

# Chapter 17: Continental Arc Magmatism

## Potential differences with respect to Island Arcs:

- ✦ Thick sialic crust → more pronounced effects of contamination
- ✦ Low density of crust may retard ascent
  - ▲ stagnation of magmas
  - ▲ more potential for differentiation
- ✦ Low melting point of crust allows for partial melting and crustally-derived melts

# Continental Magmatic Arcs

Common characteristic – mixture of rock types

- basalt and rhyolite
- called bimodal volcanism

Direct result of magma interactions w/thicker continental crust

Tendency to explosive activity

- High  $\text{SiO}_2$  content
- High viscosity
- Increase in  $\text{H}_2\text{O}$  content
- Gas expansion during low P boiling of  $\text{H}_2\text{O}$

# Continental Magmatic Arcs

Batholiths – peculiar to continental margins

- Enormous, 10s to 100s thousands of km<sup>2</sup>  
Composed of 100s of individual plutons
- Called granite but actually dominated by granodiorite, tonalite and qtz diorite

# Petrography of continental arc volcanics

## **Andesites** – phenocryst-rich

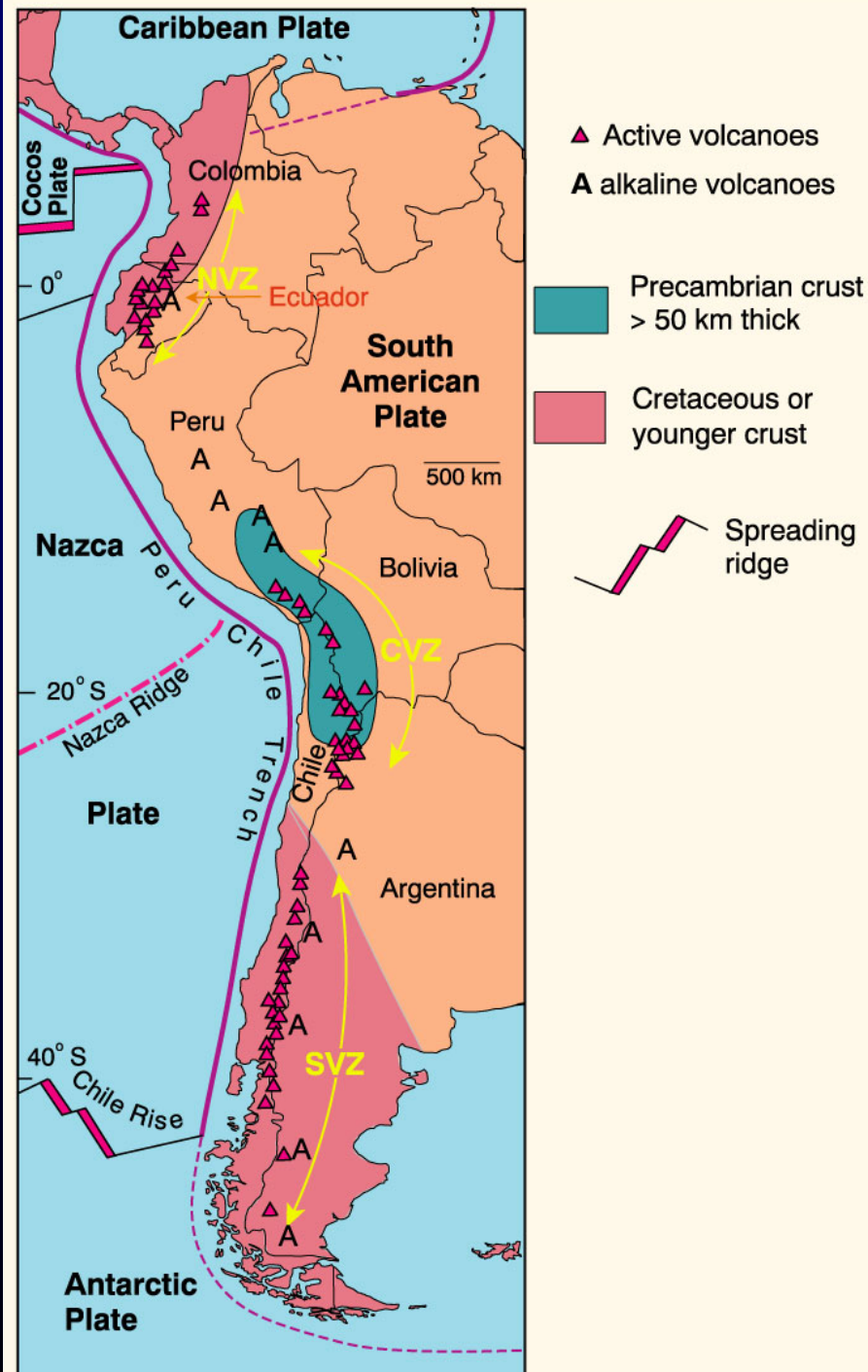
- strongly zoned plagioclase often with sieve texture
- partially resorbed hydrous minerals such as biotite and hornblende
  - Oxidation forms fine-grained magnetite in irregular outer margin of resorbed xstals

