Lecture 11

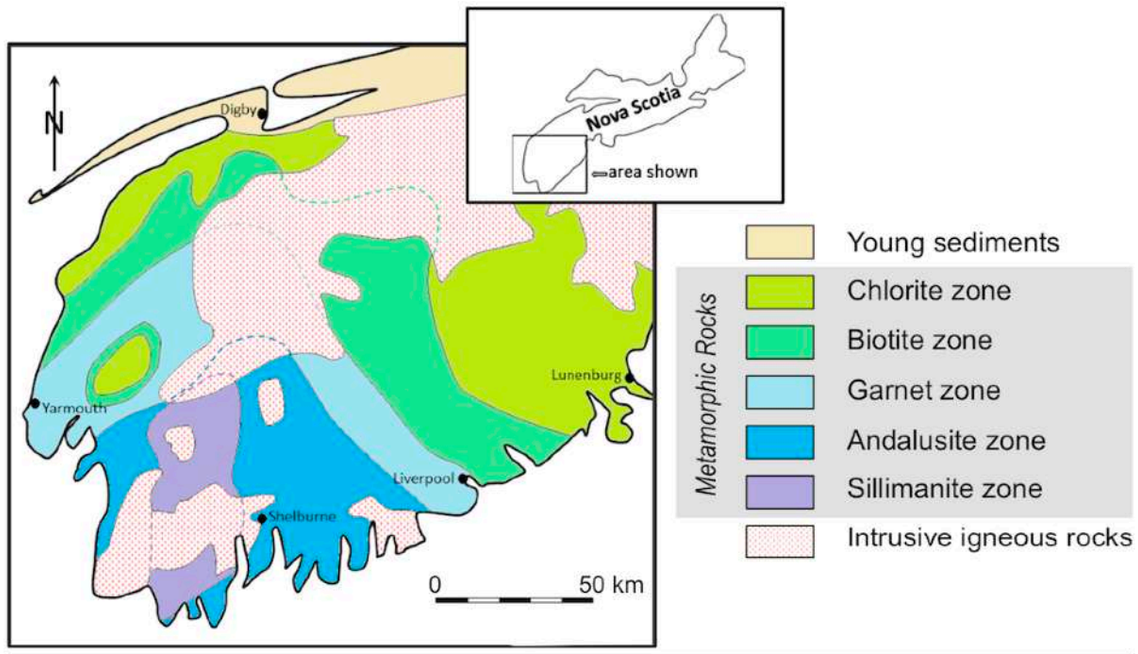
Metamorphic Rocks

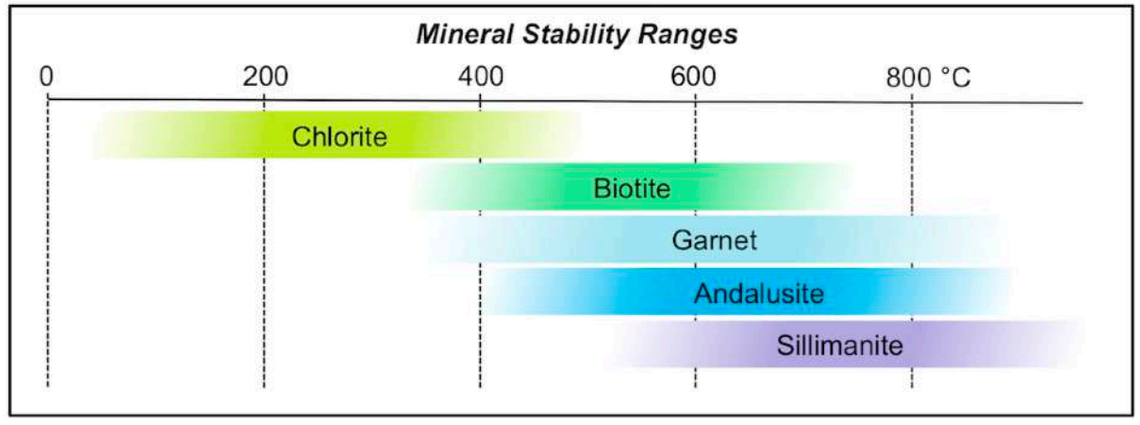
Metamorphism

Metamorphic Textures

Metamorphic Rocks

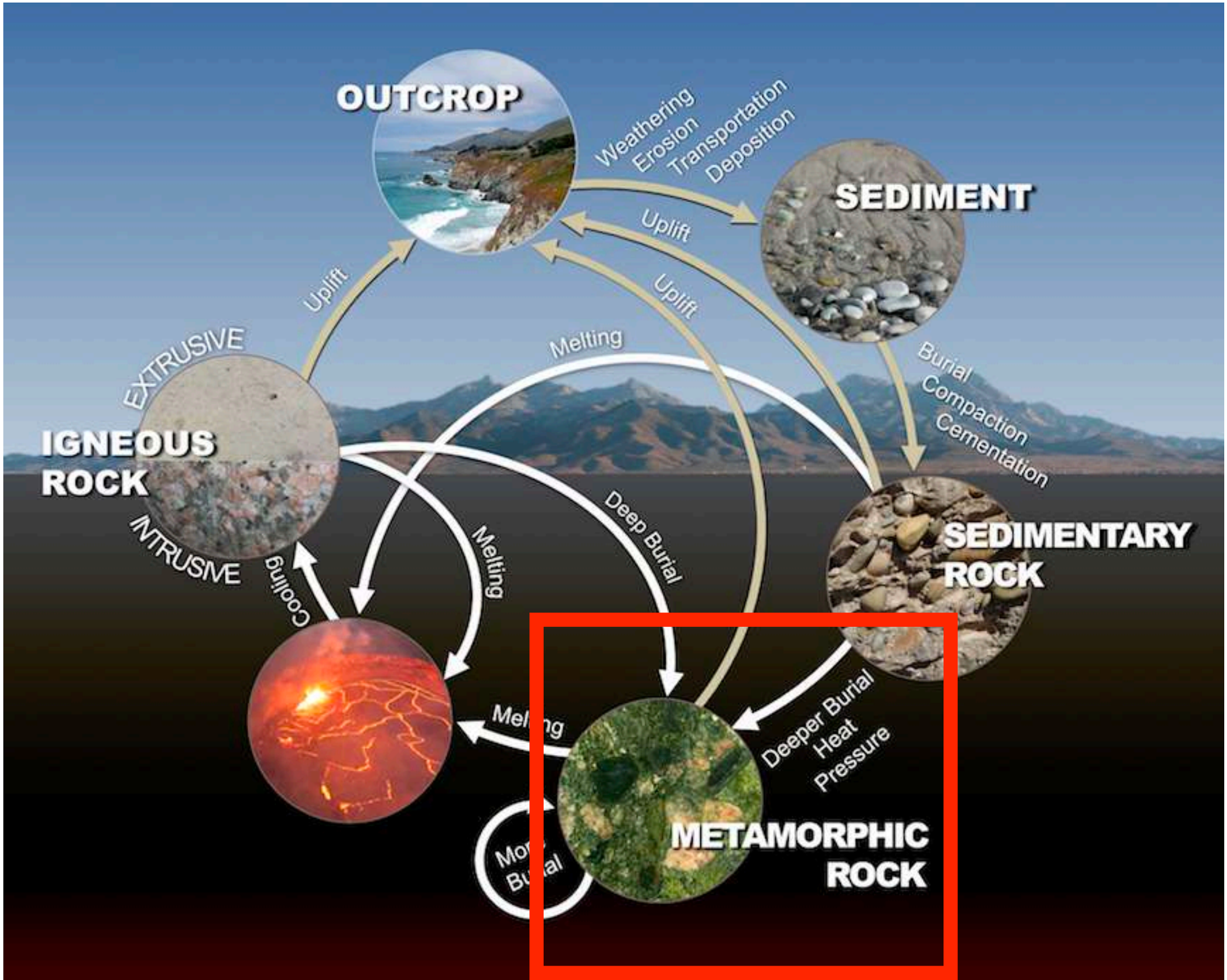
Metamorphic Environments





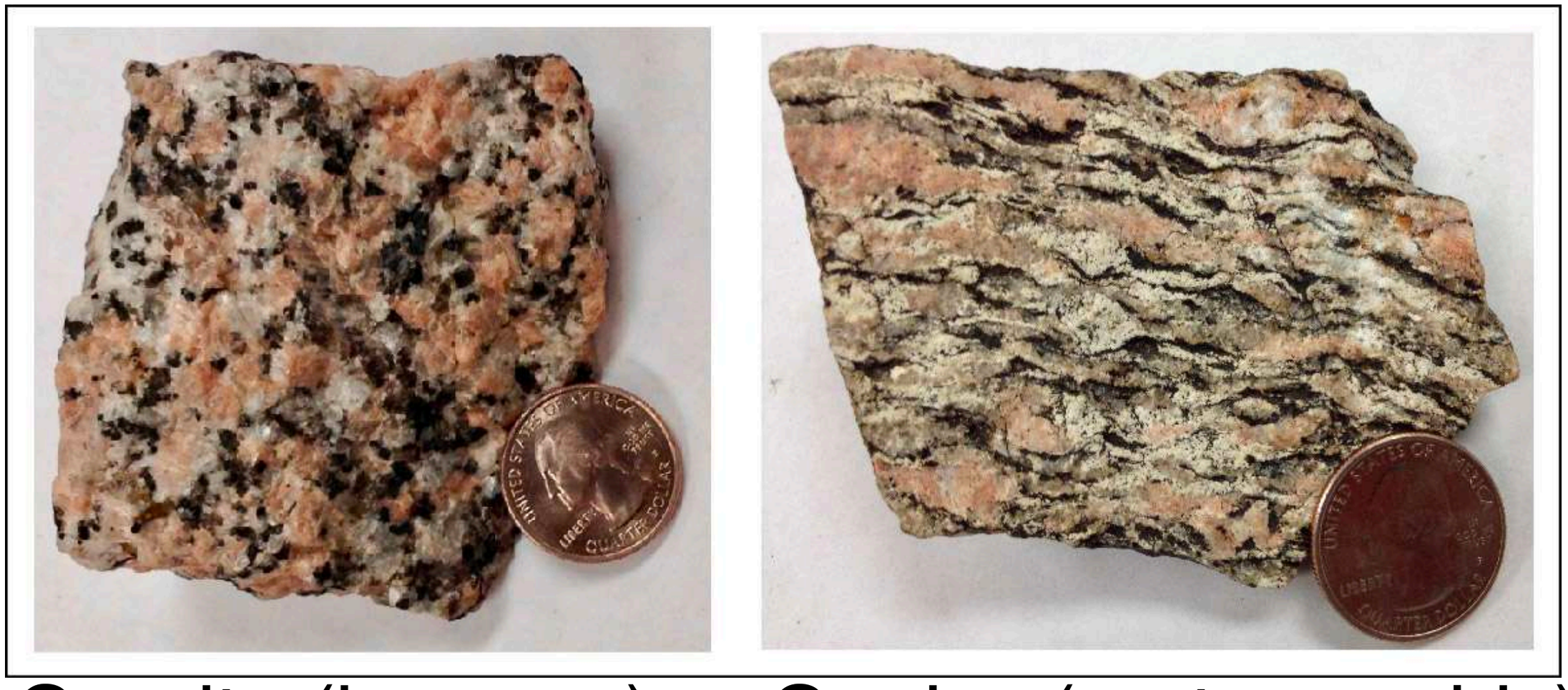
Metamorphism

THE ROCK CYCLE



Metamorphism

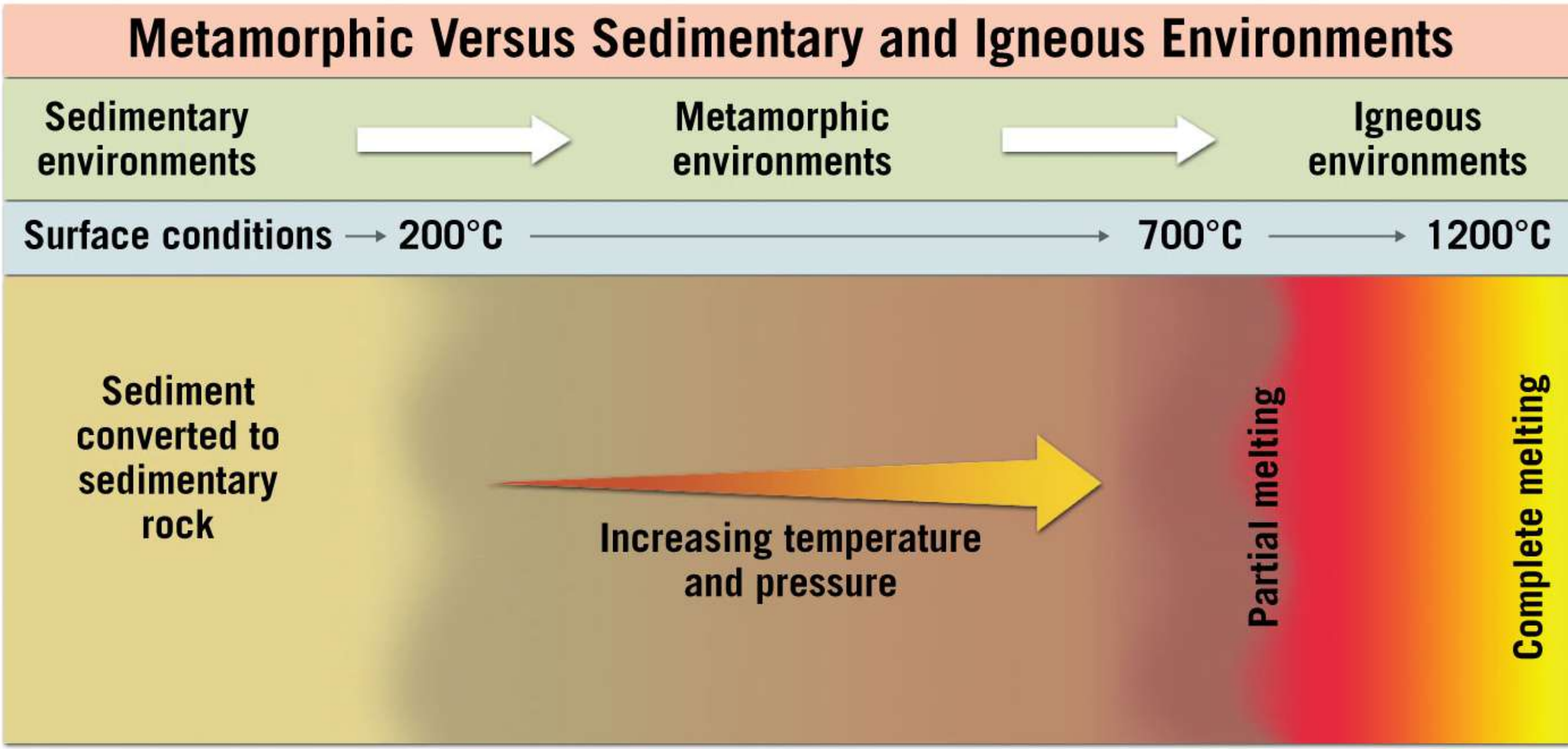
- **Metamorphism** is the the solid-state change in composition and/or texture of a rock due to **high temperature and/or pressure**
  - Composition = minerals
  - Texture = size and orientation of minerals



Granite (igneous) Gneiss (metamorphic)

Metamorphism

- Temperature ranges at which rocks form
  - Metamorphic rocks form 200˚-700˚



Metamorphism

