

Natural Disasters

Lecture 16

Ch 4 – Plate Tectonics and Earthquakes

Text Source Today:

Chapter 4

4.2: Ch. 4 – Plate Tectonics and Earthquakes

♦ **Subduction Zone EQs:** Most of the really large EQs in world history are due to **subduction**. The insertion of an oceanic plate tens of kilometers thick into the mantle involves a **tremendous amount of energy**.

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TABLE 4.2
Earth's Largest Earthquakes, 1904–2011

Rank	Location	Year	M_w	Cause
1.	Chile	1960	9.5	Subduction—Nazca plate
2.	Alaska	1964	9.2	Subduction—Pacific plate
3.	Indonesia	2004	9.1	Subduction—Indian plate
4.	Japan	2011	9.0	Subduction—Pacific plate
5.	Kamchatka	1952	9.0	Subduction—Pacific plate
6.	Chile	2010	8.8	Subduction—Nazca plate
7.	Ecuador	1906	8.8	Subduction—Nazca plate
8.	Alaska	1965	8.7	Subduction—Pacific plate
9.	Indonesia	2005	8.6	Subduction—Indian plate
10.	Assam	1950	8.6	Collision—India into Asia
11.	Alaska	1957	8.6	Subduction—Pacific plate
12.	Indonesia	2007	8.5	Subduction—Indian plate
13.	Kuril Islands	1963	8.5	Subduction—Pacific plate
14.	Banda Sea	1938	8.5	Subduction—Pacific/Indian plate
15.	Russia	1923	8.5	Subduction—Pacific plate
16.	Chile	1922	8.5	Subduction—Nazca plate

● **Alaska, 1964, “The Good Friday EQ”** : at 5:36 PM on 27 March, a nearly 1000 km (>600 mile) long slab of the Pacific plate, 400 km (250 miles) in width, lurched its way deeper into the mantle; the M_w was **9.2**, with hypocenter depths from 20-50 km (12-30 miles) and ground shaking that lasted for **7** minutes!

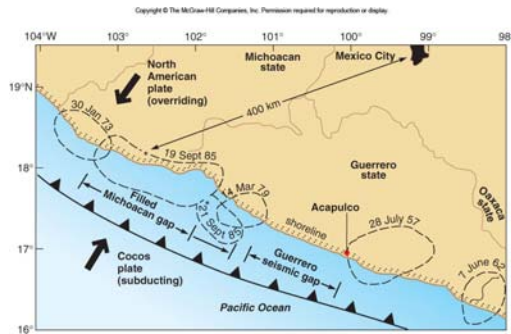
♦ The EQ induced many avalanches, landslides, ground settlements and tsunamis. Of the 131 deaths, 122 were due to **tsunami**.

♦ The **low death toll** is attributed to the EQ occurring late on a Friday, tides were low, it was off-season for fishing, and the weather was seasonally warm.

● The **2004 Indian Ocean Earthquake/Tsunami**, a similar-sized EQ at **9.1 M_w** , occurred in a much more **densely inhabited area** and the death toll was **245,000**.

♦ **Haiti, 2010:** a **7.0 M_w** EQ killed an estimated 230,000, injured 300,000 and displaced 1.1 million, due mostly to **bad buildings** (bad materials and bad construction practices, including concrete-blocks-as-filler style of slab construction).

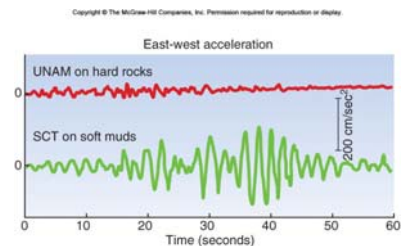
● **Mexico City, 1985:** at 7:17 AM on 19 September, the Cocos plate dropped downward and eastward about 2.3 m (7.5 ft) in two distinct jerks, 26 seconds apart. The mainshock had a **surface wave magnitude (M_S) of 8.1**, followed 2 days later by a 7.5 M_S aftershock and another 4 days later at 7.3 M_S . (Fig. 4.12)



