GY303 Igneous & Metamorphic Petrology

Lecture 7: Magma Sources and Tectonic Environments
Factors controlling Magma production

- Source rock composition
- Amount of fluids, especially H₂O
- Pressure (Depth)
- Influence of tectonics on isotherms and isobars
Source Rock Composition

• Generally ultramafic and mafic compositions require higher temperatures to generate melting
• Most compositions are modeled best with 3 or 4 component systems
• Eutectic or peritectic invariant points will control initial melt composition
• Eutectic melts may be much different in composition compared to original rock
Effect of Fluids

- Presence of small amounts of H$_2$O (<1 wt %) will dramatically lower melting point
- Fluids can help transmit heat to rocks inducing melting

![Diagram showing effect of fluids on melting point](image_url)
Effect of Pressure on Solidus

• Increasing pressure stabilizes the solidus so that it occurs at higher temperatures
Origin of Tholeiitic Magma

- Produced by low pressure fractional crystallization
- Source = mantle peridotite
- Applicable to oceanic divergent tectonic plate boundary

![Diagram showing the origin of tholeiitic magma](image-url)
High Pressure Mafic Magma

- Fractional crystallization leads to alkali-rich composition
- High pressure fractional crystallization
- Applicable to oceanic Hot-Spot or deeper portions of Subduction zones

![Diagram of P-T diagram with minerals Ne, Pl, Cr, Di, OI, and E, showing Thermal Divide at P=20 Kb and Source Rock]
Layered Gabbroic Intrusions

• Lopolith geometry
• Good examples of fractional crystallization, low viscosity allows settling of crystals
• Examples
  – Bushveld Complex, South Africa
  – Duluth Gabbro, Minnesota
  – Skaergaard Intrusion, Greenland
  – Stillwater Complex, Montana
  – Sudbury, Ontario
Economic Geology of Layered Mafic Intrusions

- Layered gabbro lopoliths often contain economic concentrations of:
  - Precious metals: Au, Ag, Pt
  - Base metals: Cu, Ni, Cr
- Sulfide magma may exsolve from silicate magma to form a separate sulfide layer termed a “reef”
- Most large gabbro lopoliths are Precambrian
- Some large gabbro lopoliths may be related to meteorite impacts (i.e. Sudbury – high Ni content)
Origin of Intermediate to Felsic Magma

- Generated mostly at convergent plate boundaries by partial melting of hydrated ocean lithosphere
- Magma generated by partial melting of subducted ocean lithosphere has a Calc-Alkaline chemical signature
Calc-Alkaline Trend

- Displayed best by a AFM ternary

F = FeO
A = Na2O + K2O
M = MgO

Tholeiitic trend
Calc-Alkaline trend
Calc-Alkaline Trend Controls

- Hydrated slab releases H2O that is absorbed by magma
- At magmatic temperatures H$_2$O disassociates:
  - H$_2$O = H$_2$ + 1/2O$_2$
- Oxygen in the melt oxidizes Fe to Fe oxides such as magnetite early in the fractional crystallization sequence
- Calc-Alkaline magma therefore never fractionates toward the “F” apex of the AFM ternary
S- vs. I-type Granites

- S-type: generated by partial melting of crustal rocks in the high-T, Low-P zone of regional metamorphism
- I-type: generated by slab melts that fractionate to felsic composition
I- vs. S-type Characteristics

- **I-type**
  - Sr 87/86 < 0.704
  - Normative Co < 1%
  - Mineralogy: Hbl+Mt
  - Economic: Fe+Cu+Pb+Ag sulfides

- **S-type**
  - Sr 87/86 > 0.708
  - Normative Co > 1%
  - Mineralogy: Mu+Bi+Ilm
  - Economic: Sn+W+U+Li+B+Ta sulfides and oxides in pegmatites
A-type Granites

- Produced in continental rift tectonic environments
- Because of depth of origin magma fractionates under high pressure (> 20 kbar)
- Alkalis are enriched producing silica-undersaturated nepheline syenites
Review for Test 2

- Phase Diagrams:
  - Melt/Solid paths
  - Phenocryst vs. Groundmass assemblages
  - Magma chamber layering from fractional
- Trace Element Problem
- REE discussion and interpretation
- Goldschmidt's rules
- Tholeiitic vs. Alkaline Basalt Fractionation
- Calc-Alkaline vs. Tholeiitic Fractionation
- I- vs. S-type Magma sources