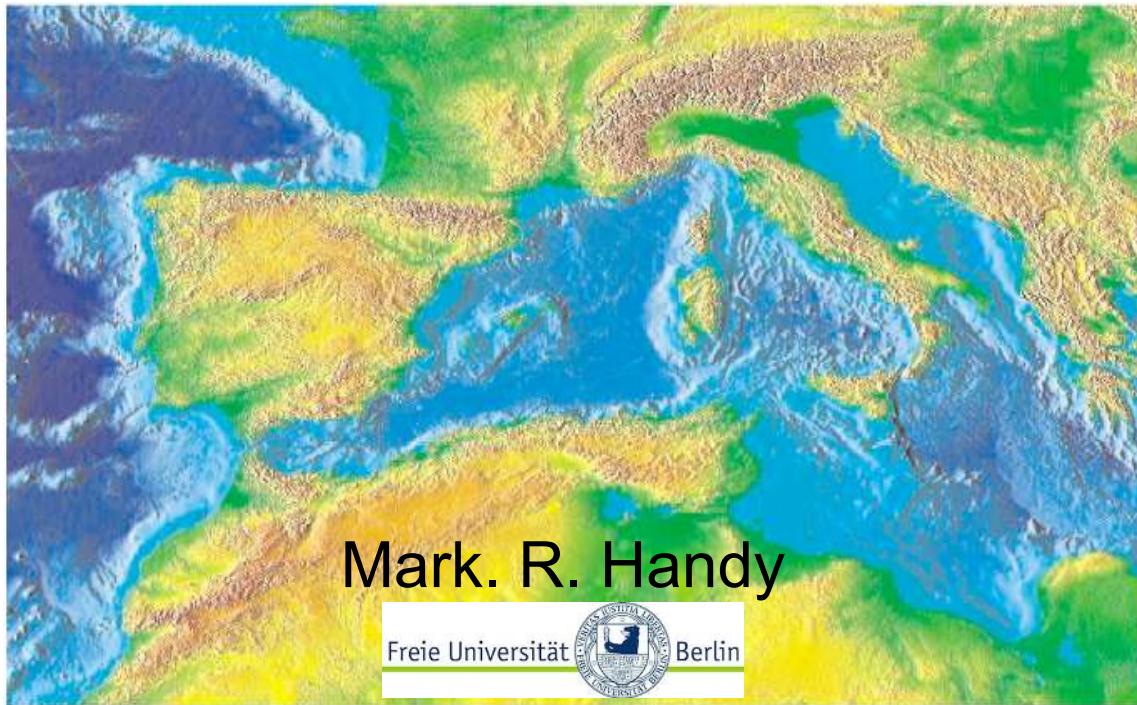


# Understanding the Alpine Mediterranean chains

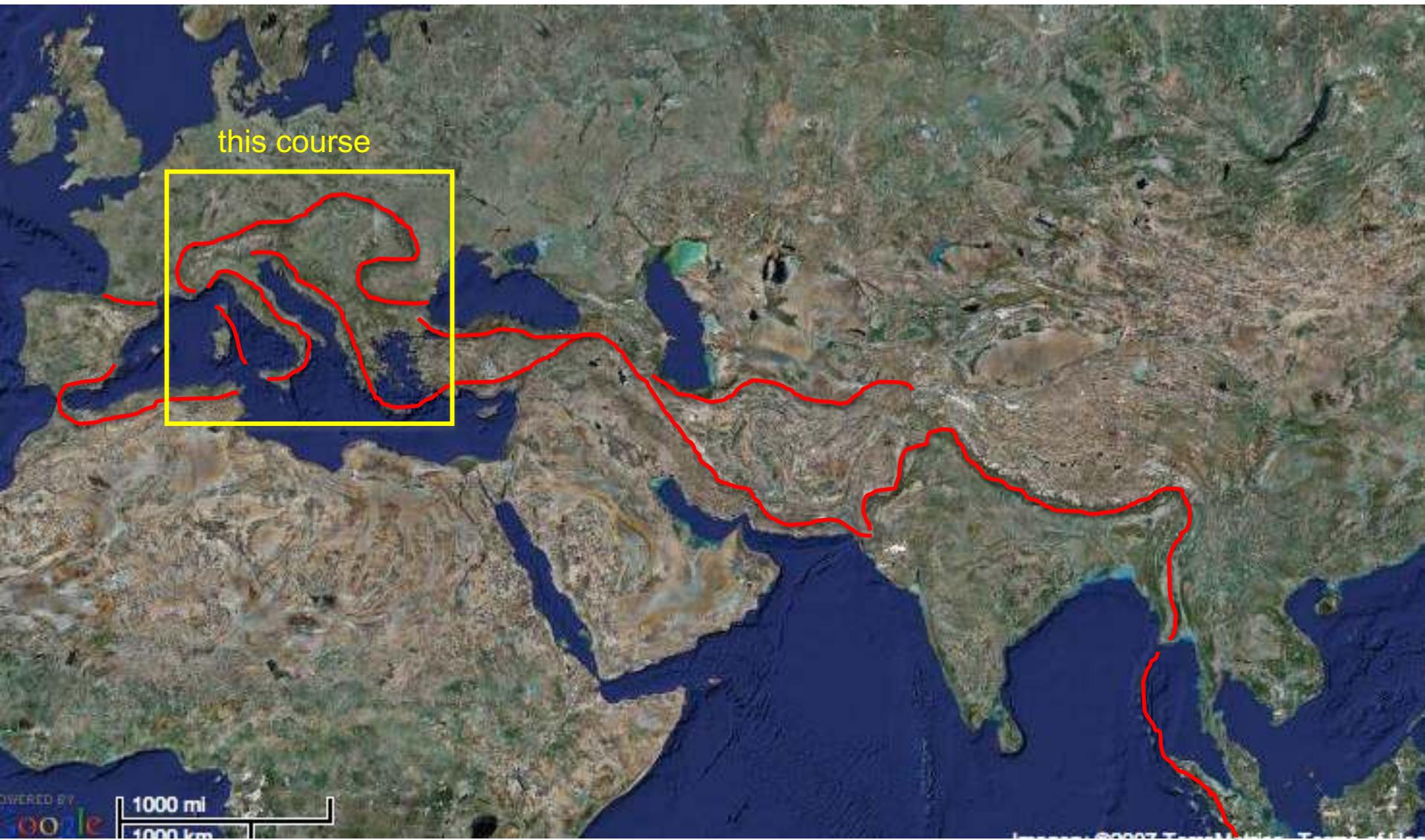
