

# What is metamorphism?

- Metamorphism represents processes by which rocks undergo **solid-state changes** in mineralogy, texture, or both to reach equilibrium with its changing environment
- Changes in any/all of the following:
  - ~ Mineralogy
  - ~ Texture
  - ~ Chemical composition
- As a convention the domain of metamorphism is confined to the crust, but below the zone of diagenesis and up to the Moho

**Metamorphism in open system (change in chemical composition) is named**  
**Metasomatism**

# Agents of metamorphism?

-Three main agents are responsible for almost all of the metamorphic event.

1. Heat

2. Pressure

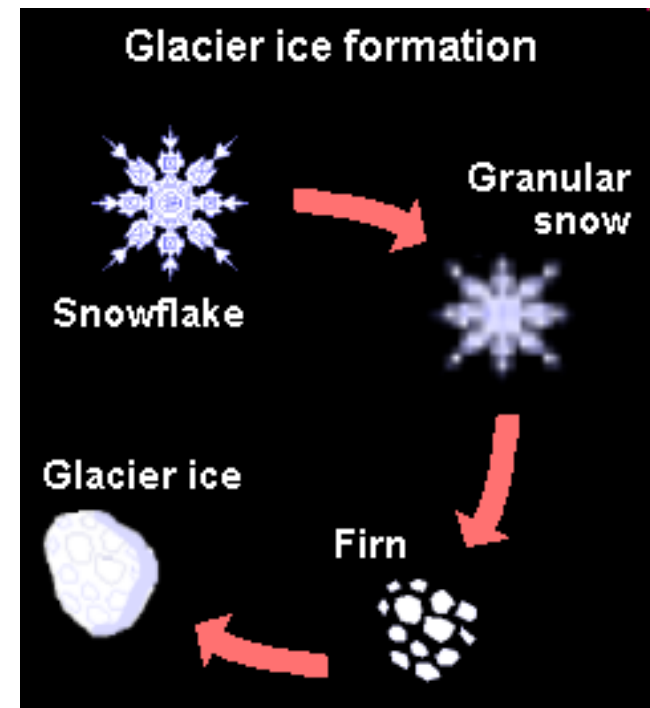
3. Chemically active fluids

-Most of the metamorphic changes involve all three agents.

-The proportion of influence of the agent varies between types of metamorphism.

## Some exceptional case:

- Glacial ice is a metamorphic rock
- The agents here are pressure and temperature
- The snowflakes recrystallize to form more dense ice crystals.



# Agents of metamorphism: Heat

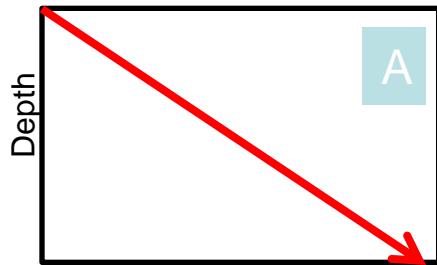
- Heat provides the energy to drive the re-crystallization process
- Two major change caused by heat
- Crystallization of new minerals & Re-crystallization of earlier minerals to larger size

# Source of heat

Earth's internal heat comes from

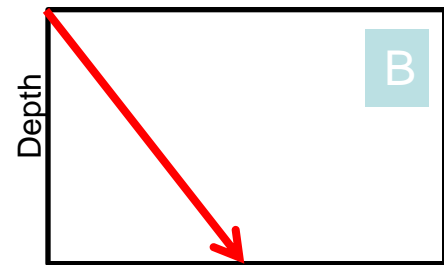
- Continuous radioactive decay
- Thermal energy generated during the formation

- Geothermal gradient varies in different parts of the world
- Tectonics plays an important role in determining the nature of the gradient.



