Laarbi Ben M'hidi University Oum El Bouaghi

Faculty of Earth Sciences and Architecture

Geology Department

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Dr. Y- BOUROUBI

Metamorphic rocks

Metamorphic rocks

What is metamorphism?

It's the transformation of a rock into a solid state.

What causes this transformation?

A rock is characterized by a mineralogical assemblage. This assemblage is stable only under given pressure and temperature conditions.

If P and T vary, then the minerals transform into new, stable minerals under the new P-T conditions.

Consequences of changing pressure-temperature conditions

Recrystallization of the rock:

-acquisition of a new paragenesis

- recrystallized inherited minerals:

-remain stable under new T and P conditions.

- -Neoformed minerals:

-formed from the chemical constituents of minerals that have not withstood the increase in P and T.

Metamorphism can affect :

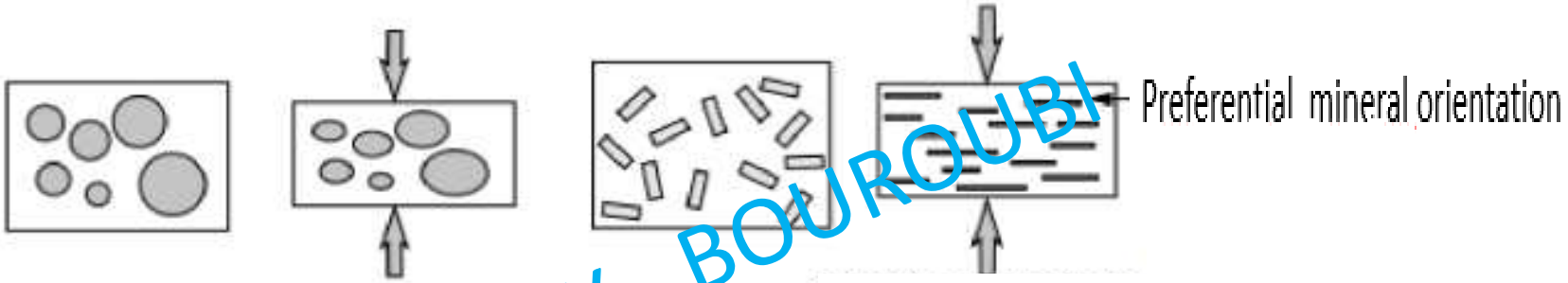
- sedimentary rocks, in which case they are referred to as parametamorphic rocks;
- magmatic rocks, which are referred to as orthometamorphic rocks;
- metamorphic rocks, we refer to them as polymetamorphic rocks.

The lower limit of metamorphism corresponds to a temperature of **200°C** and a pressure of 3000 atmospheres. The upper limit of metamorphism corresponds to partial melting of the rock. When the rock begins to melt, we enter the realm of magmatism.

Factors in metamorphism

The main factors in metamorphism are :

- **Temperature**: increases with depth (the geothermal gradient is 3°C/100m) and/or with the emplacement of plutonic or volcanic rocks.
- **Pressure**: also increases with depth. It is due to the weight of layers, and rocks subjected to this pressure show no preferential orientation: this is lithostatic pressure (1 kbar at a depth of 4km, 5 kb at 15 km and 10 kb at 30 km for an average crustal density of 2.5). Pressure can also increase as a result of stress (in regions of high tectonic activity, such as mountain ranges). These are referred to as oriented pressures or stresses. When a rock is subjected to oriented pressures, the minerals orient themselves along defined planes (figure), and the rock takes on a layered appearance: **schistosity or foliation**.