## Introduction



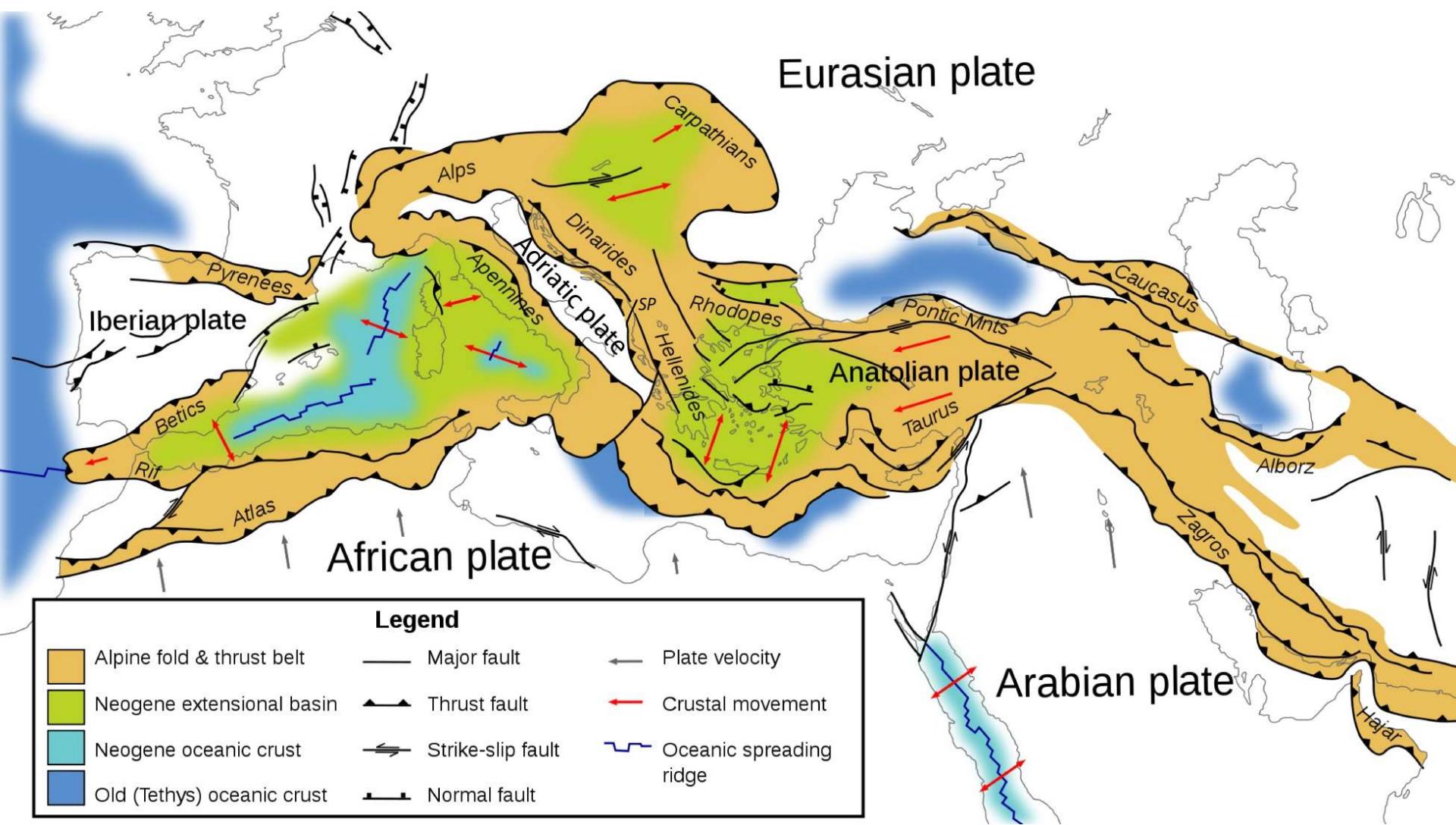
# Outline

- Mountains belts and basins
- Tectonic plates
- Oceans
- Deep structure
- Seismicity

