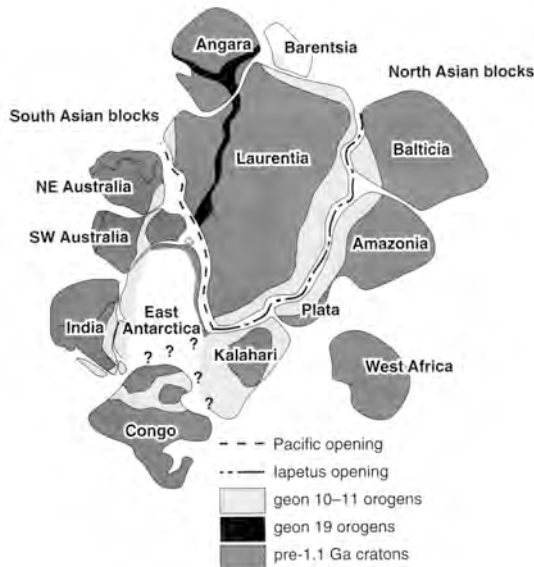


### Rifting of Rodinia

1. Super continent assembled during the Grenville Orogeny breaks up ~800 Ma
2. **Extensional basins** form in the Grand Canyon and California/Nevada
3. May reflect rifting from **Australia or Antarctica**



### Passive margin system from ~800 –350 Ma

1. Get typical **blue-grey limestones** of the Paleozoic
2. Mostly shallow marine and accumulating in large shallow **‘epicontinental’ seas** analogous with the modern Hudson Bay, North Sea and Sunda Sea

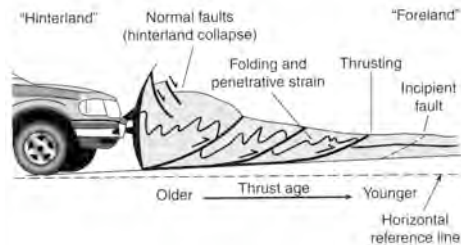
### Renewed convergence in the Devonian— Antler Orogeny—350 Ma

1. **See thrusting of passive margin sediment** up onto the continent without development of an arc
2. Suggests a **west-dipping subduction zone** with island arc offshore

### Mesozoic-Cenozoic Arc

1. Starting in **late Permian time** and extending into the Cenozoic (Oligocene) have a magmatic arc along W. North America.
2. Margin evolves from a **“SW Pacific”-style margin** (with offshore magmatic arcs) **to an “Andean”-style margin** (a continental arc)
3. **Intrudes old accreted terranes** and obducted passive margin sediment
4. Jurassic and Cretaceous arc intrudes older accretionary deposits and ophiolites in Sierra Nevada; **arc shuts off ~80 Ma** probably because shallow angle of subduction.
5. **Extensive back arc thrusting** creates foreland basins in **“Ancestral Rockies”**
  - a. In **compressional system**, get thrust sheets and **“overthrust” belt** where crystalline rocks rest on sedimentary rocks. Also see **“nappes”** (“tablecloths”) where there has been **overturning** of beds.

## b. Shortening by 100-200 km

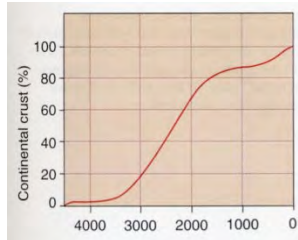


### How does continental crust form?

1. **Emplacement** of passive margin sediments **onto continents during thrusting**
2. **Formation of foreland basins** and further recycling of continental crust
3. **Underplating**
4. **Terranes:** Addition of new island arcs, seamounts, scraps of continents, compressed accretionary complexes

### Growth of continents:

1. Gradual addition to the periphery of 'shield areas' or "**cratons**"—the oldest crust around
2. **Crust added as accreted material**
3. Ages of terrane accretion suggest a relatively fast rate of growth during the later Precambrian and slower rates since.



4. Accretion does not just reorganize old crustal bits on the Earth's surface, but also adds to them by:
  - a. **recycling sediments** from continents and the ocean floor in accretionary complexes
  - b. **adding water** to fuel partial melting and differentiation of the upper mantle to form buoyant plutons;
  - c. Formation of plutons also adds to crust by **underplating**

### Why do continents grow by lateral accretion?

1. rifting tends to **re-use old structural features** and so reactivates old convergent tectonic thrust systems for extension
2. **plates are big**—even large transform boundaries usually have displacements of a 1000 km or less; hence it is **hard to fundamentally reorganize** which plates are opposite from each other

### Terrane tectonics

**Terranes:** fault bounded sequences of rocks whose origin is distinctly different from that of rock bodies adjacent to them.

