Geos 3010: Minerals and Rocks Lab #10

Metamorphic Grade, Metamorphic Facies, & Metamorphic Rock Classification

Metamorphic Mineral Assemblages, Crystal Size, and Metamorphic Grade

In many regionally metamorphosed areas at the Earth's surface, geological mapping shows that metamorphic rocks vary progressively in the intensity of metamorphic alteration from rocks containing finer grained mineral crystals stable at lower temperatures and pressures to rocks containing an assemblage of coarser-grained minerals stable at higher temperature and pressure. The boundaries between these areas containing different assemblages of metamorphic minerals (in many cases formed from essentially the same precursor rock or protolith) are referred to as isograds. Isograds separate regions (like topographic contour lines separate elevation) of different intensity or **Grade** of metamorphism.

In addition to the different minerals species present in an area as a result of varying temperature and pressure conditions of formation, the metamorphic mineral **crystal size** is also somewhat indicative of the grade of metamorphism. The growth of large metamorphic mineral crystals, both neo-crystallized and re-crystallized metamorphic minerals, and the development of parallel to sub-parallel alignment of mineral grains of unequal size in a **foliated texture**, is produced by prolonged exposure to elevated temperatures.

Larger grains have less surface area and there fore lower surface free energy (like sharp angular objects with larger surface area tend to round to shapes with less surface area). **In general**, larger crystals in a metamorphic rock (if neo- or recrystallized!!) indicate higher grades (temperature and pressure) of metamorphism.

a. **Prograde** Metamorphism:
   i. Metamorphism that has progressed with indications of mineral neo formation first at lower temperature and then at higher temperature conditions
   ii. determined by the observation of lower temperature of formation minerals only partially replaced by minerals formed at higher temperatures
b. **Retrograde** Metamorphism:
   i. "re-metamorphism", metamorphic re-crystallization has progressed from higher to lower temperature and pressure
   ii. determined by the observation of minerals formed at higher temperature partially replaced by minerals formed at lower temperatures

Metamorphic Facies; Indication of metamorphic conditions in rocks of different protolith composition

We know that different protolith rocks will respond differently to different temperature and pressure regimes. In Figure 1 silica-rich rocks begin to melt between 600° and 900°C, (depending on pressure and other factors) while basaltic rocks do not reach Anatexis until well above 1000°C. What this means is that different protolith rocks will experience different degrees of metamorphic re- and

neo-crystallization **AND** produce very different metamorphic mineral assemblages and textures when exposed to EXACTLY the same metamorphic temperatures and pressures.

None-the-less, some sense can be made of the complex mineralogy and texture of metamorphic rocks by first considering rock texture, crystal size, mineral assemblage (in terms of temperature stability) and finally the mineral associations or the chemical classes of metamorphic rocks.

Chemical Classes of Metamorphic Rocks

Mineral associations are the result of metamorphic conditions and protolith chemical composition (and any added chemical components in the sense of allochemical metamorphism). The simplest **Chemical Classes of Metamorphic Rocks** (with the shorthand descriptor **bold and highlighted**) are as follows:

1. derivatives of iron-magnesium rich (**ultramafic**or **ultrabasic**) rocks
2. derivatives of melancratic **(basic)**igneous rock
3. derivatives of calcareous (or **carbonate-rich**) sedimentary rock
4. derivatives of pelitic (**aluminous**, clay-rich) sediment
5. derivatives of quartzo-feldspathic sandstone & silica-rich igneous rock (including **siliceous** & **alkili-calcic**rocks)

Selected Common Minerals of Metamorphic Rock Chemical Groups

Ultrabasic Rocks	Basic Rocks	Carbonate Rocks	Aluminous Rocks	Siliceous-Alkali-Calcic Rocks	Siliceous Rocks
Olivines	Augite	Calcite	Quartz	Quartz	Quartz
Augite	Omphacite	Dolomite	White micas	Plagioclases	Plagioclases
Diopside	Jadeites	Aragonite	Biotite	Alkali feldspar	Alkali feldspar
Orthopyroxenes	Orthopyroxenes	Olivine	Chlorites	Chlorites	Biotite
Tremolite	Glaucophane	Diopside	Plagioclases	Biotite	White micas
Anthophyllite	Hornblende	Tremolite	Alkali feldspar	White micas	Chlorites
Serpentines	Actinolite	Wollastonite	Pyrophyllite	Sillimanite	Garnets
Chlorites	Epidotes	Talc	Sillimanite	Kyanite	Sillimanite
Talc	Lawsonite	Phlogopite	Kyanite	Andalusite	Kyanite
Phlogopite	Plagioclases	Periclase	Andalusite	Garnets	Andalusite
Chromite	Biotite	Idocrase	Staurolite	Cordierite	Cordierite
Magnetite	Zeolites	Graphite	Garnets	Jadeites	Aegirine
	Quartz	Garnets	Calcite	Lawsonite	Crossite
	Calcite	Pyrite	Chloritioid	Epidotes	Stilpnomelane
	Sphene	Pyrrhotite	Cordierite	Pumpellyite	Hematite
	Garnets		Tourmaline	Zeolites	Magnetite
	Magnetite		Kaolinite	Glaucophane	
	Ilmenite		Magnetite	Calcite	
			Ilmenite	Magnetite	

Metamorphic Rock Classification

Using the composite characteristics of texture, mineralogy, and protolith composition the concept of **Metamorphic Facies** can be used as an initial classification scheme to infer general petrologic derivation. Metamorphic Facies refers to the **Aspect** of the rock as a whole; mineralogy, texture, and protolith composition although the intent in the scheme is to define the **physical conditions** indicated by the minerals and textures present regardless of which minerals are actually present.