rocks subjected to oriented stress

Metamorphism types

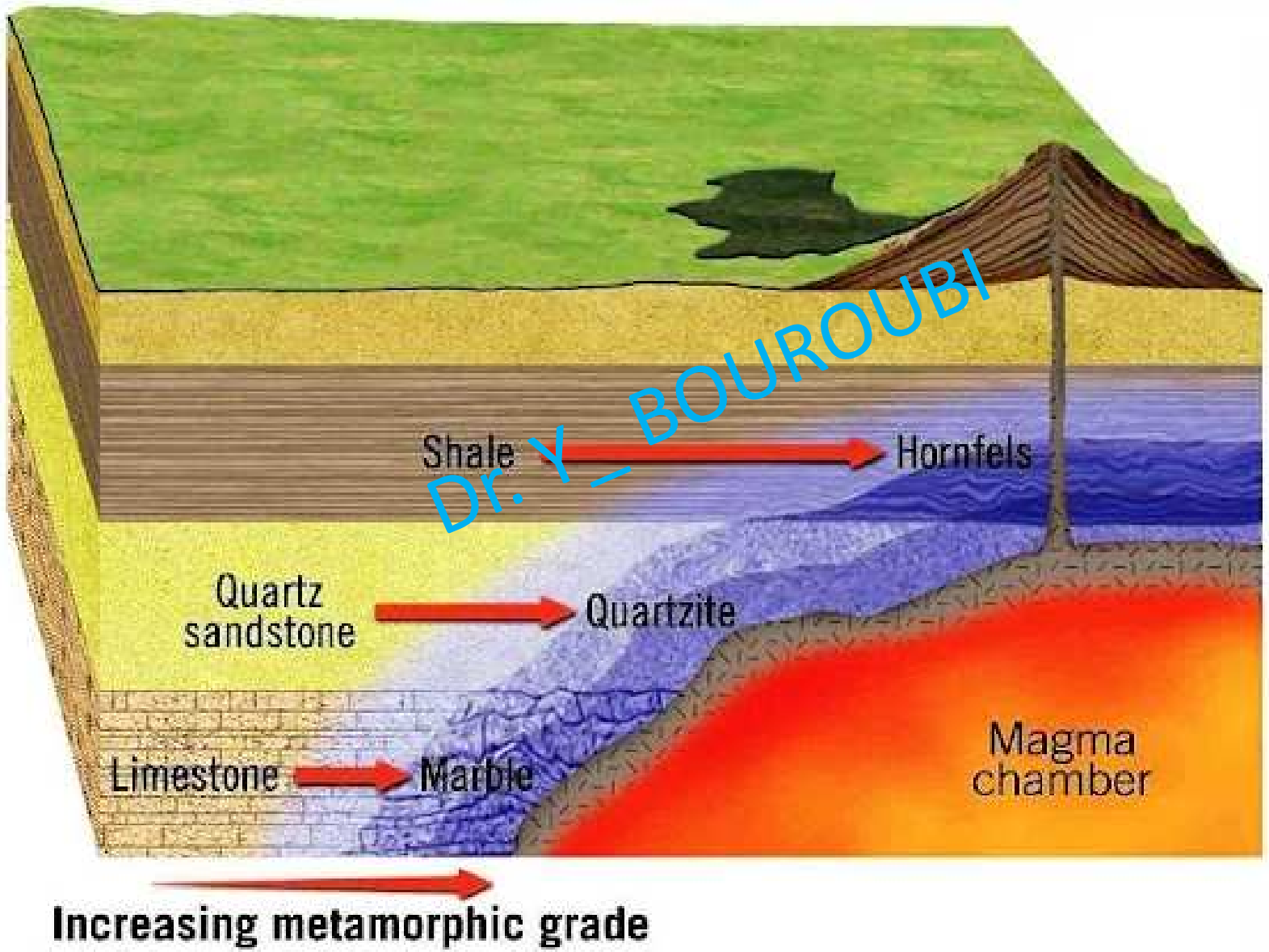
1. **Contact metamorphism** takes place around magmatic intrusions and results from the increase in temperature at magma contact. This type of metamorphism leads to the chemical recrystallization of surrounding rocks (many reactions between minerals) with very little deformation. A metamorphic halo is the envelope of metamorphosed rock surrounding an intrusion. It can range in thickness from a few meters to several hundred meters (the width of the halo depends on the size of the intrusive mass). The degree of metamorphism increases in all directions as you approach the intrusion.

