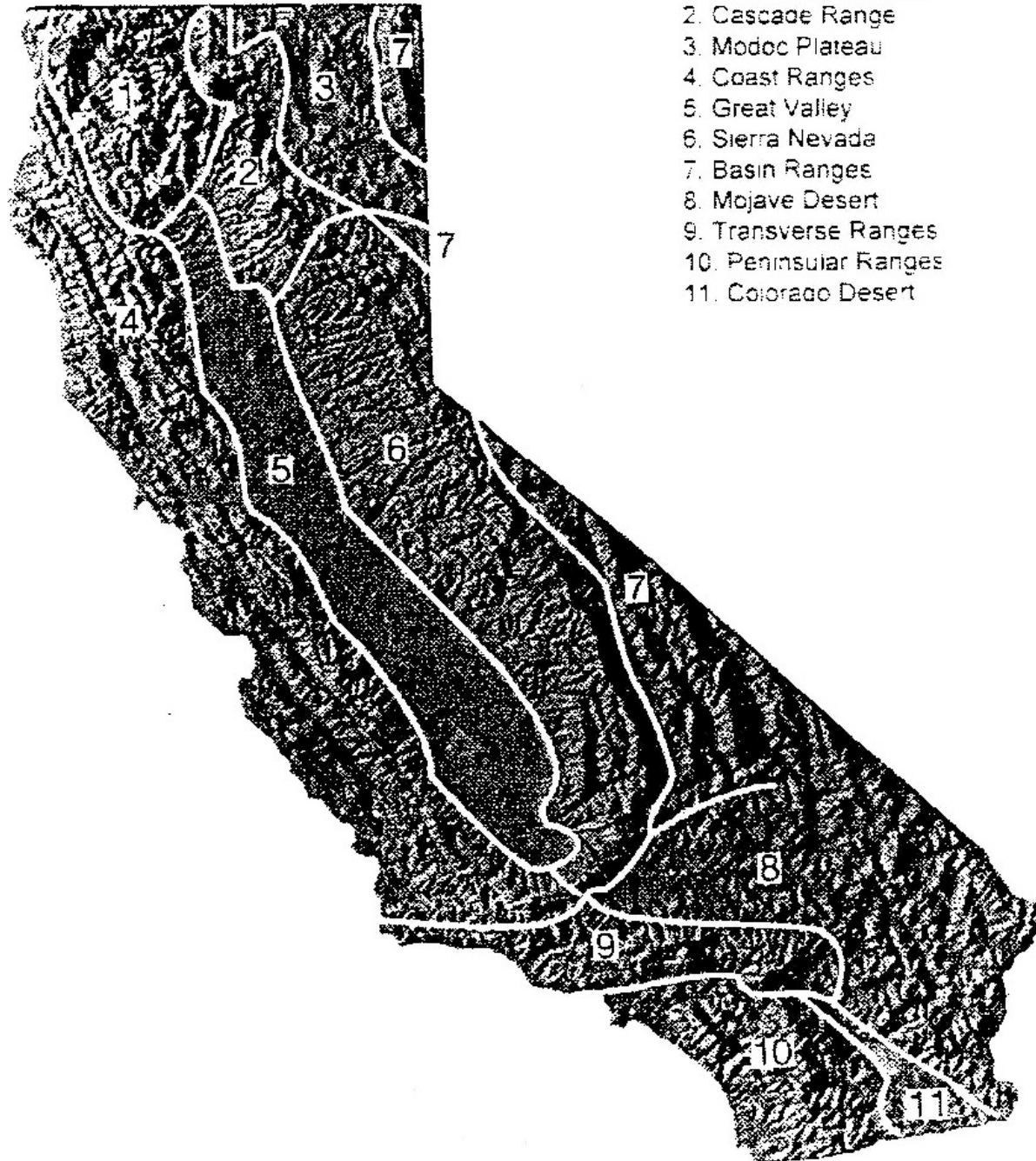
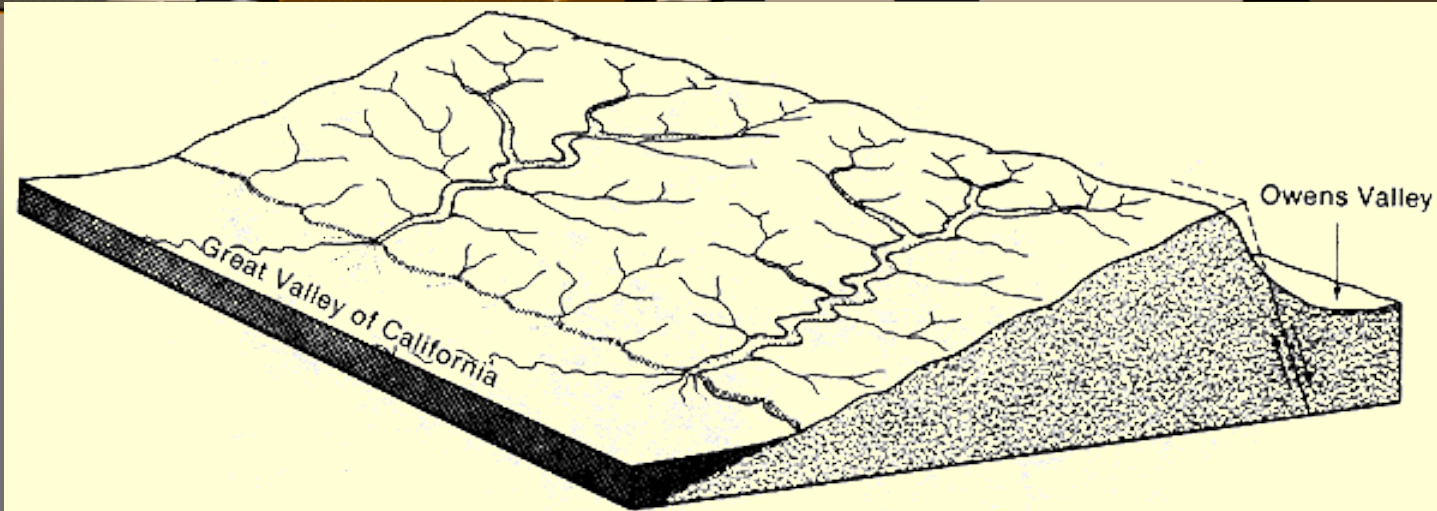




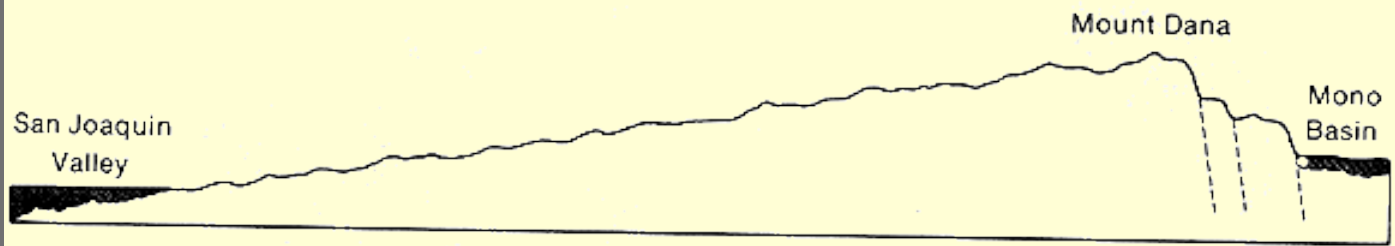
# **California Geologic History**



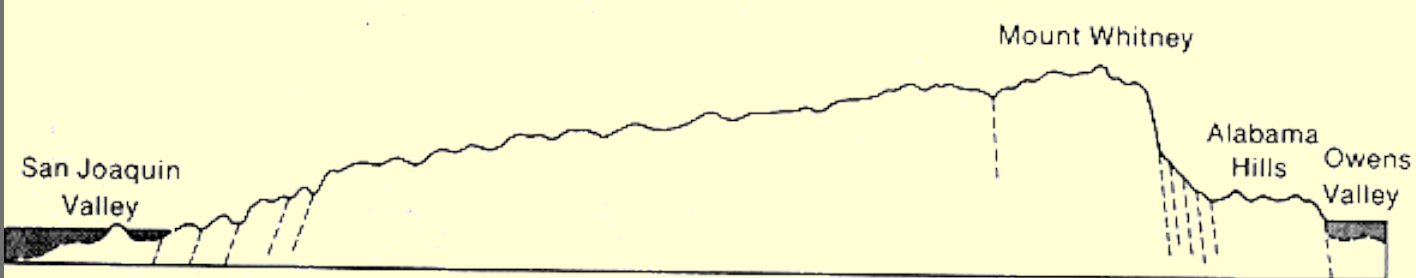
1. Klamath Mountains
2. Cascade Range
3. Modoc Plateau
4. Coast Ranges
5. Great Valley
6. Sierra Nevada
7. Basin Ranges
8. Mojave Desert
9. Transverse Ranges
10. Peninsular Ranges
11. Colorado Desert



(a)



(b)



Why do Sierra Nevada look this way?

