Announcements

- Presentations today?
- Homework (5) due today
- Reading: p.260-269
- Last Homework up on web tomorrow.

Chapter 13: Mid-Ocean Rifts

The Mid-Ocean Ridge System

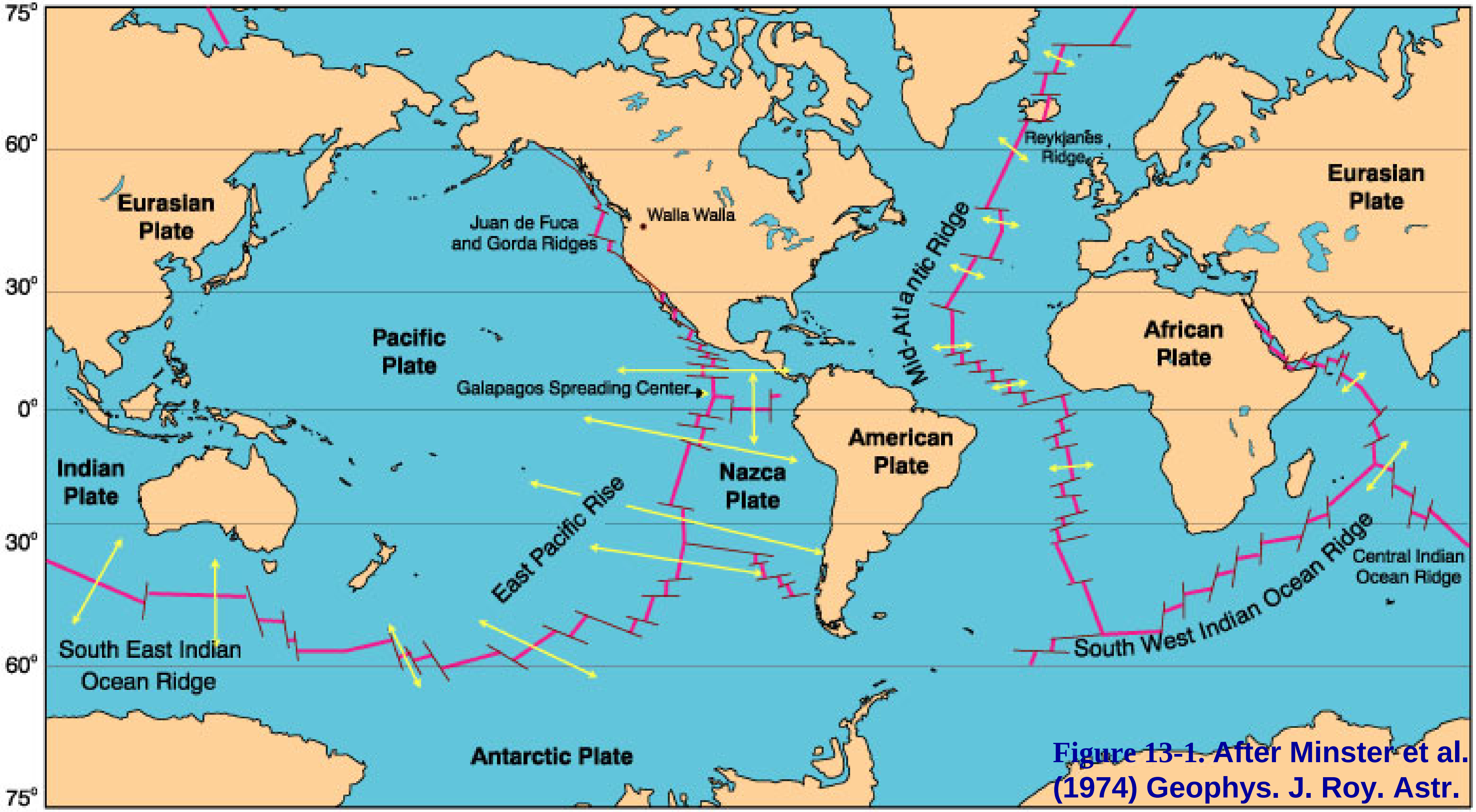


Figure 13-1. After Minster et al. (1974) Geophys. J. Roy. Astr. Soc., 36, 541-576.

Ridge Segments and Spreading Rates

- Slow-spreading ridges:
  < 3 cm/a
- Fast-spreading ridges:
  > 4 cm/a are considered
- Temporal variations are also known

Table 13-1. Spreading Rates of Some Mid-Ocean Ridge Segments

Category	Ridge	Latitude	Rate (cm/a)*
Fast	East Pacific Rise	21-23°N	3
		13°N	5.3
		11°N	5.6
		8-9°N	6
		2°N	6.3
		20-21°S	8
		33°S	5.5
		54°S	4
		56°S	4.6
Slow	Indian Ocean	SW	1
		SE	3-3.7
		Central	0.9
	Mid-Atlantic Ridge	85°N	0.6
		45°N	1-3
		36°N	2.2
		23°N	1.3
		48°S	1.8

From Wilson (1989). Data from Hekinian (1982), Sclater *et al*. (1976), Jackson and Reid (1983). *half spreading

The Axial Magma Chamber

Original Model

- Semi-permanent
- Large
- Periodic reinjection of fresh, primitive MORB from below
- Dikes upward through the extending and faulting roof

