Overall outline
- Plate tectonics
- Earthquakes
- Structure of the Earth
- Measuring intensity
- Seismometers, magnitude
- Where are west coast faults?
- Some famous quakes
- More Tsunamis
- Rest of quarter - Hazards of quakes

Plan for this lecture
- Faults on the west coast

Where are faults, exactly?
- We'll swing down the coast
- Alaska
- British Columbia, Oregon, Washington
- California
- Wasatch Fault Zone
  - Utah, Idaho, Montana, Wyoming

North America map
- Pacific and North American plates are main players

Press, 20-12
- Map of North America showing tectonic plates and fault lines.
Subduction under Alaska & Aleutian Is.

- 8 cm/yr of plate convergence
  - almost strike-slip in Aleutian Is.
- Site of large underthrusting earthquakes
  - 1964 Alaska Earthquake $M_W=9.2$
- Volcanic arc & eruptions

Alaska - Pacific boundary

- Not subduction! Embarrassing. (UT Austin)
- Strike-slip

Queen Charlotte Fault System

Alaska

- Most dangerous faults in US
  - 8 quakes over $M=8$ in last 100 years
- Sparsely populated
- Main fault is subduction thrust
  - Only surfaces on ocean floor
  - Many secondary faults
- Also has volcanoes, tsunamis

Tectonic Setting of N. America

- Old stable interior
- East coast “passive margin”
- West coast “active margin”
  - Pacific - N. Am. plate interactions
    - Transform motion at SAF
    - Subduction under Alaska & Aleutian Is.
  - Juan de Fuca - N. Am. interactions
    - Subduction under Northern California, Oregon, Washington, and British Columbia

1899-1979 Alaska quakes

- Stars - $M > 7.5$
- Triangles - 6.5 to 7.5
  - 6.7 & 8 quakes in 2002
Continental collision is cause of Appalachian Mts

USA seismicity
- Notice that all the action is in the West
  - most dramatic topography in the West
    - Yosemite, Cascade Mts., Big Sur coast, etc.
  - few earthquakes in the East
- Some faults as far east as Yellowstone
- No action to west in Pacific plate either
  - Hawaii is special case - hot spot volcano

US Topography

Topographic action mark tectonic activity

US Seismicity
Western boundary of North American Plate

- Type of boundary depends on orientation
- Plate boundaries move and change in time
- Past 30 My saw major changes & development of San Andreas Fault
- From 80 to 30 My Farallon plate subducted under west coast.
  - Juan de Fuca & Cocos plates are remnants of Farallon plate

Details: US and Mexico coast

- Three little plates subducting offshore
  - Oregon, Washington, and B. Columbia
  - Juan de Fuca Plate
  - Gorda Plate
  - Explorer Plate
- Spreading ridge splitting Gulf of California
  - Separating Baja from N. America
  - Oblique because ridges are combined with transform faults
- Cocos Plate subducting to the south

Exotic terrains

Western N. Am (Cordillera) assembled from small pieces over past 200 My
Changes in west coast

- A mid-ocean ridge subducted
- Before that, just subduction on coast
- First hit near LA 25 Mya
- San Andreas fault system started then
- As ridge is subducting, two triple junctions are moving apart on coast
  - Mendocino Triple Junction moving north
  - NA-Pacific-Juan de Fuca junction
  - NA-Pacific-Rivera junction off Baja California

Oregon-Washington

- M 9 every 1000 years, last in 1700
- Recent quakes
  - M 7.0 in 2000, 6.5 in 1965 in Seattle
  - M 7.1 in 1949 in Olympia
- Main fault is subduction zone
- Also volcanoes (like Mt. St. Helens)
- Not adequately prepared
- We’ve looked at these faults before
  - But biggest surface offshore

Pacific - Juan de Fuca spreading

- Cascadia subduction zone
- 4 cm/yr convergence rate

Note: Plate motions Triple Junctions
Subduction under Pacific Northwest

- 4 cm/yr of plate convergence
  - Like small convection cell - up at ridge down at subduction zone
- Site of great underthrusting earthquakes
  - None in historic record
  - But evidence for magnitude 9 quake in 1700
    - Tsunami sands in buried marsh
    - Tsunami in Japan in 1700
- Volcanic arc & eruptions
  - Mt. St. Helens, Mt. Rainier, Mt. Shasta

Cascadia cross-section

Keller, 7-5
Tsunami sand associated with the 1700 earthquake covering a Native fire pit on the banks of the Salmon River in Oregon. Fire-cracked rocks, charcoal and ashes delineate the fire pit that was dug into the sandy beach.