## **Intrusive rocks** – dominated by plagioclase, K-feldspar, qtz, biotite, and hornblende

- Granodiorite, tonalite, diorite

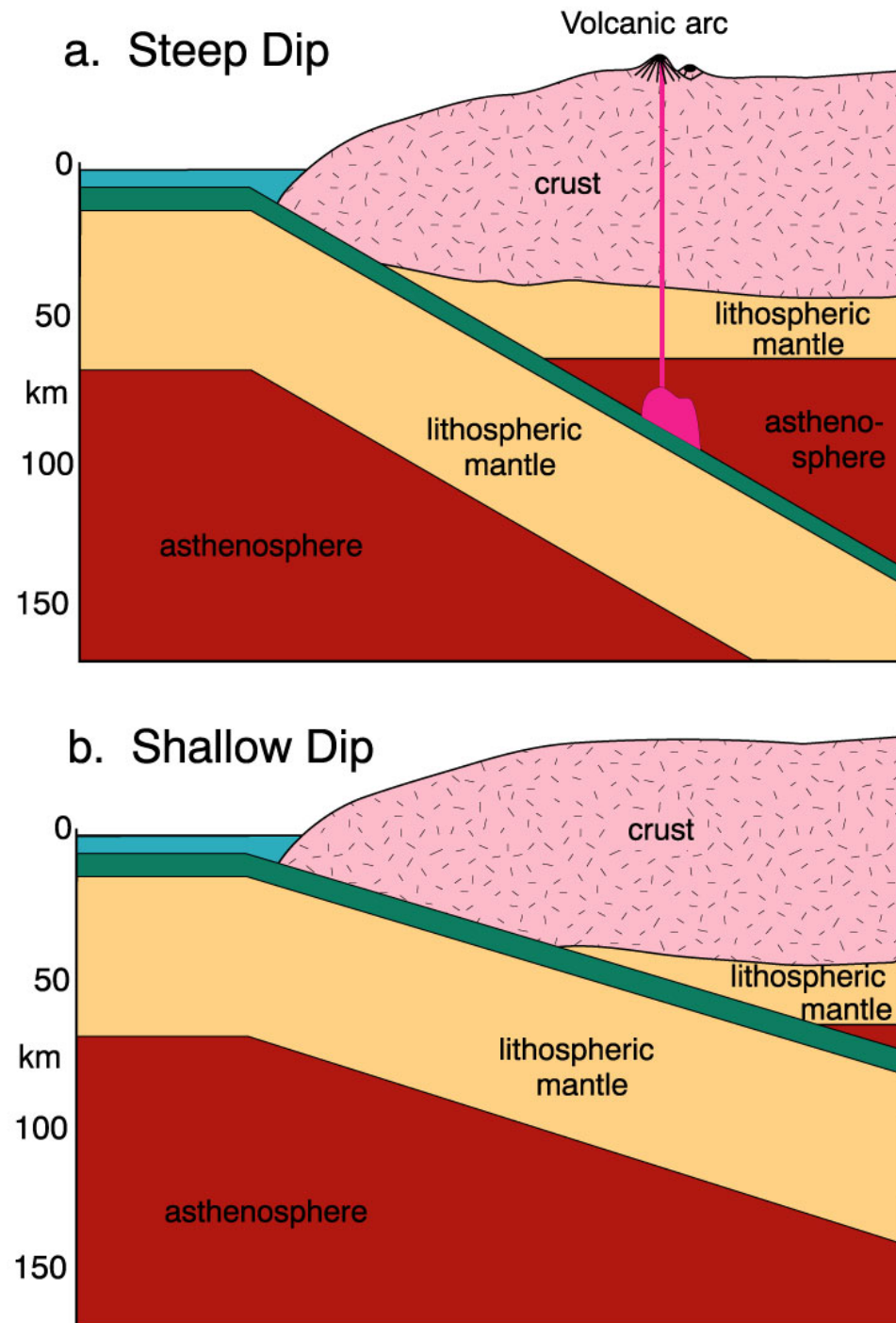
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**Figure 17-1.** Map of western South America showing the plate tectonic framework, and the distribution of volcanics and crustal types. NVZ, CVZ, and SVZ are the northern, central, and southern volcanic zones. After Thorpe and Francis (1979) *Tectonophys.*, 57, 53-70; Thorpe *et al.* (1982) In R. S. Thorpe (ed.), (1982). *Andesites. Orogenic Andesites and Related Rocks*. John Wiley & Sons. New York, pp. 188-205; and Harmon *et al.* (1984) *J. Geol. Soc. London*, 141, 803-822. Winter (2001) *An Introduction to Igneous and Metamorphic Petrology*. Prentice Hall.

