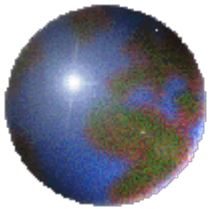
Introduction to Physical Geology



Chapter 12 Part II Mountain Ranges, and Continents

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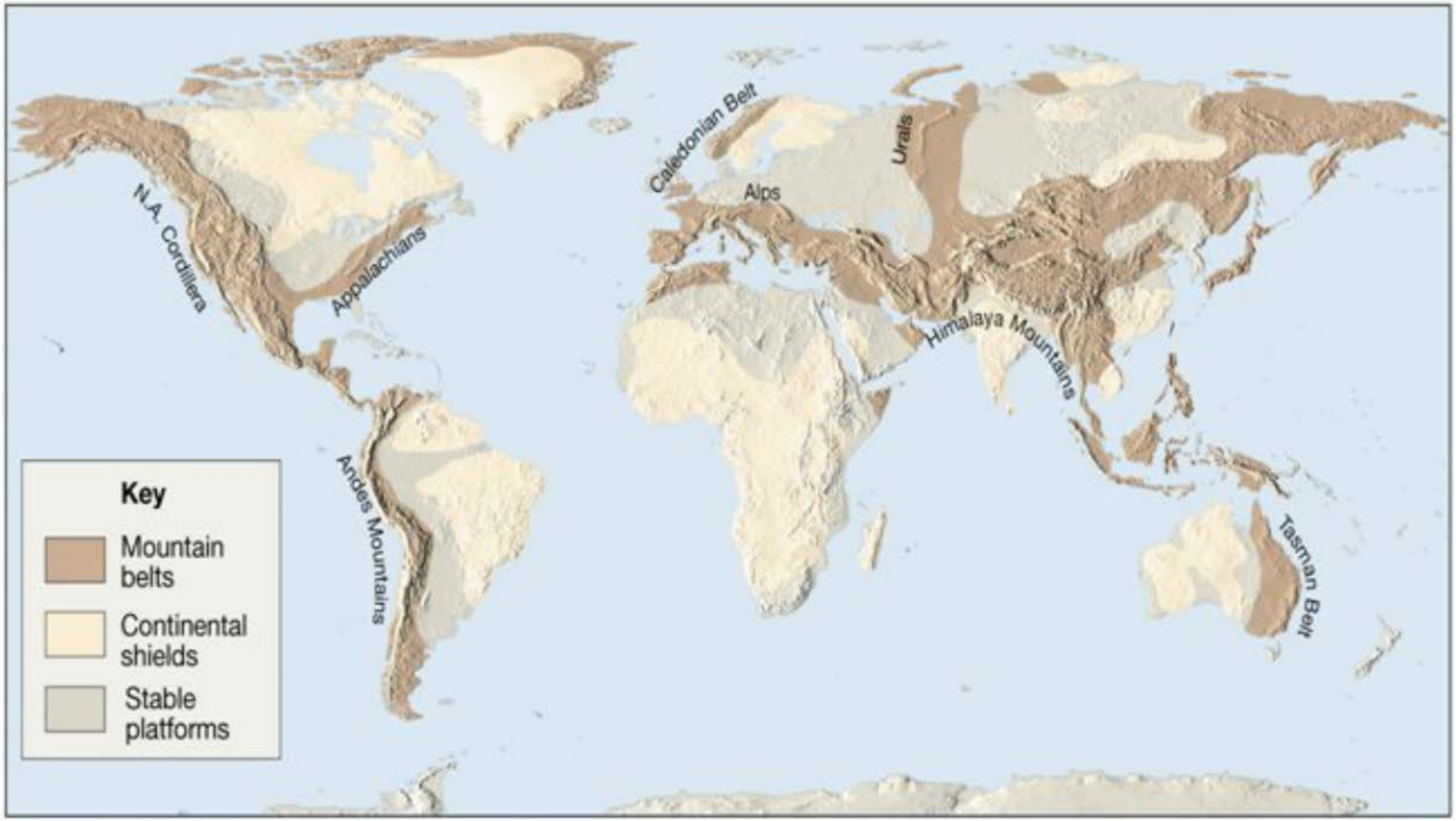
- 12.1 Stress and Strain
- 12.2 Geologic Mapping
  - A) Plan View
  - B) Cross Section
- 12.3 Folds
  - A) Geometry
  - B) Interpretation
- 12.4 Fractures
  - A) Joints
  - B) Faults (Dip-Slip Faults & Strike-Slip Faults)
- 12.5 Conclusions

Mountain Belts

- *Orogenesis* – the processes that collectively produce a mountain belt
  - folding and thrust faulting
  - metamorphism and igneous activity
- Recent mountain building
  - Alpine-Himalayan chain
  - American Cordillera
  - Island Arcs in western Pacific
- Older mountain building
  - Appalachians, eastern US
  - Urals, Russia

