

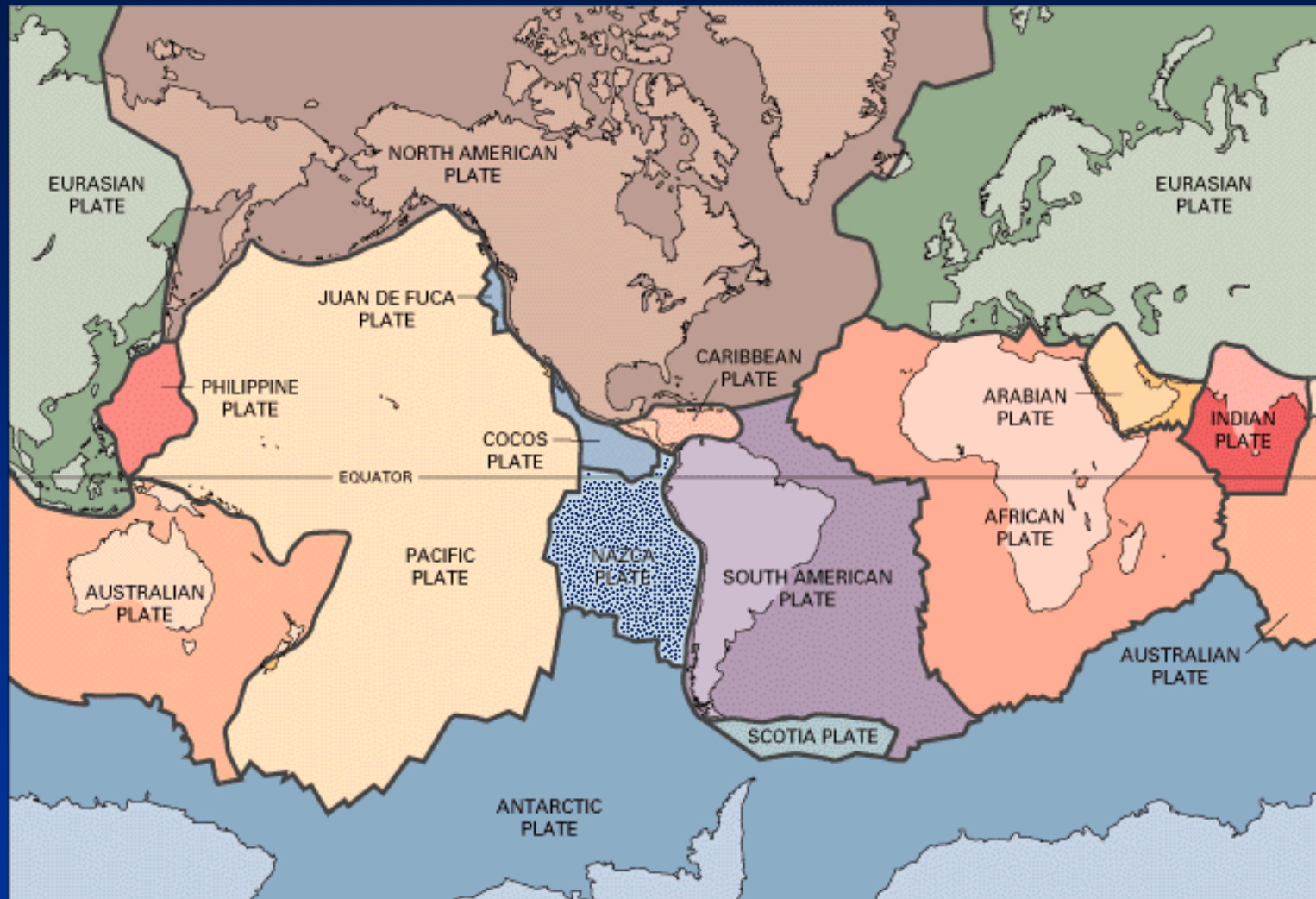
# **Associazioni di strutture tettoniche**

**Dalla scala  
dell'affioramento alla scala  
regionale**

Immagini e fotografie tratte da:

- Bally A.W., Catalano R., Oldow J.S., 1985. Elementi di tettonica regionale. Pitagora Editore.
- Buchanan P.G., McClay K.R., 1991. Sandbox experiments of inverted listric and planar fault systems. *Tectonophysics*, 188, 97-115.
- Chorowitz J., 2005. The East African rift system. *Journal of African Earth Sciences*, 43, 379–410.
- Dijkshoorn L, Clauser C., 2013. Relative importance of different physical processes on upper crustal specific heat flow in the Eifel-Maas region, Central Europe and ramifications for the production of geothermal energy. *Scientific Research*, 5, Article ID:28354.
- Guinot D., Segonzac M., 2018. A review of the brachyuran deep-sea vent community of the western Pacific, with two new species of *Austinograea* Hessler & Martin, 1989 (Crustacea, Decapoda, Brachyura, Bythograeidae) from the Lau and North Fiji Back-Arc Basins. *Zoosystema*, 40, 75-107.
- Hatcher R.D., 1995. *Structural Geology: Principles Concepts and Problems*. Prentice Hall International.
- Kuebler, S. 2013. *Active Tectonics of the Lower Rhine Graben (NW Central Europe): Based on New Paleoseismological Constraints and Implications for Rupture Processes in Unconsolidated Gravels*. PhD thesis, LMU Munich.
- Mantovani, E., Albarello, D., Babbucci, D., Tamburelli, C., Viti, M., 2002. Trench-Arc-BackArc systems in the Mediterranean area: examples of extrusion tectonics. *Journal of Virtual Explorer*, 8, 125–141.
- Mège D. et al., 2015. A major dyke swarm in the Ogaden region south of Afar and the early evolution of the Afar triple junction. In: *Magmatic Rifting and Active Volcanism*. Chapter: 7. Geological Society, London, Special Publications, 420.
- Mercier J., Vergely P., 1996. *Tettonica*. Pitagora Editore.
- Nicolas A., 1984. *Principes de tectonique*. Masson.
- Pini, materiale inedito.
- Ramsay J. G., Huber M. I., 1987. *The Techniques of Modern Structural Geology*. Volume 2: Folds and Fractures. Academic Press Inc.
- Stein S. et al., 2015. Challenges in assessing seismic hazard in intraplate Europe. In: *Geological Society, London, Special Publications*, 432.
- Suppe J., 1985. *Principles of Structural Geology*. Prentice-Hall Inc.
- van der Pluijm B., Marshak S., 2004. *Earth Structure: An Introduction to Structural Geology and Tectonics*, Second Edition. WW Norton & Company.

# Placche tettoniche (semplificate)



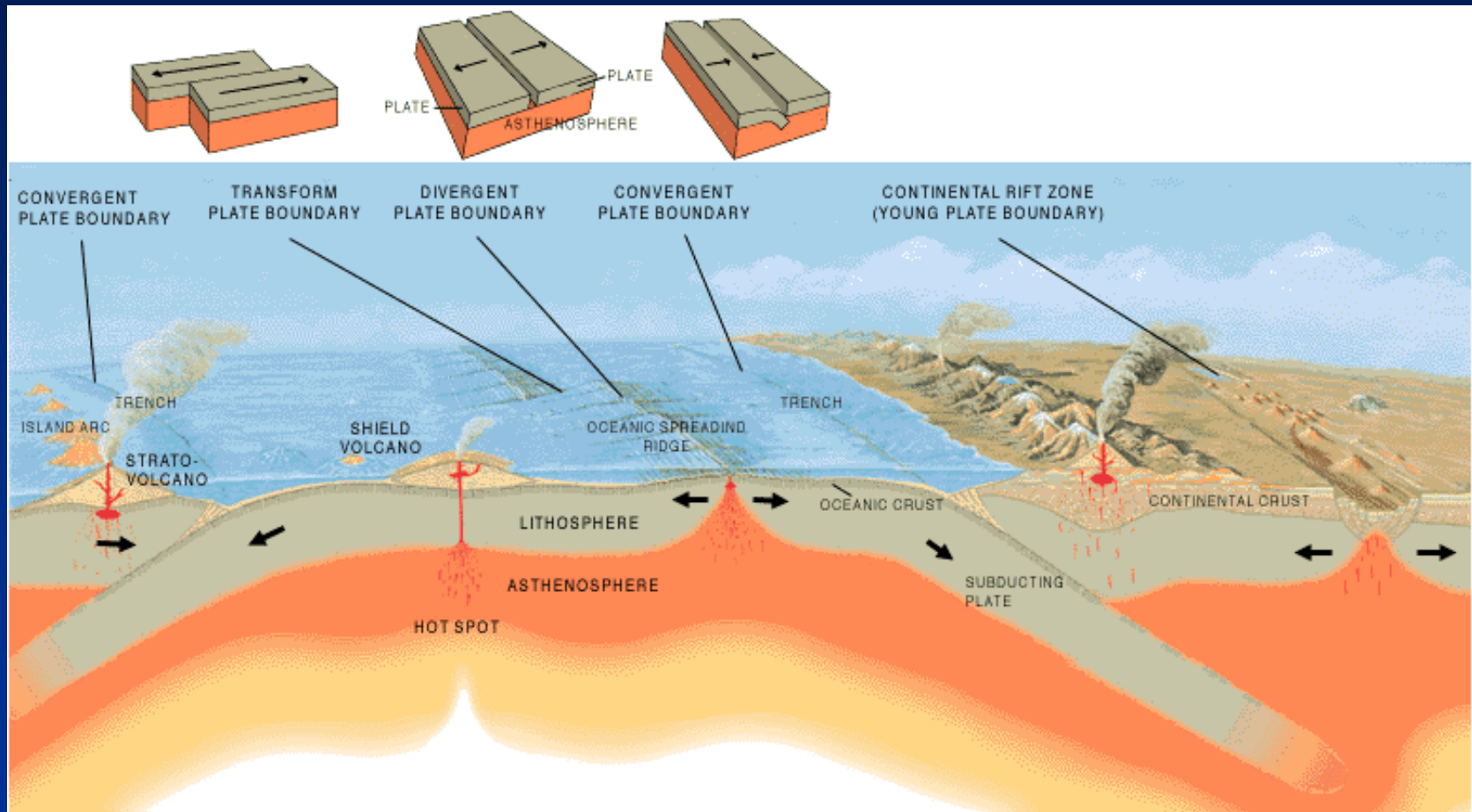
Da "The dynamic Earth" in USGS Web Site

# Placche tettoniche e limiti tra placche



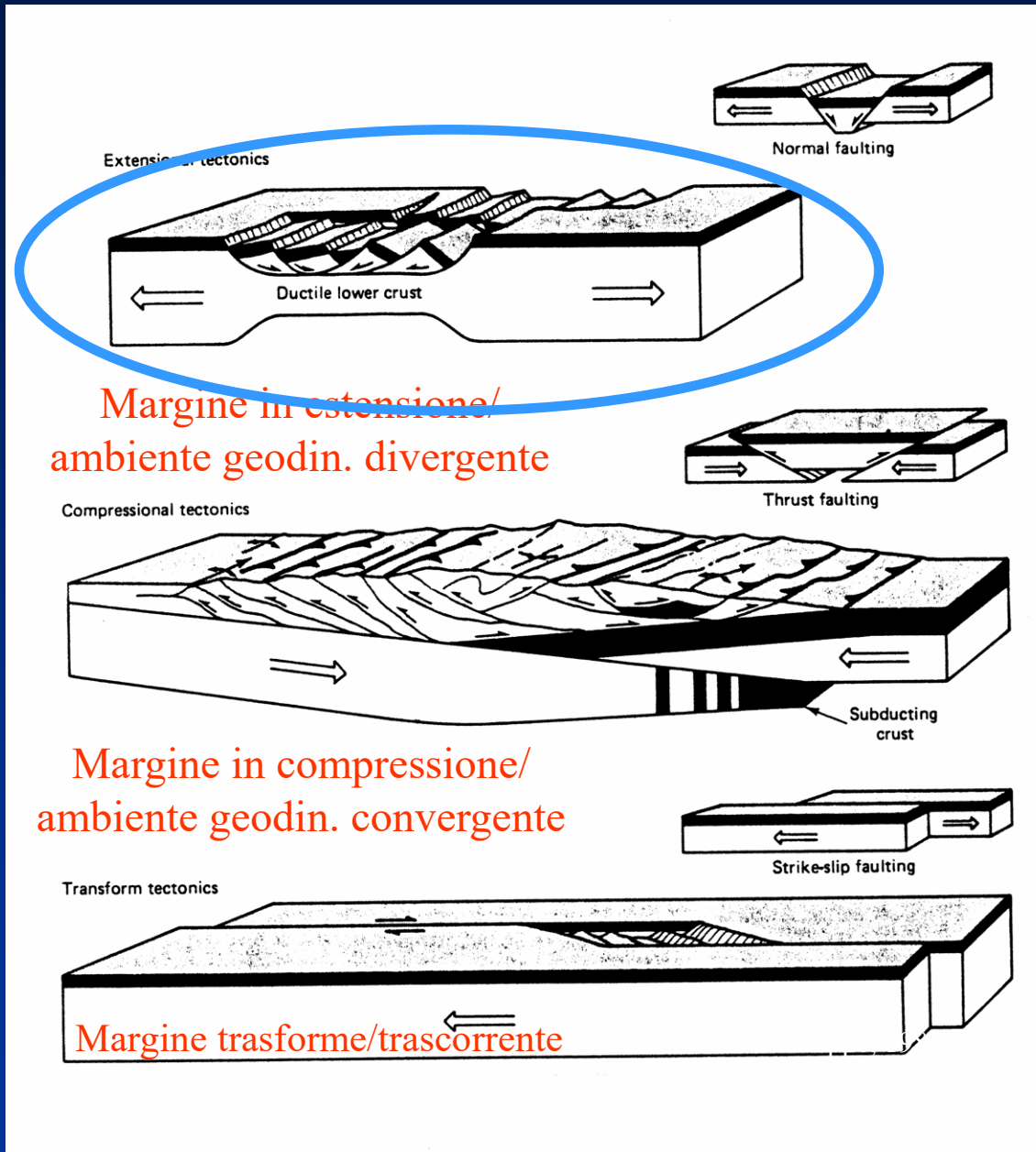
[https://commons.wikimedia.org/wiki/File:Tectonic\\_plates\\_boundaries\\_detailed-en.svg](https://commons.wikimedia.org/wiki/File:Tectonic_plates_boundaries_detailed-en.svg)

# Tipo di margini di placca e ambienti geodinamici



<http://factsanddetails.com/world/cat51/sub323/item2212.html>

# Tipo di margini di placca e ambienti geodinamici



Margine in estensione/  
ambiente geodin. divergente

Margine in compressione/  
ambiente geodin. convergente

Margine trasforme/trascorrente

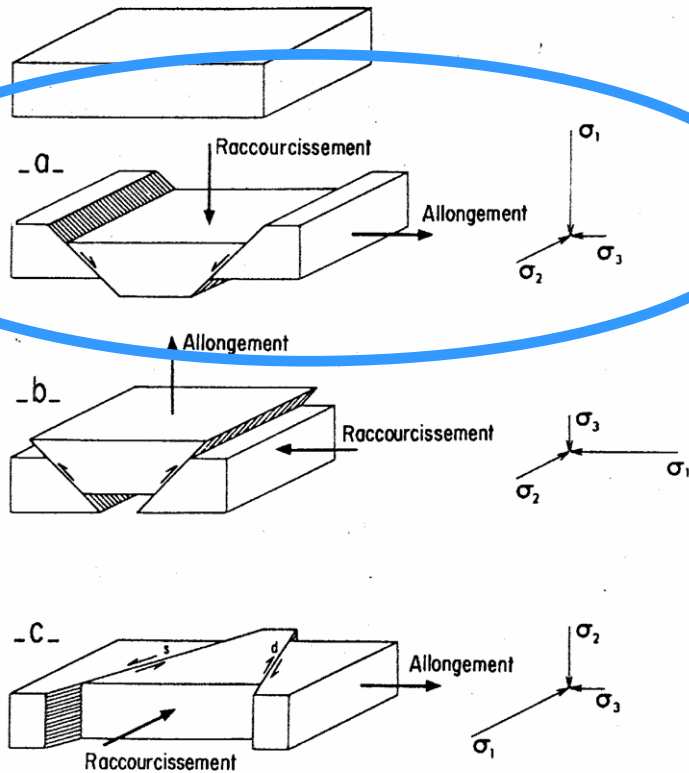
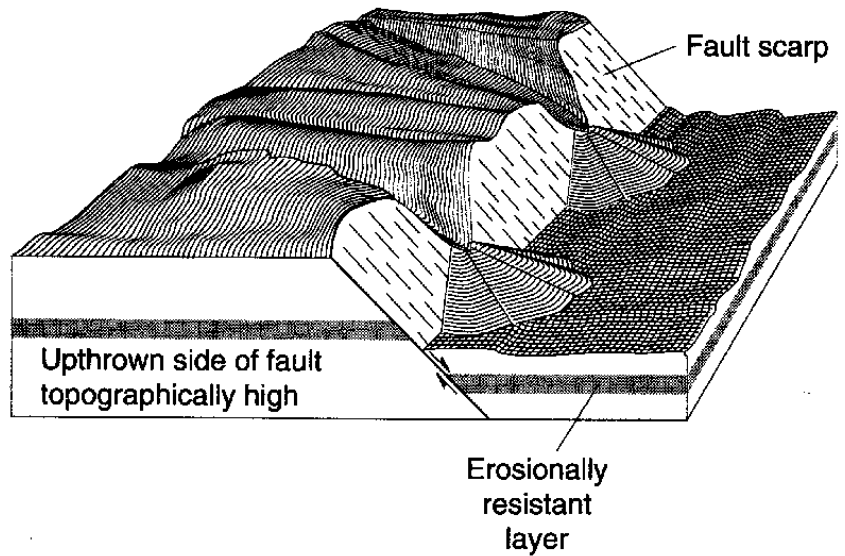


Fig. 5.12 - Systèmes de failles conjuguées. a- Failles normales conjuguées, b- Failles inverses conjuguées, horst. c- Décrochements dextre et senestre conjugués. (Blès et Feuga, 1981. BRGM éd., Orléans).

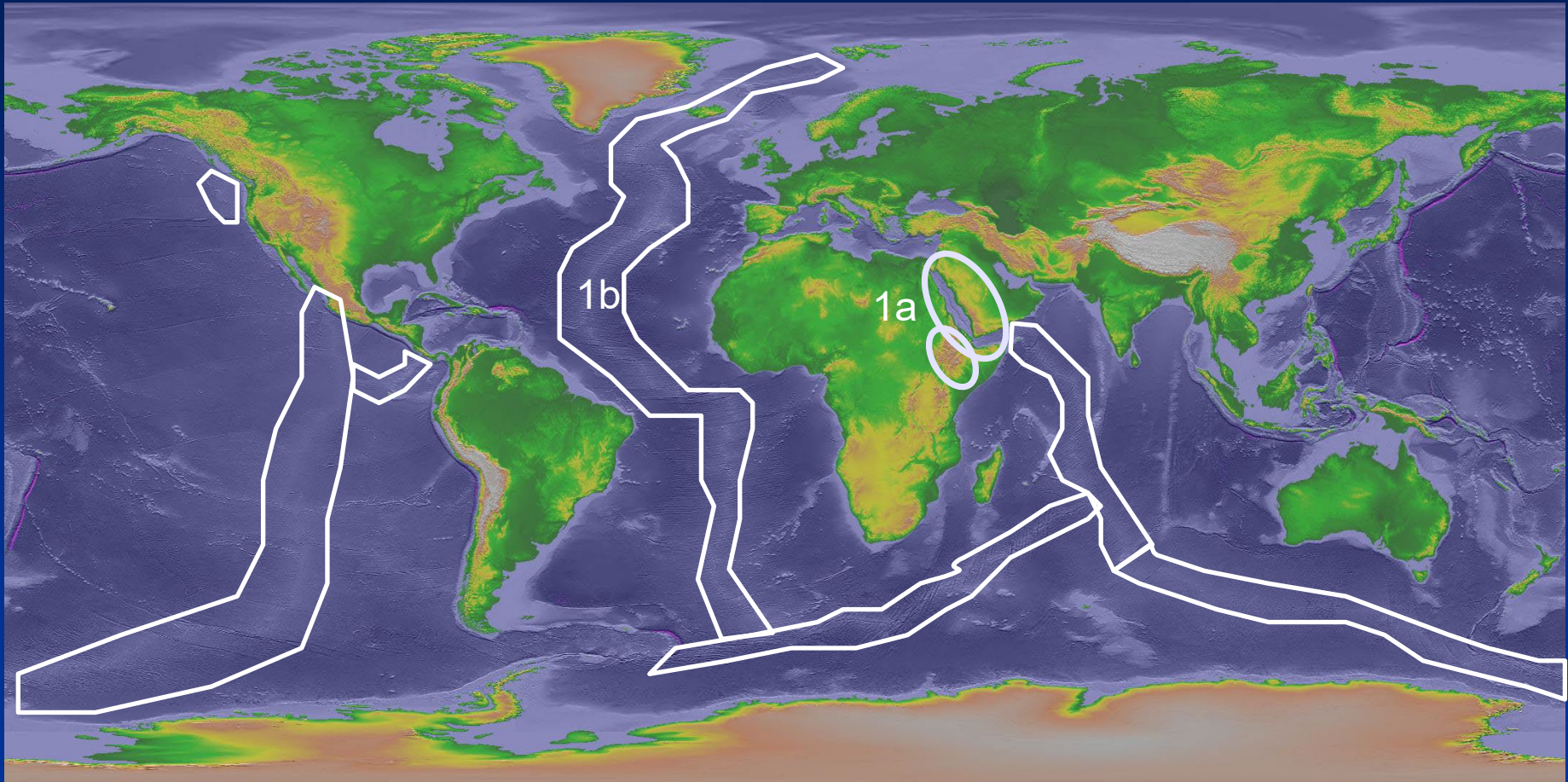
Da Nicolas, 1984



Da Hatcher, 1995

# Associazioni di faglie normali

## 1) associazioni estensionali in ambienti geodinamici divergenti



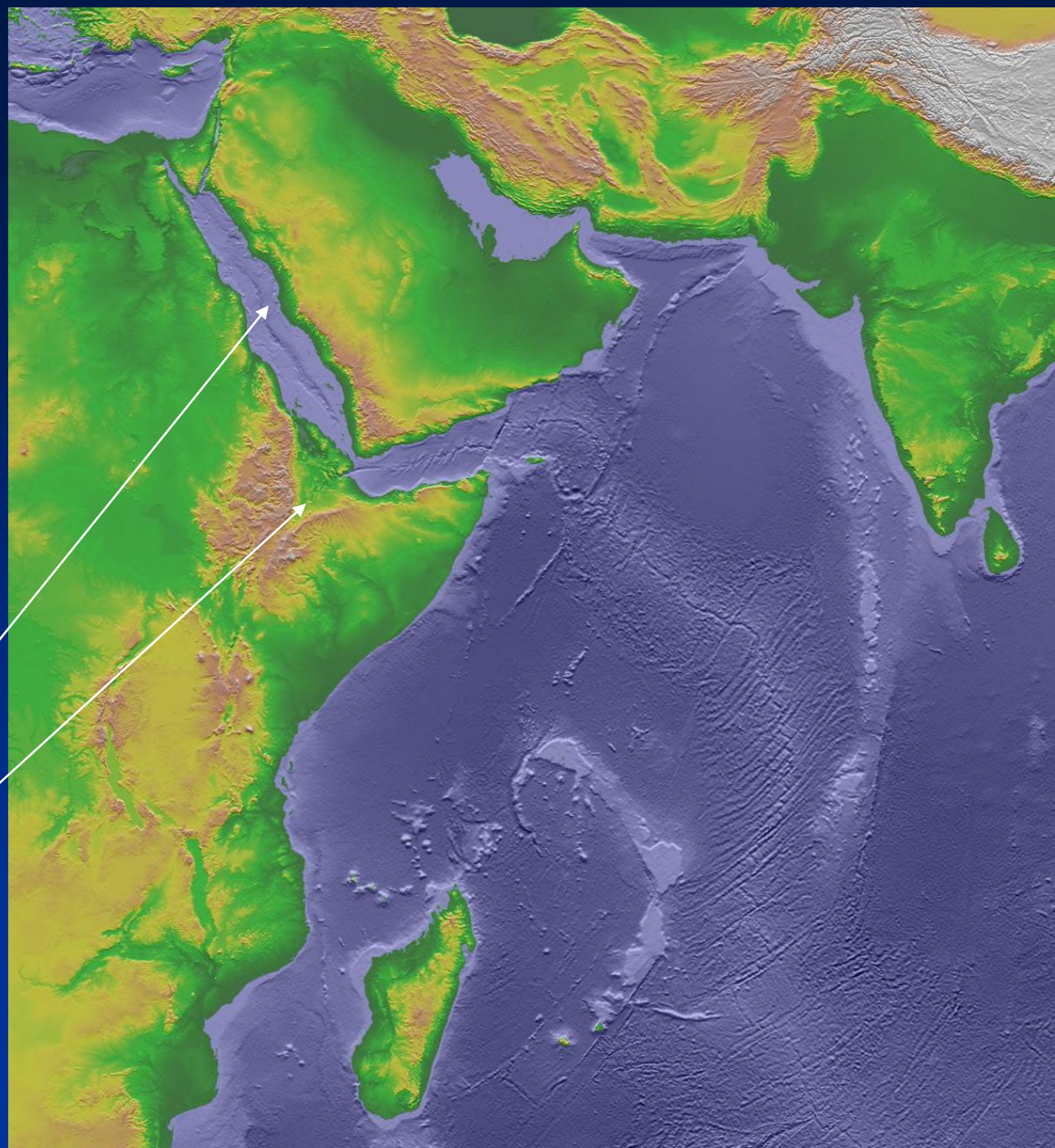
Shaded reliefs e batimetria da NOAA National Centers for Environmental Information (NCEI)



1a) estensione e  
assottigliamento  
di crosta  
continentale che  
porta a crosta  
oceanica (*from  
rift to drift*)