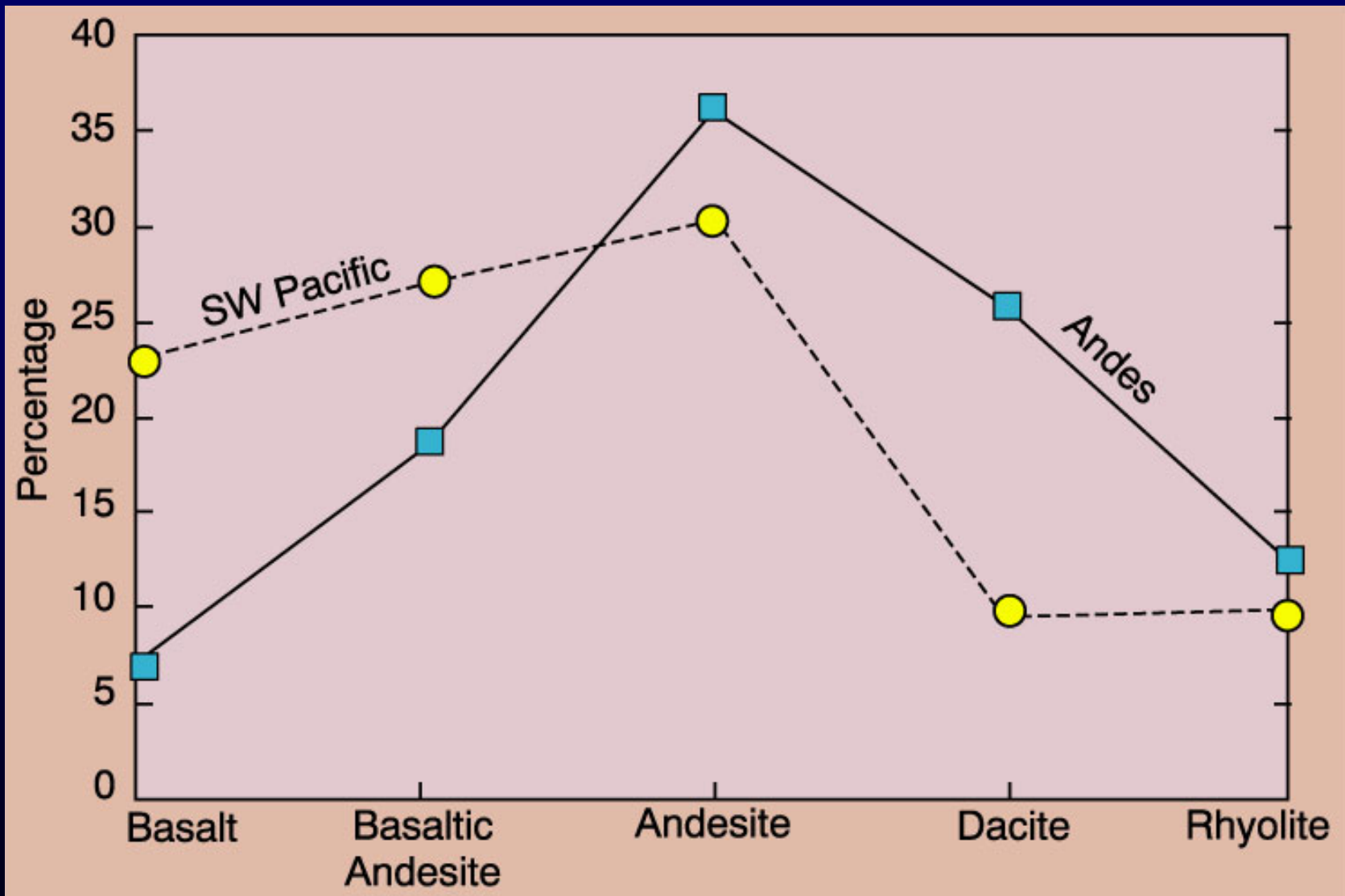


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**Figure 17-2. Schematic diagram to illustrate how a shallow dip of the subducting slab can pinch out the asthenosphere from the overlying mantle wedge.** Winter (2001) *An Introduction to Igneous and Metamorphic Petrology*. Prentice Hall.



