Mountain Belts and the Continental Crust

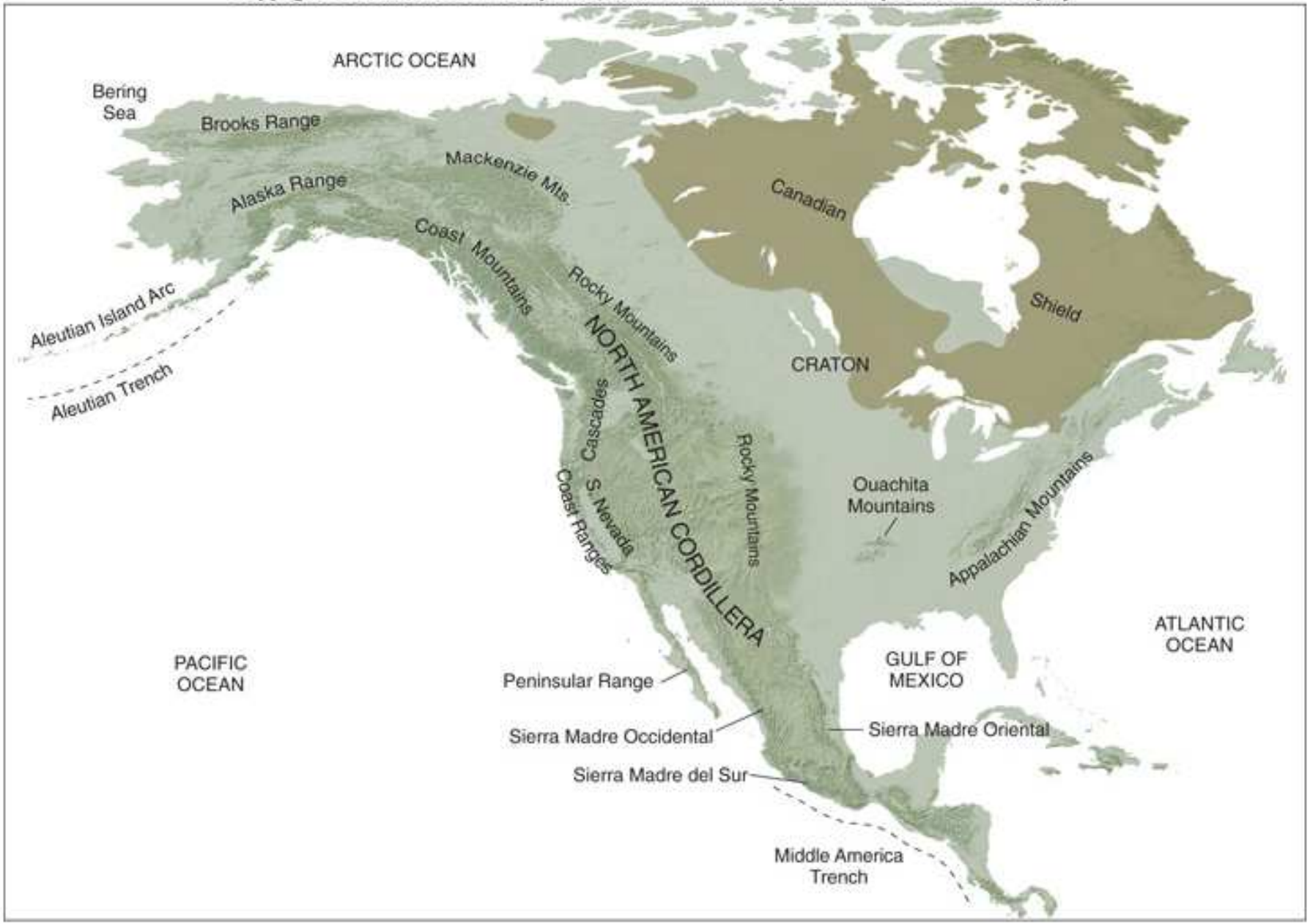
Chapter 5

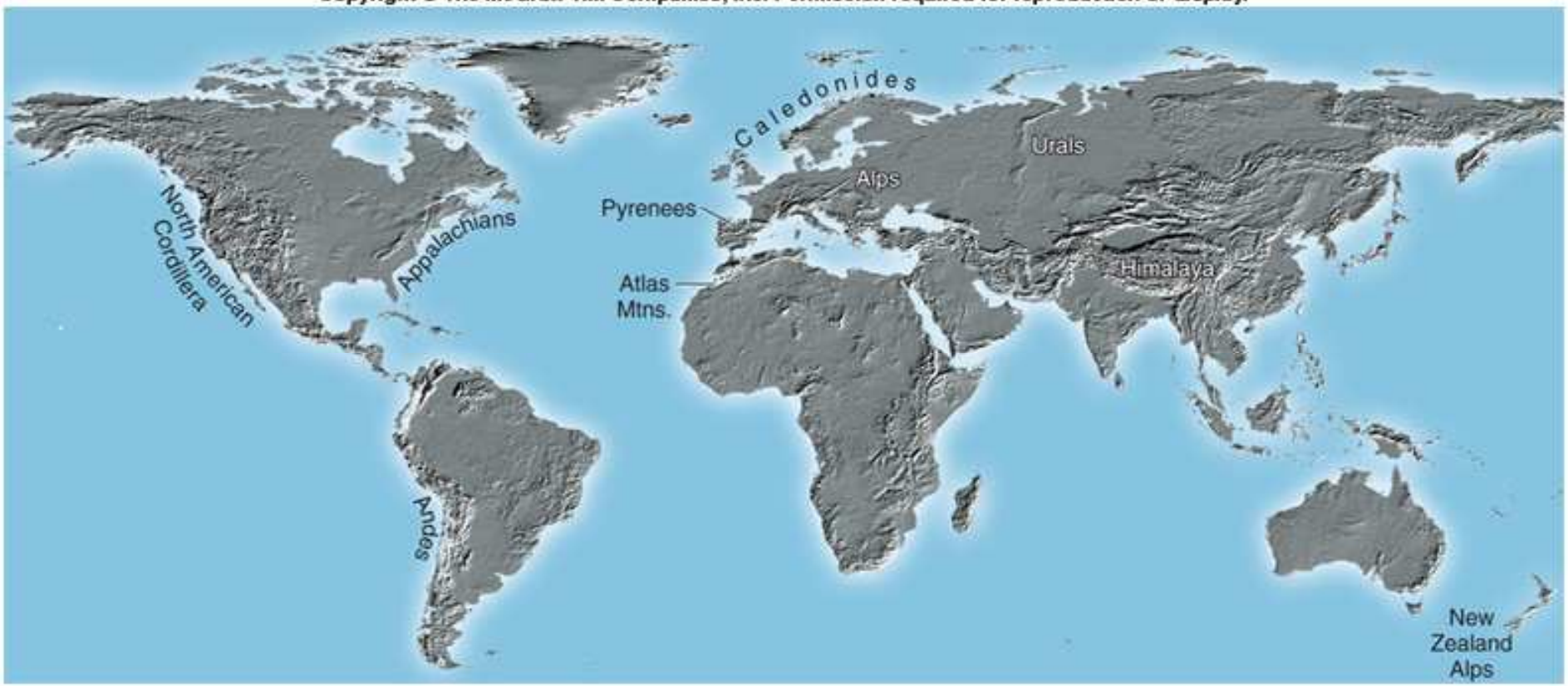
C. C. Plummer

Mountain Belts and Earth's Systems

- *Mountain belts* are chains of *mountain ranges* that are 1000s of km long
  - Commonly located at or near the edges of continental landmasses

- Mountain belts are part of the *geosphere*
  - Form and grow by tectonic and volcanic processes over tens of millions of years





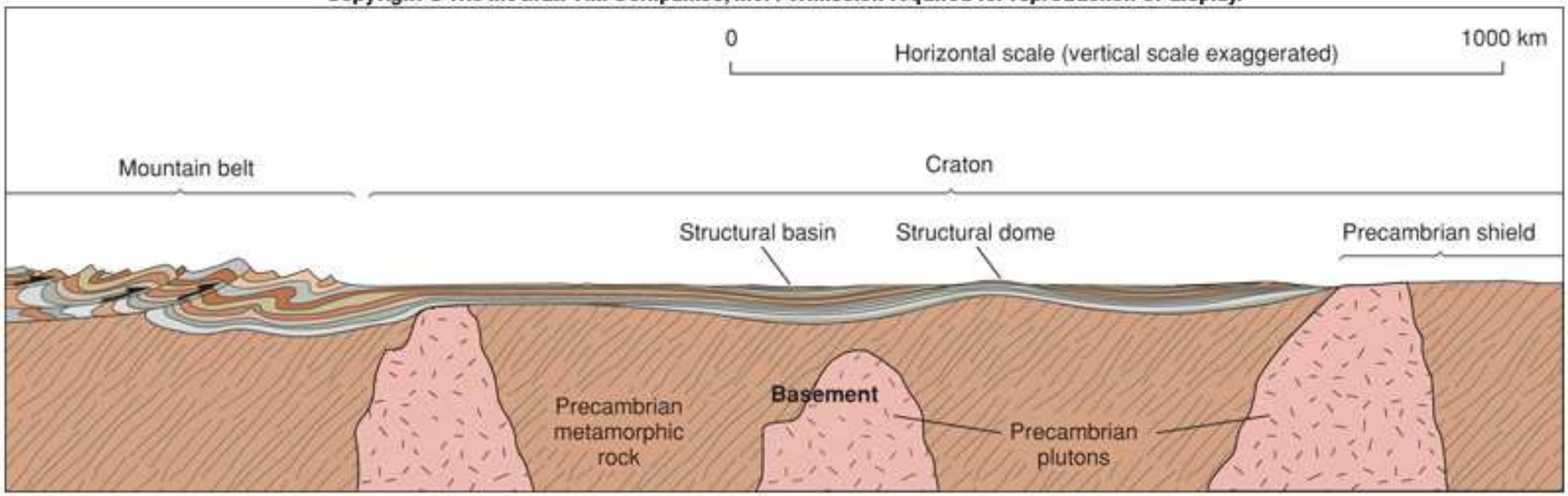
Mountain Range

- A *Mountain range* is likely to be composed of tectonically deformed sedimentary, volcanic, or metamorphic rocks
- It may also show a history of intrusive igneous activity
- High mountains have steep faces and broad exposures of bedrock

Characteristics of Mountain Belts

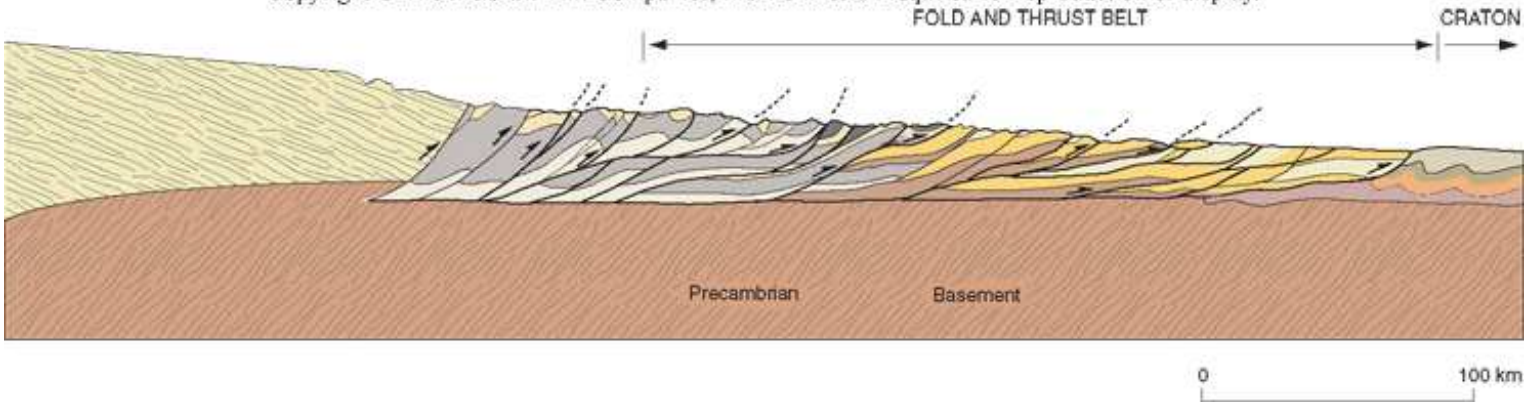
- *Mountain belts* are very long compared to their width
  - The *North American Cordillera* runs from southwestern Alaska down to Panama