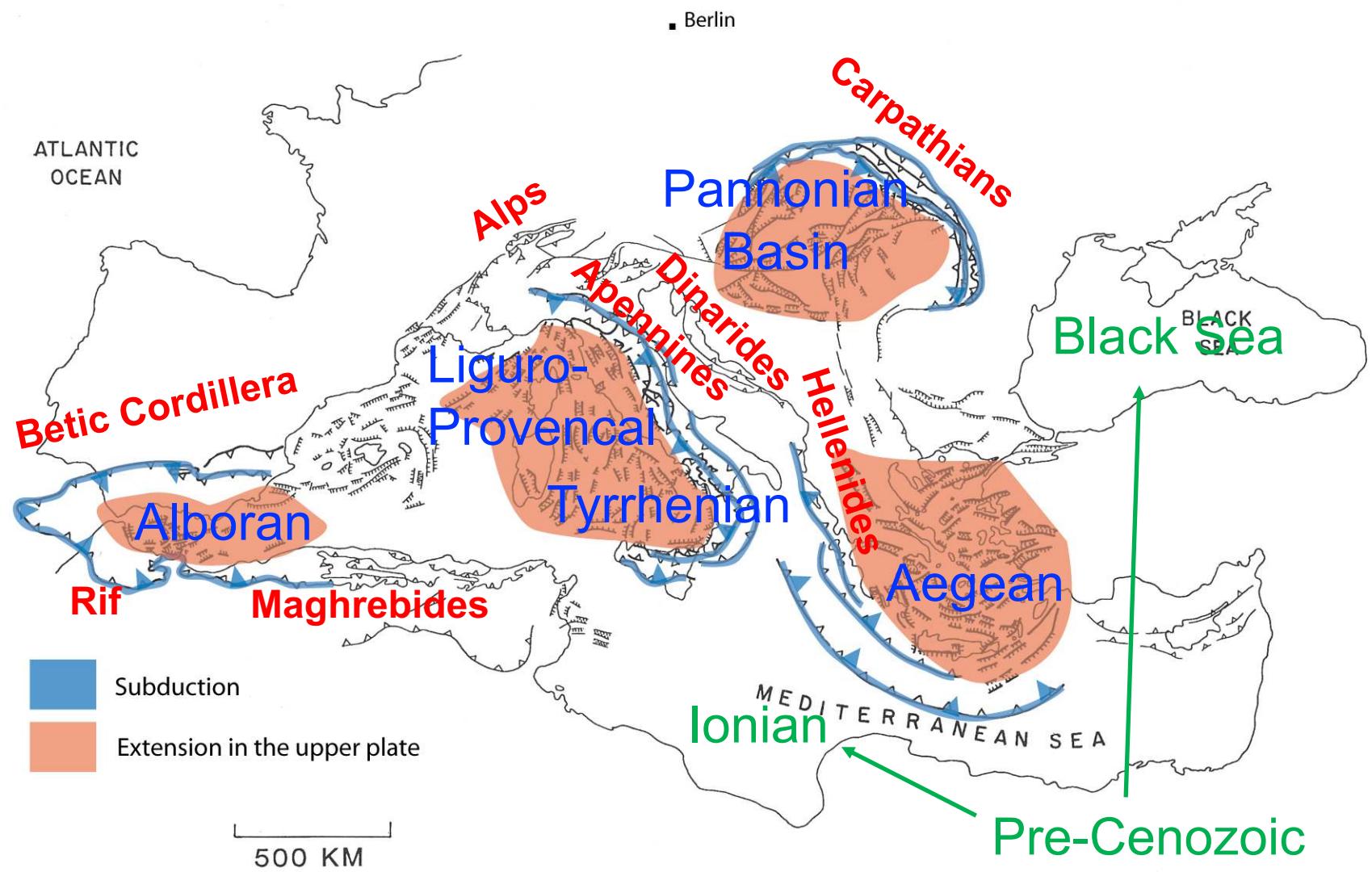
# Alps-Himalayas



