GY303 Igneous & Metamorphic Petrology

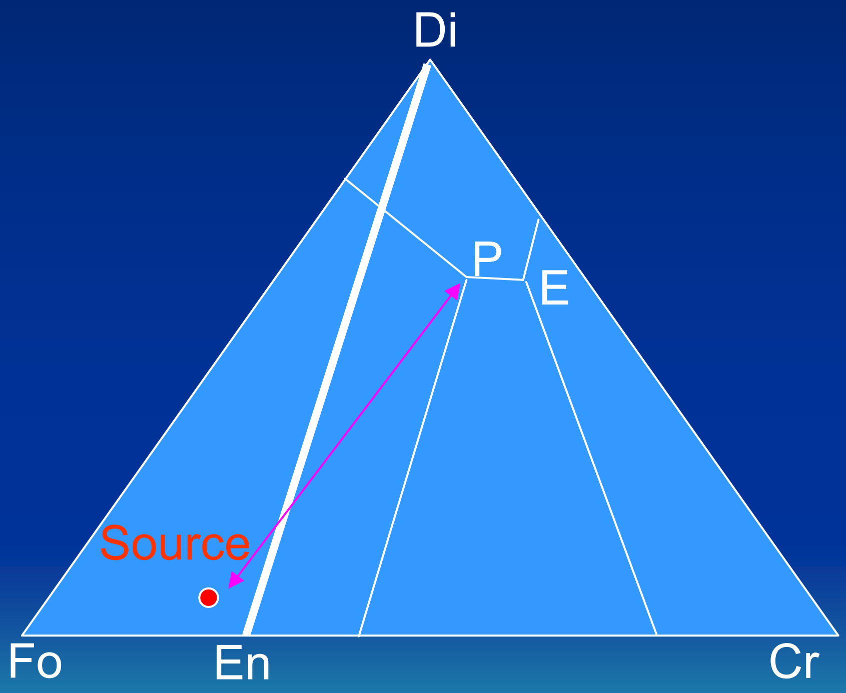
Lecture 7: Magma Sources and Tectonic Environments

Factors controlling Magma production

- Source rock composition
- Amount of fluids, especially H_2O
- Pressure (Depth)
- Influence of tectonics on isotherms and isobars