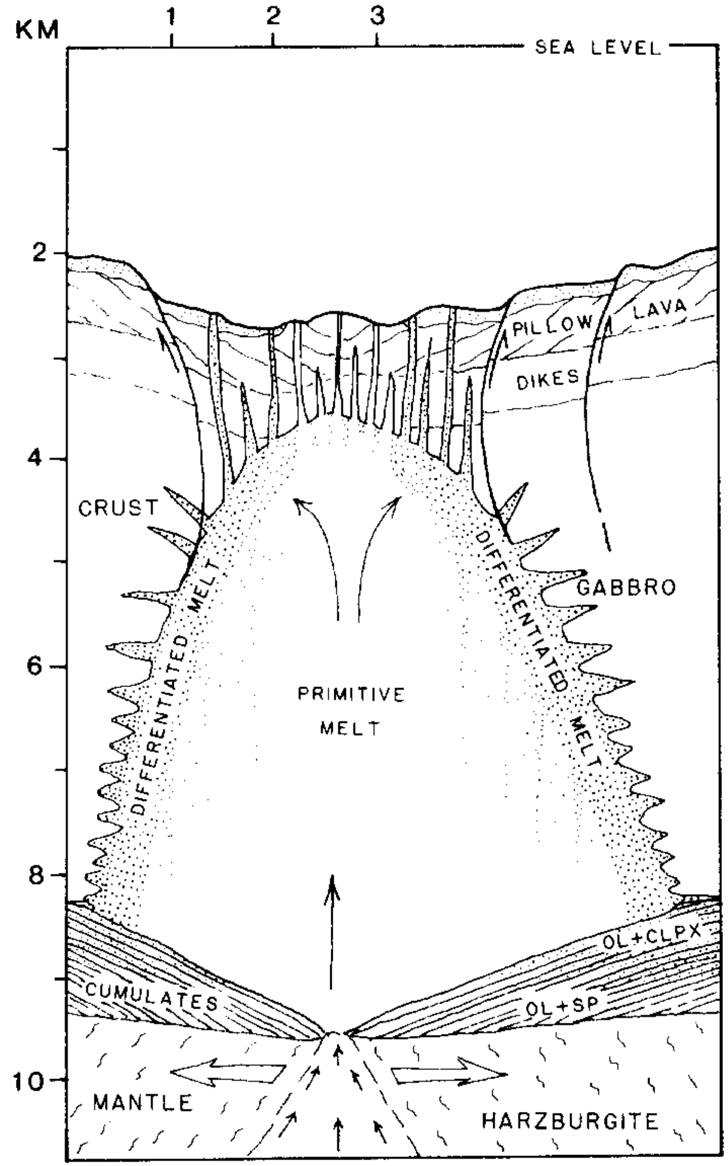
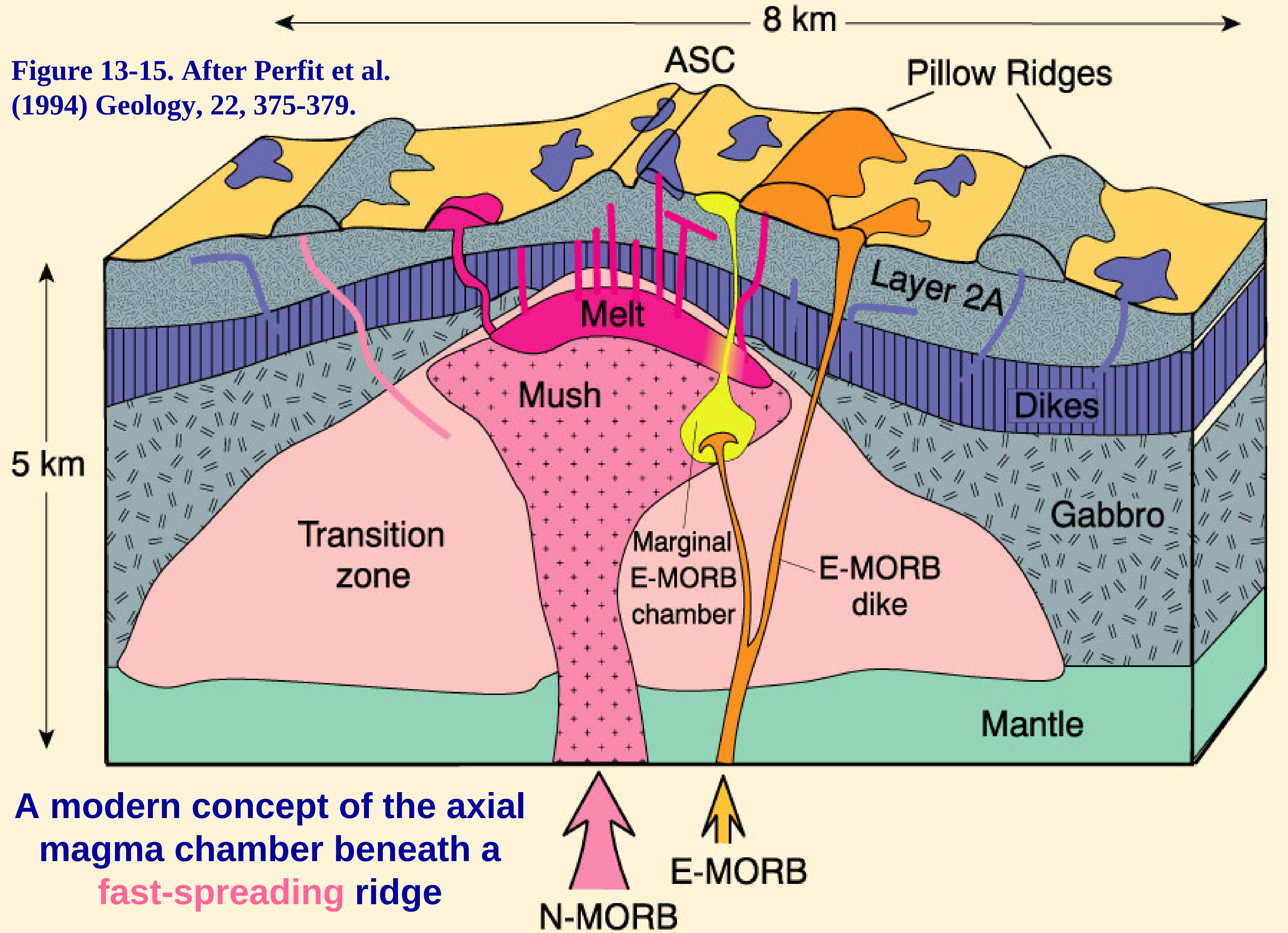