Mar Rosso

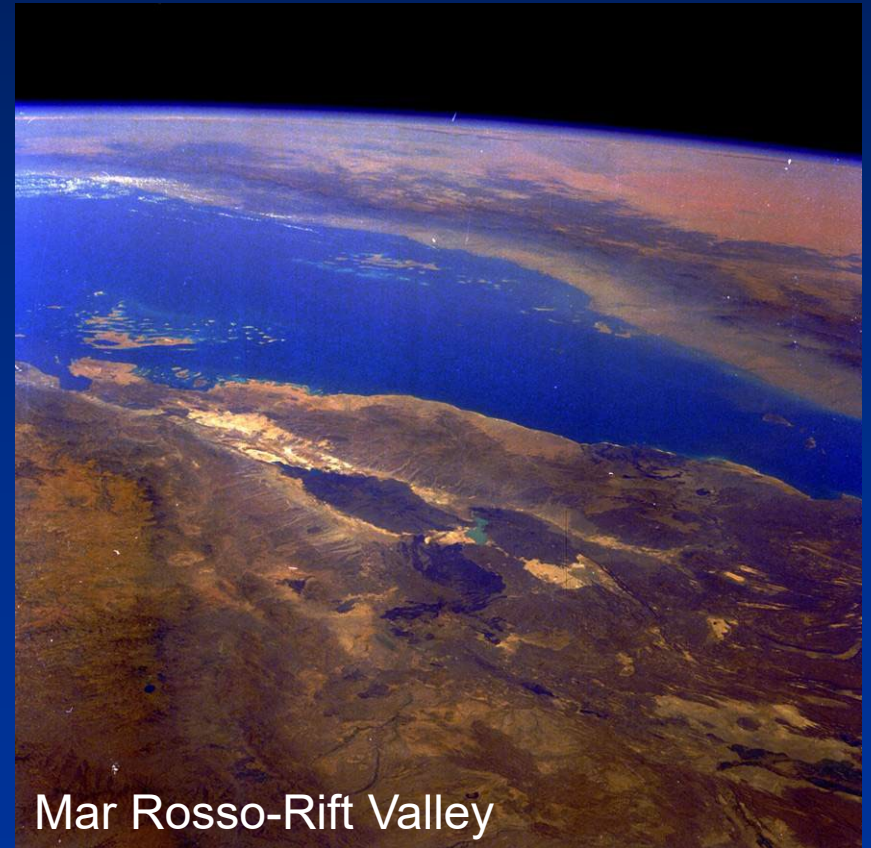
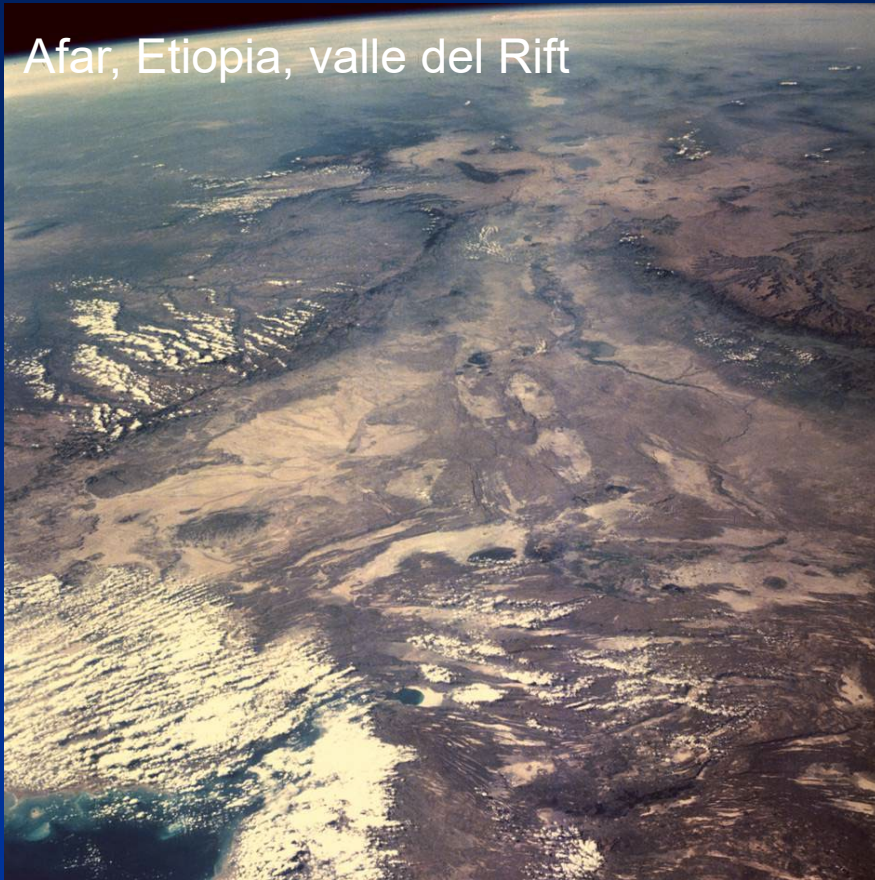
Afar, Etiopia, valle del Rift



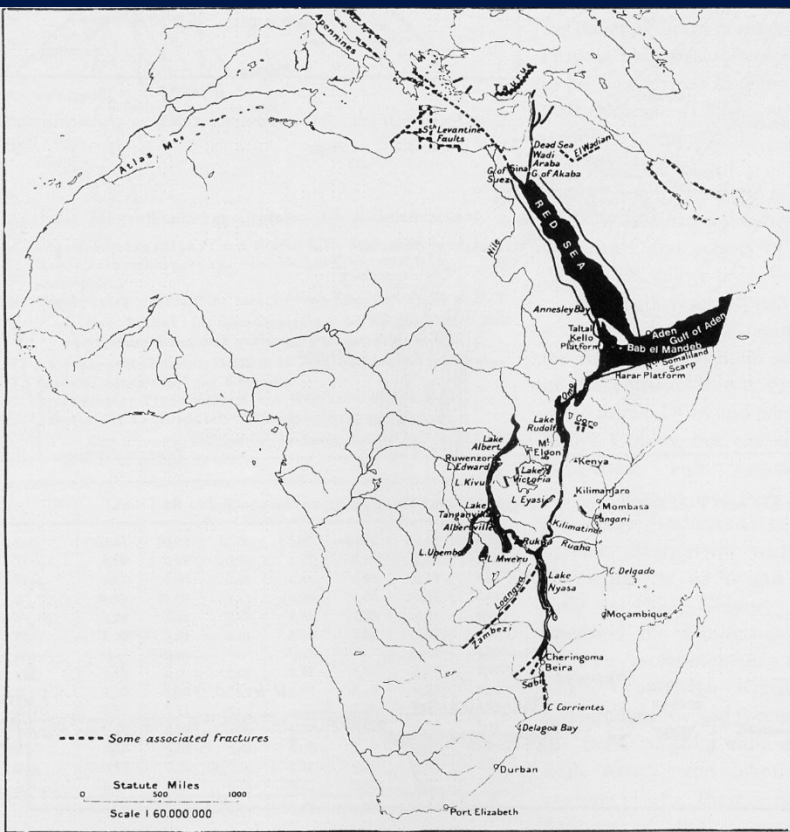
# Associazioni estensionali, ambienti geodinamici divergenti

1a) estensione e assottigliamento crosta continentale che porta a crosta oceanica (*from rift to drift*)

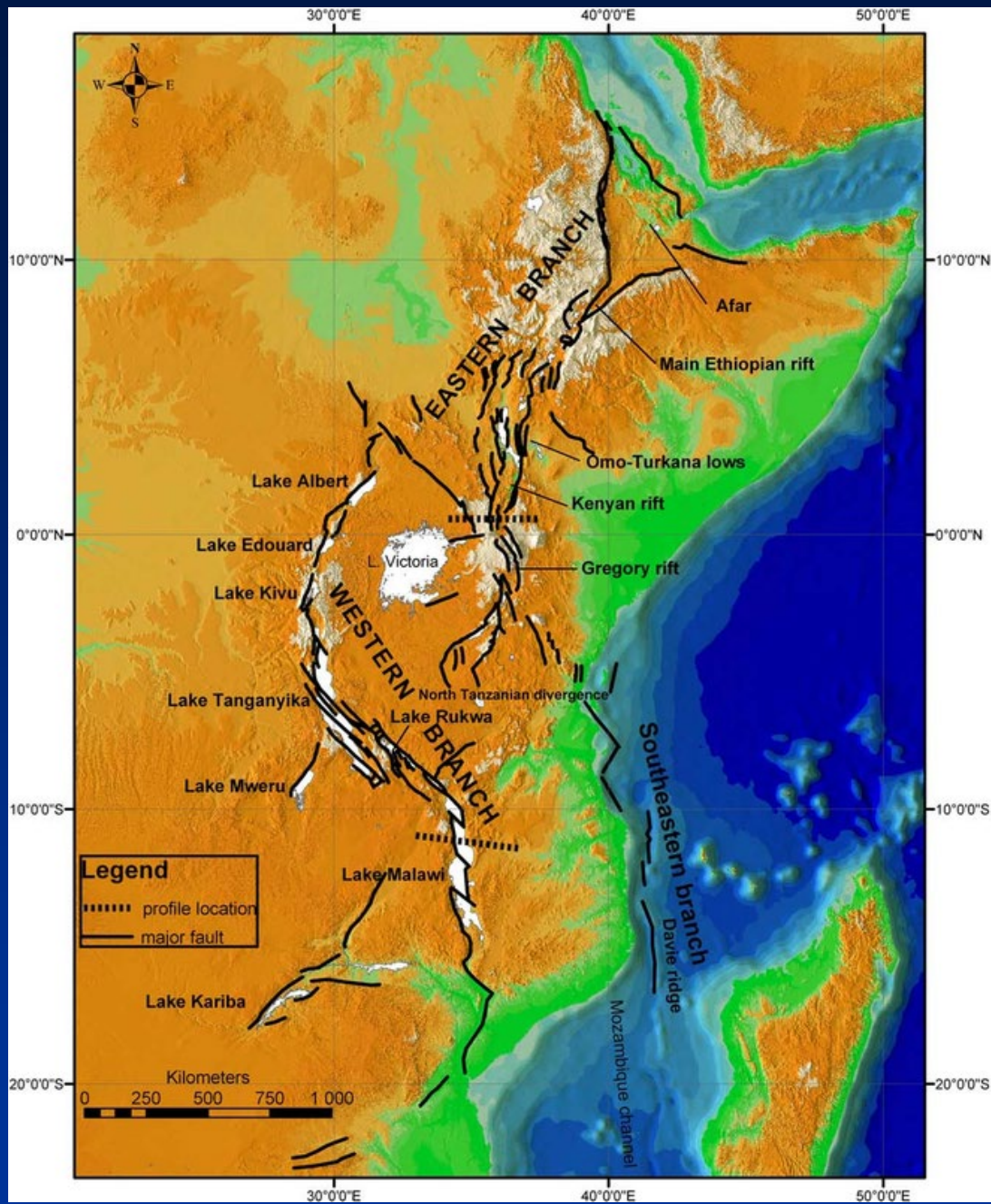
Afar, Etiopia, valle del Rift



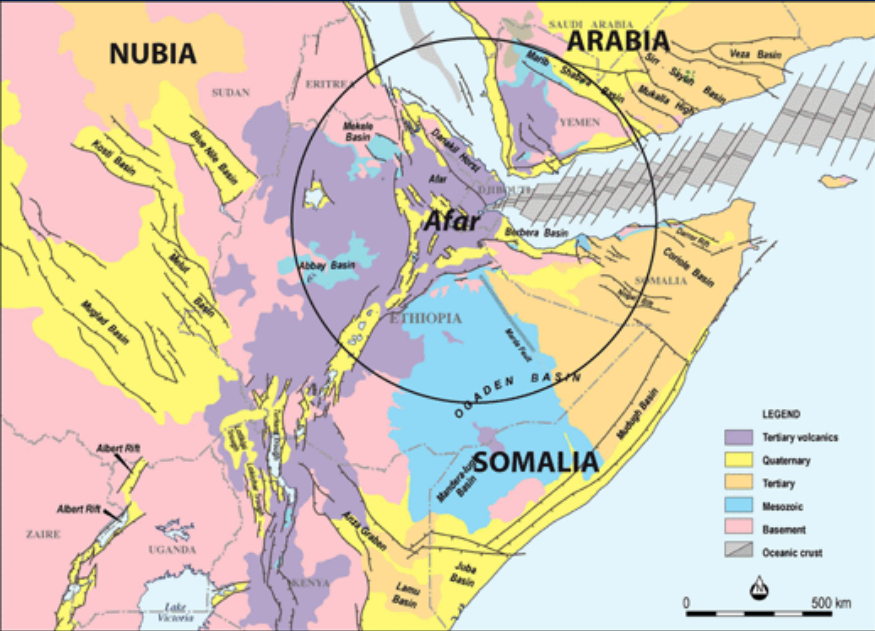
Mar Rosso-Rift Valley



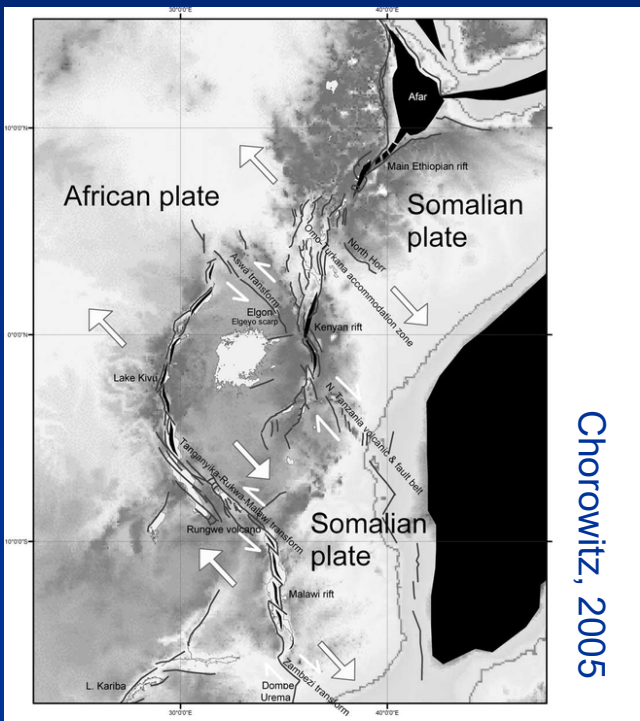
J. Gregory's 1920 map of the East African rift v.



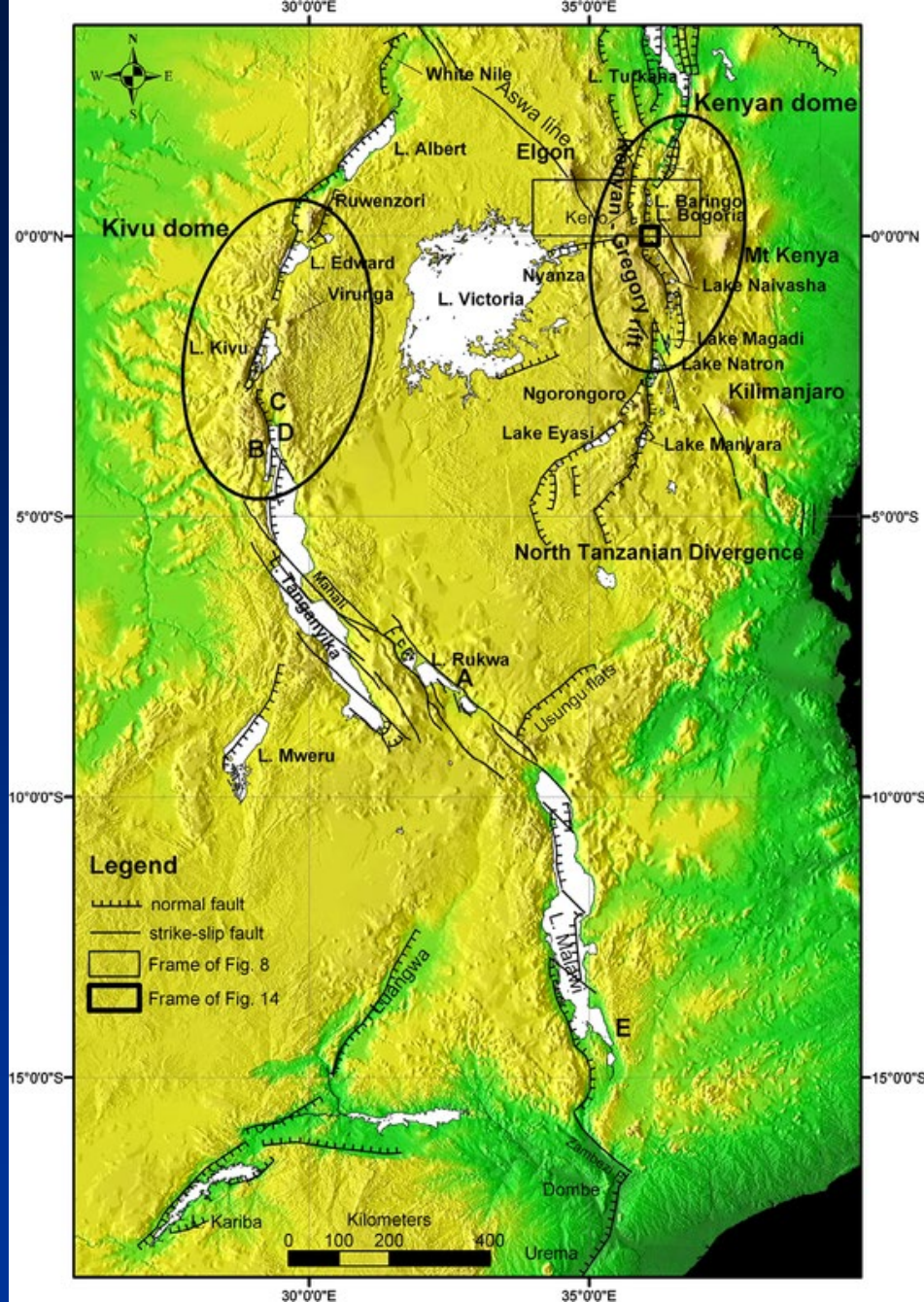
Chorowitz, 2005



Mège et al., 2015



Chorowitz, 2005



Chorowitz, 2005

# associazioni estensionali, ambienti geodinamici divergenti

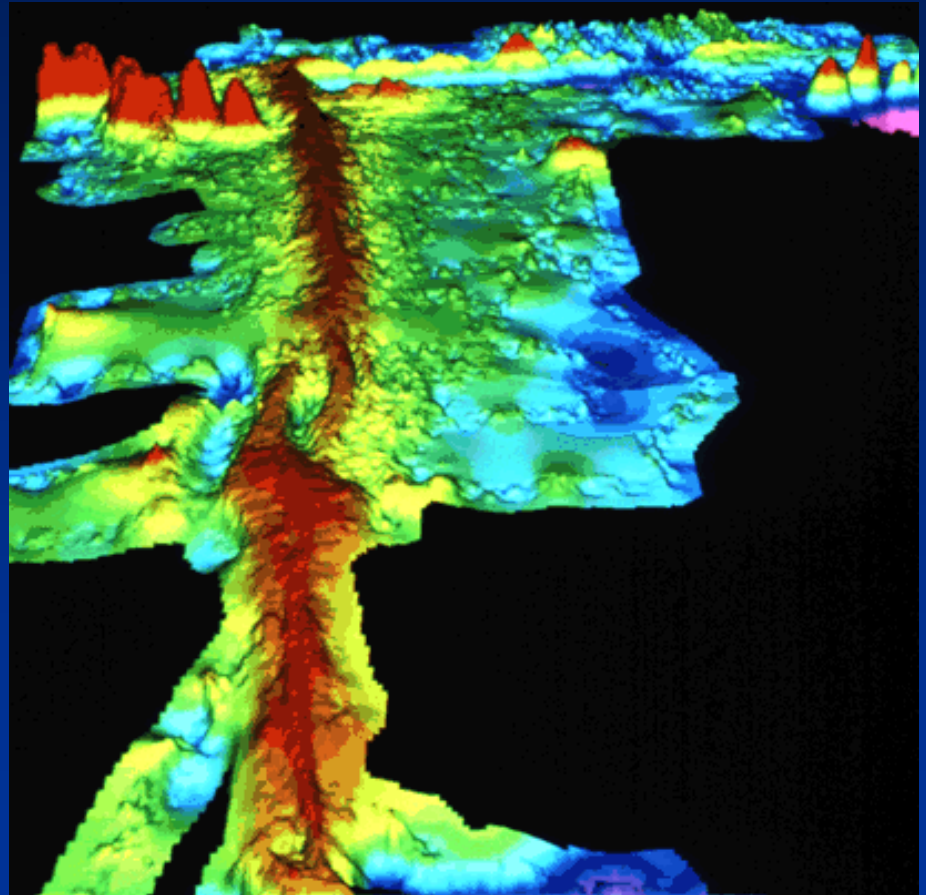
## 1b) formazione di crosta oceanica, dorsali !!

Islanda, zona di dorsale Thingvellir national park



Da Oddur Sigurdsson, National Energy Authority, Iceland

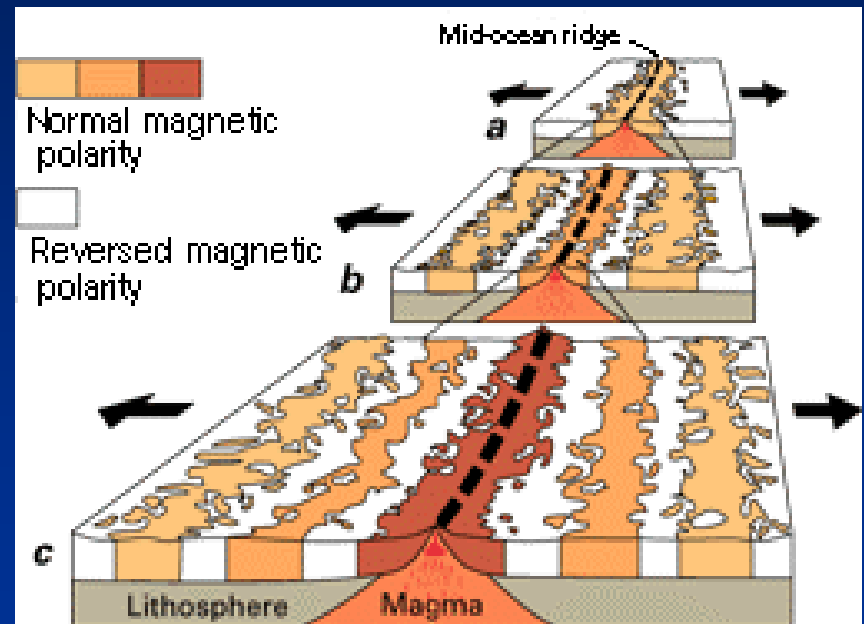
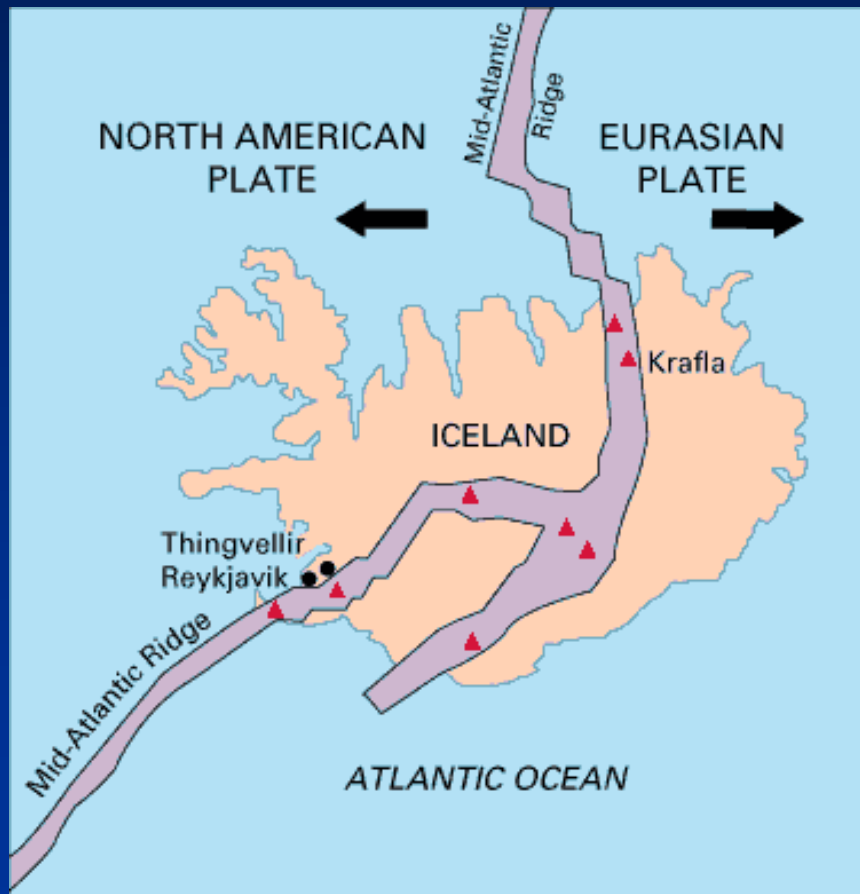
Zona di dorsale medio-oceanica pacifica



<https://pubs.usgs.gov/gip/dynamic/topomap.html> (from Stacey Tighe, University of Rhode Island)

# associazioni estensionali, ambienti geodinamici divergenti

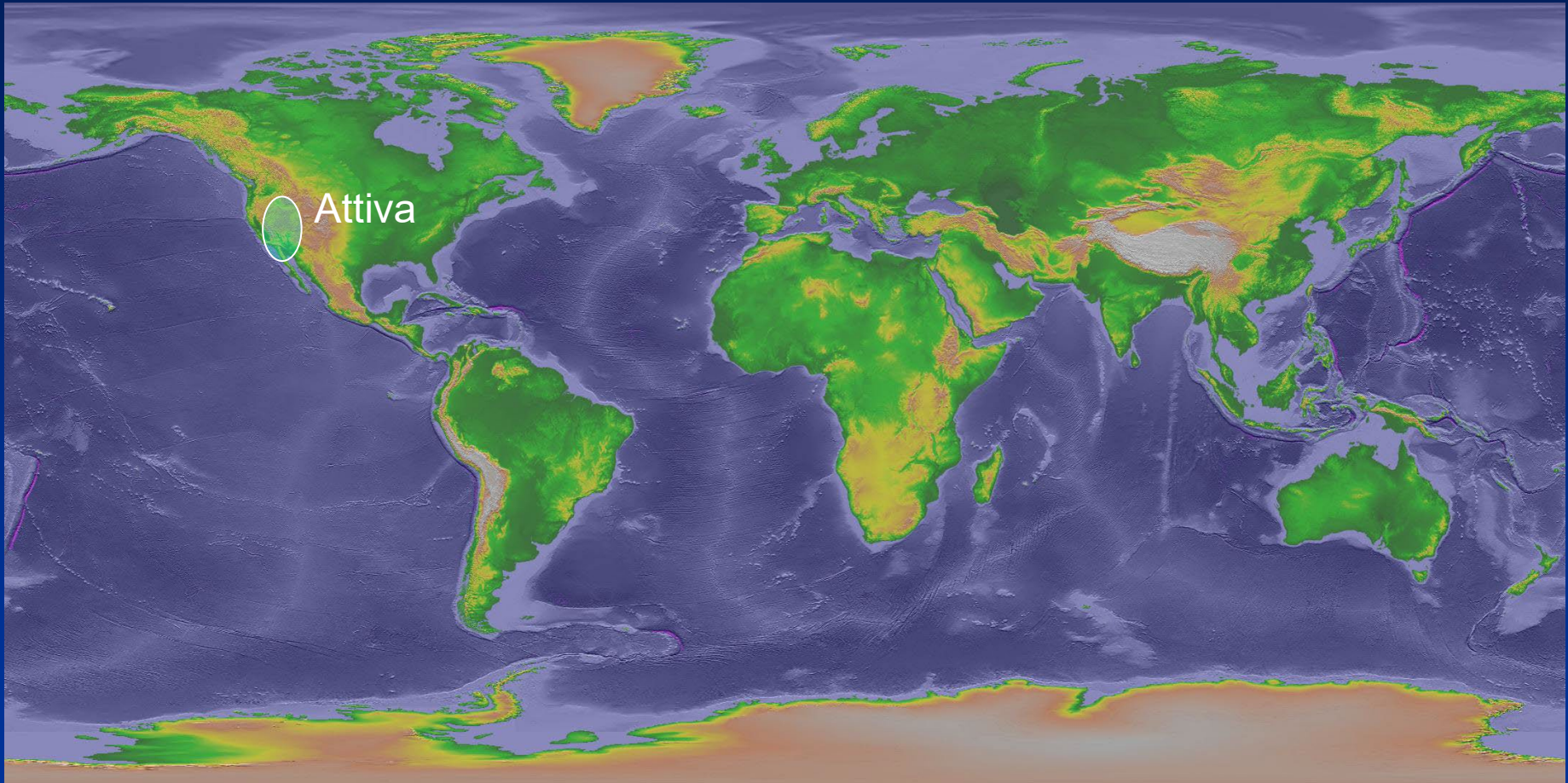
## Formazione di crosta oceanica, dorsali !!



