

Metamorphic Rocks:

A rock whose original mineralogy, texture and/or composition has changed due to pressure, temperature and/or fluids. It can be formed from igneous, sedimentary, or previously metamorphosed rocks by recrystallization in the solid state.

Metamorphism:

Is derived from the Greek for “change of form”. It is the change in form of rocks, under the influence of high pressure and temperature.

The original rock that has undergone metamorphism is called the **protolith**.

Protolith can be any type of rock changes in texture and mineralogy in the solid state and are caused by changes in physical or chemical conditions.

Metamorphism occurs at *temperatures* and *pressures* higher than **200 C°** and **300 MPa** (MPa stands for Mega Pascals).

Factors cause Metamorphism:**1. Temperature**

- Temperature increases with depth in the Earth. Thus higher temperature can occur by burial of rock.
- Temperature can also increase due to igneous intrusion.

2. Pressure

Pressure increases with depth of burial, thus, both pressure and temperature will vary with depth in the Earth.

3. Fluid Phase

Open space between mineral grains in a rock can contain a **fluid**. If chemical alteration of the rock takes place as a result of these fluids, the process is called **metasomatism**.

4. Time

Metamorphism is a slow process need a time for changing the rock.

The processes occur during metamorphism:

1. Recrystallization causes changes in minerals size and shape.

2. Chemical reactions occur between the minerals to form new sets of minerals that are more stable at the pressure and temperature.
3. New minerals form as a result of polymorphic phase transformations.

Polymorphs are compounds with the same chemical formula, but different crystal structures.

Grade of Metamorphism:

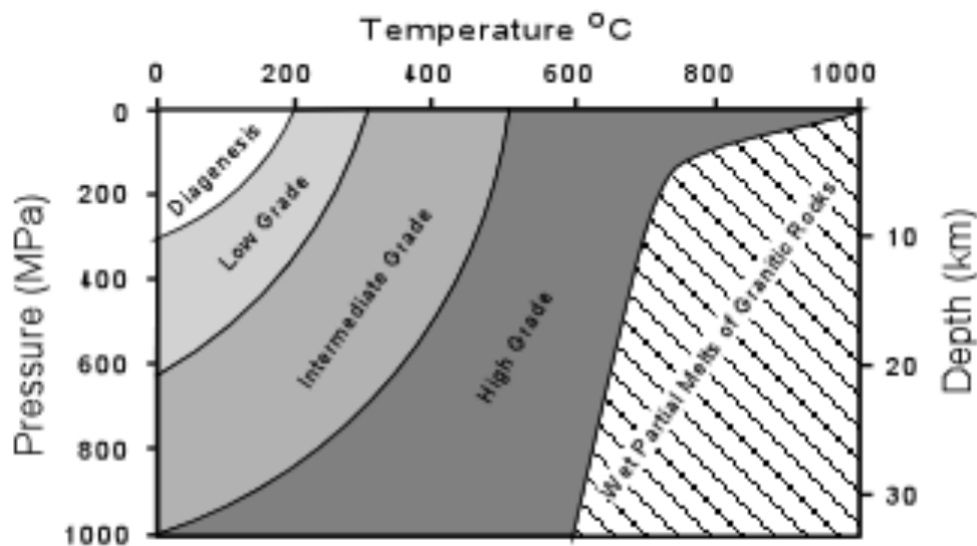
Metamorphic grade is a general term for describing the *relative temperature* and *pressure* conditions under which metamorphic rocks form.

1. **Low-grade metamorphism** takes place at temperatures between about 200 to 320°C, and relatively low pressure.

Examples of minerals: Clay Minerals , Serpentine , Chlorite

2. **High-grade metamorphism** takes place at temperatures greater than 320°C and relatively high pressure.

