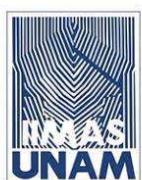


Lithospheric structure and seismotectonics in Southern Mexico, a brief insight

Vladimir Kostoglodov

Institute of Geophysics, UNAM, Mexico

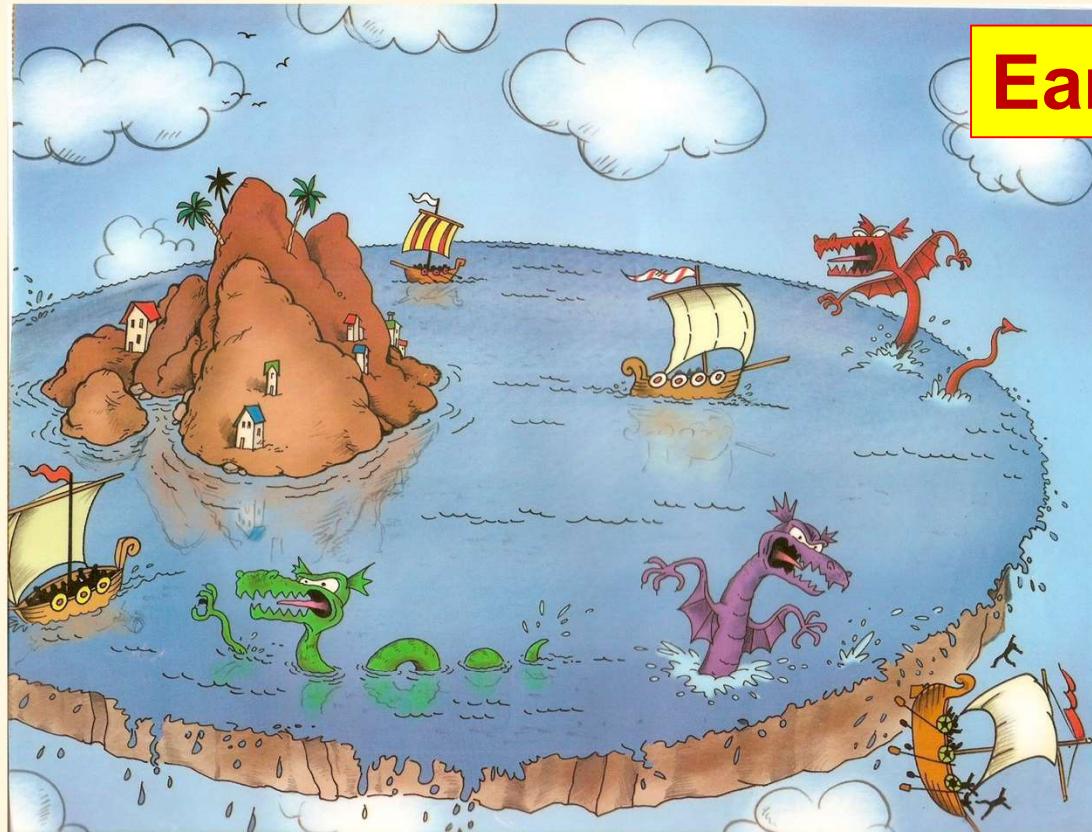


July 20, 2022, IIMAS UNAM



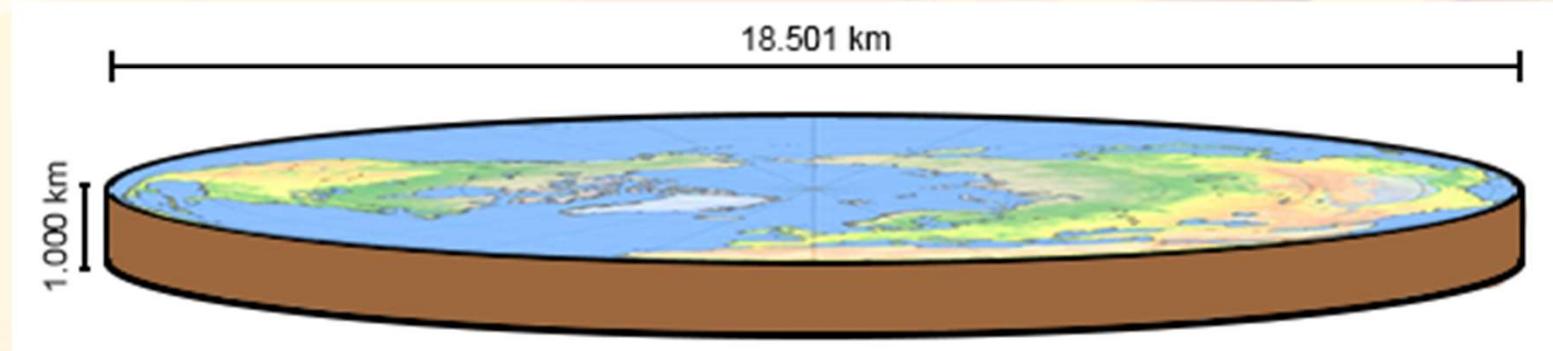
www.DesktopDre

Earth Structure



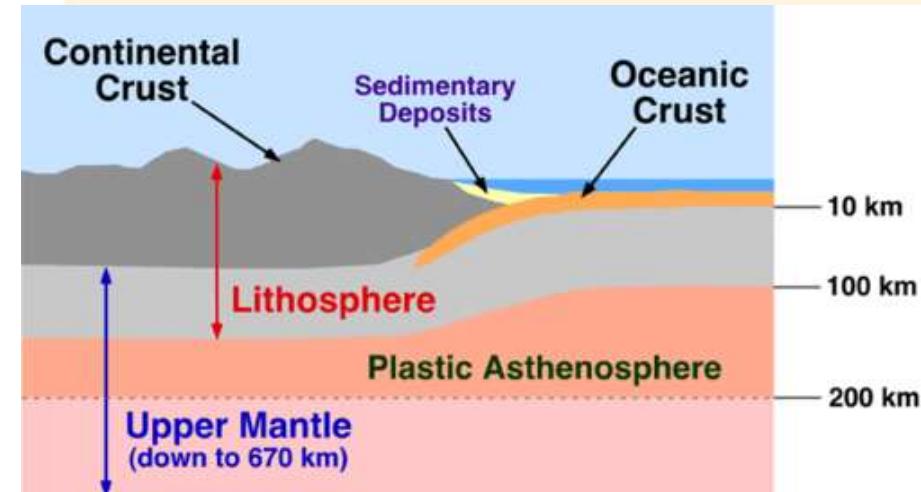
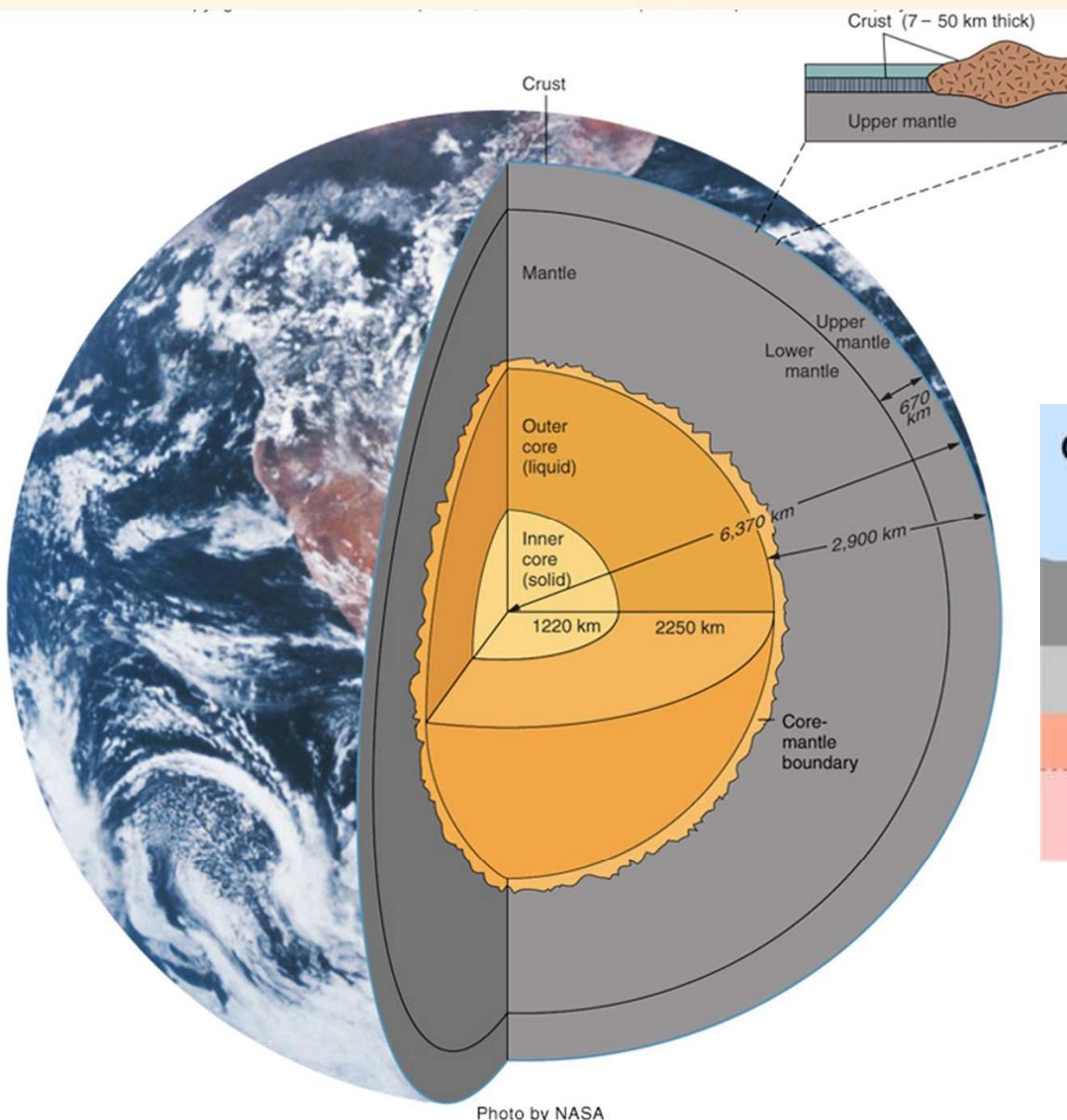
Doubtful Hypothesis !

But bizarrely it is still persists to this day



The Earth

from scientific data



Emil Wiechert, 1896 - an iron core and stony shell

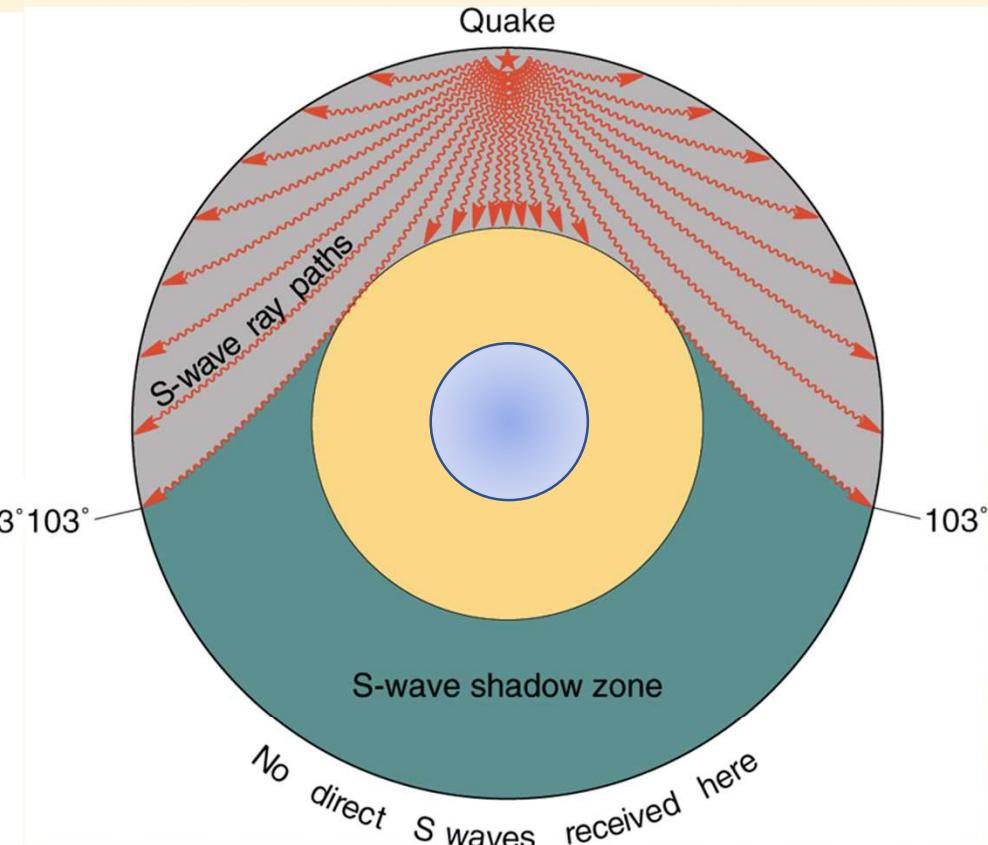
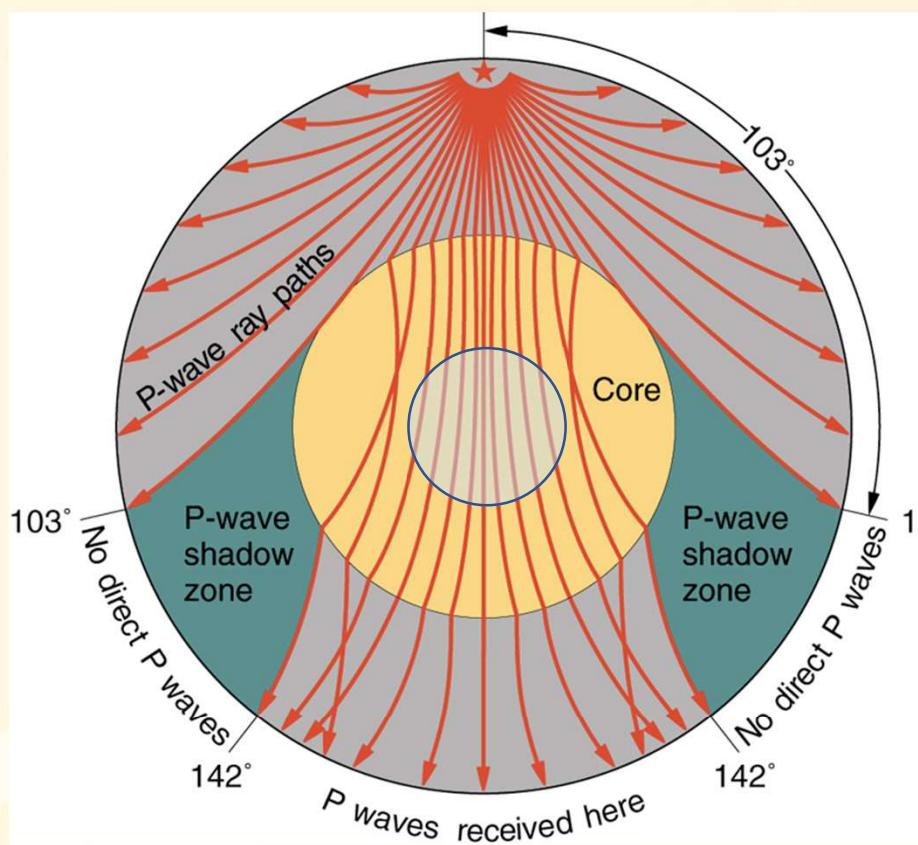
R. D. Oldham, 1906 - a discontinuity between core and shell (mantle)

Beno Gutenberg, - established the depth of this boundary as 2900 km

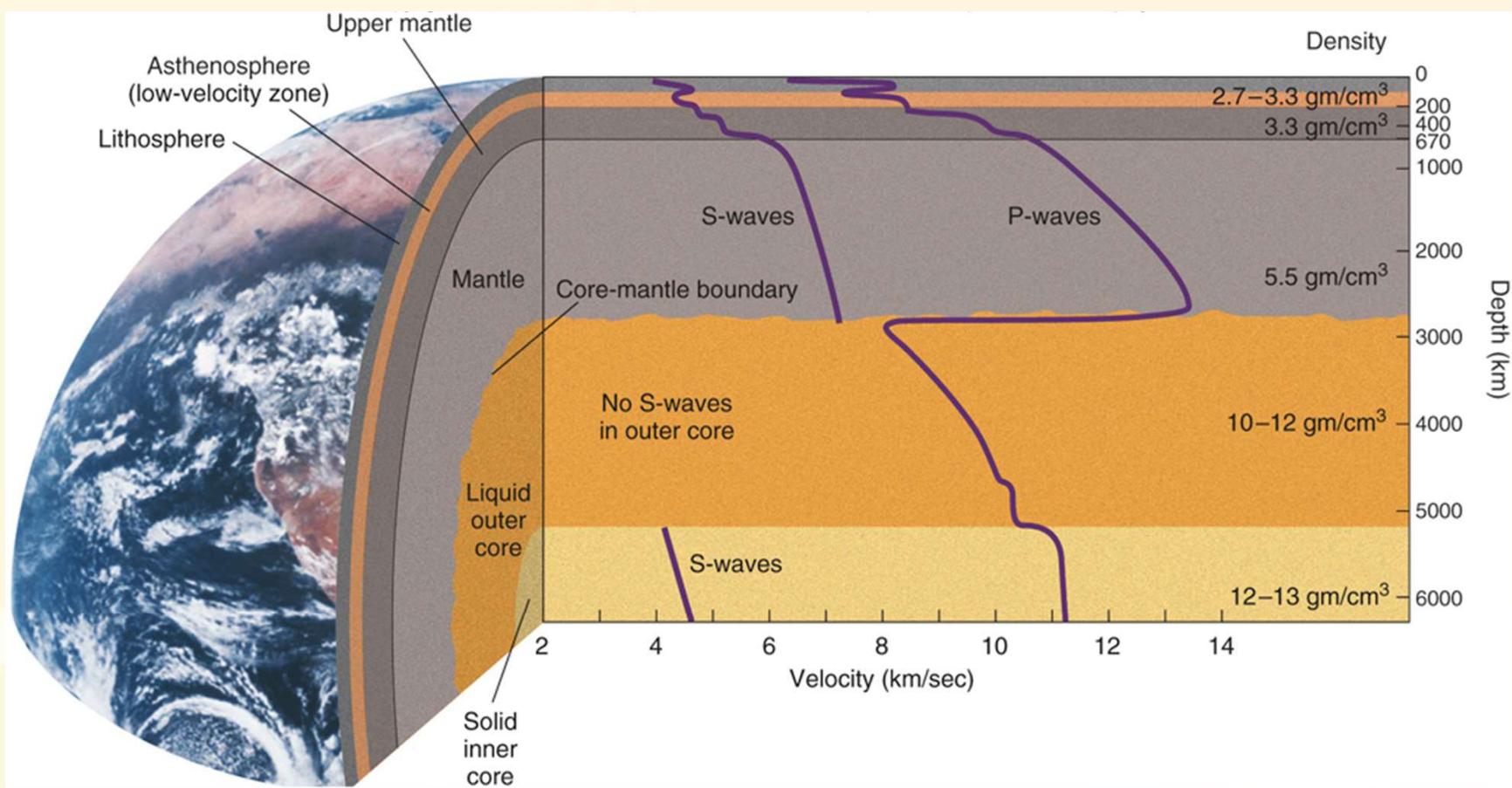
Harold Jeffreys, 1926 - the core is liquid

Inge Lehmann, 1936 – the inner core (S-?)

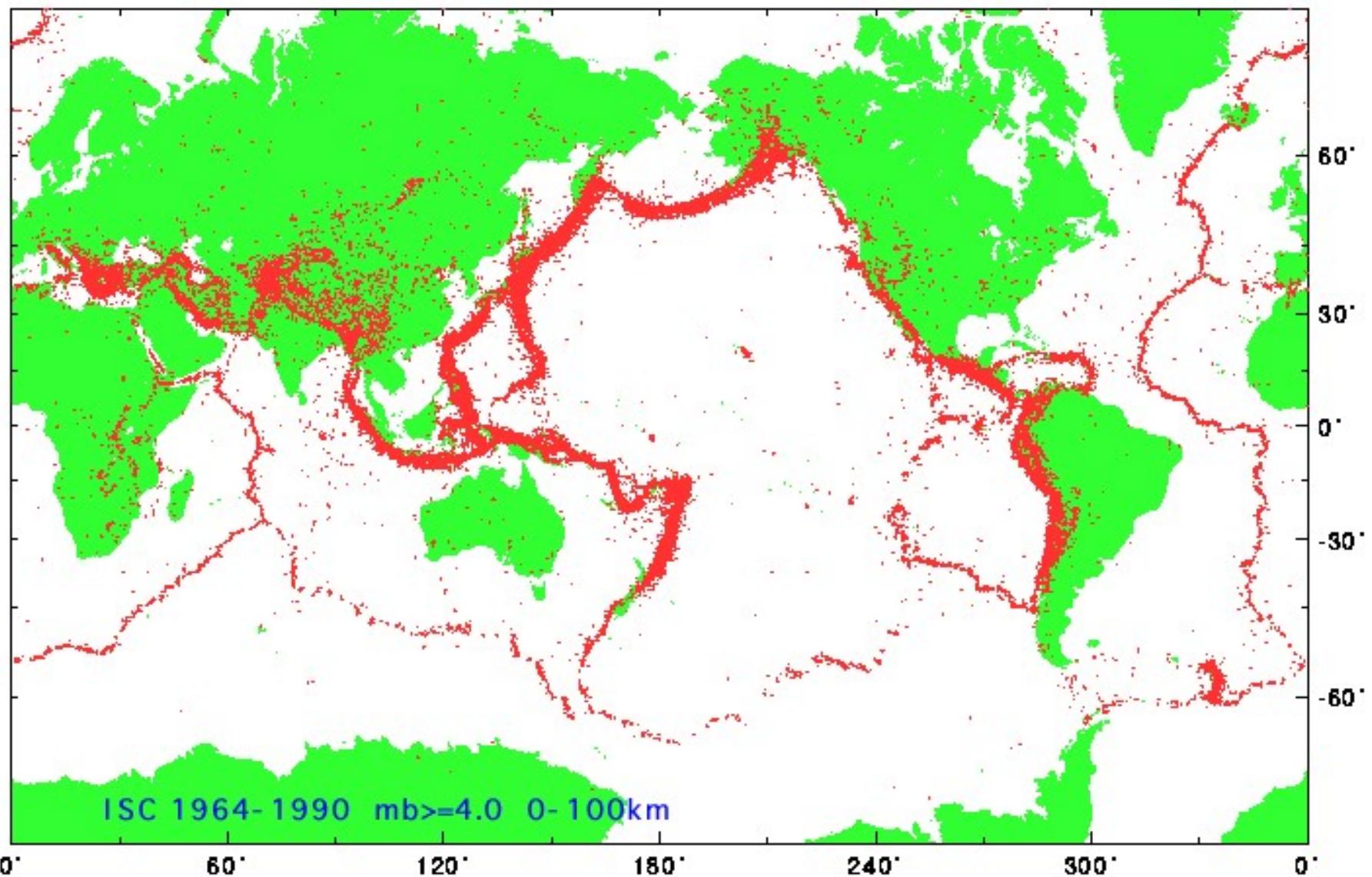
He et al., 2022 – the IC is superionic iron alloys ????????????