- **Heat** is the most important agent in metamorphism
- Causes **recrystallization** - atoms of minerals become rearranged
  - No new elements introduced, just rearranges the elements already present
- Mineral composition may or may not change
- Example: If a shale undergoes metamorphism, the clay minerals will recrystallize as chlorite and mica

Metamorphism

- Did minerals change?

Granite

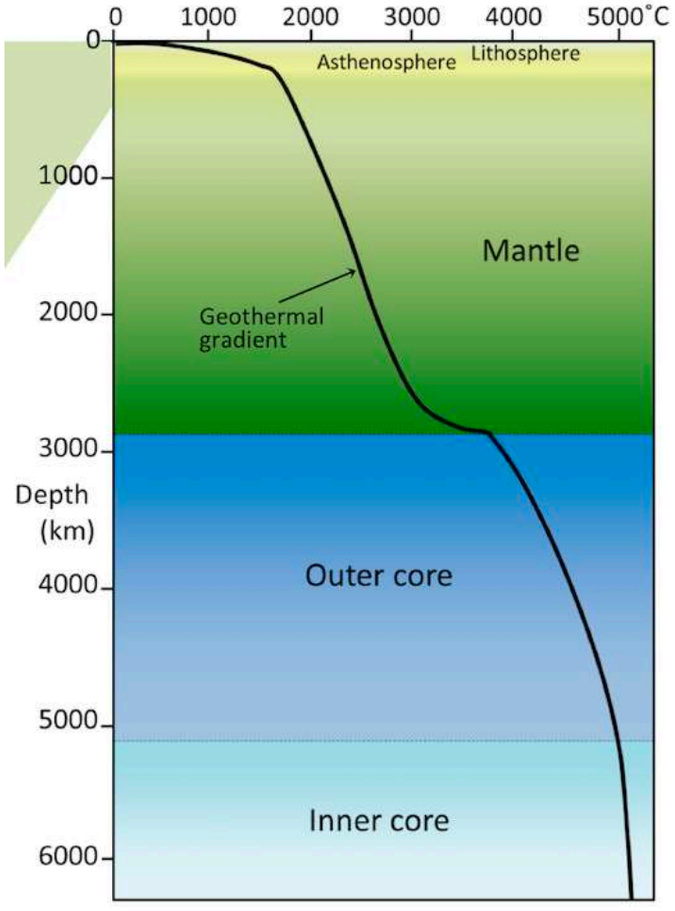
Gneiss

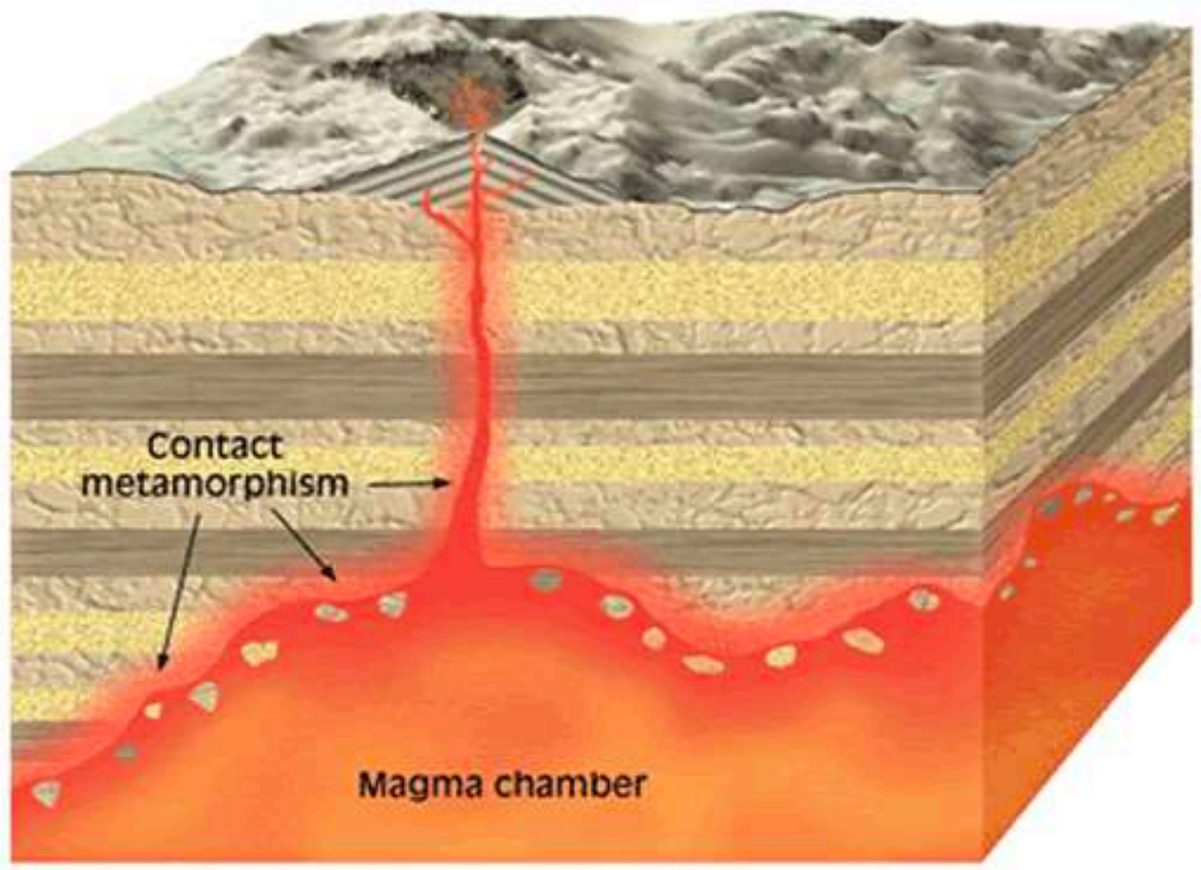
Shale

Schist

Metamorphism

- 2 Sources of heat
- Heat within the Earth, interior is extremely hot
  - Increase in temperature with depth
- Heat from a magma chamber
  - The rock walls containing a magma chamber are heated by the magma



