The AKF Diagram

Because pelitic sediments are high in Al_2O_3 and K_2O, and low in CaO, Eskola proposed a different diagram that included K_2O to depict the mineral assemblages that develop in them

- In the AKF diagram, the pseudo-components are:

  $A = Al_2O_3 + Fe_2O_3 - Na_2O - K_2O - CaO$

  $K = K_2O$

  $F = FeO + MgO + MnO$

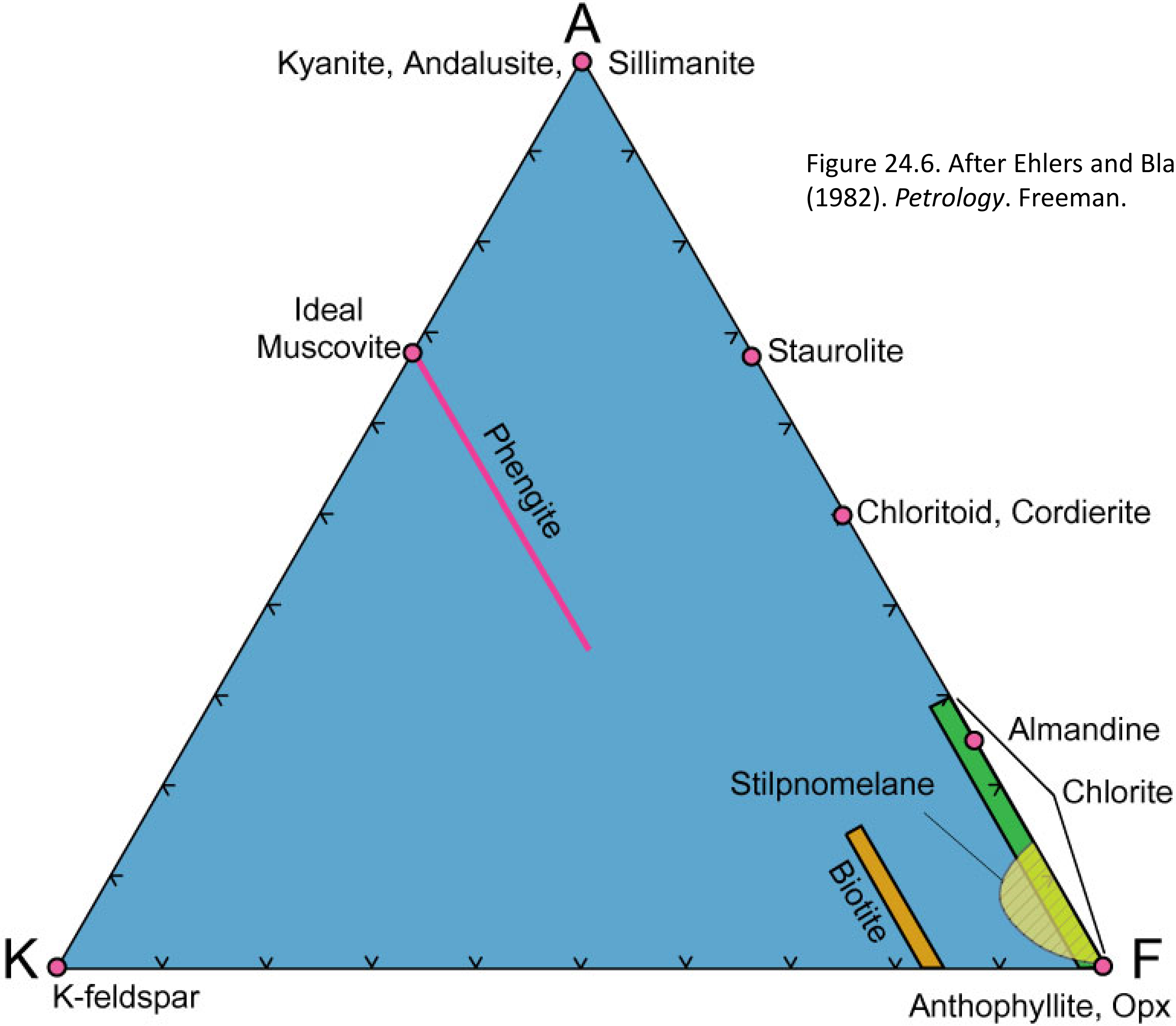
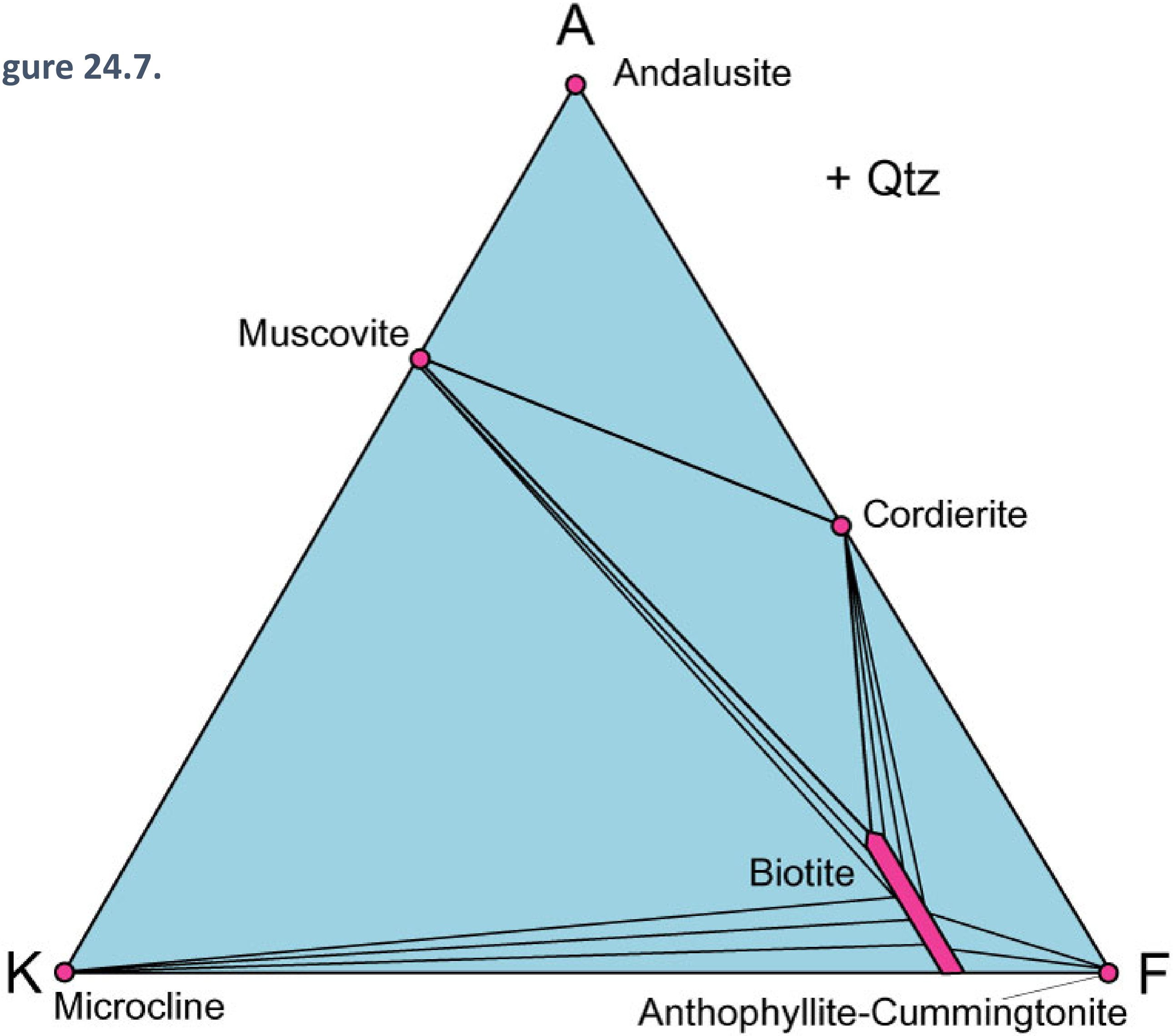


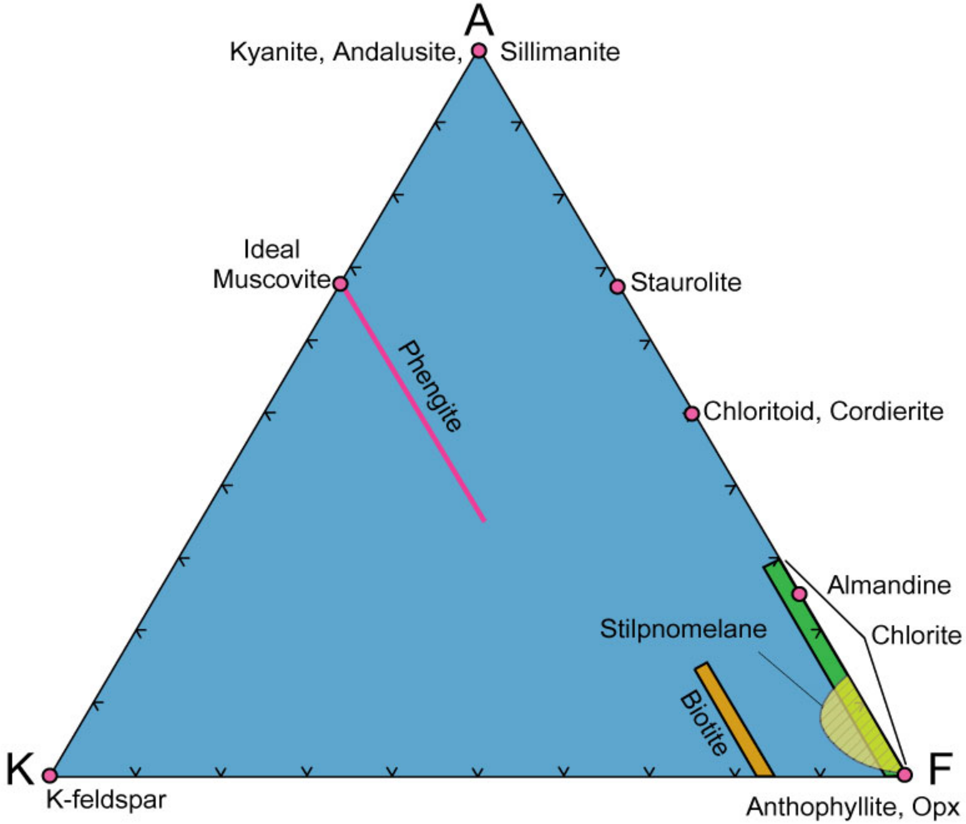
Figure 24.6. After Ehlers and Blatt (1982). *Petrology*. Freeman.

AKF compatibility diagram (Eskola, 1915) illustrating paragenesis of pelitic hornfelses, Orijärvi region Finland

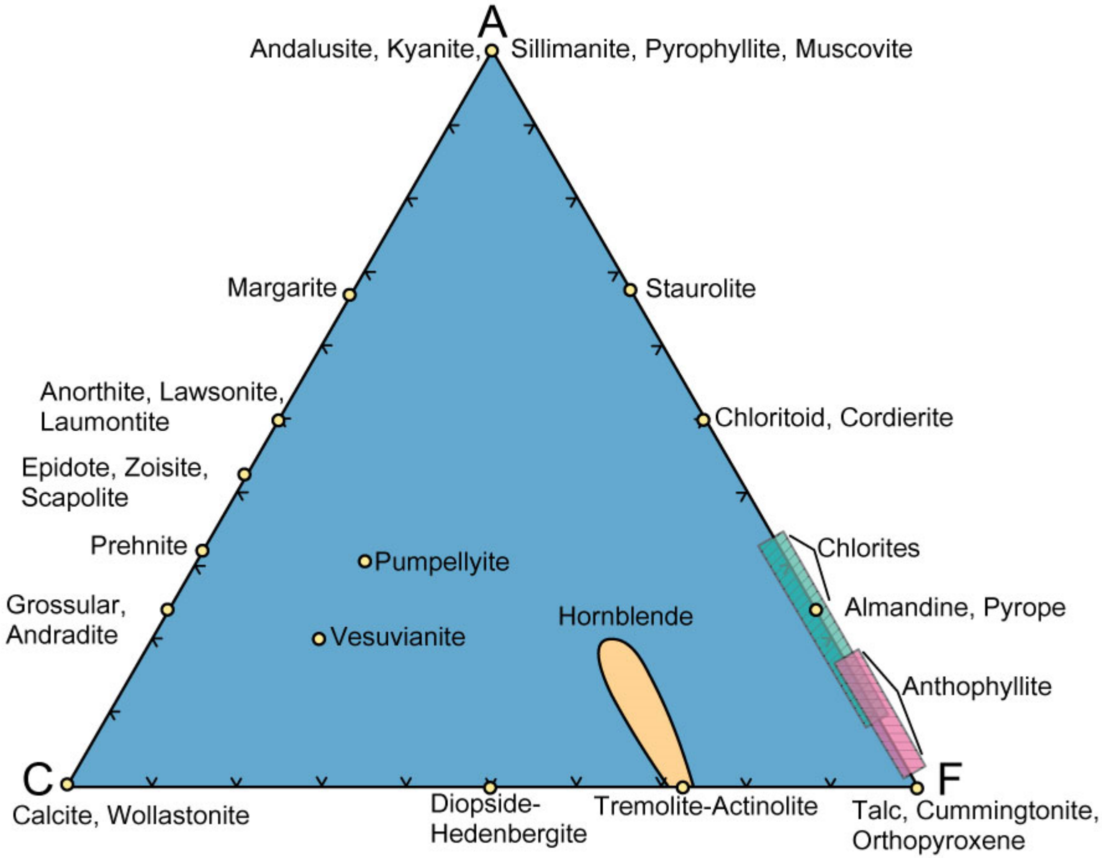
Figure 24.7.



Three of the most common minerals in metapelites: **andalusite**, **muscovite**, and **microcline**, all plot as distinct points in the AKF diagram



- And & Ms plot as the same point in the ACF diagram, and Microcline doesn’t plot at all, so the ACF diagram is much less useful for pelitic rocks (rich in K and Al)



Projections in Chemographic Diagrams

When we explore the methods of chemographic projection we will discover:

- Why we ignored SiO_2 in the ACF and AKF diagrams
- What that subtraction was all about in calculating A and C
- It will also help you to better understand the AFM diagram and some of the shortcomings of projected metamorphic phase diagrams

Projection from Apical Phases

Example- the ternary system: CaO-MgO-SiO_2 ("CMS")

Straightforward: C = CaO, M = MgO, and S = SiO_2… none of that fancy subtracting business!

