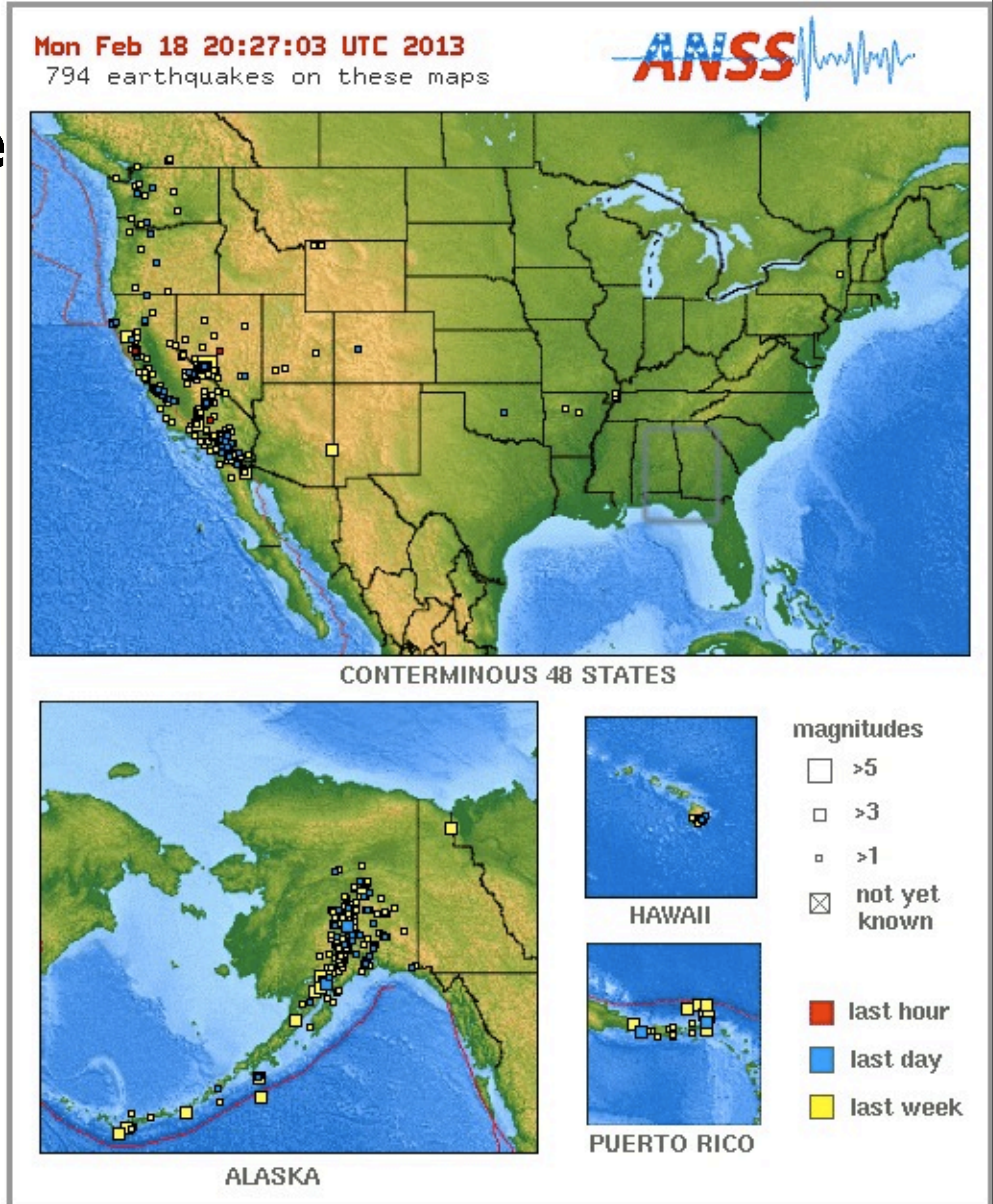
Earthquakes and Earth's Structure

Chapter 10 and 11(review)



EXAM I Wednesday

88 pts. total

- 62 pts. PassSheet

- 26 pts. Better-Than

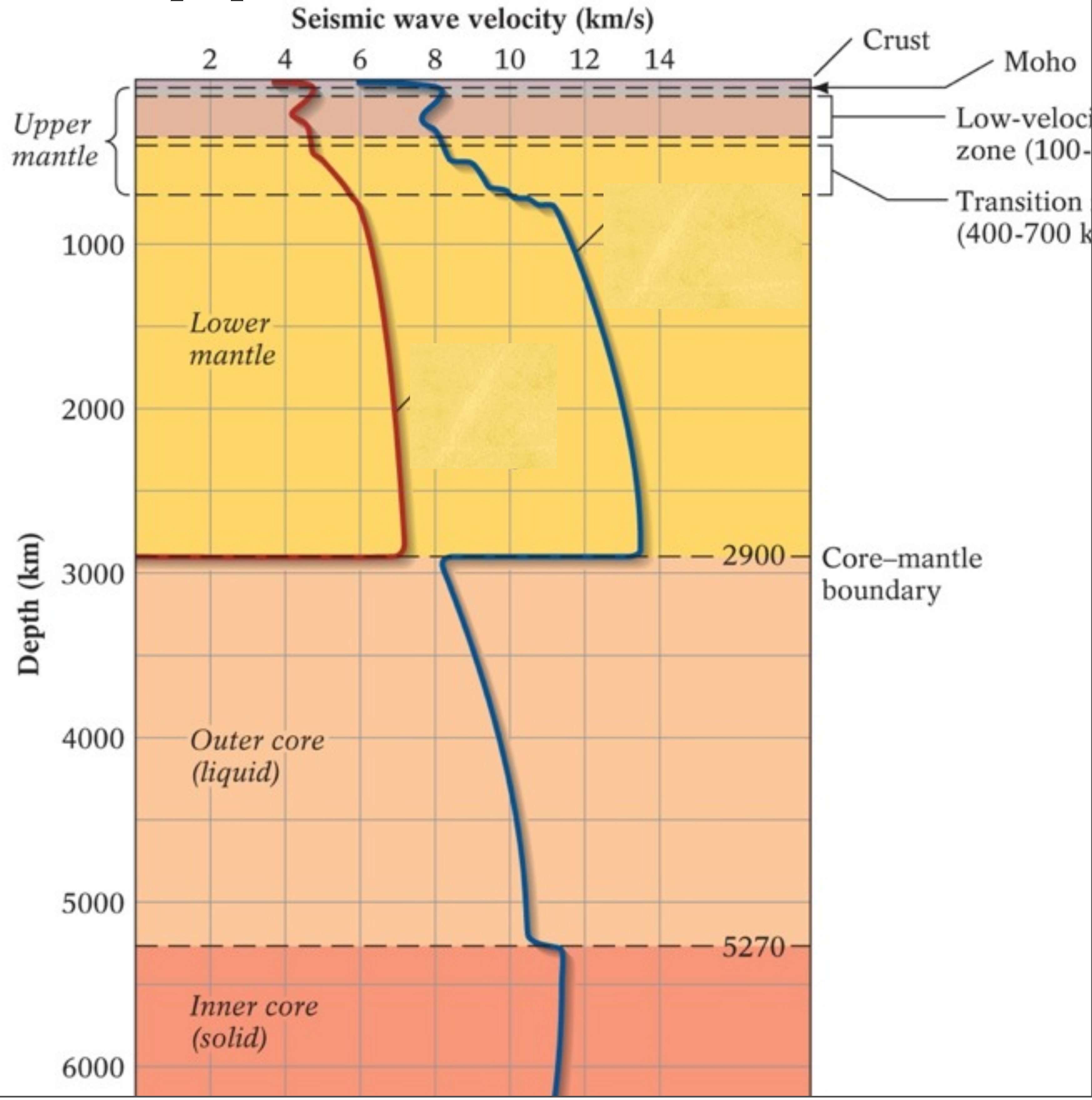
+ 8 pts. Extra Credit

http://earthquake.usgs.gov/earthquakes/recenteqsus/

The red and blue lines on the graph show two different velocity profiles for seismic waves in Earth.

The blue line likely represents______.

a) Love waves
b) P-waves
c) Rayleigh wave
d) S-wave
e) not enough information



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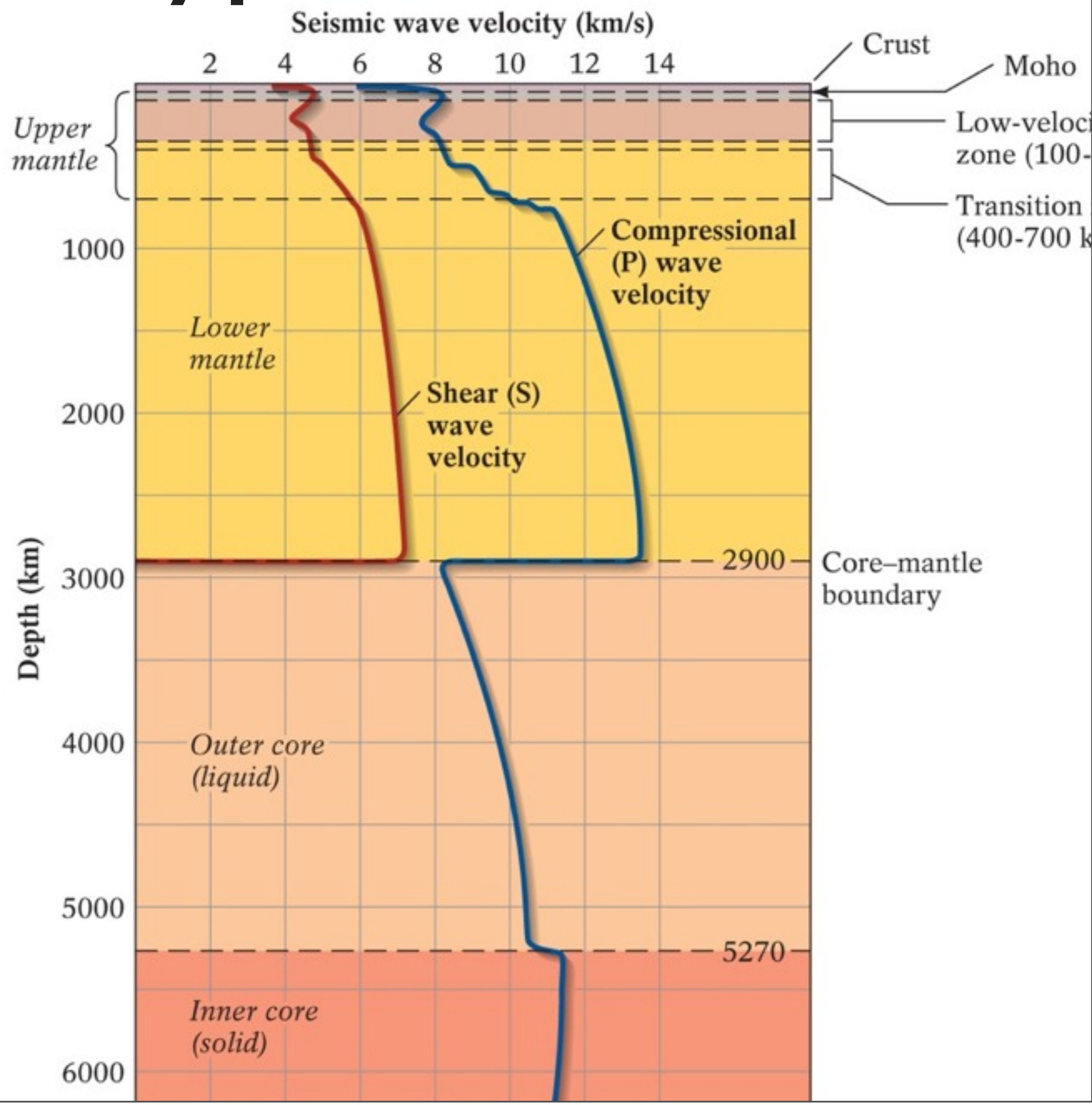

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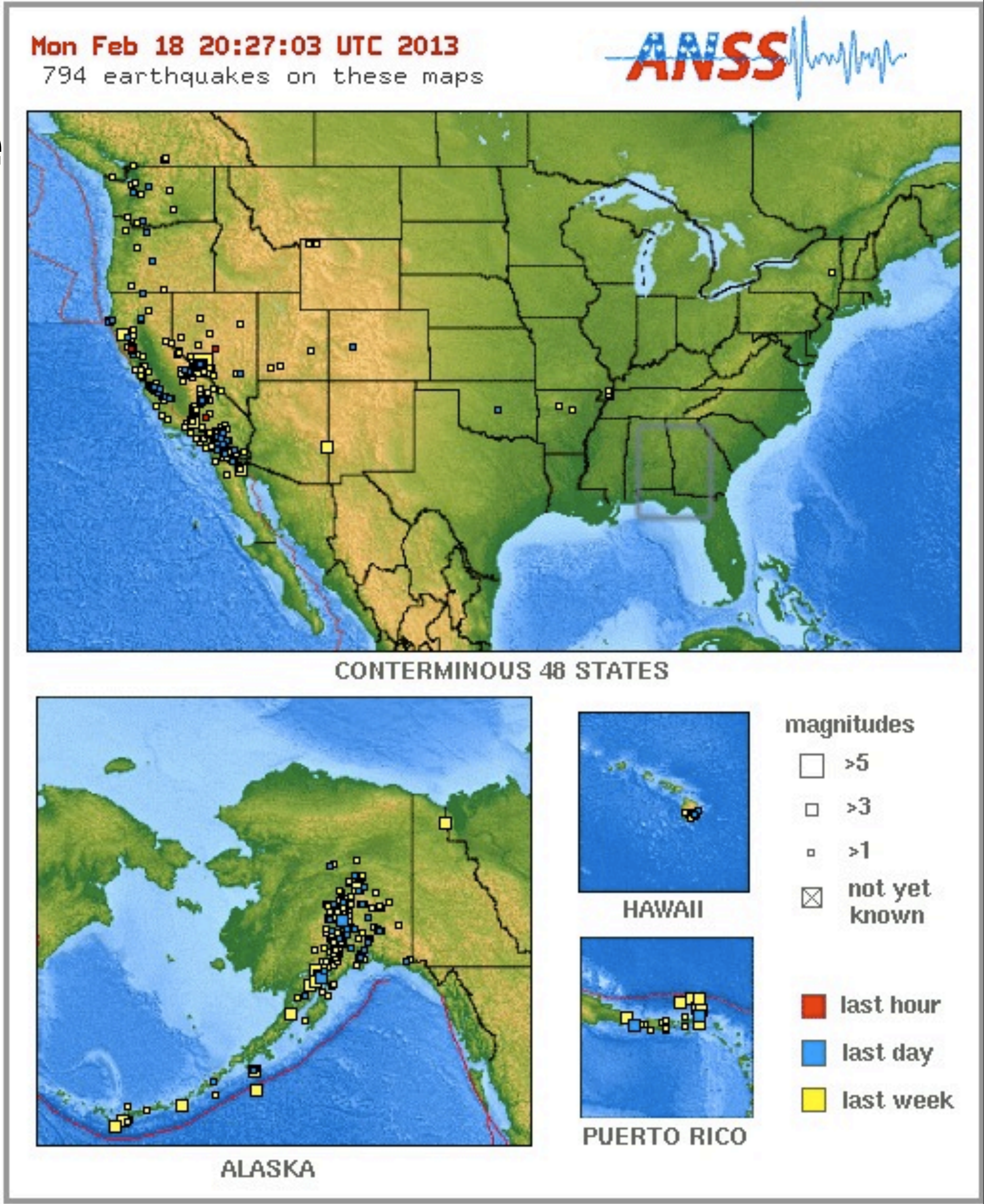
Chapter 10 and 11(review)



http://earthquake.usgs.gov/earthquakes/recenteqsus/

Earthquake Magnitude Scales

Mercalli Intensity Scale - defines the intensity of an earthquake by the amount of Damage. Measured from I-XII. Effected by distance, building code, human interpretation and underlying geology.