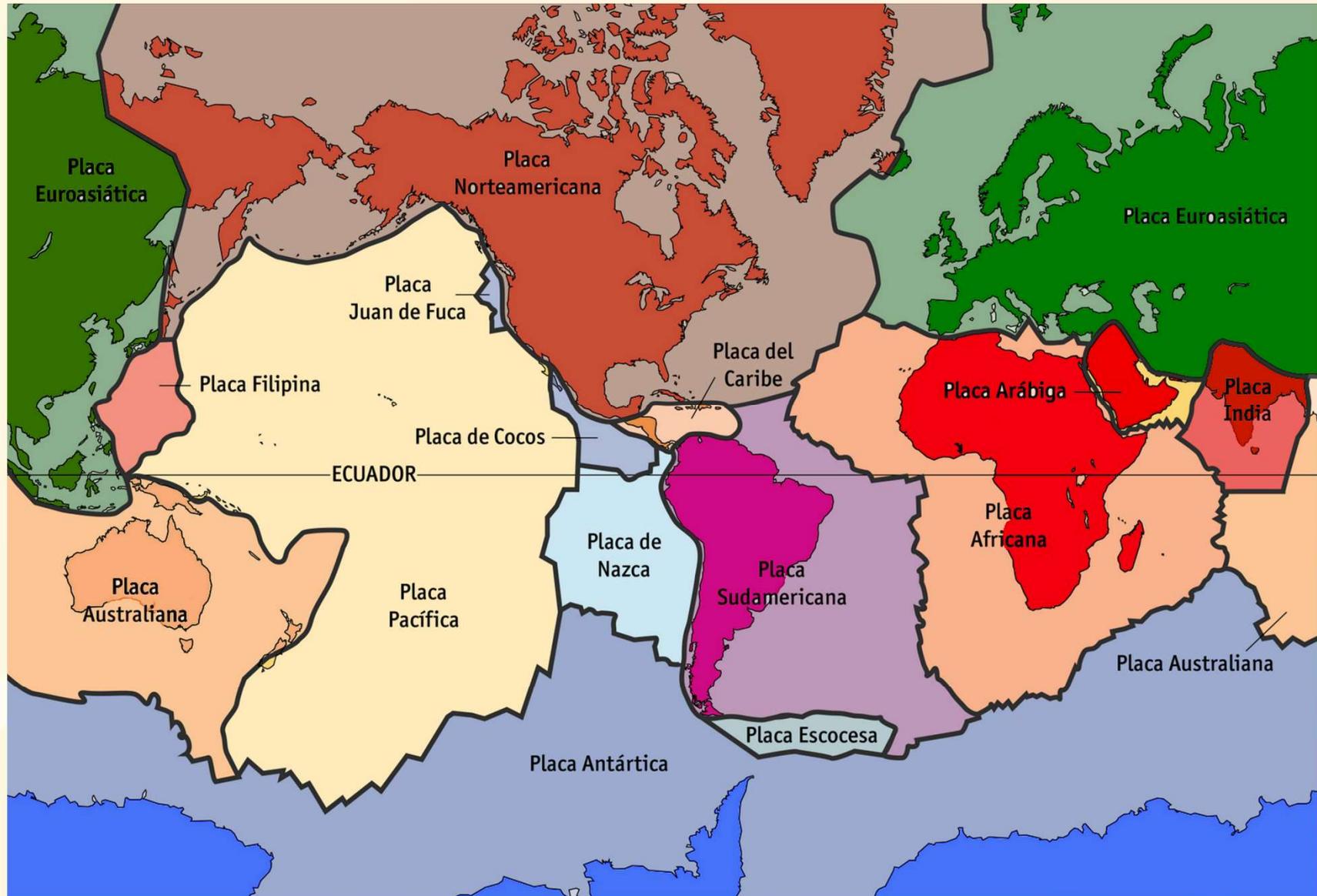
P wave velocities drop suddenly at 2900 km depth, and S waves cannot pass through this layer (the liquid outer core)



World seismicity



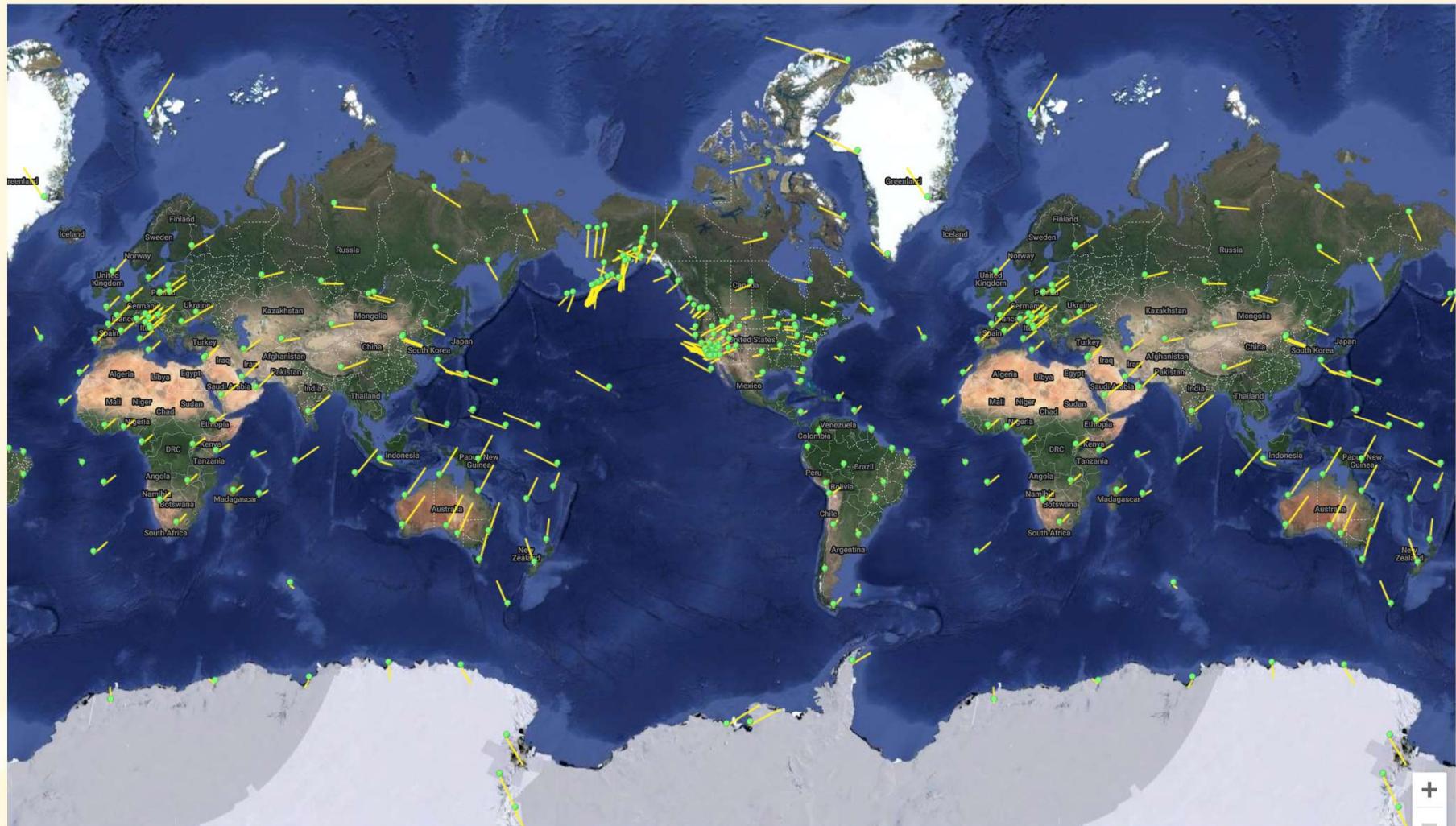
Main tectonic plates





Jet Propulsion Laboratory
California Institute of Technology

Velocities of GPS stations



<https://sideshow.jpl.nasa.gov/post/series.html>

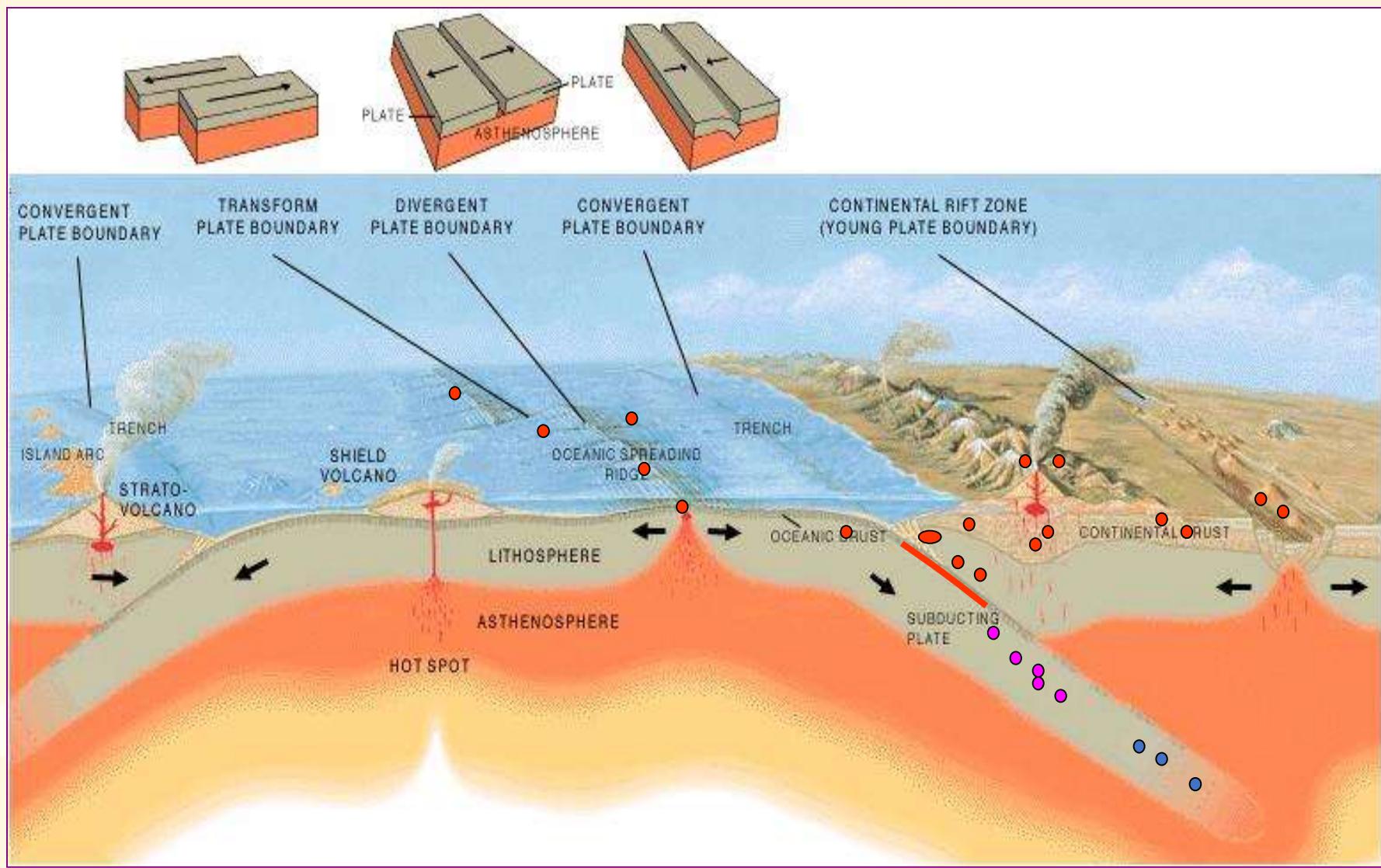


Plate motion forces

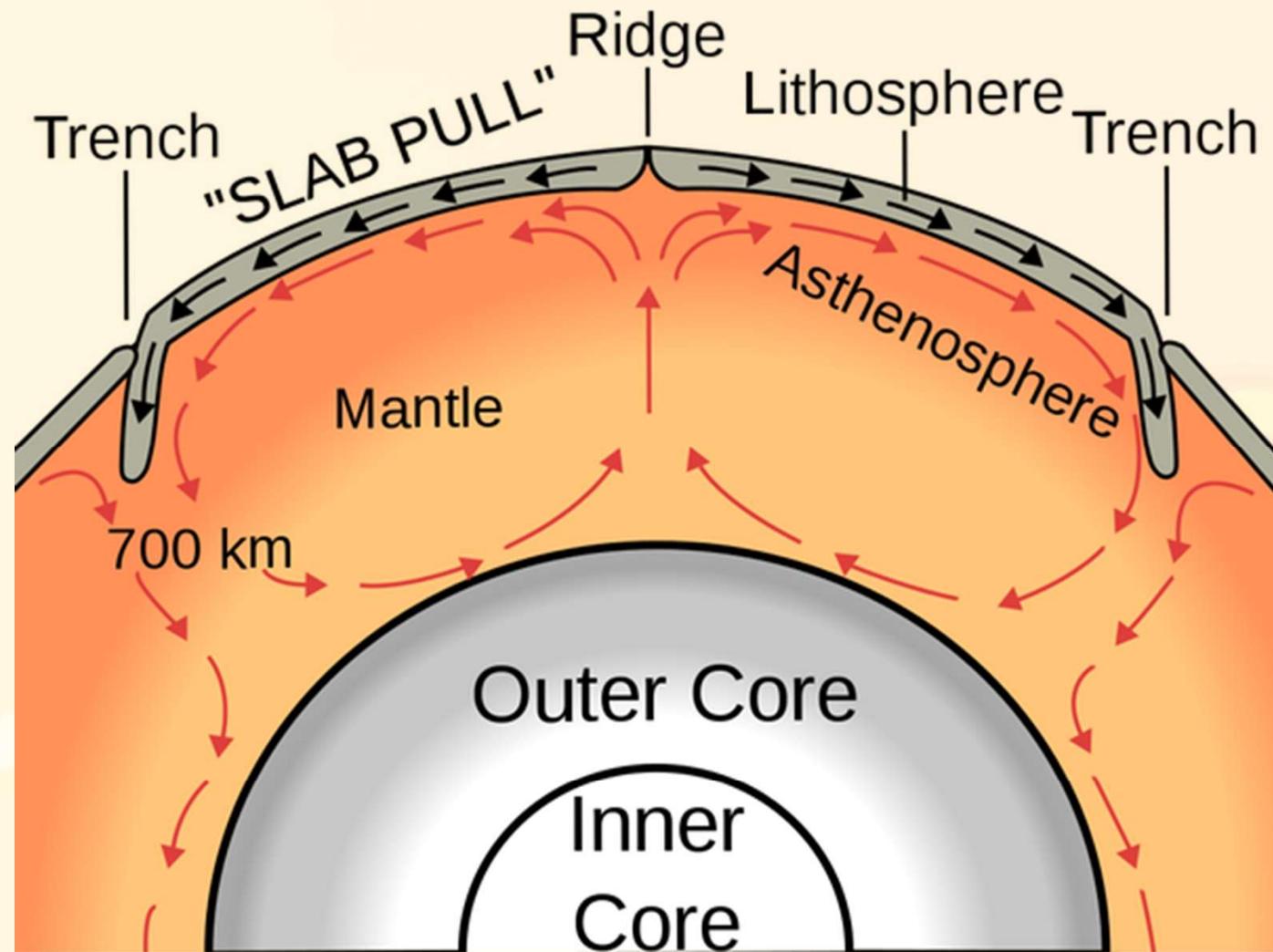
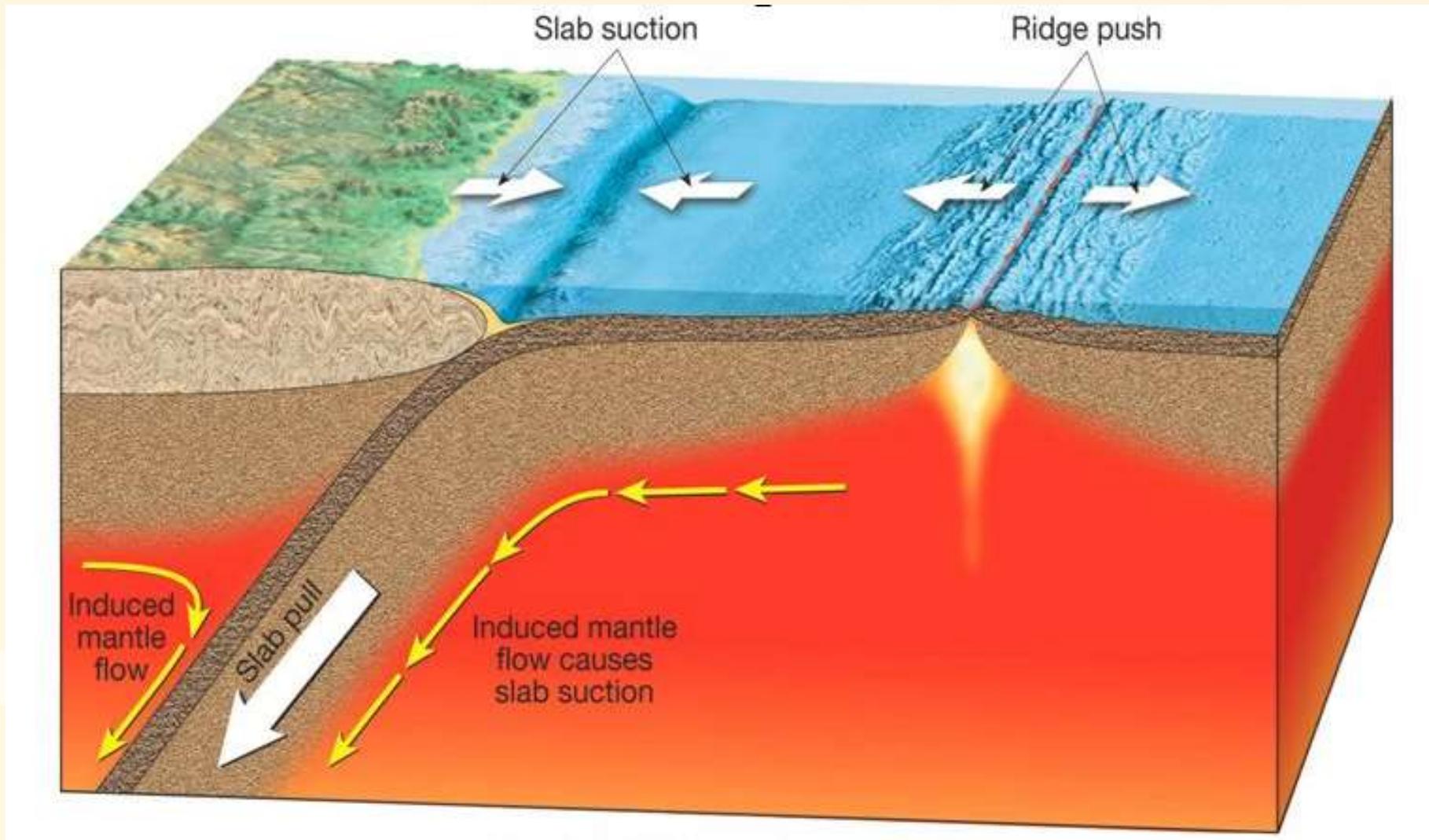
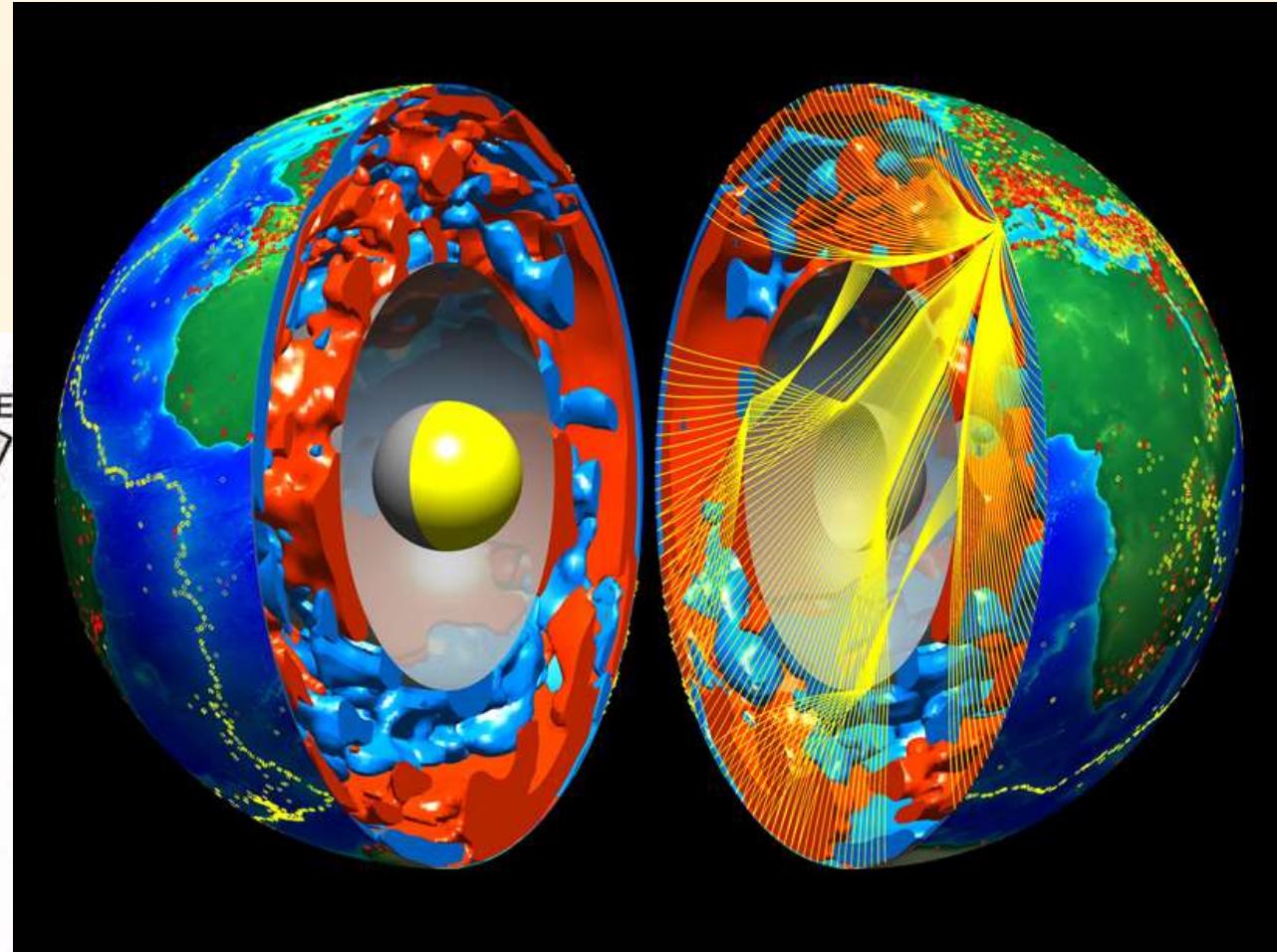
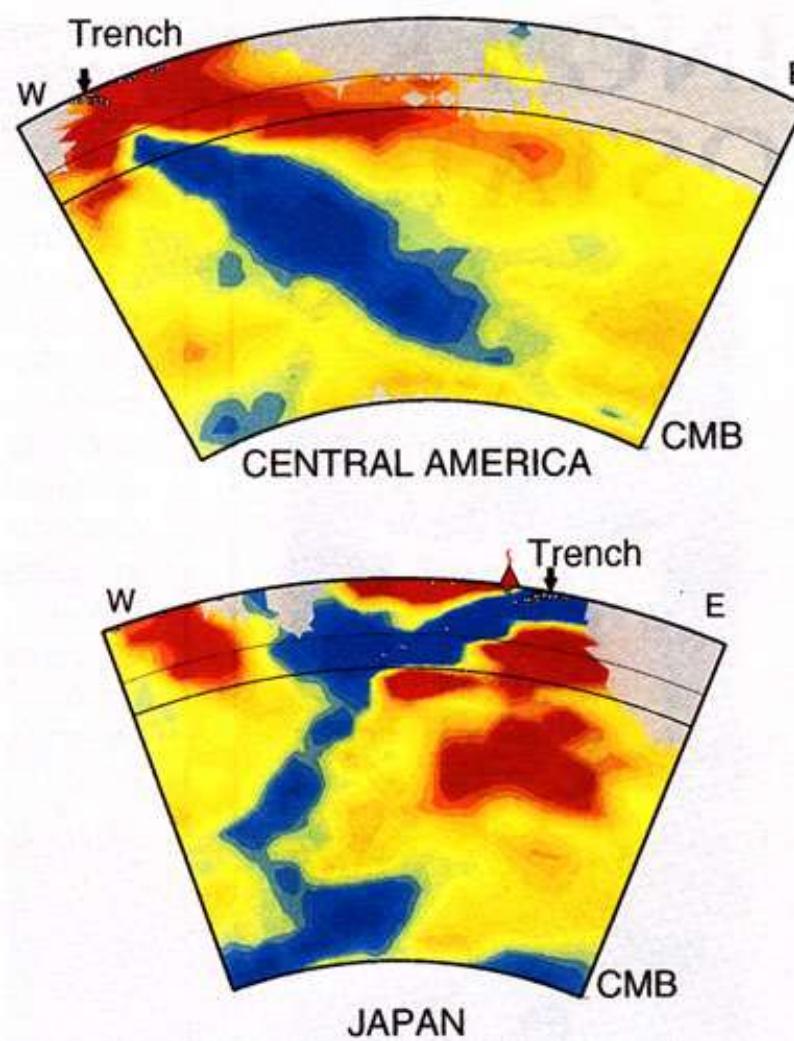