# Alabama Hills











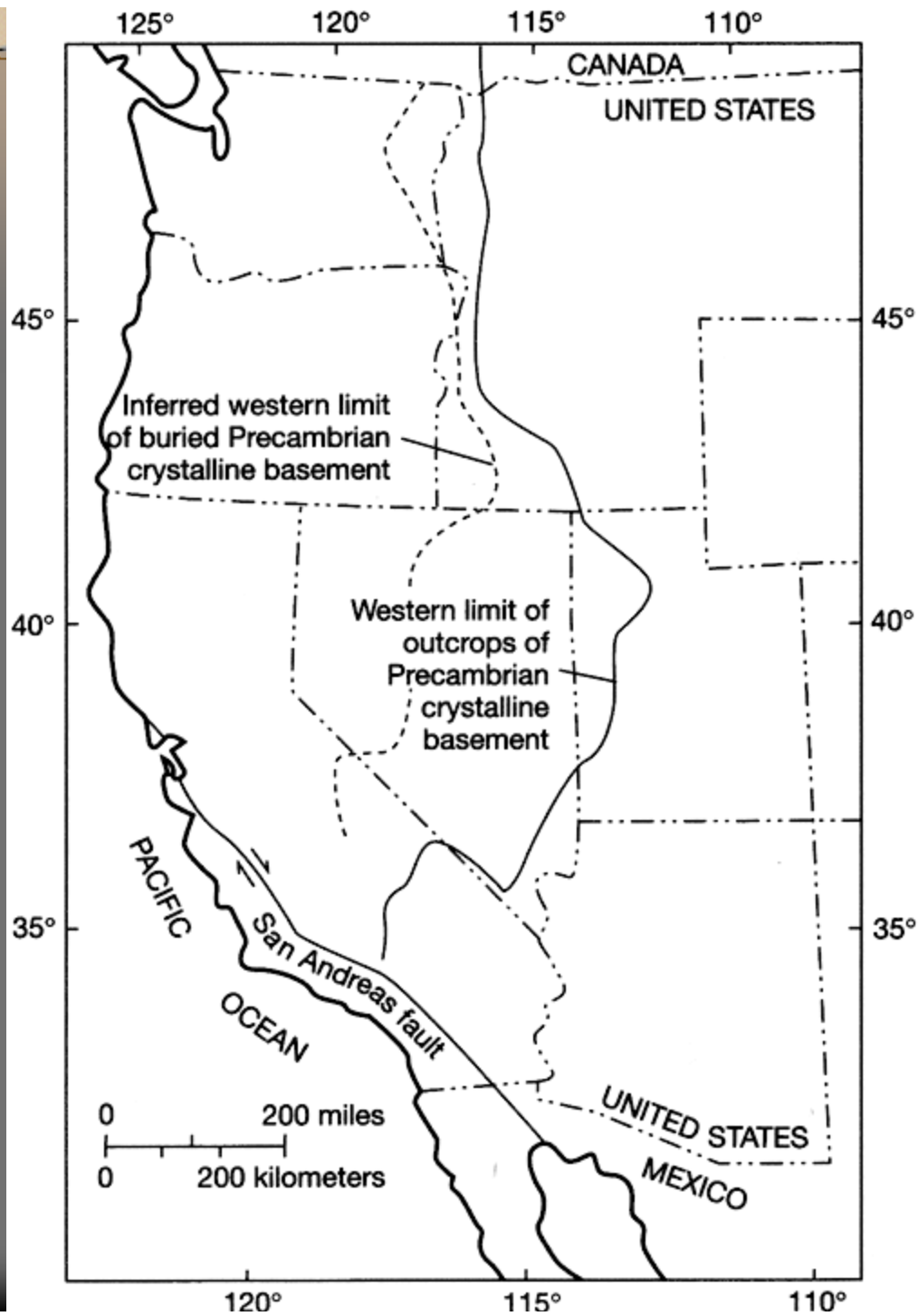
# Introduction

- ⇒ California's geologic history is very complex, most of the state did not exist as a coherent piece of the earth's crust until relatively recently in geologic terms.
- ⇒ Rock formations that are now adjacent often have very different histories.
- ⇒ Some of the larger collisions were associated with major episodes of tectonic activity—intrusive and extrusive volcanic activity, folding and faulting, and mountain building.
- ⇒ The most recent period of mountain building is still going on, and practically all of the current landforms and geographic features are very young in geologic terms—only a few million years old.

# Proterozoic and Paleozoic Era (2,500-245 mya)

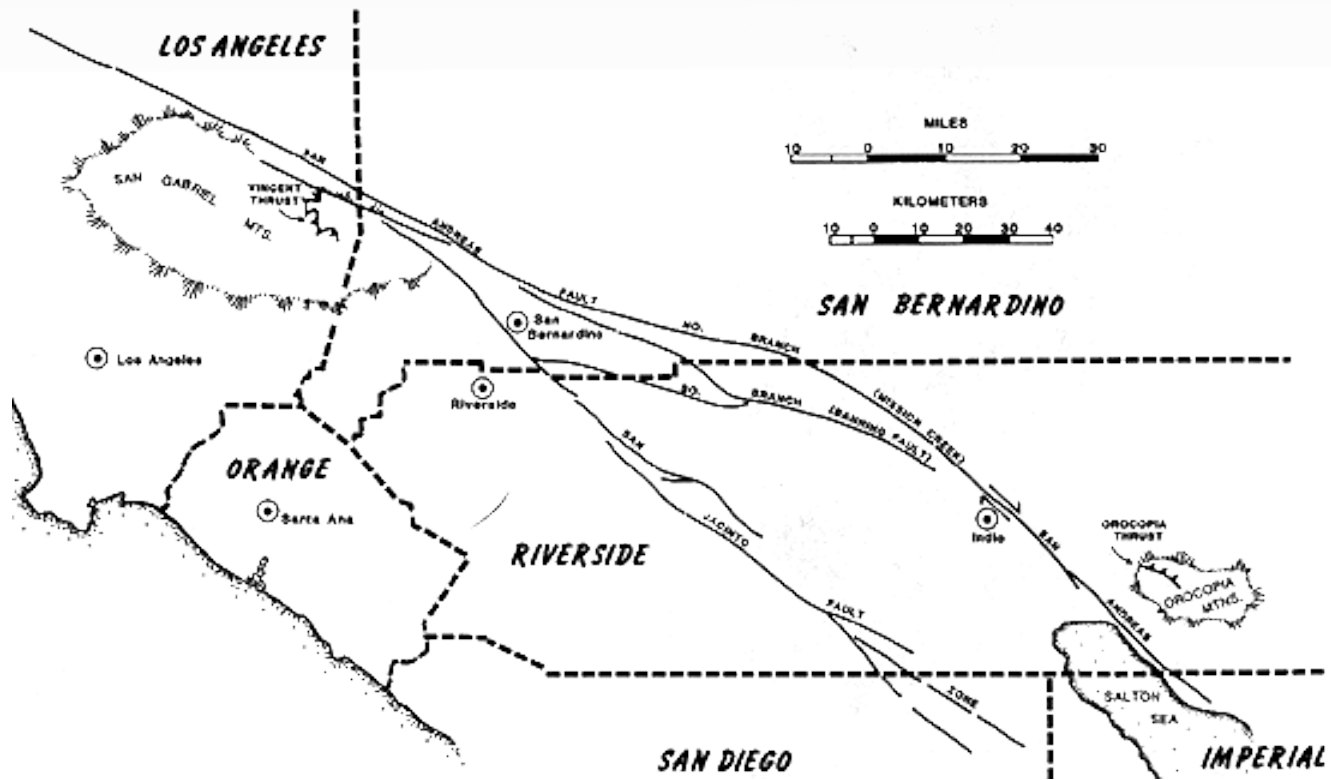
- ⇒ Rocks older than 600 million years are rare in California.
- ⇒ The oldest rocks, which are more than 1,000 million years old, are located in the eastern deserts and the eastern Transverse Ranges (San Bernardino and San Gabriel Mountains).
- ⇒ The distribution of rocks of these ages suggests that the west coast of the North American Continent was well to the east of all but the southern end of what is now California.





# Proterozoic and Paleozoic Era

- ⇒ All of these very old formations have been extensively metamorphosed-difficult to determine the conditions that existed when they were originally formed.
- ⇒ Some of the oldest (around 1,800 million years old) are located in the mountains around Death Valley and are much like the rocks exposed in the inner gorge of the Grand Canyon.
- ⇒ Metamorphic rocks around 1,000 million years old in the San Gabriel Mountains and the Orocopia Mountains east of the Salton Sea.