Richter Scale-

Moment Magnitude Scale-

1886 Charleston South Carolina Earthquake

Mercalli Intensity Scale

Based on response of humans and structures

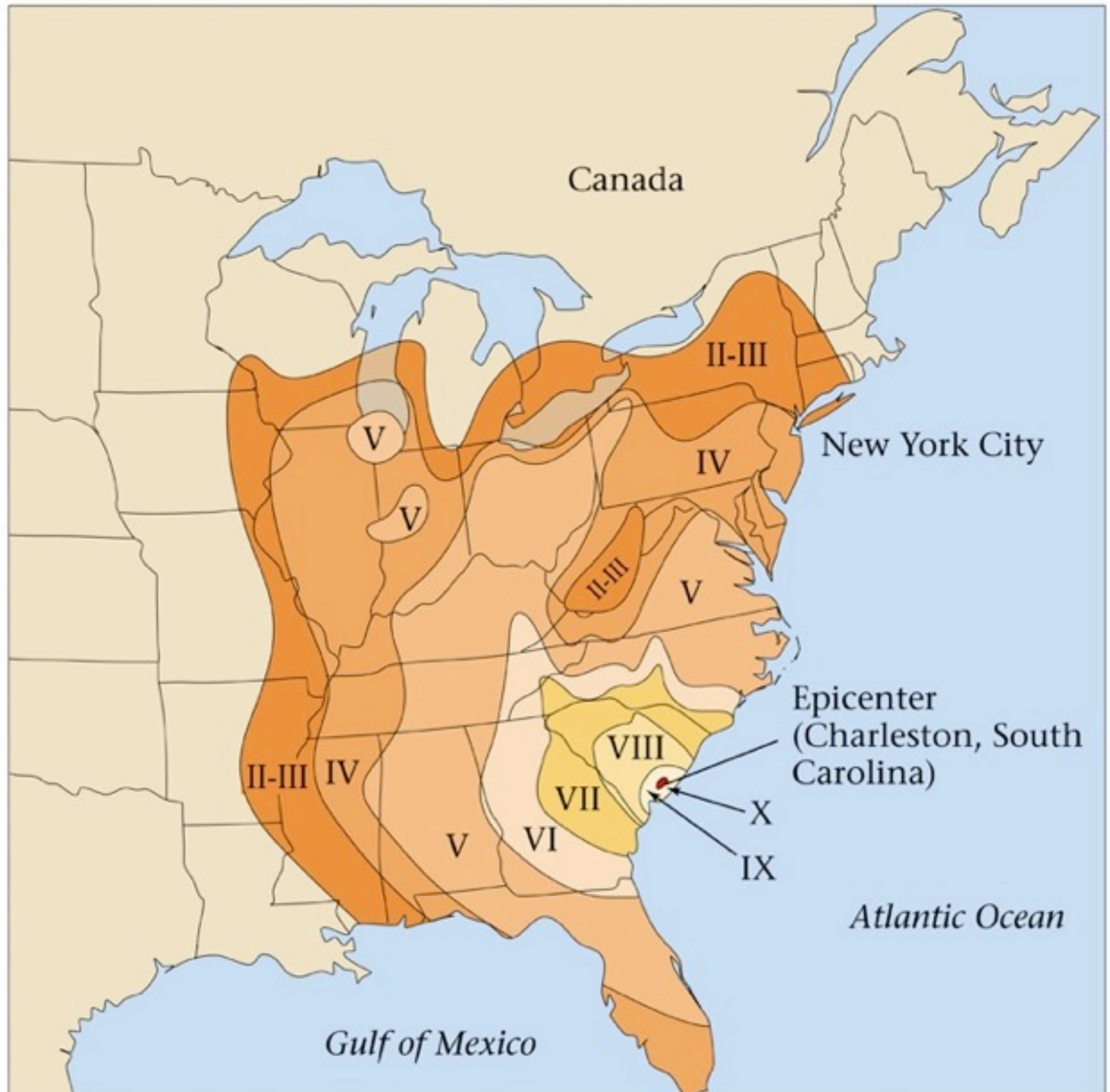
I not felt except for a few

V Most people awakened

X Masonry structures collapse

XII Complete destruction and surface waves seen

Full description of the scale on page 320



Earthquake Magnitude Scales

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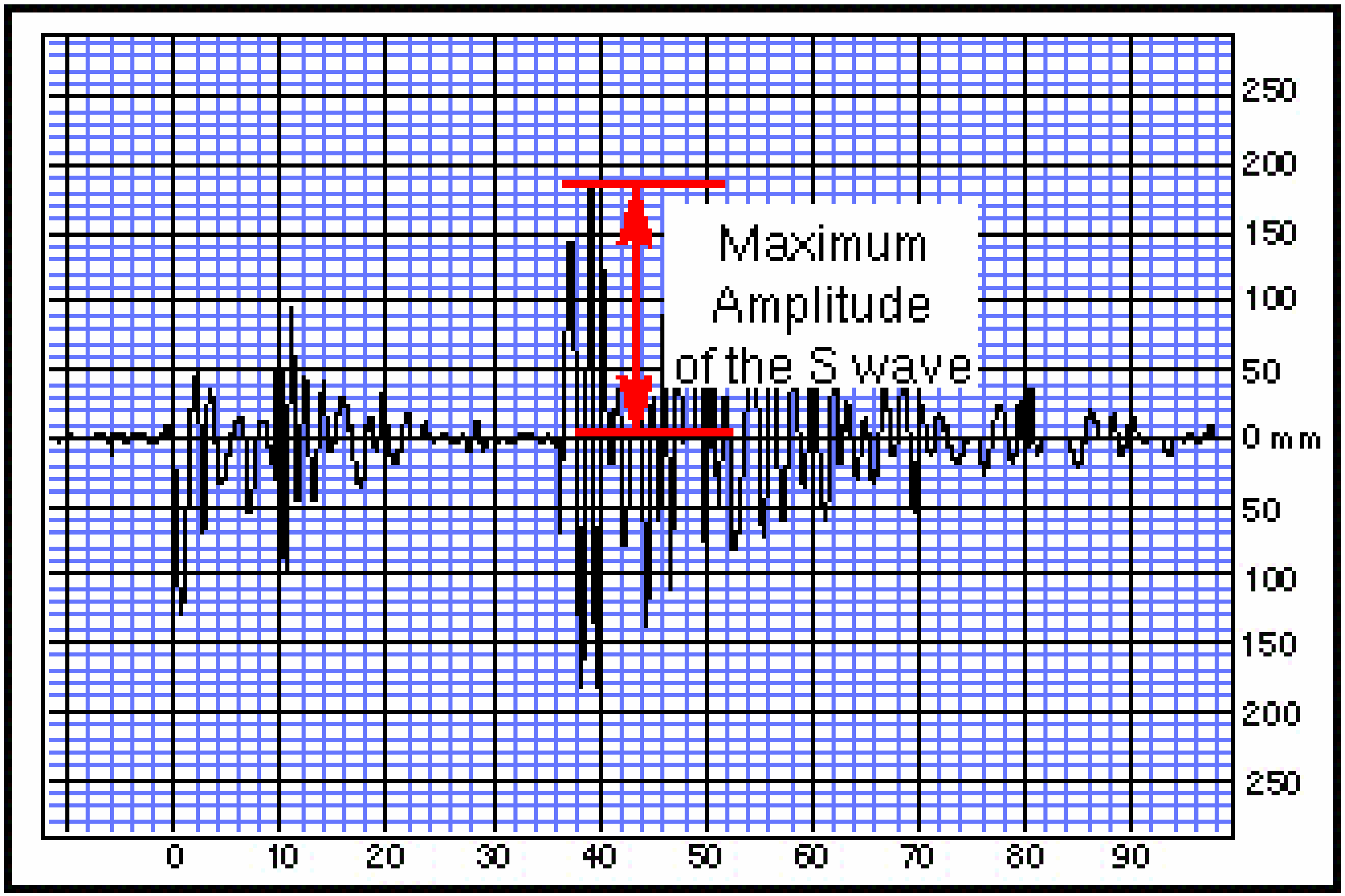
Richter Scale - measure of the largest deflection of the S-wave on a seismic gram as compared to a characteristic Earthquake. Can have negative magnitude values (10x change between units). Effected by distance from the epicenter.

Moment Magnitude Scale-

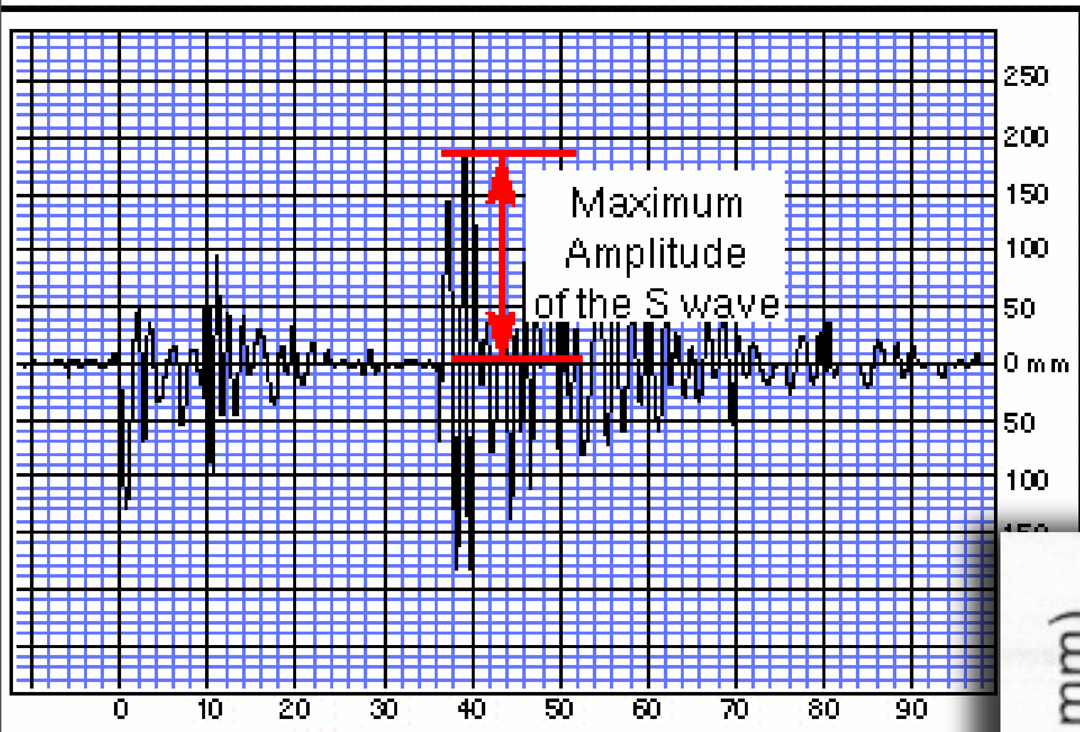
Richter Magnitude Magnitude

$$D = \Delta t \times \left(\frac{v_p \times v_s}{v_p - v_s} \right)$$



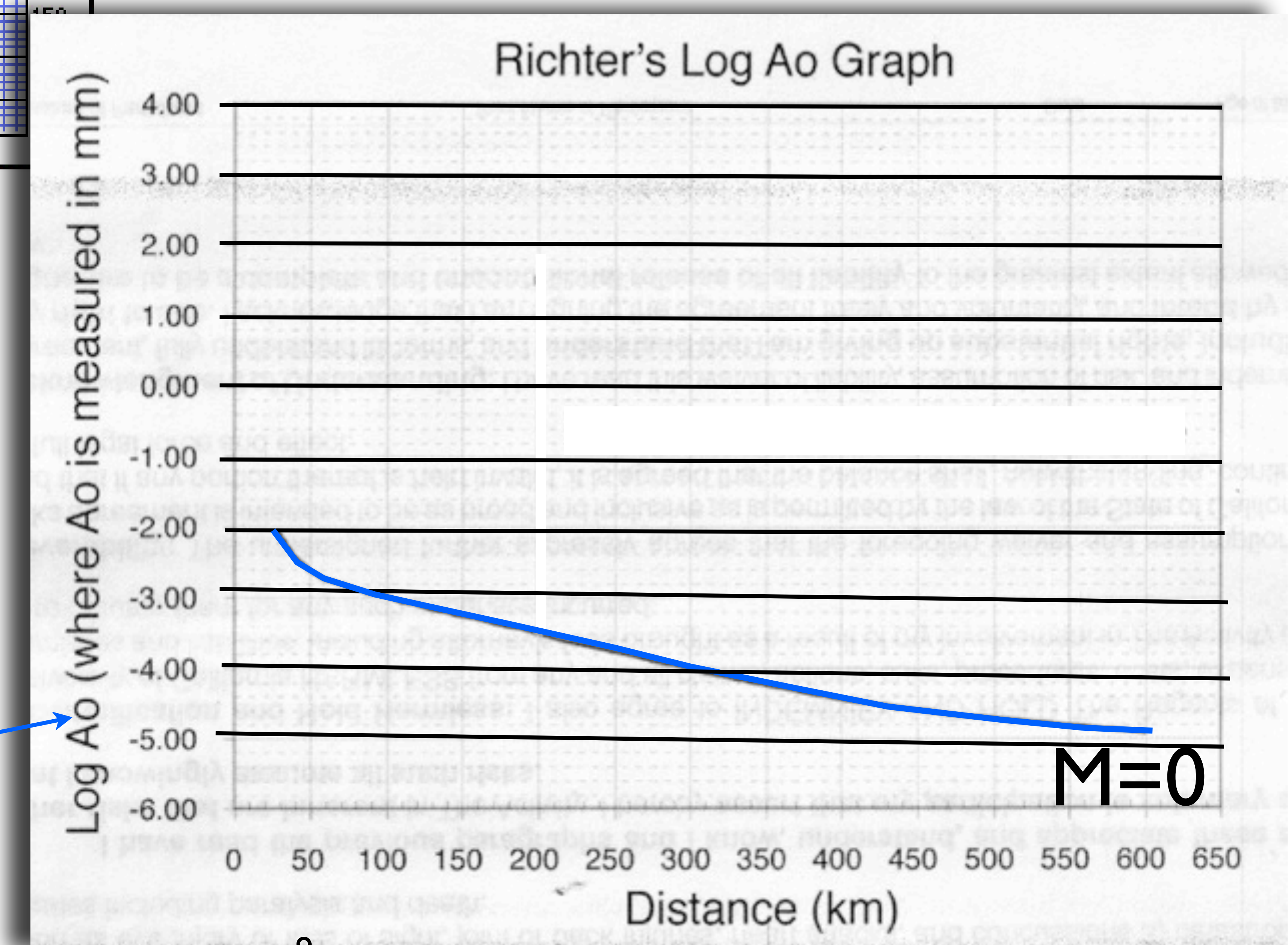
Vp = 6 km/s
Vs= 3 km/s

Richter Magnitude Magnitude



What does the Richter curve tell us about the relationship between ground shaking and distance from the epicenter?