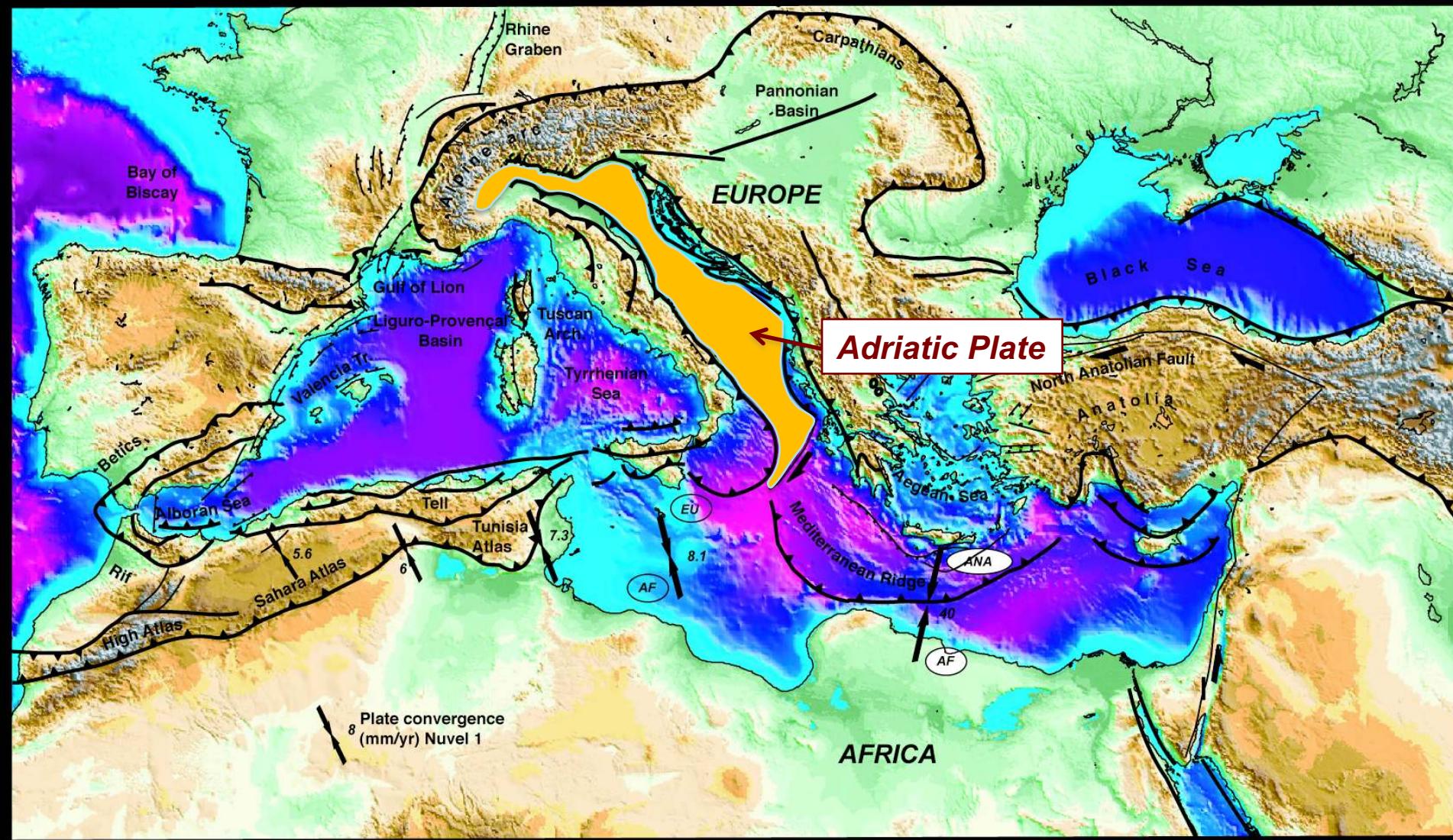
# Mediterranean plates & subduction directions