- Ancient mountain belts (*billions* of years old) have eroded nearly flat to form the stable cores (*cratons*) of the continents
  - *Shields* - areas of cratons laid bare by erosion



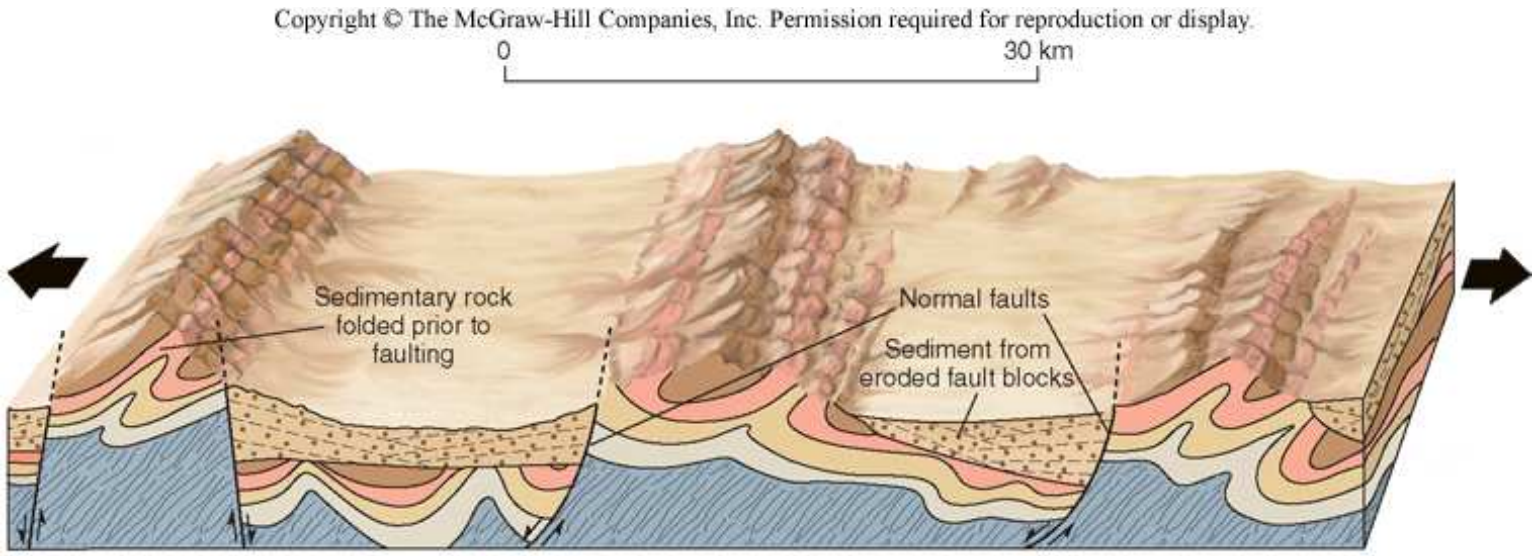
Rock Patterns in Mountain Belts

- *Mountain belts* typically contain thick sequences of folded and faulted sedimentary rocks, often of marine origin
  - May also contain great thicknesses of volcanic rock
- *Fold and thrust belts* (composed of many folds and faults) indicate crustal thickening produced by compression
  - Common at convergent boundaries
  - Typically contain large amounts of metamorphic rock

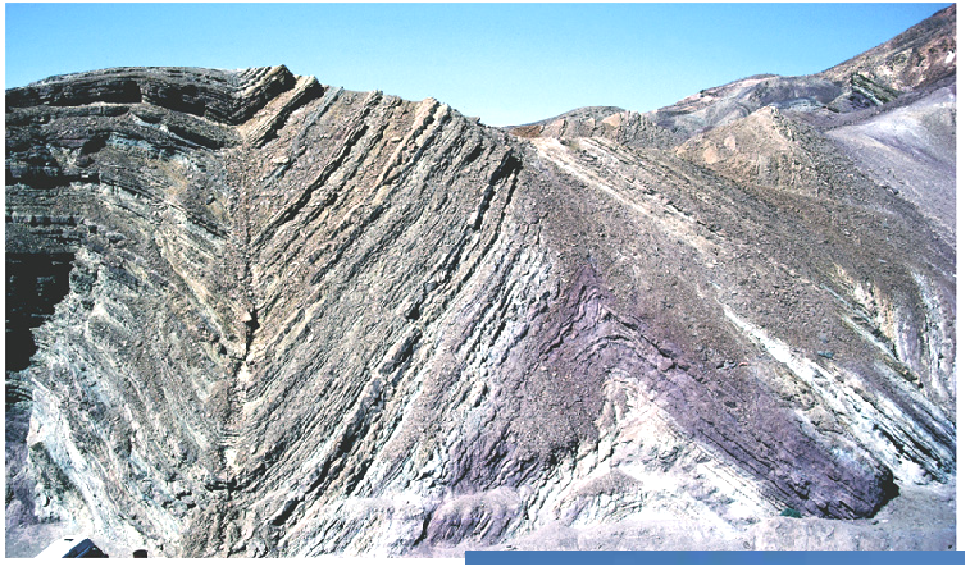


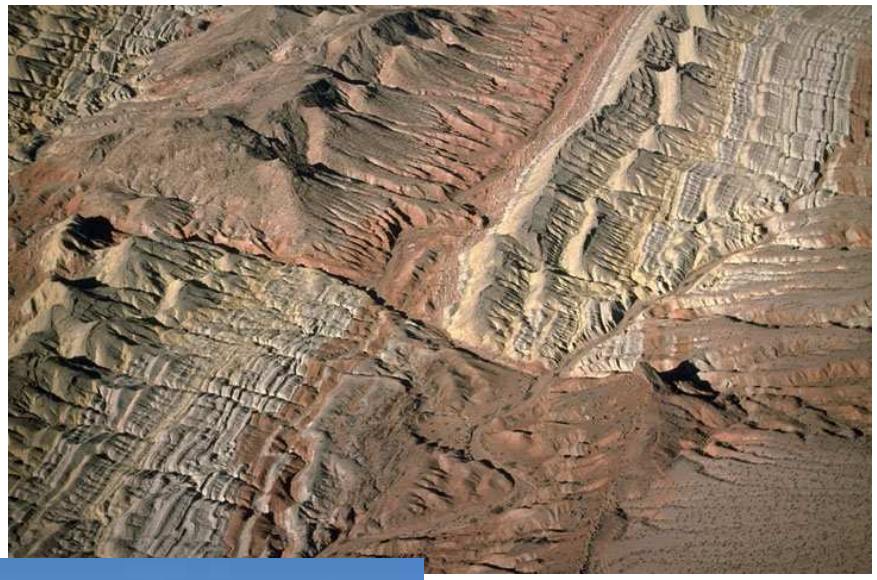
Rock Patterns in Mountain Belts

- Erosion-resistant batholiths may be left behind as mountain ranges after long periods of erosion
- Localized tension in uplifting mountain belts can result in *normal faulting* and *thrust faulting*
- *Earthquakes* common along faults in mountain ranges



Intense Deformation, and Mountain Building





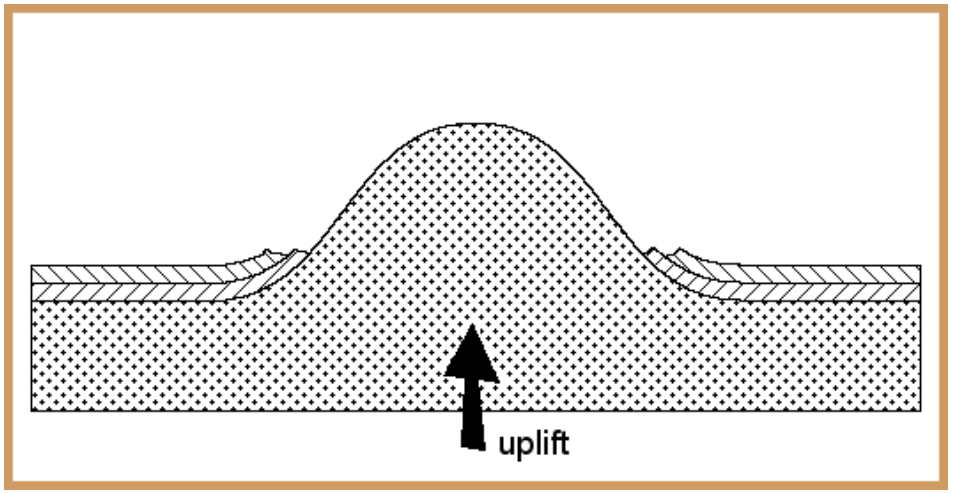
Mountain Belts and Earth's Systems

- Mountain belts differ from one another because each has undergone a unique combination of events that contributed to its present characteristics.