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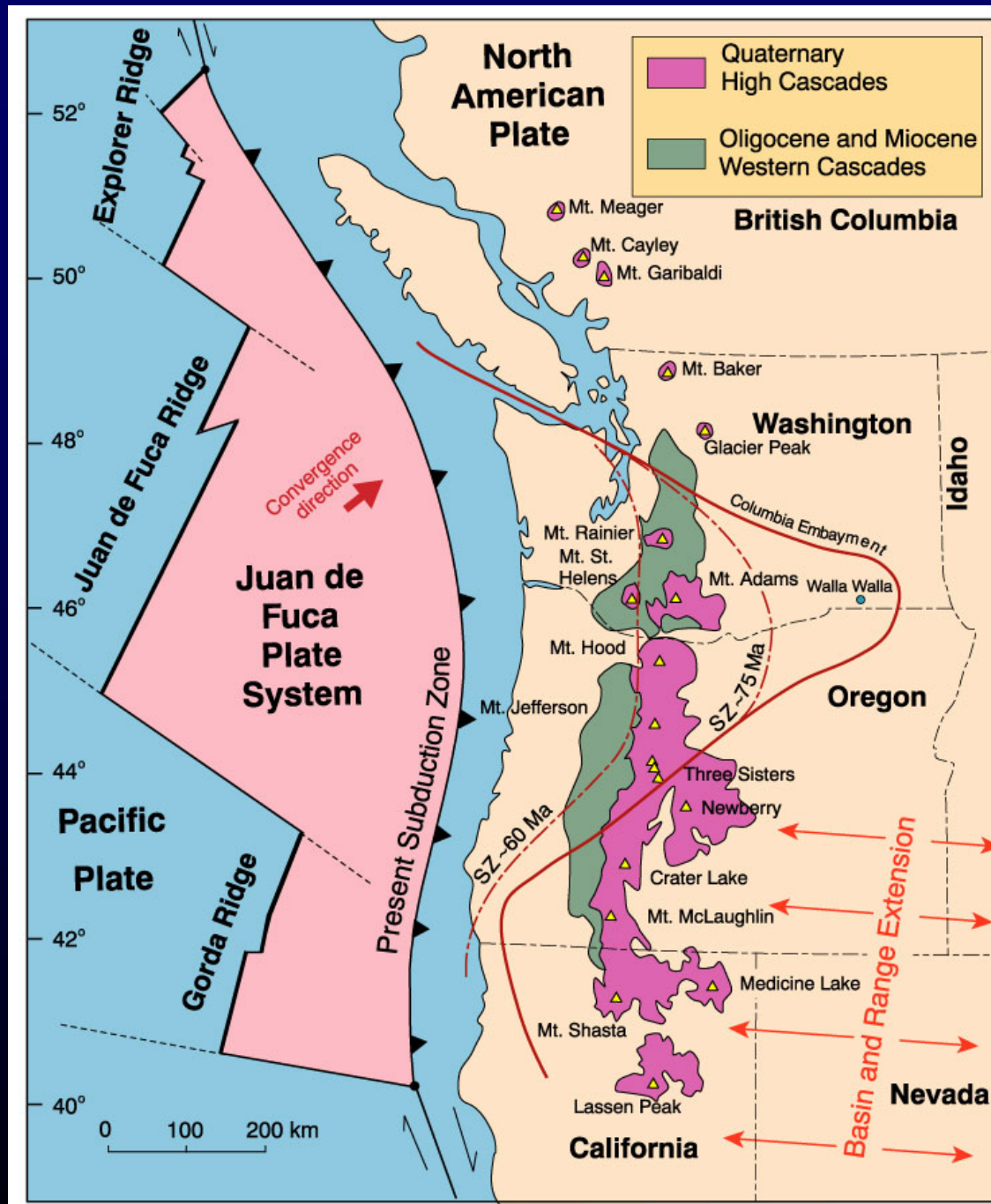


**Figure 17-9.** Relative frequency of rock types in the Andes vs. SW Pacific Island arcs. Data from 397 Andean and 1484 SW Pacific analyses in Ewart (1982) In R. S. Thorpe (ed.), *Andesites*. Wiley. New York, pp. 25-95. Winter (2001) *An Introduction to Igneous and Metamorphic Petrology*. Prentice Hall.



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**Figure 17-10.** Map of the Juan de Fuca plate-Cascade Arc system, after McBirney and White, (1982) *The Cascade Province*. In R. S. Thorpe (ed.), *Andesites, Orogenic Andesites and Related Rocks*. John Wiley & Sons, New York. pp. 115-136. Also shown is the Columbia Embayment (the western margin of pre-Tertiary continental rocks) and approximate locations of the subduction zone as it migrated westward to its present location (after Hughes, 1990, *J. Geophys. Res.*, 95, 19623-19638). Due to sparse age constraints and extensive later volcanic cover, the location of the Columbia Embayment is only approximate (particularly along the southern half). Winter (2001) *An Introduction to Igneous and Metamorphic Petrology*. Prentice Hall.