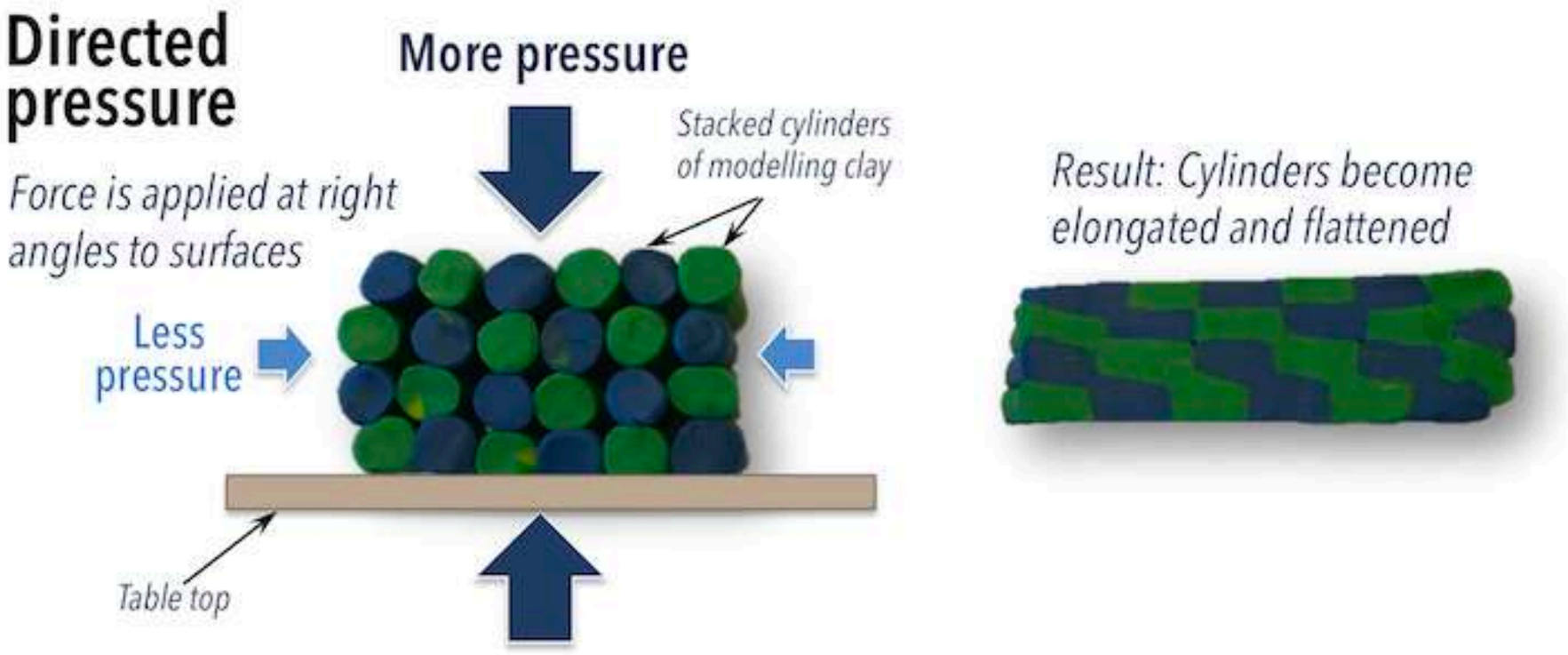


Metamorphism

- **Pressure** also increases with depth
  - Confining pressure is when stress is equal in all directions, like burying sedimentary rocks

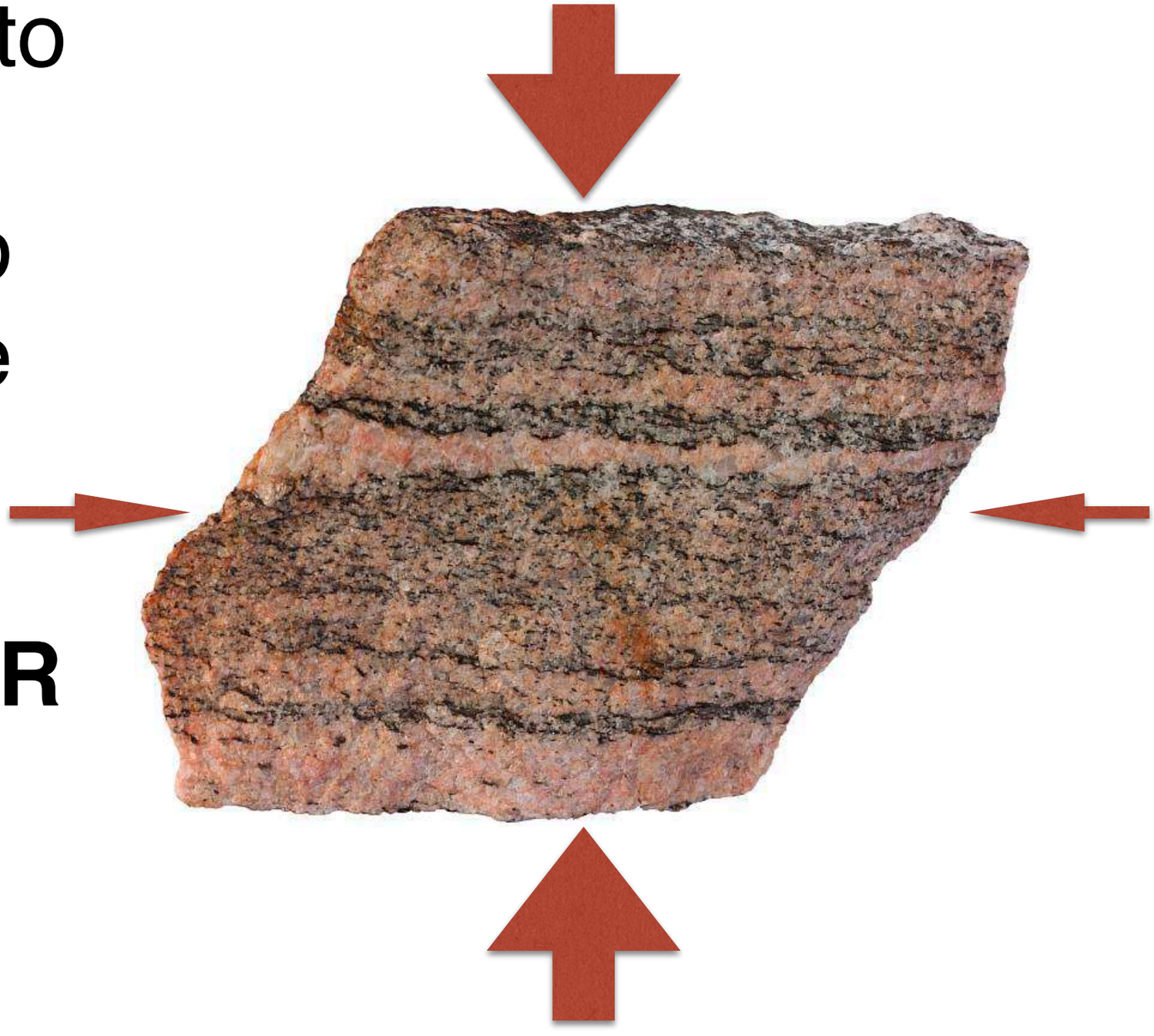
Metamorphism

- Differential pressure is when pressure is stronger from some directions and not others
  - Happens near tectonic plate boundaries



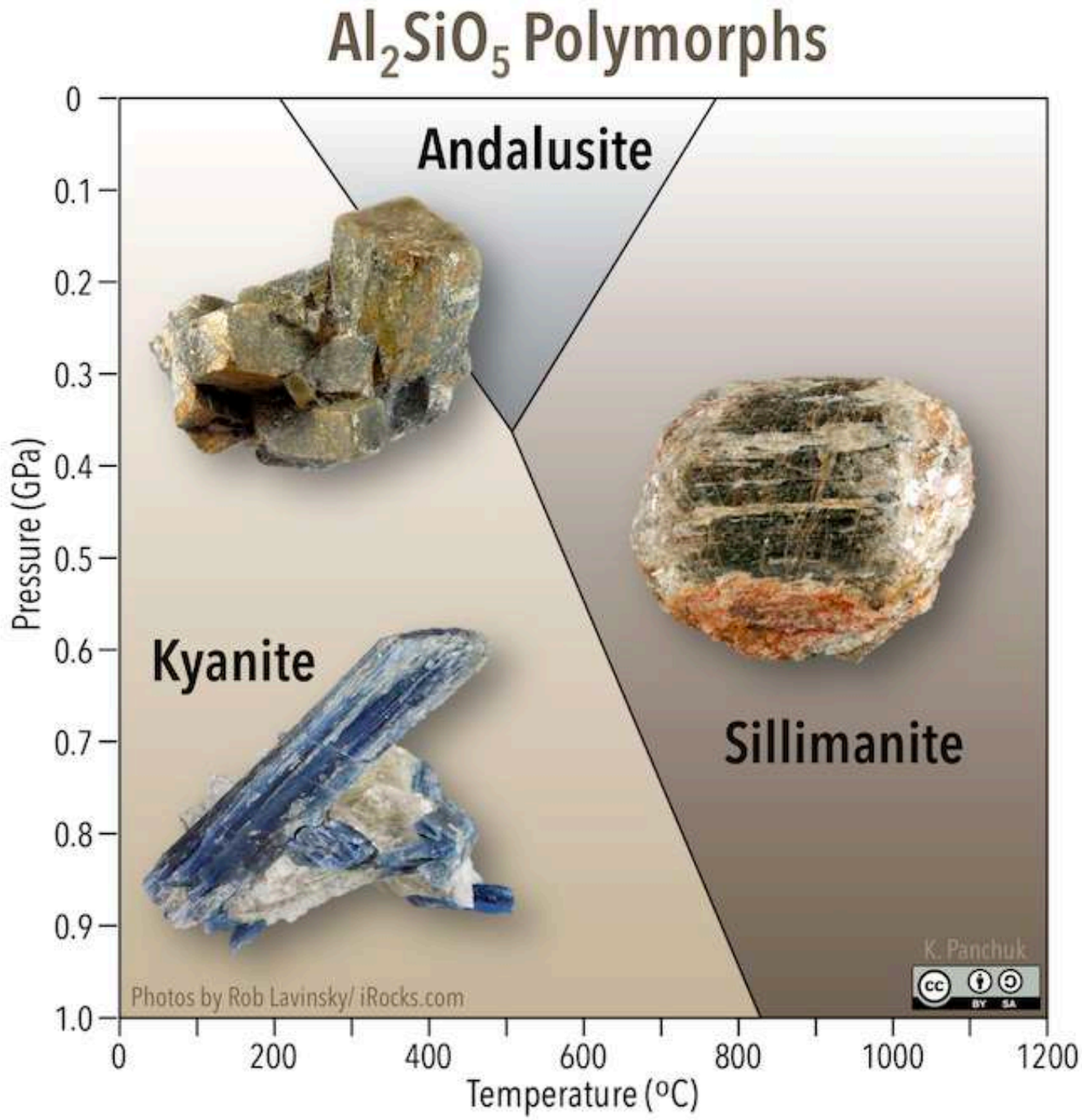
Metamorphism

- Rocks act similar to putty or play-doh when subjected to heat and pressure
- Minerals grains align themselves **PERPENDICULAR** to the differential stress