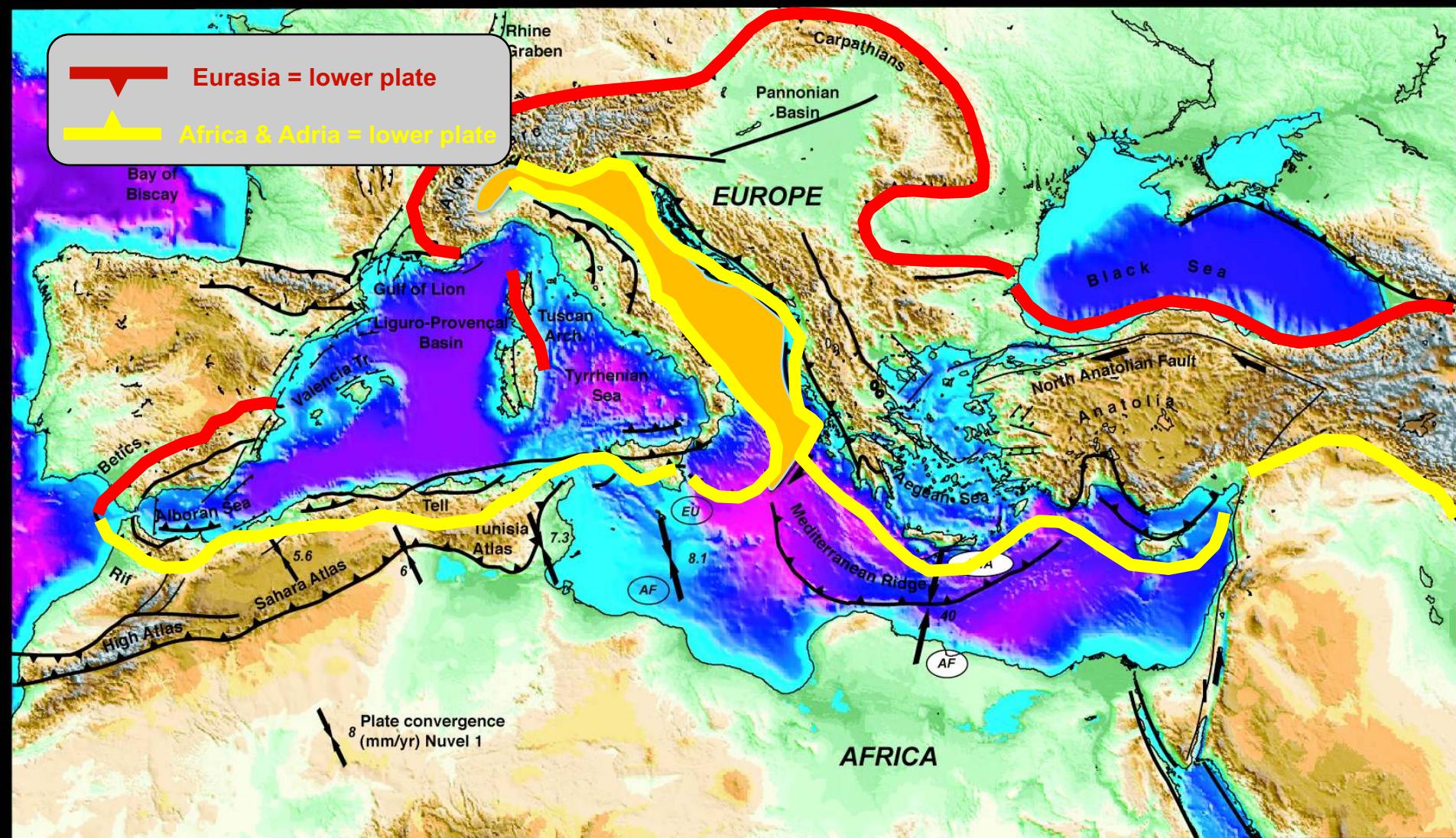
# Cenozoic orogens & basins



# Tectonic plates & their boundaries today