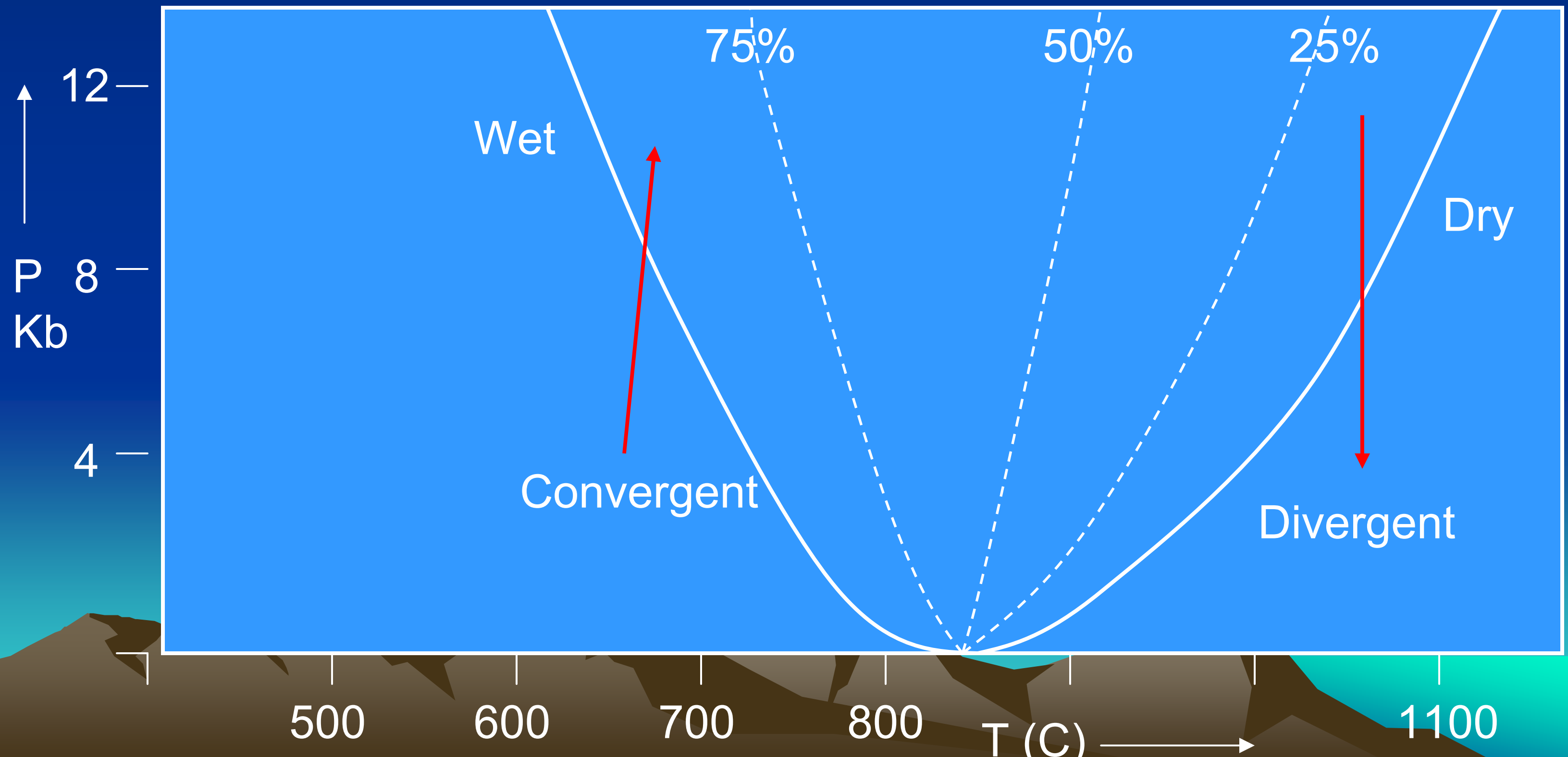
Source Rock Composition

- 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



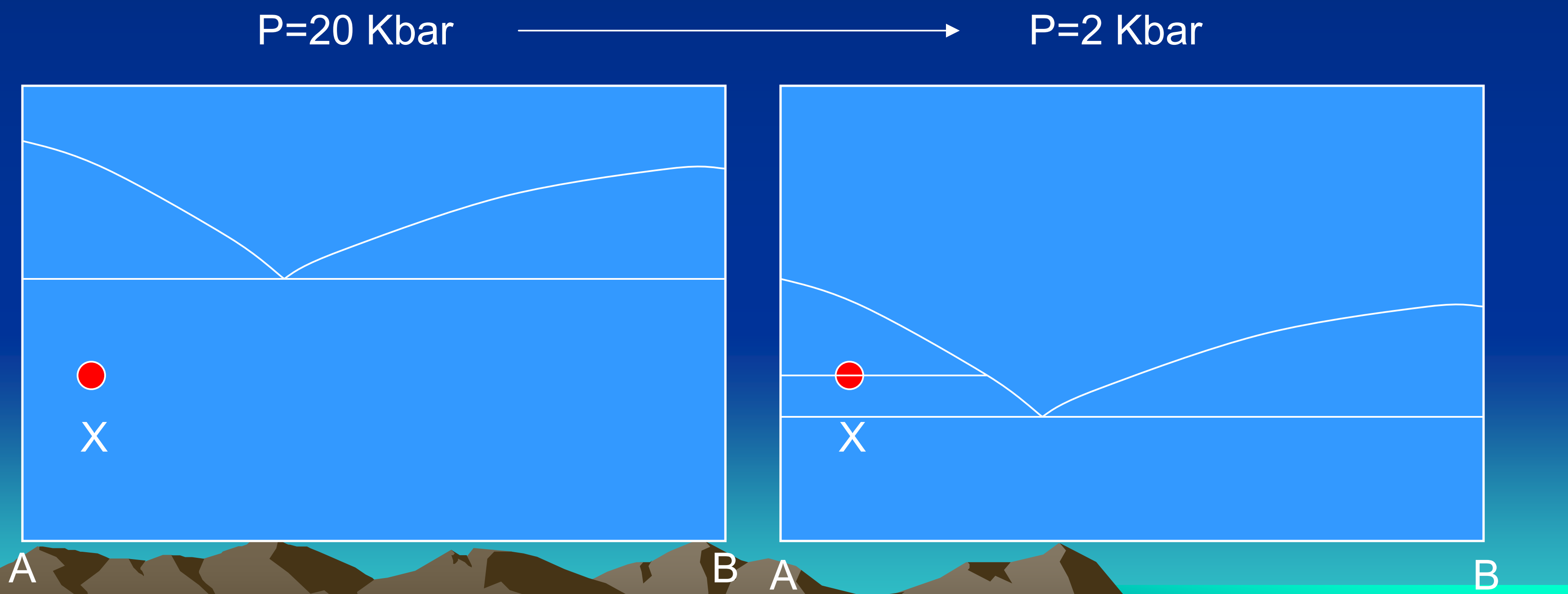
Effect of Fluids

- Presence of small amounts of H_2O (<1 wt %) will dramatically lower melting point
- Fluids can help transmit heat to rocks inducing melting