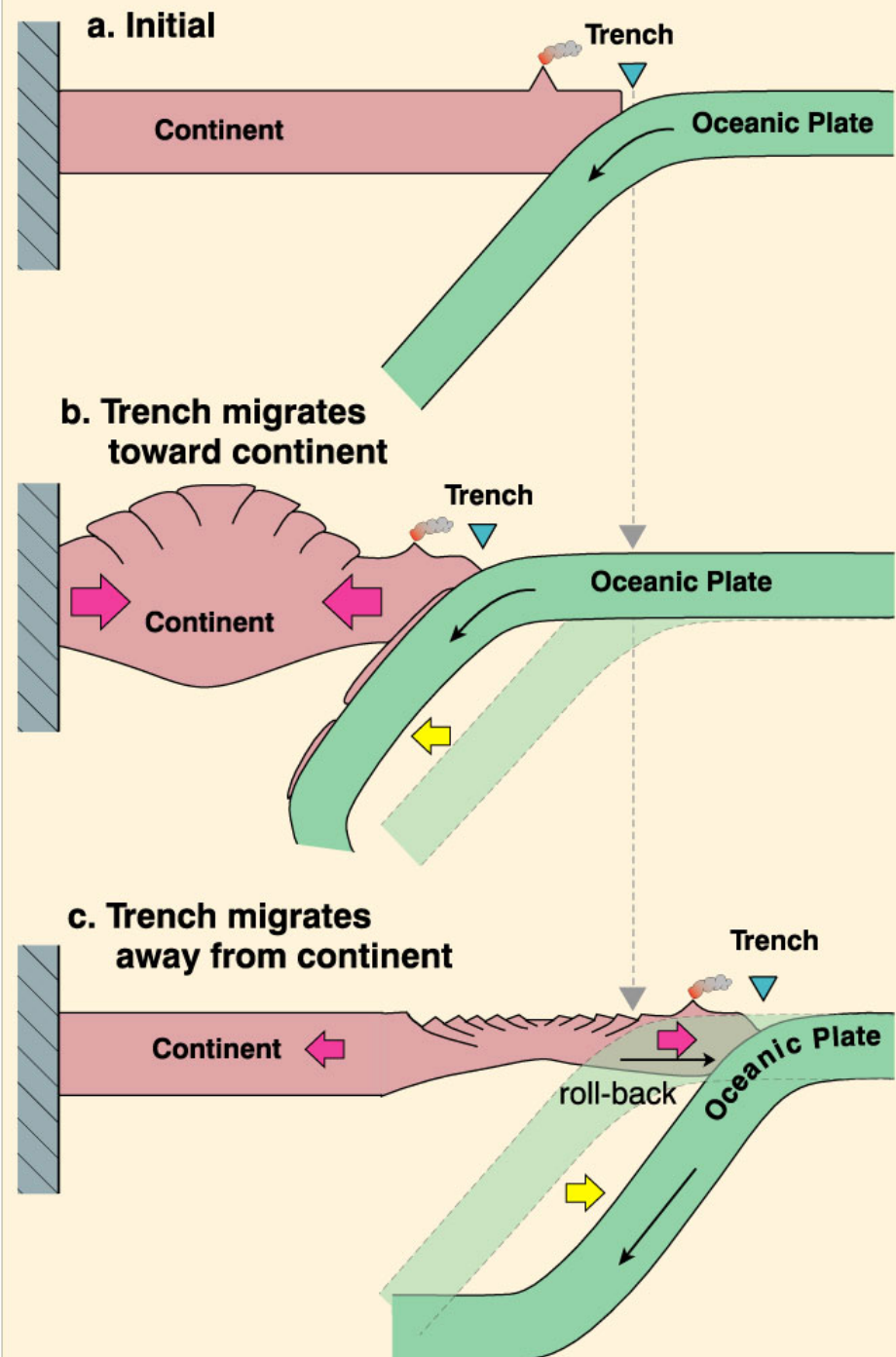


# Chapter 17: Continental Arc Magmatism

## a. Initial state

- Destructive Boundary – trench migrates toward continent
- Constructive Boundary – trench migrates away from continent

**Figure 17-11.** 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) *An Introduction to Igneous and Metamorphic Petrology*. Prentice Hall.