Metamorphism

- **Recrystallization** re-arranges the elements already present into new minerals
  - Dependent on heat and pressure



Metamorphism

- Metamorphic rocks retain the chemical composition of the rocks they formed from **(parent rock or protolith)**
- The minerals in the parent rocks determines how much the rock will change during metamorphism
- Parent rocks made mainly of the resistant mineral quartz will not change much
- Parent rocks made of less resistant minerals (amphibole, olivine, etc…) will alter significantly

Metamorphic Textures

- **Texture** refers to the size, shape, and ***arrangement*** of mineral grains
- Describe how the minerals look in these rocks

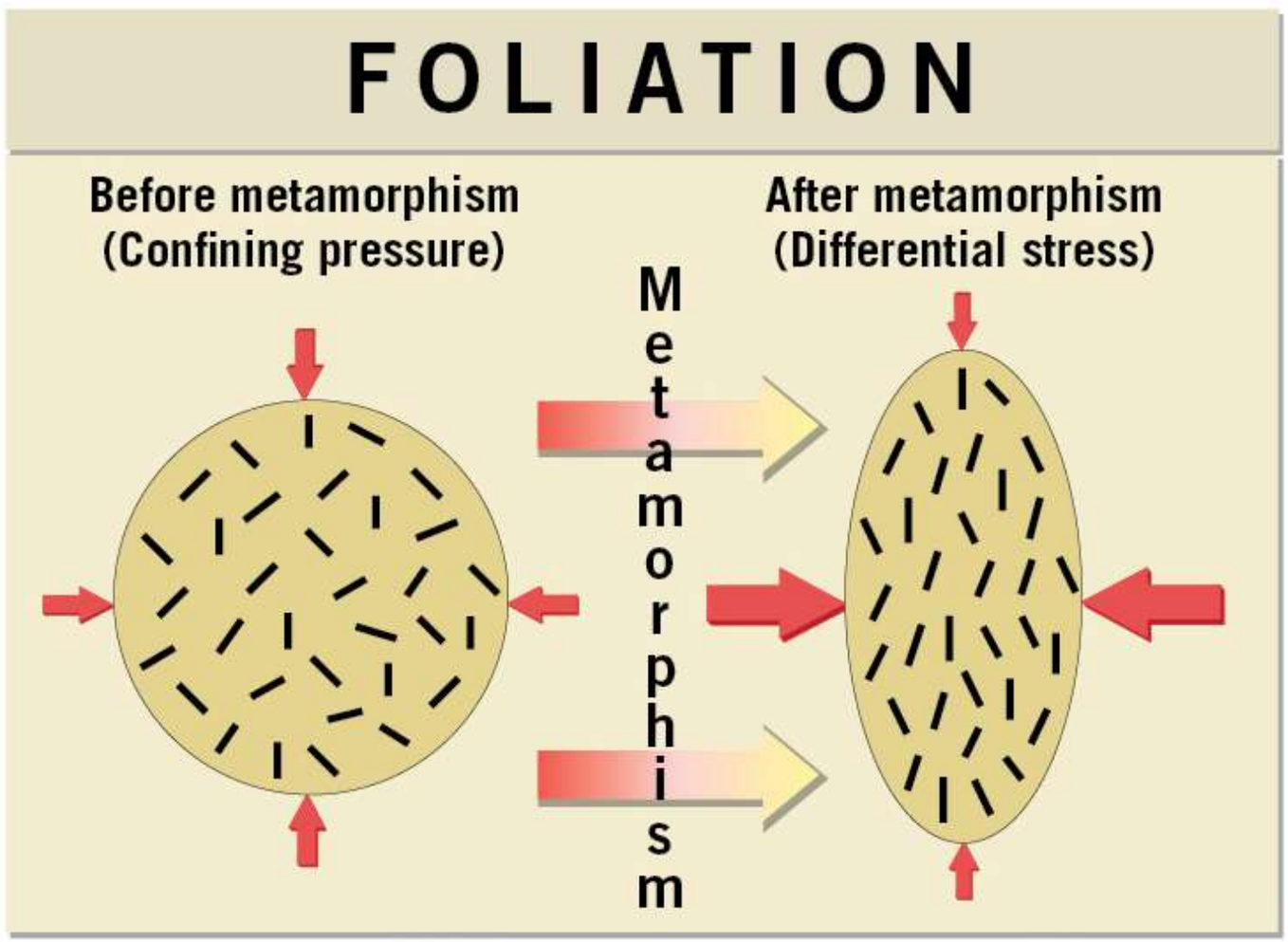
Metamorphic Textures

- **Foliation** is any planar (flat) arrangement of minerals
  - Pressure squeezes minerals, causing them to flatten or form parallel alignments

https://mediaplayer.pearsoncmg.com/assets/secs-geology-animation-Foliation

Metamorphic Textures

- Pressure squeezes minerals, causing them to flatten or form parallel alignments
- Anytime minerals have a pattern, they have been foliated



Platy and elongated mineral grains having random orientation.

Mineral grains that are aligned roughly perpendicular to the direction of maximum differential stress.

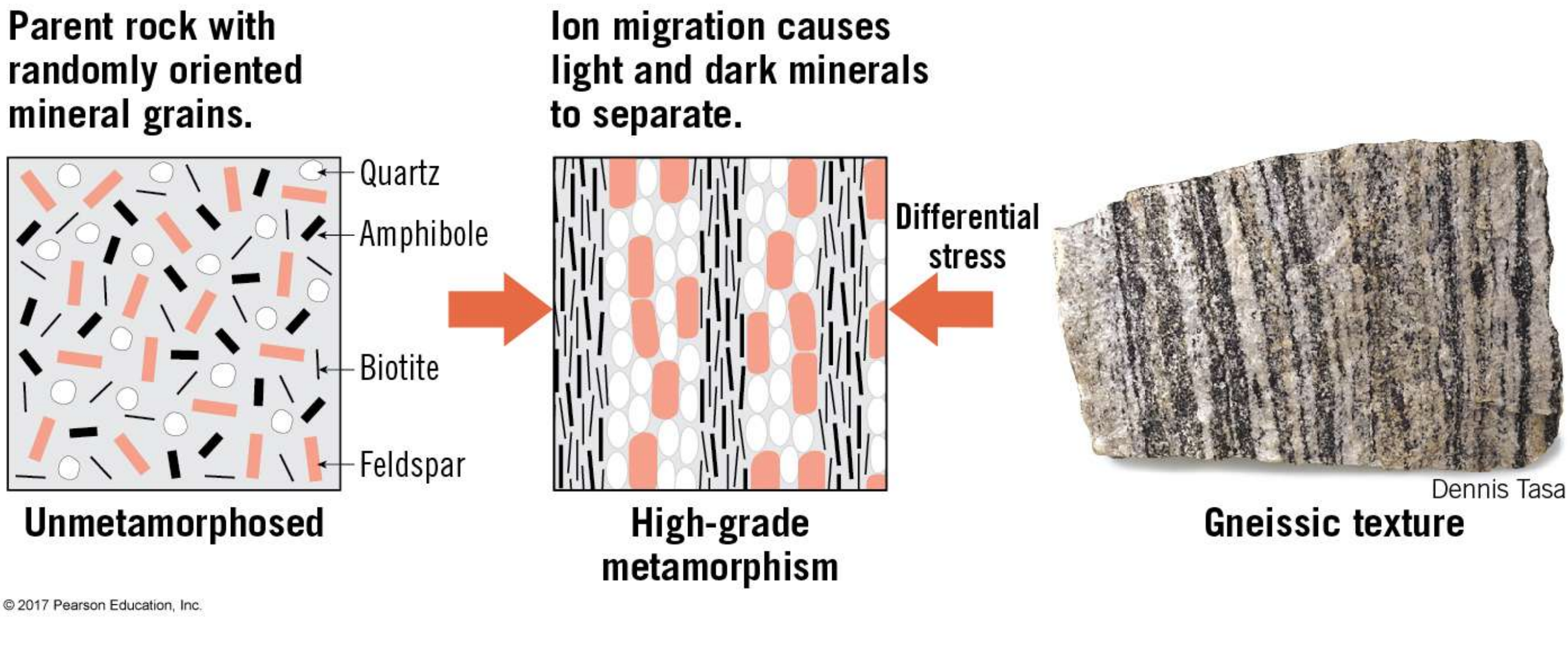
Metamorphic Textures

- Minerals become foliated by rotating or recrystallizing
  - Perpendicular to the direction of maximum stress
- Rotation is linked to low grade metamorphic environments
- Recrystallization occurs during high grade metamorphism

These “minerals” rotated to new positions

Metamorphic Textures

- Under high-grade metamorphic conditions, minerals can become segregated into parallel bands, called “banding”

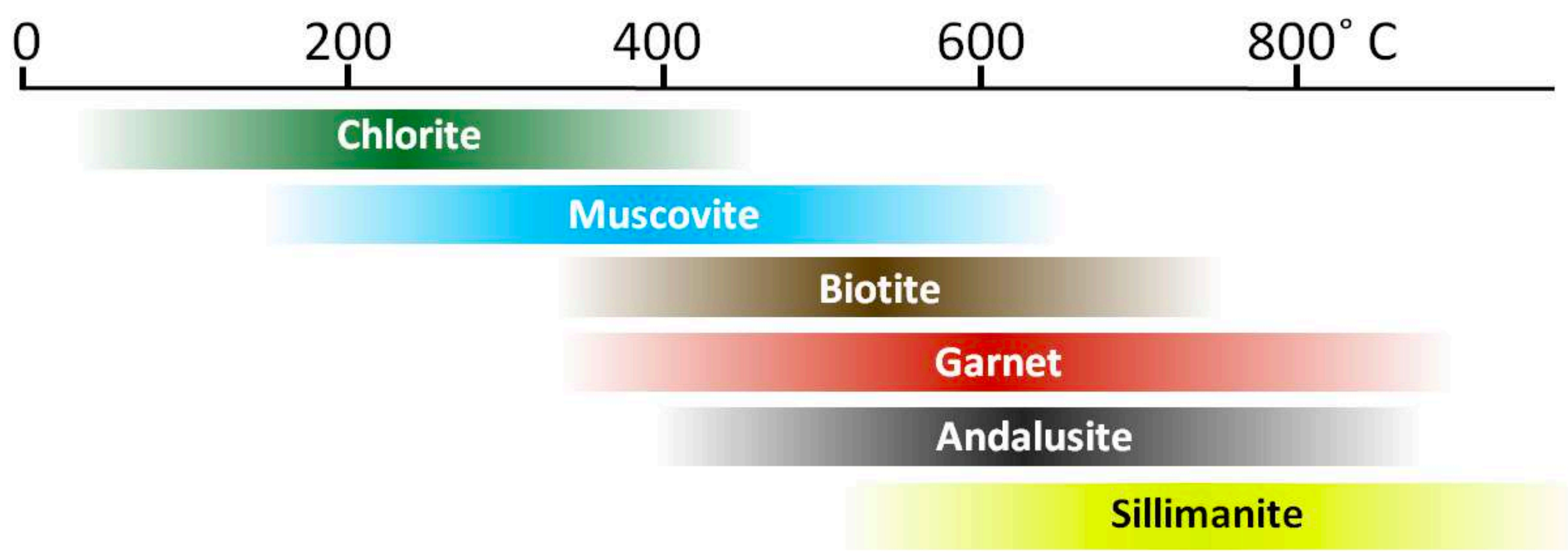


Metamorphic Textures

- Sometimes completely new minerals crystallize
- These are an indicator of metamorphic grade
  - Temperature and Pressure conditions