Major Mountain Belts



Mountain Belts

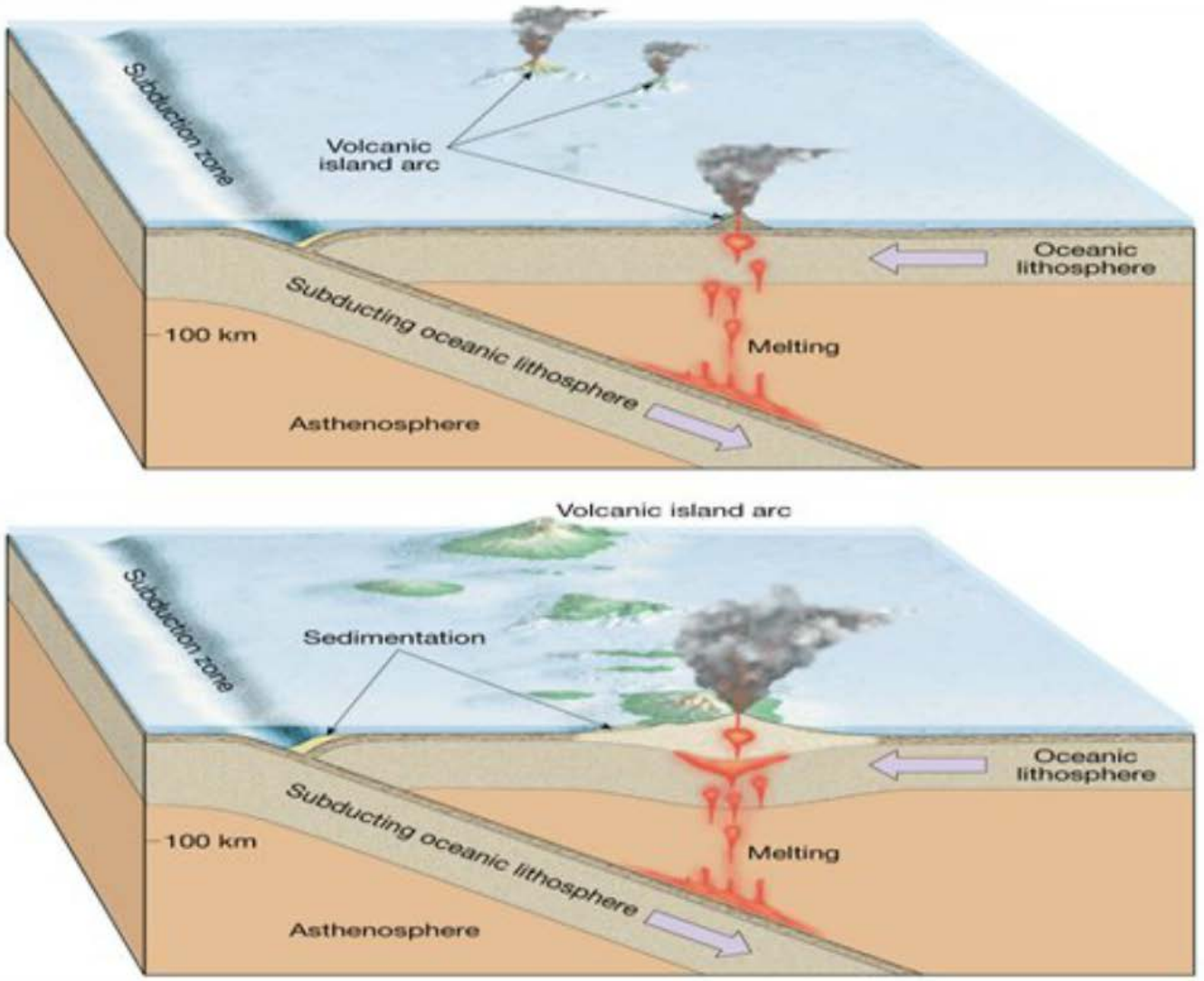
- Plate tectonics theory provides a good model for orogenesis
- Mountain building at convergent boundaries
  - Aleutian-type
  - Andean-type
  - Continental collisions
  - Continental accretion
- Mountain building away from plate margins