- Let's plot the following minerals:

Fo - Mg_2SiO_4

En - $MgSiO_3$

Di - $CaMgSi_2O_6$

Per - MgO

Qtz - SiO_2

Cc - $CaCO_3$

Projection from Apical Phases

Fo - Mg_2SiO_4

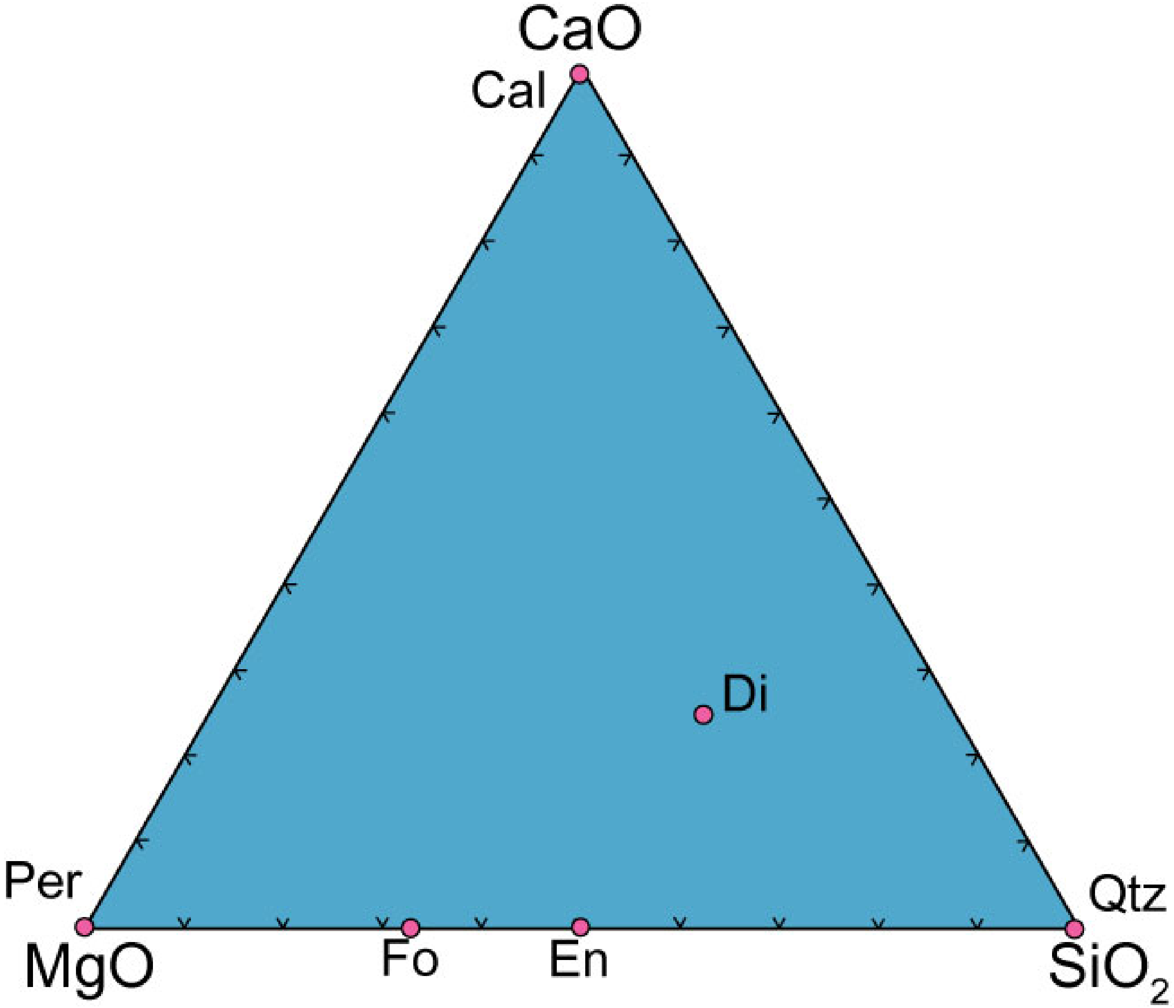
Per - MgO

En - $MgSiO_3$

Qtz - SiO_2

Di - $CaMgSi_2O_6$

Cc - $CaCO_3$

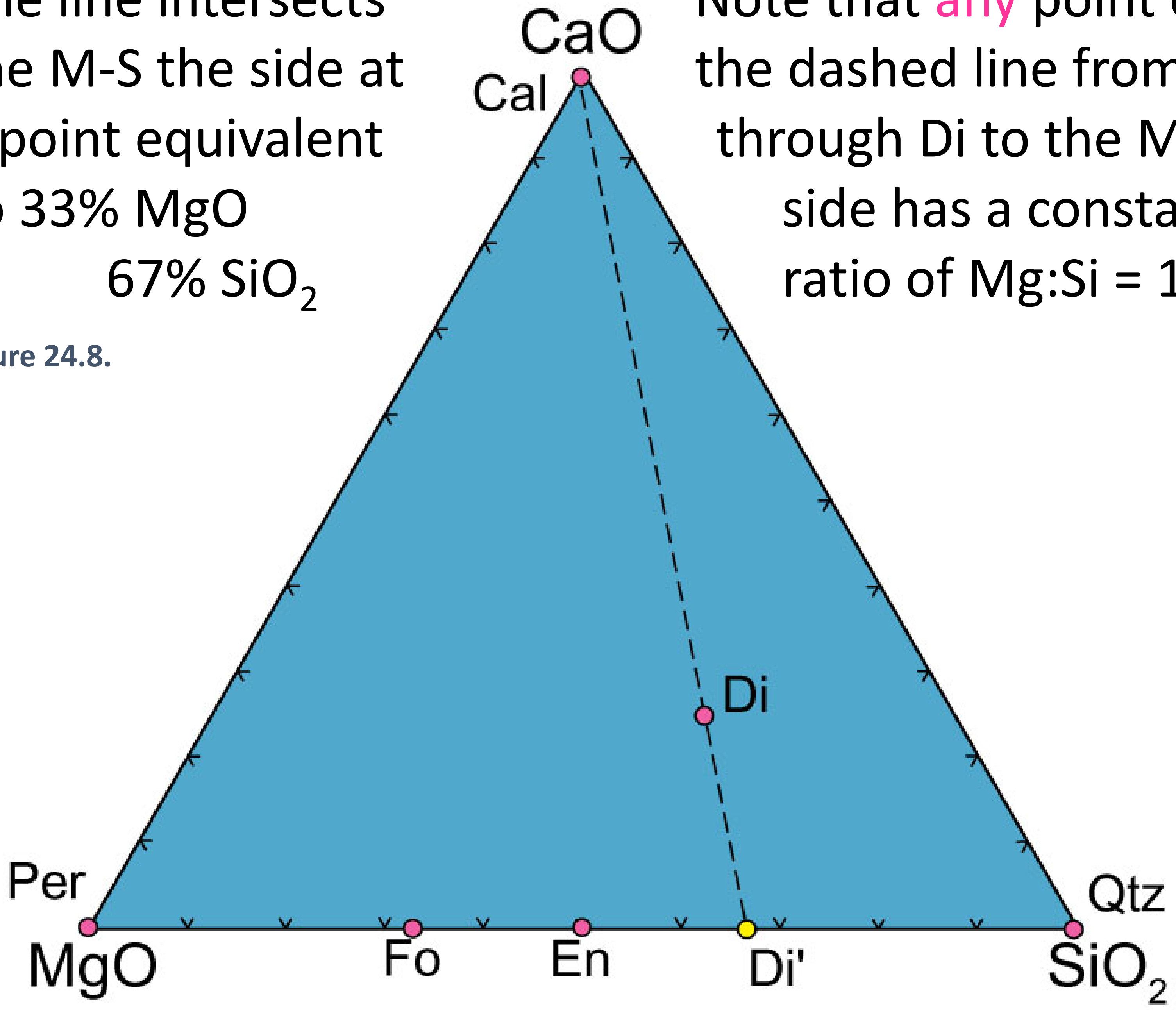


The line intersects the M-S the side at a point equivalent to 33% MgO

67% SiO_2

Note that any point on the dashed line from C through Di to the M-S side has a constant ratio of Mg:Si = 1:2

Figure 24.8.

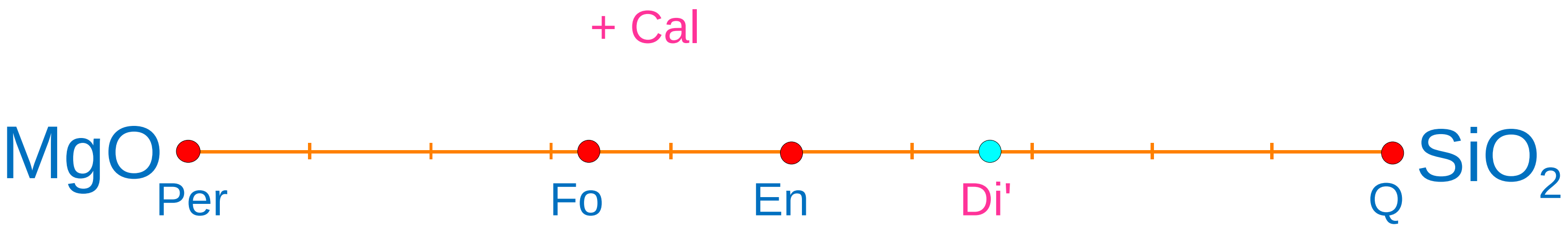


Projection from Apical Phases

Fo - Mg_2SiO_4 Per - MgO En - $MgSiO_3$

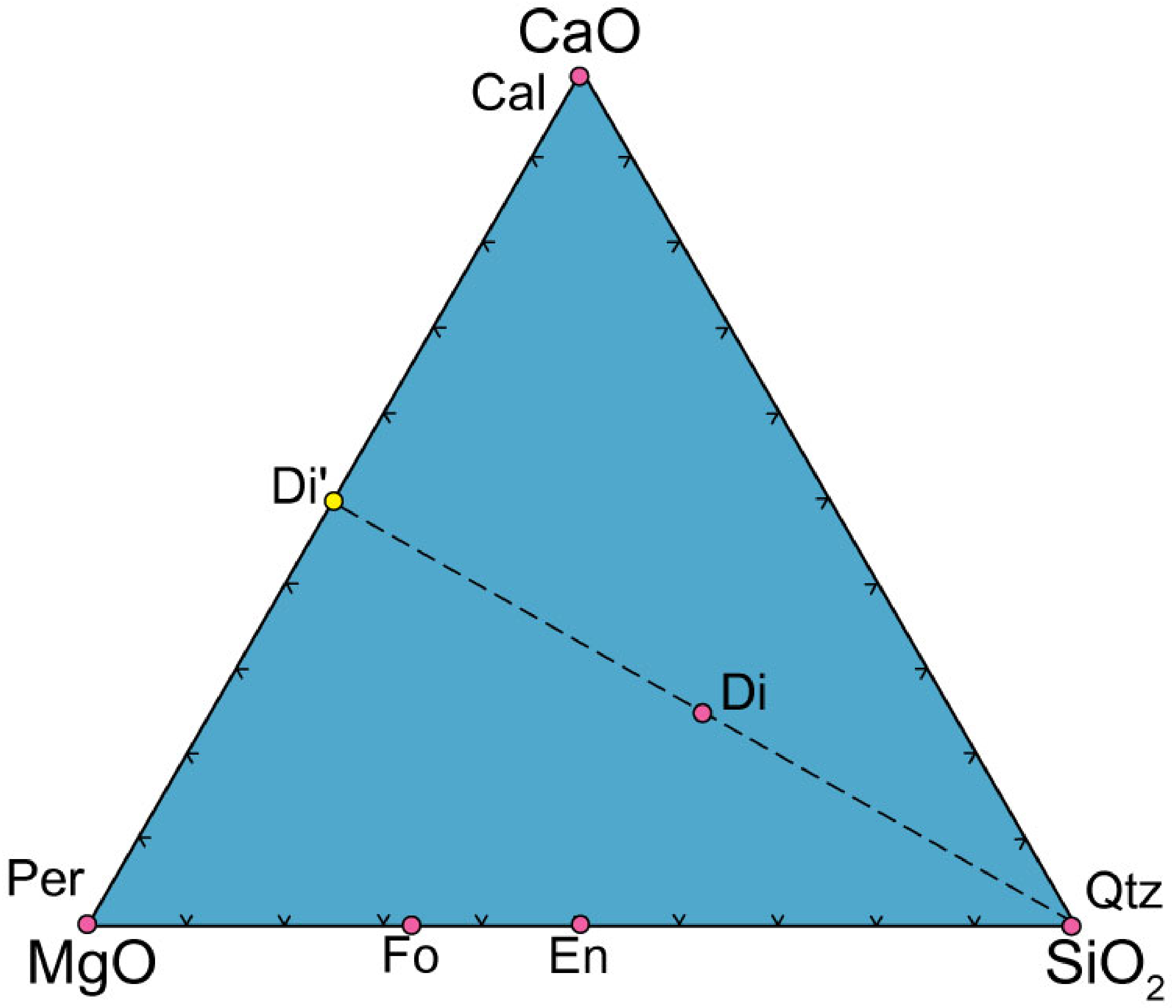
Qtz - SiO_2 Di - $CaMgSi_2O_6$ Cc - $CaCO_3$

Pseudo-binary Mg-Si diagram in which Di is projected to a 33% Mg - 66% Si

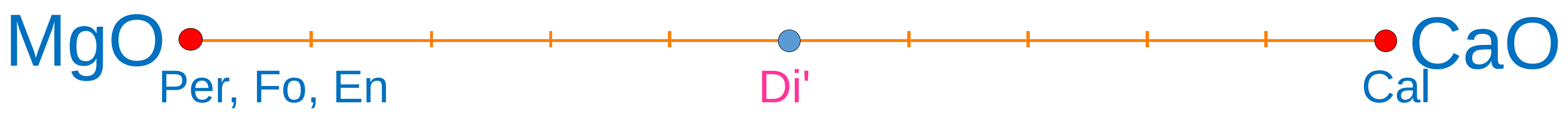


Projection from Apical Phases

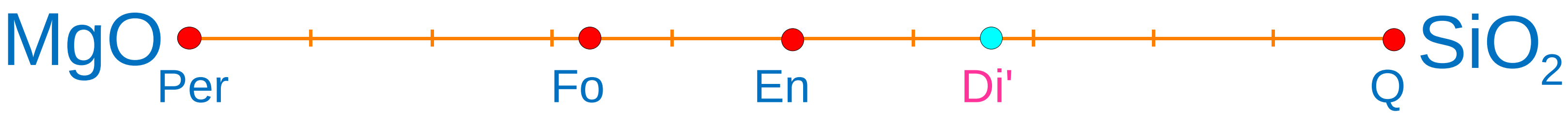
- Could project Di from SiO_2 and get C = 0.5, M = 0.5



+ Qtz



Projection from Apical Phases



- In accordance with the mineralogical phase rule (ϕ = C) get any of the following 2-phase mineral assemblages in our 2-component system:

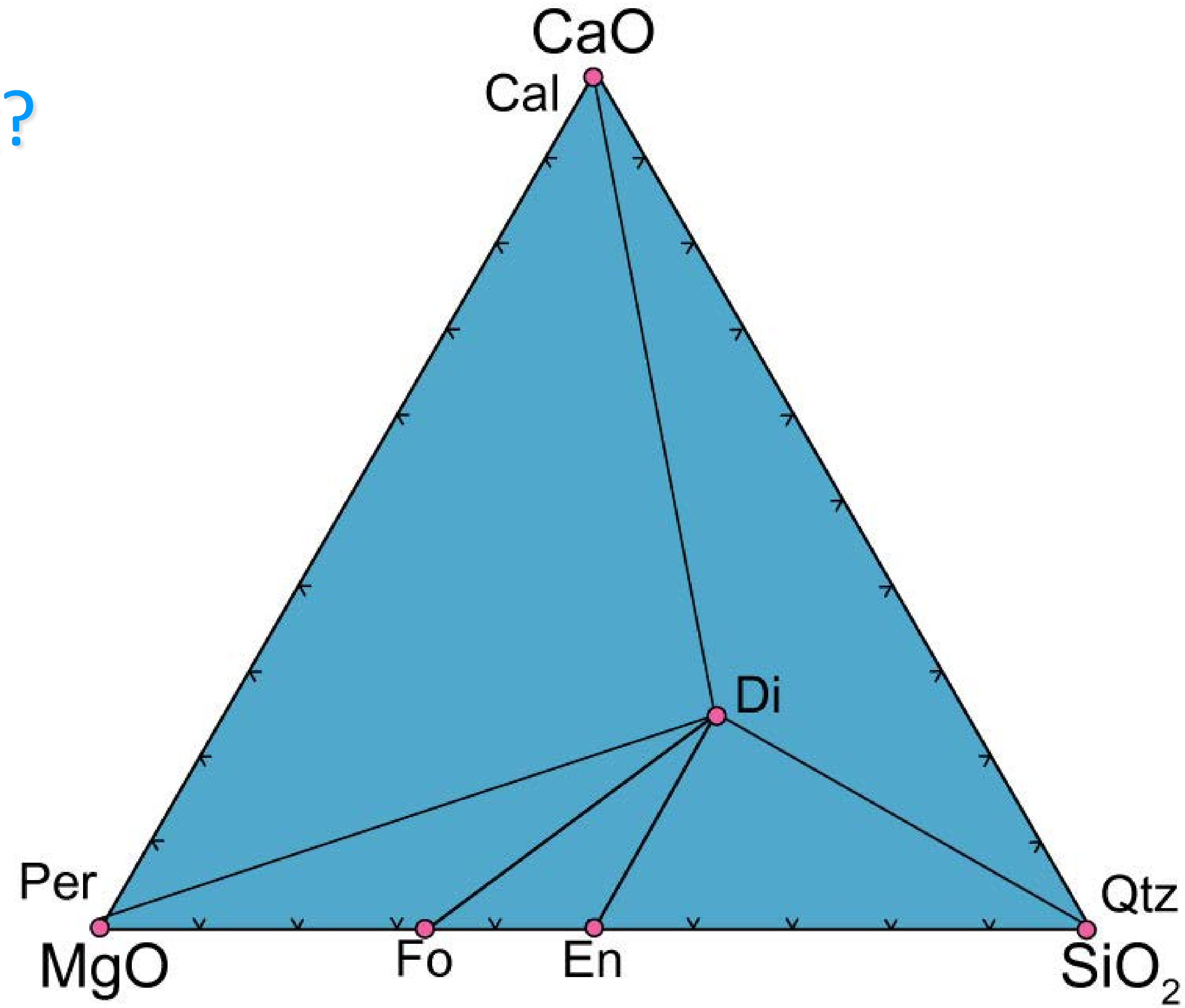
Per + Fo Fo + En

En + Di Di + Q

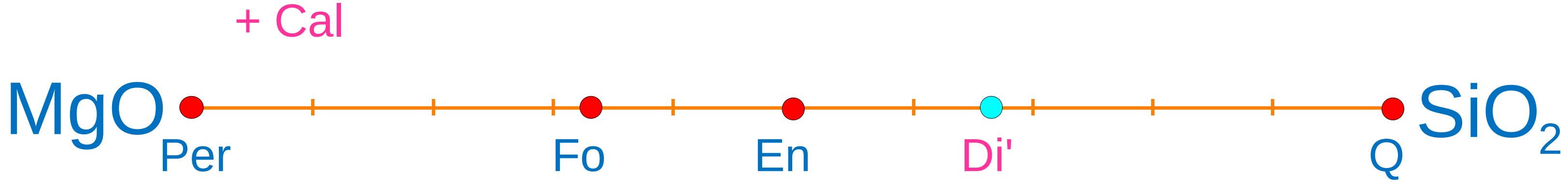
Projection from Apical Phases

What’s wrong?

Figure 24.11. **Winter (2010) An Introduction to Igneous and Metamorphic Petrology. Prentice Hall.**



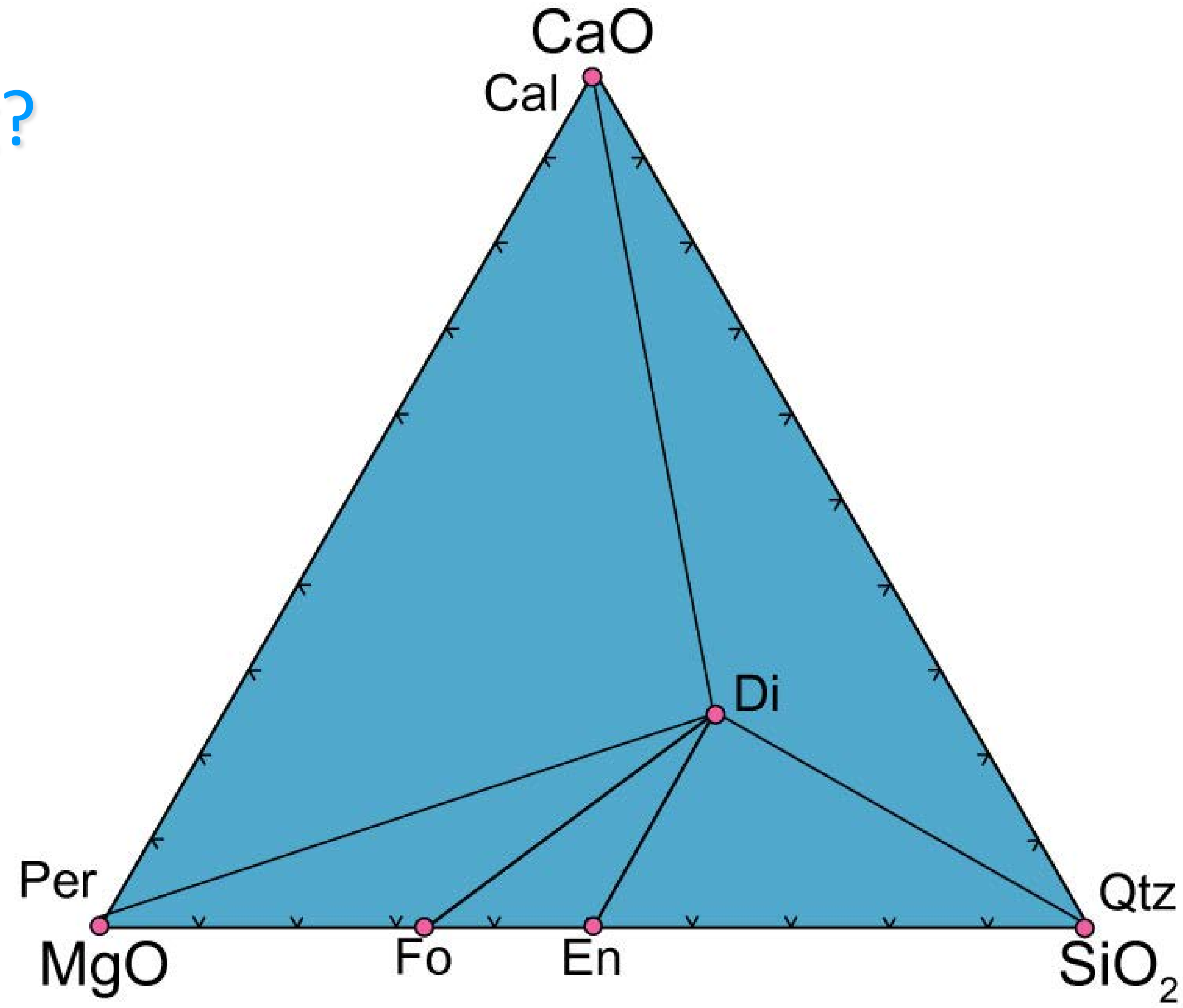
Projected from Calcite



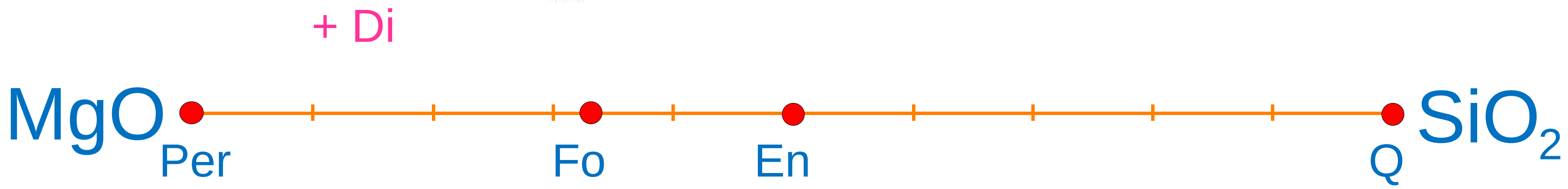
Projection from Apical Phases

What' s wrong?

Figure 24.11. **Winter (2010) An Introduction to Igneous and Metamorphic Petrology. Prentice Hall.**



Better to have projected from Diopside



Projection from Apical Phases

- ACF and AKF diagrams eliminate SiO_2 by projecting from quartz
- Math is easy: projecting from an apex component is like ignoring the component in formulas
- The shortcoming is that these projections compress the true relationships as a dimension is lost

Projection from Apical Phases

Two compounds plot within the ABCQ compositional tetrahedron,

- x (formula ABCQ)
- y (formula A_2B_2CQ)

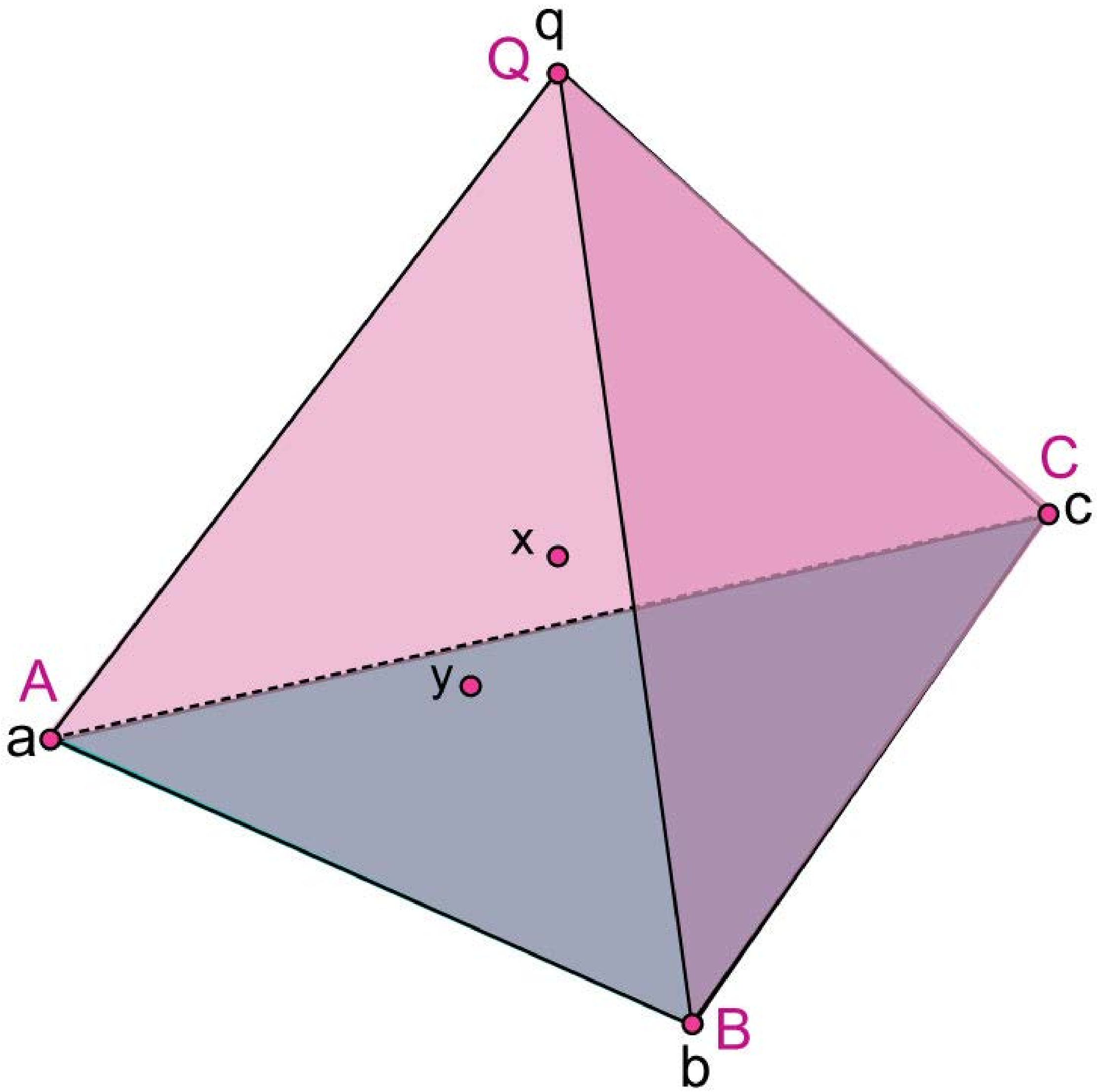


Figure 24.12. Winter (2010) An Introduction to Igneous and Metamorphic Petrology. Prentice Hall.

Projection from Apical Phases

x = ABCQ
y = A_2B_2CQ

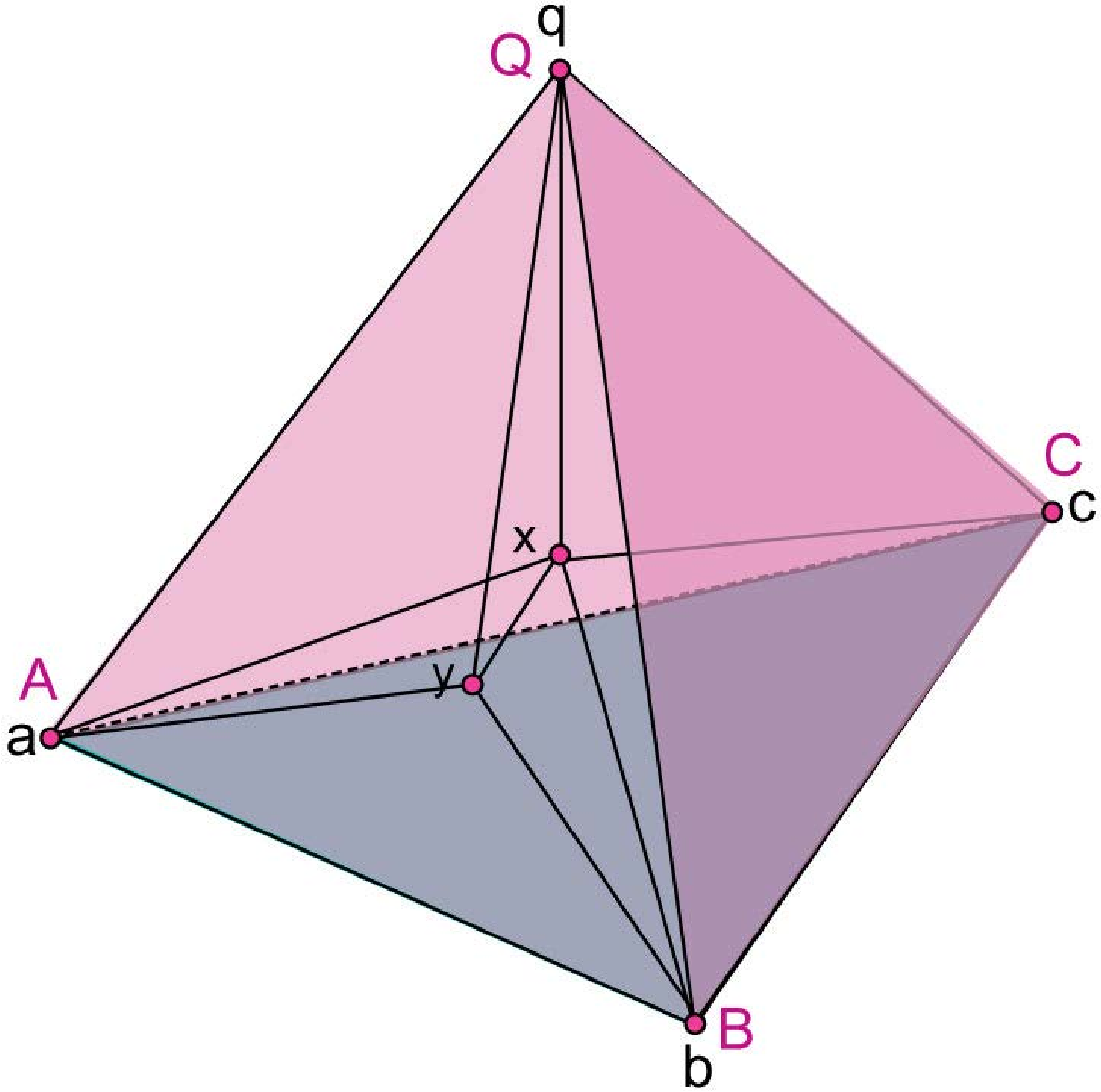


Figure 24.12. Winter (2010) An Introduction to Igneous and Metamorphic Petrology. Prentice Hall.

