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

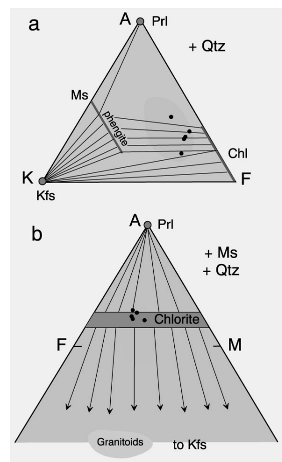
Chemical Characteristics

- 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.



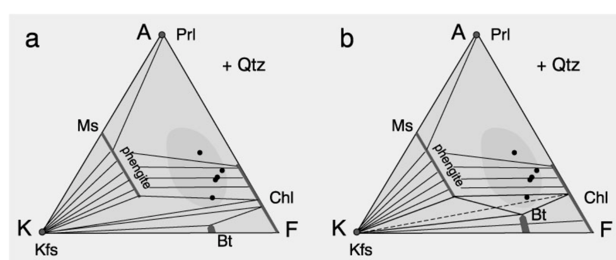
Biotite Zone

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

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

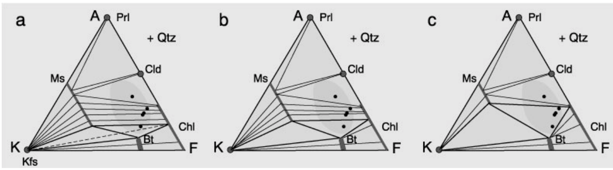
- K-spar is generally consumed before all chlorite is consumed, thus it persists

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



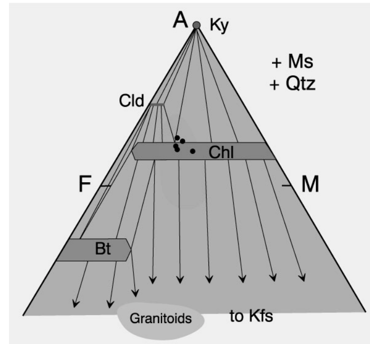
In (a), below the isograd, the tie-lines connecting chlorite and K-Feldspar shows that the mineral pair is stable. As grade increases the Chl-Kfs field shrinks to a single tie-line. In (b), above the isograd, biotite + phengite is now stable, and chlorite + K-feldspar are separated by the new biotite-phengite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

Biotite Zone



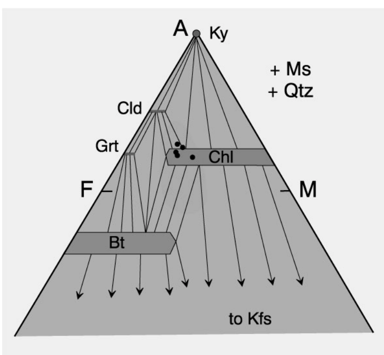
Series of AKF diagrams illustrating the migration of the Ms-Bt-Chl and Ms-Kfs-Chl sub-triangles to more Al-rich compositions via continuous reactions in the biotite zone of the greenschist facies above the biotite isograd. Winter (2001)

Biotite Zone



AFM projection for the biotite zone, greenschist facies, above the chloritoid isograd. The compositional ranges of common pelites and granitoids are shaded. 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 > 250º

  Chl + Prl = Cld (+ Qtz + H_2O)

- Chloritoid goes out at T = 590°

  Cld = Grt + St (+Qtz +H_2O)

Garnet Zone

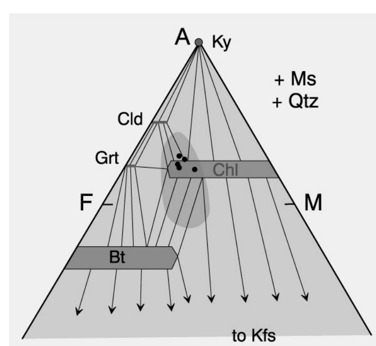
- In Fe-rich rocks at ~ 525°

  Fe-Chl (+ Qtz) = Alm (+ H_2O)

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

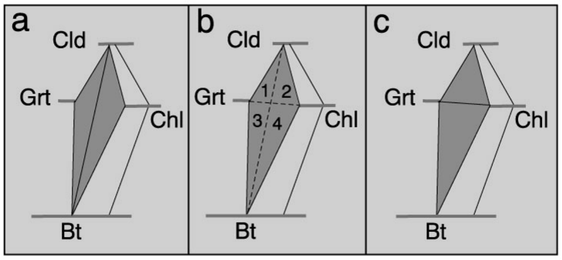
  Chl (+Ms + Qtz) = Grt + Bt (+ H_2O)

