Topic 7: Earthquake Seismology

https://geowiki.ucsd.edu/sio15

- Homework #1 expect answersheet by Monday
- Homework #2 online (due Tuesday)
- For-credit test#2 online Sunday, due Monday

each test is 5 points
each homework is 20 points -> 20/4 = 5 points

late submissions will no longer receive extra credits

How Often Do Earthquakes Occur?

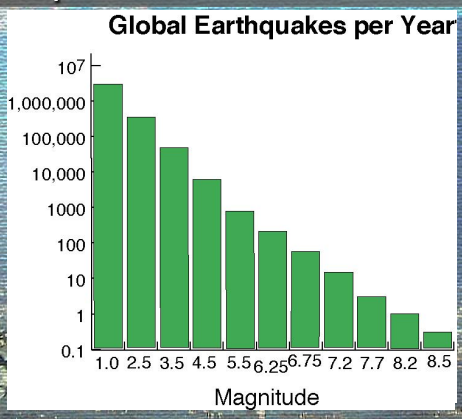
Table 5.5 Annual Worldwide Seismicity by Moment Magnitude (modified from [3])

Magnitude	# of EQs/year	Estimated Radiated Seismic Energy ($\times 10^{17}$ J)
8.5 and up	0.3	11.1
8.0-8.4	1	5.0
7.5-7.9	3	2.7
7.0-7.4	15	2.4
6.6-6.9	56	1.7
6.0-6.5	210	1.4
5.0-5.9	800	0.59
4.0-4.9	6200	0.15
3.0-3.9	49,000	0.04
2.0-2.9	350,000	0.008
0.0-1.9	3,000,000	0.002

- > 3.5 Mio per year
- small events often
- large events rare

Earthquake Recurrence Time

Fig. 5.13



Get recurrence time from # of EQ per year

E.g. 3 Mio EQ/year -> 1 EQ every 10.5s
0.3 EQ/year -> 1 EQ every 3.3 years

Quiz

we have 24 EQs per day
-> recurrence time is …..

The Different Types of Seismic Waves

P and S Waves are body waves

video 5c

review lecture notes and book chapter

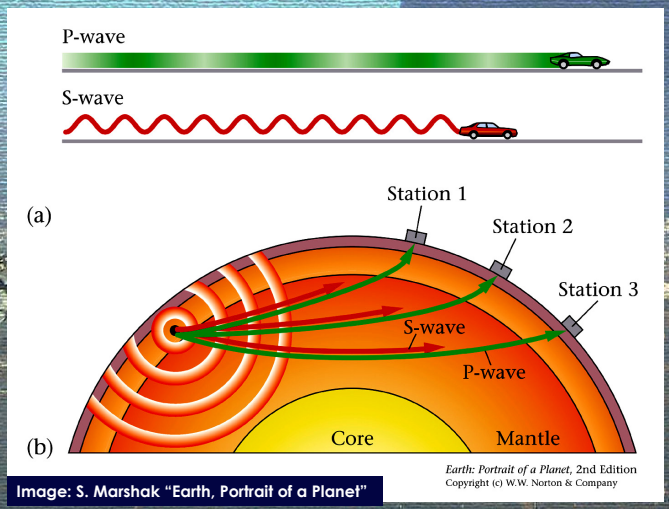
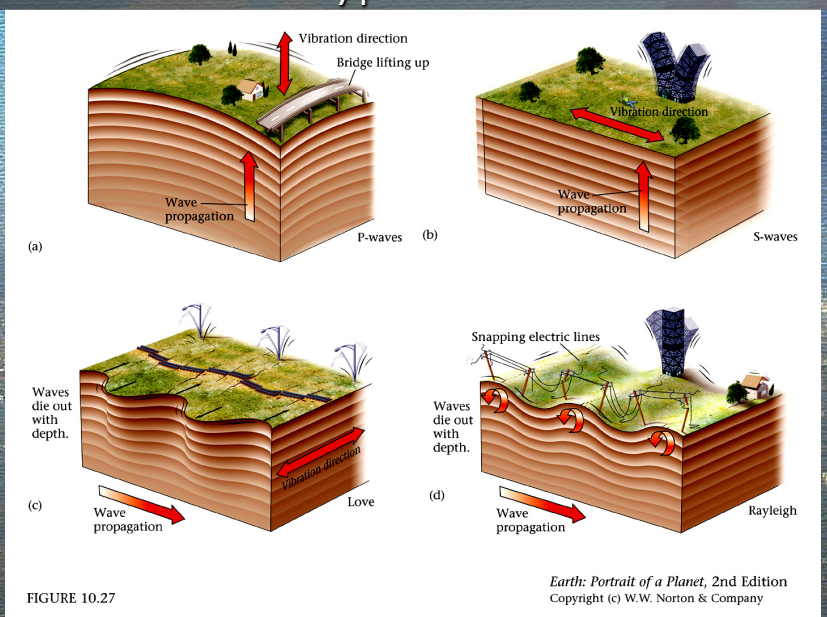