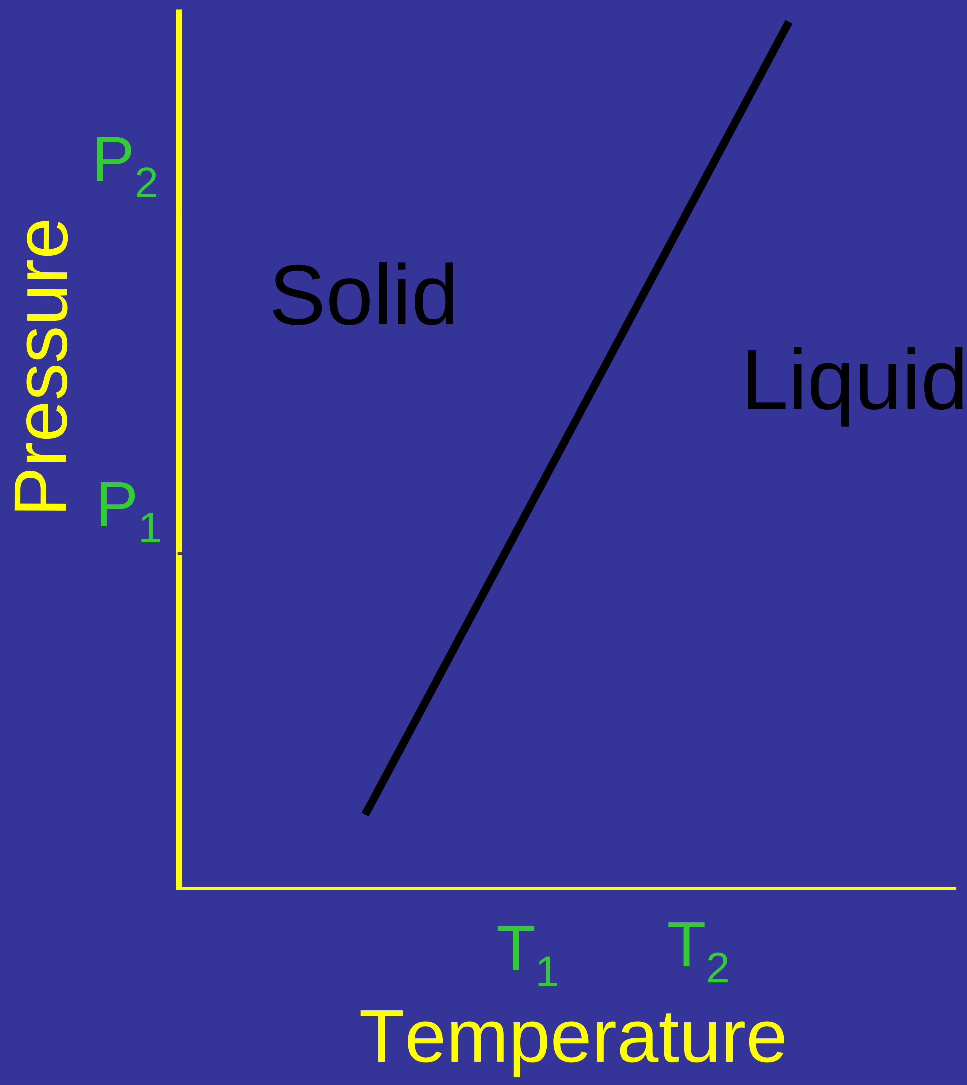
Figure 13-14. From Byran and Moore (1977) Geol. Soc. Amer. Bull., 88, 556-570.

Figure 13-15. After Perfit et al. (1994) Geology, 22, 375-379.