Convergent Boundaries

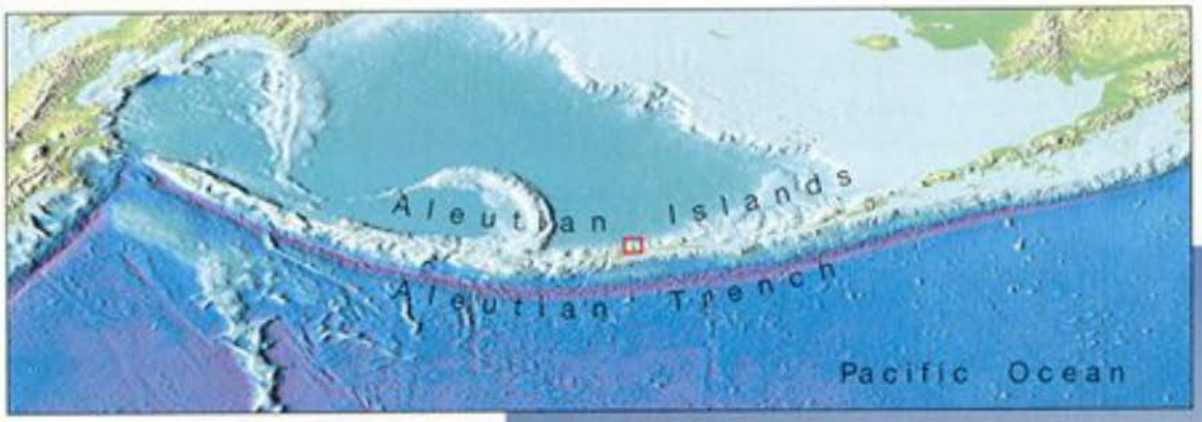
Aleutian-type mountain building

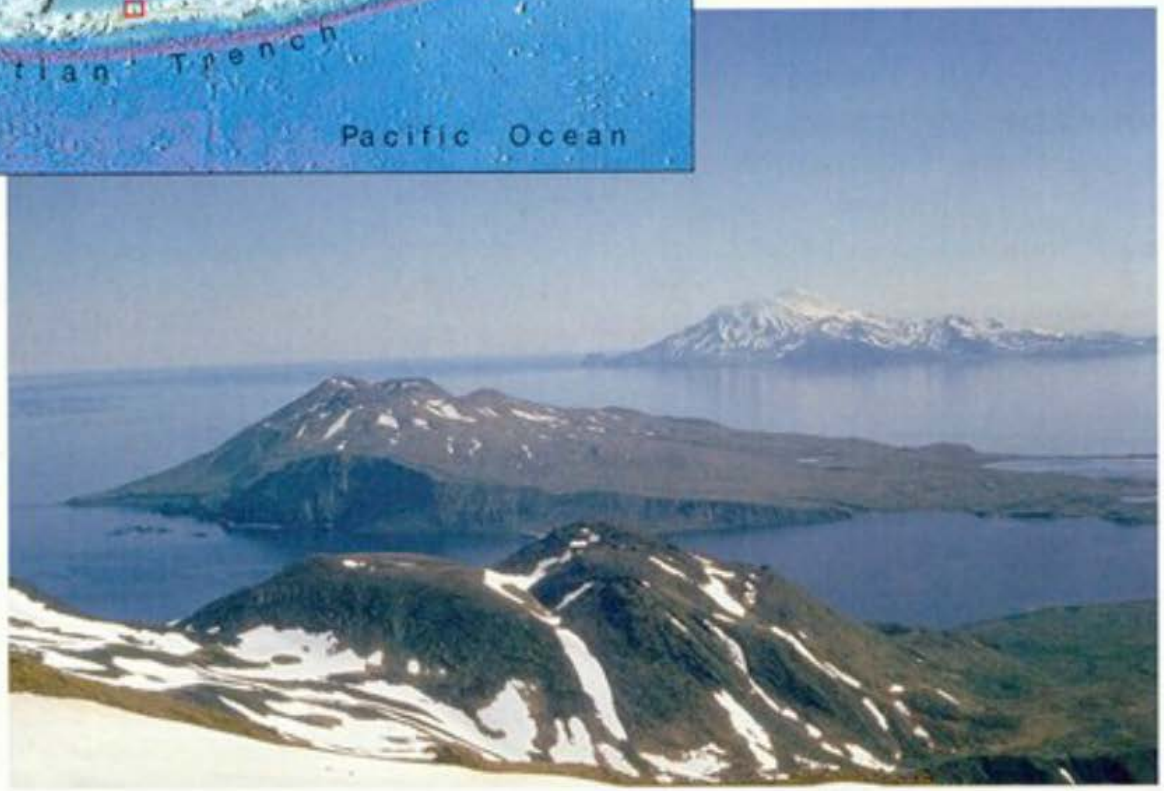
- Where two ocean plates converge and one is subducted beneath the other
  - Located on margin of shrinking ocean basins
  - Most are found in the Pacific
- Volcanic island arcs result from the steady subduction of oceanic lithosphere
  - forms on ocean floor
  - partial melting of mantle above subducted plate
  - Mountainous topography consisting of igneous and metamorphic rocks

Volcanic Island Arc



Aleutian Island Arc, Alaska





Convergent Boundaries

Andean-type mountain building

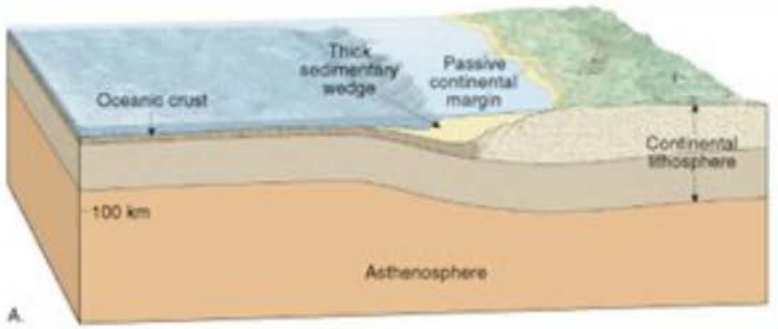
- **Mountain building along continental margins**
  - **Convergence of an oceanic plate and a plate whose leading edge contains continental crust**
  - **volcanic and tectonic features located inland of continental margin**
  - **Exemplified by the Andes Mt., South America**
- **Stages of development**
  - ***passive margin***
  - ***active continental margins***

Andean-Type Mountains

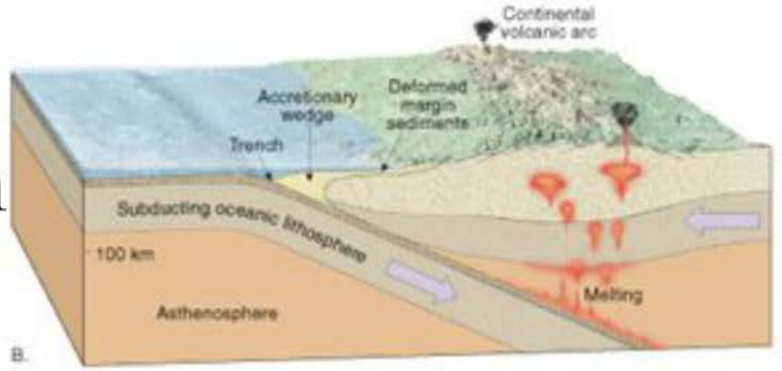
- *Passive margin*
  - Continental margin is part of the same plate as the adjoining oceanic crust (not a plate boundary)
  - Sediment deposition on continental shelf produces a thick wedge of shallow-water sediments
- *Active continental margins*
  - Subduction zone forms, deformation begins
  - Oceanic plate descends ~100 km, partial melting of mantle above subducting slab generates magma
  - Continental volcanic arc develops
- *Accretionary wedge*
  - Deformed sedimentary and metamorphic rocks
  - Scraps of ocean crust

