Advanced Structural Geology, Fall 2022

Earthquake magnitude background

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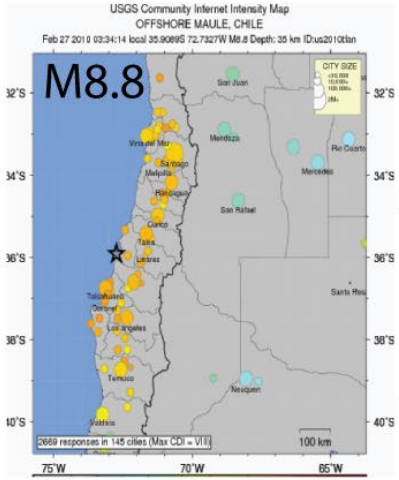
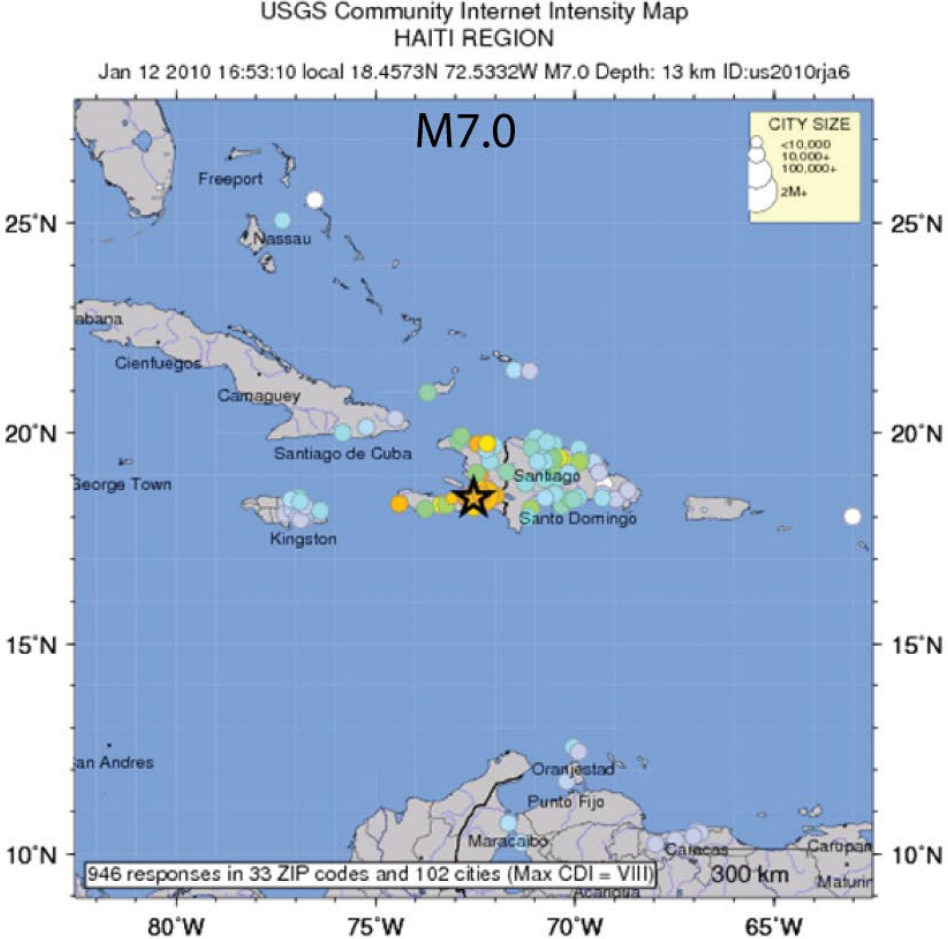
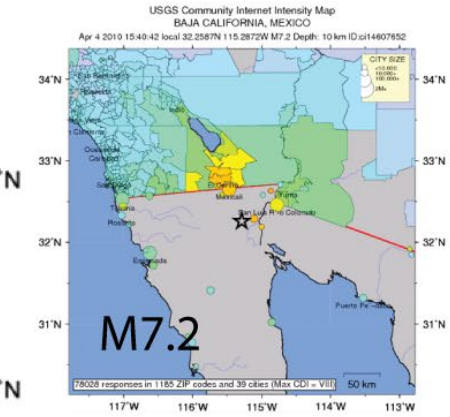
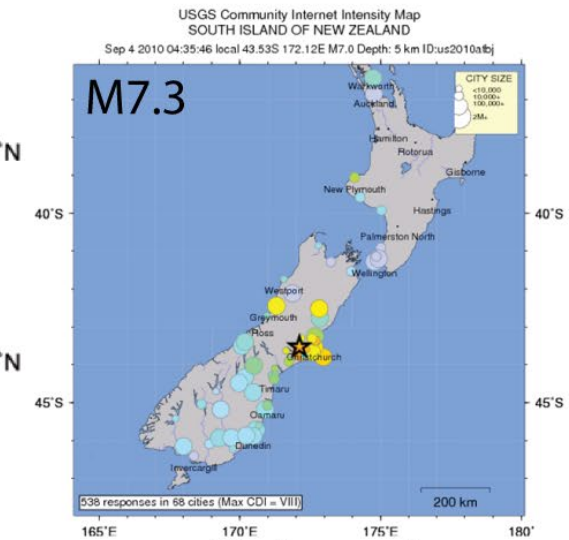
Key Issues for Earthquakes

