



**The Abdus Salam
International Centre for Theoretical Physics**



2265-18

**Advanced School on Understanding and Prediction of Earthquakes and
other Extreme Events in Complex Systems**

26 September - 8 October, 2011

Plate Tectonics, Earth Asymmetries, and Seismology

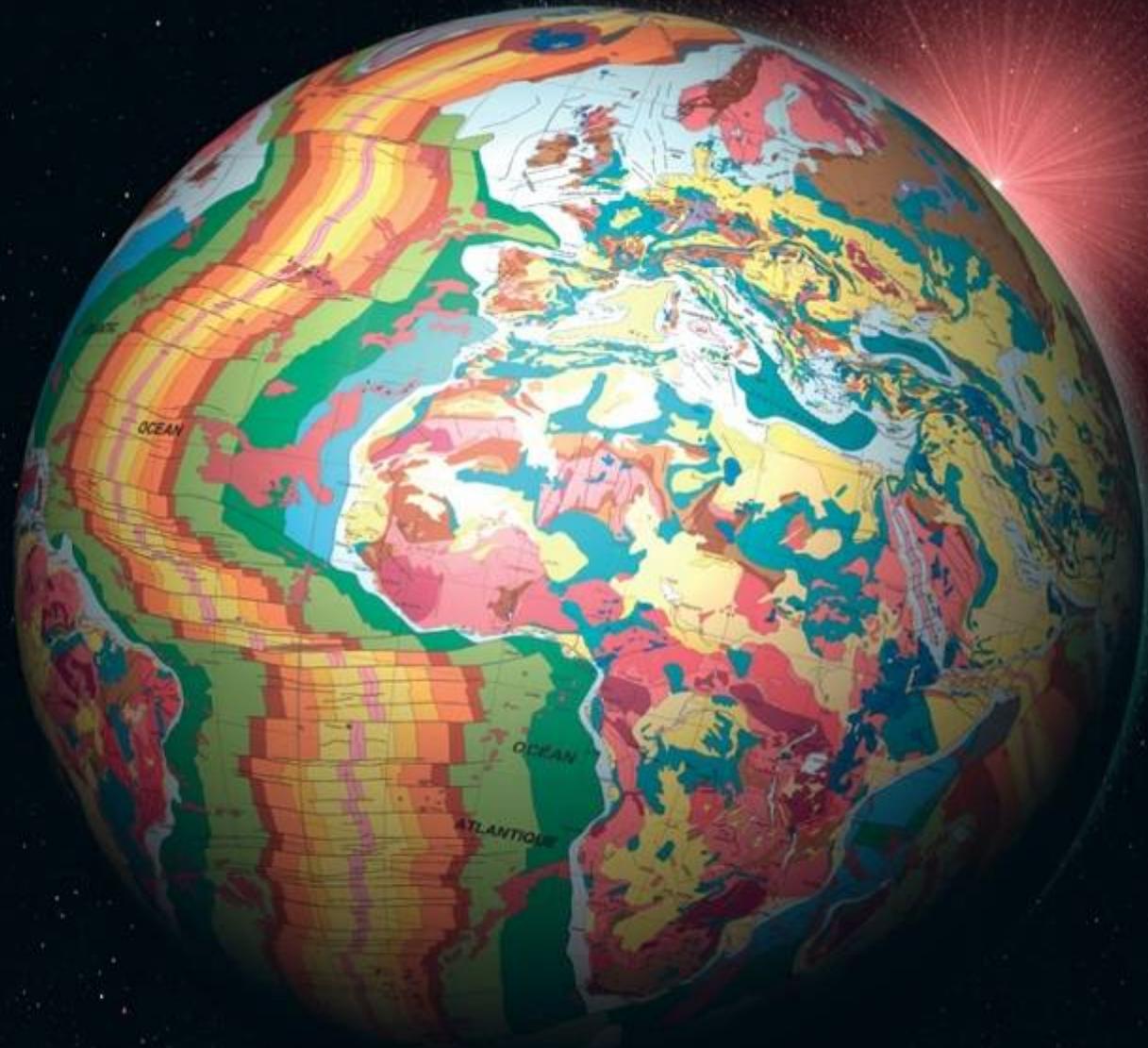
C. Doglioni

Universita' degli Studi di Roma "La Sapienza"

Roma

Italy

TERRA ASIMMETRICA



Glossario di base:

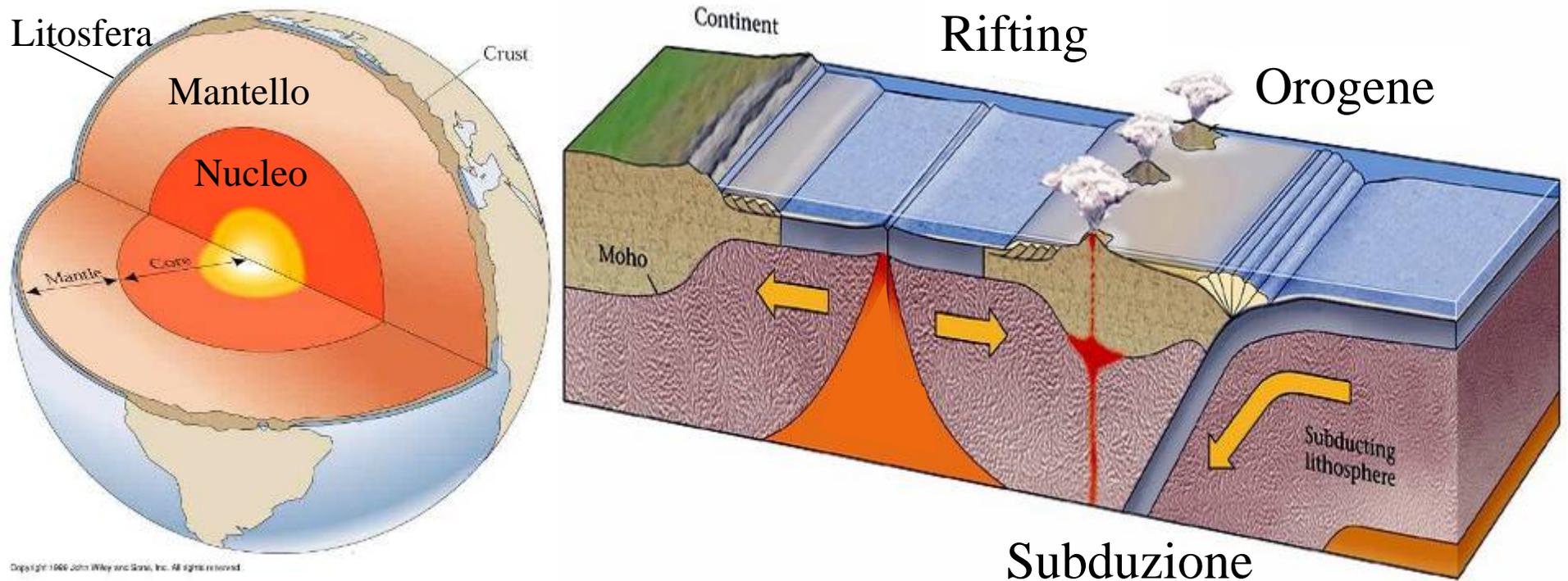
Litosfera = 100 km del guscio esterno della Terra

Mantello = Sotto la litosfera fino a 2900 km

Placche = frammenti di litosfera (continenti e/o oceani)

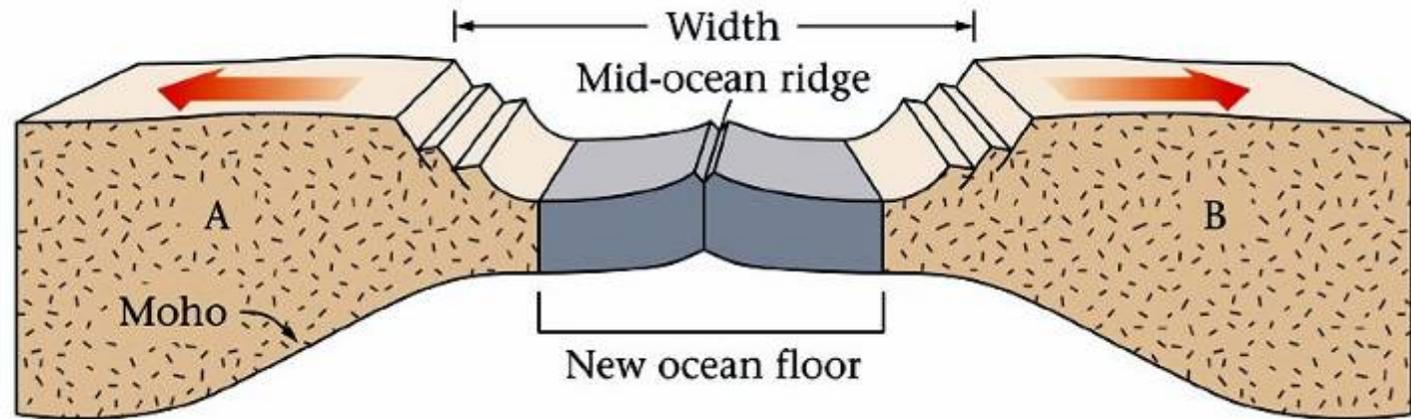
Rifting = dove le placche si allontanano --> oceani

Subduzione = dove le placche si avvicinano e
la litosfera scende nel mantello --> orogeni



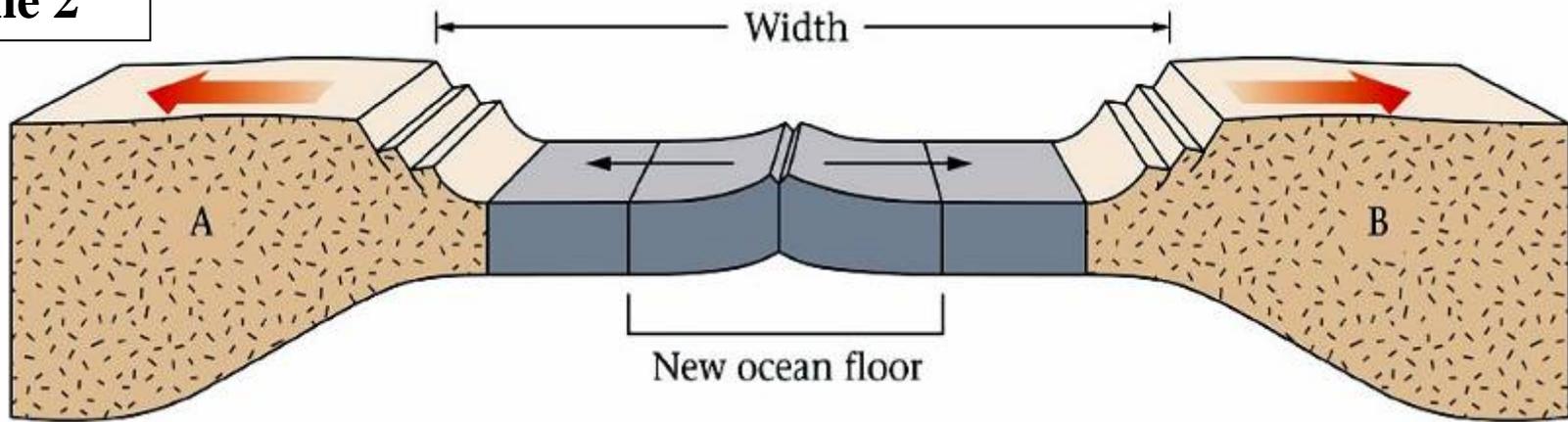
RIFTING

Time 1

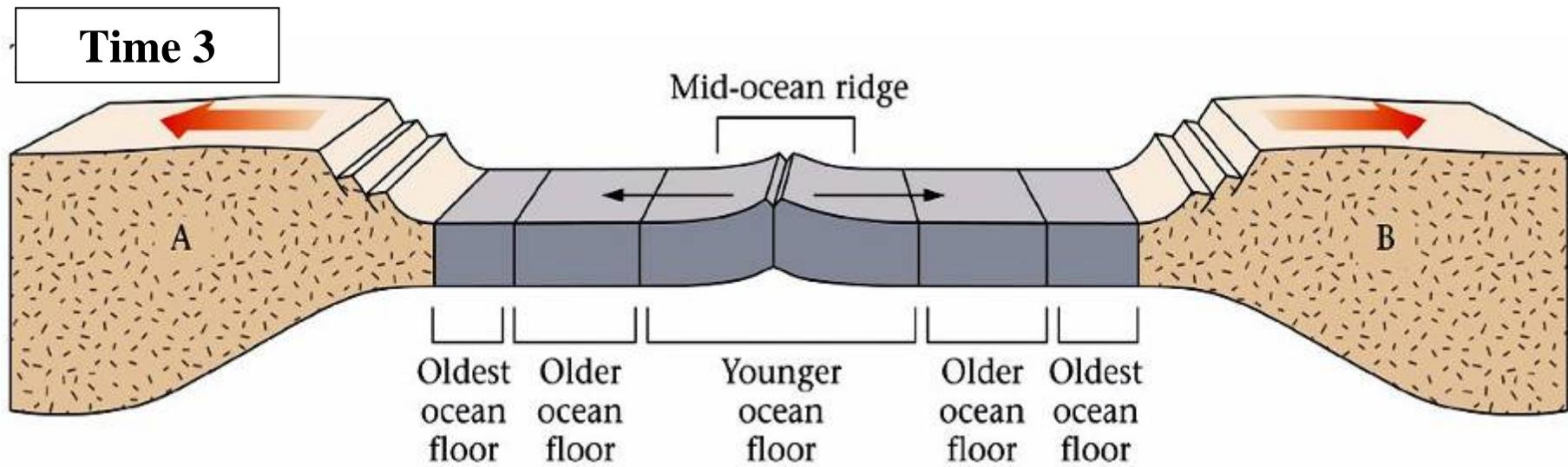


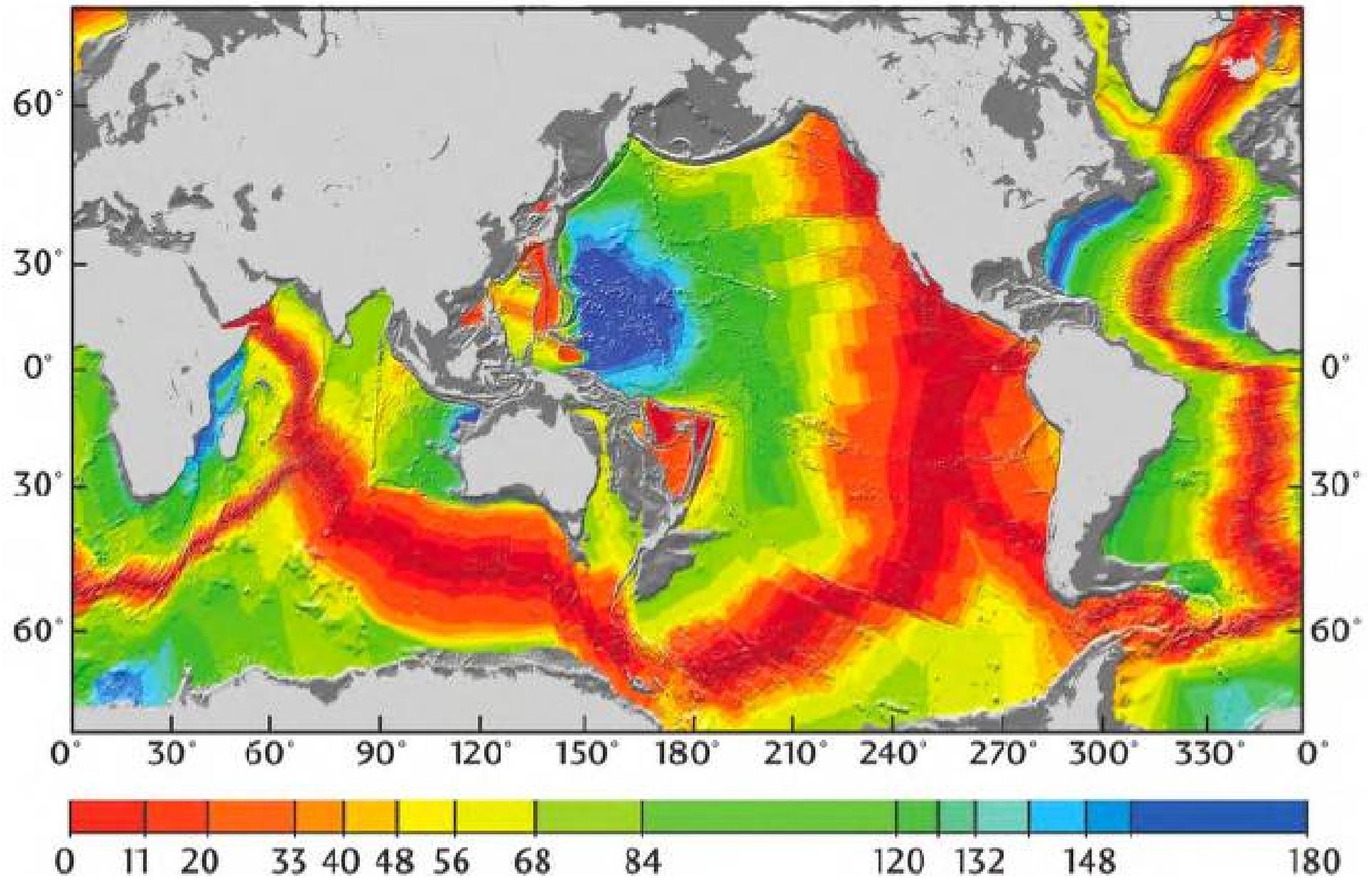
RIFTING

Time 2



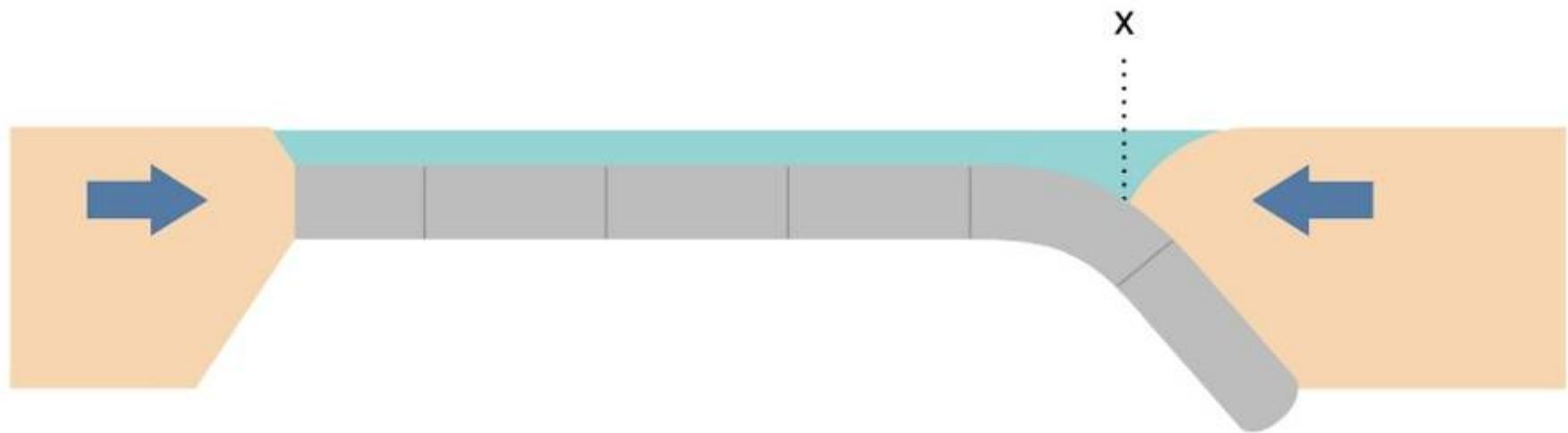
RIFTING



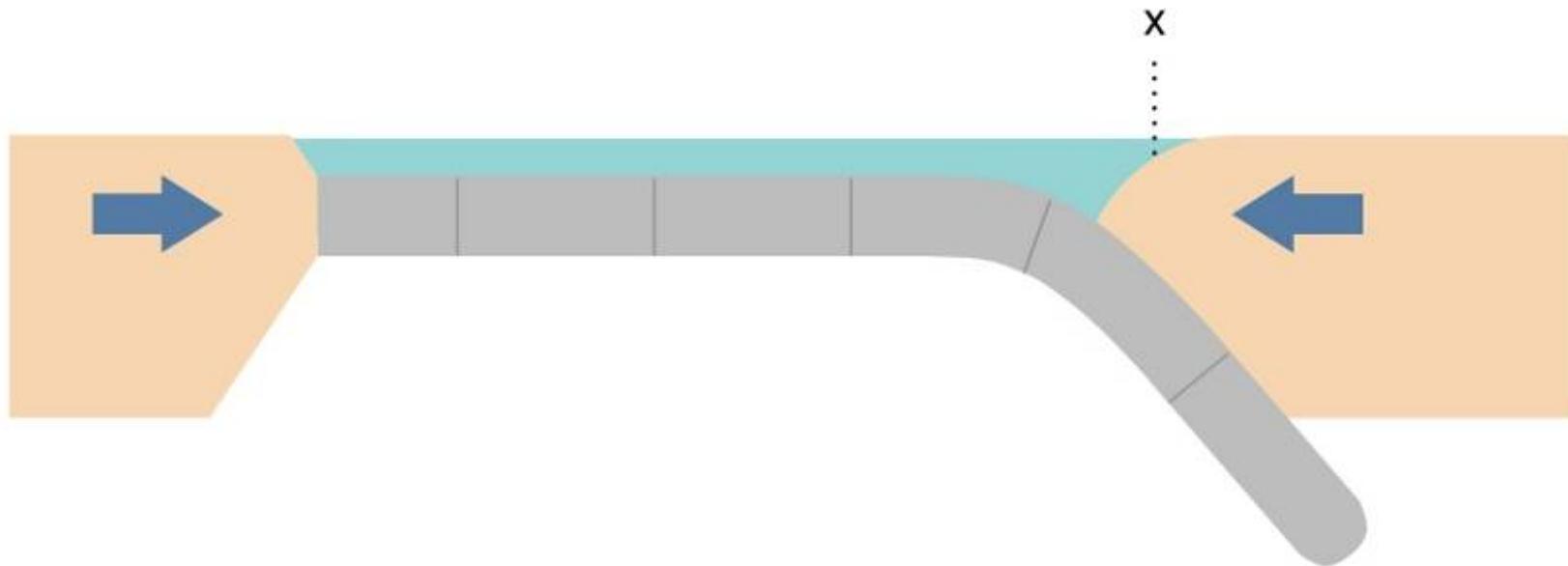


milioni di anni

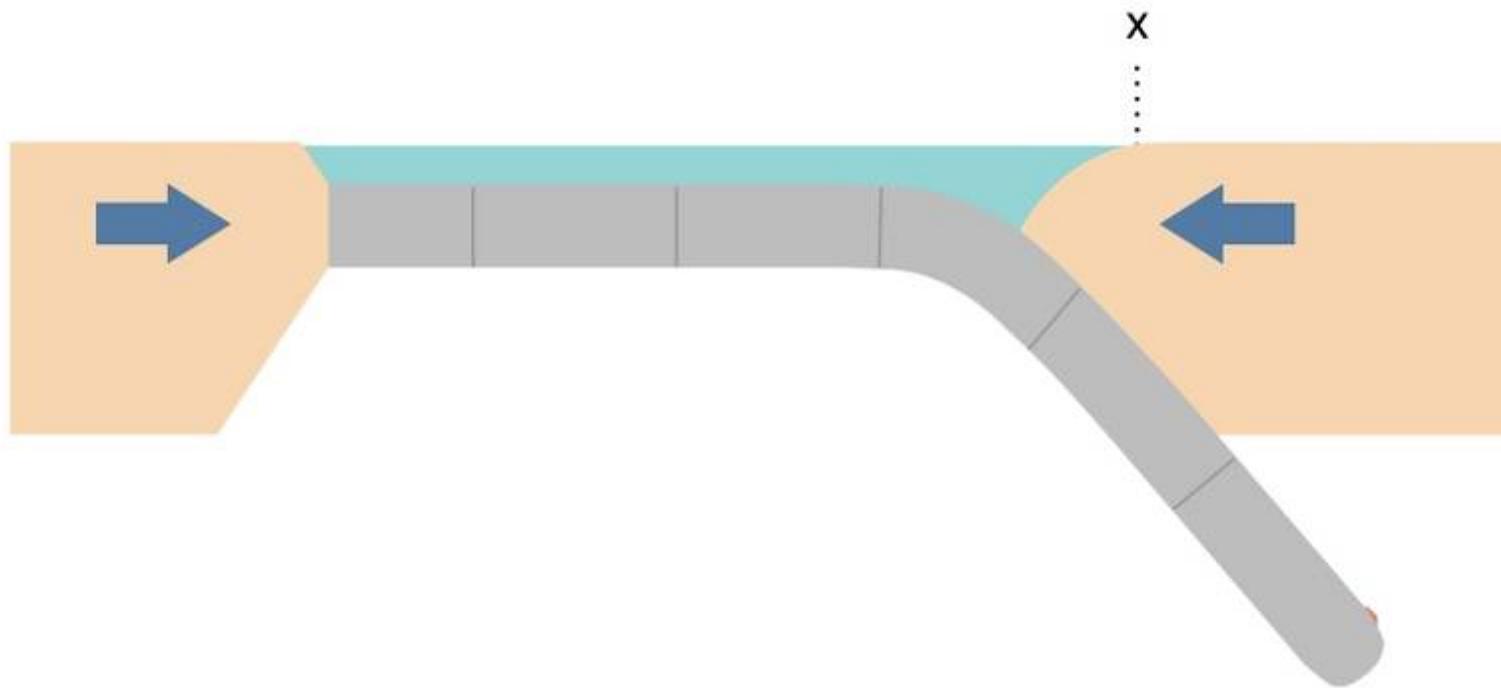
SUBDUZIONE



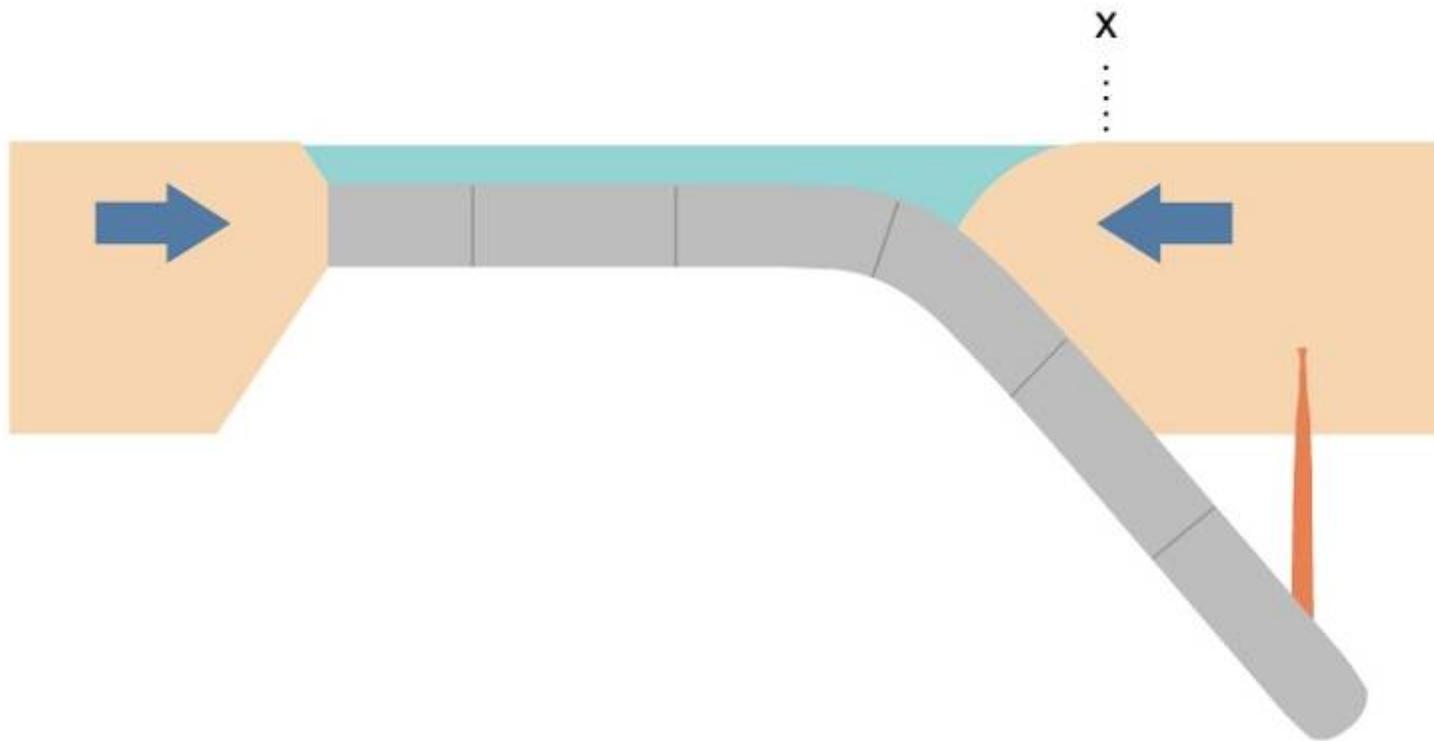
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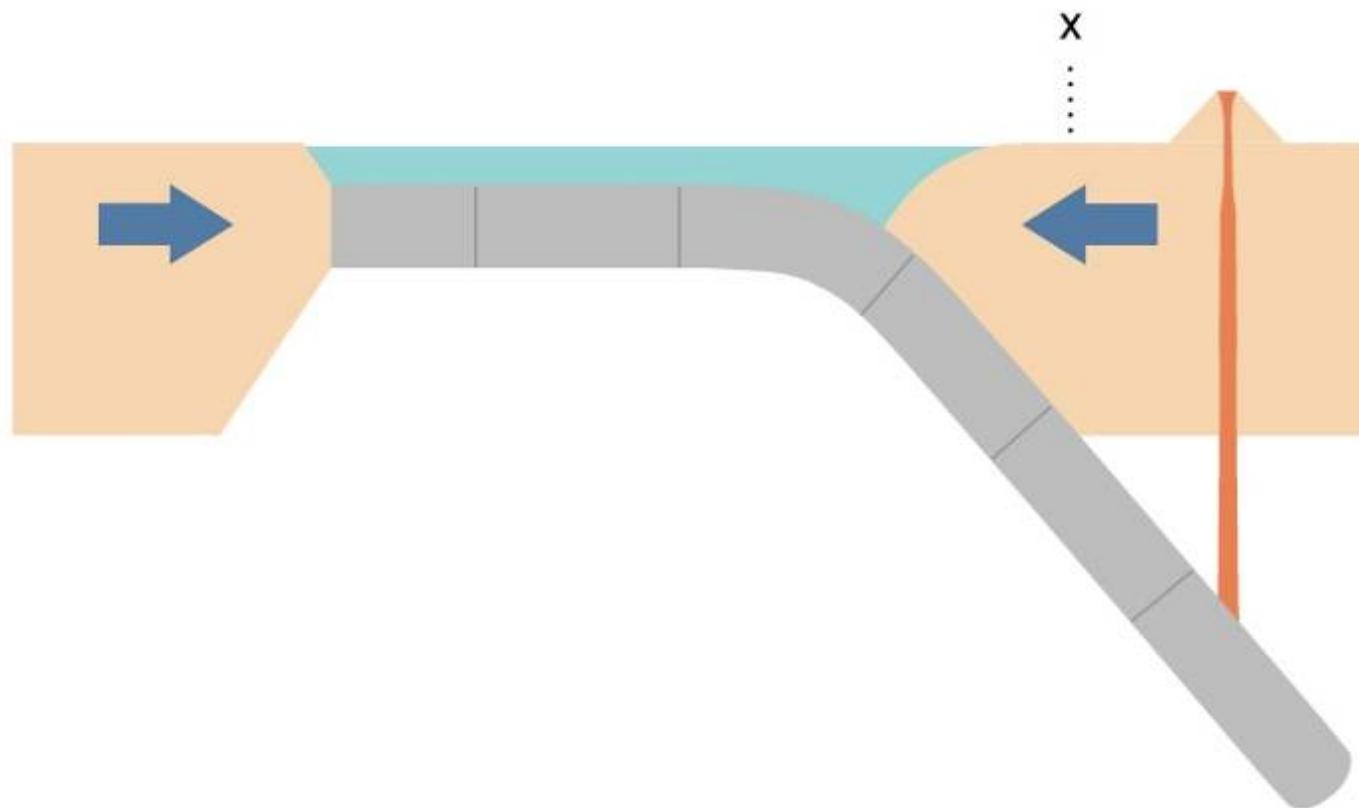
SUBDUZIONE



SUBDUZIONE



SUBDUZIONE



from Shuttle

Ande cilene

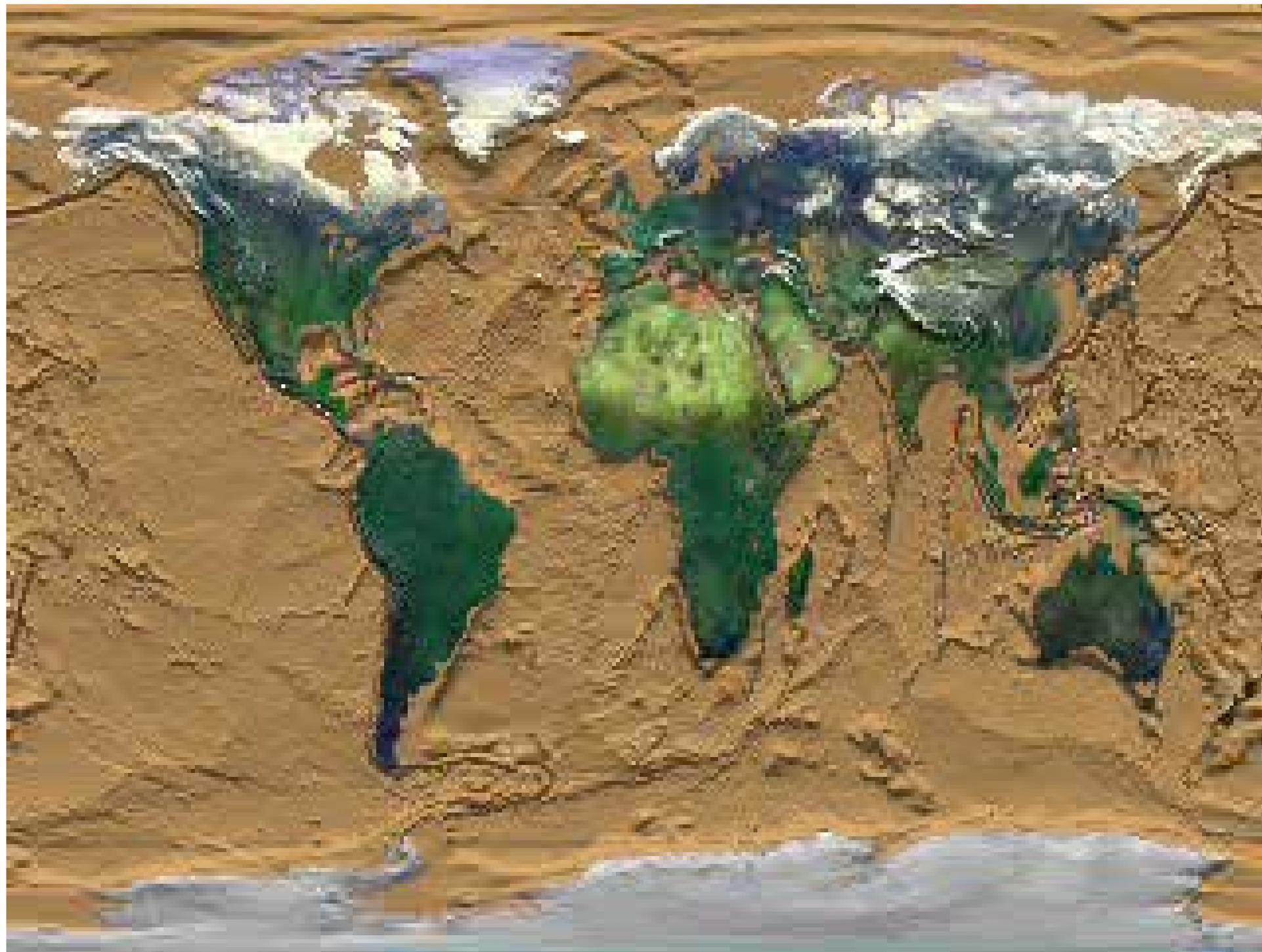
S-America

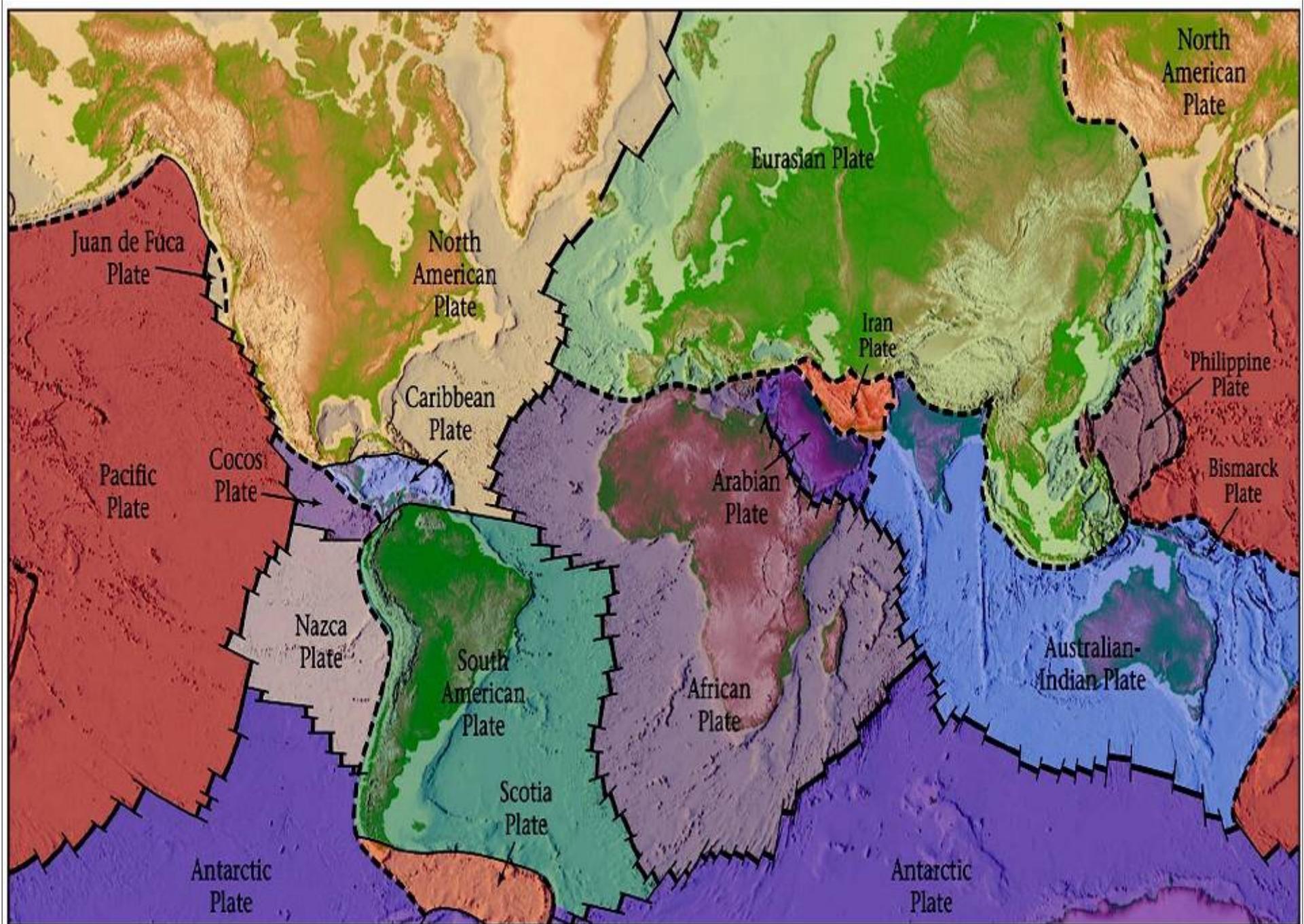
Nazca



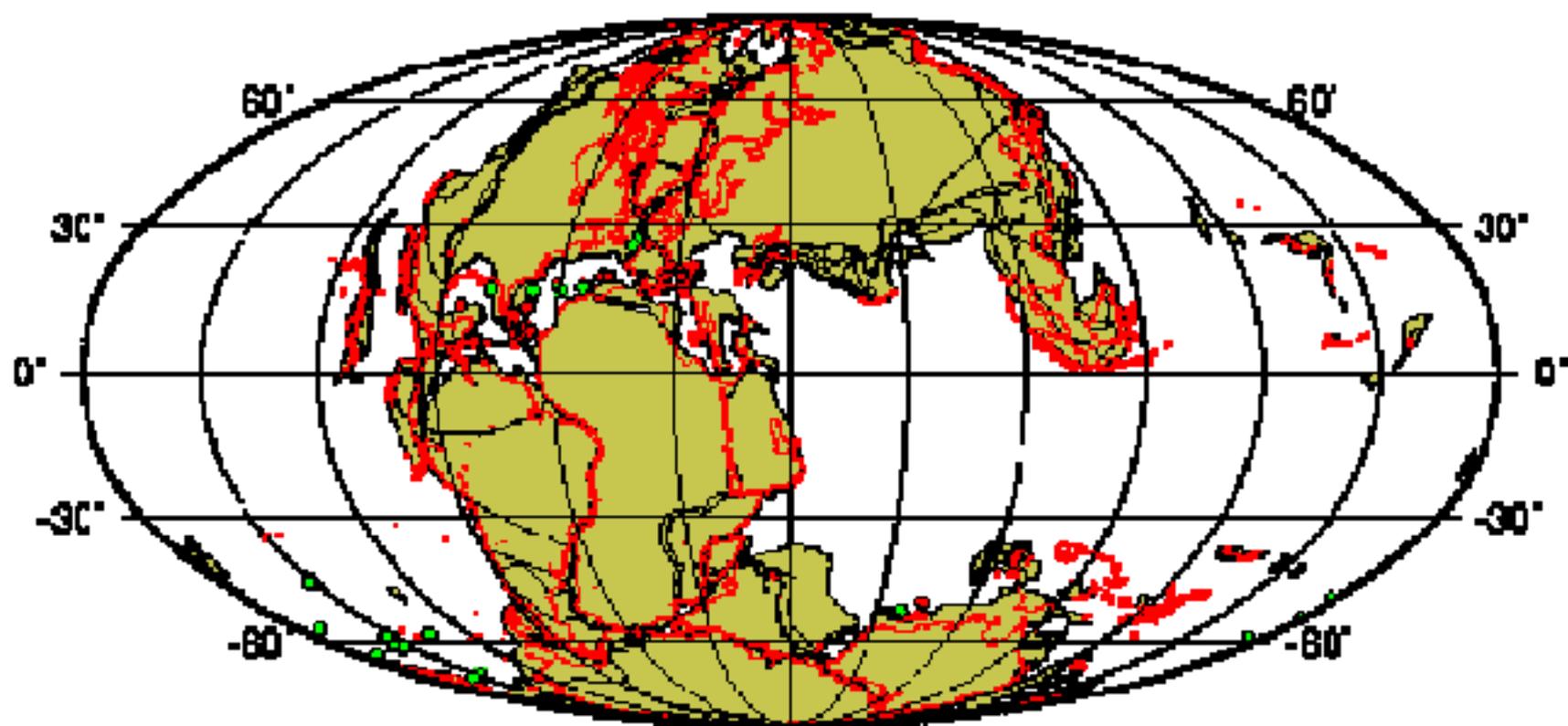
subduzione







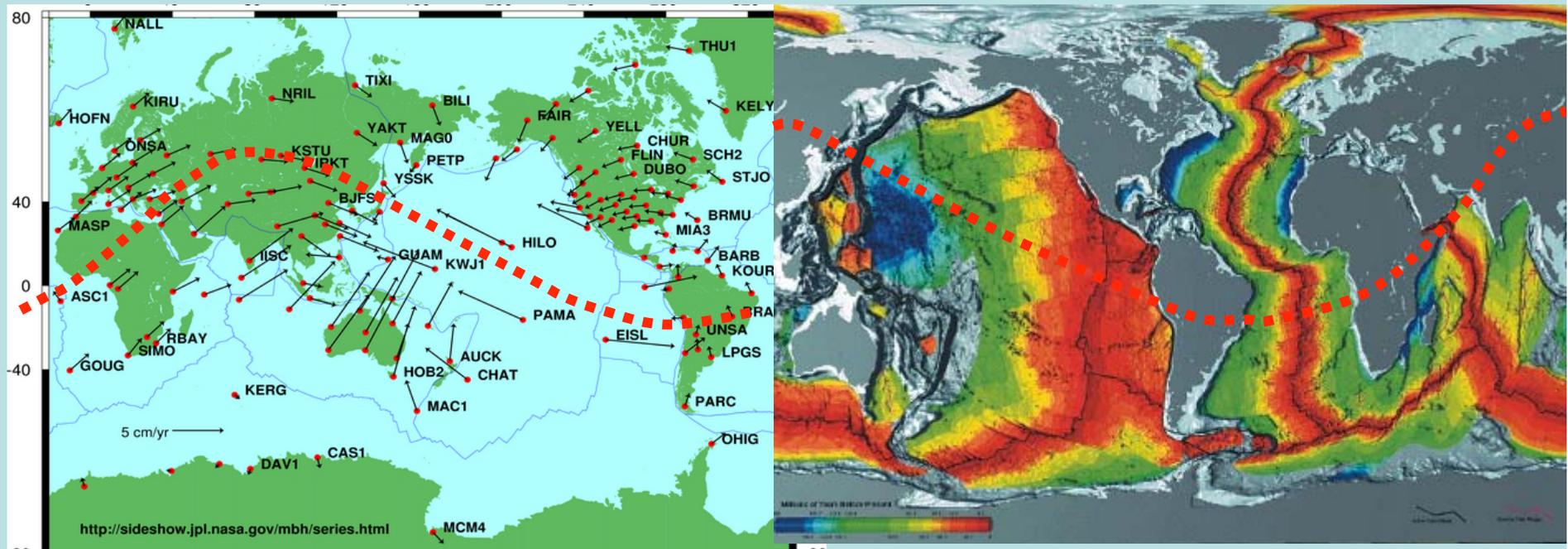
--- Trench or collision zone — Ridge — Transform boundary