Log of millimeters displacement by peak S-wave



Earthquake Magnitude Scales

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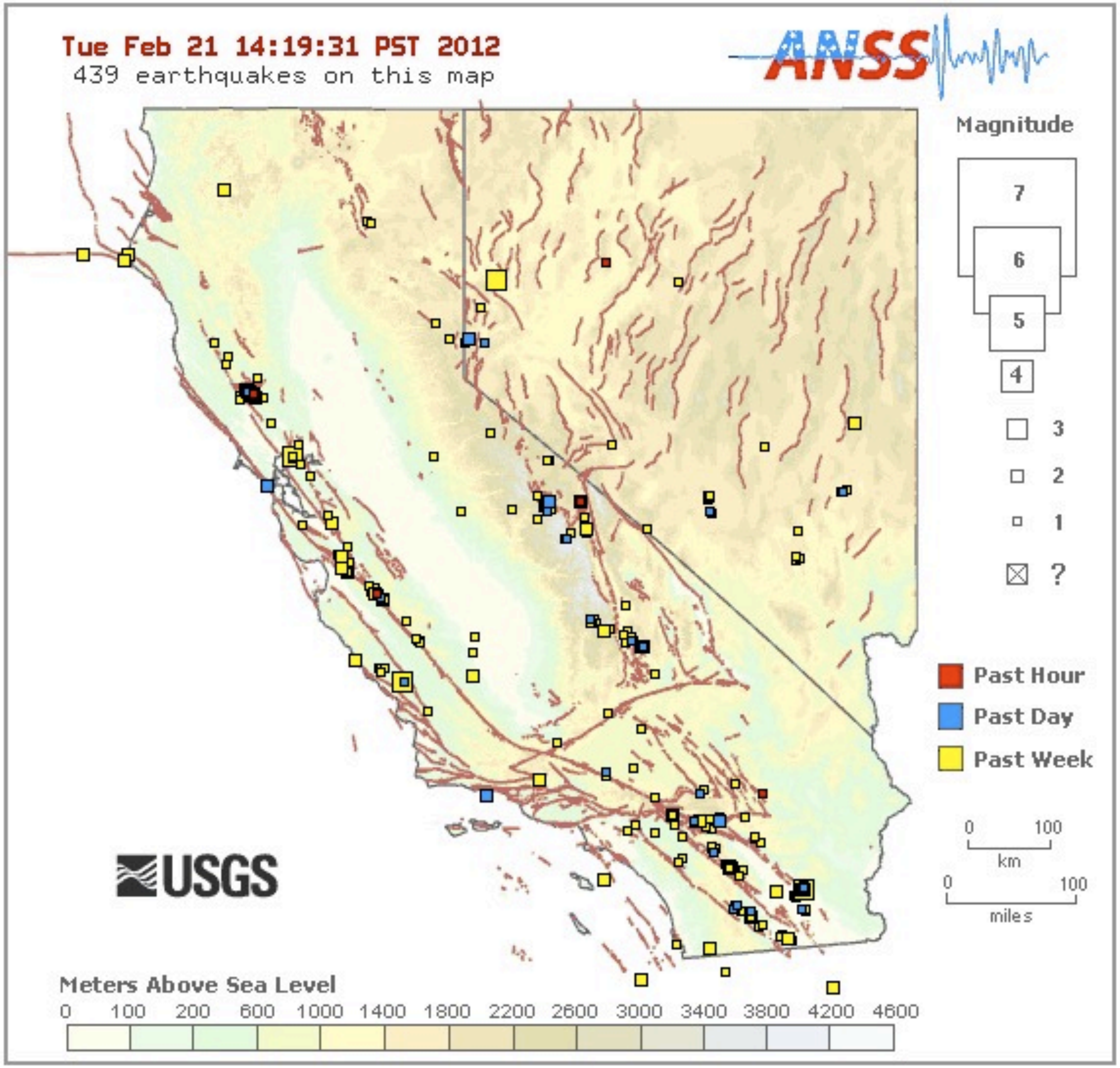
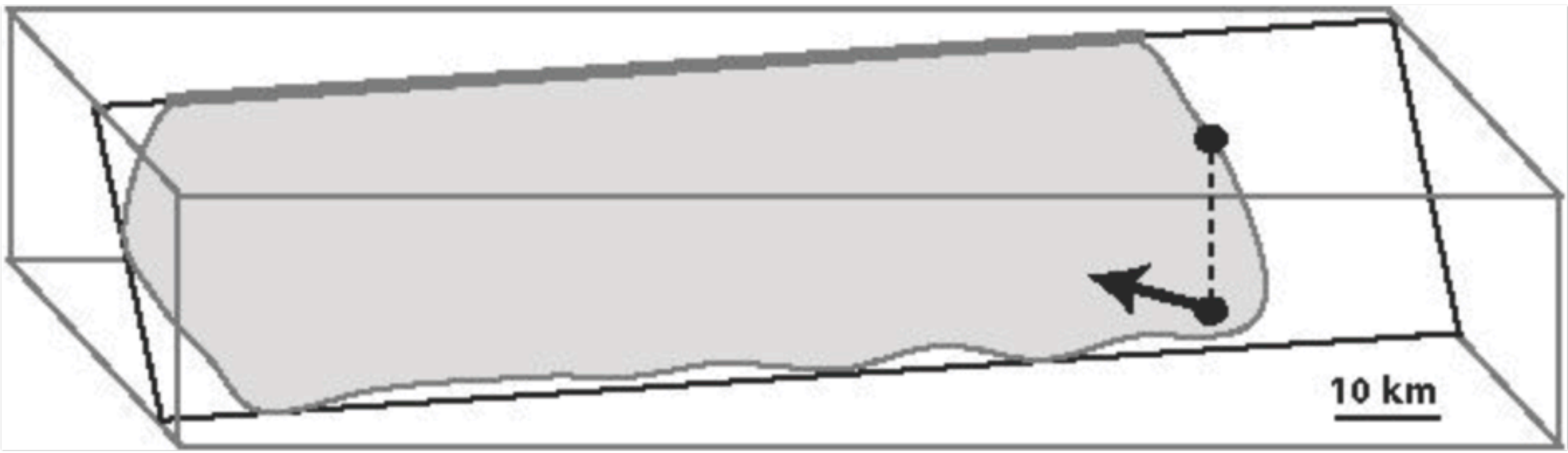
Moment Magnitude Scale - A measure of the energy released. Magnitude = Area * Displacement * (rock property) 33x energy change between units.

Do small earthquakes relieve stress on the fault and help to prevent large EQ's?

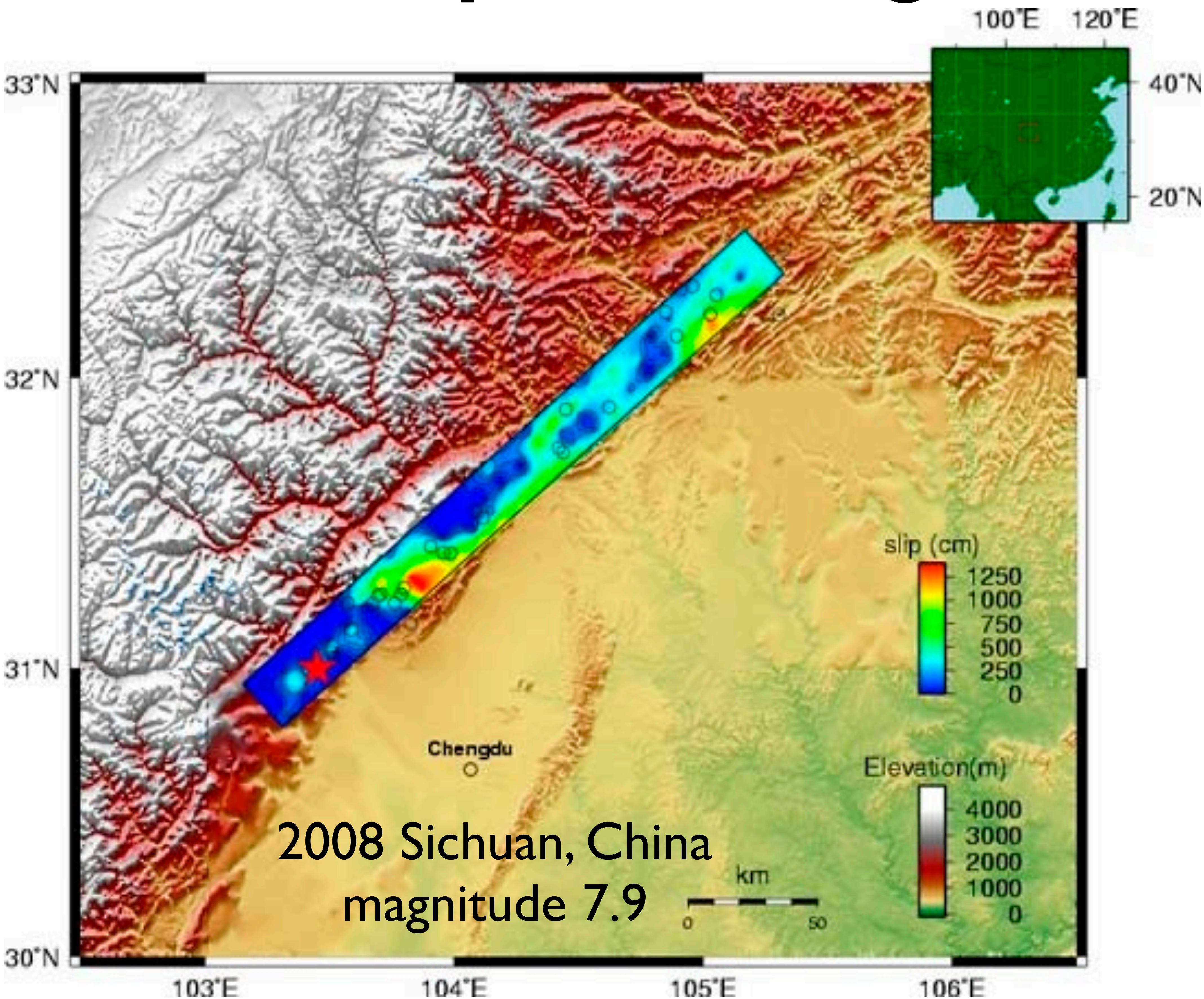


Area of Fault Rupture During and EQ



Moment Magnitude Scale - A measure of the energy released. Magnitude = Area * Displacement * (rock property)

Area of Fault Rupture During and EQ



Late Pleistocene structural evolution of the Camarillo fold belt: Implications for lateral fault growth and seismic hazard in Southern California

Duane E. DeVecchio[1], Edward A. Keller[2], Markus Fuchs[3], and Lewis A. Owen[4]
[1]EARTH RESEARCH INSTITUTE, UNIVERSITY OF CALIFORNIA, SANTA BARBARA, CALIFORNIA 93106-9630, USA
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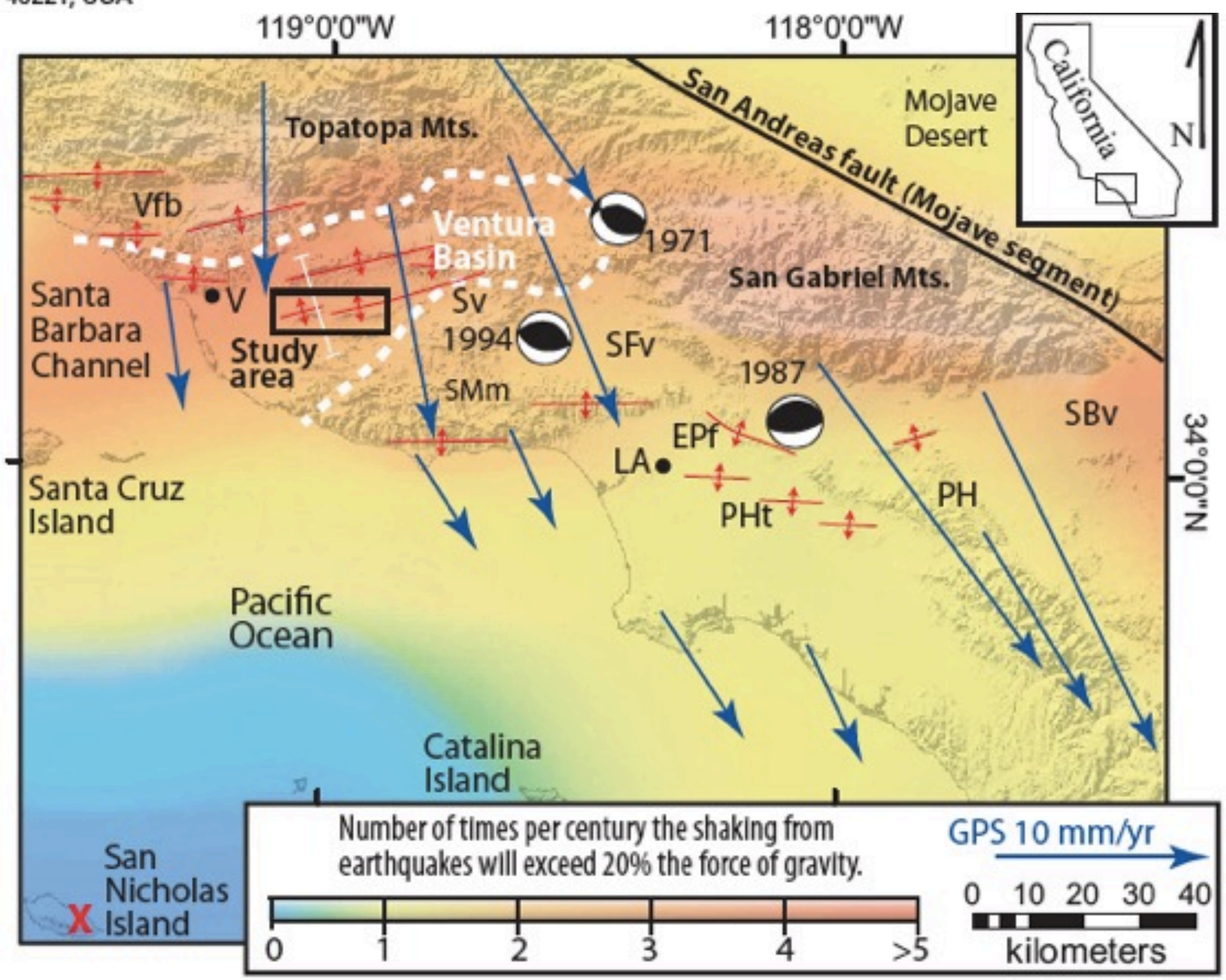
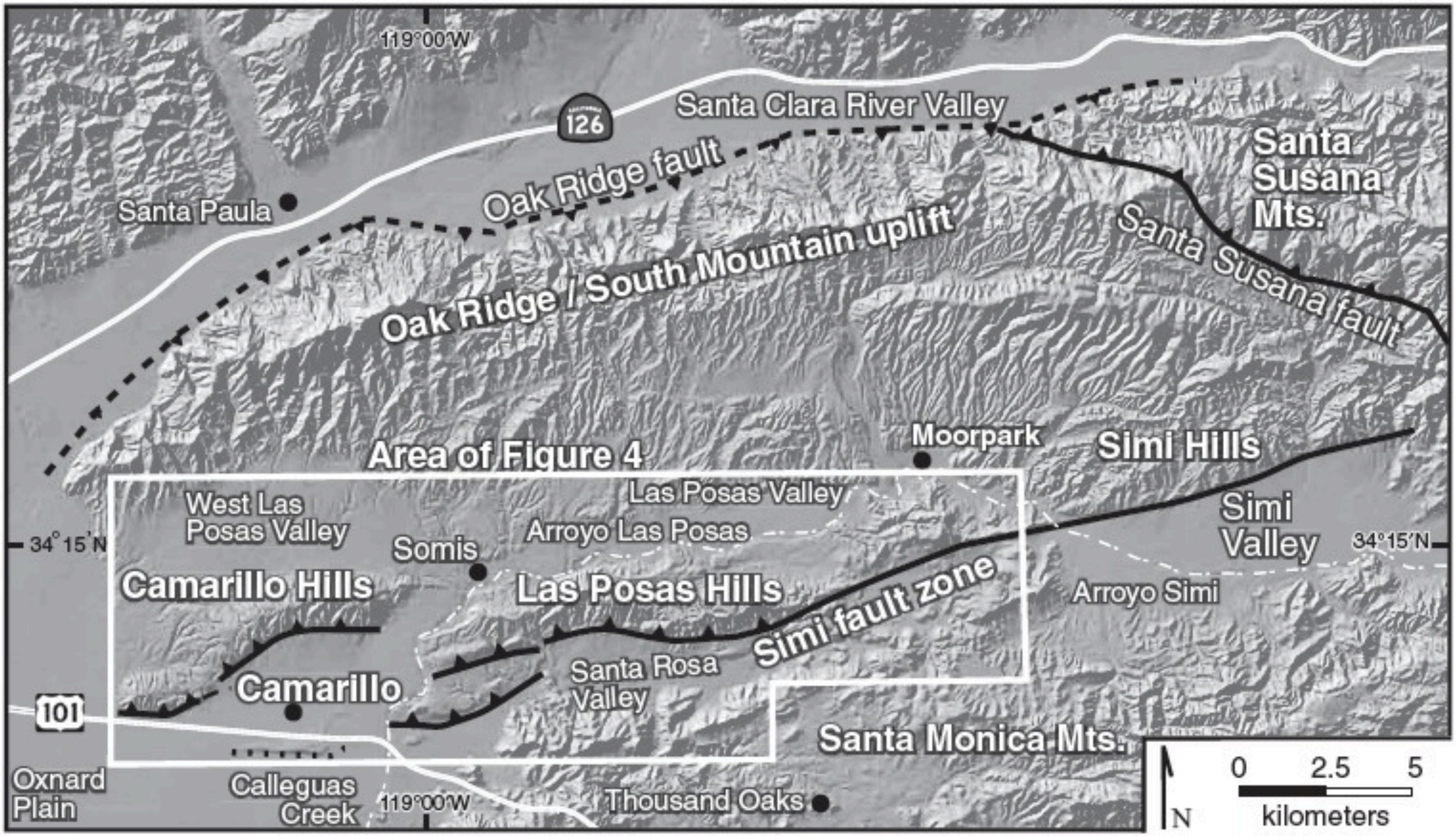
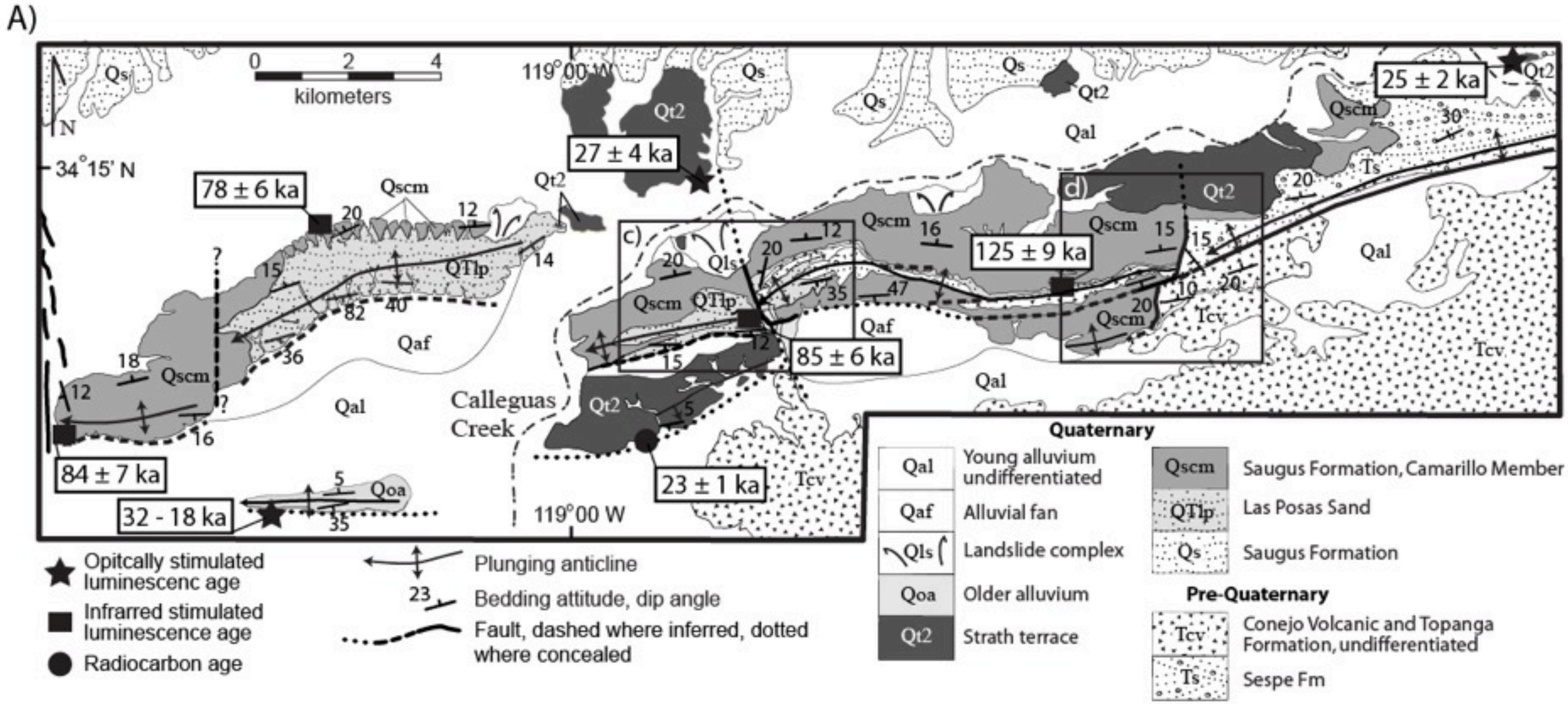