Metamorphic Textures

- Sometimes completely new minerals crystallize
- These are an indicator of metamorphic grade
  - Temperature and Pressure conditions



Metamorphic Textures

- **Non-foliated** textures also exist
  - No alignment or preferred orientation of minerals
  - Recrystallization does occur
  - No platy or elongated minerals to “flatten”

Metamorphic Textures

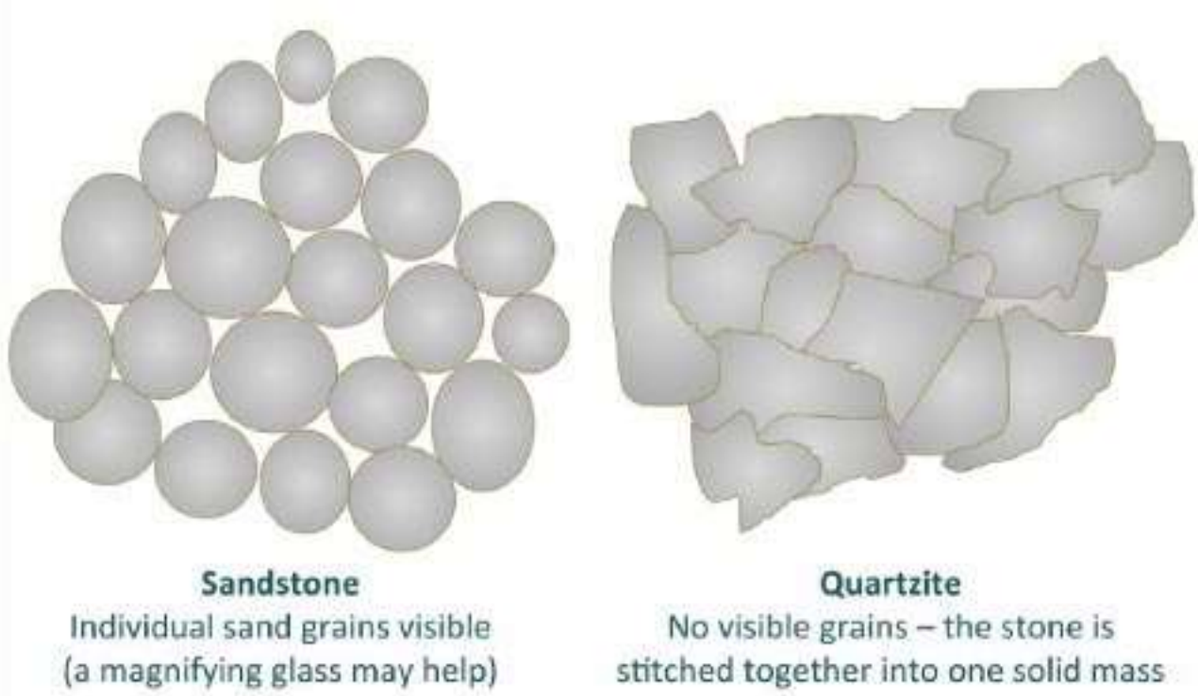
- A limestone that gets metamorphosed is a marble
  - No foliation

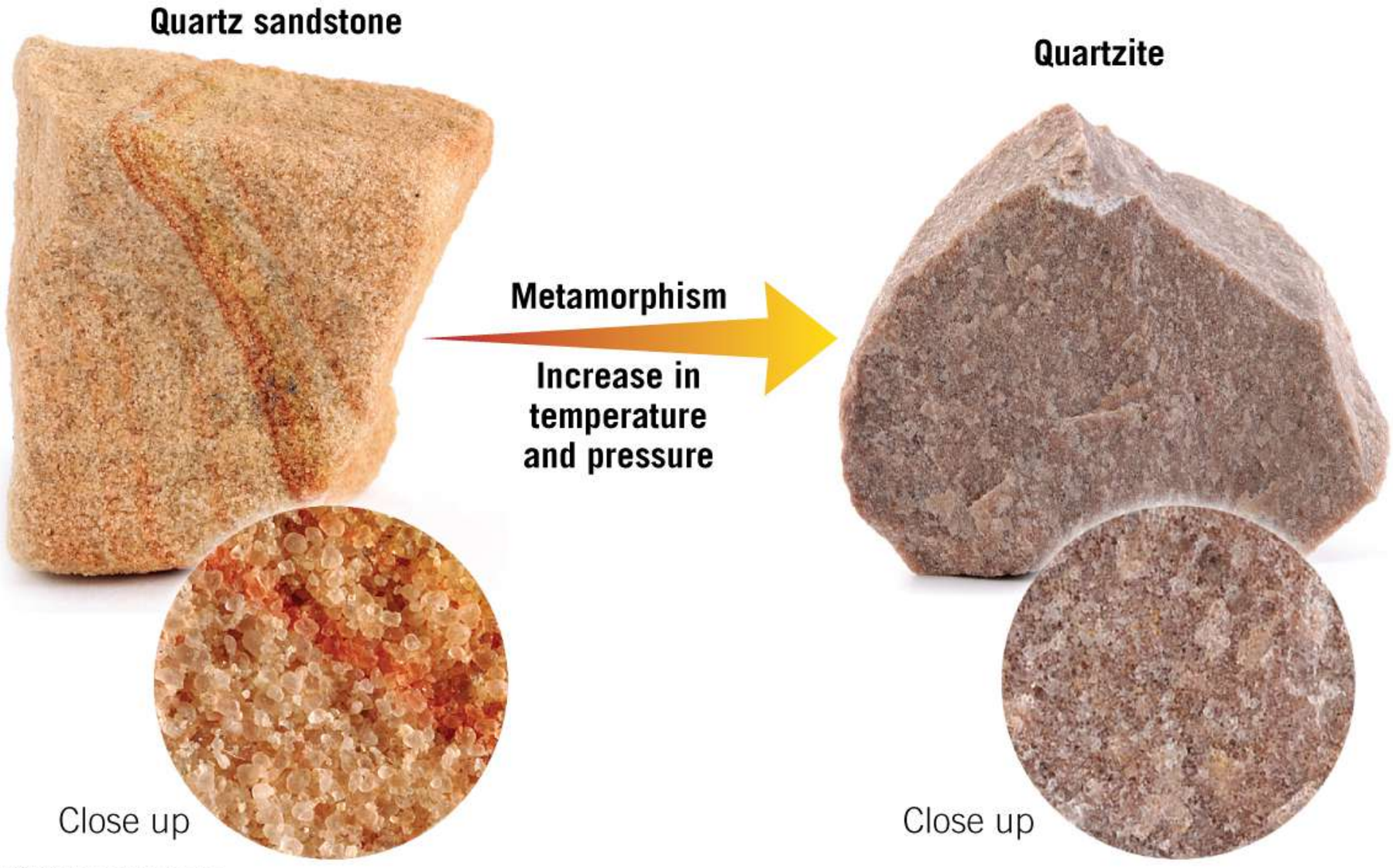
Limestone

Marble

Metamorphic Textures

- A quartz sandstone that gets metamorphosed is a quartzite
  - No foliation





Metamorphic Rocks

- Metamorphic rocks are classified by the grade of metamorphism, texture, and composition.
  - Protolith - what rock was before metamorphism happened

Metamorphic Rocks

- **Slate**
  - Low-grade, foliated metamorphic rock
  - Minerals too small to see
  - Protolith = Shale

3D Model

Metamorphic Rocks

- **Phyllite**
  - Low-grade, foliated metamorphic rock
  - Slightly higher temperature than shale
  - Minerals too small to see, but the rock appears shiny and “wavy”
  - Protolith = Shale

3D Model

Metamorphic Rocks

- **Schist**
  - Med-high grade, foliated metamorphic rock
  - Large mica crystals
  - Other minerals may be visible
  - Protolith = Shale

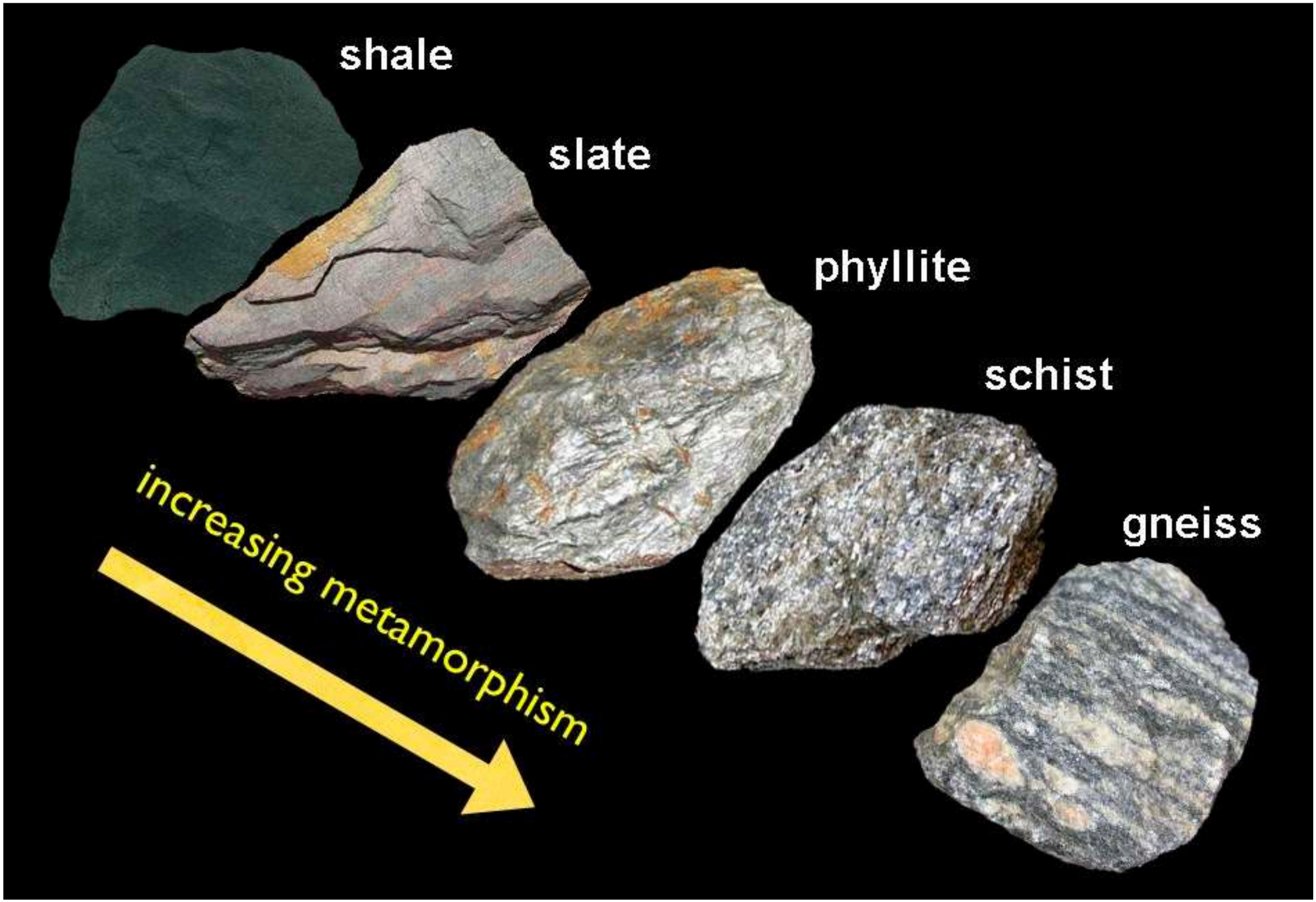
[3D Model]