Examples of minerals: Muscovite , Pyroxene , Garnet



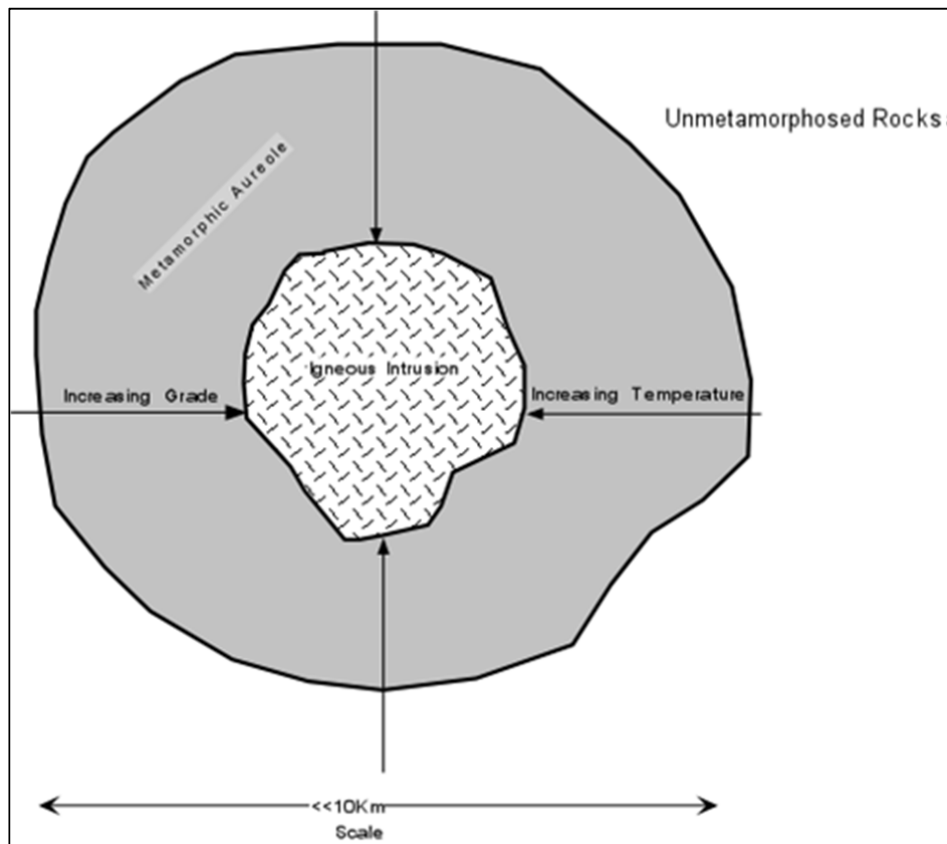
Types of Metamorphism:

There are three major type and two minor types of metamorphism:

1. Contact Metamorphism (thermal metamorphism)

- a) Occurs where hot magma intrudes cooler country rock.
- b) Metamorphism is restricted to a zone surrounding the intrusion, called a **metamorphic aureole**.

- c) The grade of metamorphism increases in all directions toward the magma intrusion.
- d) Contact metamorphism commonly occurs without deformation. Example rock is **Hornfels**



2. Dynamic Metamorphism

- a) It is due to mechanical deformation by sliding along a fault zone.
- b) Heat is generated by the friction of sliding along the zone.
- c) The rocks tend to be crushed and pulverized due to the sliding.
- d) The rock that is produced is called a **mylonite**.

3. Regional Metamorphism

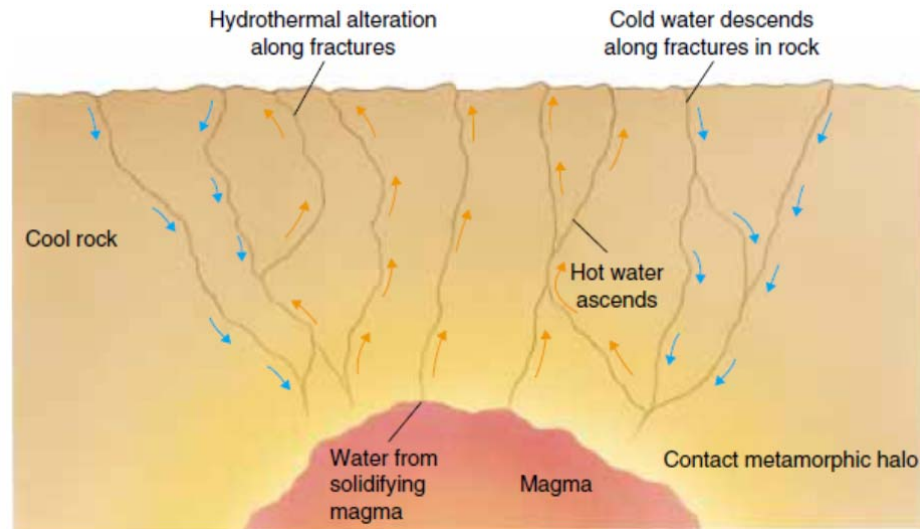
- a) This type of metamorphism occurs over large areas in high degrees of deformation under differential stress.
- b) Occur in higher temperatures and pressures
- c) Occur in the cores of mountain ranges or in eroded mountain ranges. Example rock is *Gneiss*

4. Burial Metamorphism

- When sedimentary rocks are buried to depths of several hundred meters.
- Temperatures greater than 300°C may develop in the absence of differential stress.
- New minerals grow, but the rock does not appear to be metamorphosed.
- The main minerals produced are the **Zeolites** and **argillite**.

