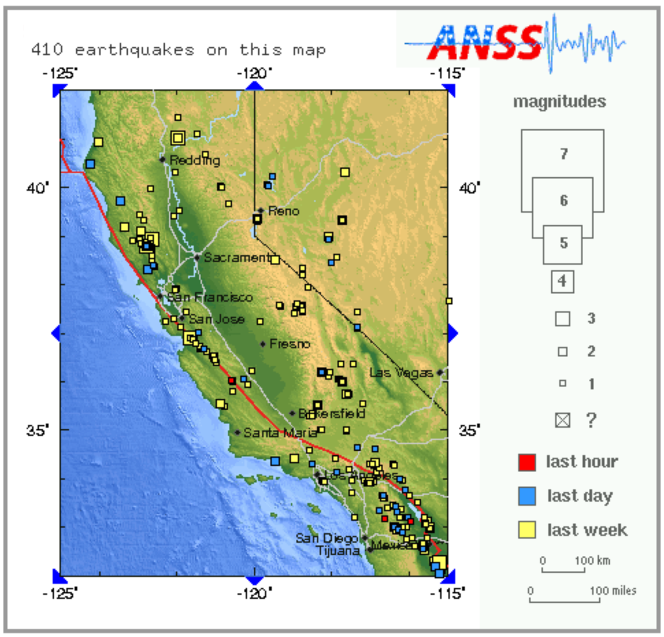
LECTURE #6: Earthquake Disasters: Monitoring & Mitigation

Date: 8 February 2021

I. Earthquakes

- what are earthquakes (EQ's)?
  - ground movement caused by the release of seismic energy
  - seismic energy is caused by the brittle failure of rocks under stress

- *always a relevant topic, but particularly so recently*
  - *M6.4 EQ in Puerto Rico (7 Jan 2020), 1 death*
  - *M6.7 EQ in Turkey (24 Jan 2020), 38 deaths*



Earthquakes in CA/NV during one week: *http://earthquakes.usgs.gov*

- important hazards to understand:
  - they kill the most people per year *(> 1 million in total over the past century)*
  - commonly strike without precursors or warning
    - not time for evacuation

  - not a linear trend
    - 1000's of large EQ's every year
      - only ~ 20 are > M7.0
      - these account for 90% of the energy released
      - and 80% of all the fatalities

  - recall: most of the fastest growing cities lie on the Pacific Rim and are threatened by large EQ's

Descriptor	Magnitude	Average Annually
Great	8 and higher	1
Major	7 - 7.9	18
Strong	6 - 6.9	120
Moderate	5 - 5.9	800
Light	4 - 4.9	6,200 (estimated)
Minor	3 - 3.9	49,000 (estimated)
Very Minor	2 - 3	about 1,000 per day
	1 - 2	about 8,000 per day

II. Earthquakes Background

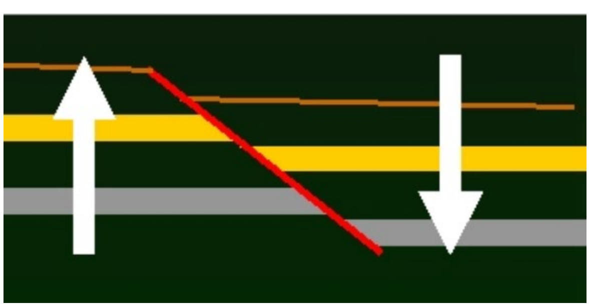
- where and how do they occur?
  - sudden release of stored energy as the result of rapid movement between two blocks (can be plate boundaries or simply at a fault)
  - energy stored because of plate movement and the slow buildup of friction
    - release point is the focus or hypocenter
      - energy radiates out in all directions

    - point on the surface directly above the focus is the epicenter
    - fault trace: line where the fault/fracture intersects the surface

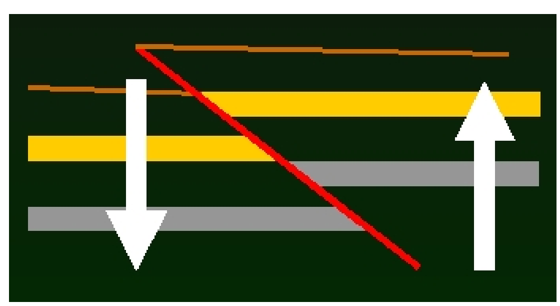
- fault terminology:
  - headwall: rock layers above the fault plane
  - footwall: rock layers below the fault plane

