

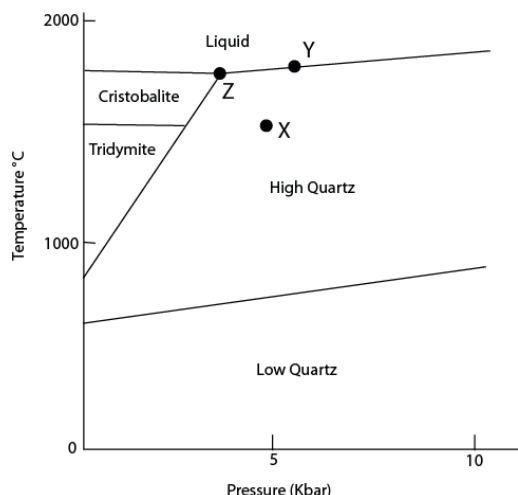
# LECTURE SEVENTEEN: Introduction to Metamorphism 2

## IN THIS LECTURE

- Importance of Understanding Metamorphic Mineral Assemblages
- Progressive Nature of Metamorphism
- Stable Mineral Assemblages
- The Phase Rule in Metamorphic Systems
- The MgO-H<sub>2</sub>O system

## Equilibrium Mineral Assemblages

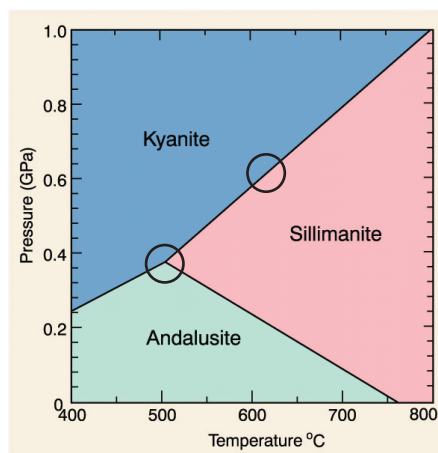
- At equilibrium, the mineralogy (and the composition of each mineral) is determined by T, P, and X
- "Mineral paragenesis" refers to such an equilibrium mineral assemblage
- Relict minerals or later alteration products are thereby excluded from consideration unless specifically stated



For  $P > C$  then the following three situations could apply

1.  $F < 2$
2. Equilibrium not attained
3. Choice of  $C$  not correct

If (1) applies then the sample was collected from a location right on a univariant reaction curve or invariant point



2. Equilibrium is not attained

The situation with (2) is more important in terms of optical mineralogy.

The phase rule only applies to systems that are in equilibrium.

If equilibrium is not attained or maintained then there could be any number of minerals co-existing

Unfortunately, this is often the case, especially in rocks that have been partially retrogressed or rocks in the blueschist and eclogite facies.

Optical Mineralogy is the main tool for deciding which minerals represent the equilibrium mineral assemblage

3. The number of components was not correct

Some guidelines for an appropriate choice of  $C$

Begin with a 1-component system, such as CaAl<sub>2</sub>Si<sub>2</sub>O<sub>8</sub> (anorthite), there are 3 common types of major/minor components that we can add

a) Components that generate a new phase

Adding a component such as CaMgSi<sub>2</sub>O<sub>6</sub> (diopside), results in an additional phase: in the binary Di-An system diopside coexists with anorthite below the solidus

b) Components that substitute for other components

Adding a component such as NaAlSi<sub>3</sub>O<sub>8</sub> (albite) to the 1-C anorthite system would dissolve in the anorthite structure, resulting in a single solid-solution mineral (plagioclase) below the solidus

c) "Perfectly mobile" components

Either a freely mobile fluid component or a component that dissolves in a fluid phase and can be transported easily. The chemical activity of such components is commonly controlled by factors external to the local rock system

They are commonly ignored in deriving  $C$  for metamorphic systems

## Progressive Nature of Metamorphism

- A rock at a high metamorphic grade probably progressed through a sequence of mineral assemblages rather than hopping directly from an unmetamorphosed rock to the metamorphic rock that we find today
- All rocks that we now find must also have cooled to surface conditions. Therefore, at what point on its cyclic P-T-t path did its present mineral assemblage last equilibrate?

- The preserved zonal distribution of metamorphic rocks suggests that each rock preserves the conditions of the maximum metamorphic grade (temperature)

## The Phase Rule in Metamorphic Systems

Phase rule, as applied to systems at equilibrium:

$$F = C - P + 2 \quad \text{the phase rule}$$

$P$  is the number of phases in the system

$C$  is the number of components: the minimum number of chemical constituents required to specify every phase in the system

$F$  is the number of degrees of freedom: the number of independently variable intensive parameters of state (such as temperature, pressure, the composition of each phase, etc.)

Pick a random point anywhere on a phase diagram. Likely point will be within a divariant field and not on a univariant curve or invariant point

The most common situation is divariant ( $F = 2$ ), meaning that  $P$  and  $T$  are independently variable without affecting the mineral assemblage

If  $C$  has been determined for a particular rock then there are three potential situations according to the phase rule

1.  $P = C$

This is the standard divariant situation in metamorphic rocks

The rock probably represents an equilibrium mineral assemblage from within a metamorphic zone

2.  $P < C$

A situation that commonly arises in systems that display solid solution.

We've seen this already with the binary phase diagrams for the albite-anorthite system

3.  $P > C$

A more interesting situation, and at least one of three situations must be responsible

See also the example on the periclase-brucite system in the powerpoint presentation