Metamorphic Rocks

- **Gneiss**
  - High-grade, foliated metamorphic rock
  - Minerals have aligned into parallel bands
  - Protolith = Shale or granite

[3D Model]

Metamorphic Rocks



Metamorphic Rocks

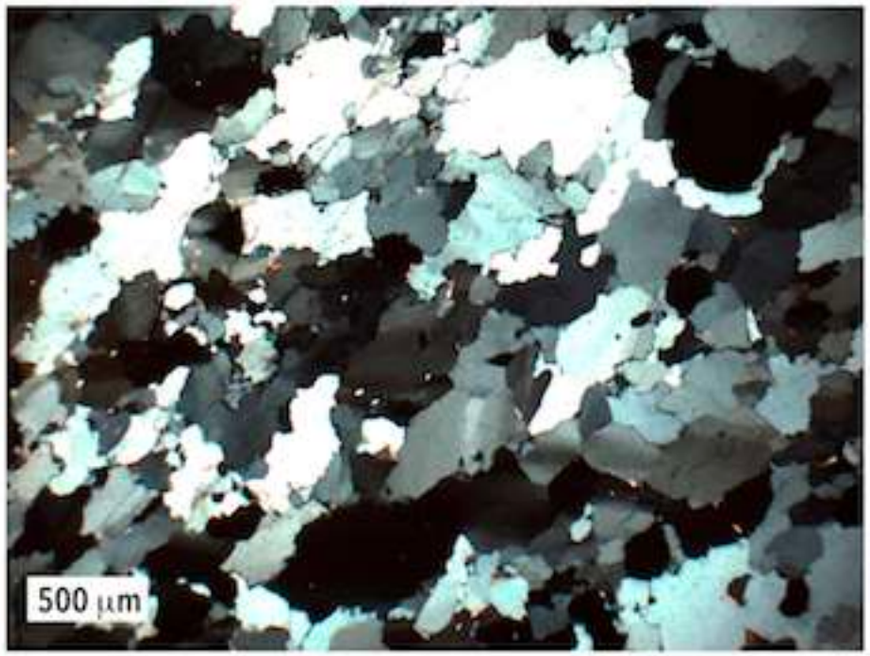
- **Marble**
  - Med-high grade, non-foliated
  - Calcite recrystallizes
  - May contain other minerals like graphite
  - Protolith = Limestone

[3D Model]

Metamorphic Rocks

- **Quartzite**
  - Med-high grade, non-foliated
  - Quartz recrystallizes
  - Protolith = Sandstone

Hand sample
Karla Panchuk



Photomicrograph
Geologian

[3D Model]

Metamorphic Rocks

Table 10.1 A Rough Guide to the Effect of Metamorphism on Different Protoliths

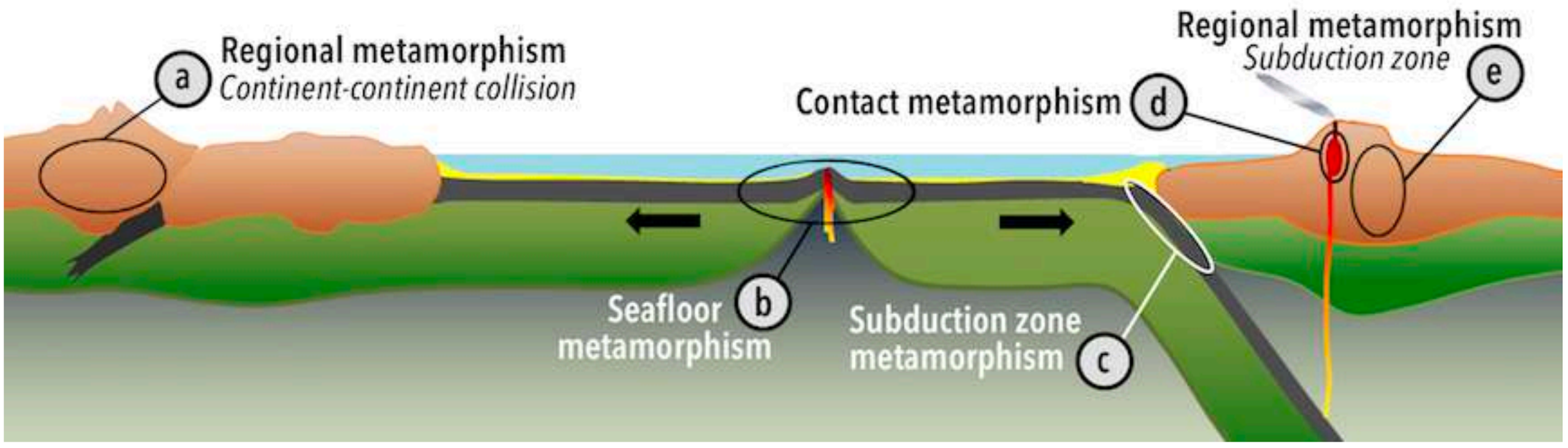
Protolith	Very Low Grade 150-300°C	Low Grade 300-450°C	Medium Grade 450-550°C	High Grade Above 550°C
Mudrock	slate	phyllite	schist	gneiss
Granite	no change			granite gneiss
Basalt	chlorite schist		amphibolite (amphibole gneiss)	
Sandstone	no change	little change	quartzite	
Limestone	little change	marble		

Note: Temperature ranges are approximate

Metamorphic Environments

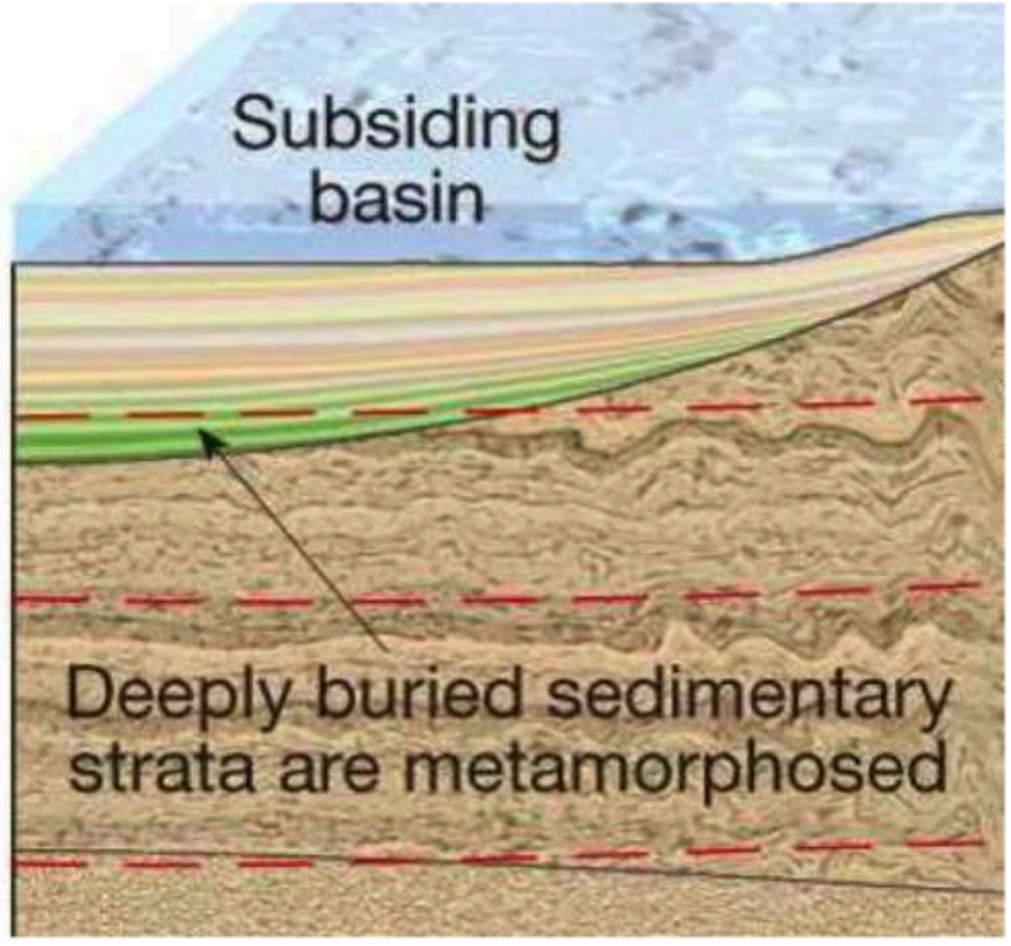
- 4 primary environments, although others exist

- **Burial Metamorphism**
- **Contact Metamorphism**
- **Subduction Zone Metamorphism**
- **Regional Metamorphism**