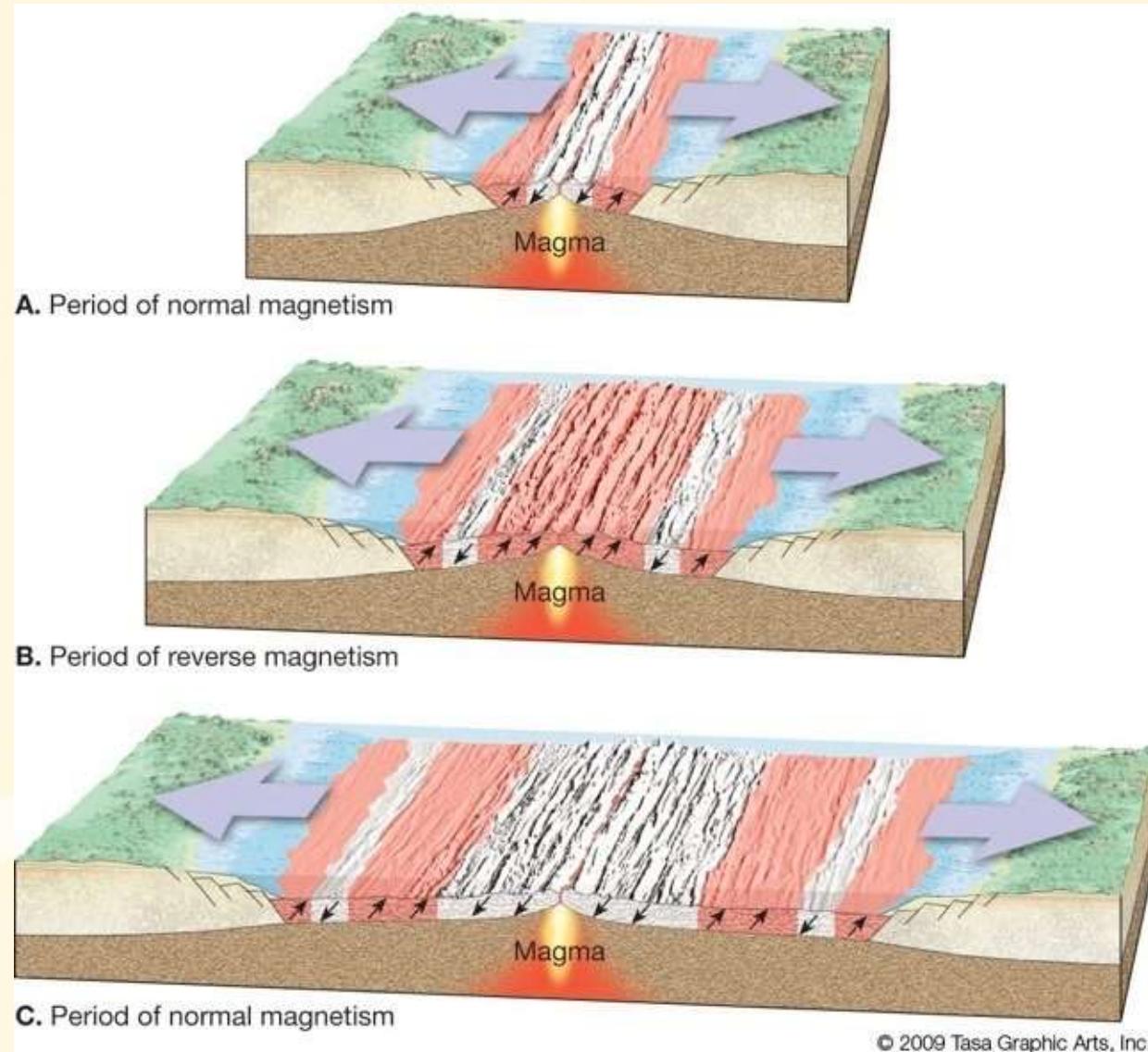
Plate motion forces



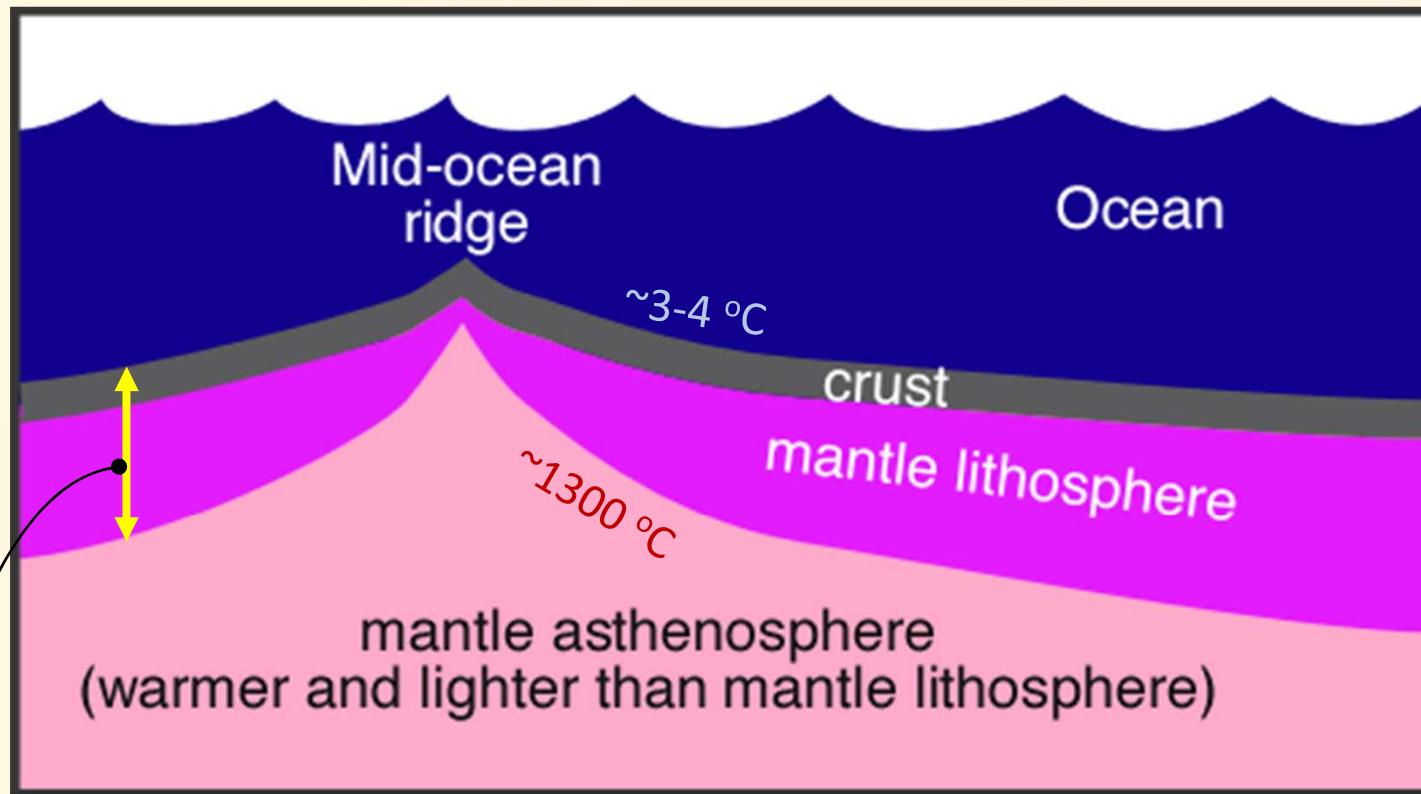


Earth mantle structure

Linear magnetic anomalies

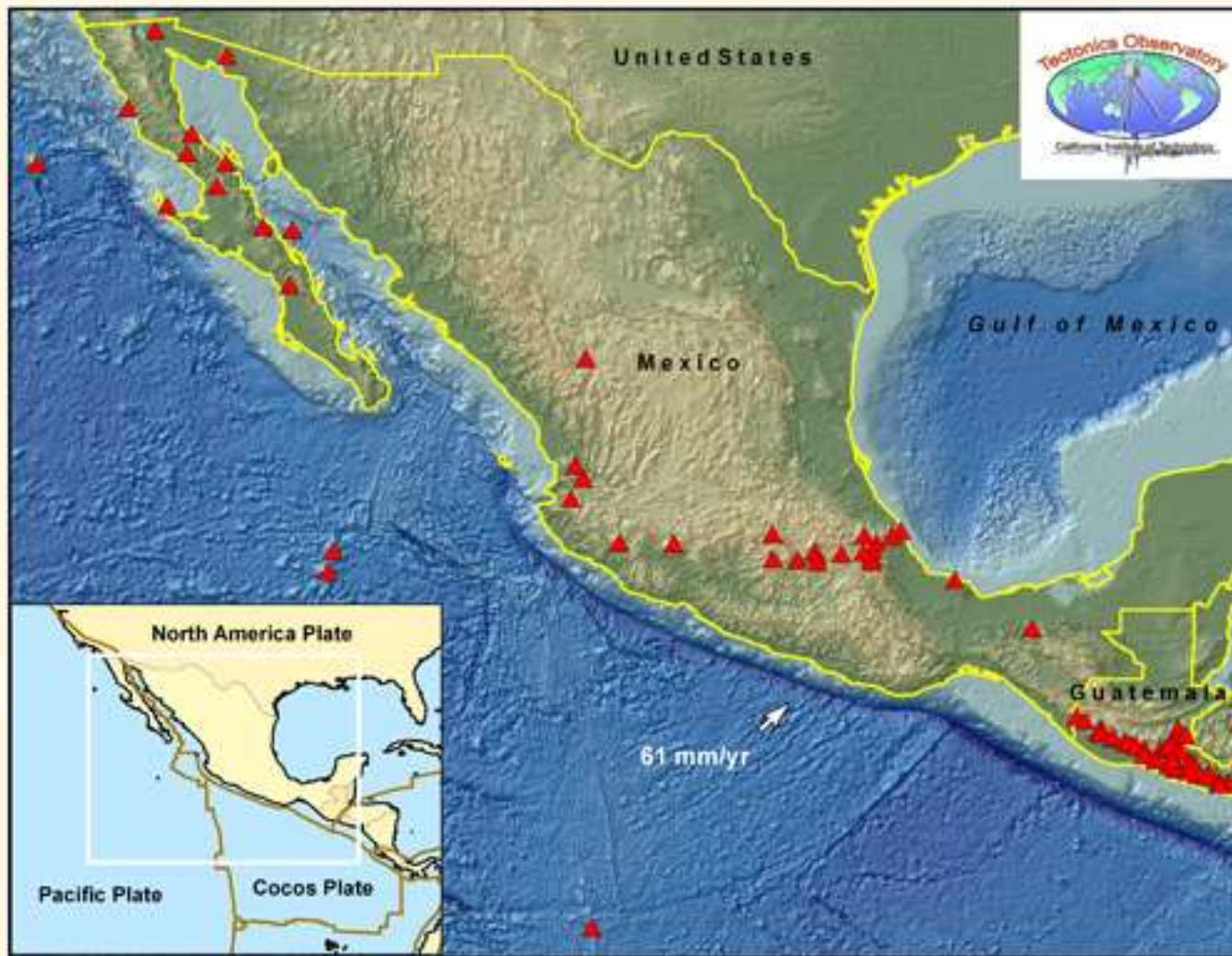


Oceanic lithosphere

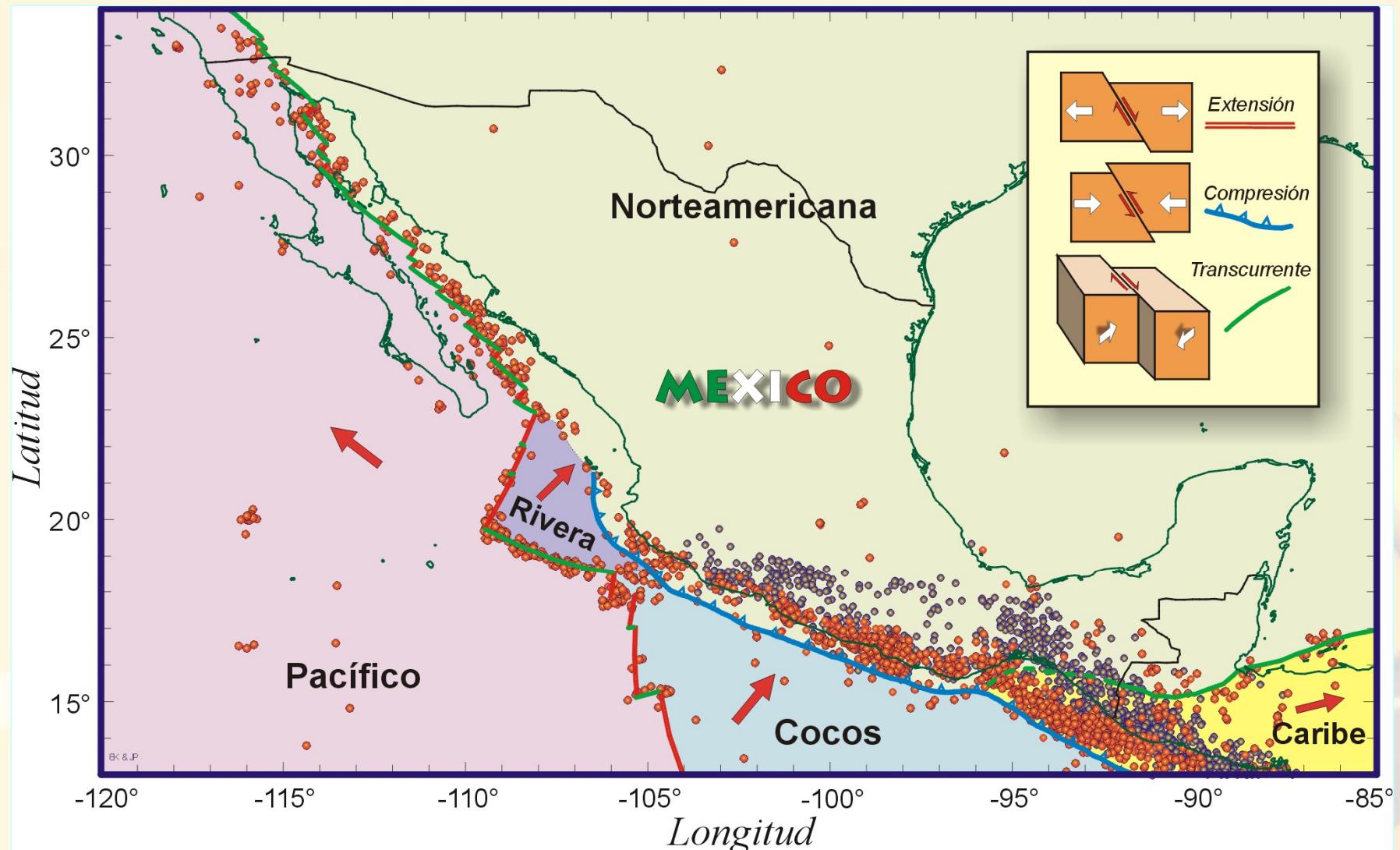


$$H(\text{km}) \sim 10 \sqrt{A(\text{my})}$$

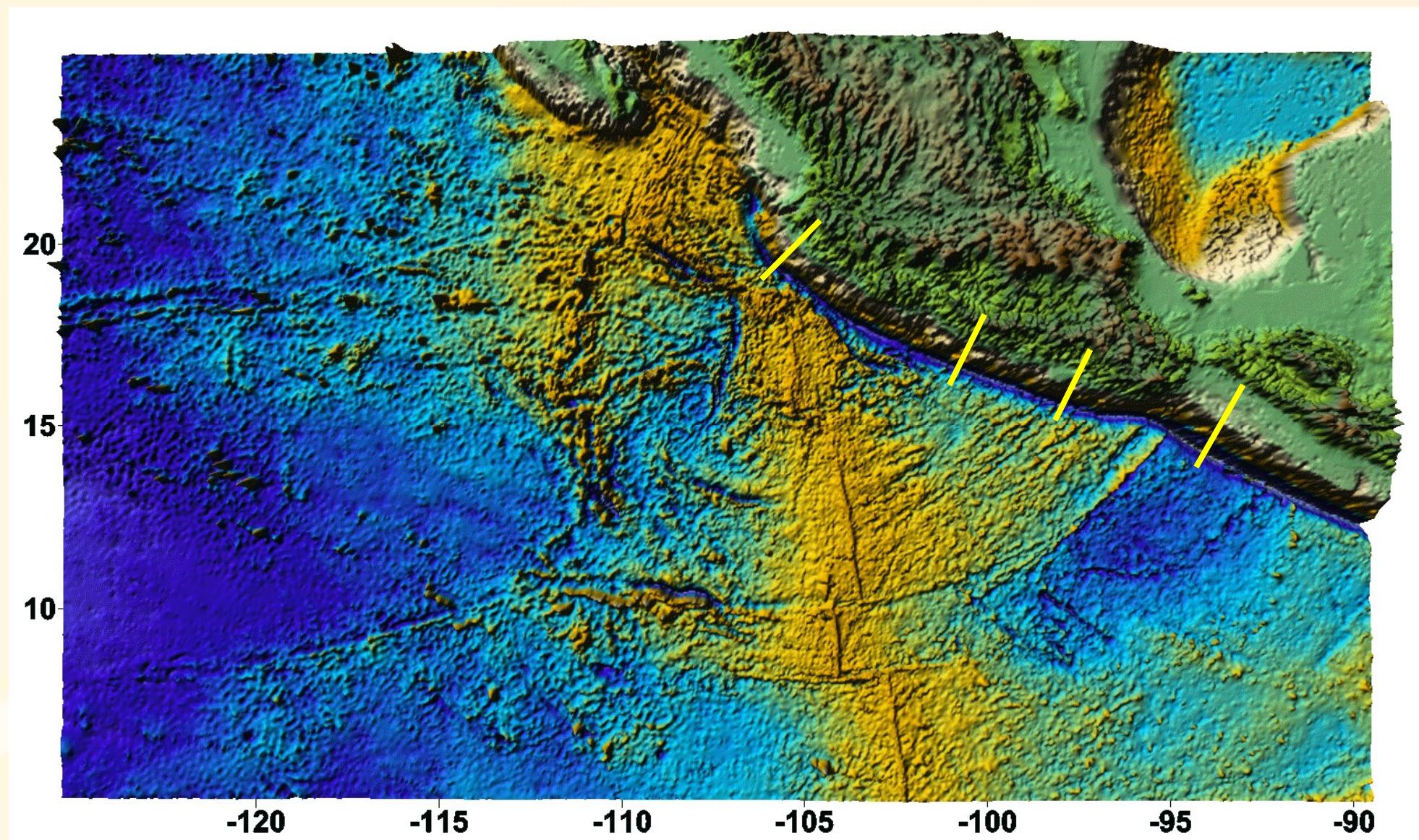
MEXICO



Tectonic plates, Mexico



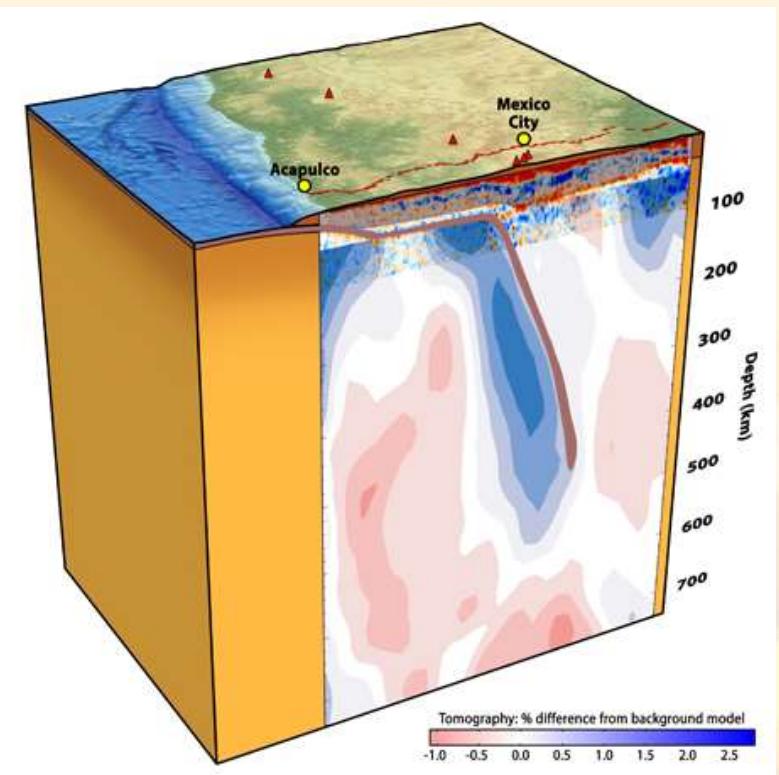
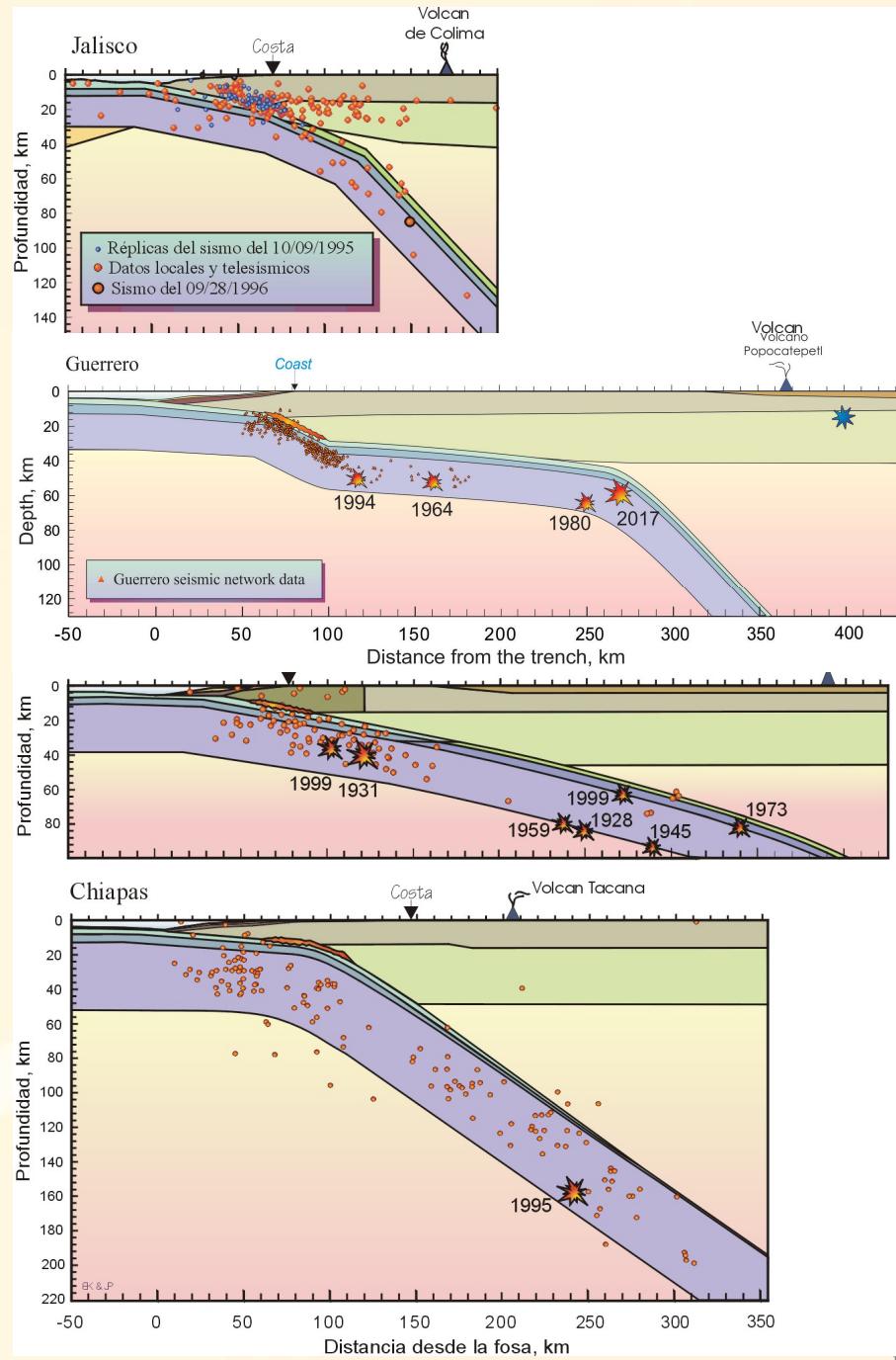
Topography - Bathymetry



Marina Manea, 2004. Data from:
ftp://topex.ucsd.edu/pub/global_topo_2min/

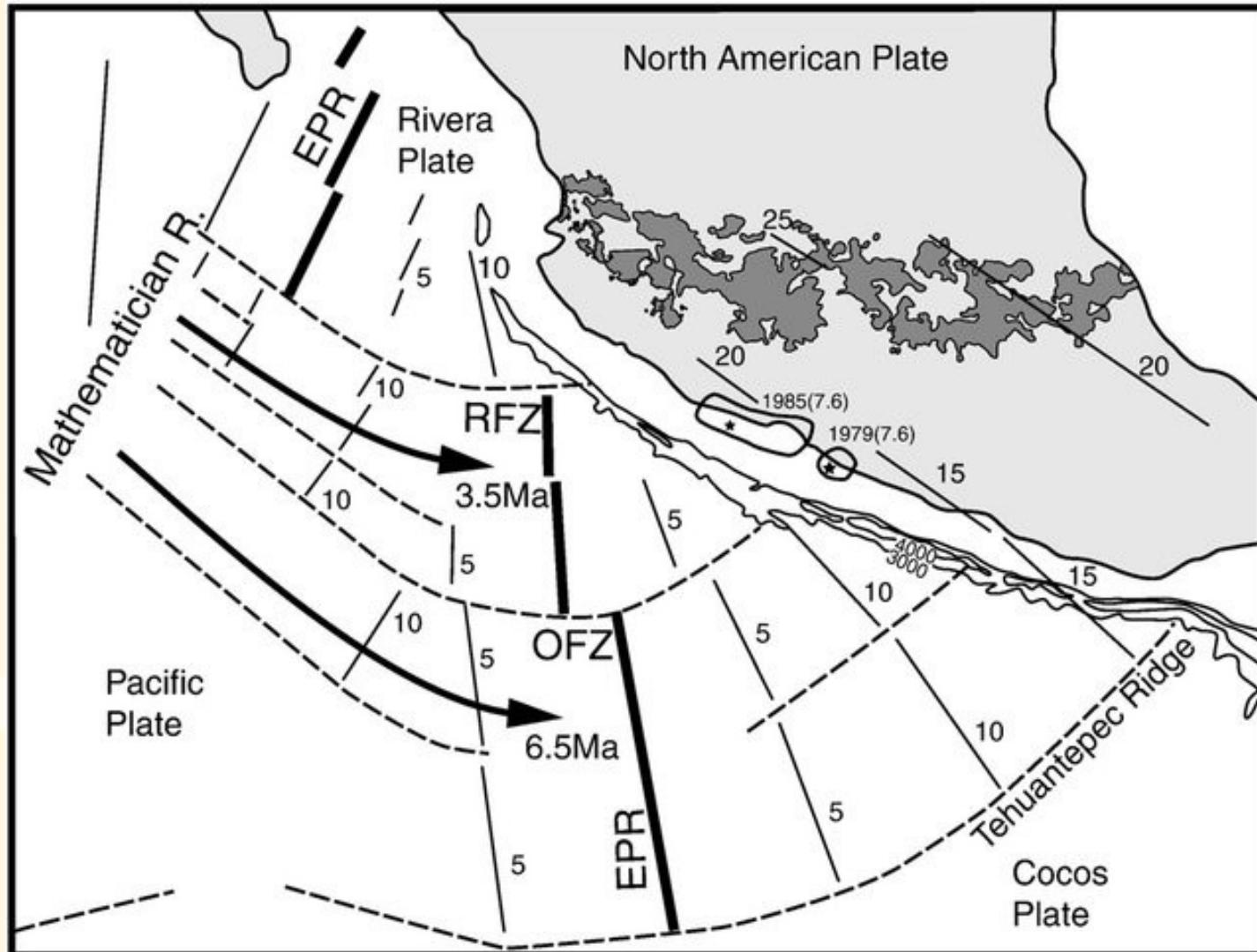
Subduction zone structure in Mexico

¿Where are earthquakes happening?

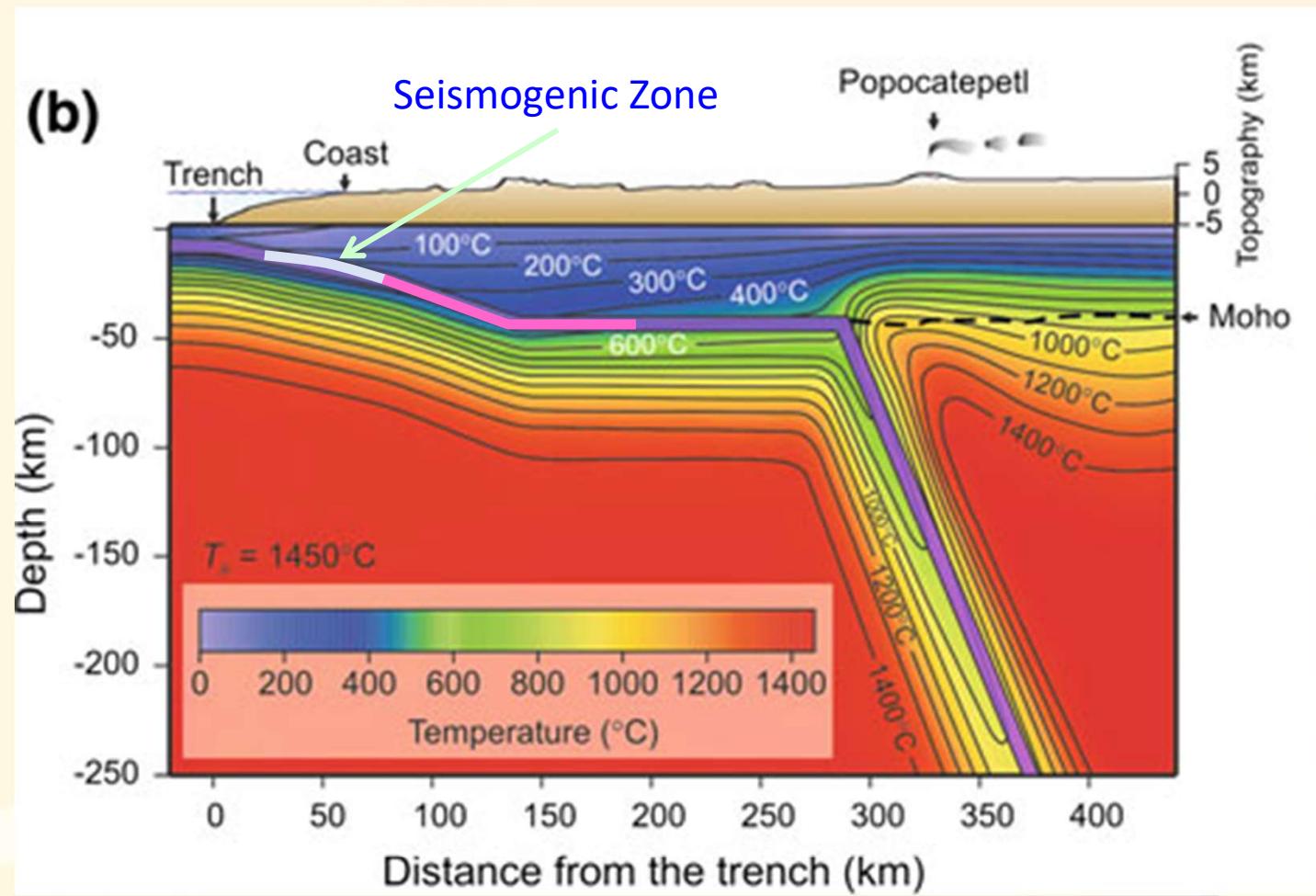


ostoglodov V. and J.F. Pacheco, CIEN AÑOS DE SISMICIDAD EN MEXICO, poster,
IGF UNAM, 1999.