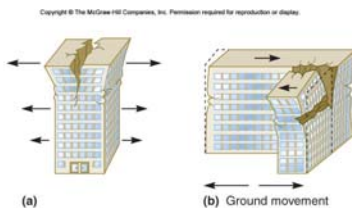
◆ Despite being closer to the epicenter, coastal areas had little damage, yet in Mexico City (220 miles away), over 5700 buildings were severely damaged! This was caused by **resonance** between the

seismic waves, soft lake-sediment foundations, and improperly designed buildings:

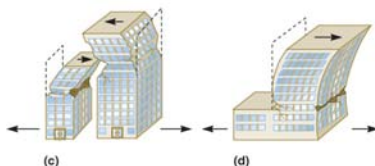
- (1) EQs sent a tremendous amount of energy in **seismic waves** in the 1- to 2-second frequency band;
- (2) The areas underlain by thick, **soft clays** vibrating at 1- to 2-second frequencies amplified the seismic waves;
- and, (3) Buildings of **6-16 stories** vibrated in the 1- to 2-second frequency band.



(Fig. 4.13)



(Fig. 4.14)



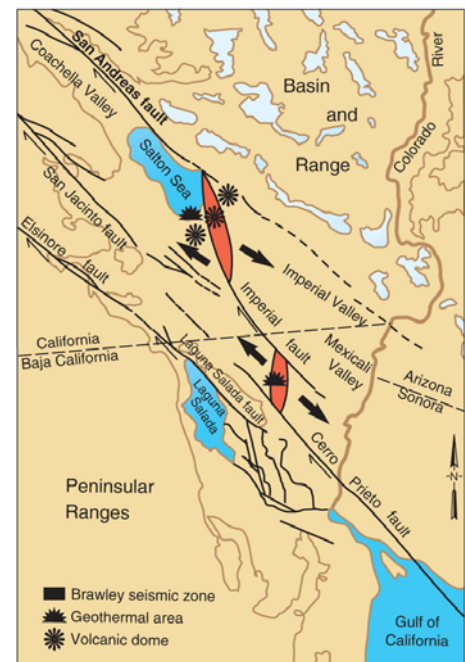
(Fig. 4.15)



◆ **Earthquakes don't kill, buildings do!**

- **Pacific Northwest, 20??**: active volcanoes above the **Cascadia** subduction zone indicate that, as in the past, this region could be rocked by a **9+ M_w EQ** later this century!
 - ◆ The last great EQ, **9.0 M_w** , in the **Pacific NW** was in **1700**, as indicated by (1) **tree rings** that end in 1699 on trees that are now underwater due the land dropping in the EQ; and, (2) Japanese records of **tsunami** occurrences and sizes.
 - The next **9+ M_w EQ** in the Pacific NW will produce **3-5 minutes** of violent ground shaking, followed by a tsunami **10 m (33 ft)** high surging onshore **15-40 minutes** after the EQ.
 - **Spreading Center EQs**: There is an analogue with the **Red Sea** spreading center and **Dead Sea** transform fault zone, to the **Gulf of California** and the **San Andreas fault**.
- (Fig 4.8)
- The opening ocean floor extends from the Gulf of California up into the Imperial Valley to the Salton Sea and southern end of the Coachella Valley (at the **southern end** of the San Andreas).
 - This region is marked by **earthquake swarms** (i.e., hundreds of EQs, **1.5-4.0 M_L** , in a several-day period) by forcefully moving **magma**. Larger EQs, **6.0-7.0 M_w** , are caused by ruptures in the brittle continental rocks, but deaths and damages are not high due to **fewer people and low profile buildings**.