Projection from Apical Phases

x = ABCQ
y = A_2B_2CQ

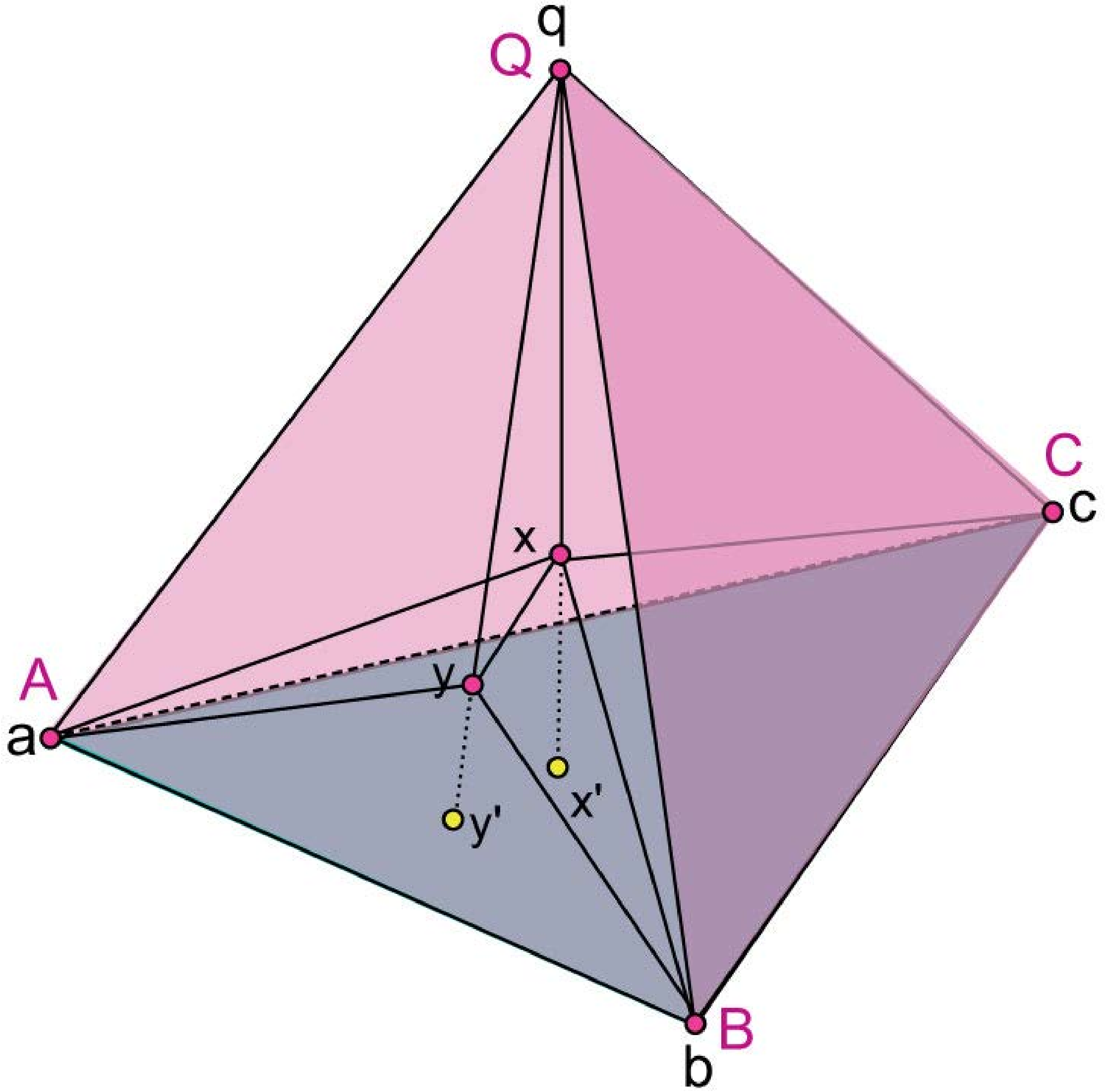


Figure 24.12. Winter (2010) An Introduction to Igneous and Metamorphic Petrology. Prentice Hall.

Projection from Apical Phases

x plots as x' since A:B:C = 1:1:1 = 33:33:33

y plots as y' since A:B:C = 2:2:1 = 40:40:20

x = ABCQ
y = A_2B_2CQ

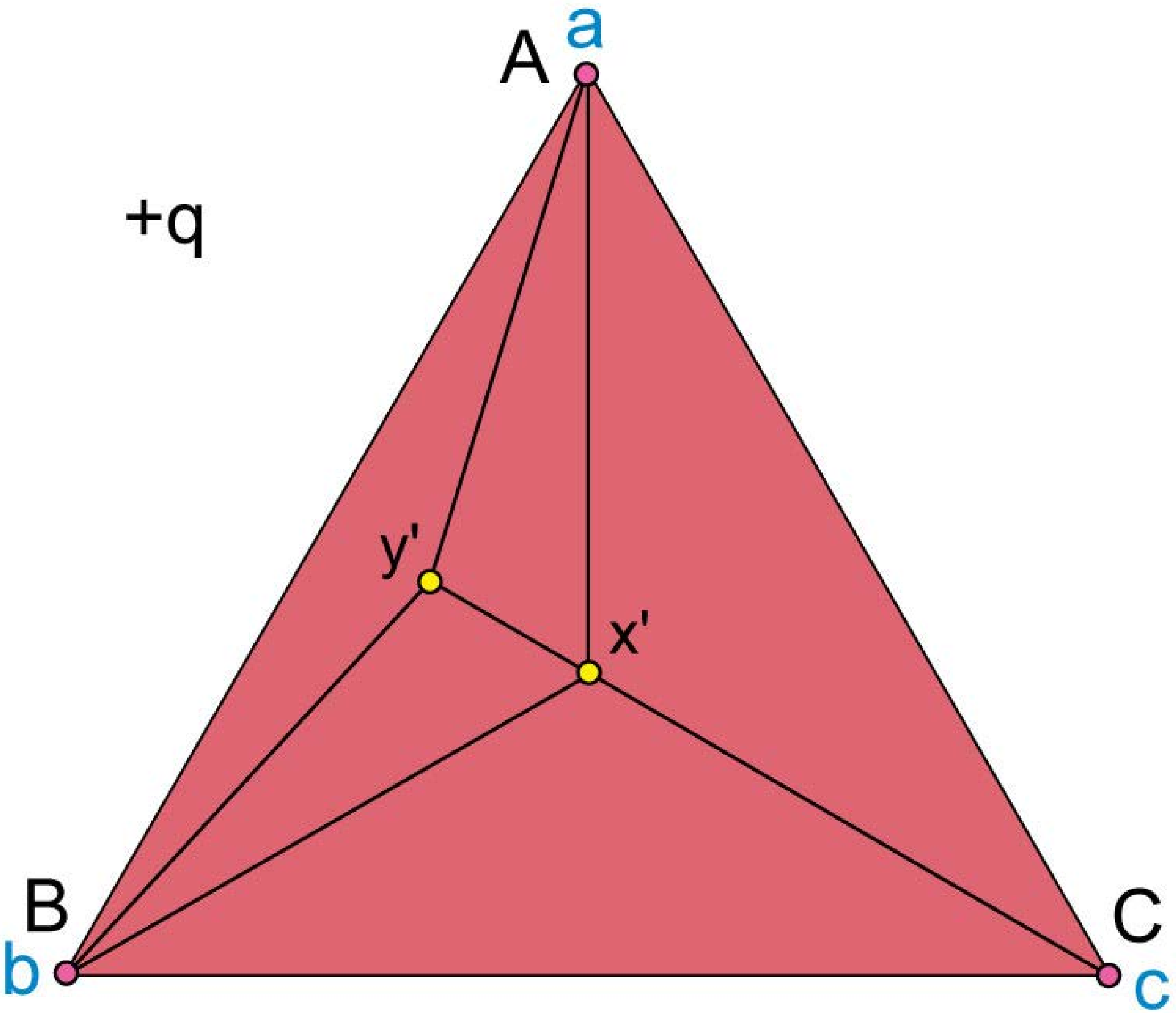


Figure 24.13. **Winter (2010) An Introduction to Igneous and Metamorphic Petrology. Prentice Hall.**

Projection from Apical Phases

If we remember our projection point (q), we conclude from this diagram that the following assemblages are possible:

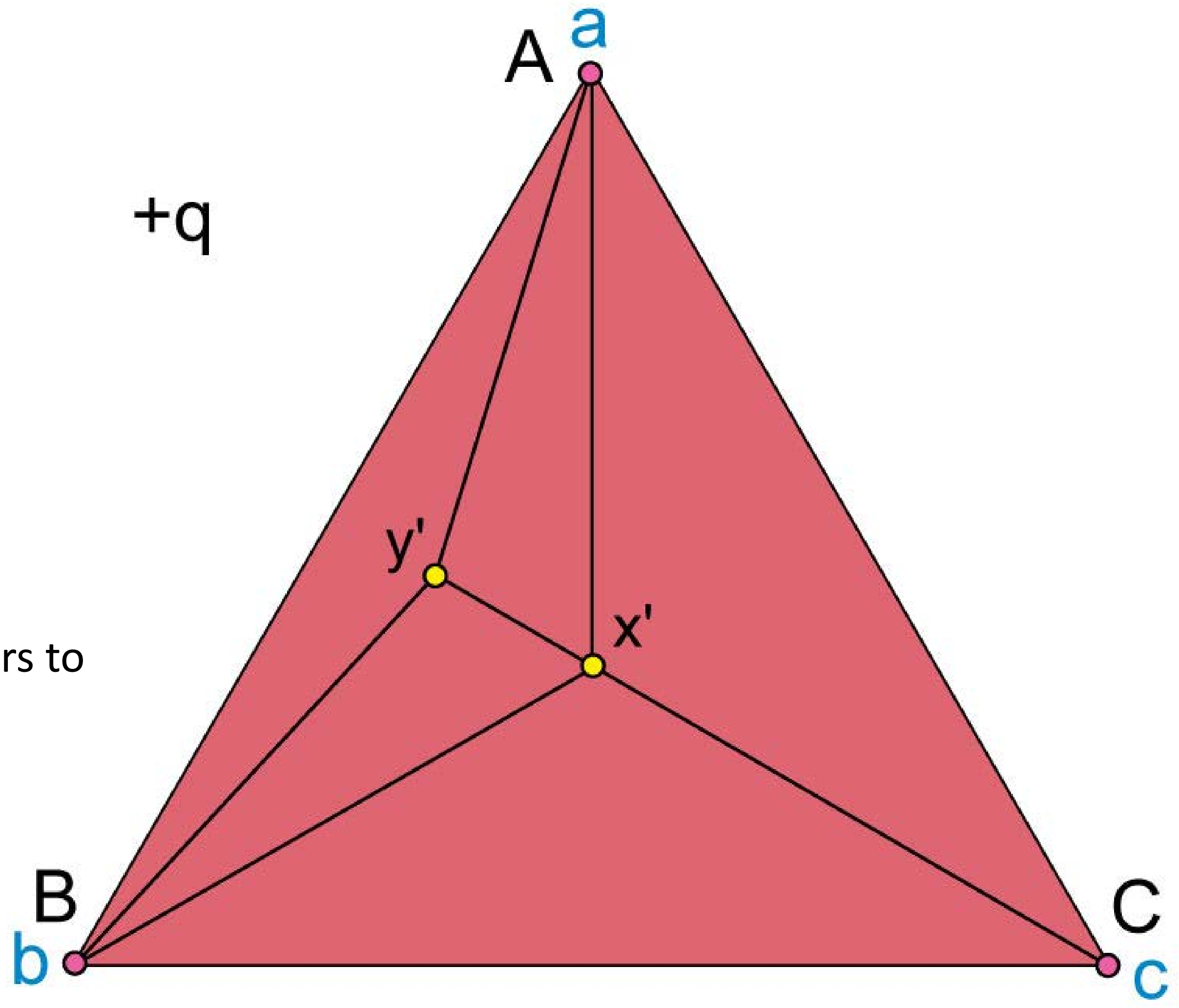
(q)-b-x-c

(q)-a-x-y

(q)-b-x-y

(q)-a-b-y

(q)-a-x-c



The assemblage a-b-c appears to be impossible

Projection from Apical Phases

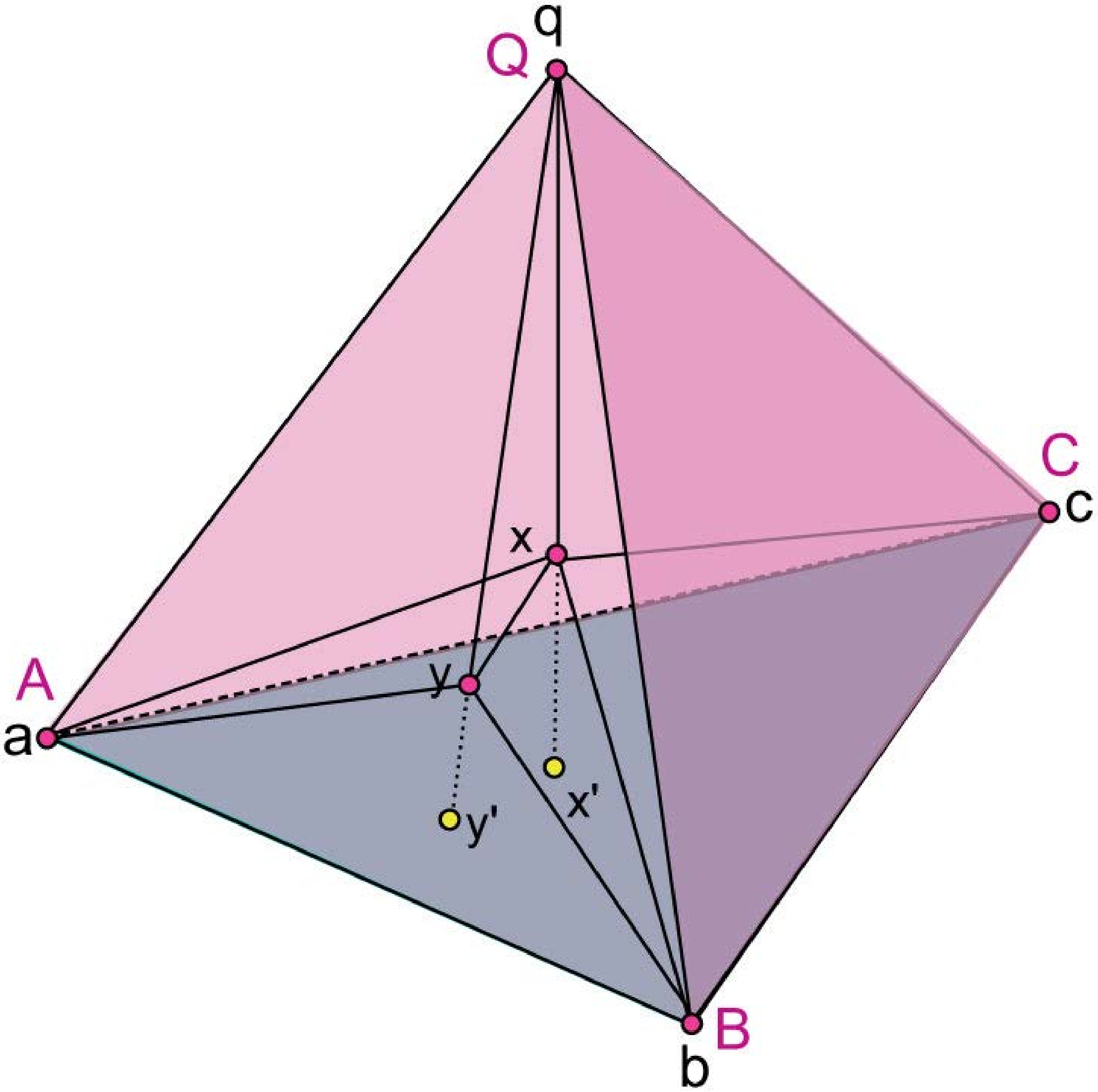
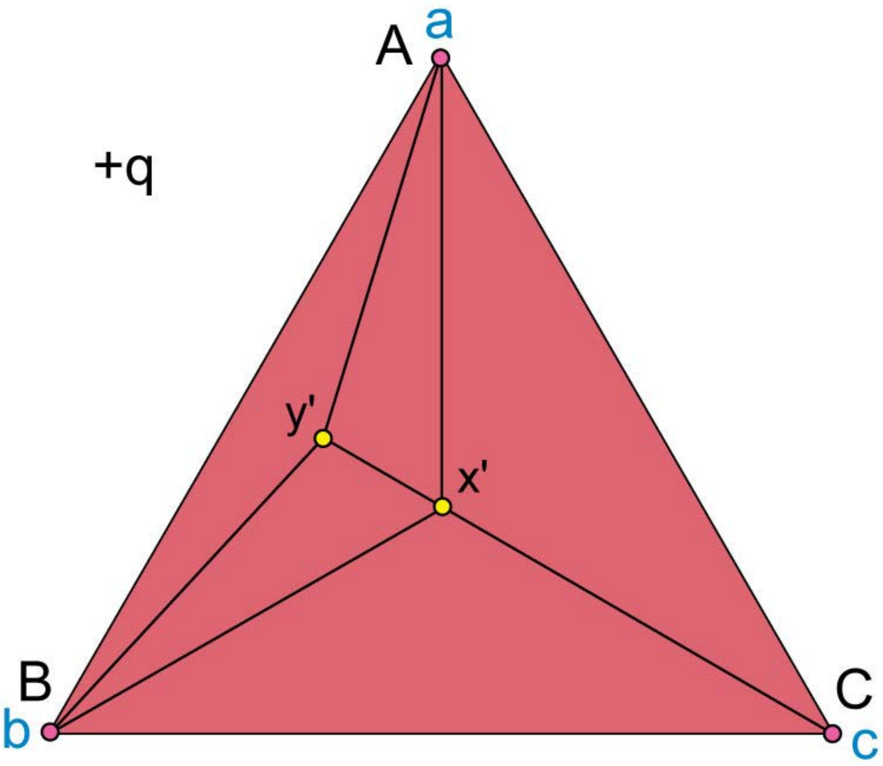
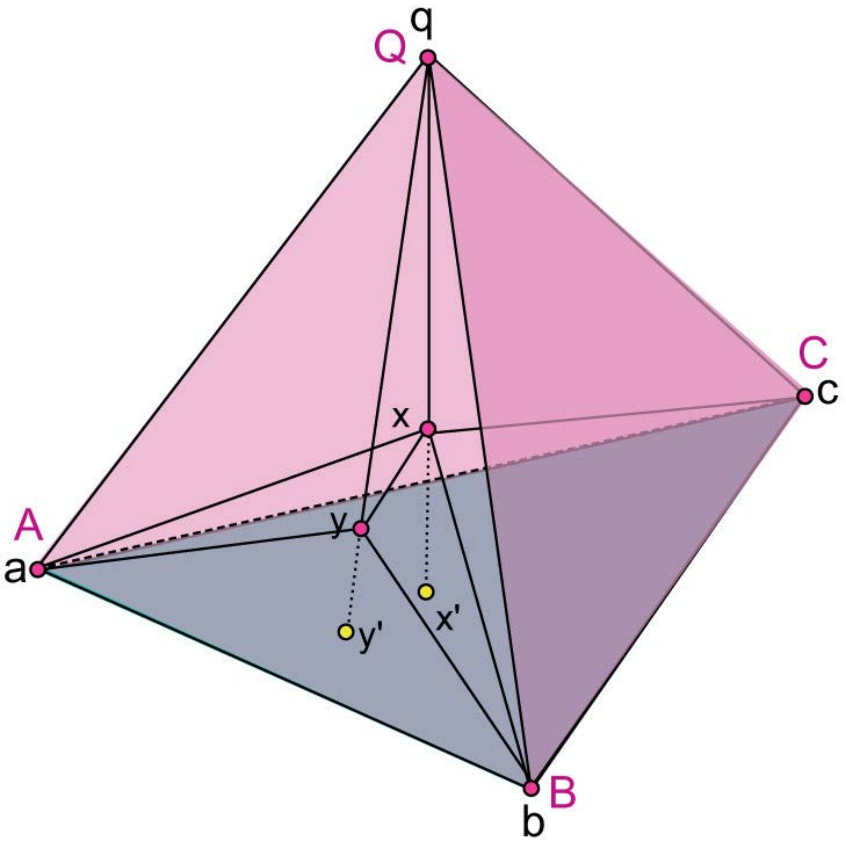


Figure 24.12. **Winter (2010) An Introduction to Igneous and Metamorphic Petrology. Prentice Hall.**

Projection from Apical Phases





J.B. Thompson’s A(K)FM Diagram

An alternative to the **AKF diagram for metamorphosed pelitic rocks**

Although the AKF is useful in this capacity, J.B. Thompson (1957) noted that Fe and Mg do not partition themselves equally between the various mafic minerals in most rocks

J.B. Thompson’s A(K)FM Diagram

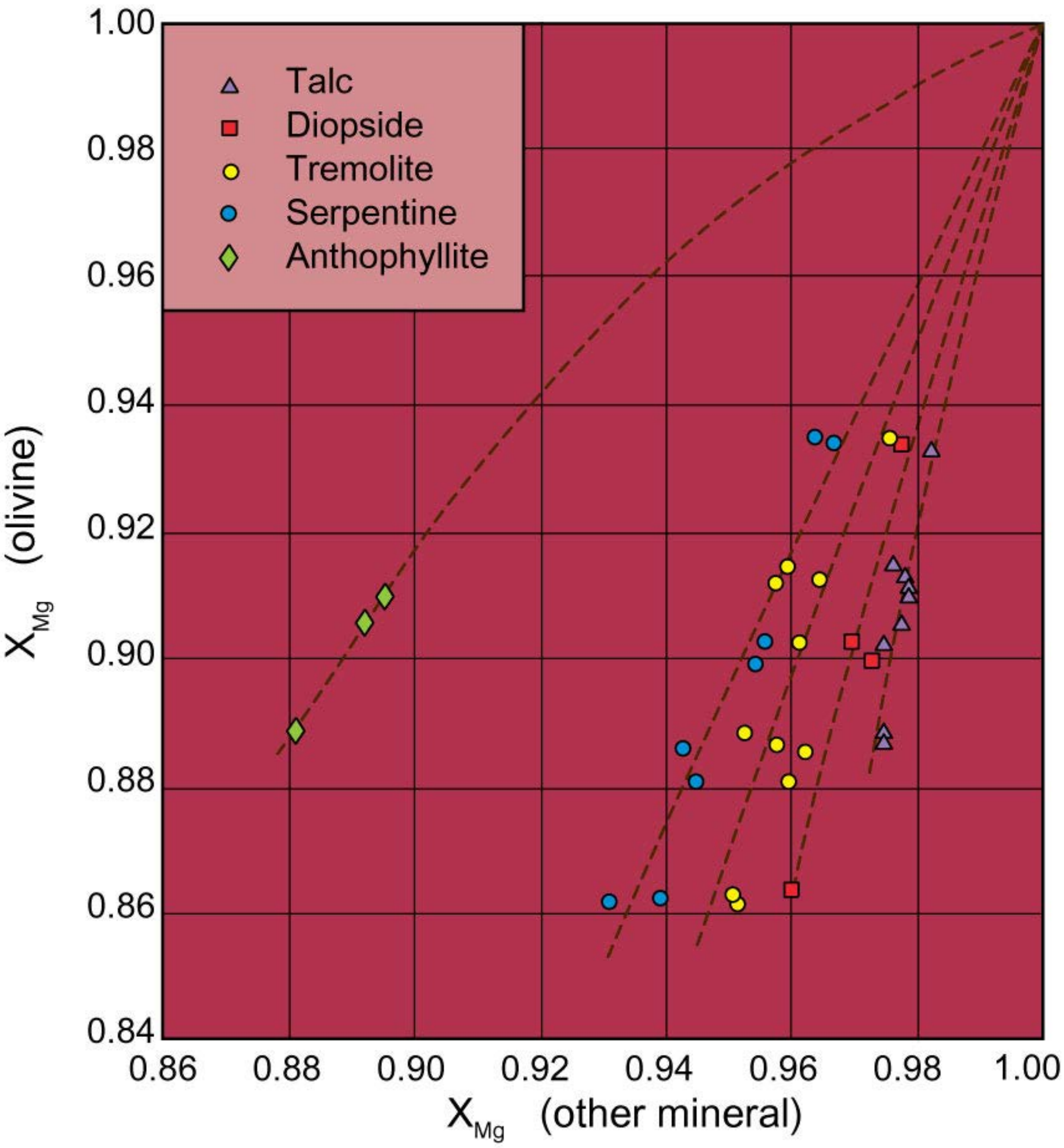


Figure 24.17. Partitioning of Mg/Fe in minerals in ultramafic rocks, Bergell aureole, Italy After Trommsdorff and Evans (1972). A J Sci 272, 423-437.