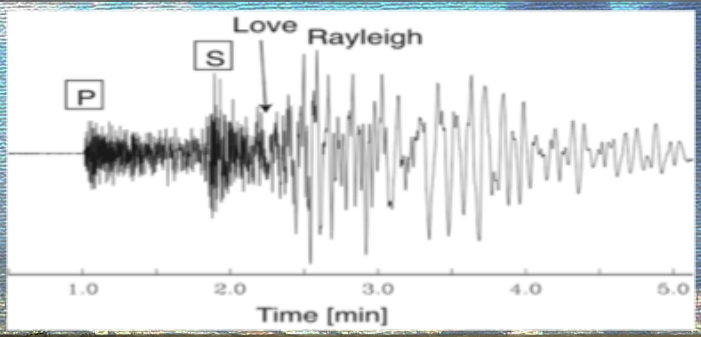
Image: S. Marshak "Earth, Portrait of a Planet"

The Different Types of Seismic Waves



The Phases in a Seismogram

video 5d

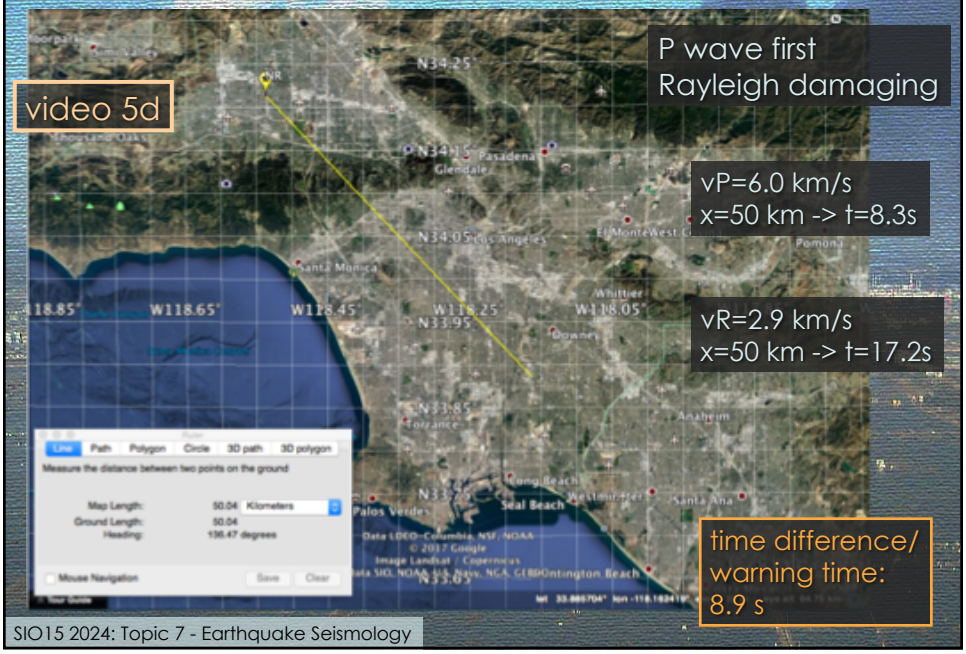


1. P first, typically smallest signal
2. S, typically larger (felt by humans)
3. Love
4. Rayleigh, longest/largest wavetrain, most damaging