  - fault types:
    - normal *(also called 'extensional')*
      - due to tensional stress
      - generally, the smallest EQ's
      - hanging wall moves down with respect to the footwall

    - reverse *(also called 'thrust' or 'compressional')*
      - due to compressional stress
      - generally, the largest magnitude EQ's, but can also be the deepest
      - opposite motion from a normal fault: hanging wall moves up with respect to the footwall



normal fault



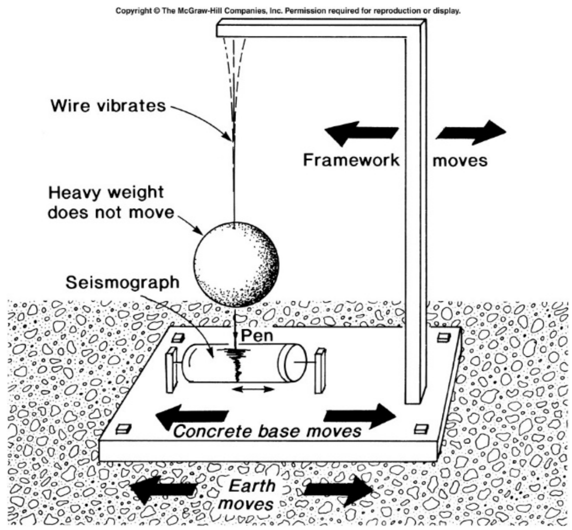
thrust fault

    - transform
      - lateral (side to side) movement
      - caused by shearing stress
      - not as strong as thrust faults

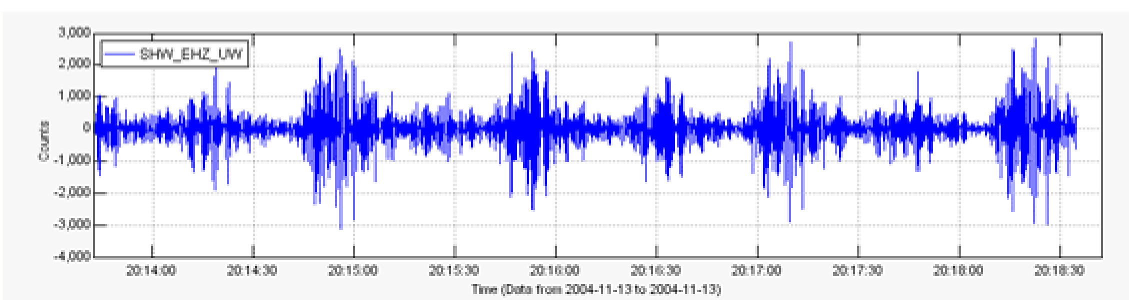
- but usually shallower and thus more damaging
- example: San Andreas fault slips ~ 2 inches/year for the last 65 million years
- therefore, a total movement = 600 km *(but not at a constant rate!)*
- large jumps of meters occur during the largest EQ's

III. Measuring EQ's

- detection:
  - seismograph
    - instrument that detects and records ground motion
    - includes the seismometer and the data (seismogram)
  - seismometer:
    - device that measures the ground vibrations
    - anchored to bedrock and moves with the ground motion
    - complex version of a mass hanging from a wire
    - can be set up to measure both horizontal and vertical motion
    - typically transmits data digitally
    - very sensitive
      - can measure movement to 1 x 10^{-8} cm *(equivalent to the depression of a car driving by several blocks away)*



  - seismogram:
    - the physical or digital recording of the seismic waves
    - on paper (originally) or digitally (most common now)



- measurement scales:
  - two scales are used to describe an EQ's size:
  - Magnitude Scale (Richter Scale)
    - quantitative measurement
    - relates ground motion on a seismogram to a number
    - log scale (not linear)
      - example: a M5.0 EQ has 10 times more ground motion and **48** times more energy released than an M4.0 EQ
      - **and a M8.0 EQ has 2.8 million times more energy than a M4.0!!**