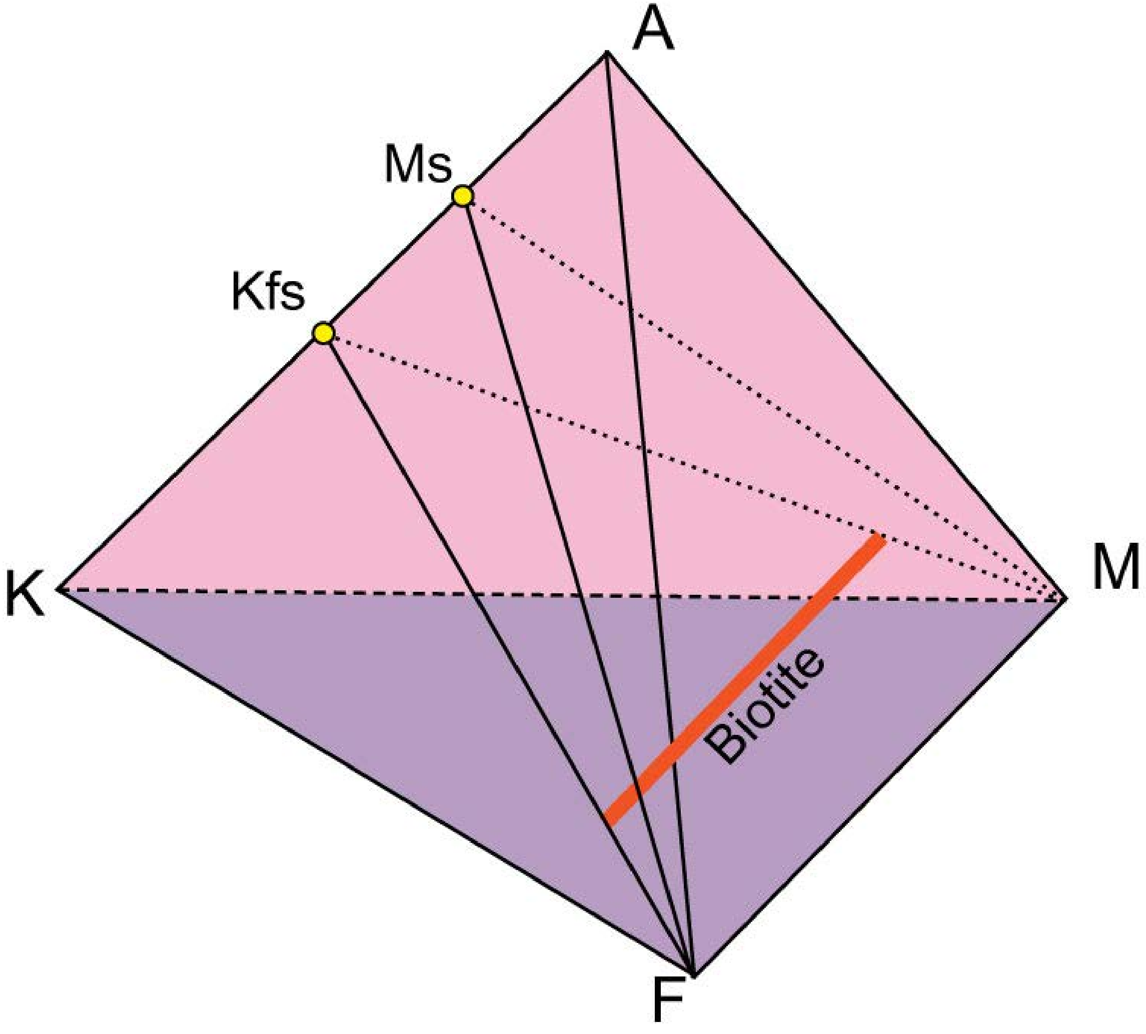
J.B. Thompson' s A(K)FM Diagram

A = Al_2O_3

K = K_2O

F = FeO

M = MgO



J.B. Thompson's A(K)FM Diagram

Project from a phase that is present in the mineral assemblages to be studied

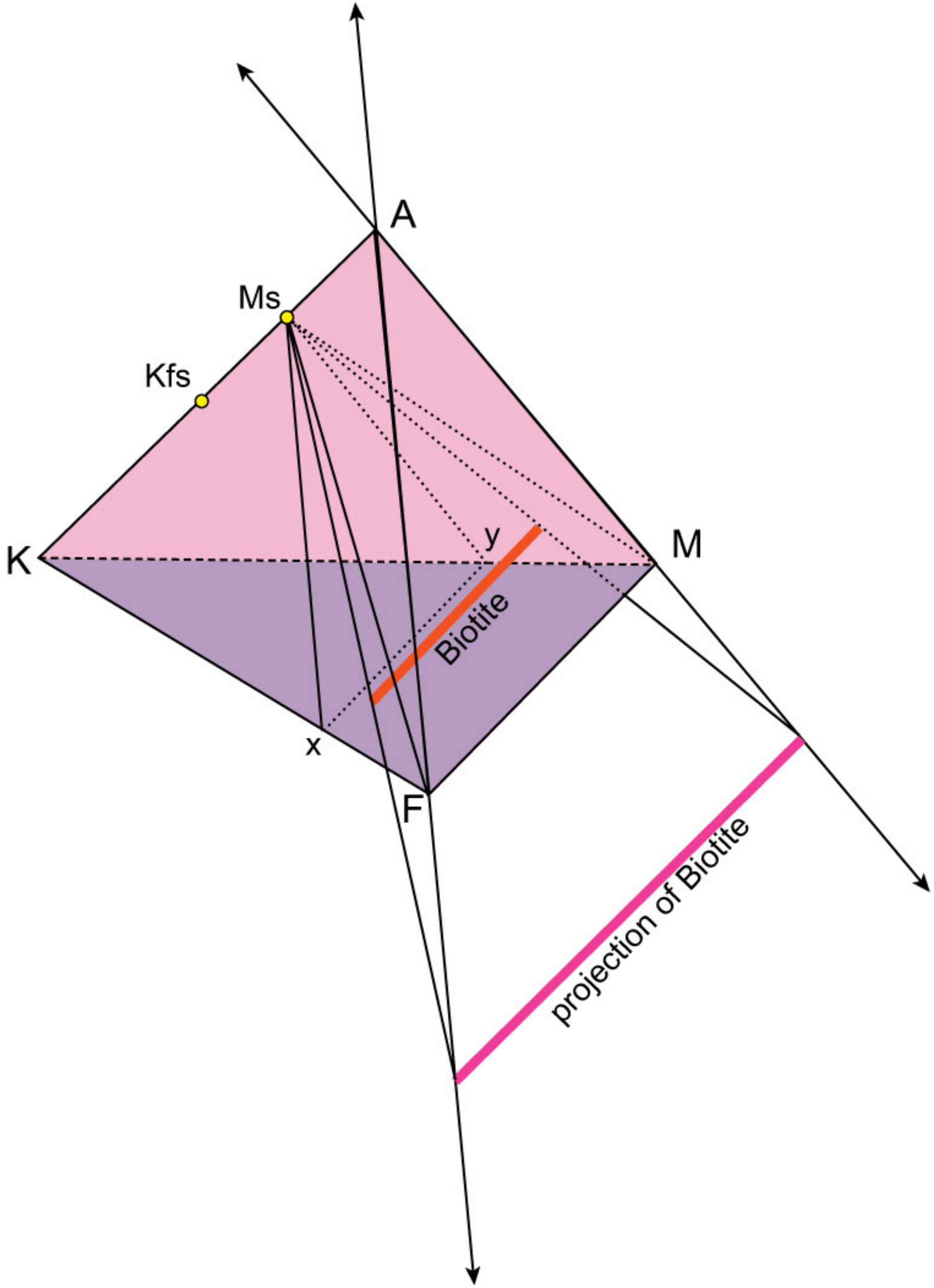


Figure 24.18. AKFM Projection from Mu. After Thompson (1957). Am. Min. 22, 842-858.

J.B. Thompson’s A(K)FM Diagram

- At high grades muscovite dehydrates to K-feldspar as the common high-K phase
- Then the AFM diagram should be projected from K-feldspar
- When projected from Kfs, biotite projects within the F-M base of the AFM triangle

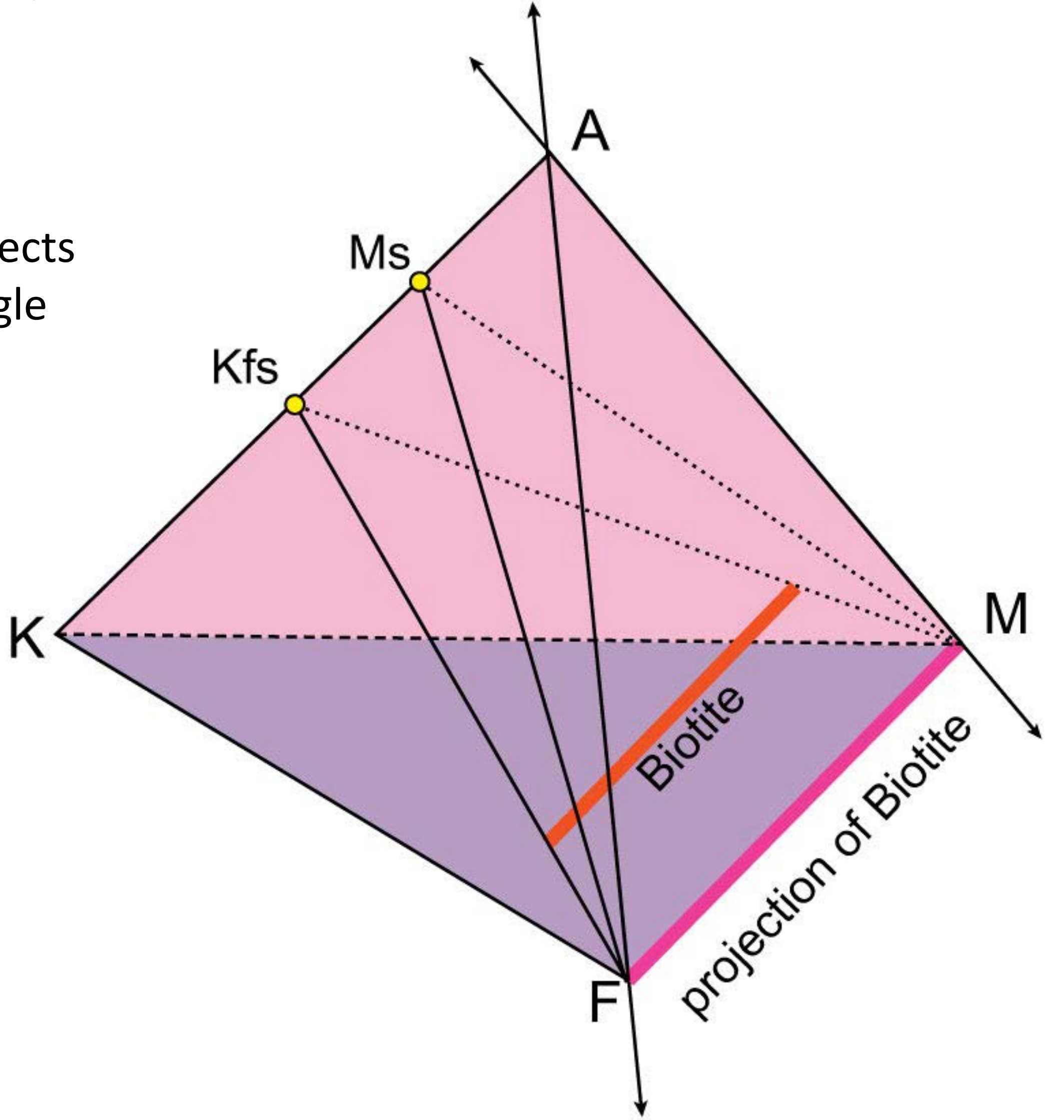
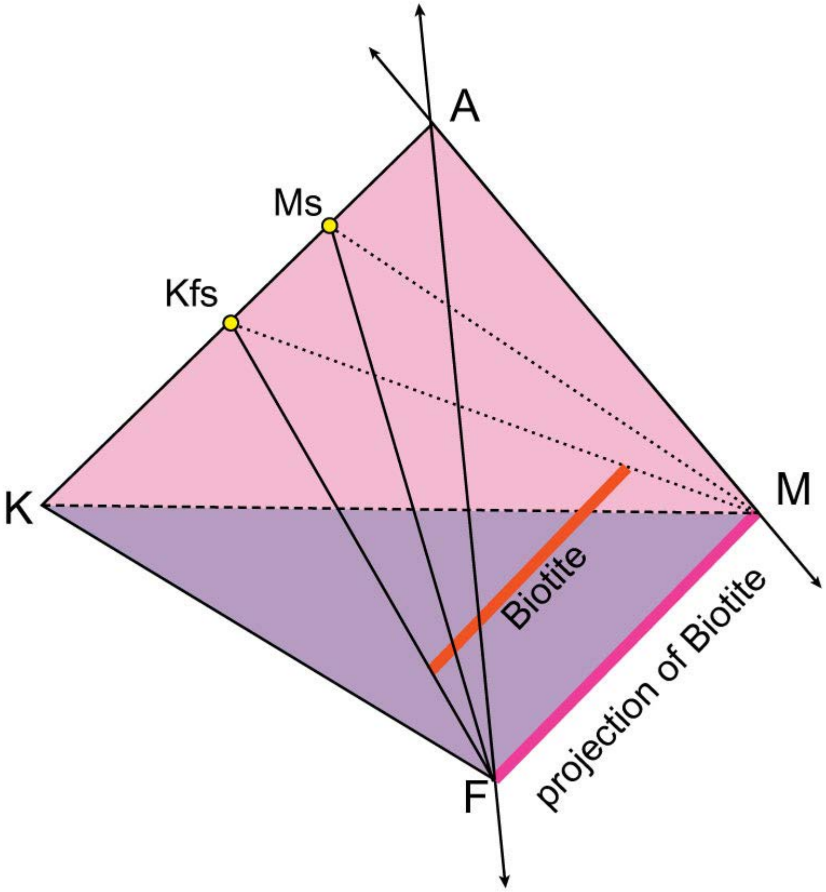


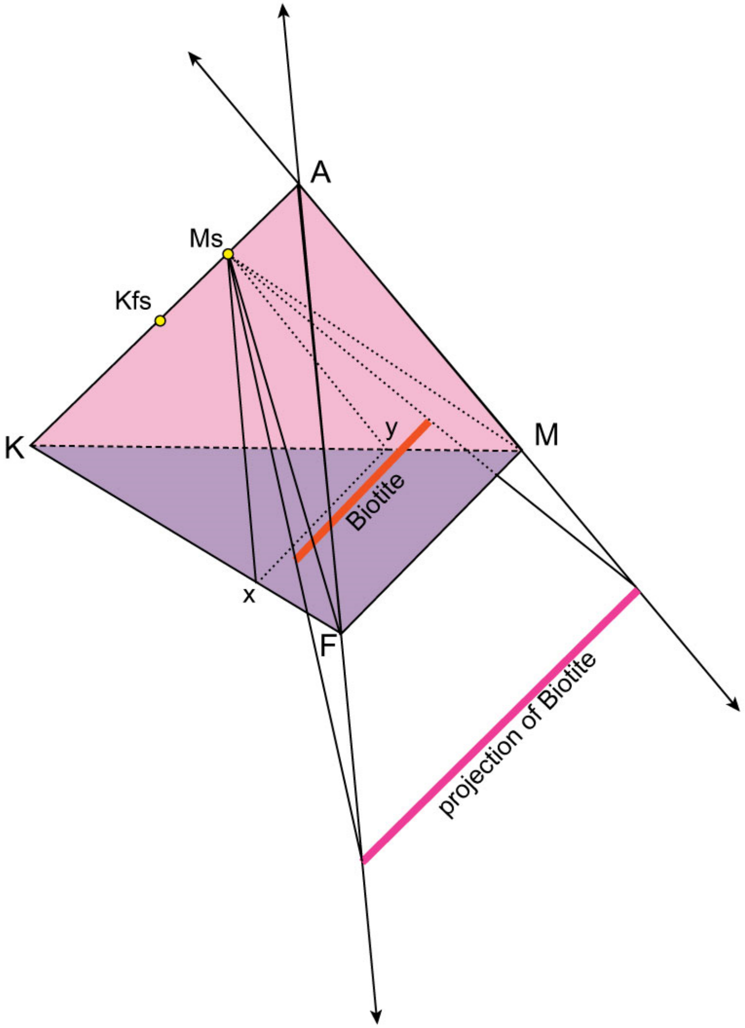
Figure 24.18. **AKFM Projection from Kfs. After Thompson (1957). Am. Min. 22, 842-858.**

J.B. Thompson’s A(K)FM Diagram

- A = Al_2O_3 - $3K_2O$ (if projected from Ms)

  = Al_2O_3 - K_2O (if projected from Kfs)
- F = FeO





J.B. Thompson's A(K)FM Diagram

Biotite (from Ms):