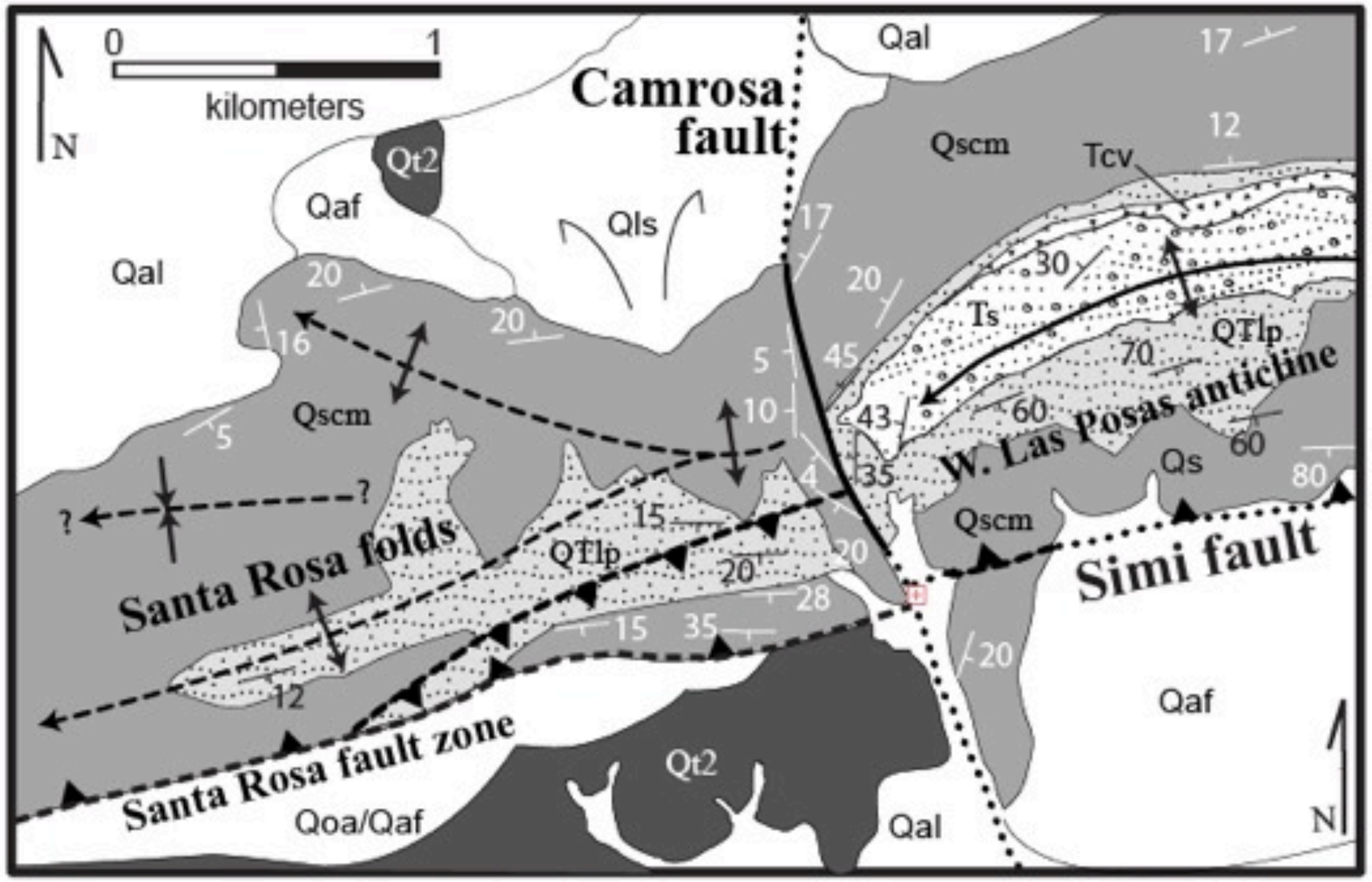
Camarillo Fold Belt

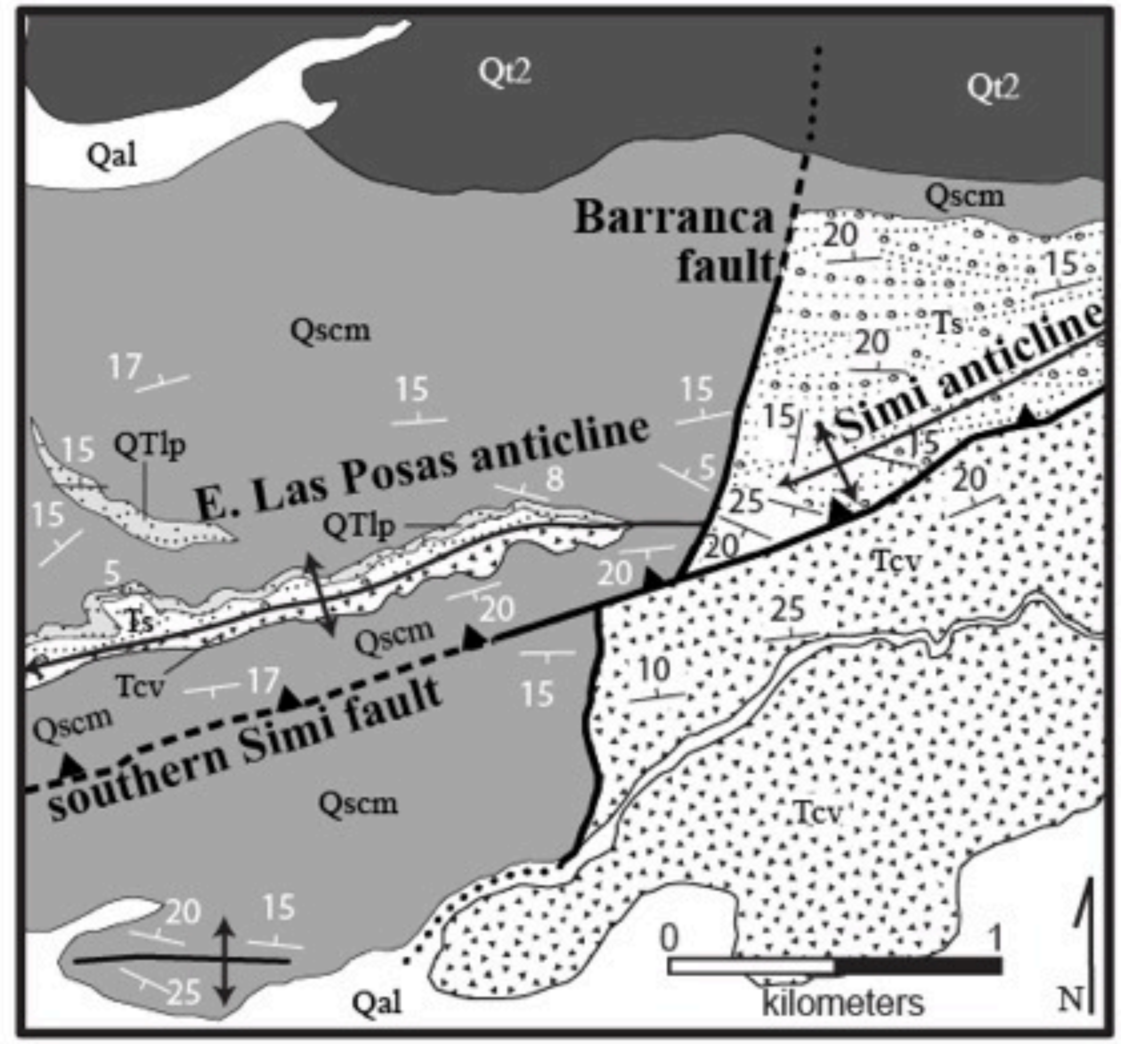


Camarillo Fold Belt
Geologic Map and Chronology

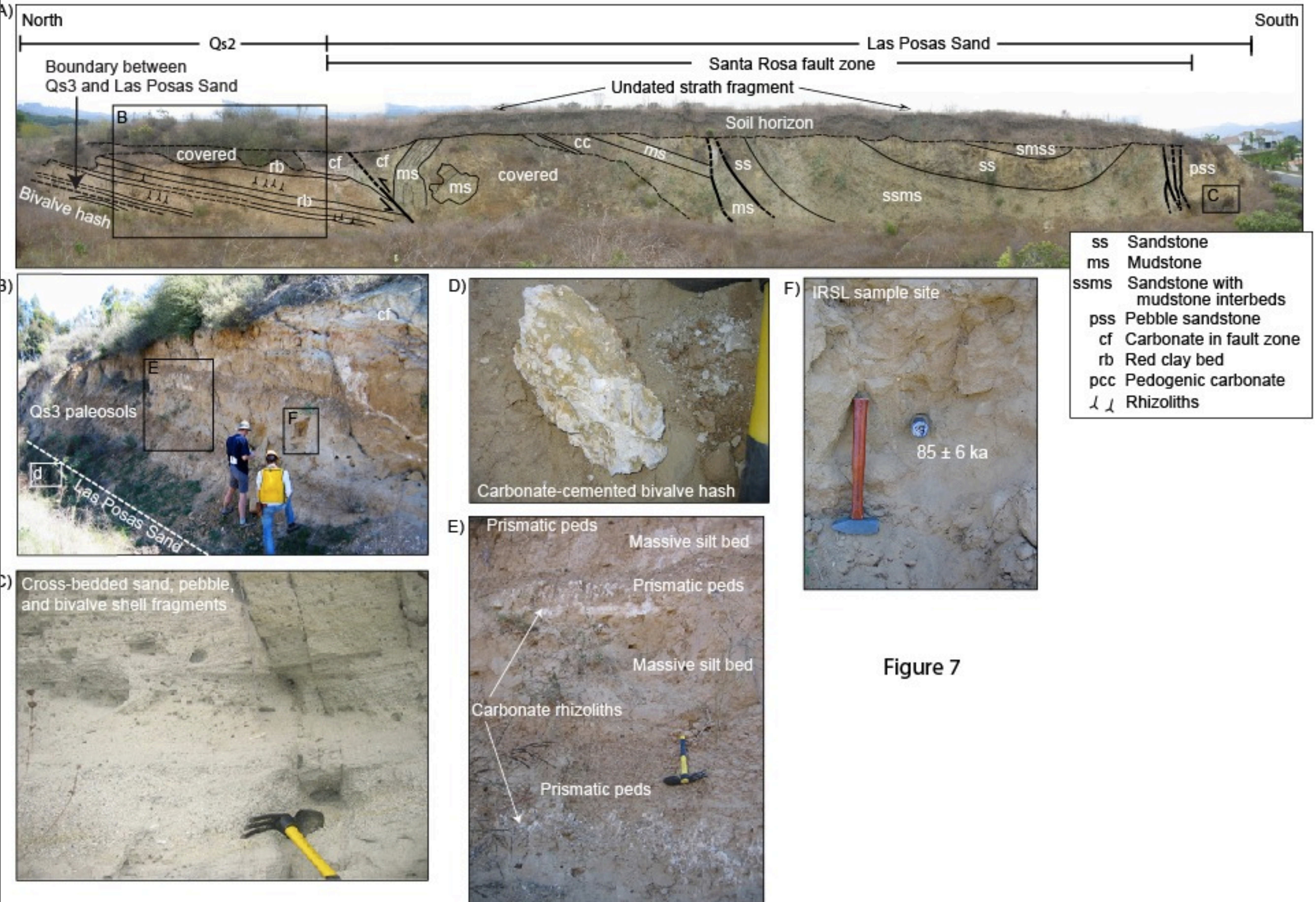


Camarillo Fold Belt

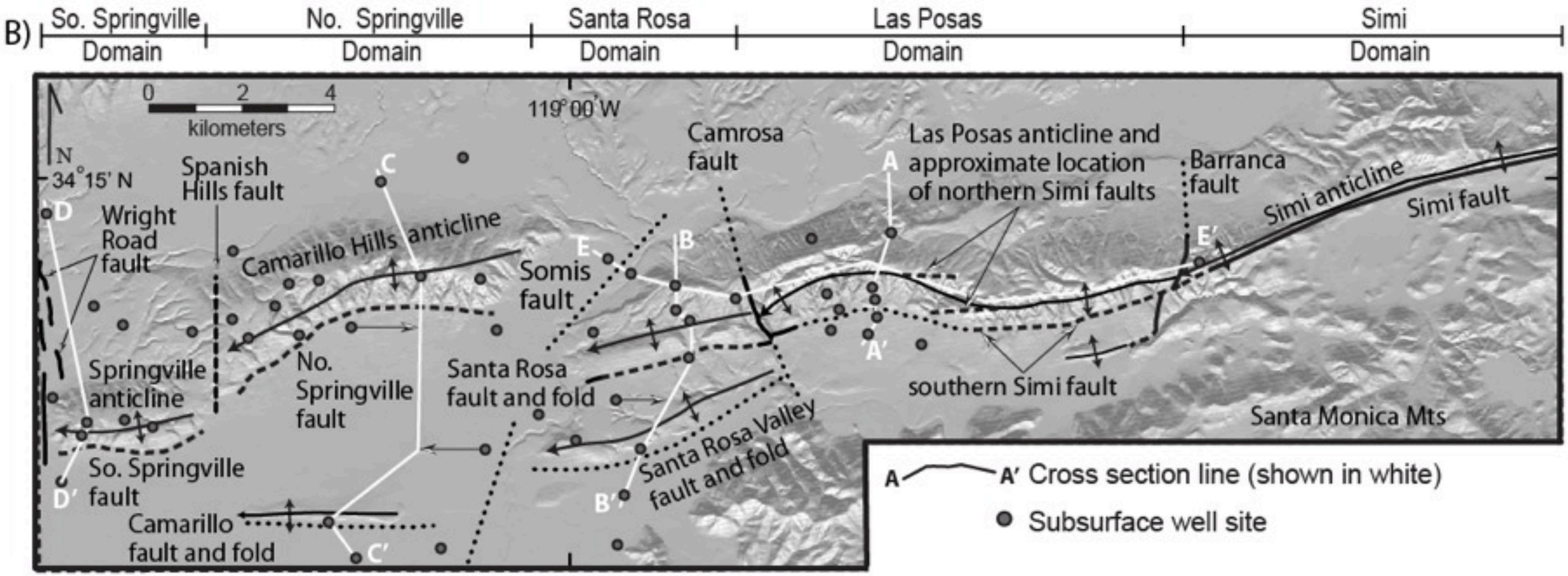




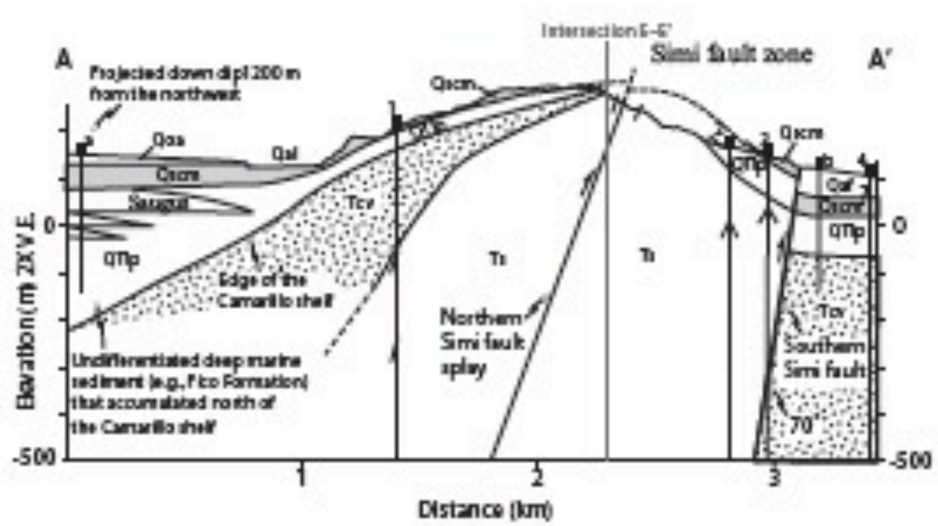
Santa Rosa fault zone



Cross Section lines and Subsurface well locations



Cross Sections



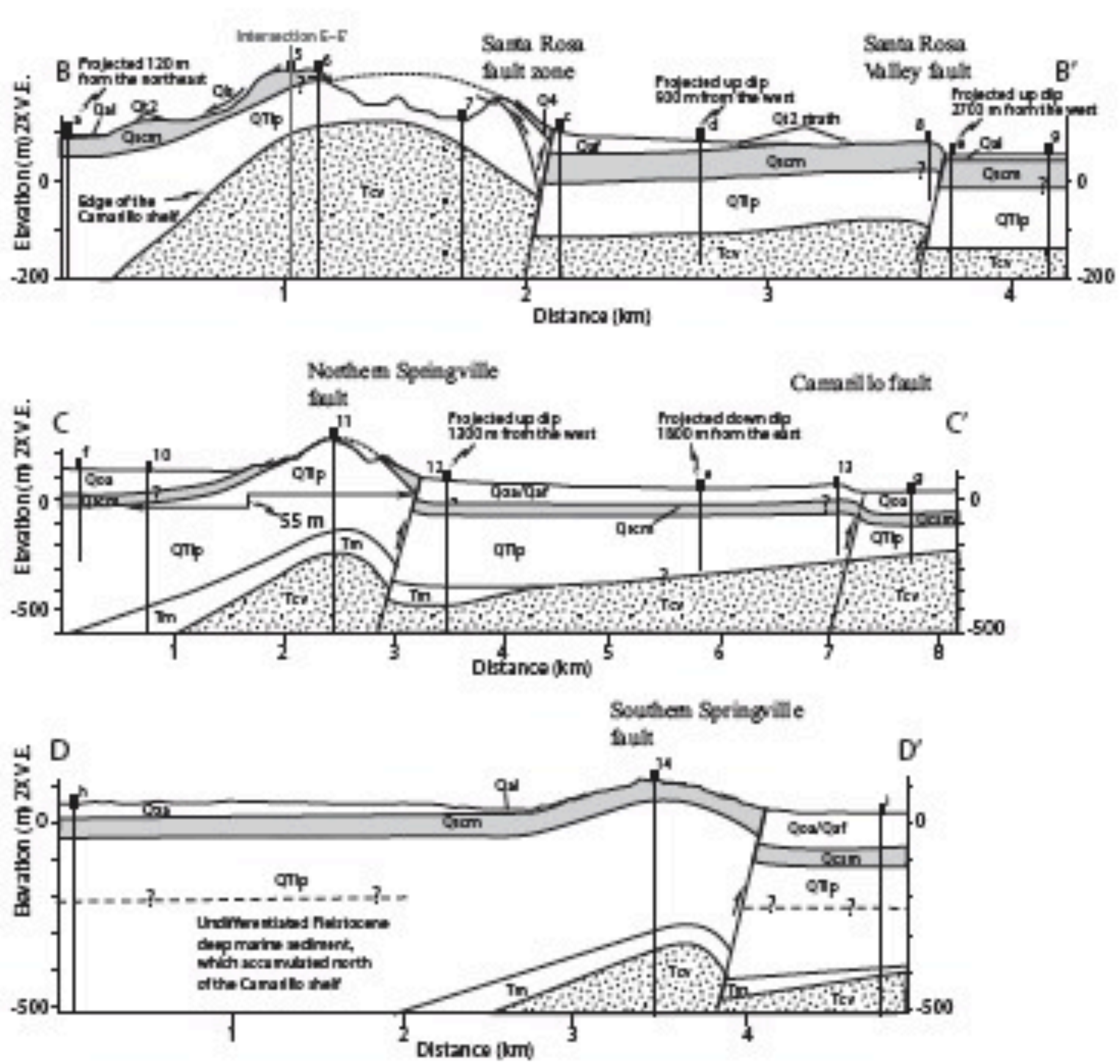
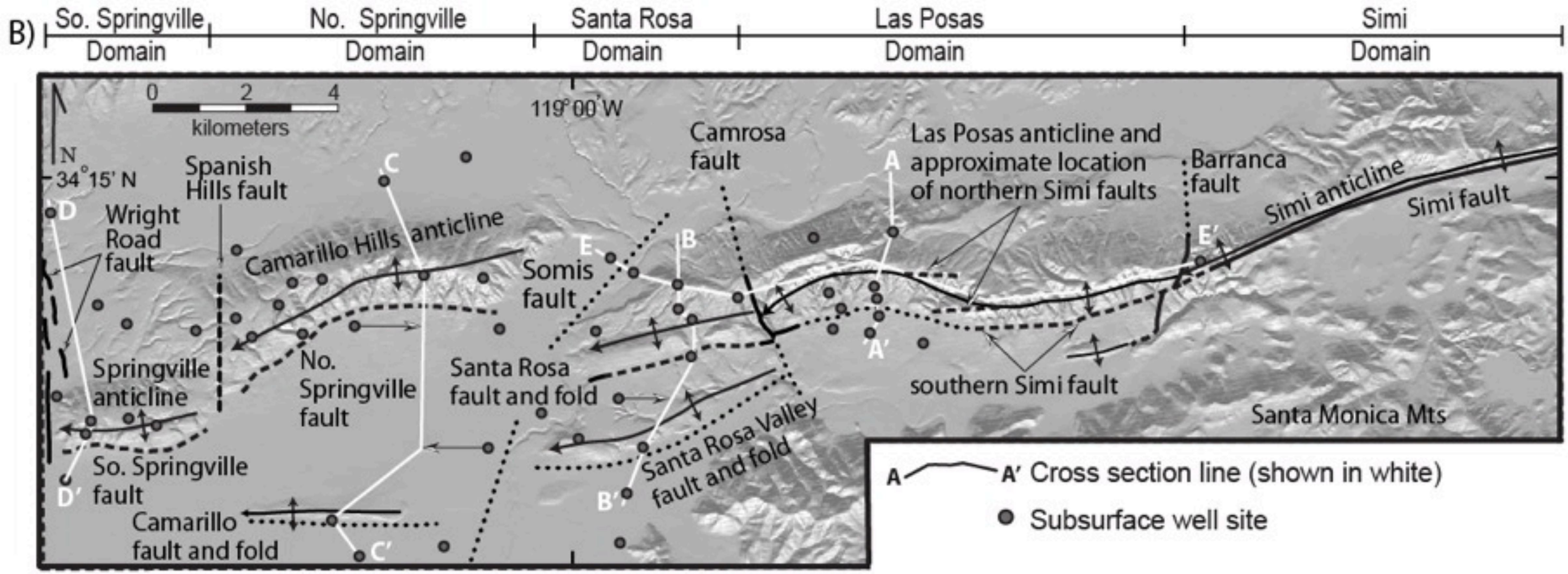


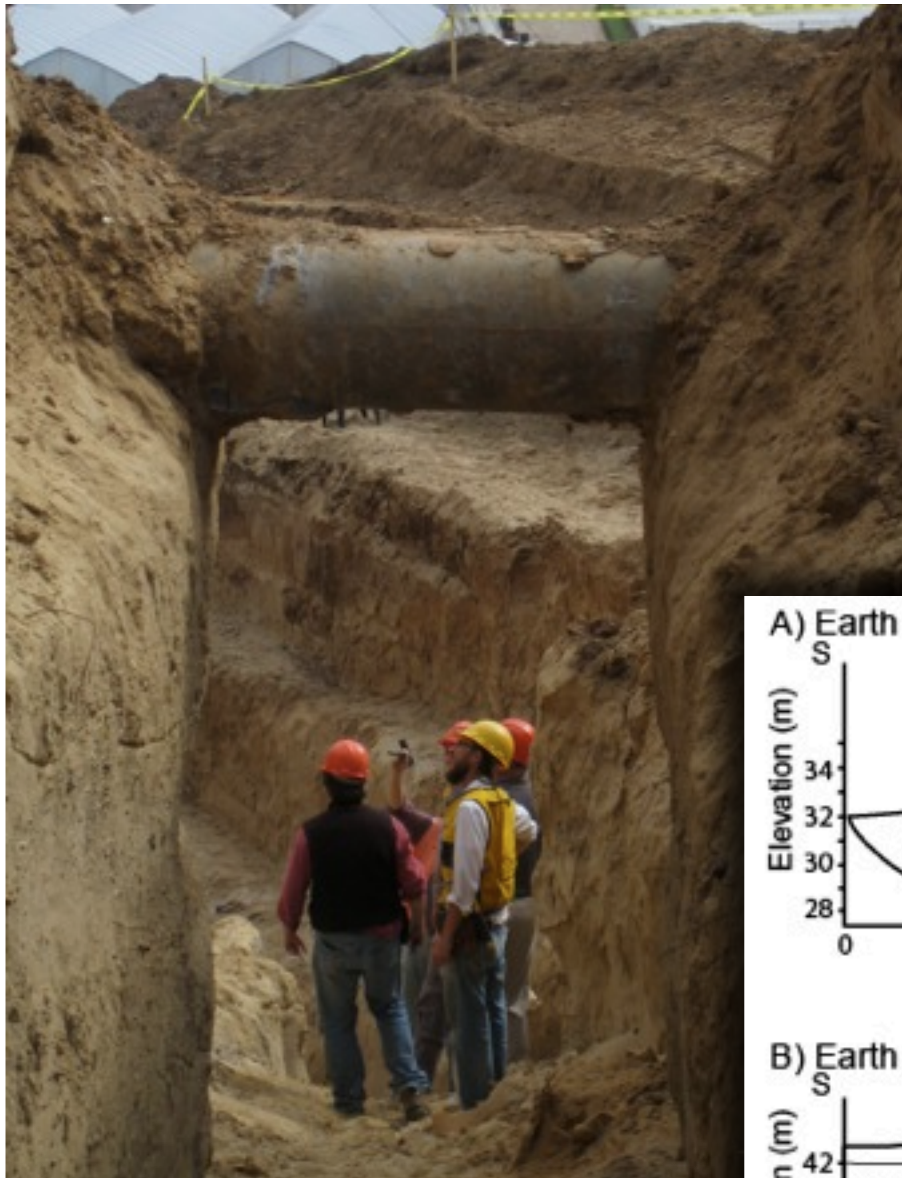
Figure 6. Four north-south–oriented cross sections across the Camarillo fold belt. See location of cross section lines (A–D) and explanation of geologic units on Figure 4. All sections have 2× vertical exaggeration and different horizontal scales. Lithologic interpretations of wells numbered 1–14 were taken from Jakes (1979), whereas interpretations of wells a–g are from Hanson et al. (2003). Queried Qscm contacts appear adjacent to wells of Jakes (1979), where differentiation of Upper Pleistocene units was not made; therefore, contacts are inferred based on projection from known depths. See Figure 4A legend for lithologic abbreviations. V.E.