Andean-Type Subduction

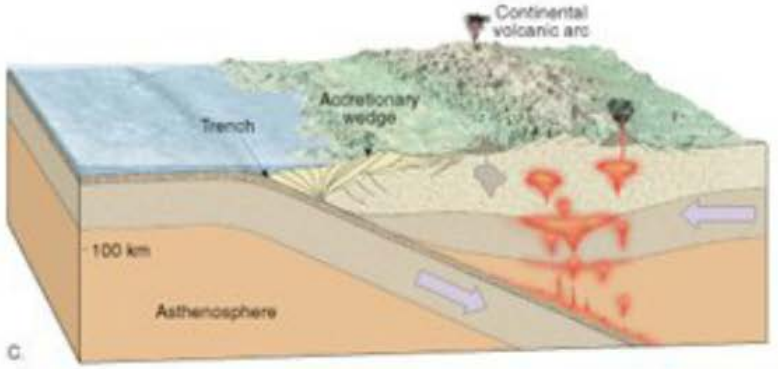
Passive margin



Active continental margin
Subduction zone



Igneous activity and deformation



Andes Mountains

Andes Mountains

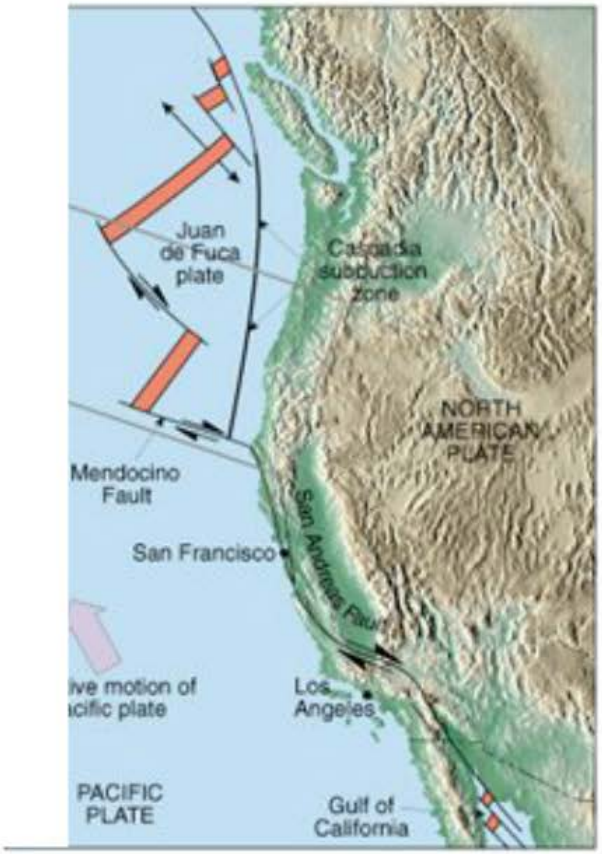
Andean-Type Mountains

- Composed of roughly two parallel zones
  - Volcanic arc
    - Develops on the continental block
    - Consists of large intrusive bodies intermixed with high-temperature metamorphic rocks
  - Accretionary wedge
    - Seaward segment
    - Consists of folded, faulted, and metamorphosed sediments and volcanic debris

Andean-Type Mountains

- **Sierra Nevada and Coast Ranges, California and Nevada**
  - One of the best examples of an inactive Andean-type orogenic belt
  - Subduction of the Pacific Basin under the western edge of the North American plate
  - Sierra Nevada batholith is a remnant of a portion of the continental volcanic arc
  - Franciscan Formation of California Coast Range – chaotic mixture of sedimentary rocks represent the accretionary wedge

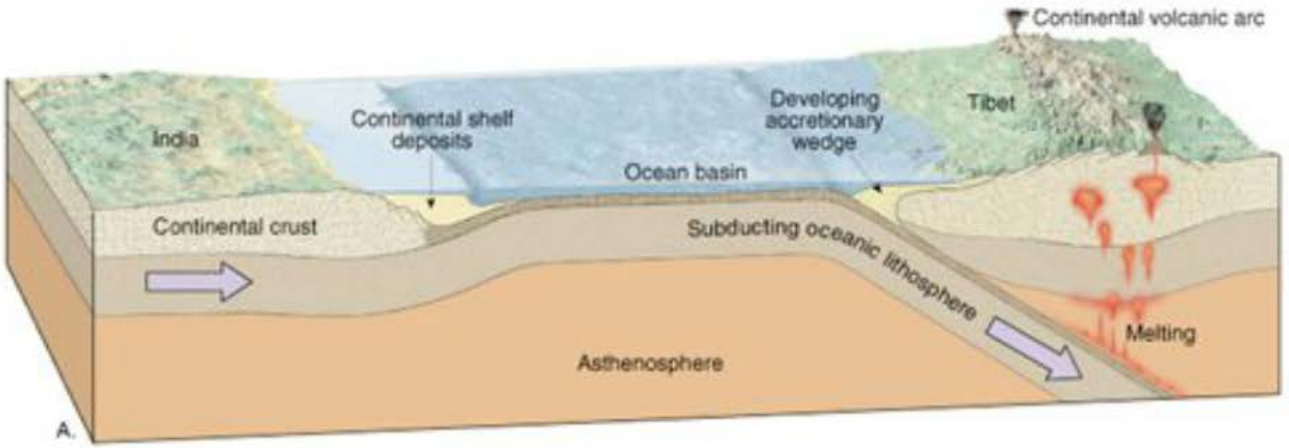
Sierra Nevada and Coast Ranges

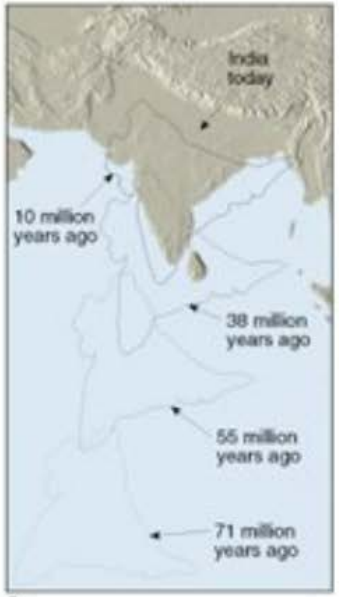


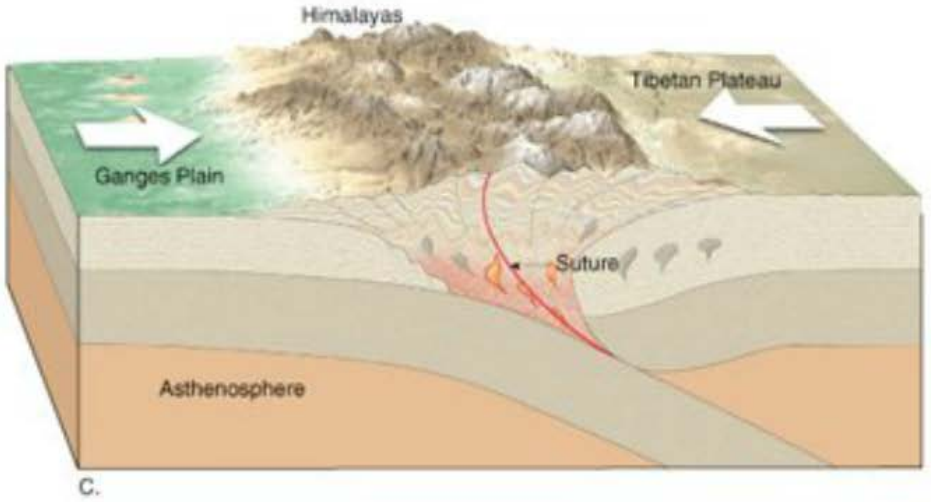
Continental Collisions

- Convergence of two lithospheric plates, both carrying continental crust
- Himalayan Mountains: young mountain range, collision of India with the Eurasian plate about 45 million years (my) ago
- Appalachian Mountains: 250 to 300 my ago, collision of North America, Europe, and Africa
- Orogenesis here is complex, includes:
  - subduction and igneous activity
  - collision of continental blocks
  - folding and uplift of the crust

