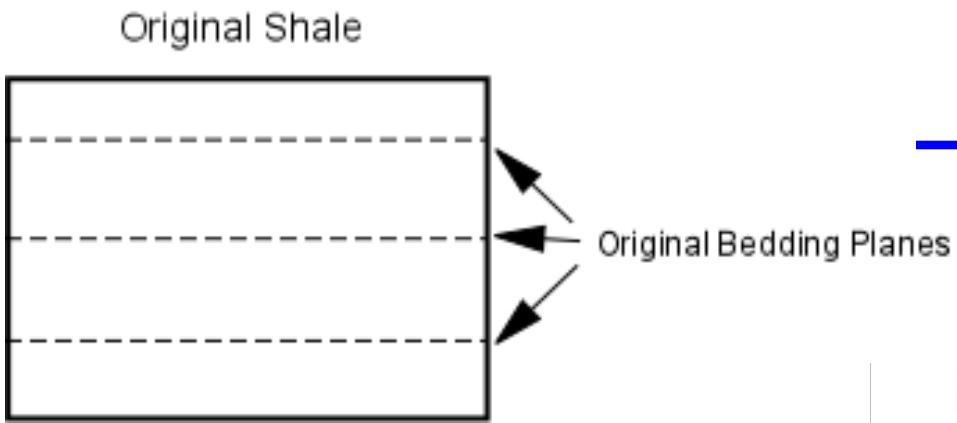
Metamorphic textures

Defined by shape and orientation of mineral grains.