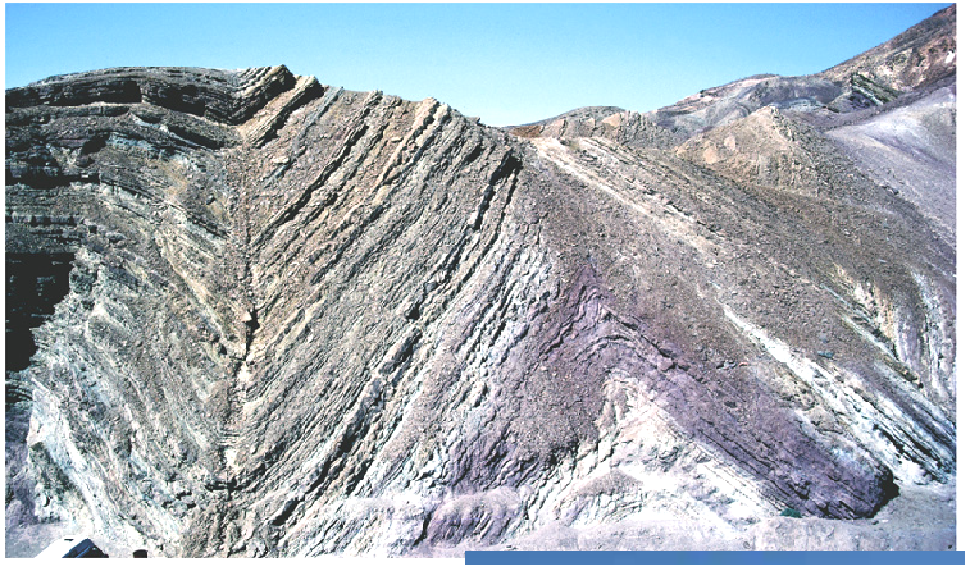
- The major controlling factor that interact with one another during a mountain belt's long history are:
  - **Intense Deformation (Orogeny)**
  - **Isostasy**
  - **Weathering and Erosion**

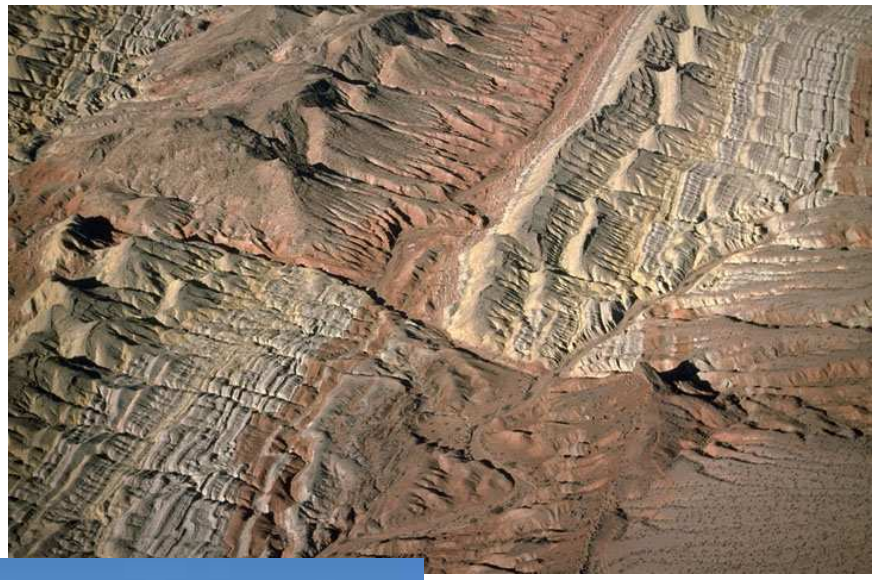
Intense Deformation

- This is mainly compression and result in intense folding and faulting of rocks
- It’s otherwise known as orogeny or mountain building
- Usually lasting millions of years
- We now attribute orogenies mainly to plate convergence



Intense Deformation, and Mountain Building





Isostasy

- Vertical movements of mountain belts, both during and after an orogeny.

- Major mountain belts with higher mountain ranges tend to be geologically younger than those where mountains are lower.

- Mountain building for the Himalaya, Earth’s highest mountain belts still taking place whereas mountain building in much lower Appalachians ceased around 250 million yrs ago.

Weathering and Erosion

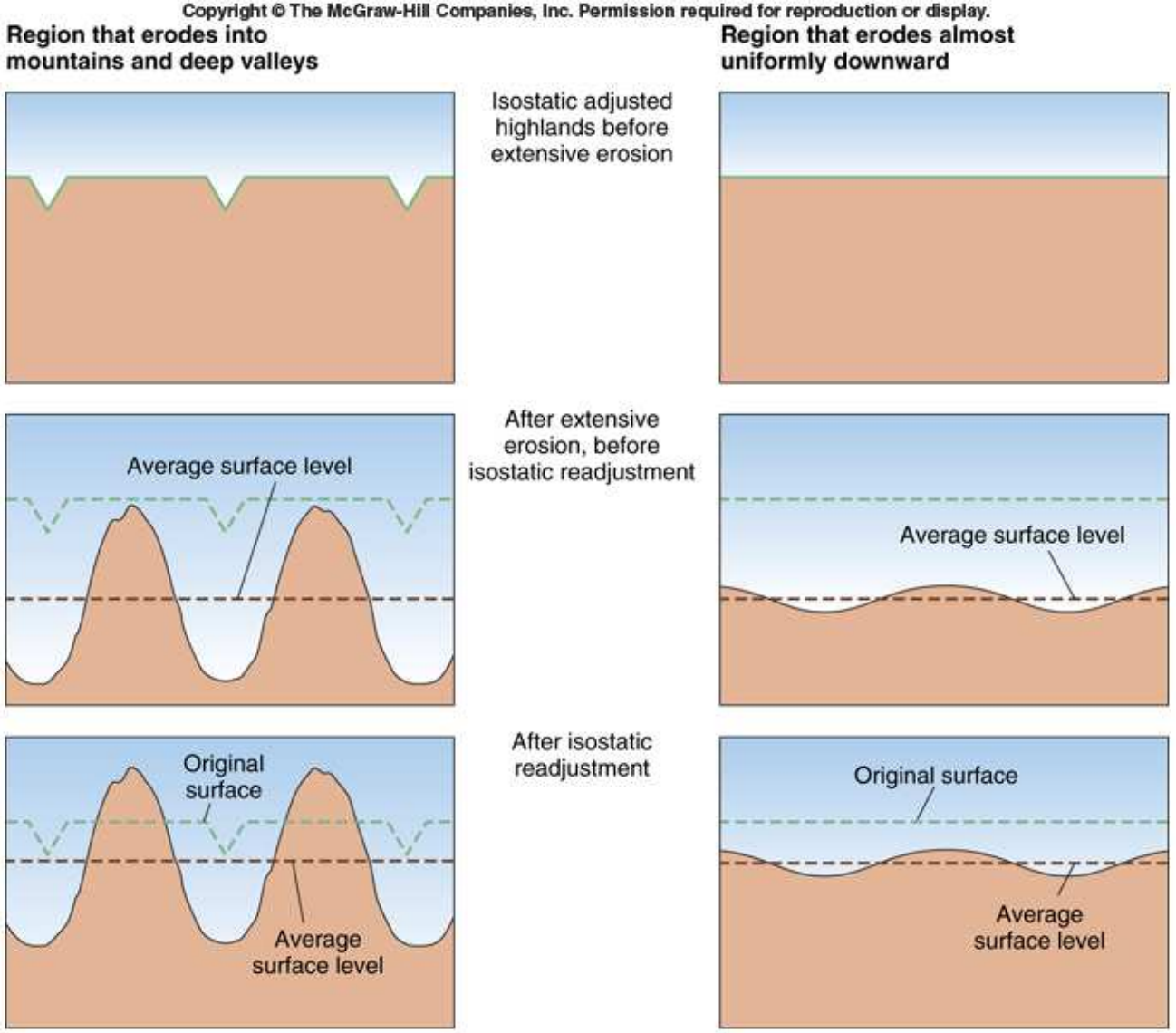
- As mountains grow higher and steeper, erosion rates (particularly from running water and ice - *hydrosphere*) increase

- Air (*atmosphere*) rising over mountain ranges results in precipitation and erosion

- Episodes of orogeny, erosion, and isostatic uplift are common during the long history of a mountain range before it stabilizes

- Mountain ranges → hills → smaller mountain ranges

Mountain Belts and Earth's Systems



Orogeny (Mountain Building)
and
Plate Convergence

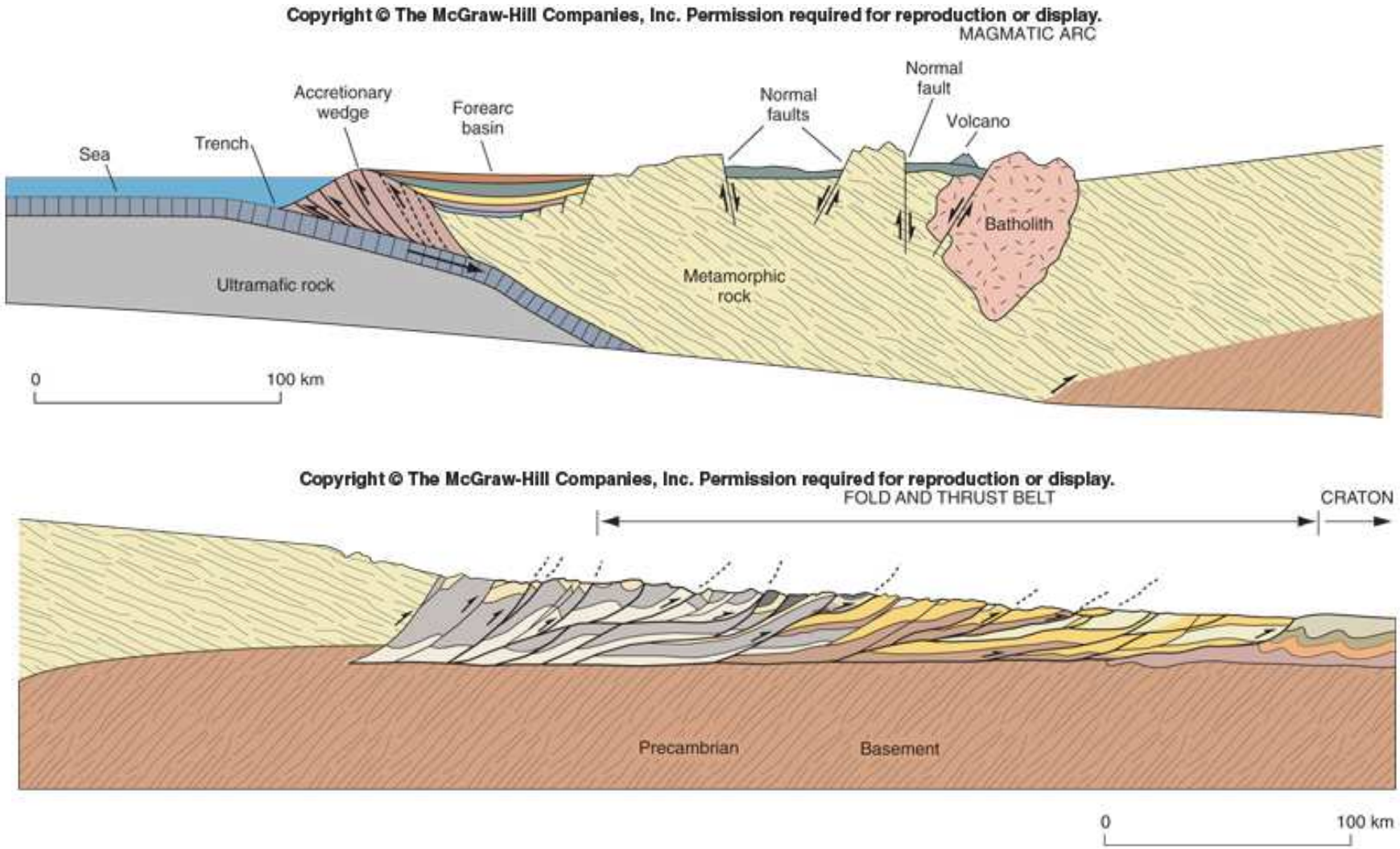
Orogeny

- Orogeny is an episode of intense deformation of rocks in a region
- The deformation usually accompanied by igneous and metamorphic activity
- Folding and normal faulting are common
- Magma from the upper mantle works its way upward to erupt in volcanoes or form *batholiths*
- One important aspect of orogeny is that the continental crust becomes thicker

Orogeny

- Orogeny → Ocean-Continent Convergence
- Orogeny → Island Arc-Continent Convergence
- Orogeny → Continent-Continent Convergence

