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")

Biotite Zone

- Under medium P-T the following reaction occurs at 400-450°

  \[ \text{Chl} + \text{Kfs} = \text{Bt} + \text{Ms} (+ \text{Qtz} + \text{H}_2\text{O}) \]
- K-spar is generally consumed before all chlorite is consumed, thus it persists

Chlorite Zone

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

Biotite-in Isograd Reaction as a "Tie-line Flip."

In (a), below the isograd, the tie-lines connecting chlorite and K-Feldspar shows that the mineral pair is stable. As grade increases the Chl-Kfs field shrinks to a single tie-line. In (b), above the isograd, biotite + phengite is now stable, and chlorite + K-feldspar are separated by the new biotite-phengite tie-line, so they are no longer stable together. Winter (2001)
**Biotite Zone**

Series of AKF diagrams illustrating the migration of the Ms-Bt-Chl and Ms-Kfs-Chl sub-triangles to more Al-rich compositions via continuous reactions in the biotite zone of the greenschist facies above the biotite isograd. Winter (2001)

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

**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 \( \sim 610^\circ \)
  \[
  \text{Chl} (+\text{Ms} + \text{Qtz}) = \text{Grt} + \text{Bt} (+ \text{H}_2\text{O})
  \]
**Tie-line Flip for Garnet Reaction**

Expanded view of the Grt-Cld-Chl-Bt quadrilateral illustrating the tie-line flip. 

- **a.** Before flip. 
- **b.** During flip (at the isograd). 
- **c.** After flip (above the isograd). 

Winter (2001)

**Staurolite zone**

- Under medium P-T may appear at 570°
  \[
  \text{Cld + Ky = St + Chl (+Qtz +H}_2\text{O)}
  \]
- An alternate reaction occurs at 610°
  \[
  \text{Grt + Chl = St + Bt (+Qtz +H}_2\text{O)}
  \]
- Staurolite goes out at ~700°
  \[
  \text{St (+Ms +Qtz) = Grt +Bt +Al}_2\text{O}_3 +H}_2\text{O}
  \]

**Lower Staurolite Zone**

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 projection showing the topology associated with the reaction in which chloritoid is lost, yielding to the Grt-St-Chl sub-triangle that surrounds it. Winter (2001)

**Tie-line Flip**

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

**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. 
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°
  
  \[
  \text{St + Chl (+Ms +Qtz)} = \text{Ky + Bt (+H}_{2}\text{O)}
  \]

- This reaction is considered the transition to the granulite facies in pelitic rocks

**Sillimanite Zone**

- A polymorphic transformation occurs at ~ 690°
  
  \[
  \text{Ky} = \text{Sil}
  \]

- Sillimanite nucleates as tiny needles on micas

- Muscovite goes out at ~ 790°
  
  \[
  \text{Ms + Qtz} = \text{Kfs + Sil + H}_{2}\text{O}
  \]

- Cordierite appears at higher temperatures
  
  \[
  \text{Phl + Sil (+Qtz)} = \text{Mg-Cdr (+Kfs + H}_{2}\text{O)}
  \]

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

**Granulite Facies**

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

**Low P/T Metapelites**

a. Cordierite forms between andalusite and chlorite in the albite-epidote hornfels facies.
b. The compositional range of chloritoid is reduced and that of cordierite expands. Andalusite may be introduced into Al-rich pelites.
c. Cordierite comes in to many Al-rich pelites in the lowermost hornblende hornfels facies.
(d) Chlorite is lost in Ms-bearing pelites (Spear, 1999) and 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

\[
\text{Ms + Ab + Qtz = Al}_2\text{SiO}_5 + \text{Kfs + liquid}
\]

Migmatites

- Dehydrated rocks become granulites
- Some high-grade rocks appear “mixed”
  - Dark schistose layers (melanosome) 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.

a. Breccia structure in agmatite.
b. Net-like structure.
c. Raft-like structure.
d. Vein structure.
e. Stromatic, or layered, structure.
f. Dilation structure in a boudinaged layer.
g. Schleiren structure.
h. Nebulitic structure.

From Mehnert (1968)