<http://factsanddetails.com/world/cat51/sub323/item2212.html>

# Associazioni di faglie normali

2a) associazioni estensionali in ambienti geodinamici divergenti prossimi a margini trascorrenti/convergenti

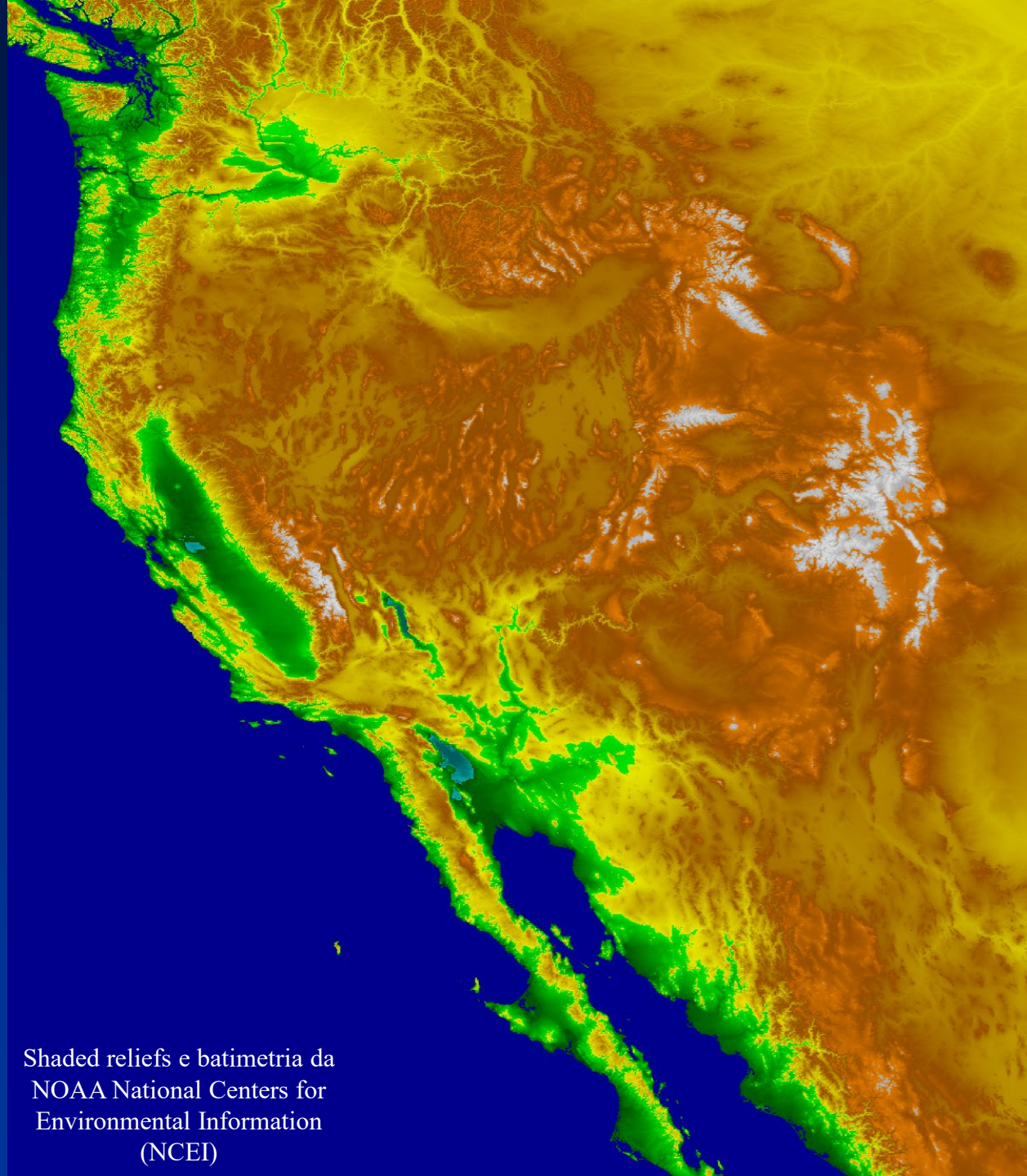


Shaded reliefs e batimetria da NOAA National Centers for Environmental Information (NCEI)

Associazioni  
estensionali in  
ambienti  
geodinamici  
divergenti  
prossimi a  
margini  
trascorrenti/  
convergenti

Basin & Range, estensione  
intra-continentale

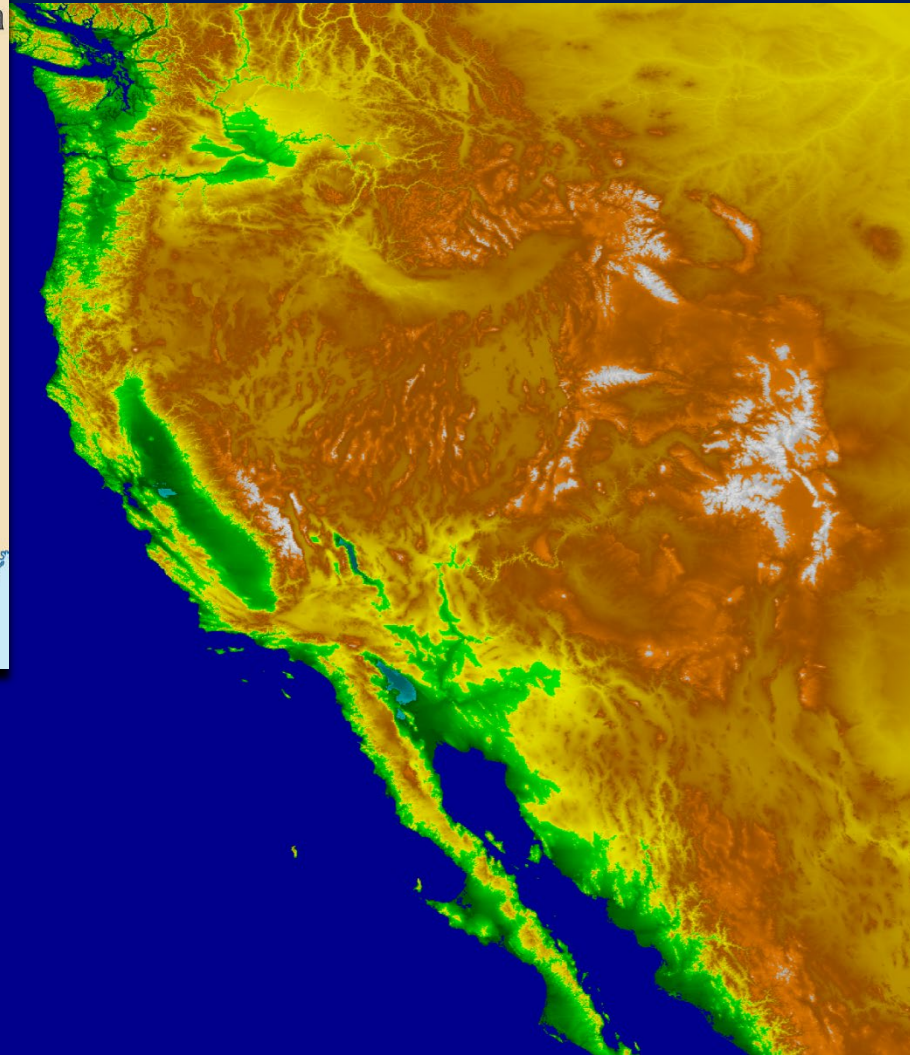
Shaded reliefs e batimetria da  
NOAA National Centers for  
Environmental Information  
(NCEI)





[https://commons.wikimedia.org/wiki/File:Tectonic\\_plates\\_boundaries\\_detailed-en.svg](https://commons.wikimedia.org/wiki/File:Tectonic_plates_boundaries_detailed-en.svg)

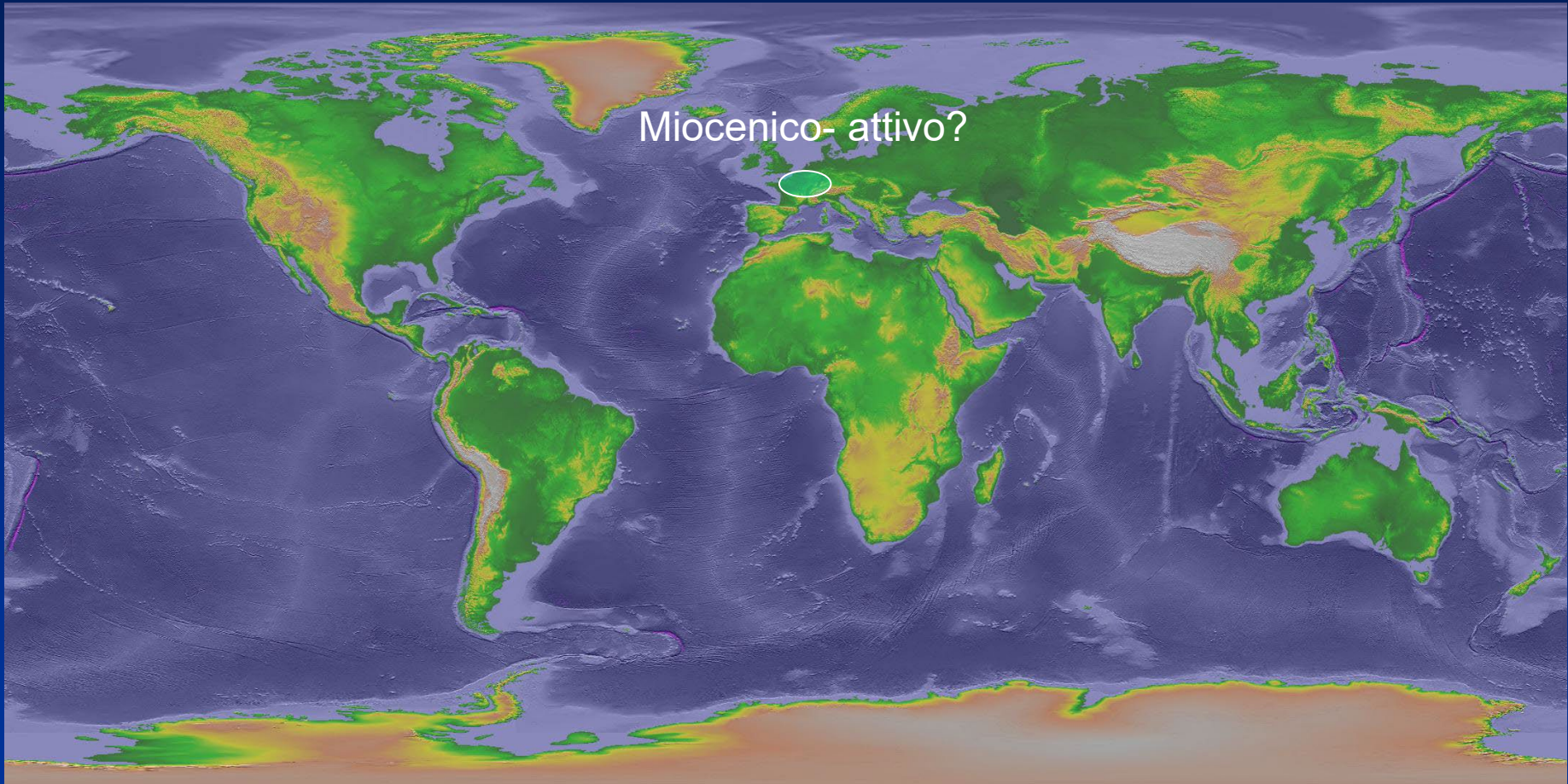
Shaded reliefs e batimetria da NOAA  
National Centers for Environmental  
Information (NCEI)



Basin & Range, estensione  
intra-continentale, situazione tettonica e  
geodinamica regionale

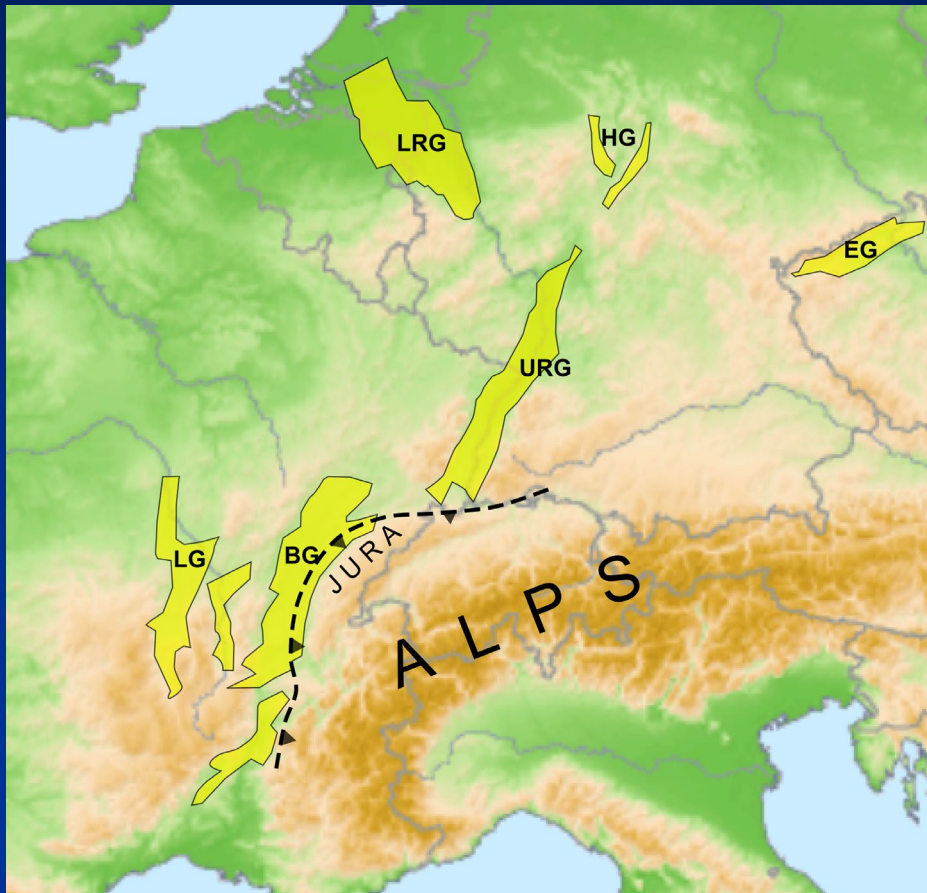
# Associazioni di faglie normali

2b) associazioni estensionali in ambienti geodinamici divergenti prossimi a margini convergenti



Shaded reliefs e batimetria da NOAA National Centers for Environmental Information (NCEI)

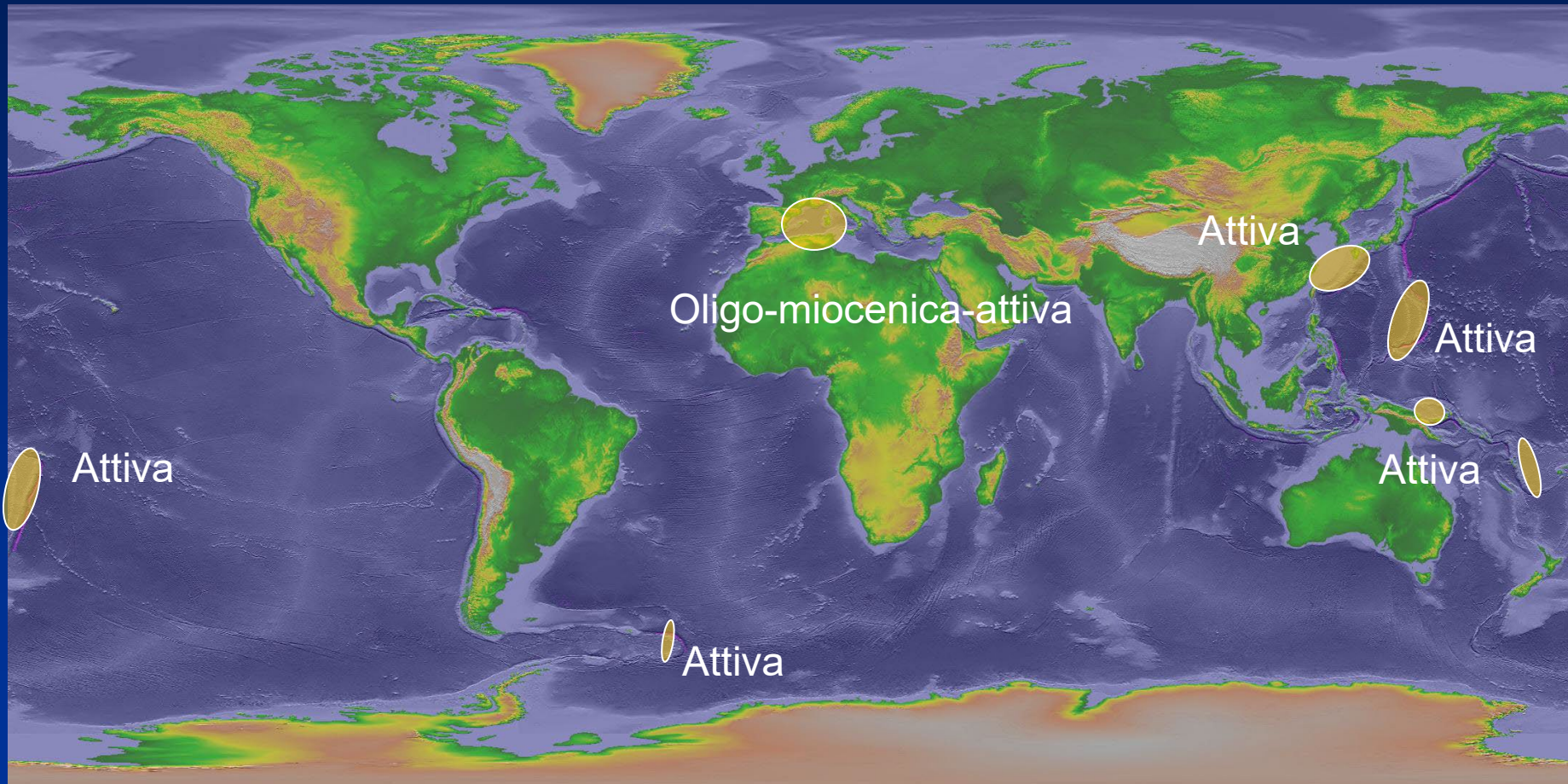
# Associazioni estensionali in ambienti geodinamici divergenti prossimi a margini convergenti



Sistema di graben centro-europeo:  
LG= g. di Limagne;  
BG= g. della Bresse;  
URG= Alto Reno;  
LRG= Basso Reno;  
HG= g. dell'Assia;  
EG= g. di Eger.

# Associazioni di faglie normali

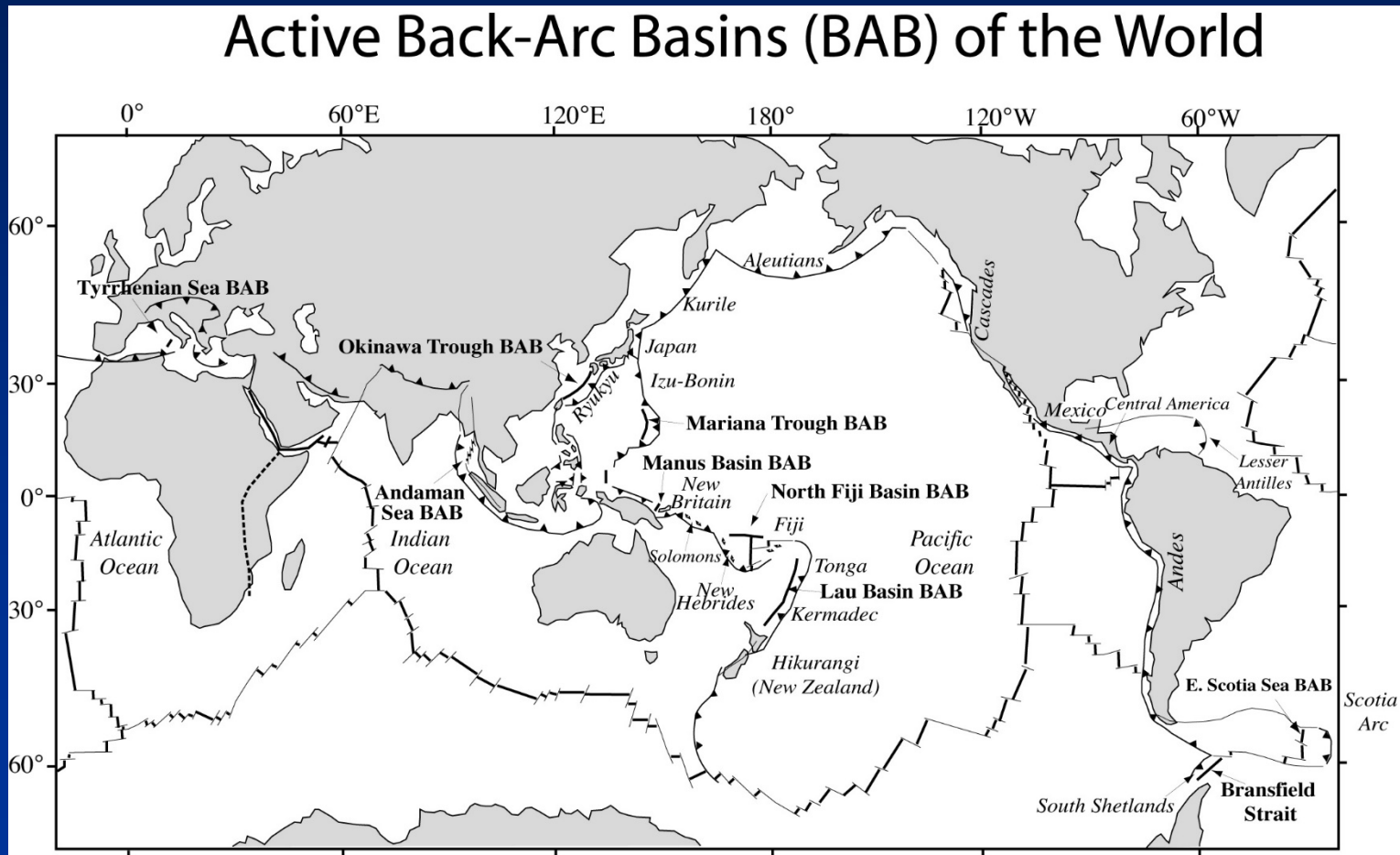
3) associazioni estensionali dovute ad ambienti geodinamici convergenti!!!



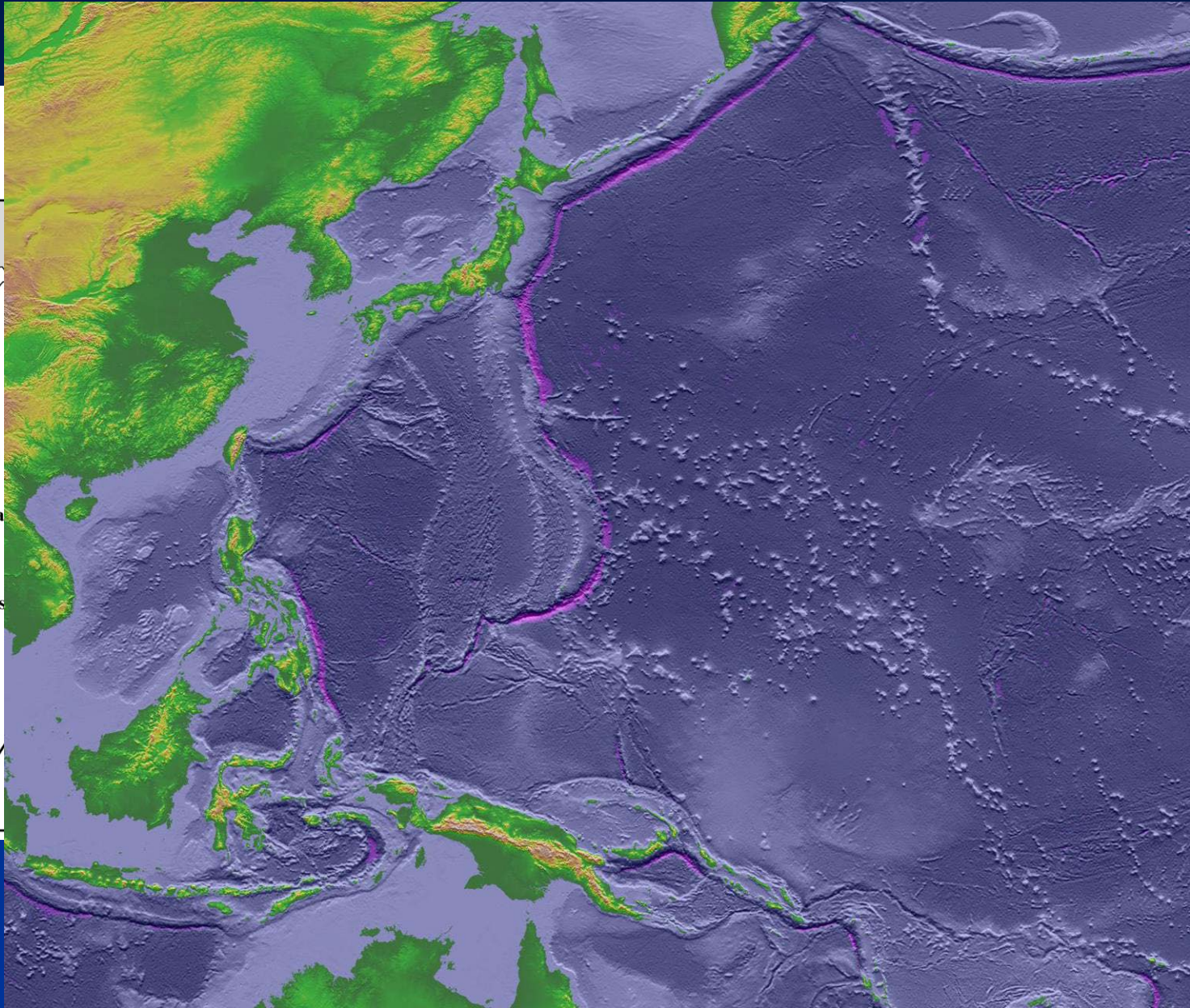
Shaded reliefs e batimetria da NOAA National Centers for Environmental Information (NCEI)

