Continental Arcs: Deep Processes

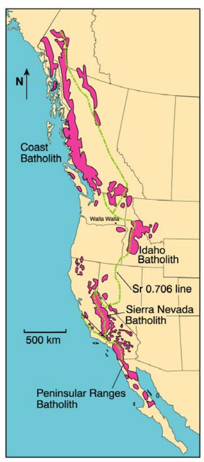
Reading:
Winter Chapter 17

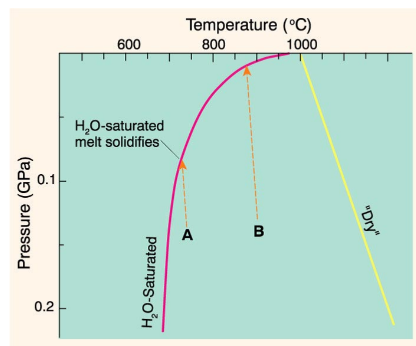
Different from Island Arcs

- •Thick sialic crust contrasts greatly with mantle-derived partial melts may produce more pronounced effects of contamination
- •Low density of crust may retard ascent leads to stagnation of magmas and more potential for differentiation
- •Low melting point of crust allows for partial melting and crustally-derived melts

North American Batholiths

Major plutons of the North American Cordillera, a principal segment of a continuous Mesozoic-Tertiary belt from the Aleutians to Antarctica. After Anderson (1990, preface to *The Nature and Origin of Cordilleran Magmatism. Geol. Soc. Amer. Memoir*, 174. The Sr 0.706 line in N. America is after Kistler (1990), Winter (2001)

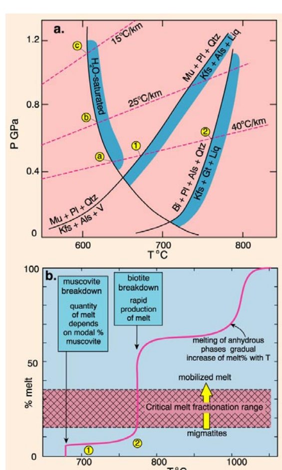




Pressure-temperature phase diagram showing solidus curves for H_2O-saturated and dry granite. An H_2O-saturated granitoid just above the solidus at A will quickly intersect the solidus as it rises and will therefore solidify. A hotter, H_2O-undersaturated granitoid at B will rise further before solidifying. Note: because the pressure axis is inverted, a negative dP/dT Clapeyron slope will appear positive. Winter (2001)

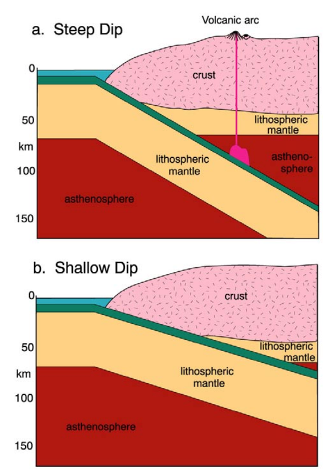
Crustal Melting

a. **Simplified P-T phase diagram**
b. **Quantity of melt generated during the melting of muscovite-biotite-bearing crustal source rocks, after Clarke (1992) *Granitoid Rocks*. Chapman Hall, London; and Vielzeuf and Holloway (1988) *Contrib. Mineral. Petrol.*, 98, 257-276.**
c. **Shaded areas in (a) indicate melt generation. Figures from Winter (2001)**



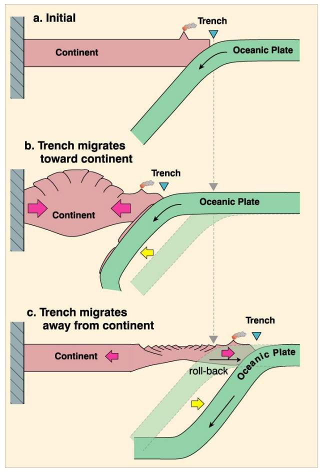
Subduction Section

Schematic diagram to illustrate how a shallow dip of the subducting slab can pinch out the asthenosphere from the overlying mantle wedge. Winter (2001)



