Regional Pelitic Rocks

Reading: Winter, Chapter 28

Metapelite Mineralogy

- Fine Al-K-rich phyllosilicates, such as clays (montmorillonite, kaolinite, or smectite), fine white micas (sericite, paragonite, or phengite) and chlorite
- The phyllosilicates may compose more than 50% of the original sediment
- Fine quartz constitutes another 10-30%
- Other common constituents include feldspars (albite and K-feldspar), iron oxides and hydroxides, zeolites, carbonates, sulfides, and organic matter

Chemical Characteristics

- High Al₂O₃ and K₂O, and low CaO
- Reflect the high clay and mica content of the original sediment and lead to the dominance of muscovite and quartz throughout most of the range of metamorphism
- High proportion of micas → common development of foliated rocks, such as slates, phyllites, and mica schists
- The chemical composition of pelites can be represented by the system K₂O-FeO-MgO-Al₂O₃-SiO₂-H₂O ("KFMASH")

Chlorite Zone

a. AKF [Spear (1993) formulation]
b. AFM (projected from Ms) diagram. Shaded areas represent the common range of pelite and granitoid rock compositions.

Biotite Zone

- Under medium P-T the following reaction occurs at 400-450°C
  \[ \text{Chl} + \text{Kfs} = \text{Bt} + \text{Ms} + \text{Qtz} + \text{H}_2\text{O} \]
- K-spar is generally consumed before all chlorite is consumed, thus it persists

Upper Biotite Zone

AFM projection for the upper biotite zone. Garnet is limited to unusually Fe-rich compositions, and does not occur in natural pelites (shaded). Winter (2001)
**Chloritoid**

- Chloritoid introduction may occur at $T > 250^\circ$
  \[ \text{Chl} + \text{Prl} = \text{Cld} \ (\text{Chl} + \text{Qtz} + \text{H}_2\text{O}) \]
- Chloritoid goes out at $T = 590^\circ$
  \[ \text{Cld} = \text{Grt} + \text{St} \ (\text{Cld} + \text{Qtz} + \text{H}_2\text{O}) \]

**Garnet Zone**

- In Fe-rich rocks at $\sim 525^\circ$
  \[ \text{Fe-Chl} \ (\text{Qtz}) = \text{Alm} \ (\text{H}_2\text{O}) \]
- Under medium P-T in normal pelites the reaction occurs at $\sim 610^\circ$
  \[ \text{Chl} \ (\text{Ms} + \text{Qtz}) = \text{Grt} + \text{Bt} \ (\text{H}_2\text{O}) \]

**Staurolite zone**

- Under medium P-T may appear at $570^\circ$
  \[ \text{Cld} + \text{Ky} = \text{St} + \text{Chl} \ (\text{Qtz} + \text{H}_2\text{O}) \]
- An alternate reaction occurs at $610^\circ$
  \[ \text{Grt} + \text{Chl} = \text{St} + \text{Bt} \ (\text{Qtz} + \text{H}_2\text{O}) \]
- Staurolite goes out at $\sim 700^\circ$
  \[ \text{St} \ (\text{Ms} + \text{Qtz}) = \text{Grt} + \text{Bt} + \text{Als} + \text{H}_2\text{O} \]

**Tie-line Flip for Garnet Reaction**

- AFM projection for the garnet zone showing the tie-line flip associated with reaction which introduces garnet into the more Fe-rich common (shaded) pelites. Winter (2001)

**AFM projection showing the change in topology in which the lower-grade Cld-Ky tie-line (dashed) is lost and replaced by the St-Chl tie-line. This reaction introduced staurolite to only a small range of Al-rich metapelites. After Spear (1993) and Winter (2001).**
### Staurolite Zone

- **AFM diagram showing the tie-line flip which introduces staurolite into many low-Al common pelites (shaded). After Carmichael (1970) and Winter (2001).**

**Kyanite Zone**
- Under medium P-T at ~630°
  
  St + Chl (+Ms +Qtz) = Ky + Bt (+H₂O)
- This reaction is considered the transition to the granulite facies in pelitic rocks

### Tie-line Flip: Staurolite

**Expanded Grt-St-Chl-Bt quadrilateral.**

- **a.** At the isograd tie-line flip. Composition Y loses Grt and gains St. b. As reaction proceeds, Fe-rich chlorite breaks down and the Chl-Grt-Bt triangle shifts to the right. c. Further shift of the Chl-Grt-Bt triangle. Rocks of composition Y lose chlorite at this grade, and staurolite develops in rocks of composition Z. Winter (2001).

### Kyanitite Zone AFM

**AFM projection showing the tie-line flip which introduces kyanite into many low-Al common pelites (shaded). After Carmichael (1970) and Winter (2001).**

### Sillimanite Zone

- A polymorphic transformation occurs at ~690°  
  
  Ky = Sil
- Sillimanite nucleates as tiny needles on micas
- Muscovite goes out at ~790°
  
  Ms + Qtz = Kfs + Sil + H₂O
- Cordierite appears at higher temperatures
  
  Phl + Sil (+Qtz) = Mg-Cdr (+Kfs + H₂O)

**AFM projection above the sillimanite and “staurolite-out” isograds. Winter (2001).**
Granulate Facies

AFM diagram above the cordierite-in isograds, granulate facies. Cordierite forms and then the dashed Sil-Bt tie-line is lost and the Grt-Crd tie-line forms. Winter (2001).

Pyroxene Hornfels

AFM diagrams (projected from Kfs) in the lowermost pyroxene hornfels facies. a. The compositional range of cordierite is reduced as the Crd-And-Bt sub-triangle migrates toward more Mg-rich compositions. Andalusite may be introduced into Al-rich pelites b. Garnet is introduced to many Al-rich pelites via reaction (28-27). Winter (2001)

Epidote Hornfels

AFM diagrams (projected from muscovite) for the eclogite facies of high P/T metamorphism of pelites. a. Talc forms between biotite and chlorite along the Mg-rich side of the diagram. b. At a higher grade the Chl-Bt tie-line flips to the Tlc-Cld tie-line c. After chlorite breaks down the kyanite forms in many metapelites. After Spear (1993) and Winter (2001)

Melting of Pelites

- Assume all the water is due to metamorphic dehydration reactions
- Muscovite decomposition causes melting, provided the pressure is high enough to retain the water
  \[ \text{Ms} + \text{Ab} + \text{Qtz} = \text{Al}_2\text{SiO}_5 + \text{Kfs} + \text{liquid} \]

Migmatites

- Dehydrated rocks become granulites
- Some high-grade rocks appear “mixed”
  - Dark schistose layers (melansome) alternate with
  - Light-colored igneous-looking layers (leucosome)
- The leucosome has a tonalite composition
  - (Not that of a minimum melt!)
- They represent high-grade metamorphic rocks in which melting is important

Migmatites

Some textures of migmatites from Mehner (1968)

- Breccia structure in agmatite.
- Net-like structure.
- Raft-like structure.
- Vein structure.
- Stromatic, or layered, structure.
- Dilation structure in boudinaged layer.
- Schleiren structure.
- Nebulitic structure.