p wave used in early warning systems
warning time: up to 1 minute

Earthquake Early Warning – Shake Alert

video 5d



P wave first
Rayleigh damaging

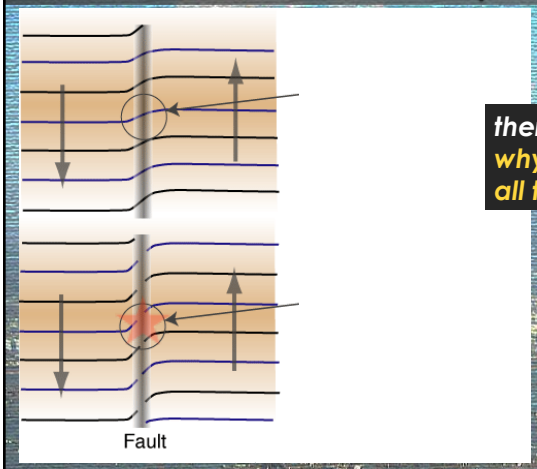
vP=6.0 km/s
x=50 km -> t=8.3s

vR=2.9 km/s
x=50 km -> t=17.2s

time difference/
warning time:
8.9 s

Fig. 5.18

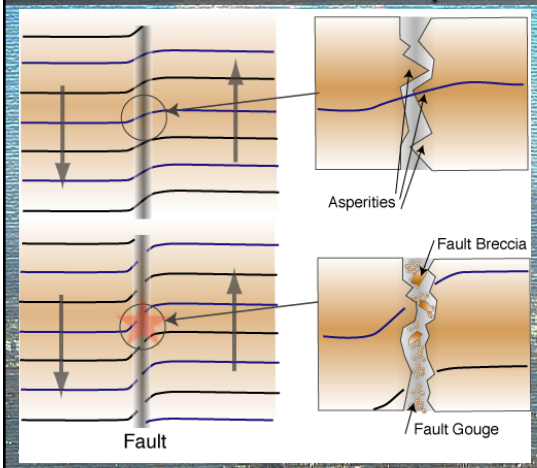
The Earthquake Fault



there is already a fault
why don't blocks move all the time?

Fig. 5.18

Asperities



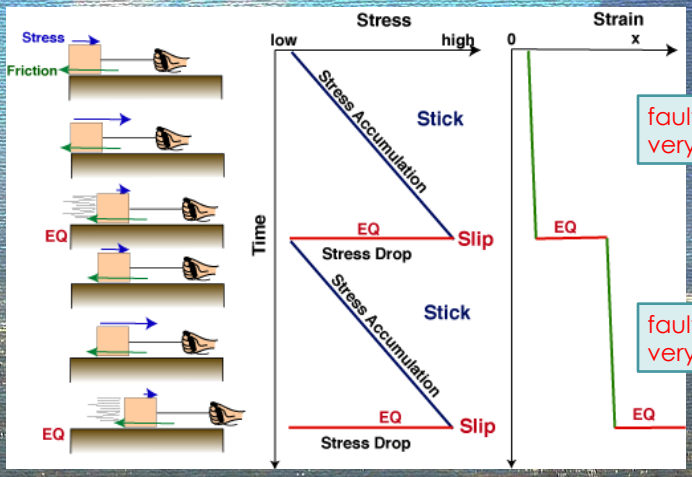
there is already a fault
why don't blocks move all the time?