—vertical exaggeration. Well names: 1—Texaco Berylwood B-1; 2—Shell Everett 1; 3—Shell Everett C-2; 4—Exxon-Burket; 5—Aminoil-Burmah-Texaco Berylwood 1; 6—Burmah-Texaco Berylwood 3; 7—Texaco-Miketta 1; 8—A.J. Singer; 9—J. Schuck; 11—Arco McFarland 1; 12—Texaco-Converse 1; 13—Chevron Camarillo 1; 14—Reverse Schumate-Surpf; a—2N/21W-3B1; b—2N/20W-23H2; c—2N/20W-21L1; d—2N/20W-29B1; e—2N/20W-30M1; f—2N/21W-12H1; g—1N/21W-1B4; h—2N/21W-17F5; i—2N/21W-32E1.

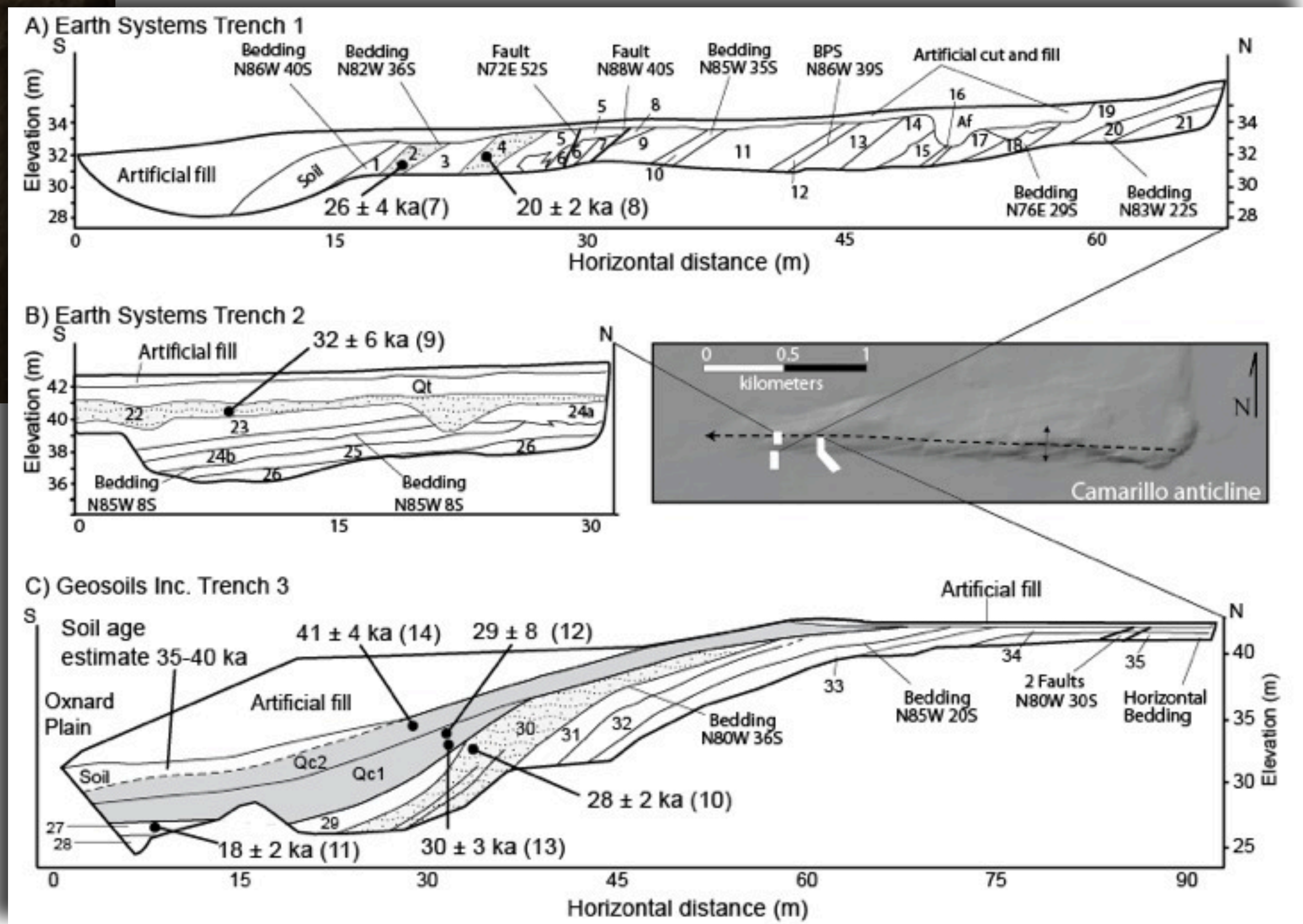
Camarillo Anticline



Paloeseismic Trench across the Camarillo Anticline

Paloeseismic Trench across the Camarillo Anticline





Results

TABLE 2. MAGNITUDES AND RATES OF DEFORMATION

Fault name	Structural domain	Total uplift (m)	Fault uplift (m)	Fold uplift (m)	Fault slip (m)	Shortening (%)	Age range of offset datum (ka)	Fault slip rate range (mm/yr)*	Total uplift rate range (mm/yr)*	Shortening rate range (mm/yr)*
Simi	Simi		24		26		23–25†	1.0–1.1		
Southern Simi (long-term)	Las Posas	297	97	200	104	5	116–134§	0.8–0.9	2.2–2.5	0.8–1.0
Southern Simi (short-term)			24		26		23–25†	1.0–1.1		
Southern Santa Rosa (long-term)	Santa Rosa	225	78	147	83	3	78–86•	1.0–1.1	2.6–2.8	0.7–0.8
Southern Santa Rosa (short-term)			25–30		27–32		23–25†	1.1–1.4		
Santa Rosa Valley	Santa Rosa	30	30	0	32		23–25†	1.3–1.4††	1.2–1.3††	
Northern Springville	No. Springville	356	92	264	98	6	78–86•	1.1–1.3	4.1–4.6	1.7–1.8
Southern Springville	So. Springville	174	74	100	78	4	78–86•	0.9–1.0	1.9–2.2	0.6–0.7
Camarillo		45					26–40**	N/A	1.1–1.7	