# Proterozoic and Paleozoic Era

- ⇒ 1,000 million years ago and 400 million years ago appears to have been quiet in western North America.
- ⇒ The coastline remained east of California, probably in Utah and Idaho. Very thick sections of marine sedimentary rocks from this period are exposed in the mountains east of the Sierra Nevada. For the most part, these rocks are carbonates (limestone and dolomite), indicating shallow, warm ocean conditions with little incoming terrestrial sediment—possibly similar to the Gulf of Mexico today.

# Antler and Sonoma Events

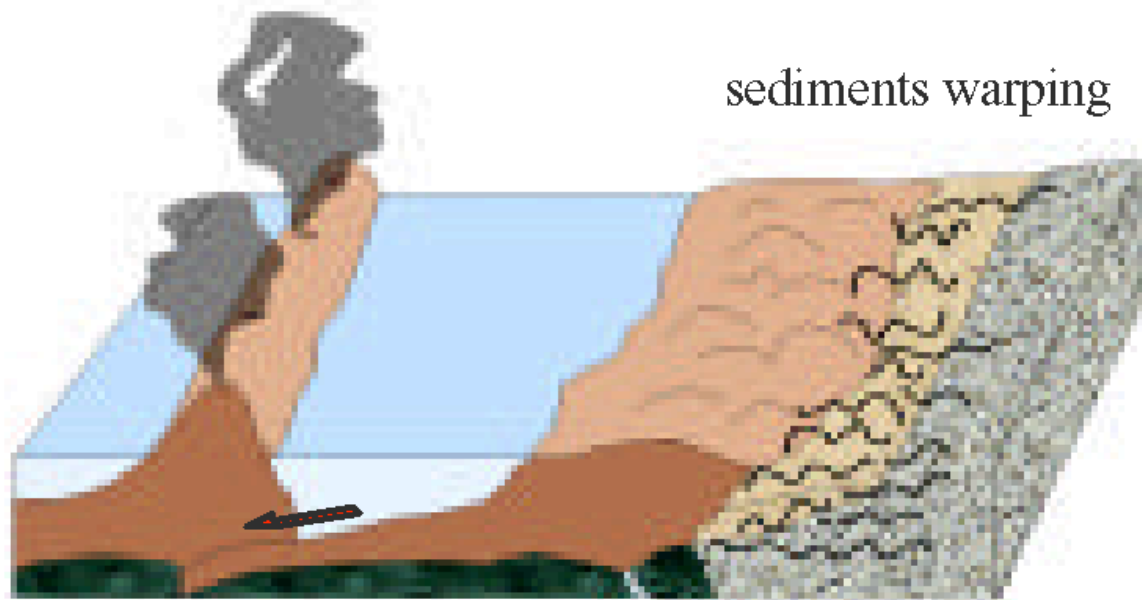
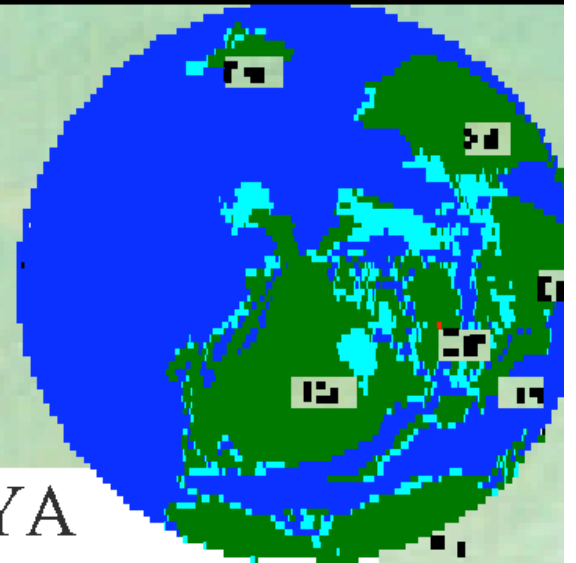
- ⇒ Around 400 million years ago the quiescent period in western North America came to an end.
  - Antler Orogeny-Development of an offshore island arc. The evidence for this event is strongest farther east, but there are indications in the northern Sierra Nevada and Klamath regions. Possibly similar to Japan today.
  - Sonoma Orogeny-250 mya-This event is most evident in central Nevada, which may have been the location of the coast at the time. The orogeny seems to have marked the joining of the island arc containing rocks now found in the Sierra Nevada foothills and central Klamath Mountains with the rest of the continent. This event appears to mark the first time the coast moved west into most of California.





# 400 MYA

- Subduction began west of the North American continental margin.
- Antler & Sonoma Orogenies
- Island arc collisions continue until 215MYA