Continental Collisions



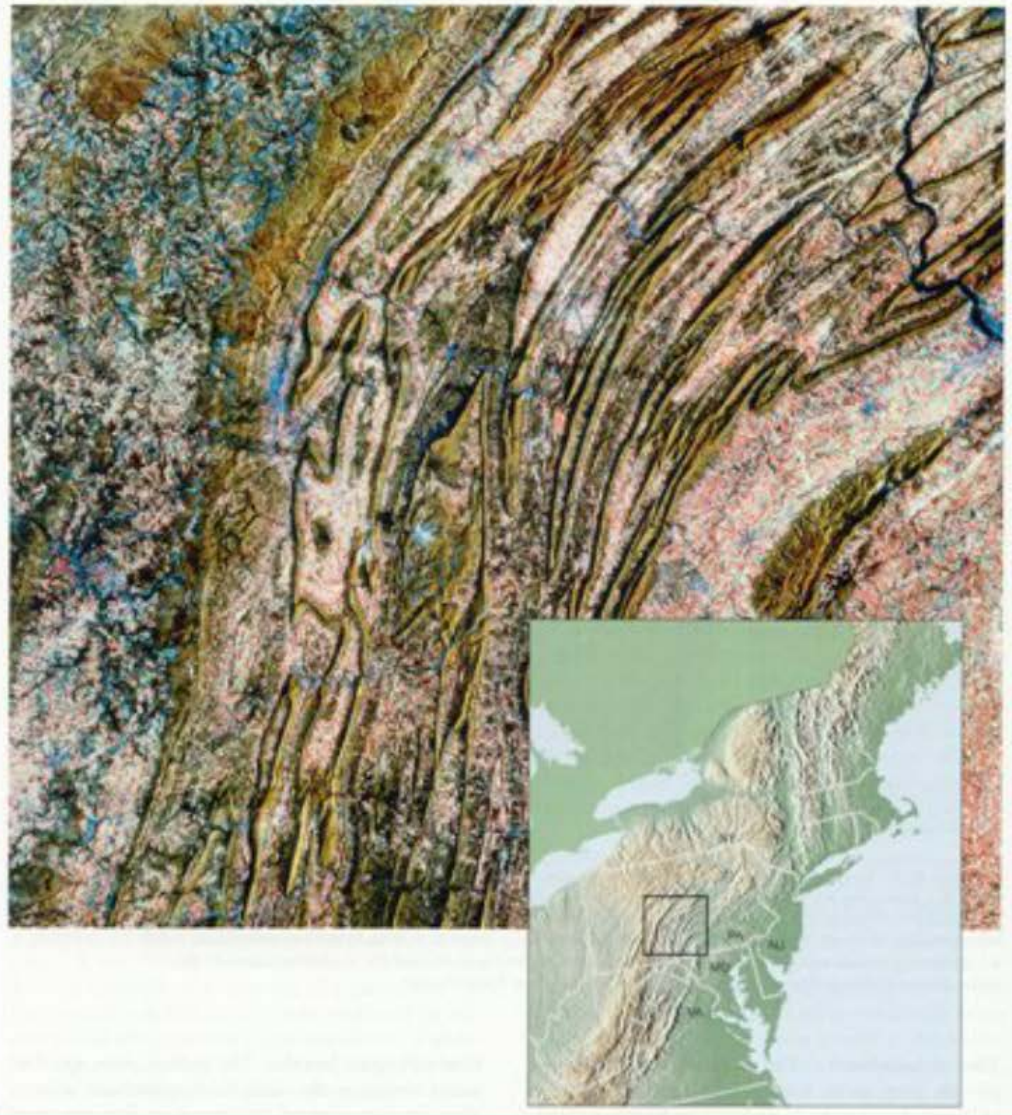




Continental Collisions

Valley and Ridge Province of the Appalachian Mountains

Folded and faulted sedimentary strata formed during several mountain building events



Convergent Boundaries

Continental accretion

- Small crustal fragments collide and merge with continental margins
- Responsible for many of the mountainous regions rimming the Pacific
- Accreted crustal blocks are called *terranes*

Accreted Terranes

Paleomagnetic and fossil data indicate terranes originated south of present locations – migrated 1000's km north

One exception:
Sonoma Terrane – may have migrated ~ 1000 km south (Skalbeck et al. 1989)