$KMg_2FeSi_3AlO_{10}(OH)_2$

A = 0.5 - 3 (0.5) = - 1

F = 1

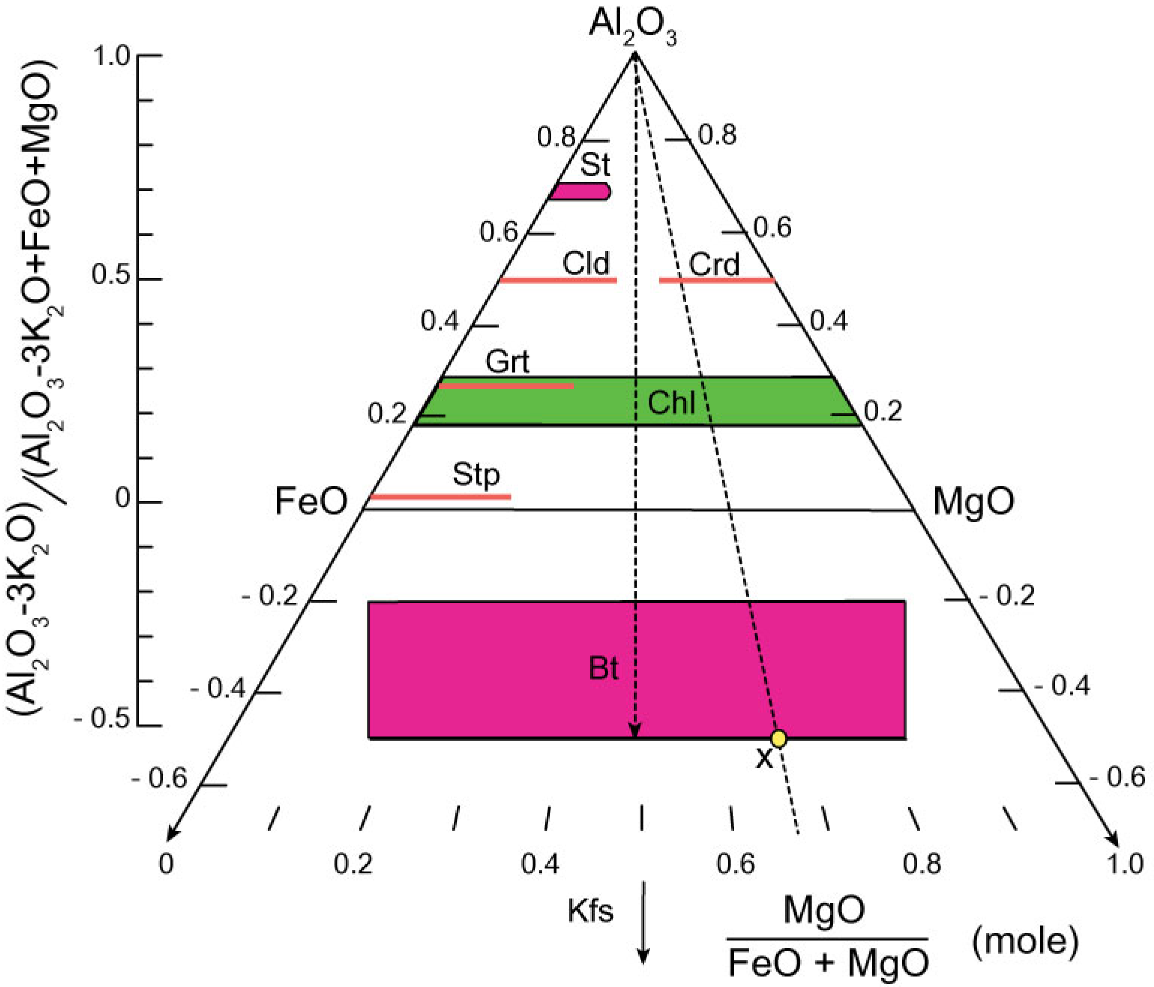
M = 2

To normalize we multiply each by 1.0/(2 + 1 - 1) = 1.0/2 = 0.5

Thus A = -0.5

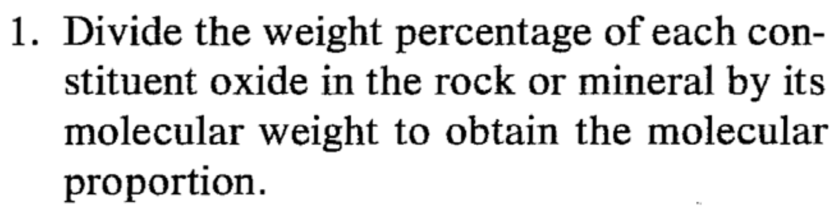
F = 0.5

M = 1

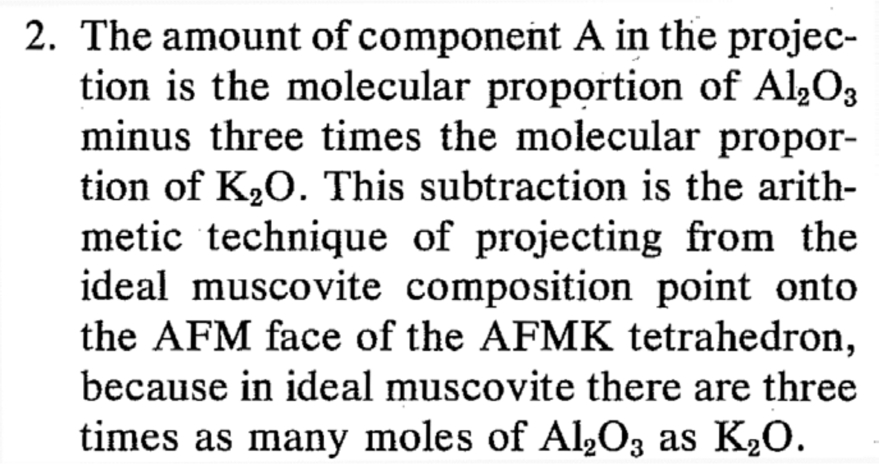


The AFM Projection for Pelitic Rocks

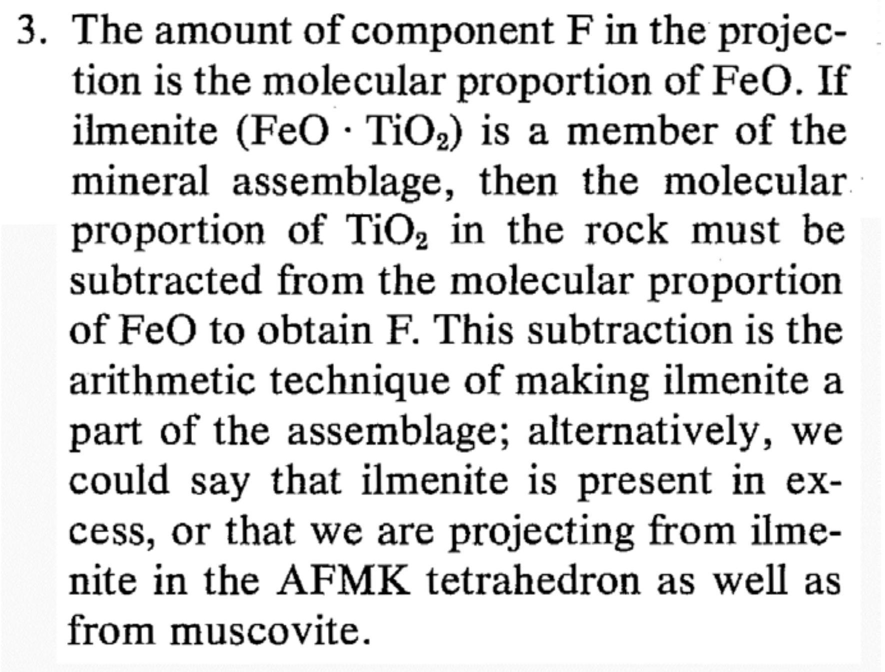
Plotting Rules



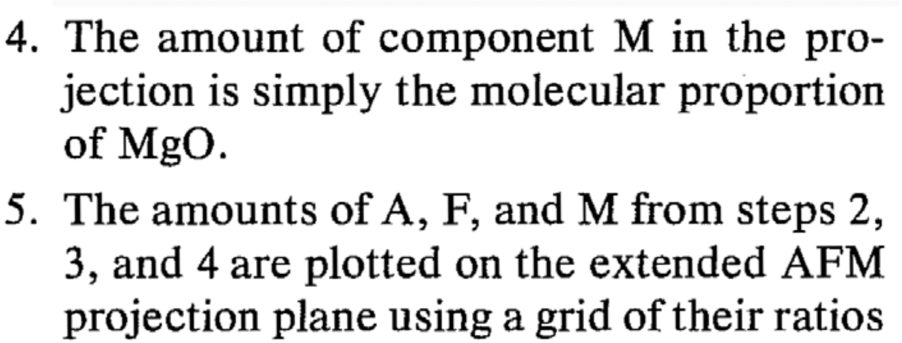
1. Divide the weight percentage of each constituent oxide in the rock or mineral by its molecular weight to obtain the molecular proportion.



2. The amount of component A in the projection is the molecular proportion of Al_2O_3 minus three times the molecular proportion of K_2O. This subtraction is the arithmetic technique of projecting from the ideal muscovite composition point onto the AFM face of the AFMK tetrahedron, because in ideal muscovite there are three times as many moles of Al_2O_3 as K_2O.



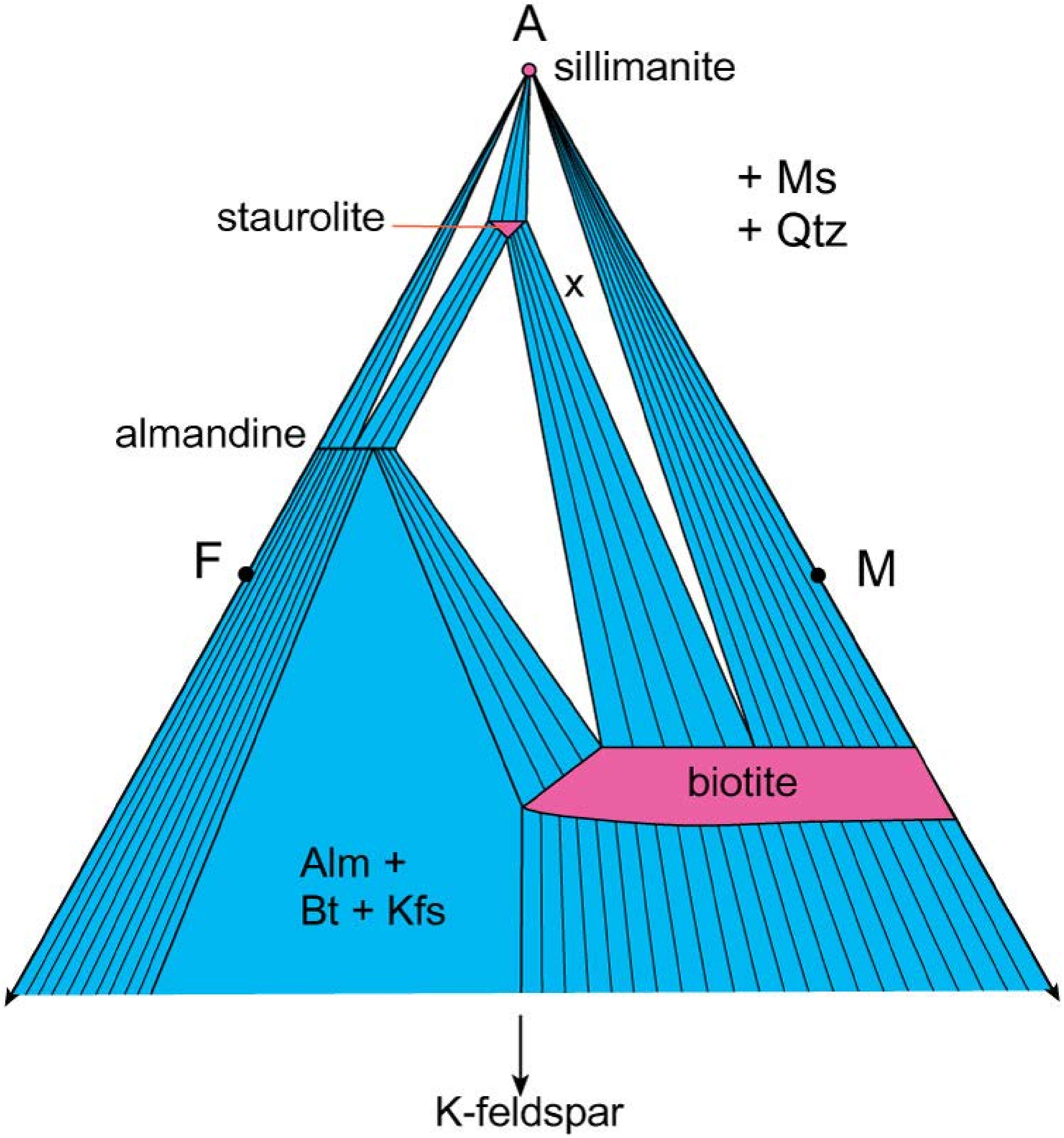
3. The amount of component F in the projection is the molecular proportion of FeO. If ilmenite ($FeO \cdot TiO_2$) is a member of the mineral assemblage, then the molecular proportion of TiO_2 in the rock must be subtracted from the molecular proportion of FeO to obtain F. This subtraction is the arithmetic technique of making ilmenite a part of the assemblage; alternatively, we could say that ilmenite is present in excess, or that we are projecting from ilmenite in the AFMK tetrahedron as well as from muscovite.



4. The amount of component M in the projection is simply the molecular proportion of MgO.
5. The amounts of A, F, and M from steps 2, 3, and 4 are plotted on the extended AFM projection plane using a grid of their ratios

J.B. Thompson’s A(K)FM Diagram

Figure 24.20. AFM Projection from Ms for mineral assemblages developed in metapelitic rocks in the lower sillimanite zone, New Hampshire After Thompson (1957). Am. Min. 22, 842-858.



Choosing the Appropriate Chemographic Diagram

- Example, suppose we have a series of pelitic rocks in an area. The pelitic system consists of the 9 principal components: SiO_2, Al_2O_3, FeO, MgO, MnO, CaO, Na_2O, K_2O, and H_2O
- How do we lump those 9 components to get a meaningful and useful diagram?

Choosing the Appropriate Chemographic Diagram

Each simplifying step makes the resulting system easier to visualize, but may overlook some aspect of the rocks in question

- MnO is commonly lumped with FeO + MgO, or ignored, as it usually occurs in low concentrations and enters solid solutions along with FeO and MgO
- In metapelites Na_2O is usually significant only in plagioclase, so we may often ignore it, or project from albite
- As a rule, H_2O is sufficiently mobile to be ignored as well

Choosing the Appropriate Chemographic Diagram

Common high-grade mineral assemblage:

Sil-St-Mu-Bt-Qtz-Plag

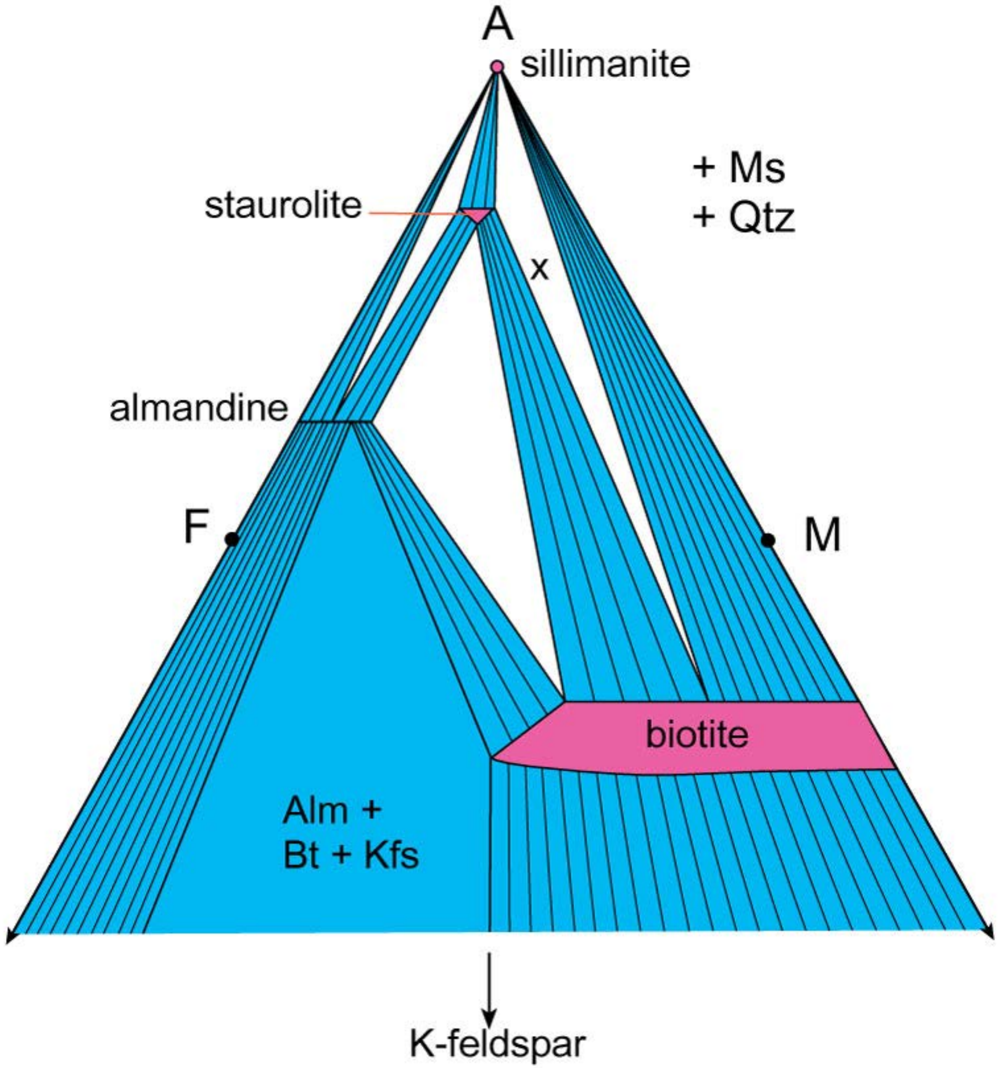
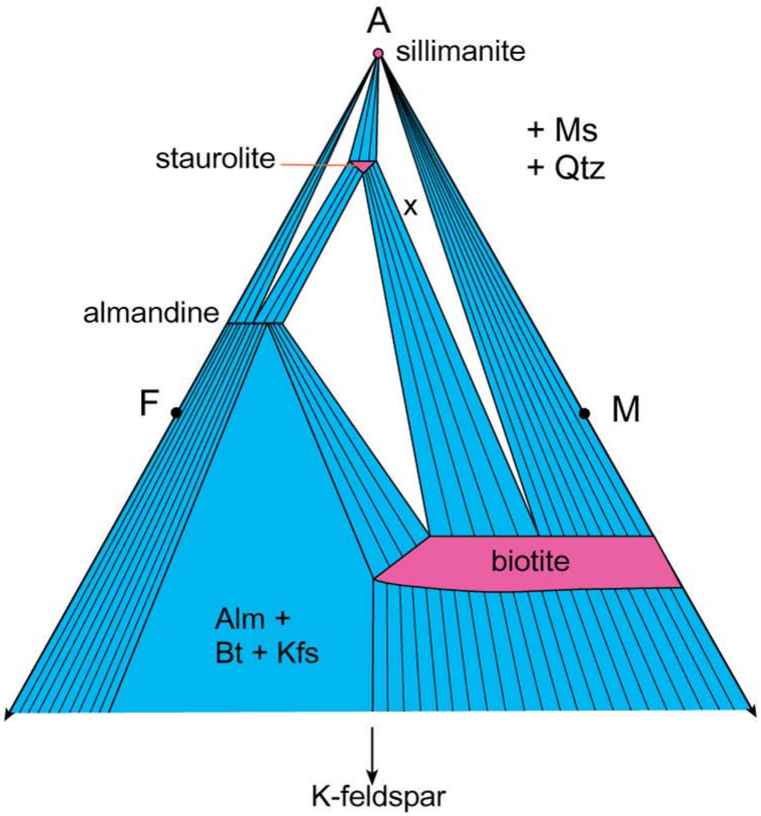


