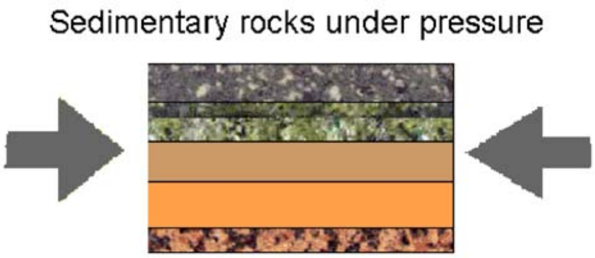
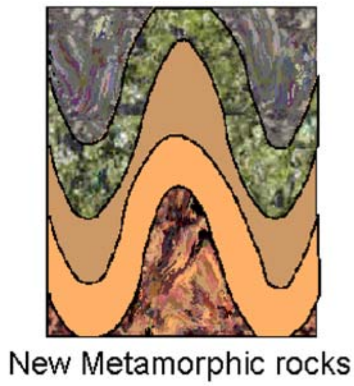

Metamorphic rocks in nature

Metamorphic rocks record how **temperature** and **pressure** affected an area when it was forming. The rocks provide clues to their transformation into a metamorphic rocks. Metamorphic rocks are best identified when looking at the rock as you see them in nature. You can clearly see the **deformation** and features that are characteristic of an entire area.

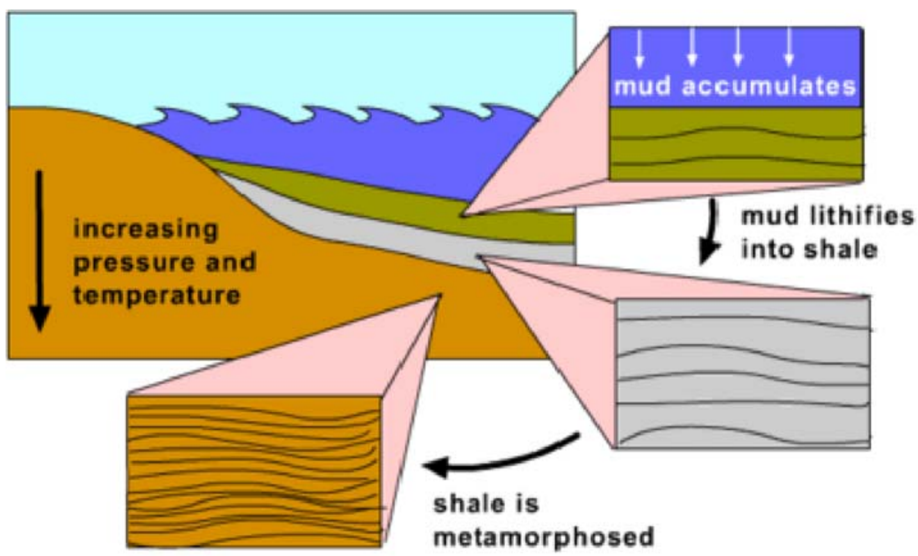
Metamorphic rocks were once sedimentary, igneous, or another metamorphic rock. These rocks are physically deformed and chemically changed due to different temperatures and pressures. The elements in the minerals can actually "move" to form new minerals. The rock does not melt, or else it would be considered an igneous rock. A rock looks different after it has been **metamorphosed**. The rocks texture and overall appearance changes also. It now has a squished look!