The age of subducting plates

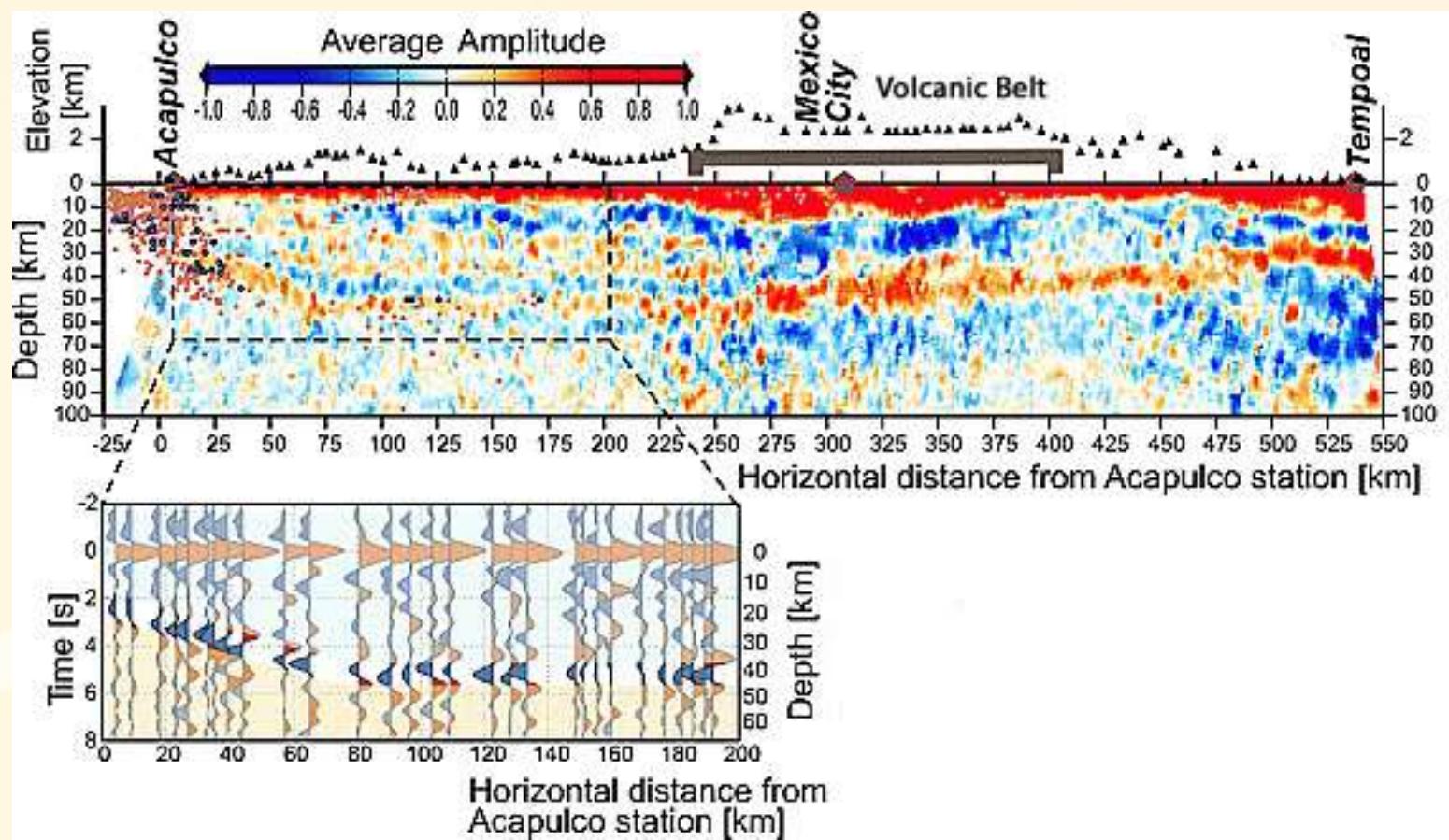


Thermal structure model

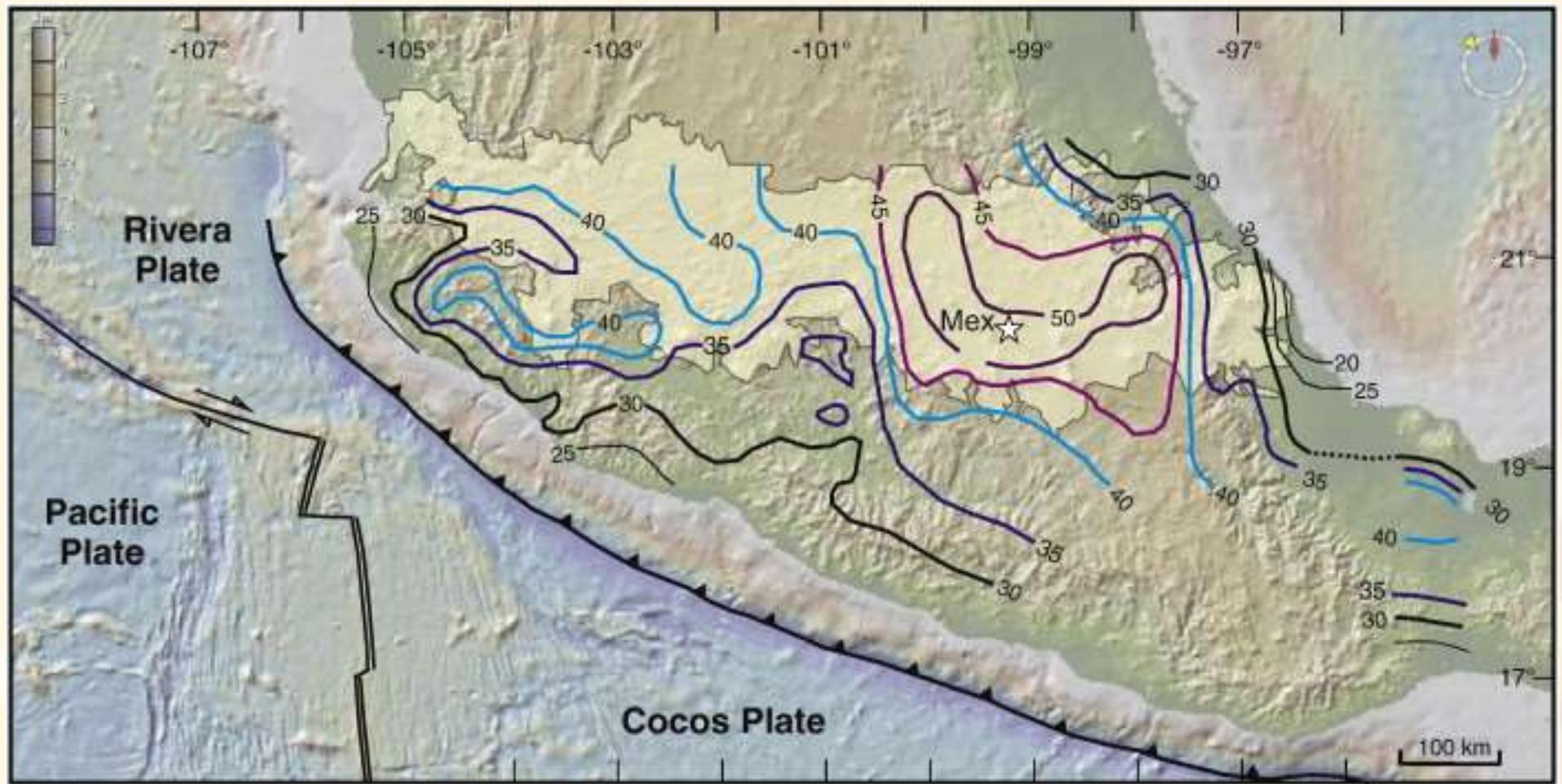


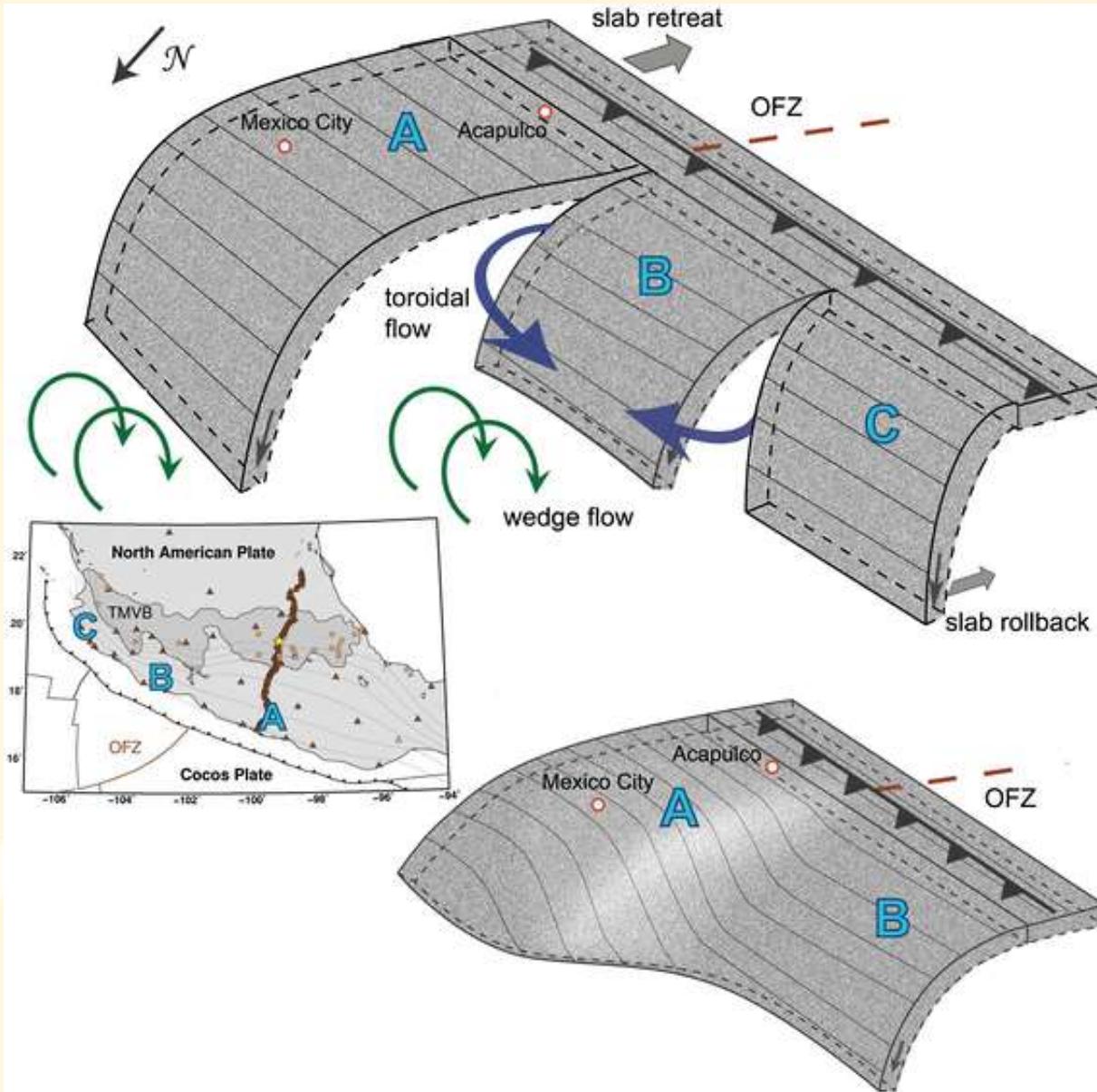
- Aseismic stable sliding : $T' = 100 - 150 \text{ }^{\circ}\text{C}$, $> 450 \text{ }^{\circ}\text{C}$,
- Locked seismogenic zone: $T' = 150 - 250 \text{ }^{\circ}\text{C}$
- Partially locked transition zone: $T' = 250 - 450 \text{ }^{\circ}\text{C}$

Continental crust from the receiver function

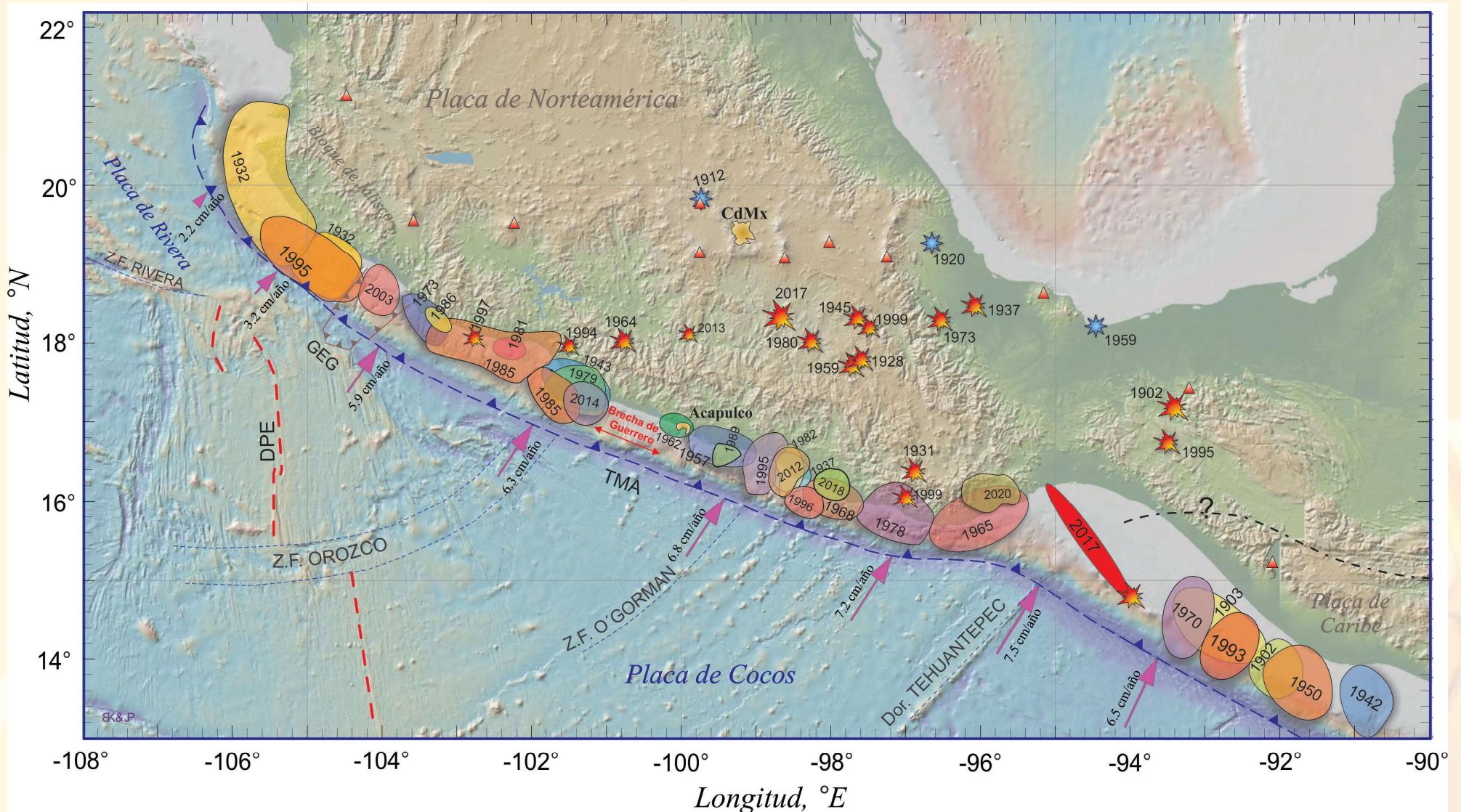


Thickness of the crust in southern Mexico (km).

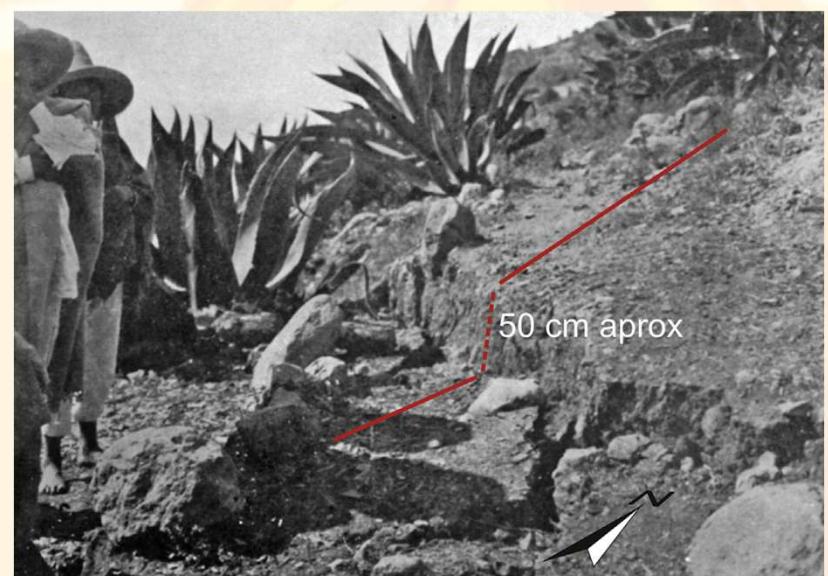
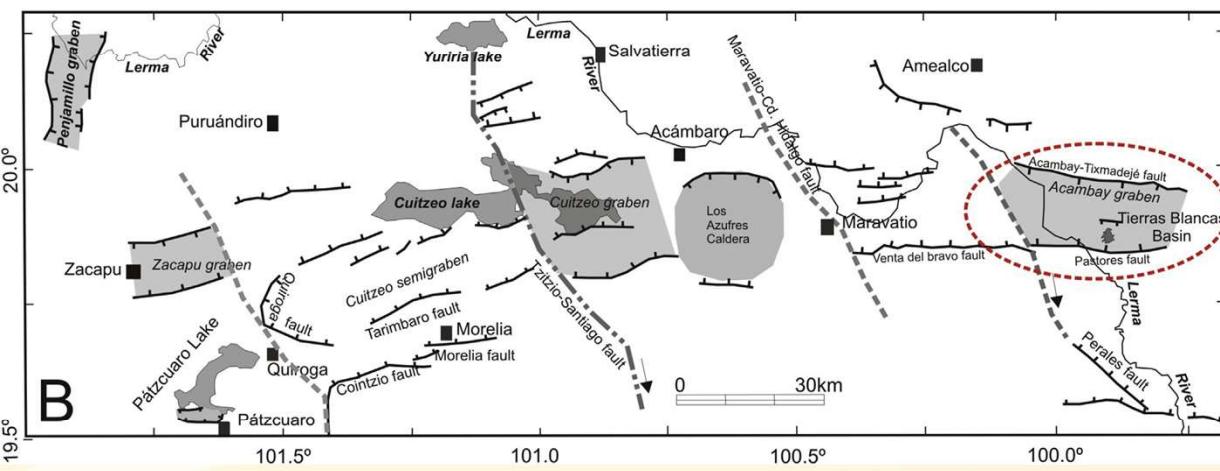
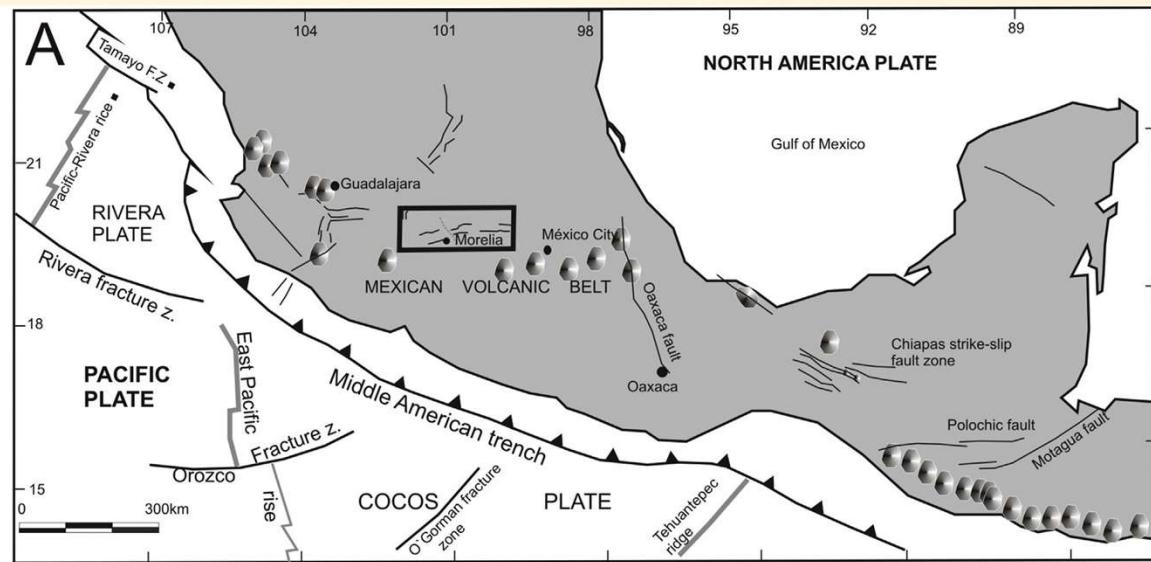


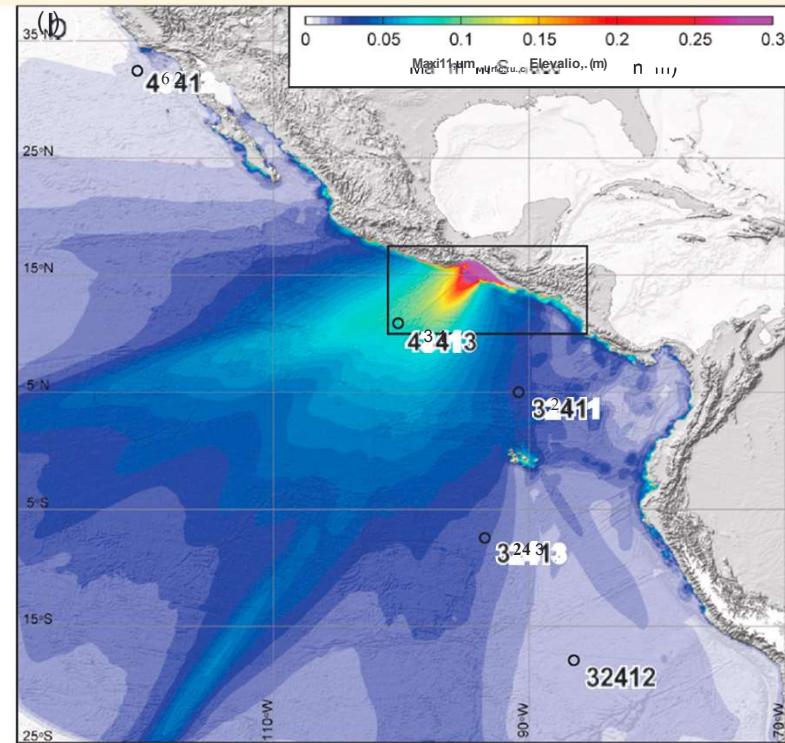
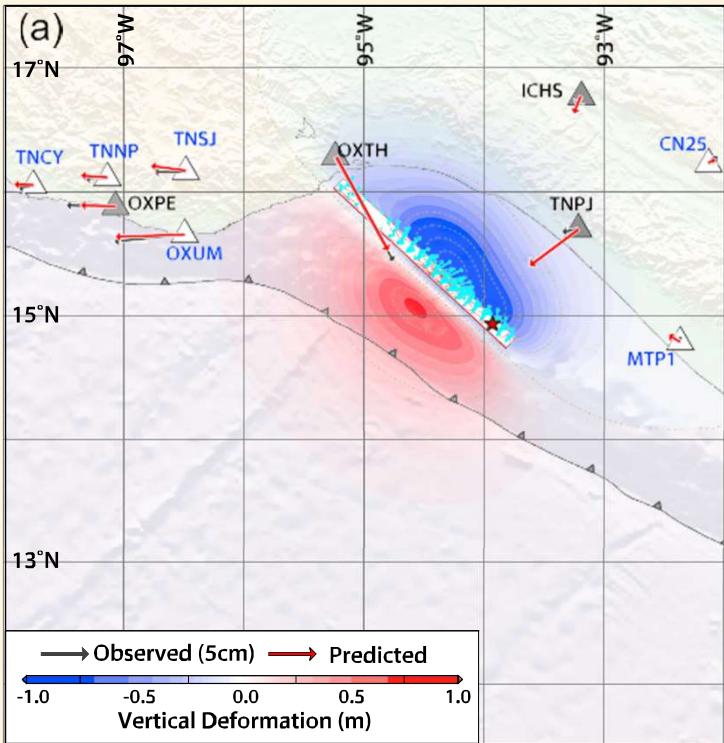