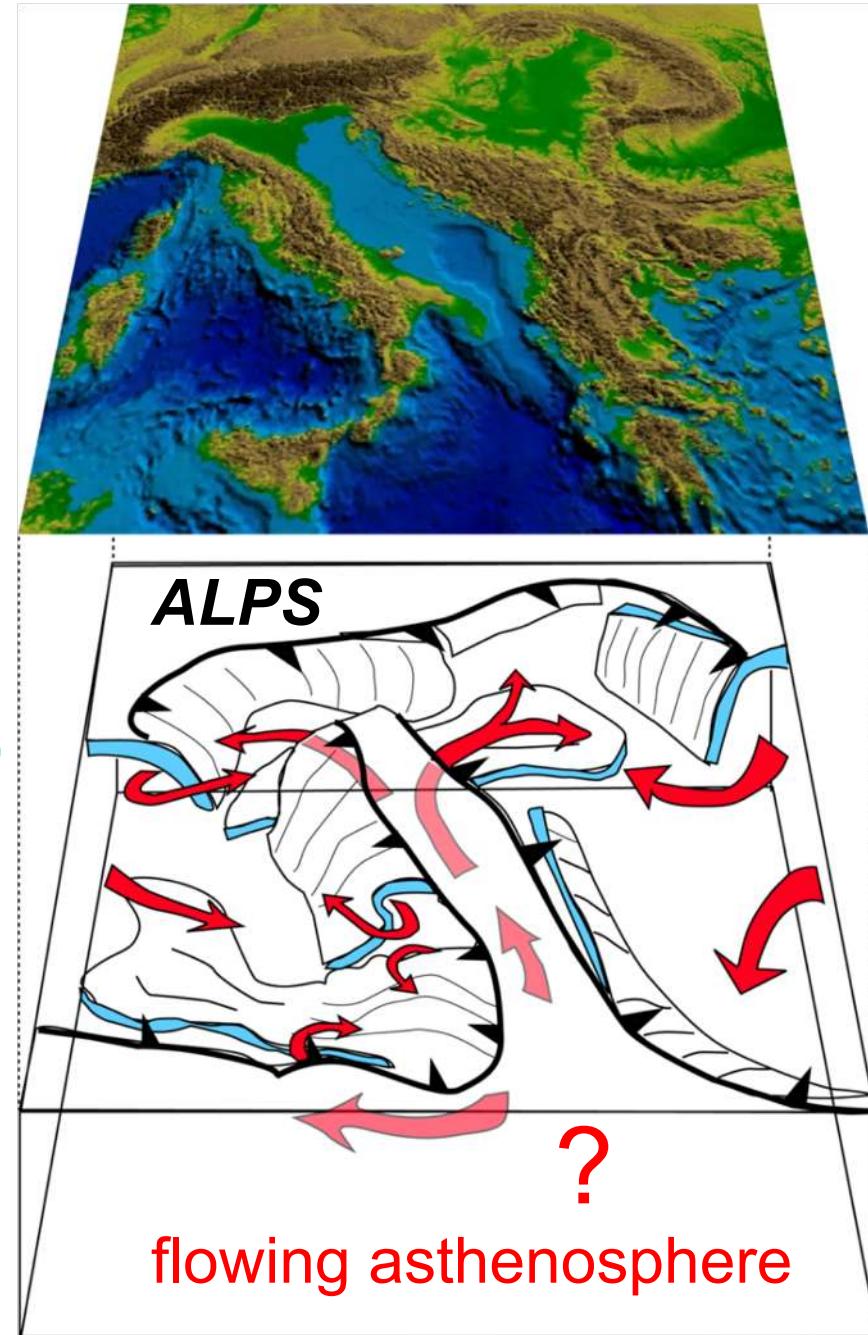


# Tectonic plates & subduction polarities

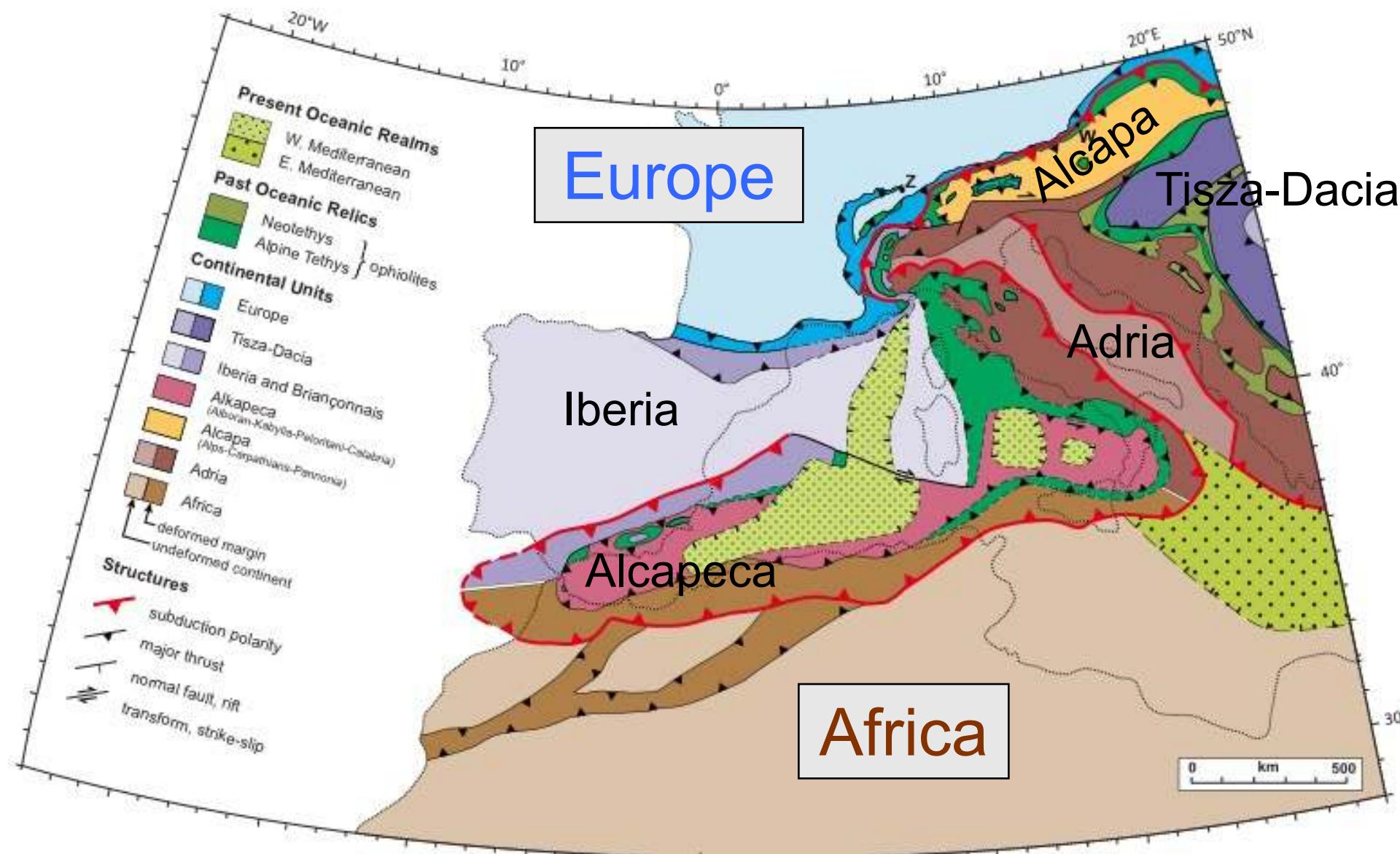


