Metamorphic Rocks - Laboratory 6

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(name)

BACKGROUND

Metamorphic rocks are derived from previously existing Earth material through solid-state crystallization. The term **protolith** refers to the material that existed prior to metamorphism. The range of temperatures under which metamorphism occurs is ~200^oC - ~650^oC. Pressures can range from a few kilobars to >20 kilobars.

Temperature changes are determined by the **geothermal gradient**. In subduction zone settings along convergent margins a typical geothermal gradient is ~10^oC/km. In order words, there is a 10^oC increase in temperature for every kilometer that we descend into the Earth's crust. In contrast, in areas of active island arc volcanism the geothermal gradient may reach 50^oC/km while in the interior of continents like North America the geothermal gradient is closer to 30^oC/km. As you may have guessed there is also a **geobarometric gradient**. In average continental crust the geobarometric gradient is ~0.33 kilobars/kilometer (i.e., in abbreviated form ~0.33 kbar/km).

Metamorphic rocks are commonly subdivided into **foliated** and **nonfoliated** groups (Figure 1). The term **foliation** refers to the alignment of inequant minerals like those in the sheet silicates muscovite, biotite, and chlorite into planar arrays. Because of this alignment the rock tends to split parallel to the foliation. The alignment of the inequant minerals is produced by a directed tectonic pressure that forces the flat faces of minerals like those in the sheet silicates to align perpendicular to the applied pressures (Figure 2).

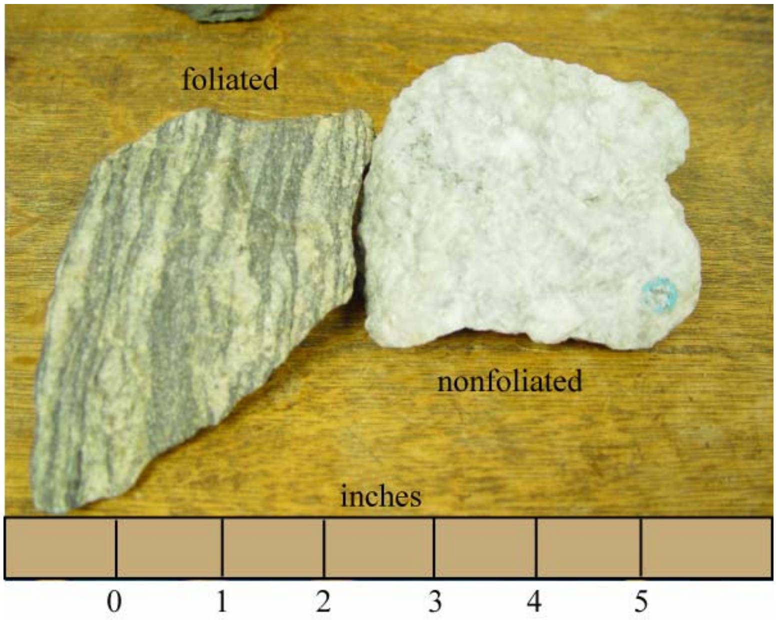

Figure 1. Nonfoliated versus foliated mudstone.