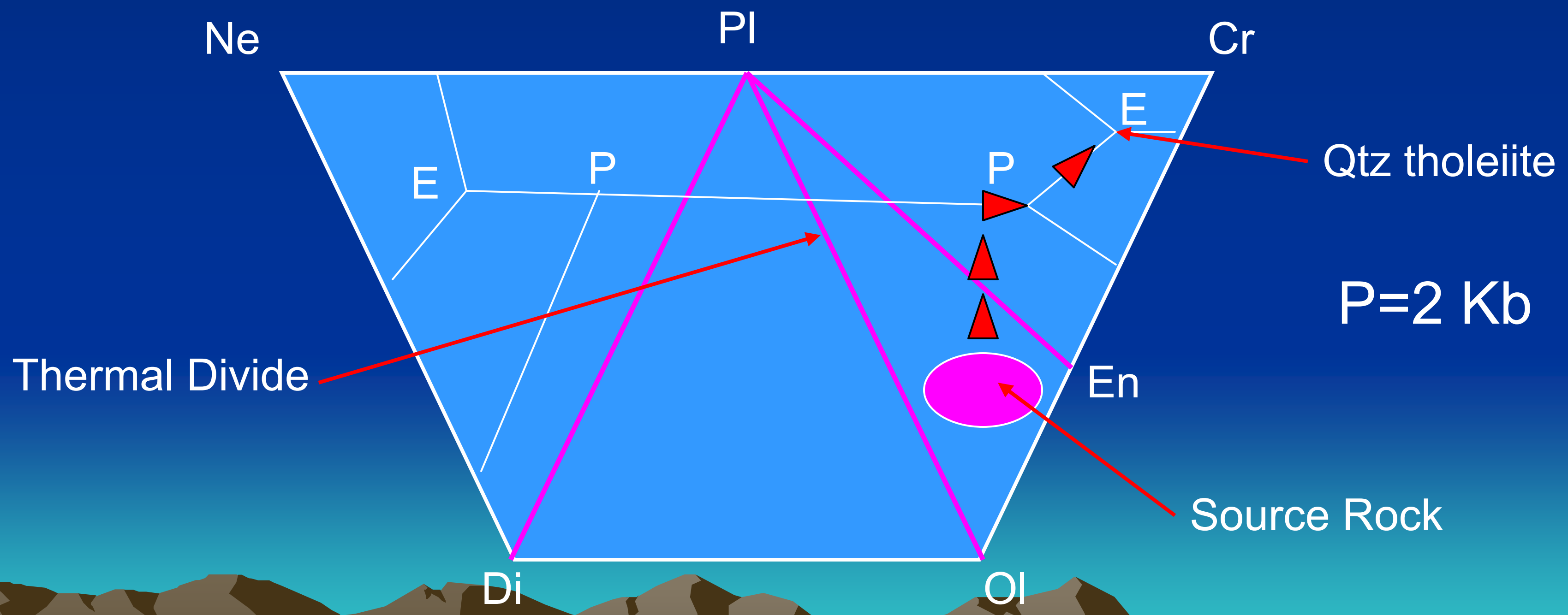
Effect of Pressure on Solidus

- Increasing pressure stabilizes the solidus so that it occurs at higher temperatures



