Lab 5 - Identification of Metamorphic Rocks

Introduction

Metamorphic rocks are the third great rock group. The term “meta” means “to change” and “morph” means “form”. Metamorphic rocks are rocks who have had their original form (meaning mineralogy and/or texture) changed in some fashion.

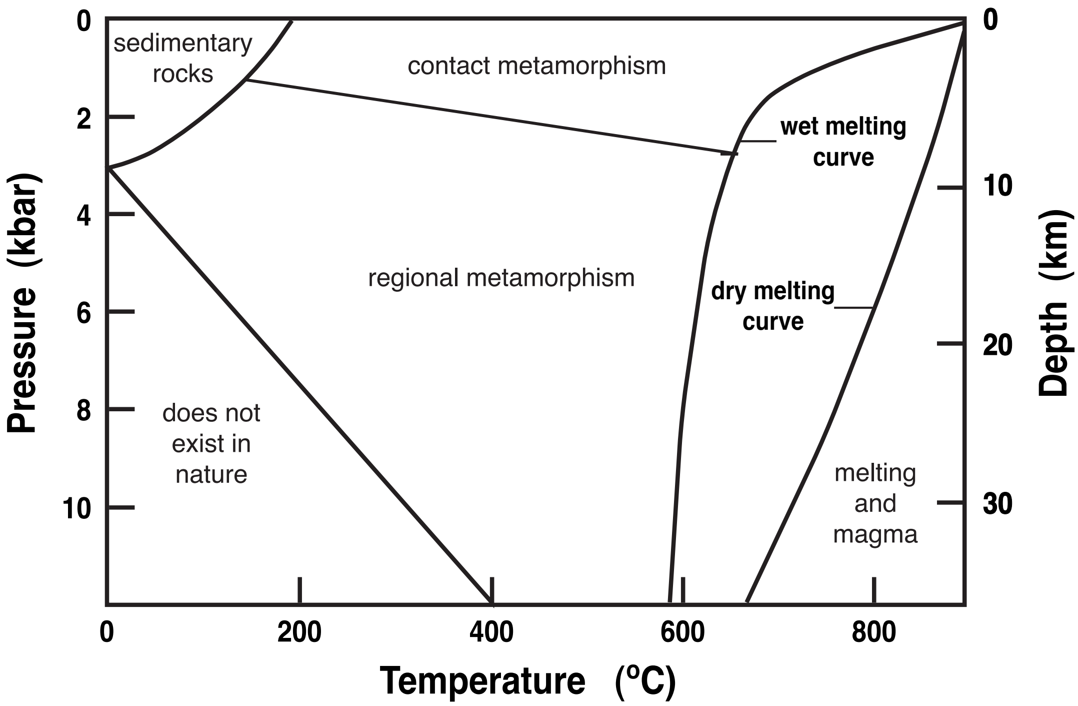
Metamorphic rocks form from preexisting rocks (called the **protoliths**) that have been subjected to intense heat, pressure, or chemically active fluids and gases (such as volatiles from a magma body). These three forces are said to metamorphose the protolith; or to change the protolith’s original texture and mineralogy. All rocks (igneous, sedimentary and, even other metamorphic rocks) may serve as the protolith for metamorphism. Metamorphic processes take place in the solid state, that is, no melting may occur. If the pressures and temperatures become high enough to partially or completely melt the rock, then magma and igneous rock are formed.

Types of Metamorphism

All rocks can be placed on a diagram that shows increasing temperature and pressure, called a **PT diagram** (see the illustration at the top of the next page). It is well-known that the deeper you descend into the earth the hotter it becomes. This is often referred to as the **average geothermal gradient** and is approximately 30^{o} C increase in temperature per every kilometer in depth. The pressure of the weight of overlying rock also increases rapidly with depth in the earth. Geologists use the kilobar (abbreviated kbar) as the unit for this pressure. One kilobar is approximately 14,700 pounds per square inch (or roughly the equivalent of balancing a 7 ton object within a square inch area).

Since sedimentary rocks form at or near the earth’s surface they occupy a very small region on the PT diagram. At very high temperatures rocks begin to melt and magma is formed. Rocks that have water in them tend to melt at lower temperatures then “dry” rocks. So there are 2 separate melting curves; one at low temperatures for wet rocks and one at higher temperatures for dry rocks. Most of the PT diagram and, in fact, most of the volume of the earth’s crust falls in between the sedimentary curve and the melting curves. This is the region where metamorphic rocks are formed.

Metamorphism that is driven by increasing heat and pressure is called **regional metamorphism**. Regional metamorphism occurs at a depth of a few miles or greater anywhere within the earth’s crust and is a consequence of the fact that the deeper you descend into the earth’s crust the higher the temperatures are and the greater the pressure created by the weight of the overlying rock. Regional metamorphism also occurs during mountain building, where tremendous heat and pressure is generated during collisions between continents and ocean basins (a topic which will be explored in the Plate Tectonic Lab). Because metamorphism at depth in the earth and at mountain building events literally takes place over a huge “region” the term regional metamorphism literally means metamorphism involving a large area.