Contact Metamorphism Causes:

Contact metamorphism is caused by the heat and fluids released by a magma intrusion into surrounding rocks. The intensity of the metamorphism depends on the temperature of the magma, the size of the intrusion, and the type of country rock being intruded. The heat from the magma causes the surrounding rocks to heat up and recrystallize. This process can change the minerals in the rocks, create new minerals, and change the texture of the rocks.

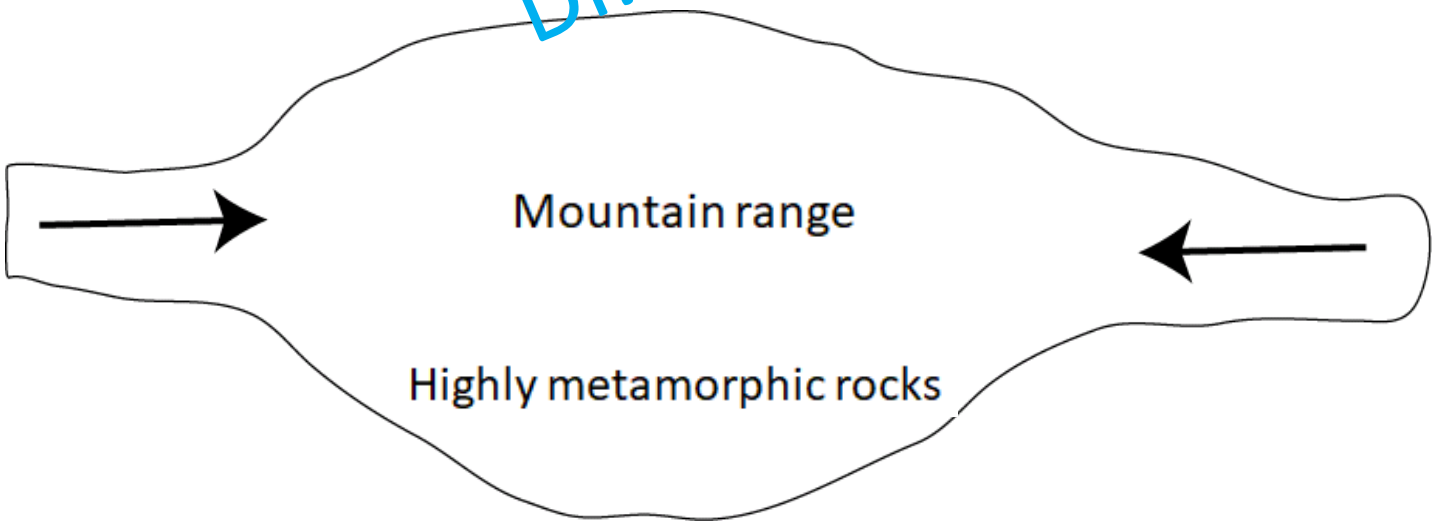
For example, limestone can be metamorphosed into marble, and sandstone can be metamorphosed into quartzite.

Contact metamorphism



2. Regional metamorphism

Regional metamorphism affects large areas (tens of thousands of square kilometers) that are the site of oriented tectonic deformation and stress. It occurs at the heart of major mountain ranges under conditions of high temperature-high pressure. The metamorphic rocks formed are always oriented and highly deformed (schists, micaschists, gneisses).



Regional metamorphism occurs in the core of mountain chains

3. Cataclastic (or dynamic) metamorphism

This type of metamorphism occurs in fault zones or major brittle faults. It is linked to the stresses and strains that develop in these fault zones, and to the rise in temperature due to friction. Rocks in these zones are crushed and pulverized, leading to the formation of rocks known as tectonic breccias and mylonites. This type of metamorphism is highly localized and limited in space.

4. Hydrothermal metamorphism

is linked to the circulation of fluids (water) at high temperatures. These fluids heat the rocks they pass through, adding chemical elements (a phenomenon known as metasomatosis). This type of metamorphism is found in volcanic regions.

5. Burial metamorphism

This type of metamorphism occurs in deep sedimentary basins at the base of sedimentary series several kilometers thick, when temperatures exceed 300°C and in the absence of oriented stresses. This metamorphism is not very pronounced and is manifested by the formation of new minerals (mainly zeolites).