5. Hydrothermal metamorphism

- Also called **hydrothermal alteration** and **metasomatism**.
- Occurs when hot water and ions dissolved react with a rock to change its chemical composition and minerals.



Metamorphic environment	Below 50°C	$50\text{--}300^{\circ}\text{C}$	$300\text{--}450^{\circ}\text{C}$	Above 450°C
	Increasing temperature and pressure			
Rock type	No change	Metamorphic rock		
	Sedimentary rock	Low grade	Intermediate grade	High grade
	Shale	Slate	Schist	Gneiss
		Ptylito	Migmatite	

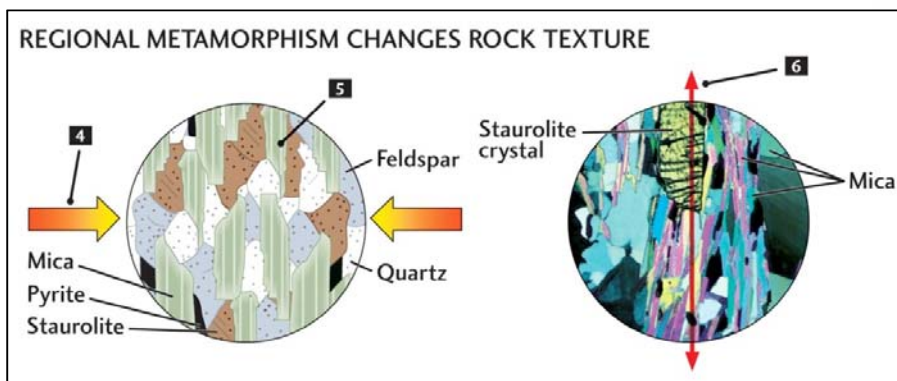
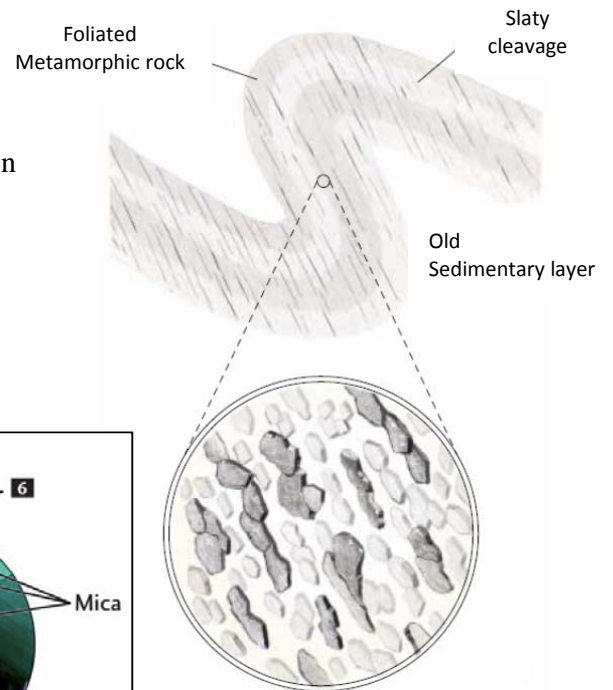
Metamorphic Rock Types:

There are two major subdivisions of metamorphic rocks:

1. Foliated Rocks

- Have a planar foliation caused by the preferred orientation (alignment) of minerals.
- Formed under differential stress.
- Comprised mainly of flaky minerals.

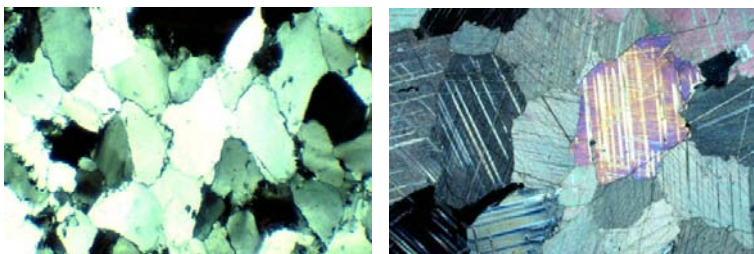
Example: Slate, Mica Phyllite, Gneiss ...



2. Non-foliated

- Have no evident planar fabric or foliation.
- Crystallized under conditions where there was no differential stress.
- Comprised of equant minerals only.

Example: Hornfels, Quartzite, Marble



Quartzite



Marble