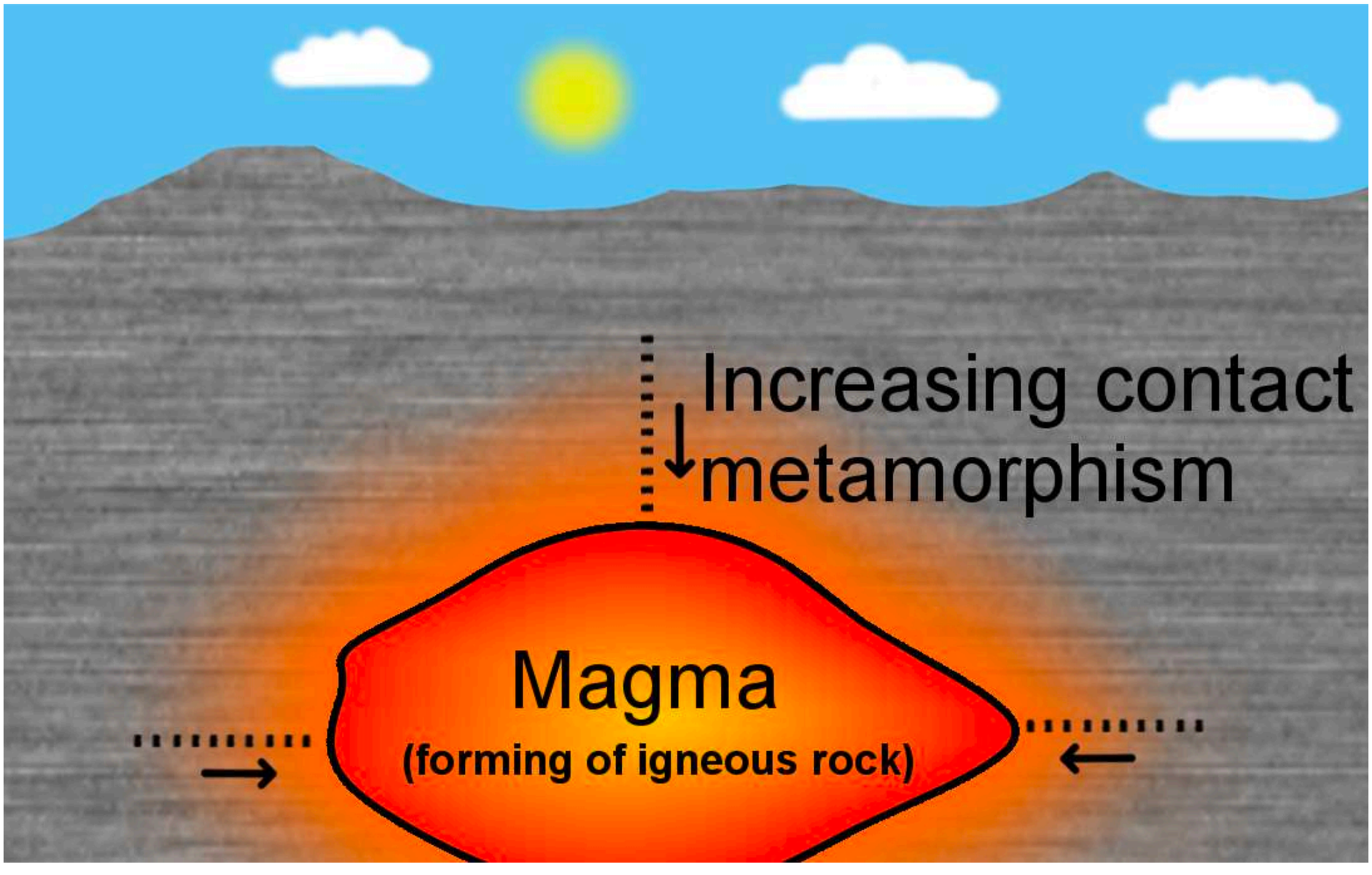
Metamorphic Environments

- **Burial Metamorphism** occurs when sediments are buried deeply enough that heat and pressure cause recrystallization
  - Low heat (< 300°C) and low pressure
  - Produces non-foliated rocks



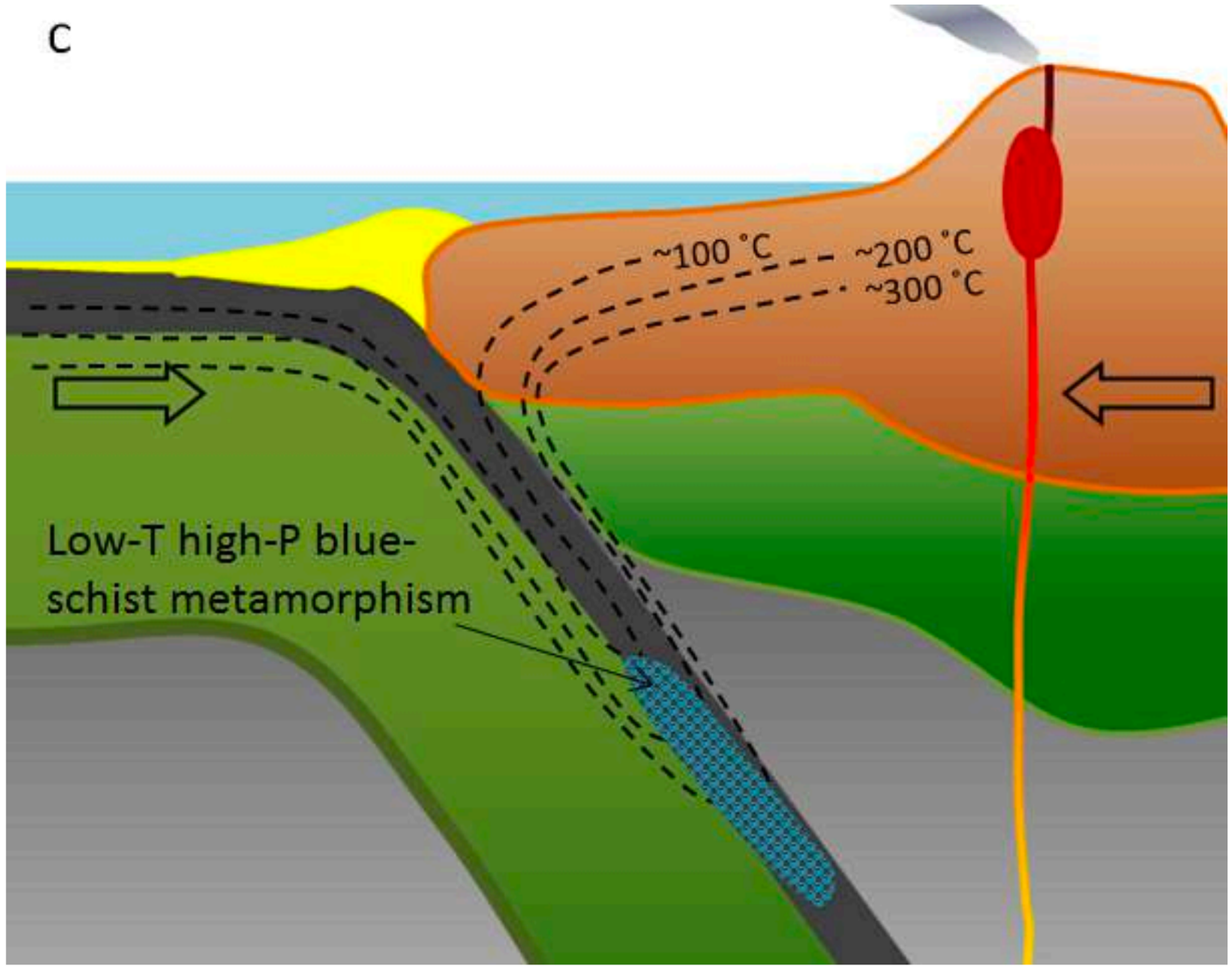
Metamorphic Environments

- **Contact Metamorphism**
  - Rock surrounding a magma chamber become altered due to the intense heat (low pressure)
  - Usually produces non-foliated rocks



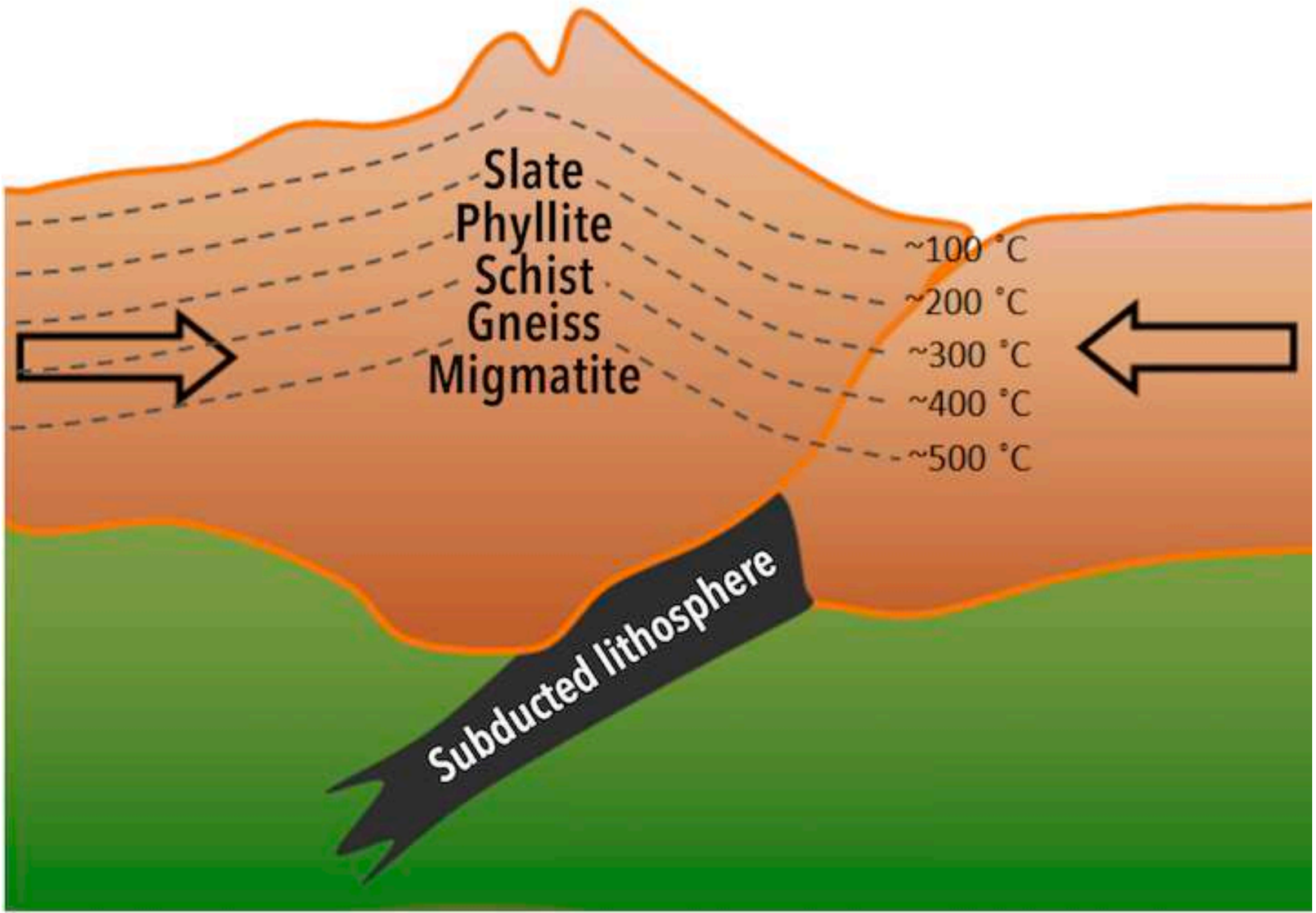
Metamorphic Environments

- **Subduction Zone Metamorphism**
  - Subducted slab is altered by low temperature and high pressure



