EVOLUTION OF MAGMAS

FRACTIONATION & FRACTIONAL CRYSTALLIZATION

- Systematic Variations in Chemical Composition
- Result from Crystalliztion of Observed Minerals
- "Fractional Crystallization"

Trend of Liquid in composition space called **liquid line of descent.**

Example: MgO content in the parent basalt (< 10% MgO)

Removal of Olivine (50% MgO) and Augite (14% MgO) *lowers* MgO in resulting magma.

Parent Basalt	- 5% olivine	- 8% augite	= DaughterBasalt
10% MgO	- 0.05*50% MgO	- 0.08*14% MgO	= (10-2.5-1.1)/.87
	= 2.5%	= 1.1%	= 7.33% MgO

PHASE RULE and BINARY PHASE DIAGRAMS

DEFINITIONS

System = isolated part of Universe.

>> Open to energy exchange
>> Closed to matter exchange (usually)

Components = Minimum number of chemically district species needed to describe system.

Phase = Chemically and physically distinct part of system.

Liquidus = In T-X space, represents maximum solubility of solid in liquid. Liquid only above, solid + liquid below.

Solidus = Solid-only below, liquid + solid above.

Eutectic = Mixture of phases with lowest possible melting point for those components. Refers both to the Eutectic Composition and to the Eutectic Temperature.

PHASE RULE of J. WILLARD GIBBS

$$\mathbf{F = c - p + 2}$$ Closed system at equilibrium

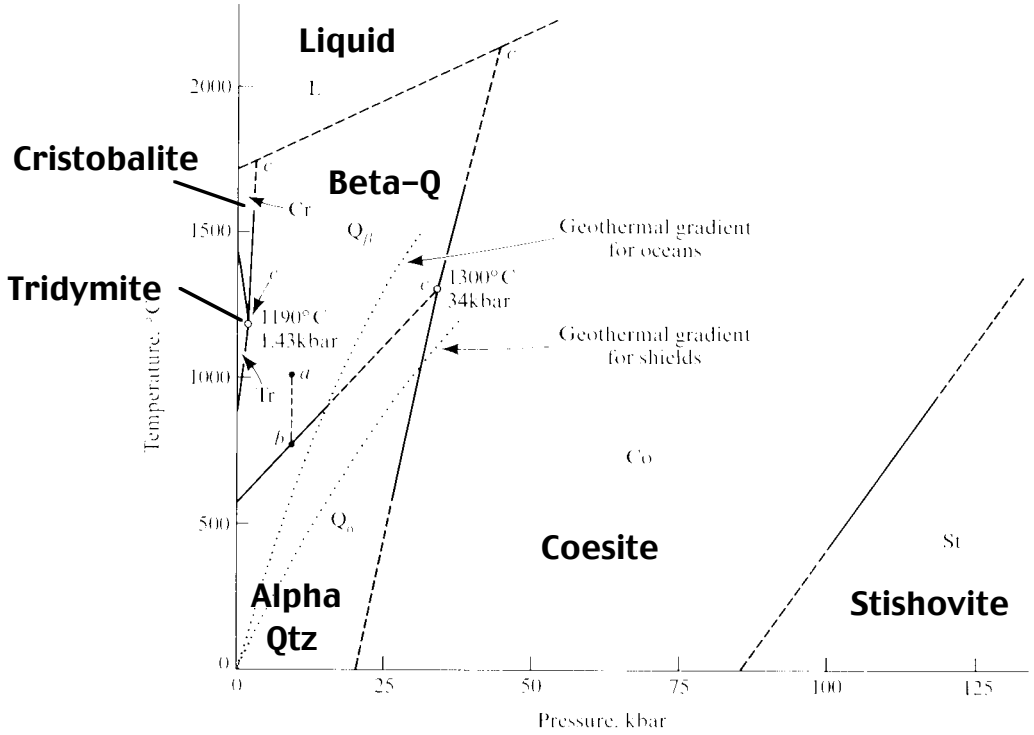
F = Variance or degrees of freedom, equals number of intensive variables needed to constrain system (T, P, or composition X).

c = Components **p** = Phases **2** = Temperature and Pressure

Condensed phase rule = isobaric or isothermal

$$\mathbf{F = c - p + 1}$$ (P or T fixed)

Unary Systems = 1 Component (e.g., SiO2)



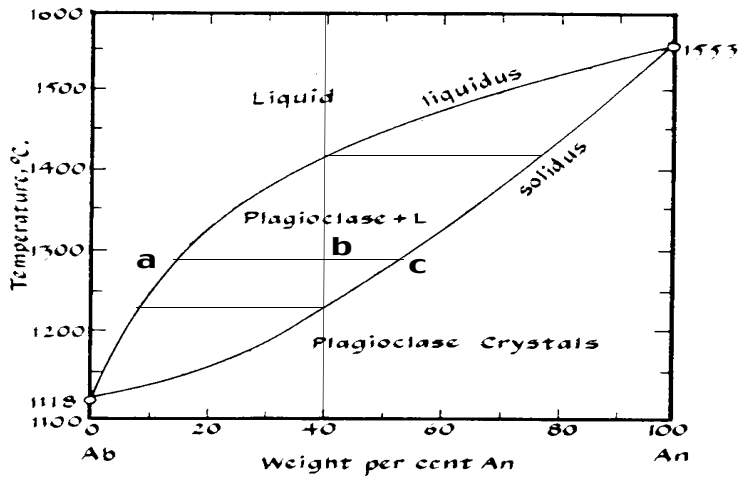
c = 1 p = 1 F = 1-1+2 = 2 T and P both can vary, **Divariant**

c = 1 p = 2 F = 1-2+2 = 1 T or P can vary, **Univariant**

c = 1 p = 3 F = 1-3+2 = 0 T and P both Fixed, **Invariant**

BINARY SOLID SOLUTIONS

Olivine (Forsterite-Fayalite) and Plagioclase (Anorthite-Albite)