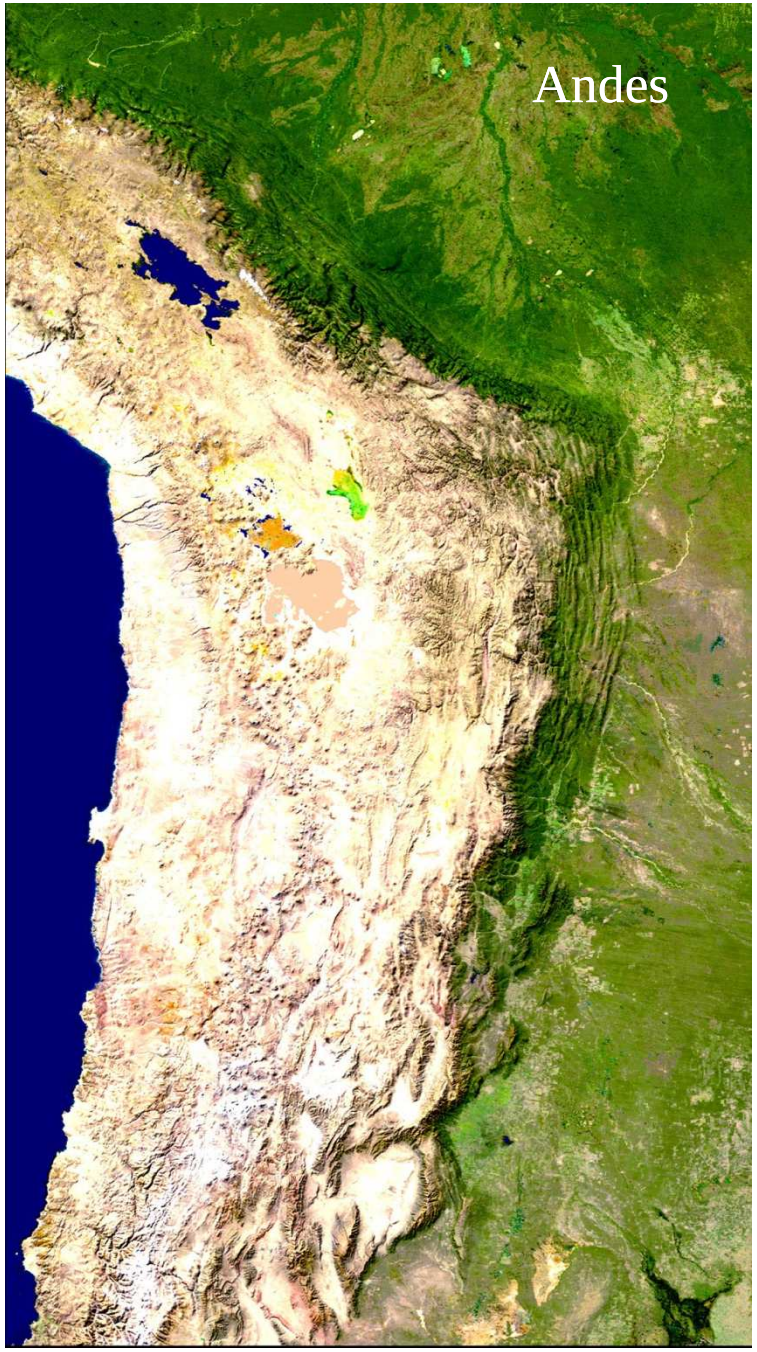
Orogeny and Ocean-Continent Convergence



Hypothetical mountain belts forms due to ocean-continent convergence. The Andes for example where the South America is overriding the Nazca plate

Orogeny and Ocean-Continent Convergence

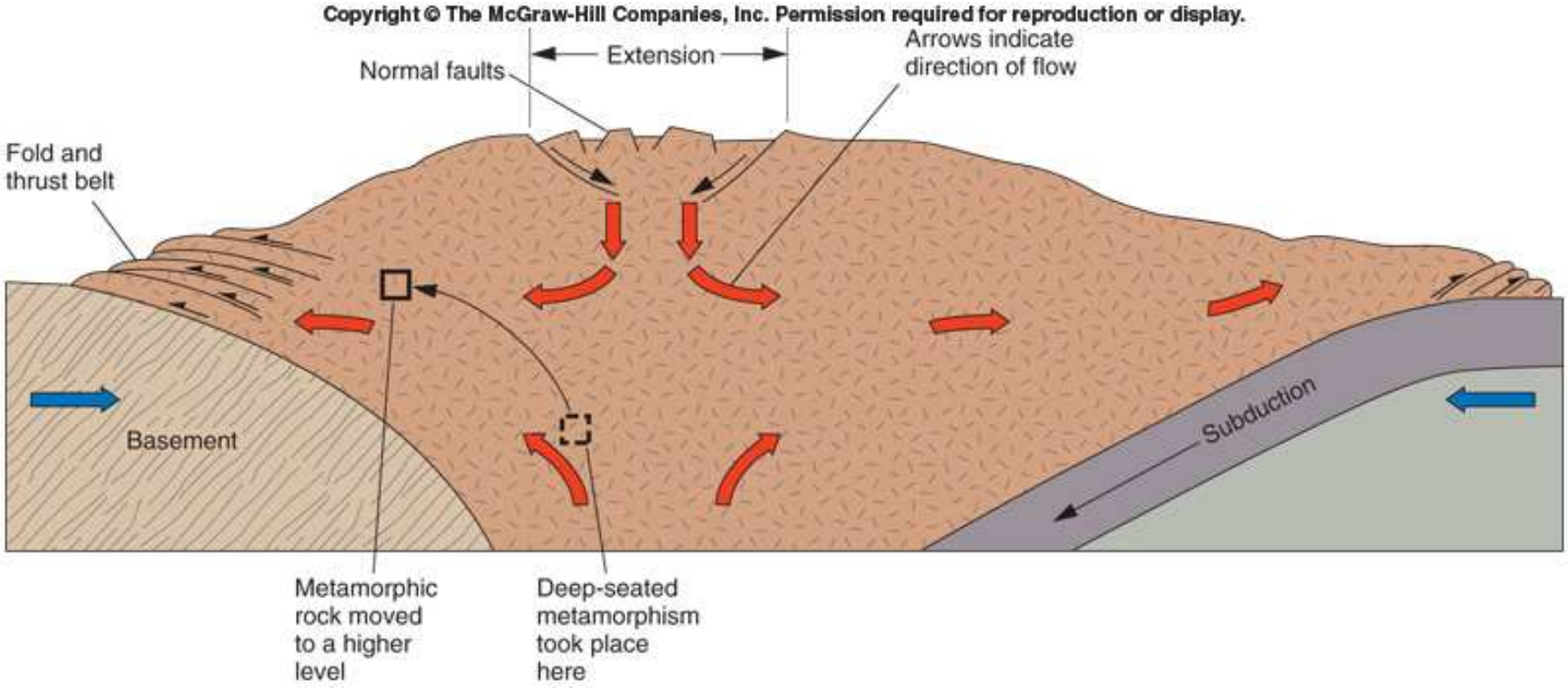
- An accretionary wedge develops by scarping up marine sediment off the suducting oceanic plate
- Rocks caught in and pulled down in subduction zone is subjected to intense shearing
- Folds and faults develop on the craton side of the mountain belt
- Magmatic arc becomes thicker and sometimes move towards the craton (ex: Rocky Mountains has created thrust faults in craton



Rocky Mountain Faulting

Orogeny and Ocean-Continent Convergence

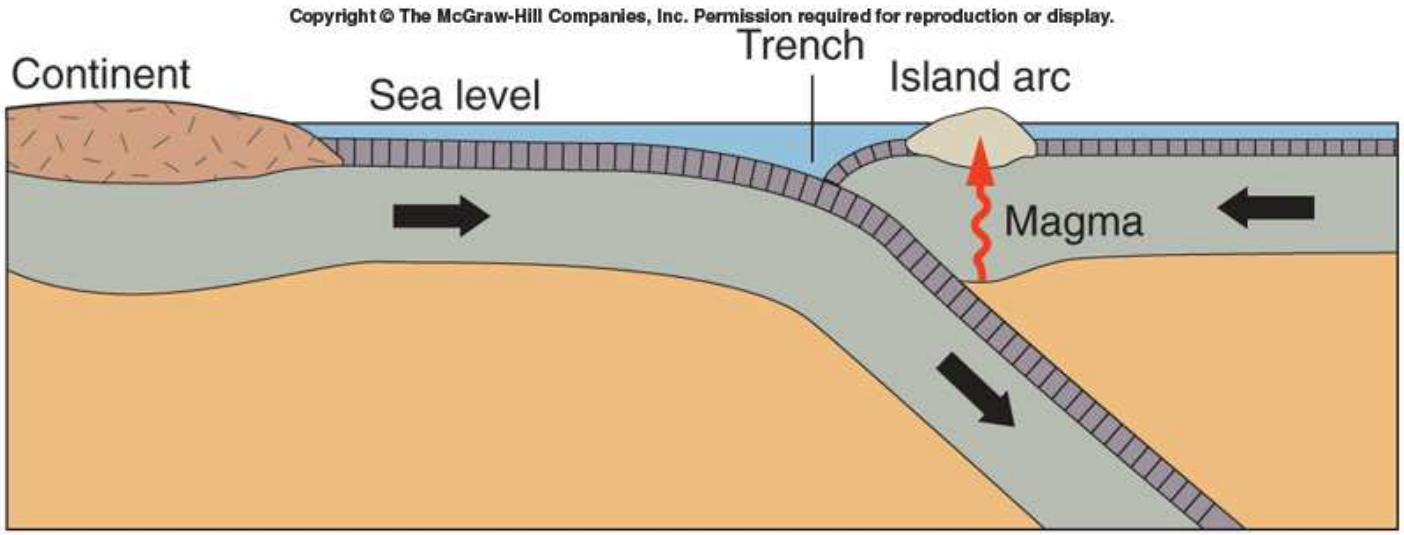
Sometime during this process mountain belt becomes too high and gravitationally unstable, resulting in gravitational collapse and spreading



Gravitational collapse and spreading: Red arrows indicate flowage of rock. Faulting occur in brittle rocks near the surface. Rock that was metamorphosed at depth, flows to a higher level in the mountain belt