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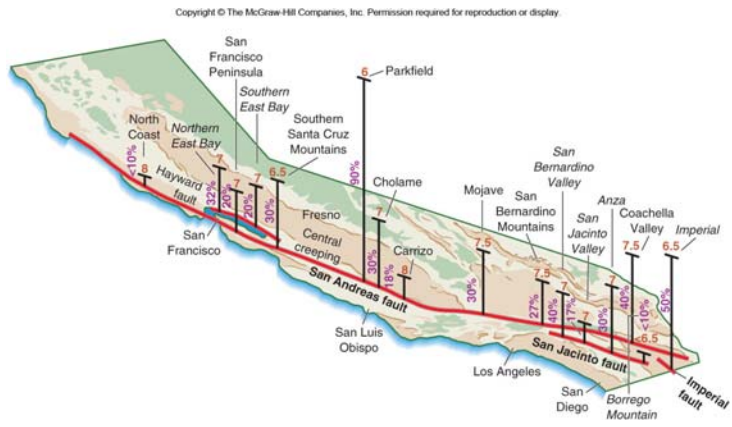


♦ Transform Fault

EQs in California:

the San Andreas is a 1200 km (750 mile) long, **right-lateral fault**.

Today, the San Francisco section and the segment north of Los Angeles are **“locked”** and will someday release the tectonic stress stored up (as elastic strain) for decades!



- **San Francisco, 1906:** at 5:12 AM, on 17 April, a massive **7.7 M_w** EQ began on the **northernmost** San Andreas fault and lasted 110 seconds. When the motion ceased, the western side had moved northward by 6 m (20 ft).

(Fig. 4.28)

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- ♦ **Unreinforced masonry** buildings collapsed, while steel-framed and wooden structures fared better.

Destruction was also high in parts of the city built on **artificial landfill**. The total death toll may have reached 5,000.

- ♦ **Fires**, due to broken gas pipes, engulfed the city and broken water pipes hindered attempts to stop the **fires**. The **fires did 10 times** the damage as the EQ itself!

- ♦ In their desire to rebuild quickly, and not increasing safety, many buildings today in San Fran are in jeopardy.

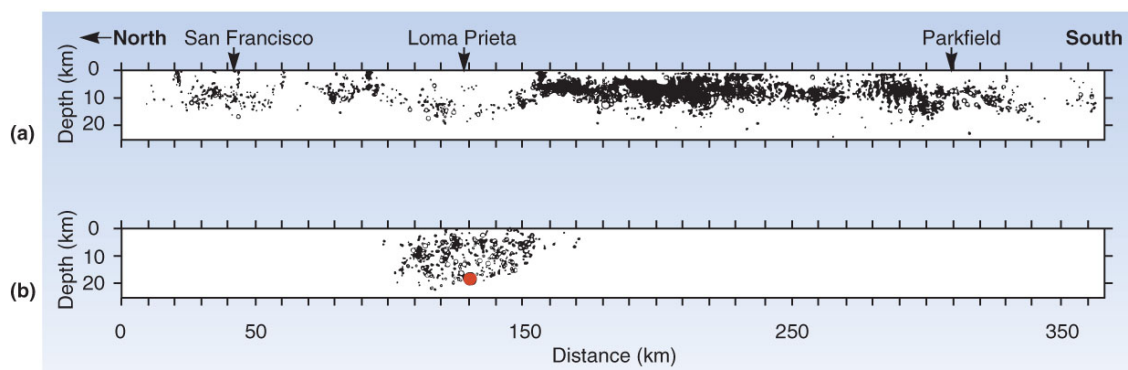
● **Loma Prieta, 1989, “The World Series EQ”**: at 5:04 PM on 17 October, 21 minutes before Game 3 of the World Series was to begin between the Oakland A’s and the home team San Francisco Giants, a **7.0 M_w EQ** occurred. It was not only witnessed by 60,000 fans in attendance, but also by an estimated 60 million TV fans in the USA and millions more around the world!

◆ Marina District of San Fran was hit hard due to **amplified shaking** on the artificial landfill and soft first story construction (for car parking). Some areas suffered **liquefaction**, as underground water and loose sediment flowed as fluids.

◆ **Interstate 880**, an elevated double-decker freeway, in Oakland failed and dropped 1¼ miles of roadbed onto the lower roadbed, crushing many people and vehicles. This section was built on **soft mud** and was compounded by a **flawed structural design**. The portion of I-880 on **firmer sand** stood intact.

◆ The southernmost section of the San Andreas fault zone that moved in 1906, had broken free and moved again. Note that the EQ occurred in a **“seismic gap.”** Is there another **“gap?”**

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(Fig. 4.34)