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

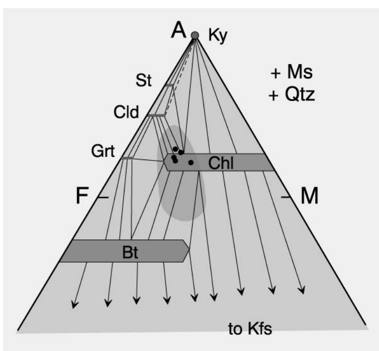
- Under medium P-T may appear at 570°

  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°

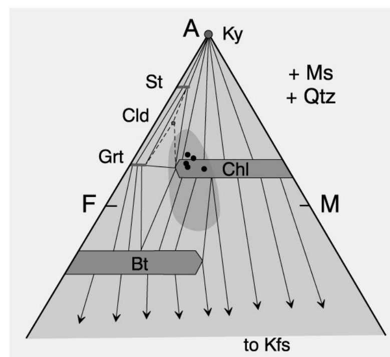
  St (+Ms +Qtz) = Grt +Bt +Als +H_2O

Lower Staurolite Zone



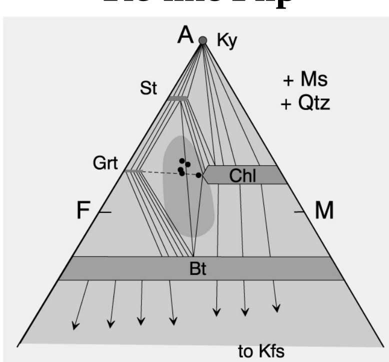
AFM projection showing the change in topology in which the lower-grade Cld-Ky tie-line (dashed) is lost and replaced by the St-Chl tie-line. This reaction introduced staurolite to only a small range of Al-rich metapelites. After Spear (1993) and Winter (2001).

Staurolite Zone



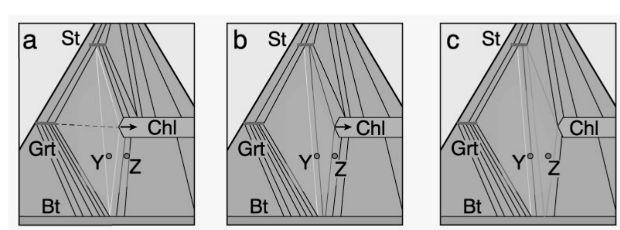
AFM projection showing the topology associated with the reaction in which chloritoid is lost, yielding to the Grt-St-Chl sub-triangle that surrounds it. Winter (2001)

Tie-line Flip



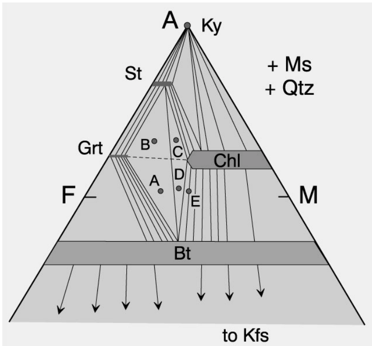
AFM diagram showing the tie-line flip associated with reaction which introduces staurolite into many low-Al common pelites (shaded). After Carmichael (1970) *and* Winter (2001).

Tie-line Flip: Staurolite



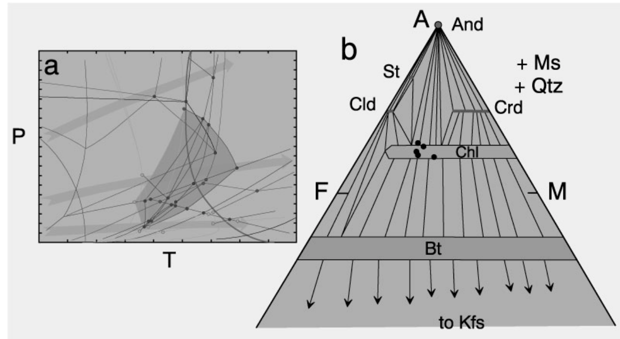
Expanded Grt-St-Chl-Bt quadrilateral. a. At the isograd tie-line flip. Composition Y loses Grt and gains St. b. As reaction proceeds, Fe-rich chlorite breaks down and the Chl-Grt-Bt triangle shifts to the right. c. Further shift of the Chl-Grt-Bt triangle. Rocks of composition Y lose chlorite at this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

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)

Staurolite Satbility



a. **The stability range of staurolite (red).**
b. **b. AFM projection ~ 530-560°C P> 0.2 GPa, in which staurolite is stable and may occur in some high-Fe-Al pelites (shaded). Winter (2001).**

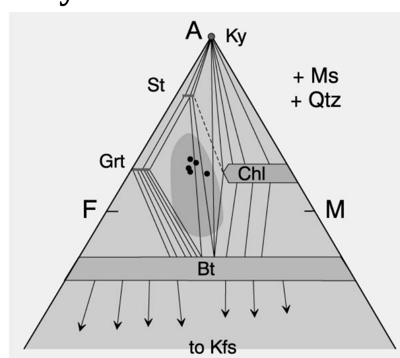
Kyanite Zone

- 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

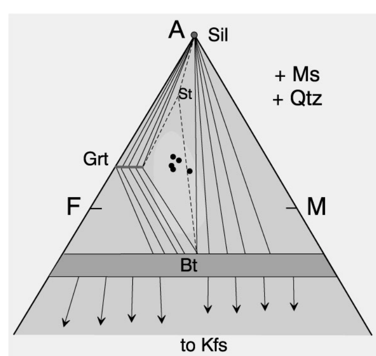
- Sillimanite nucleates as tiny needles on micas
- Muscovite goes out at ~ 790°