- **Source** (breakage at fault): When the fault slips, it generates seismic waves
- **Path** (path of seismic waves)
- **Site** (conditions at site and structure control intensity)



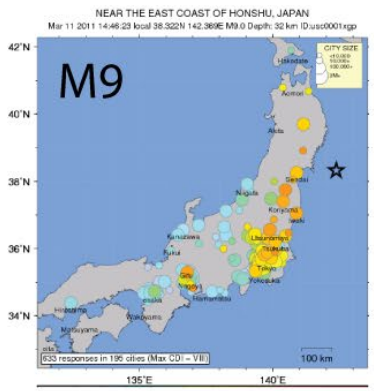






M3.6

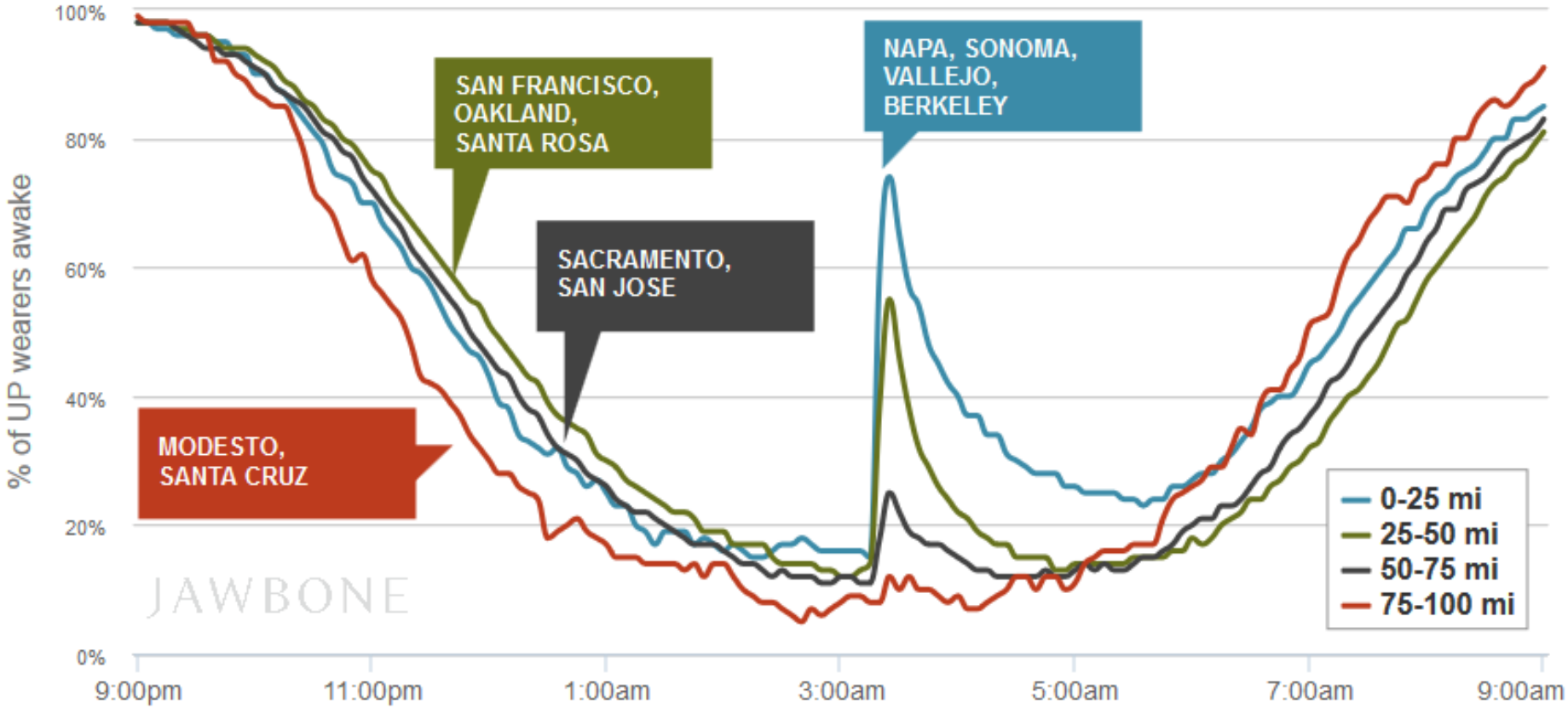
M3.8

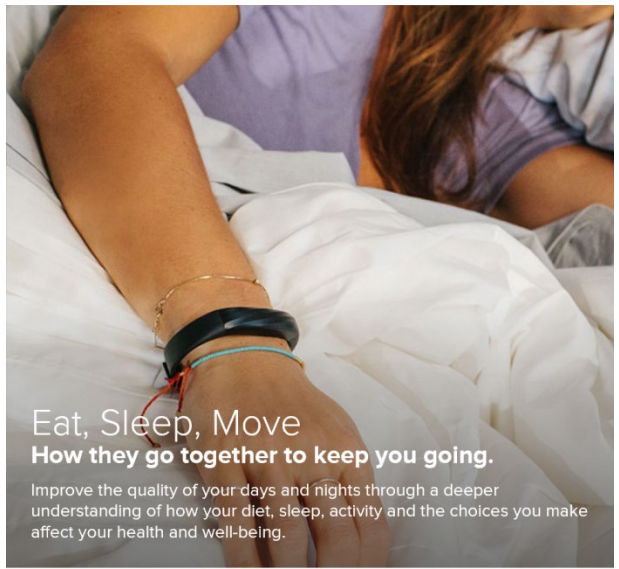


Intensity distributions at the same spatial scale

Intensity is shaking in an earthquake at a point. It can vary with position.

Magnitude is the measure of energy released in an earthquake.





Napa 2014 Earthquake: Napa, Sonoma, Vallejo, and Fairfield were less than 15 miles from the epicenter. Almost all (93%) of the Jawbone UP wearers in these cities suddenly woke up at 3:20AM when the quake struck.

https://jawbone.com/blog/napa-earthquake-effect-on-sleep/

Earthquake intensity scale (USGS)

Intensity	Shaking	Description/Damage
I	Not felt	Not felt except by a very few under especially favorable conditions.
II	Weak	Felt only by a few persons at rest,especially on upper floors of buildings.
III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Light	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very strong	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII	Severe	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Violent	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