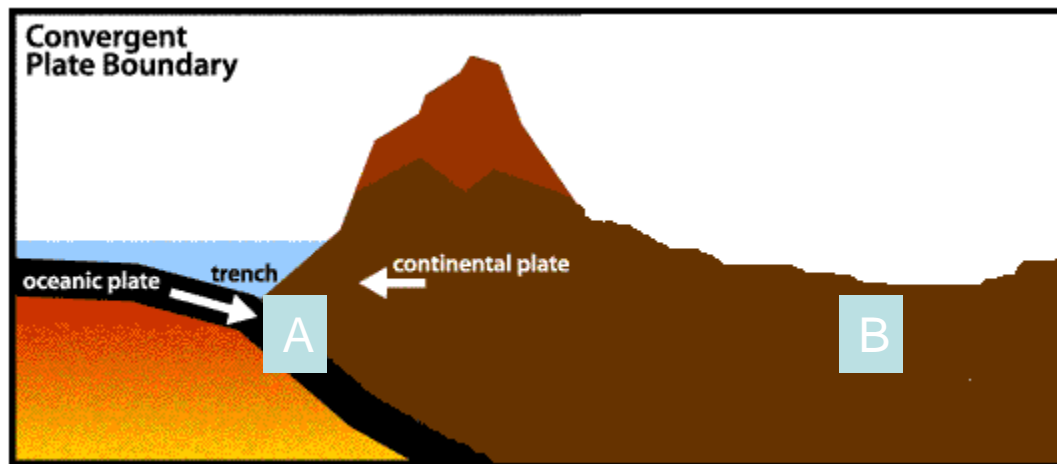
Temperature

Temperature changes at a much faster rate with depth.



Temperature

Temperature changes at a much slower rate with depth.

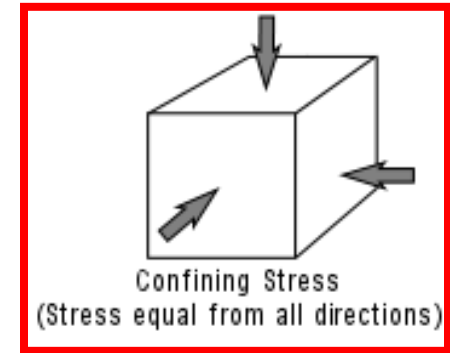
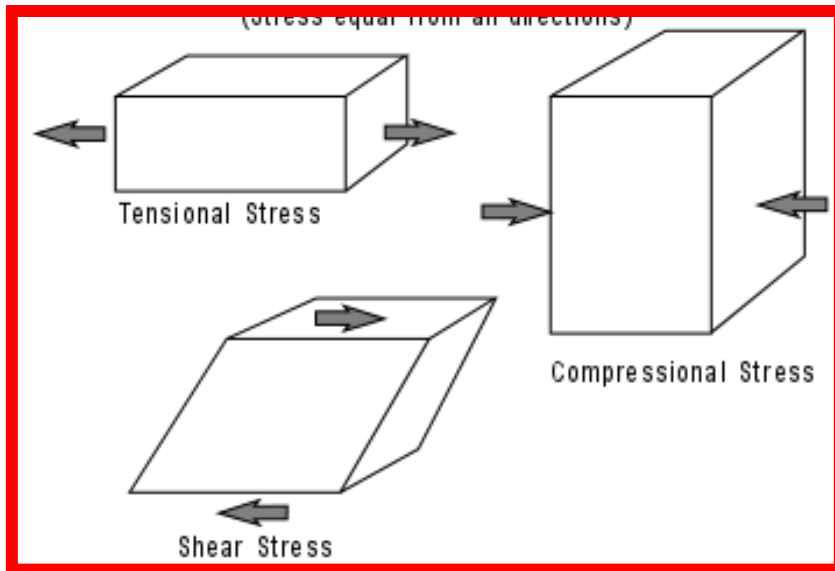


# Agents of metamorphism: Pressure

- Pressure increases with depth : Approx 1 kbar per 3 km depth
- There are two main types of pressure that operate on the rocks

1. Confining pressure: Non-directional

2. Differential stress: Directional



Near the surface at low temp. rocks are **brittle** – tend to fracture  
-- minerals tend to get crushed into smaller grain in differential stress