A modern concept of the axial magma chamber beneath a fast-spreading ridge

The Effect of Pressure on (dry) melting behavior



Eutectic system

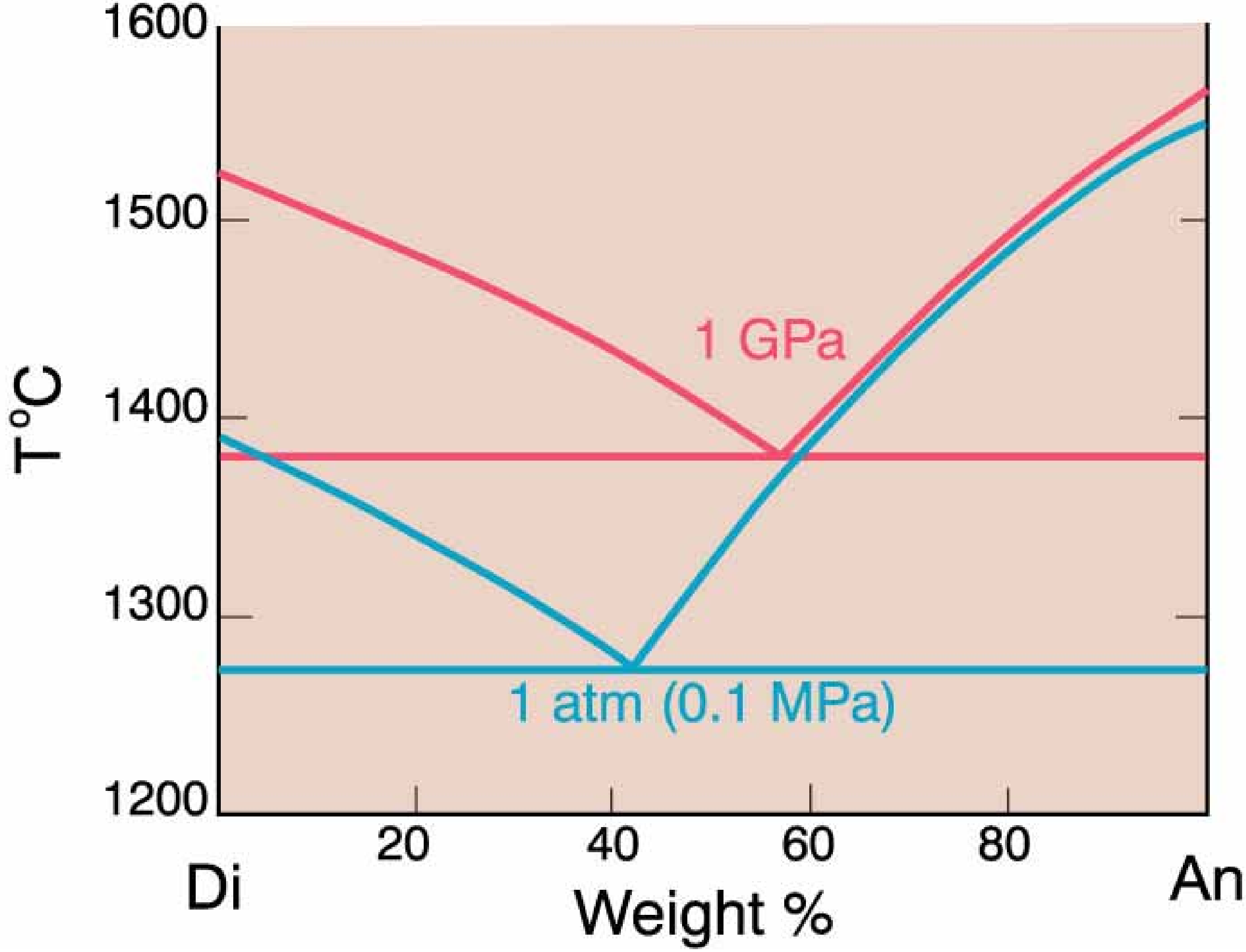


Figure 7-16. Effect of lithostatic pressure on the liquidus and eutectic composition in the diopside-anorthite system. 1 GPa data from Presnall *et al.* (1978). Contr. Min. Pet., 66, 203-220.

How does the mantle melt??

1) Increase the temperature

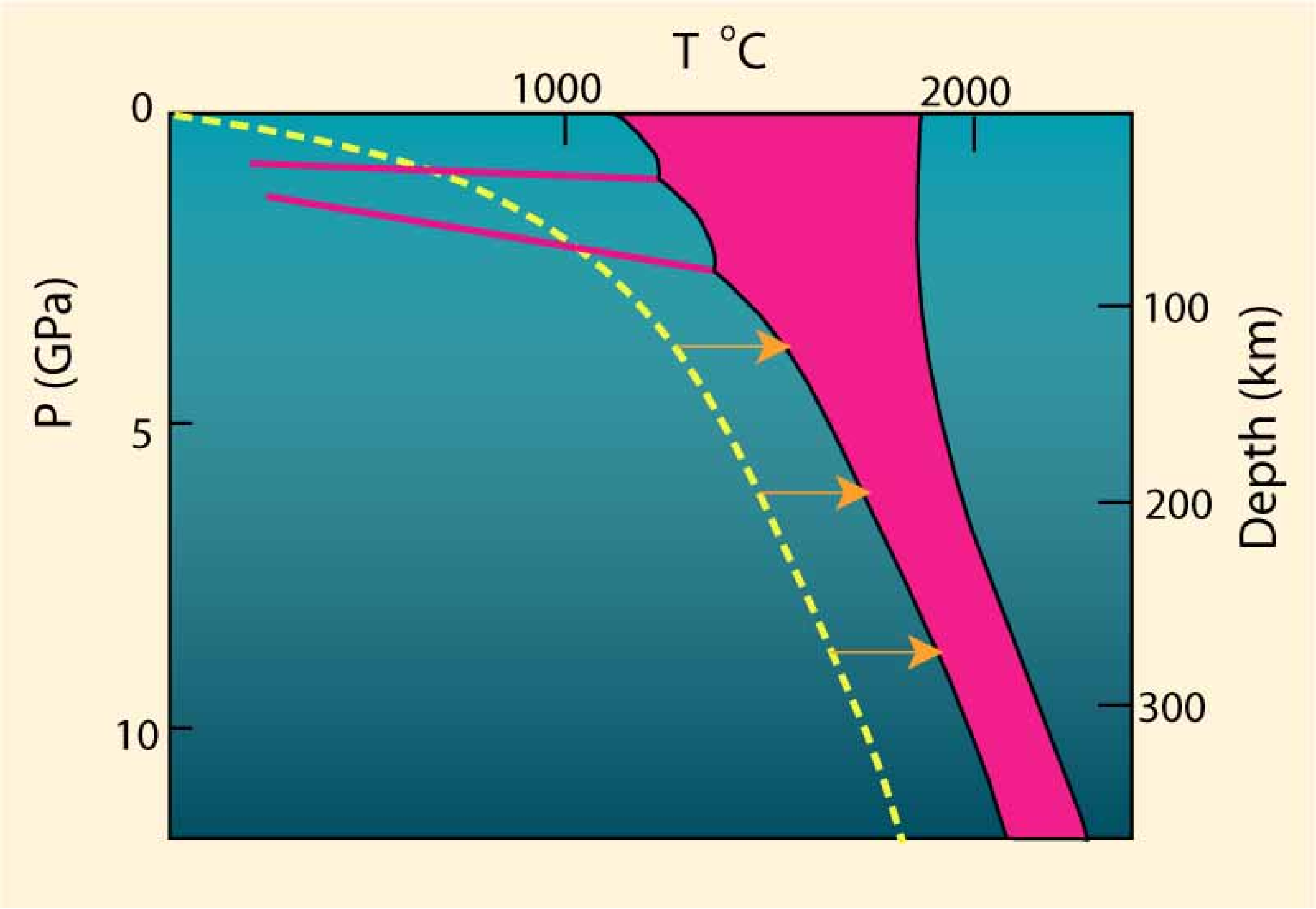


Figure 10-3. Melting by raising the temperature.

How does the mantle melt??