6. Impact (or shock) metamorphism

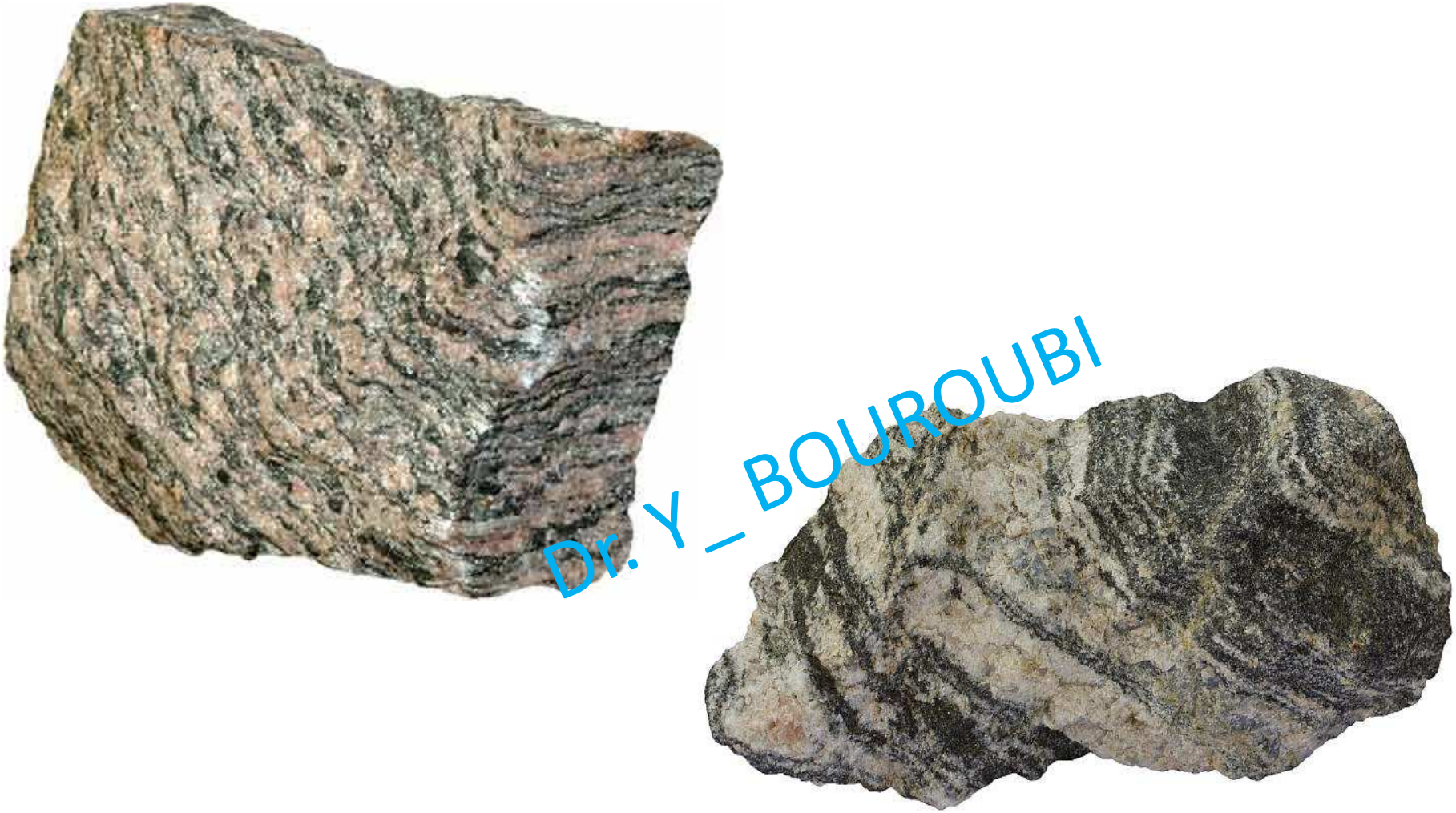
Impact metamorphism is caused by the fall of large meteorites under conditions of very high pressure. The rocks formed at the point of impact are impactites and contain minerals characteristic of very high pressures, such as coesite, stishovite and diamond. Impact also causes deformation planes to appear in minerals such as quartz (shocked quartz). Rocks can acquire particular structures called shatter-cones. This type of metamorphism is very rare.