Large Earthquakes in Mexico



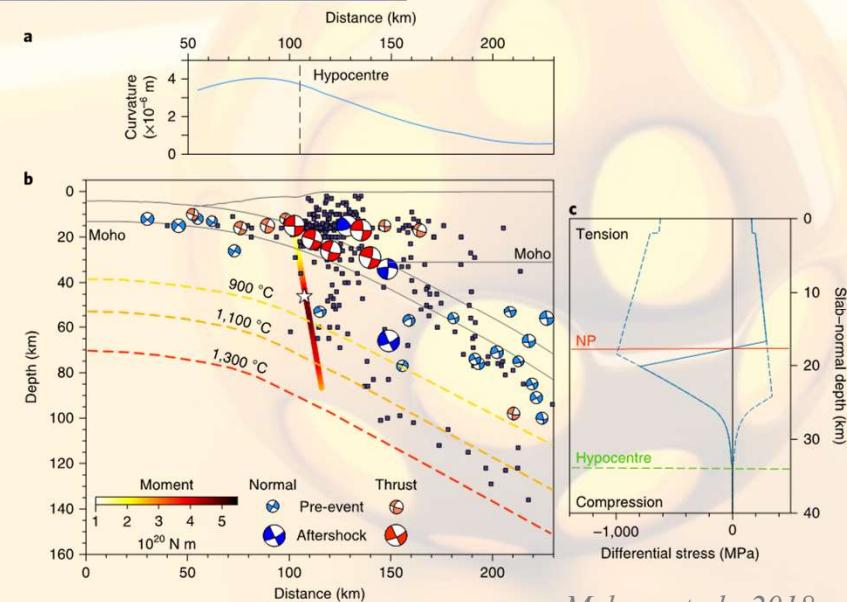
Acabay area of Nov.29,1912, M6.9 EQ





Ye et al., 2017

8 September 2017, Mw 8.2 Tehuantepec earthquake

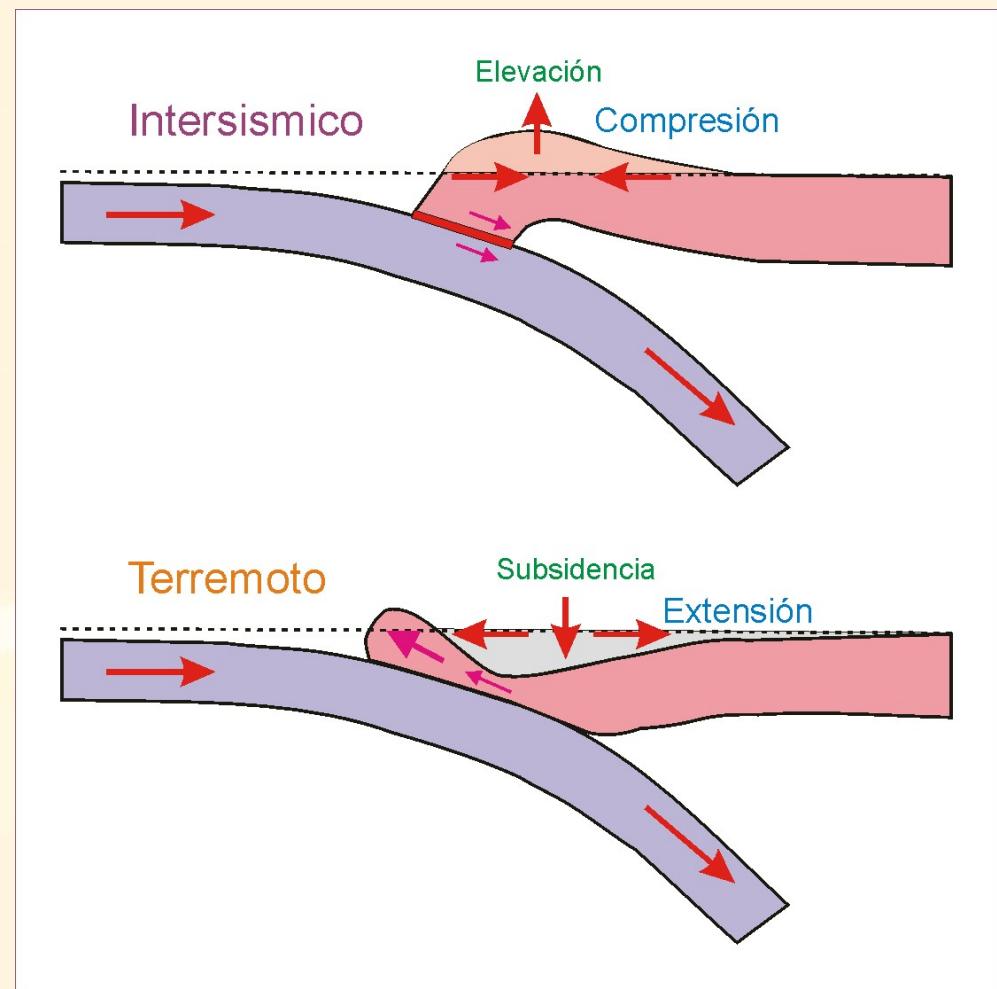


Melgar et al., 2018

Schematic seismic cycle and plate margin deformation

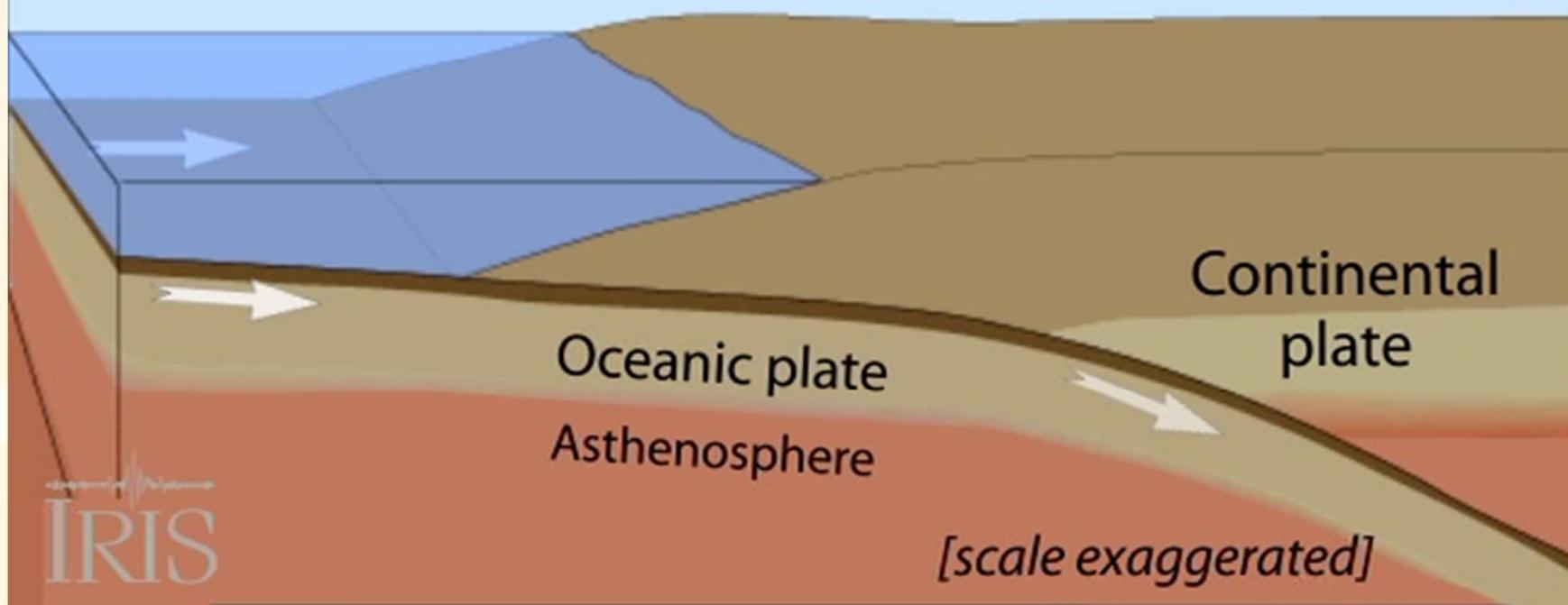


http://www.pgc.nrcan.gc.ca/geodyn/eq_cycle.htm



www.DesktopDre

Elastic rebound in a subduction zone

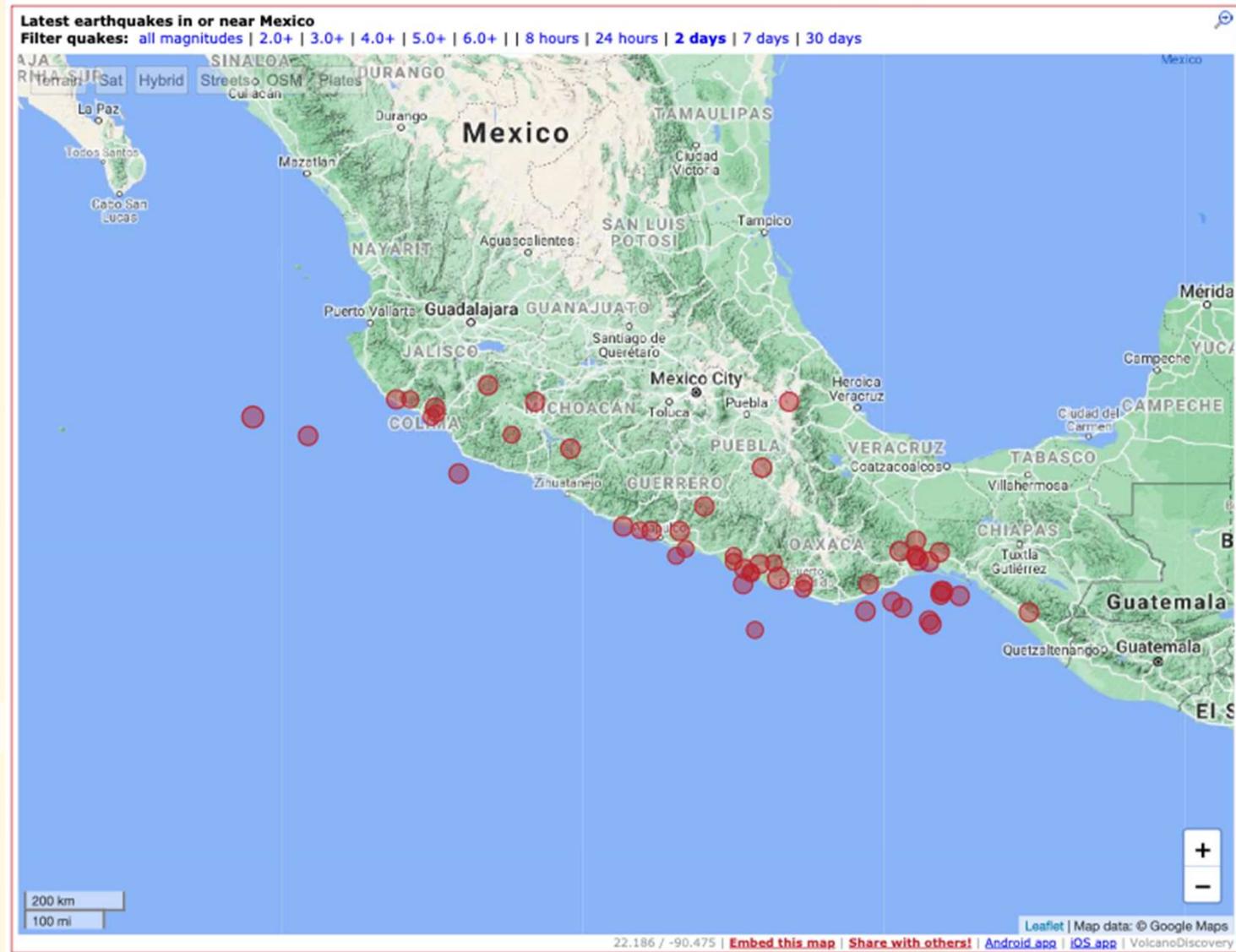


Coseismic uplift September 19, 1985



Balanus

Latest earthquakes in or near Mexico



<https://www.volcanoesandearthquakes.com/region/Mexico>

www/DesktopDre



ÚLTIMOS SISMOS.

Total: 94 Tiempo del Centro de México UTC

Información sujeta a cambios (i)

MAGNITUD	FECHA Y HORA	EPICENTRO LOCALIZACIÓN LATITUD, LONGITUD	PROFUNDIDAD
4.2	2022-07-06 13:24:25	30 km al SURESTE de TONALA, CHIS: 15.86°, -93.61°	99 km
4.0	2022-07-06 12:28:44	55 km al NOROESTE de MATIAS ROMERO, OAX: 17.28°, -94.73°	147 km
4.1	2022-07-06 05:32:52	67 km al SUR de JALTIPLAN DE MORELOS, VER: 17.38°, -94.56°	149 km
3.6	2022-07-06 04:58:42	12 km al SURESTE de PINOTEPAN NACIONAL, OAX: 16.23°, -98.02°	6 km
3.8	2022-07-06 04:49:29	94 km al OESTE de LA MIRA, MICH: 17.83°, -103.19°	12 km
4.1	2022-07-06 04:49:13	50 km al NORTE de MATIAS ROMERO, OAX: 17.32°, -95.09°	128 km
3.7	2022-07-06 04:44:22	31 km al NOROESTE de RIO GRANDE, OAX: 16.23°, -97.61°	5 km
3.9	2022-07-06 04:41:44	30 km al SURESTE de SALINA CRUZ, OAX: 15.96°, -95.03°	17 km
3.8	2022-07-06 04:18:23	21 km al NOROESTE de RIO GRANDE, OAX: 16.17°, -97.55°	13 km

Sismo de magnitud menor de 3.0 Sismo de magnitud entre 3.0 y 3.9 Sismo de magnitud entre 4.0 y 4.9 Sismo de magnitud entre 5.0 y 5.9 Sismo de magnitud entre 6.0 y 6.9 Sismo de magnitud entre 7.0 y 7.9 Sismo de magnitud mayor a 8.0

SI DESEAS MÁS INFORMACIÓN, CONSULTA NUESTRO [CATÁLOGO DE SISMOS](#).

SISMOS GRANDES.

Desde 1900 a 1973, magnitud >= 6.5
Desde 1974 a la fecha, magnitud >= 5.5

DETALLE	FECHA	HORA	LATITUD	LONGITUD	PROFUNDIDAD (KM)	MAGNITUD	LOCALIZACIÓN	FECHA UTC	HORA UTC
Ver	2022-05-25	16:43:02	16.11	-95.99	12	5.5	41 km al NOROESTE de CRUCECITA, OAX	2022-05-25	21:43:02
Ver	2022-03-29	11:13:02	15.02	-104.74	10	5.6	421 km al SUROESTE de LA MIRA, MICH	2022-03-29	17:13:02
Ver	2022-03-05	21:29:20	16.74	-95.27	88	5.6	27 km al NOROESTE de CD IXTEPEC, OAX	2022-03-06	03:29:20
Ver	2022-03-03	08:40:33	18.15	-95.51	113	5.7	14 km al NORTE de ISLA, VER	2022-03-03	14:40:33
Ver	2022-02-16	01:12:23	13.837	-91.573	62	6.2	112 km al SURESTE de CD HIDALGO, CHIS	2022-02-16	07:12:23
					10	6.0	279 km al OESTE de CIHUATLÁN, JAL	2021-12-22	23:22:57
					178	5.5	9 km al NOROESTE de MOTOZINTLA, CHIS	2021-12-13	07:03:07
					10	5.6	144 km al SUROESTE de LA CRUZ, SIN	2021-09-23	16:47:53
					15	7.1	14 km al SUROESTE de ACAPULCO, GRO	2021-09-08	01:47:46
					10	5.5	65 km al SUROESTE de H GUAYMAS, SON	2021-07-31	15:39:18
					13	5.6	108 km al NOROESTE de IXTAPA, JAL	2021-07-04	02:44:57
					10	5.7	60 km al SURESTE de SAN MARCOS, GRO	2021-03-20	03:06:31

Correo electrónico **SismologicoMX** **sismologicomx** **RSS**

UBICACIÓN **CONTACTO** **OTROS SITIOS DE INTERÉS** **ENGLISH VERSION**

Catálogo de sismos históricos

SISMOS HISTÓRICOS

Intensidad Máxima: 8 No. de Localidades: 4 Magnitud: M > 7	(MVB) Intensidad Máxima: 7 No. de Localidades: 2 Magnitud: 5.5	Intensidad Máxima: 6 No. de Localidades: 1 Magnitud:	MICHOACÁN GUERRERO (SUB 2) Intensidad Máxima: 8 No. de Localidades: 9 Magnitud: 7.5
1777/10/10 Nombre de Sismo: Zona Macro sísmica: Intensidad Máxima: 7 No. de Localidades: 3 Magnitud: M = 5	1784/1/9 Nombre de Sismo: Zona Macro sísmica: Intensidad Máxima: 6 No. de Localidades: 1 Magnitud: Mw < 5.0	1784/3/6 Nombre de Sismo: Zona Macro sísmica: Intensidad Máxima: 6 No. de Localidades: 2 Magnitud:	1785/1/6 Nombre de Sismo: Zona Macro sísmica: SUBDUCCIÓN COSTA JALISCO COLIMA (SUB1) Intensidad Máxima: 7 No. de Localidades: 4 Magnitud:
1785/10/14 Nombre de Sismo: Zona Macro sísmica: SUBDUCCIÓN COSTA JALISCO (SUB1) Intensidad Máxima: 7 No. de Localidades: 5 Magnitud: M = 5	1786/2/9 Nombre de Sismo: Zona Macro sísmica: SUBDUCCIÓN COSTA JALISCO (SUB1) Intensidad Máxima: 7 No. de Localidades: 5 Magnitud: M > 7	1786/9/14 Nombre de Sismo: Zona Macro sísmica: GOLFO DE CORTÉS (BC 2) Intensidad Máxima: 5 No. de Localidades: 1 Magnitud:	1787/3/28 Nombre de Sismo: Temblores de San Sixto Zona Macro sísmica: SUBDUCCIÓN GUERRERO OAXACA (SUB 3) Detalles de Sismo Ver Detalles
1787/3/30 Nombre de Sismo: Zona Macro sísmica: Intensidad Máxima: 6 No. de Localidades: 2 Magnitud: M > 7	1787/4/3 Nombre de Sismo: Zona Macro sísmica: Intensidad Máxima: 8 No. de Localidades: 3 Magnitud: M > 7	1788/4/5 Nombre de Sismo: Zona Macro sísmica:	1787/3/26 Nombre de Sismo: Zona Macro sísmica: Intensidad Máxima: 6 No. de Localidades: 2 Magnitud:
1790/4/16 Nombre de Sismo: Zona Macro sísmica:	1790/4/20 Nombre de Sismo: Zona Macro sísmica:		1790/4/20 Nombre de Sismo: Zona Macro sísmica:

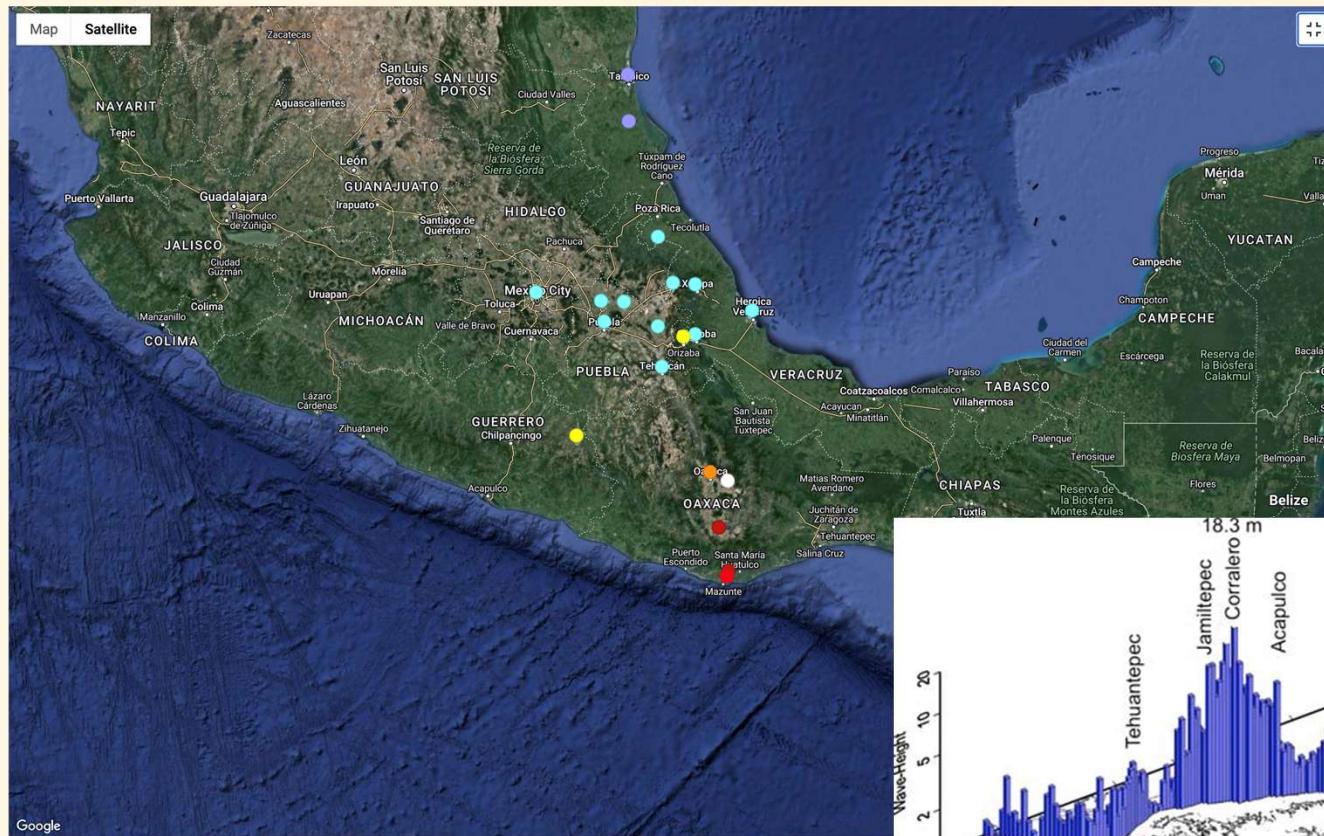


Show All X

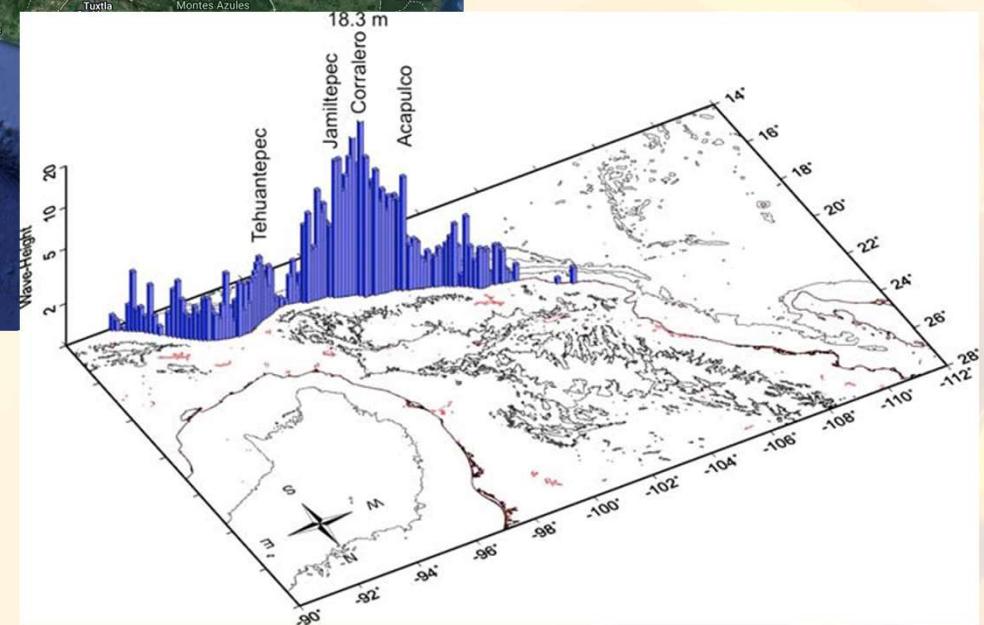
Suárez, G. (2021). Catálogo de Sismos Históricos de México,
<http://www.sismoshistoricos.org/>

<http://sismoshistoricos.org/panel/web/>

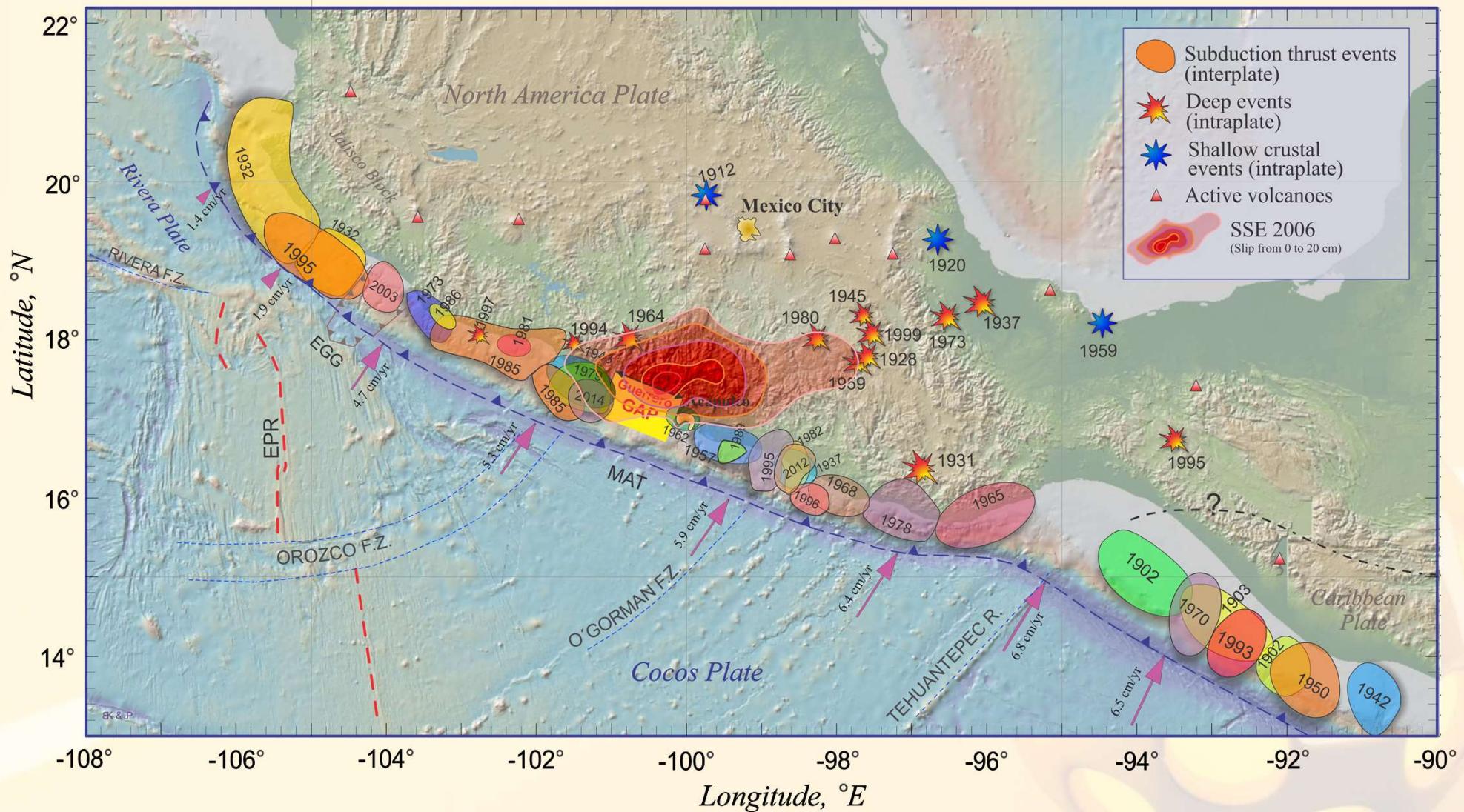
San Sixto earthquake March 28, 1787, ~Mw8.6