# Mantle structure

subducting lithosphere (slabs)



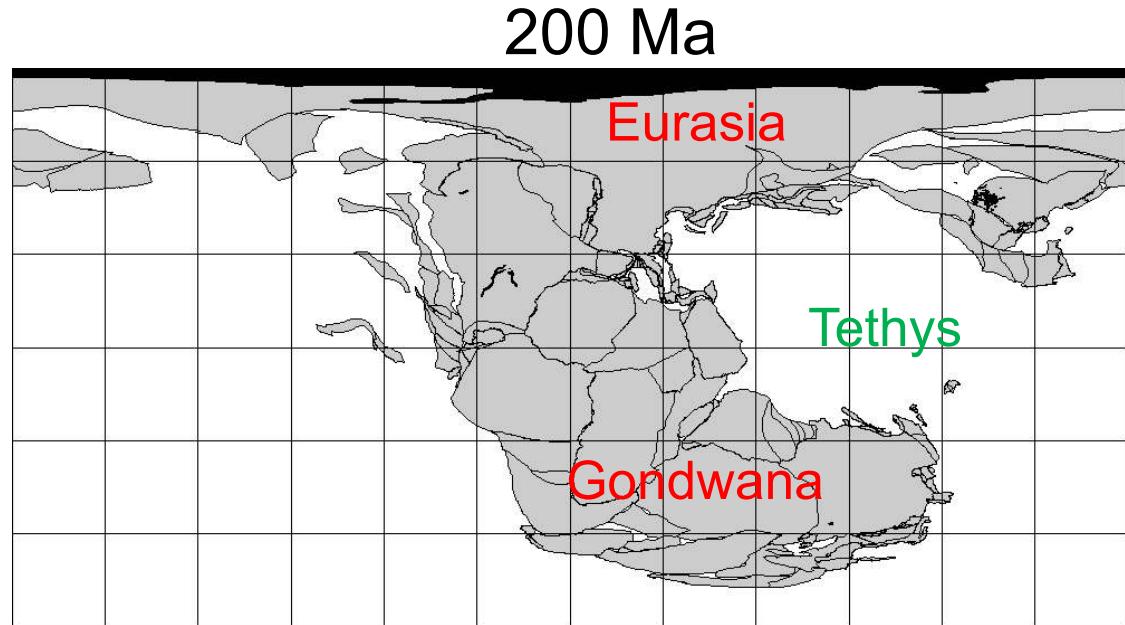
# Mesozoic & Cenozoic plates and microplates