### 3) associazioni estensionali dovute ad ambienti geodinamici convergenti:

## Estesi bacini di retroarco

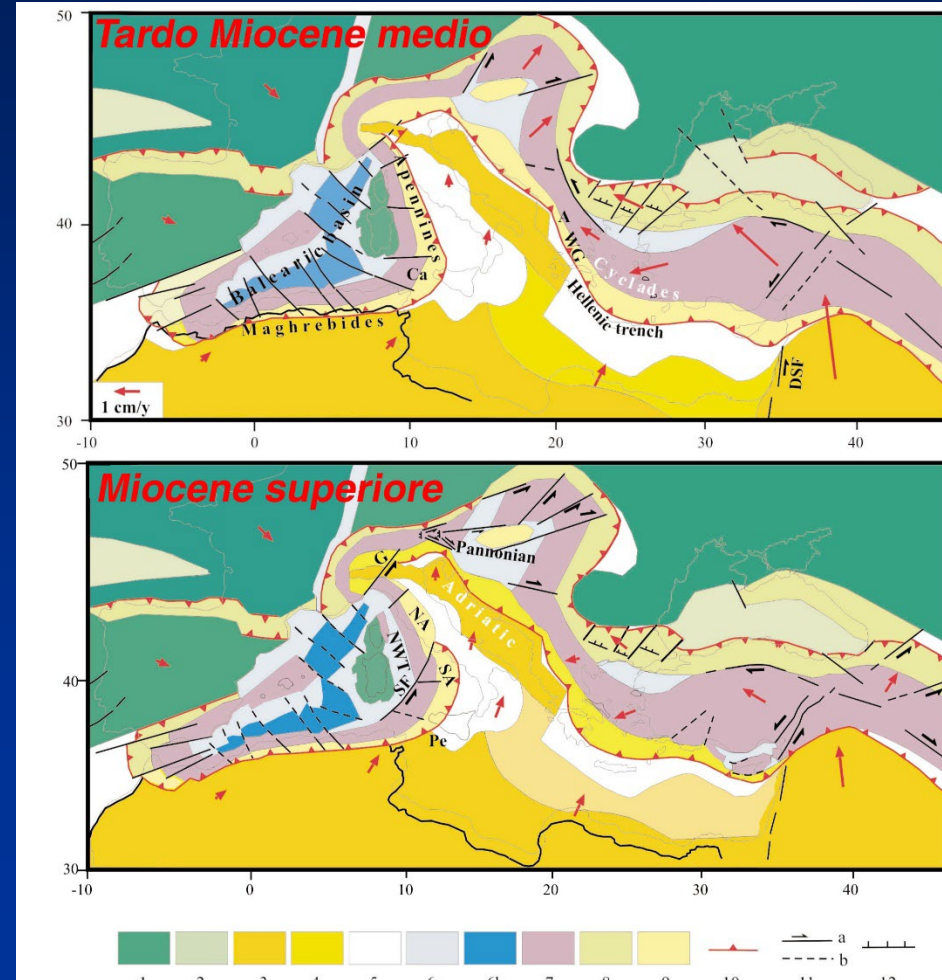
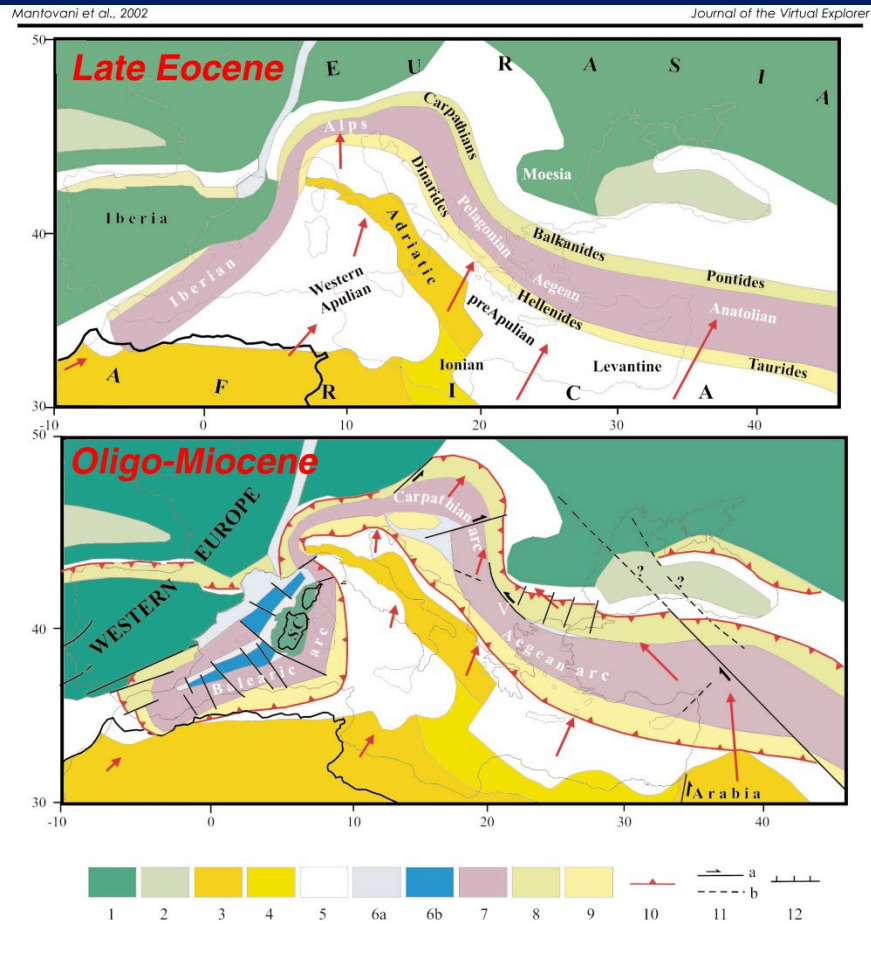


# Back-Arc Basins (BAB)

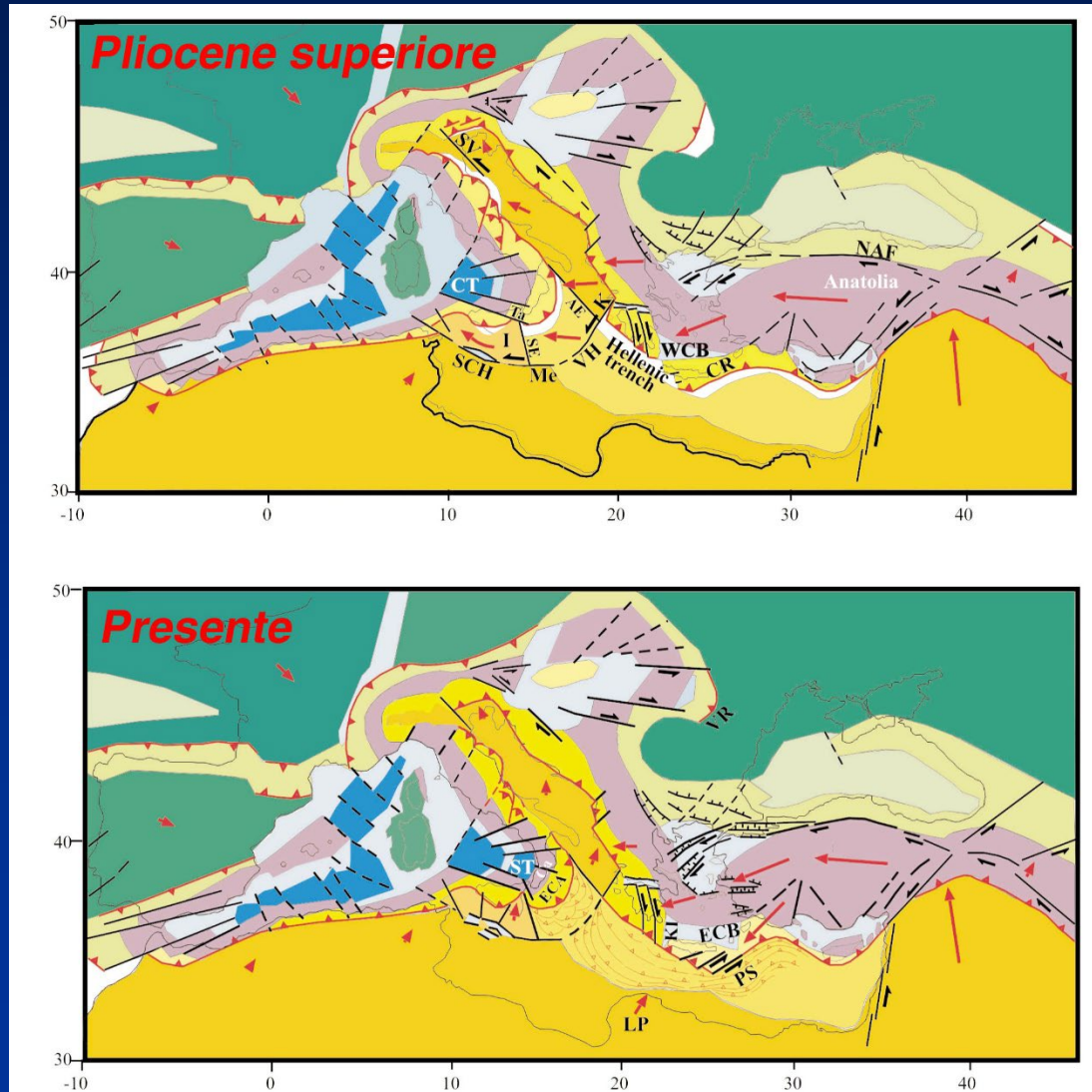


# associazioni estensionali dovute ad ambienti geodinamici convergenti: evoluzione oligo-miocenica sino all'Attuale dell'Appennino

Da Mantovani et al., 2002

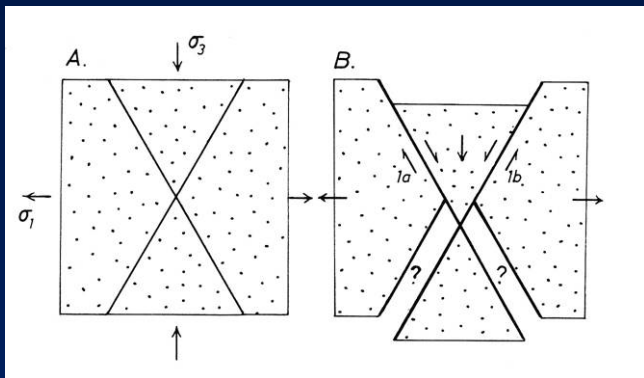


# associazioni estensionali dovute ad ambienti geodinamici convergenti: evoluzione oligo-miocenica sino all'Attuale dell'Appennino

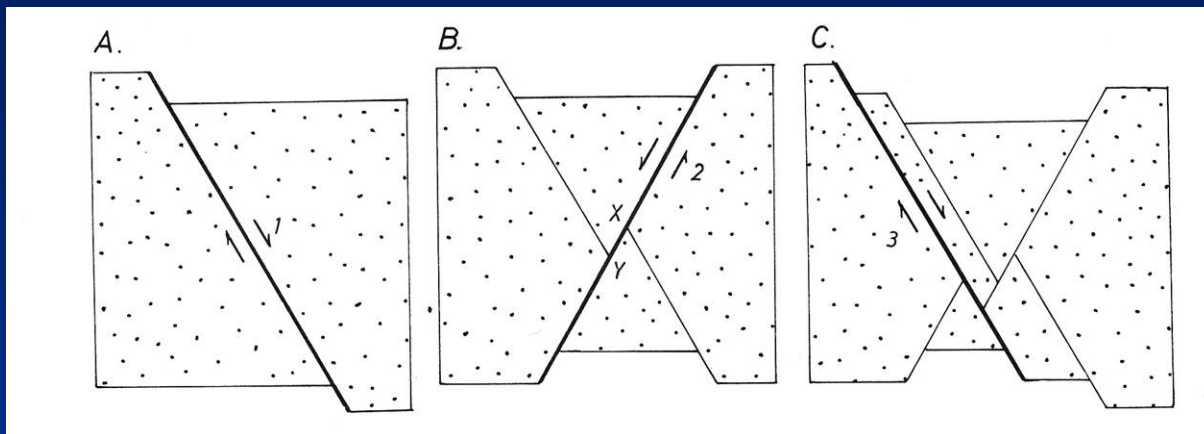


Da Mantovani et al., 2002





Da Ramsay and Huber, 1987



Solo le associazioni di faglie (coniugate) lavorano!!

FAGLIE NORMALI DIRITTE



a)

FAGLIE NORMALI LISTRICHE



b)

FAGLIE A "DOMINO"



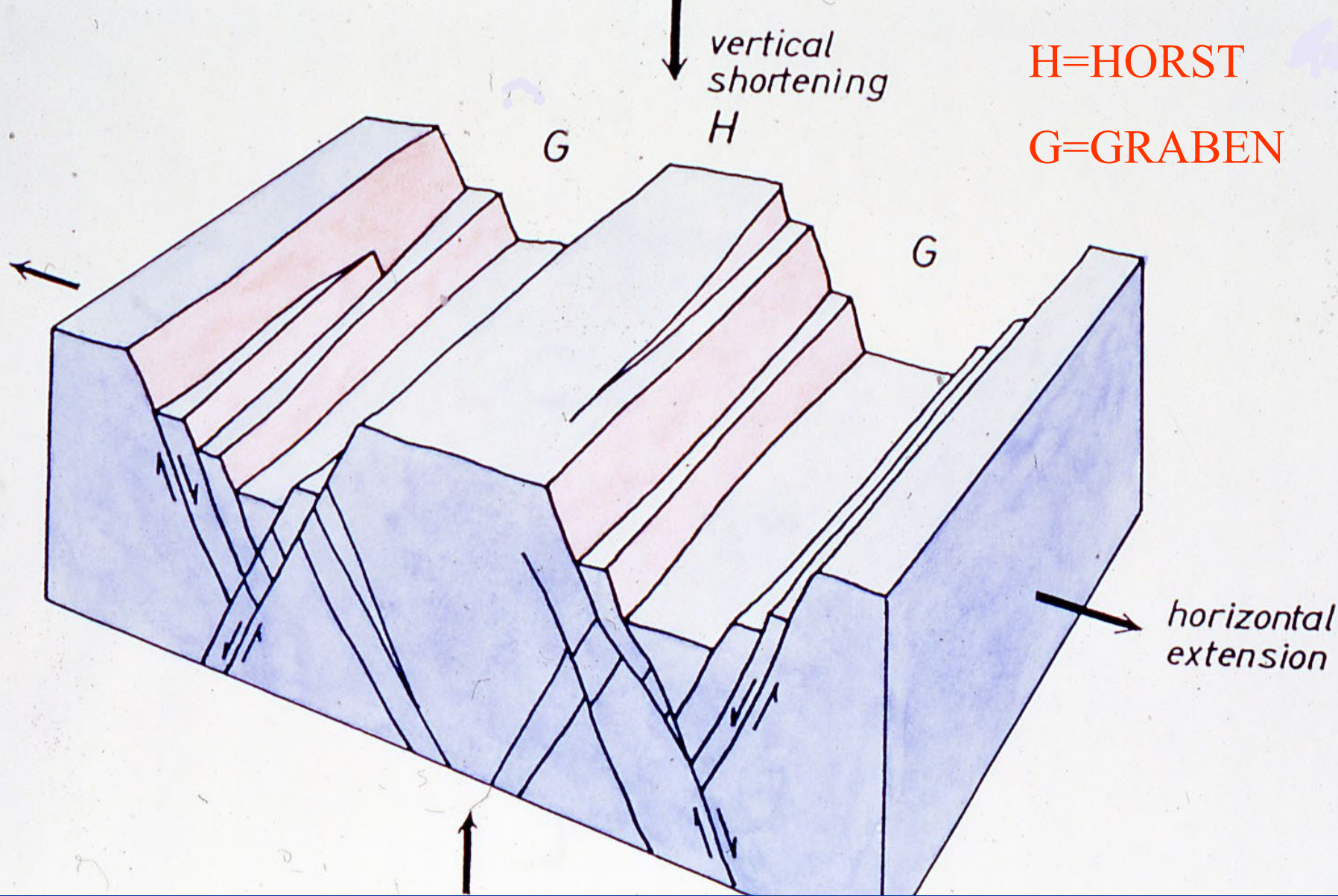
c)

FAGLIE DI DISTACCO (DETACHMENT) A BASSO ANGOLO



d)

Sistemi di  
faglie normali:  
il problema  
della  
continuazione  
in profondità.  
Diverse  
geometrie in  
superficie e  
diversi modelli  
concettuali



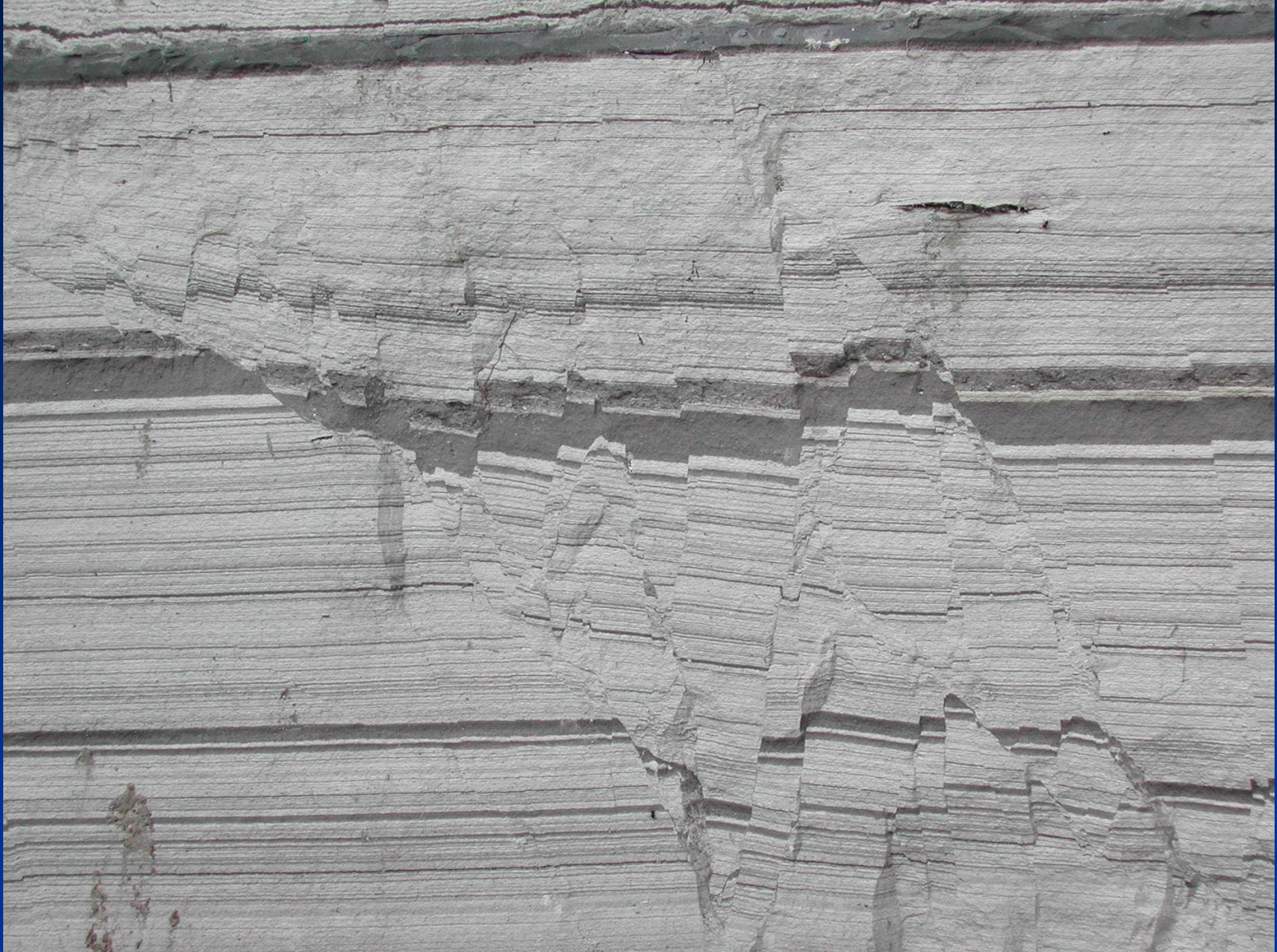
Da Ramsay and Huber, 1987

# FAGLIE PIANE

Esempio di grabe (singola fossa) recentissimo e, presumibilmente, attivo



Sistemi di faglie normali: coniugate, faglia principale (master fault) e faglie curve!



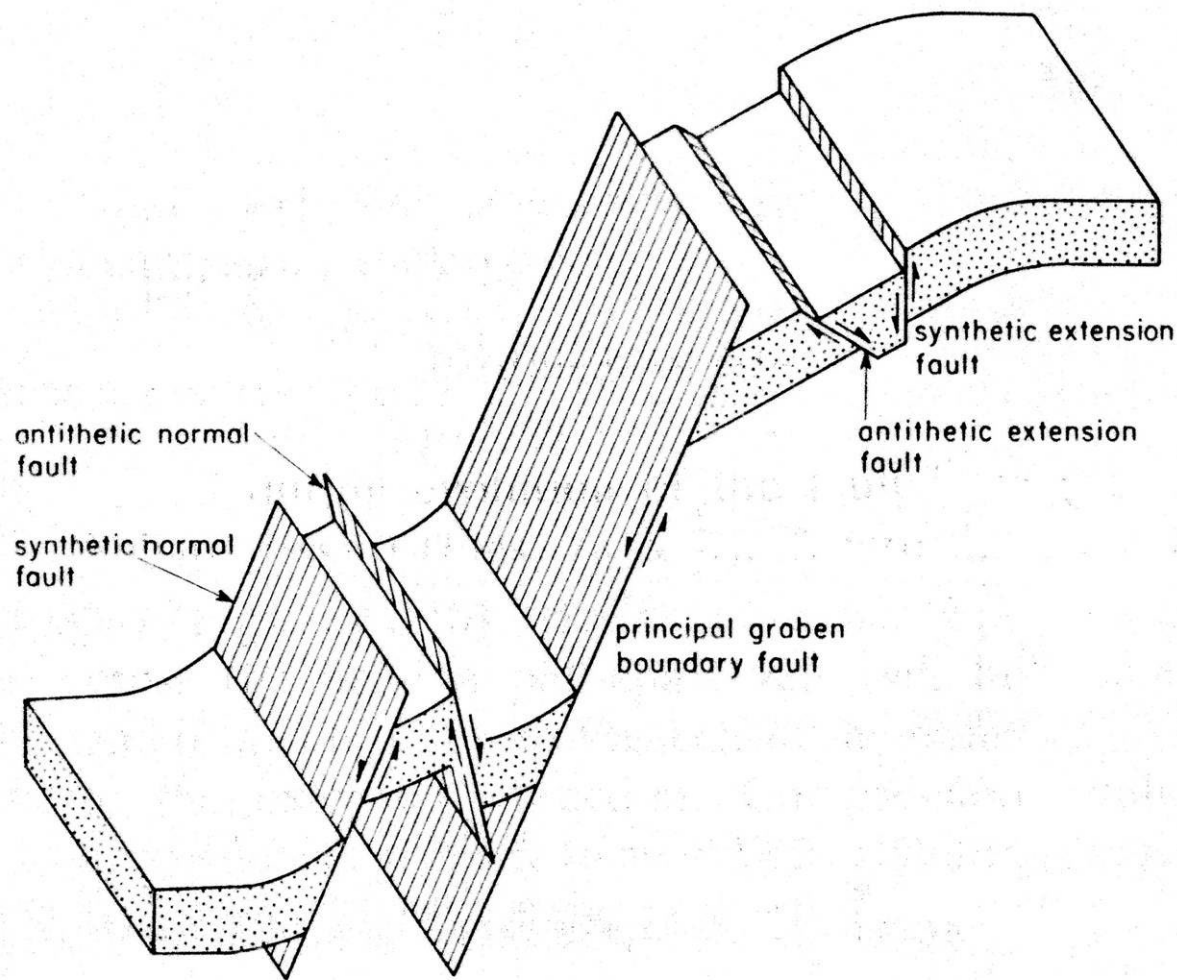


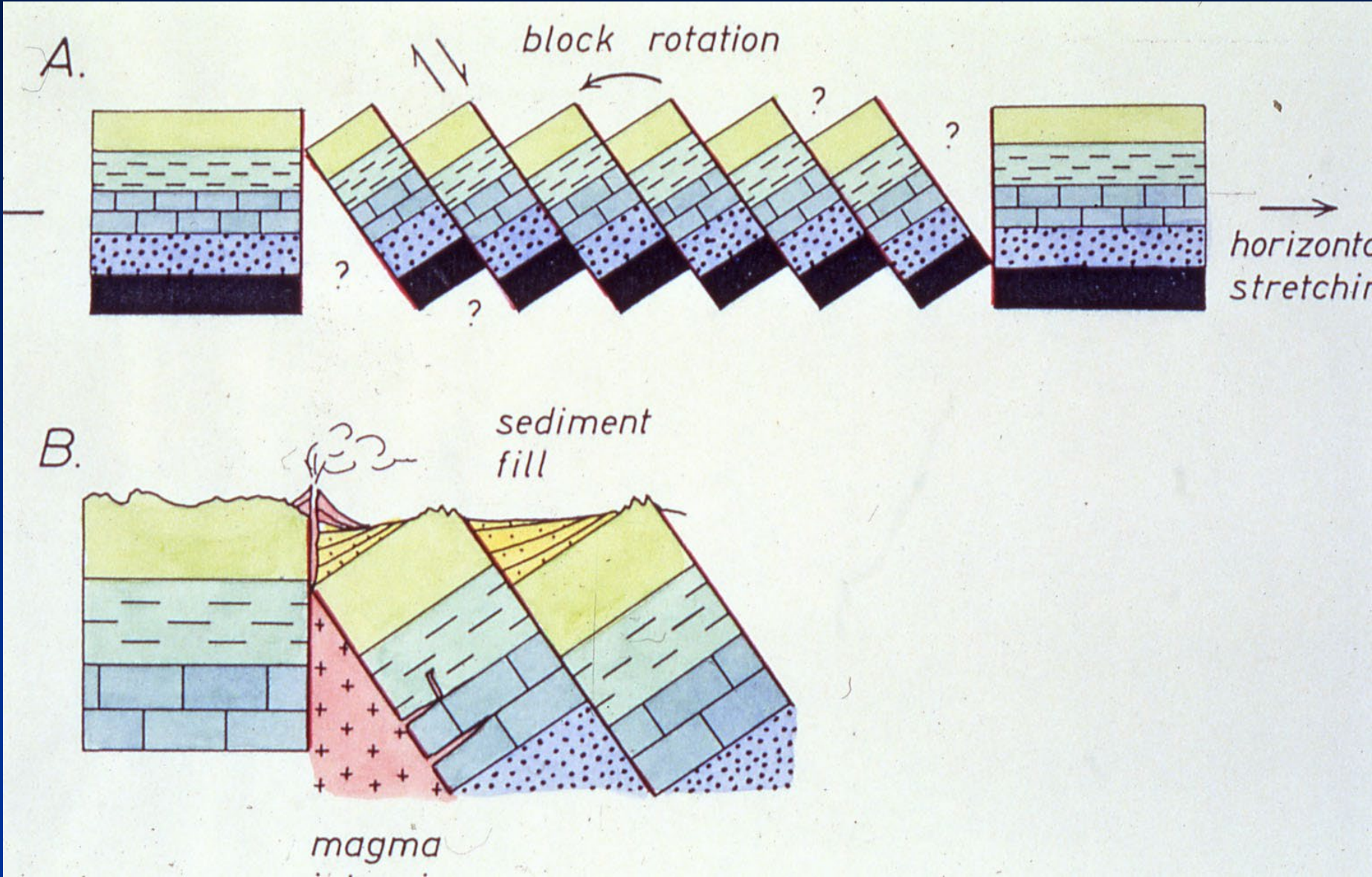
Fig. 6. Structures characteristic of planar high-angle normal fault zones such as those bounding grabens in terrains that have been inhomogeneously extended by a small percentage. After Al Kadhi & Hancock (1980, fig. 6).

Sistemi di faglie normali coniugate: faglia principale, faglie antitetiche e sintetiche

Come si vede in affioramento una faglia normale?  
(foto L. Selli)



Sistemi di faglie normali coniugate sintetiche; sistema a domino!





