Constitution of Magmas

- Hot molten rock
- T = 700 - 1200 degrees C
- Composed of ions or complexes
- Phase
  - Homogeneous
  - Separable part of the system
  - With an interface

Composition

- Most components
  - Low vapor pressure
  - Designated by mole fraction (X_i)
- Volatile components
  - Mainly exist as a gas
  - Designated by vapor pressure (p_i)
- Fluid pressure = sum of partial pressures

Gas law

$$PV = nRT$$

Atomic Structure of Magma

- Quenched to form a glass
- Si & Al are polymerized with O
- Forming networks of Si-O chains
- Short-range structural order

Structural Model

- Network formers
  - Si, Al
- Network modifiers
  - Ca, Mg, etc
- Dissolved water has a strong effect

$$H_2O + O^{-2} = 2(OH)^-$$

Magma Generation

- Magmas form at perturbations in P,T,X
- Convergent plates
- Divergent plates
- Peridotite mantle source

Source Regions

- Must originate in the mantle or crust
- At Hawaii 60 km deep
- Only 1 to 3% melt in peridotite

Melting

- **Heat of fusion**
  - **About 300 times the rock's specific heat**
  - **Melting of rock consumes much heat**
- **Mechanisms for melting**
  - **Temperature increase by mass transfer**
  - **Decompression**
  - **Changes in composition reducing melting point**

Temperature Increase

- **Mechanical deformation**
  - **Friction generates heat**
- **Mass transfer of rock**
  - **Descending oceanic lithosphere**
  - **Basaltic underplating of continental crust**

Decompression

- **Upwelling mantle**
  - **Beneath oceanic or continental rift**
- **Adiabatic system**
  - **Pressure causes all temperature change**

Changes in Composition

- **Increase in water pressure**
- **Lowers the solidus**
- **Subduction zones**
  - **Peridotite wedge**
  - **Over subducting oceanic crust**

Magma From Solid Rock

- Basalt & peridotite systems
- Granite systems

Basalt & Peridotite

- **Equilibrium fusion**
  - **Solid and liquid remain in equilibrium**
  - **Continuous but limited composition range**
- **Fractional fusion**
  - **Liquid is immediately removed from host rock**
  - **Melts are both oversaturated & undersaturated with respect to Si**

Influence of Pressure

- Pressure strongly influences the cotectic
- Partial melts of mantle peridotite are basalts
- At higher pressures partial melts are more silica deficient

Role of CO_2

- Polymerizes melt
- Contracts olivine field
- Favors silica-poor alkali melts
- Repeated melting episodes favors incompatible element enrichment

Role of H_2O

- Depolymerizes melt & stabilizes olivine
- Partial melts more silica rich
- Favors tholeiitic basalts

Mantle-derived Primary Melts

- **Wide range of melt compositions possible**
- **Fractional crystallization vs. Partial melting**
- **Primary melt**
  - **Segregated from peridotite source rock**
  - **First crystallized minerals similar to mantle source zone**
- **Derivative melt**
  - **Modified after leaving the source region**

Granitic Systems

- Impossible to generate granites by partial melting of mantle peridotite or subducted oceanic floor basalt
- Their origin is related to older sialic crust
- Granites concentrated along old subduction zones

Water Saturation

- Saturated granite melts have 10 to 15% H_2O
- Natural granite melts have about 4% H_2O

Water Undersaturation

- Common granite mineral assemblage
  - Biotite, K-spar, Fe-Ti oxide

½ O_2 + biotite = K-spar + Fe_3O_4 + H_2O

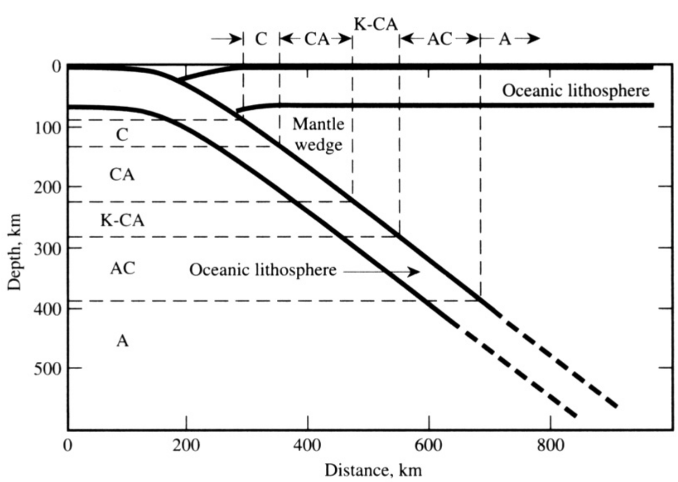
- Excess water drives this reaction to the left
- Hence, most granites are not water saturated

Origin of Granites

- Partial Melting of lower crust
- Source in mica-amphibolites
- Contain 1-2% H_2O
- Lowest T melts are K-rich granite
- Higher T, deeper melts are Ca-rich granodiorite

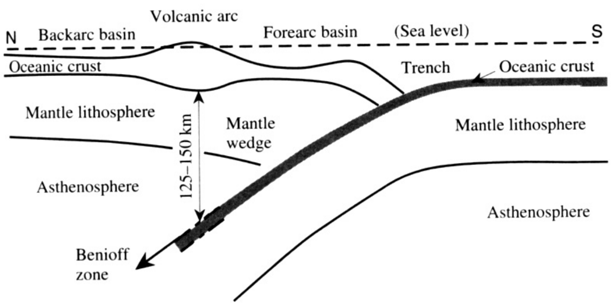
Subduction Zone Magma

- **Subducted slab**
  - **Mafic primary melts**
- **Peridotite mantle wedge**
  - **Mafic primary melts**



Dehydration Beneath Orogen

- **Large amount of water in oceanic slab**
  - **Water in pore space**
  - **Water in alteration minerals**
- **Heating dehydrates the slab**
- **Liberated water promotes partial melting of peridotite**
- **Composition is Si-saturated tholeiite**



Magma Diversification

- Magmatic differentiation
- Gravitational settling
- Liquid immiscibility

Crystal-liquid Fractionation

- Regular pattern of compositional variation
- Variation of MgO is a good measure of olivine fractionation
- Computer mixing programs can be used

Magma Mixing

- Two different magmas may blend to produce a hybrid
- Common with calc-alkali magma
- Blended magmas should have linear composition with the parents