Phase Diagrams

Best, Chapter 14

Gibbs Phase Rule

$$F = 2 + C - \phi$$

$F$ = degrees of freedom (P-T-X)

$C$ = components

$\phi$ = phases

Degrees of Freedom

- Rule applies to a phase or assemblage
- Divariant indicates two degrees of freedom
- Univariant means one degree of freedom
- Invariant means there are no degrees of freedom

Petrogenetic Grid

- The grid define stability limits
  - End-member minerals
  - Mineral assemblages
- More thermodynamic data is needed to construct a useful grid

Anhydrous Phase Diagrams

- Solid-solid reactions
- Governed by Clapeyron equation
  - $\frac{dP}{dT} = 10 \frac{\Delta H}{T} \frac{\Delta V}{\Delta S}$
  - $\Delta H$ is the heat of reaction
  - $\Delta S$ is the change in entropy
  - $\Delta V$ is the change in volume
- The slope of the stability is $\frac{dP}{dT}$

Jadeite + Quartz $=\text{Albite}$

![Phase diagram showing Jadeite + Quartz = Albite](image_url)
System Open to $\text{H}_2\text{O}$

- Dehydration curves
- Example of the general case
- Specific minerals
  - Breakdown of chlorite, muscovite, biotite, etc

Univariant Curves

- Curves that define reactions with one degree of freedom
- In P-T space this means that if T is changed, than P must also change to maintain equilibrium
- Many important metamorphic reactions are defined by these curves

Important Reactions

- $\text{Al}_2\text{O}_3$ phase stability
- Dehydration curves

Stability of Iron Oxides

- $P_{02} (f_{O2})$ vs. Temp.
- Main phases
  - Hematite
  - Magnetite
  - Fayalite
  - Native Iron/Wustite
**Miyashiro’s Facies Series**

- Low geothermal gradient
  - Zeolite, pumpellyite-prehnite, blueschist
- Intermediate geothermal gradient
  - Barrow’s zones
- High geothermal gradient
  - Andalusite present in pelitic rocks

**Relation to Geotherms**

- High pressure series
- Medium P/T series
- High temperature series

---

**Facies in P-T Space**

**Granite Solidus (Wet)**

**Metamorphic Path**

**Polymetamorphism**

- Sometimes there are repeated episodes of metamorphism
- The last event may be weak or of short duration
- Polymetamorphism is common in post tectonic environments and in contact aureoles
### Material Transport

<table>
<thead>
<tr>
<th>Diffusion</th>
<th>Infiltration</th>
</tr>
</thead>
</table>

#### Diffusion
- Materials move through crystal lattices or a stationary pore fluid
- Rate of movement controlled by a diffusion coefficient (Fick’s Law)
  \[ Q = k \left( \frac{\delta C}{\delta x} \right) \]
- Material moves about 1 cm/m.y.

#### Infiltration
- Passive mass transport of a solute in a moving fluid medium
- Driven by fluid pressure
- Microfractures are important
- Reaction-enhanced permeability
  - Volume reduction due to reactions
- Dilatency pumping

### Reaction Textures

\[ \text{olivine} + \text{plagioclase} = \text{hypersthene} + \text{diopside} + \text{spinel} \]