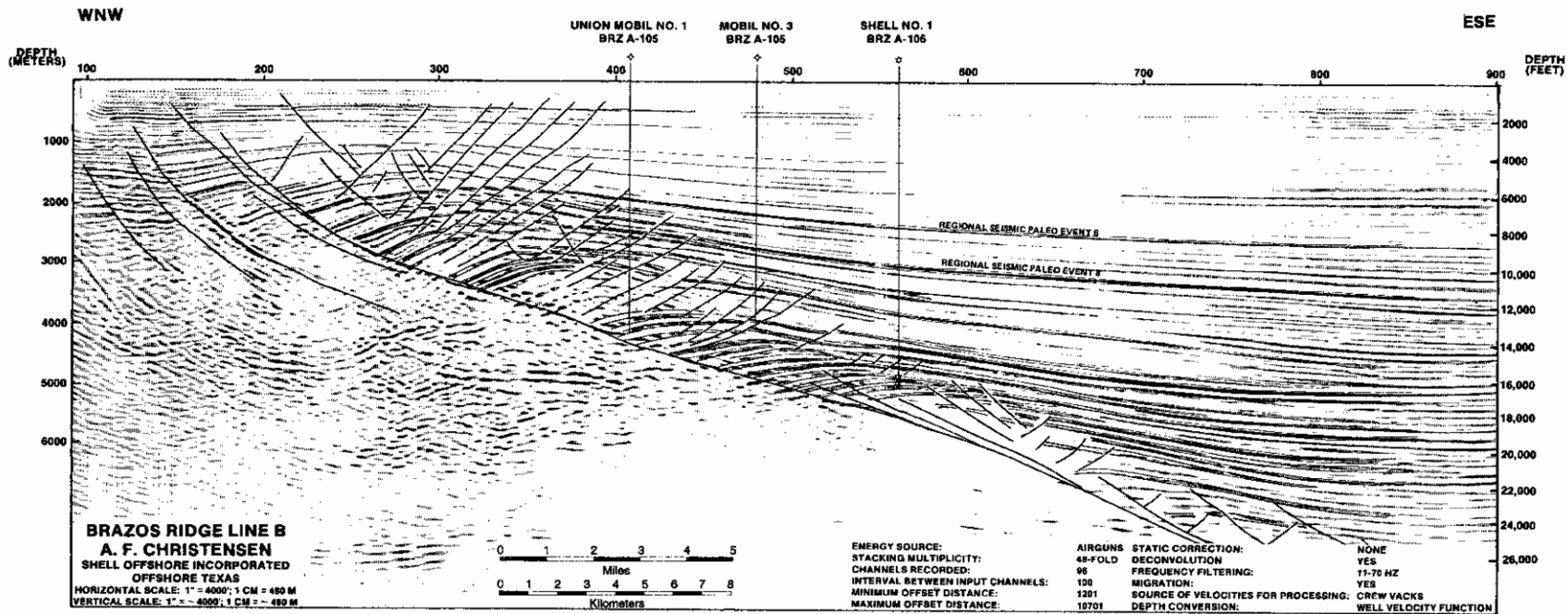
Sistemi di faglie normali coniugate sintetiche; sistema a domino!



Da Ramsay and Huber, 1987

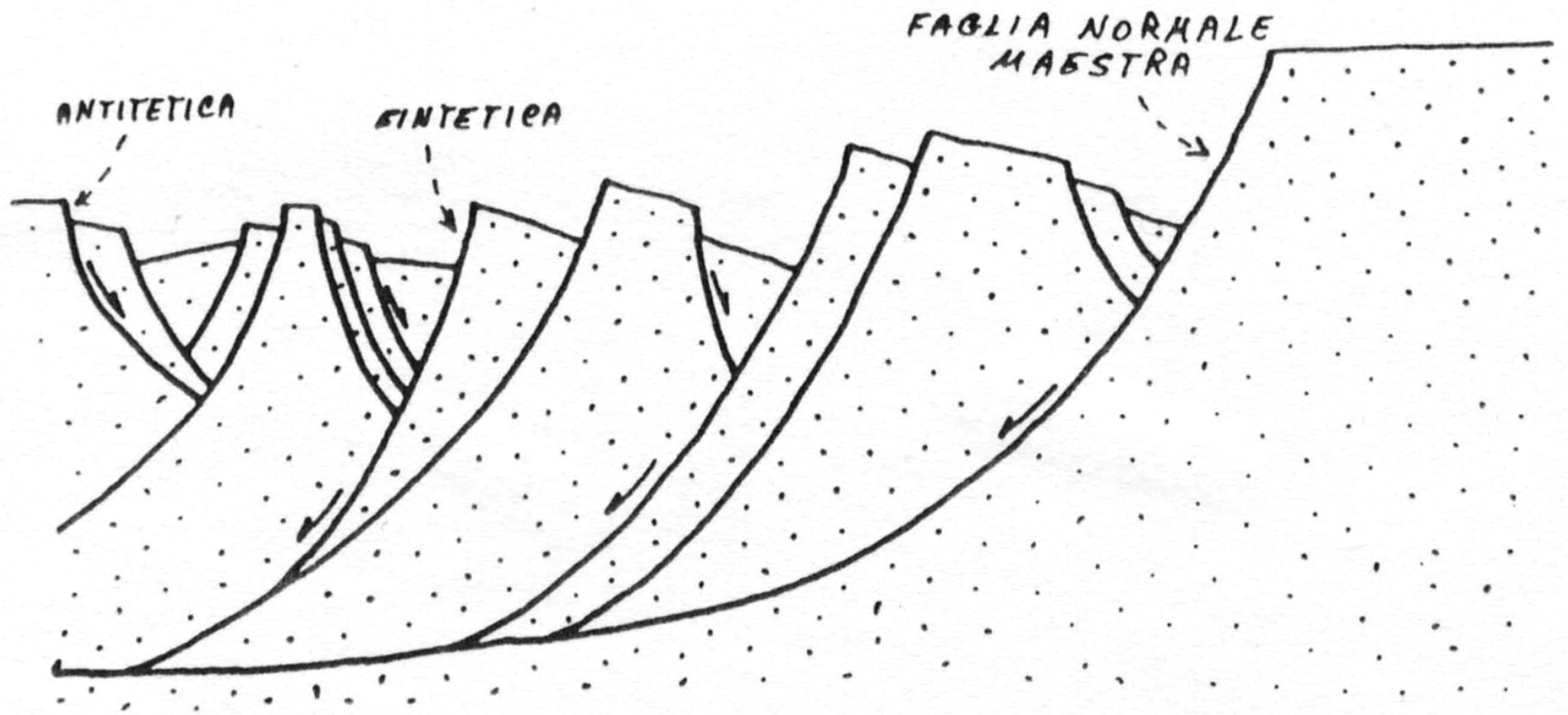


Da Ramsay and Huber, 1987

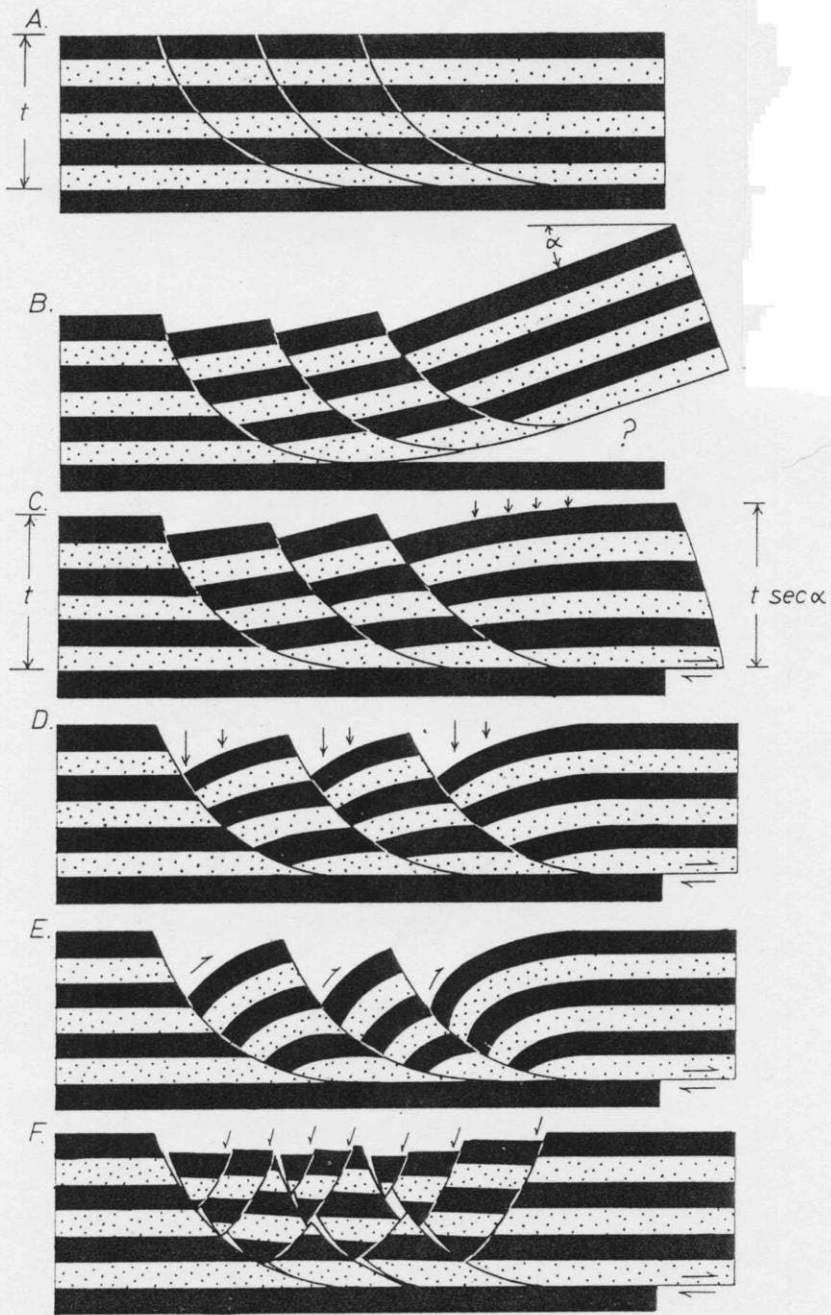


(b)

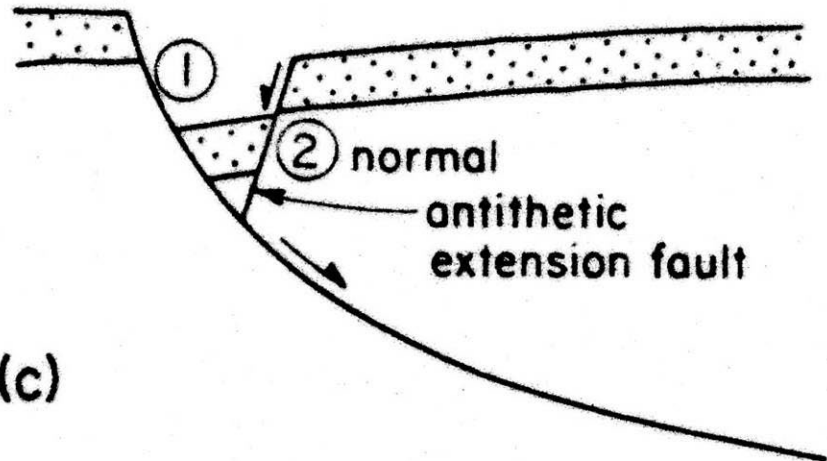
Da Hatcher, 1995



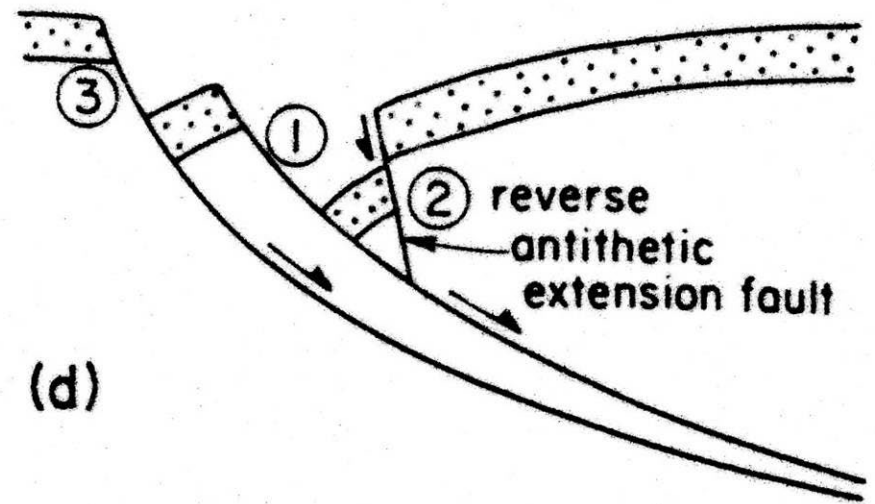
Faglia listrica



Da Ramsay and Huber, 1987

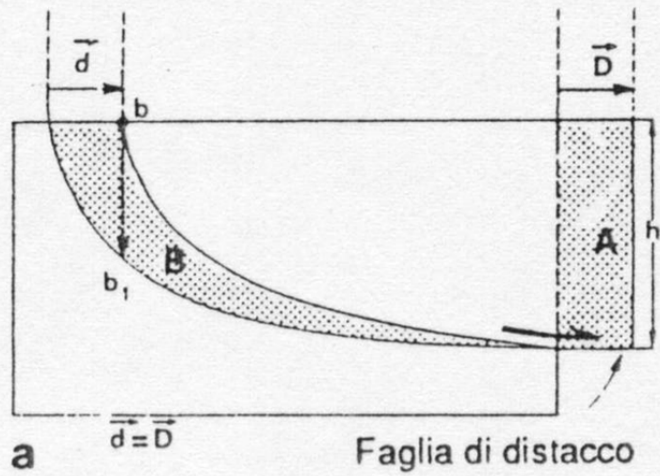


(c)

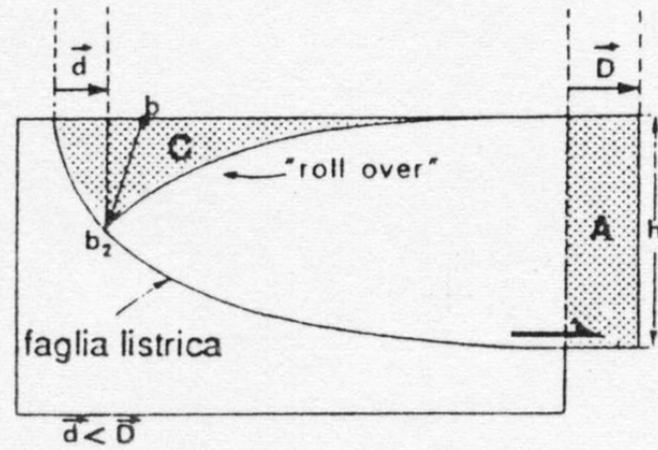


(d)

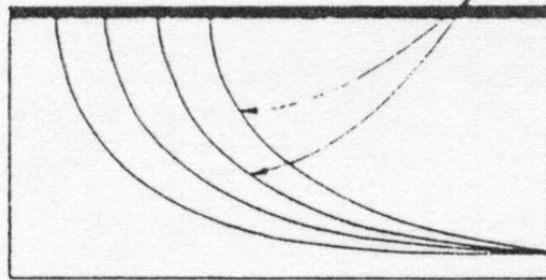
Da Hancock, 1985



Faglia di distacco

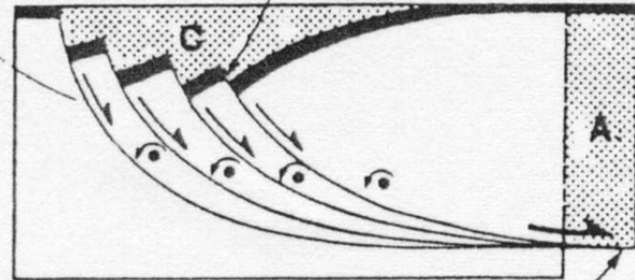


faglie listriche embriciate

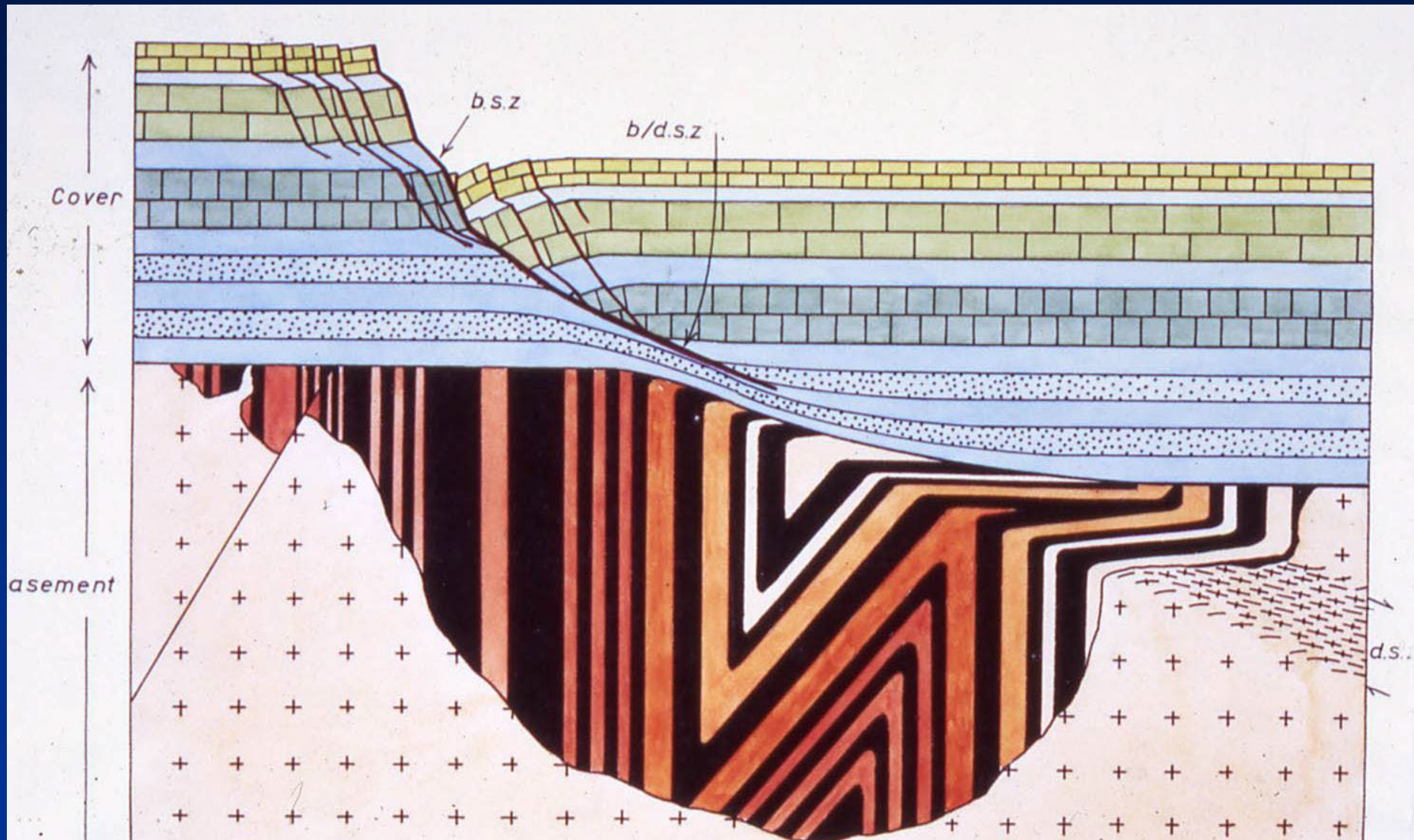


**b**

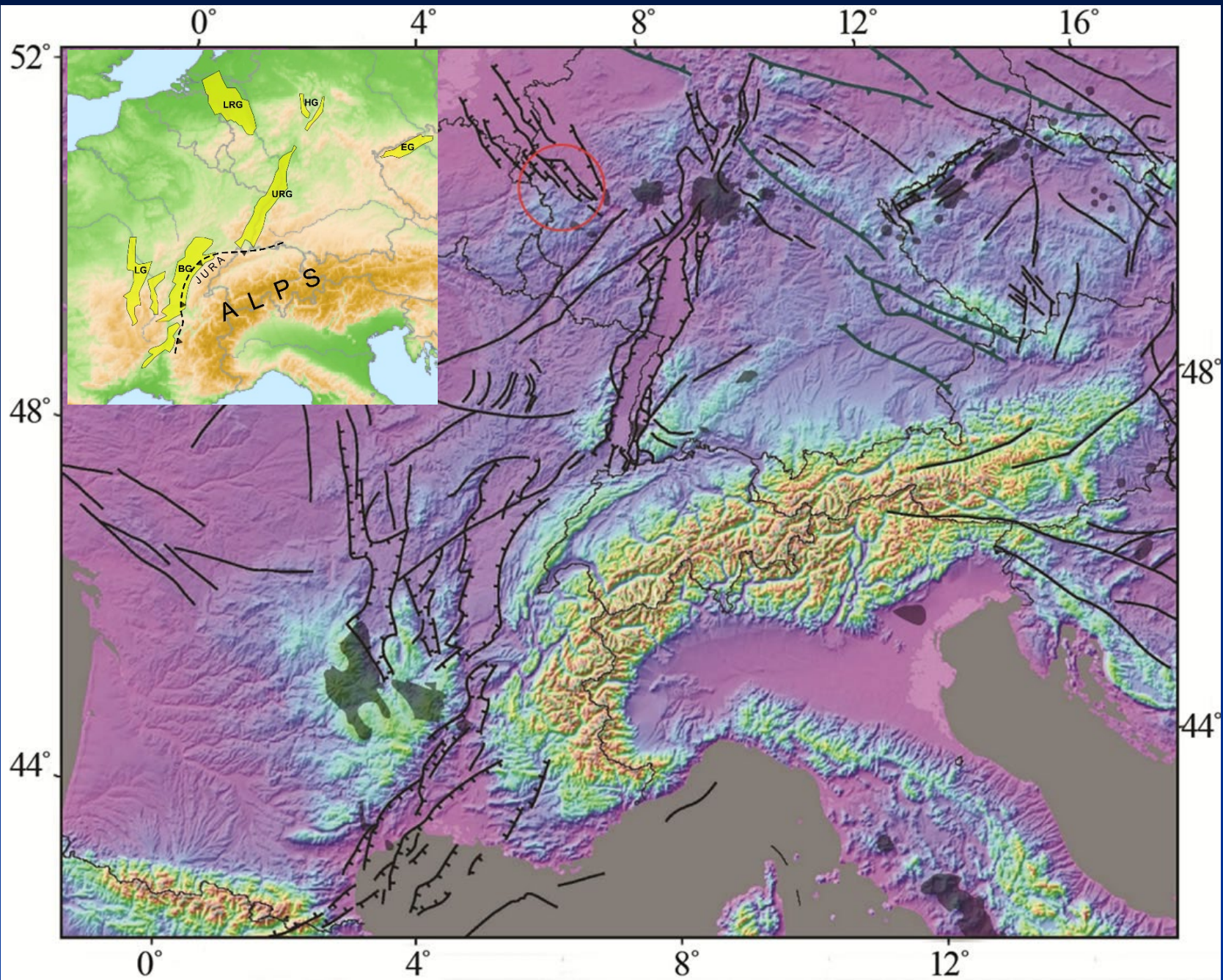
basculamenti differenziali

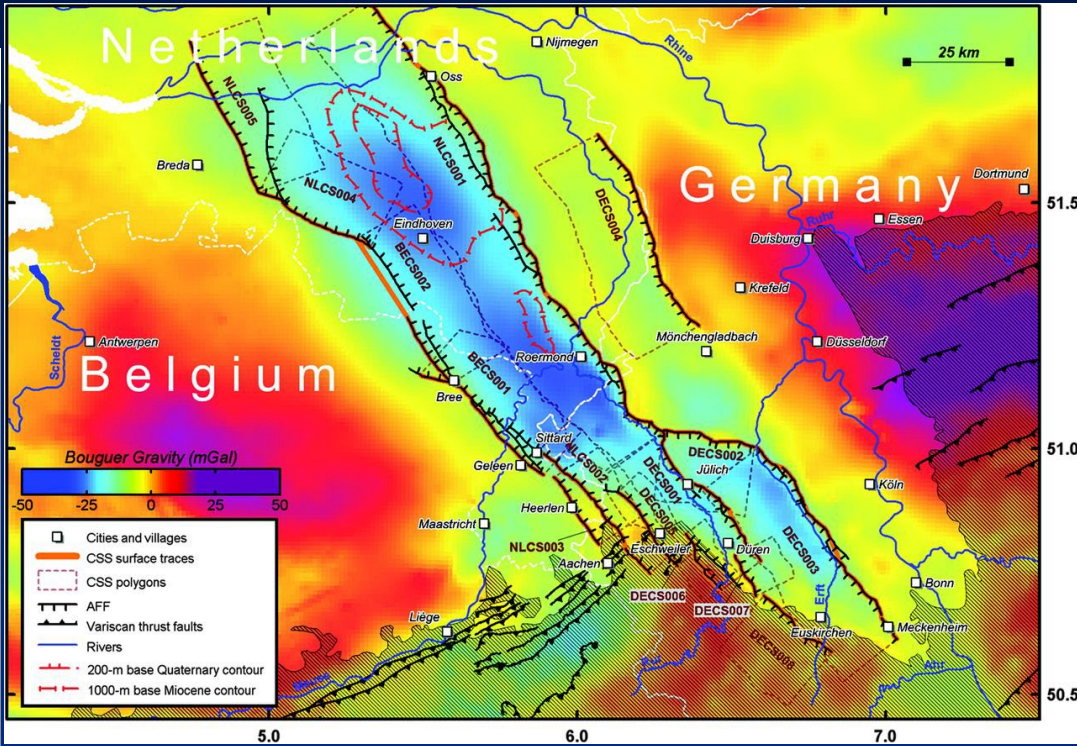
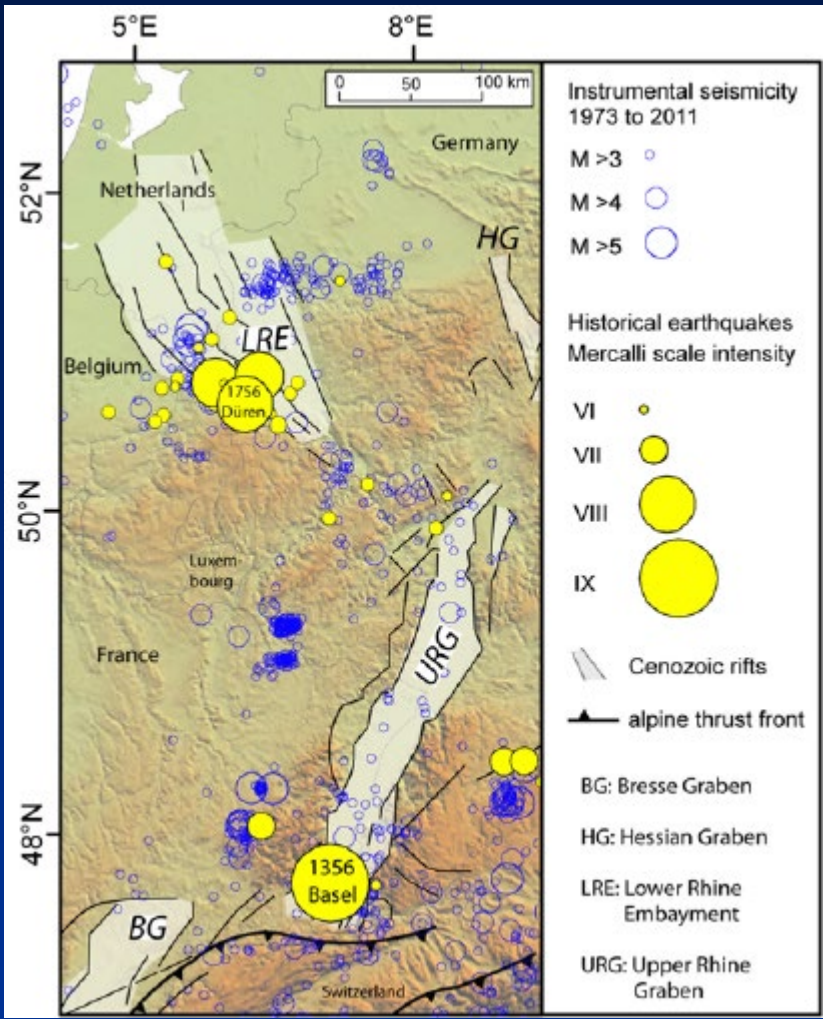


