Metamorphic rocks lab — Part I
Barrovian metamorphism
Due Tuesday 4/13

Learn to identify the metamorphic minerals common in Barrovian metamorphism of pelitic rocks. Take note of metamorphic textures and develop a sense for the sequence of metamorphic mineral growth and deformation.

**Chlorite zone** (chloritoid subzone)

#73. Chloritoid phyllite, of Paleozoic age, Vermont. Phyllite with distinct, green porphyroblasts of chloritoid.

Quartz — 35
Muscovite — 39
Chloritoid — 20: Euhedral porphyroblasts, pleochroic in blue and blue-green. Can be confused with chlorite or amphibole, but it has much lower birefringence than amphiboles. It lacks the micaceous cleavage of chlorite and can be distinguished by its polysynthetic twinning
Chlorite — ≥ 5: Compare its distinguishing features and habit with chloritoid
Ilmenite and pyrite — 1: The pyrite is locally altered to hematite
Sphene?: very small crystals with ilmenite
Stilpnomelane (??): is more probably a weathering product that has formed on muscovite.

Is the chloritoid pre-, syn-, or post-kinematic [i.e. - did it grow before, during, or after the deformation which produced the schistosity of this rock]?

**Biotite zone**

#74. Biotite schist, of Paleozoic age, Belfast area, Maine.

Quartz — 60
Muscovite — 10
Biotite — 20: Porphyroblastic
Tourmaline — trace
Chlorite — 5-10
Apatite — trace
Garnet (spessartine): a trace in slides a, b, c, d, and f. Don't necessarily expect to find it without an exhaustive search! Why does this rock not belong to the garnet zone, given the presence of garnet in these slides?
Garnet zone (More properly, the almandine zone)

#75. Garnet phyllite, of Paleozoic age, Belfast area, Maine. Metamorphic grade transitional with amphibolite-facies.

Quartz — 50  
Muscovite — 8  
Biotite — 20  
Garnet — 20: almandine  
Chlorite — 2

This rock superficially resembles #65, but notice that this rock contains muscovite, whereas #65 contains calcite and abundant chlorite. This rock is pelitic and #65 is not.

Staurolite zone

#83. Staurolite schist, of Paleozoic age, Belfast, Maine.

Quartz — 40  
Muscovite — 20  
Biotite — 10: altered to chlorite  
Chlorite — 10: replaces biotite and staurolite. What is the approximate ratio Fe/(Fe+Mg) of the Chlorite?  
Staurolite — 20: weak pleochroism: colorless and pale yellow. Some has anomalous bluish and yellowish interference color which is unusual. Porphyroblastic and poikiloblastic textures. Some are twinned. Partly replaced by chlorite and muscovite.

Replacement of biotite and staurolite by chlorite occurred as a late, retrogressive metamorphic event. Notice that the schistosity is folded. If, as is usual, the schistosity formed parallel to the axial planes of tight folds, there must have been a second, later period of folding. Is the staurolite pre- or post-kinematic?
Kyanite zone

#84. Quartz-kyanite rock (too aluminous to be called a quartzite; lacks foliation necessary to call it a schist).

Quartz — <35  
Muscovite — 15  
Plagioclase ?: considerable untwinned plagioclase is present  
Kyanite — 45: high relief, well-developed cleavage; biaxial (-); high 2V; elongated crystals with inclined extinction. The extinction appears parallel in orientations that display the cleavage most clearly. Very weak blue color. Moderate birefringence.  
Ilmenite — 3  
Rutile — trace: associated with ilmenite; yellow-brown color  
Calcite — 1: secondary  
Tourmaline: variable abundance from slide to slide

The rock is unfoliated. The calcite probably is secondary (i.e., introduced long after the rock last equilibrated), for it would not have coexisted with an aluminum silicate mineral in a high-grade metamorphic rock. Instead, calc-silicate minerals would have formed.
Sillimanite zone

#86. Sillimanite-K feldspar gneiss, of Paleozoic age, Belfast area, Maine. A very weakly foliated rock.

Quartz — 12  
Plagioclase? — 20: untwinned  
Cordierite — 5: distinguished from the plagioclase only where there are pleochroic yellow halos around very minute inclusions. Thus its modal abundance is uncertain.  
Microcline — 16  
Muscovite — 10  
Biotite — 15  
Sillimanite — 20: both fibrolitic and coarse sillimanite are present  
Pyrrhotite — 2

Slide e contains minor hercynite (Fe-Al spinel) in one crystal of biotite. Do not bother looking for it if you did not happen to get slide #e. Slide e also contains a possible trace of garnet in the muscovite. Slide d contains minor rutile.

Sillimanite and K-feldspar are found together only in very high grade metamorphic rocks, in which the following (simplified) reaction has occurred:

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\text{muscovite} + \text{quartz} \rightarrow \text{K-feldspar} + \text{sillimanite} + \text{H}_2\text{O}
\]

The fibrolitic sillimanite likely was produced by the above reaction; the coarse sillimanite in this rock likely was produced by inversion of andalusite. Further increase of temperature leads to the complete breakdown of micas and other hydrous minerals, under the conditions of the pyroxene granulite facies. Notice that the rock is essentially unfoliated, but there is a slight orientation of the sillimanite; for that reason, the rock is called a "gneiss", but it is not a very respectable example of a gneiss.