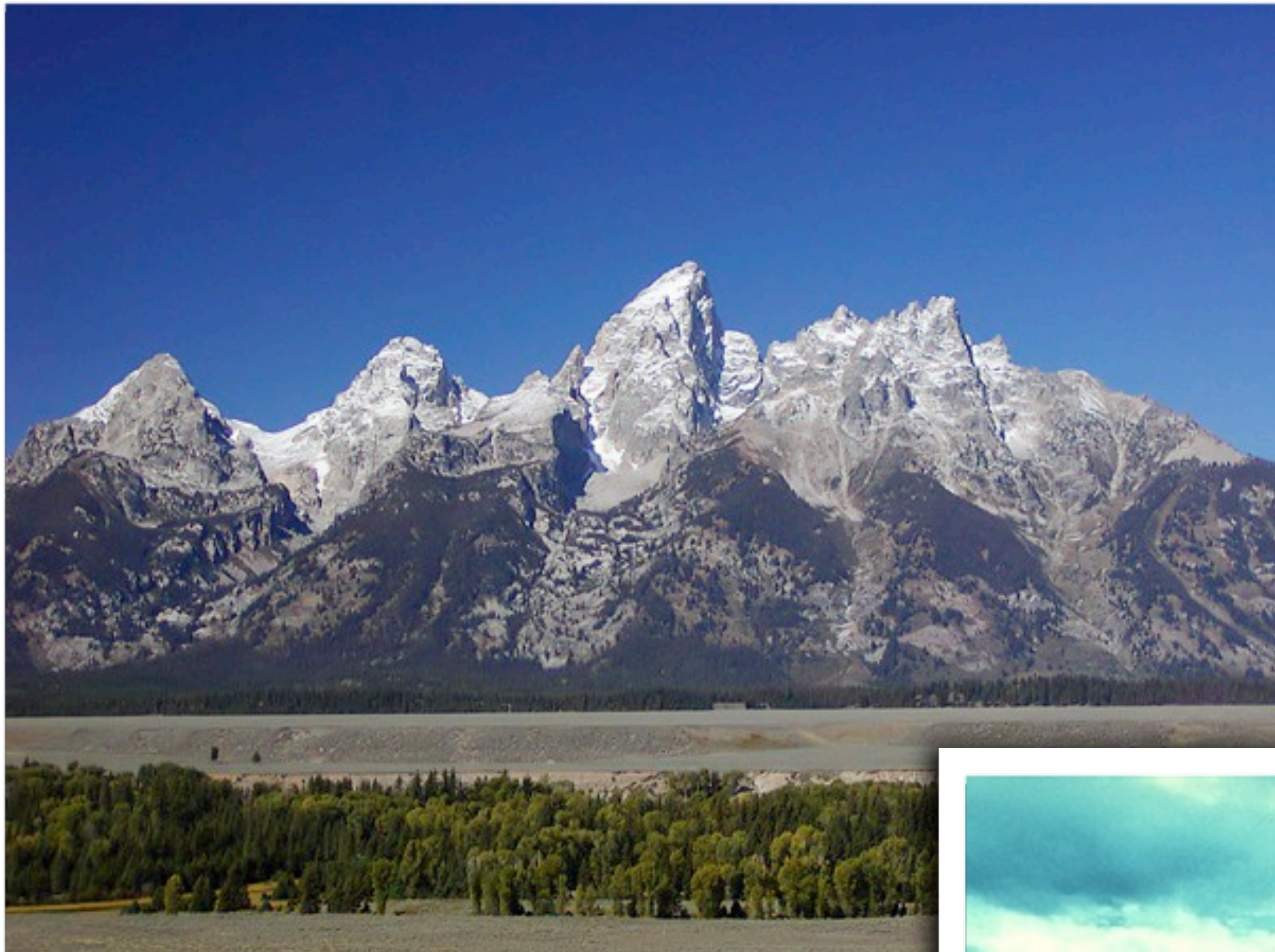
Note: Gray boxes represent compound systems discussed in text.
*Rate estimate represents minimums where based on the age of Qcsm and Qoa, which is always older than the timing of tectonic deformation.
†Age of the Qt2 surface based the weighted mean of two optically stimulated luminescence (OSL) dates (Table 1) and a single radiocarbon age DeVecchio et al. (2012).
§Age range estimate based on infrared stimulated luminescence (IRSL) age and associated error on deformed Qscm strata within the Las Posas domain (see Fig. 4A; Table 1).
•Age range estimate based on the weighted mean of three IRSL ages from the base of Qscm west of the Camrosa fault (see Fig. 4A; Table 1).
**The upper age limit is based on the minimum possible age of the soil and the minimum age of OSL samples from the forelimb of the anticline assuming a water content of 50%, whereas the lower age is based on the maximum age of the soil (see text for discussion).
††Rate estimate is a maximum because deformation began before the Qt2 strath was cut (see text for discussion).

TABLE 3. CAMARILLO FOLD BELT EARTHQUAKE MAGNITUDE MODEL AND FAULT RECURRENCE INTERVALS

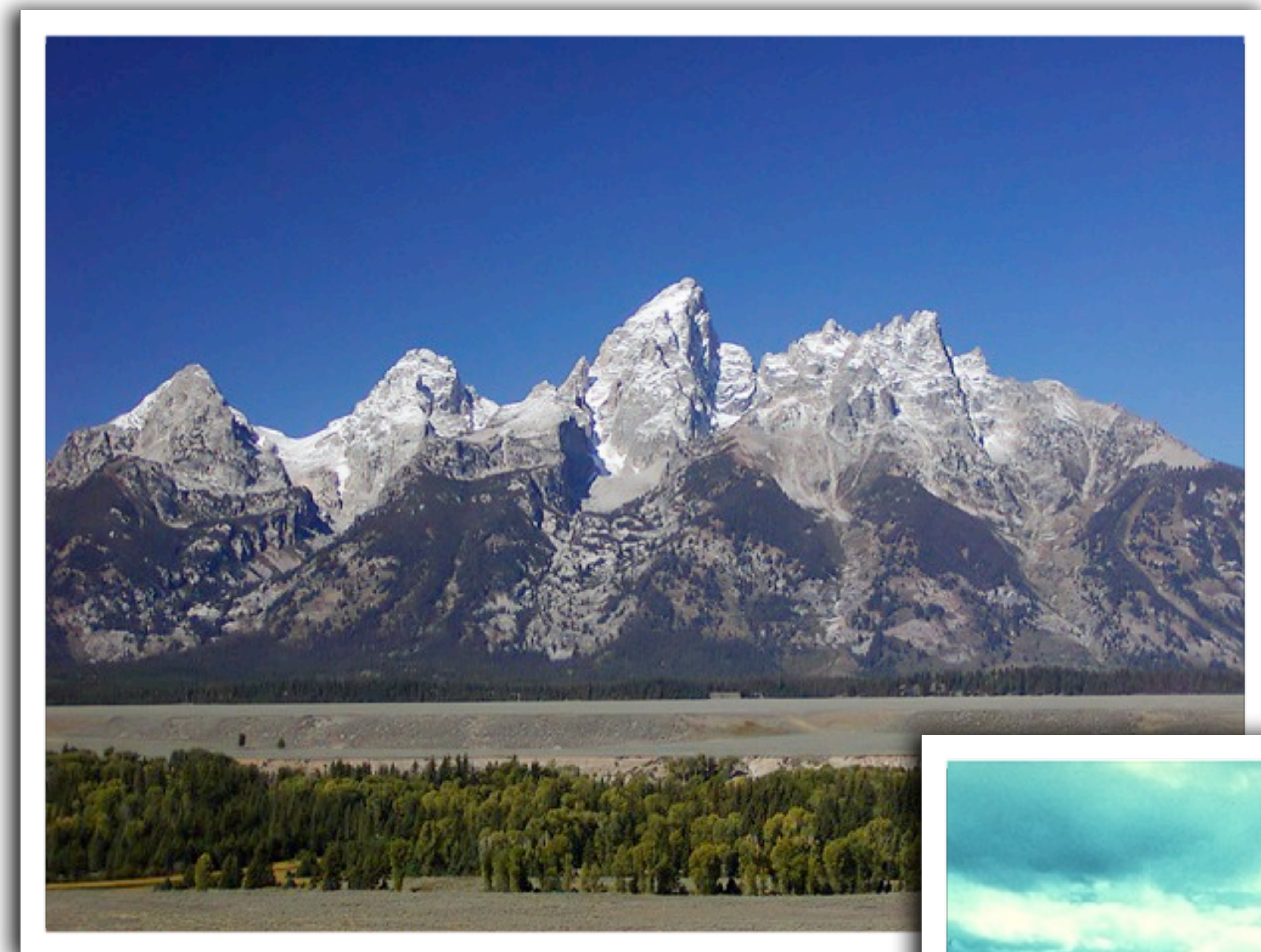
Fault name	Structural domain	Length (km)*	Area (km²)†		Max (M_w)§		Max (M_w)•		Recurrence interval (yr)**
			Depth (5 km)	Depth (17 km)	Min	Max	Min	Max	
Simi fault system	Simi–Las Posas–Santa Rosa	31.4	267.3	401.0	6.5	6.7	6.6	6.8	715–1000
Southern Santa Rosa	Santa Rosa	4.4	37.5	79.6	5.7	6.0	5.9	6.2	900–1000
Santa Rosa Valley	Santa Rosa	4.8	40.9	86.8	5.8	6.1	5.9	6.2	770
No. Springville Fault	Northern Springville	6	51.1	108.5	5.9	6.2	6.0	6.3	715–910
So. Springville	Southern Springville	3.5	29.8	63.3	5.7	6.0	5.8	6.1	910–1100
Camarillo	–	5.5	46.8	99.5	5.8	6.1	6.0	6.3	590–910

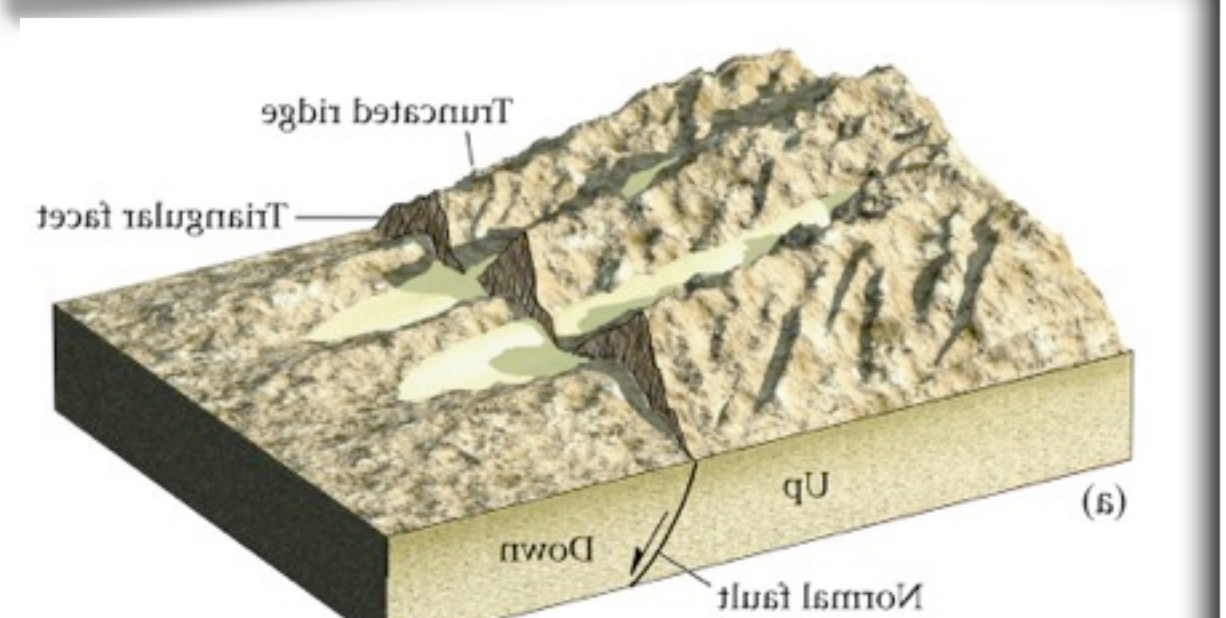
Note: Gray box represents the compound Simi–Las Posas–Santa Rosa system discussed in text.
*Fault length is assumed to be the surface rupture length and may be slightly different than map length.
†Calculated fault area extends from 5 km and 17 km to the surface.
§Moment magnitude calculated from fault plane area with rupture at a depth of 12 km, using a regression of global reverse-motion earthquakes, $M_w = 4.33 + 0.90*\log(\text{area})$ from Wells and Coppersmith (1994).
•Moment magnitude calculated from fault plane area with rupture at a depth of 12 km, using a regression of global reverse-motion earthquakes, $M_w = 4.56 + 0.86*\log(\text{area})$ from Dolan et al. (1995).
**Average coseismic slip was assumed to be 1 m based on previous paleoseismic observations from the Springville and Simi faults (Gonzalez and Rockwell, 1991; Hitchcock et al., 1998). Recurrence interval was calculated by dividing average slip by the rate of fault slip (Table 3).

Grand Tetons



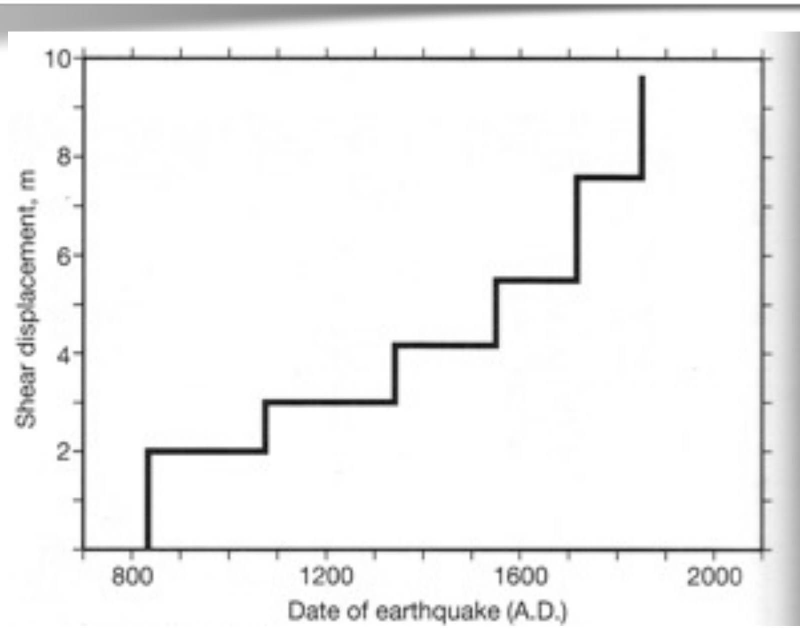
Grand Tetons





1954 Fairview Peak fault Scarp (M=7.2)

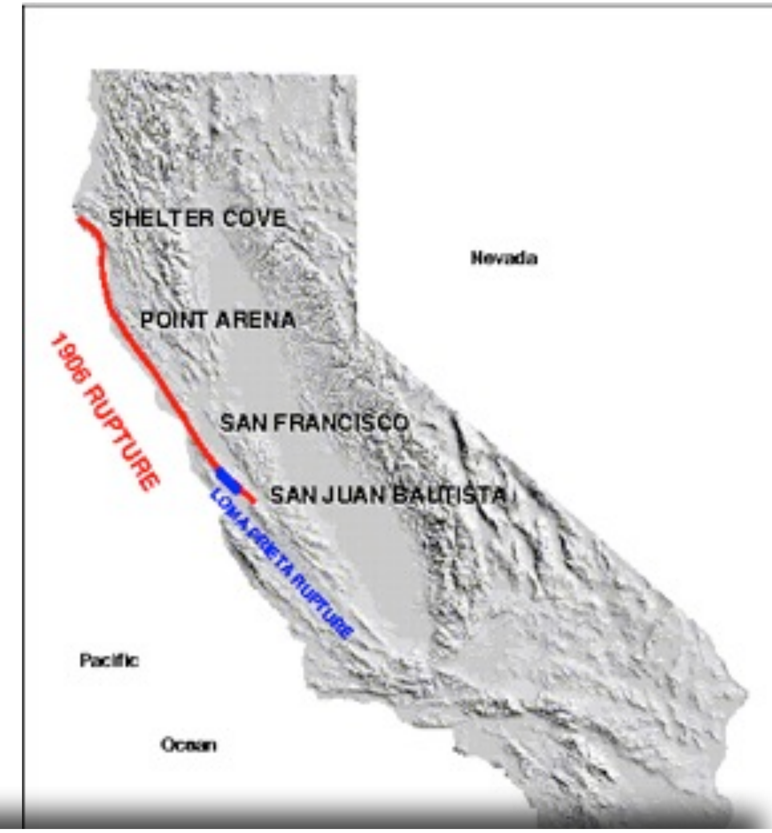
Normal
Displacement
32 km long
Avg. 1.2 m