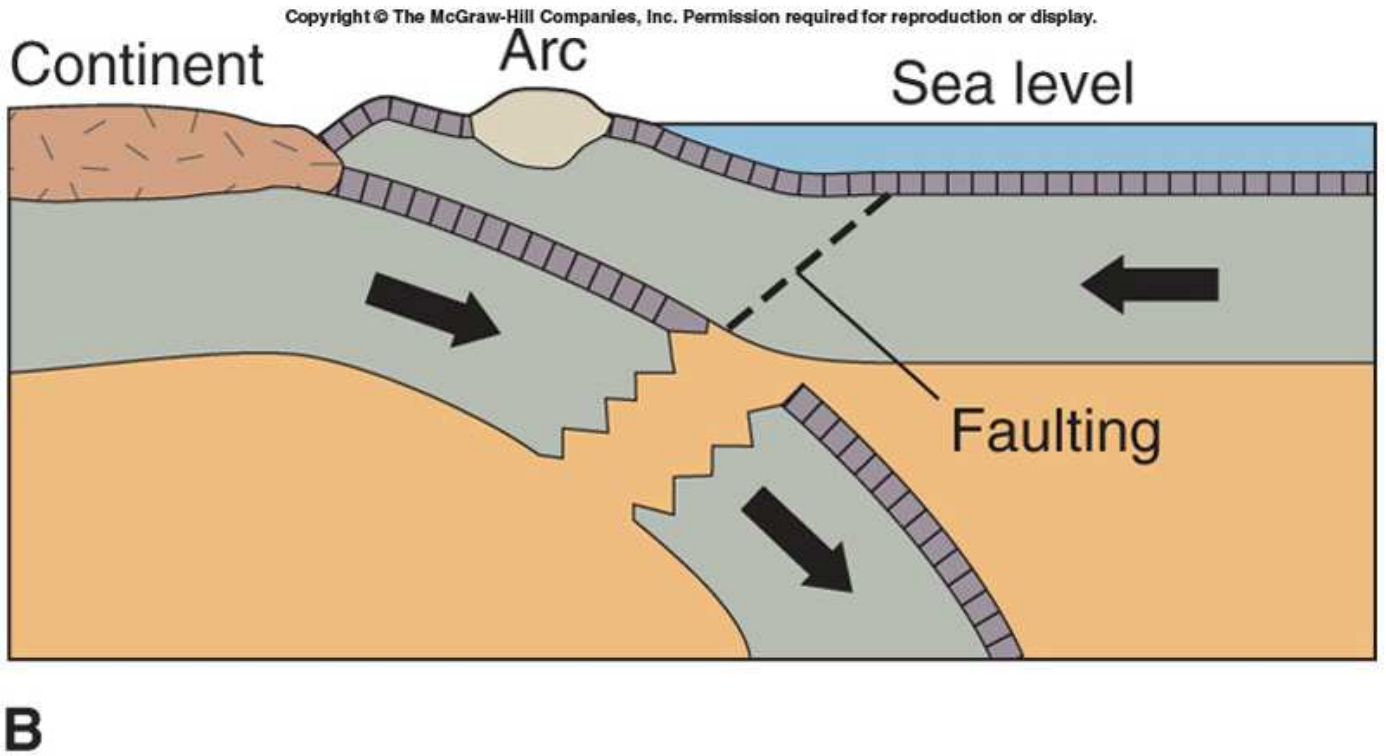
Orogeny and Island Arc-Continent Convergence

- Sometimes an island arc collides with a continent
- As the arc and continent converge, the intervening ocean floor is destroyed by subduction



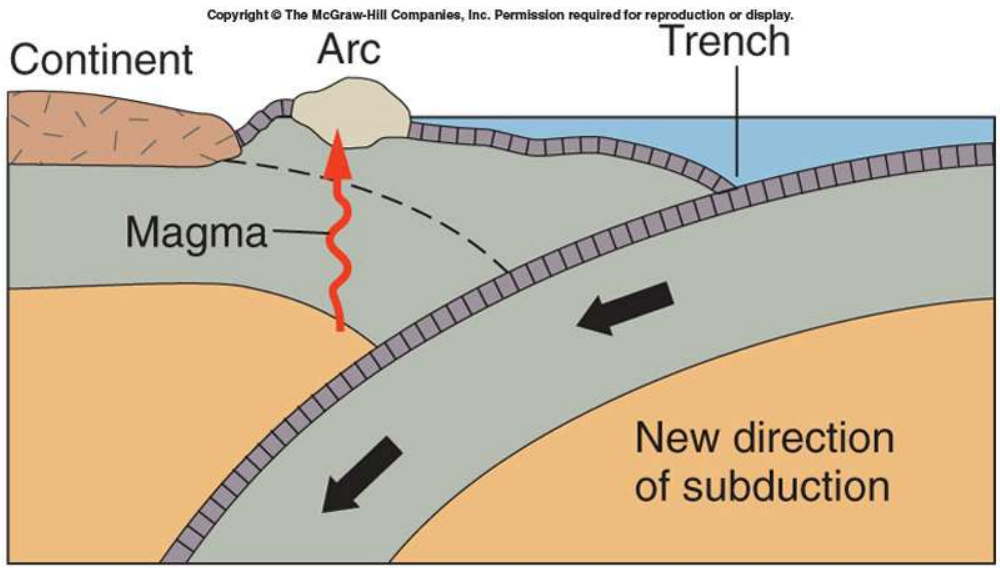
Orogeny and Island Arc-Continent Convergence

- When collision occur, the arc, like a continent, is too buoyant to be subducted
- The remaining seafloor break away from the arc



Orogeny and Island Arc-Continent Convergence

- A new site of subduction and a new trench seaward of the arc is created
- Note that the direction of new subduction is opposite to the direction of the original subduction : *Flipping subduction zone*



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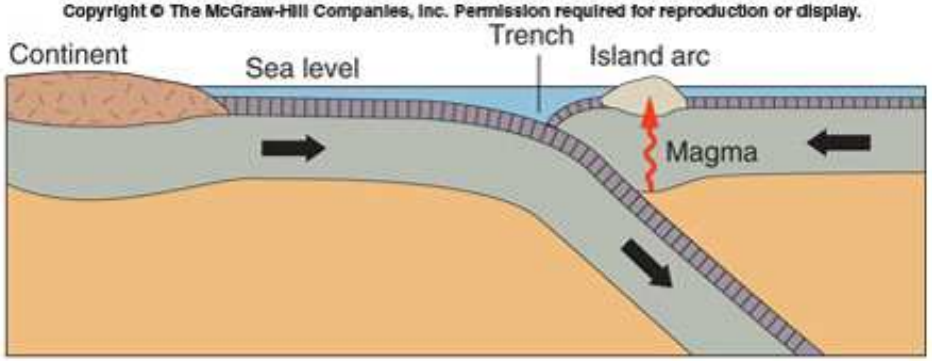
Orogeny and Island Arc-Continent Convergence



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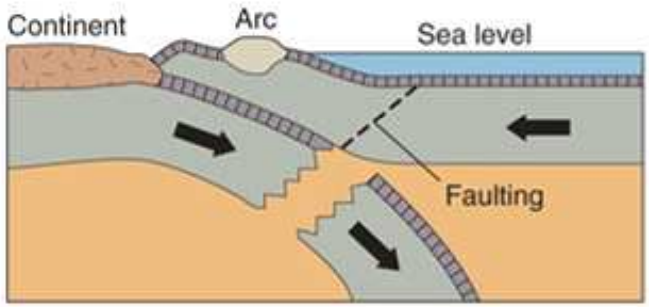

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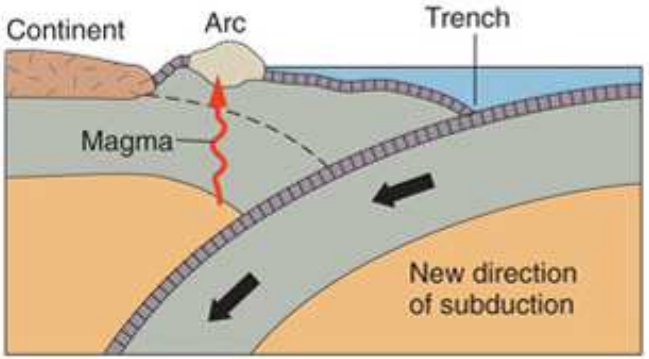

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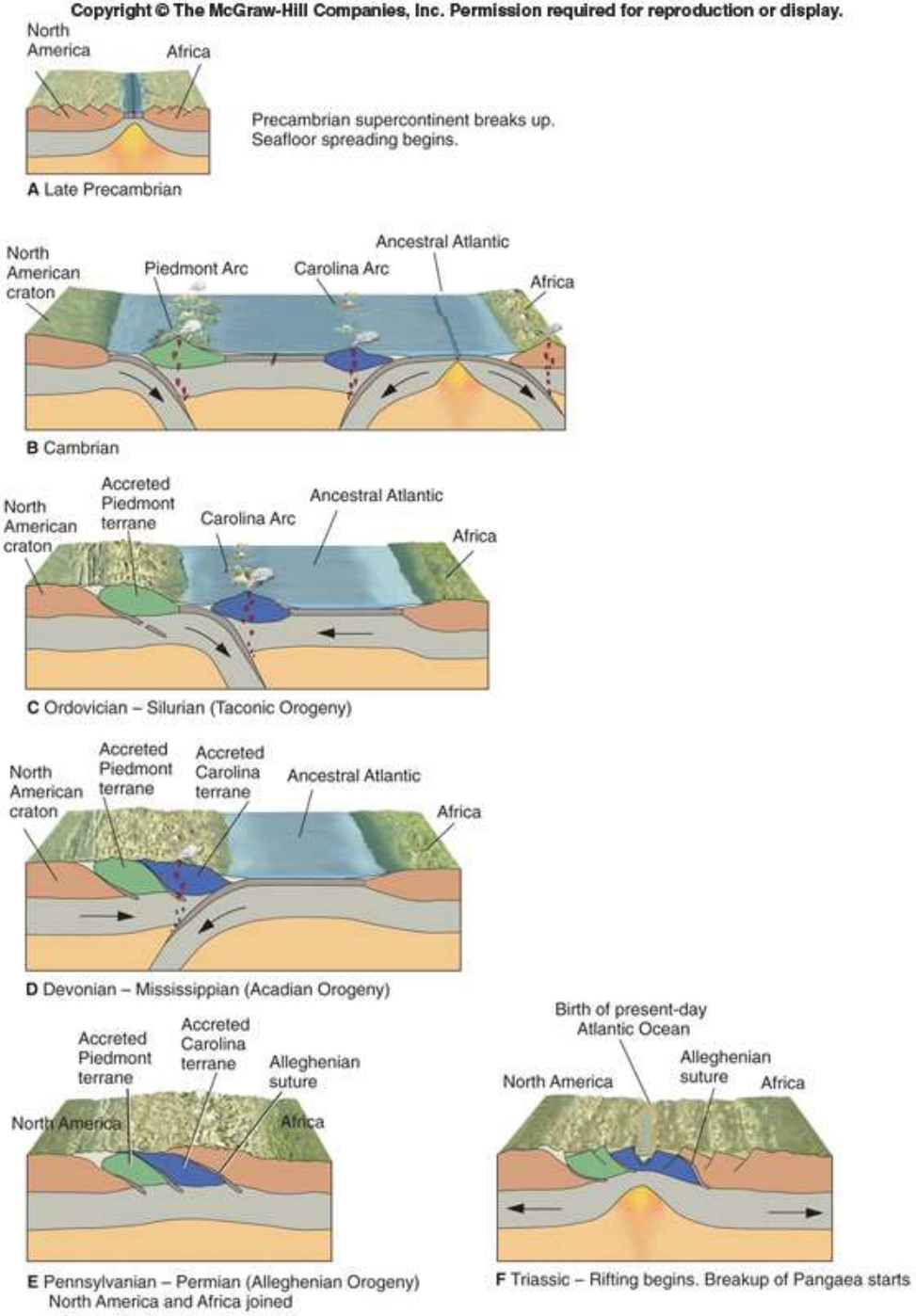
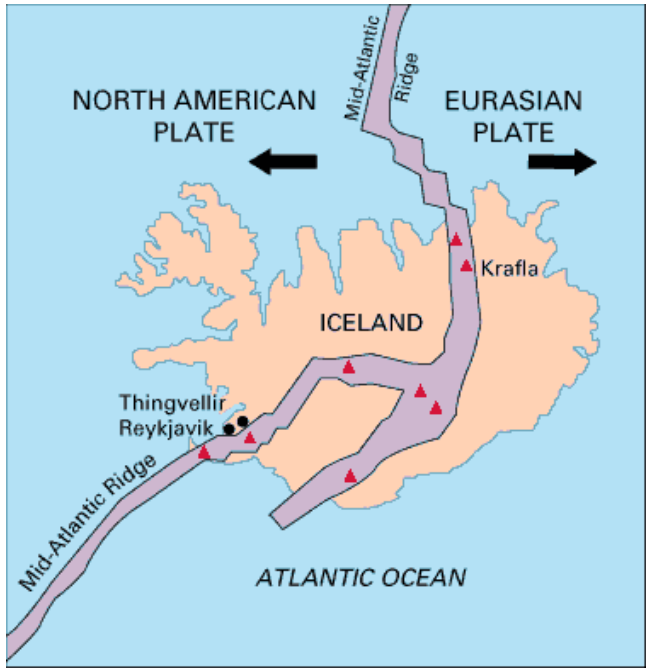