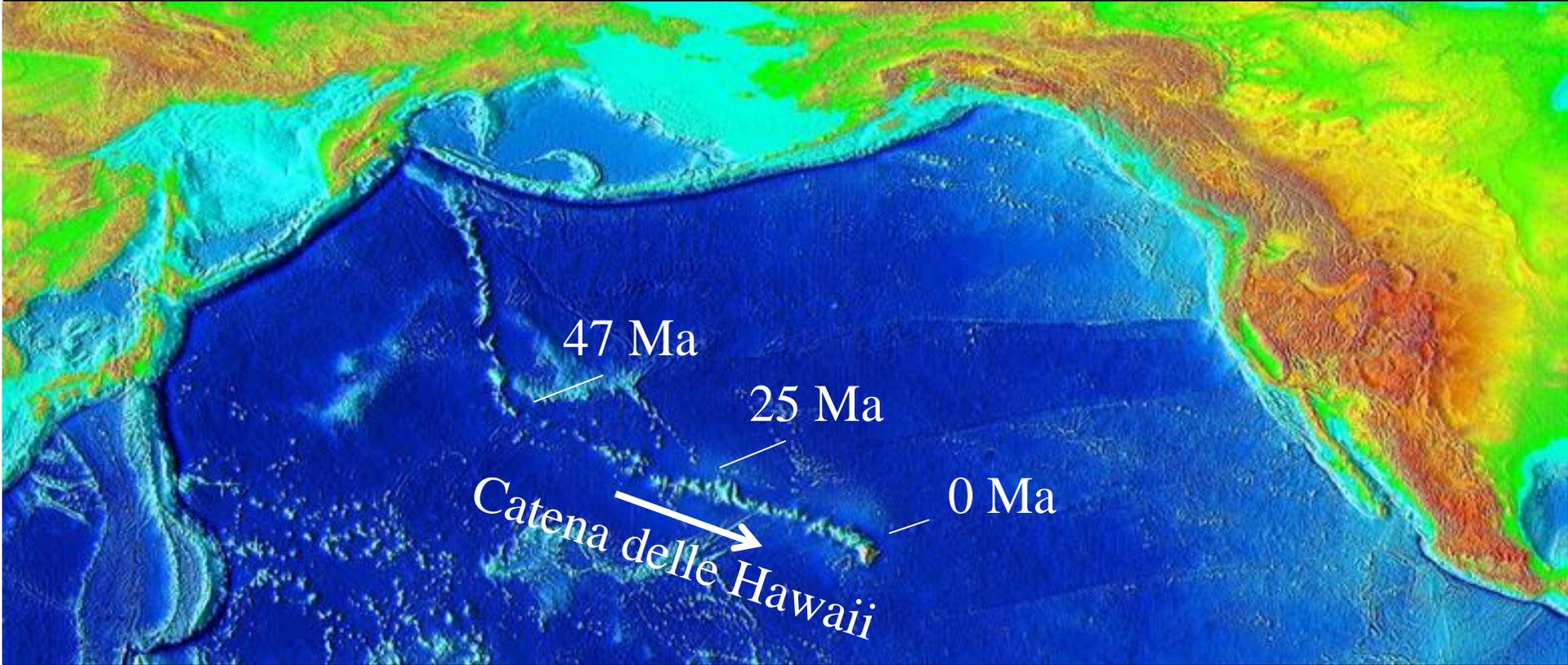


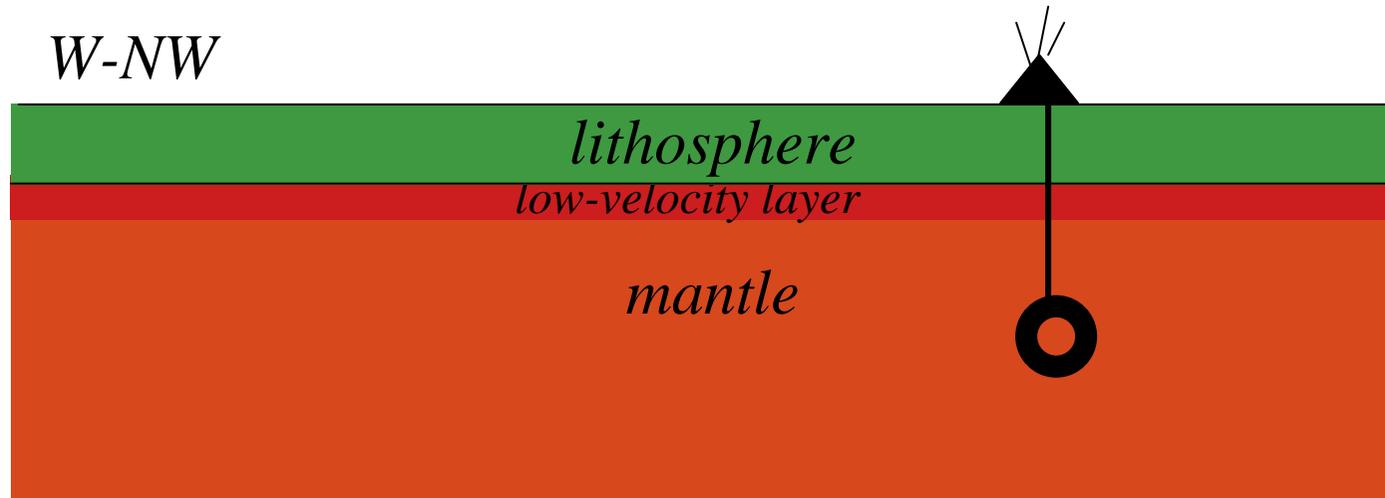
150 My Reconstruction

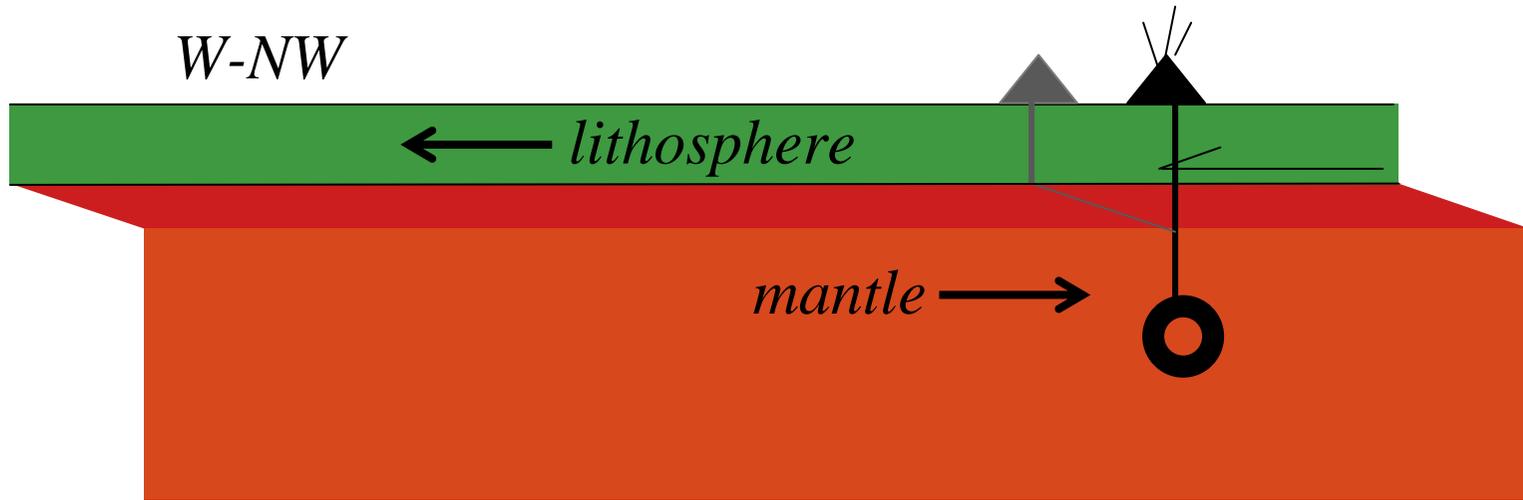
Movimenti attuali

Movimenti passati

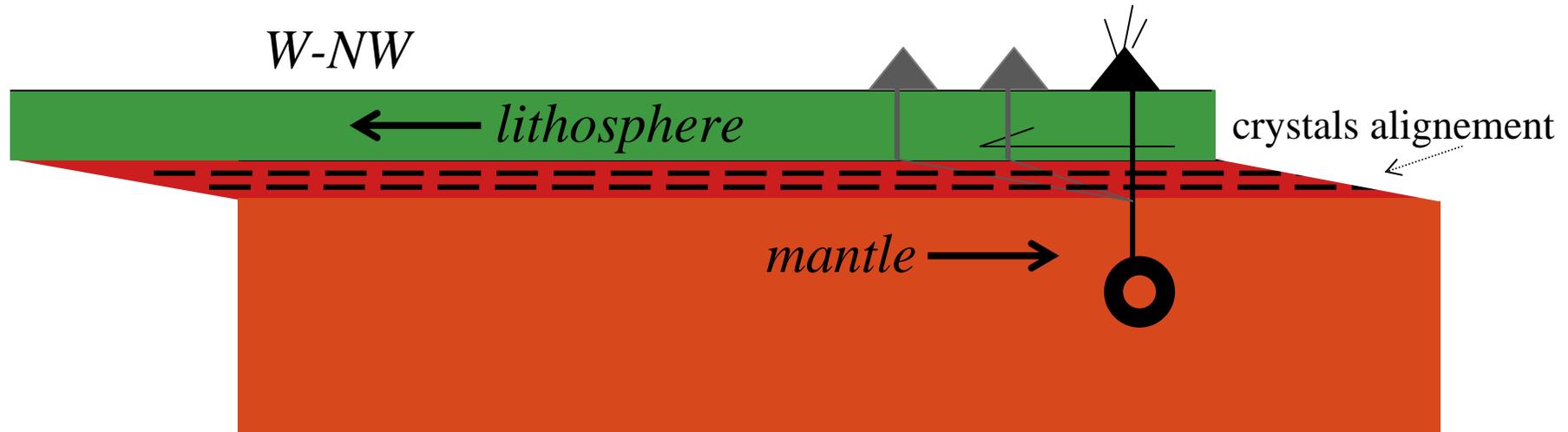


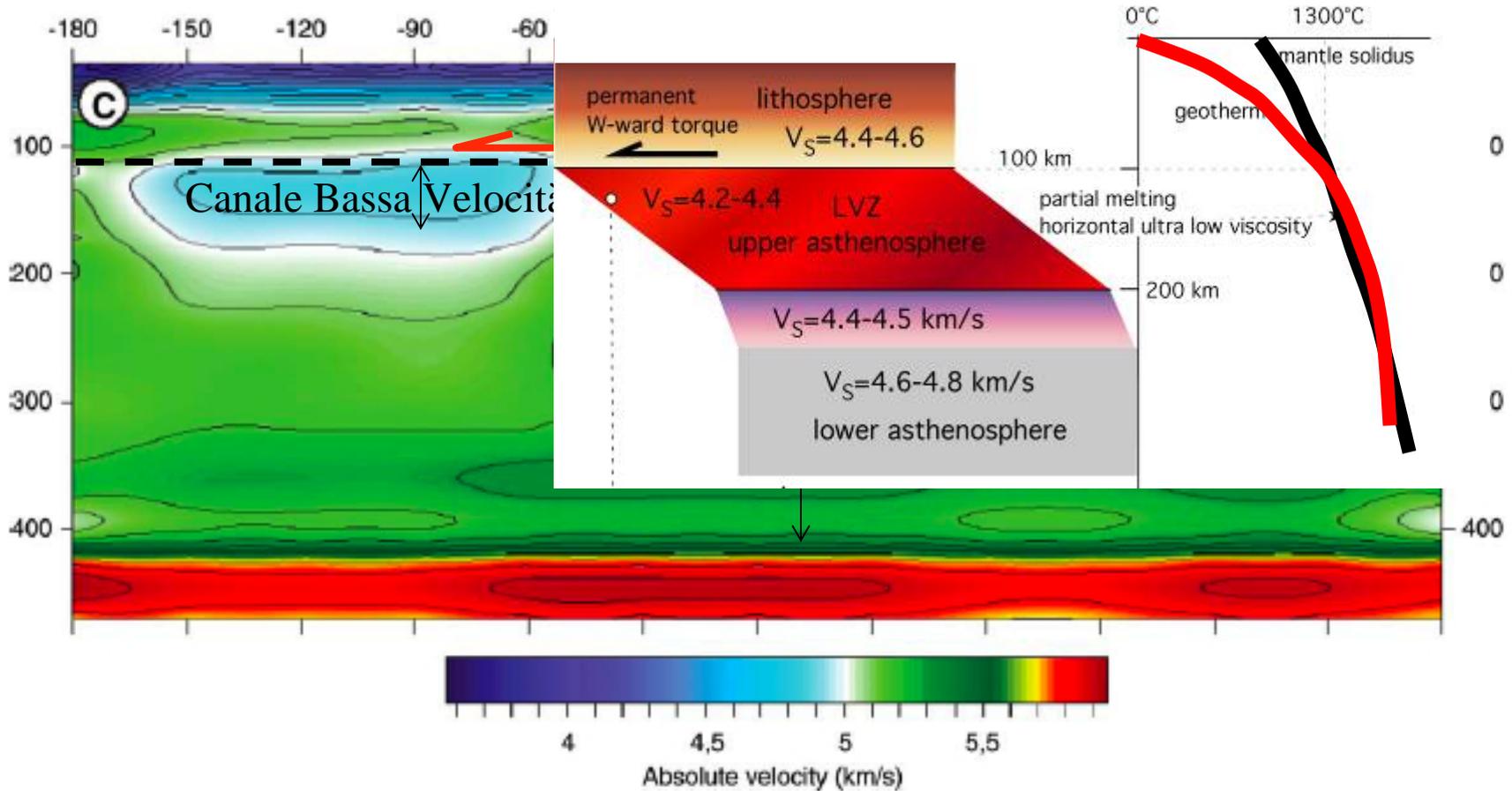
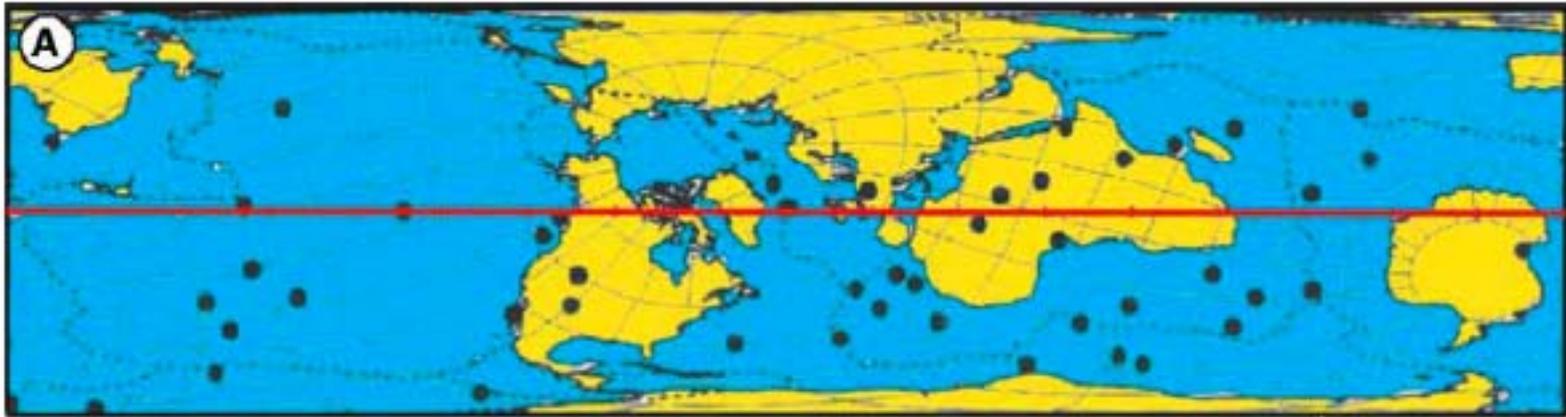


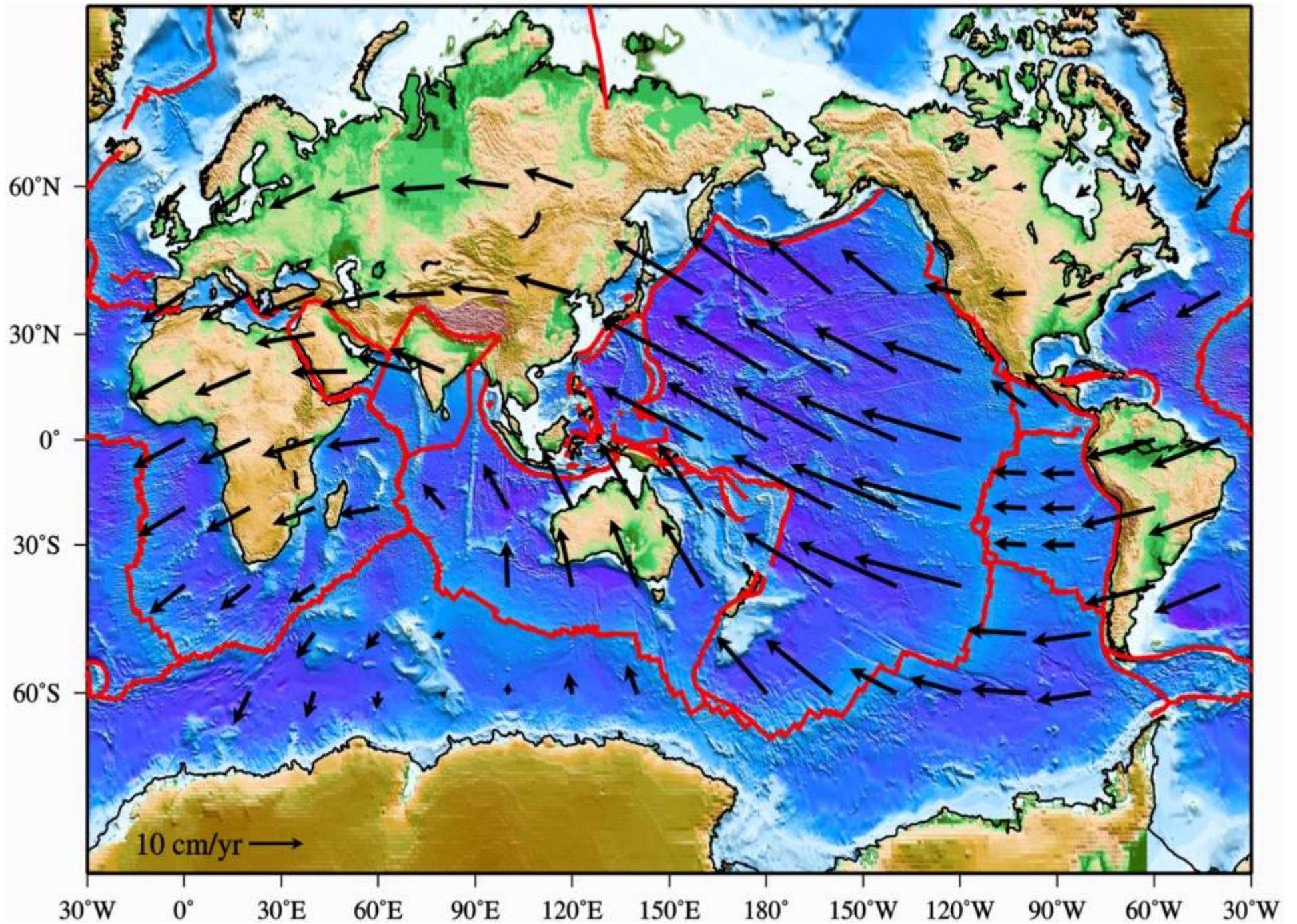




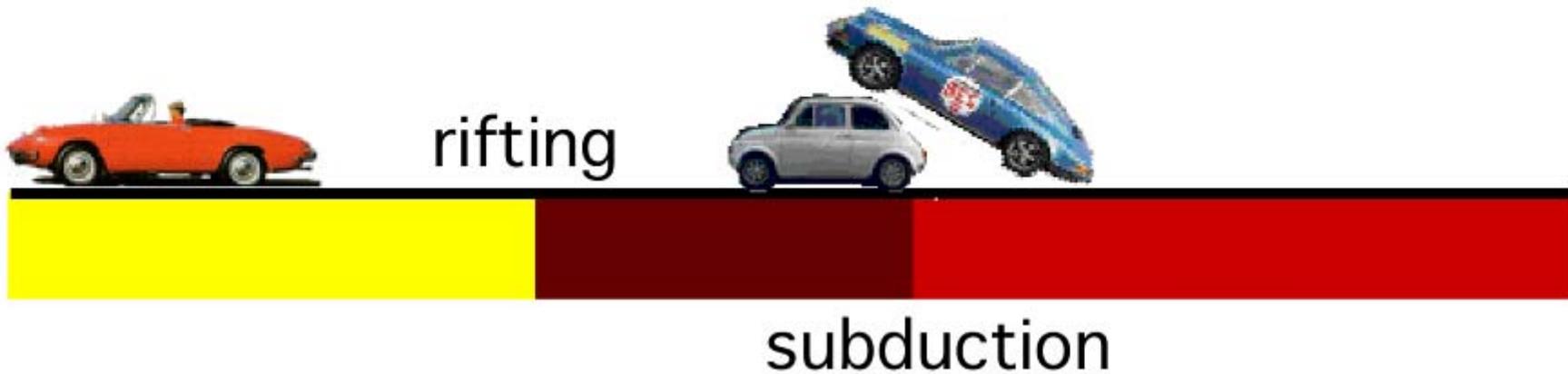
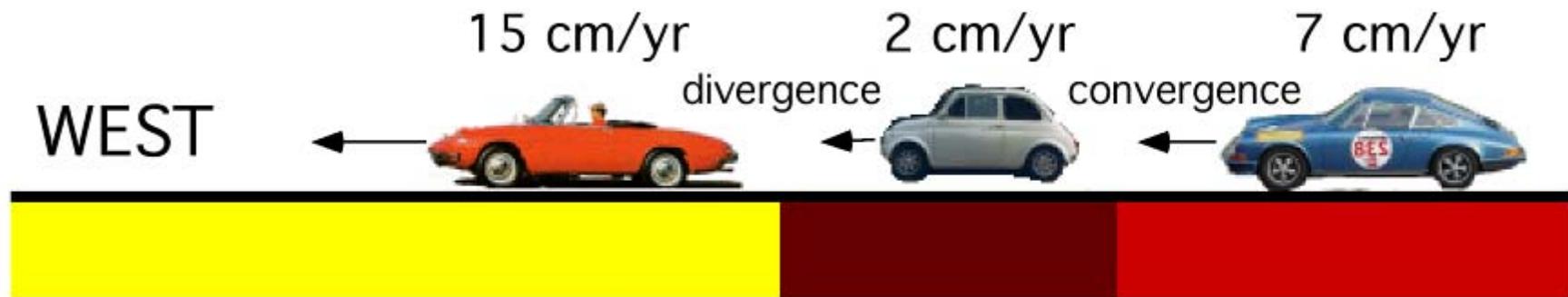
“Westward” drift of the lithosphere (or “eastward” mantle flow)





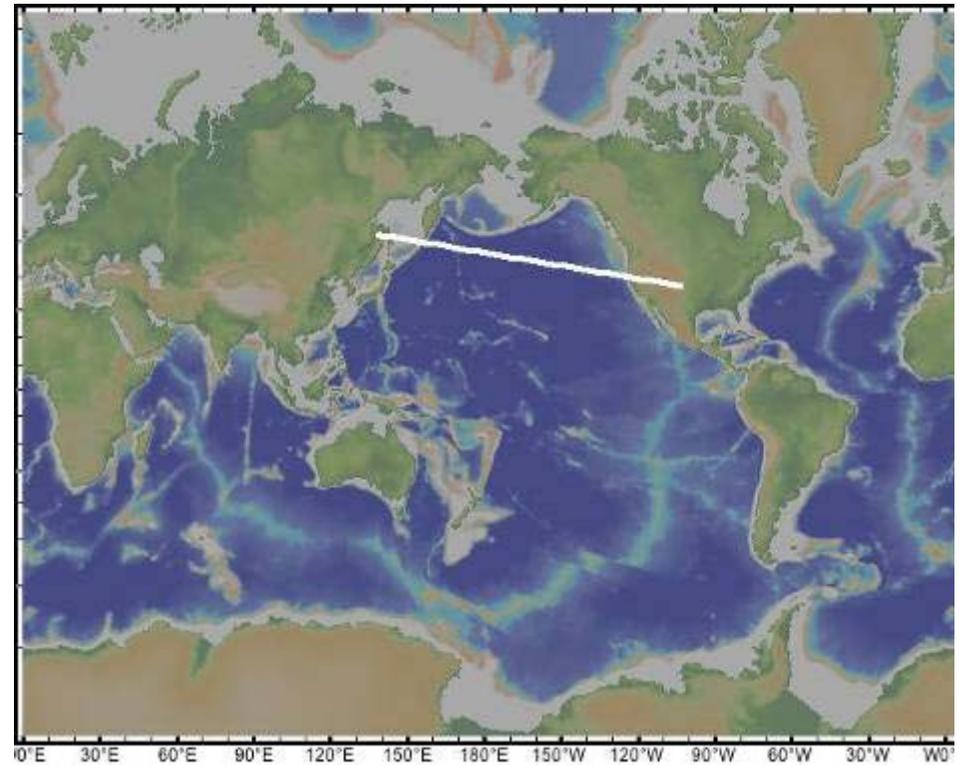
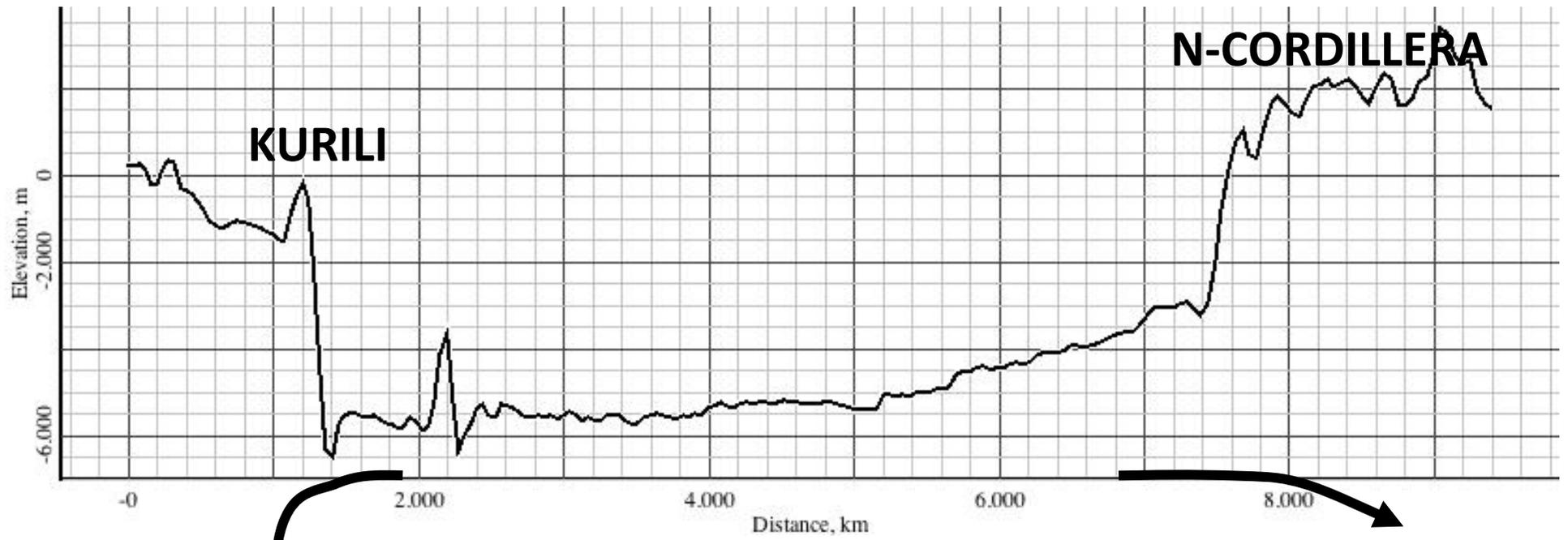


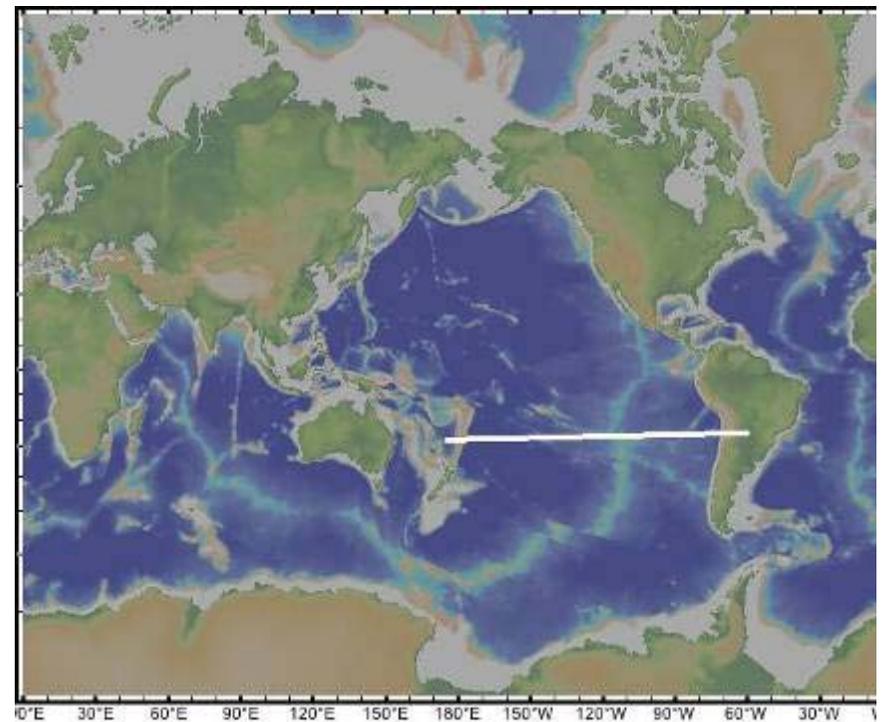
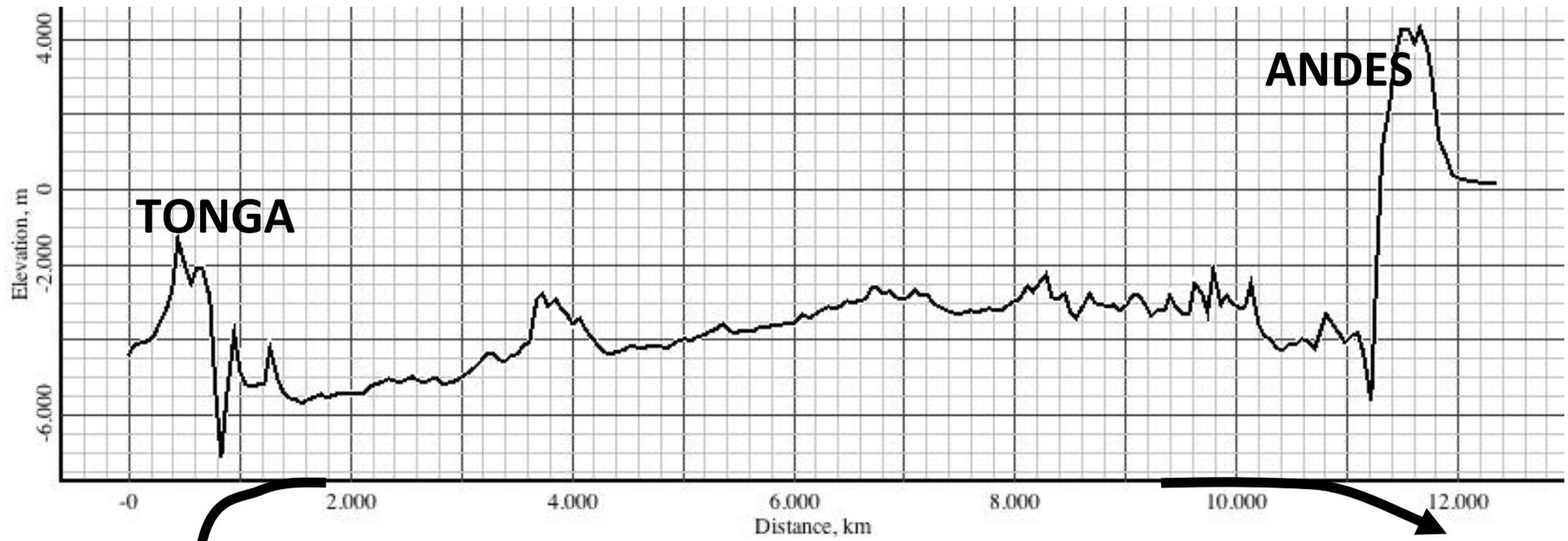
Cuffaro & Doglioni, 2007



**It is the asymmetry
that generates the phenomenon**
Pierre Curie

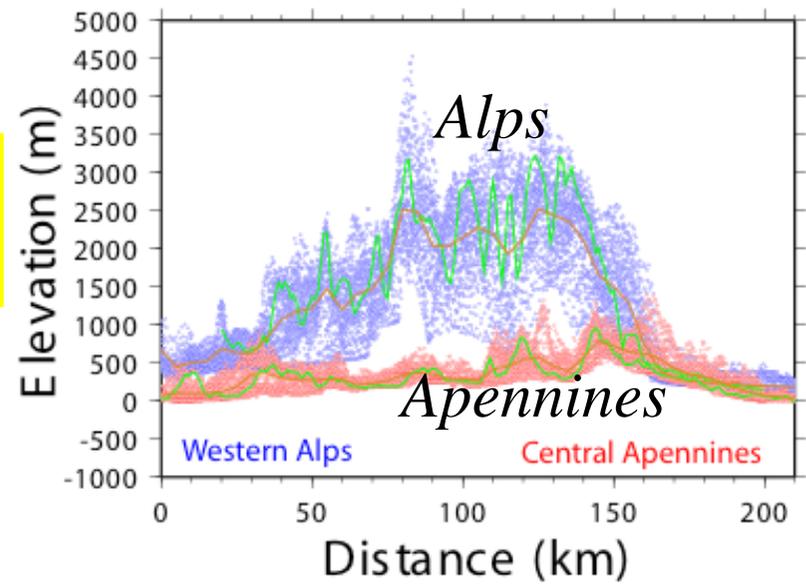
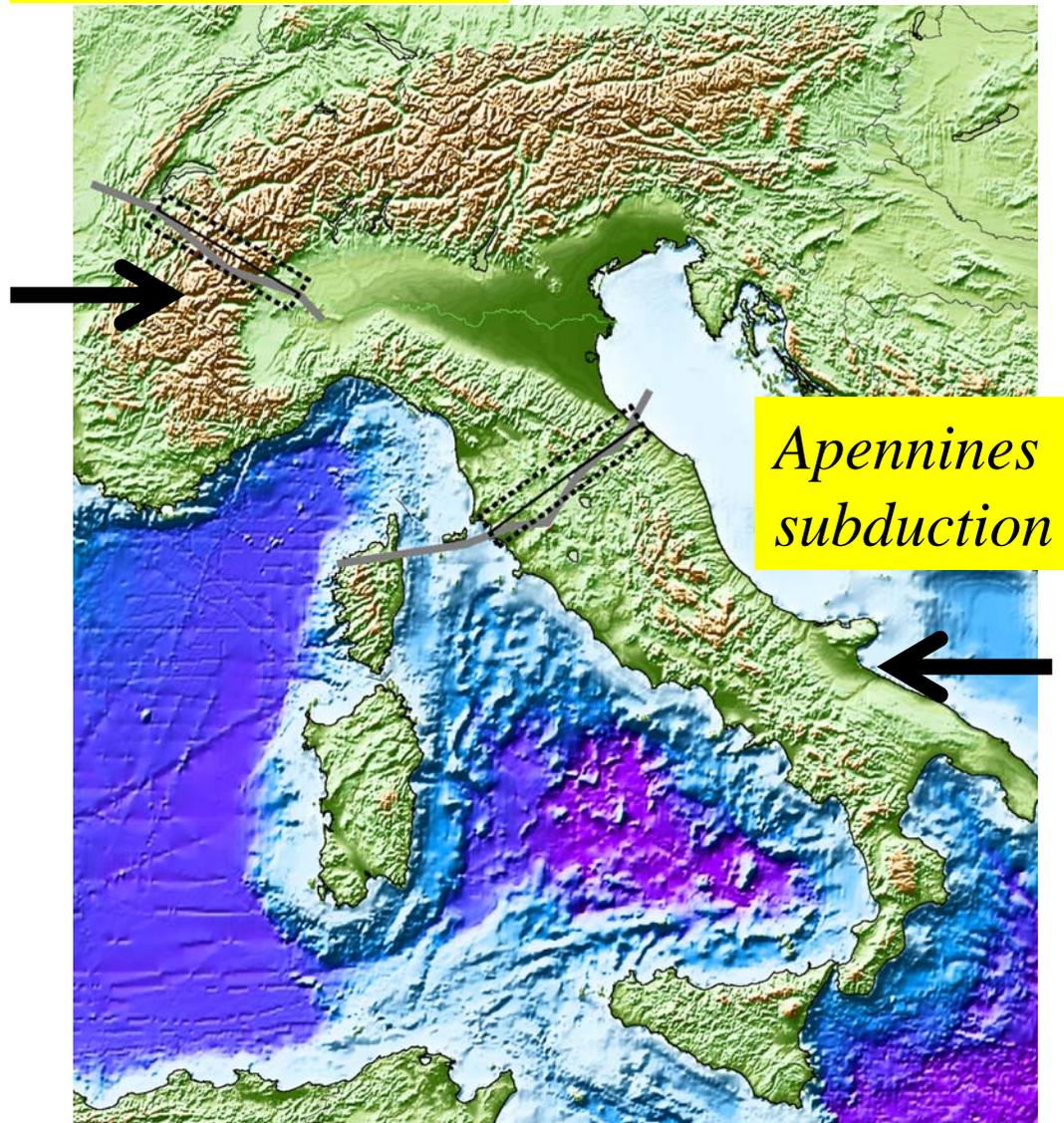