PT diagram showing the fields for the 3 major rock groups.

Contact metamorphism occurs when a hot, volatile-rich magma body comes in contact with colder surrounding crust. This normally takes place close to the earth's surface where pressure is not an important process. Contact metamorphism is driven by the high temperatures of a magma body and by the volatiles or very chemically-active fluids and gases that escape the magma body as it ascends toward the surface.

Classification of Regional Metamorphic Rocks

How rocks react to the increase in temperature and pressure of regional metamorphism depends on the amount of heat or pressure applied (called the **metamorphic grade**) and the composition of the protolith; the original rock before it is metamorphosed. In general three distinct changes can be seen in nearly all protoliths with an increase in regional metamorphic grade:

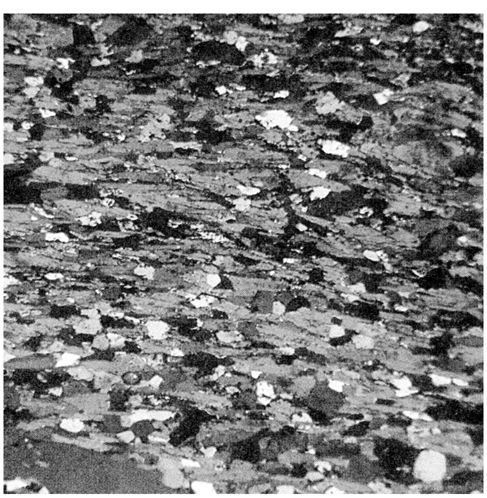
- **recrystallization** or an increase in mineral size,
- **rotation and alignment** of elongate minerals in response to increasing pressure
- **chemical reactions** take place between the minerals of the protolith to form new minerals.

The type of regional metamorphic rock produced also depends largely on the protolith that you start out with. A common starting protolith is a shale or a siltstone. Under low grade regional metamorphism the microscopic clays in the original shale rotate and become aligned. This produced a much harder, more brittle rock that has a direction of weakness (called **rock cleavage**) where it will tend to split into thin layers when broken. This hardened shale is very fine grained, has a rather dull surface and is known as a **slate**.

Under medium grade regional metamorphism the clays in the shale protolith will undergo recrystallization and, although the individual are still too small to see, they will become large enough to reflect more light and will have a bright sheen or what is known as a **phyllitic luster**. And because the clays are quite soft and ductile, they will become wrinkled into tiny microfolds called **crenulations**. Medium grade regional metamorphic rocks that display a phyllitic luster and crenulations are called **phyllites**. Under medium grade conditions it is also common for chemical reactions to take place to create a new mineral, garnet, within the rock. These garnets are very fine-grained and are usually of the reddish or almandine variety.

Under high grade regional metamorphism a shale protolith will undergo intense recrystallization. The clays with the shale will grow to the point where they become large enough to see. Clays that are visible are no longer called clays, but are now referred to as **micas** and the rock is know known as a **schist**. Several different types of micas may be present in a schist and the full name of a schist depends on the type of mica present. Common schists include; muscovite schists, biotite schists, chlorite schists and talc schists. Like slates and phyllites, schists display a prominent rock cleavage, i.e. they tend to break in flat layers. Almandine garnets as will as thin layers of quartz are also common constituents in a schist. Depending on the amount of metamorphism the garnets can range from the size from bee bees to the size of golf balls.

Another common starting protolith is a granite. Like shales, granites are fairly common rock types. Granites also undergo recrystallization under increasing metamorphism. But, unlike shales, the minerals in a granite separate out into distinct band of different compositions during increasing metamorphism. A gray granite protolith will yield a banded rock with alternating



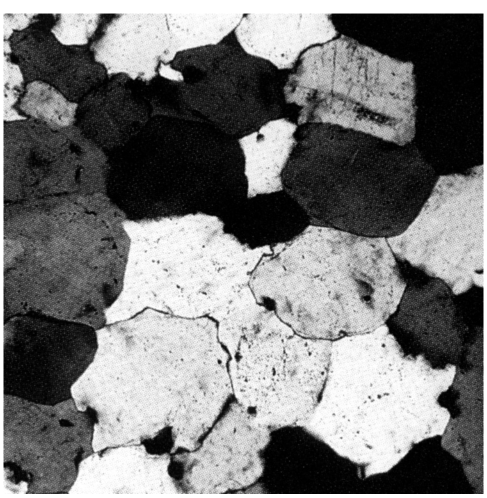
Alignment of large micas due to the pressure of regional metamorphism producing the foliated texture in a schist white and black bands. A pink granite protolith will yield a banded rock with alternating red and black bands. A regional metamorphic rock that contains alternating light and dark band is called a **gneiss** (pronounced ‘nice’). With increasing regional metamorphism, the individual bands in a gneiss become thicker. But, unlike rocks formed from a shale protolith, it is difficult to determine the grade of metamorphism displayed within a gneiss. Gneisses also display rock cleavage. in that they tend to break into layers parallel to the direction of the banding.