Suárez and Paola Albini, 2009



Núñez-Cornú et al., 2008

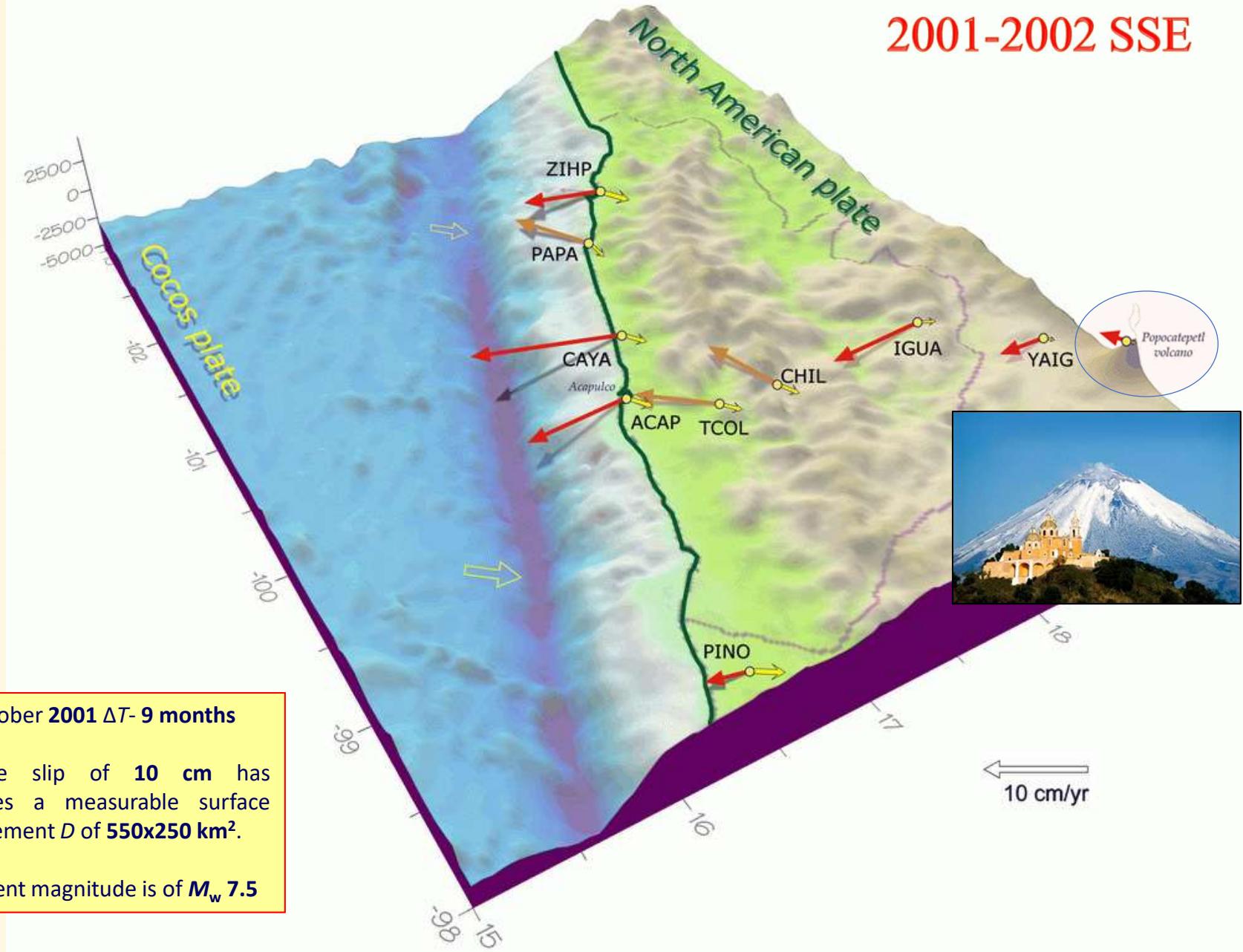


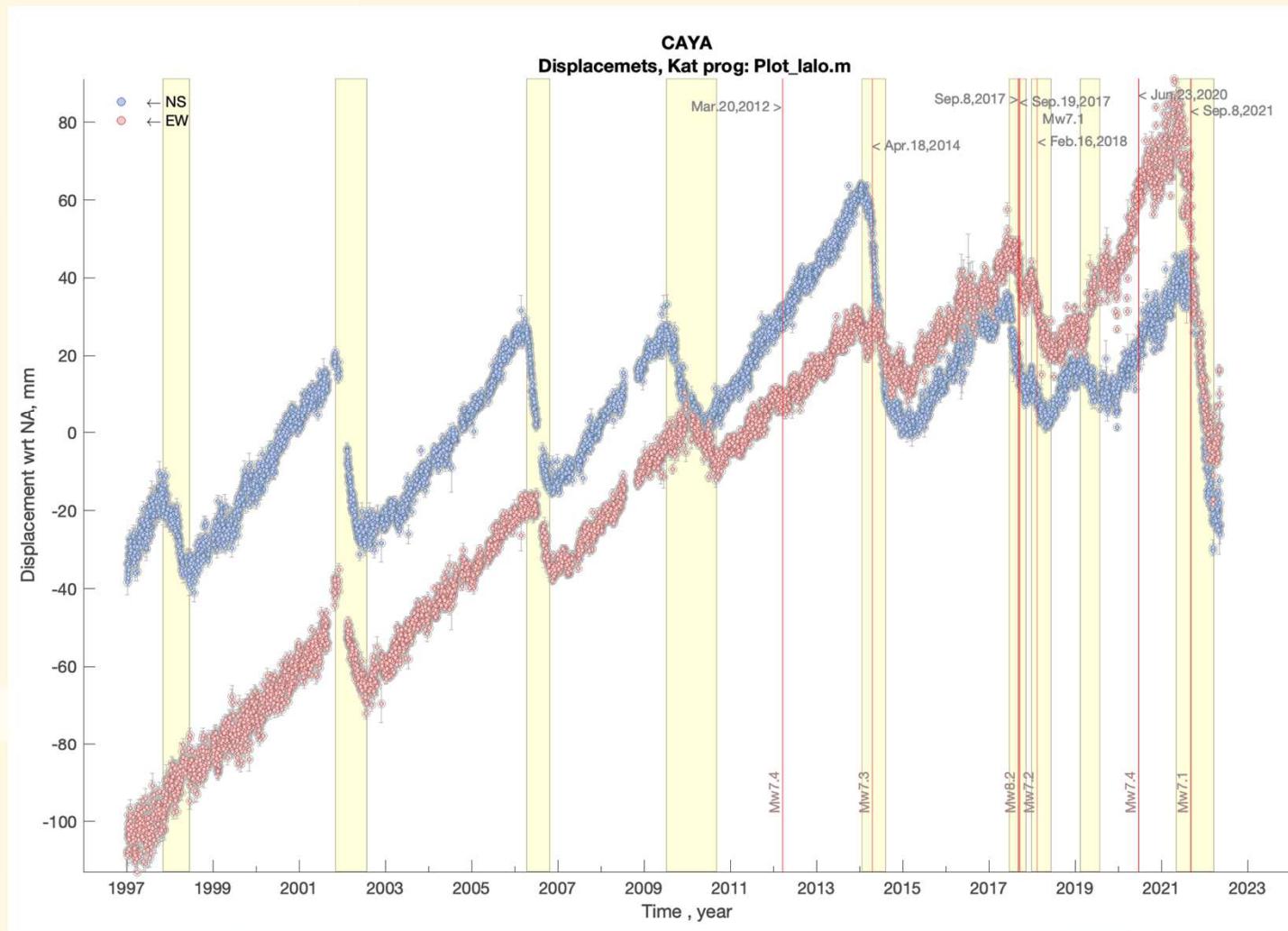
2006 LT SSE area,

joint inversion of InSAR and GPS data

Cavalié et al., EPSL 2013

2001-2002 SSE





La Venta – Chacalapa fault system

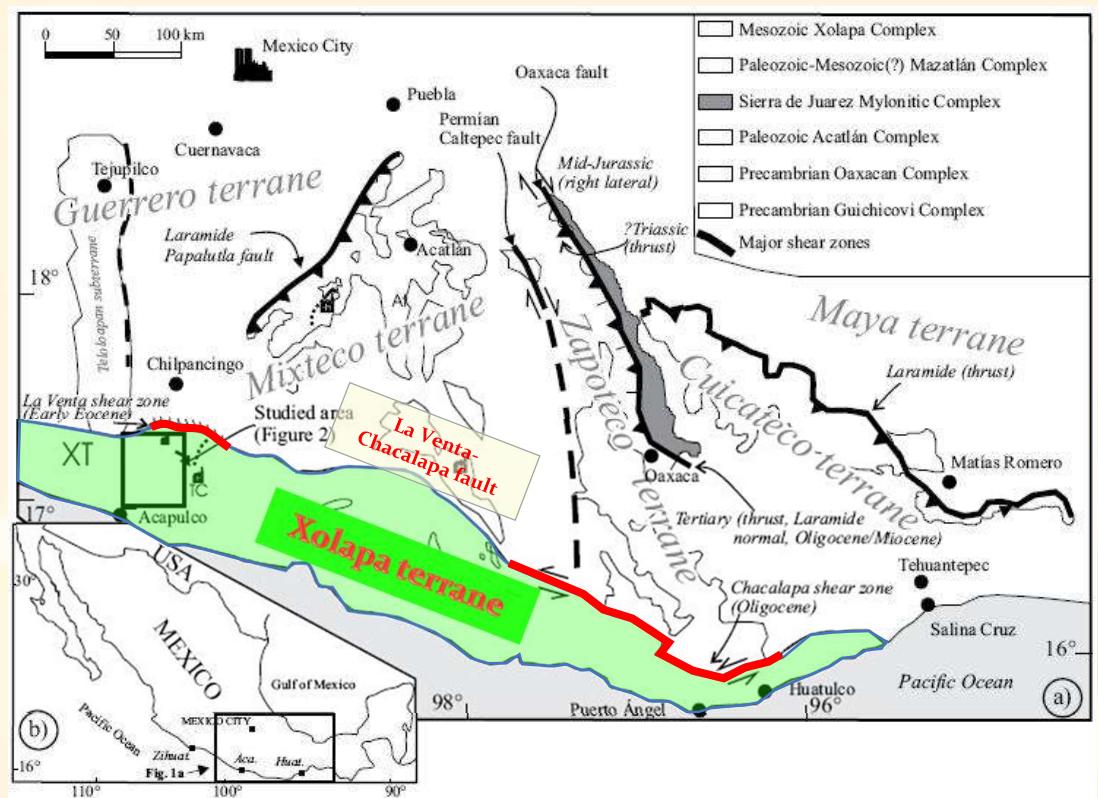
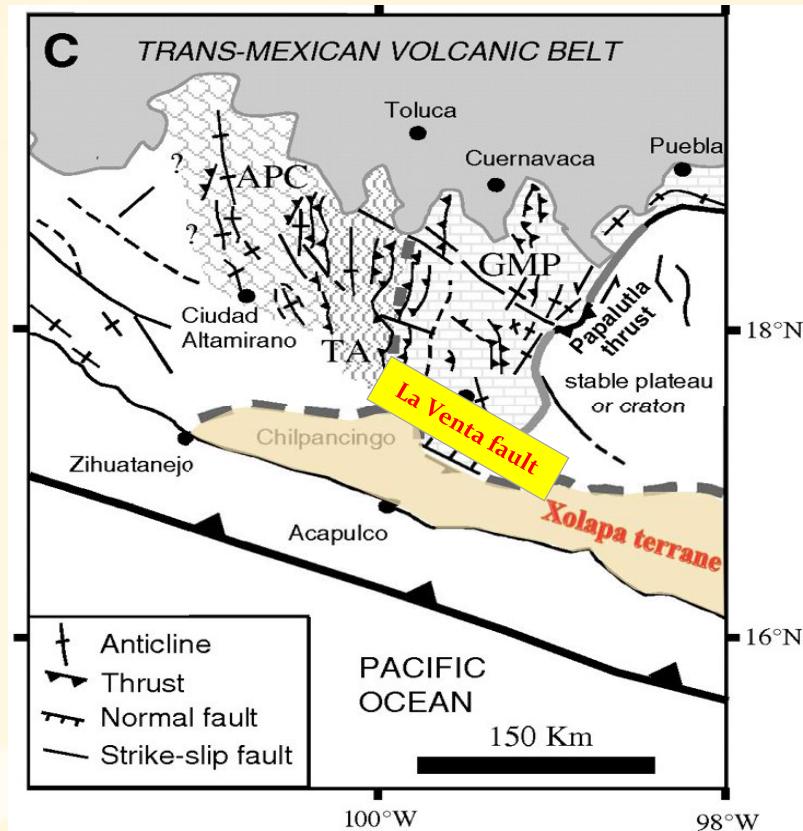
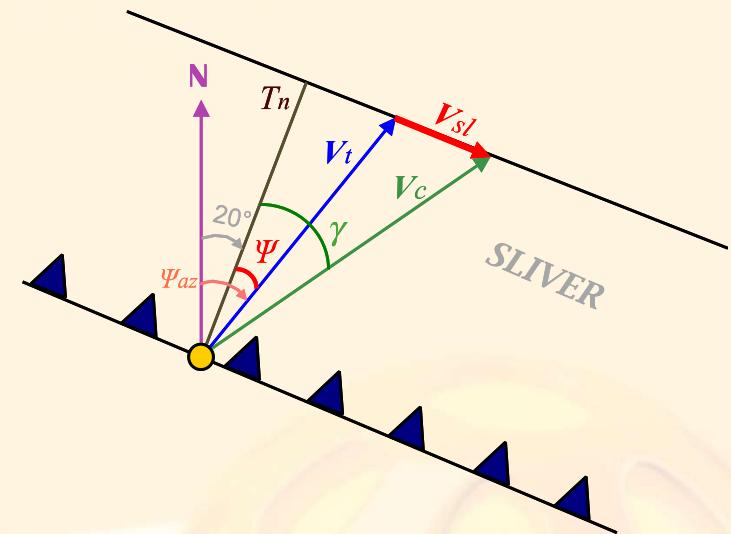
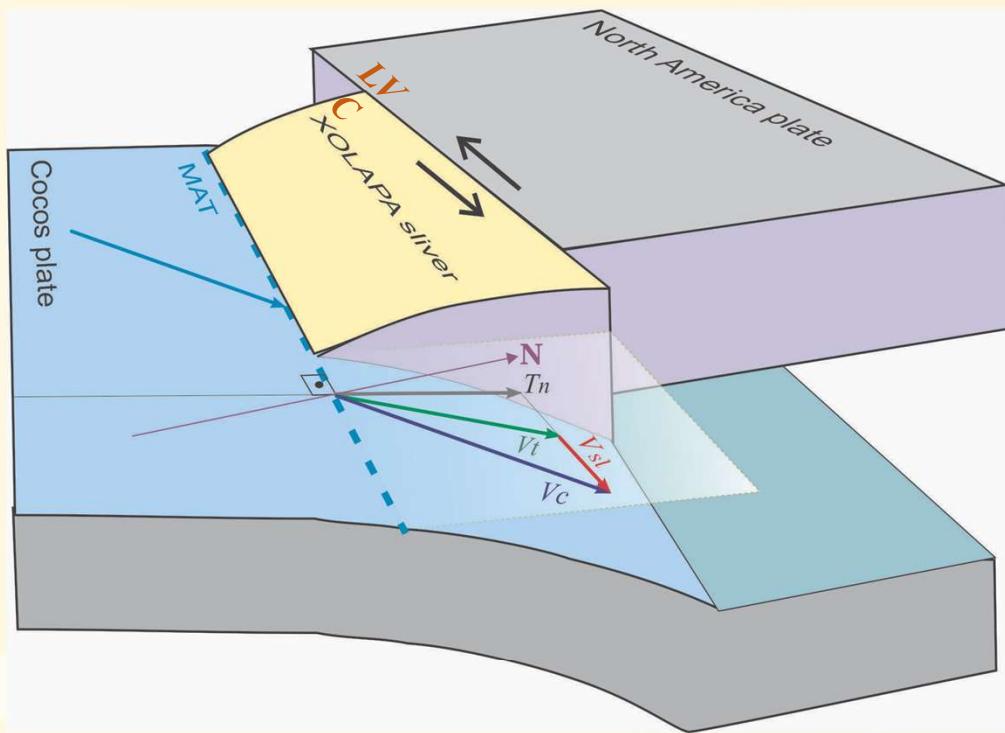


Figure 1. Simplified terrane subdivision of southern Mexico. Main basement complexes are also indicated. Modified from Solari *et al.* (2007). Terrane subdivision according to Campa and Coney (1983), Sedlock *et al.* (1993), and Keppe (2004).

Cerca *et al.*, 2009, Solari *et al.*, 2007;

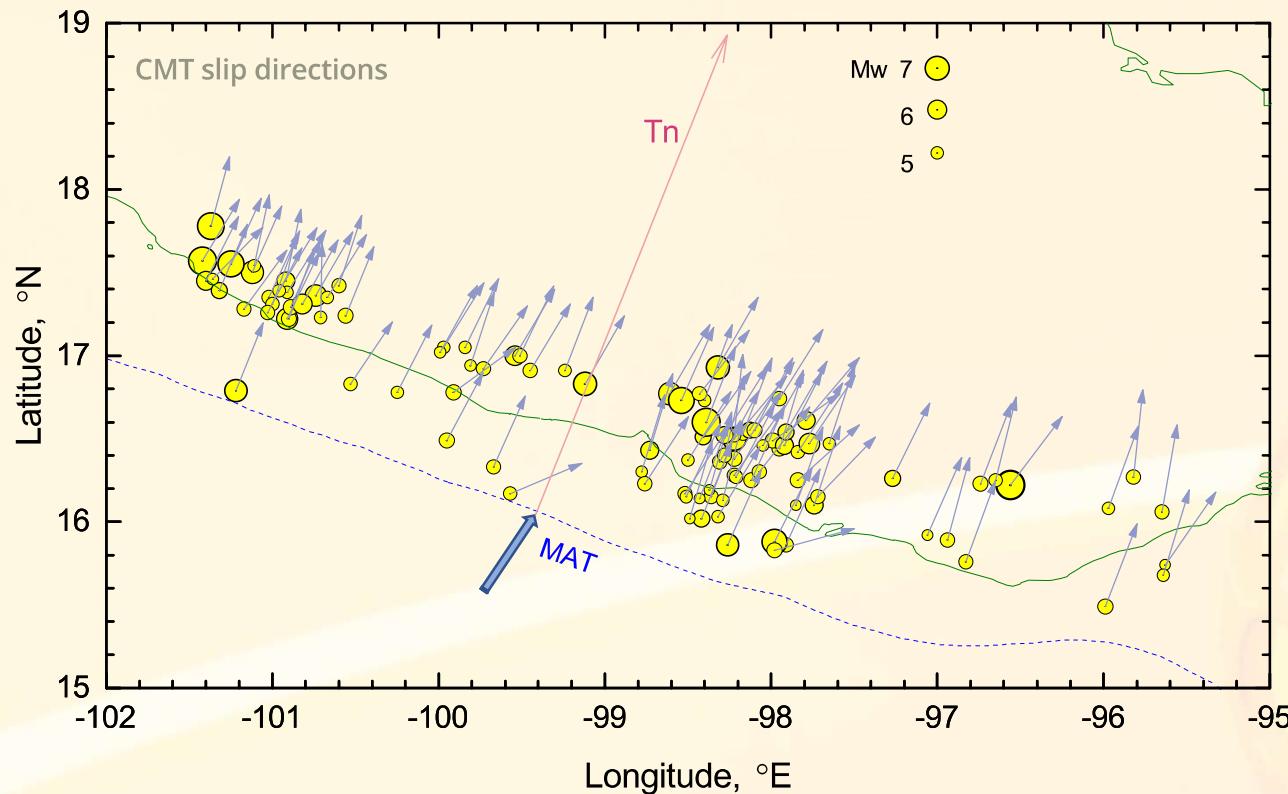
Slip partitioning model



$$V_{sl} = V_c (\sin \gamma - \cos \gamma \tan \Psi)$$

McCaffrey, 1992

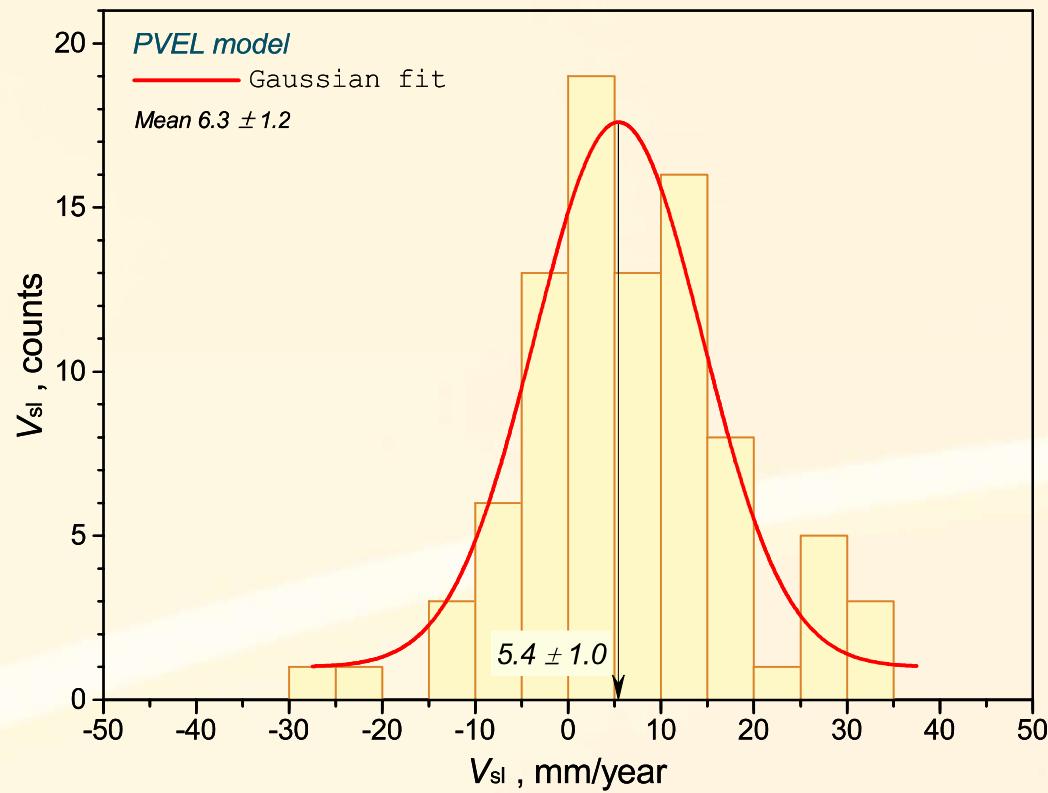
CMT slip vectors (subduction thrust EQs)



96 CMT of subduction thrust EQ Mw>5
are used From the Global CMT catalog

15° ≤ Latitude ≤ 18°
-101.5° ≤ Longitude ≤ -95.5°
0 ≤ Depth ≤ 60
0 ≤ Mw ≤ 10
45° ≤ tension plunge ≤ 90°
0° ≤ null plunge ≤ 45°
Strike1 > 200 °E
Dip1 < 45°
Double couple component (DC) ≥ 80%

