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

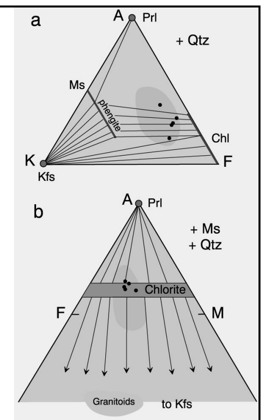
Chemical Characteristics

- High Al_2O_3 and K_2O, 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 K_2O-FeO-MgO-Al_2O_3-SiO_2-H_2O ("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.**



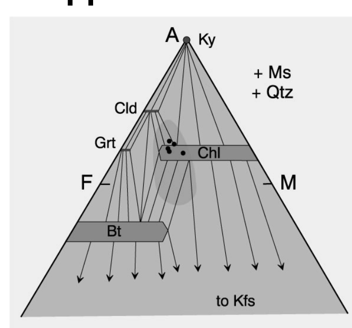
Biotite Zone

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

  Chl + Kfs = Bt + Ms (+ Qtz + H_2O)

- 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°

$$Chl + Prl = Cld \ (+ Qtz + H_2O)$$

- Chloritoid goes out at T = 590°

$$Cld = Grt + St \ (+Qtz + H_2O)$$

Garnet Zone

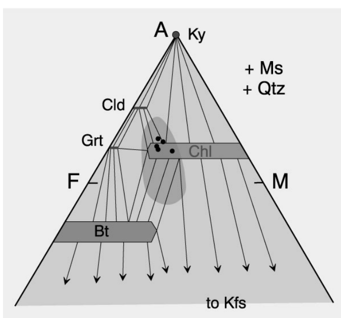
- In Fe-rich rocks at ~ 525°

$$Fe\text{-}Chl \ (+ Qtz) = Alm \ (+ H_2O)$$

- Under medium P-T in normal pelites the reaction occurs at ~ 610°

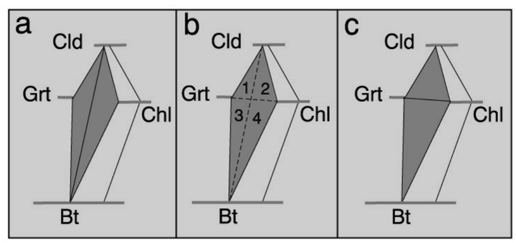
$$Chl \ (+Ms + Qtz) = Grt + Bt \ (+ H_2O)$$

Garnet Zone



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)

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°

$$Cld + Ky = St + Chl \ (+Qtz + H_2O)$$

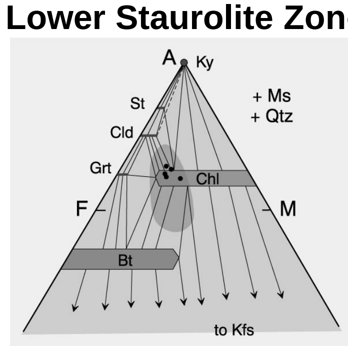
- An alternate reaction occurs at 610°

$$Grt + Chl = St + Bt \ (+Qtz + H_2O)$$

- Staurolite goes out at ~700°

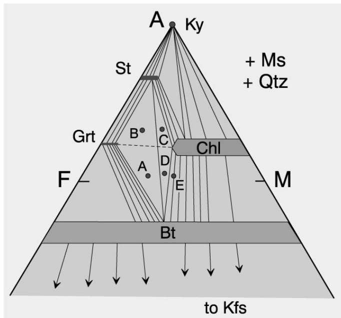
$$St \ (+Ms + Qtz) = Grt + Bt + Als + H_2O$$

Lower Staurolite Zone



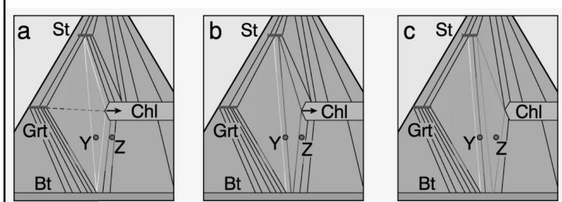
AFM projection showing the change in topology in which the lower-grade Cld-Ky tie-line (dashed) is lost and replaced by the St-Chl tie-line. This reaction introduced staurolite to only a small range of Al-rich metapelites. After Spear (1993) and Winter (2001).

Staurolite Zone



AFM diagram showing the tie-line flip 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. 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).

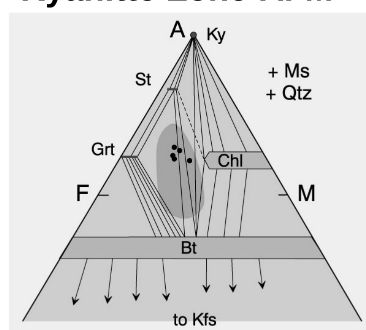
Kyanite Zone

- Under medium P-T at ~630°

  St + Chl (+Ms +Qtz) = Ky + Bt (+H_2O)

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

Kyanitte 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

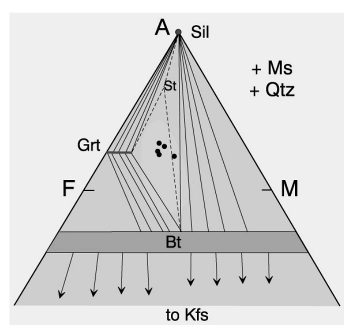
- Sillimanite nucleates as tiny needles on micas
- Muscovite goes out at ~ 790°

  Ms + Qtz = Kfs + Sil + H_2O

- Cordierite appears at higher temperatures

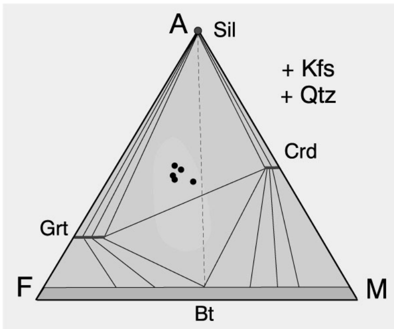
  Phl + Sil (+Qtz) = Mg-Cdr (+Kfs + H_2O)

Sillimanite Zone



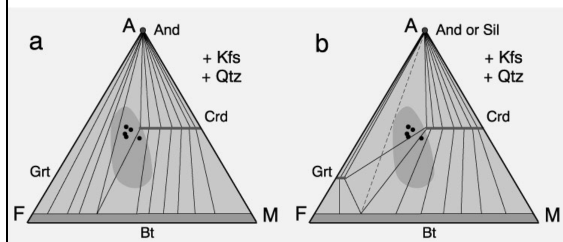
AFM projection above the sillimanite and "staurolite-out" isograds. Winter (2001).

Granulite Facies



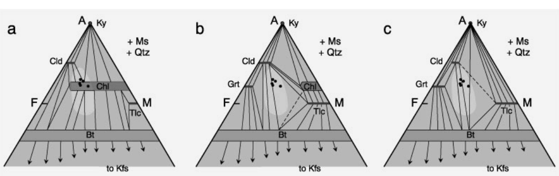
AFM diagram above the cordierite-in isograds, granulite facies. Cordierite forms and then the dashed Sil-Bt tie-line is lost and the Grt-Crd tie-line forms. Winter (2001).

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

$$Ms + Ab + Qtz = Al_2SiO_5 + Kfs + liquid$$

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 from Mehnert (1968)

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.