Metamorphic rock classification

Metamorphic rocks are subjected to temperatures and/or pressures different from those at which they were formed. Rocks undergo transformations in their solid state. These transformations are : mineralogical, with the appearance of new minerals that are more stable under the new temperature and/or pressure conditions. structural, with recrystallization of minerals and/or alignment of minerals along well-defined planes due to the application of oriented stresses.

A simplified classification of metamorphic rocks is based on rock structure: oriented (or foliated) or non-oriented. Oriented rocks are classified according to the grade (degree) of metamorphism (tableThe following oriented structures are distinguished:

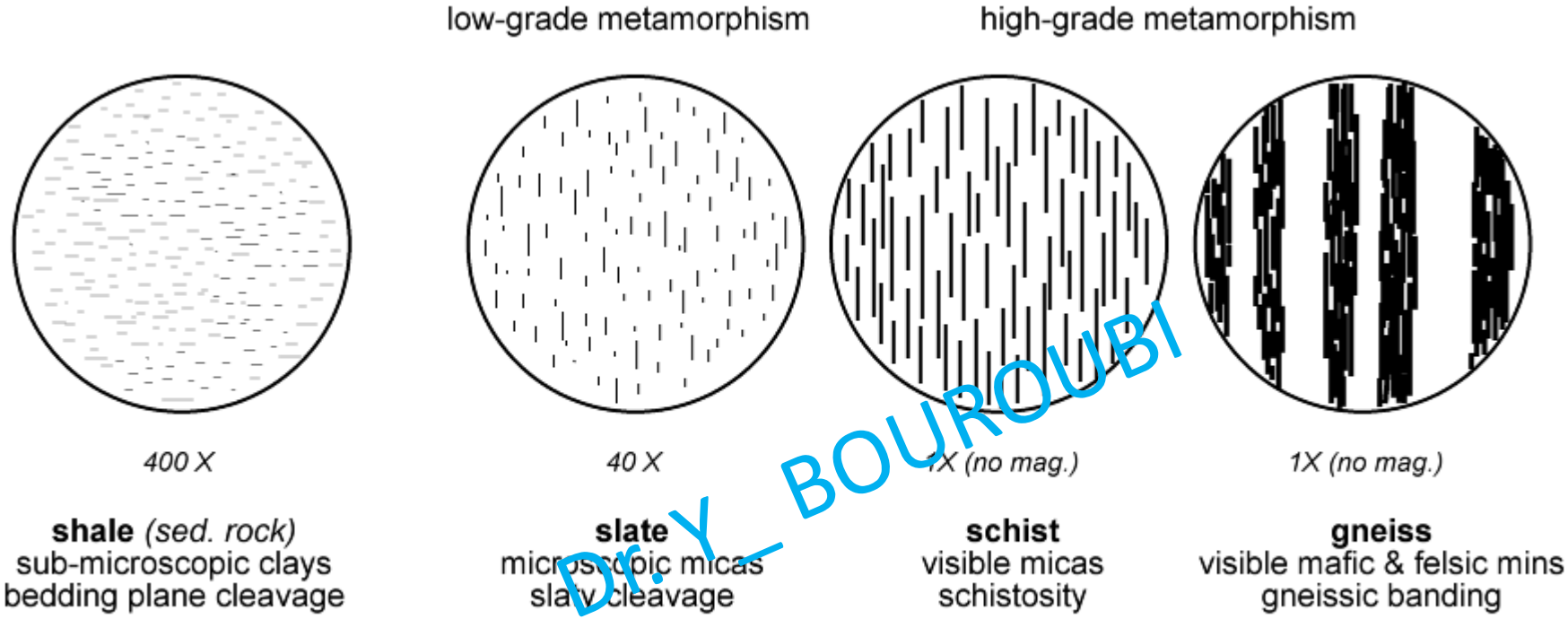
- **Schistosity**: more or less tightly laminated rock formed under the influence of oriented tectonic stresses,
- **Foliation:** metamorphic rock structures, where schistosity is combined with petrographic differentiation between the layers. The result is alternating light and dark bands, each characterized by specific minerals (e.g. gneiss with alternating quartzo-feldspathic and micaceous bands).