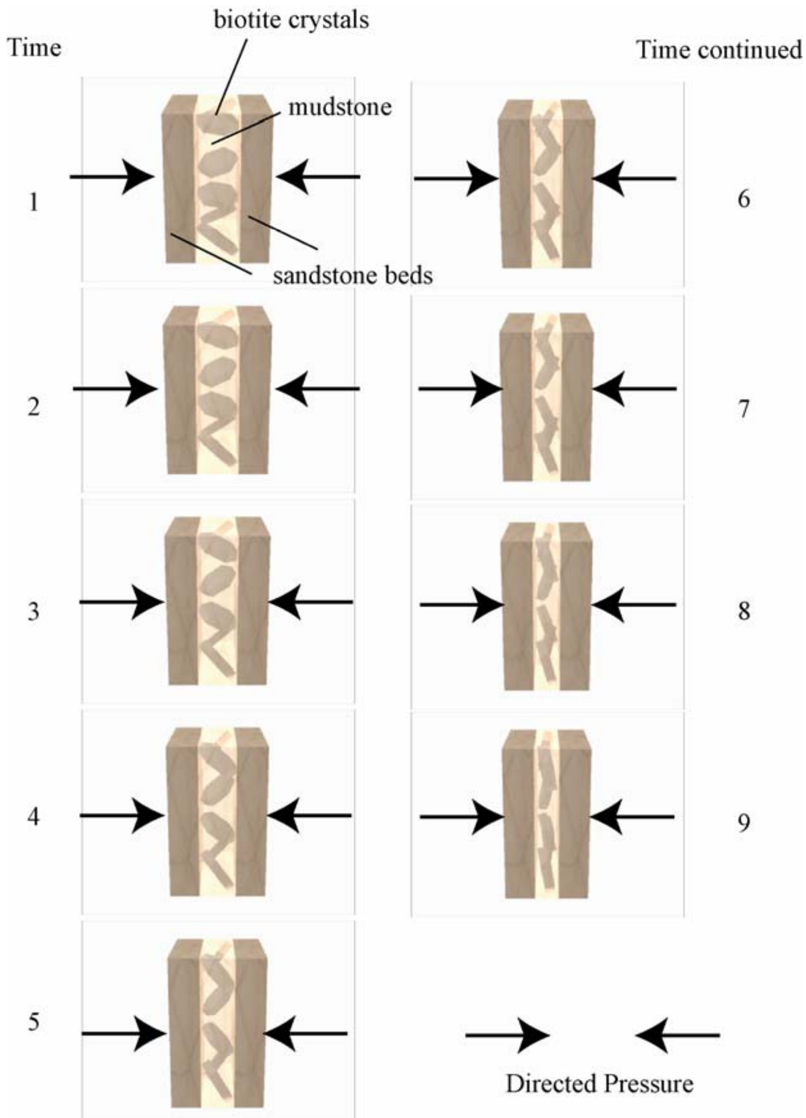

Figure 2. Time sequence showing biotite crystals progressively rotating during a directed pressure event.

The term **metamorphic grade** refers to the pressure and temperatures under which a rock recrystallized. If we assume that the protolith is mudstone, then with increasing metamorphic grade the mudstone will be converted to a **slate**, **phyllite**, **schist**, and **gneiss**. Each of these rock types will in turn have a characteristic foliation. For example, the foliation in a slate is referred to as **slaty cleavage** (Figure 3), in a phyllite as **phyllitic cleavage** (Figure 4**)**, in schist as **schistosity**, and in gneiss as **gneissosity** (Figure 5).

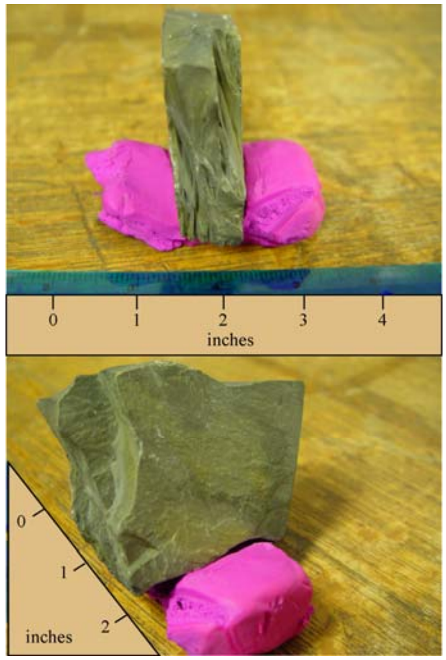

Figure 3. Slate and slaty cleavage. Note that there is not a marked sheen on the foliation surface (lower photograph), and that the surface would be described as dull and earthy in aspect. The clay and micaceous grains are all less than about 1 mm and as a result their outlines cannot be made out without the aid of a hands lens or microscope. Compare with Figure 4 below.