At depths at high temp. rocks are **ductile**  
-- tend to flow  
-- mineral grains tend to flatten in differential stress

# Agents of metamorphism: Fluids

**Fluids that play important role in metamorphism is mainly composed of**

- Water**
- CO<sub>2</sub>, SO<sub>2</sub>**
- These fluids help in recrystallizing minerals**

## **Where do we get the water from??**

- Minerals often carry water in their structure (mica, clay etc)**
- Temperature causes dehydration of the minerals**
  - Those expelled water molecules could play important role in ion transport.**
- The water could also come from rocks when subjected to extreme heat.**

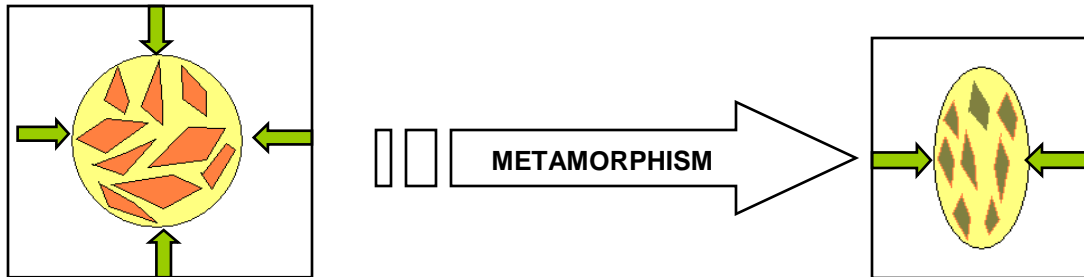
# Causes of metamorphic texture

- Two main types of texture: Foliated and non-foliated
- Mineral grains are often oriented in a preferred direction. This is called foliation (leaflike)
- Foliation could form in any of the following ways:

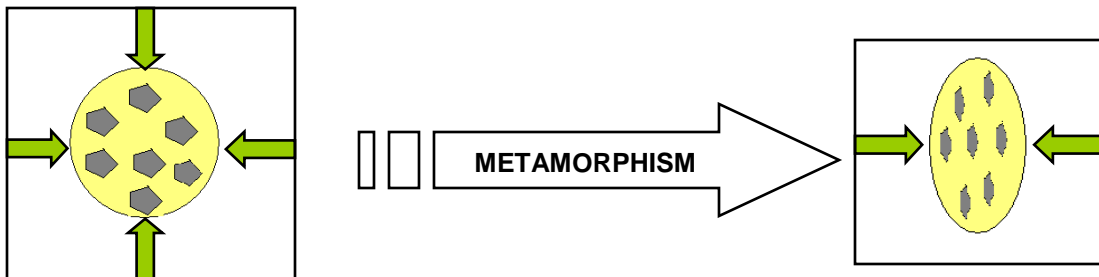
1. Rotation of platy and/or elongated minerals



2. Neocrystallization of minerals to form crystals in new preferred direction.



3. Changing the shape of existing mineral in a preferred manner.



# Metamorphic texture

1. Foliated: Shows preferred arrangement

a. **Rock / Slaty cleavage**: Closely spaced surfaces which split easily.

Product of low grade metamorphism. Example: Slate

b. **Schistosity**: Layered structure with high mica content with a sparkly appearance