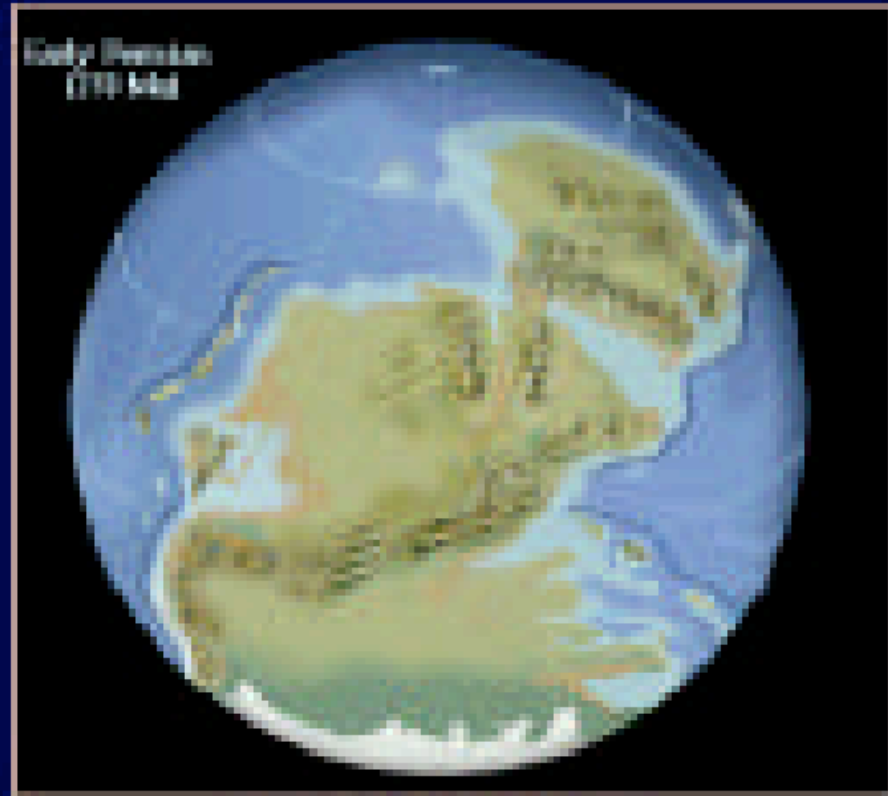


Island arc forming

Island arc colliding and accreting

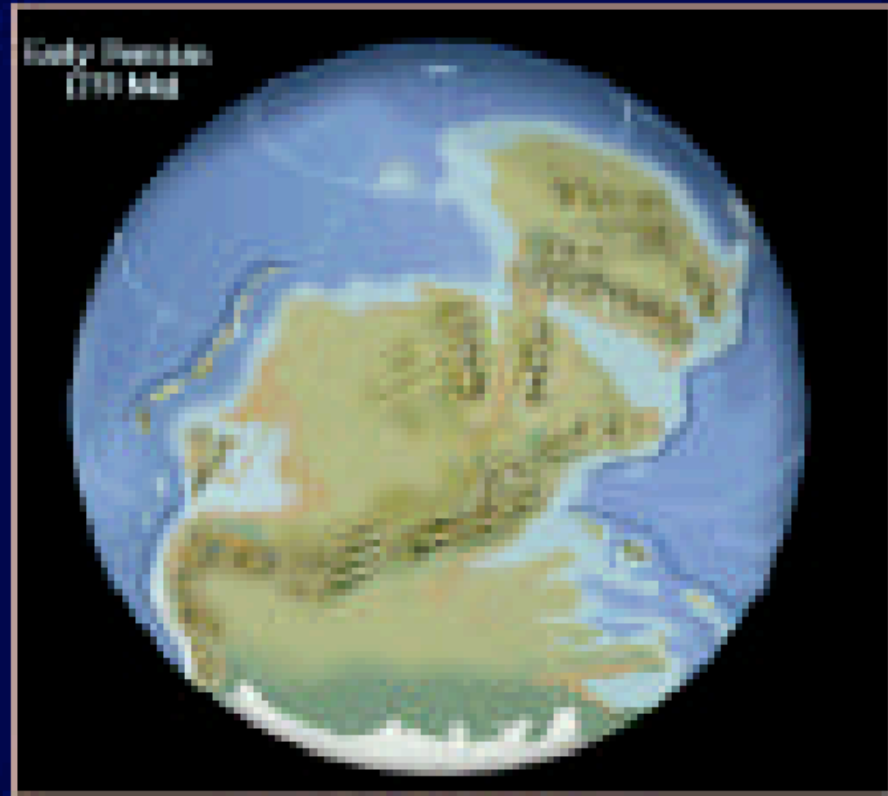
# 270 MYA

☞ All continents joined once again to form the super-continent Pangaea



# 270 MYA

☞ All continents joined once again to form the super-continent Pangaea





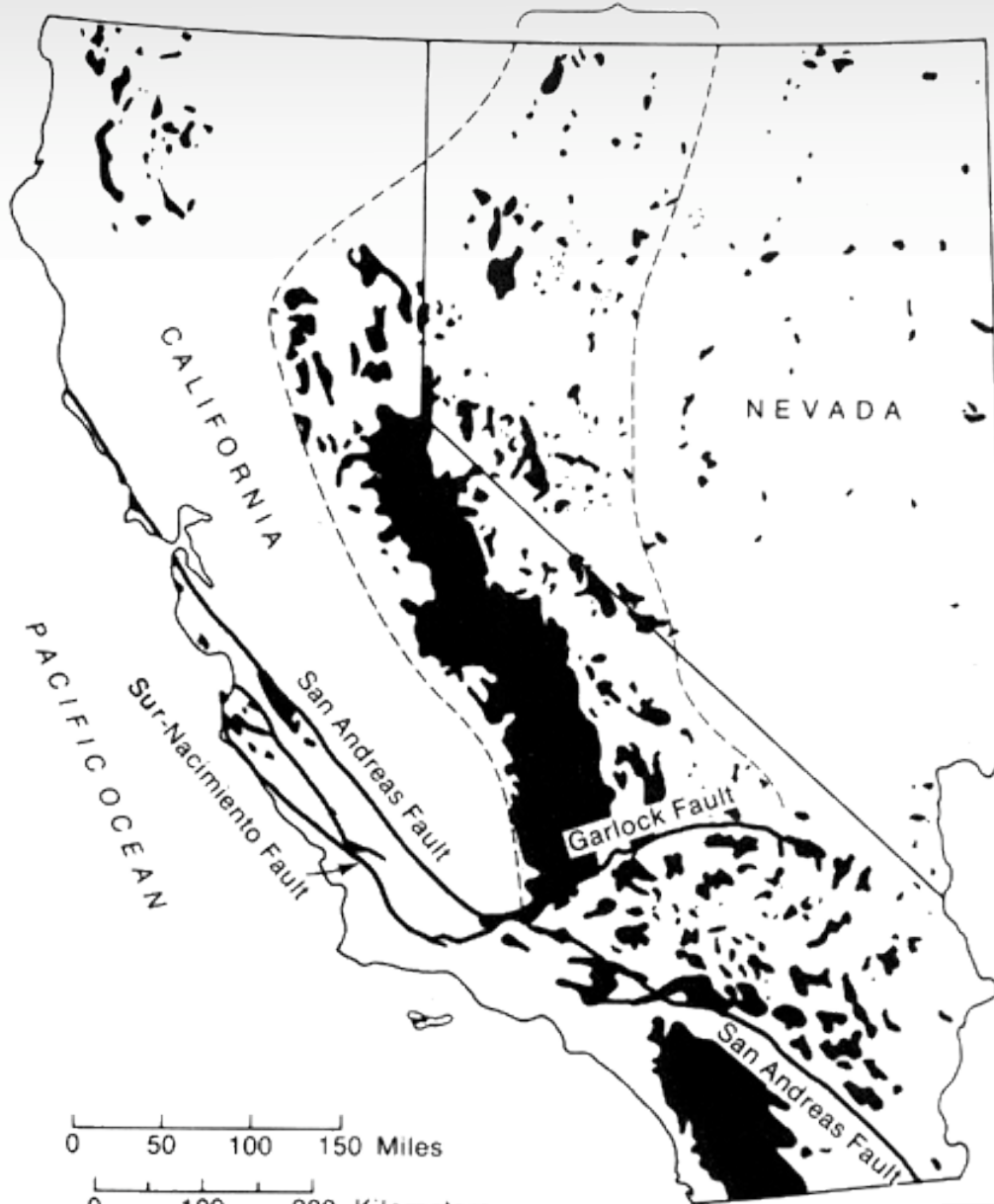
# Mesozoic Era (245-65 million years ago)

- ⇒ Nevadan Orogeny – 210 mya. Uplift of the ancestral Nevadan Mountains caused by the formation of the main body of intrusive granitic rocks that now make up most of the Sierra Nevada (subduction zone probably similar to the current situation along the West Coast of South America).

# Mesozoic Era 245-65 mya

- ⇒ By 150 million years ago the Nevadan Mountains composed the western coast of North America and the sea never again extended farther east than the eastern edge of what is now the Central Valley.
- ⇒ At roughly the same time the granitic rocks were forming that are now found in the Peninsular Range of Southern California and in the Salinian block that runs along the western edge of the San Andreas Fault in the central and southern Coast Ranges.

Approximate limits of the  
Sierra Nevada batholith



## The Extent of Sierran Arc Volcanism

- 215 - 70 MYA
- Nevadan and Sevier Orogenies
- South American analogs:  
Andes Mountains