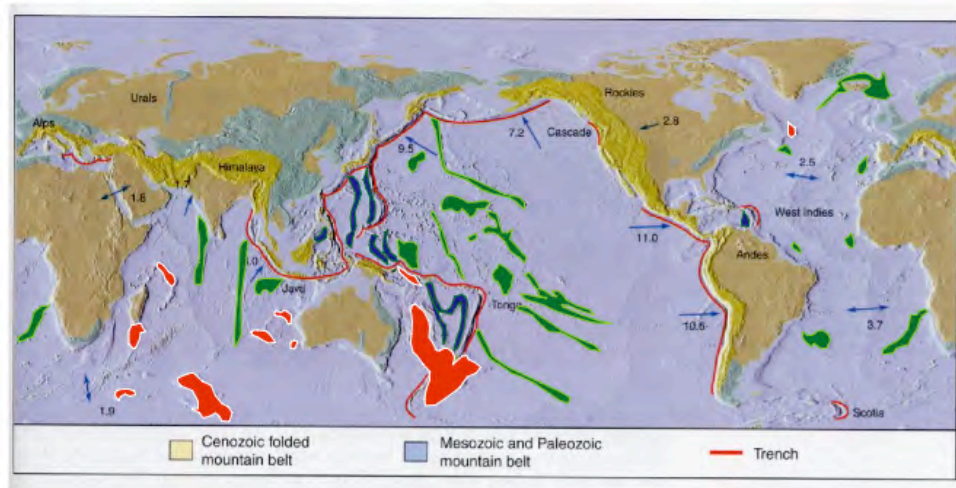
**Need not be far traveled**—could include **obducted passive margins** sediments (Antler Orogeny) or pieces of **ocean crust formerly attached to the continent** as part of the old rifted margin

Alternatively: some “**exotic terranes**” can be far traveled as

- a. Micro-continents (Pieces of rifted continental crust),
- b. island arcs,
- c. seamounts
- d. oceanic plateaus (related to hotspot or plume volcanism)

Have **modern analogs in the Pacific** that will wind up in accretionary belts in the Western and N. Pacific

Become scrapped off or subduction zone jumps to outboard position around the obstruction.



### End of Convergent tectonics

Had **large offsets in age of ocean crust across different fracture zones** suggesting:

- a. **age of subducting crust varied a lot along the subduction zone**
- b. probably affected the **subduction angle** along the margin and hence the type and position of magmatic activity in N. America
- c. first contact with N. America long predates extinction of the whole subduction zone—hence **transform margin gradually replaces subduction system**
- d. **When the spreading ridge contacts the Continent, spreading stops and the subducted slab sinks out from under the continent creating a “window”**

### Some implications:

**Arc volcanism gradually turns off** as the transform elongates to the north and south of the original triple junction formed by subduction of the first part of the ridge

1. Perhaps no coincidence that point of **first ridge-trench contact is in S. Calif** (Off San Diego) where **borderland basin rifting begins**
2. **Rifting starts where the “slab window” first opens** exposing the lower crust to the hot asthenosphere below
3. **Rifting of the borderland exposes deep crustal rocks** in the floors of the basins—**metamorphic core complexes** of blueschist grade metamorphics from the old accretionary wedge.—become the Orcopia schist, and Schist of the Sierra de Salinas
4. **Transform tearing at the margin propagates inboard**—accounts for the broader zone of faulting in S. Calif than in N. Calif
5. **The big bend in the San Andreas** forms when the main transform motion jumps from the San Jacinto fault system to the Southern Strand of the San Andrea with rifting of the Gulf of California.

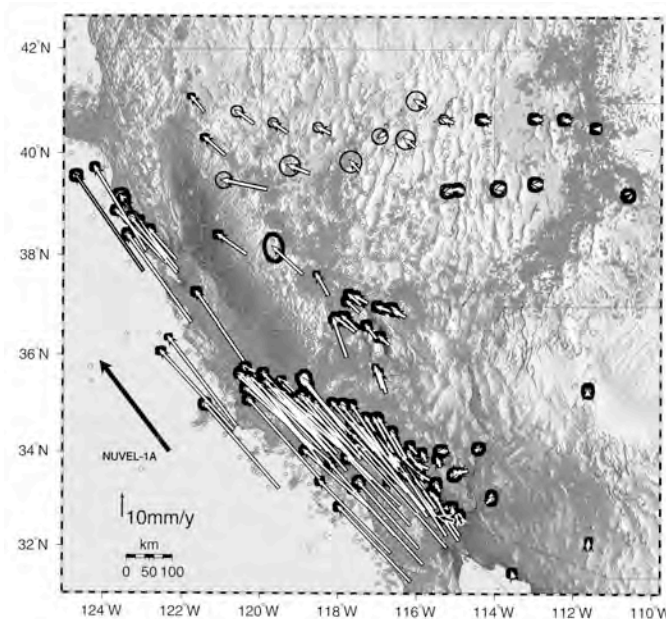
#### How do we know the history of offset on the San Andreas?

1. Use **tie points** like the Poway Conglomerate discussed in lab
2. Since **tie points of different age** occur along the fault, can reconstruct the overall offset through time: e.g.
  - a. **Cretaceous plutons** (Pokka dot Granite), **Orcopia Schist** (Probably **Mesozoic accretionary wedge** exposed in matamorphic core complex), **Butano Sandstone** (Eocene turbidites), **Neenach and Pinnacles Volcanics** (Miocene)....