Medium-high grade metamorphism. Example: Mica schist

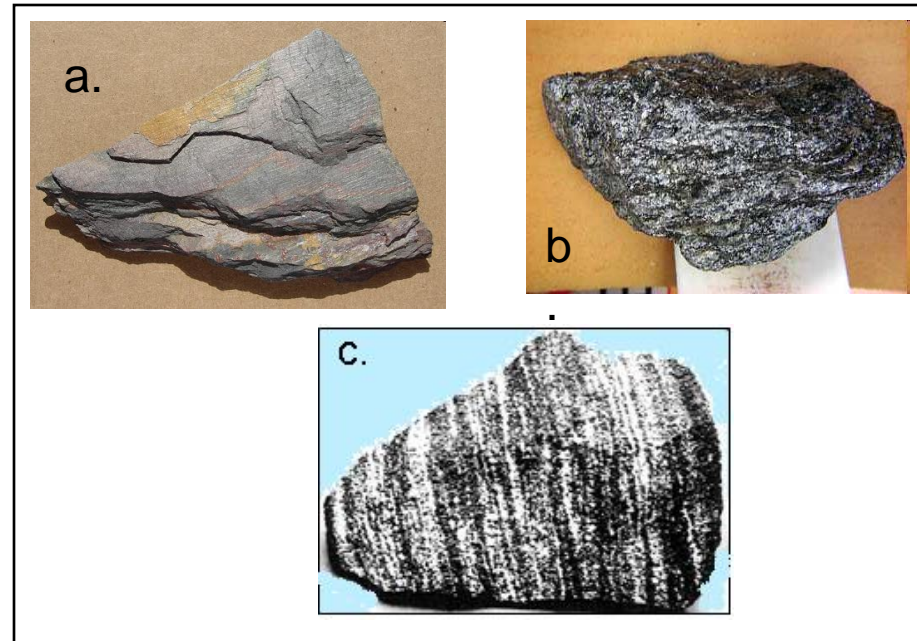
c. **Gneissic texture**: Layers of alternating dark and light bands.

High grade metamorphism. Example: Granite gneiss

2. Non-foliated texture

When there is no preferred orientation.

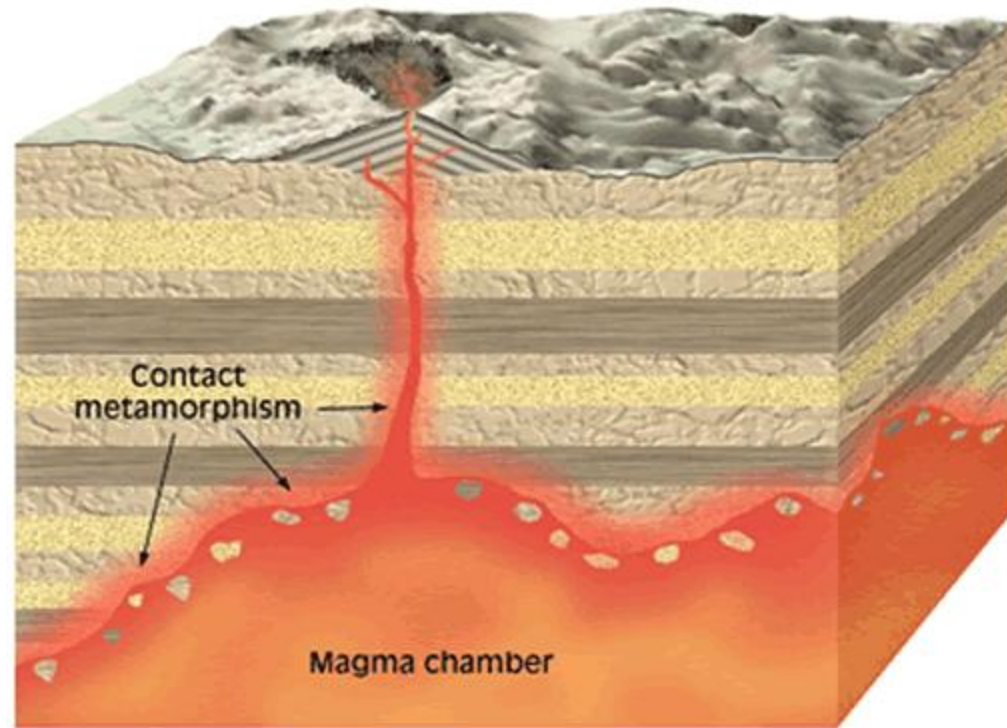
Example: Marble





# Contact / thermal metamorphism

- Rocks immediately surrounding a molten igneous body are “baked”.
- Main agent is heat.
- Generally no preferred orientation of mineral grains – non-foliated texture.