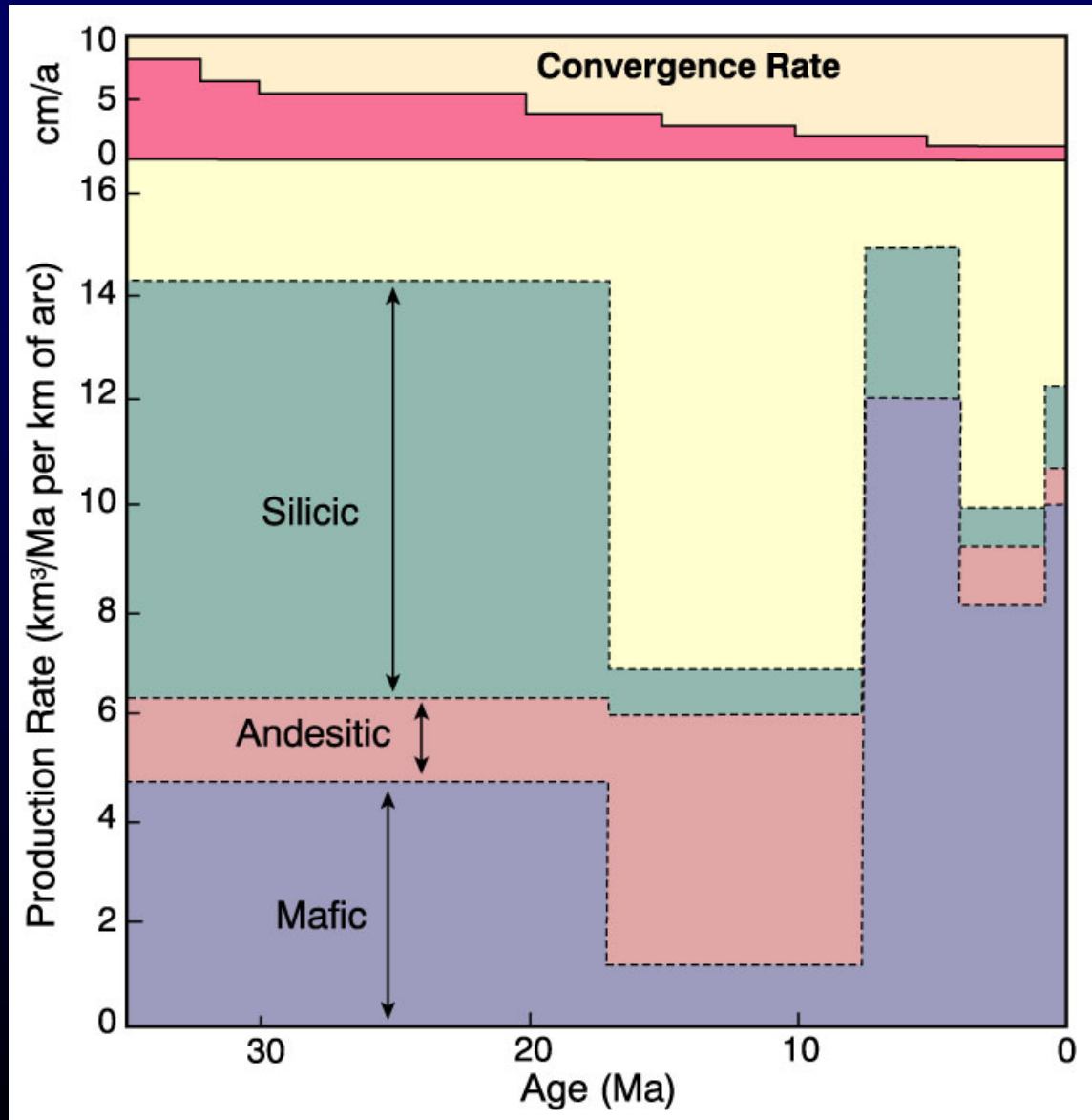
# Chapter 17: Continental Arc Magmatism

## Juan de Fuca-North American plate convergence rates for the past 35 Ma.

(Verplanck and Duncan, 1987 *Tectonics*, 6, 197-209)

**Figure 17-12. Time-averaged rates of extrusion of mafic (basalt and basaltic andesite), andesitic, and silicic (dacite and rhyolite) volcanics (Priest, 1990, *J. Geophys. Res.*, 95, 19583-19599) .**

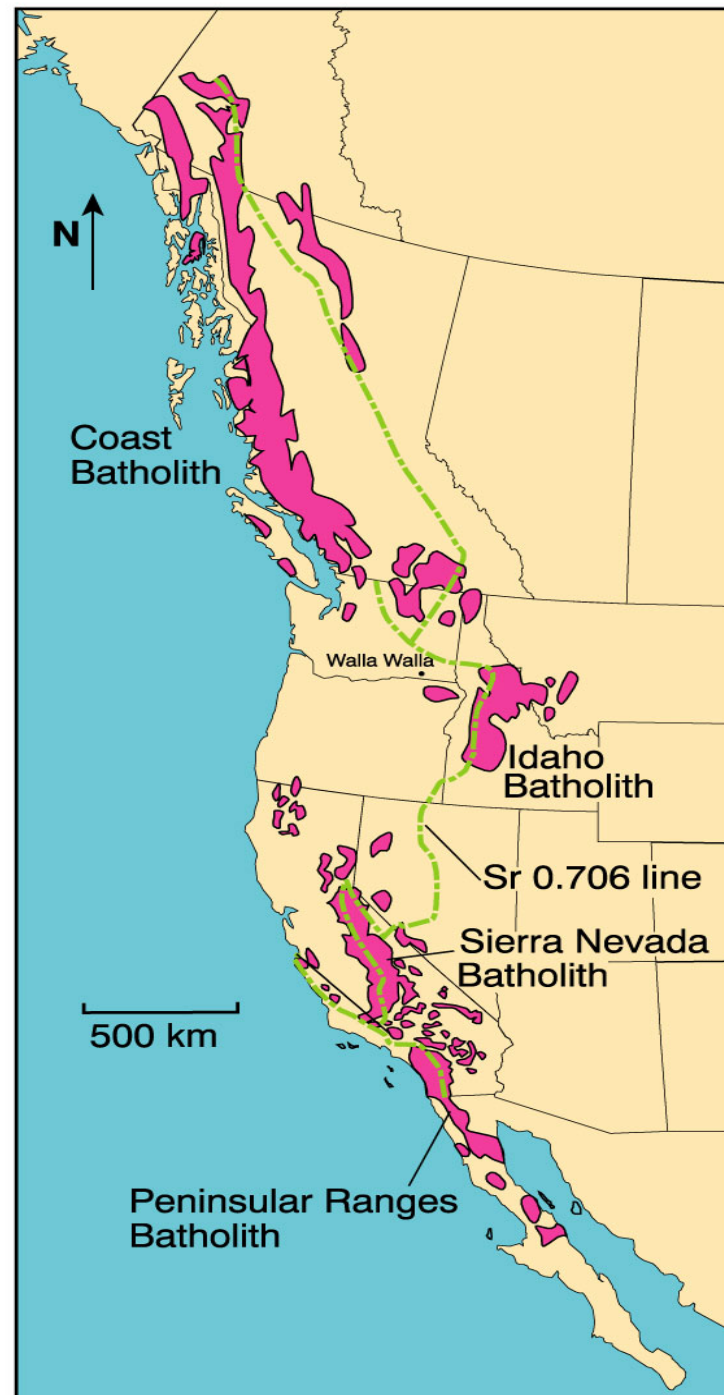
**The volcanics are poorly exposed and sampled, so the timing should be considered tentative. Winter (2001) *An Introduction to Igneous and Metamorphic Petrology*. Prentice Hall.**



