Ternary system (Fo-An-SiO₂) with intermediate compound (peritectic)

Phase rule:
At points c and d: \( f = ? \)

Reaction along line labeled “peritectic”:
\( \text{Fo} + \text{L} \leftrightarrow \text{En} \)

All other field boundaries are cotectics, e.g., from 1543 to d, reaction is:
\( \text{L} \leftrightarrow \text{En} + \text{Silica} \)
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Eq\textsuperscript{m} Xtl\textsuperscript{n} of comp\textsuperscript{n} a:

\textit{a-b:} Fo

\textit{b-c:} Fo + L ↔ En

\textit{c:} Fo + L ↔ En + An

Eq\textsuperscript{m} Xtl\textsuperscript{n} of comp\textsuperscript{n} d:

\textit{d-e:} Fo

\textit{e-f:} Fo + L ↔ En

\textit{f-g:} En

\textit{g-d':} En + An

\textit{at d':} En + An + Silica:
(\textit{at d':} L ↔ En + An + Silica)

Recall: tangent rule and how to determine nature of reactions along univariant boundaries and at invariant points

Note: Fields of crystallization of An, Fo, En and silica
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*Fractional crystallization of composition a:*

- **a - b:** Forsterite
- **b - e:** Enstatite
- **e - d:** En + An

For melting of a solid assemblage of bulk composition **a**, what would be the first liquid produced?

What differences are there between equilibrium melting and fractional melting of composition **a**?
Important systems with more than 3 components

1. “Granite” system \((\text{Ab-Or-Qz-H}_2\text{O})\) This 4 component (Quaternary) system has been studied extensively since the publication of the classic memoir in 1958 by Tuttle and Bowen (GSA Memoir 74). There are 4 ternary sub-systems (Ab-Or-Qz; Ab-Or-H\(_2\)O; Ab-Qz-H\(_2\)O; Or-Qz-H\(_2\)O) and 6 binary sub-systems. We have discussed the phase equilibria in the Ab-Or-H\(_2\)O system. Time does not permit an extensive discussion of all the ternary systems so we will just focus on some of the key results at \(P = 5\) kbars.

To represent the phase equilibria in the quaternary (“granite”) system, the phase relations obtained under water-saturated conditions are projected from the water apex on to the triangular base of the tetrahedron, e.g., point \(a\) within the tetrahedron projects to \(a'\) on the base.
“Granite” System at 5 kb

Schematic perspective projection of the H$_2$O-saturated liquidus surface in the Ab-Or-Qz-H$_2$O system at 5 kb

This surface is labeled a-b-c-d-e-f-g and the numbers correspond to the temperatures in ºC at each point

b(730ºC) – g(645ºC): L(Or$_{ss}$,Ab$_{ss}$,V)
f(690ºC) – g(645ºC): L(Ab$_{ss}$,Qz,V)
f(730ºC) – g(645ºC): L(Or$_{ss}$,Qz,V)
g(645ºC): L(Ab$_{ss}$,Or$_{ss}$,Qz,V)

At 5 kb, H$_2$O-sat$^d$ liquids contain ~10 wt% H$_2$O

Heavy lines show the location of liquid compositions in equilibrium with various crystalline assemblages

Light lines (below the V-sat$^d$ surface are water present but V-undersat$^d$ equilibria, e.g., 690ºC-1130ºC line represents L(Ab,Qz)

Fluid compositions lie close to H$_2$O apex
“Granite” [Ab-Or-Qz-H$_2$O] System at 2 kb and 10 kb (water saturated)

Note: There is no ternary eutectic at P$_{H_2O}$ = 2kb. Instead, there is a minimum at 680°C in the field boundary separating the fields of quartz and alkali feldspar. Recall the Ab-Or system which shows that the solidus has not intersected the solvus at low P.

At P$_{H_2O}$ = 10 kb, there is a ternary eutectic at T = 635°C and the fields of Ab$_{ss}$, Or$_{ss}$ and quartz are distinct. Basically, the solvus and the solidus have intersected.

Phase Rule: variance at the eutectic?

Crystallization and melting behavior?
Solidus in “Granite” [Ab-Or-Qz-H$_2$O] System to 20kb (water saturated)

Note: Curve shows the water saturated solidus in the “granite” system as a function of P. The diagonal line shows the one feldspar—two feldspar boundary (in effect the P and T of the crest of the solvus)

The inset diagram shows the composition of the minima (at 1 and 2 kb) and the eutectic (at 5, 10 and 20 kb).

At pressures above ~16 kb, albite is unstable and breaks down to jadeite + quartz. This produces an invariant point. What phases at present at the invariant point?

The shaded area show the composition of most natural granites plotted on this diagram.