Alpine subduction

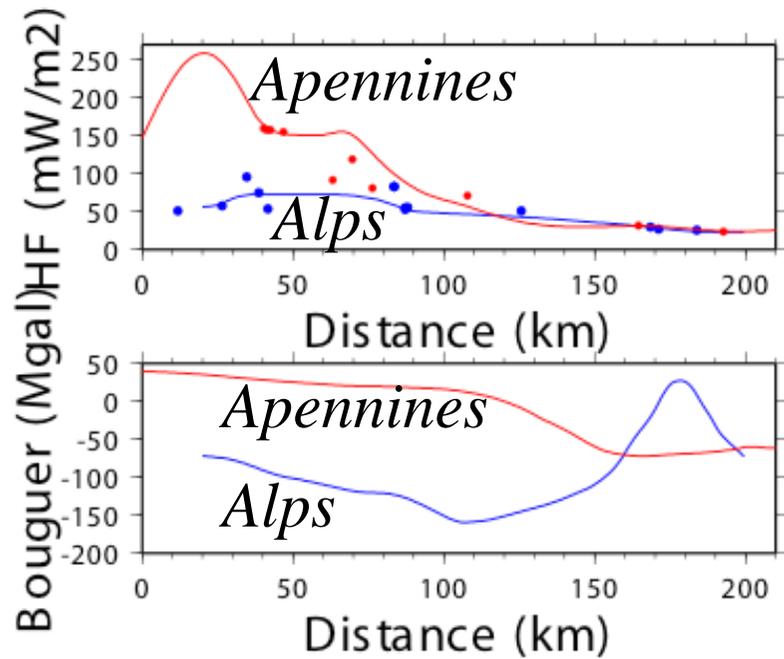
TOPOGRAPHY



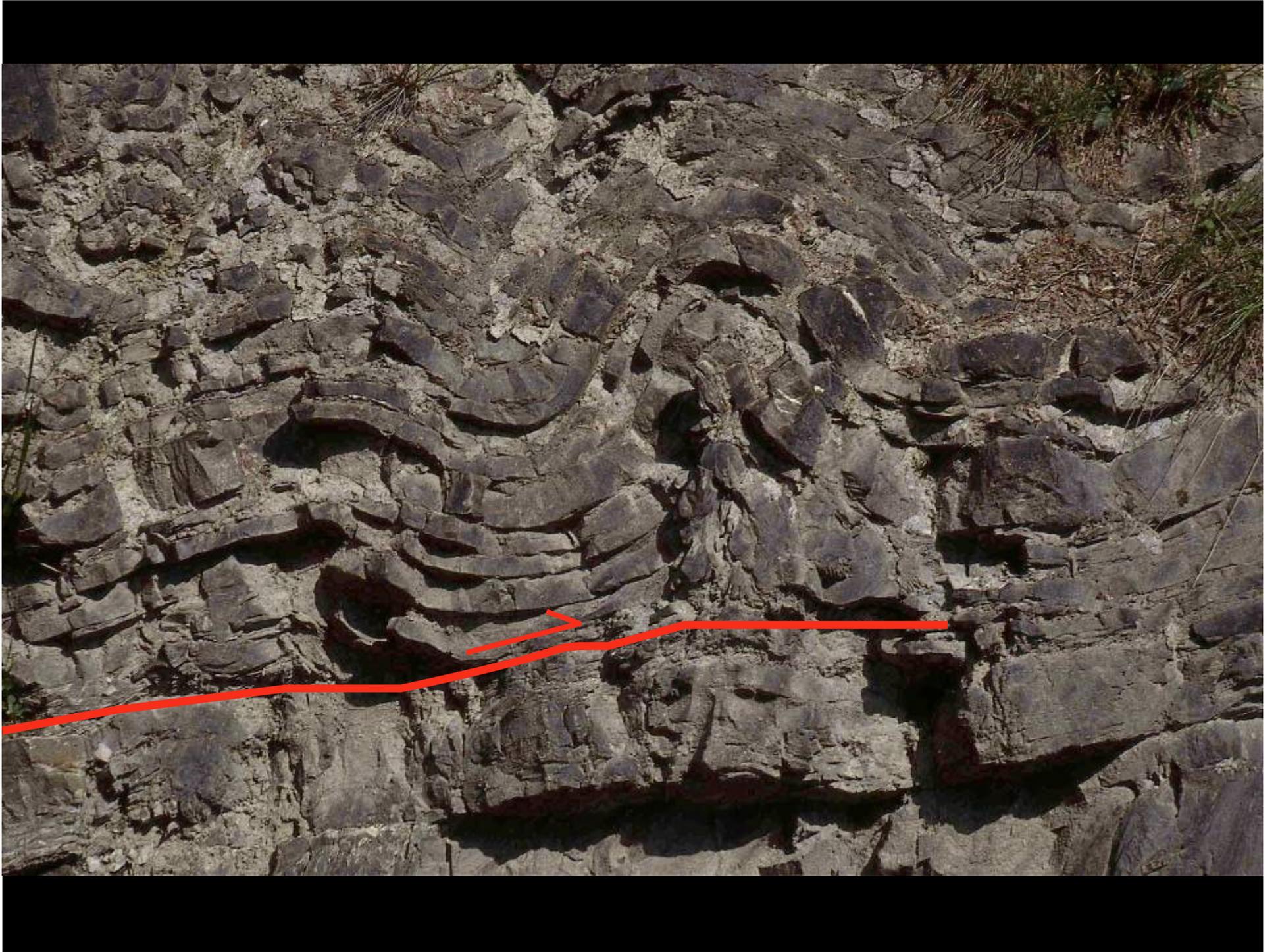
BOUGER ANOMALY & HEAT FLOW

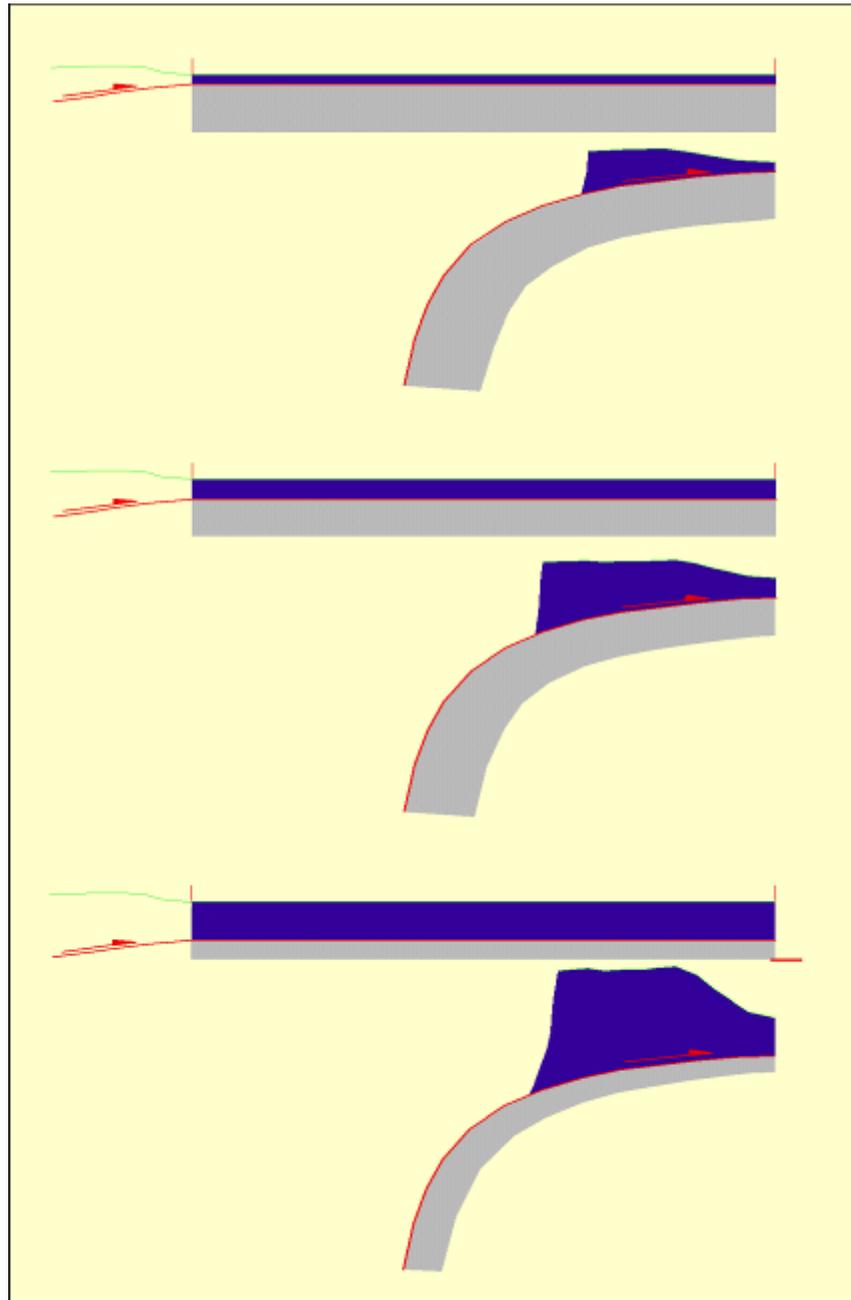
Alpine subduction

Apennines subduction

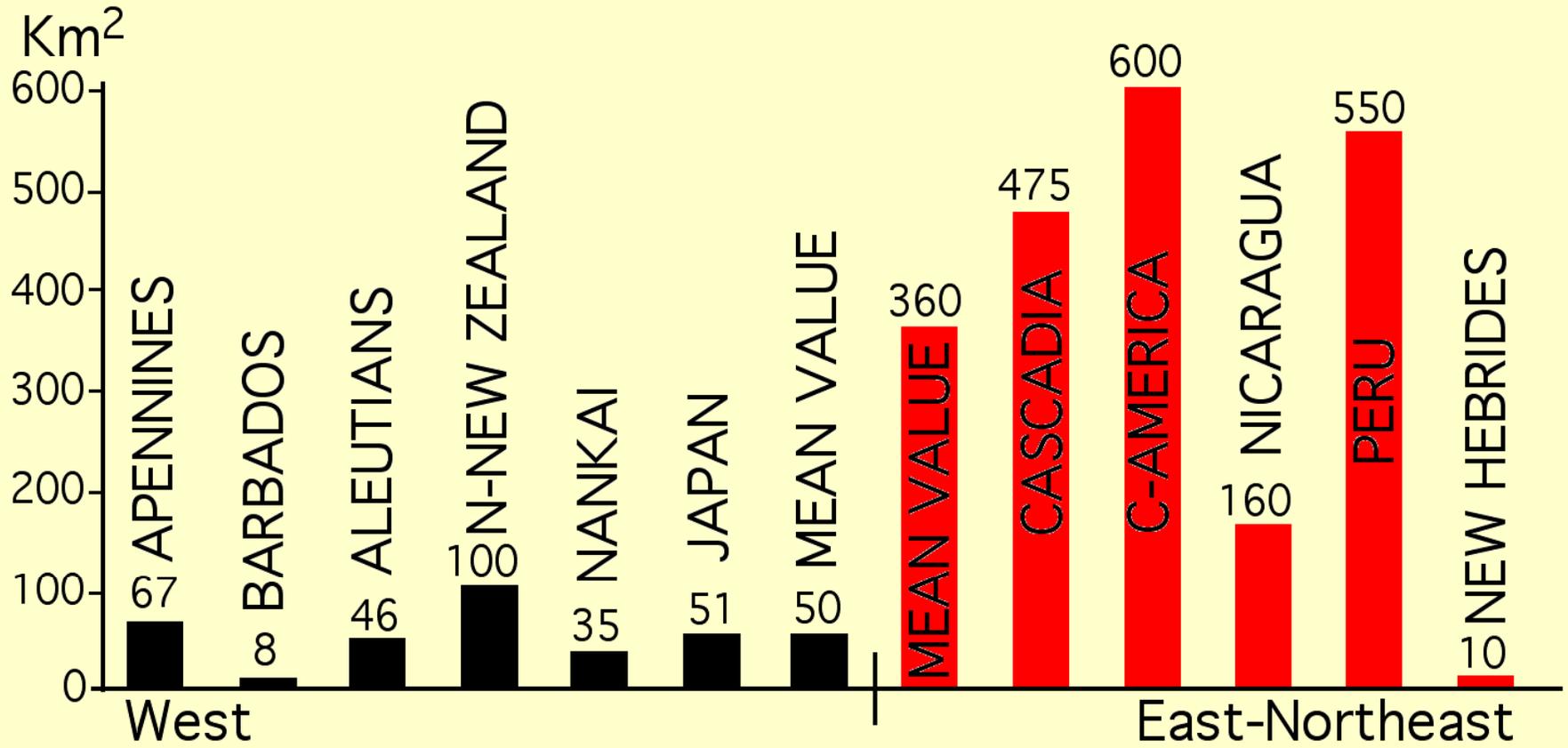


6 8 10 12 14 16 18



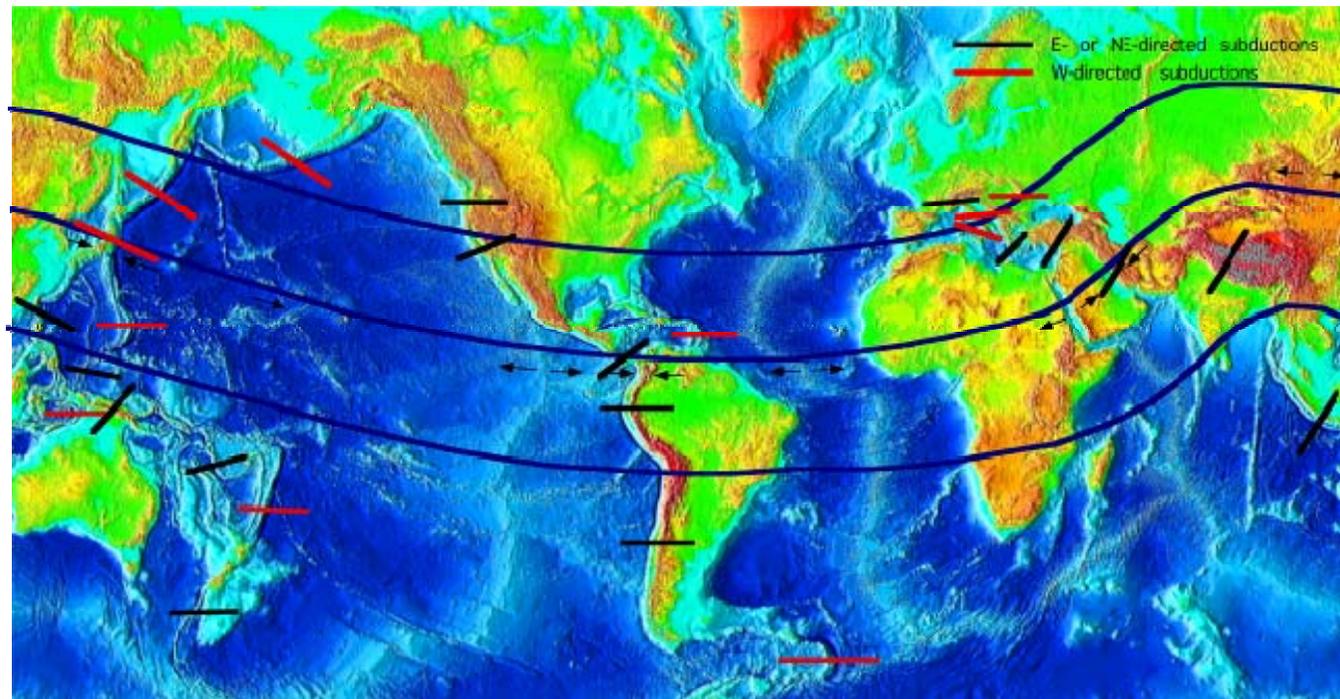
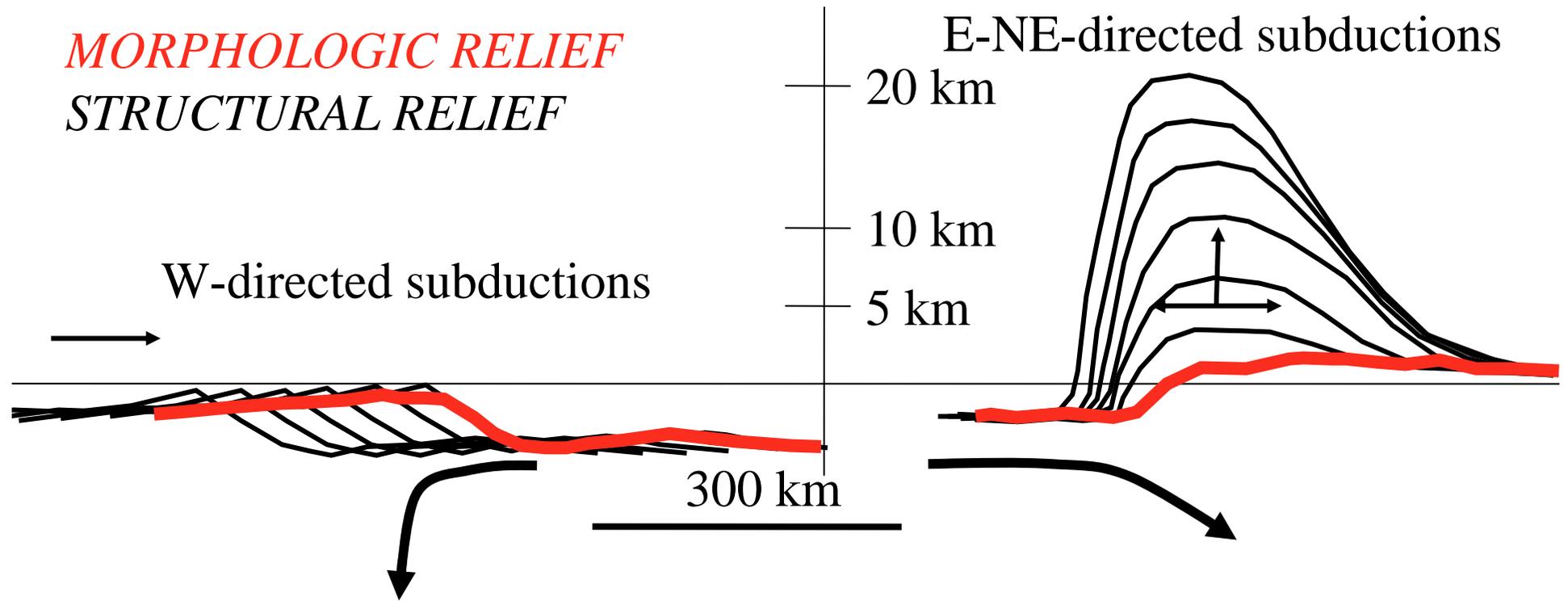


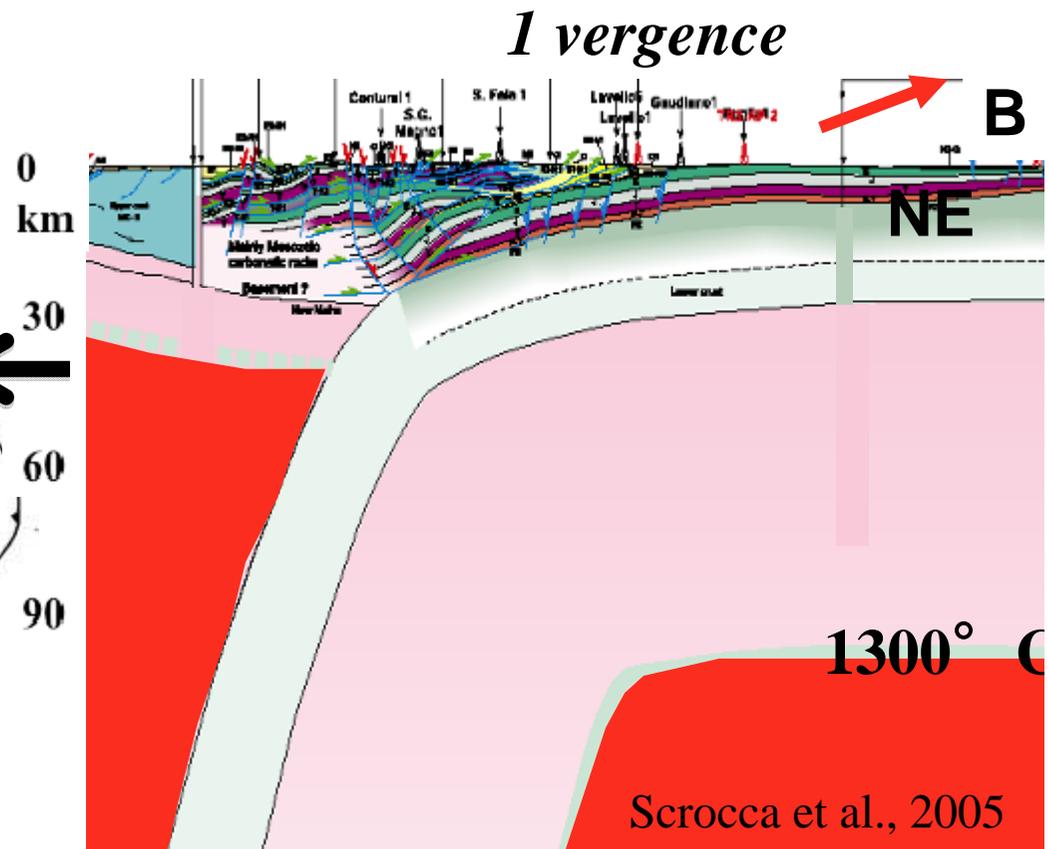
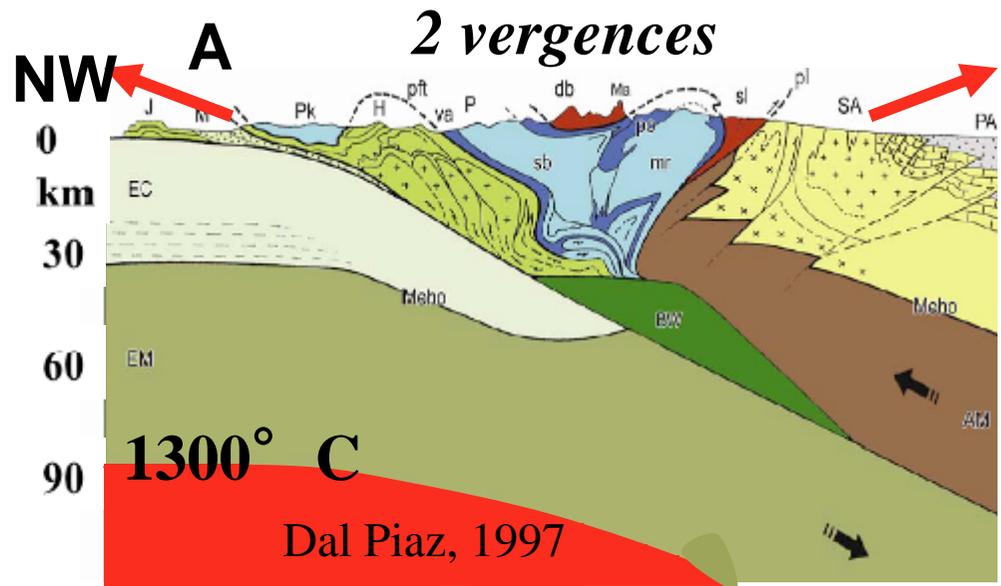
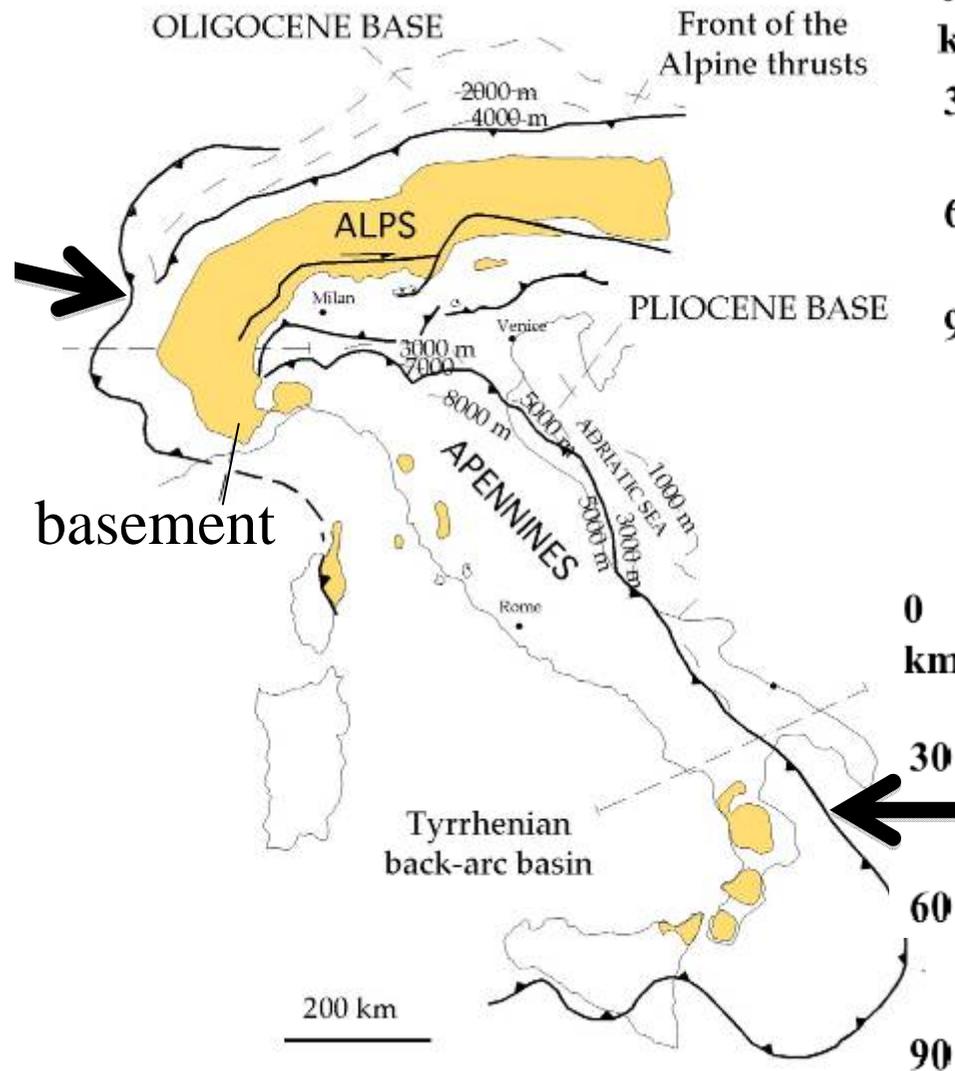
Deeper Decollement = Thicker Prism

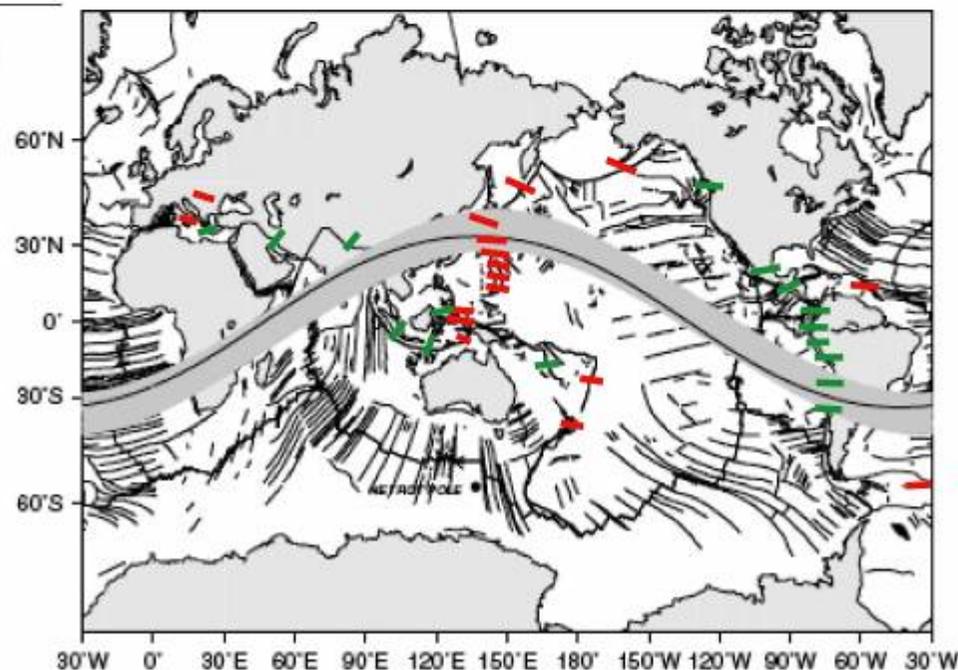
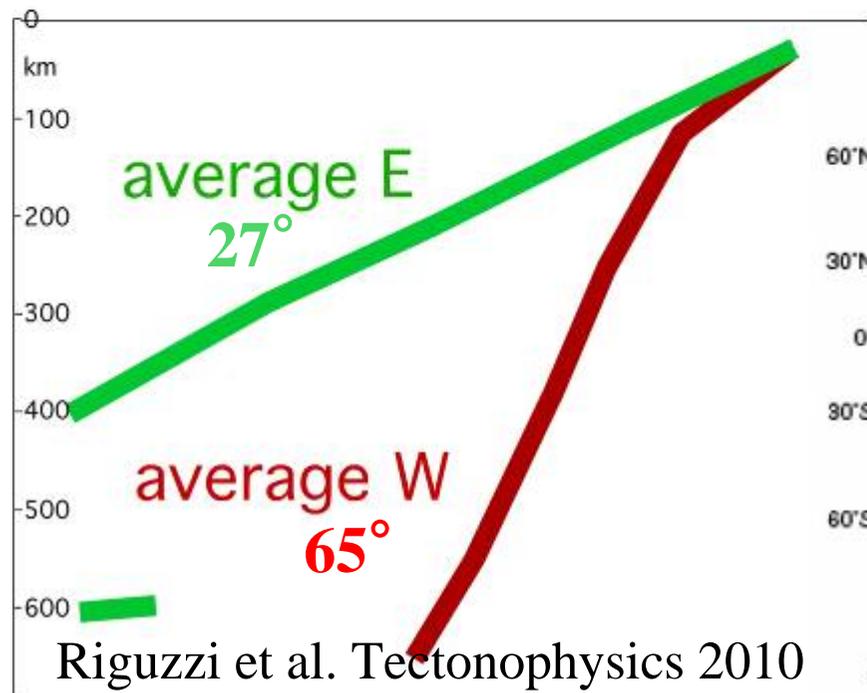
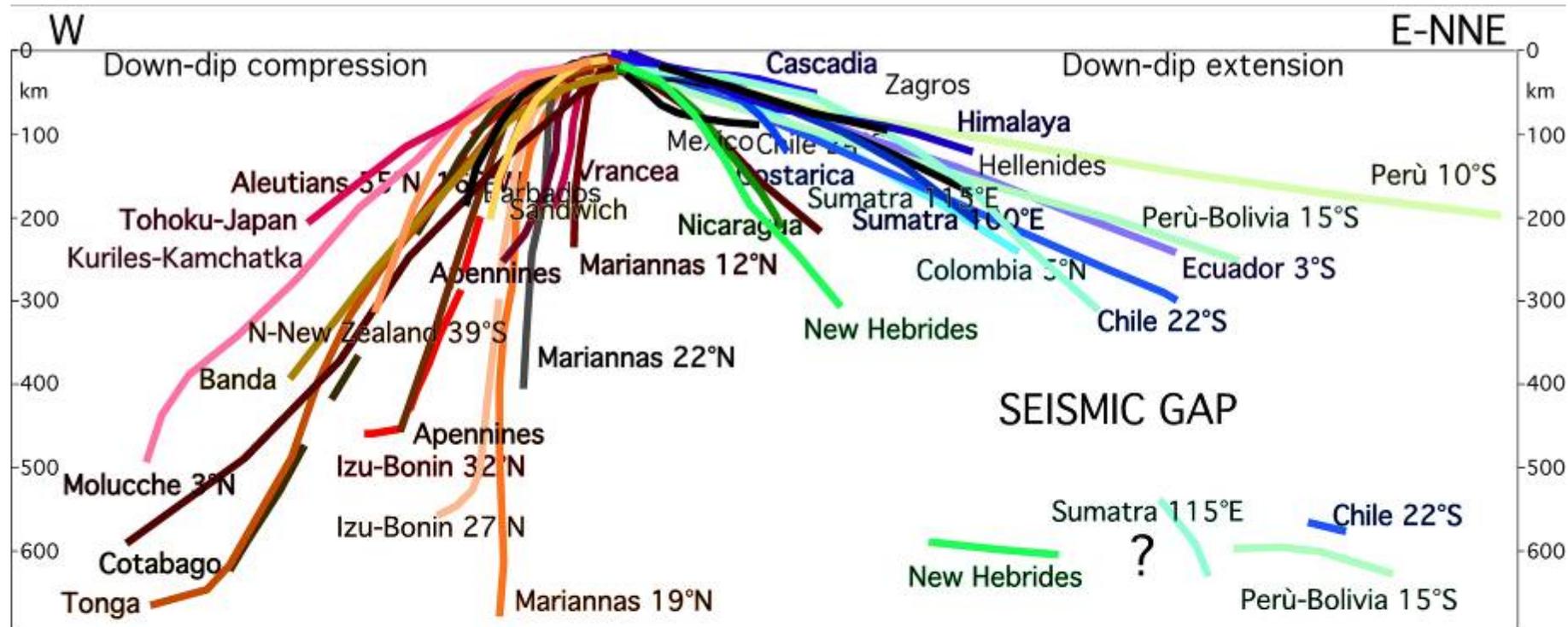


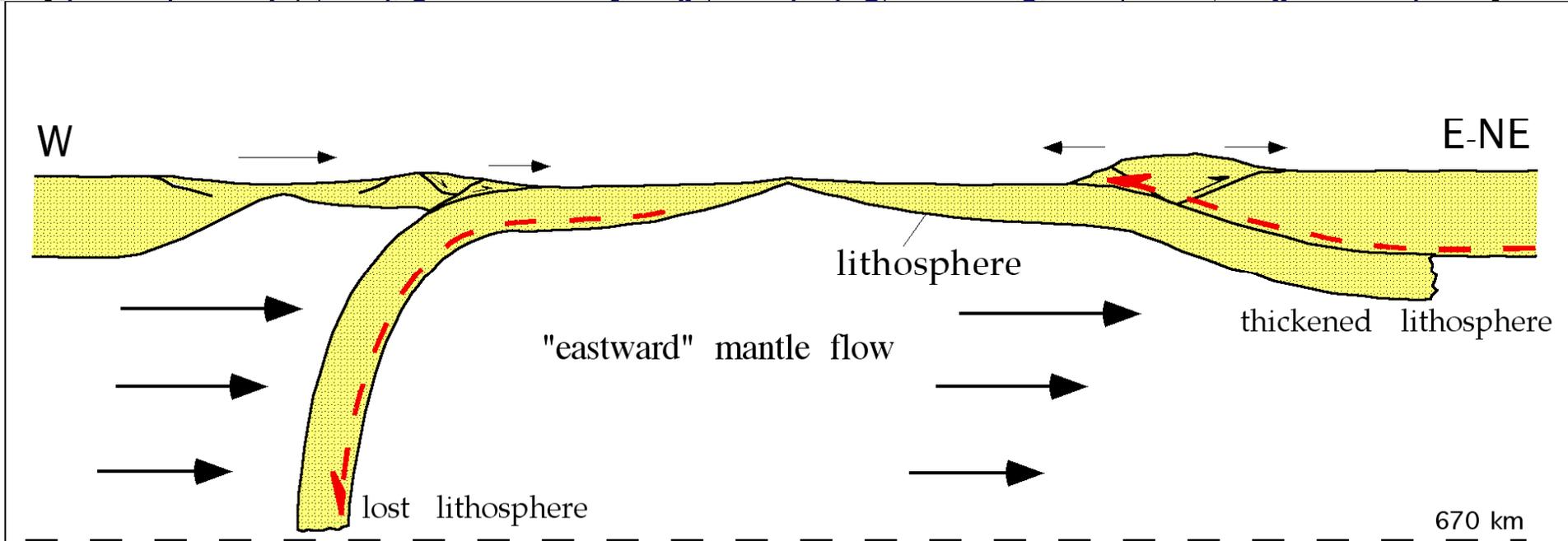
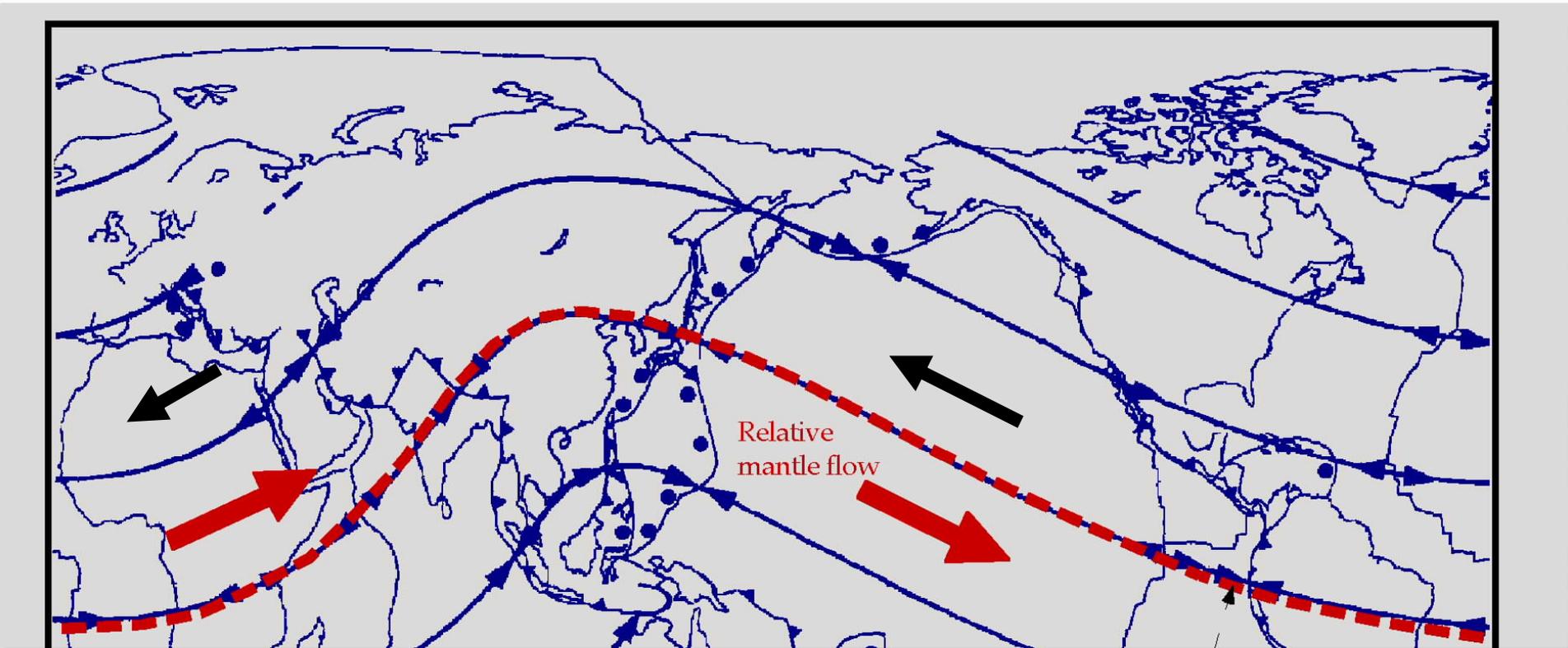
orogens area above sea level