2)Add volatiles (H_2O, CO_2)

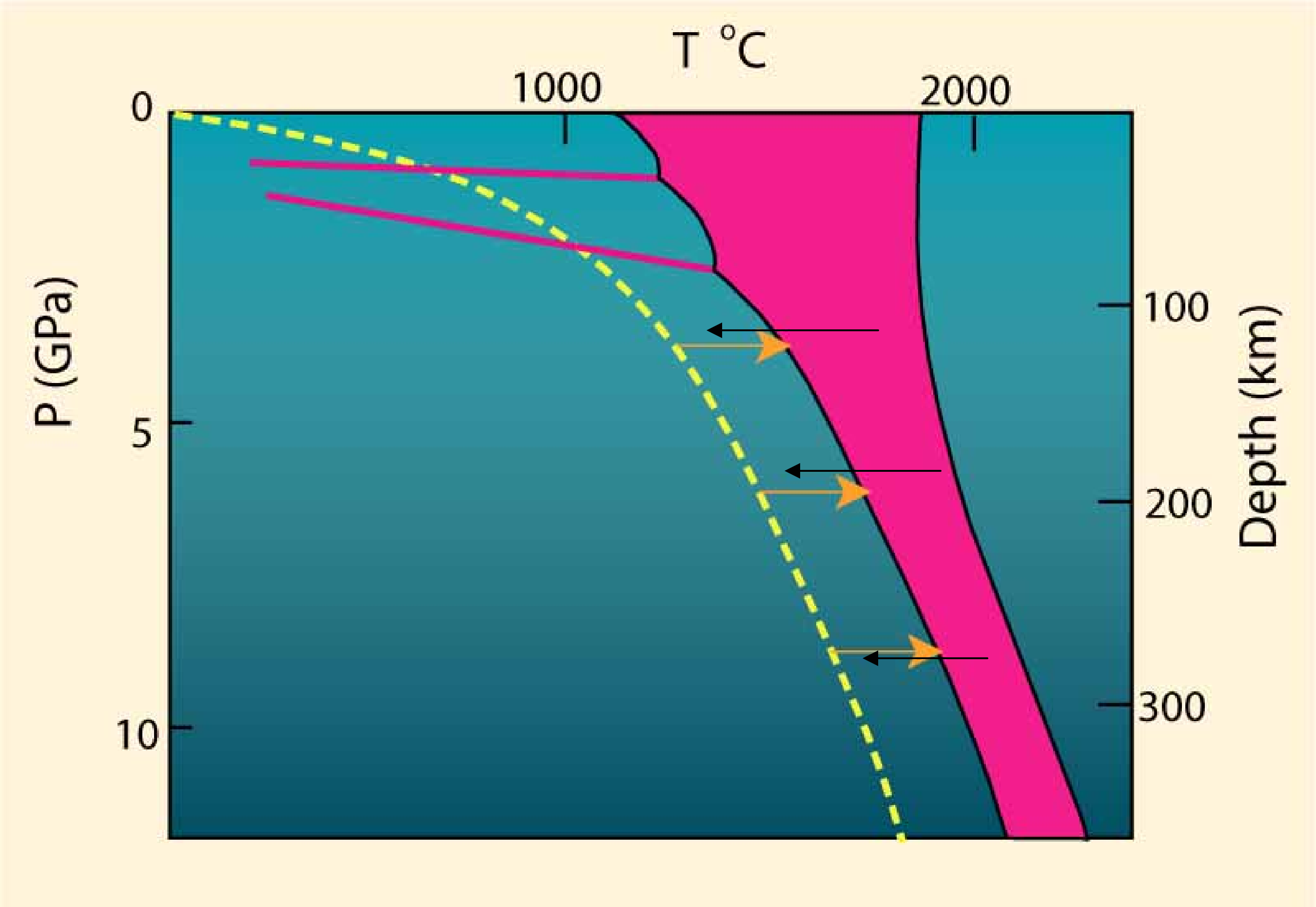


Figure 10-3. **Melting by raising the temperature.**

3) Lower the pressure

– Adiabatic rise of mantle with no conductive heat loss

– Decompression melting could melt at least 30%

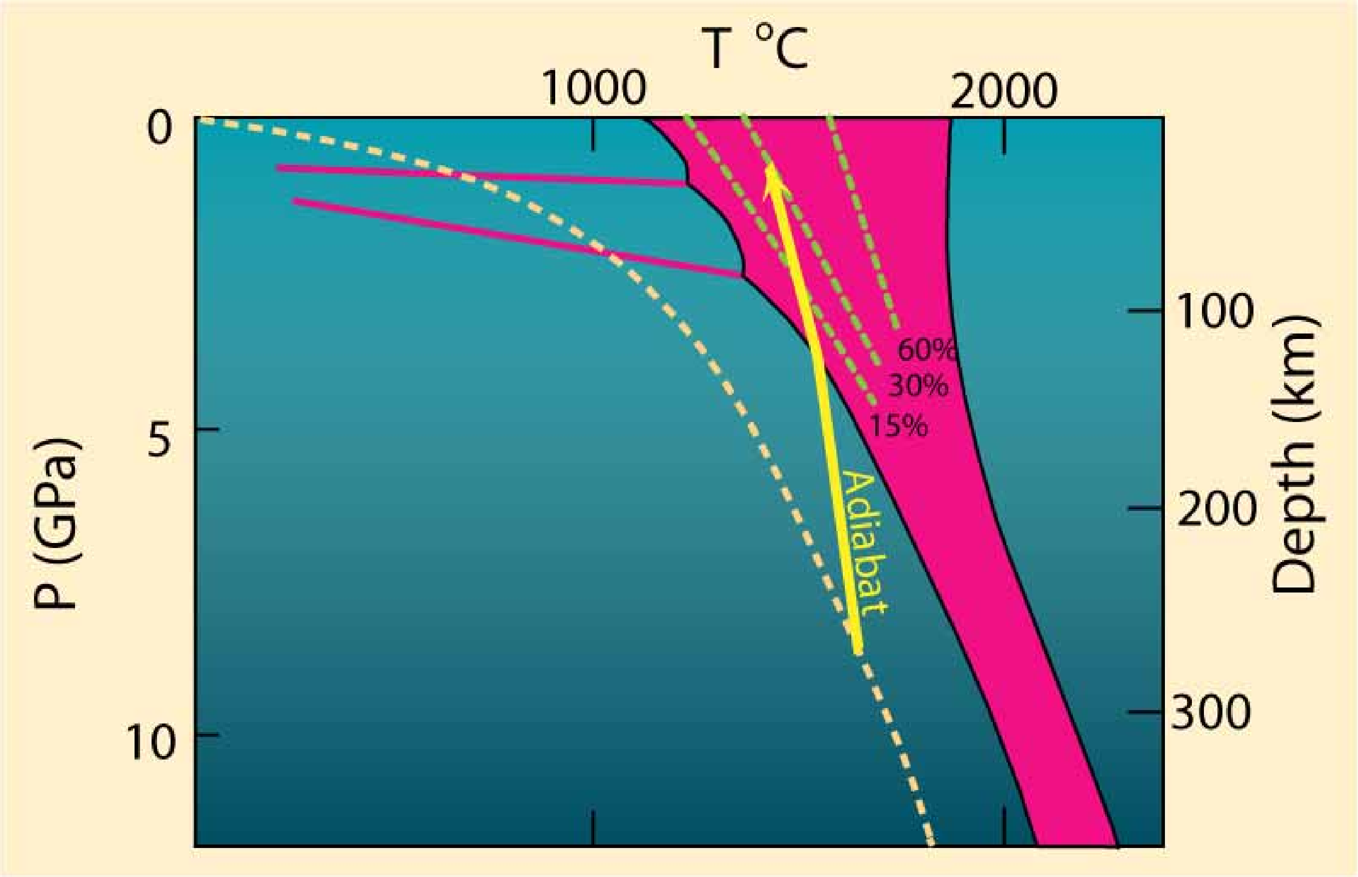


Figure 10-4. Melting by (adiabatic) pressure reduction. Melting begins when the adiabat crosses the solidus and traverses the shaded melting interval. Dashed lines represent approximate % melting.

How does melting happen at MOR?

- Or, whoops, wrong variables.

Went about minimizing Gibbs Free Energy (measure of chemical energy)