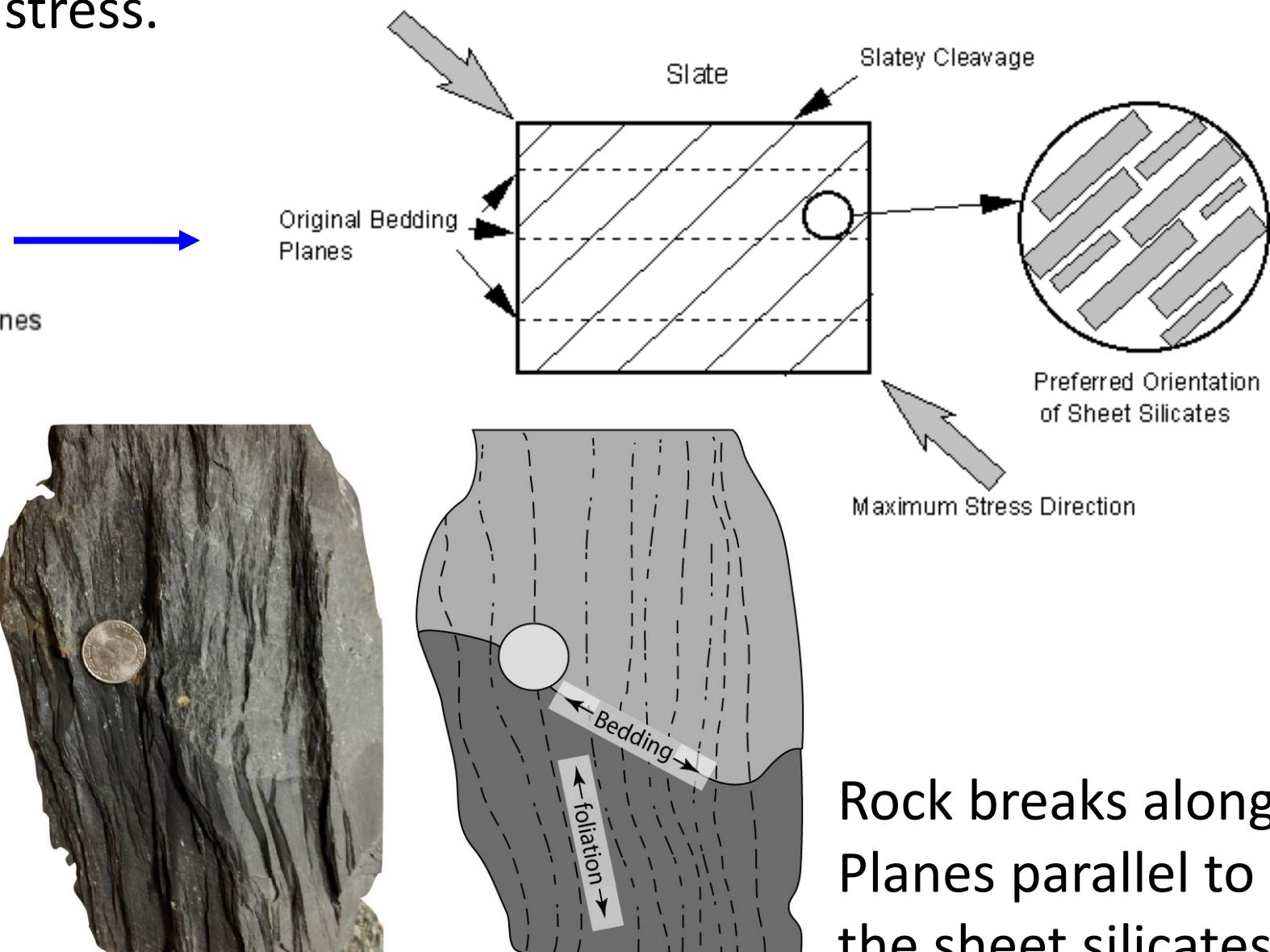
1. Foliated
2. Non-foliated
3. Lineated

Foliation

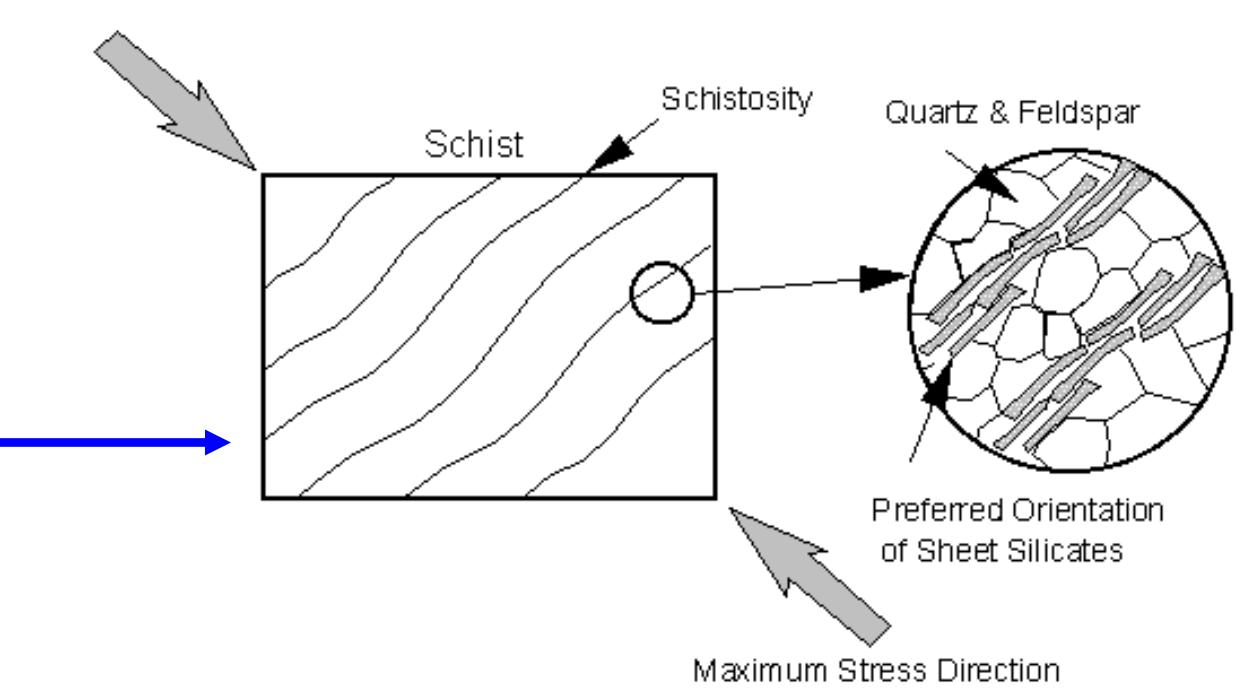
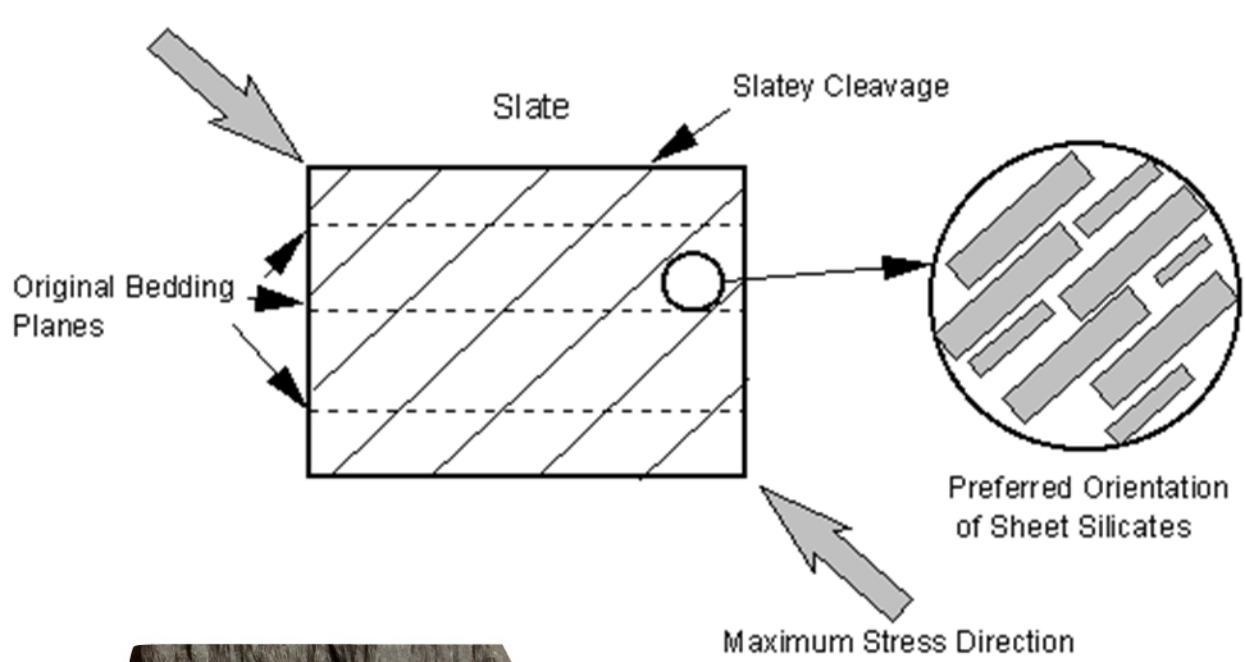
- Defined by preferred orientation of sheet silicates or platy minerals.
- Formed under differential stress.



made up of clay minerals & quartz all of clay or silt size.