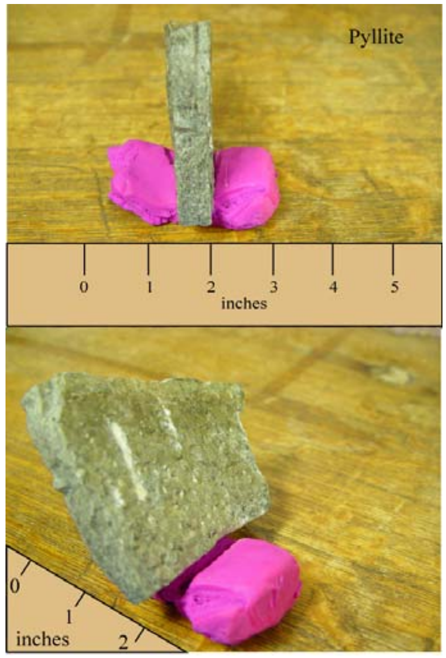

Figure 4. Phyllite and phyllitic cleavage. Note that though there is a marked sheen to the foliation surface, the micaceous grains are less than about 1 mm and as a result their outlines cannot be made out without the aid of a hands lens or microscope. This is the critical characteristic for distinguishing a schist from a phyllite. Compare with Figure 3 above.

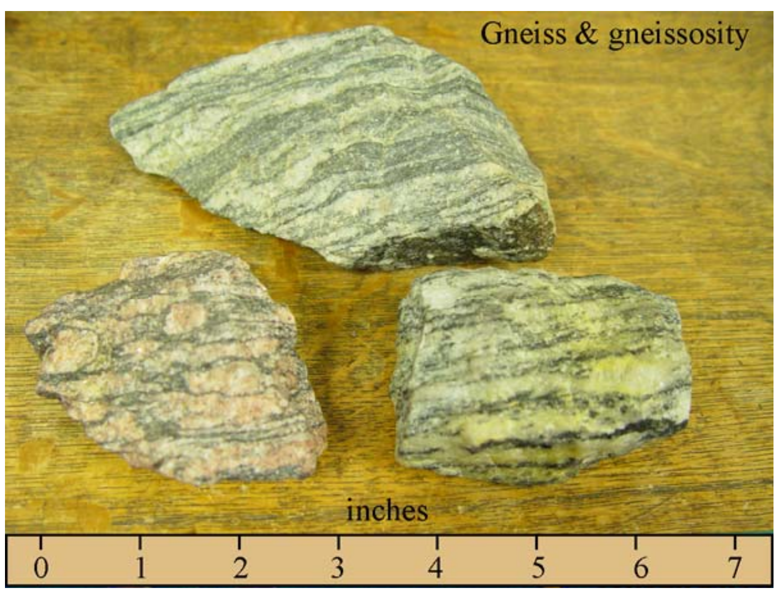

Figure 4. Gneiss and gneissosity. The black and white or black and pink banding is produced by variations in the proportion of quartz + feldspar (white and pink) and biotite + amphibole (hornblende). Note the relative coarse grain size as compared to Figures 3 and 4.

The term **metamorphic facies** refers to a group of rocks that were crystallized under similar pressures and temperatures. **Zeolite facies** rocks were subjected to very low metamorphic grades while **greenschist** and **amphibolite facies** were subjected to higher grades of metamorphism. **Blueschist facies** rocks are recognized by the presence of a blue-colored amphibole called glaucophane while **eclogite facies** contain red garnet and green pyroxene.

Metamorphism is generally thought to be **isochemical**. The term isochemical means that ions did not move into or leave the system of interest. If the metamorphic environment is **static** as the result of an absence of directed pressure then rocks like quartz arenites, cherts, and limestones will simply recrystallized. Recrystallization is often indicated by a coarsening in grain size and the development of a dense interlocking network of grains. When struck with a hammer such a rock breaks across grains rather than around them. Rocks characteristic of static isochemical metamorphism include the nonfoliated varieties of **quartzite**, **marble**, and **amphibolite** (Figure 6).

Figure 6. Nonfoliated varities of metamorphic rocks include quartzite, amphibolite, and marble. The protoliths of these includes are quartz arenite (or chert), basalt, and limestone.

LABORATORY

Your TA will lead you through the identification and characteristics of each of the types of metamorphic rocks listed below in Table 1. Make sure that you know how to distinguish one type from another and which belong to the classes foliated and nonfoliated.

Table 1. Common metamorphic rocks and their characteristics

Sample	**Characteristics**
Quartzite	
Marble	
Amphibolite	
Slate	
Phyllite	
Muscovite schist	

Biotite schist	
Chlorite schist	
Gneiss	