Stress Friction
no EQ
Stress Friction
EQ!

asperities: protrusions that increase friction along a fault
EQ: when stresses high enough to overcome friction

fault breccia/fault gouge: broken-off, ground up asperities

Stress, Friction and Stick-Slip Behavior

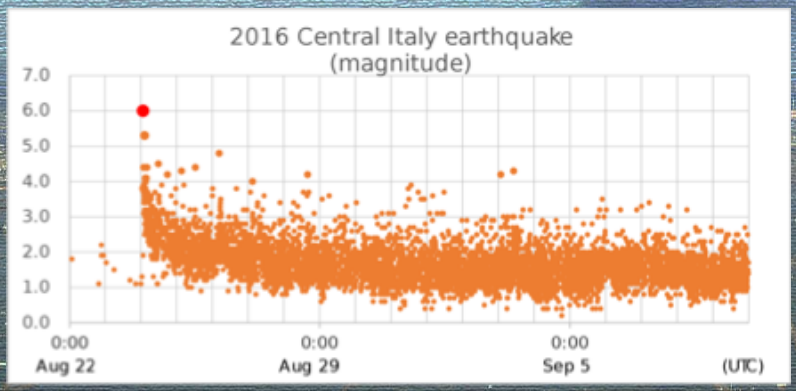


1. stress builds up; asperities; no motion
2. stress overcomes friction -> EQ + aftershocks
3. slip along fault; stress drop
- start from 1)

Fig. 5.19

Earthquakes and Aftershocks

typically:
max. Magnitude has exponential decay
with exceptions
broad level of subsequent magnitudes



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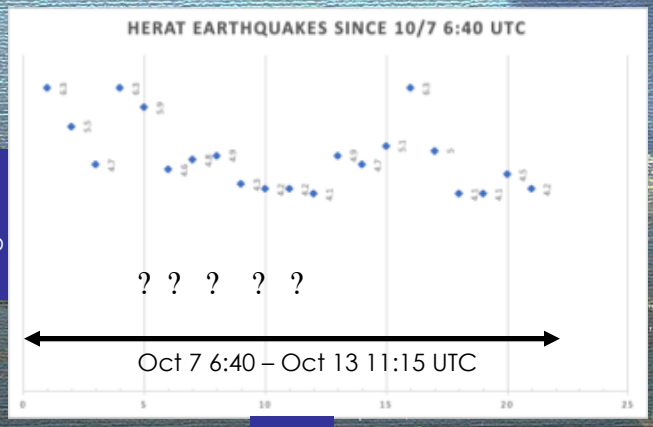
Earthquakes and Aftershocks

2023 Herat sequence:
many large aftershocks
no knowledge of low-magnitude events (lack of regional stations)



sorry for the crummy/ad hoc display!

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EQ Recurrence Time and Probability

- EQs not regular
- recurrence time has a certain probability < 100%

source: Abbott "Natural Disasters"