# Estensione crostale



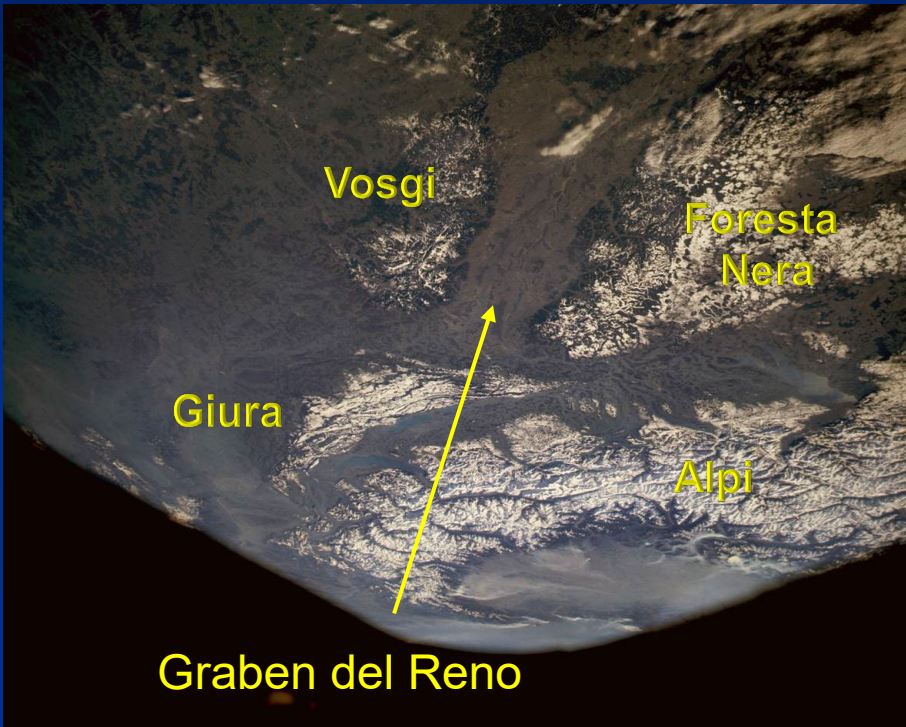


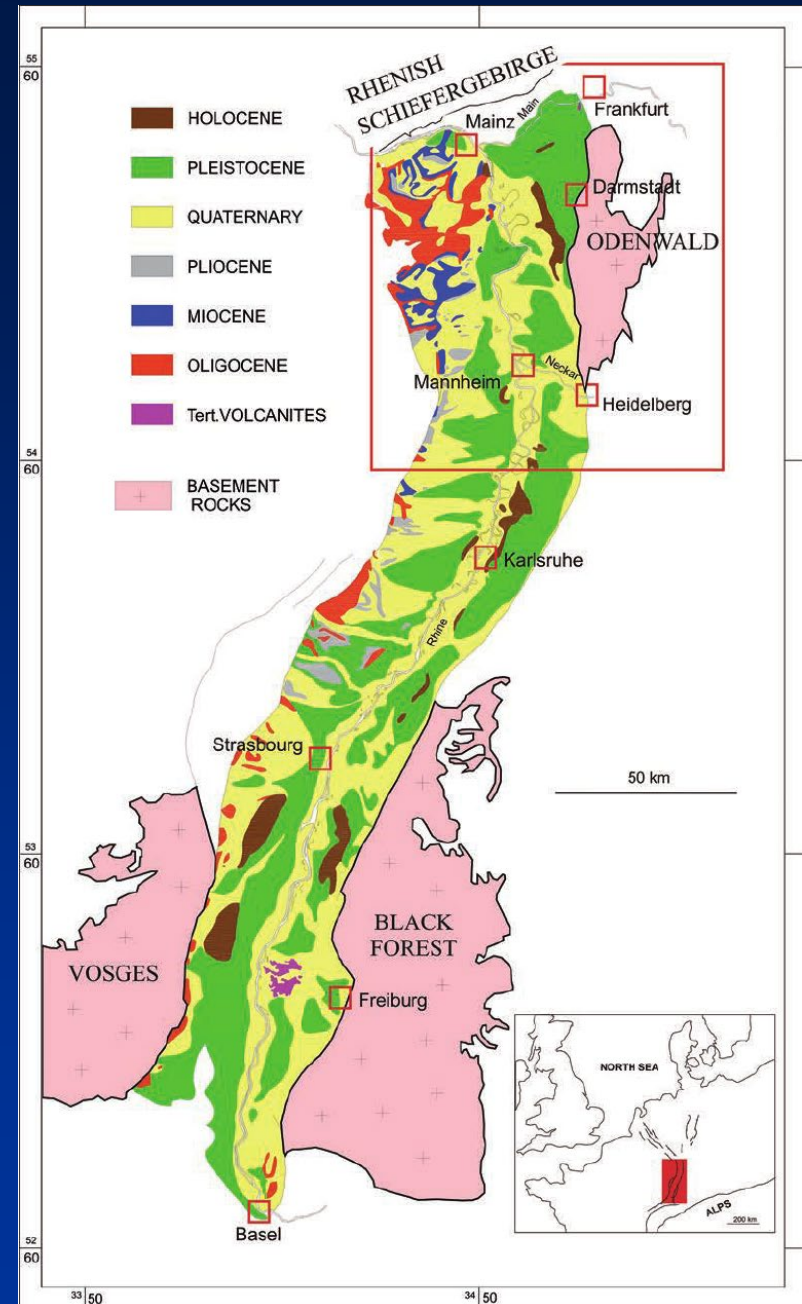
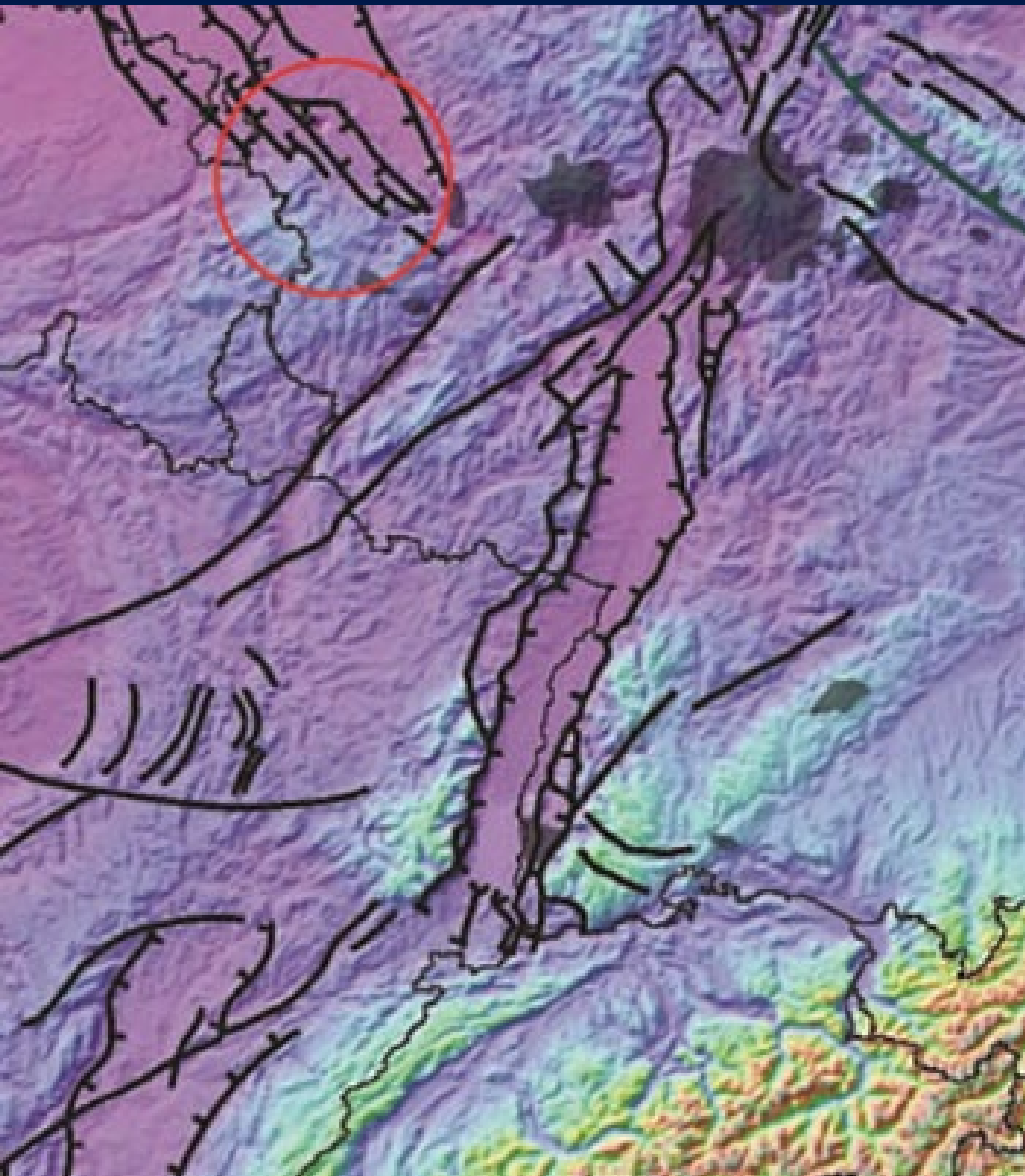




Da Kuebler, 2012

# Graben del Reno

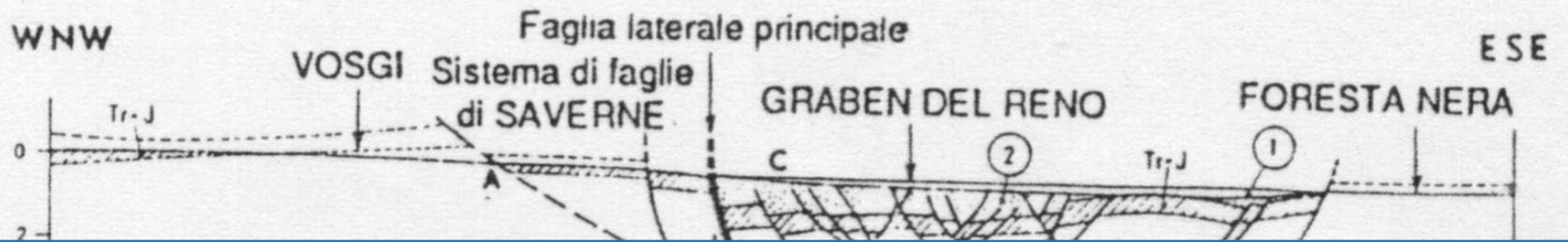




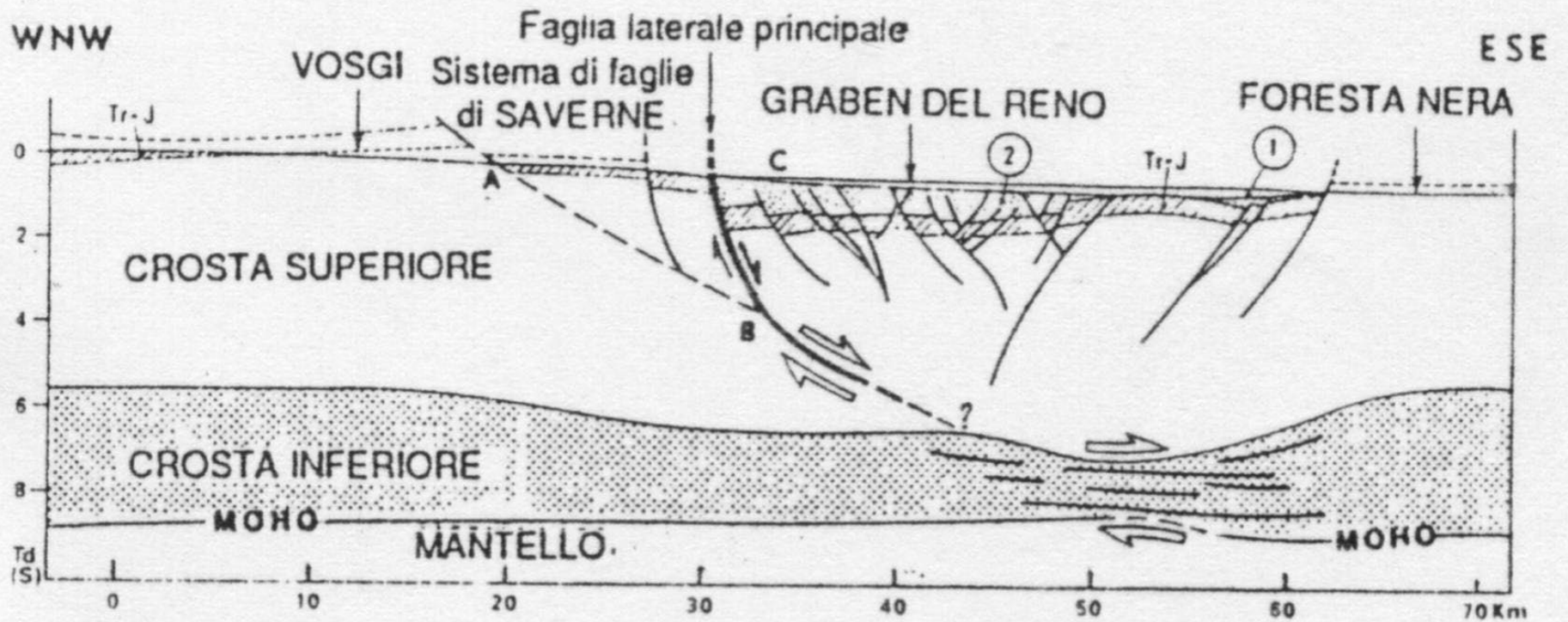
Da Dijkshoorn & Clauser, 2013

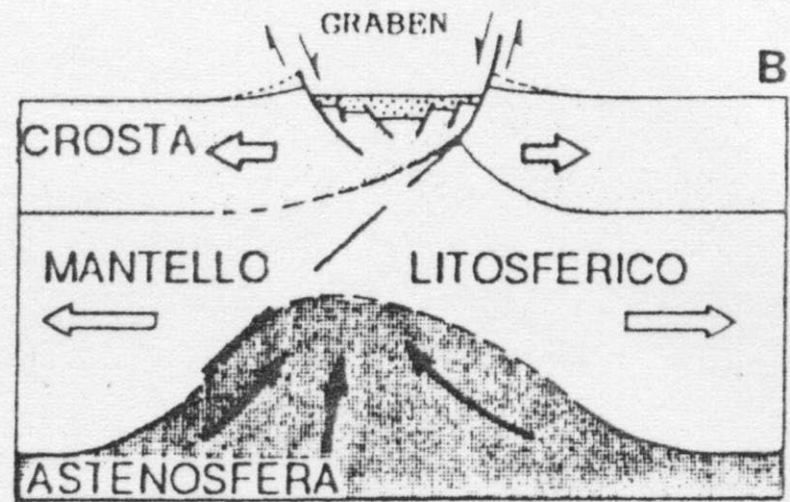
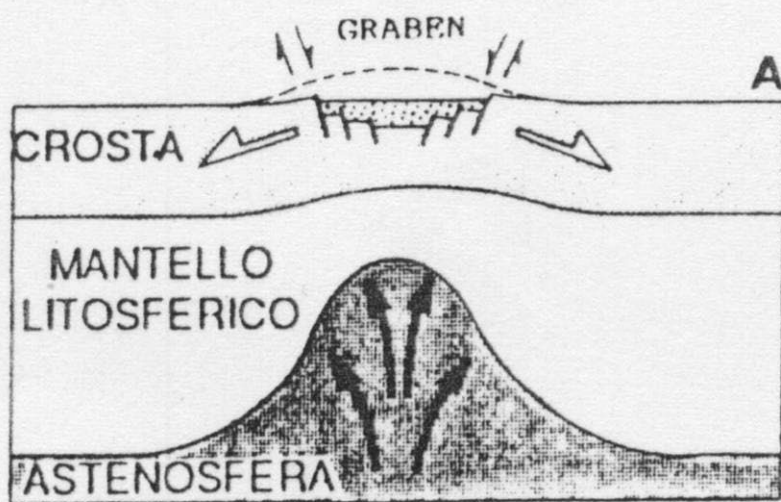
Przyrowski & Schäfer, 2015

Da Mercier & Vergely, 1996

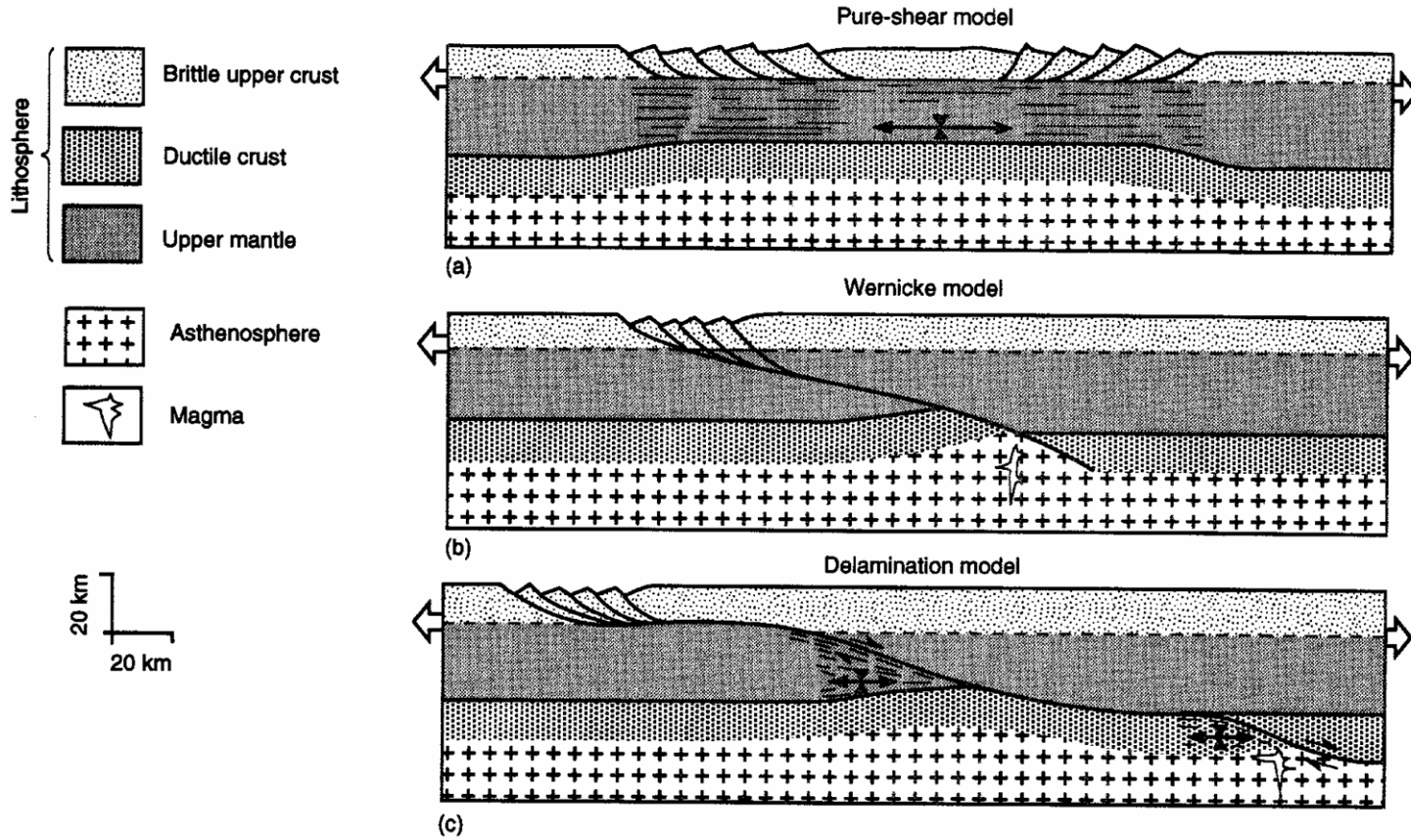


Da Mercier & Vergely, 1996





Da Mercier & Vergely, 1996



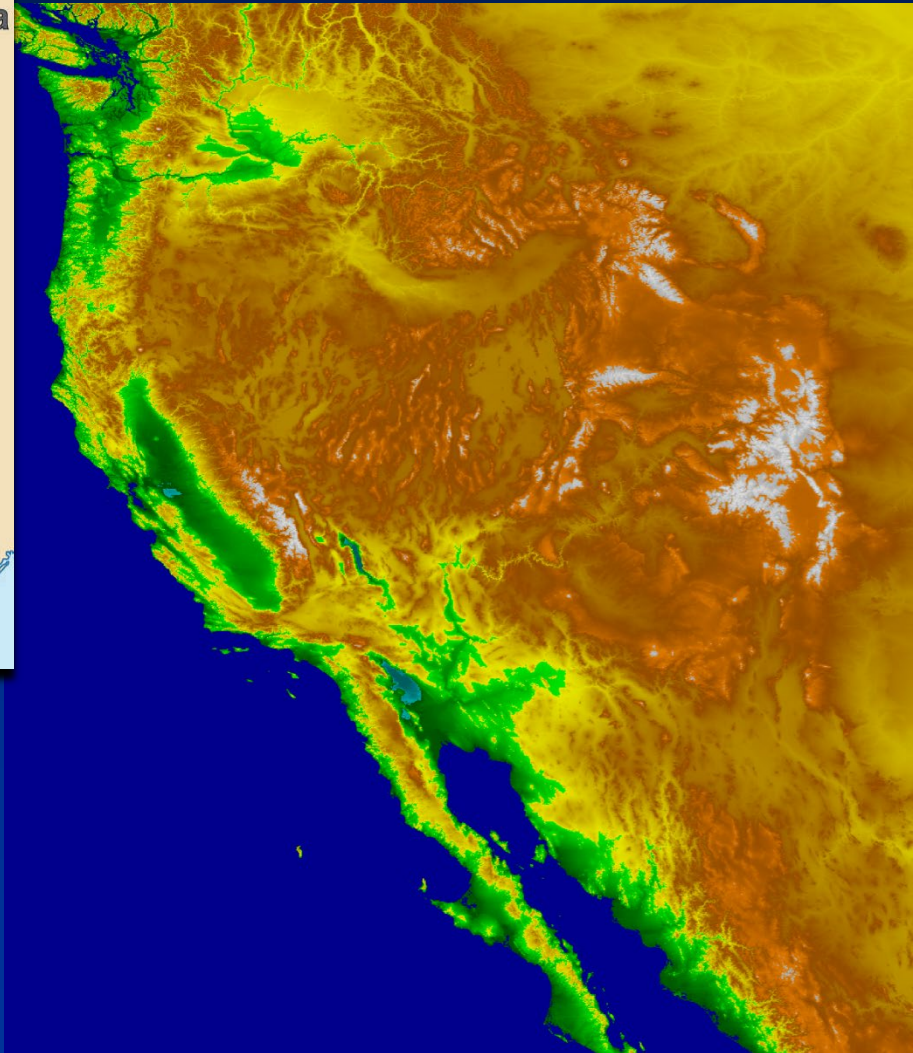
**FIGURE 13-15** Three models of extension of continental crust. (a) McKenzie "pure-shear" model: symmetrical rifting and pure shear. (b) Wernicke model: asymmetric rifting with simple shear. (c) Delamination model: asymmetric rifting with simple shear and delamination. (From G. S. Lister, M. A. Etheridge, and P. A. Symonds, *Geology*, v. 14, 1986.)