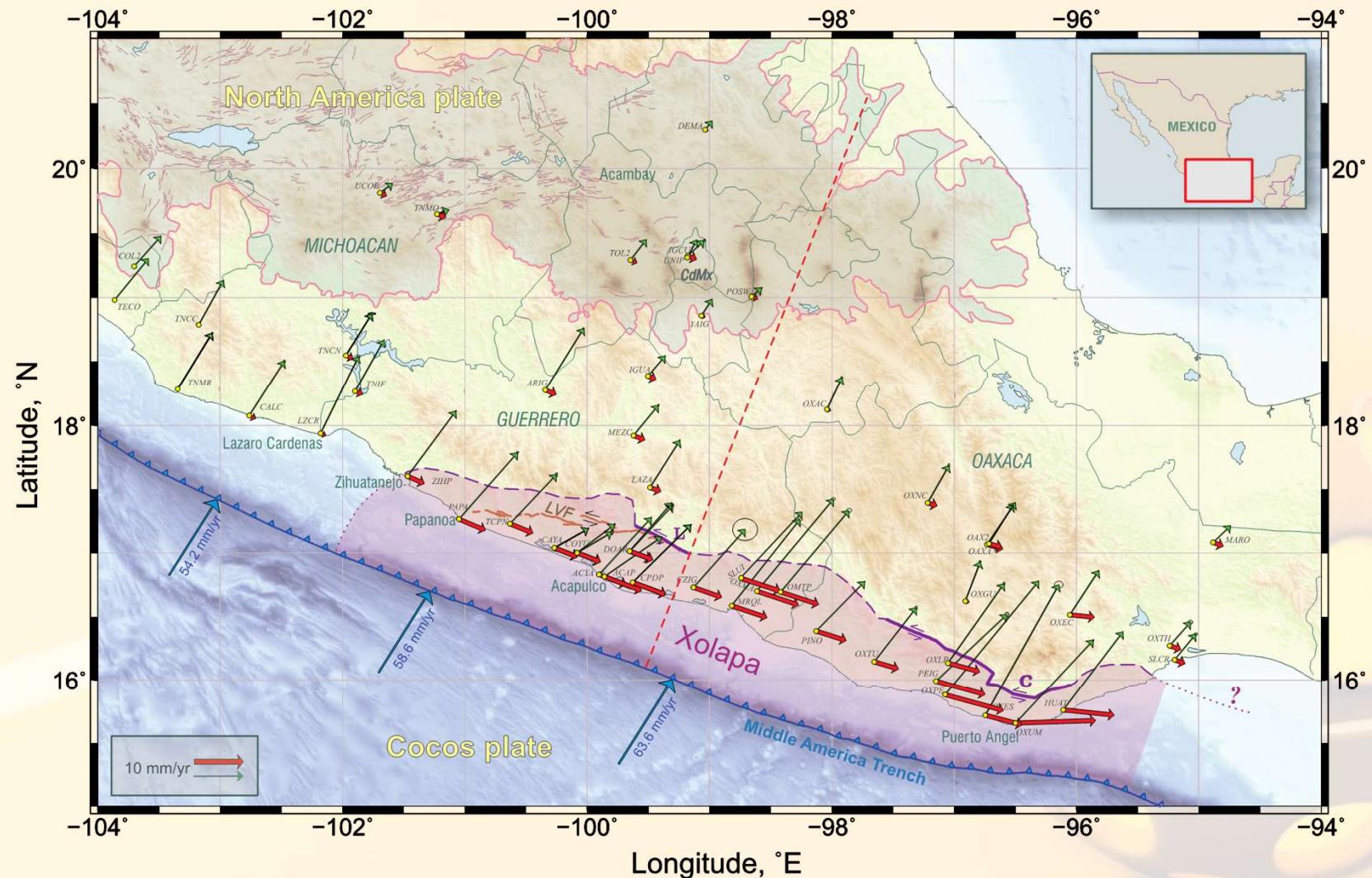
Analysis of slip partitioning



$$V_{sl} = V_c \sin(\gamma) - \cos(\gamma) \tan(\Psi)$$

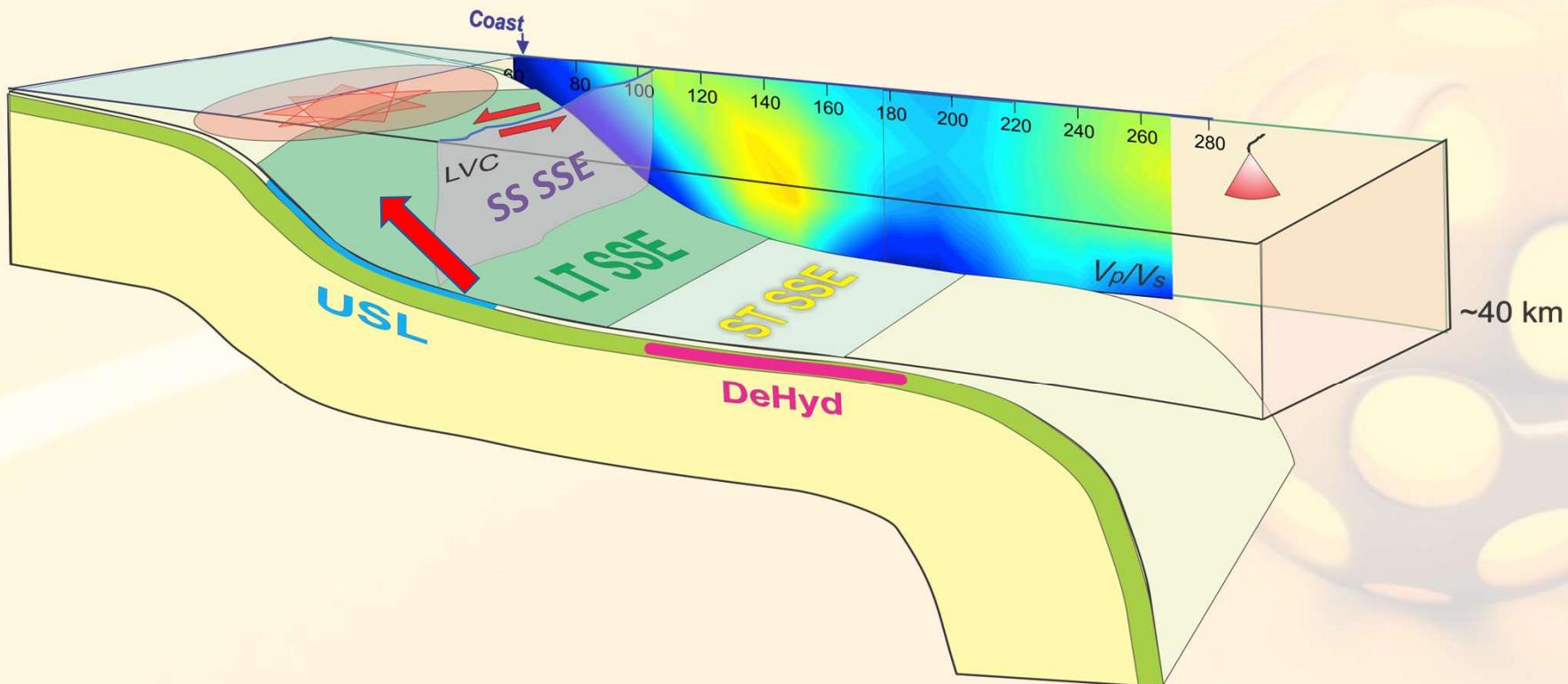
$V_{sl} \sim 5.4 - 6.3$ mm/year

Secular GPS velocities and their oblique components wrt MAT

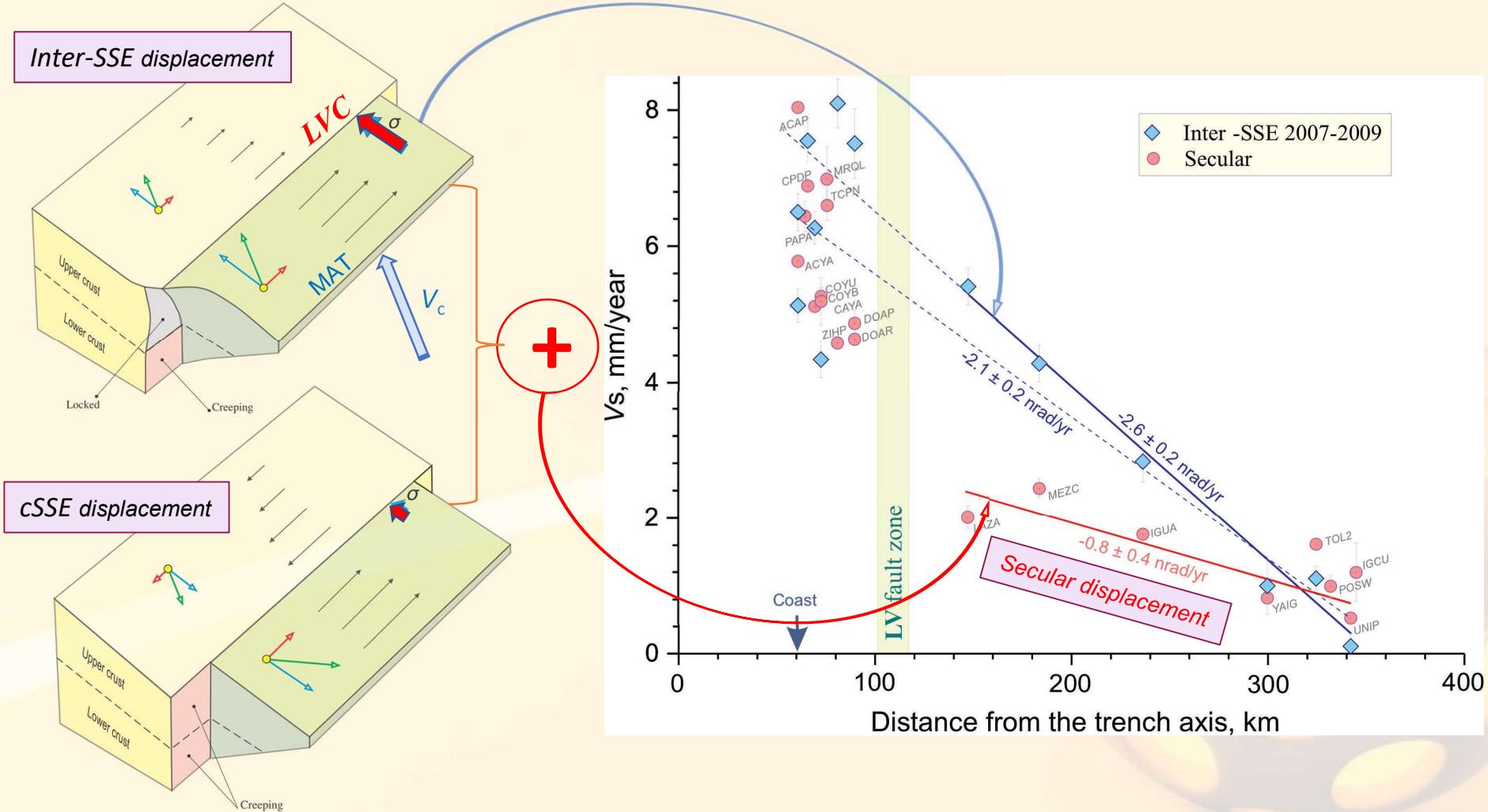


Crustal slow slip (cSSEs) occur on the LVC during large subduction sSSEs

Large long-term subduction sSSEs reduce normal stress on the creeping LVC shear zone. This effectively drops the friction resistance on it, and the LVC slip velocity and displacement increase.

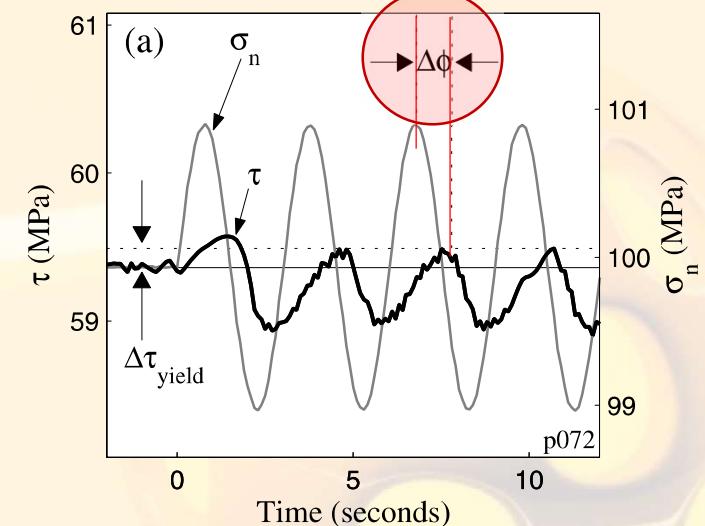
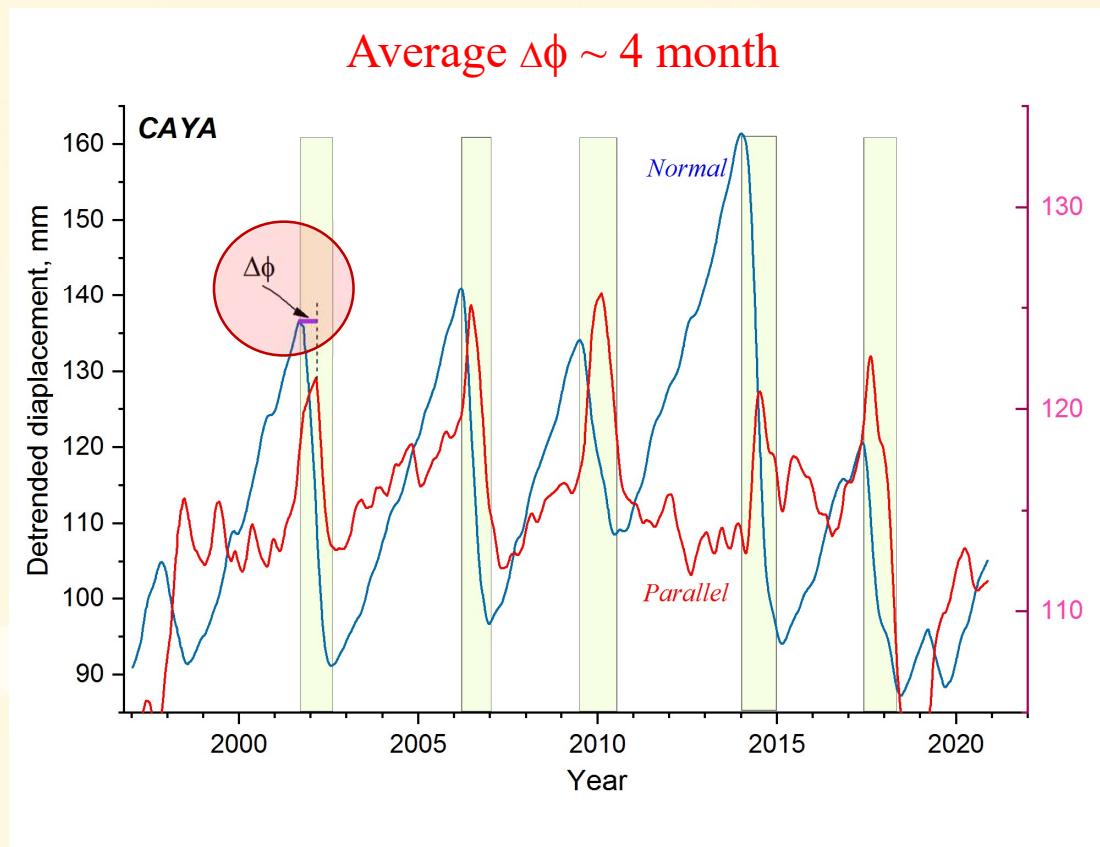


Inter-SSE vs secular displacements on the LVC

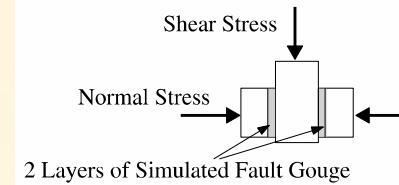


Phase lag ($\Delta\phi$) between the normal and along the MAT displacements

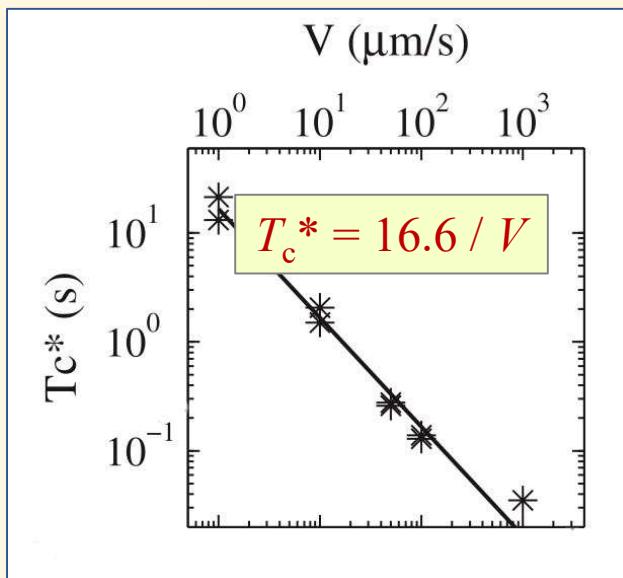
Normal stress oscillates on the creeping fault



Critical period (T_c^*) of normal stress oscillations



Boettcher & Marone, 2003

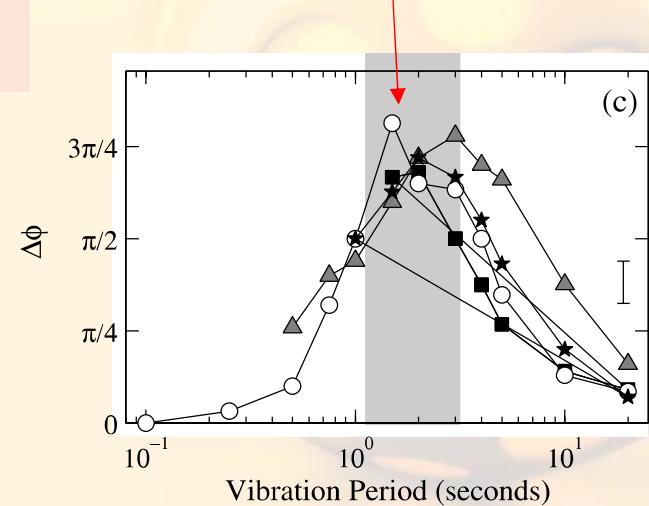


In Guerrero and Oaxaca,
 $V \sim 5 \text{ mm/year}$

$$T_c^* \sim 3.3 \text{ year}$$

The largest $\Delta\phi$ were
observed near T_c^*

G-GAP $T = 3\text{-}4 \text{ year}$
Average $\Delta\phi \sim 4 \text{ month}$

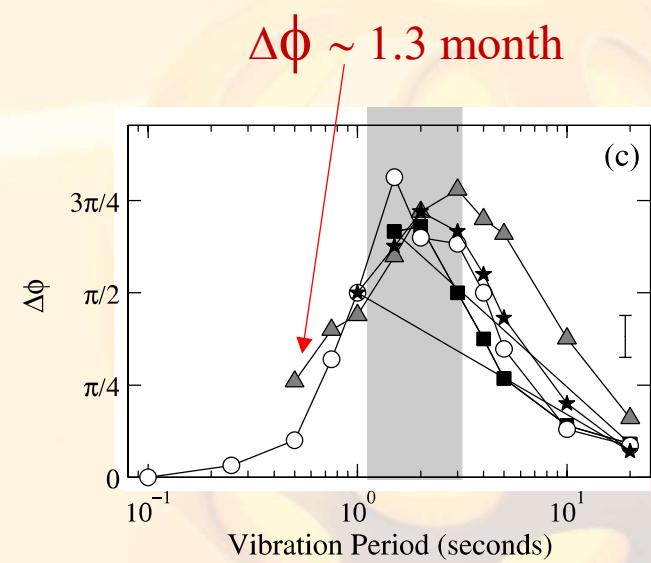
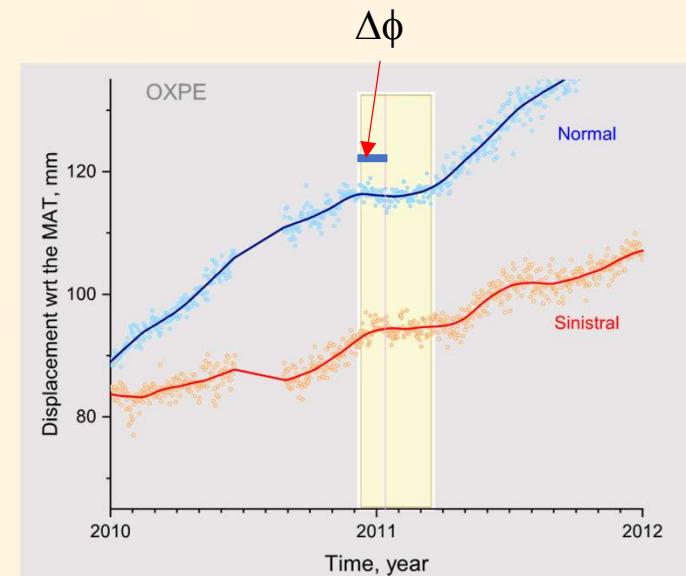
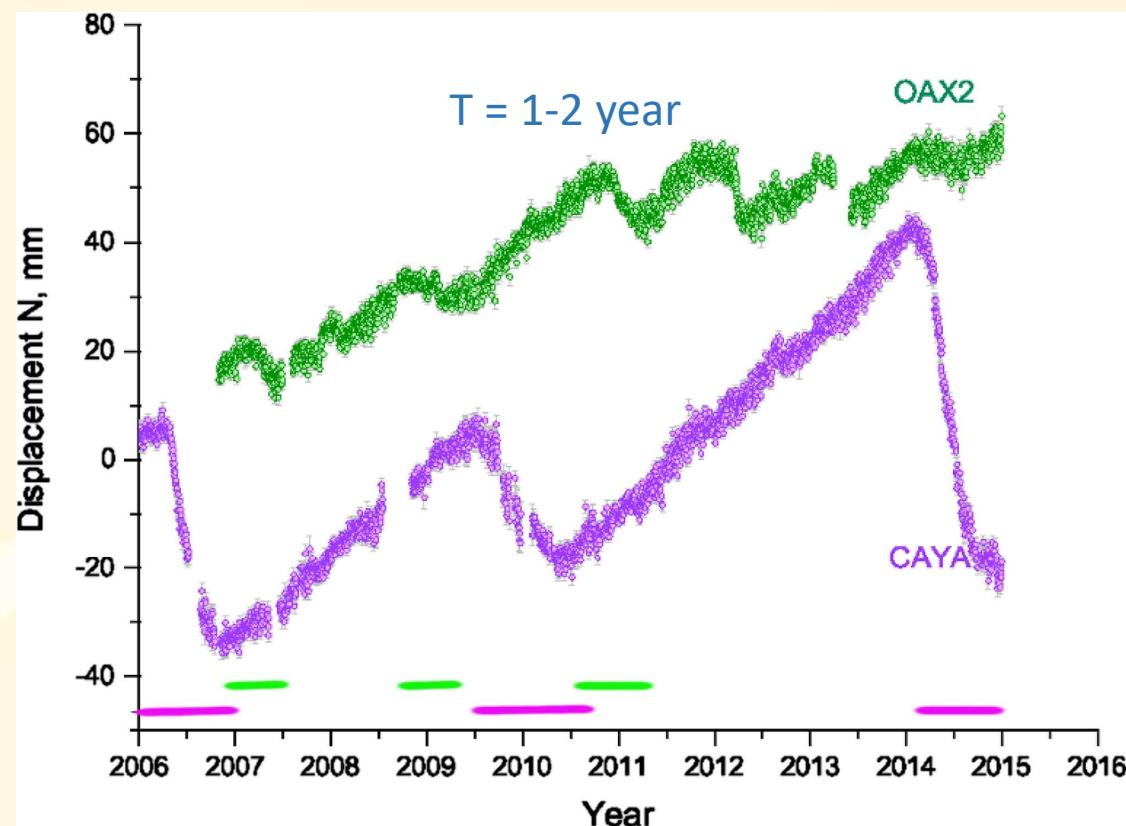


Spatiotemporal Variations in Slow Earthquakes Along the Mexican Subduction Zone

$$T_c^* \sim 3.3 \text{ year}$$

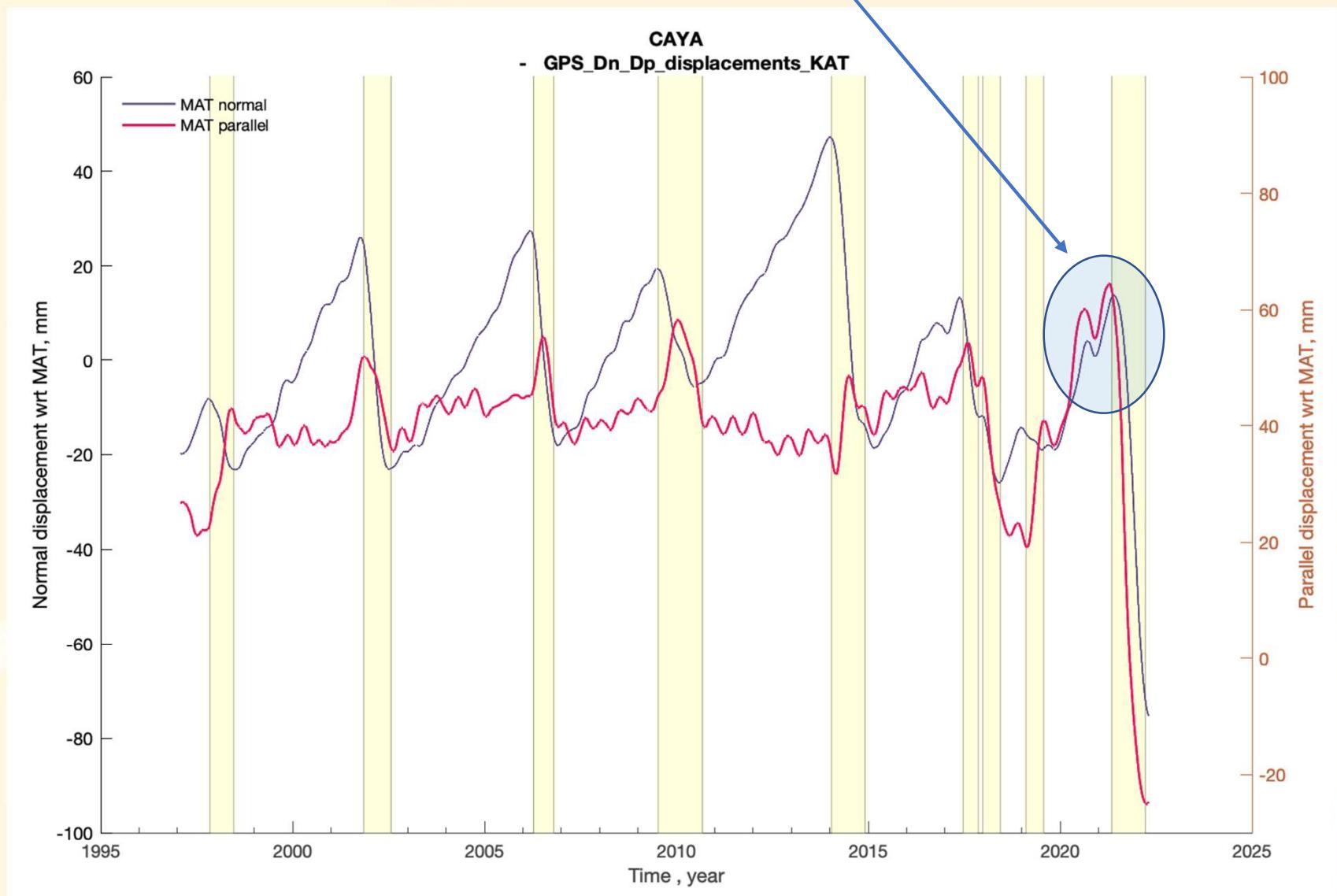
$$\text{Oaxaca } T = 1-2 \text{ year}$$

$$\Delta\phi \sim 1.3 \text{ month}$$



Maury et al., 2018

Unexpected ($\Delta\phi$)



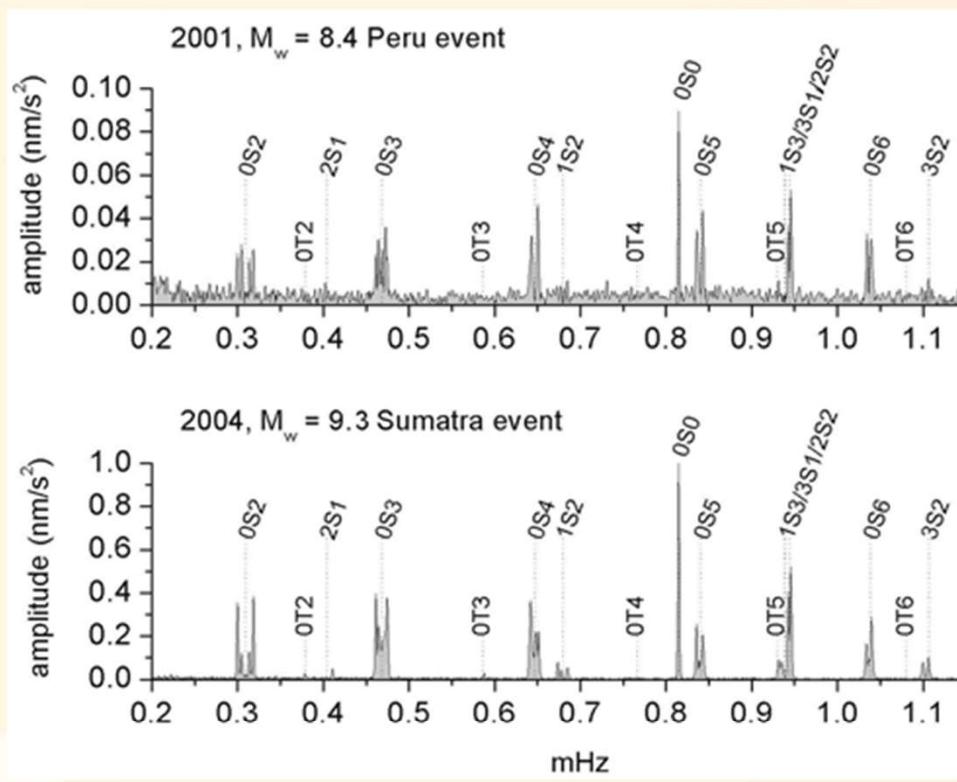
DATA

Absolute gravimeter

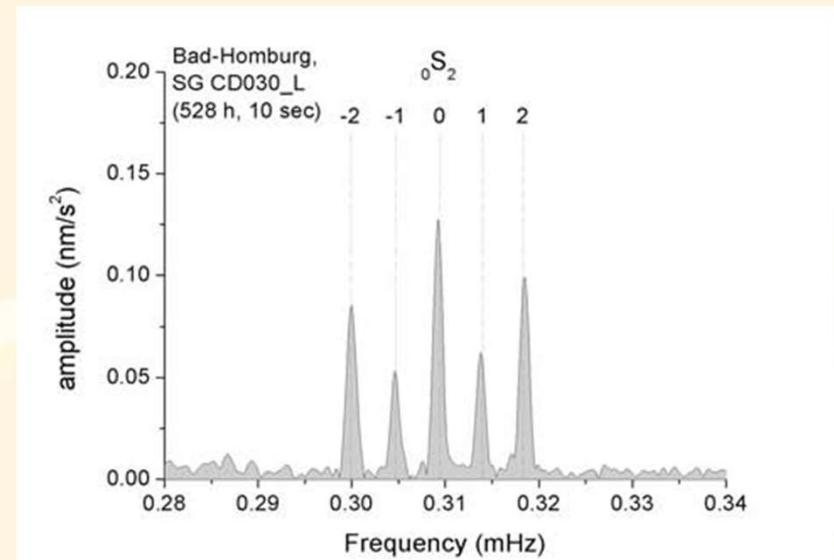
GNSS – GPS

Seimological records

Superconducting Gravimeter data for analysis of the seismic normal modes



Amplitude spectra of SG data at Canberra (240 hours)



five singlets of 0S₂ at Bad-Homburg using 528 hours
of data after the 2004 Sumatraevent.