MORPHOLOGIC RELIEF
STRUCTURAL RELIEF

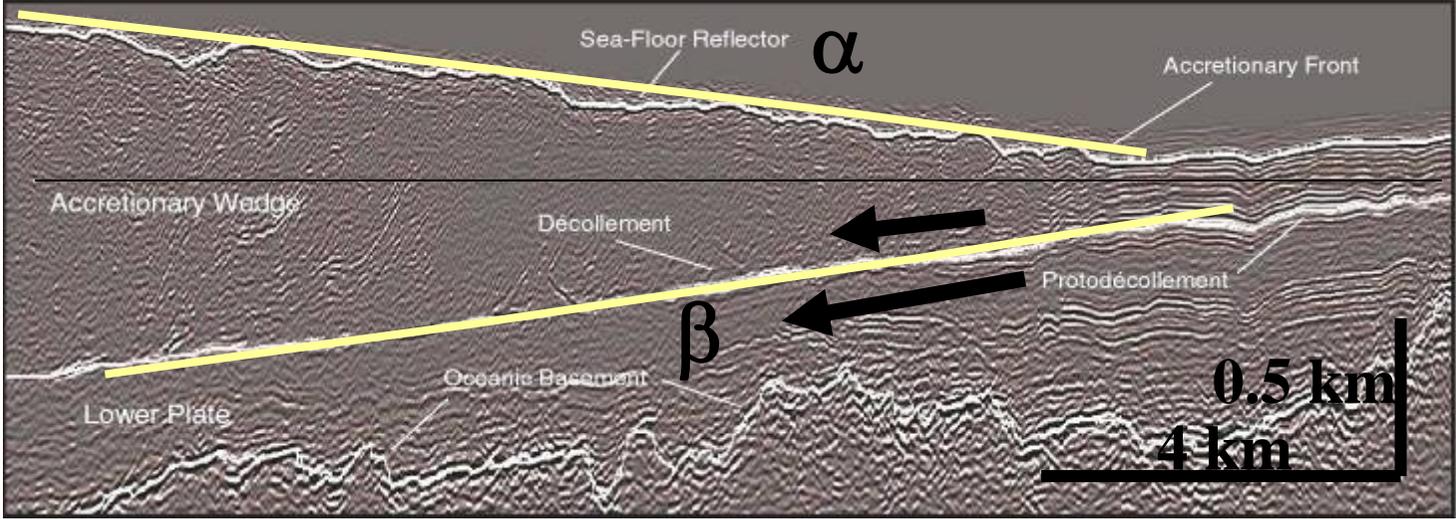
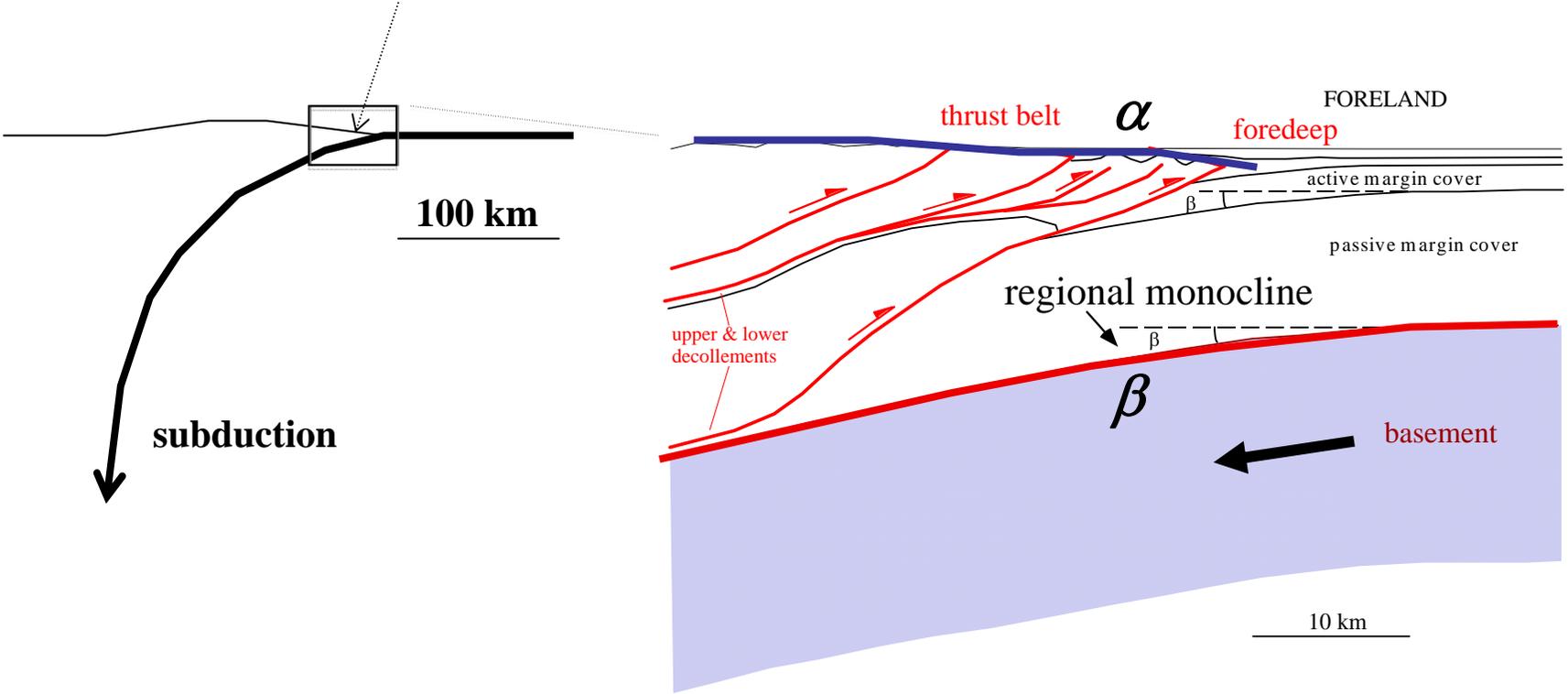




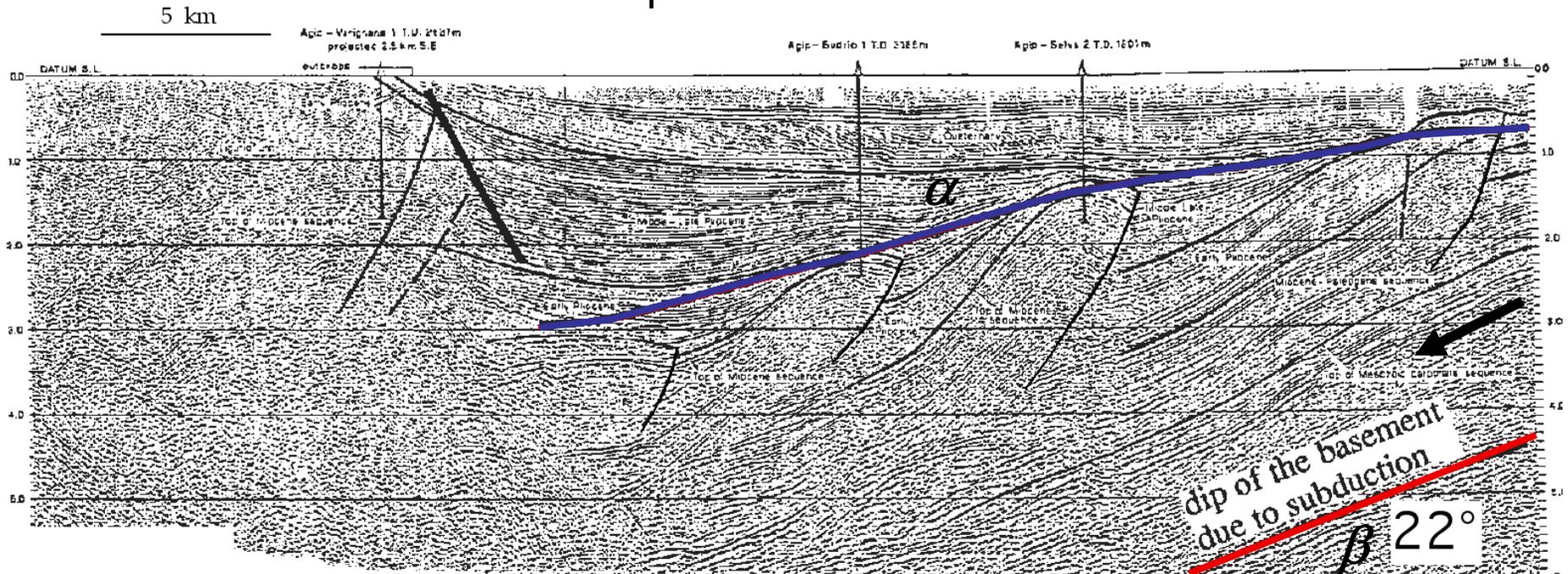




REGIONAL MONOCLINE

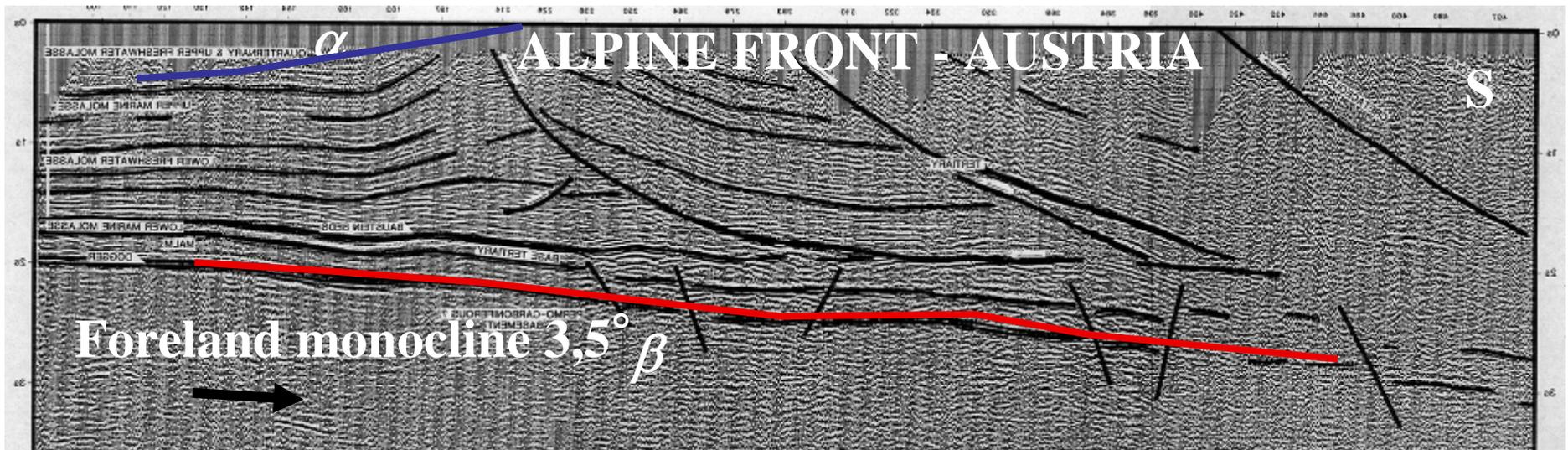


Northern Apennines - Po Basin



Subsidence rate 1600m/Ma

Pieri, 1983

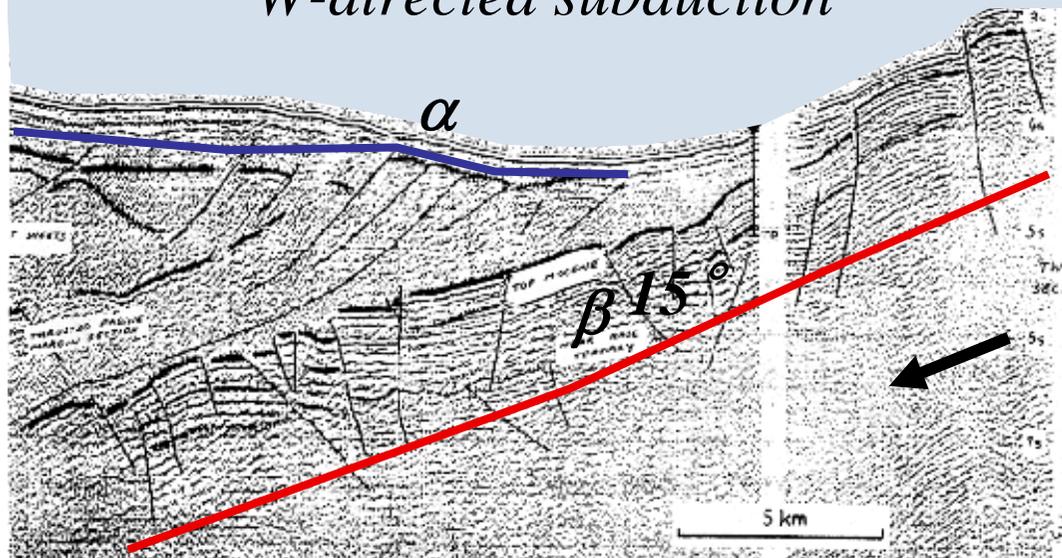


Subsidence rate 150m/Ma

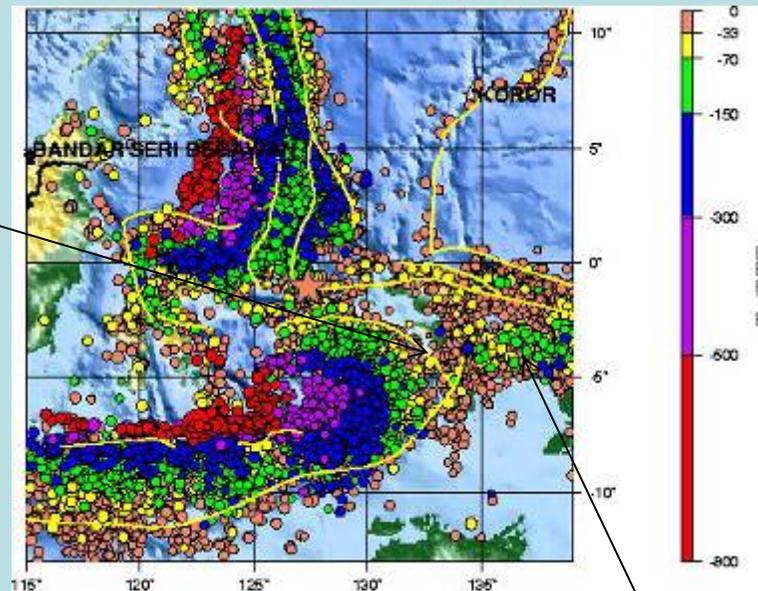
Bachmann & Koch, 1983

W

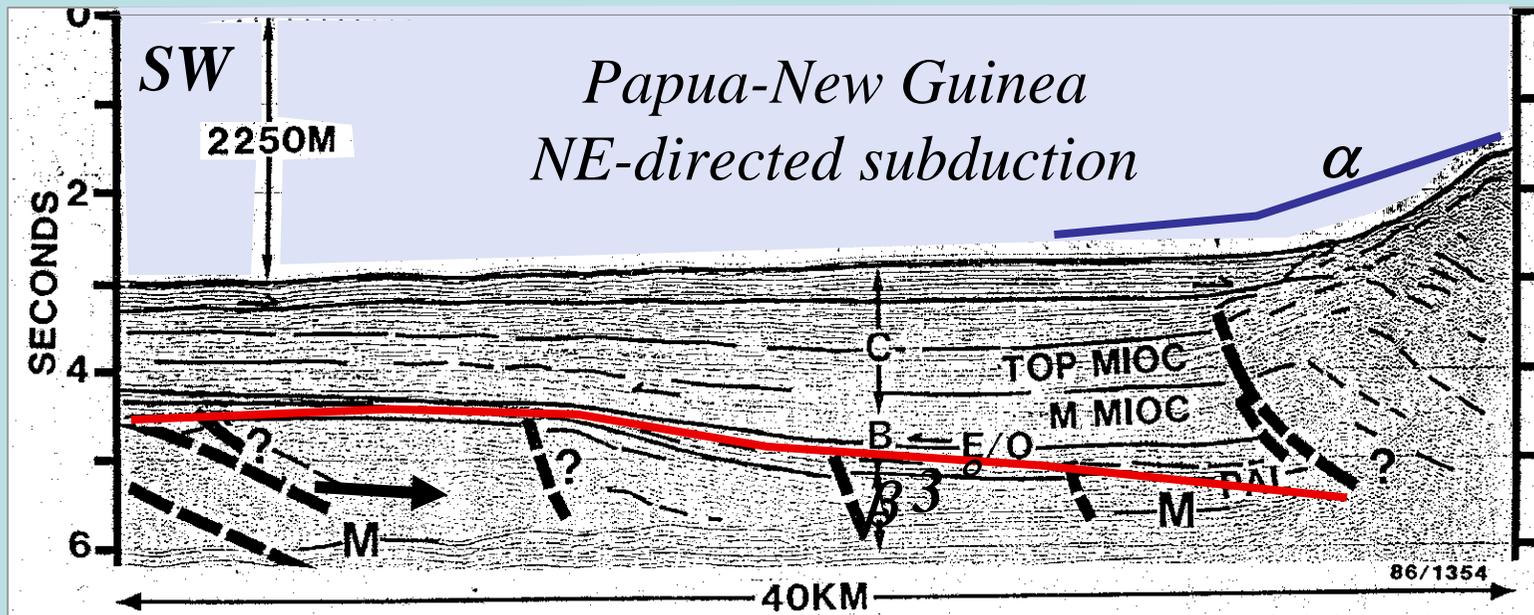
Banda arc
W-directed subduction

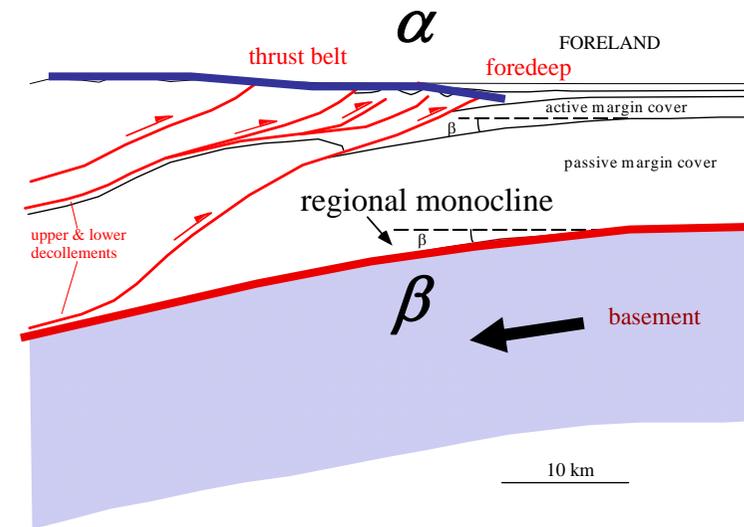
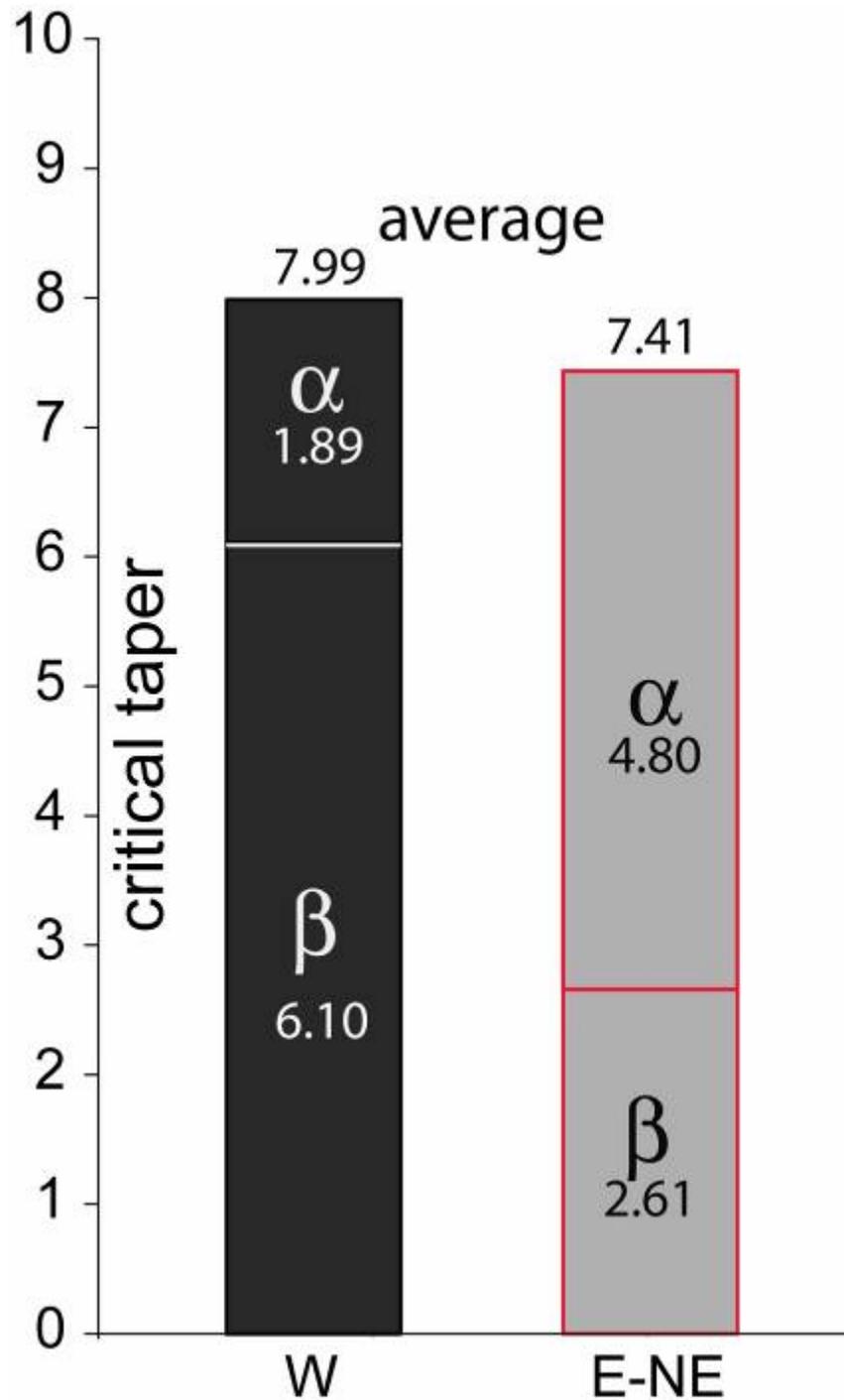


Subsidence rate 1500m/Ma

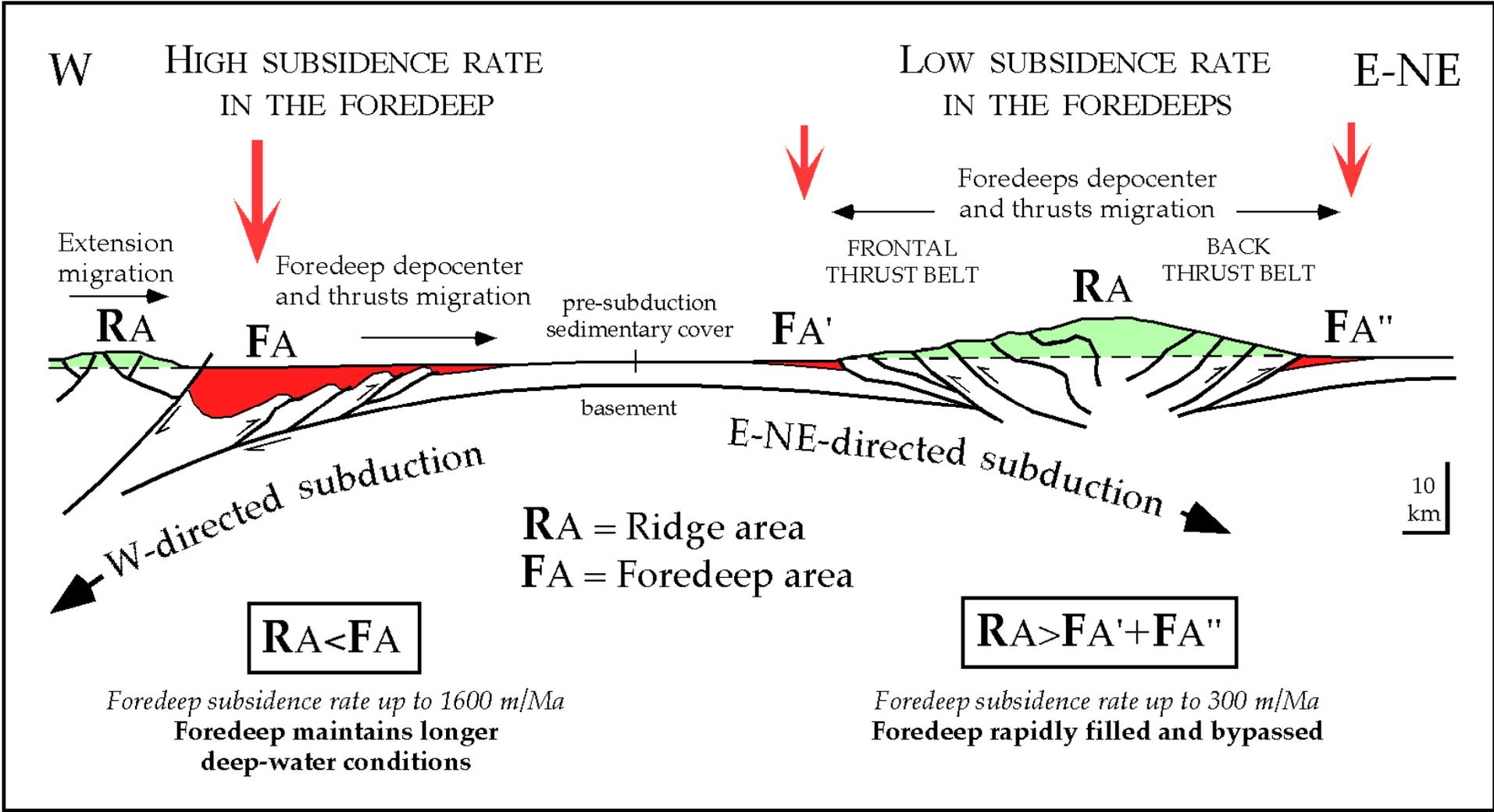


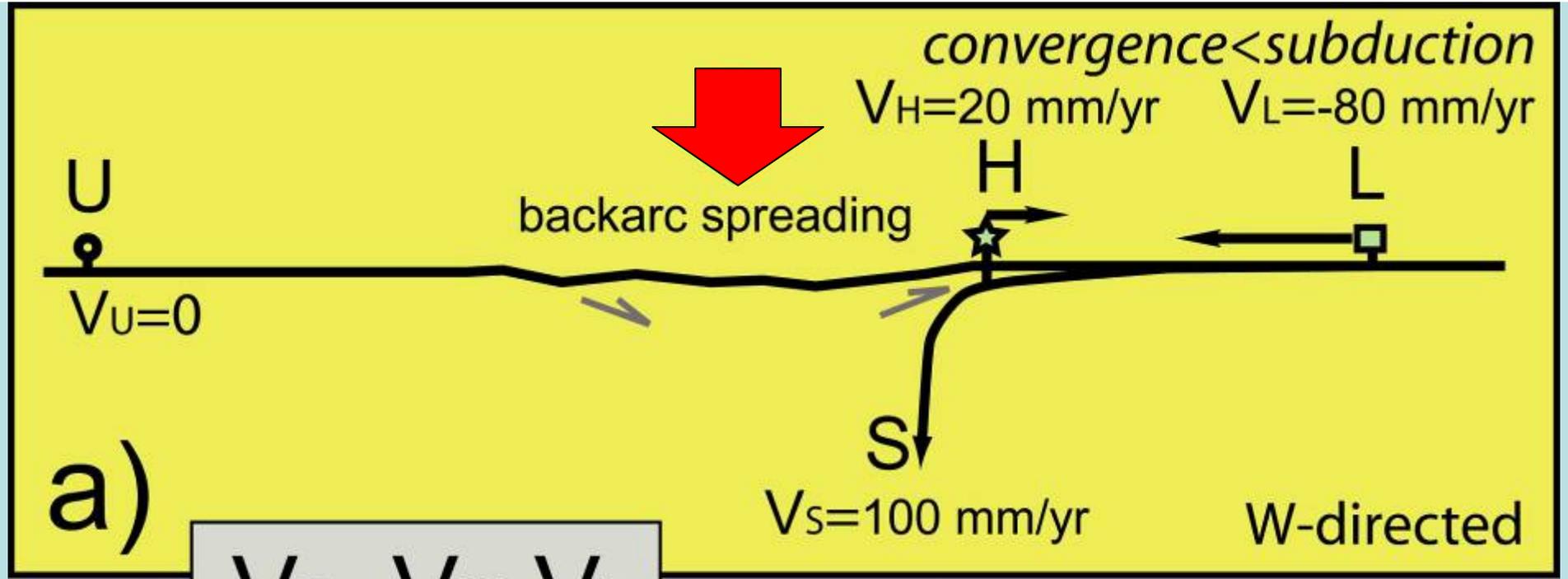
Subsidence rate 100m/Ma



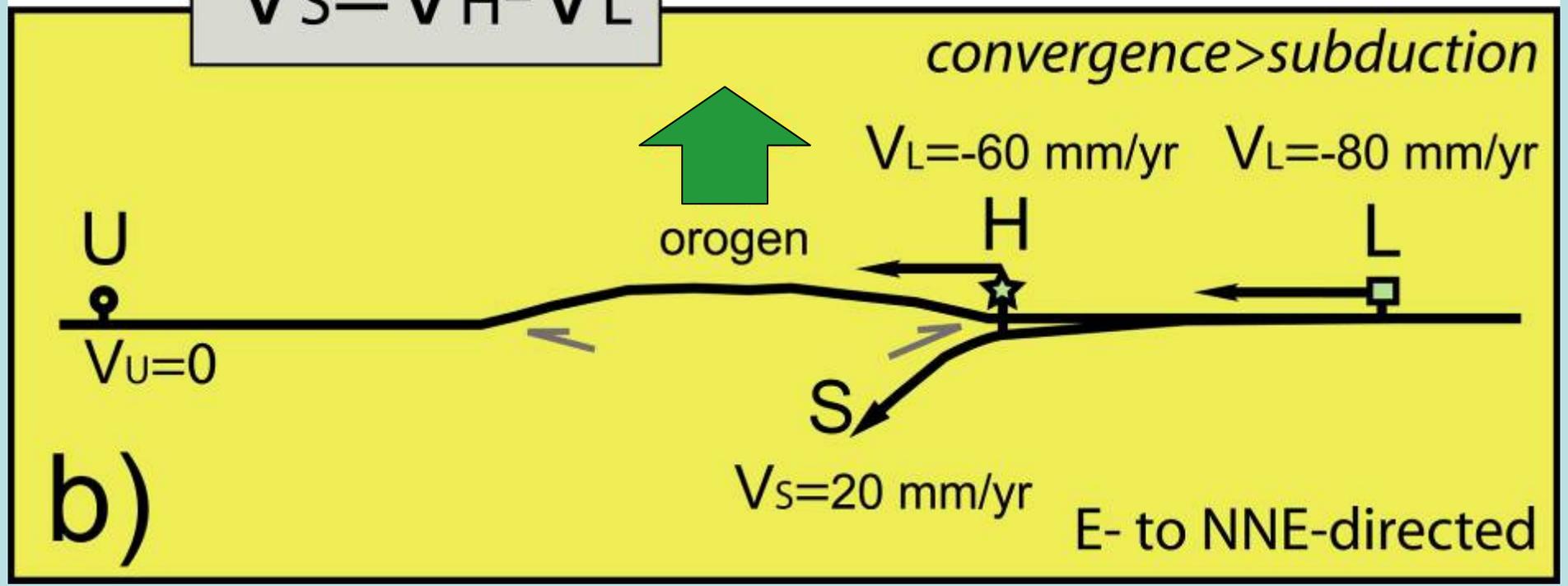


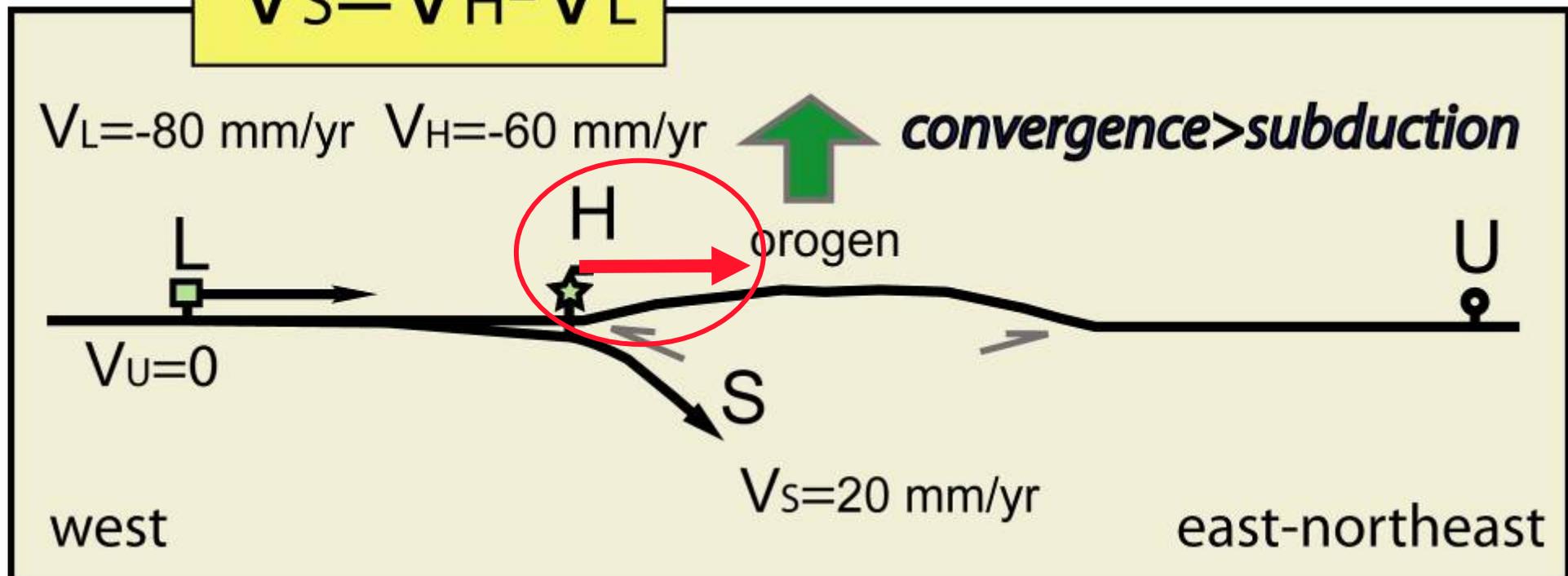
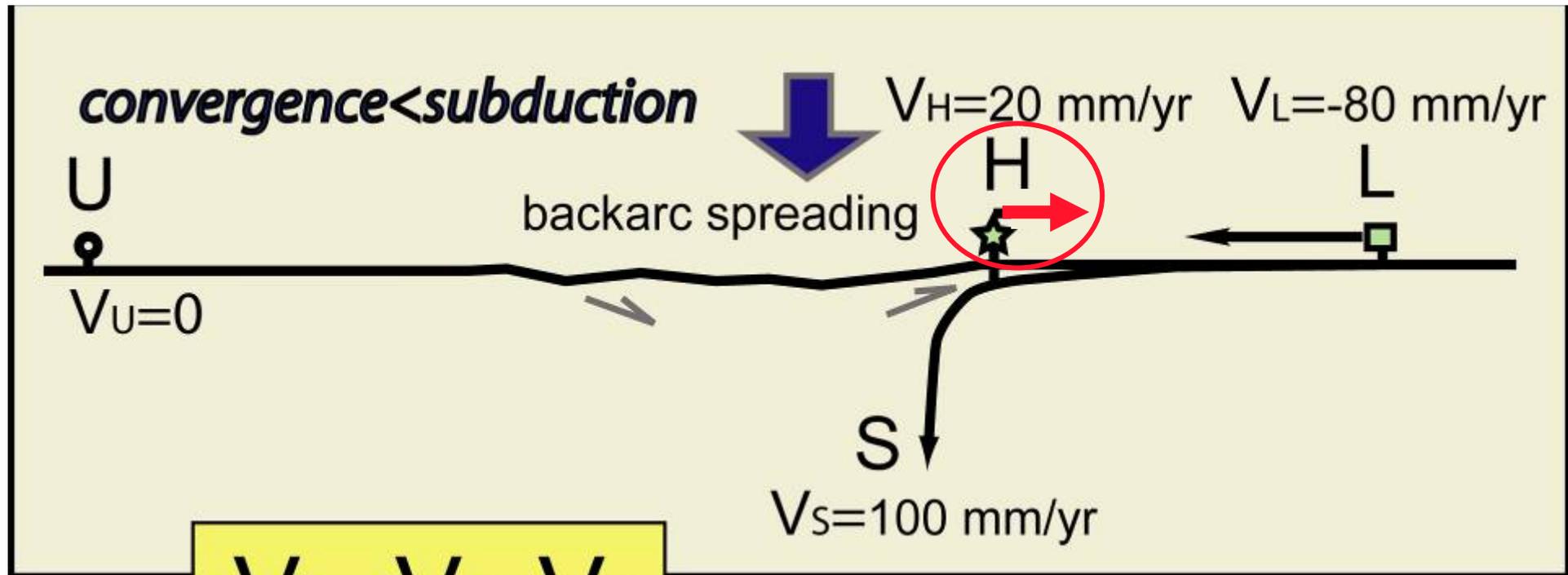
Lenci & Doglioni, 2007

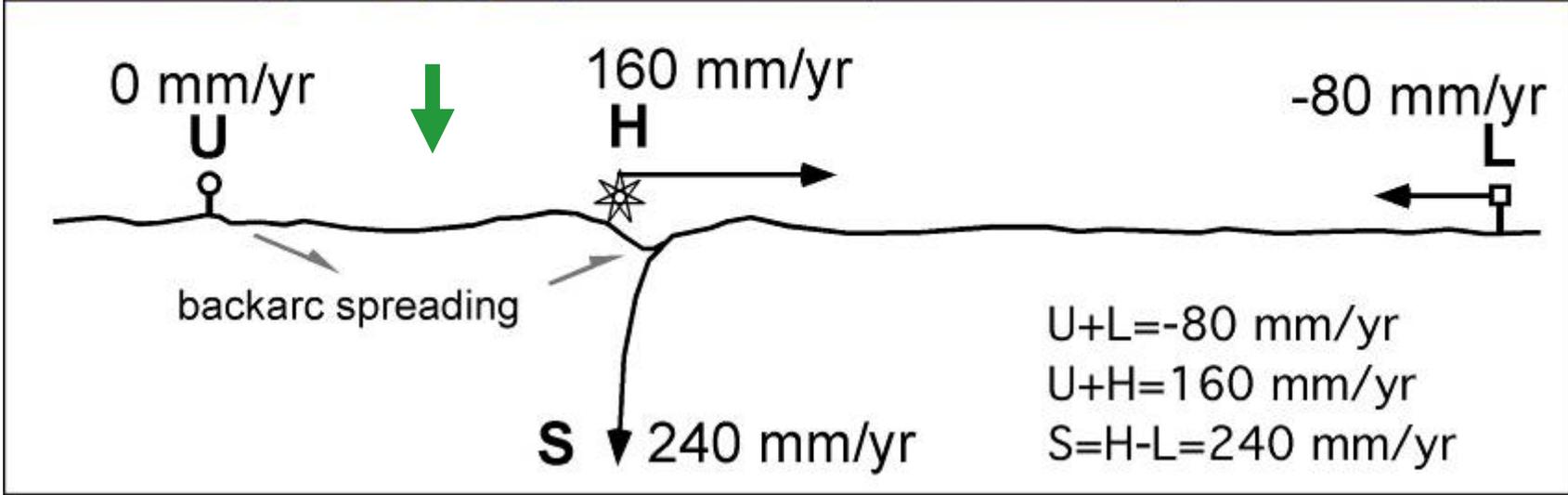
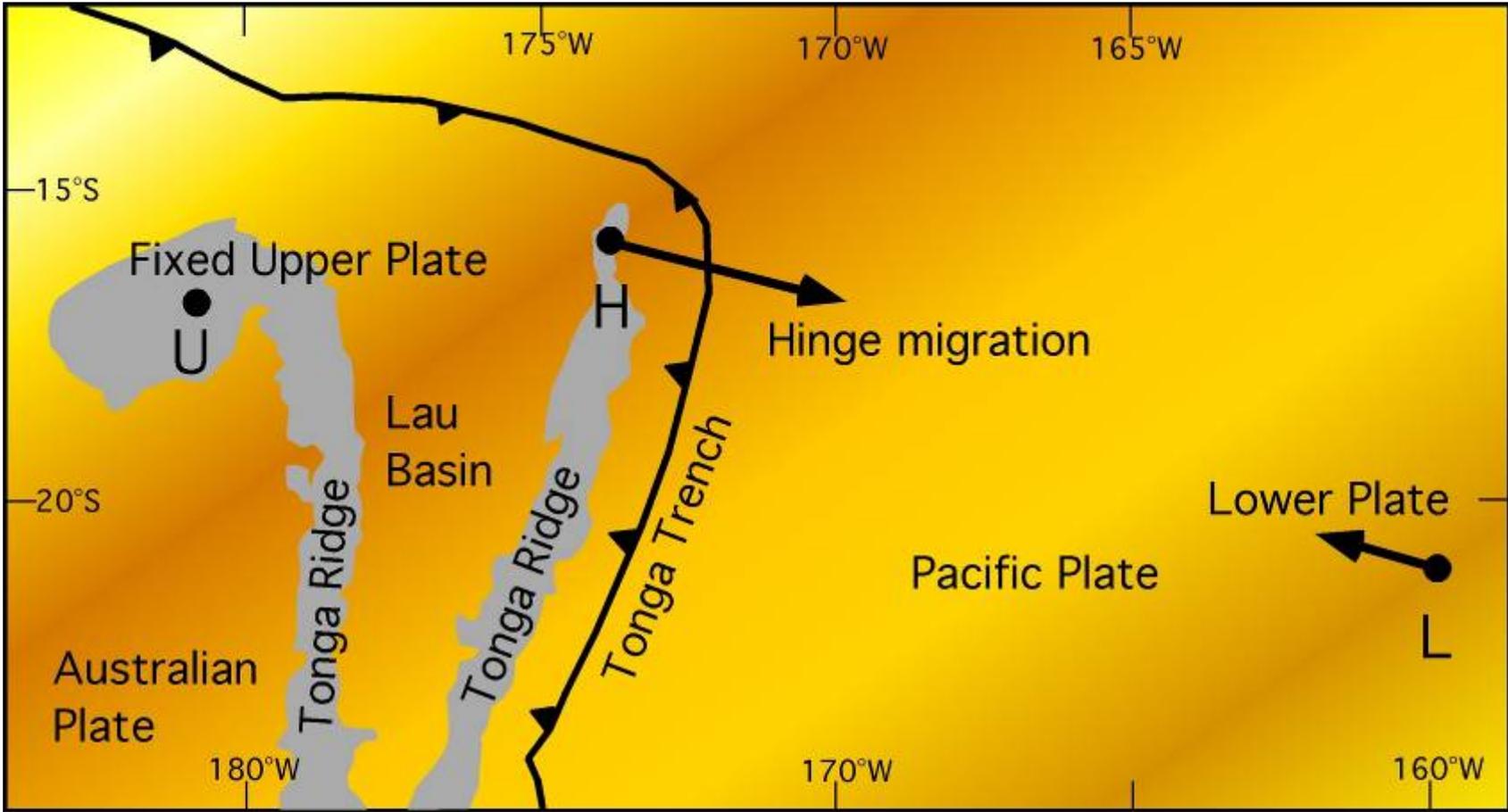