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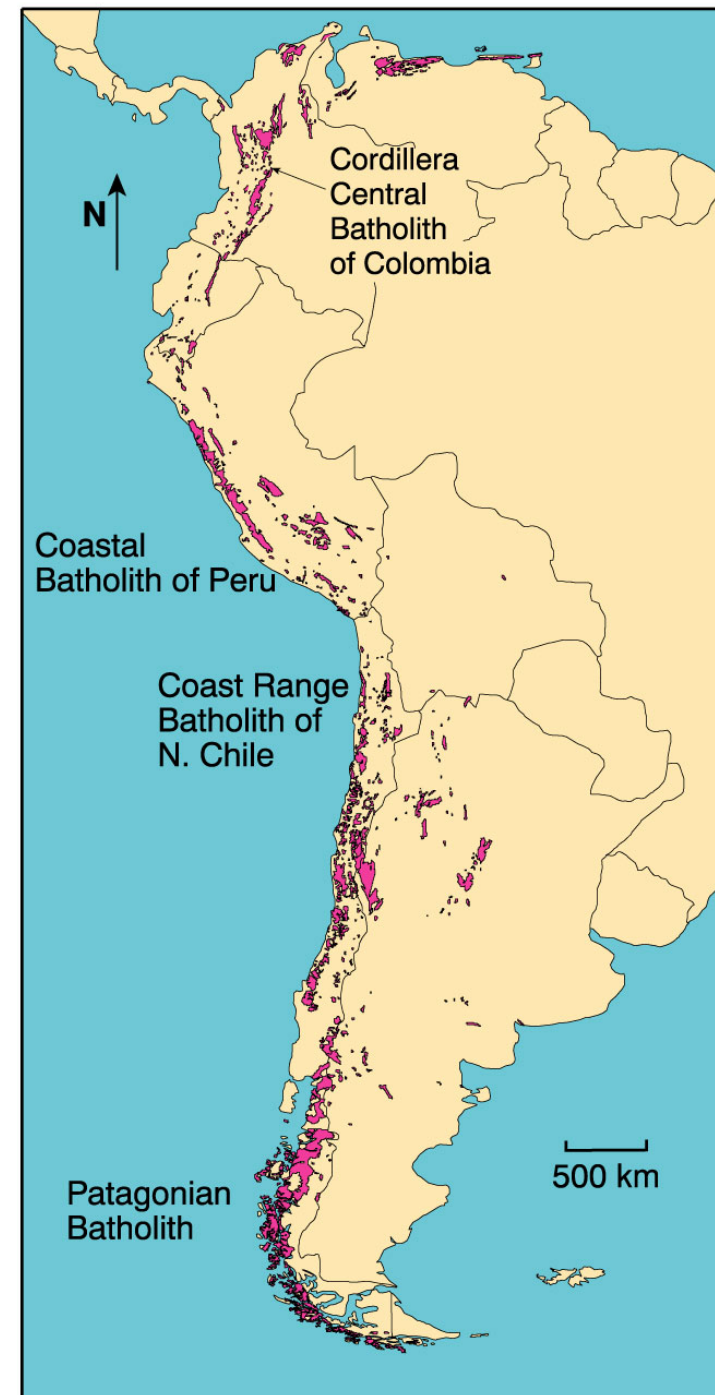
## Figure 17-15a. Major plutons of the North American Cordillera, a principal segment of a continuous Mesozoic-Tertiary belt from the Aleutians to Antarctica.

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), Miller and Barton (1990) and Armstrong (1988). Winter (2001) *An Introduction to Igneous and Metamorphic Petrology*. Prentice Hall.