Earthquake intensity scale

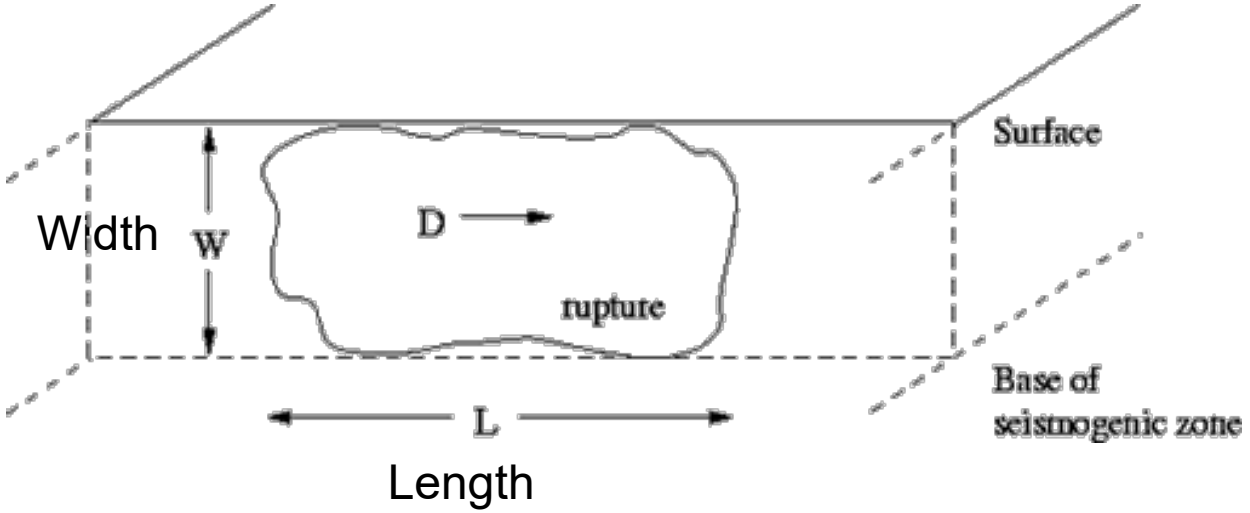
- “Mercalli” intensity scale was developed to quantify what people feel during an earthquake
- Used for earthquakes before instrumentation or current earthquakes in areas without instrumentation
- Assesses effects on people and buildings

Giuseppe Mercalli Director of Vesuvius Observatory
https://commons.wikimedia.org/wiki/User:Sailko

Seismic moment (M_0)

Measures amount of strain energy released by movement along whole rupture surface; more accurate for big earthquakes

Calculated using rocks' shear strength times rupture area of fault times displacement (slip) on the fault