Rocks with visible parallel structure (foliates and banded rocks)	
Slate	Schist (continued)
Mylonite (in part)	Tremolite
Phyllite	Actinolite
Schist	Staurolite
Muscovite	Graphitic
Chlorite	Gneiss
Talc	Granitic, diorite, etc.
Biotite	Hornblende
Quartz-mica	Biotite
Garnetiferous	Banded
Hornblende	Augen
Rocks apparently lacking parallel structure	
Quartzite	Soapstone
Marble	Amphibolite
Dolomitic	Granulite
Serpentine, etc.	Eclogite
Hornfels	

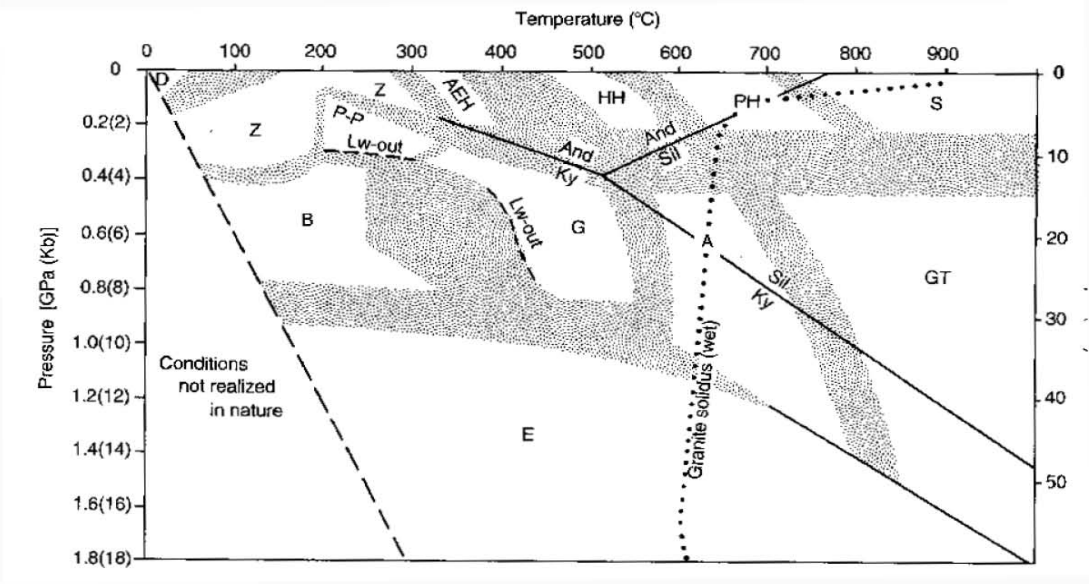
Principle Textural Classes of Metamorphic Rocks

1. ***Hornfels:*** Non-foliated rocks without preferred grain orientation and a mosaic of equidimensional grains.
2. ***Slate:*** Fine-grained metamorphic rocks with strong planar foliation (slatey cleavage)
3. ***Phyllites:*** fine-grained, foliated rocks with a larger, more pronounced mineral segregation, typically the result of the growth of mica.
4. ***Schists:*** Strongly foliated and/or lineated rocks with coarse-grained (mesoscopic) re- or neo-crystallized metamorphic minerals typically including coarse-grained mica.
5. ***Amphibolites:*** Medium- to coarse-grained metamorphic rocks typically with amphibole and plagioclase feldspar; generally less pronounced foliation but with strong parallel alignment of inequant mineral grains.
6. ***Gneisses:*** Coarse-grained, irregularly banded metamorphic rocks with poorly developed foliation due to the general absence of inequant mineral grains: contains mostly quartz and feldspar
7. ***Granulites:*** Equigranular metamorphic rocks with little or no foliation; grano-blastic textures
8. ***Marbels:*** Metamorphic rocks containing calcite and/or dolomite found in anhedral (xenoblastic) crystals and generally lacking a foliated fabric
9. ***Mylonites:*** Almost completely granulated, fine-grained, metamorphic rocks with remnant lenses of less completely broken protolith mineral grains. Little re- or neo-crystallization or chemical alteration
10. ***Cataclasites:*** Slightly less obliterated (by mechanical granulation) metamorphic rock compared to mylonites

P(ressure) T(emperature) fields for the common Metamorphic Facies (figure 1)

The common Metamorphic Facies are as follows:

1. **Z**: Zeolite Facies
2. **P-P**: Prehnite-Pumpellyite Facies
3. **B**: Blueschist Facies
4. **G**: Greenschist Facies
5. **A**: Amphibolite Facies
6. **E**: Eclogite Facies
7. **GT**: Granulite Facies
8. **AEH**: Albite-Epidote Hornfels Facies
9. **HH**: Hornblende Hornfels Facies
10. **PH**: Pyroxene Hornfels Facies
11. **S**: Sanidinite Facies



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