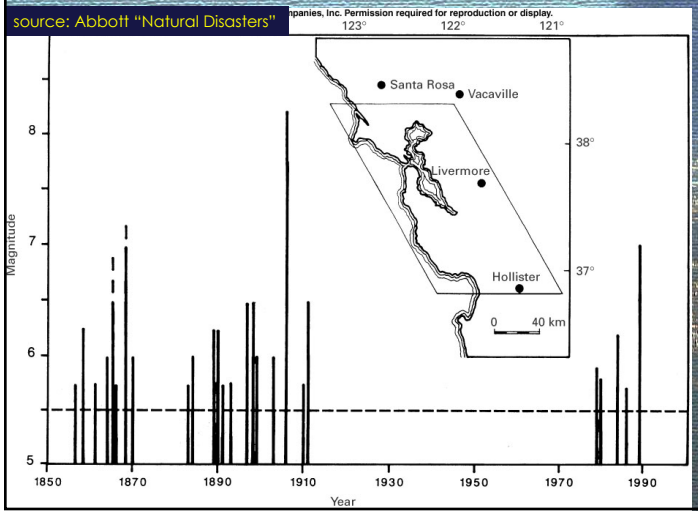
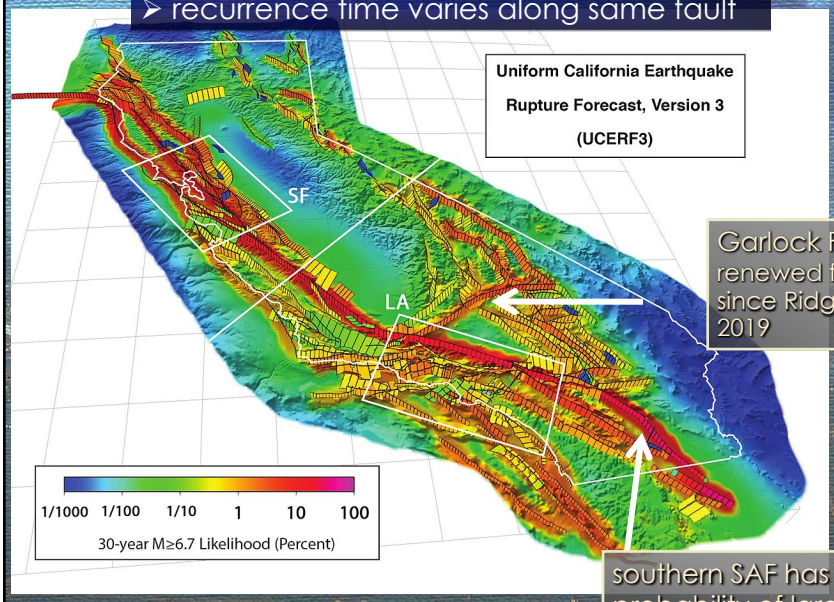


Fig. 5.15

Updated EQ Probability

- recurrence time varies along same fault



Garlock Fault: renewed focus since Ridgecrest 2019

southern SAF has highest probability of large EQ

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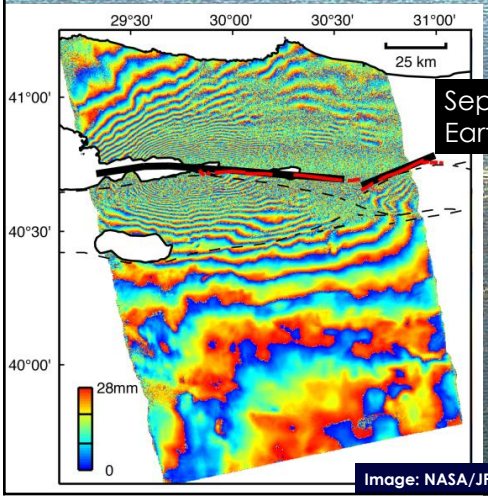
Fig. 6.43

InSAR – EQ Analysis

InSAR: Interferometric Synthetic Aperture Radar

overlay satellite altimetry map before and after EQ
-> interferogram -> fringes show amount of slip along fault



