LAB 11: HIGH-PRESSURE METAMORPHIC ROCKS

Pacheco Pass, Diablo Range, California

**Purpose:** High-pressure metamorphism is unique for two reasons. First, the high pressures of metamorphism (often accompanied by low temperatures) yield unusual and interesting mineral assemblages. Second, recognition of high-P metamorphism is extremely important in tectonics – if you can recognize high-pressure conditions, then you might be looking at the heart of a subduction zone or a collision zone, both of which are very exciting from a tectonic perspective. However, preservation of high-P mineral assemblages is relatively rare, and as you go deeper into the geological past, there are fewer and fewer high-P rocks preserved. This is primarily because the minerals stabilized at high P (and commonly low T) are easily re-equilibrated during even modest temperatures of younger events, so the high-P assemblages are commonly overprinted and lost. Still, active tectonic processes related to subduction and collision act to raise these deeply-buried rocks relatively quickly to the surface, allowing us to see deep into the crust.

In this lab, you will be examining rocks from world-famous localities of two major settings of high-P metamorphism: (1) subduction zones (e.g., Franciscan complex of California); and (2) collisional zones (e.g. Swiss-Italian Alps). In both settings, the main rock type is metabasalt, so keep this in mind as you become familiar with the mineral associations.

**Part I. Subduction zones**

Here you will examine metamorphic rocks from three different high-P terranes in the western North American Cordillera. During much of the Paleozoic and through the Mesozoic, the western margin of North America was characterized by convergence between the paleo-Pacific oceanic plate and the North American continental plate. During this time, the Pacific plate was being subducted to the east beneath North America. Preserved within the western Cordillera are many so-called subduction or accretionary complexes that represent fragments of oceanic igneous and sedimentary rocks scraped off during subduction. These rocks represent the remnants of subduction (everything else went down the tube!), but they tell us a lot about the nature of plate-margin convergence. The samples below are from three such metamorphic complexes in California and Washington that show different mineral assemblages and textures reflecting different conditions or settings during subduction.

**Franciscan complex**

The following samples are from the Diablo Range of the central California Coast Ranges, and they are representative of the Franciscan subduction complex. These rocks represent blueschist and eclogite facies metamorphism of marine sediments and volcanics. As you study these rocks, you should not only think about their protolith and relative metamorphic facies, but you should also plot the approximate conditions represented by their mineral assemblages on the P-T grid provided. Estimation of physical conditions via mineralogy is a first-order approximation and serves as a basis for more detailed studies of P-T conditions using mineral compositions and reactions.
A geologic map of the Pacheco Pass area is provided for the purpose of placing these samples in geologic and geographic context. Be thinking about how these Franciscan rocks relate to one another and consider any possible geographic relationships. There are multiple lithologies and metamorphic grades represented here; there may (or may not) be a pattern. After you have plotted all of the rocks on the attached P-T diagram, draw what you consider a likely P-T path for the Franciscan rocks. As always, sketch key metamorphic and deformation textures.

**F-3** This sample is in fact a metamorphic rock! Look closely. It formed at high P from a sedimentary protolith in a relatively static kinematic setting. Note that relict sedimentary textures and mineralogy are present. For protolith, give a textural description (using sedimentary terminology) of this rock and a sedimentary rock name.

- **Mineralogy**
- **Texture**
- **Complete name**
- **Metamorphic facies**
- **Protolith**

**F-4D** In contrast to sample F-3, this sample represents both a different protolith bulk composition and a different deformation regime associated with subduction.

- **Mineralogy**
- **Texture**
- **Complete name**
- **Metamorphic facies**
- **Protolith**
The next two samples are from particularly high-grade rocks. Look at 4E first, then compare to 2D. Is there evidence for retrograde metamorphism? Estimate the P-T conditions represented by the prograde path and plot them on your diagram.