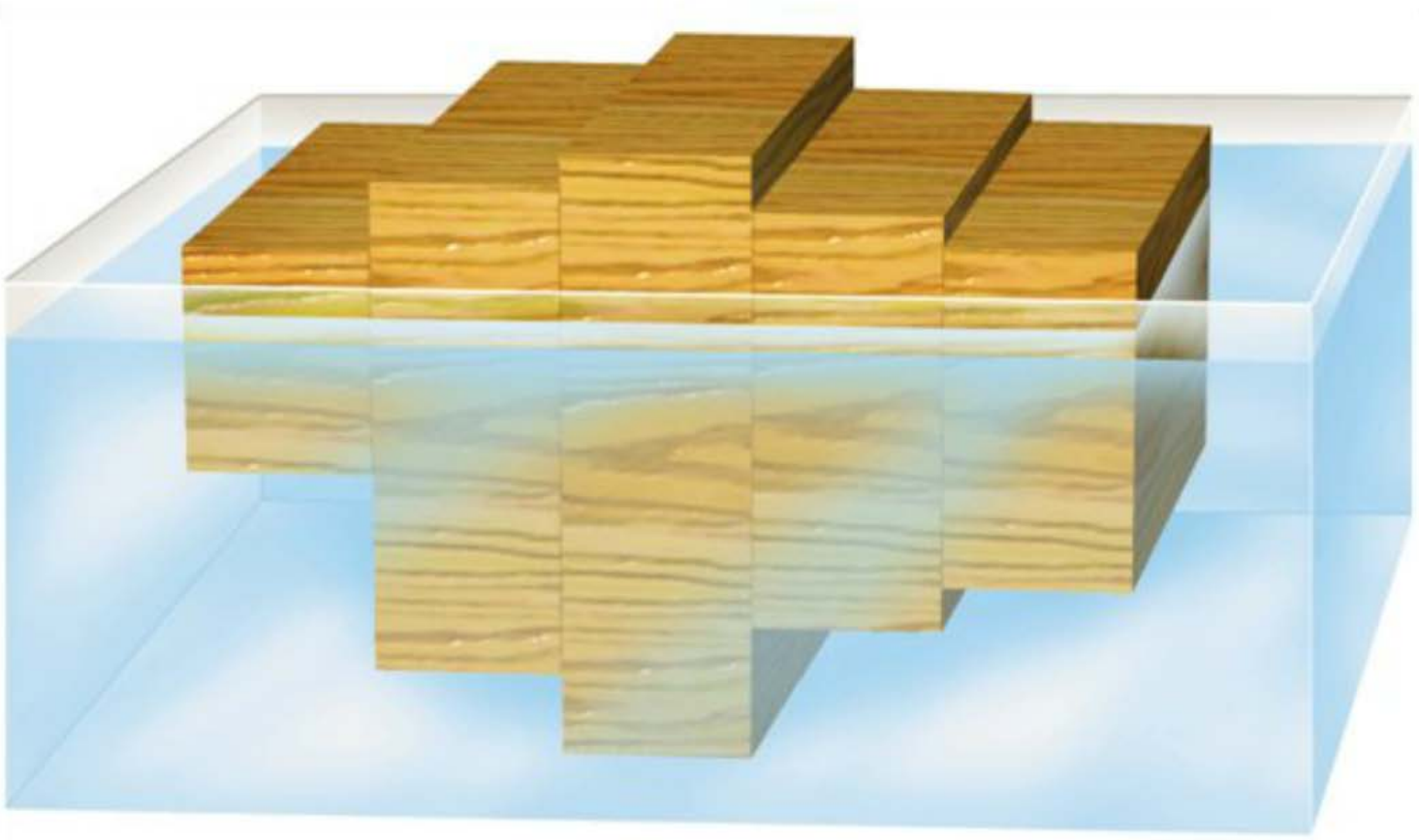
Vertical Crustal Movements

- Isostatic adjustment
- Vertical motions and mantle convection
- Possible mechanism for crustal subsidence

Vertical Crustal Movements

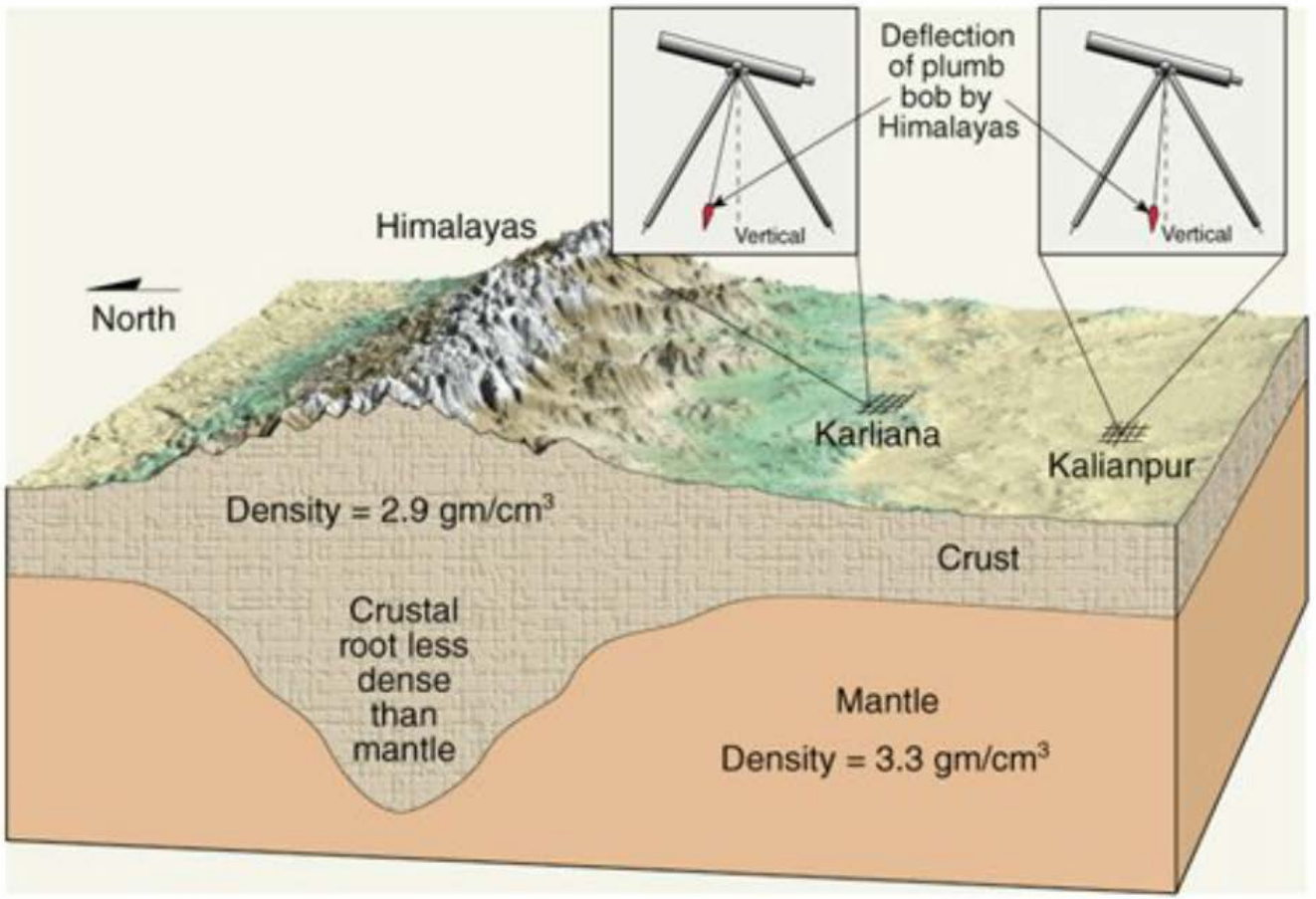
- **Isostatic adjustment**
  - **Less dense crust floats on top of the denser and deformable rocks of the mantle**
  - **Concept of floating crust in gravitational balance is called *isostasy***
  - **Higher mountains have deeper roots**