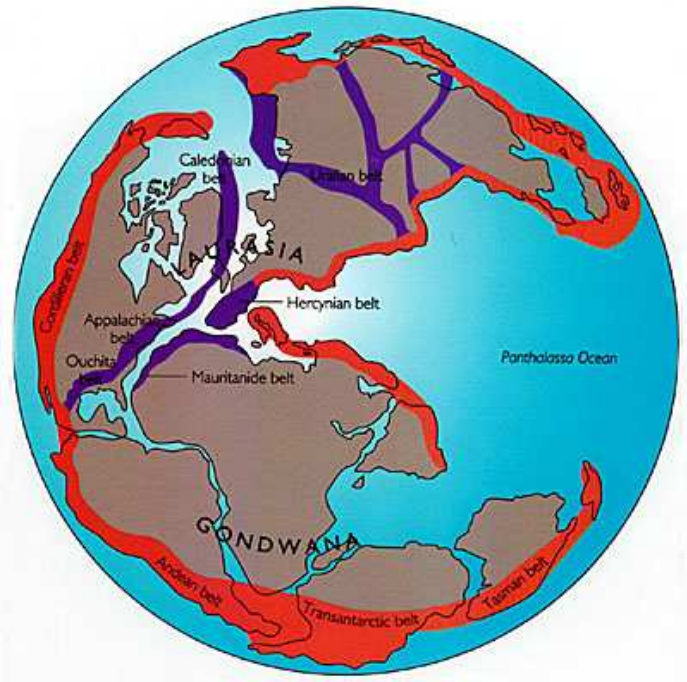
Origin of Appalachians



Origin of Appalachians

- The Appalachians and what is now the Caledonide mountain belt of Great Britain and Norway and the Atlas mountain of North Africa were part of a single mountain belt within the supercontinent Pangaea.
- Again, early in Mesozoic

era, the supercontinent (Pangaea) split, roughly parallel to the old suture zone.



Origin of Appalachians

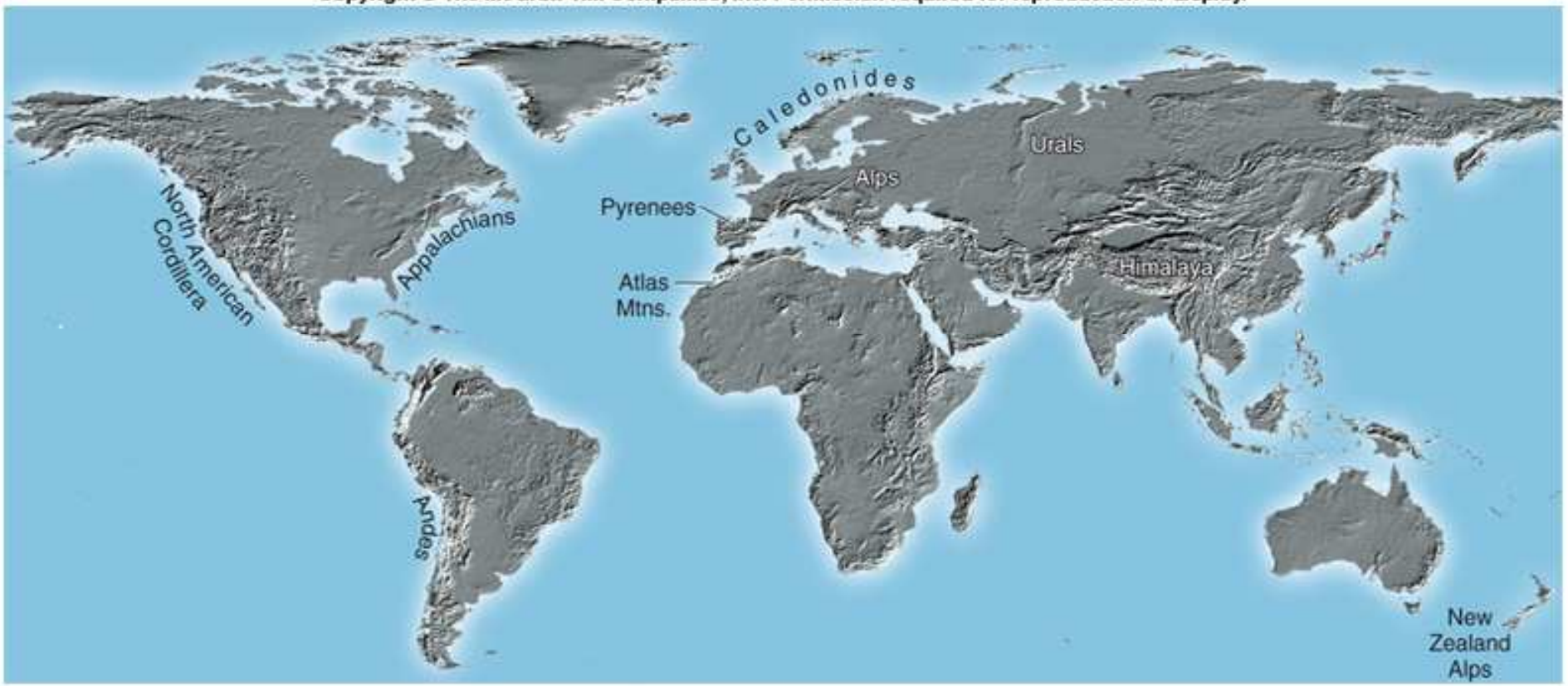
- If one examines the rocks and structures in the Appalachians (and their counterparts in Europe and Africa), the argument for this sequence of events is convincing.

- The cycle of splitting of supercontinent, opening of an ocean basin, followed by closing of the basin and collision of continents is known as the ***Wilson Cycle***.

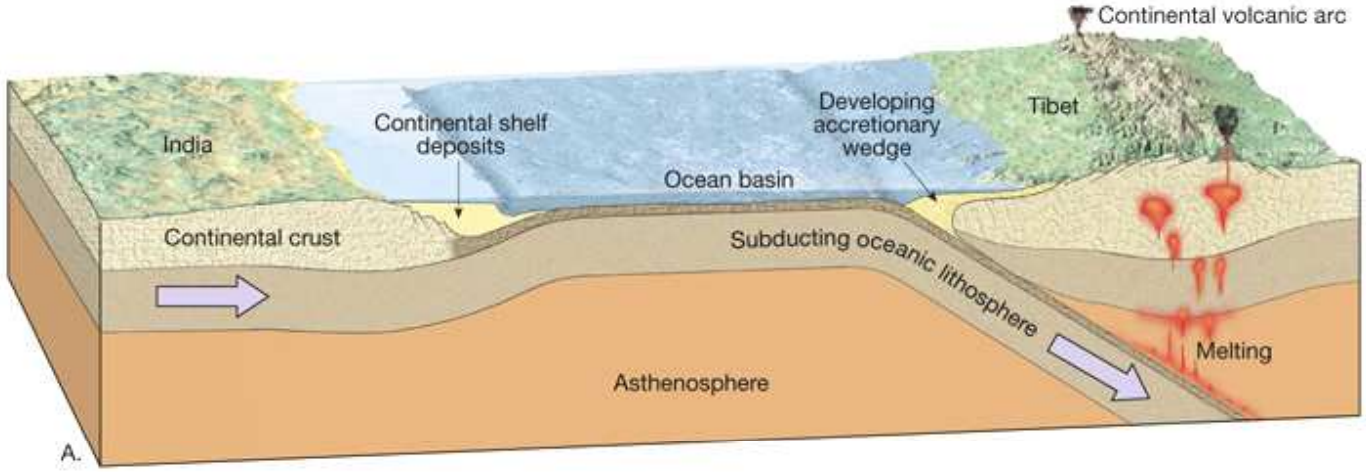
- Canadian geologist Tuzo Wilson proposed the cycle in the 1960s

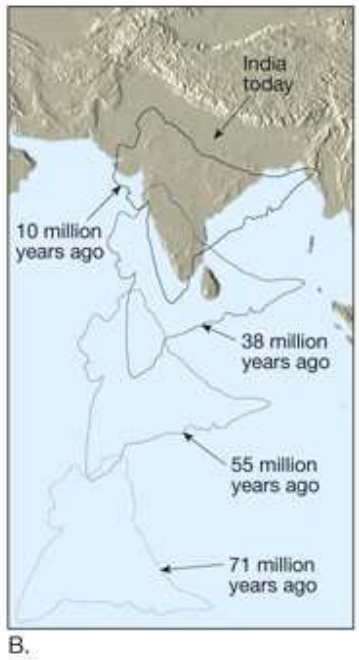
Orogeny and Continent-Continent Convergence

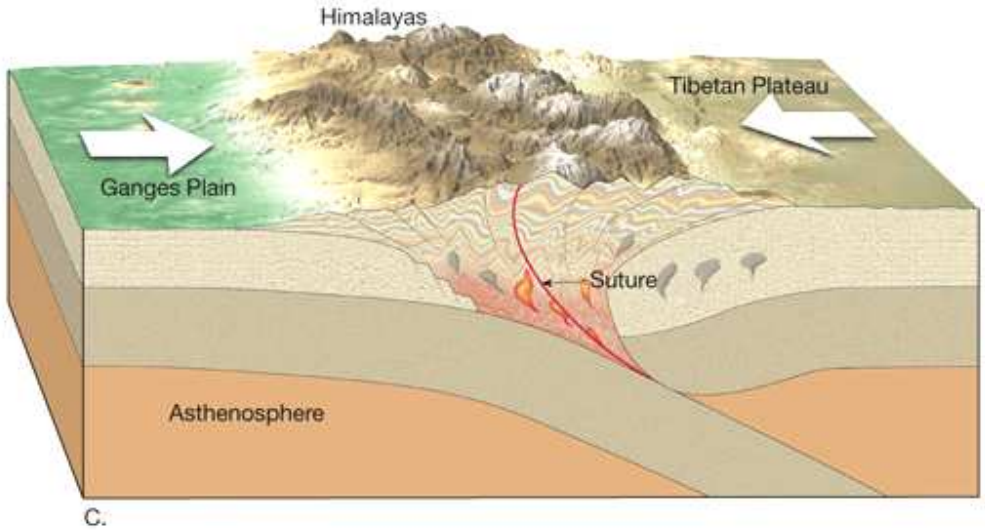
- Some examples of orogeny from continent -continent convergence
- The Ural mountains resulted from the collision of Asia and Europe
- Convergence of African and European plates created Alps
- Himalayan orogeny started around 45 million years ago when India began colliding with Asia