Rock breaks along
Planes parallel to
the sheet silicates



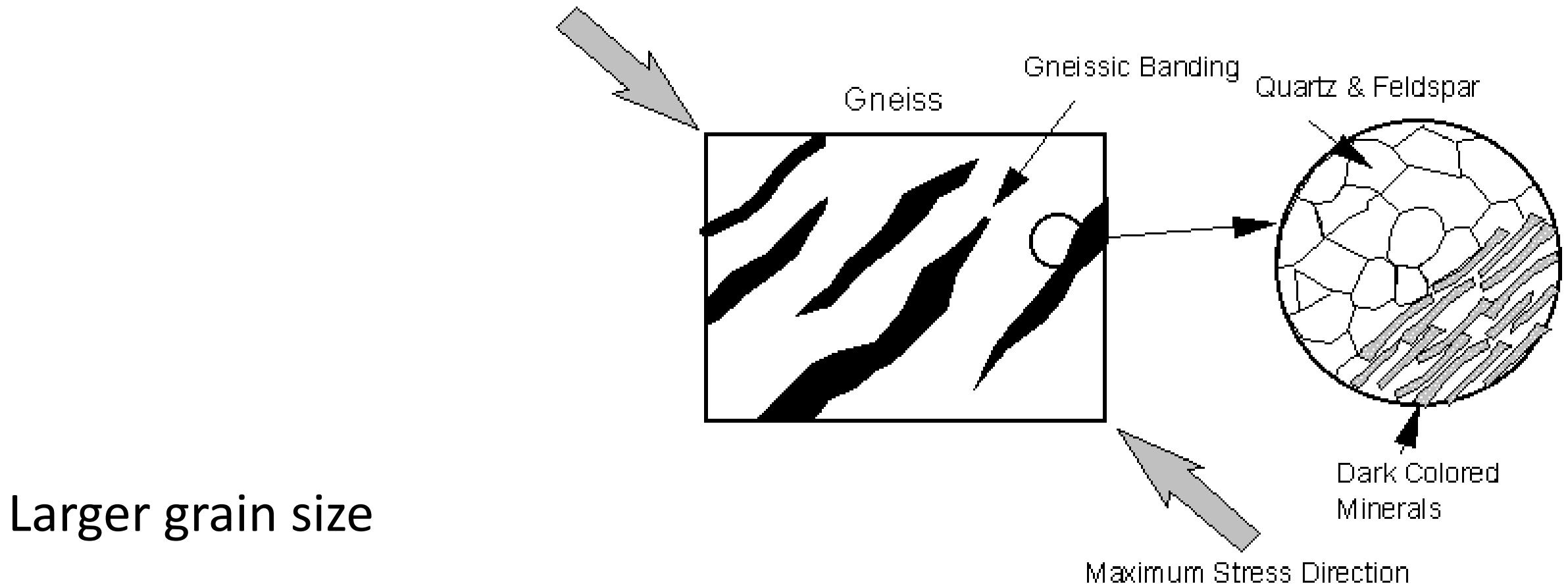
Coarser,
shining look

Garnet staurolite muscovite schist



Gneiss

- As metamorphic grade increases, silicate minerals separate into light and dark layers giving the rock a gneissic banding.
- light-colored layers - composed of feldspars & quartz
dark-colored - hornblende and biotite.



Gneiss



Augen gneiss characterized by large ovoidal megacrysts of feldspar known as "augens" (derived from the German for "eyes").