3. One clear lesson—the **San Andreas is taking up only a part (~32%; ~315 km)** of the relative motion between the Pacific and N. American plates—significant motion accommodated on:

- a. Other Southern California faults (**~28%; 208 km**) in the San Andreas system
- b. Other Northern California faults (**~10%**) and
- c. on **Basin-and-Range rifting** (**~30%; 221 km**) (particularly just east of the Sierra Nevada and along the Wasatch Front in Utah)



### **Tectonic erosion and redistribution of Tectonic terranes**

1. Initial rifting of the Borderland **strips the fore-arc and accretionary wedge off S. California**
2. Displaces part of the Sierra Nevada Arc into the Coast Ranges as the **Salinian Block**
3. **Opens numerous Wrench basins**
  - a. These accumulate organic –rich sediments and **become oil reservoirs**
  - b. Also creates **numerous ‘pop-up’ structures** at restraining bends—some are big—San Jacinto Mountains.

### **Basin and Range Rifting**

1. **Reactivates faults** from the time of Laramide Orogeny (Mesozoic shortening)
2. **Stretches 400-500%** from pre-rift stage.
3. **Sierra Nevada moves as a coherent block**
4. **Seismicity shows most activity** around margins of Basin-and-Range—Wasatch front and E. Sierra Nevada

### **Gulf of California**

1. **Shows initial rifting ~13-15 Ma**
2. **First Marine sediments ~5 Ma**
3. **Rift propagates north opening transform-bounded basins**

4. **Propagation** looks like it **will extend up through the Owen's Valley** east of the Sierra Nevada

**Modern movement of the San Andreas system**

1. Big earthquakes **break only a few 10's to 100 km or so of the fault**, so it takes many quakes to release the stress building up because of Pacific-N. American motion
2. Consequently there **are always high stress regions** along the fault, poised to produce earthquakes.

**Sketch of W.N. America history**

1. Rifting of Rodinia (~800 ma)
2. Passive margin system from ~800 –350 Ma
3. Renewed convergence in the Devonian—Antler Orogeny—350 Ma
4. Mesozoic-Cenozoic Arc
  - a. Extensive back arc thrusting creates foreland basins in “Ancestral Rockies”
5. Transform tectonics in past ~20 my, basin and Range rifting

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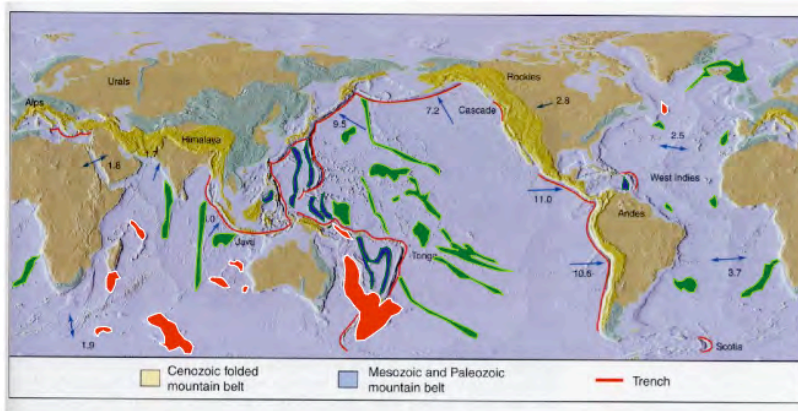
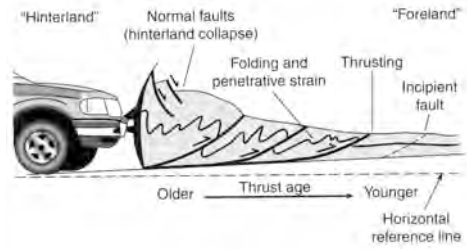
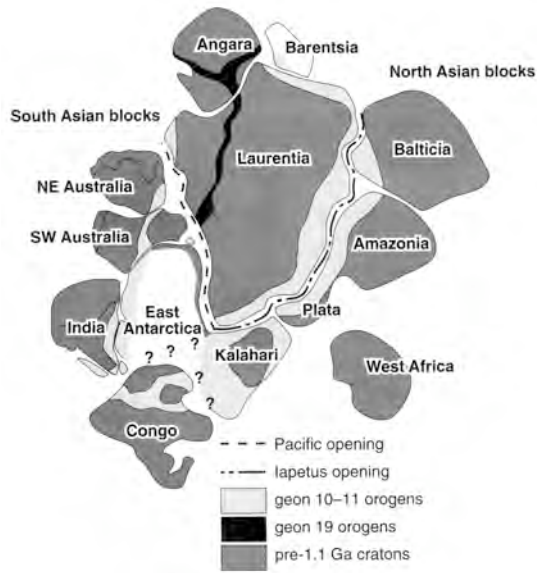
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### San Andreas Tie Points