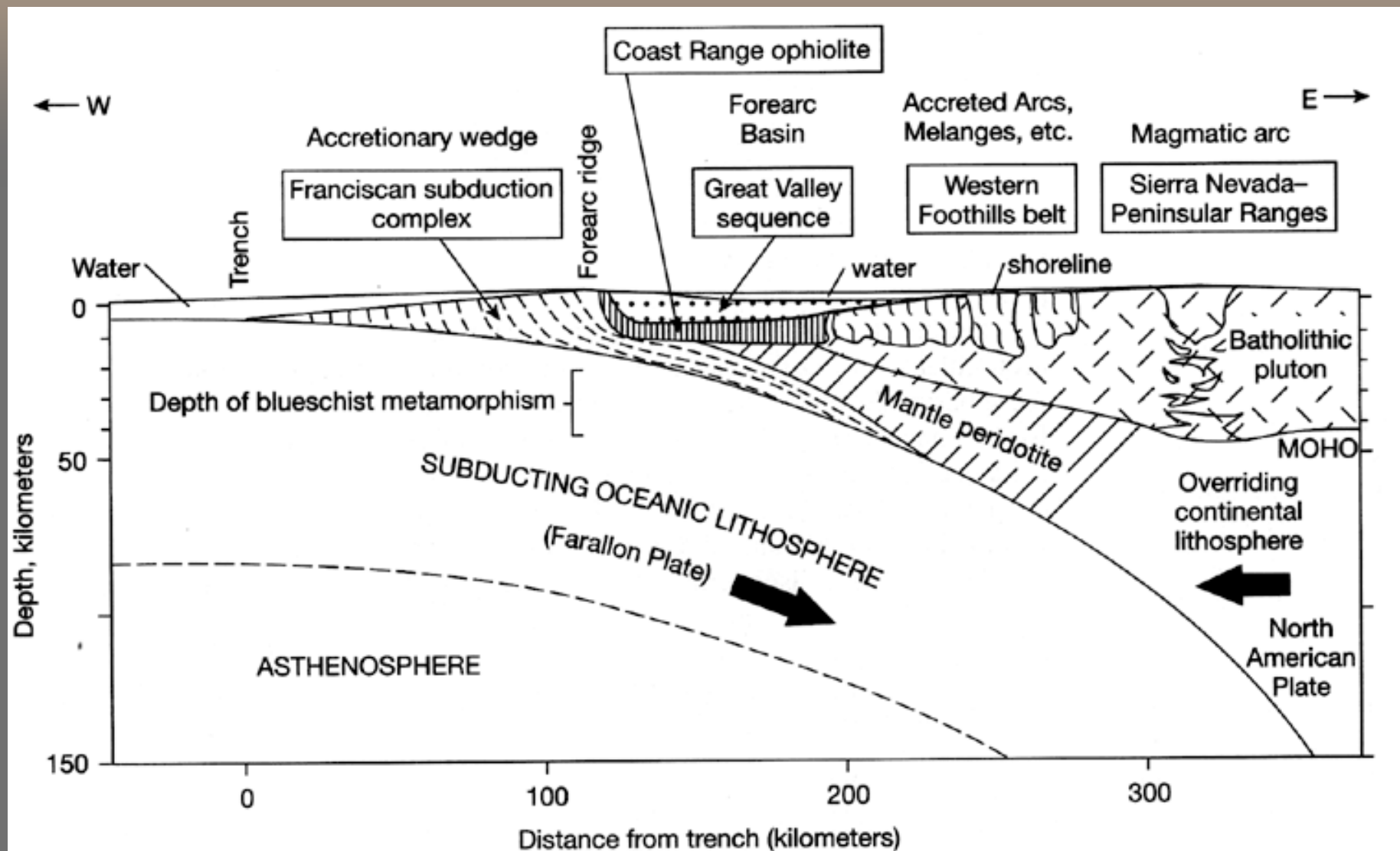
# Cretaceous

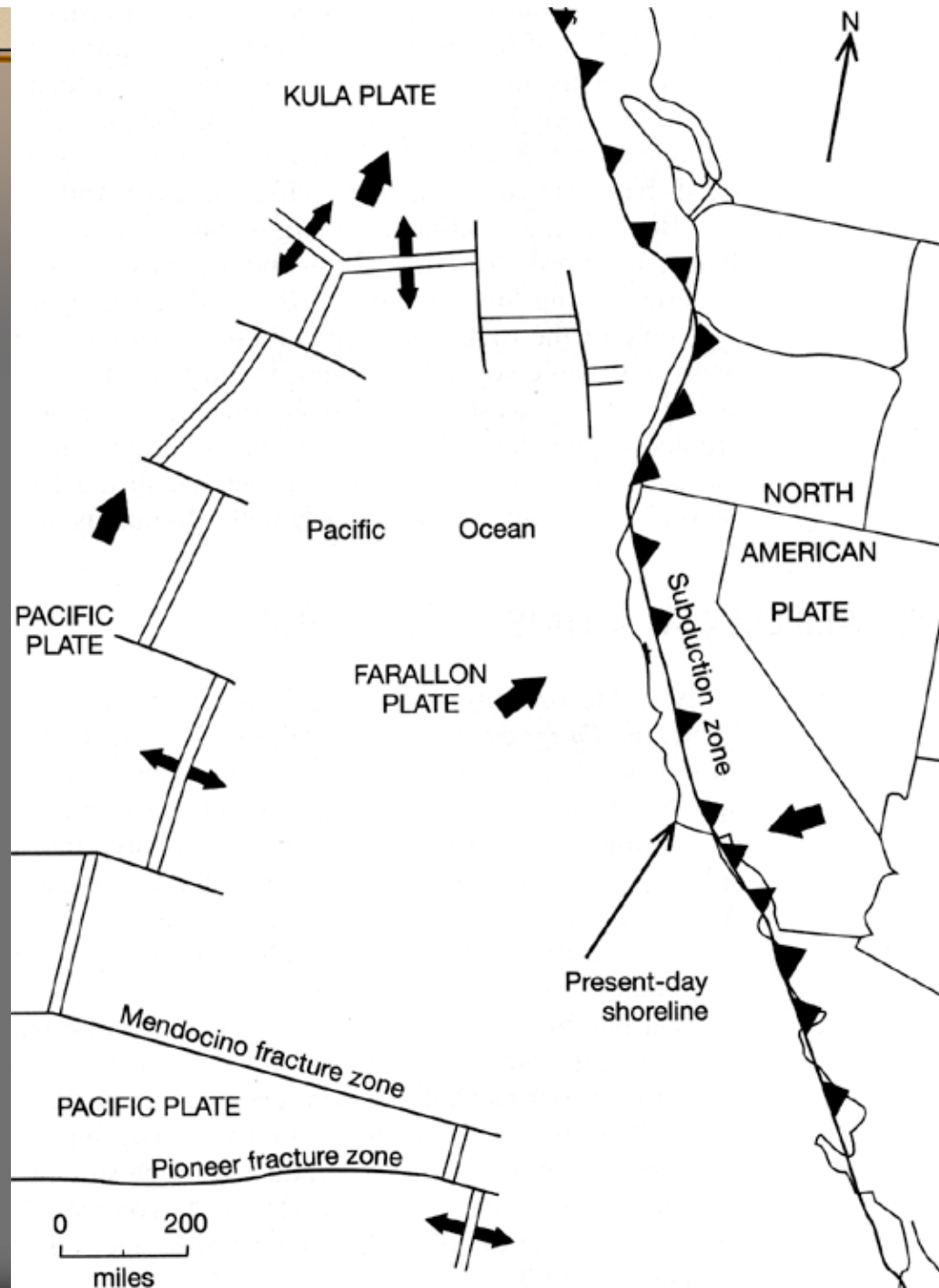
- ⇒ Forces that created the intrusive granitic rocks of the Sierra Nevada and Southern California continued episodically until about 90-100 million years ago. During the same period sedimentary deposits were accumulating on the continental shelf, slope, and in an offshore subduction zone.



# Cretaceous

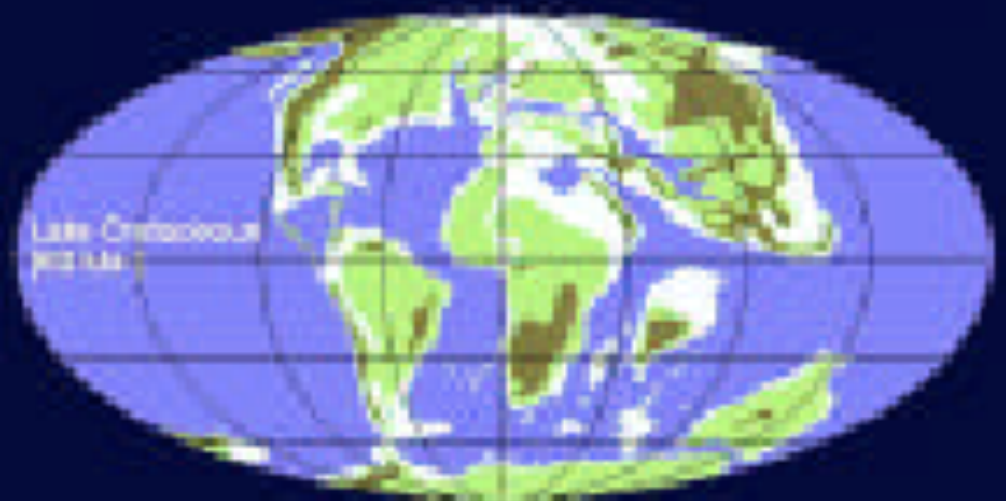
- ⇒ By that time the subduction zone had shifted west to about the current location of the Coast Ranges
- ⇒ Deposits in the subduction zone were mixed with rocks from the upper mantle beneath the crust producing the Franciscan Formation (extends from northern Santa Barbara to the northern California coast).
- ⇒ The oceanic crustal material in the Franciscan formation was thrust up against the Sierran block by about 75 million years ago, extending the boundary of the North American plate further west.





# 70 MYA

- North America rifts farther from Europe, overriding the sea floor to the west.
- Laramide Orogeny





# Cenozoic

- ⇒ By about 50 million years ago the ancestral Nevadan Mountains had eroded down to relatively low-lying hills.
- ⇒ Large rivers flowed through the region and deposited gravels rich in gold.
- ⇒ The southern Sierra Nevada and Mojave region were elevated enough to allow for the erosion and deposition of thick layers of marine sedimentary rocks in what are now the southern Coast Ranges and western Transverse Ranges.



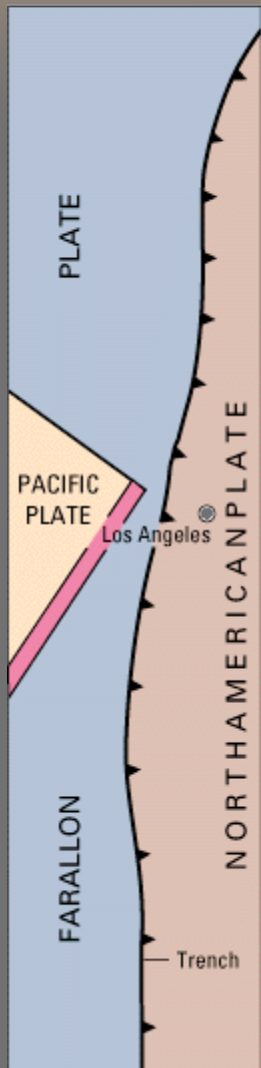
# Cenozoic

- ⇒ This deposition continued without interruption until around 40 million years ago. Over the next 10 million years the coast shifted back and forth, producing a patchwork of marine and non-marine sedimentary rocks in the Coast Ranges and western Transverse Ranges.

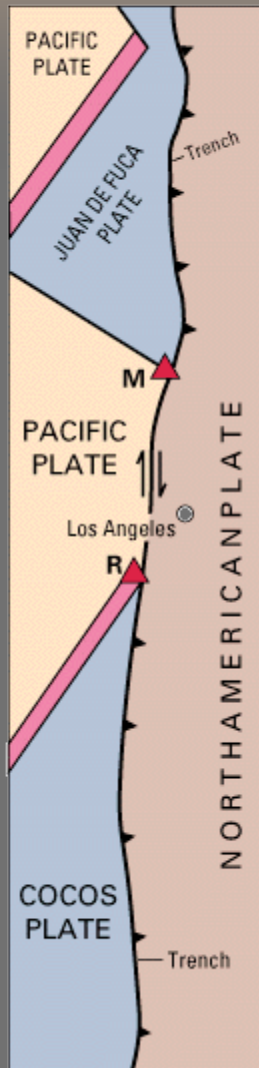
# Cenozoic

- ⇒ 25-29 million years ago. The oceanic plate that had been subducting beneath the western edge of North America became completely overridden, starting in the south, and the North American and Pacific plates came into direct contact for the first time.
- ⇒ Tangential motion and expansion replaced convergent motion as the North American plate began interacting with the Pacific plate.
- ⇒ The San Andreas Fault system was formed.
- ⇒ In far northern California and the Pacific Northwest, north of the Mendocino triple junction, convergent motion has continued right up to present times.