1999 Chi Chi Earthquake, Taiwan (M= 7.6)

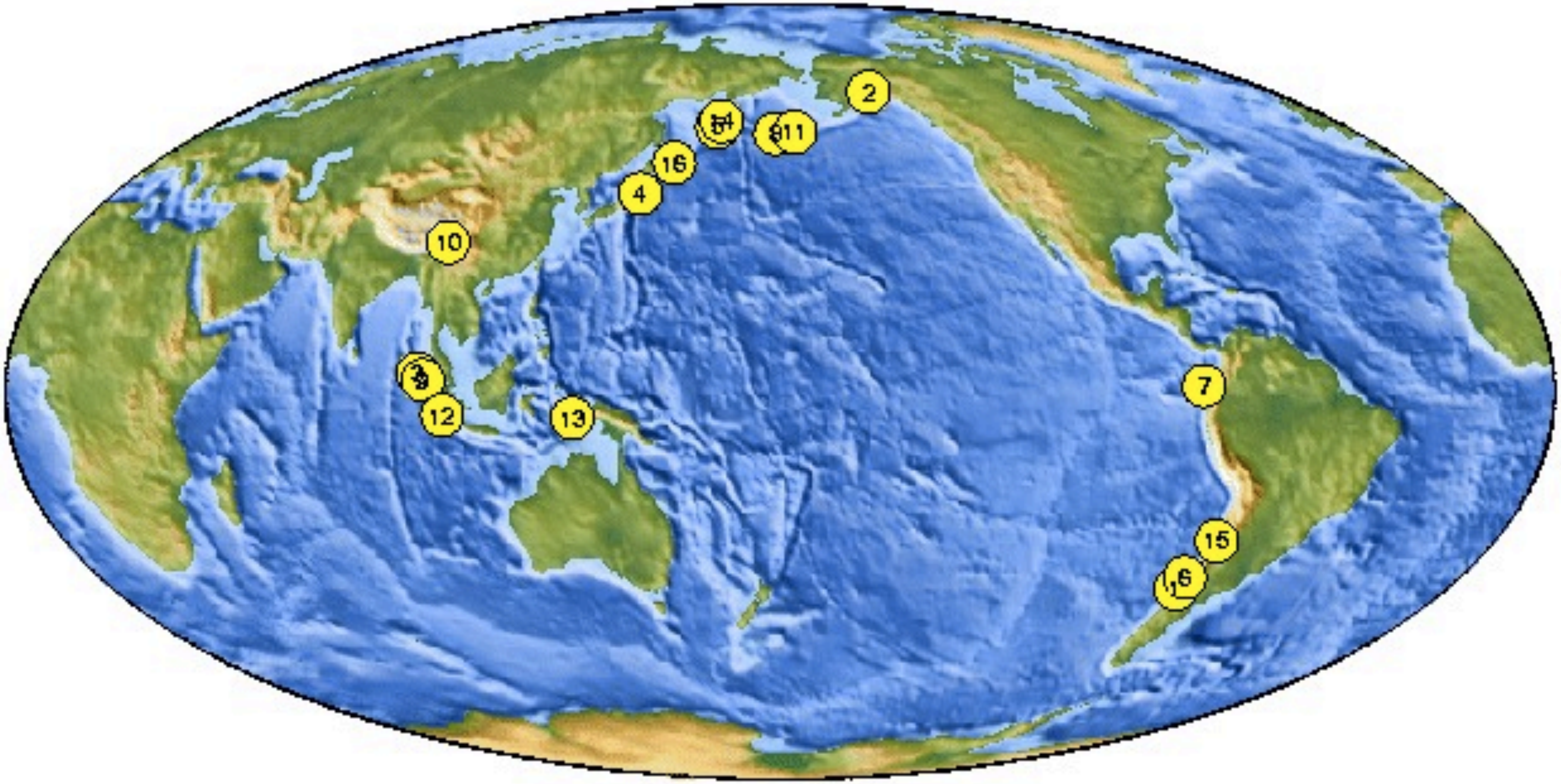
Reverse Displacement
400 km long
as much as 16m offset

1906 San Francisco (M= 7.9)



Strike-slip Displacement
477 km Rupture length
as much as 8m offset

Largest Earthquakes in the World Since 1900



Four largest Recorded Earthquakes

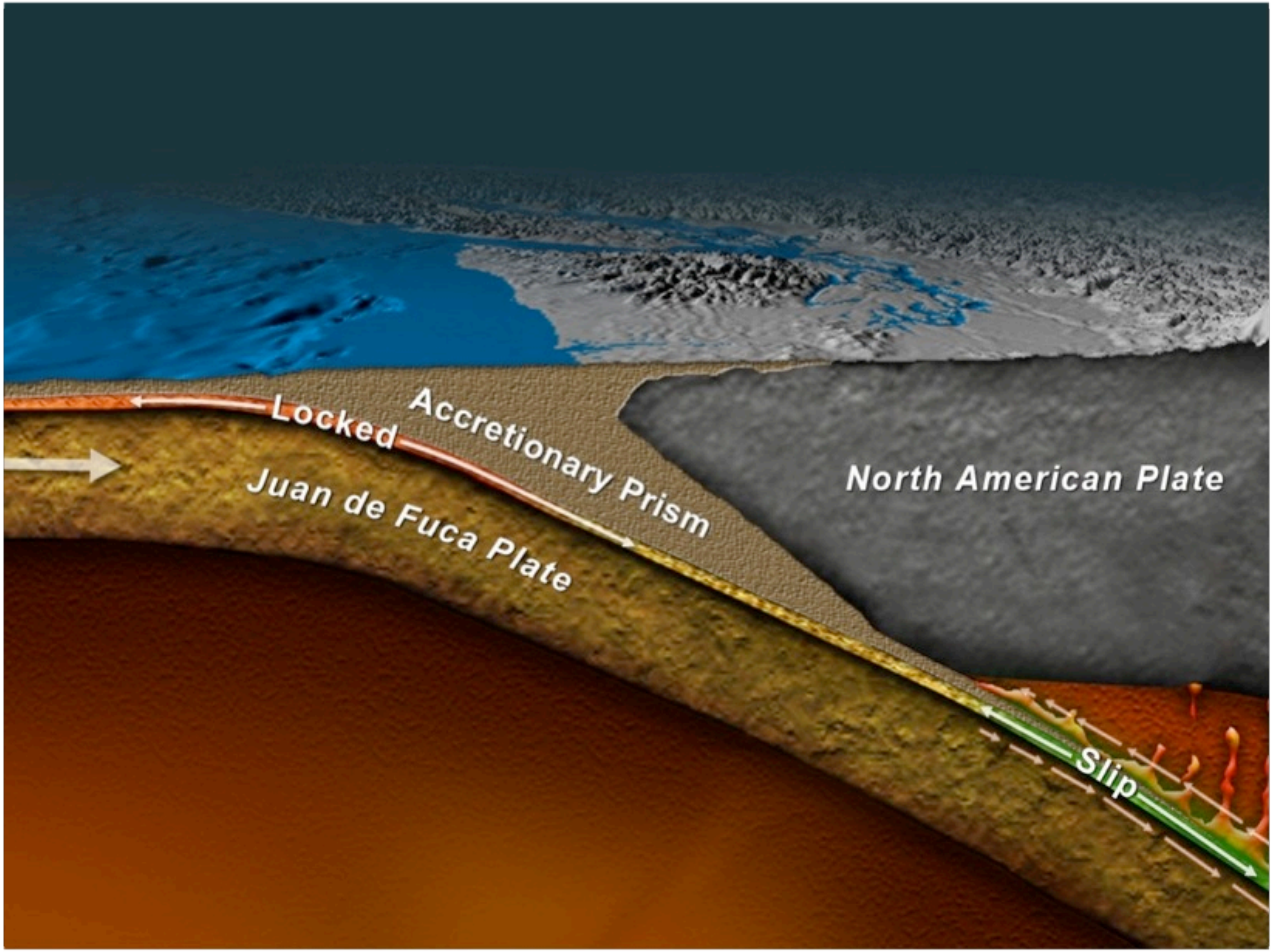
1) 1960 Chile Earthquake (M =9.5)
   Reverse displacement, 1000 km offset 20 m

2) 1964 Great Alaskan Earthquake (M=9.2)
   Reverse displacement, 1000 km offset 15 m

3) 2004 Sumatra Earthquake (M =9.1)
   Reverse displacement, 1600 km offset 10 m

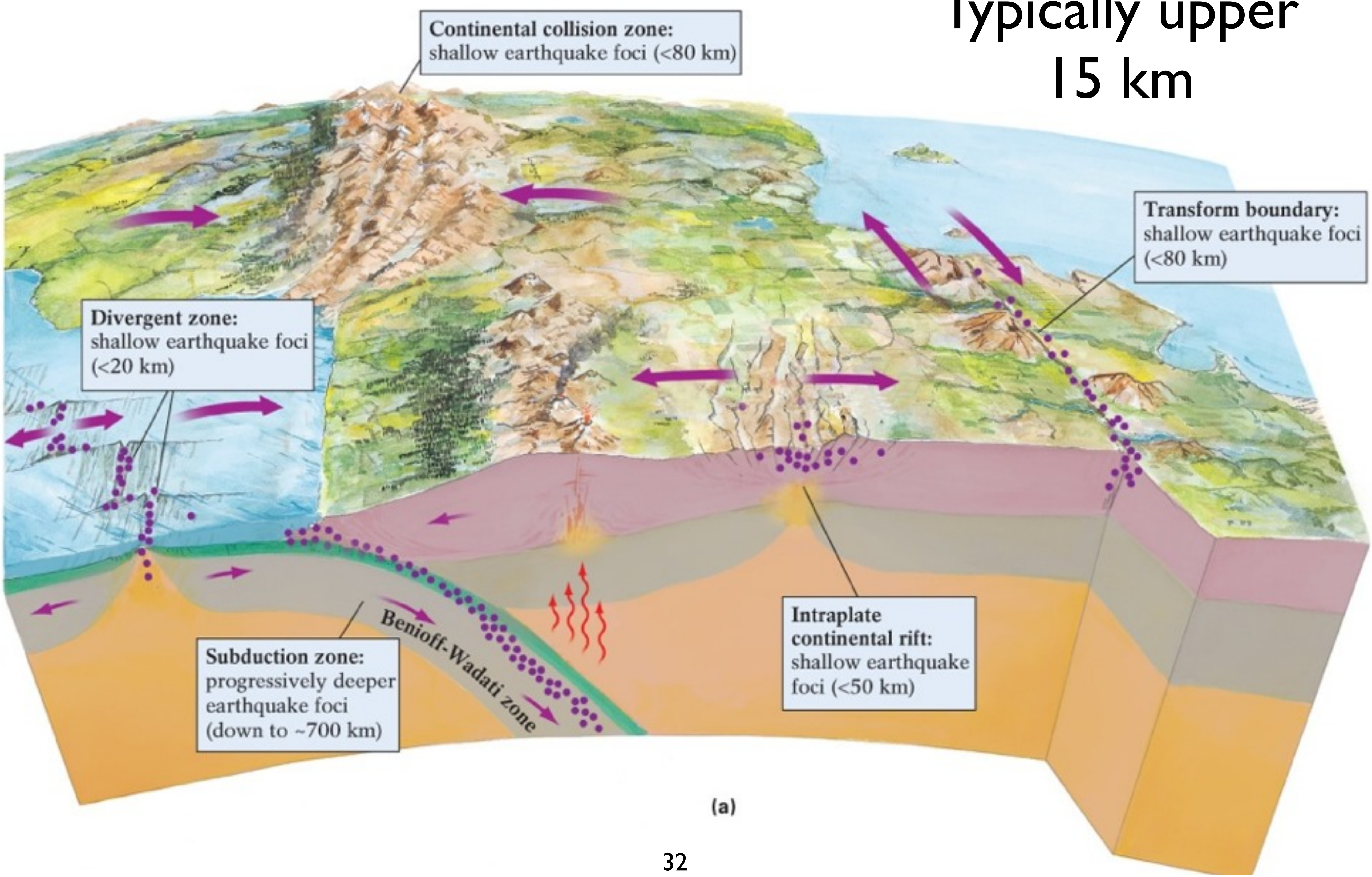
5) 2011 Tohoku Earhquake (M =9.0)
   Reverse displacement, 1600 km offset 5 m

What is happening at subduction zones?



Where Earthquakes Happen

Typically upper 15 km



Hazards Associated with Earthquakes

Permanent fault offset

Shaking

- Ground Acceleration
- Amplification
- Liquifaction
- Resonance

Tsunami

Fire

Permanent Fault Offset

1999 Izmet, Turkey

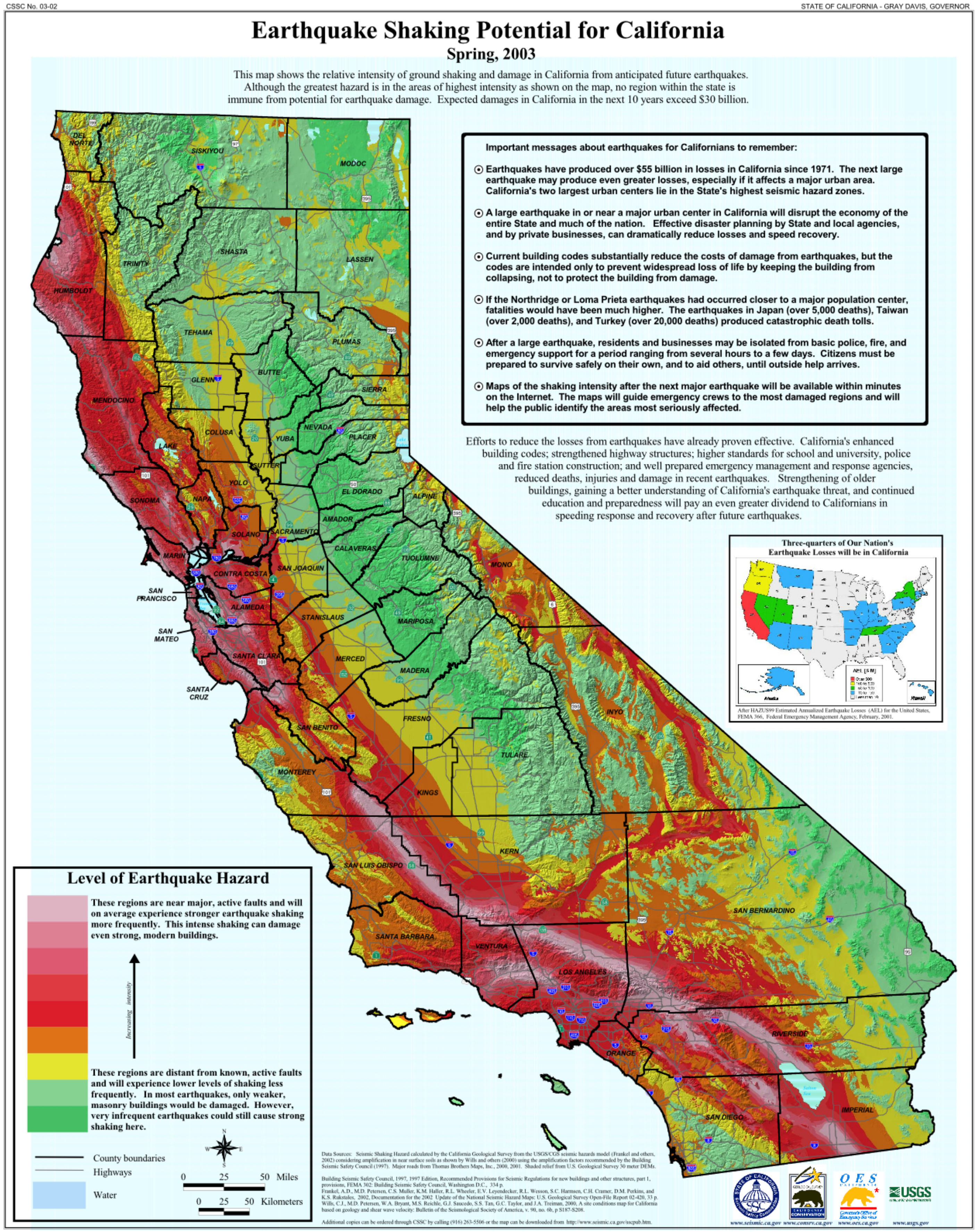
Shaking Ground Acceleration

The rate of change of ground velocity as seismic waves propagate both vertically and horizontally