The Principle of Isostasy



Thicker block floats higher

The Principle of Isostasy



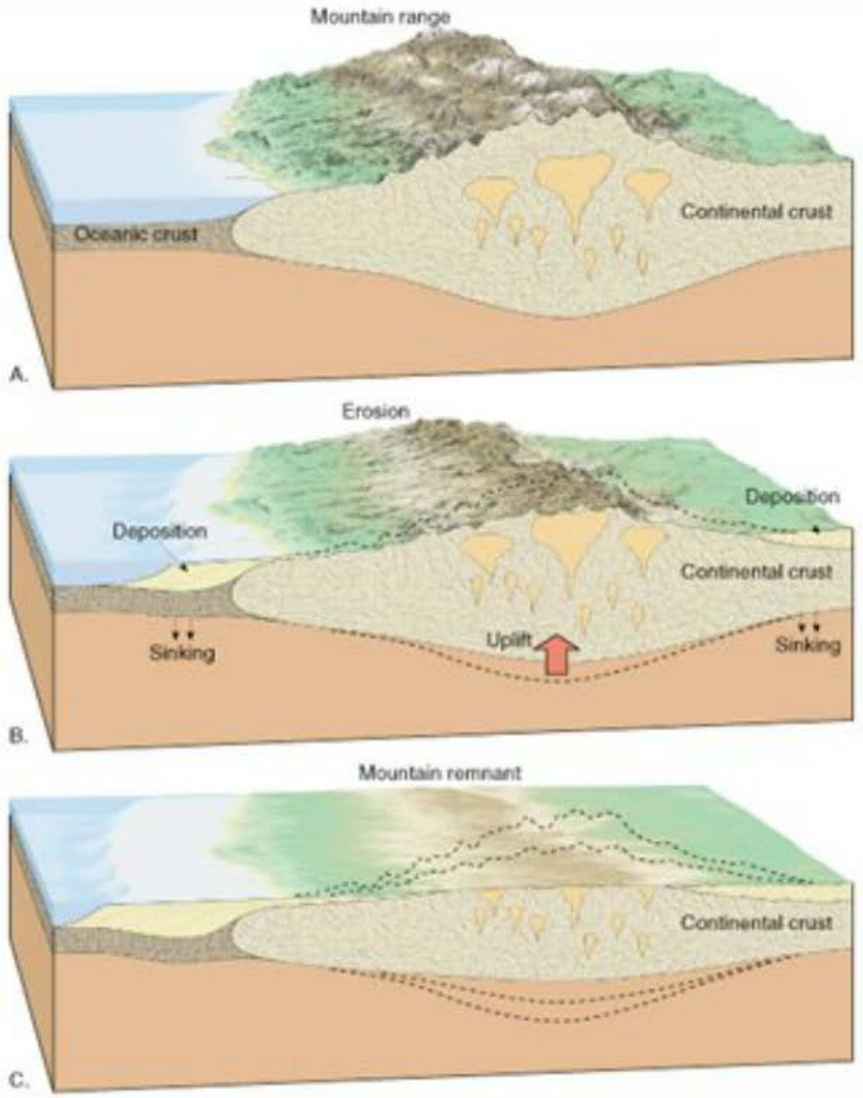
Airy model of crustal root

Erosion & Isostatic Adjustment

Young Mountains
Thick crust

Erosion lowers mountains, crust rises in response

Continued erosion and uplift, thinner crust



Vertical Crustal Movements

- **Vertical motions and mantle convection**
  - **Buoyancy of hot rising mantle material**
    - **accounts for broad upwarping in the overlying lithosphere**
    - **Uplift whole continents, Southern Africa**
  - **Downward crustal displacements**
    - **Regions once covered by ice during last Ice Age**
    - **Continental margins where sediments are deposited, such as the Mississippi River delta**
    - **Circular basins found in the interiors of some continents (Illinois and Michigan basins)**

Vertical Crustal Movements

- **Possible mechanism for crustal subsidence**
  - **May be linked to subduction of oceanic lithosphere**
    - **Subducting, detached lithospheric plate**
    - **Creates downward flow in its wake**
    - **Tugs on the base of the overriding continent**
    - **Continent floats back into isostatic balance**
  - **More observational data is needed to test the hypothesis**

Mountain Building Away From Plate Margins

- Rocky Mountains
- Colorado Plateau
- Basin and Range province
- Black Hills
- Bighorns