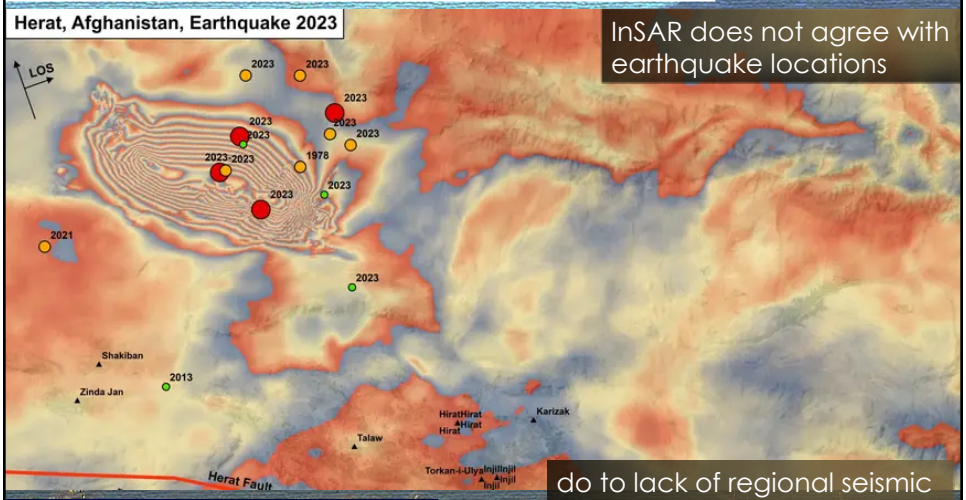
Sep 17, 1999 Izmit, Turkey Earthquake

same physics as GPS except different wavelength
λ: m to mm

Image: NASA/JPL; wikipedia

2023 Herat Earthquake

InSAR: Interferometric Synthetic Aperture Radar



InSAR does not agree with earthquake locations

do to lack of regional seismic stations, some earthquakes may be mislocated

Fig. 5.17

Can EQs Trigger other EQs?

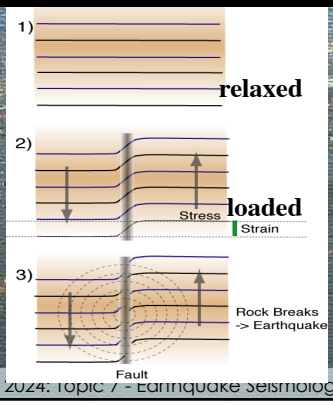
- Mw= 6.5 December 22, 2003 San Simeon EQ increased stress at Parkfield
-made #8 more likely???
-but why did #7 not happen?

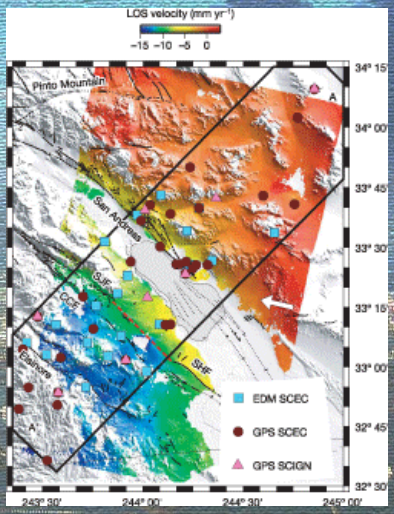
-EQs can trigger/influence other EQs on nearby faults (1992 Landers/Big Bear)
-very large EQs may trigger volcanism far away (Rayleigh waves!) (2002 Denali EQ/Yellowstone; 2004 Sumatra/Alaska volcanoes)

INSAR - EQ Forecast and the SAF

InSAR useful in aseismic times

- example: southern SAF
- last major EQ: 250 years ago, while north and middle SAF ruptured 1906, 1989 and 1857
- typical co-seismic slip for big EQs: 7-10m