Good old Pressure and Temperature have been our independent variables so far

Why?

Fractional crystallization and melting ~ constant P, decrease T

Thermodynamics of mantle melting

- 1st law of thermodynamics: energy is conserved

$dU = q + w$

$w = -PdV$

- Definition of enthalpy (heat energy)

$H = U + PV$

$dH = dU + d(PV)$

$dH = dU + VdP + PdV$

- $dH = q - \cancel{PdV} + VdP + \cancel{PdV}$

Mantle melting model

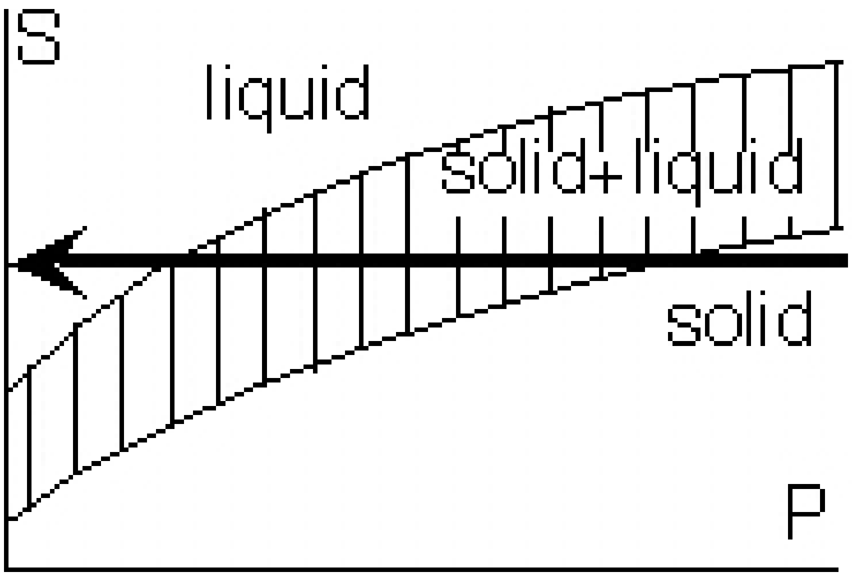
- $dH = q + VdP$
- Second Law: $q = TdS$ for reversible processes

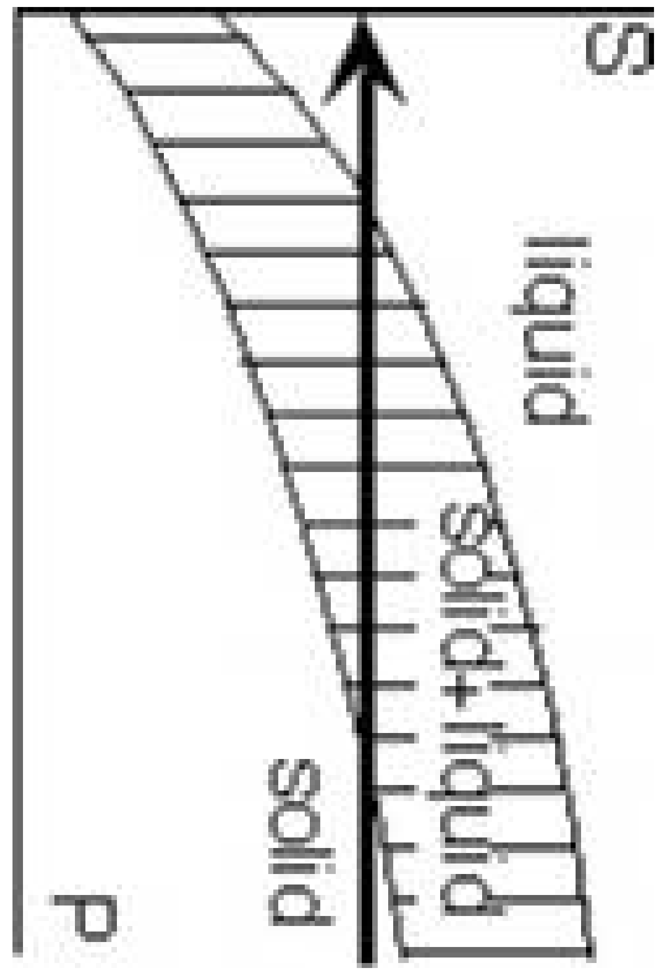
- $dH = TdS + VdP$

- Adiabatic : $dq = 0$ so $dS = 0$.