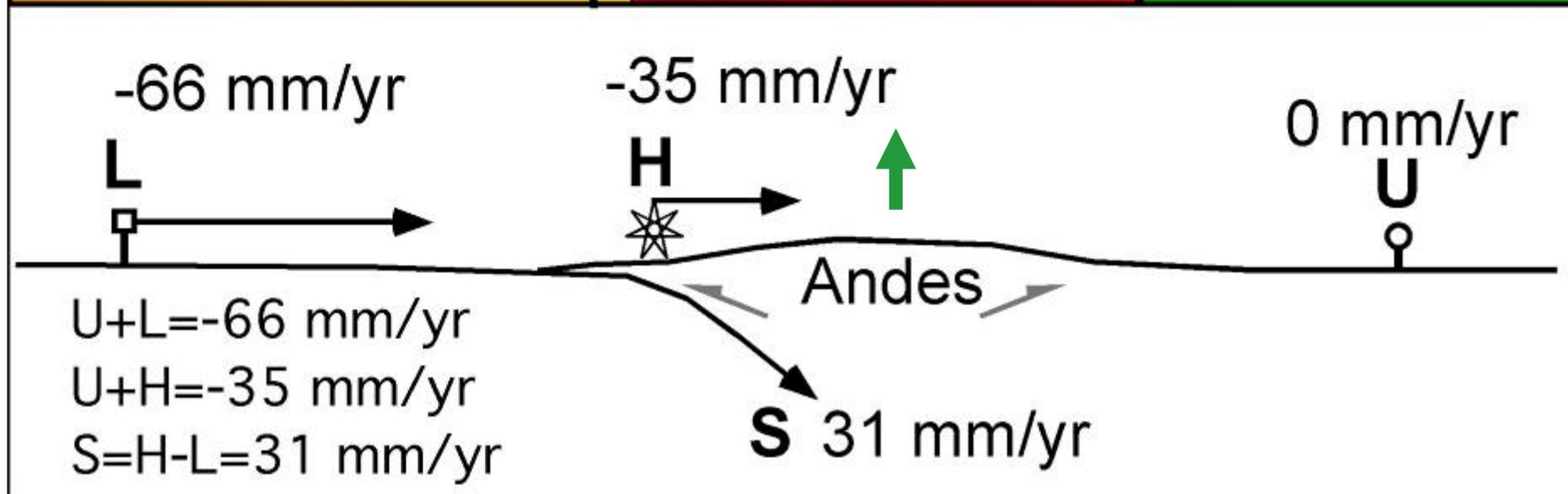
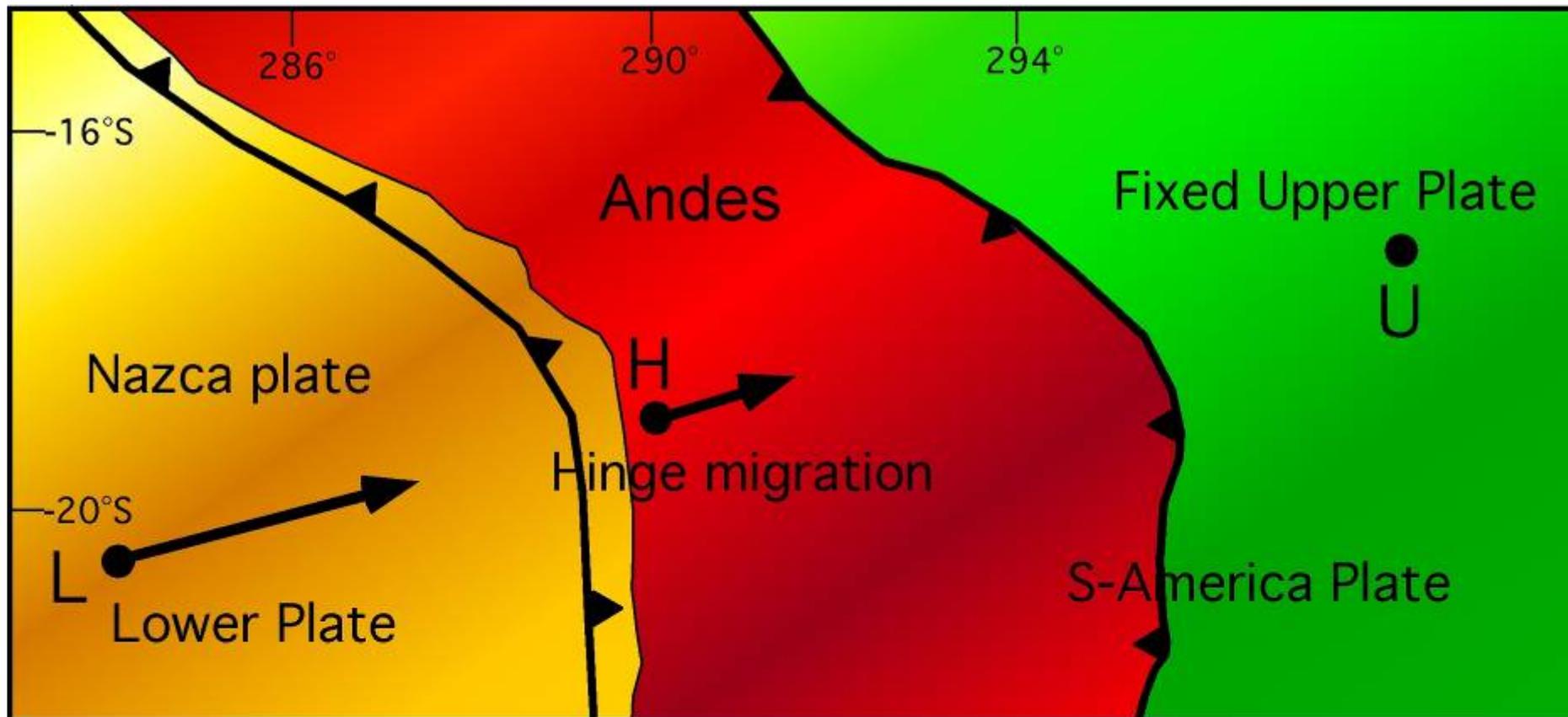


$$V_S = V_H - V_L$$

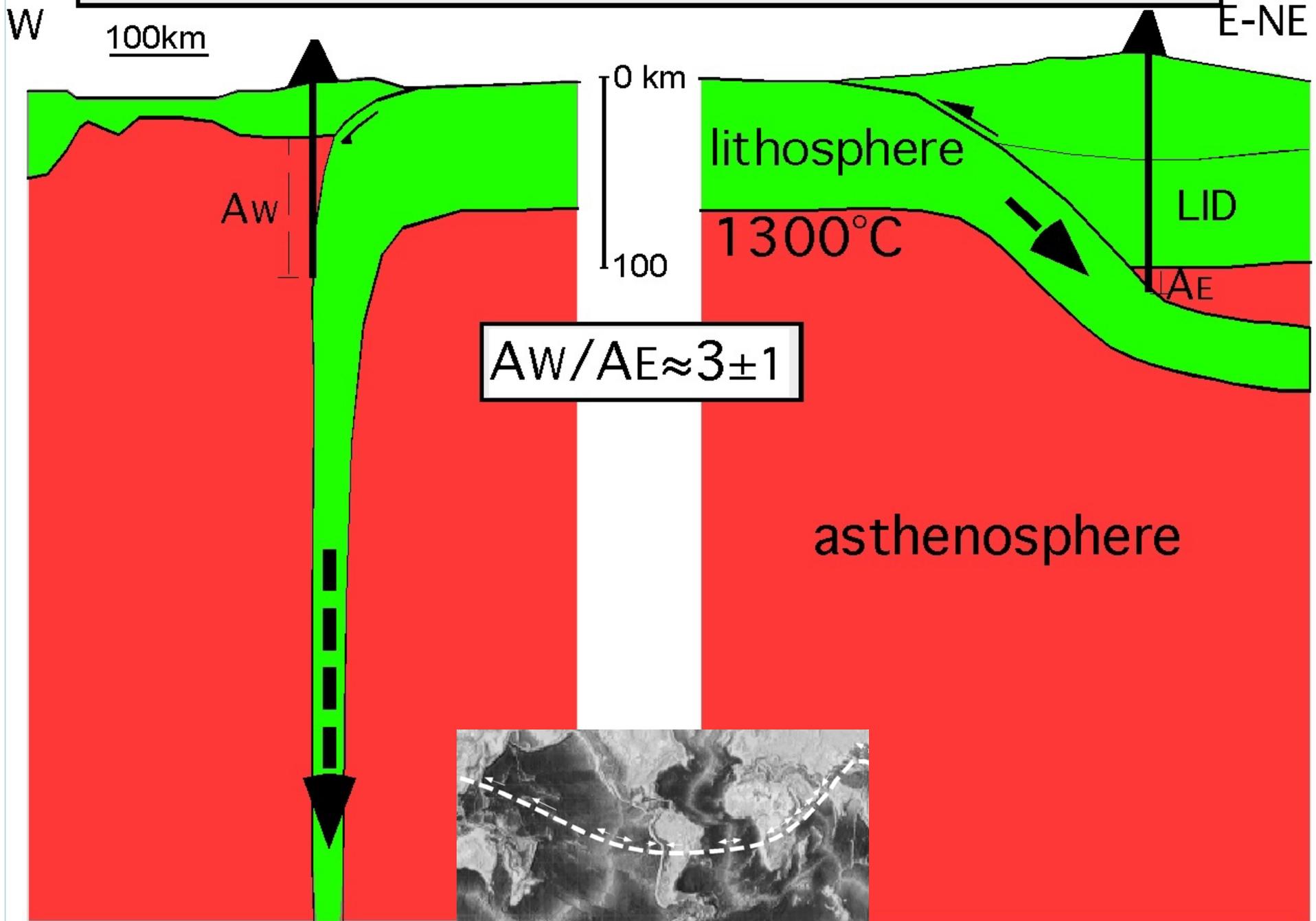


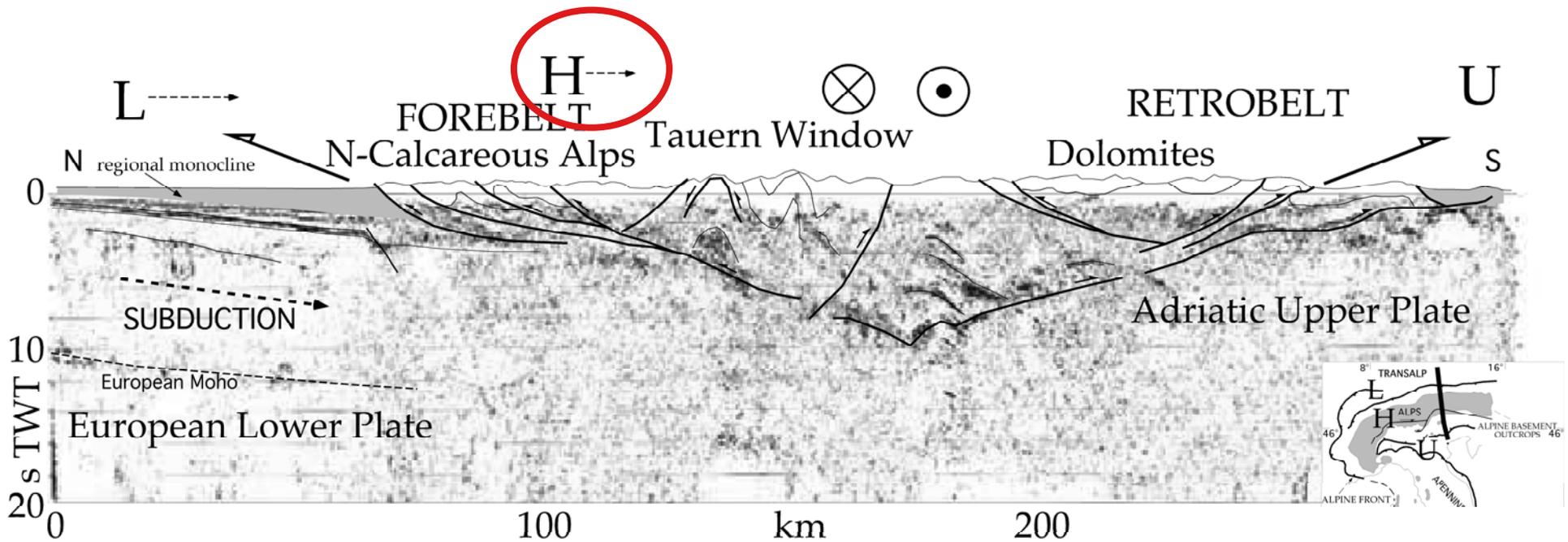
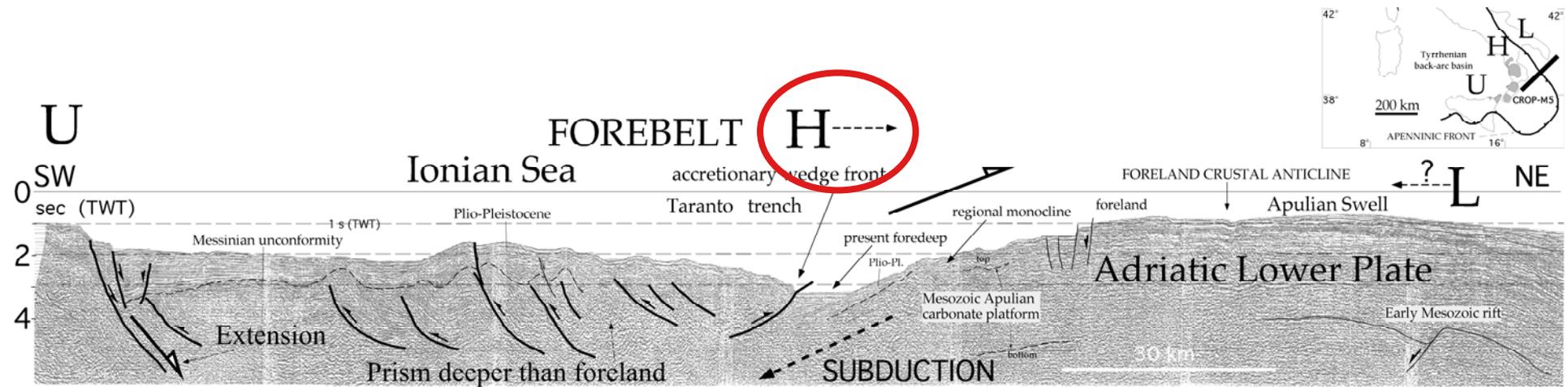


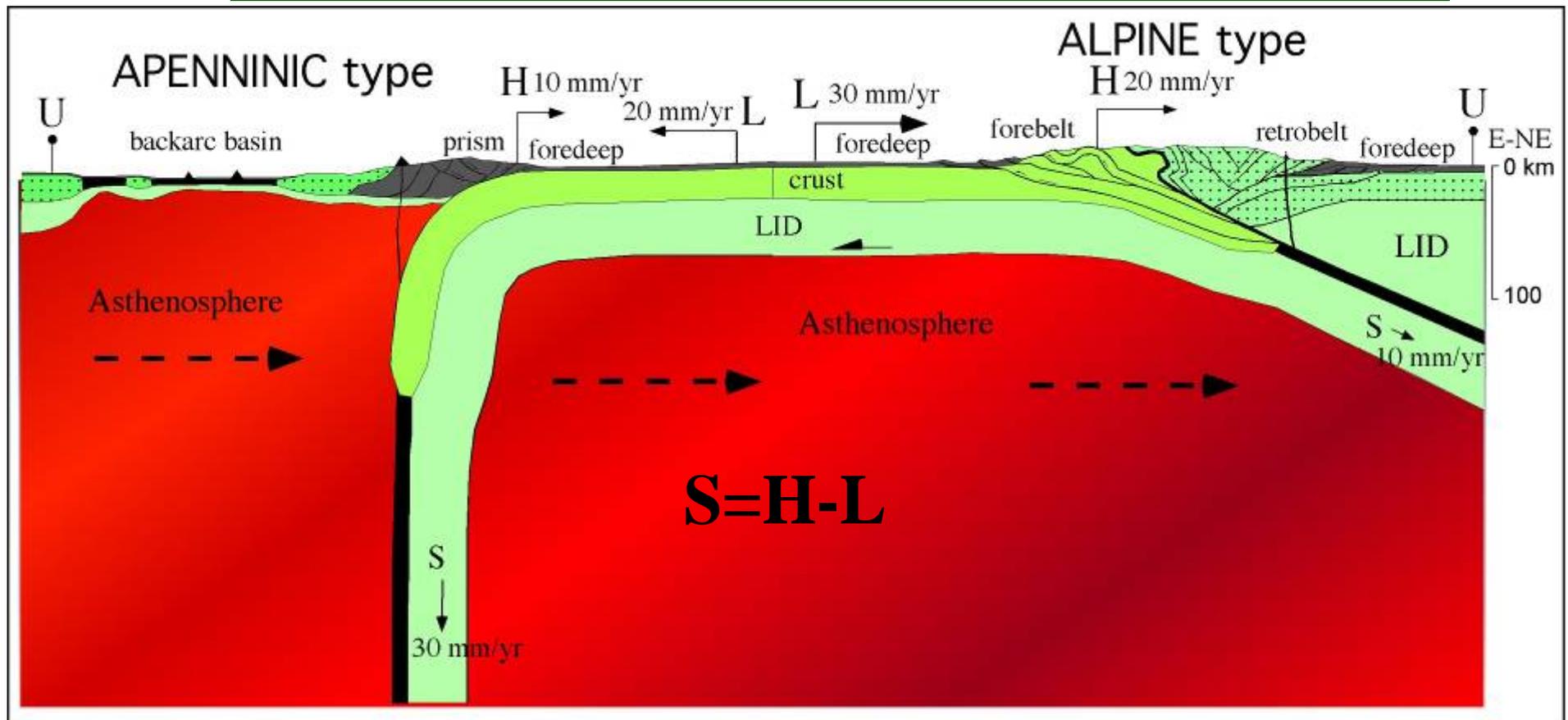
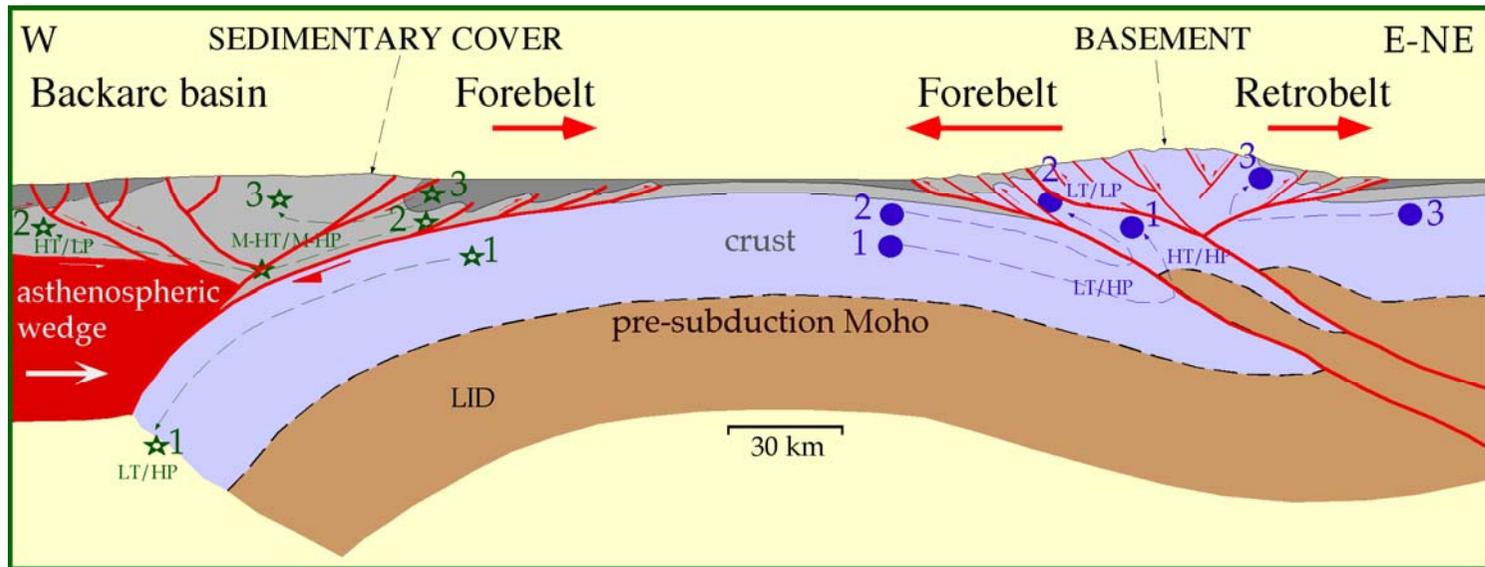


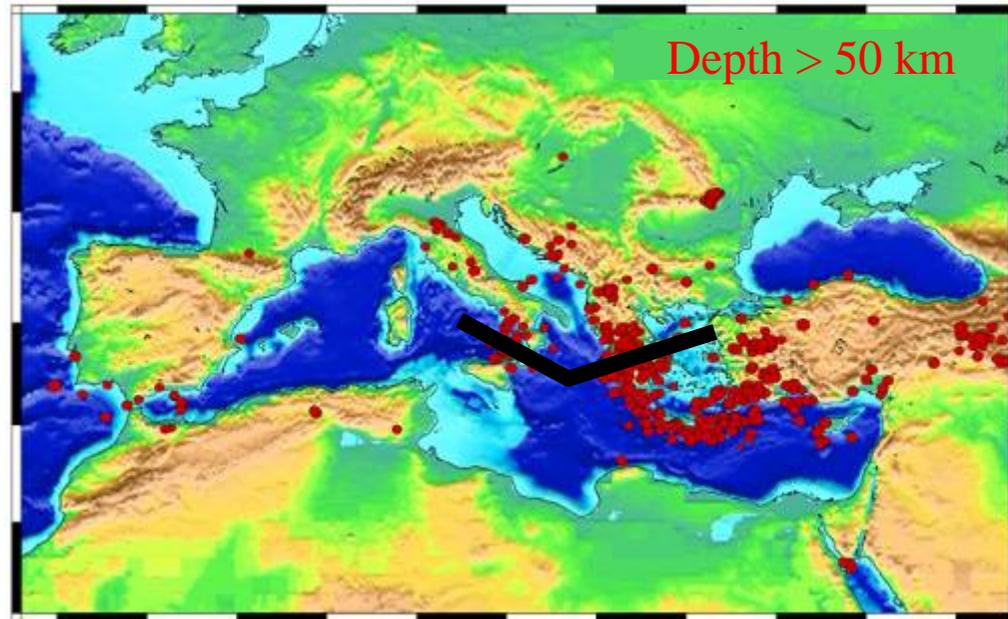


W-subduction rate / E-subduction rate $\approx 3 \pm 1$



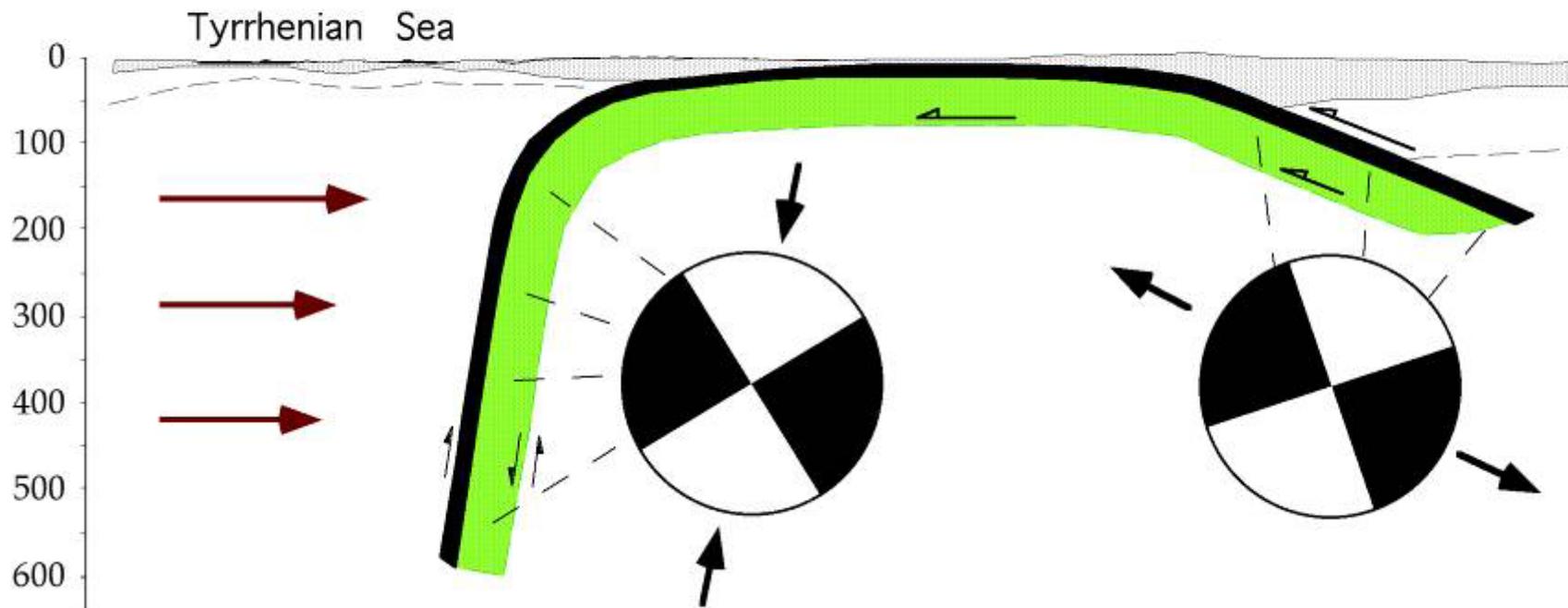


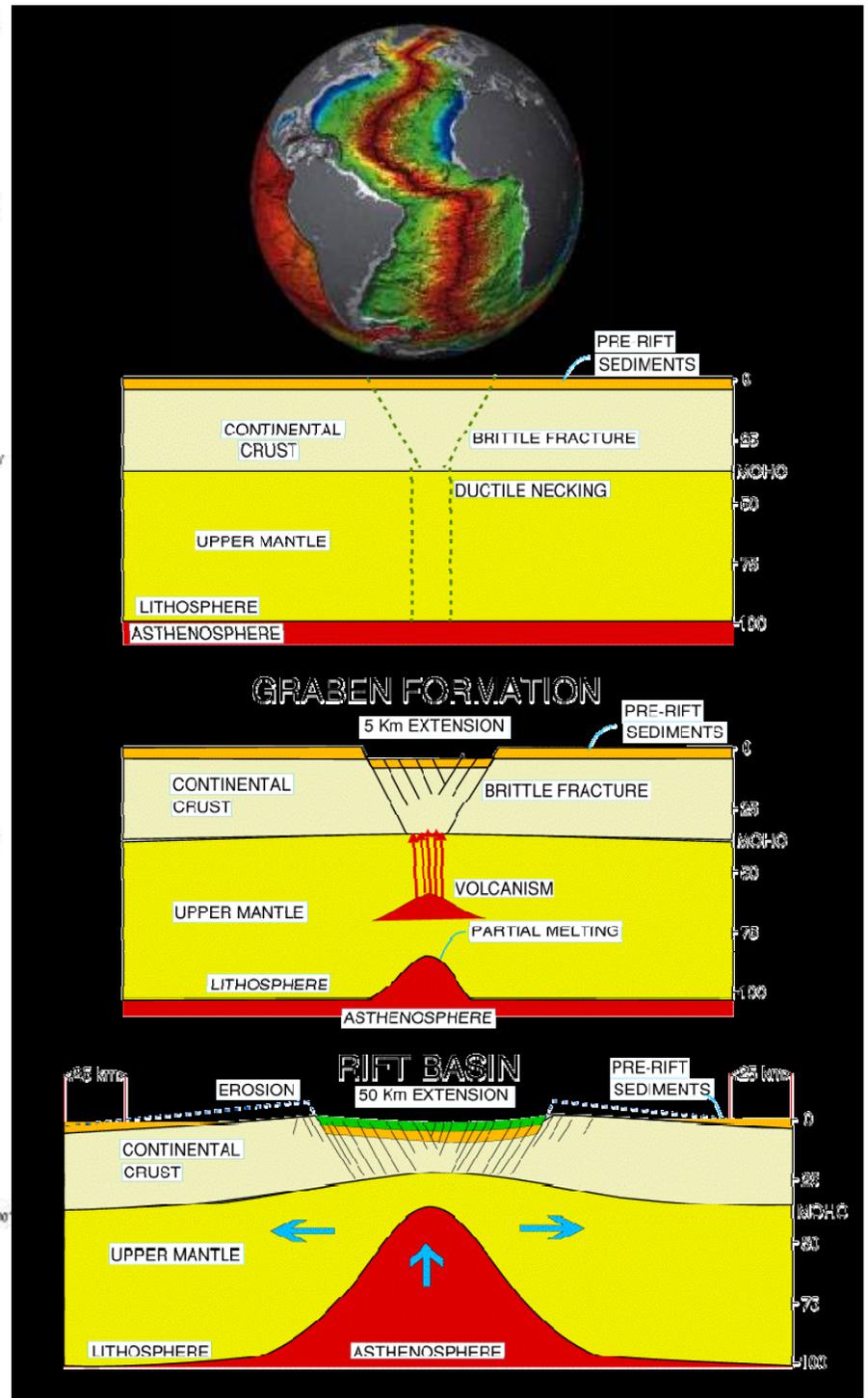
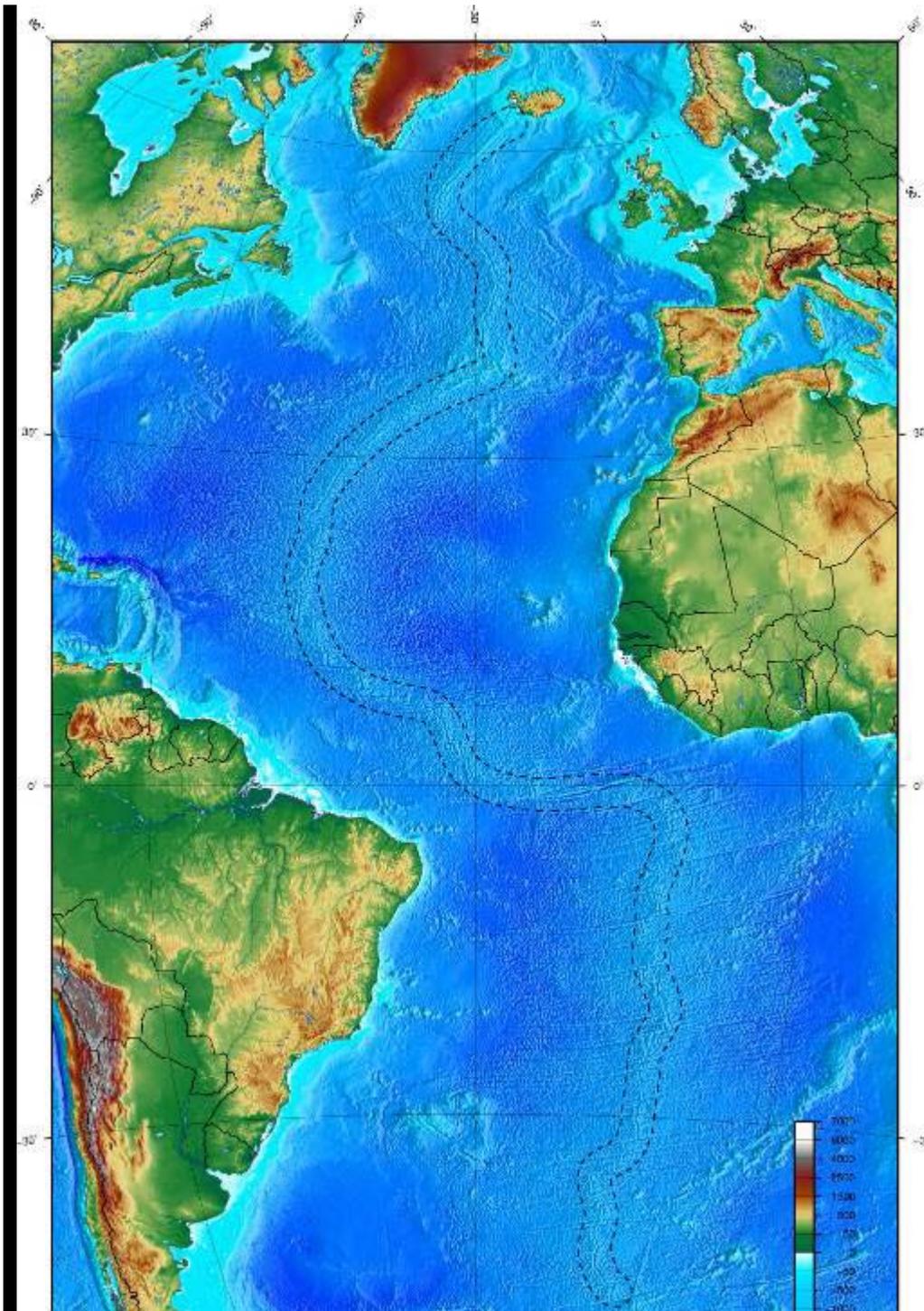




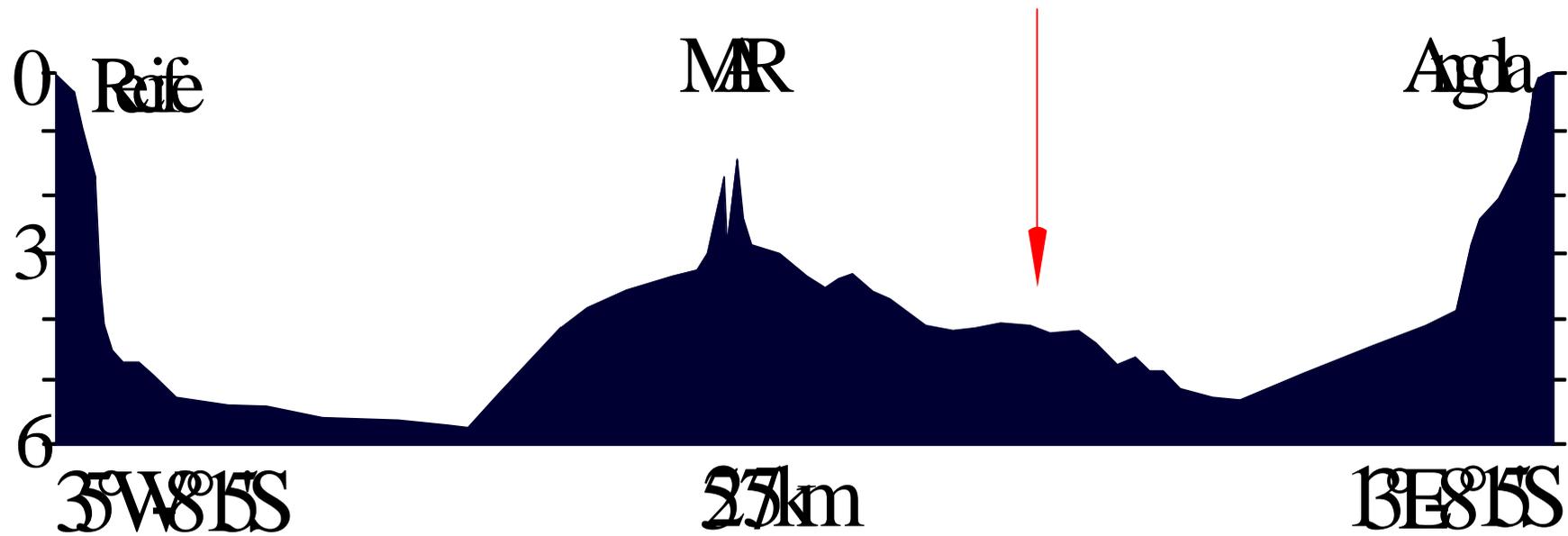
DOWN-DIP COMPRESSION
Apennines slab

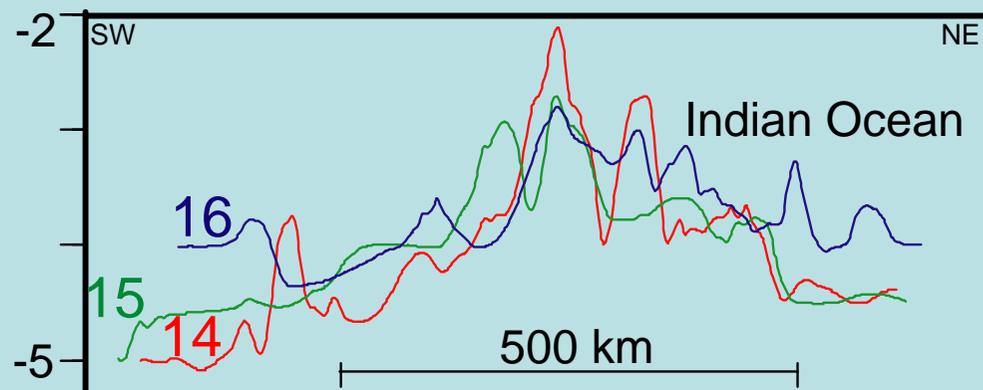
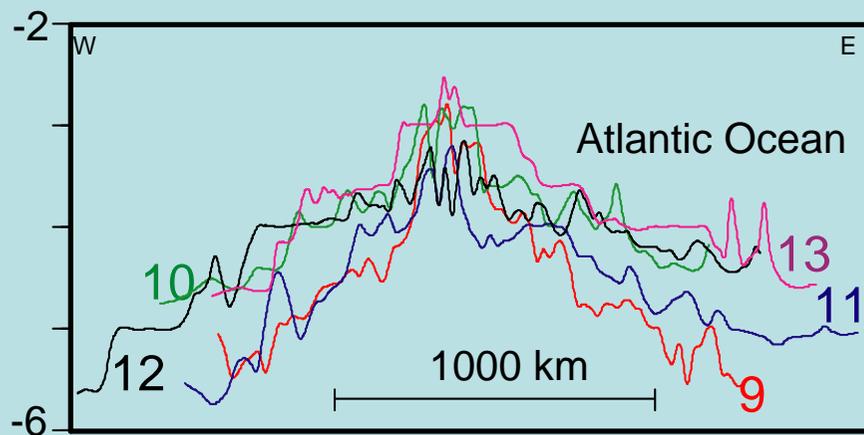
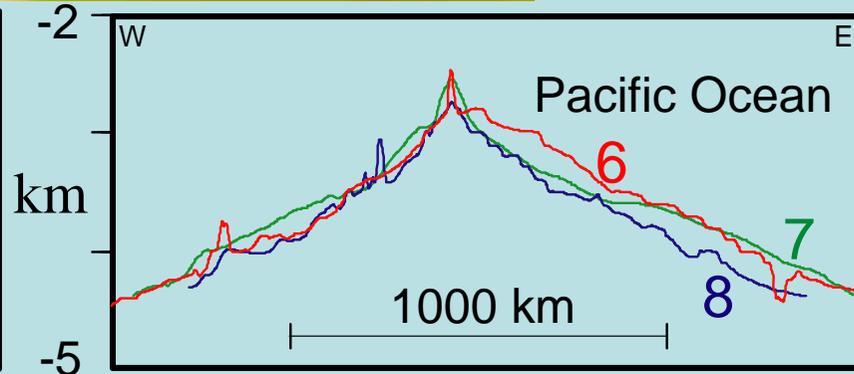
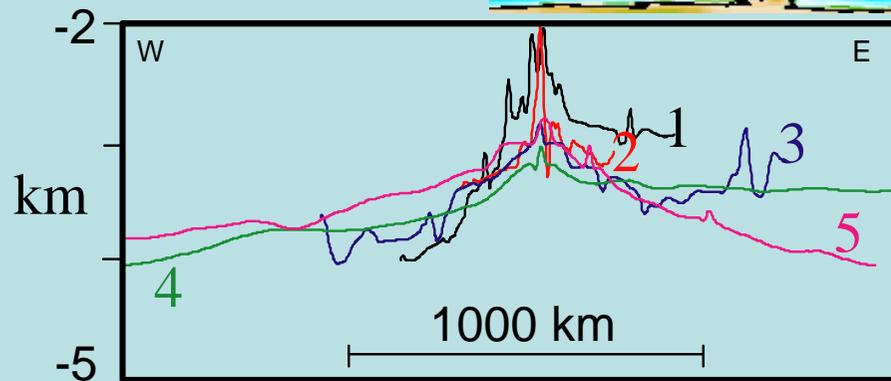
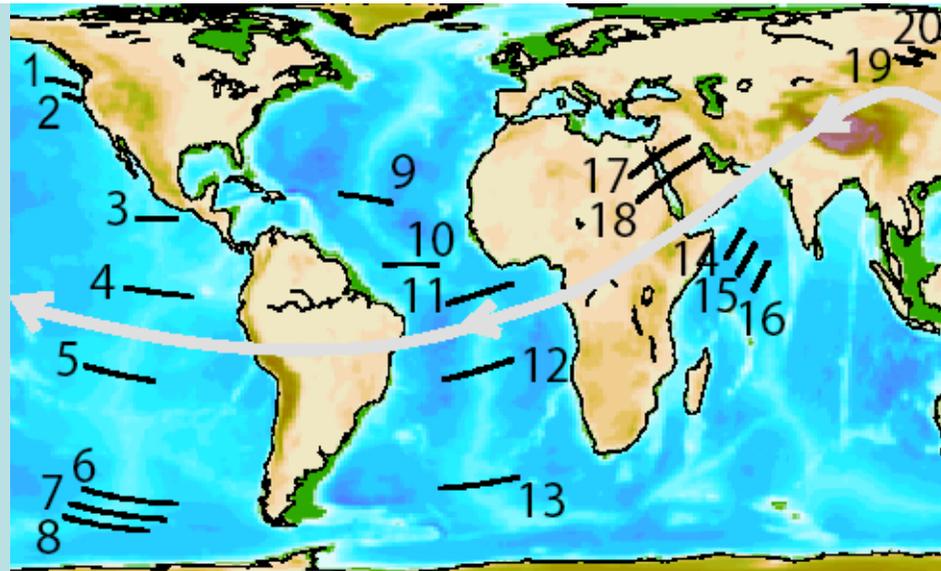
DOWN-DIP EXTENSION
Hellenides slab