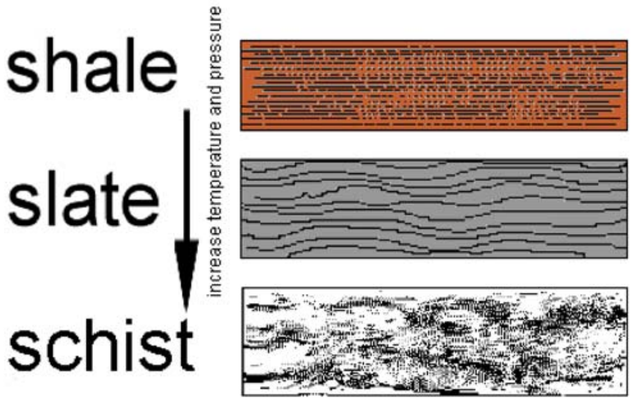


Deformation of sedimentary rocks

Metamorphism is difficult to understand because there are many combinations of temperature and pressure that can create rocks. For example, mud and clay quietly settle on the ocean floor. As more mud and clay settle on top of it, the weight of the sediments "squeezes" the water from the mud and clay on the bottom. It becomes cemented together by chemical interactions and it becomes a sedimentary rock called **shale**. The shale is put under moderate pressure and low temperature due to burial or plate movements. The new pressure and temperatures changed the chemical make up of the shale into the metamorphic rock called **slate**.



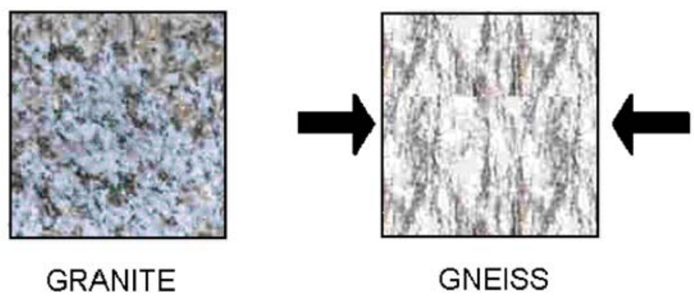
Shale to slate metamorphism

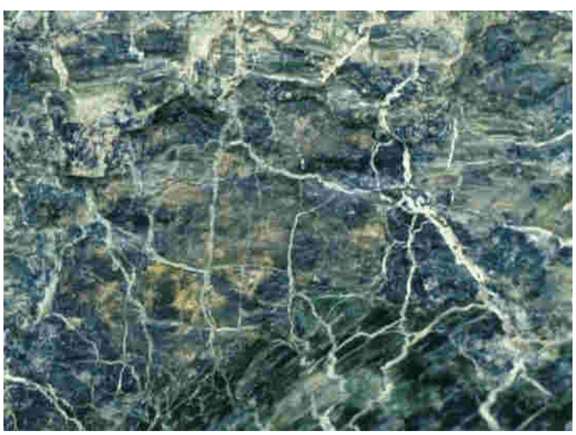


If not enough heat and temperature were applied another metamorphic rock could have been formed called **phyllite,** which is not as hard as slate.

However, if the shale was in an area that was exposed to higher pressures and moderate temperatures, it might have been transformed into **schist**. The clay in the shale could have been converted to **mica**, which gives schist its shiny look.

Granite is a light-colored rock made of quartz, feldspars, mica, and small amounts of hornblende. The crystals of all these minerals are randomly arranged. Granite can be metamorphosed into a rock called **gneiss** (pronounced like "nice"). Gneiss has about the same mineral composition as granite, but the pressure of metamorphism causes the minerals to line up, giving gneiss a distinct **banded** appearance. Schist may also be converted into gneiss, if increased pressure and temperature is added. Metamorphic rocks are a mixed up group that have been under a lot of **stress**!

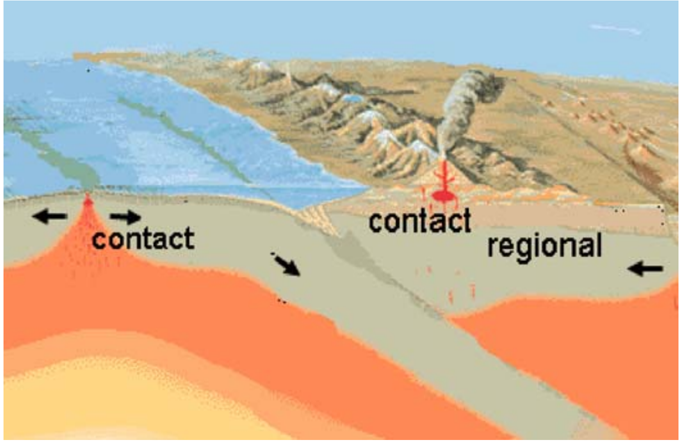



Serpentinite with quartz veins

The metamorphic system can also react differently if fluids are part of the system. Serpentinite, a mottled green rock, is usually formed with high pressure and low temperature. The original rock could contain a large amount of olivine (i.e., basalt). The **olivine** (Mg_2SiO_4) reacts with water (H_2O) to form the mineral serpentine ($Mg_3Si_2O_5(OH)_4$)plus magnesium oxide (MgO).