<table>
<thead>
<tr>
<th>F-4E</th>
<th>Mineralogy</th>
<th>Texture</th>
<th>Complete name</th>
<th>Metamorphic facies</th>
<th>Protolith</th>
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<tr>
<th>F-2D</th>
<th>Mineralogy</th>
<th>Texture</th>
<th>Complete name</th>
<th>Metamorphic facies</th>
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**Shuksan complex**

This sample is from the Shuksan complex of the North Cascades Range, Washington, and represents slightly different physical conditions when compared to the Franciscan rocks (above). Although the conditions are different, these rocks also represent P-T conditions commonly encountered in subduction complexes. Plot your estimation of P-T on the diagram, but label it separately from the Franciscan rocks in order to compare them.

<table>
<thead>
<tr>
<th>S-1A</th>
<th>Mineralogy</th>
<th>Texture</th>
<th>Complete name</th>
<th>Metamorphic facies</th>
<th>Protolith</th>
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What key mineral makes the Shuksan rocks different from the Franciscan complex?
Mélange Rock

90GTR-79 This sample is from the Hayfork terrane in the Klamath Mountains of northern California and represents a typical mélange (from the French for “mixture”) sediment. It formed in an accretionary complex where oceanic sediments are accreted by “offscraping” during subduction (see diagram below, showing a convergent plate boundary with the upper-level accretionary complex and the deeper metamorphic parts of the subduction zone). In addition to examining this under the microscope, hold the sample up to the light and look at macroscopic textures.

In your estimation, has this rock seen significant metamorphism? Why or why not?

How about deformation? Why or why not?

Have you seen other rocks in this lab that may be similar in composition? Which?

What is the composition of most of the rock fragments?

If you subjected this rock to high pressure metamorphism, what mineralogical changes would you expect?
Part II. Collisional zones

The second suite of rocks come from the Western Alps in Switzerland and Italy. Here, beneath the Matterhorn, some of the deepest zones of the Alpine Orogen are exposed. As you examine these rocks, keep in mind textural evidence for equilibrium, relative density of the minerals, and a comparison of mineral assemblages with the Cordilleran blueschists.

WA-7A

Mineralogy

Texture

Complete name

Metamorphic facies

Protolith

Note: Sample WA-7A has three important metamorphic minerals. In addition, it contains sphene, quartz and trace amounts of muscovite.

Marked by a red circle is a garnet with some mineral inclusions. Draw a sketch of this texture. What is the biggest of these inclusions? Can you find it in the groundmass of the rock outside of garnet? What does this tell you about metamorphic reactions and mineral stability?

WA-7G

Mineralogy

Texture

Complete name

Metamorphic facies

Protolith

Note: Sample WA-7G contains textural evidence for strong shear deformation, including fine-grained mosaics of recrystallized quartz, often distributed in “ribbons” parallel to the main foliation, and the presence of minerals shaped like “fish” (these are elongate minerals with curving shapes and tapered ends like candles). They are called fish because they appear to swim in the matrix of surrounding
minerals. In this case, quartz was the weakest mineral in the rock and underwent continuous recrystallization (shown by the fine grains) in order to flow under the influence of deformation. The other “fishy” minerals were stronger, but still were bent and sheared to form the tapered ends. During the Alpine deformation, quartz-rich rocks like this one would have taken up much of the total shear strain (because quartz is so weak under metamorphic conditions), whereas the mafic rocks (such as sample 7A) are relatively strong. Sketch an example of these mineral fish.

Sample WA-7G is a pelitic rock collected in the same outcrop area as WA-7A; compare the mineralogy of the two. Were these two rocks metamorphosed under the same P-T conditions? Why or why not?

WA-8B
This one is just for fun! It is a Mn-rich quartzite protolith that contains quartz + Mn-rich epidote (var. piemontite) + Mn-rich muscovite + an opaque mineral. Note the strong pink color of the epidote (due to Mn concentration) and the orange-pink pleochroism in the muscovite (it too is Mn rich). Another common Mn-silicate is spessartite, a pink variety of garnet, that occurs in some metamorphic rocks but is not present here.

Also note the very strong shear fabrics in this rock, including fine mosaics of recrystallized quartz and the muscovite “fish”.
Fig. 26.19 (Winter, 2nd Ed.)