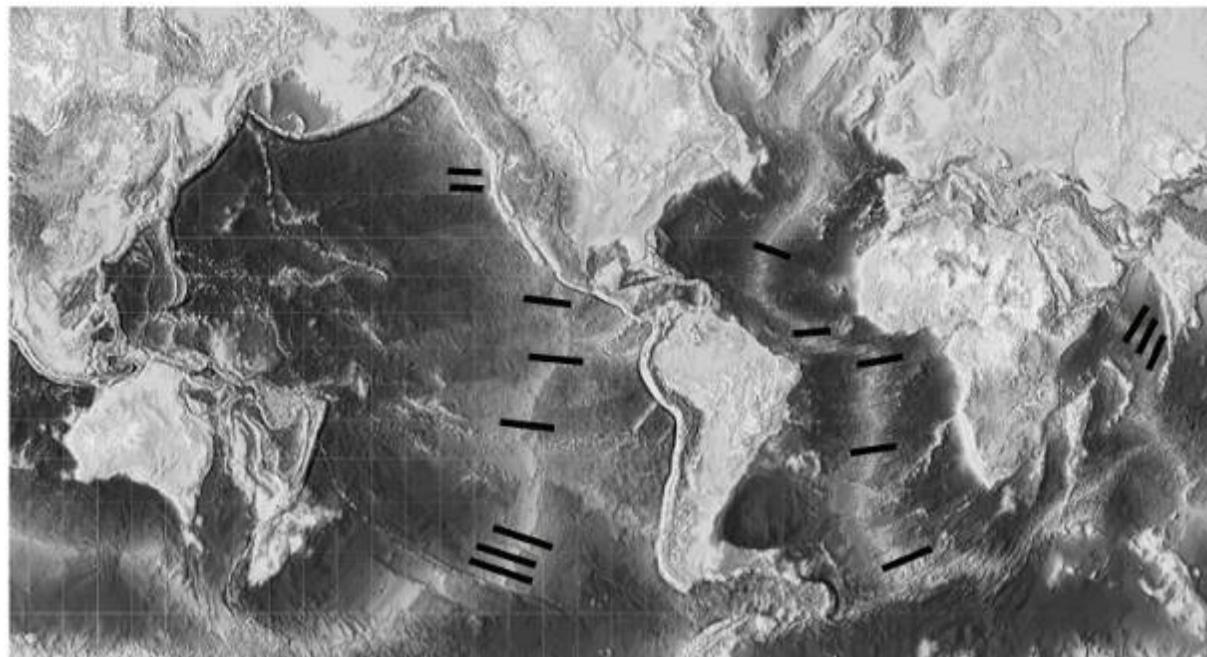
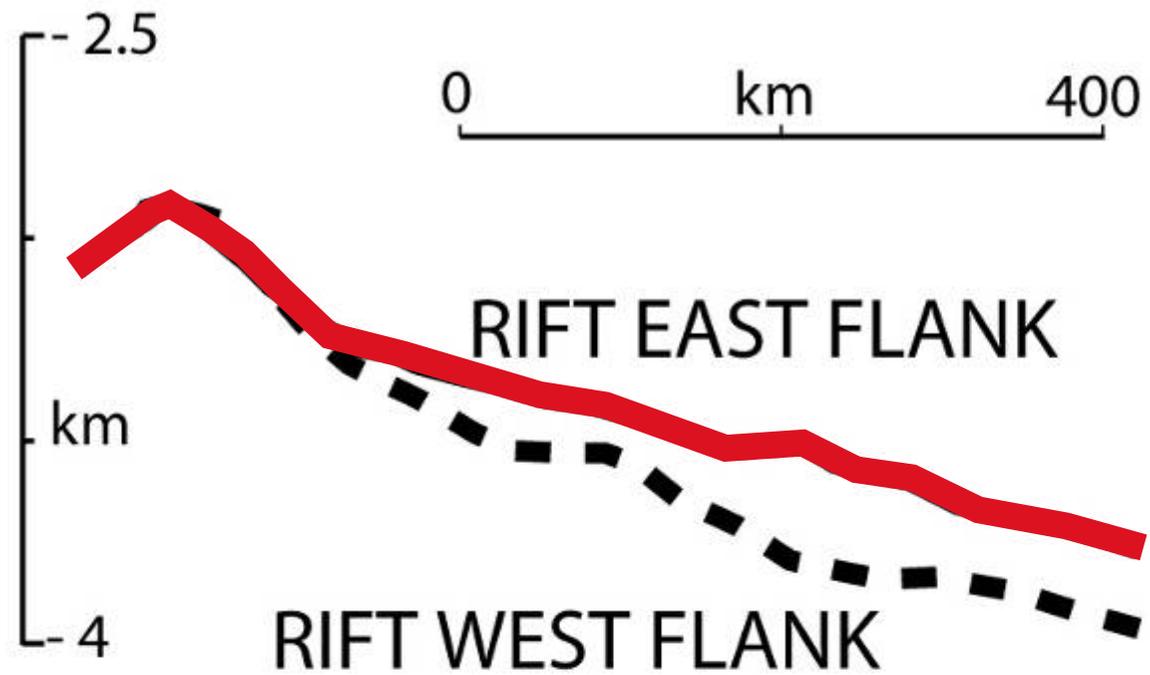




Shallower and less







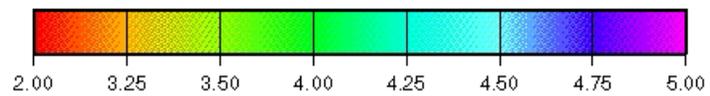
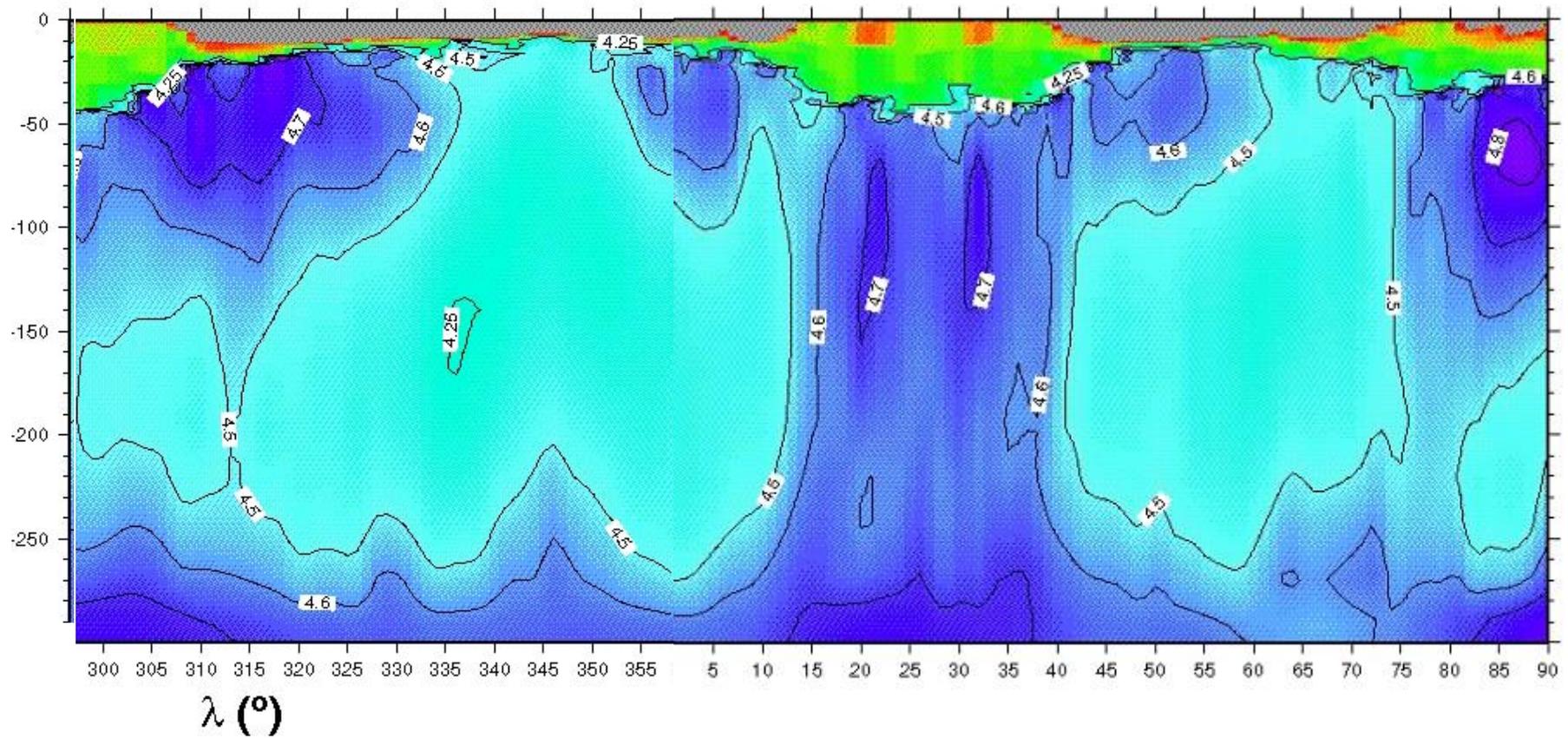
S-America

MAR

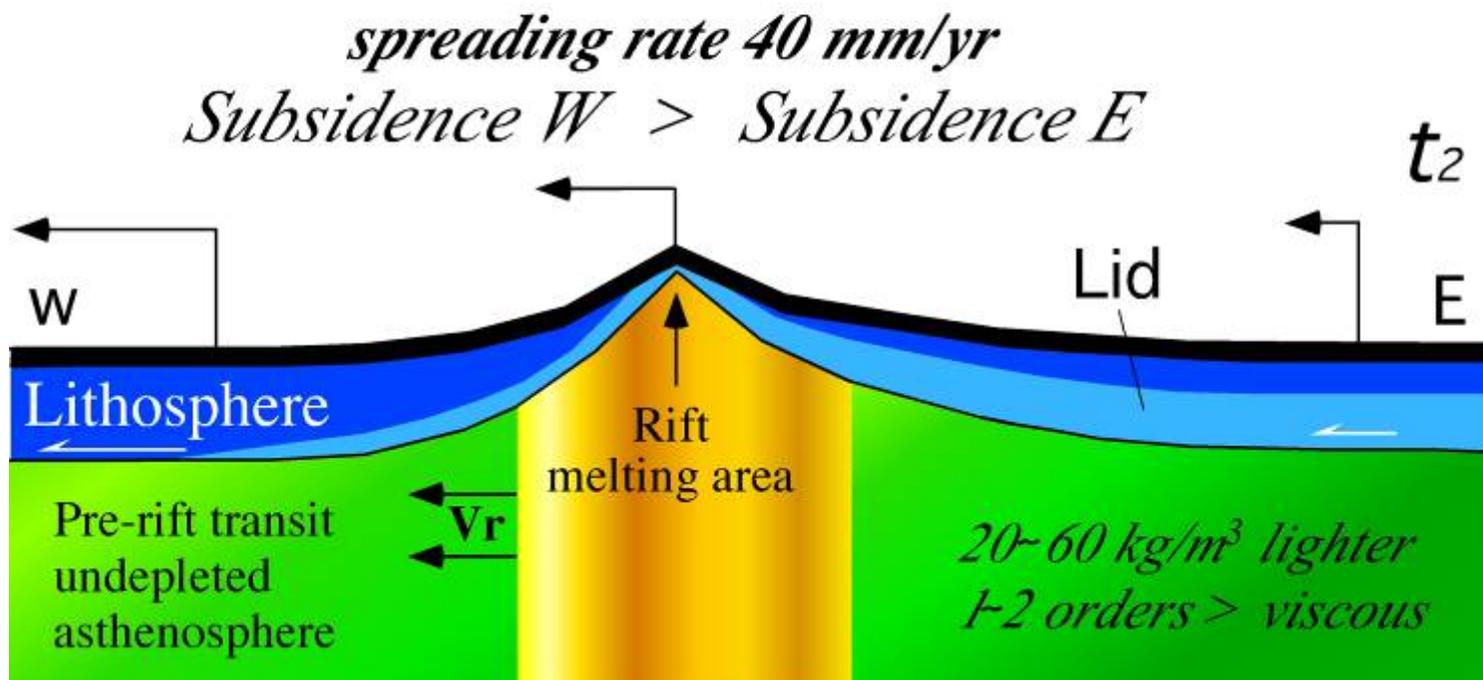
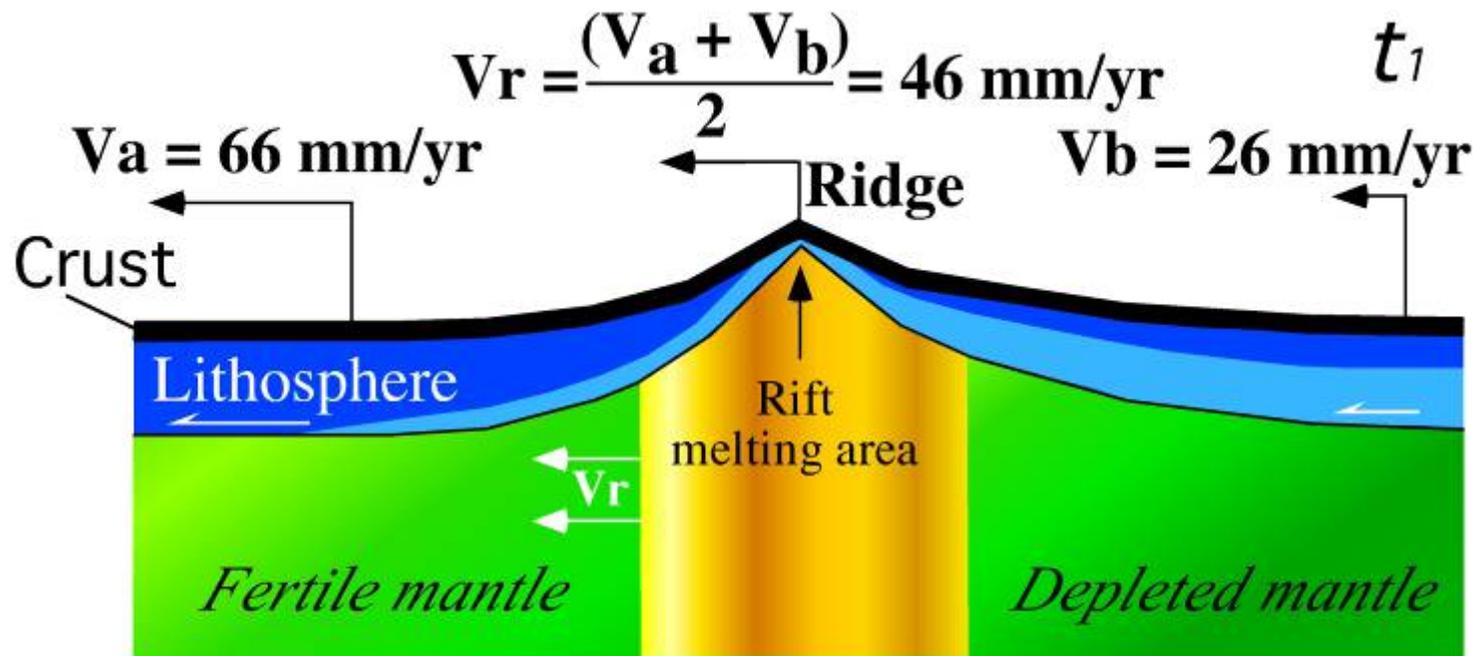
Africa

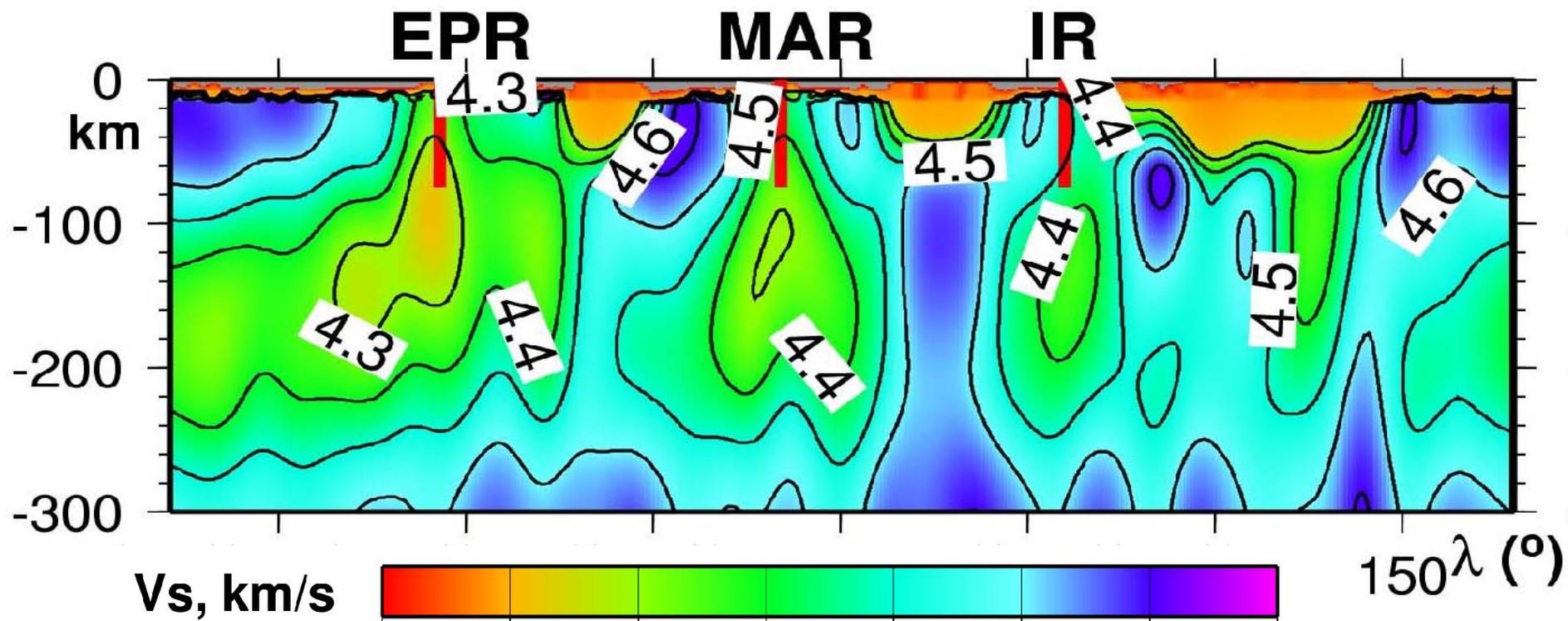
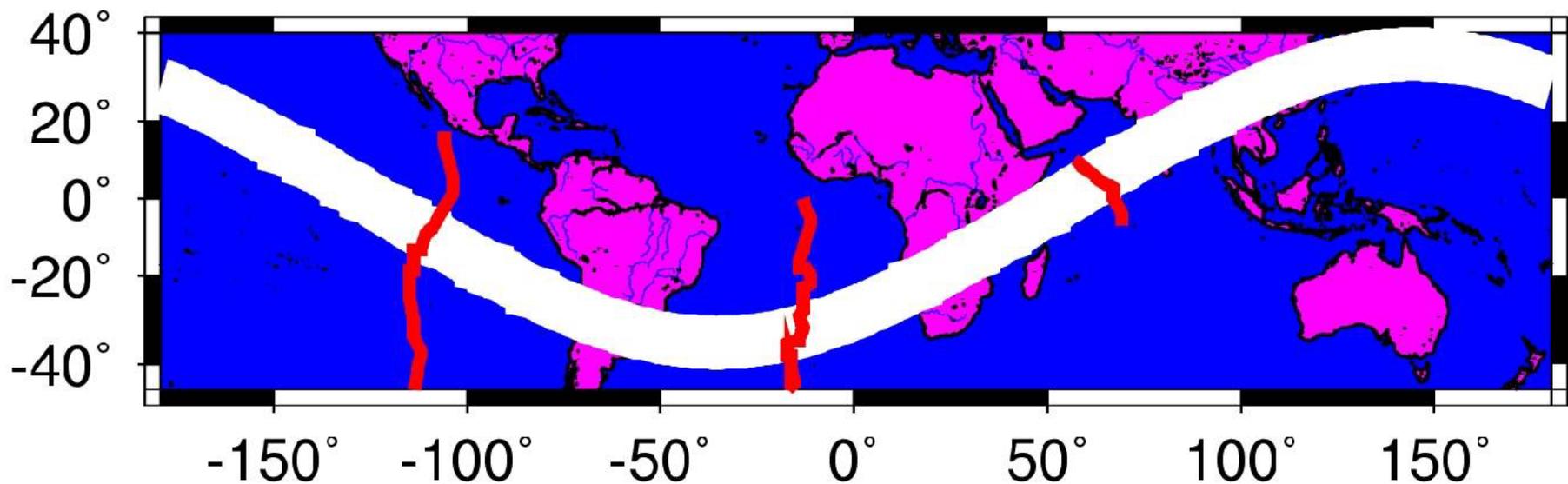
IR

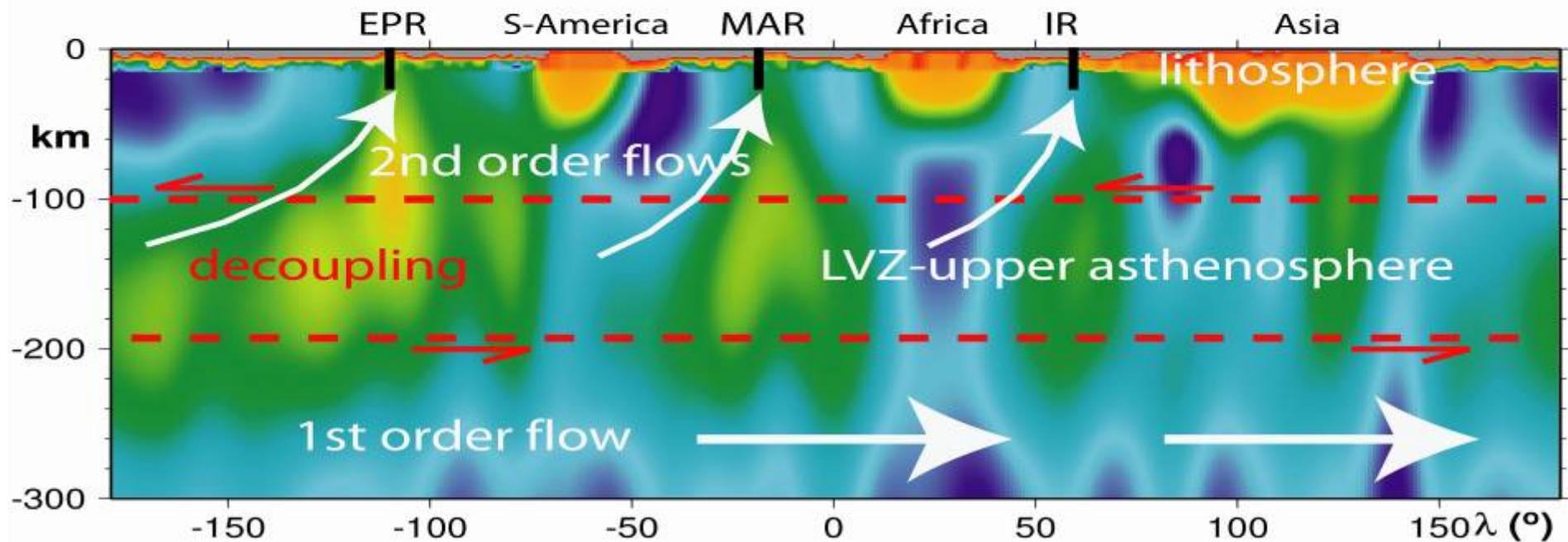
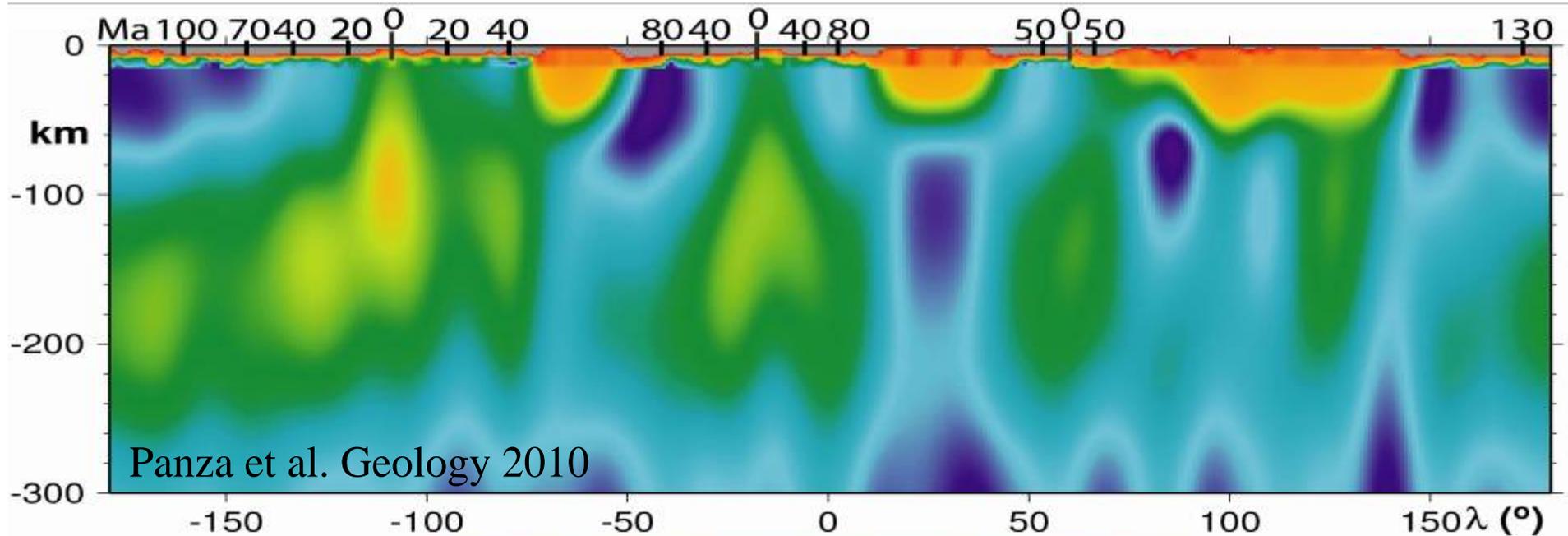
India

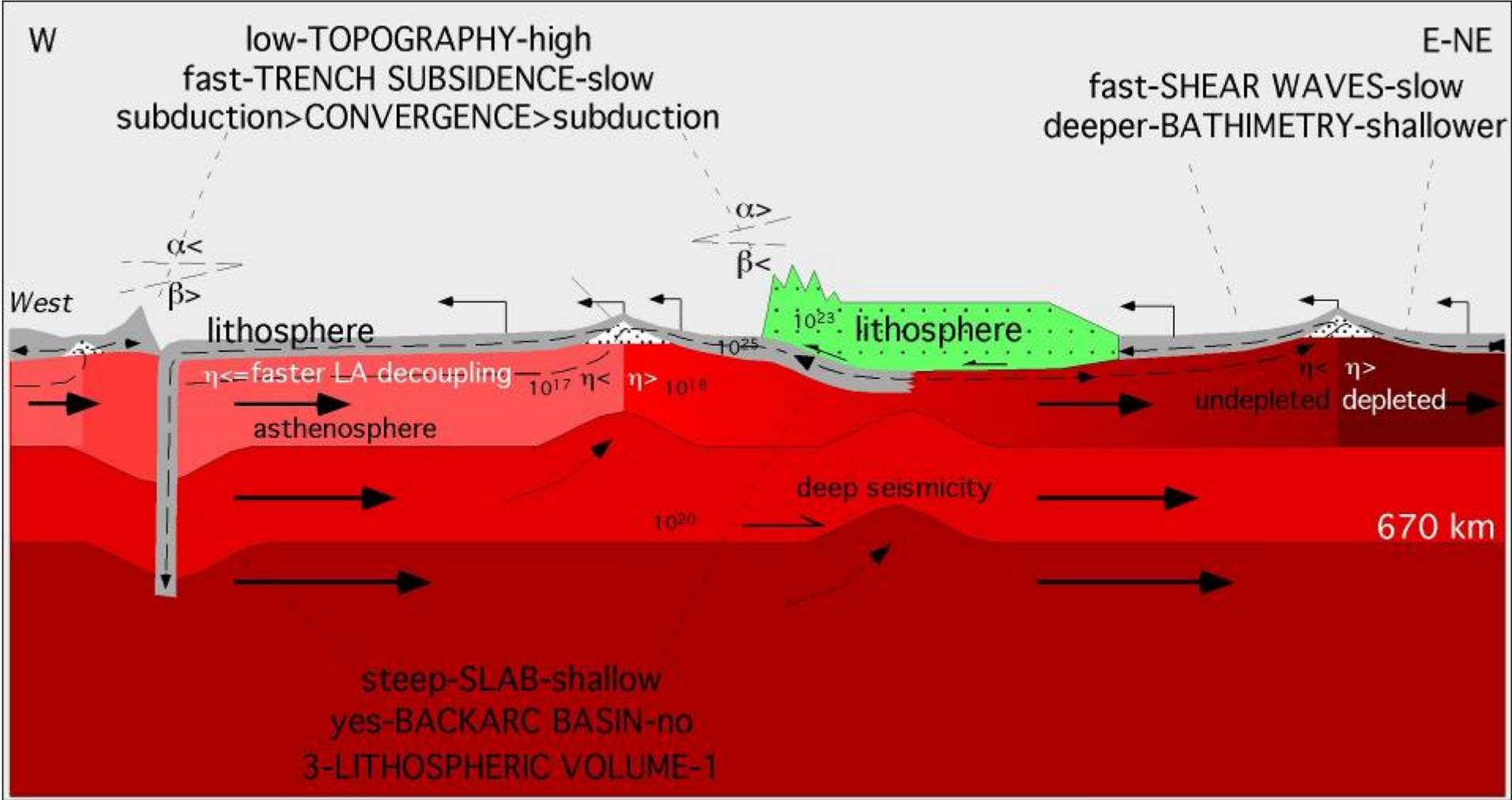


V_s , km/s



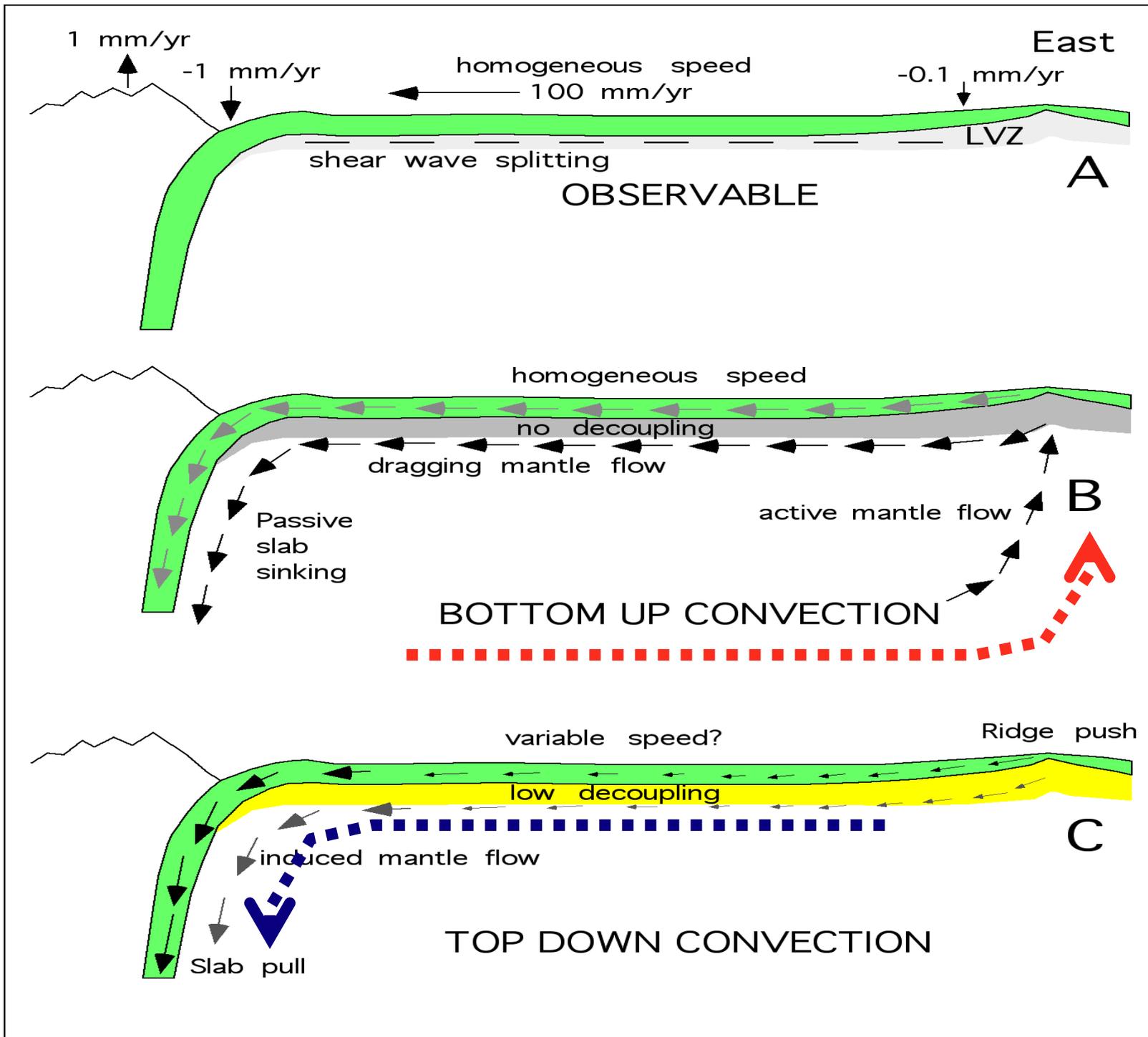


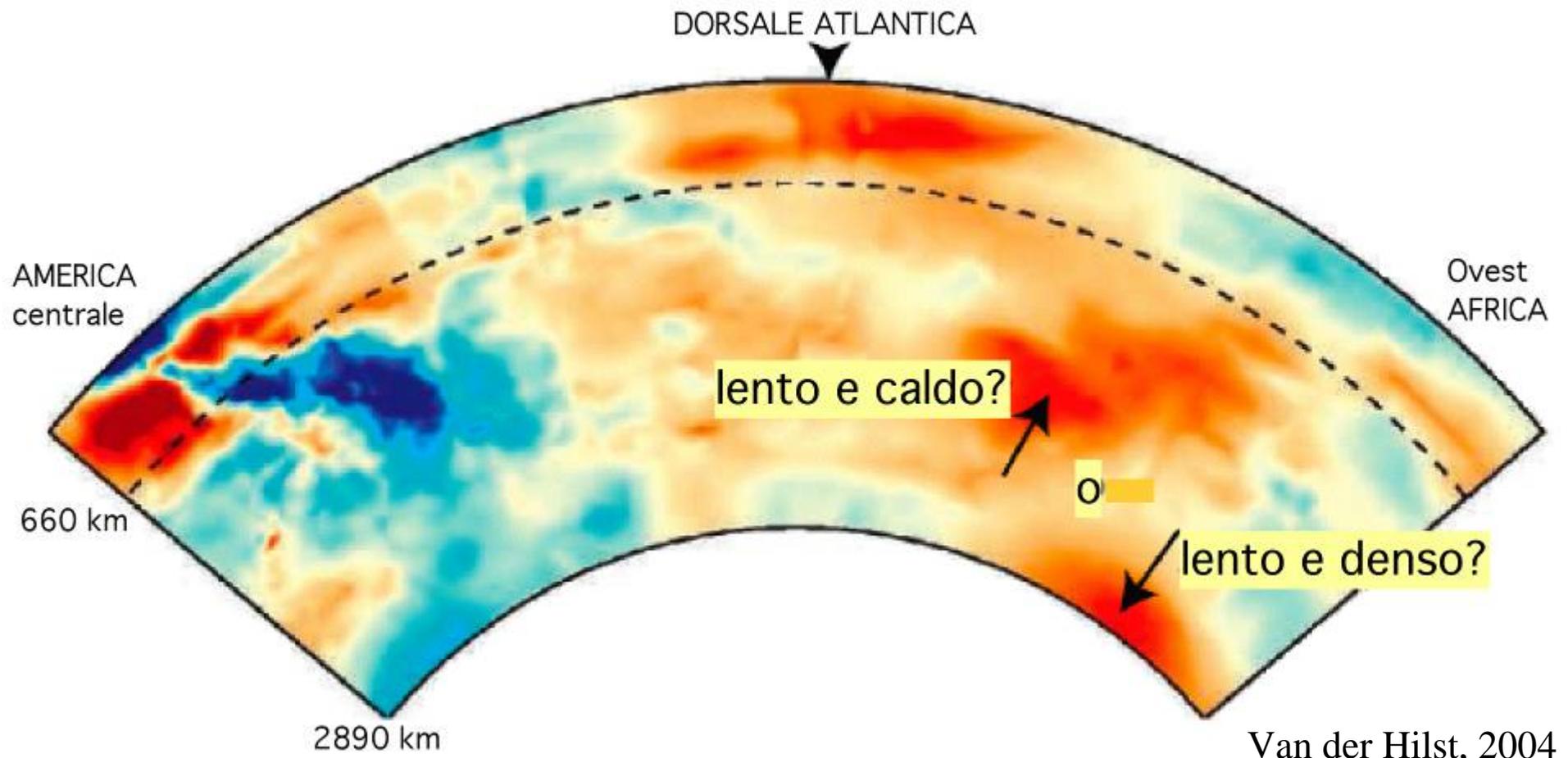




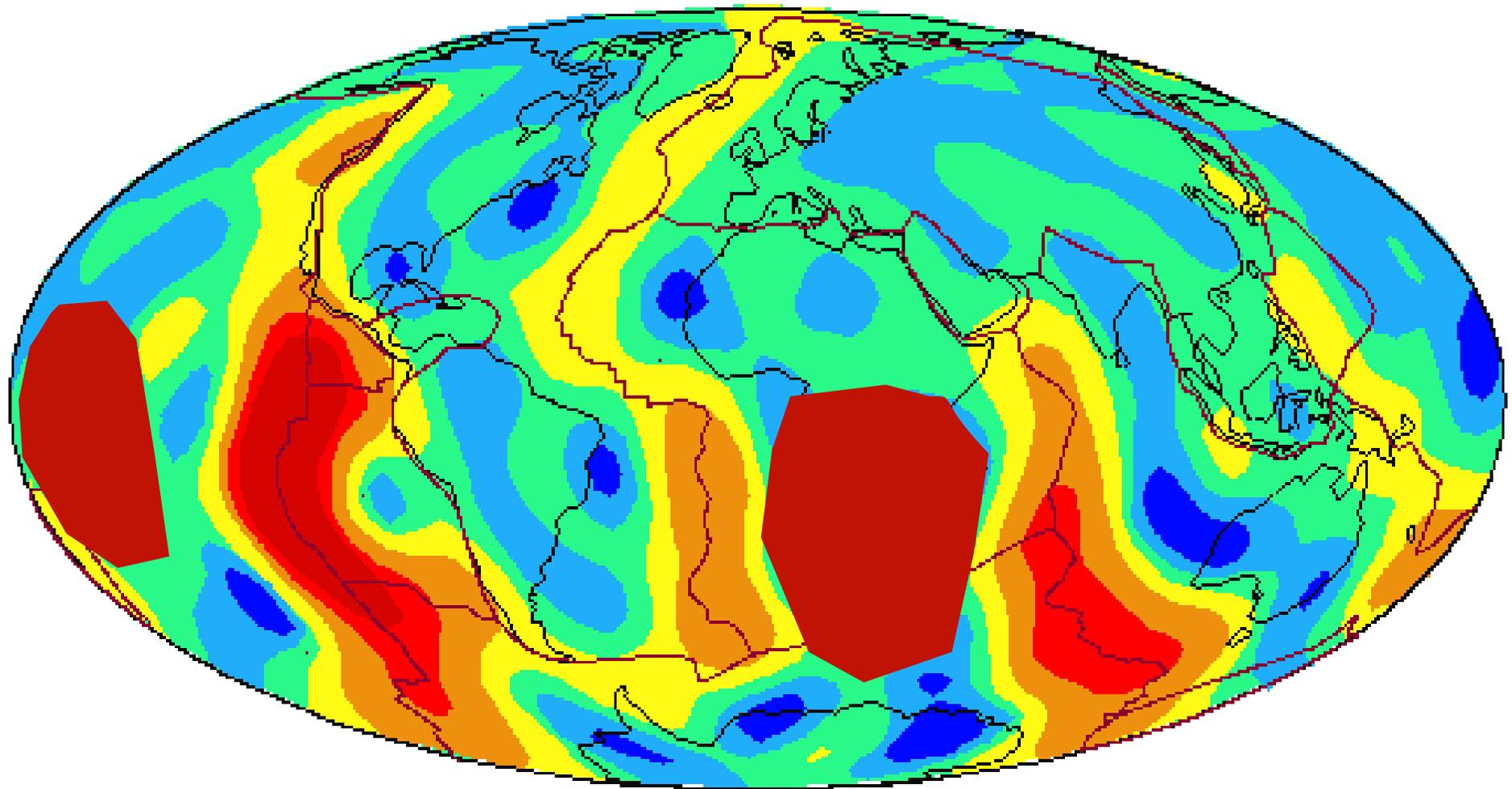
LE PLACCHE SI MUOVONO: MA CHI LE SPINGE??!!