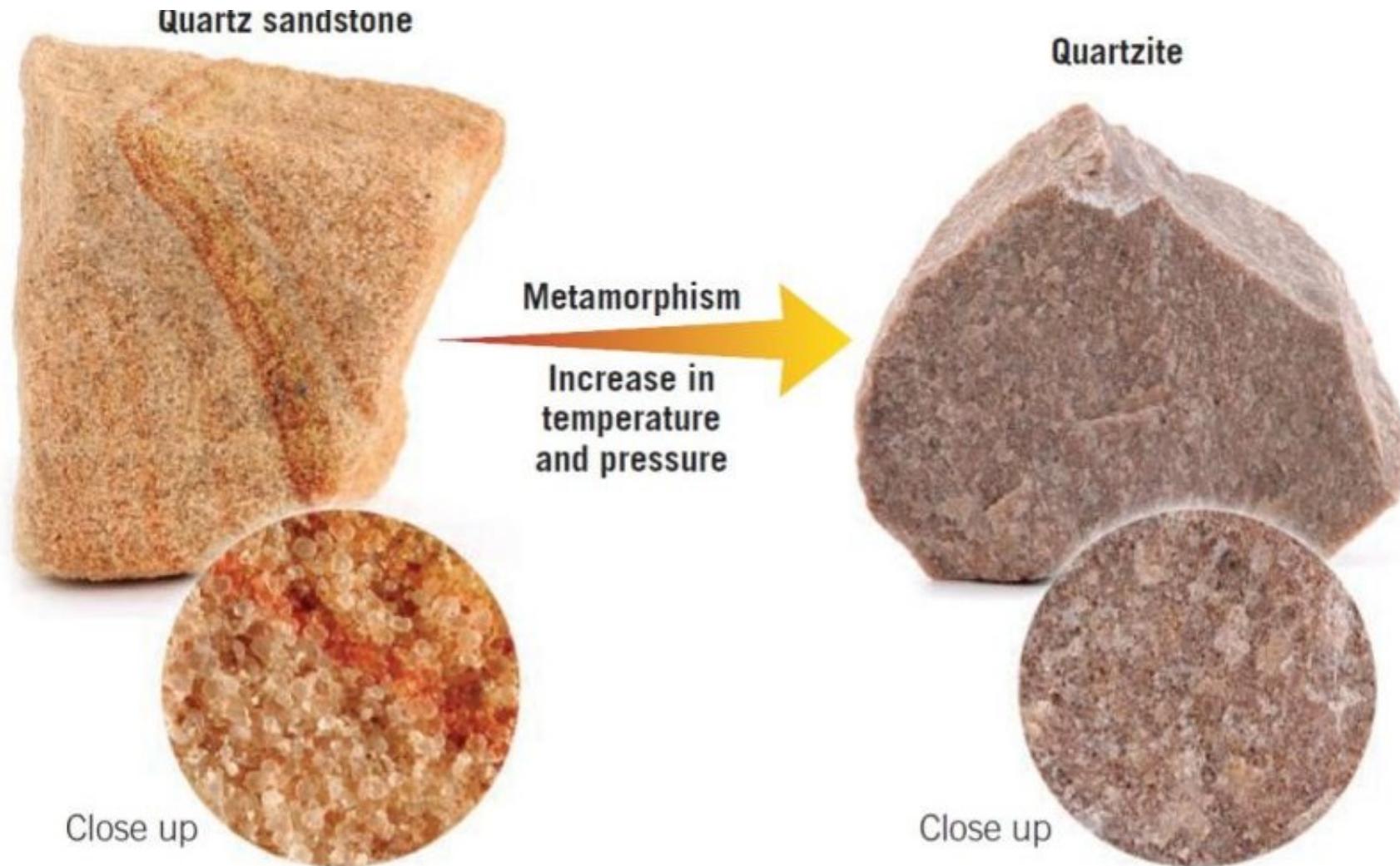
2. Non-foliated metamorphic rocks

Do not have lineations, foliations, or other alignments of mineral grains.

Typically composed of just one mineral.

So, show the effects of metamorphism with recrystallization in which crystals grow together, but with no preferred direction.

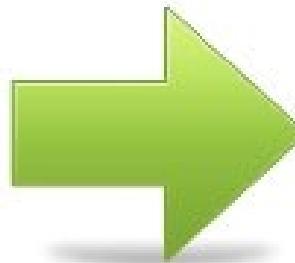
- **Quartzite** (non-foliated) formed by metamorphism of sandstone.
- In quartzites, the quartz grains from the original sandstone are enlarged and interlocked by recrystallization.



- **Marble** (non-foliated) is metamorphosed limestone - composed of calcite.
- Recrystallization typically generates larger interlocking crystals of calcite.



Limestone



*Recrystallization
(caused by heat)*



Marble