[https://commons.wikimedia.org/wiki/File:Tectonic\\_plates\\_boundaries\\_detailed-en.svg](https://commons.wikimedia.org/wiki/File:Tectonic_plates_boundaries_detailed-en.svg)

Shaded reliefs e batimetria da NOAA National Centers for Environmental Information (NCEI)



Basin & Range, estensione intra-continentale

# Death Valley National Park, California

compiled by Marli Bryant Miller

## Sediments and Sedimentary Rocks

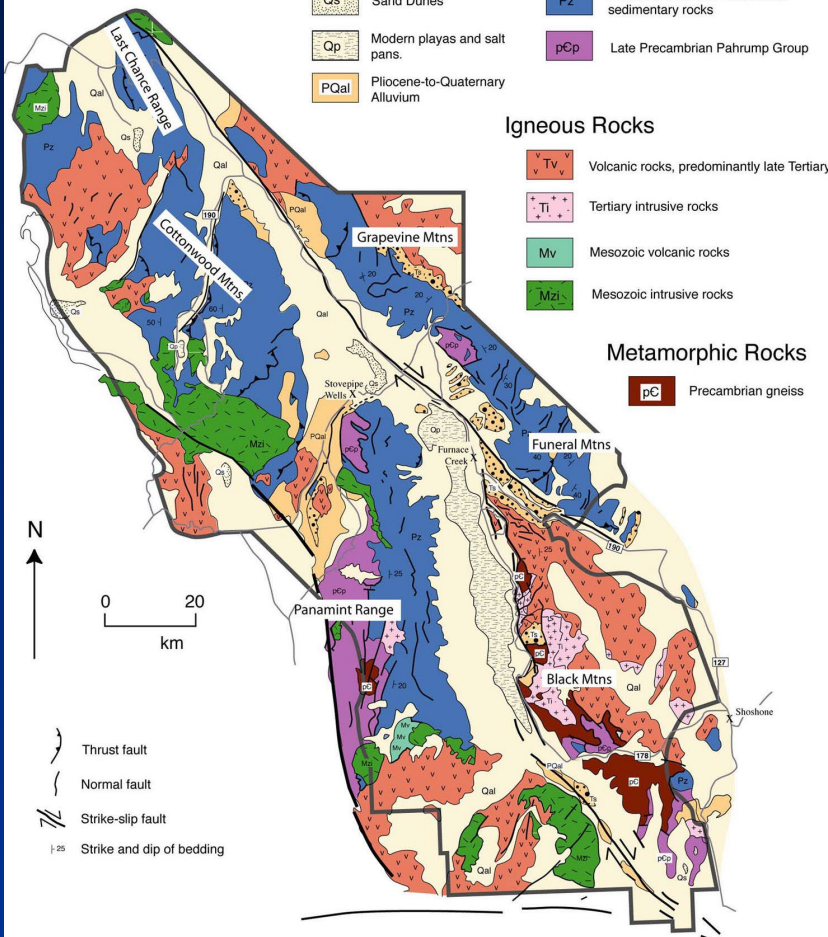
Qal	Quaternary Alluvium	Ts	Tertiary sedimentary rocks
Qs	Sand Dunes	Pz	Paleozoic and Late Proterozoic sedimentary rocks
Qp	Modern playas and salt pans.	pCp	Late Precambrian Pahrump Group
PQal	Pliocene-to-Quaternary Alluvium		

## Igneous Rocks

Tv	Volcanic rocks, predominantly late Tertiary
Ti	Tertiary intrusive rocks
Mv	Mesozoic volcanic rocks
Mzi	Mesozoic intrusive rocks

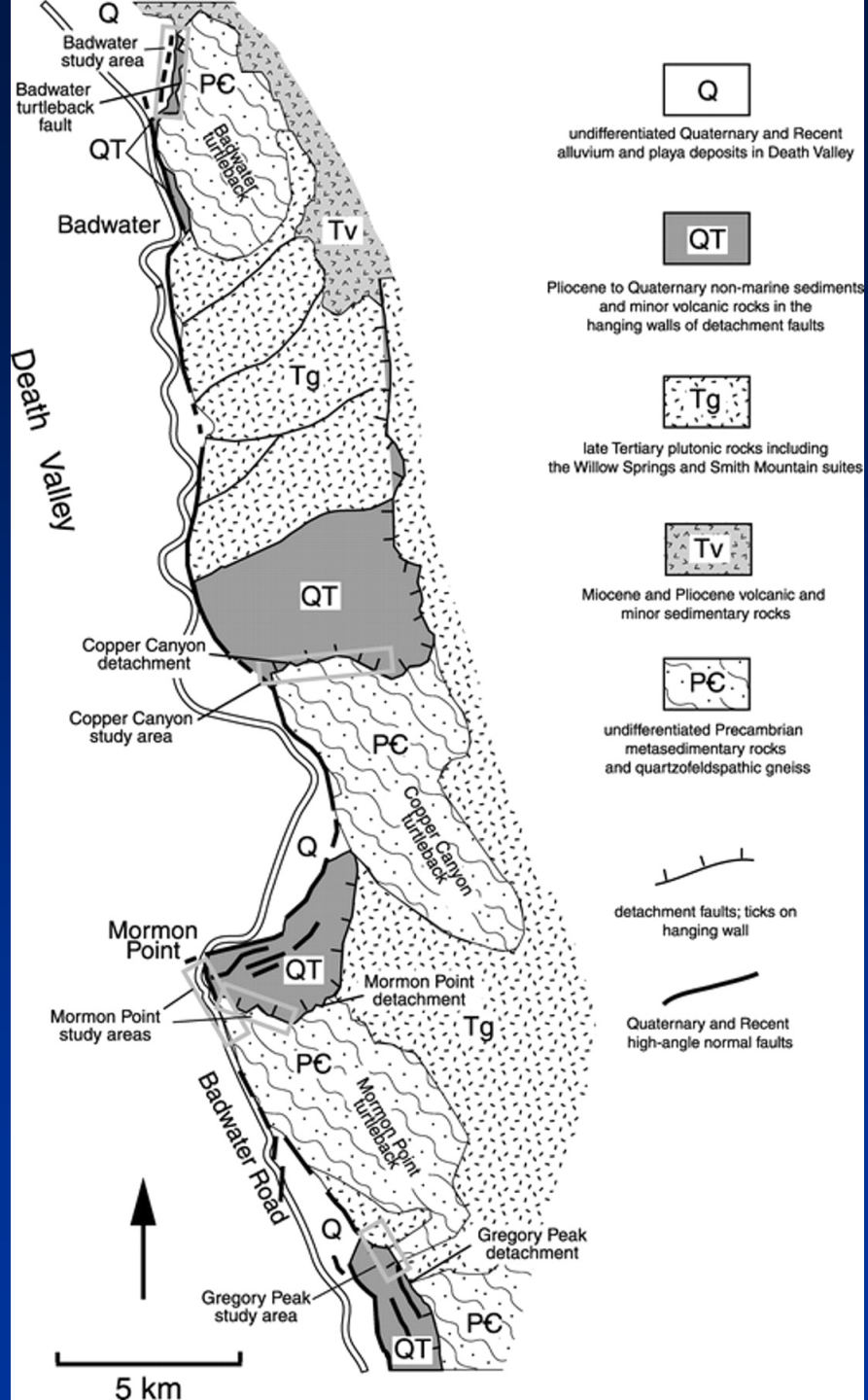
## Metamorphic Rocks

pC	Precambrian gneiss
----	--------------------



Da Bryant Miller M.

Valle della morte  
(Basin & Range)



Q

undifferentiated Quaternary and Recent alluvium and playa deposits in Death Valley

QT

Pliocene to Quaternary non-marine sediments and minor volcanic rocks in the hanging walls of detachment faults

Tg

late Tertiary plutonic rocks including the Willow Springs and Smith Mountain suites

Tv

Miocene and Pliocene volcanic and minor sedimentary rocks

PC

undifferentiated Precambrian metasedimentary rocks and quartzofeldspathic gneiss

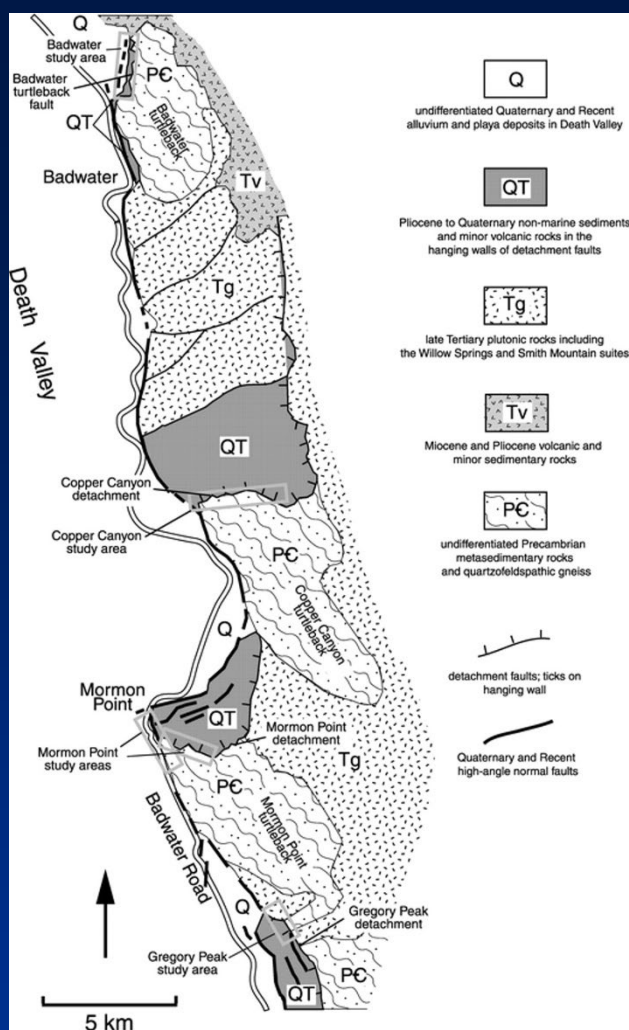


detachment faults; ticks on hanging wall

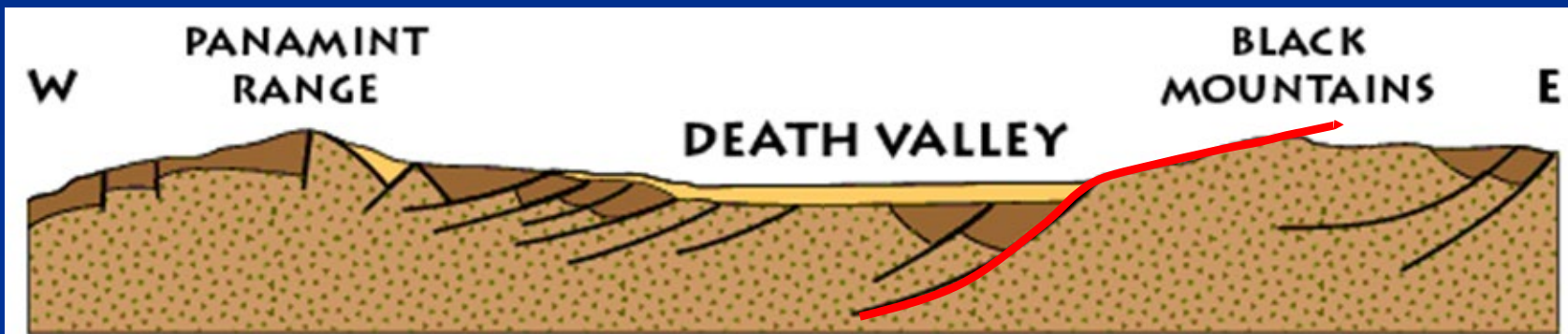


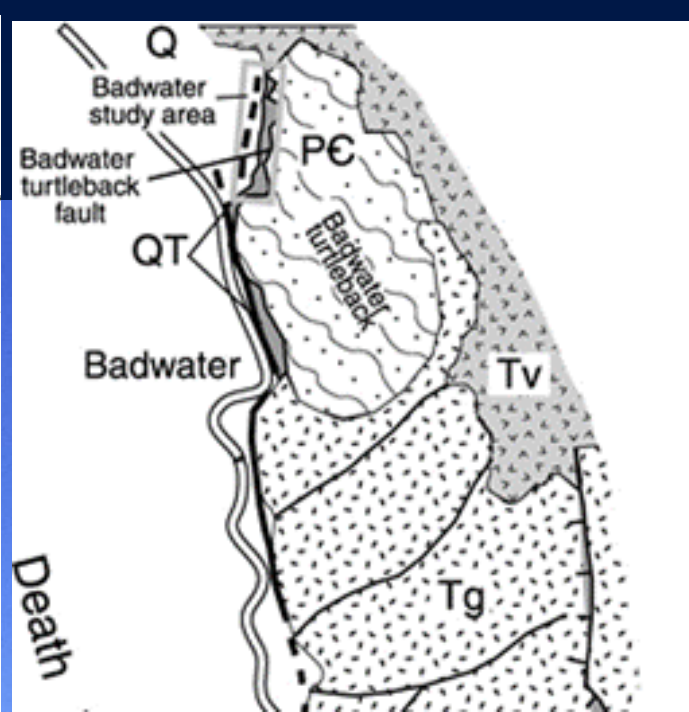
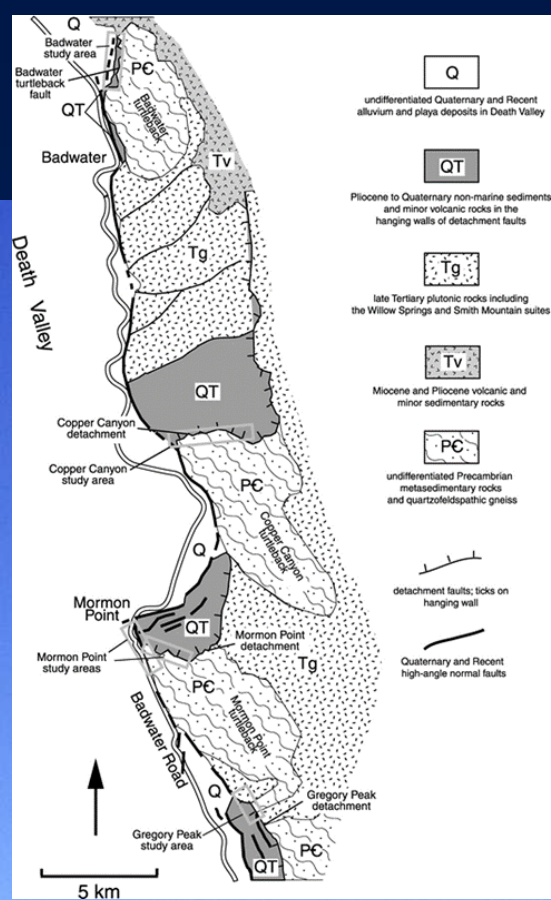
Quaternary and Recent high-angle normal faults

5 km



USGS Geology of Death Valley National Park

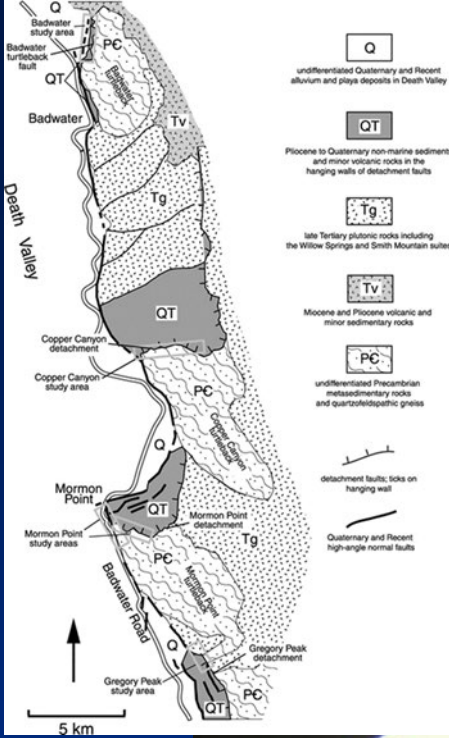




# Badwater Turtleback normal fault



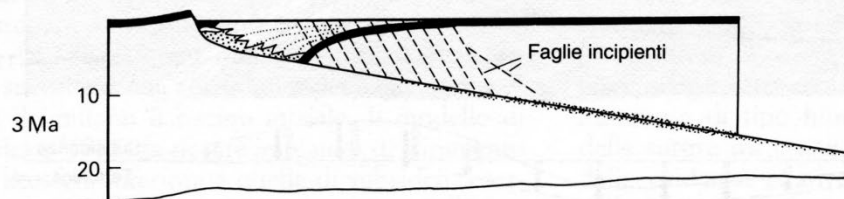
# Badwater Turtleback normal fault: Copper Canyon fault zone



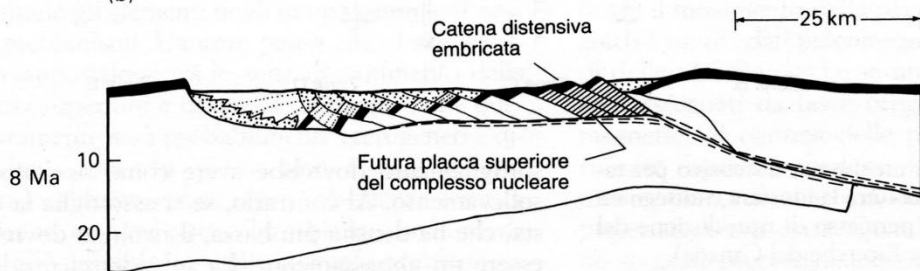
Tempo a  $5 \text{ mm a}^{-1}$



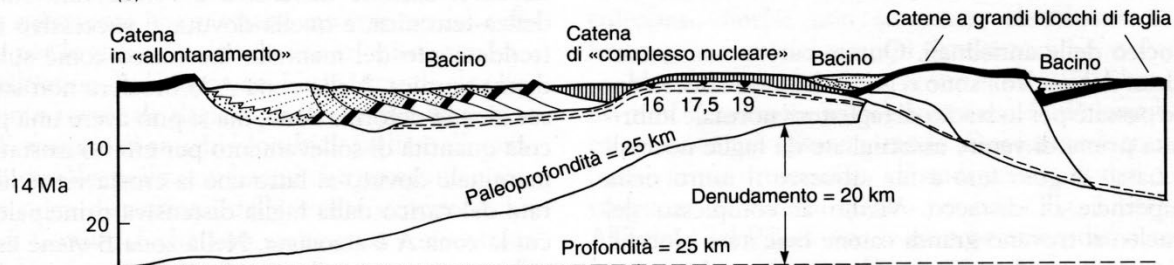
(a)  $\leftarrow 15 \text{ km} \rightarrow$



(b)



(c)

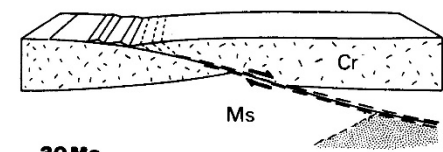


(d)

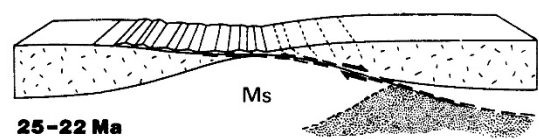
- Riferimento pre-orogenico
- Depositi clastici orogenici: fini-lacustri grossolani
- Rocce molto assottigliate e stirate
- Zona di taglio duttile
- 16,5 Paleopropfondità della placca inferiore del «complesso nucleare»

Estensione totale = 72 km (100%)

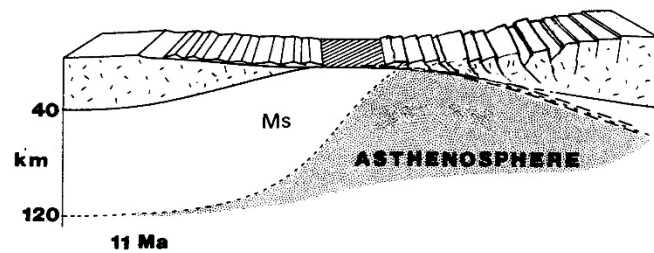
SW NE



30 Ma

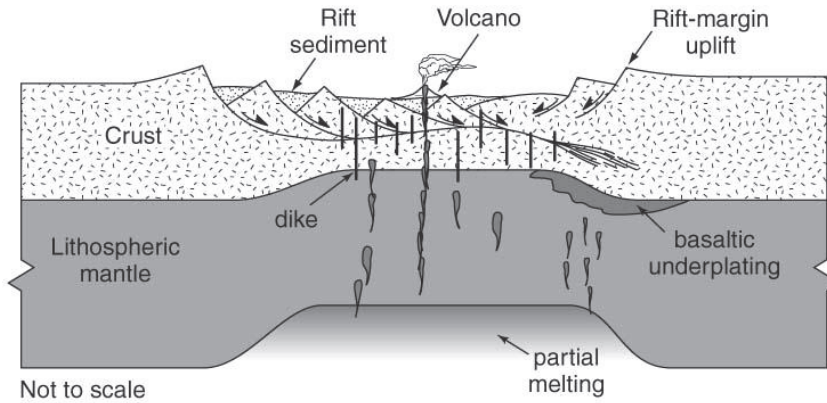


25-22 Ma

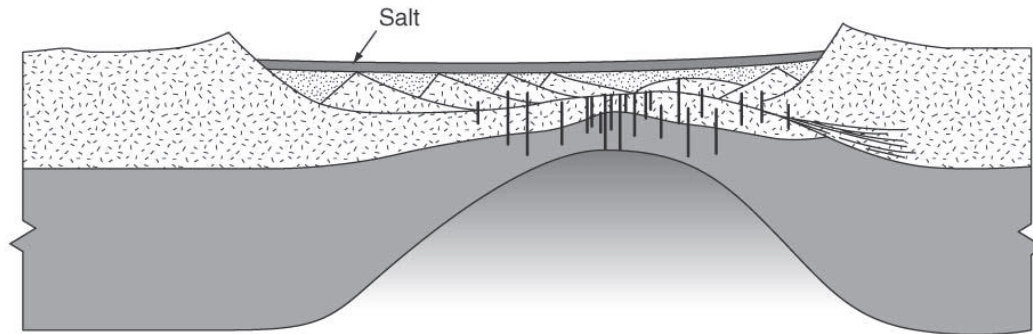


11 Ma

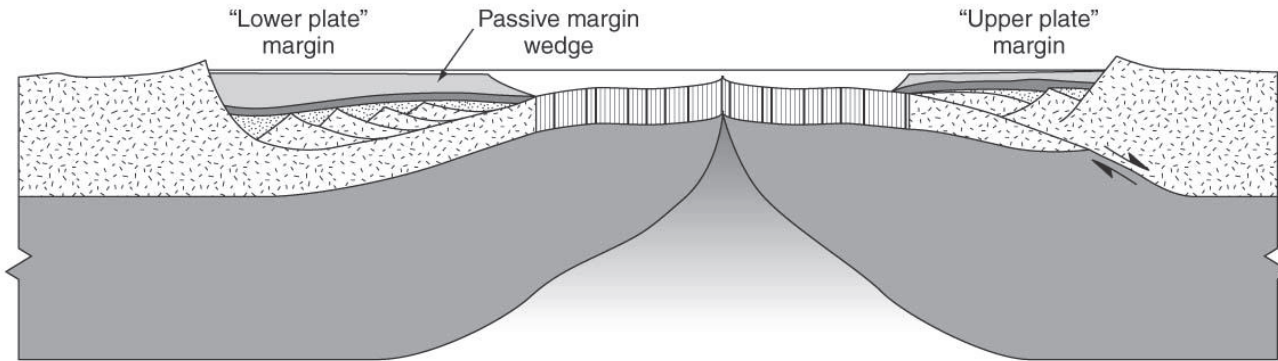
Da van der Pluijm & Marshak, 2004



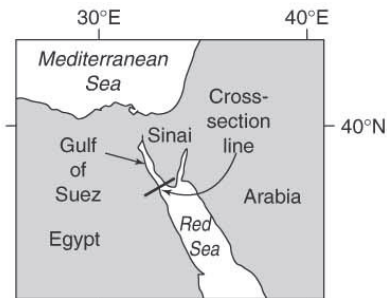
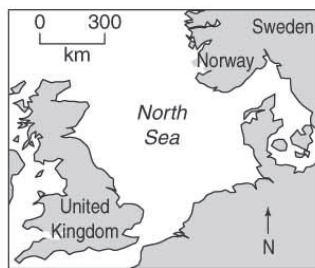
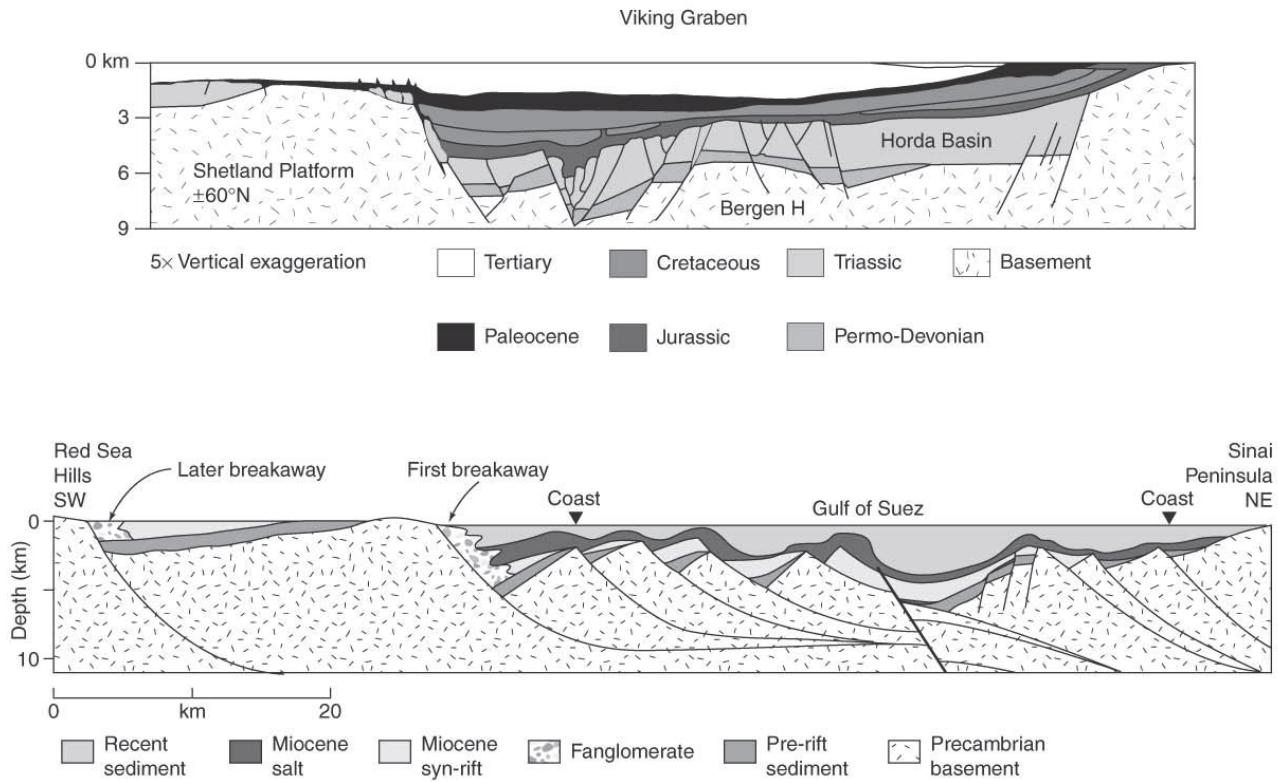
(a)



(b)



(c)



Da van der Pluijm & Marshak, 2004



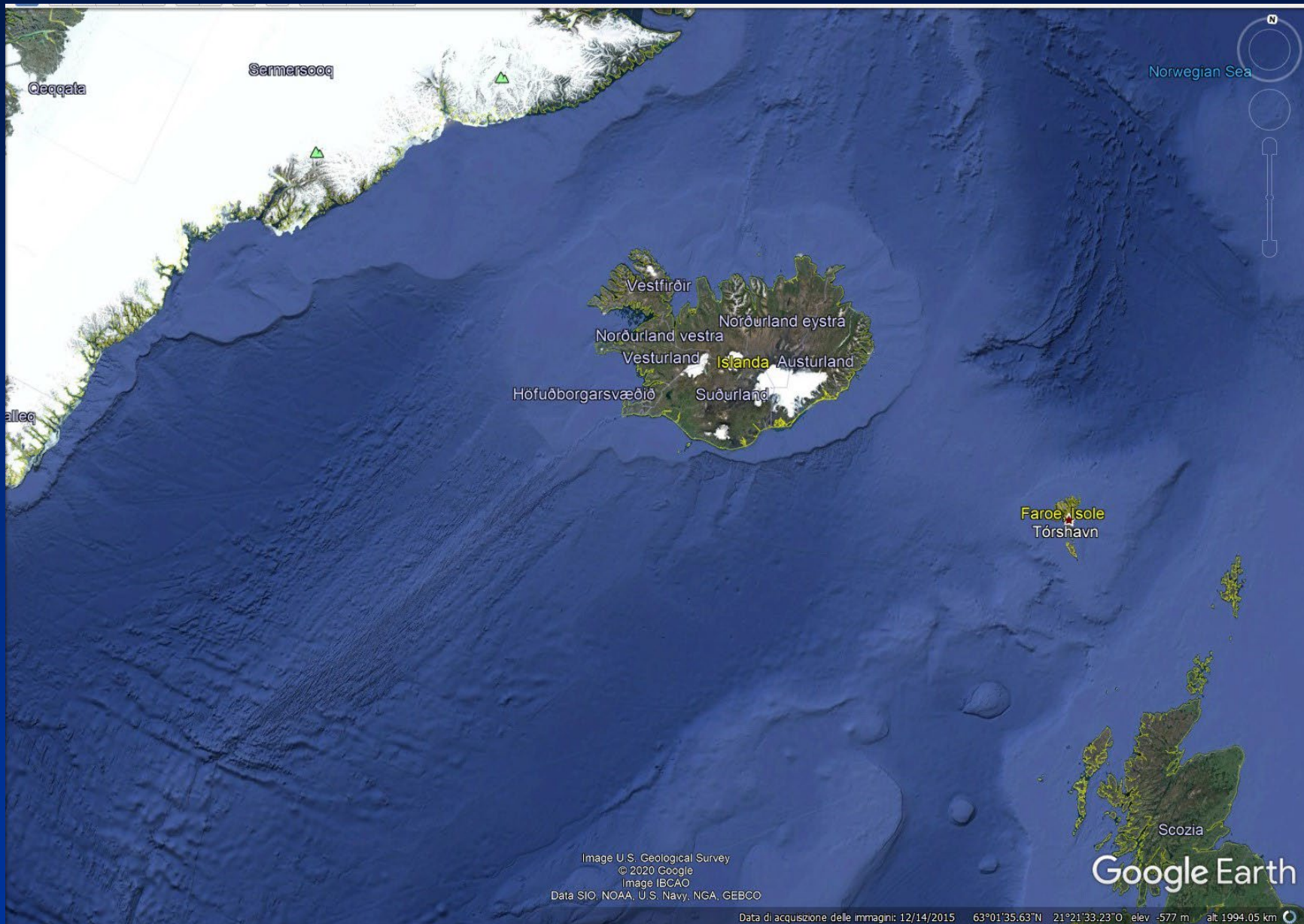
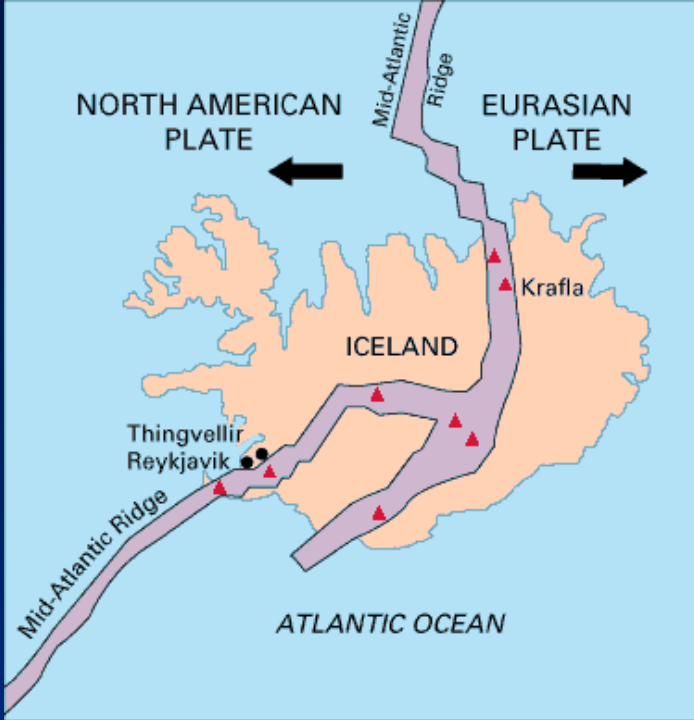