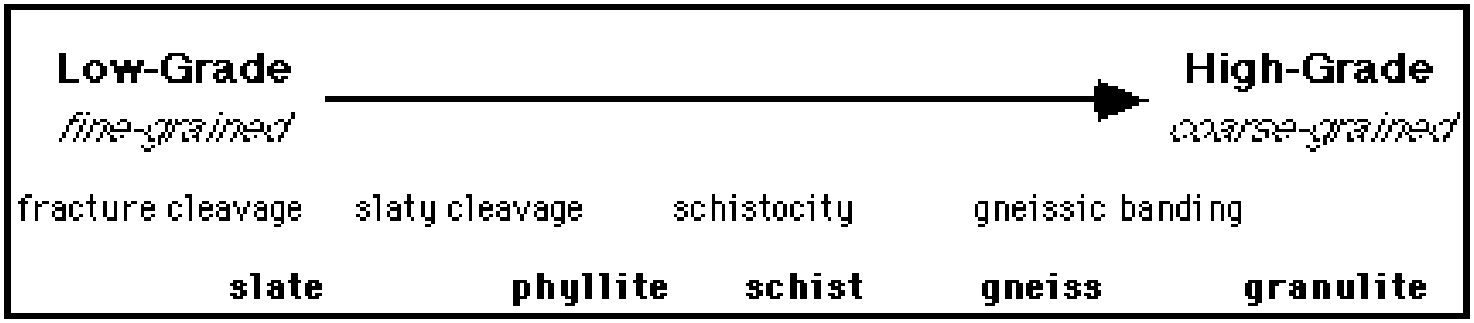
Gneiss

Micaschists

Slates



Slate is a product of ***low grade metamorphism*** (not terribly great burial temperatures and pressures are required). Schist and gneiss are produced by medium to ***high grade metamorphism***. In some cases gneisses are produced by higher grade metamorphism than schists. Low-grade metamorphic rocks tend to be fine-grained (the newly formed metamorphic mineral grains that is). High-grade metamorphic rocks tend to be coarse-grained.



Classification of Metamorphic Rocks

There are two main types of metamorphic rocks:

- those that are **foliated** because they have formed in an environment with either directed pressure or shear stress, and
- those that are **not foliated** because they have formed in an environment without directed pressure or relatively near the surface with very little pressure at all. Some types of metamorphic rocks, such as quartzite and marble, which also form in directed-pressure situations, do not necessarily exhibit foliation because their minerals (quartz and calcite respectively) do not tend to show alignment.

A rough guide to the types of metamorphic rocks that form from different parent rocks at different grades of regional metamorphism

	Very Low Grade	Low Grade	Medium Grade	High Grade
Approximate Temperature Ranges				
Parent Rock	150-300°C	300-450°C	450-550°C	Above 550°C
Mudrock	slate	phyllite	schist	gneiss
Granite	no change	no change	no change	granite gneiss
Basalt	chlorite schist	chlorite schist	amphibolite	amphibolite
Sandstone	no change	little change	quartzite	quartzite
Limestone	little change	marble	marble	marble

Metamorphic rocks that form under either low-pressure conditions or just confining pressure do not become foliated. In most cases, this is because they are not buried deeply, and the heat for the metamorphism comes from a body of magma that has moved into the upper part of the crust. This is **contact metamorphism**. Some examples of non-foliated metamorphic rocks are **marble**, **quartzite**, and **hornfels**.

The rock cycle

The rock cycle describes the processes through which the three main rock types (igneous, metamorphic, and sedimentary) transform from one type into another