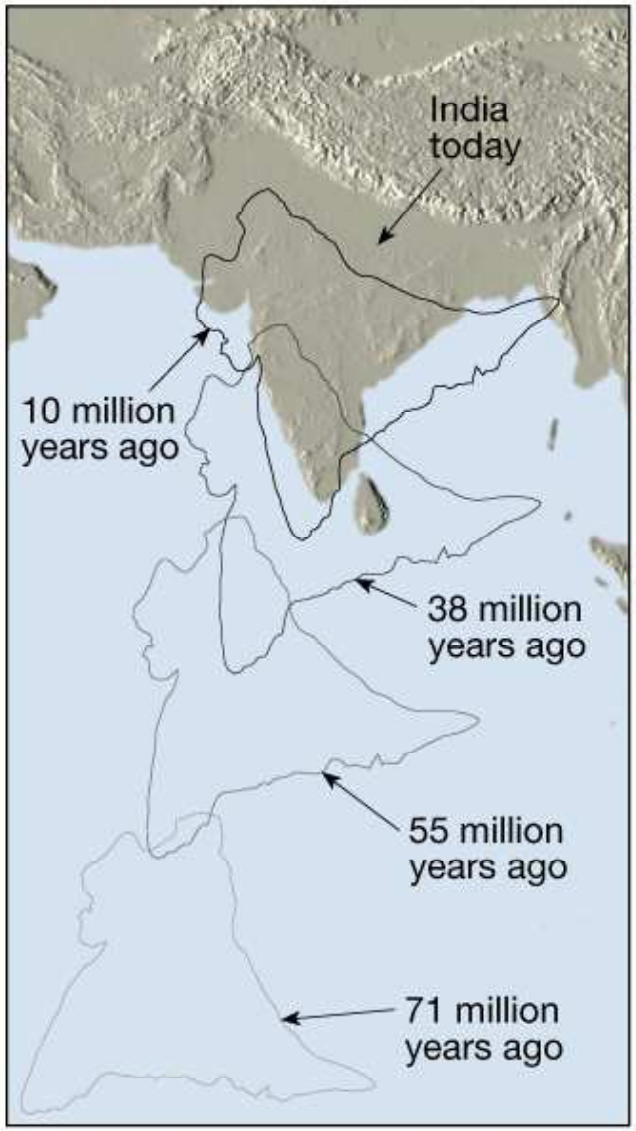
Generation of the Himalayas through continent-continent collision







Continent-Continent Collision



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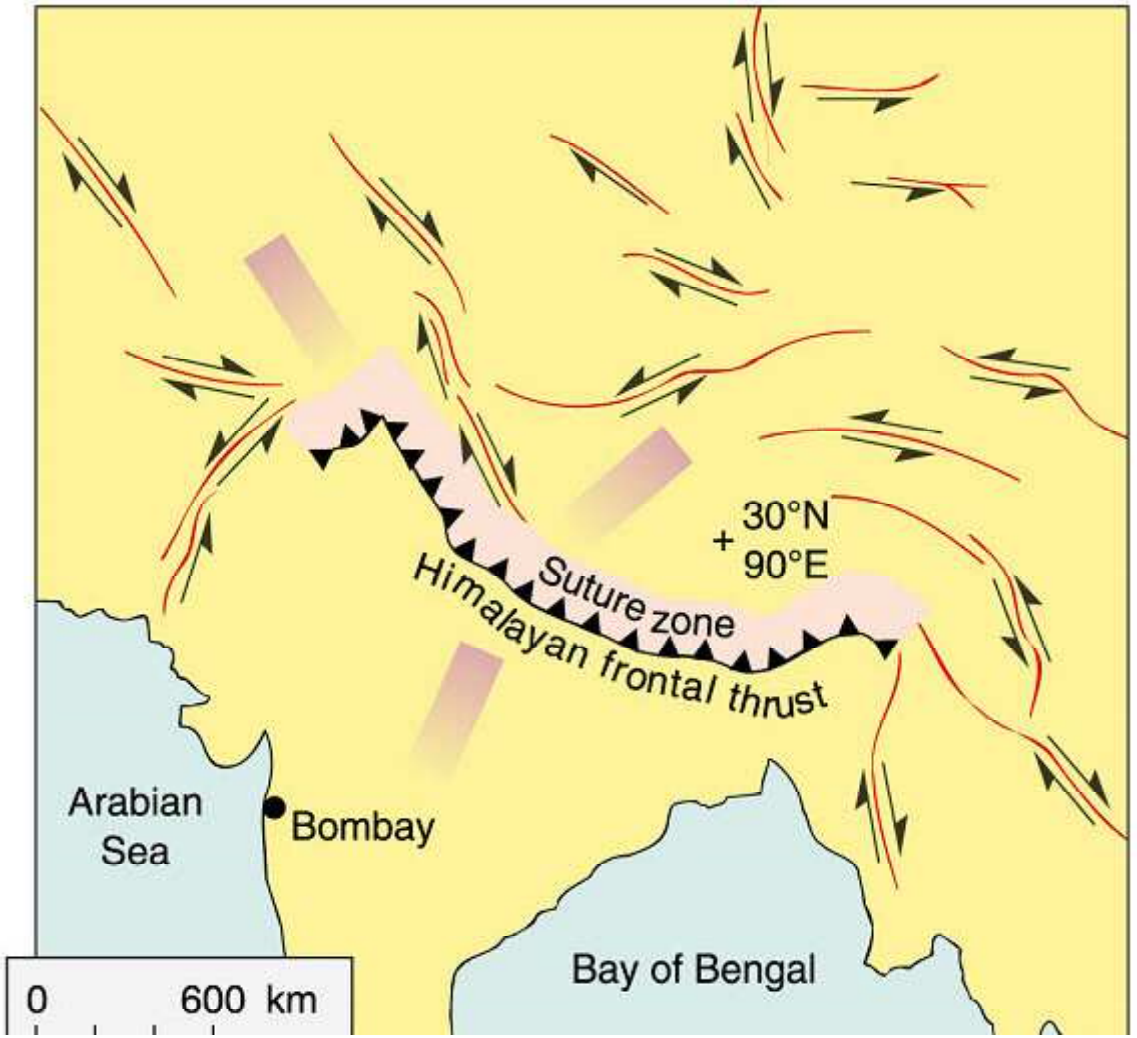
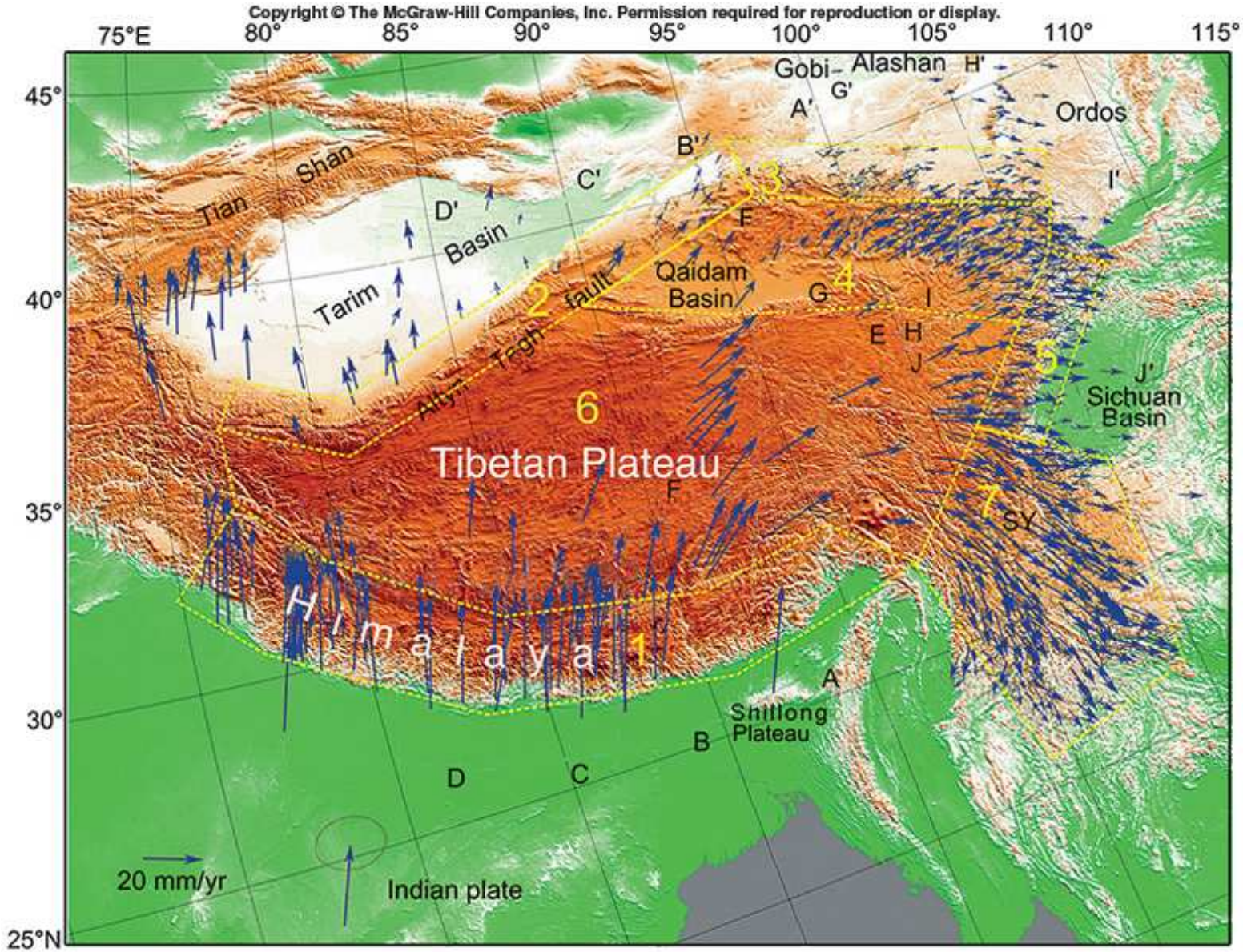


Himalayan Orogeny

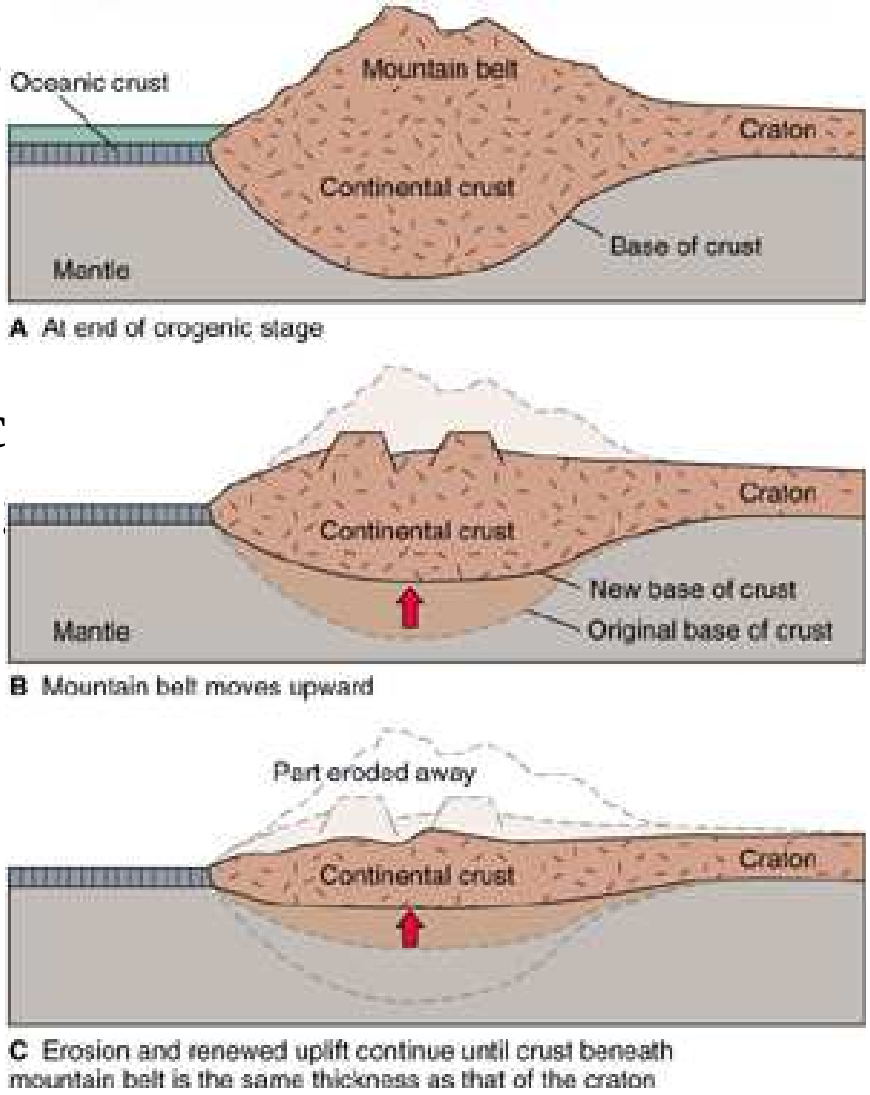


Matterhorn, Alps

The upper part of the Matterhorn is actually "a part of 'Africa' thrust bodily northwards over Europe