30 million years ago



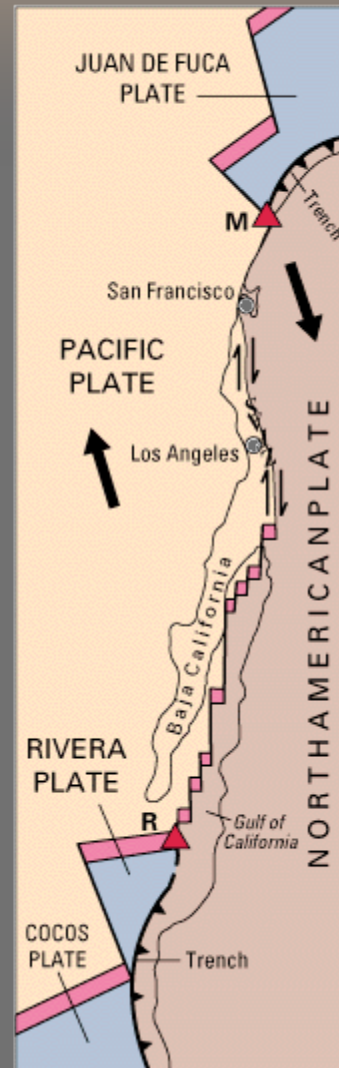
20 million years ago



10 million years ago



Present



### EXPLANATION

- Spreading center (divergent boundary)
- Subduction zone (convergent boundary)
- Transform fault, arrows show relative movement  
*SAFZ*, San Andreas fault zone
- Triple plate junction  
M, Mendocino  
R, Rivera

# Cenozoic

- ⇒ Volcanic activity, related to extension and thinning of the crust, became widespread in the Sierra Nevada and Mojave regions around 20 mya.
- ⇒ Around 10-15 mya a series of deep marine basins formed along the coast between Orange County and the San Francisco region. The appearance of the basins may have signaled the passage of what is now coastal southern and central California over the spreading zone.
- ⇒ The rocks formed in these basins (Monterey Formation) are composed mainly of material derived from marine organisms, rather than terrestrial sediments.



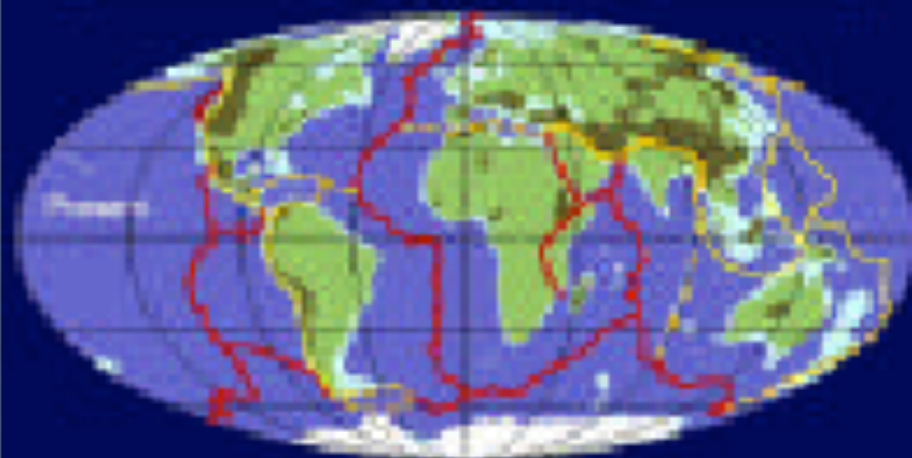
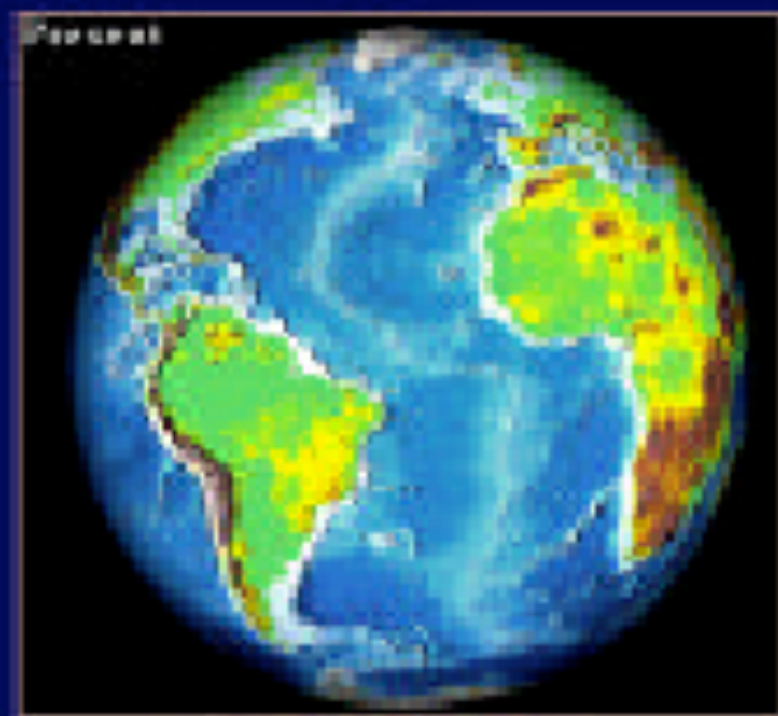
# Cenozoic

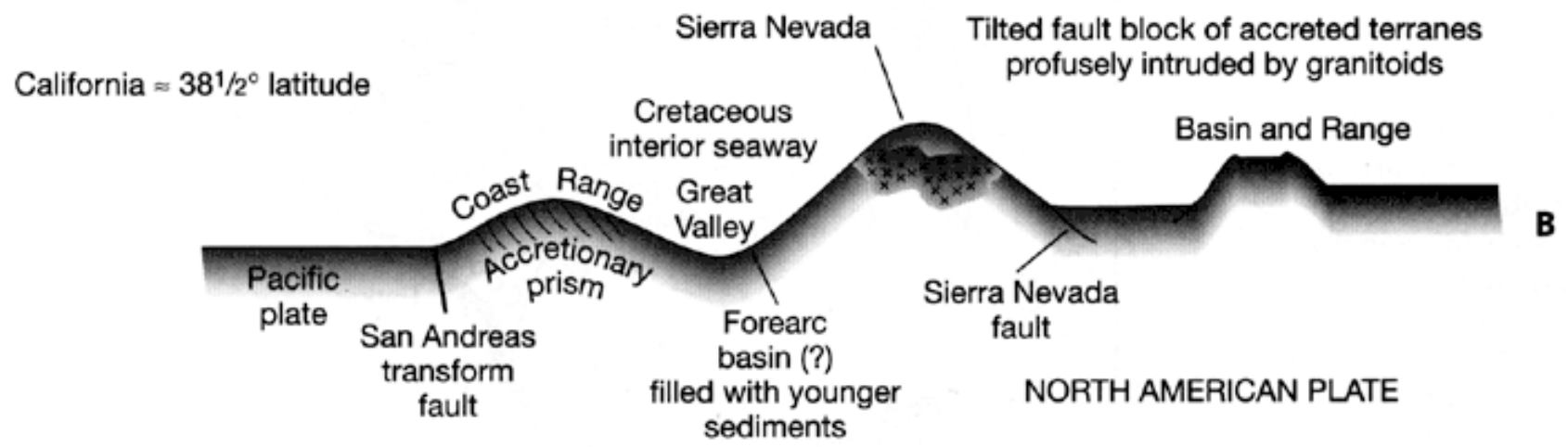
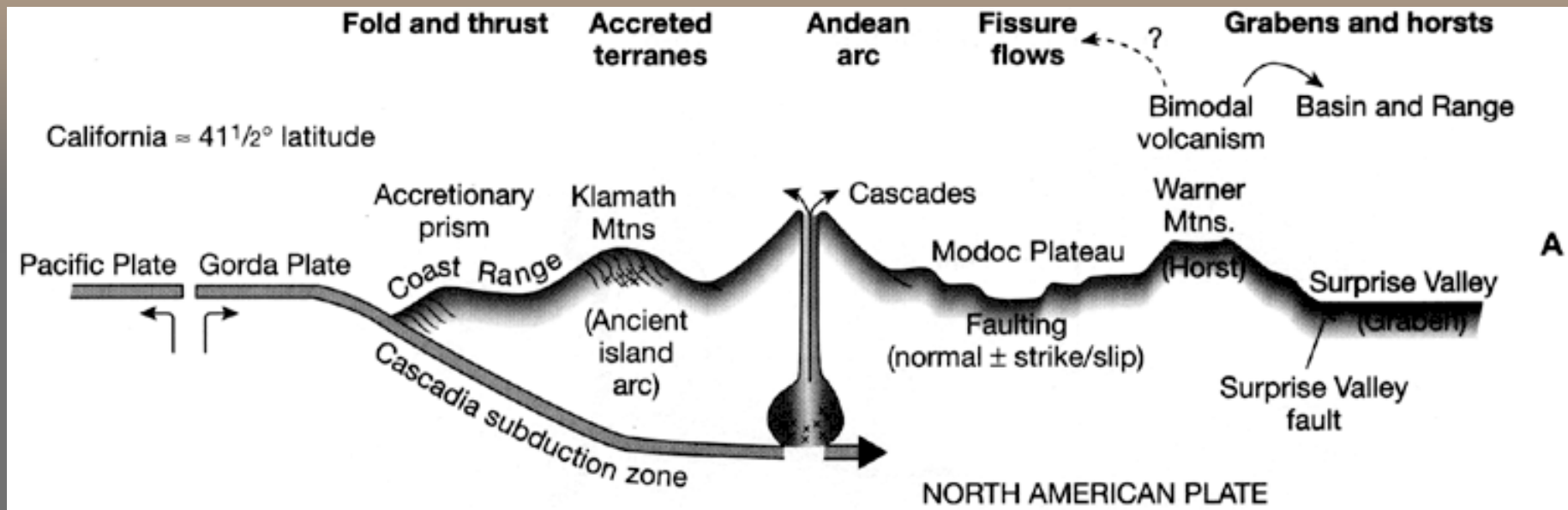
- ⇒ About 5 million years ago mountain-building activity rapidly accelerated, and finally most of the modern mountain ranges were uplifted, including the Sierra Nevada and the large fault-block ranges to the east, the Coast Ranges, the Transverse Ranges, and the Peninsular Ranges. San Andreas Fault jumps inland.
- ⇒ Subduction continued in the north forming the major volcanoes of the Cascades.
- ⇒ Pleistocene glaciation in the Sierra Nevada and, to a minor extent, in the San Bernardino Mountains; recent volcanic eruptions in the Mojave and Great Basin regions; and the widespread volcanic activity that created the southern Cascade volcanoes (Mt. Shasta and Mt. Lassen) and the lava flows of the Modoc Plateau region.