INTRODUCING THE FG5-X

The new state of the art
in absolute gravity measurement

Improved reliability
and accuracy
New extended free-fall
length chamber
Improved Electronic Control



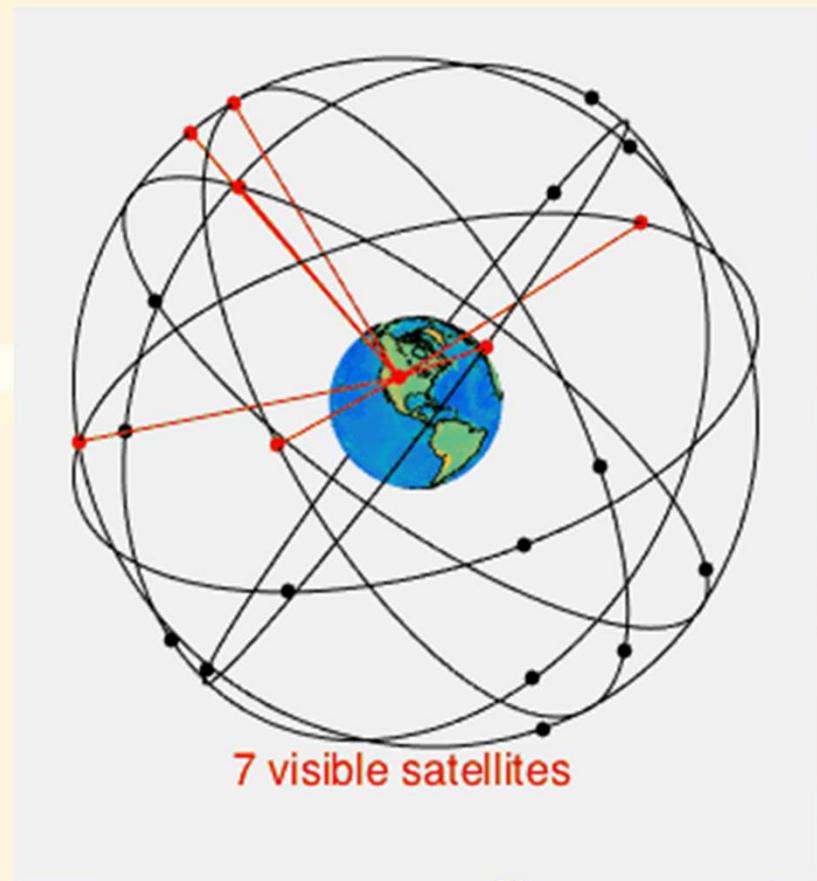
FG5X-252 gravimeter

Mro. Alfredo Esparza

Centro Nacional de Metroología (CENAM)



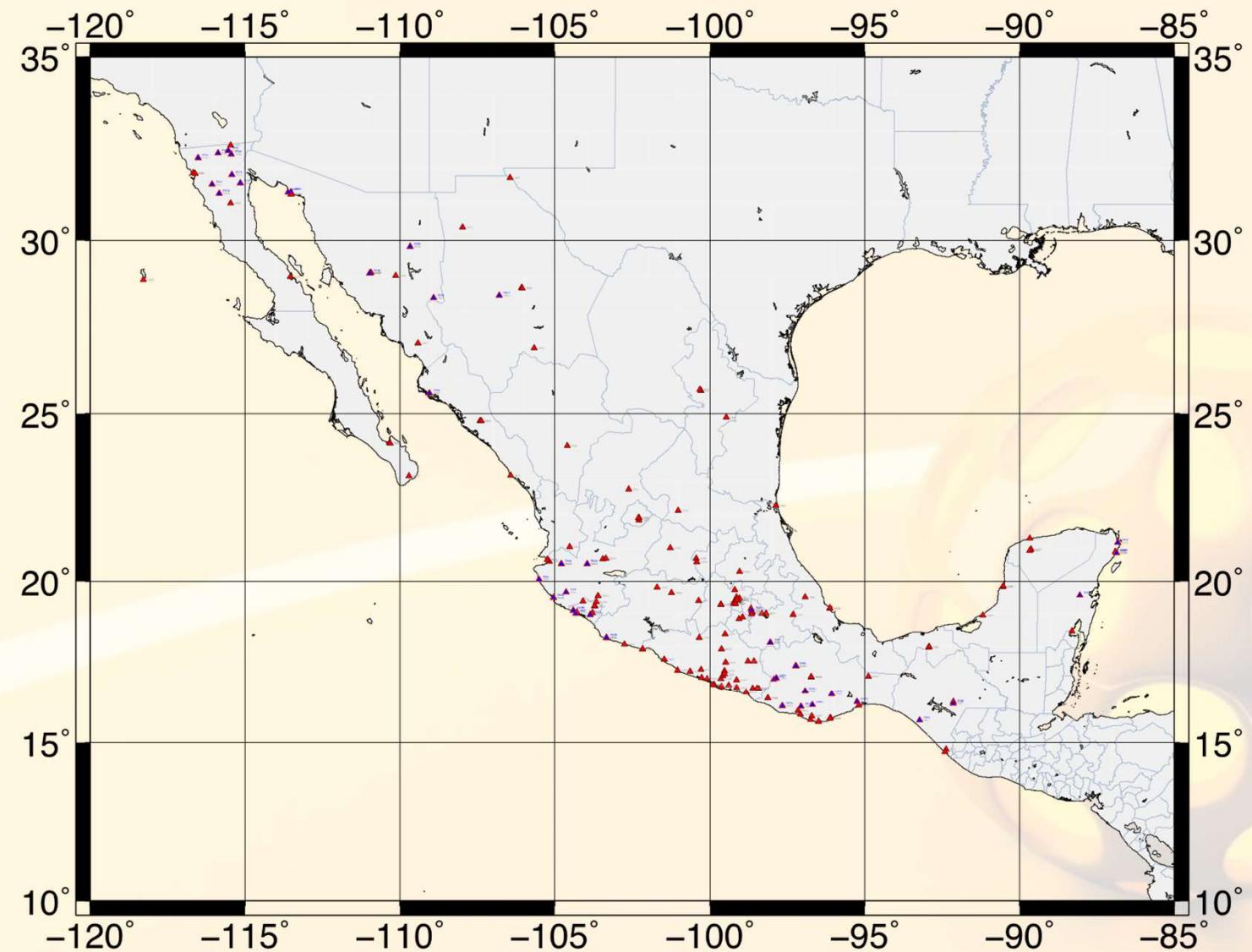
GPS

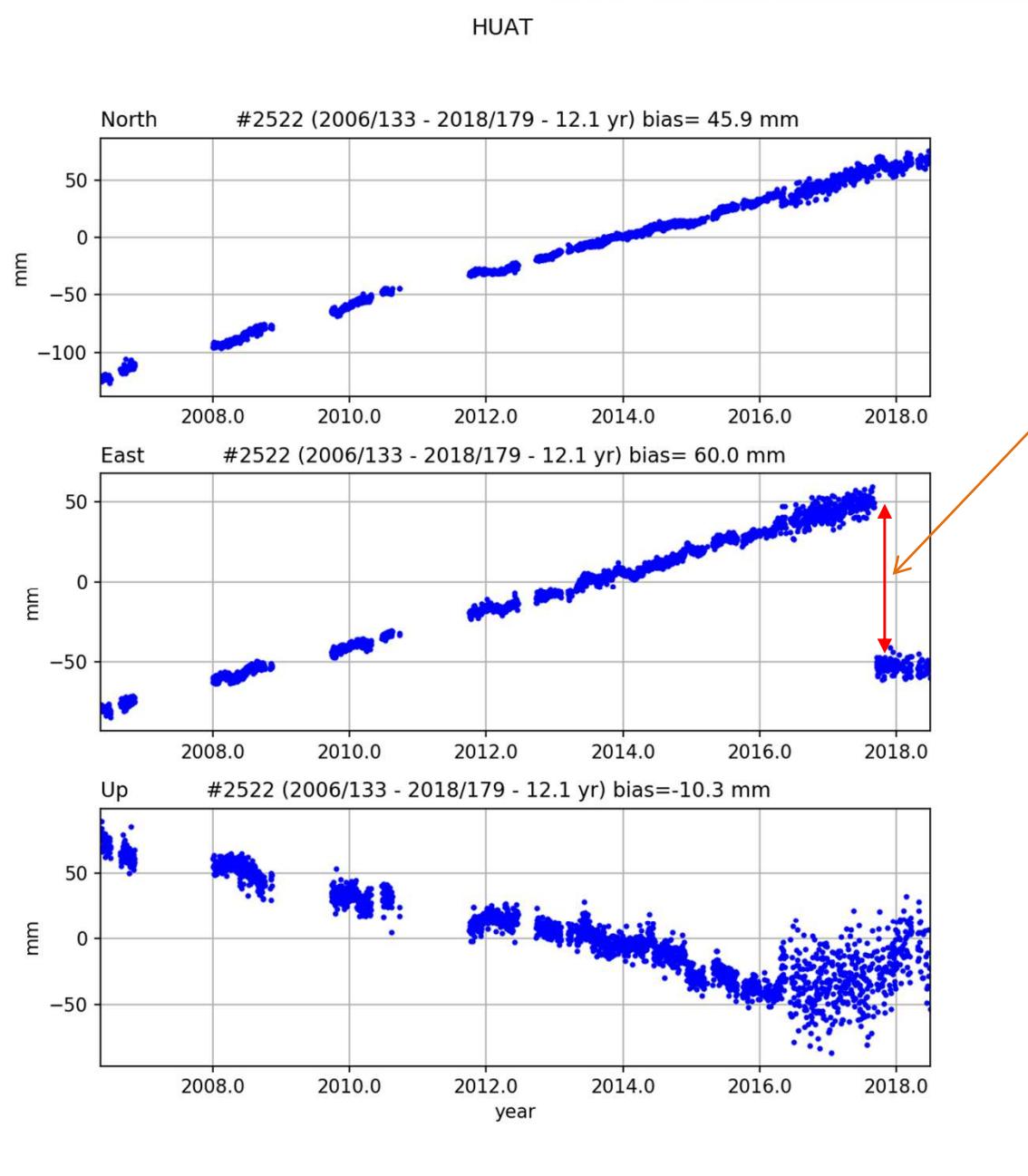


Acapulco GPS station



~260 GPS stations exist in Mexico

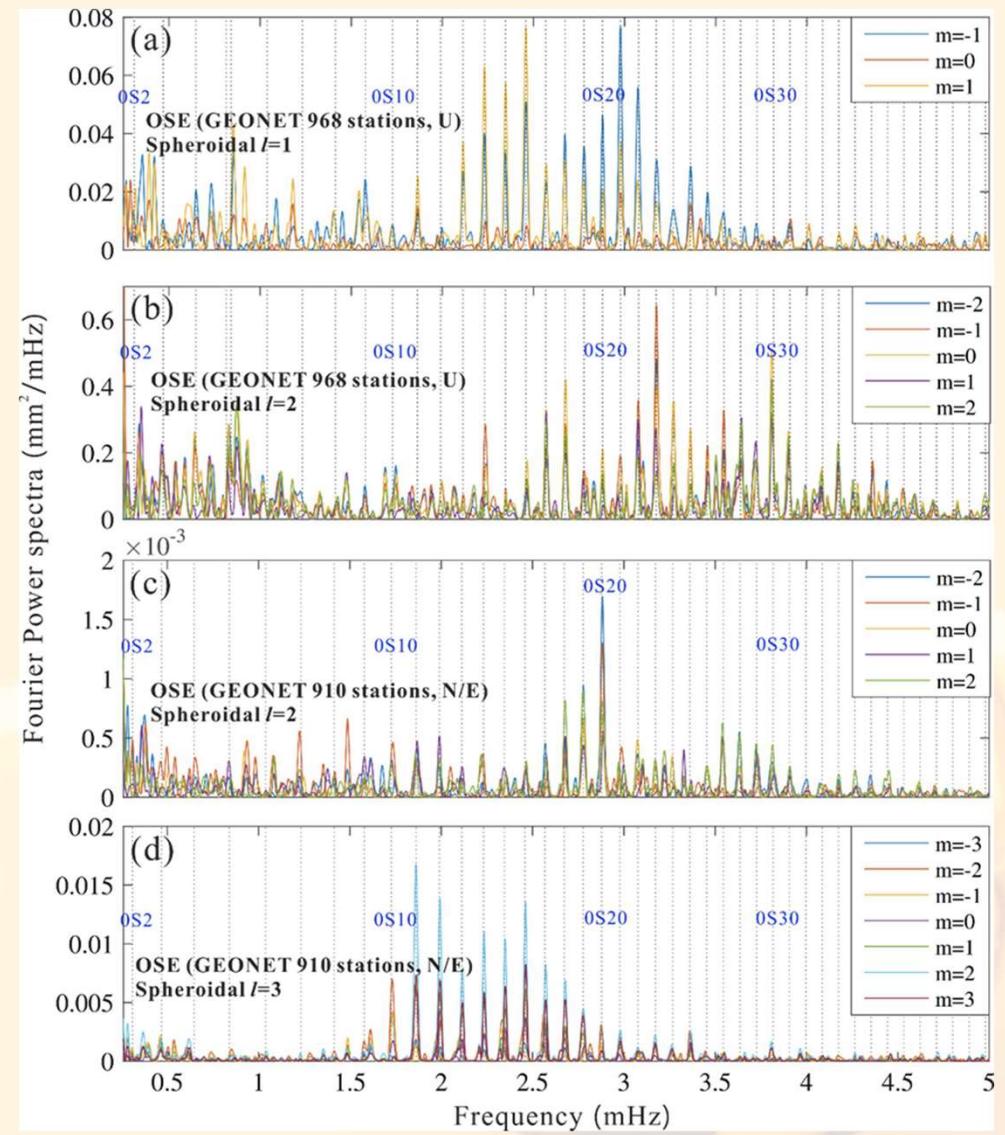
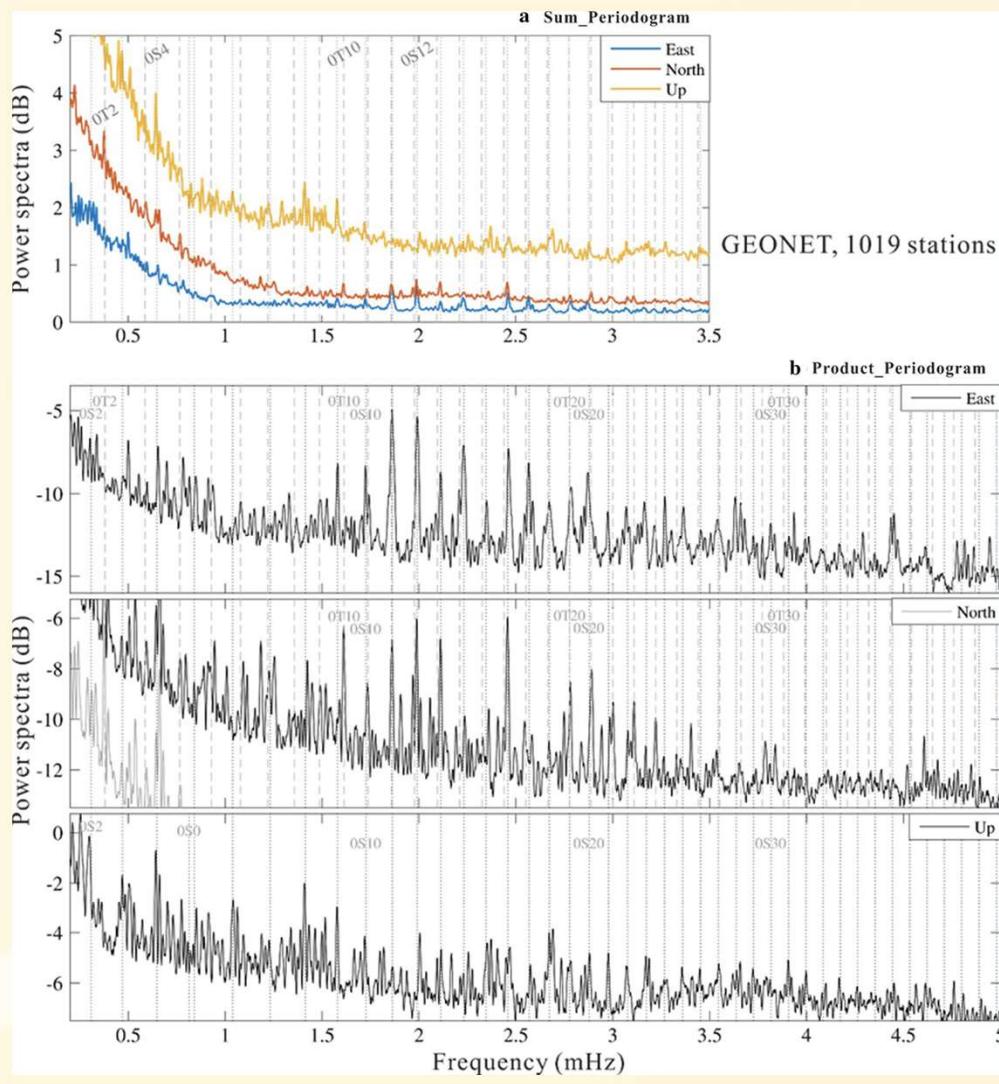




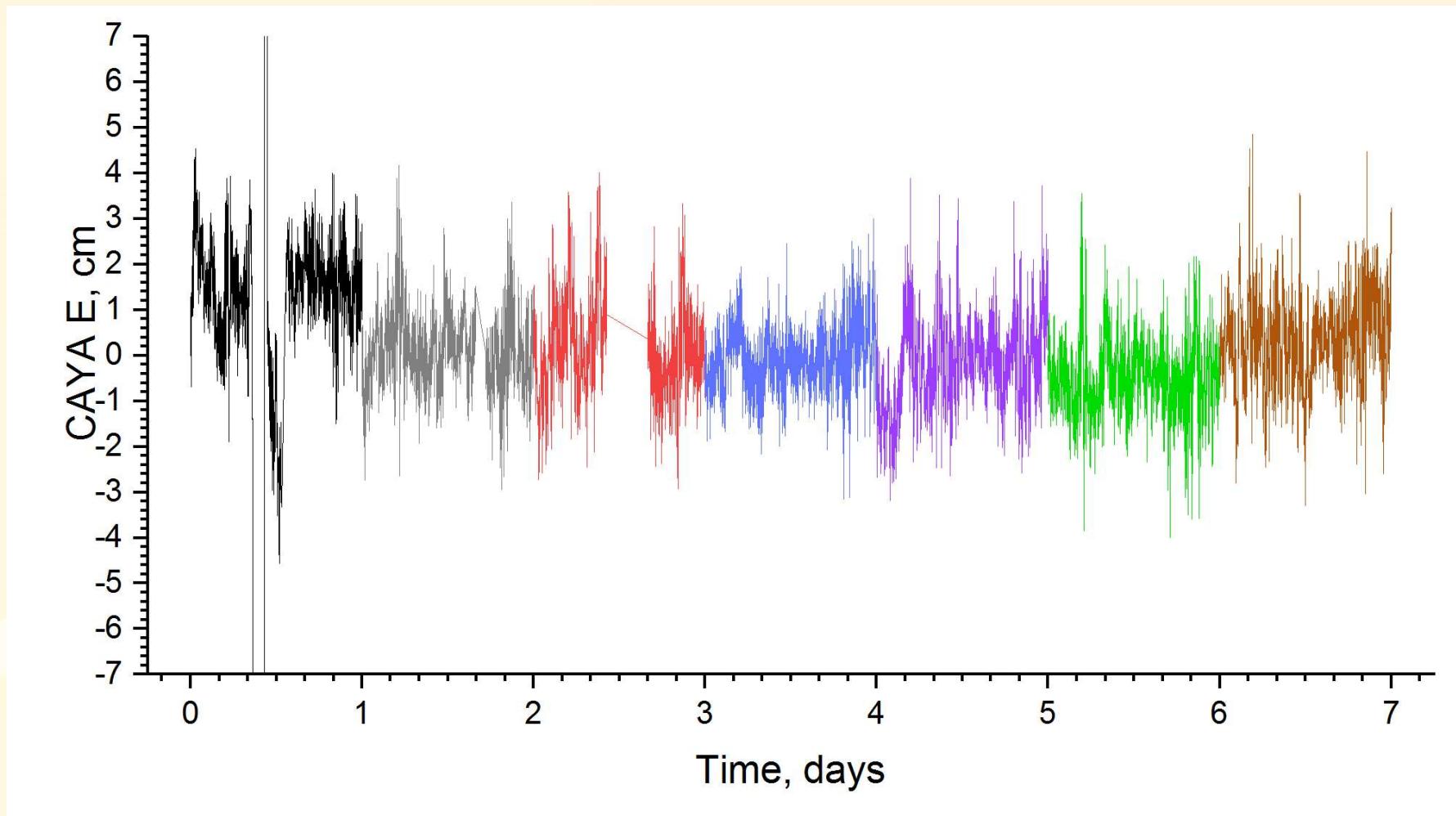
Chiapas
7 sep. 2017, Mw 8.2

Crustal strain rate at
HUAT
~2 cm/year

Earth's free oscillations from GPS records

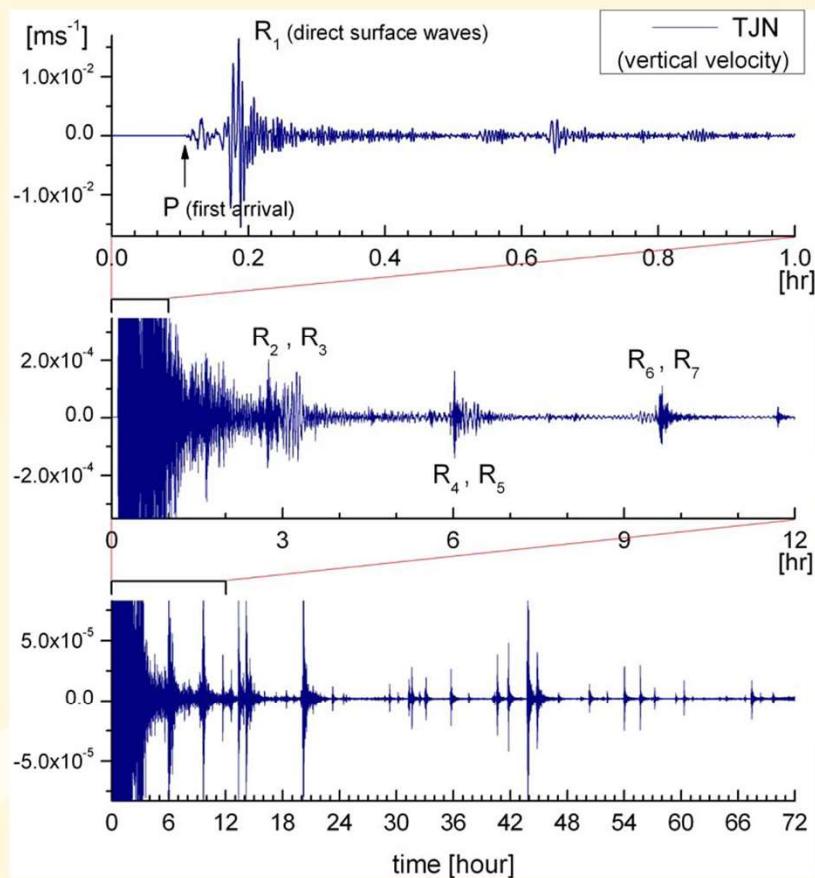


CAYA 30 sec daily GPS records



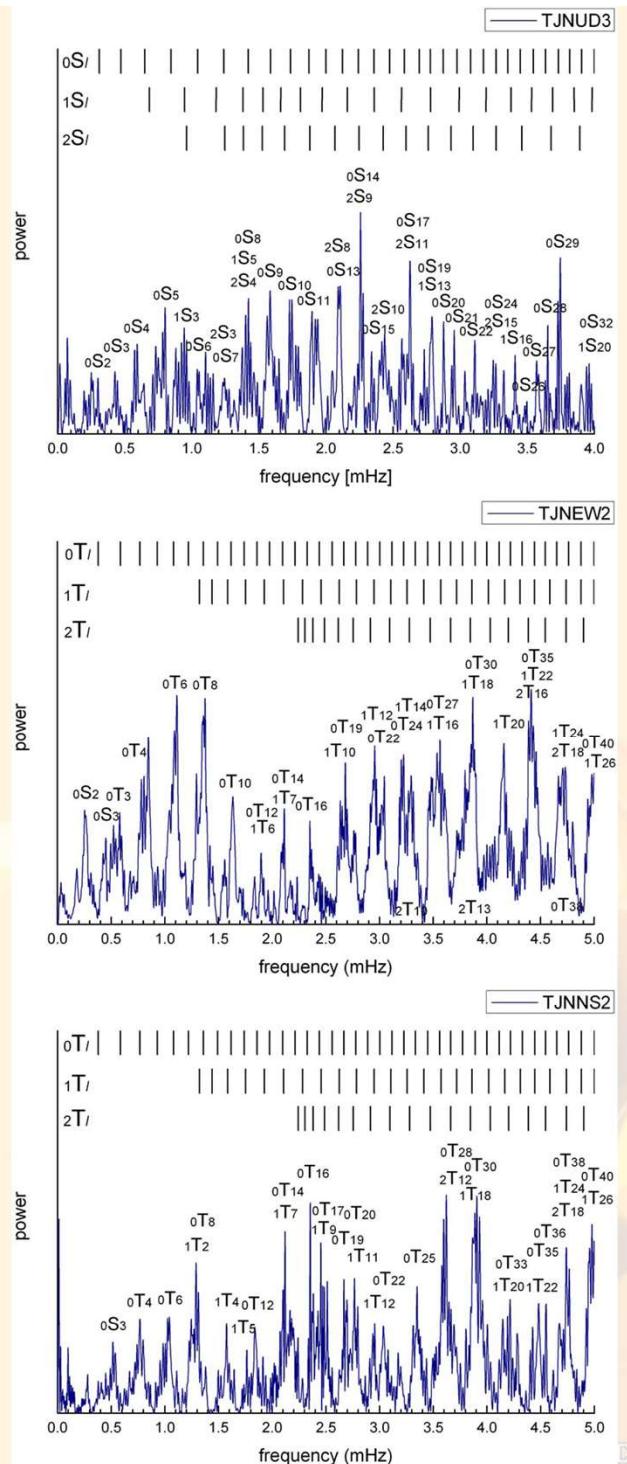
Seismic data

*Amplitudes on the order of $nGal$ (10^{11} sm^{-2})
can now be observed by modern seismometers*



Daejeon seismic station record of the 2011
Tohoku earthquake (up-down velocity component)

Chung et al., 2017





Phase	Division Discontinuity	Dens- ity	Depth (km)	State	Temp (°C)	Composition (as oxides)
I	CRUST	2.7	-10	solid	20	Si, Al
			-0			Si, Mg, Fe/Ca
II	UPPER MANTLE	3.3	30-40	solid	400	
			60-100	mushy		
			200	??		
			700			Si, Mg, Fe
III	LOWER MANTLE	4.3	1000	??	1800	
			2000			
			2900			2250
IV	OUTER CORE	10.0	2500	liquid	2500	
			5150			Fe, Ni
V	INNER CORE	12.3	13.3	solid	3000	
		13.6	6370			