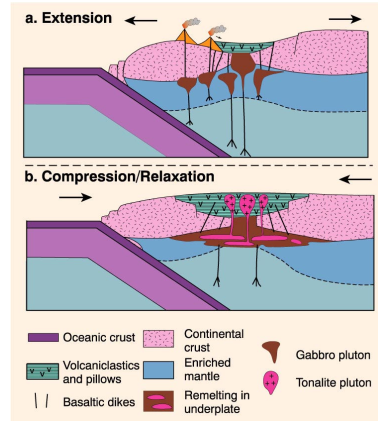
Thick Crust Model

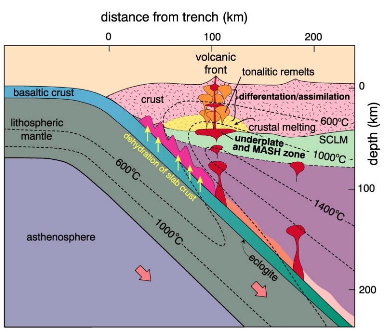
Schematic cross sections of a volcanic arc showing an initial state (a) followed by trench migration toward the continent (b), resulting in a destructive boundary and subduction erosion of the overlying crust. Alternatively, trench migration away from the continent (c) results in extension and a constructive boundary. In this case the extension in (c) is accomplished by "roll-back" of the subducting plate. An alternative method involves a jump of the subduction zone away from the continent, leaving a segment of oceanic crust (original dashed) on the left of the new trench. Winter (2001) .



Continental Underplating

Schematic diagram illustrating (a) the formation of a gabbroic crustal underplate at an continental arc and (b) the remelting of the underplate to generate tonalitic plutons. After Cobbing and Pitcher (1983) in J. A. Roddick (ed.), *Circum-Pacific Plutonic Terranes. Geol. Soc. Amer. Memoir*, 159. pp. 277-291.



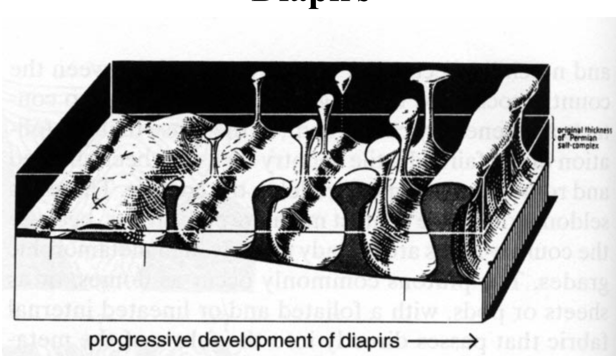


Schematic cross section of an active continental margin subduction zone, showing the dehydration of the subducting slab, hydration and melting of a heterogeneous mantle wedge (including enriched sub-continental lithospheric mantle), crustal underplating of mantle-derived melts where MASH processes may occur, as well as crystallization of the underplates. Remelting of the underplate to produce tonalitic magmas and a possible zone of crustal anatexis is also shown. As magmas pass through the continental crust they may differentiate further and/or assimilate continental crust. Winter (2001)

Instabilities

- A layer of less dense material overlain by a denser material is unstable
- The upper layer develops undulations and bulges (Rayleigh-Taylor instabilities)
- The spacing of the bulges depends on the thickness of the light layer and its density contrast with the heavy layer

Diapirs

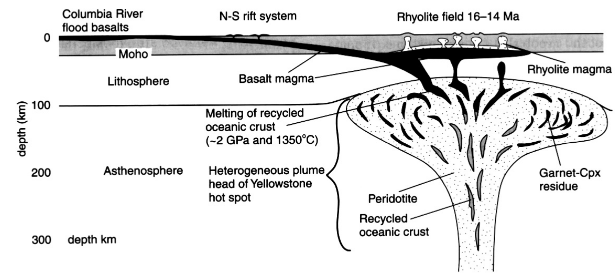


Diapir Ascent

- Velocity of ascent depends on diapir size and shape
- A sphere is the most efficient shape
- Surface area ~ frictional resistance
- Volume ~ buoyant driving force
- Rise velocity proportional to area squared

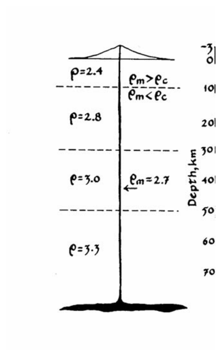
Neutral Buoyancy

- Positively buoyant
  - Melt that is less dense than surrounding rocks
  - Primary basalt magma surrounded by mantle peridotite
- Negatively buoyant
  - Melt that is more dens than surrounding rocks
  - Olivine basalt intruded into continental crust



Density Filter

- Crustal rocks block the ascent of denser magmas
- Heat from these magmas melt the lower crust
- Residual melts may rise
- Exsolved volatiles also facilitate rise



How Can Dense Magma Rise?

- Volumetric expansion on melting?
- Exsolution of bubbles?
- There must be another cause.

Magma Overpressure

- For a magma lens, pressure is equal to the lithostatic load

$$P_m = \rho_r g z$$

- The pressure can be greater in a conduit connecting a deeper pocket to the surface
- This overpressure can be great enough to bring denser magma to the surface

Magma Ascent

- Dikes
  - Sub-vertical cracks in brittle rock
- Diapirs
  - Bodies of buoyant magma
  - They squeeze through ductile material