**The affected area of the rock is called Contact Aureole.**  
**Size of the aureole depends on**  
**Temperature of the intruding magma,**  
**Size of the intrusion, depth of**  
**intrusion and nature of the intruded rock**

Example:

Marble (from limestone)

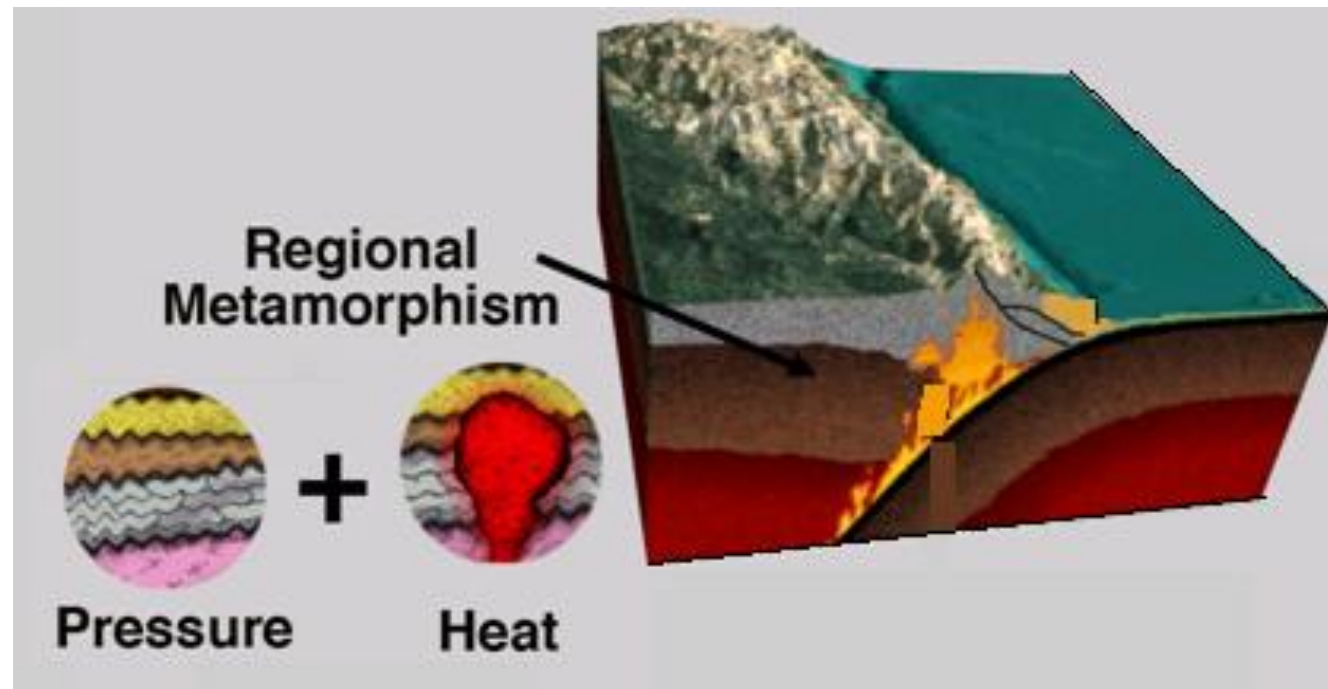
# Regional metamorphism

-Where metamorphism occurs over a very broad area of crust.

Example: subduction zones, volcanic arcs, and regions of continental crust collisions.

-Agents high temperature and confining pressure with directional pressure

- Destroys original textures of both igneous and sedimentary rocks through growth of new minerals.



# Shock / impact metamorphism

- It occurs when meteorites strike Earth's surface.
- Agent of metamorphism intense heat and pressure.
- Could cause pulverization and sometimes even melting of some mineral grains.



The products of these impacts are called **Impactites**.