COMPOSITIONS read DIRECTLY off the BOTTOM scale on Diagram (%An).

>> ISOPLETH = Constant Composition

PROPORTIONS Calculated from LEVER RULE

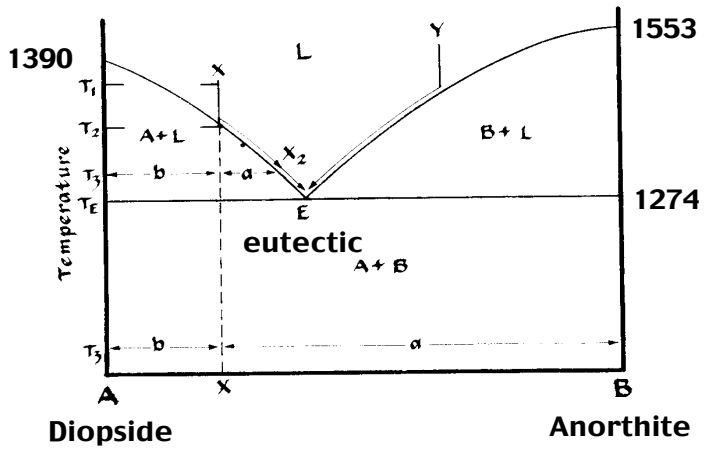
%xtls = (100 * ab)/ac

% liq = (100 * bc)/ac

Equilibrium Crystallization: Final Plagioclase = Bulk Composition

Fractional Crystallization: Liquid and Plagioclase both evolve to compositions more sodic (Na-rich) than bulk composition of system.

SIMPLE BINARY EUTECTIC WITH NO Solid Solution



Example: Diopside-Anorthite system (A = Diopside, B = Anorthite).

Compositions from bottom of diagram %A or %B (Both Crystals and Liquid)

PROPORTIONS FROM LEVER RULE:

%xtls = (100 * a)/(a+b)
% liquid = (100 * b)/(a+b)

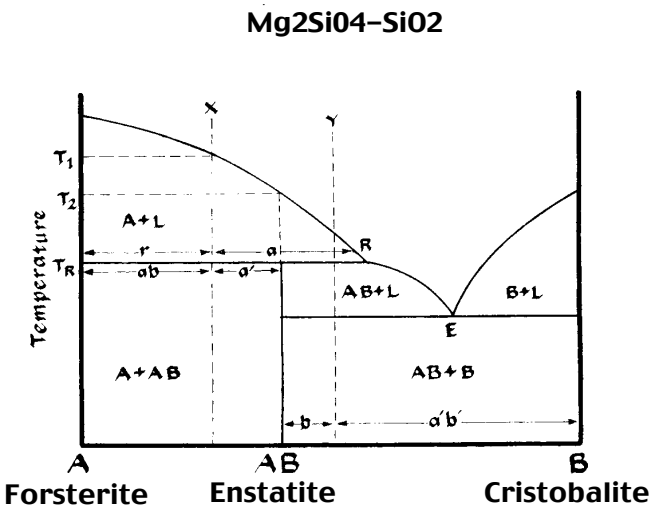
Equilibrium crystallization = Fractional crystallization
>> Liquid Follows Continuous Path
>> Crystal Compositions "Jump"

But Equilibrium melting NOT = Fractional melting

Equilibrium melting:
>> Liquid, Crystals Follows Continuous Path

Fractional melting:
>> Crystals Follows Continuous Path
>> Liquid Compositions "Jump"

PERITECTIC SYSTEMS



Example: System Forsterite-SiO2 (A=Forsterite, B=SiO2, AB=Enstatite)

R = Reaction Point or "Peritectic"

Phase Rule at Peritectic: F= 2-3+1= 0 **Invariant**

EQUILIBRIUM CRYSTALLIZATION:

BC X : Ol+L, Ol+En+L (at Peritectic), Stop at Peritectic (Final= Ol+En)

BC Y : Ol+L, Ol+En+L (at Peritectic), En+L, En+SiO2 (at Eutectic)

How do we know which final assemblage?

>> If Bulk Comp to Left of AB, Final Assemblage Must = A + AB.
>> If Bulk Comp to Right of AB, Final Assemblage Must = AB + B.

FRACTIONAL CRYSTALLIZATION:

BOTH BC X & BC Y: OL+L --> EN+L (at Peritectic) --> En+SiO2+L (Eutectic)

WHY ?? NO olivine to react with liquid during fractional crystallization.

TERNARY PHASE DIAGRAMS