- open ended scale (no theoretical upper limit)
  - rocks are not strong enough to keep accumulating that much strain

- limitations:
  - expensive to set up and operate seismometers
  - cannot describe historic or very distant smaller EQ's

- intensity scale (Mercalli Scale)
  - qualitative measurement based on human perception and property damage
  - only scale available before 1935
  - good for assessing and describing historical EQ's

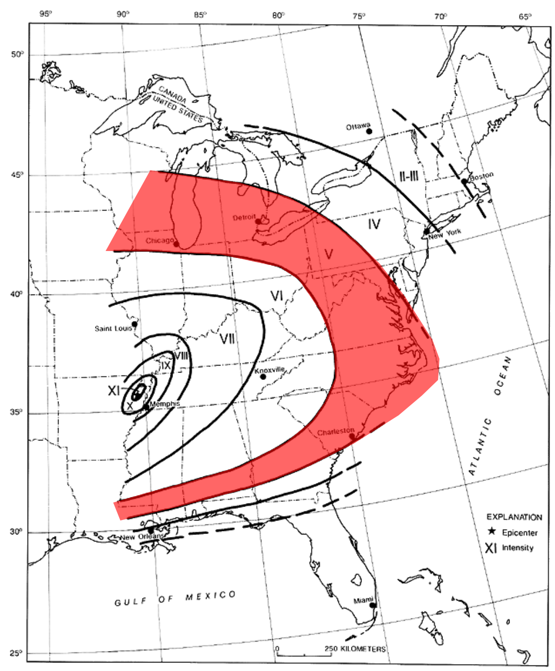
  - 12 levels of detailed descriptions of damage
    - based on these, an EQ is assigned a Mercalli value (I - XII)
    - lines of equal Mercalli values are known as i*soseismal maps*

  - limitations:
    - bias toward populated regions (need man-made structures)
    - subjective human opinions
    - local geology is not taken into account

  - example: New Madrid EQ of 1811-12
  - used historical reports to reconstruct the isoseismal maps

  - descriptions here in Pittsburgh:
    - *"sleepers wakened"*
    - *"felt outdoors"*
    - *"unsecured objects moved"*
    - *"not much property damage"*

  - based on the Mercalli Scale descriptions, Pittsburgh experienced an intensity of five (V)



IV. Earthquake Distribution *(in 2-D)*

- In the US:
  - of the 10 largest EQ's in the US's history
  - 9 were in Alaska and 1 in the Pacific NW
    - despite the attention, CA is not as hazardous as most think
    - *however, the population is much higher!*

Location	**Date**	**Magnitude**
Prince William Sound, Alaska	1964	9.2
Cascadia	1700	~ 9.0
Rat Islands, Alaska	1965	8.7
Andreanof Islands, Alaska	1957	8.6

Shumagin Islands, Alaska	1938	8.2
Unimak, Alaska	1946	8.1
Yakutat Bay, Alaska	1899	8.0
Andreanof Islands, Alaska	1986	8.0
Denali, Alaska	2002	7.9
Gulf of Alaska	1987	7.9

- around the world:
  - all of the largest EQ's are centered around the Pacific Ocean rim

Location	**Date**	**Magnitude**
Chile	1960	9.5
Prince William Sound, Alaska	1964	9.2
Sumatra	2004	9.1
Honshu, Japan	2011	9.0
Kamchatka	1952	9.0
Chile	2010	8.8
Ecuador	1906	8.8
Rat Islands, Alaska	1965	8.7
Sumatra	2005	8.6
Tibet	1950	8.6

- Earthquake Classifications *(in 3-D)*
  - based on the depth of the EQ
  - direct bearing on the hazard magnitude

  - shallow focus (0 - 70 km)
    - 85% of the total energy released per year
    - can occur on any type of fault
      - mostly associated with transform and normal faults

  - intermediate focus (70 - 300 km)
    - 12% of the total energy released per year
    - mostly associated with thrust faults at convergent plate boundaries

  - deep focus (300 - 800 km)
    - 3% of the total energy released per year
    - only at convergent plate boundaries
    - cannot be from brittle failure at these depths *(in the asthenosphere)*
      - too hot and material deforms plastically

    - probably due to mineral transformations within the subducting slab
      - change of mineral structure
      - from larger volume to smaller