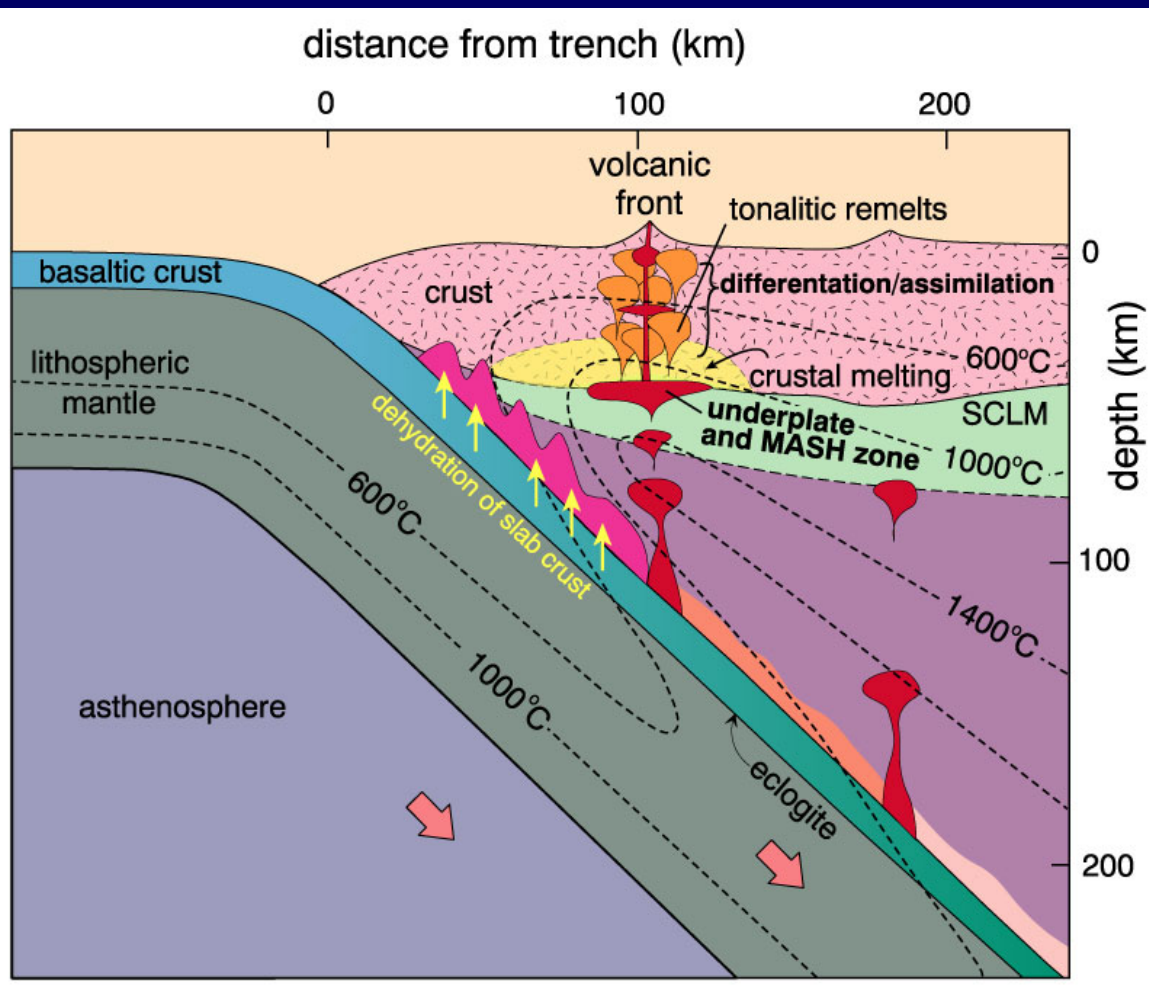


# Chapter 17: Continental Arc Magmatism

**Figure 17-15b. Major plutons of the South American Cordillera, a principal segment of a continuous Mesozoic-Tertiary belt from the Aleutians to Antarctica. After USGS.**



# Petrogenesis of continental arc magmas



- Complex, multi-source, multi-stage
- Origin – peridotites of mantle wedge
- Melting induced by addition of LIL-enriched fluids from subducting slab
- Primary magma = olivine tholeiite basalt
- Pond at base of thick cont crust and undergo fractional xstallization, assimilation, and melting of lower crustal rocks

**Figure 17-23.** Winter (2001) *An Introduction to Igneous and Metamorphic Petrology*.



# Differences between continental arc and island arc volcanics

1. Sub-continental lithospheric mantle (SCLM) – different from oceanic lithosphere

Anchored to overlying continent since formation

Xenoliths from kimberlites suggest SCLM locally enriched during its stagnation beneath continent

Enriched mantle becomes part of subduction zone wedge

2. MASH – various combinations of melting, assimilation, storage and homogenization at base of crust

Great deal of magma crystallizes at base of crust adding to it in process called underplating

3. Continental arc magmas – biased toward more siliceous magmas w/higher concentrations of  $K_2O$ , Rb, Cs, Ba, Th and LREE and more enriched isotopes

Correlates w/presence of thick continental crust



# Differences between continental arc and island arc volcanics

Old re-enriched subcontinental lithospheric mantle contributes to enrichment of continental magmatic arcs

4. Plutonic rocks more evolved than volcanics – voluminous tonalites, monzonites and granites w/lesser amounts of gabbros and qtz diorites
5. Combination of mantle-derived melting that solidified before reaching surface and remelts of mafic magmas that solidified as crustal underplates
6. Continental arc sources include: subducted oceanic crust and sediments, mantle wedge, heterogeneous continental crust, crustal underplates and sub-continental lithospheric mantle