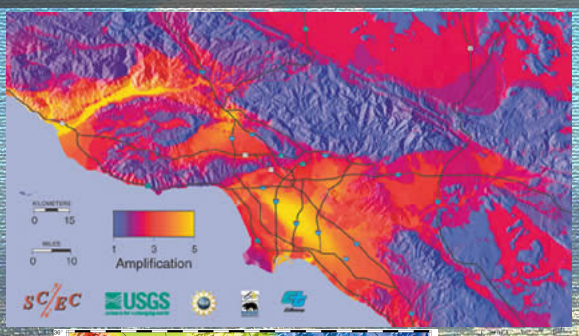




- use stack of INSAR images to get strain rate
- extrapolate to 250 yrs

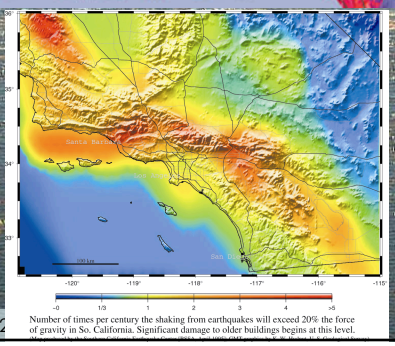
Fig. 6.44

Hazard Assessment



site amplification

takes into account local geology



probability of strong shaking

takes into account local geology, tectonics, seismicity

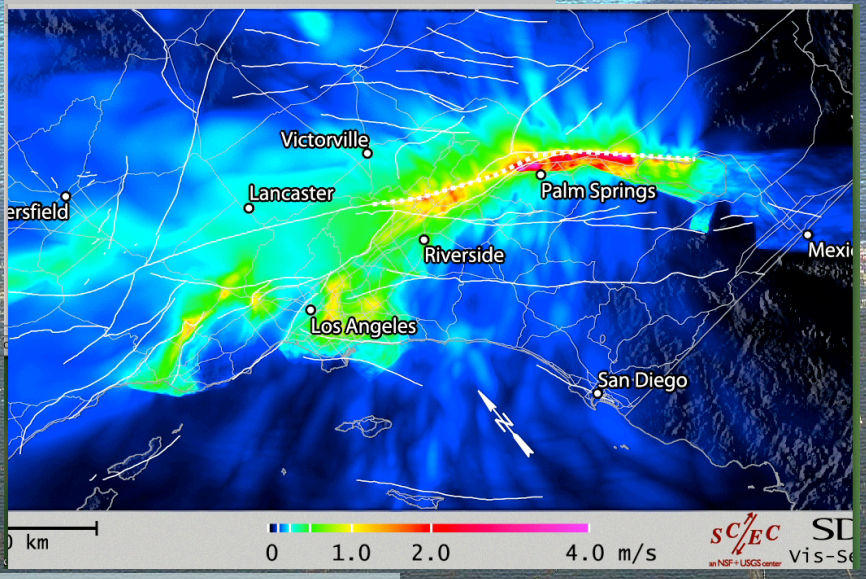
Fig. 6.45

Fig. 6.46

SCEC's TERASHAKE - 2009

SCEC: Southern California Earthquake Center

http:movie



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Public Input Required!

USGS Did-you-feel-it map

Mw=7.2 El Mayor Easter (4 Apr) 2010

* understand shaking characteristics of EQs
* improve local forecasts for strength of shaking

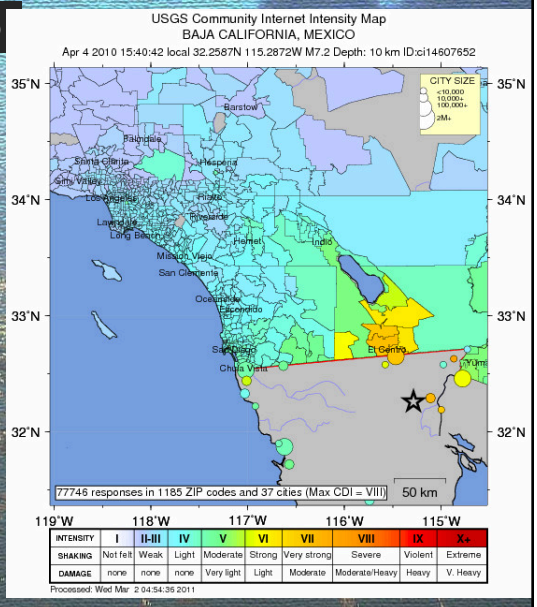

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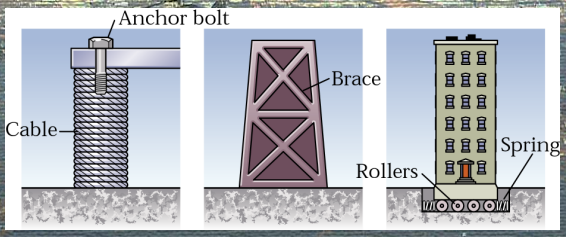
Fig. 6.42