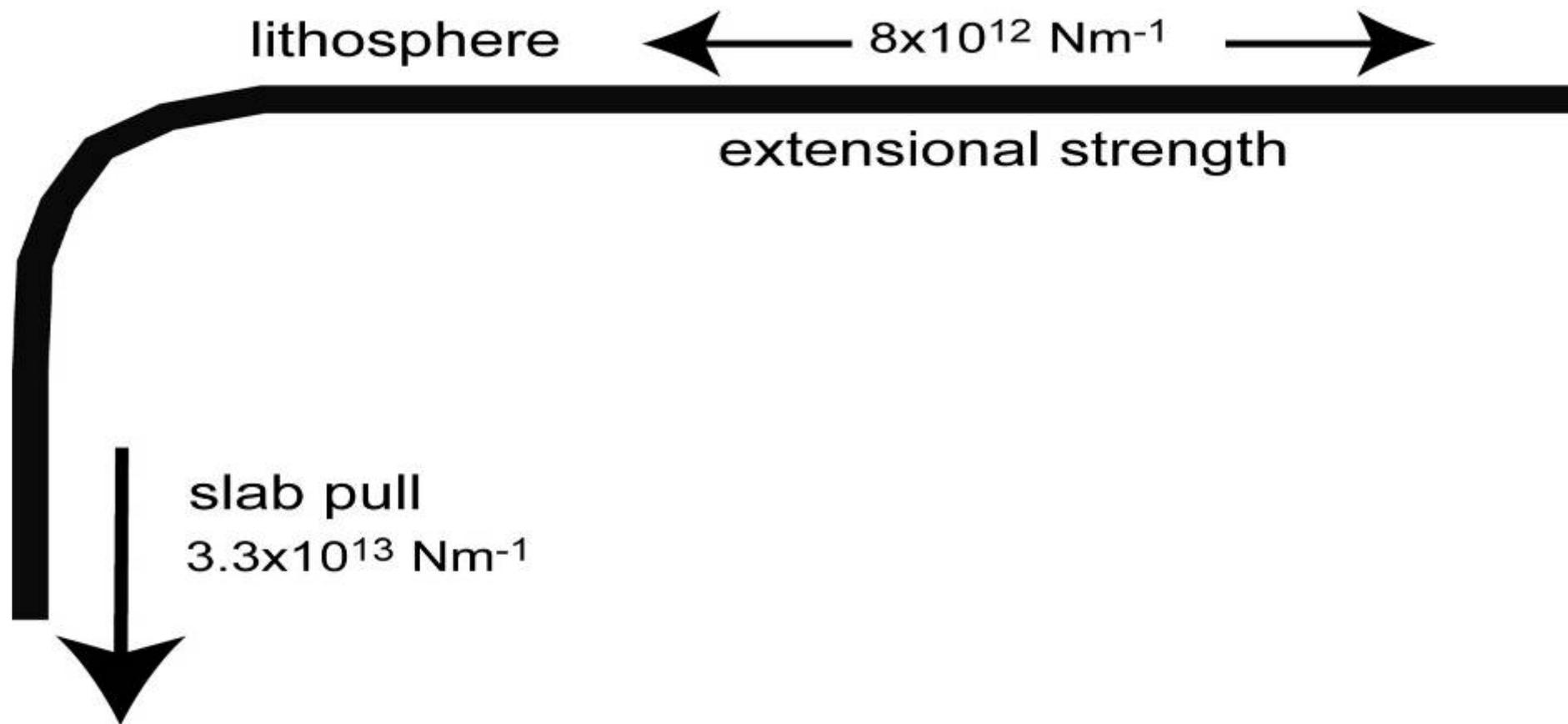
Heat Flow



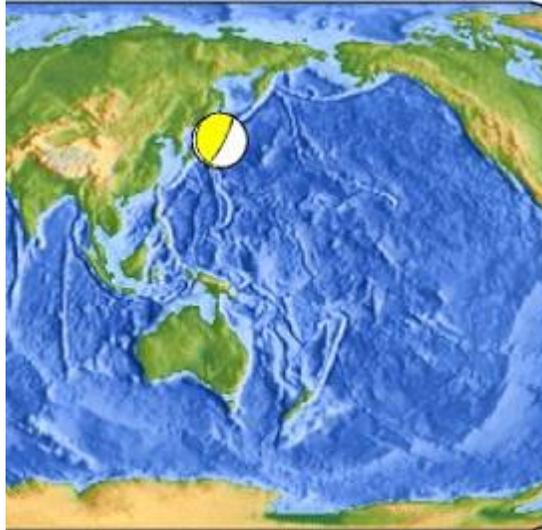
0 40 60 85 120 180 240 350

mW m^{-2}

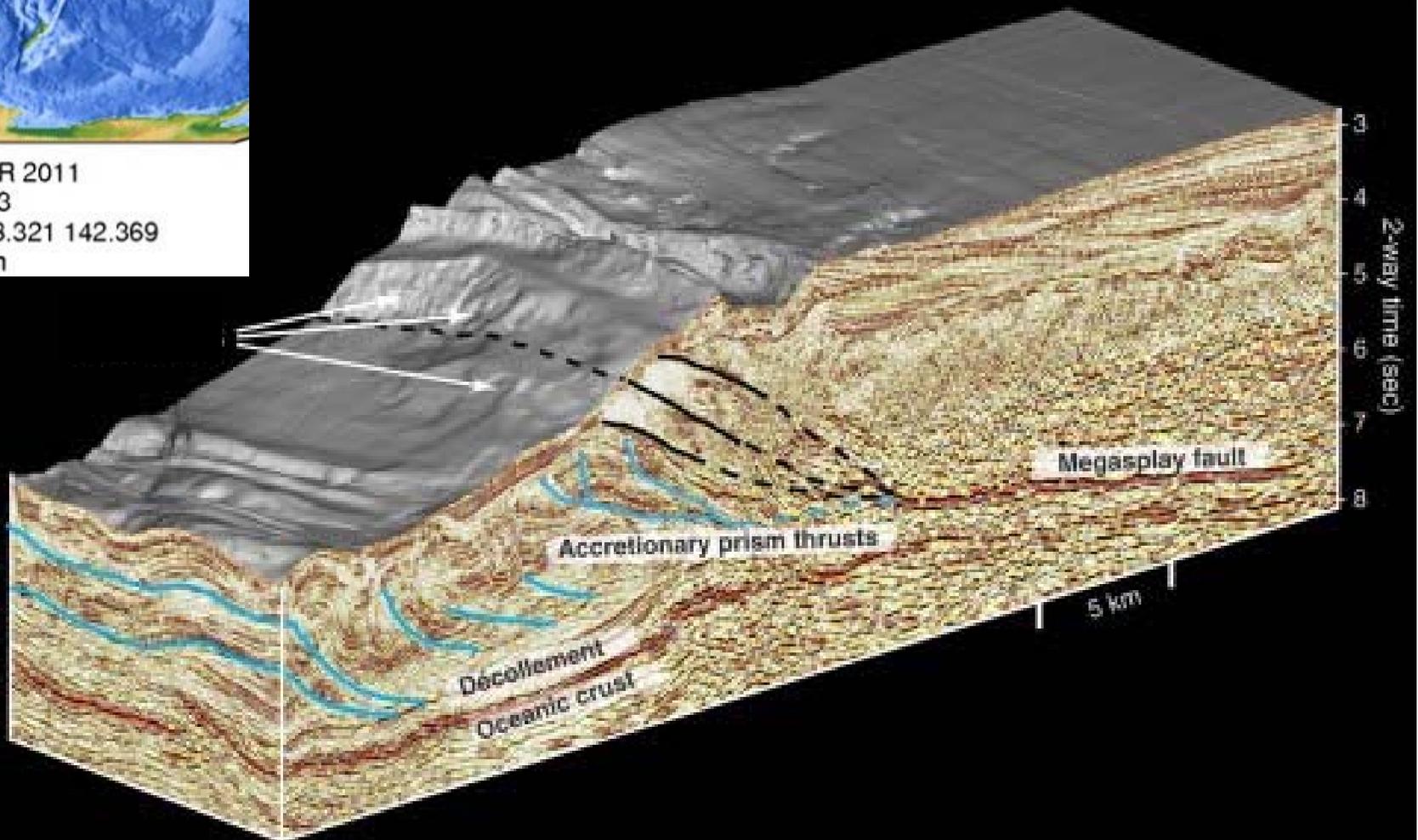
Pollack, 1996



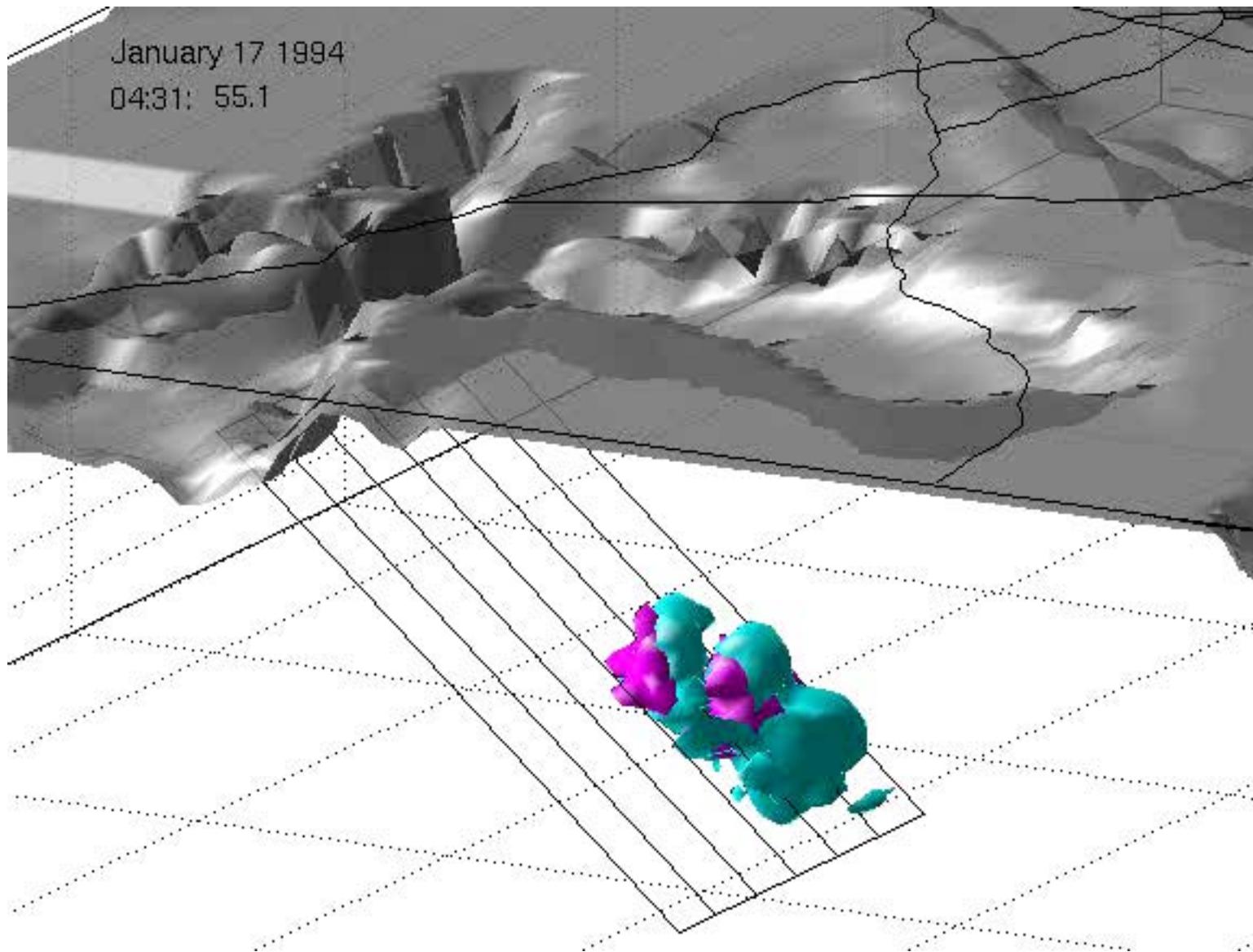
Mw 8.9
SGS WPhase Moment Tensor Solution



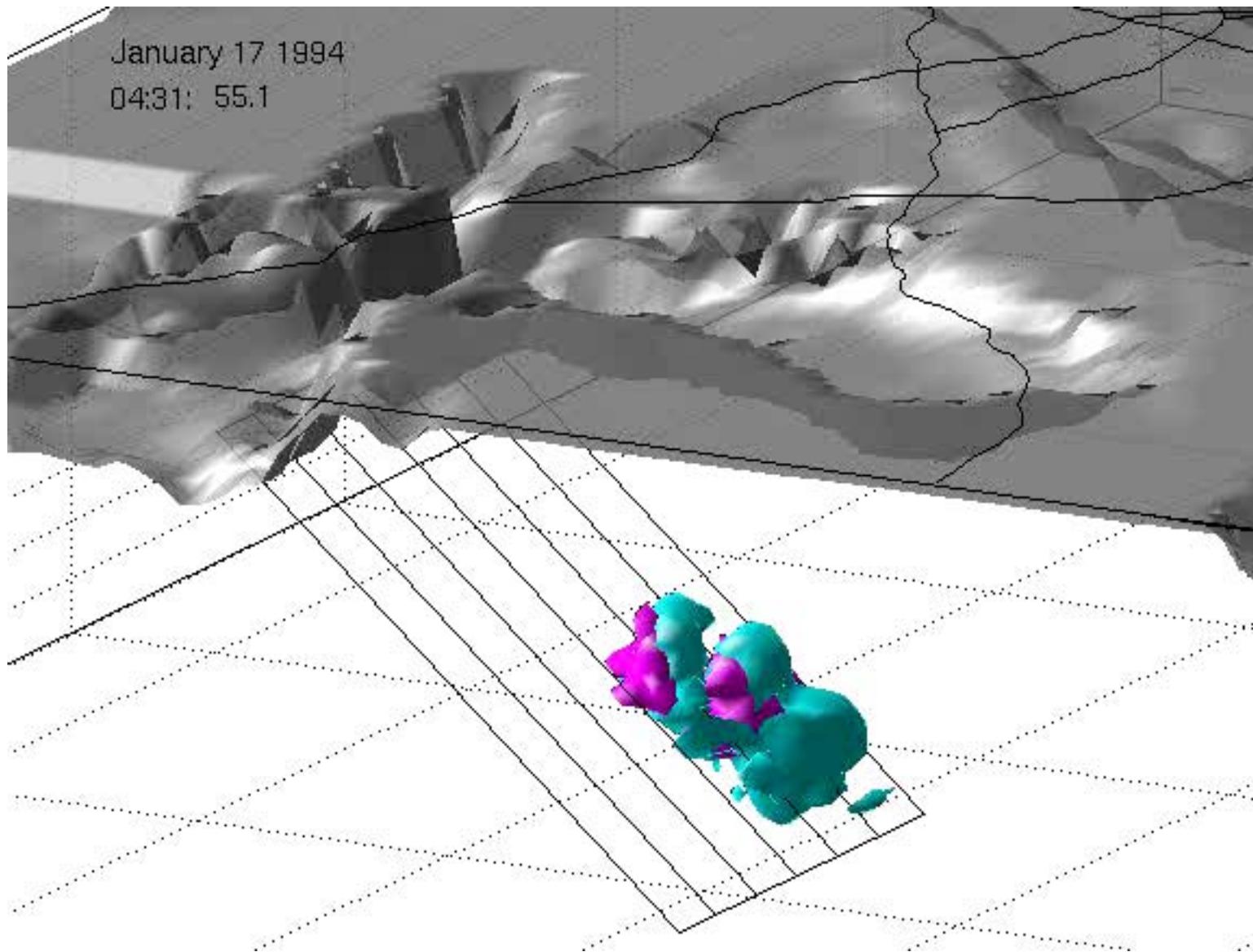
Date: 11 MAR 2011
Time: 5:46:23
Epicenter: 38.321 142.369
Depth: 24 km



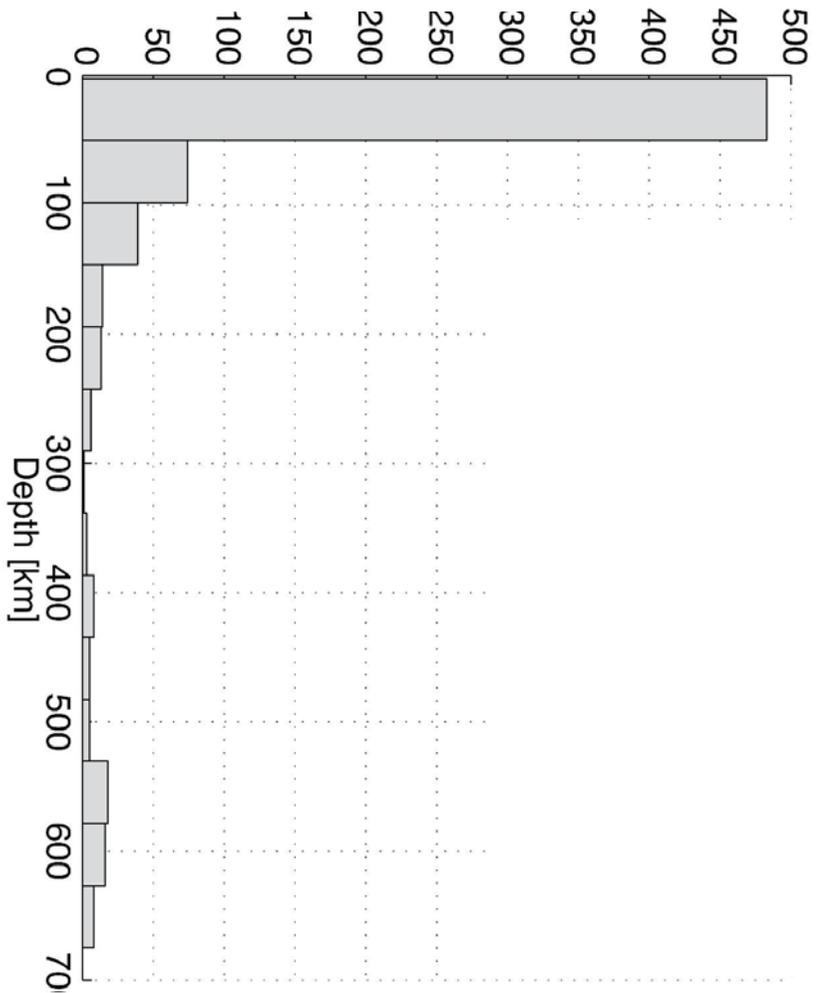
January 17 1994
04:31: 55.1



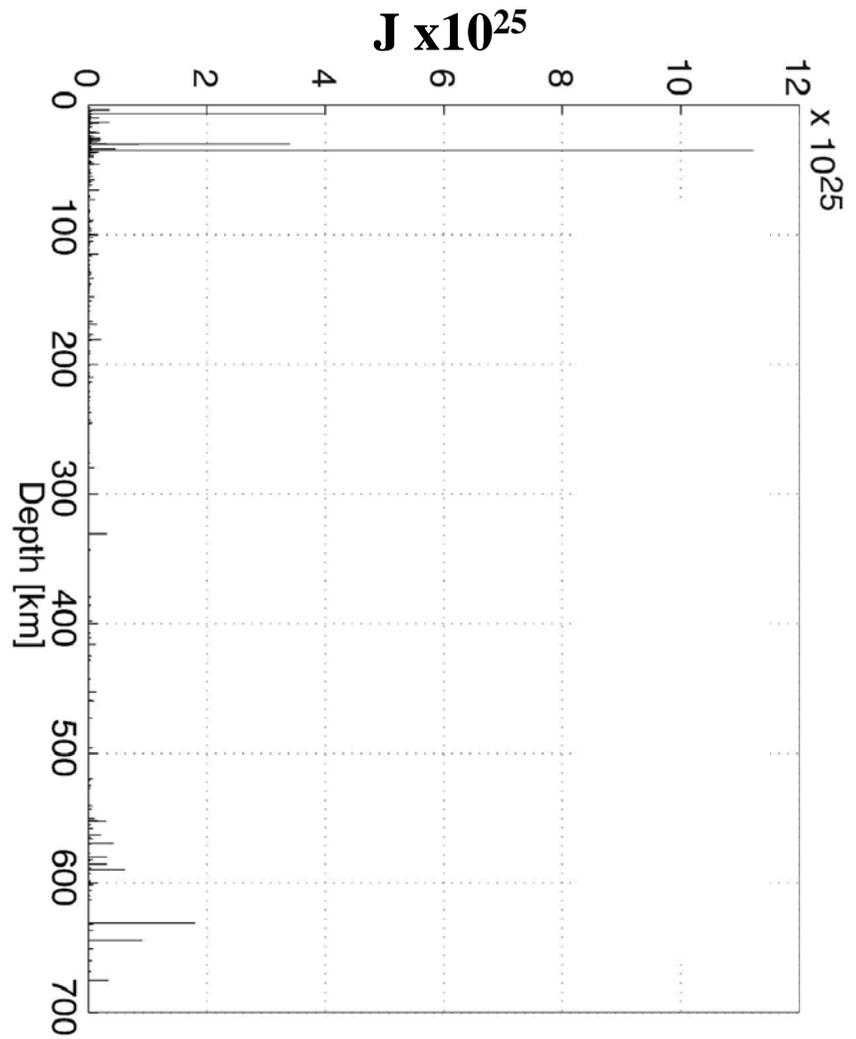
January 17 1994
04:31: 55.1



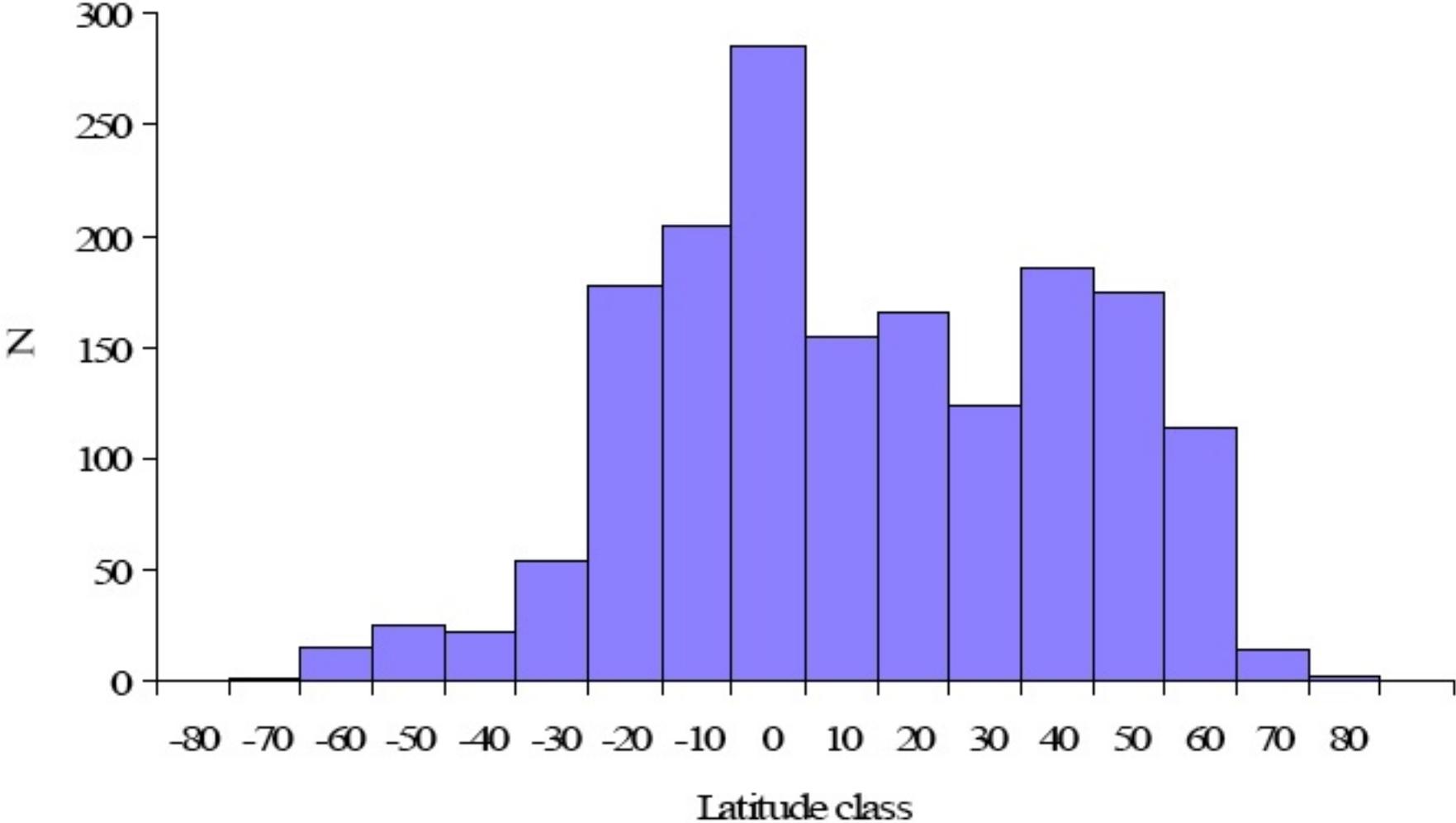
Number of earthquakes



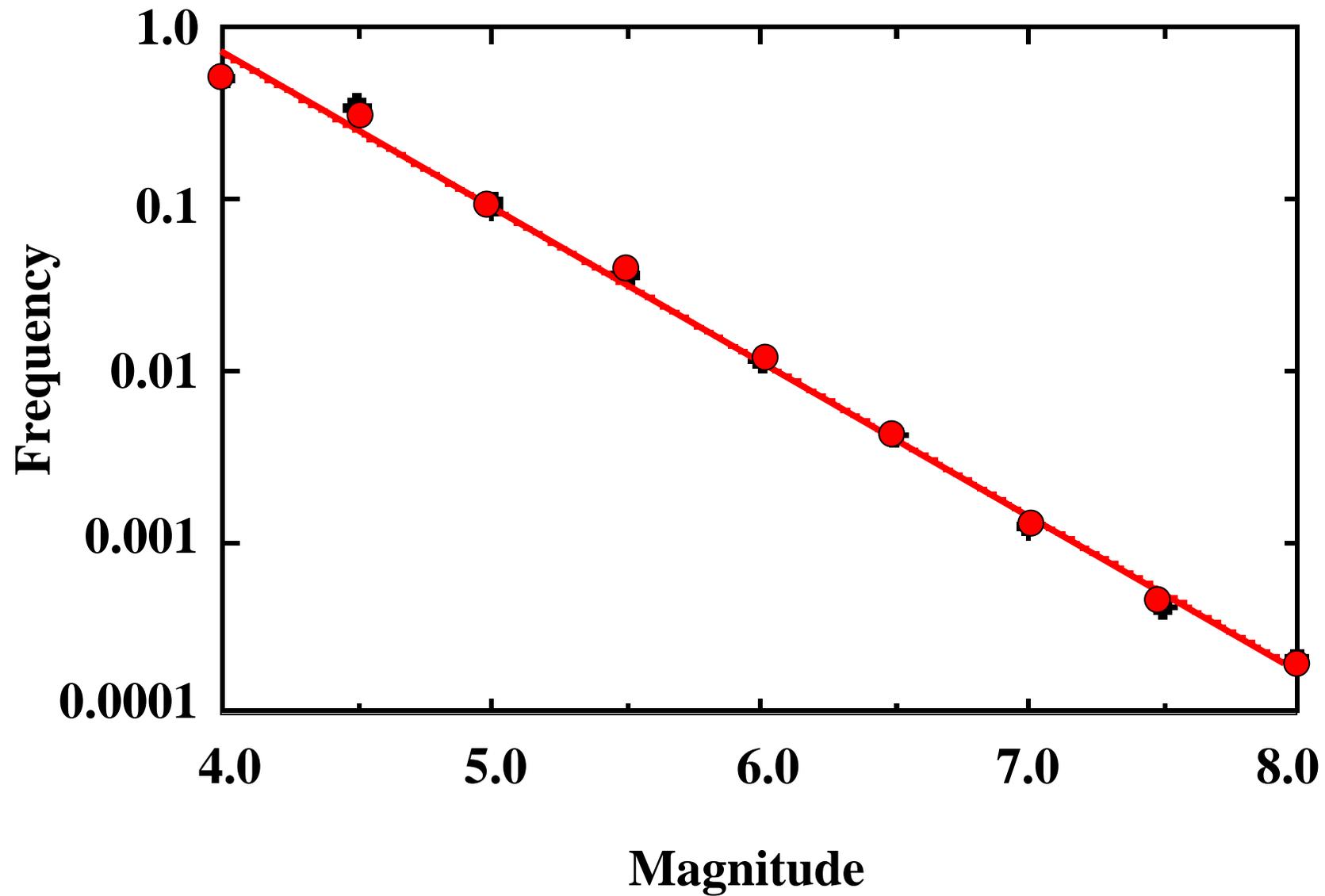
Energy

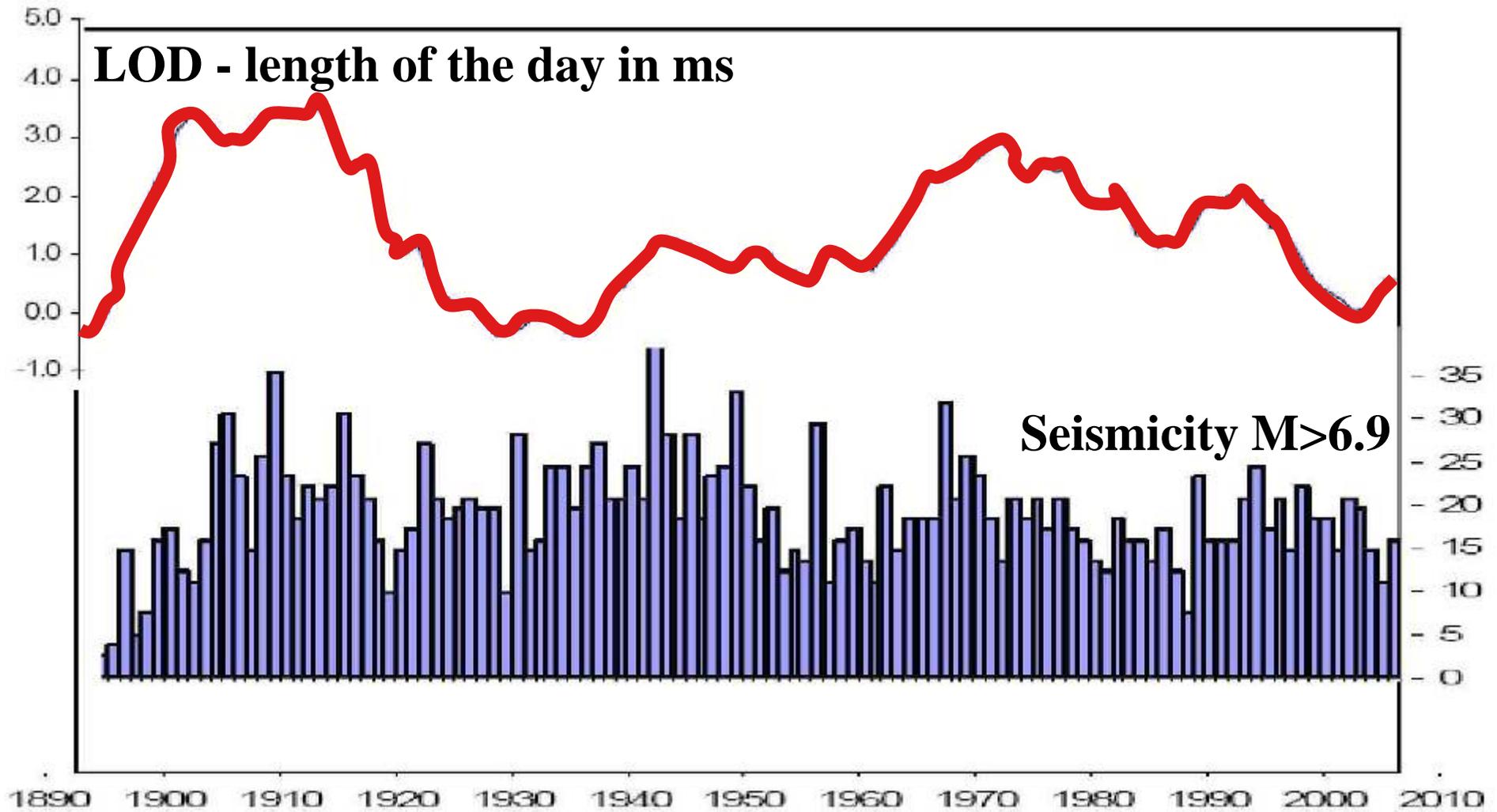


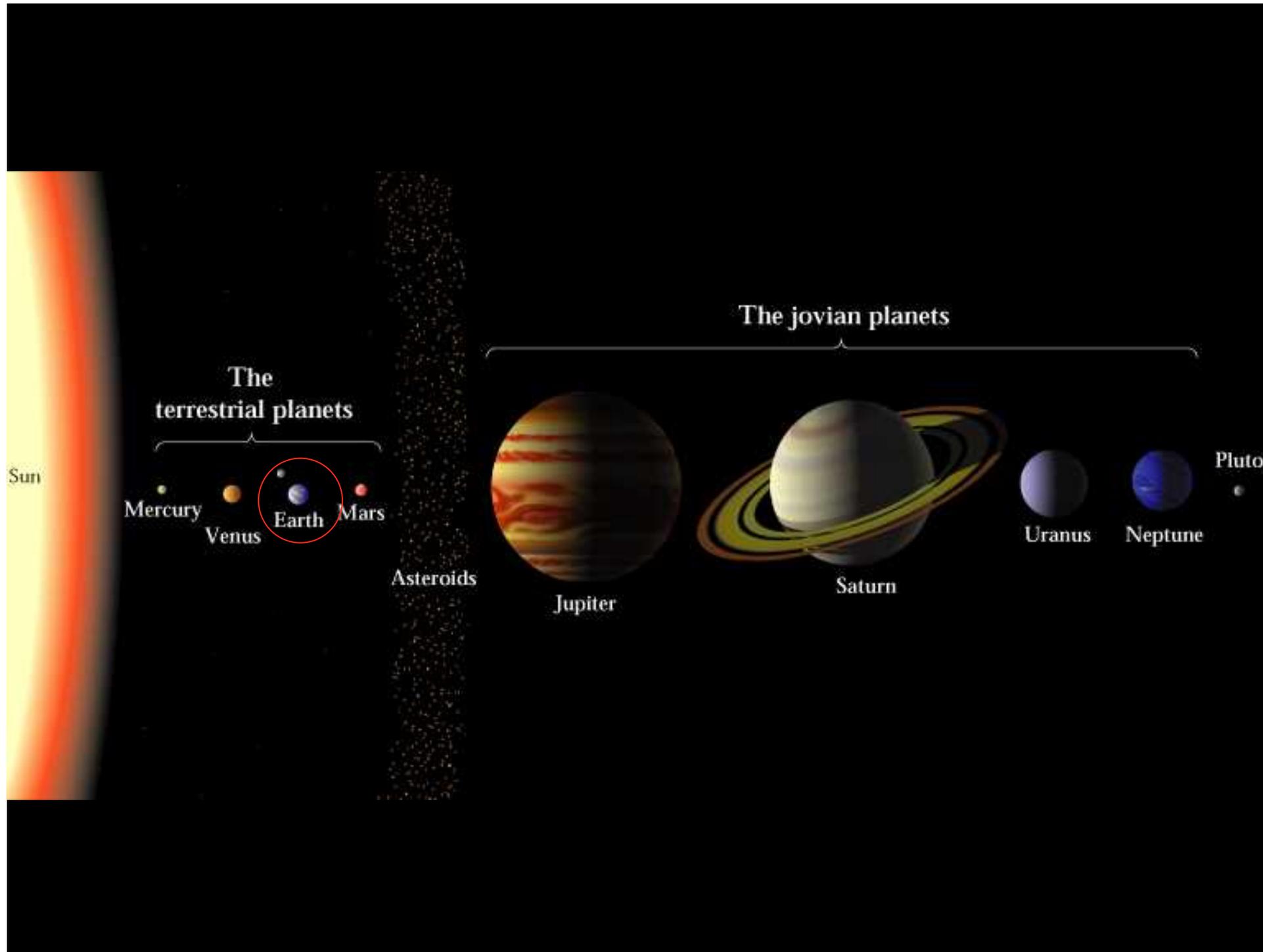
Global seismicity



Gutenberg-Richter scale







Sun

The terrestrial planets

Mercury Venus Earth Mars

Asteroids

The jovian planets

Jupiter

Saturn

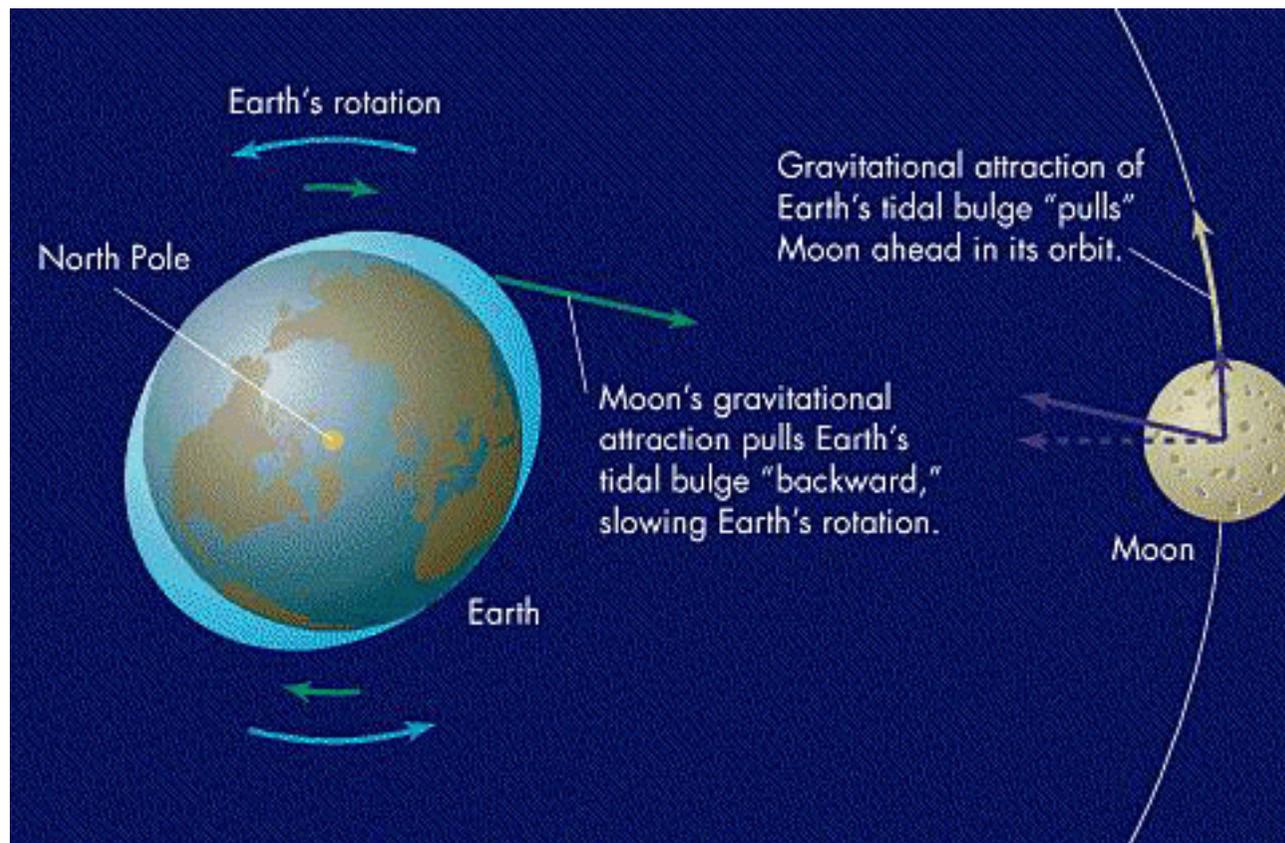
Uranus

Neptune

Pluto

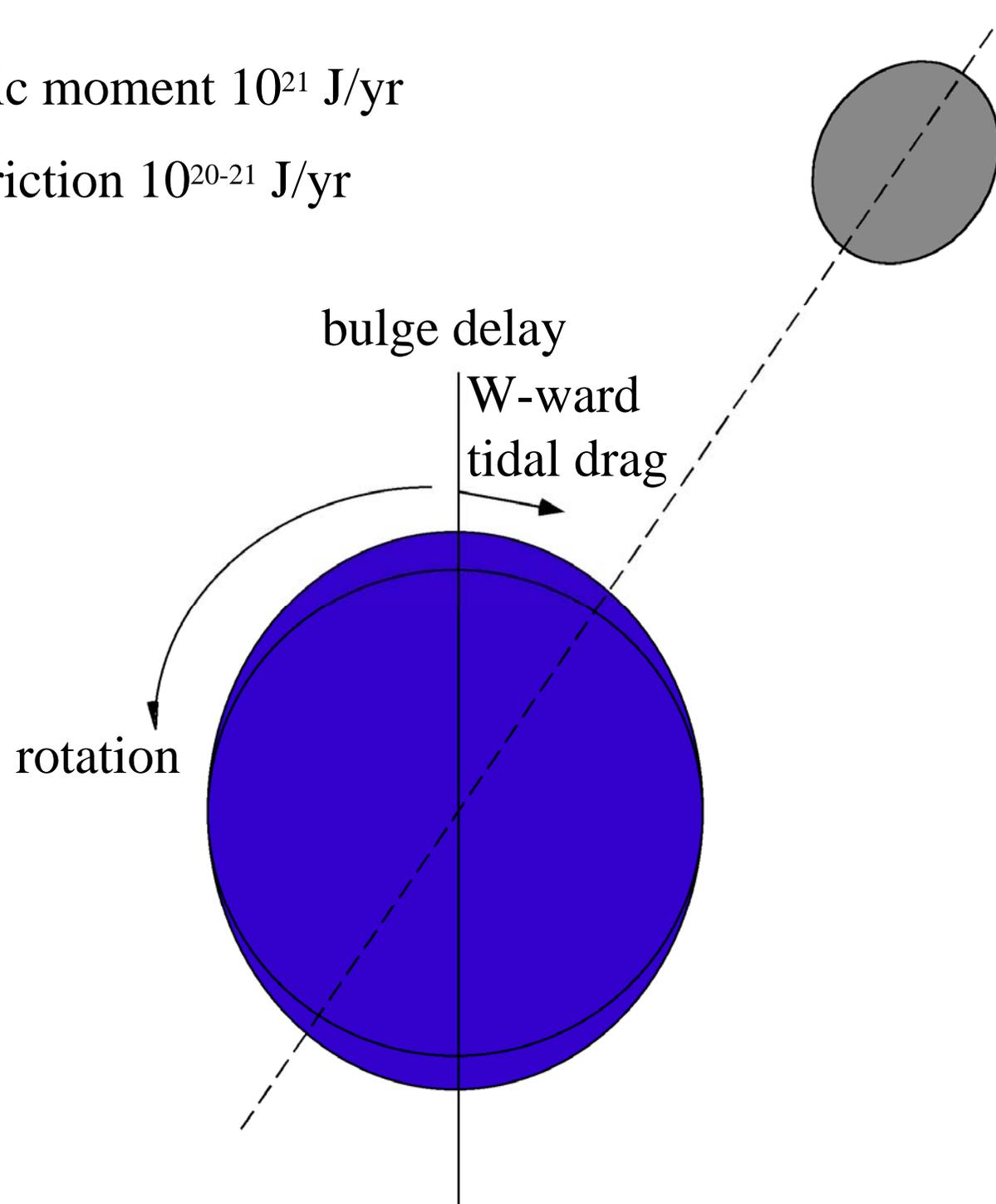
Frizione Tidale

- Rallenta la Terra: quando i dinosauri popolavano il pianeta un giorno durava 22 ore
- Allontana la luna di circa 38 mm/anno.