Image U.S. Geological Survey  
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Image IBCAO  
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

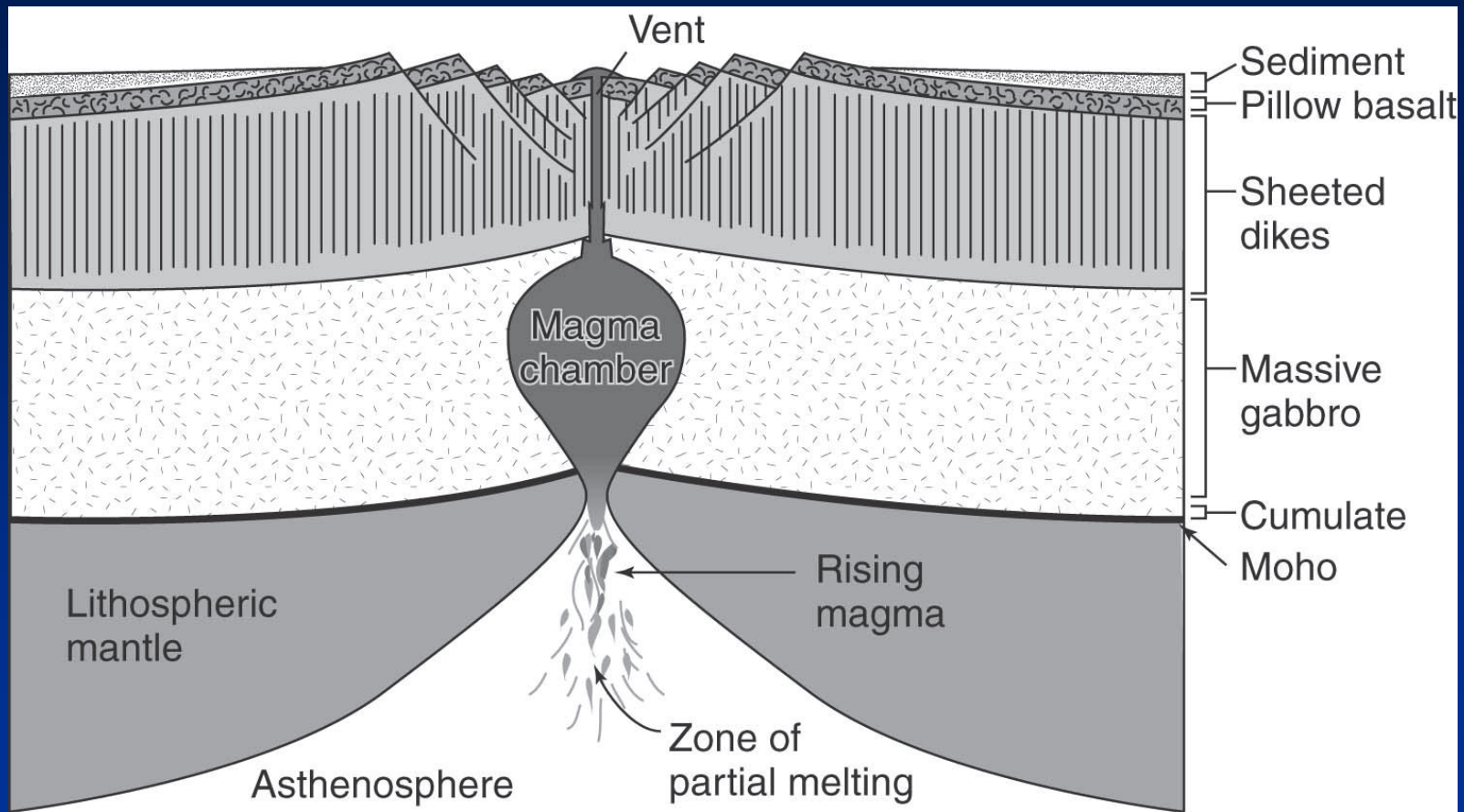
Google Earth

USGS:  
<https://pubs.usgs.gov/gip/dynamic/understanding.html>

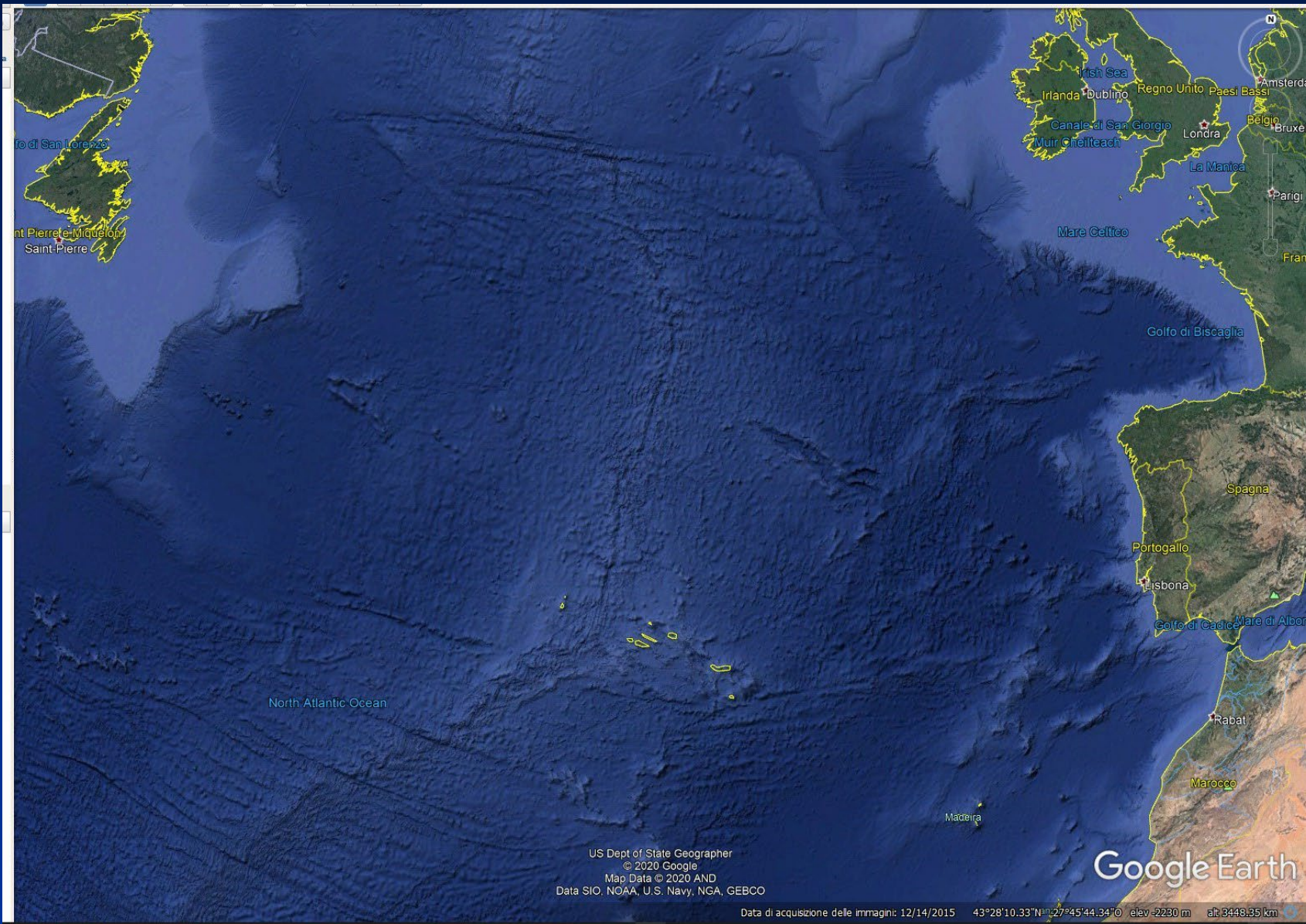


Thingvellir National Park, Iceland

[https://commons.wikimedia.org/wiki/File:Iceland\\_mid\\_atlantic\\_ridge.JPG](https://commons.wikimedia.org/wiki/File:Iceland_mid_atlantic_ridge.JPG)



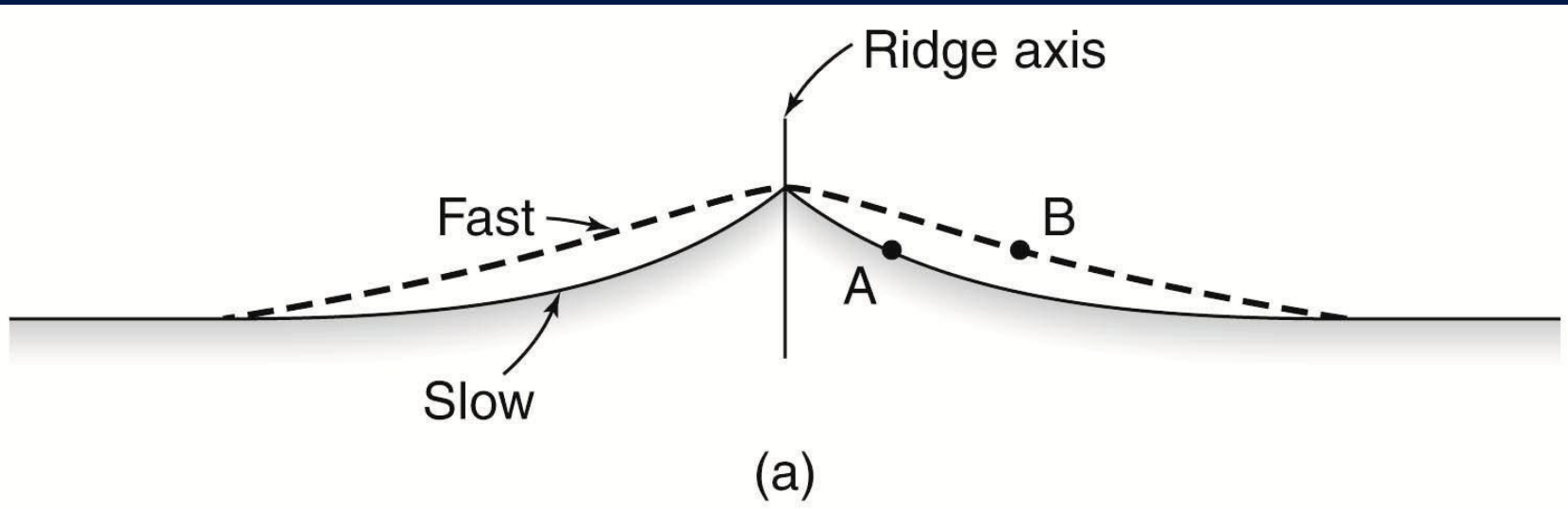
Da van der Pluijm & Marshak, 2004



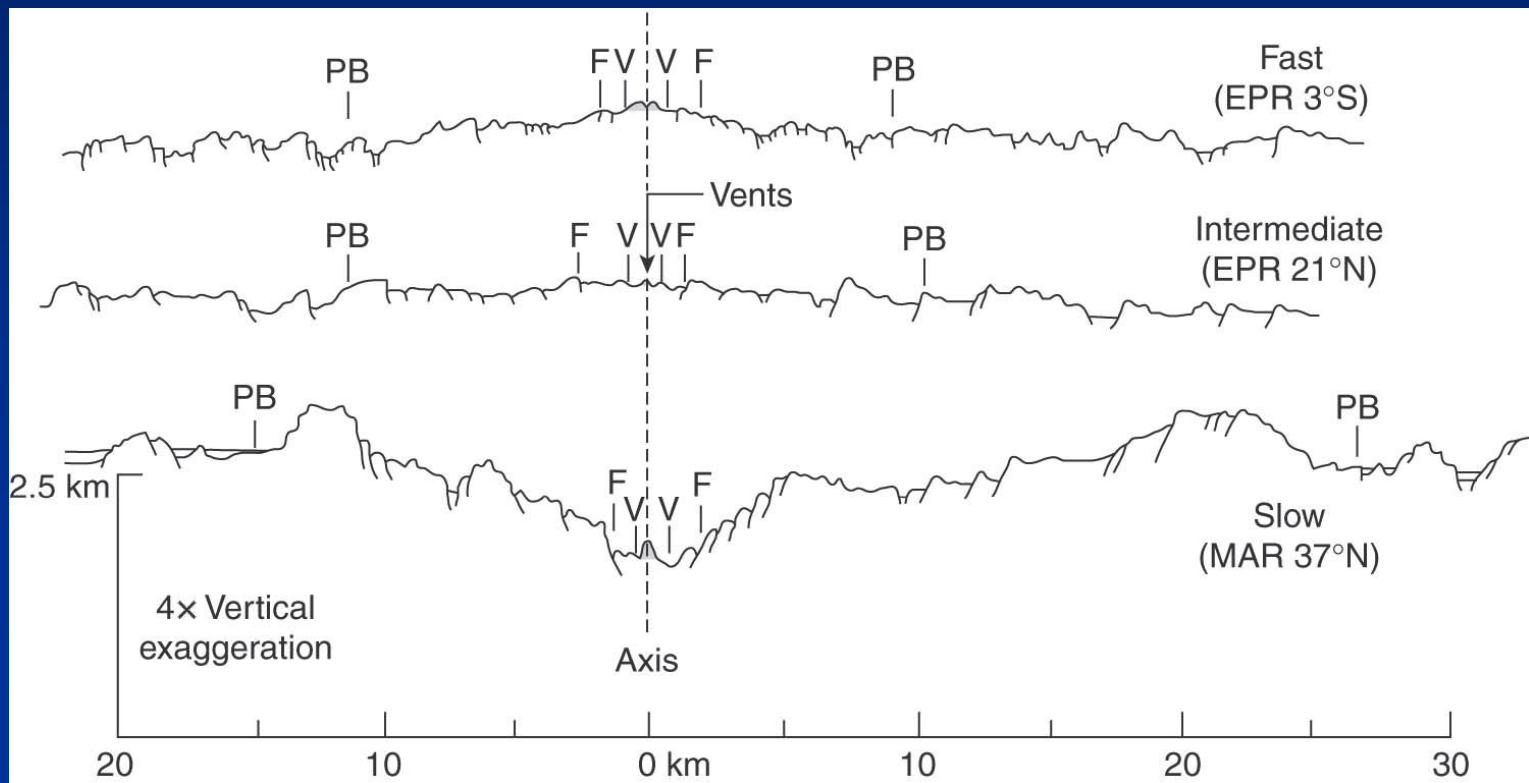
US Dept of State Geographer  
© 2020 Google  
Map Data © 2020 AND  
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Google Earth

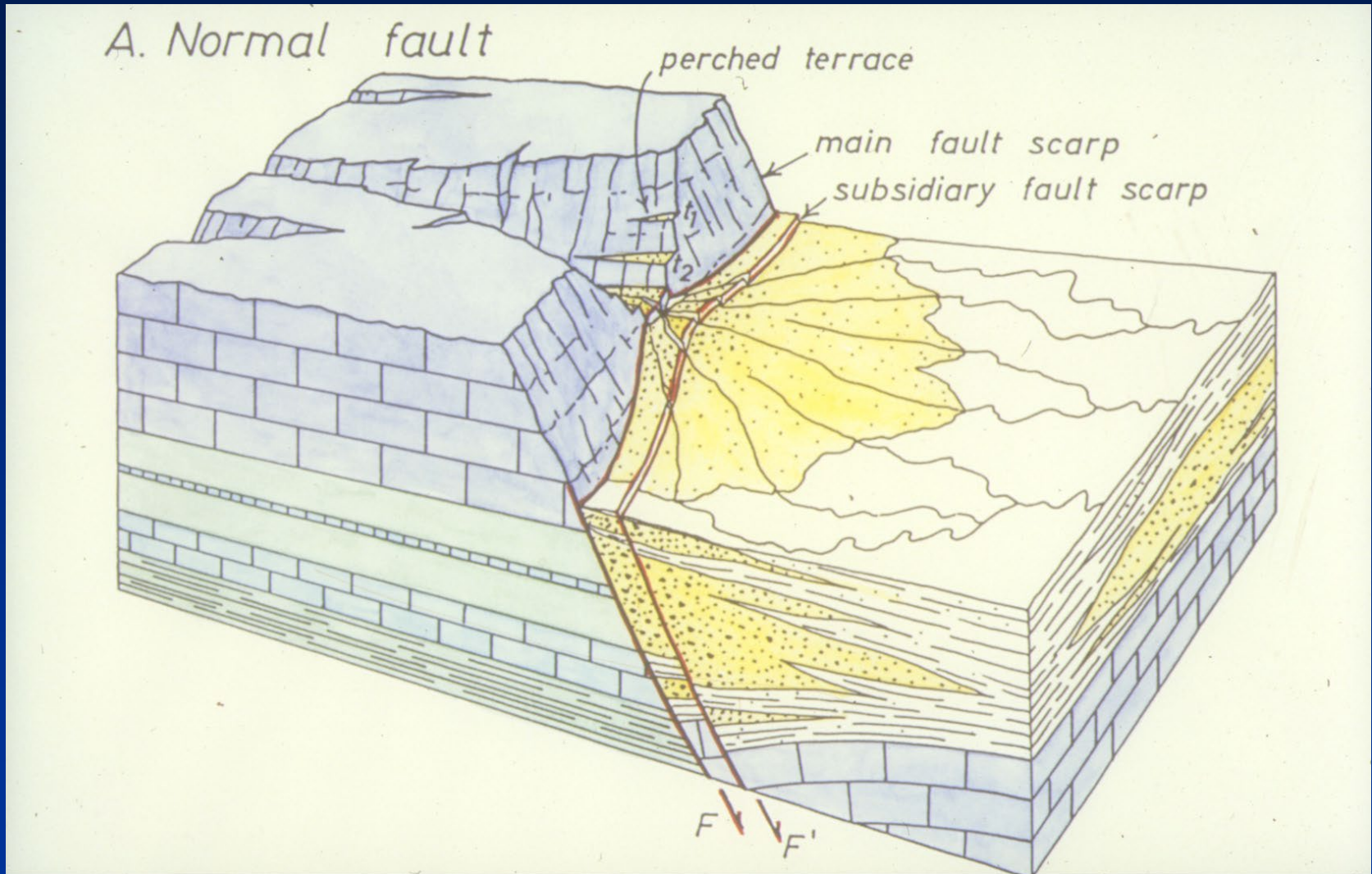
Data di acquisizione delle immagini: 12/14/2015 43°28'10.33"N 127°45'44.34"O elev -2230 m alt 3448.35 km



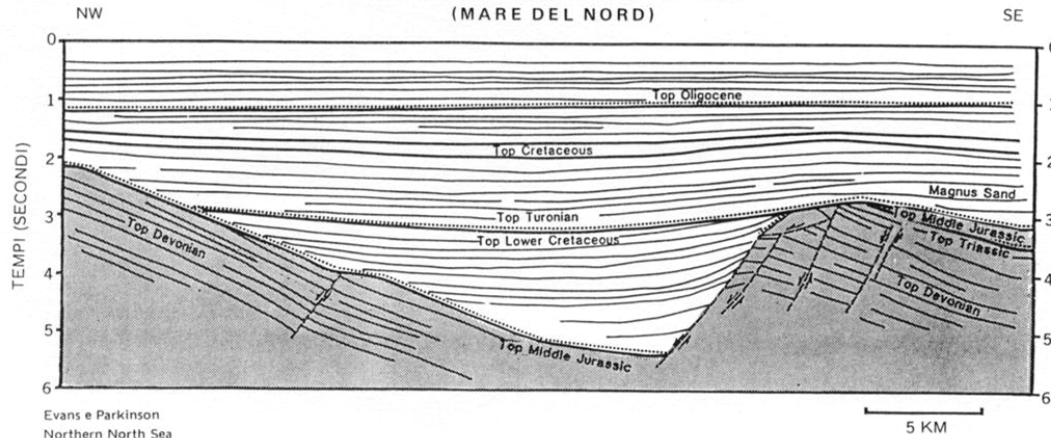
Da van der Pluijm & Marshak, 2004



Faglia normale associata ad erosione (letto) e deposizione (sul lembo di tetto). La forma del bacino sedimentario e la stratigrafia dei depositi è controllata dalla attività della faglia



SEMIGRABEN DEL NORD SHETLAND  
(MARE DEL NORD)

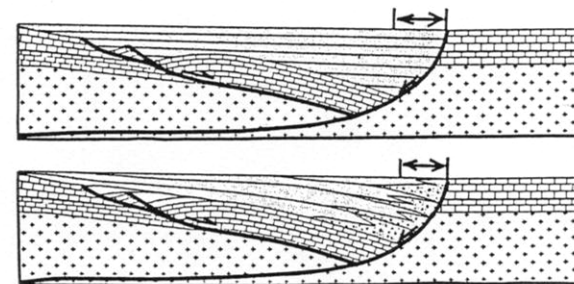
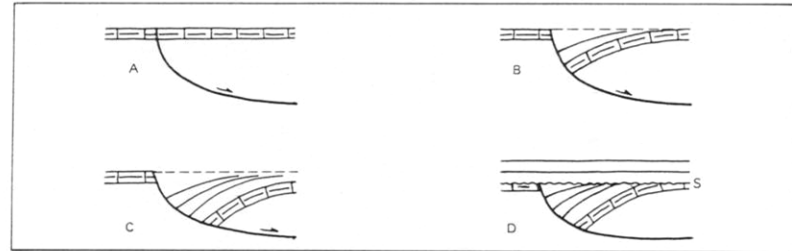


Evans e Parkinson  
Northern North Sea  
AAPG Studies in Geology Series 15 II (2.2.2 - 9)

Velocità di attivazione della faglia elevata, basso tasso di sedimentazione

Da Bally et al., 1985

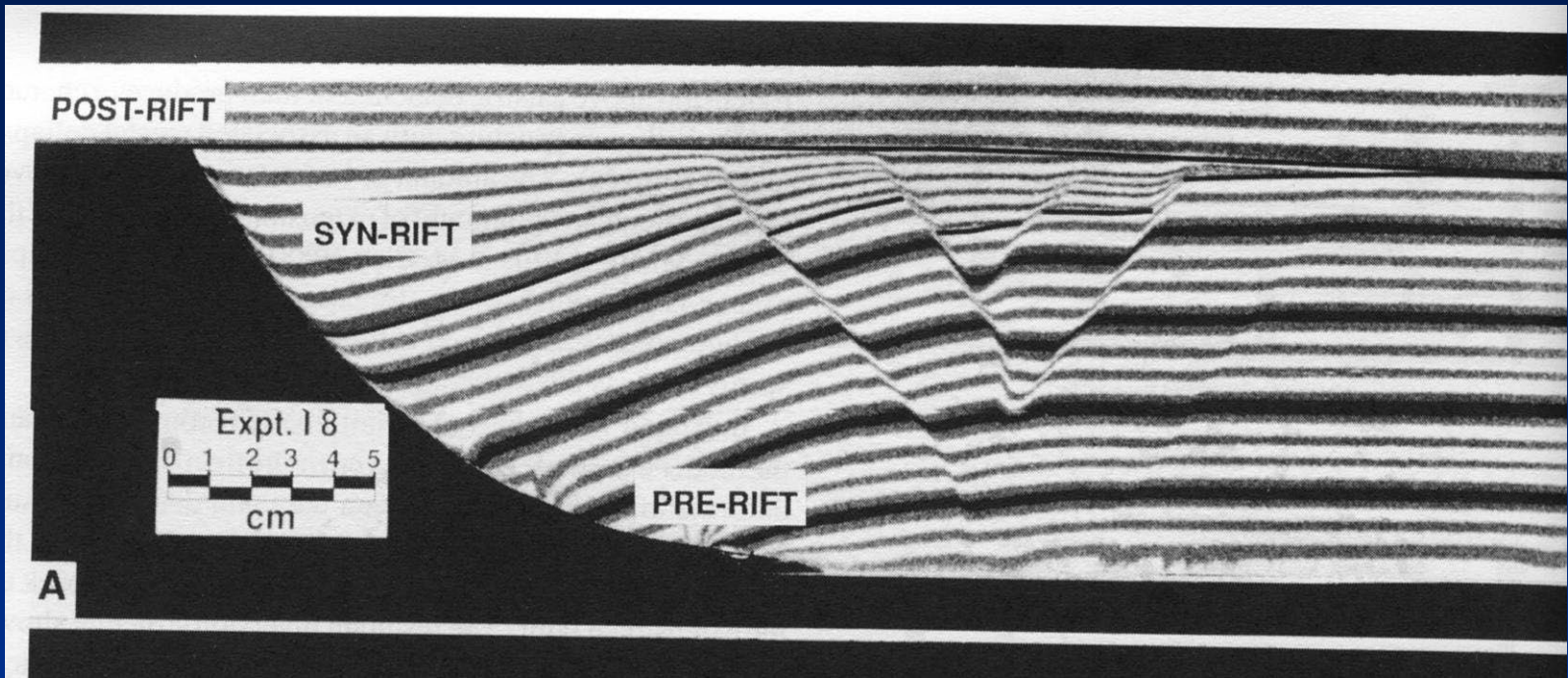
Tasso di sedimentazione elevato, movimento della faglia protratto nel tempo.



I due casi precedenti a confronto

Da Bally et al., 1985

Depositi di pre-, sin- e post-rift.



Da Buchanan & McClay, 1991