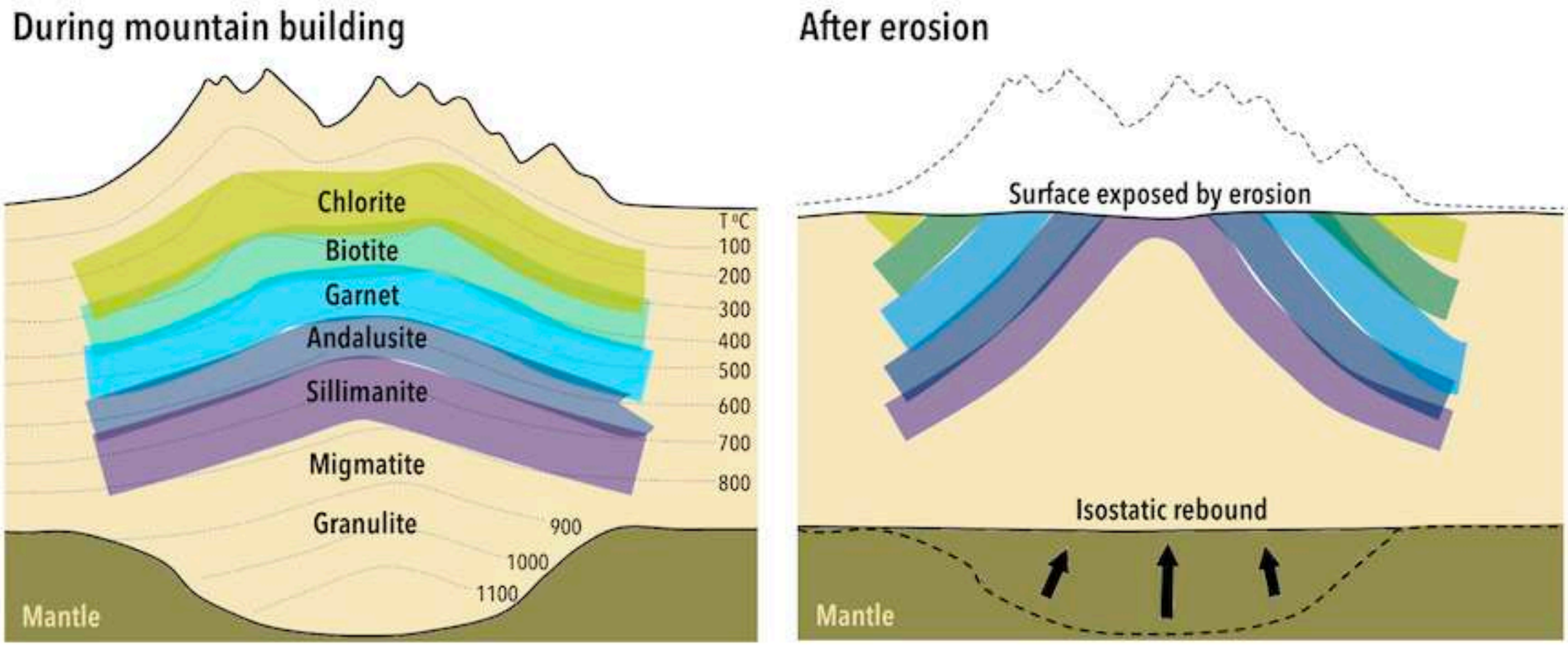
Metamorphic Environments

- **Regional Metamorphism**
  - Large-scale metamorphism, usually along convergent boundaries
  - High heat and high pressure

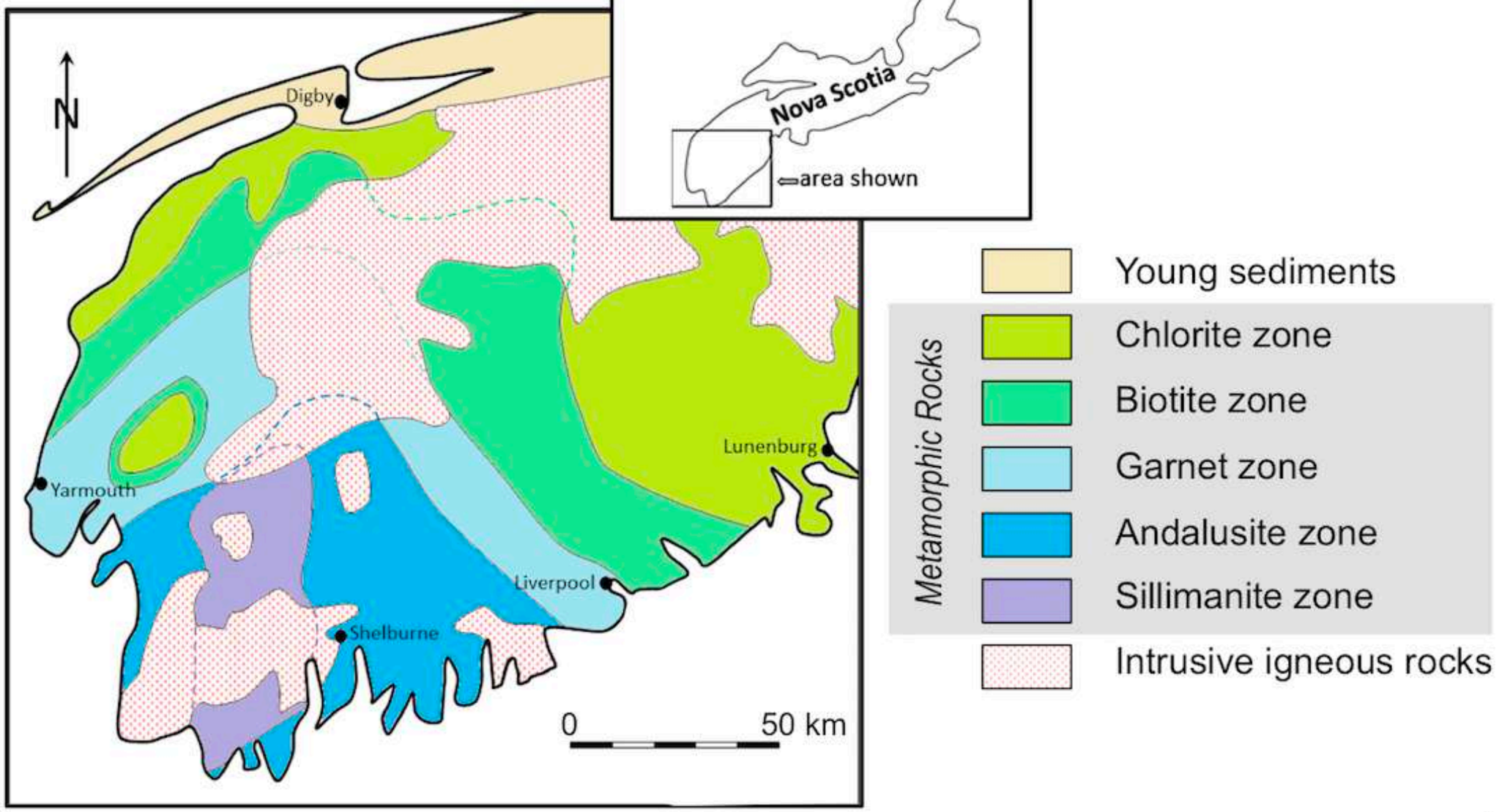


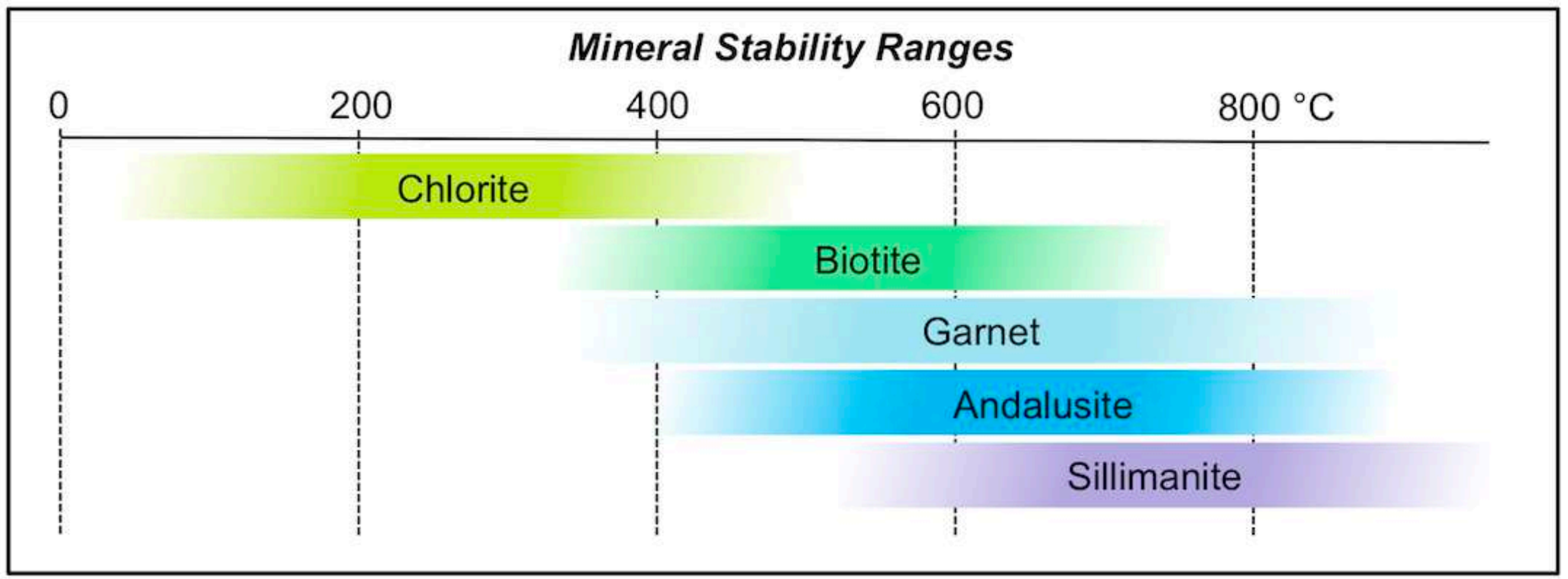
Metamorphic Environments

- Metamorphic rocks formed deep in the earth become exposed at the surface by weathering
  - As the surface erodes, the crust rebounds, helping to uplift deeper rocks



Meta


N
Digby
Yarmouth
Lunenburg
Liverpool
Shelburne
0
50 km
Nova Scotia
area shown
Metamorphic Rocks
Young sediments
Chlorite zone
Biotite zone
Garnet zone
Andalusite zone
Sillimanite zone
Intrusive igneous rocks


Mineral Stability Ranges
0
200
400
600
800 °C
Chlorite
Biotite
Garnet
Andalusite
Sillimanite