### LECTURE #7: Earthquake Disasters: Science & Monitoring

#### Date: 3 February 2025

#### I. Reminder:

- exam 1 is one week from today
  - o make sure that you bring a #2 pencil (or 2), an eraser, and a photo ID
  - o please be on time!
  - o come talk to me during office hours if something is not making sense
  - I will show a few example questions at the start of Wednesday's lecture

#### II. Earthquakes

- what are earthquakes (EQs)?
  - o ground movement caused by the release of seismic energy
  - o seismic energy is caused by the brittle failure of rocks under stress
- always a relevant topic due to the number of deadly EQs around the world



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

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

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

<b>Descriptor</b>	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

o recall: most of the fastest growing cities lie on the Pacific Rim

these are most threatened by large EQs

### III. 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)
  - o stress stored because of plate movement + friction
    - release point is called the <u>focus</u> or <u>hypocenter</u>
      - > energy radiates out in all directions
    - point on the surface directly above the focus is the <u>epicenter</u>
    - <u>fault trace</u>: line where the fault/fracture intersects the surface

### • fault terminology:

- o headwall: rock layers above the fault plane
- o <u>footwall:</u> rock layers below the fault plane
- o fault types:
  - <u>normal</u> (also called 'extensional')
    - $\succ$  due to tensional stress  $\leftarrow \rightarrow$
    - generally, the smallest EQs
    - hanging wall moves <u>down</u> with respect to the footwall
  - reverse (also called 'thrust' or 'compressional')
    - $\succ$  due to compressional stress  $\rightarrow$   $\leftarrow$
    - > generally, the largest magnitude EQs
    - but can also be deep, which weakens the amount of energy reaching the surface
    - opposite motion than a normal fault: hanging wall moves <u>up</u> with respect to the footwall



- transform
  - ➢ lateral (side to side) movement
  - caused by shearing stress
  - > not as strong as thrust faults
  - but usually shallower and thus more damaging
  - <u>example</u>: 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 EQs

#### IV. Measuring EQs

- detection:
  - o seismograph
    - instrument that detects and records ground motion
    - includes the seismometer and the data (called a seismogram)
  - o 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<sup>-8</sup> cm (equivalent to the depression of a car driving by several blocks away)



- o 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 EQs size:
  - Magnitude Scale (Richter Scale)
    - <u>quantitative</u> measurement
    - relates ground motion on a seismogram to a number
    - log scale (not linear)
      - <u>example:</u> a M5.0 EQ has 10 times more ground motion but <u>48</u> times more energy released than an M4.0 EQ
      - > and a M8.0 EQ has <u>2.8 million</u> times more energy than a M4.0!
    - open ended scale (no theoretical upper limit)
      - but rocks are not strong enough to keep accumulating strain that results in magnitudes much greater than the middle 9s
    - Iimitations:
      - > expensive to set up and operate seismometers
      - cannot describe historic or very distant smaller EQs
  - intensity scale (Mercalli Scale)
    - <u>qualitative</u> measurement based on human perception and property damage
    - only scale available before 1935
    - good for assessing and describing historical EQs
    - 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 isoseismal maps
    - Iimitations:
      - bias toward populated regions (need humans and man-made structures)
      - subjective human opinions
      - local geology is not considered

M	Richter Magnitude Scale	
Т	Detected only by sensitive instruments	1.5
П	Felt by few persons at rest, especially on upper floors; delicately suspended objects may swing	2
ш	Felt noticeably indoors, but not always recognized as earthquake; standing autos rock slightly, vibration like passing truck	2.5
IV	Felt indoors by many, outdoors by few, at night some may awaken; dishes, windows, doors disturbed; autos rock noticeably	3
v	Felt by most people; some breakage of dishes, windows, and plaster; disturbance of tall objects	3.5
VI	Felt by all, many frightened and run outdoors; falling plaster and chimneys, damage small	4.5
VII	Everybody runs outdoors; damage to buildings varies depending on quality of construction; noticed by drivers of autos	5
VIII	Panel walls thrown out of frames; fall of walls, monuments, chimneys; sand and mud ejected; drivers of autos disturbed	5.5
IX	Buildings shifted off foundations, cracked, thrown out of plumb; ground cracked; underground pipes broken	6
x	Most masonry and frame structures destroyed; ground cracked, rails bent, landslides	6.5 7
хі	Few structures remain standing; bridges destroyed, fissures in ground, pipes broken, landslides, rails bent	7.5
XII	Damage total; waves seen on ground surface, lines of sight and level distorted, objects thrown up in air	8

- <u>example:</u> 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 (and everywhere in the red in the image) experienced an intensity of five (V)



# V. Earthquake Distribution (in 2-D)

- in the US:
  - o of the 10 largest EQs in US history
  - o 9 were in Alaska and only 1 was in the continental US
    - despite the attention, CA is not as hazardous as most think
    - however, the population is much higher!

Location	<u>Date</u>	<u>Magnitude</u>
Prince William Sound, Alaska	1964	9.2
Cascadia (Pacific NW)	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:
  - nearly all of the largest EQs are centered around the Pacific Ocean rim ("Ring of Fire")

<u>Location</u>	<u>Date</u>	<u>Magnitude</u>
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

## VI. Earthquake Distribution (in 3-D)

- based on the depth of the EQ
  - has a 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
  - o intermediate focus (70 300 km)
    - 12% of the total energy released per year
      - > mostly associated with thrust faults at convergent plate boundaries
  - o deep focus (300 800 km)
    - 3% of the total energy released per year
    - <u>only</u> 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