  Ms + Qtz = Kfs + Sil + H_2O

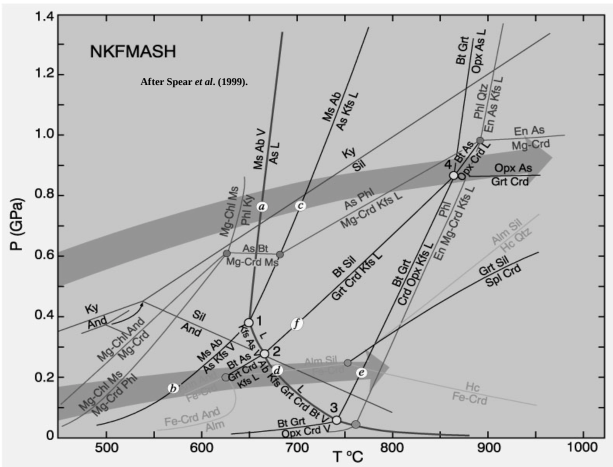
- Cordierite appears at higher temperatures

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

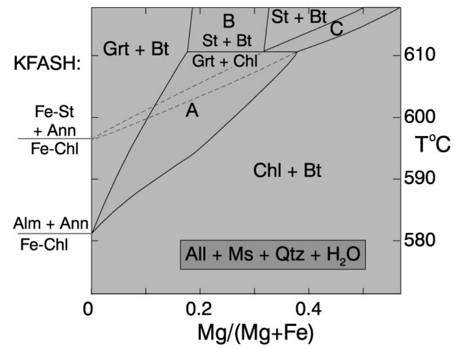
Sillimanite Zone



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

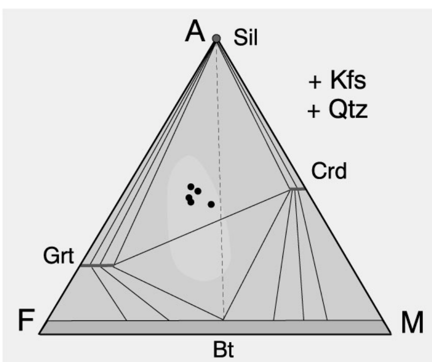


Pelite KFMASH



T-X_{Mg} "pseudosection" diagram of Mg/Fe for a pelite with molar A:F:K = 0.92:1:0.28, calculated by Powell *et al.* (1998) modified by 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).

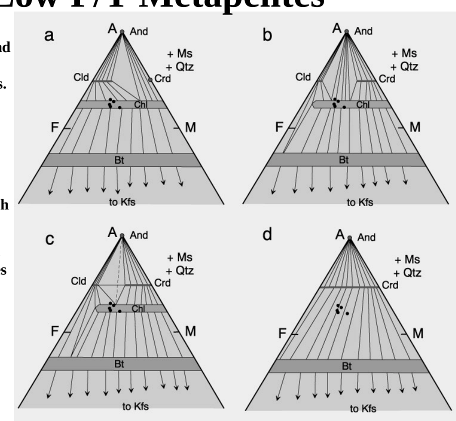
Low P/T Metapelites

a. Cordierite forms between andalusite and chlorite in the albite-epidote hornfels facies.

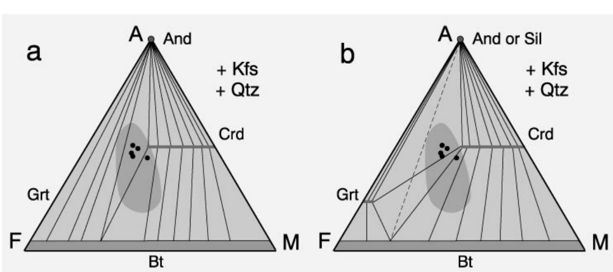
b. The compositional range of chloritoid is reduced and that of cordierite expands. . Andalusite may be introduced into Al-rich pelites.

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).

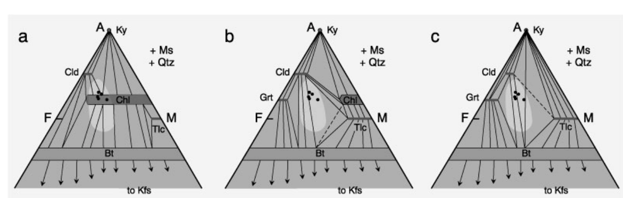


Pyroxene Hornfels



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

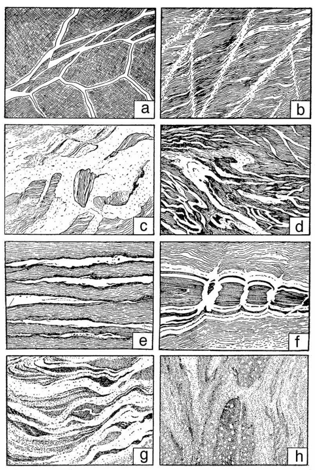
- Assume all the water is due to metamorphic dehydration reactions
- Muscovite decomposition causes melting, provided the pressure is high enough to retain the water

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.

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)