## 0 MYA: Present

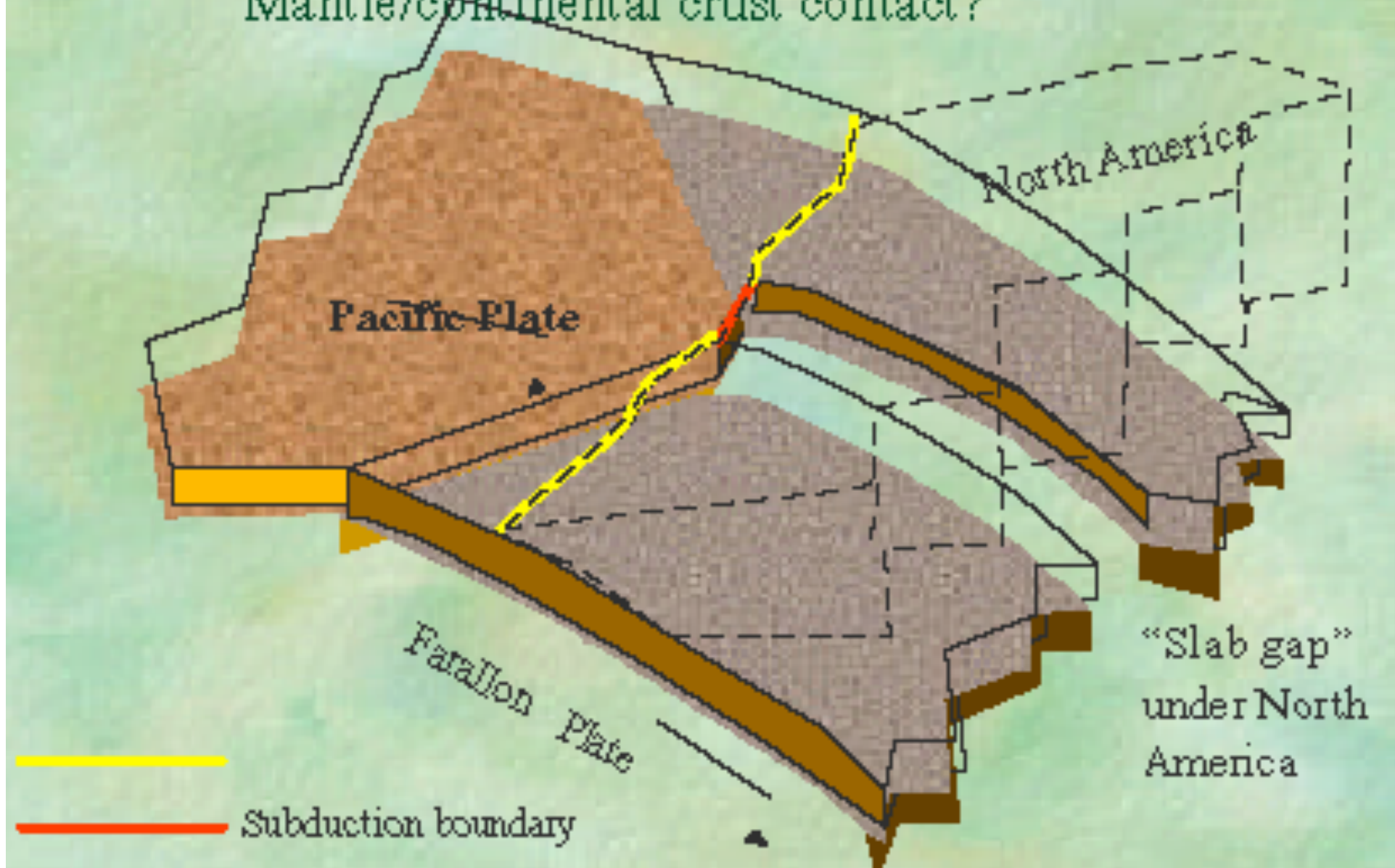
- Farallon Plate Subduction (20 MYA)
- Continental extension (>300 km.)
- Continental thinning (<15 km.)
- Basin and Range Province





# Basin and Range Evolution (1)

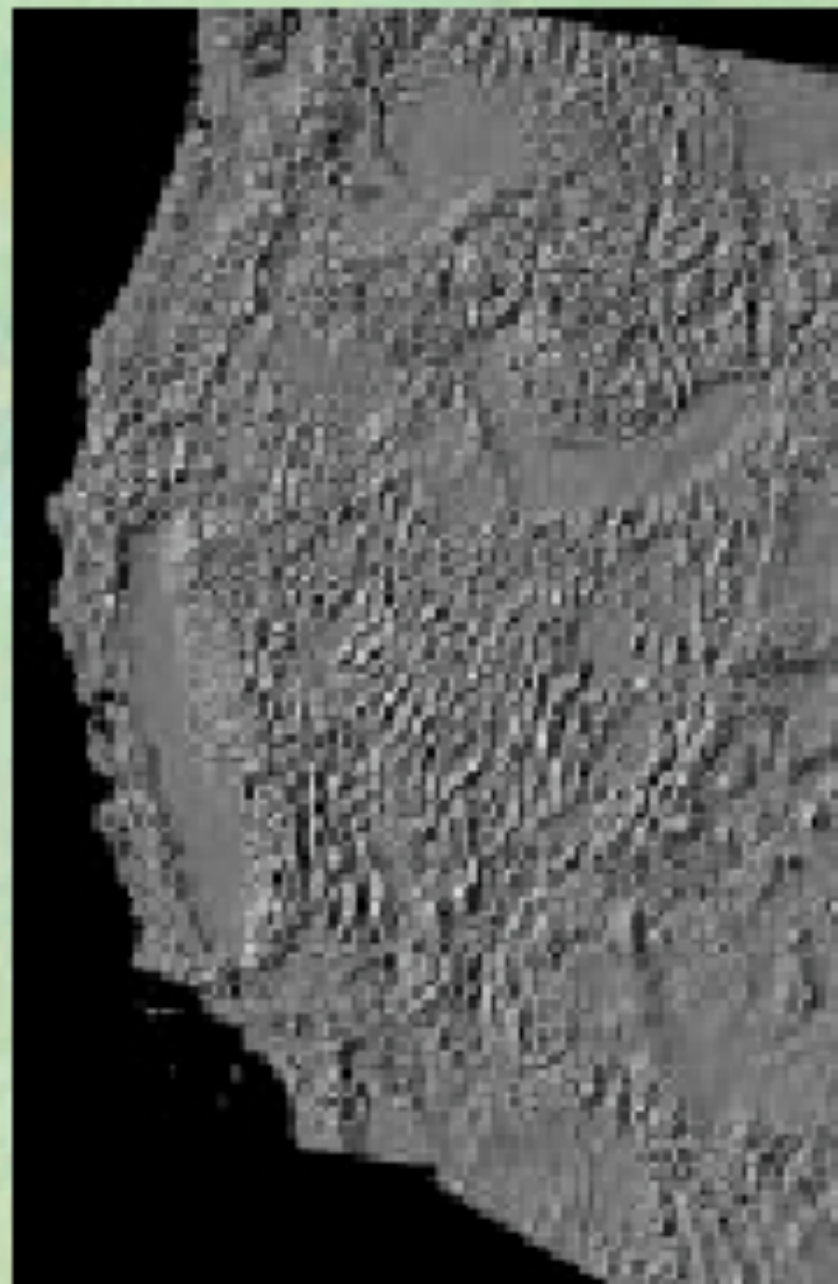
Mantle/continental crust contact?