New variables

- No heat enters or leaves the system
- Minimizing ΔH, not ΔG ($\Delta H = q_P$)





P. Asimow

MORB Petrogenesis

Generation

- Separation of the plates
- Upward motion of mantle material into extended zone
- Decompression partial melting associated with near-adiabatic rise
- N-MORB melting initiated ~ 60-80 km depth in upper depleted mantle where it inherits depleted trace element and isotopic char.

- **Adiabatic = constant heat content**
- **"Decompression melting"**

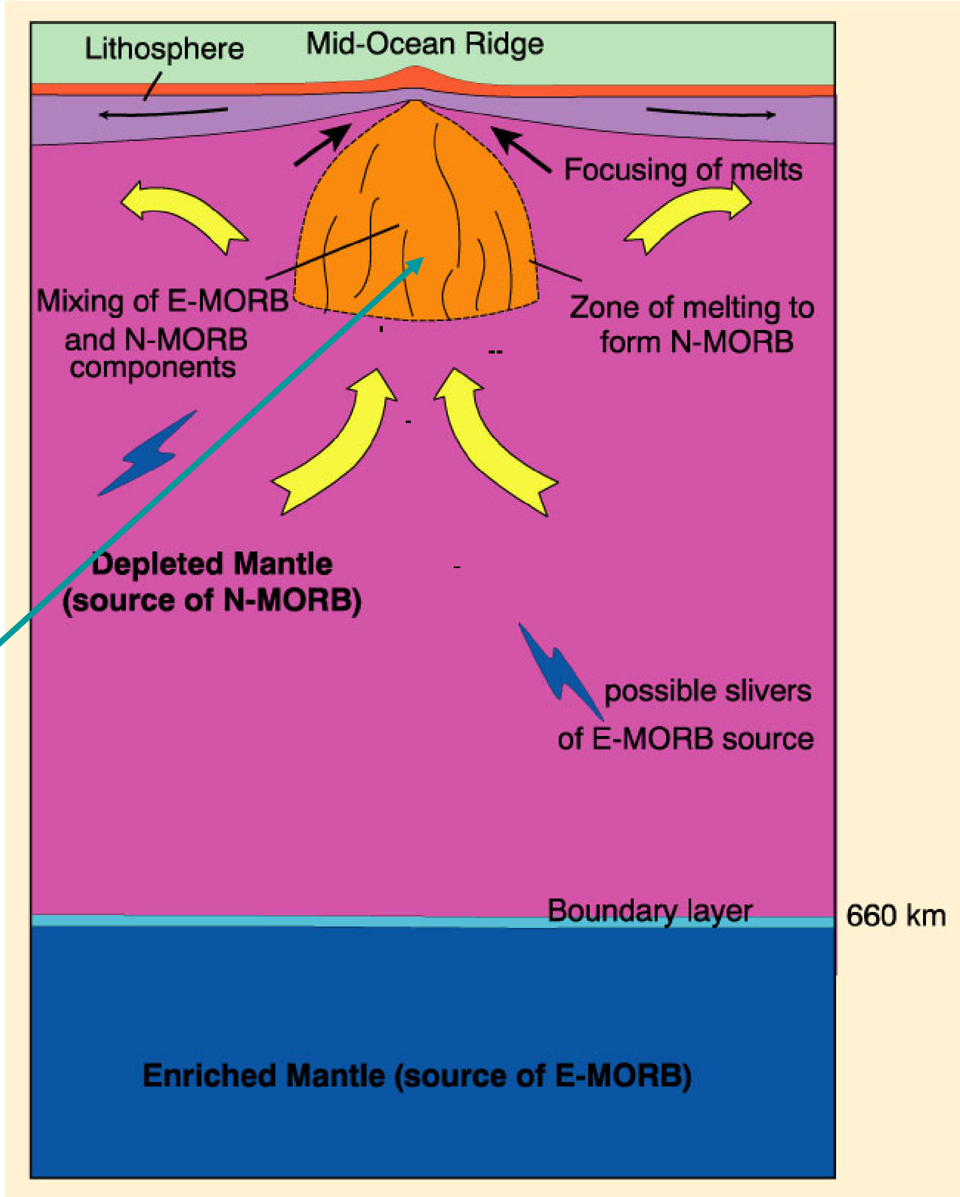
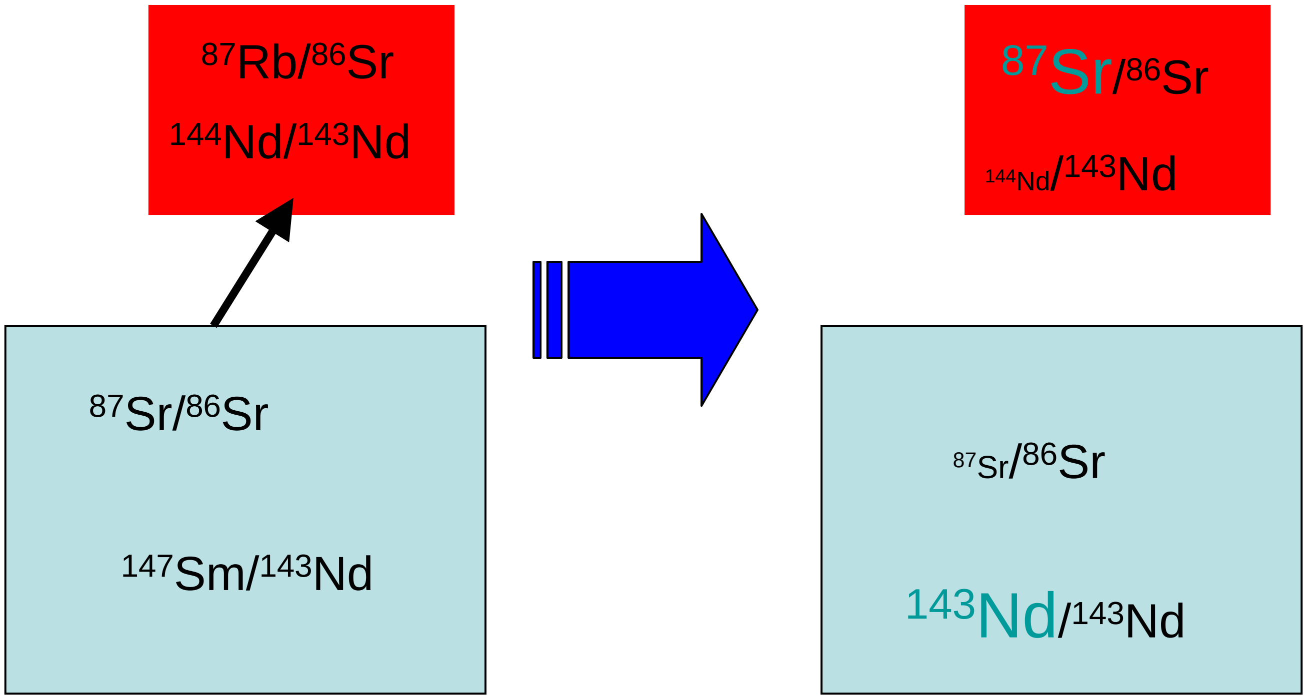