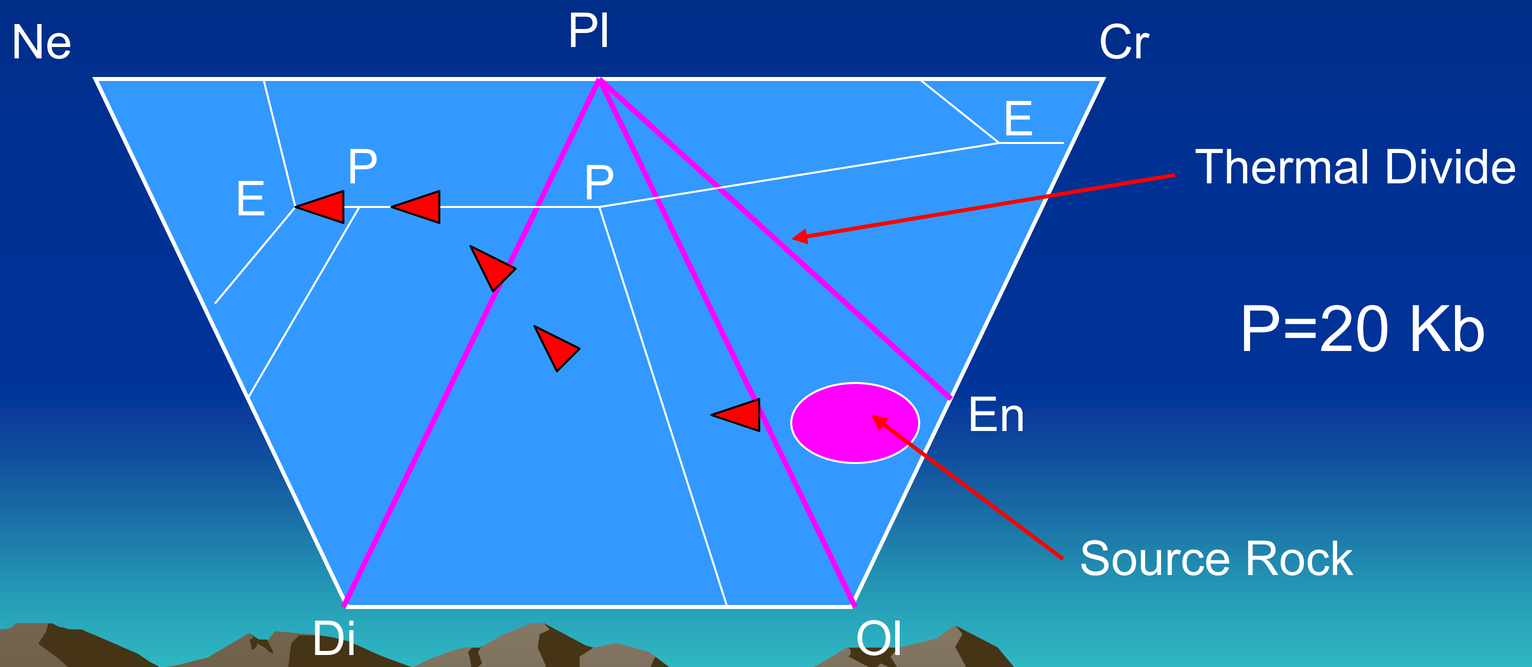
Origin of Tholeiitic Magma

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



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



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

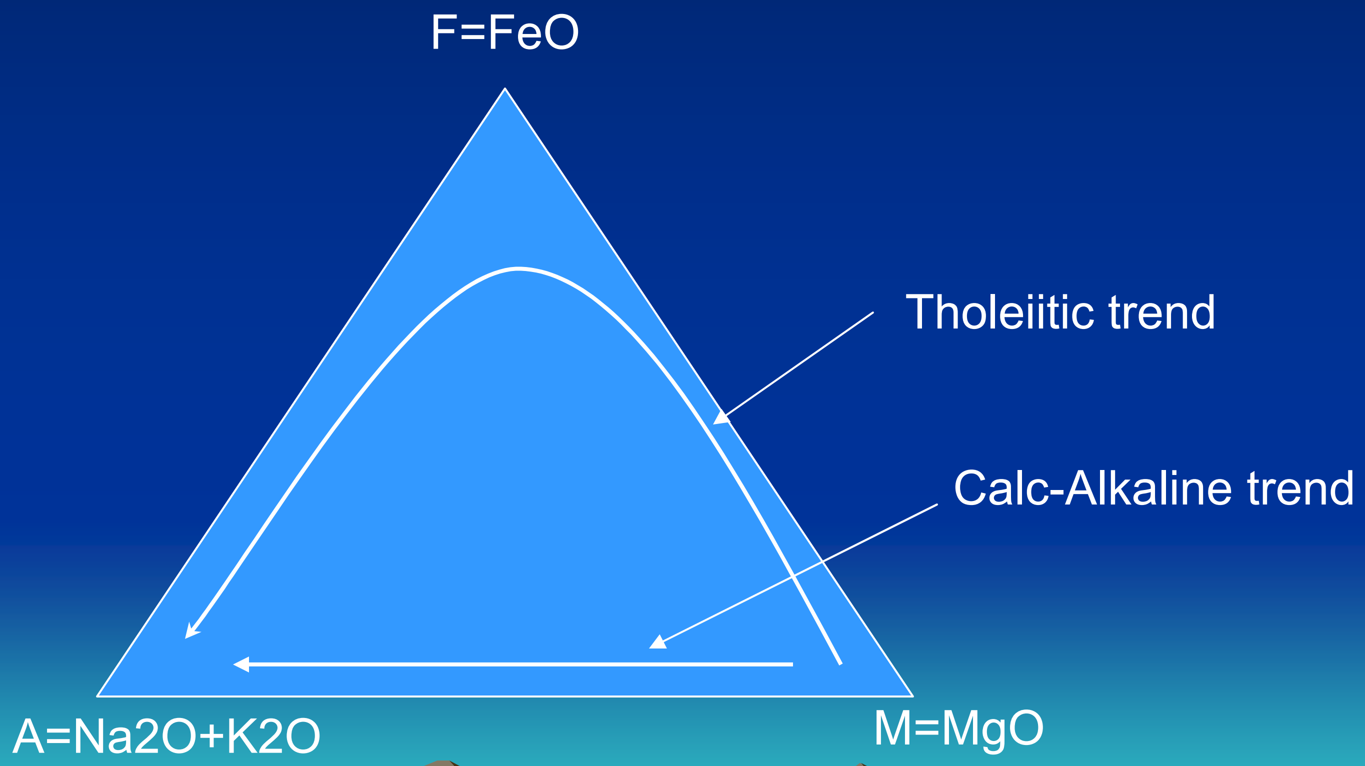
- Layered gabbro lopoliths often contain economic concentrations of:
  - Precious metals: Au, Ag, Pt
  - Base metals: Cu, Ni, Cr
- Sulfide magma may exsolve from silicate magma to form a separate sulfide layer termed a “reef”
- Most large gabbro lopoliths are Precambrian
- Some large gabbro lopoliths 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



Calc-Alkaline Trend Controls

- Hydrated slab releases H2O that is absorbed by magma
- At magmatic temperatures H_2O disassociates:
  - $H_2O = H_2 + 1/2O_2$
- 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