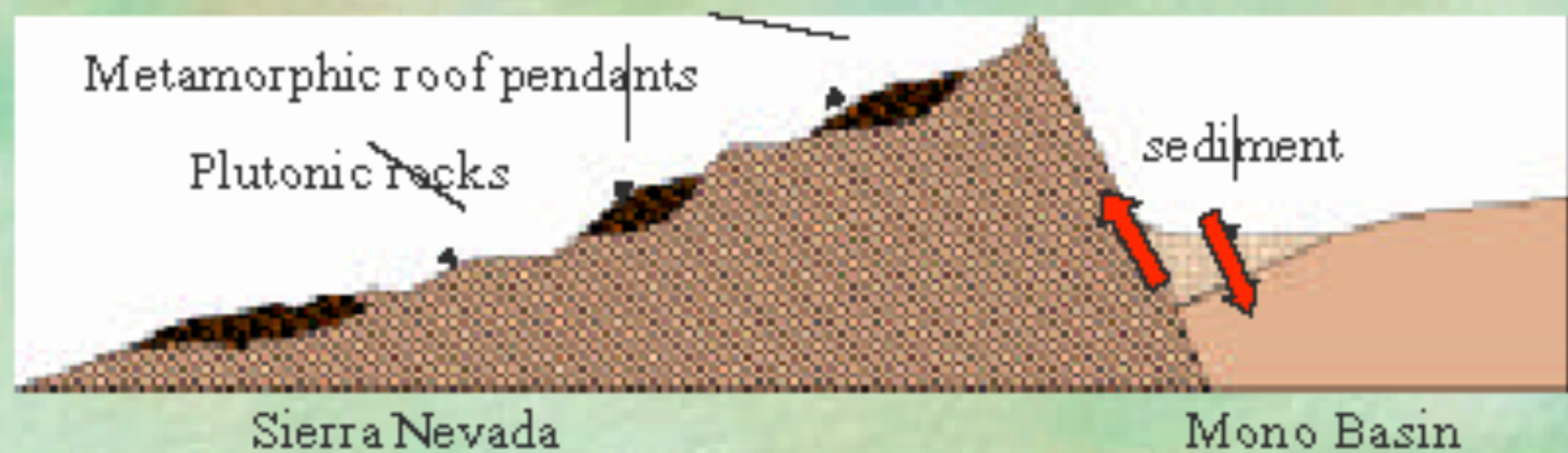
# Basin and Range

- ❖ Sierra Nevada:  
westernmost range
- ❖ Mono Basin:  
westernmost basin



# Sierra Nevada/Mono Basin Cross-section

- >10,000 feet of offset in 3 - 4 million years;
- Sierra/Mono relief • 7,000 feet;
- Uplift/down-warping continues today.

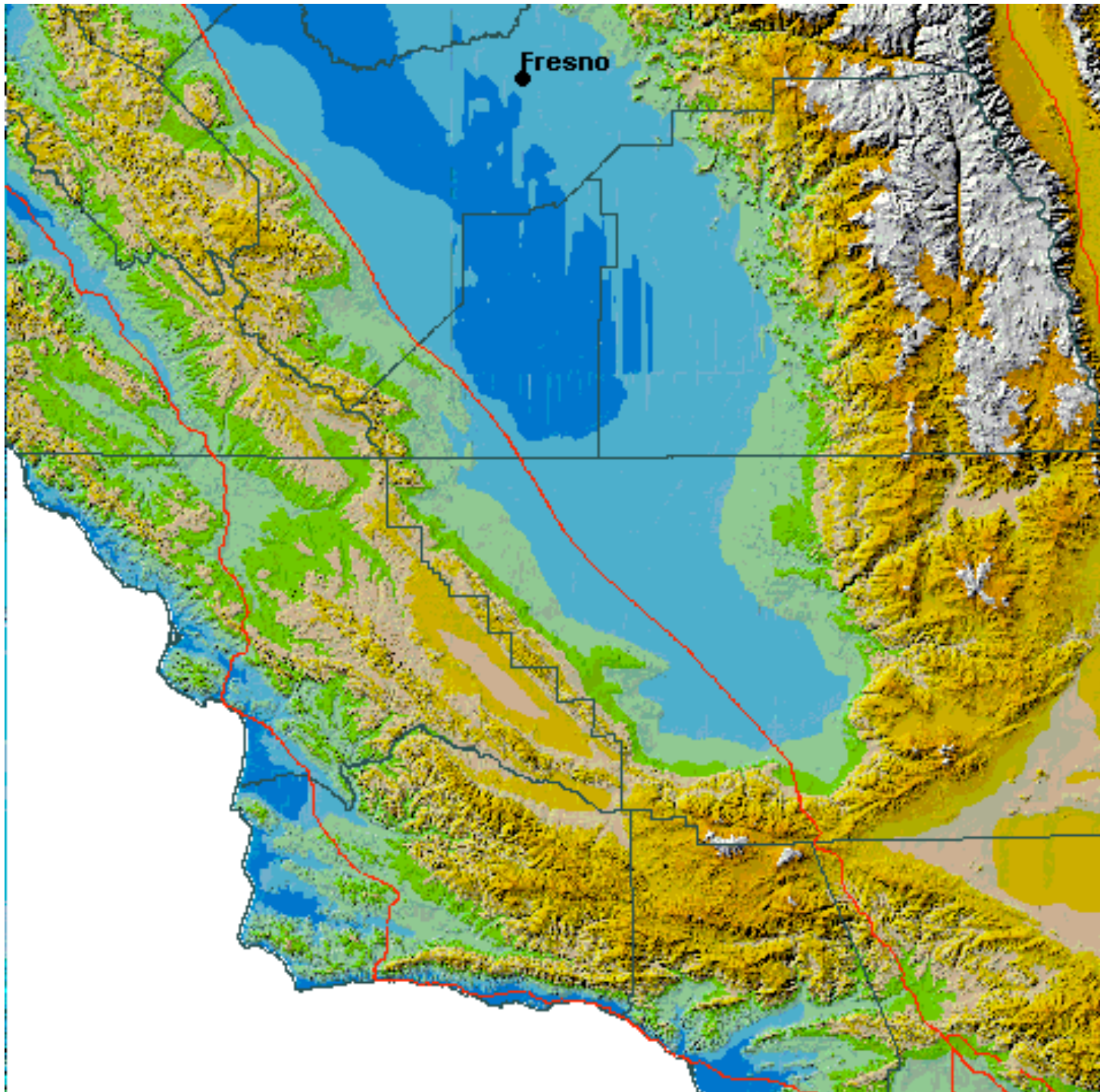




# Recent Processes

## Glacial Chronology of the Sierra Nevada (adapted from Yount and La Pointe, 1997)

Sierra Glaciation	Age (Approximate)	Comments
Tioga	>9990 yrs BP < 25500 yrs BP	Minimal gullying of flanks. Terminal nearly complete but for narrow branching hybrid stream me
Tenaya	37,000 +/- 2,700 yrs BP	Crests sharper than Tahoe. Terminal widely breached by streams.
Tahoe (Tahoe II)	> 56,000 yrs BP <118,000 yrs BP	Flanks deeply gullied. Terminal eroded, mostly removed.
Mono Basin (Tahoe I)	>131,000 yrs BP	Generally preserved only where Tahoe ice streams followed different courses.
Sherwin	>760,000 yrs BP	Scattered erratic boulders and formless bodies of till



The big knot:  
Killer  
Earthquakes  
In the future!

# SUMMARY

- ⇒ Accreted terranes
- ⇒ Nevadan orogeny
- ⇒ Farallon plate
- ⇒ San Andreas Fault
- ⇒ Present uplift