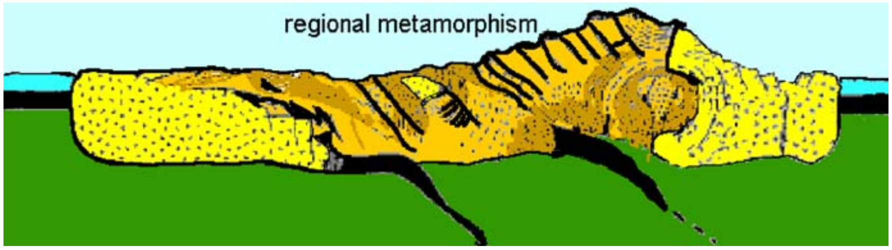
Serpentinite is found in areas where faulting occurs. Along the San Andreas fault zone in California, serpentinite is so abundant it is recognized as the California state rock. The pressure of **shearing** seems to be ideal for the serpentinite to form a fibrous pattern. This form of serpentinite is a variety of asbestos, which is used as a fire retardant.

There are several ways that metamorphic rocks form at or near plate boundaries. There is localized metamorphism called **contact metamorphism**. Usually this occurs near molten magma or lava, under high temperature and low pressure. Metamorphism affecting a large area or **regional metamorphism** involves large increases of temperature and pressure. Contact metamorphism is common at both **convergent** and **divergent** plate boundaries, in areas where molten rock is produced. Regional metamorphism largely occurs at convergent plate boundaries.

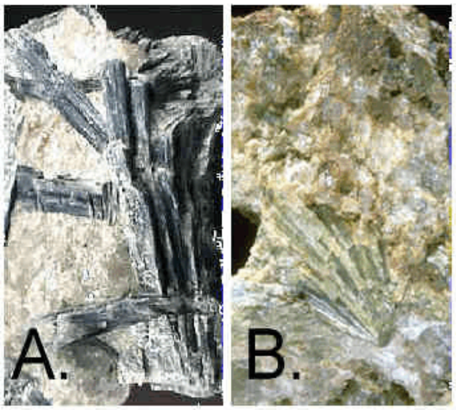


Each of these types of metamorphism produces typical metamorphic rocks, but they may occur in different sequences. For example, both regional and contact metamorphism produce schists and shales. However, gneiss would be common in regional metamorphism.

In regional metamorphism conditions can range from low to high pressures and temperatures that occur over a large area. This will produce different zones or rocks that have characteristic minerals. The minerals are like a pressure gauge and thermometer and record the history of the conditions under which the rocks formed.



Finding these minerals in metamorphic rocks are clues to the temperature and pressure. For example, **chlorite**, **muscovite**, and **biotite** (all micas) are common in low grade metamorphism which is low temperatures (200°C) and pressure. (Remember water boils at 100°C). Intermediate grade metamorphisms usually contains the minerals **garnet** and **staurolite**. High grade metamorphism (800°C) usually produces **kyanite** and **sillimanite**.



A. Kyanite, B. Sillimanite

Contact metamorphism does not affect as large an area as regional metamorphism. It is associated with areas around a magma chamber as well as other smaller igneous structures like dikes or sills. Contact metamorphism zones can be a few centimeters to several kilometers, especially around large plutons. The rocks that are formed will depend on the country rock that the intrusion invades.

There are other conditions that form metamorphic rocks. **Burial metamorphism** is a special type of low grade metamorphism with low temperatures and pressures. **Cataclastic** metamorphism only occurs along fault zones, usually associated with subduction or transform zones. Conditions include high pressures under lower temperatures.

The formation of many metamorphic rocks is still debated. Observation of extreme pressure and temperature inside the crust and upper mantle and how they affect rocks is difficult. Some rocks are only slightly metamorphosed and given the term meta-igneous or meta-sedimentary.