Figure 13-13. After Zindler et al. (1984) Earth Planet. Sci. Lett., 70, 175-195. and Wilson (1989) Igneous Petrogenesis, Kluwer.

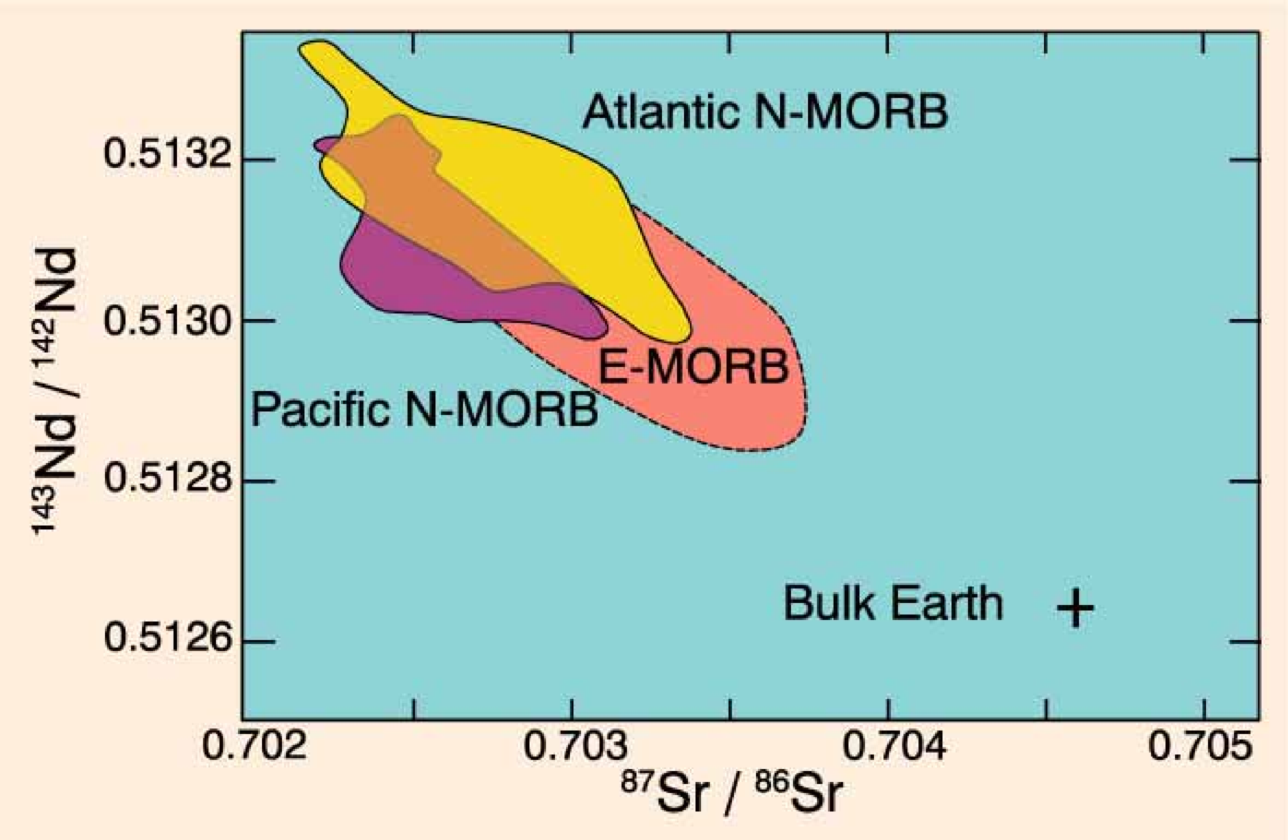
Using Rb-Sr and Sm-Nd as tracers

- $^{87}Rb \rightarrow {}^{87}Sr + \beta$ $t_{1/2}$ = 48 billion years ^{86}Sr stable
- $^{147}Sm \rightarrow {}^{143}Nd + \alpha$ $t_{1/2}$ = 106 billion years ^{144}Nd stable



- N-MORBs: $^{87}Sr/^{86}Sr < 0.7035$ and $^{143}Nd/^{144}Nd > 0.5030$, → depleted mantle source
- E-MORBs extend to more enriched values → stronger support distinct mantle reservoirs for N-type and E-type MORBs

Figure 13-12. Data from Ito et al. (1987) Chemical Geology, 62, 157-176; and LeRoex et al. (1983) J. Petrol., 24, 267-318.



Gibbs Free Energy

Gibbs free energy is a measure of chemical energy

All chemical systems tend naturally toward states of minimum Gibbs free energy

$$G = H - TS$$

Where:

G = Gibbs Free Energy

H = Enthalpy (heat content)

T = Temperature in Kelvins

S = Entropy (can think of as randomness)

Gibbs Free Energy

The change in some property, such as G for a reaction of the type:

$$2\,A \;+\; 3\,B \;=\; C \;+\; 4\,D$$

$$\Delta G = \Sigma\,(n\,G)_{products} - \Sigma(n\,G)_{reactants}$$

$$= G_C + 4G_D - 2G_A - 3G_B$$

- Is negative when products are more stable than reactants
- Is positive when the other way around