Earthquake Hazard Mitigation

What Government and People can do

- don't build, build to code, retrofit
  (e.g. use wood, not bricks)
- construct lifelines to EQ building codes
- problematic in less developed countries
- grading according to code (landslides!)
- secure life lines/make disaster plans



Got water?
flashlight
canned food
batteries
battery-op radio

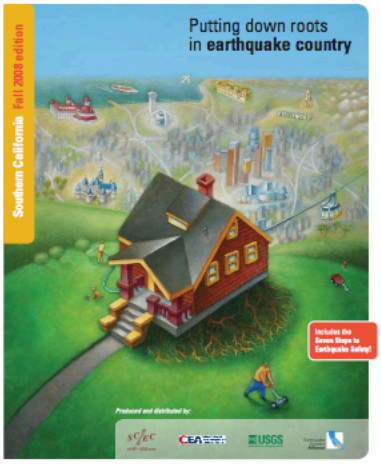
cell phones may not work!

20 October 2022 Great ShakeOut Drill

20 October 2022 Great ShakeOut Drill

Great ShakeOut
Earthquake Drills

DROP! COVER! HOLD ON!



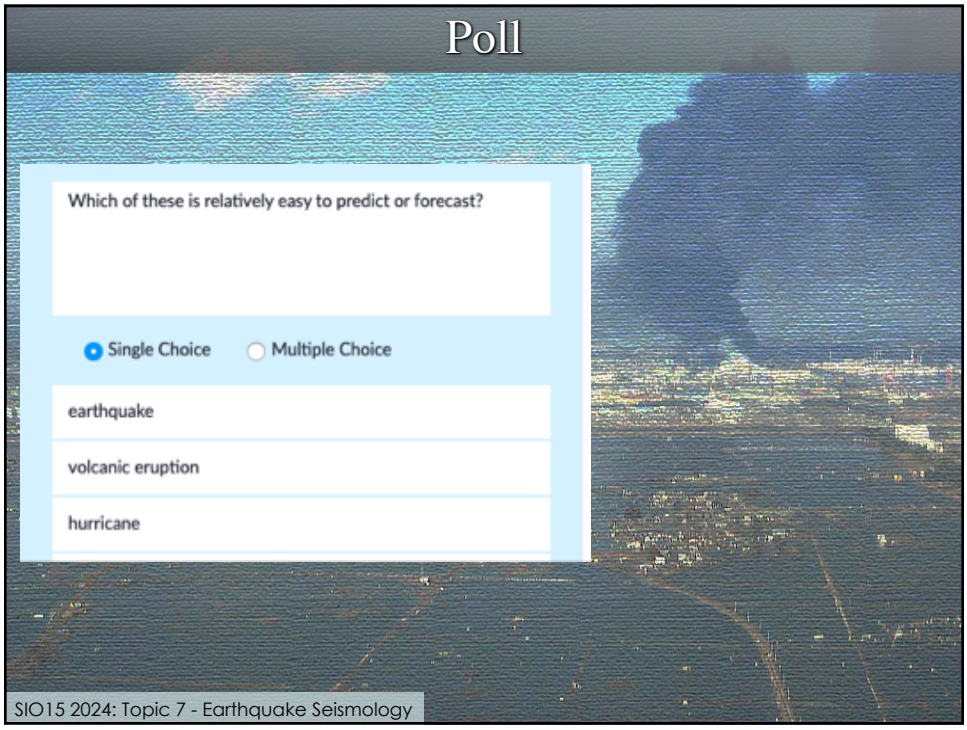
So, when is it coming?

We just don't know!

……yet…..

forecasting weather is much easier!

Poll


Poll
Which of these is relatively easy to predict or forecast?
Single Choice
Multiple Choice
earthquake
volcanic eruption
hurricane
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