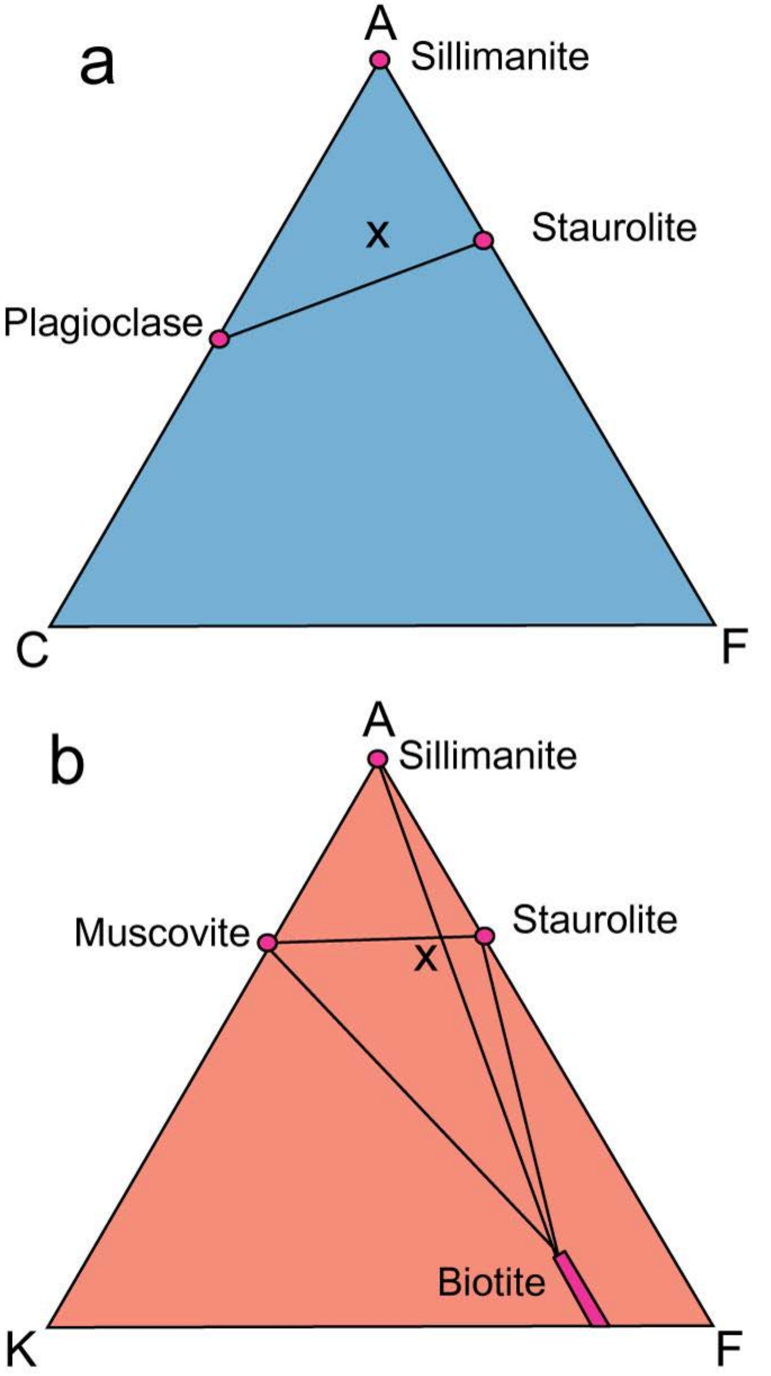
Figure 24.20. **AFM Projection from Ms for mineral assemblages developed in metapelitic rocks in the lower sillimanite zone, New Hampshire After Thompson (1957). Am. Min. 22, 842-858.**

Choosing the Appropriate Chemographic Diagram

Sil-St-Mu-Bt-Qtz-Plag

Figure 24.21. **After Ehlers and Blatt (1982). *Petrology*. Freeman.**





Choosing the Appropriate Chemographic Diagram

Sil-St-Mu-Bt-Qtz-Plag

- We don’t have equilibrium
- There is a reaction taking place (F = 1)
- We haven’t chosen our components correctly and we do not really have 3 components in terms of AKF

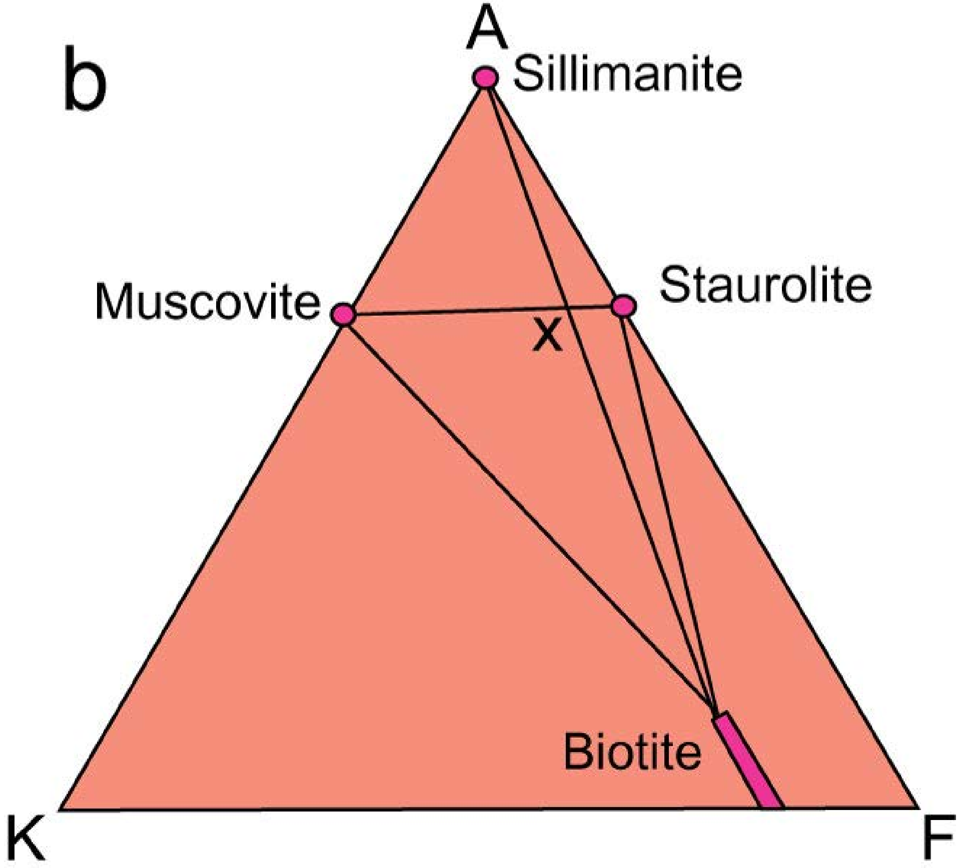


Figure 24.21. After Ehlers and Blatt (1982). *Petrology*. Freeman.

Choosing the Appropriate Chemographic Diagram

Sil-St-Mu-Bt-Qtz-Plag

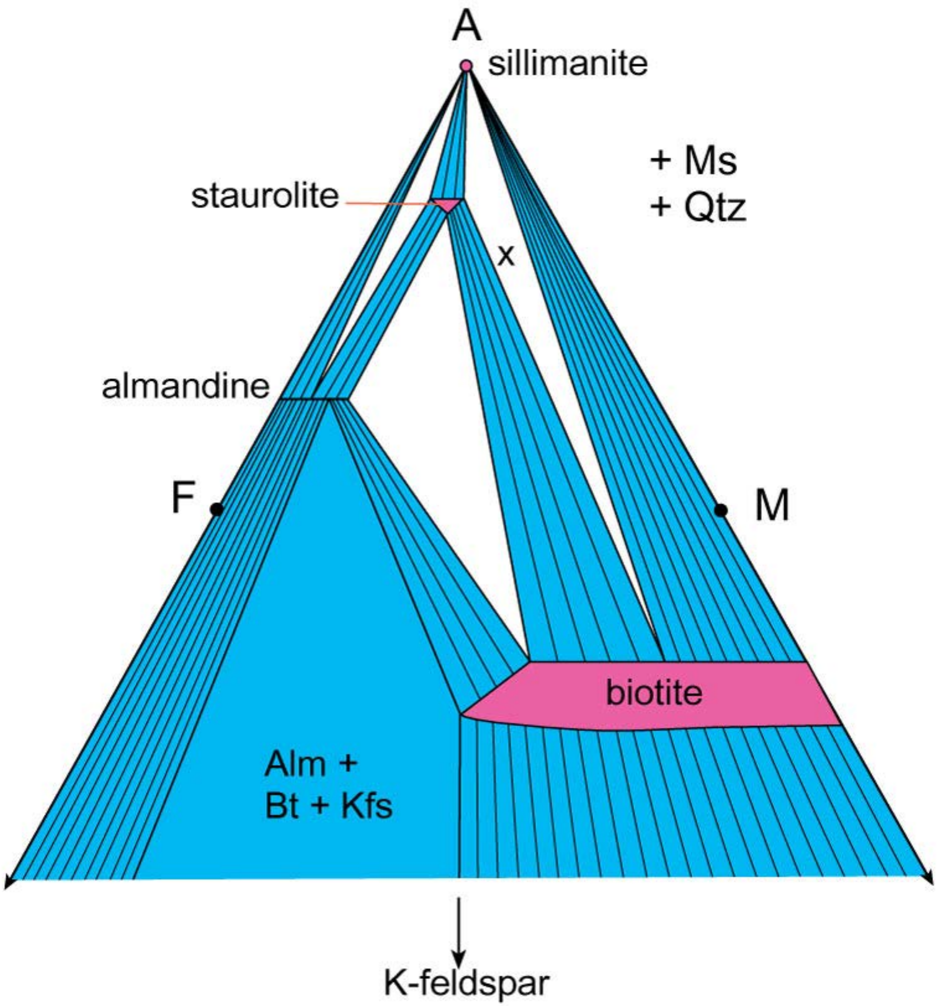
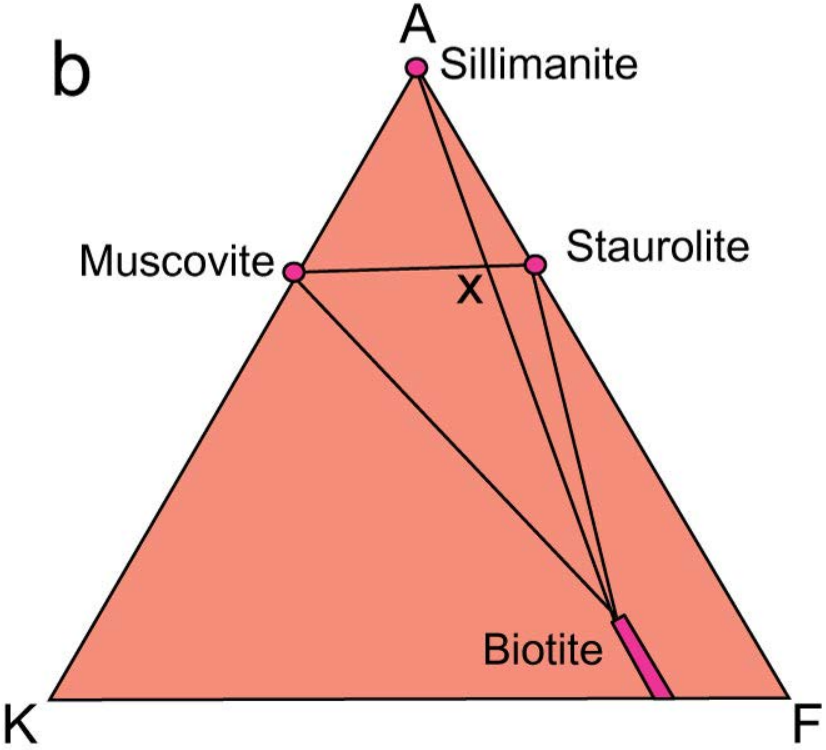


Figure 24.21. After Ehlers and Blatt (1982). *Petrology*. Freeman.



Choosing the Appropriate Chemographic Diagram

- Myriad chemographic diagrams have been proposed to analyze paragenetic relationships in various metamorphic rock types
- Most are triangular: the maximum number that can be represented easily and accurately in two dimensions
- Some natural systems may conform to a simple 3-component system, and the resulting metamorphic phase diagram is rigorous in terms of the mineral assemblages that develop
- Other diagrams are simplified by combining components or projecting

Choosing the Appropriate Chemographic Diagram

- Variations in metamorphic mineral assemblages result from:
  1) Differences in bulk chemistry
  2) differences in intensive variables, such as T, P, P_{H_2O}, etc (metamorphic grade)
- A good chemographic diagram permits easy visualization of the first situation
- The second can be determined by a balanced reaction in which one rock's mineral assemblage contains the reactants and another the products
- These differences can often be visualized by comparing separate chemographic diagrams, one for each grade