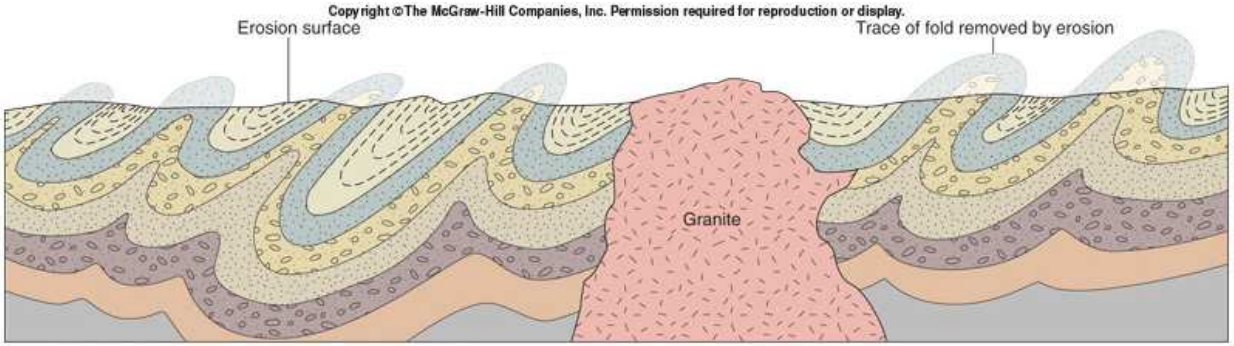
Post-Orogenic Eolution

- After convergence stops, a long period of *erosion*, *uplift* and *block-faulting* occurs
  - As erosion removes overlying roc the *crustal root* of a mountain ran rises by *isostatic adjustment*

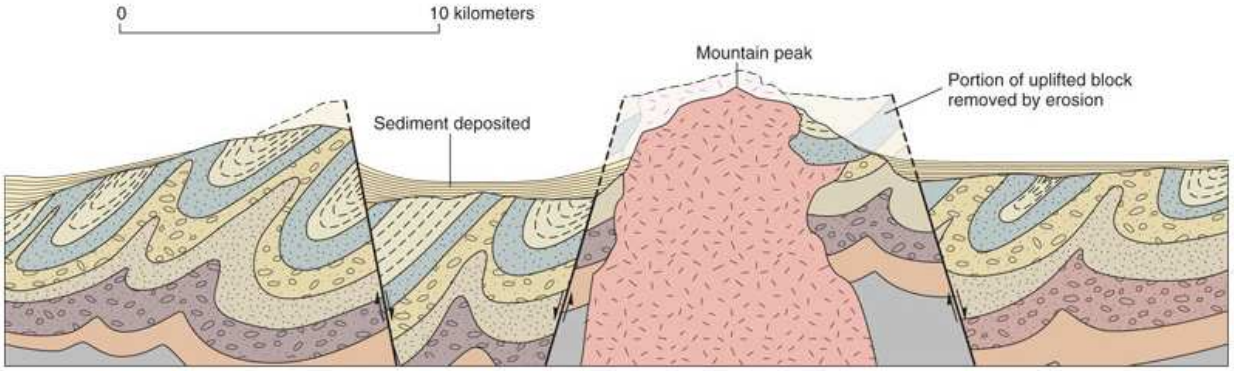


Post-Orogenic Events

– Tension in uplifting and spreading crust results in normal faulting and *fault-block mountain ranges*



A Before block faulting. Folding and intrusion of a pluton during an orogeny has been followed by a period of erosion.

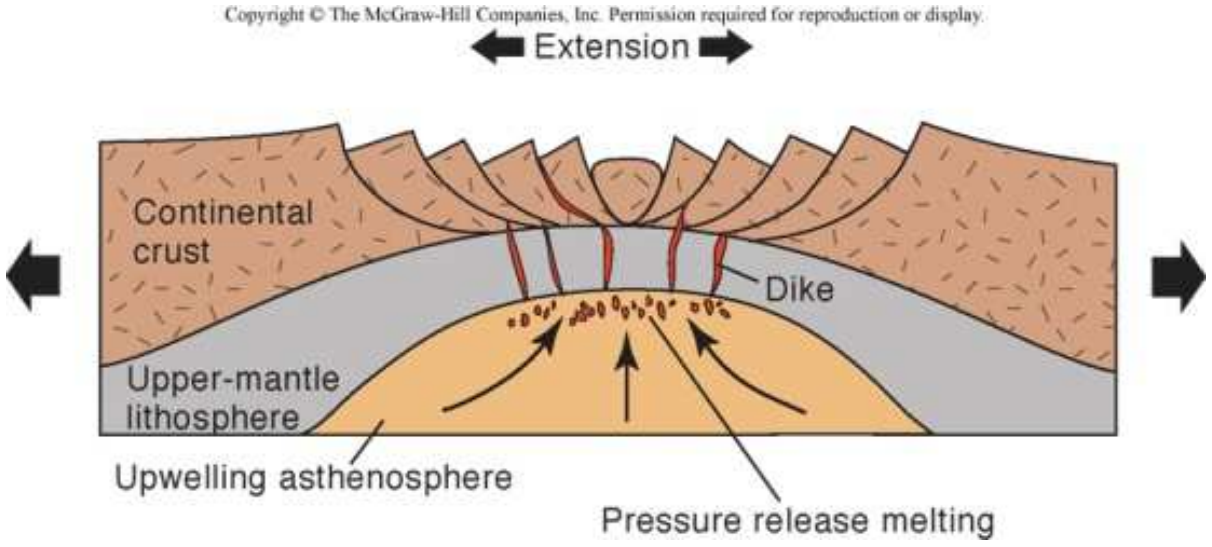


B The same area after block-faulting. Tilted fault-block mountain range on left. Range to right is bounded by normal faults.

The Teton Range, Wyoming

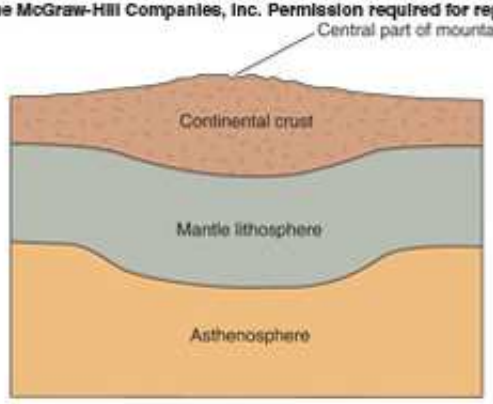
Evolution of Mountain Belts Through Delamination

- *Delamination*
  - Overthickened mantle lithosphere beneath old mountain belt may detach and sink into *asthenosphere*
  - Resulting inflow of hot *asthenosphere* can stretch and thin overlying crust, producing normal faults

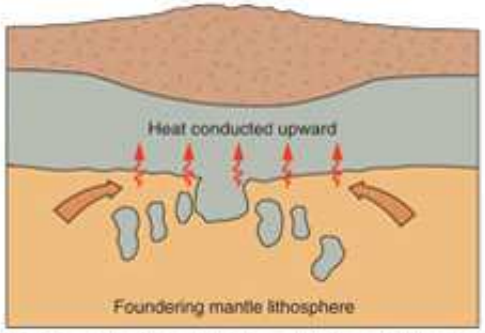


Evolution of Mountain Belts Through Delamination

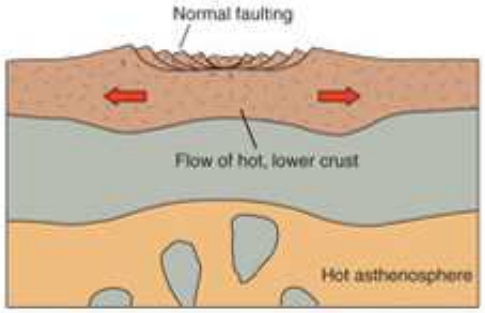
- Delamination is still a hypothesis and needs further testing to become widely accepted as a theory.



A Thick continental crust of a mountain belt produced during orogeny.



B Delamination of gravitationally unstable mantle lithosphere. Hot asthenosphere flows and replaces foundering lithosphere, heating overlying lithosphere.

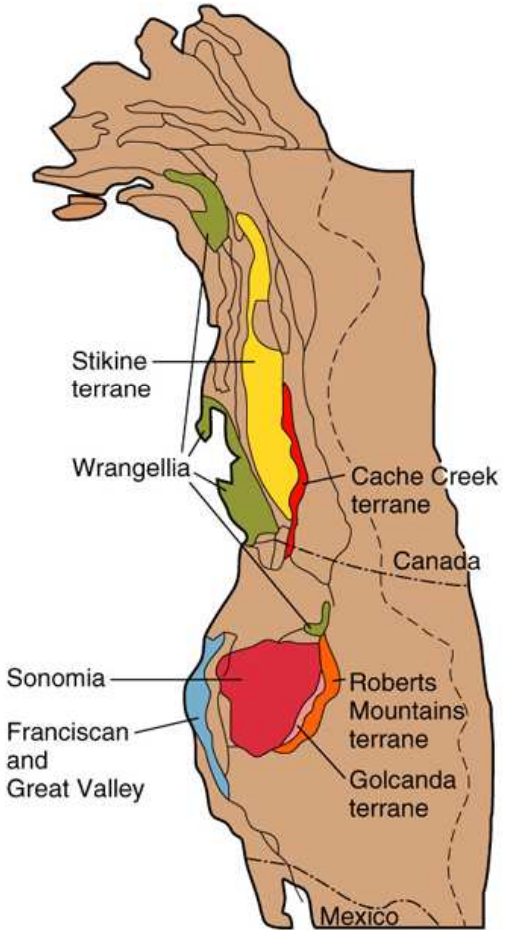


C Extension with hot, lower crust flows outward.

Growth of Continents

- Continents grow larger as mountain belts evolve along their margins
  - Accumulation of sediment and igneous activity add new continental crust

- New *accreted terranes* can be added with each episode of convergence
  - Western North America (especially Alaska) contains many such terranes



Exotic Terranes along western North America

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