Don't forget to convert all to meters

M_0= mu*A*D

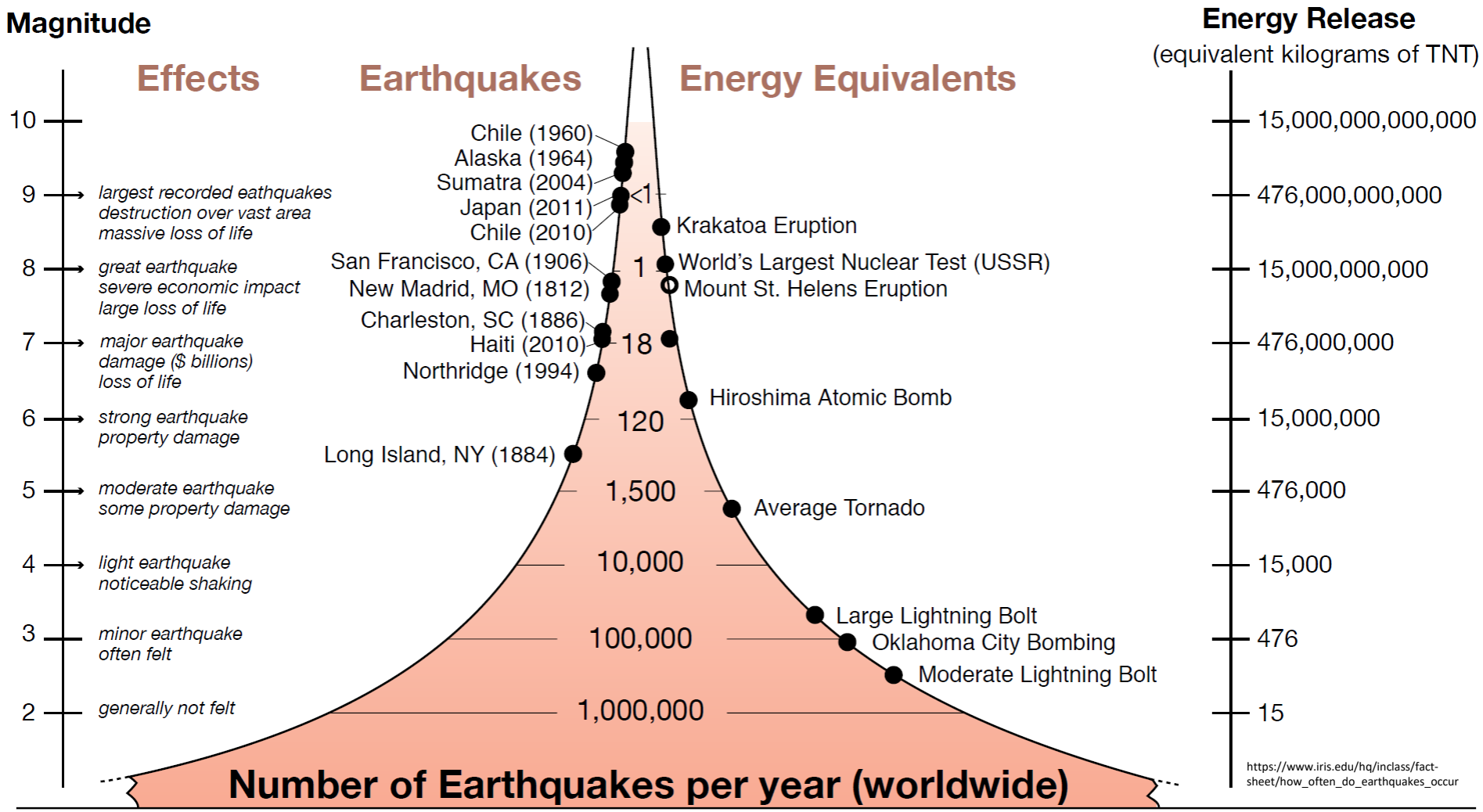
--mu is shear modulus (how stiff is the rock?), typical value is 30 GPa ($3x10^{10}$ N/m^2)

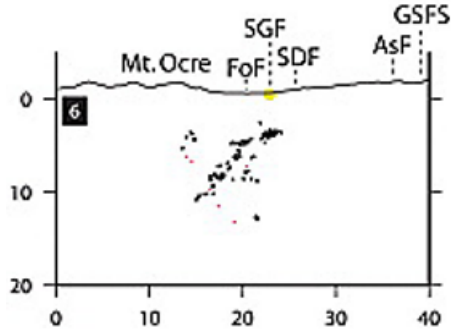
--A is surface area that slipped (m^2) [width x length]

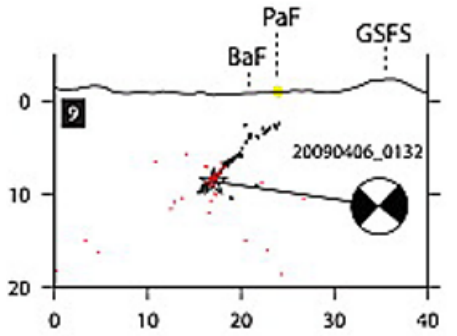
--D is the average slip in meters

Moment Magnitude Scale:

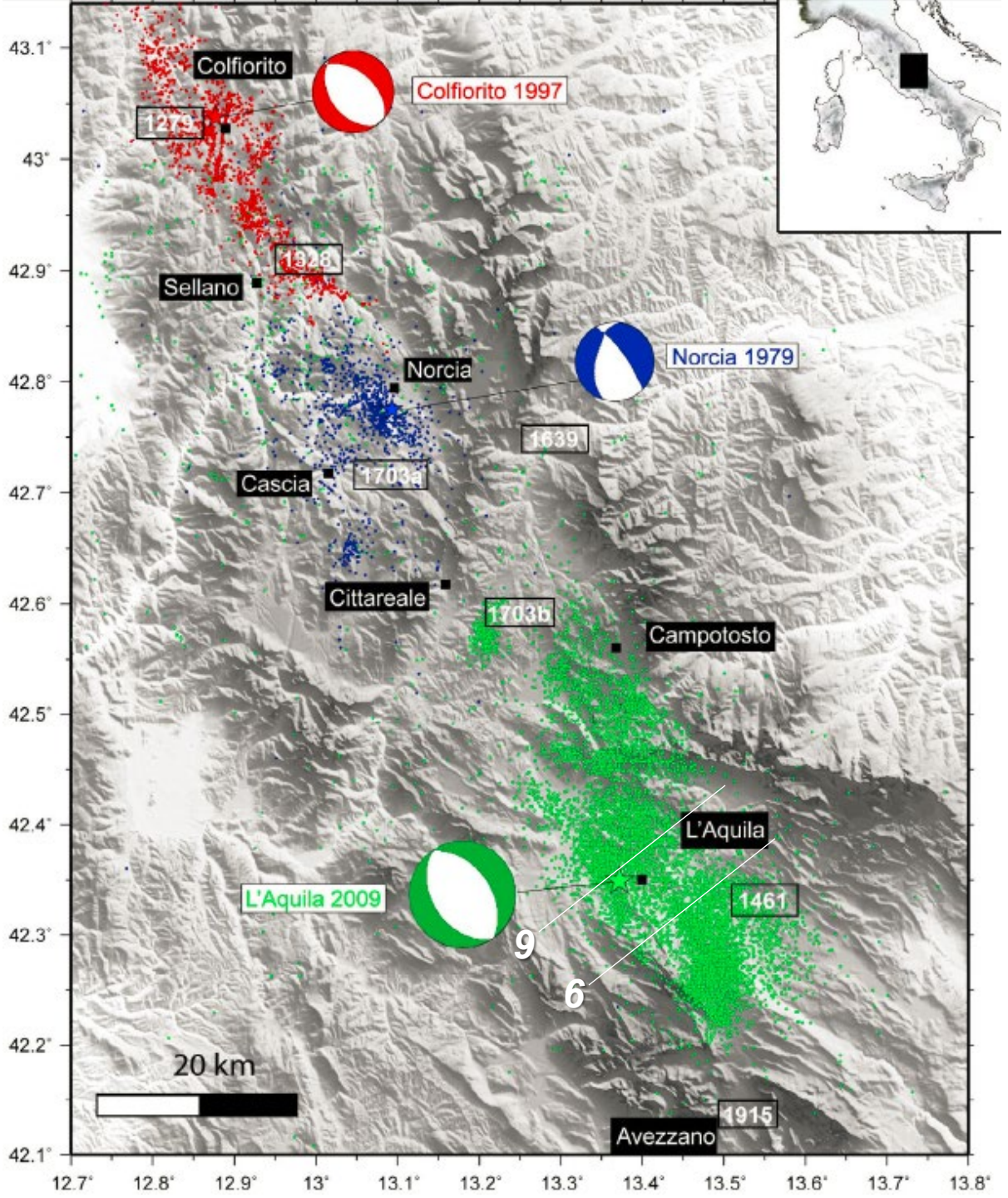
- **Moment magnitude scale** uses seismic moment:
  - $M_w = 2/3 \log_{10} (M_o) - 6$ (basically gets it to a similar range as the original Richter scale)







Parameters to define:		
mu	30	GPa
Horizontal length	30	km
Seismogenic thickness	8	km
average fault dip	45	degrees
Average slip	0.5	m
Intermediate calculations:		
mu	30000000000	Nm
Horizontal length	30000	m
Seismogenic thickness	8000	m
Down dip width	11314	m
Seismic moment:	5.0912E+18	Nm
Moment magnitude:	6.47	



Earthquakes as pulse like ruptures