Mountain of Western US

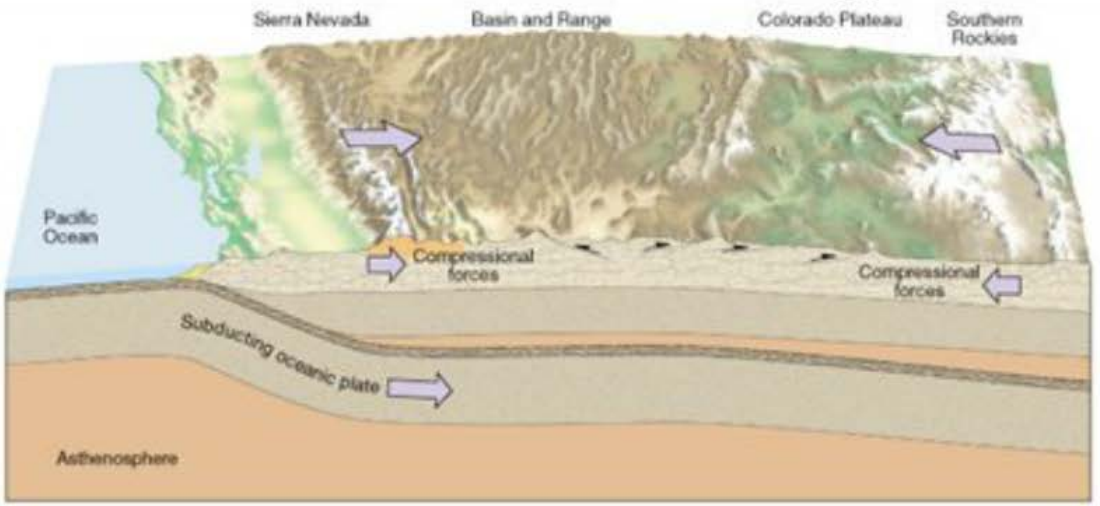
Colorado Rockies

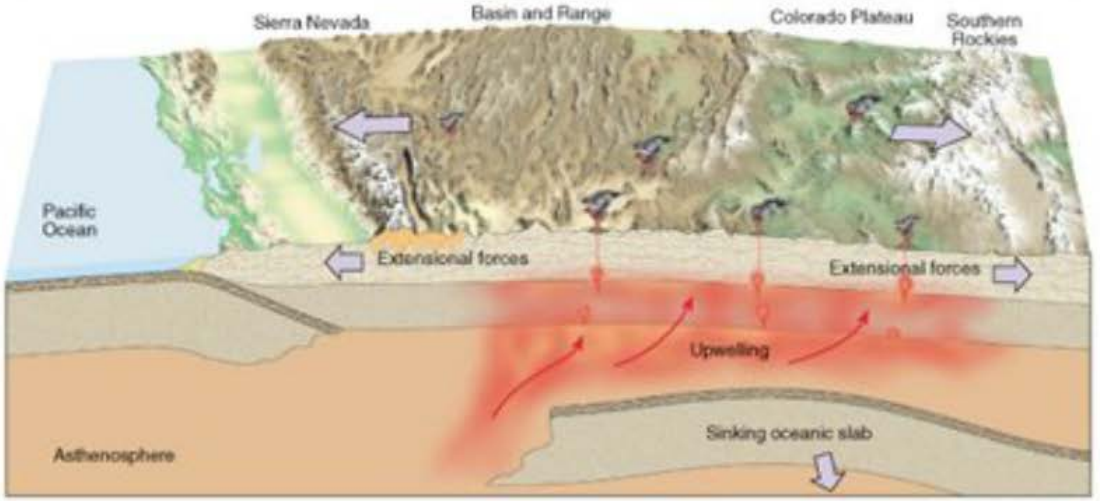
Maroon Bells, Aspen, CO

Mountain Building Away From Plate Margins

- Crustal thickness suggests elevation difference between Great Plains and the Rockies must be the result of mantle flow
  - Hot mantle may have provided the buoyancy to raise the Rockies, Colorado Plateau, and Basin and Range province
  - Upwelling associated w/ Basin and Range started about 50 my age, active today
  - Alt. hypothesis: addition of terranes to North America produced the uplift

Mountain Building Away From Plate Margins





The Origin and Evolution of Continental Crust

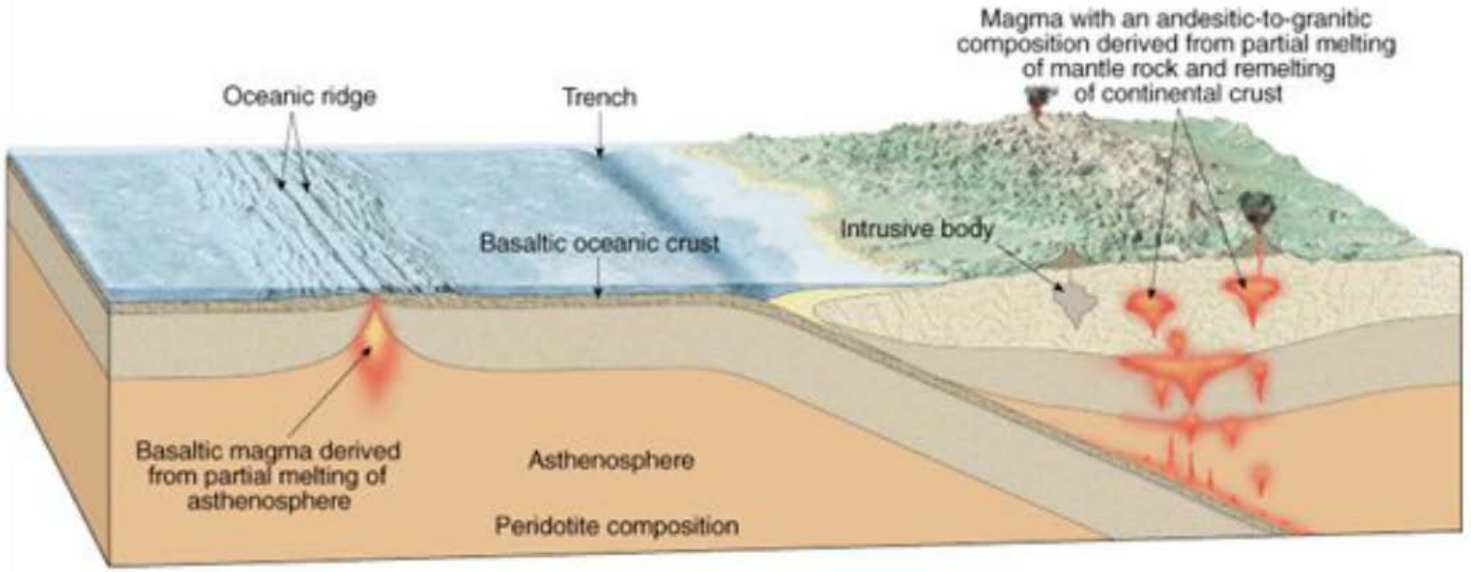
- Lack of agreement among geologists as to the origin and evolution of continents

- Early evolution of the continents model
  - One proposal is that continental crust formed early in Earth's history
  - Total volume of continental crust has not changed appreciably since its origin

The Origin and Evolution of Continental Crust

- **Gradual evolution of continents model**
  - Continents have grown larger through geologic time by the gradual accretion of material derived from the upper mantle
  - Earliest continental rocks came into existence at a few isolated island arcs
  - Evidence supporting the gradual evolution of the continents comes from research in regions of plate subduction, such as Japan and the western flanks of the Americas

The Origin and Evolution of Continental Crust



Multistage evolution process

Precambrian Mountain Belts