Tectonic moment 10^{21} J/yr

Tidal friction 10^{20-21} J/yr

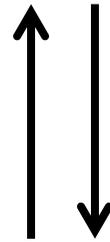


384.000 km

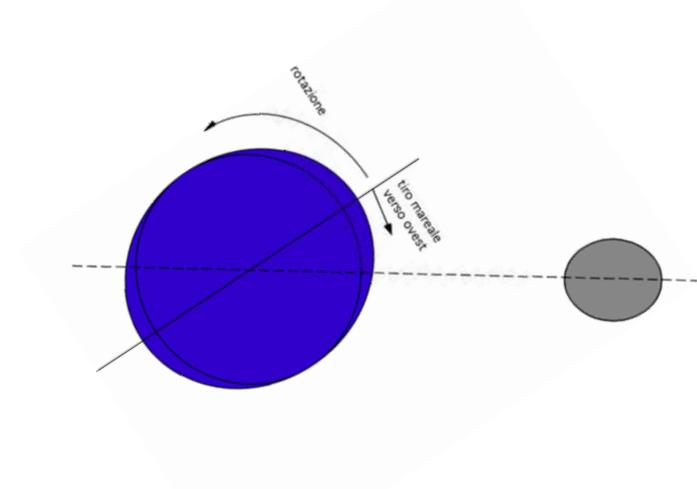
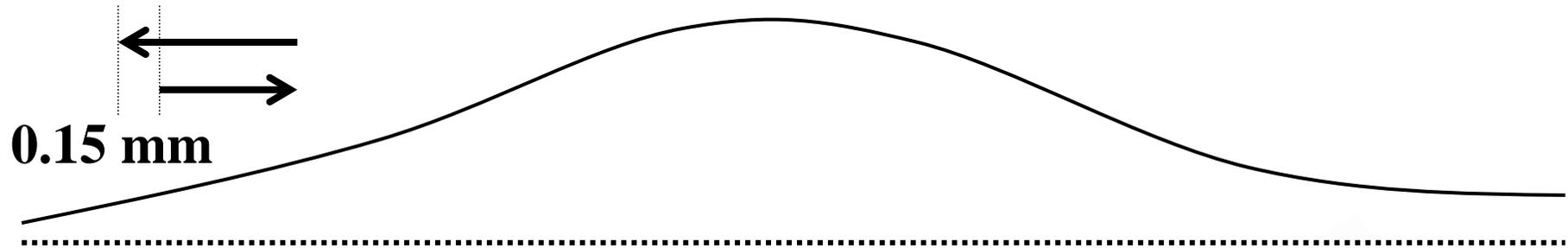


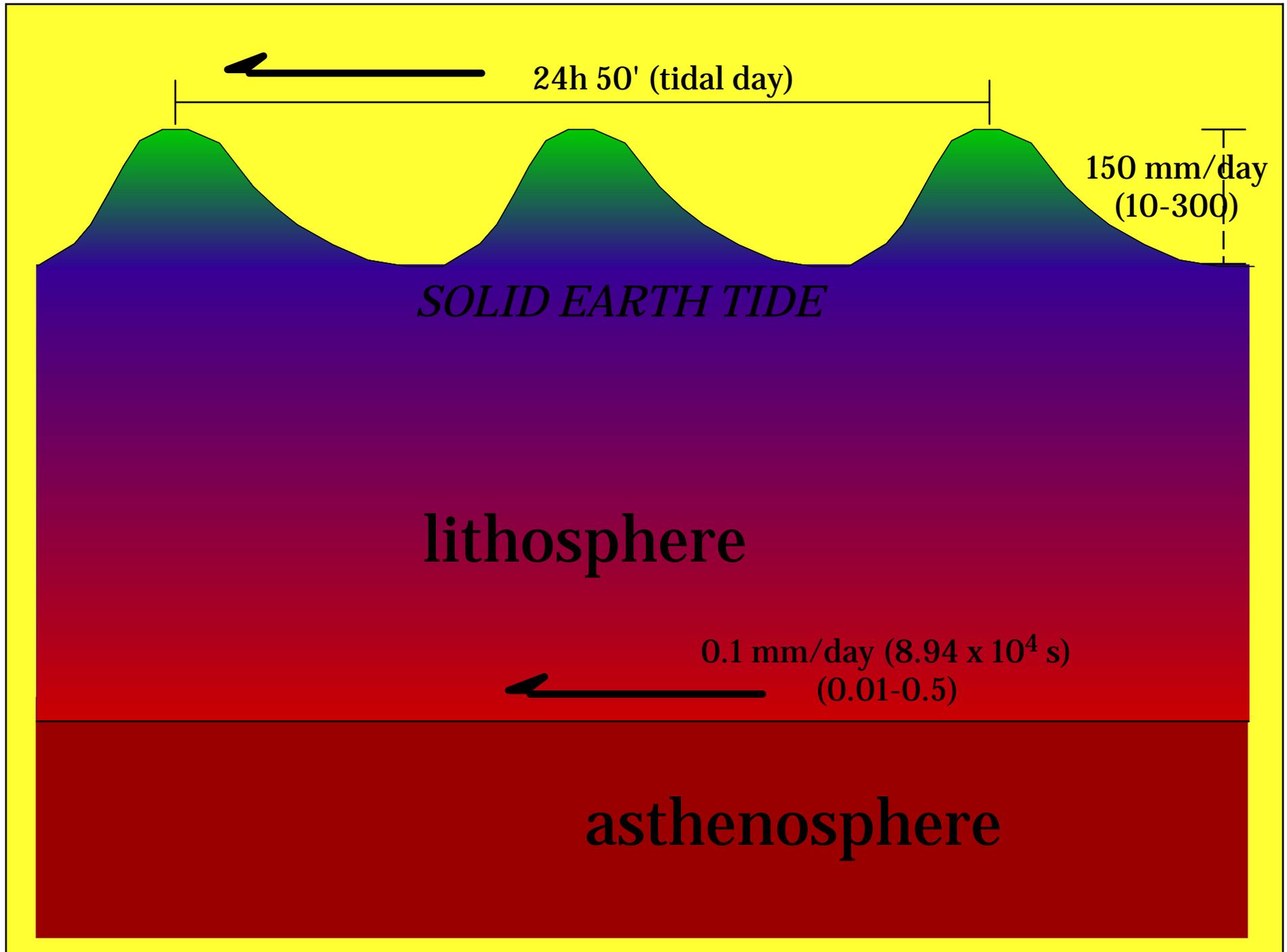
SOLID EARTH TIDE

horizontal component
15-20 cm/12h25':
stress loading

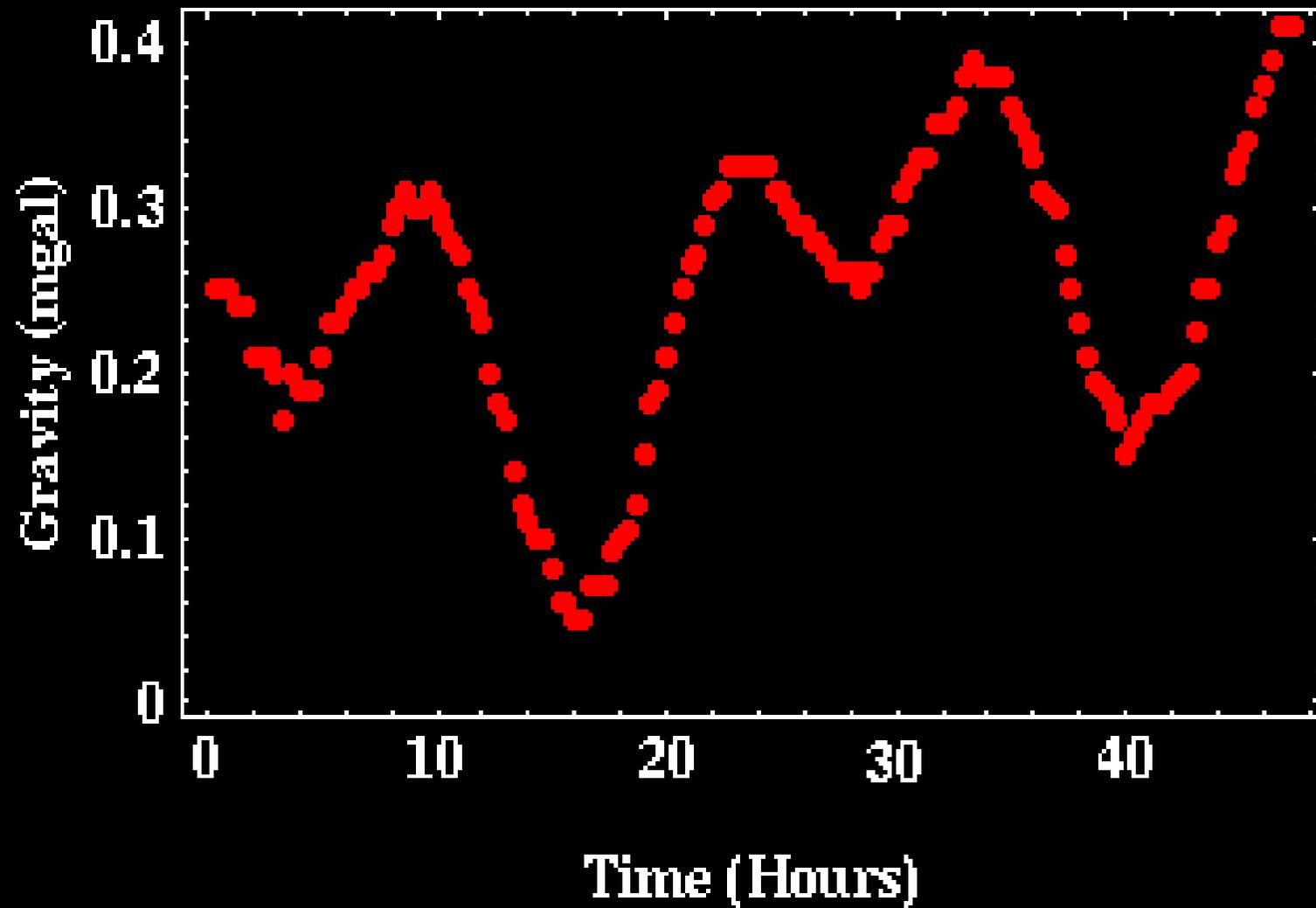


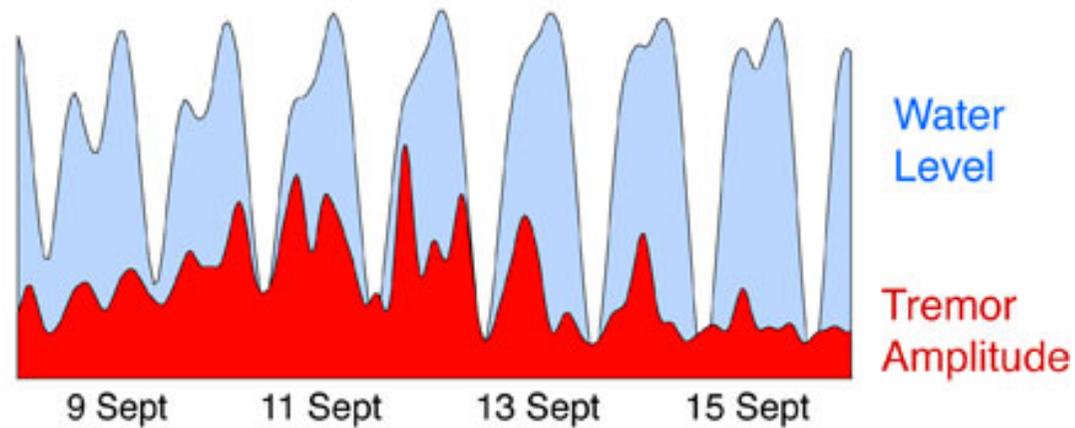
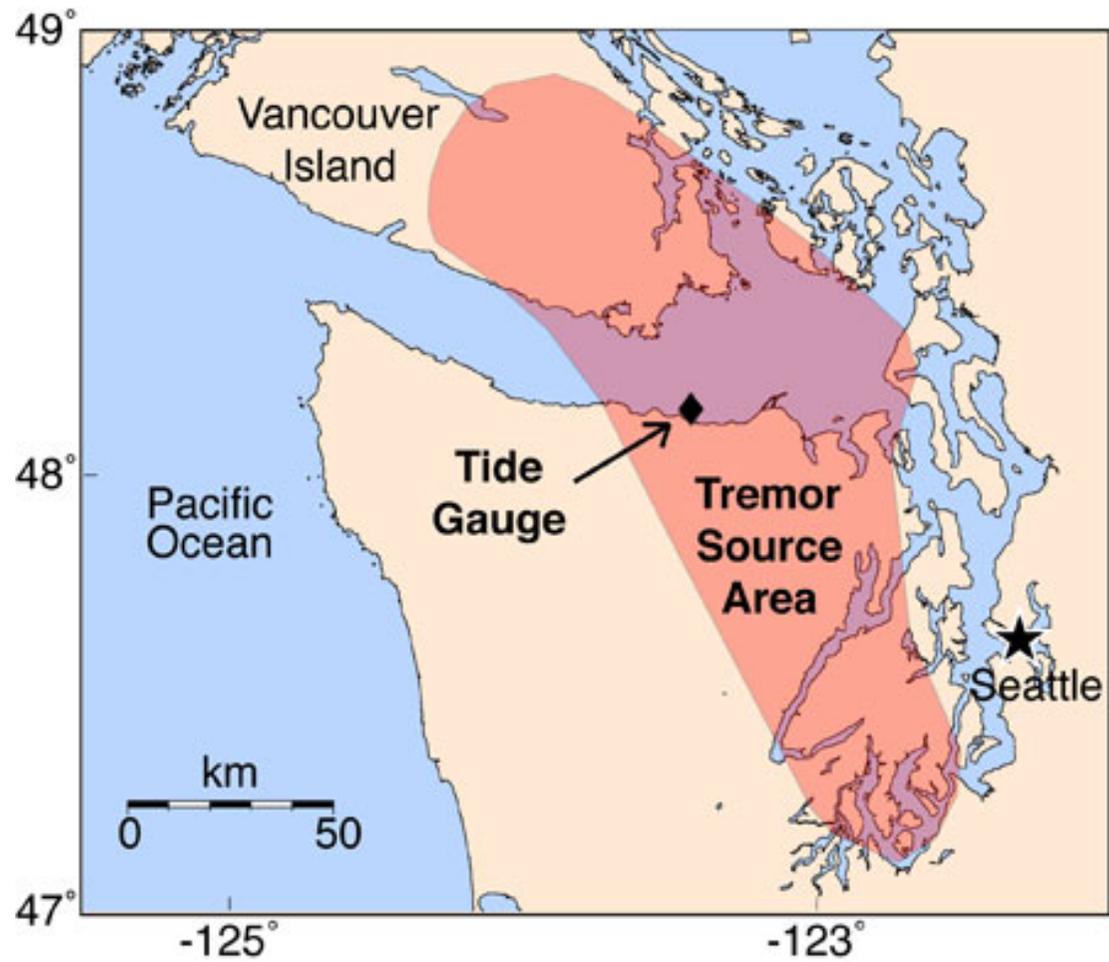
vertical component
30-40 cm/12h25':
stress unloading



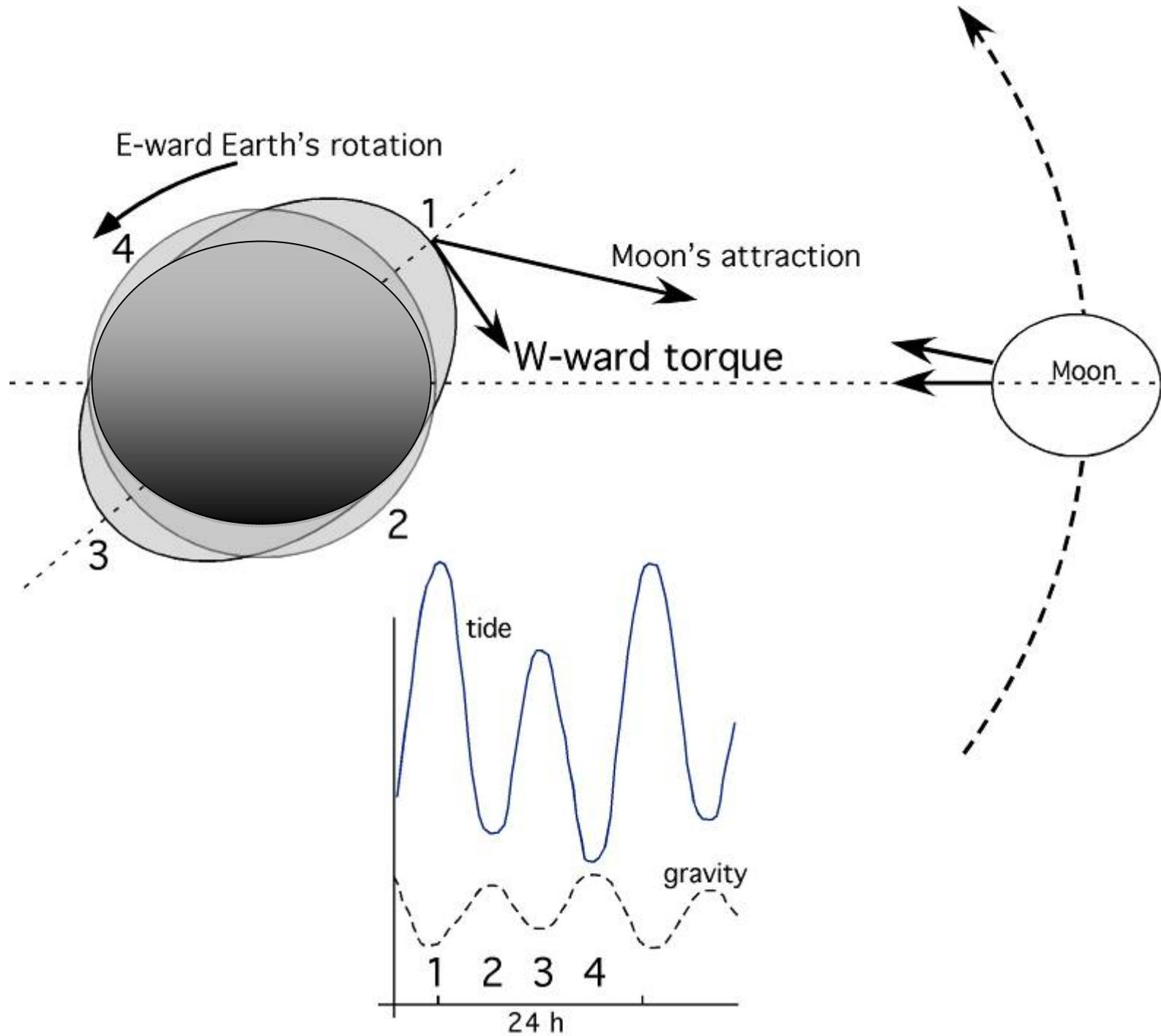


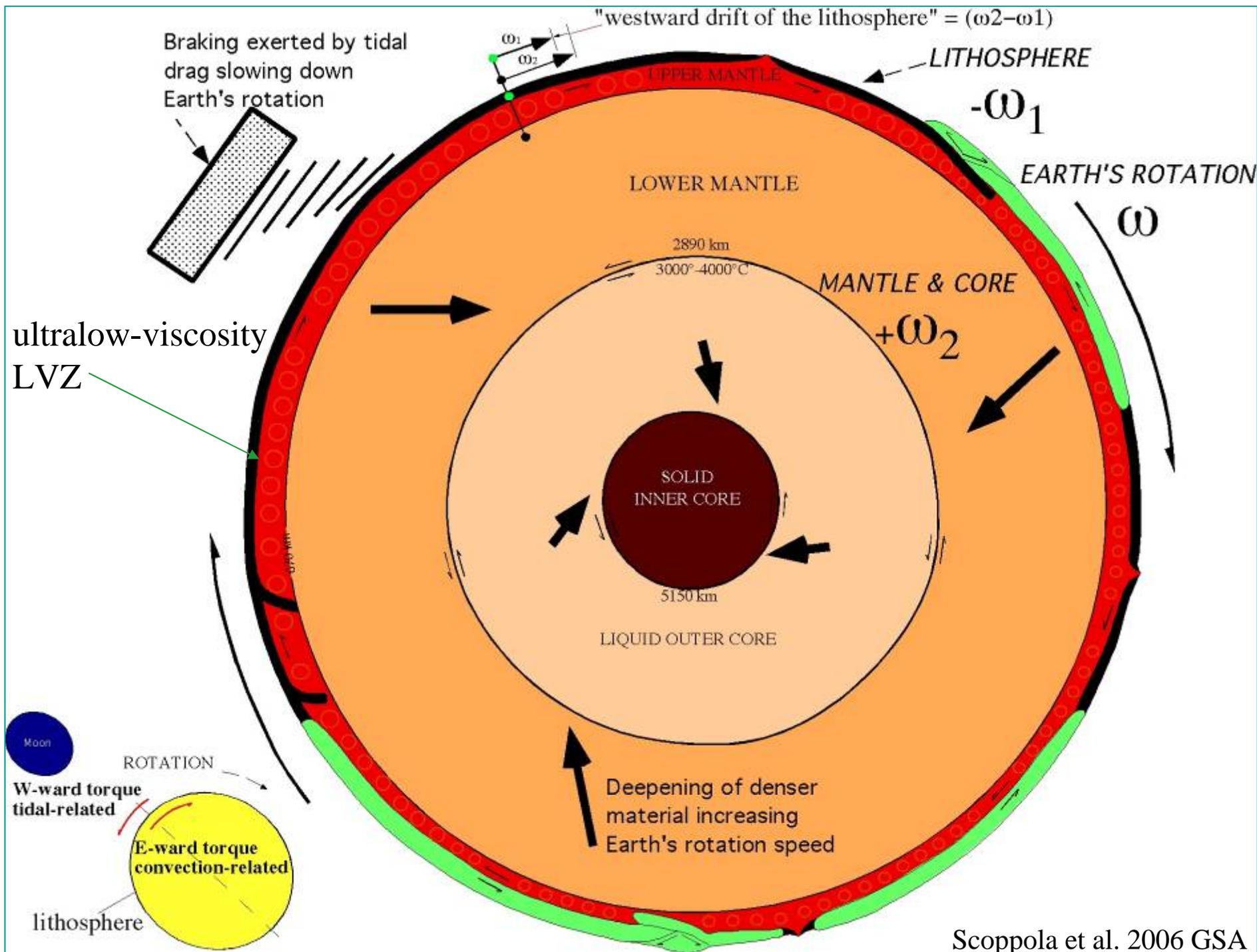
Variation in Gravity, Tulsa Oklahoma, 12/10 - 12/12 1939

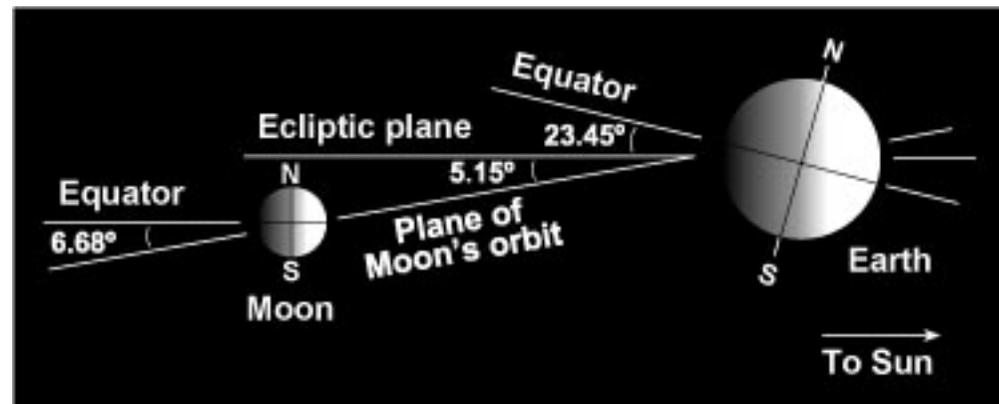
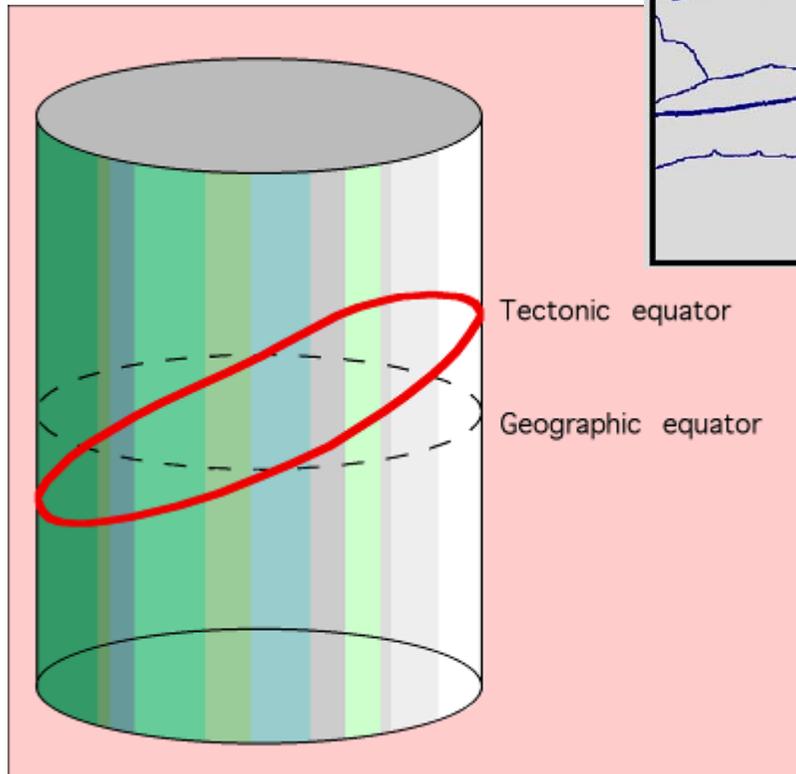
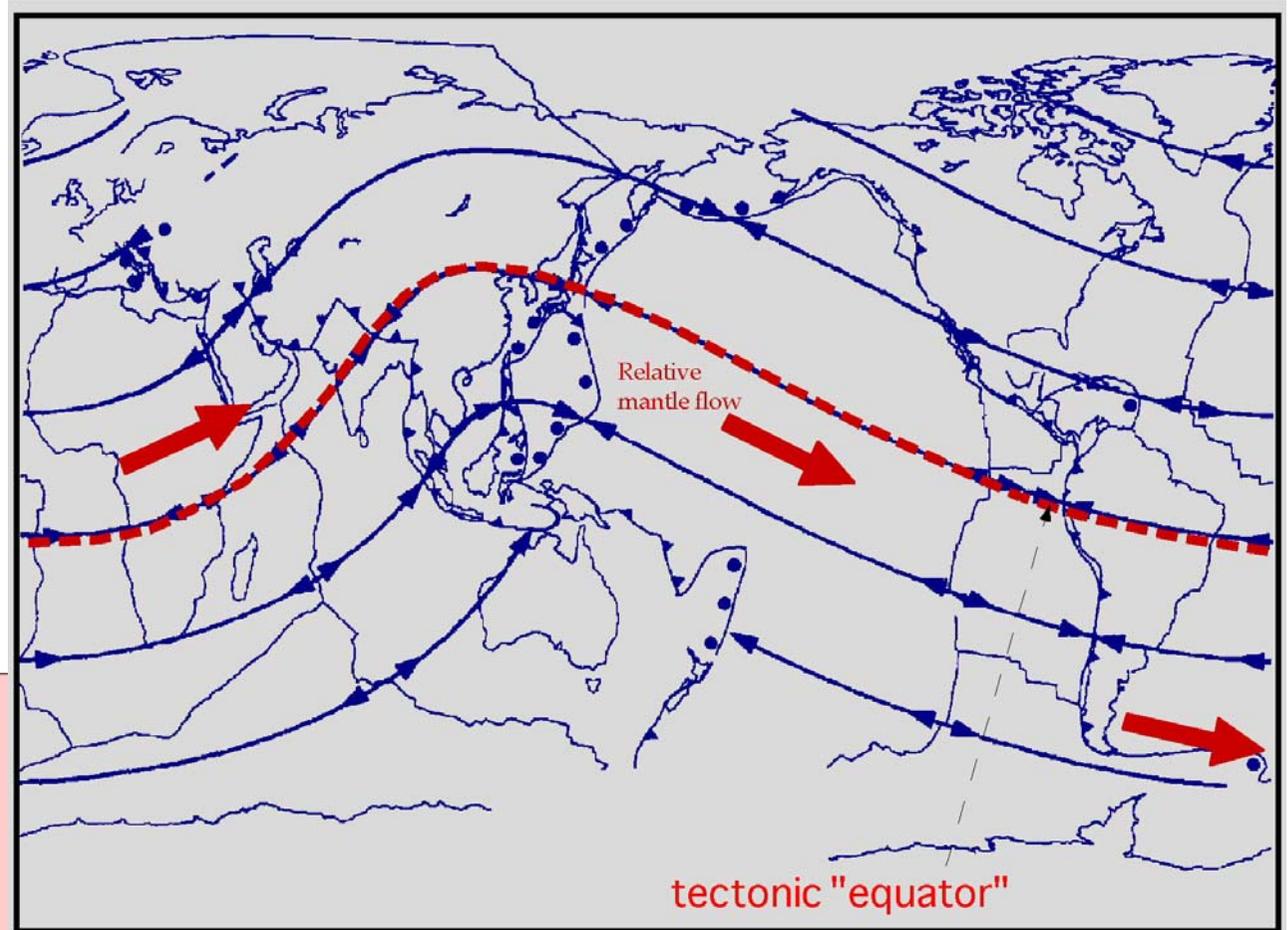




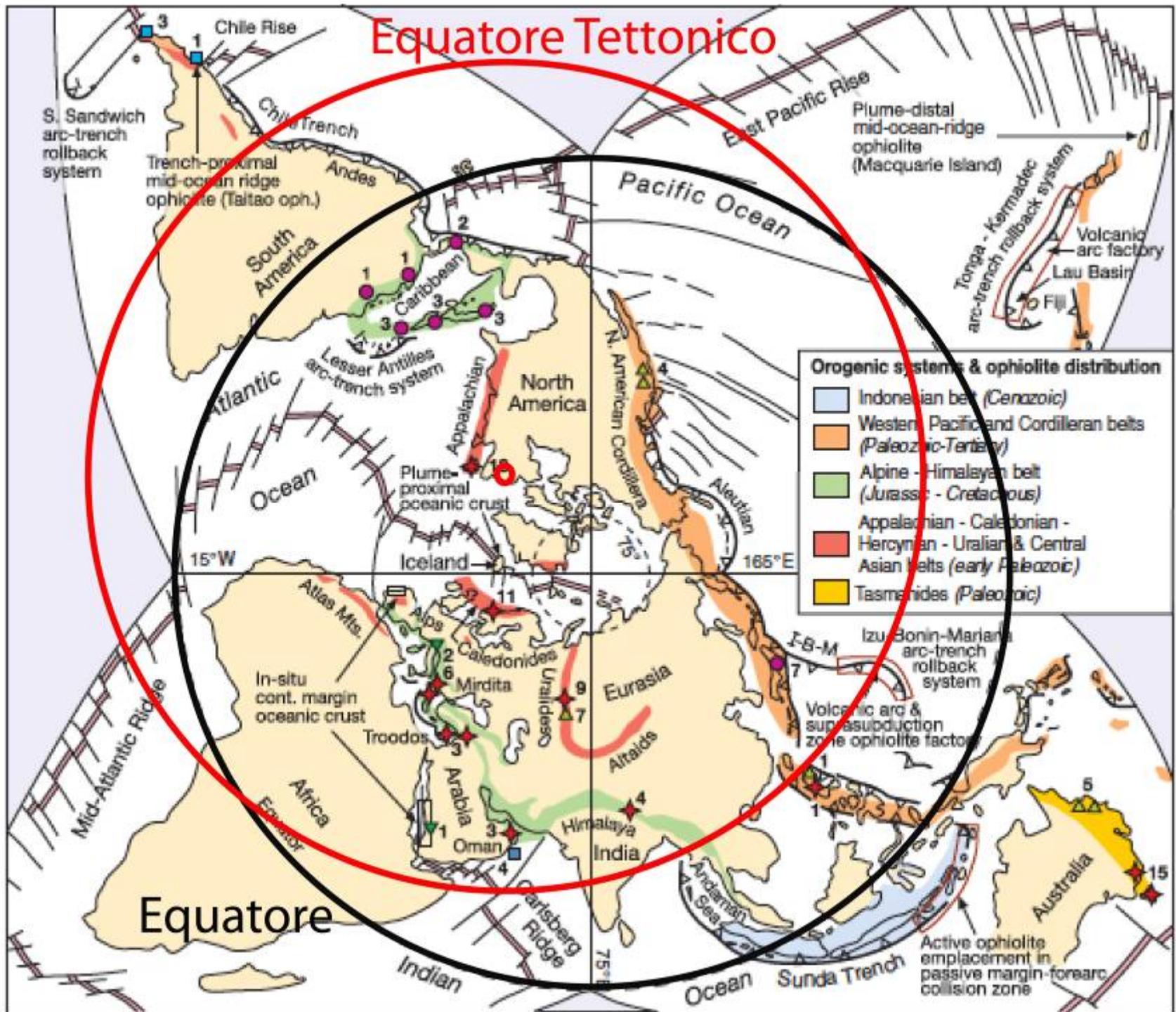
Rubinstein et al.,
2009 Science

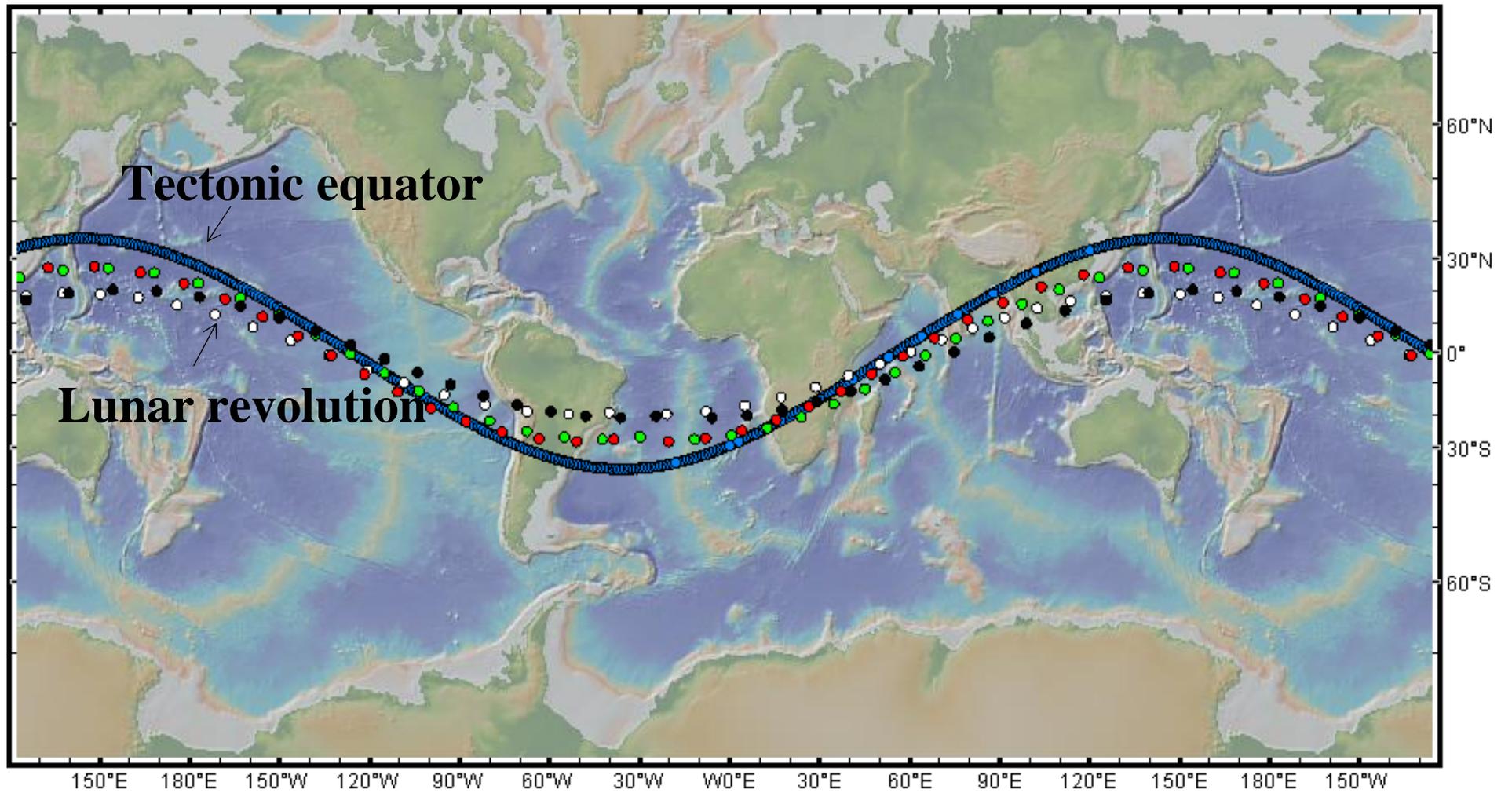


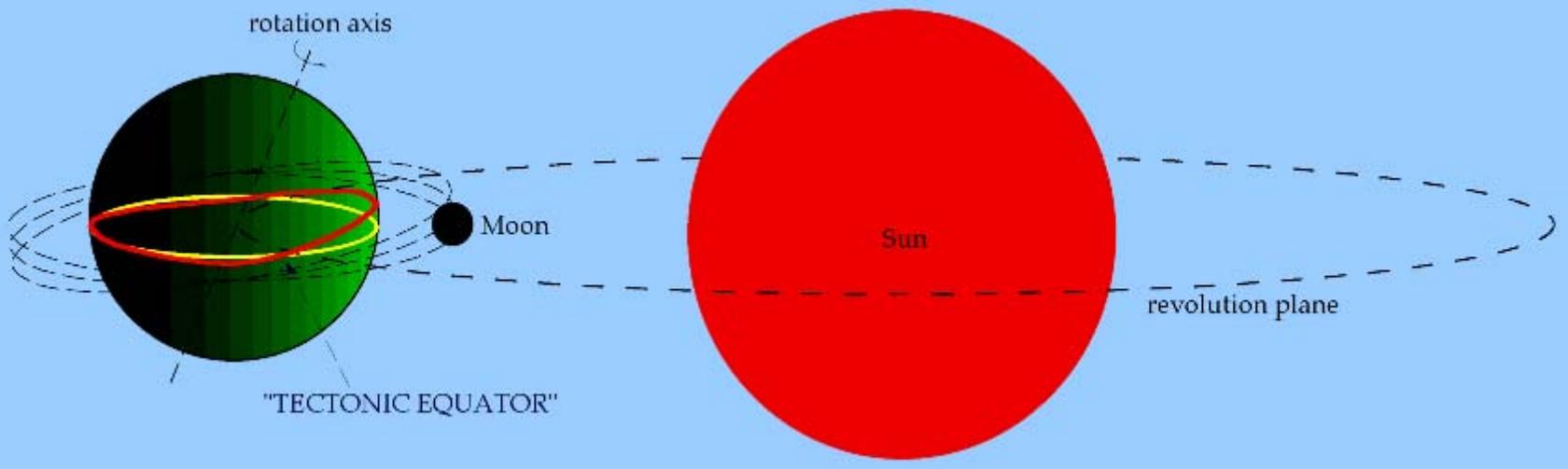


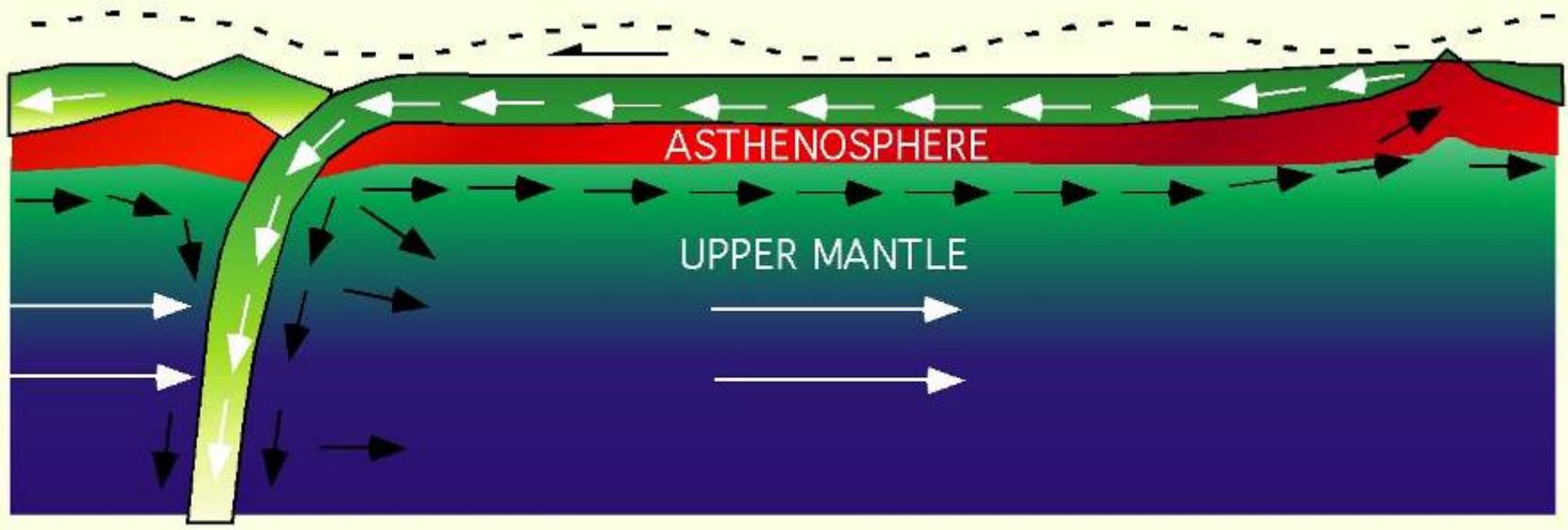
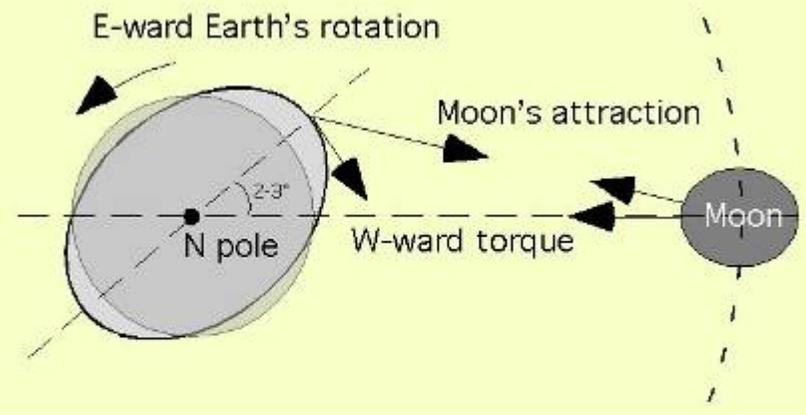


Equatore Tettonico









*Eugenio Carminati
Mattia Crespi
Marco Cuffaro
Fabrizio Innocenti
Giuliano Panza
Federica Riguzzi
Davide Scrocca*



Daumier : "Monsieur Babinet prévenu par sa portière de la visite de la comète"