**Quakes in California**
- The highest concentration is near the big faults; San Andreas, Cape Mendocino
- Other areas also have many little quakes
  - Mammoth Mts. - 1000’s of quakes per year
  - Coso Hot Springs - geothermal activity
- Probably no area in California is safe from occasional little quakes

**California**
- Last 150 years, 2-3 quakes of M8
- Main fault is strike-slip, on land
  - San Andreas fault zone
- Easy to map in detail
- Many secondary faults
  - Some offshore, most farther East

**San Andreas Fault**
- Right-lateral slip - LA moving northwest
  - 3.5 cm/yr
- Segments
  - 1906 San Francisco quake
  - Creeping section (gradual aseismic slip)
  - Parkfield segment
  - 1857 Fort Tejon quake
  - Southern segment
- Big Bend
  - causes N-S compression in So. Cal.

**Last 30 Mya of west coast tectonics**
- Cape Mend.
Fault segments

San Francisco

PACIFIC OCEAN

Los Angeles

Active faults and segments

Big bend

Official faults

Special Studies Zone Act of 1972 (Alquist-Priolo Act)

San Andreas, Garlock, SoCal and Bay Area branches

Yanev, p. 42

Alquist-Priolo Map Detail

Fault zones and Faults

Complication #1

The ideal fault:

San Gabriel Fault

Photo Matt D’Allesio
Complication #2: Gouge zones

Northern California

- San Andreas
  - Runs through Point Arena, Point Reyes, San Francisco, San Jose, Watsonville
- East Bay Faults
  - Calaveras-Hayward-Rodger’s Creek
  - Some farther east
- Offshore faults?

Bay Area faults
- San Andreas
- Hayward
- Calaveras

GPS view of Bay Area

Location of Loma Prieta break

Bay Area faults

Notice relation of faults and topography
Marin County
San Andreas

More Point Reyes

San Francisco
San Andreas Fault

Oakland: Problems with the Hayward Fault

SF to Salinas

From AAA map
Hollister - city on a creeping fault

Sierra Nevada Mts.
- From 80 to 30 My Farallon plate was subducting under west coast.
- Produced great range of volcanoes, like present-day Andes Mt.
- Sierras are the cooled, solidified, uplifted magma chambers of the volcanic arc (Yosemite granite)

Present Sierra mountains:
cooled, solidified, uplifted magma chambers, which formed during Farallon subduction

Subduction of Farallon plate
- Subduction slows then ceases
- Erosion occurs
- Regional uplift and tilt
  - exposes solidified magma chambers
San Andreas Fault in the Carrizo Plain

Right-lateral slip
LA moving northwest
3.5 cm/yr

Mojave Fault - the Garlock

Southern California Faults
- Complex system driven by Pacific-North America interaction and Big Bend
- Some faults don’t reach surface
- NW-SE trending faults mostly right-lateral strike-slip
- E-W trending faults mostly thrust
  - usually thrust faults, “blind thrusts”
Big Bend builds mountains

Show Movie #03

Southern California

- San Andreas
  - Runs 30 km north of LA, thru San Bernadino, Palm Springs, Salton Sea, into Mexico
- LA to San Diego - system of faults
  - SAF, San Jacinto, Elsinore faults
- Faults under LA are hard to find
  - Mostly not strike-slip
  - Surface reworked by civilization

Southern Cal. Faults

Show movie #14

Diblee Maps

- Tom Diblee single-handedly mapped large sections of California geology … mainly on foot
- Tom often mapped in remote areas, camping out with enough food and water for a week, sleeping each night sheltered from the wind on the car seat with one door open and a board extending outward on which to rest his legs. This enabled him to cover a lot of ground at little expense.
Example of Geological Map

Newport-Inglewood schools and hospitals

San Andreas meets I5 at Tejon Pass

San Andreas near LA

Northern LA faults
Seismicity cross-section

- Locked? Salton Sea
- Continuously deforming

USGS, 5-10

Depth of California quakes

- Definite lower limit to seismicity that varies from 5-25 km
- Set by temperature and composition of rock
- Mostly temperature
- Shallowest under the Salton Sea
- Where it is the hottest
- Spots surrounded by seismicity with fewer quakes may be either creeping or locked
- Not so many earthquakes in top few km
- Rock is not so strong there?

Rest of US

- Wasatch fault zone
  - Utah, Idaho, Montana, Wyoming
  - About 10-25% as active as San Andreas
  - Mainly normal faults
- New Madrid
  - Had some big quakes
  - We don’t know how often they strike
    - Every 5000 years? Every 500?
- Charleston, plus a few others
- We’ll talk about because of old quakes
  - Next one of my lectures

Gulf of California

- Spreading center

Wasatch fault zone

- Yanev, 203

Basin and Range Topography
Where are the faults?

- Alaska
  - Subduction and Queen Charlotte fault zone
- British Columbia, Oregon, Washington
  - Subduction, Juan de Fuca,
- California
  - Mendocino, San Andreas, Big bend
- Utah, Idaho, Montana, Wyoming
  - Wasatch Fault Zone