All regional metamorphic rocks that display rock cleavage are said to have a f**oliated texture**. This is a texture that has a tendency to break into thin sheets or layers due to the alignment of platy minerals from the pressure involved with increasing regional metamorphism.

Classification of Contact Metamorphic Rocks

Contact metamorphism occurs when a hot, volatile-rich magma body comes in contact with colder surrounding crust. This normally takes place close to the earth’s surface where pressure is not an important process. Therefore contact metamorphic rocks lack the distinct alignment of minerals found in the high-pressure processes of regional metamorphism. Contact metamorphic rocks are said to have a **nonfoliated texture**, a texture resulting from an absence or pressure and, hence, an absence or any mineral alignment or banding. Contact metamorphism does, however, drastically alter the texture of the rock that is in contact with the magma body. The intense heat and chemically-reactive volatiles act to recrystallize the mineral components in the cooler protolith, making them grow in size and destroying the original texture of the protoliths.

The type of contact metamorphic rock produced depends on the protolith that you start out with. If the original protolith was a sandstone, the detrital quartz grains of the sandstone will grow in size and literally weld themselves together at their grain boundaries. This will produce an incredibly hard rock (remember quartz has a hardness of 7) that, unlike the original sandstone, will not readily break across the softer cementing mineral. Such a rock is a nonfoliated metamorphic rock called a quartzite. If the original protolith was a limestone, recrystallization of the original calcite fossils by contact metamorphism will cause the calcite to grow in size,



Recrystallization of a quartz sandstone under contact metamorphism producing a quartzite destroying the original calcite fossils and creating a rock that is made up of coarse, blocky-looking calcite called a **marble**. Marbles are also nonfoliated metamorphic rocks, as the coarse calcite crystals will not display any form of mineral alignment. Like quartzites, they appear to be hard, strong rocks but are composed entirely of calcite (which has a hardness of 3 and can easily be scratched by a steel nail). If the original limestone protolith contained impurities (such as clays and/or iron oxides) these impurities with react chemically and create new minerals (such as garnet and augite). Such a 'dirty' or impure marble is called a **skarn**. Finally, if the original protolith was a shale, the clays will recrystallize and harden into a very dense, very strong rock called a **hornfels**. A hornfels is actually a natural form porcelain, as it is the artificial heating of clays in an oven that creates porcelain pots and other items.

Metamorphic Rock Key

Texture	Diagnostic Features	Rock Name
Foliated texture	Very fine-grained rock cleavage. Dense, microscopic clay grains. Black and gray common, but may also be green or red.	SLATE
	Very fine-grained rock cleavage. Dense, microscopic clay grains. Shiny phyllitic luster and small wrinkle or crenulations present. Commonally gray to black.	PHYLLITE
	Medium to coarse-grained rock cleavage. Commonly contains micas, quartz and garnet. Micas present may be a combination of chlorite, biotite, muscovite, talc. Color depends on dominate mica.	SCHIST
	Coarse-grained rock cleavage. Foliation present as alternating light and dark bands. Abundant quartz and feldspar in light bands. Dark bands may contain hornblende, augite and biotite.	GNEISS
Nonfoliated texture	Dense, very hard, very fine grained. Various shades of gray, gray-green to nearly black.	HORNFELS
	Coarse crystalline appearance. Very hard (nearly pure quartz). Breaks across the grains. Color widely variable but pink, white, brown and red are common.	QUARTZITE
	Coarse crystalline appearance. Hardness of 3 (nearly pure calcite). Color widely variable but pink and white are common.	MARBLE
	Coarse crystalline appearance. Hardness variable. Mostly white calcite, but may contain patches or reddish garnet and yellow to green mixtures of pyroxenes and garnet.	SKARN

Rock Texture	Rock Composition	Characteristic Features	NAME

Lab 5 - Metamorphic Rocks

1. What were the protoliths of each of your regional metamorphic rocks?

2. What were the protoliths of each of your contact metamorphic rocks?

3. How can you tell the difference between a shale and slate?

4. Compare the luster between the slate and phyllite. How can this be used to distinguish between the two samples ?

5. In your own word contrast foliated and non-foliated textures ?

6. What simple test can be used to distinguish the marble samples from the quartzite ?

7. How could one distinguish the quartzite sample from it’s protolith (a red arenite) ?

8. Why is the pink marble pink in color ?

9. What simple characteristic can be used to distinguish a schist from a gneiss ?

10. Both slate and hornfels have a shale protolith. Comment on why these rocks have distinctive textures and appearances.