Based on the acceleration due to gravity

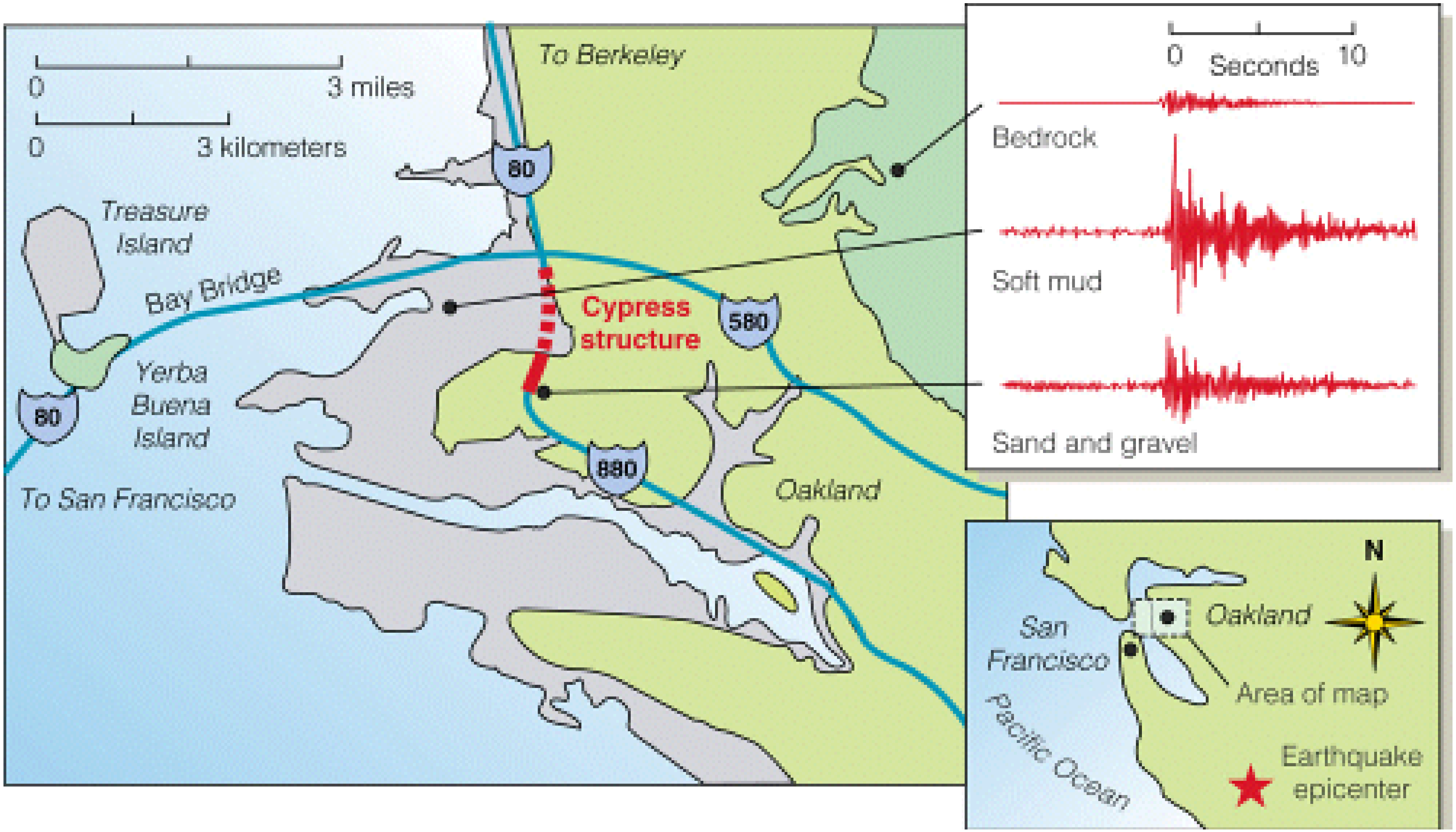
- $9.8 m/s^2$ ($32 ft/s^2$) = 1.0g
- Weak buildings experience damage at 0.1g
- People begin to loose footing around 0.2g

In Tarzana during 1994 Northridge Earthquake accelerations reached 1.2g vertical and 1.8g horizontal



Shaking Potential in California

Shaking Amplification



Loma Prieta, 1989

Shaking Liquefaction

The pressure of water increases with shaking pushing individual grains apart allowing substrate to flow as a liquid.

Shaking Liquefaction

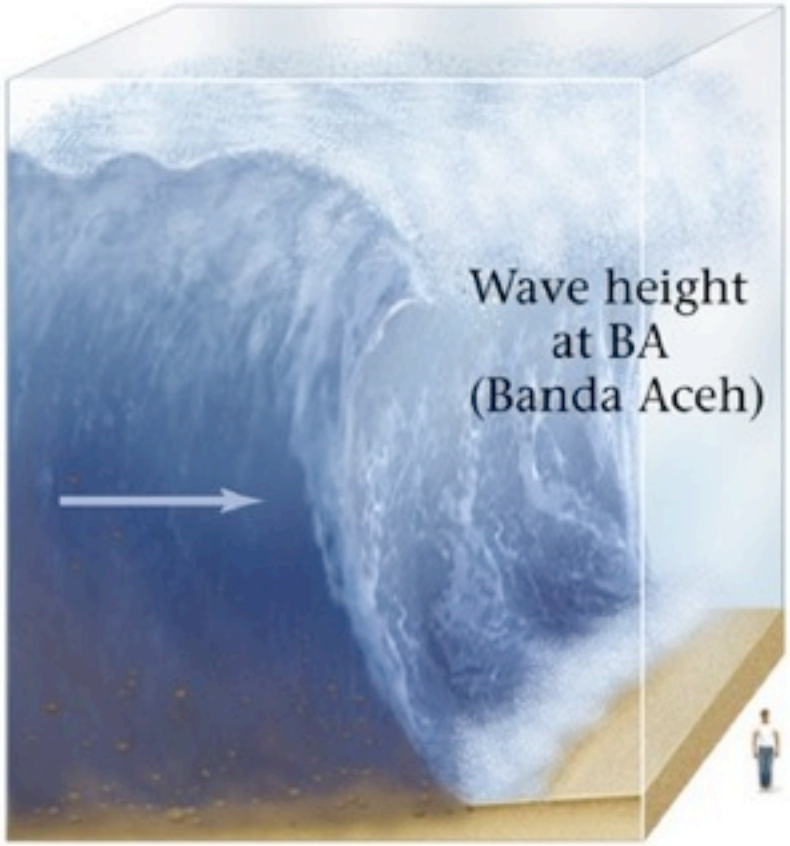
Anchorage, AK 1964

Shaking Resonance

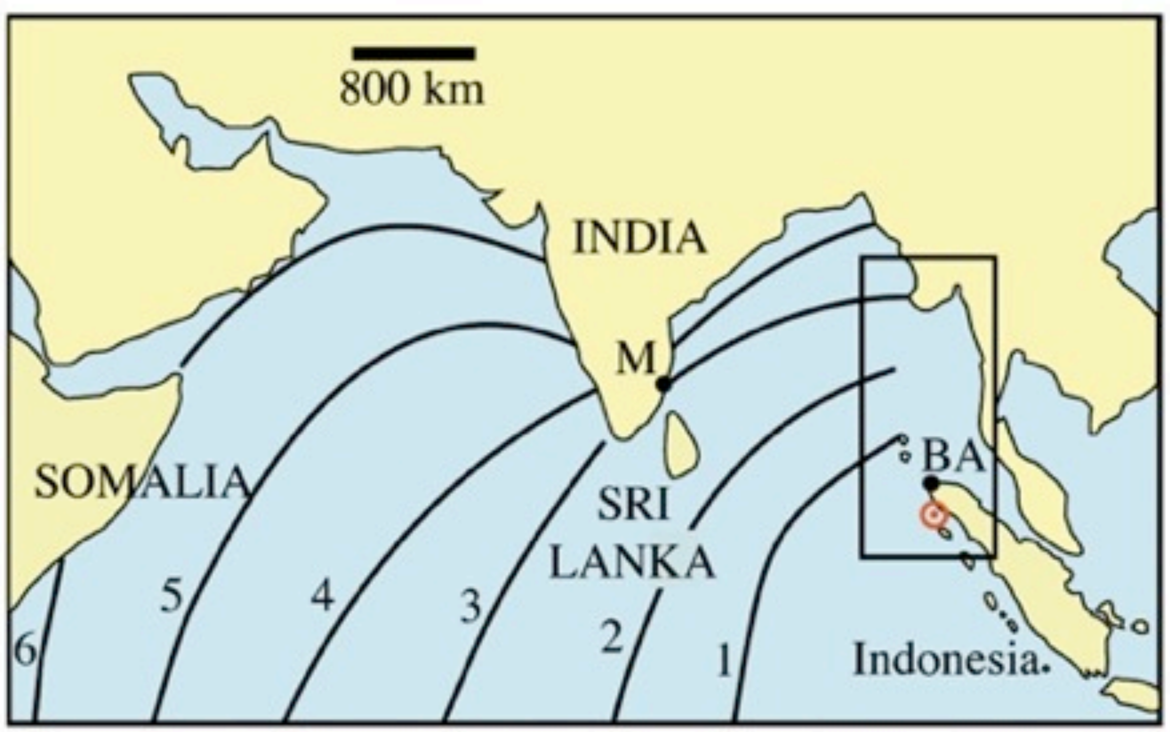
if seismic waves and a particular building has the same vibrational frequency*, enhanced motion occurs

* every object has a natural vibration frequency based on SIZE and MASS

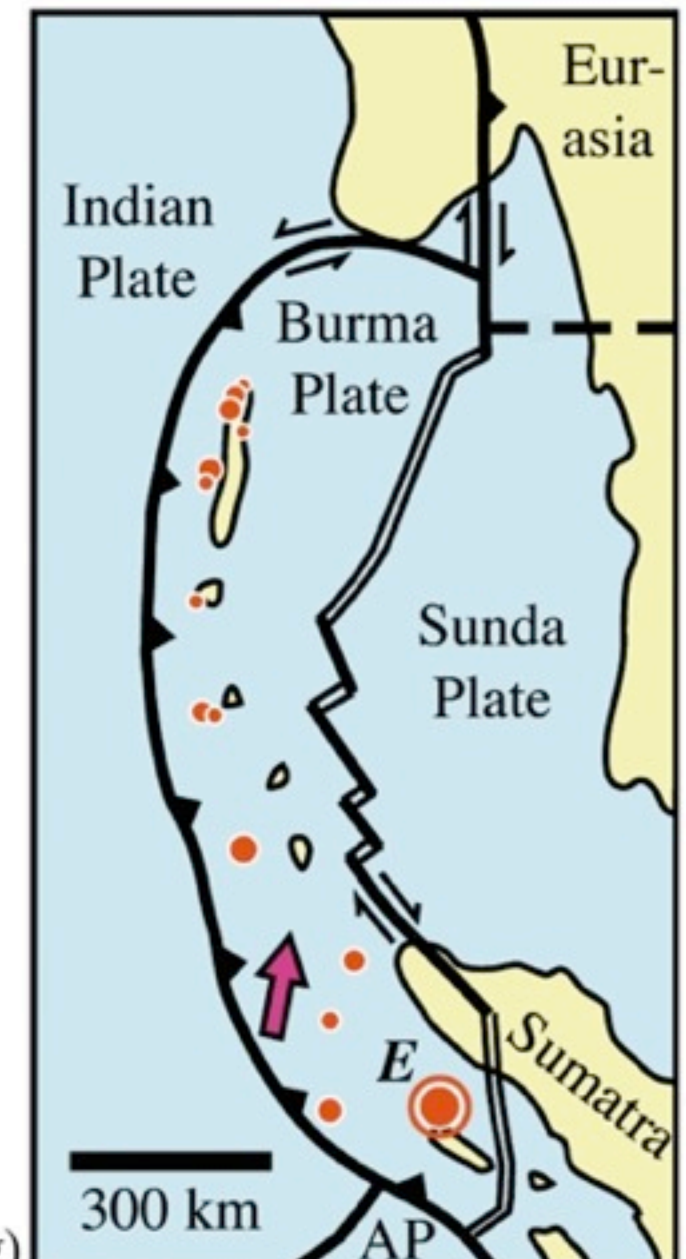
Tsunami


Wave height
at BA
(Banda Aceh)

(b)

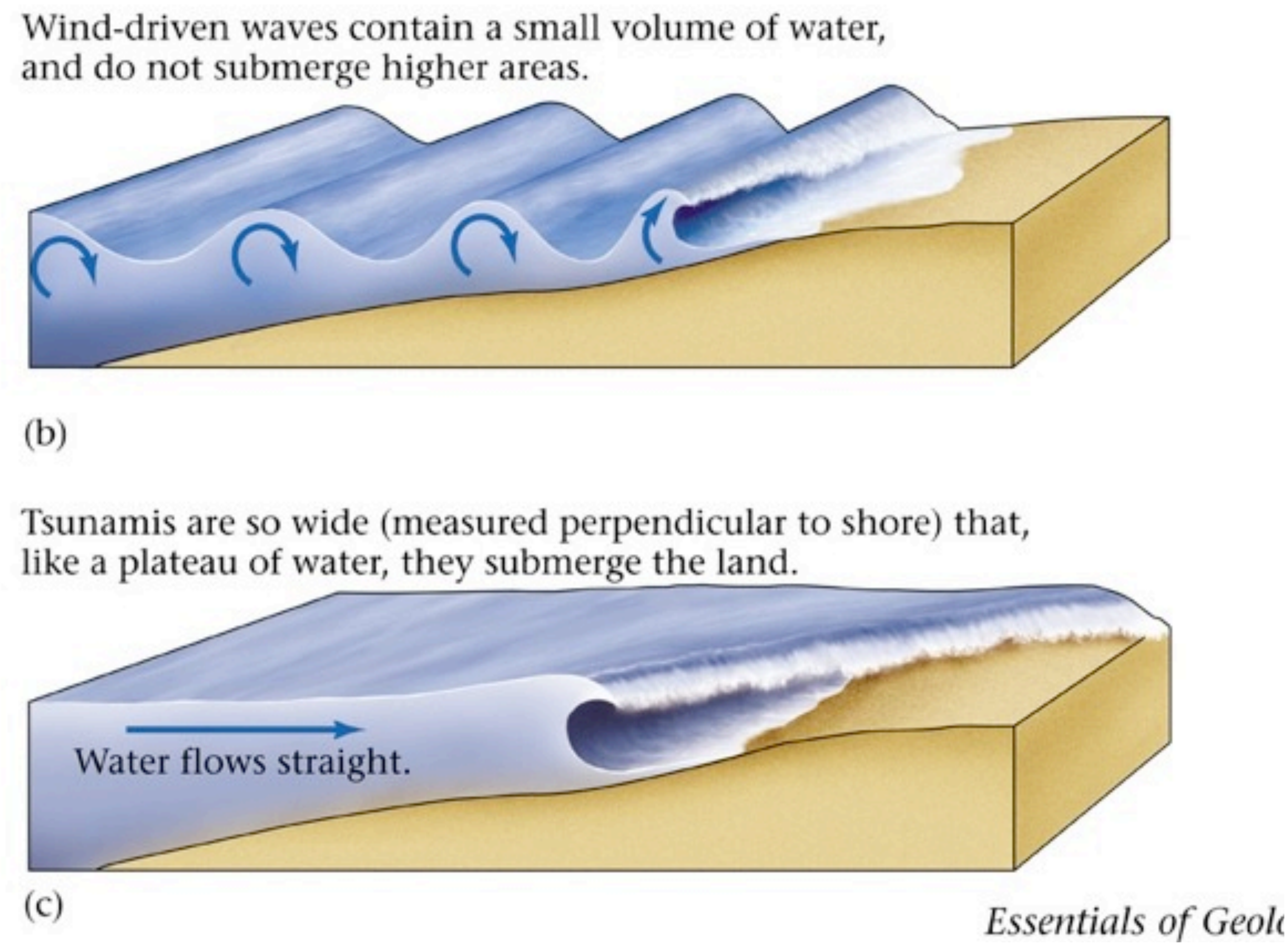

800 km
INDIA
M
SOMALIA
SRI
LANKA
BA
Indonesia
6
5
4
3
2
1

(f)


Eur-
asia
Indian
Plate
Burma
Plate
Sunda
Plate
Sumatra
E
300 km
AP

(g)

Tsunami


Wind-driven waves contain a small volume of water, and do not submerge higher areas.
(b)
Tsunamis are so wide (measured perpendicular to shore) that, like a plateau of water, they submerge the land.
Water flows straight.
(c)
Essentials of Geol

Fire

San Francisco 1906

Buildings, Fires, and Tsunami Kill!

Earthquakes are Fun!

US Geological Survey Headquarters
Menlo Park, CA

2011 Tohoku Japan Tsunami Video

2011 Tohoku Japan Tsunami Video

2011 Tohoku Japan Tsunami Video

2011 Tohoku Japan Tsunami Video