Kara, Drillcore, 35g



## Some common foliated metamorphic rocks



Slate



Phyllite



Schist



Gneiss

# Non-foliated metamorphic rock

## Quartzite:

- Made up of mineral quartz ( $\text{SiO}_2$ )
- Very hard
- Scratches glass
- Parent rock: generally a sedimentary rock (sandstone)



## Marble:

- Made up of mineral calcite ( $\text{CaCO}_3$ )
- Soft
- Fizzes in reaction with acid
- Parent rock: generally a sedimentary rock (limestone)



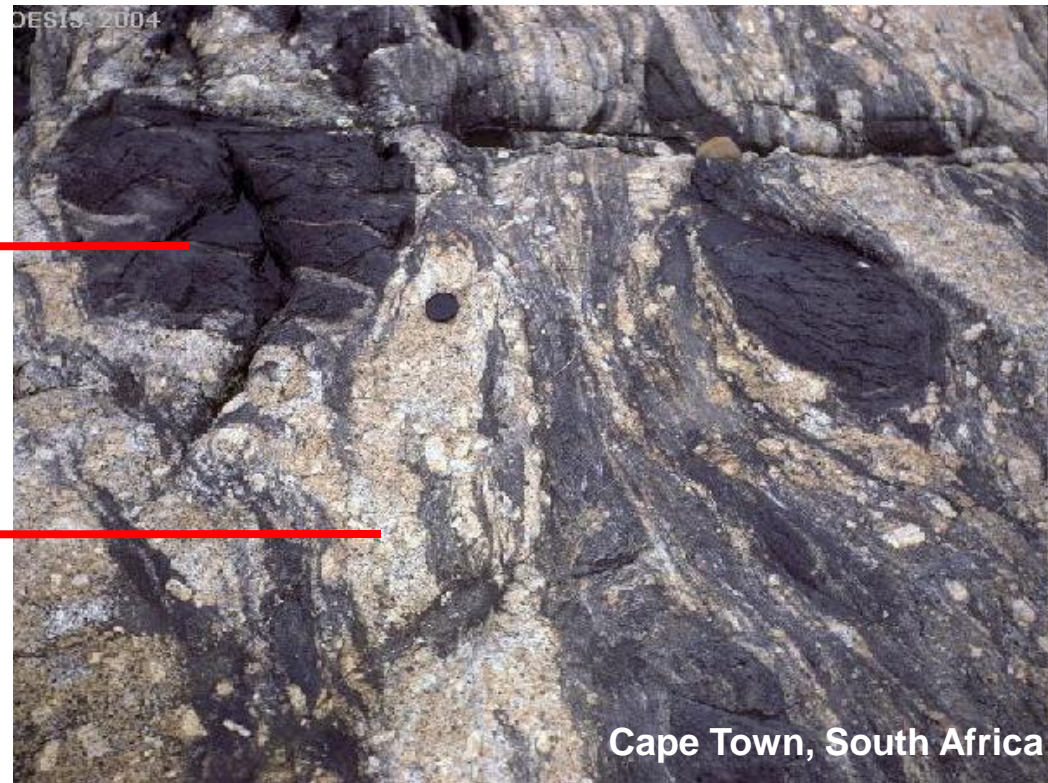


# Migmatites: most extreme environment

- Migmatites are mixed rocks -- part igneous, part metamorphic.
- They form when rocks are heated to the point where they begin to melt.
- The molten material partly separates out, but crystallises before it can move right away.
- Light silicates melt first, they will flow.
- Dark silicates remain solid.

Unaltered metamorphic rocks

Molten and recrystallized material



**Any mineral association in a metamorphic rocks is a function of**

- a. Pressure,**
- b. Temperature,**
- c. Composition of the original rock and**
- d. Nature of the chemically active fluids**

**The Pressure term refers to Confining Pressure**

**Directional Pressure influences the texture of the rock**  
**How to describe metamorphic P-T conditions?**

**Metamorphic Grade: Based on single minerals**

**Metamorphic facies: Based on association  
of minerals in rocks as function of composition**