# Tethys



Tethys: goddess of the seas, sister & wife of Oceanus, mother of Achilles and of all rivers

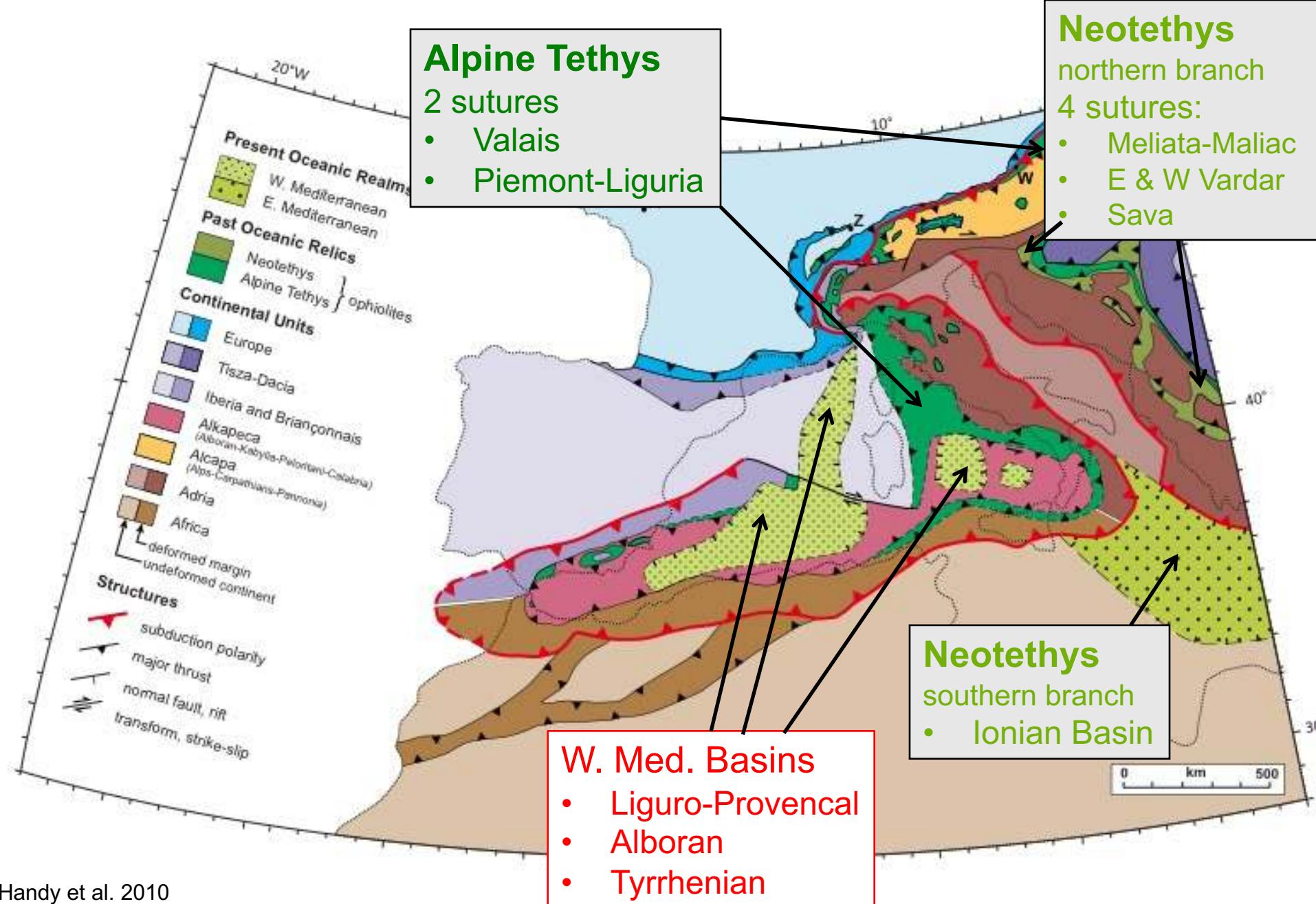


<http://www.serg.unicam.it/Reconstructions.htm>

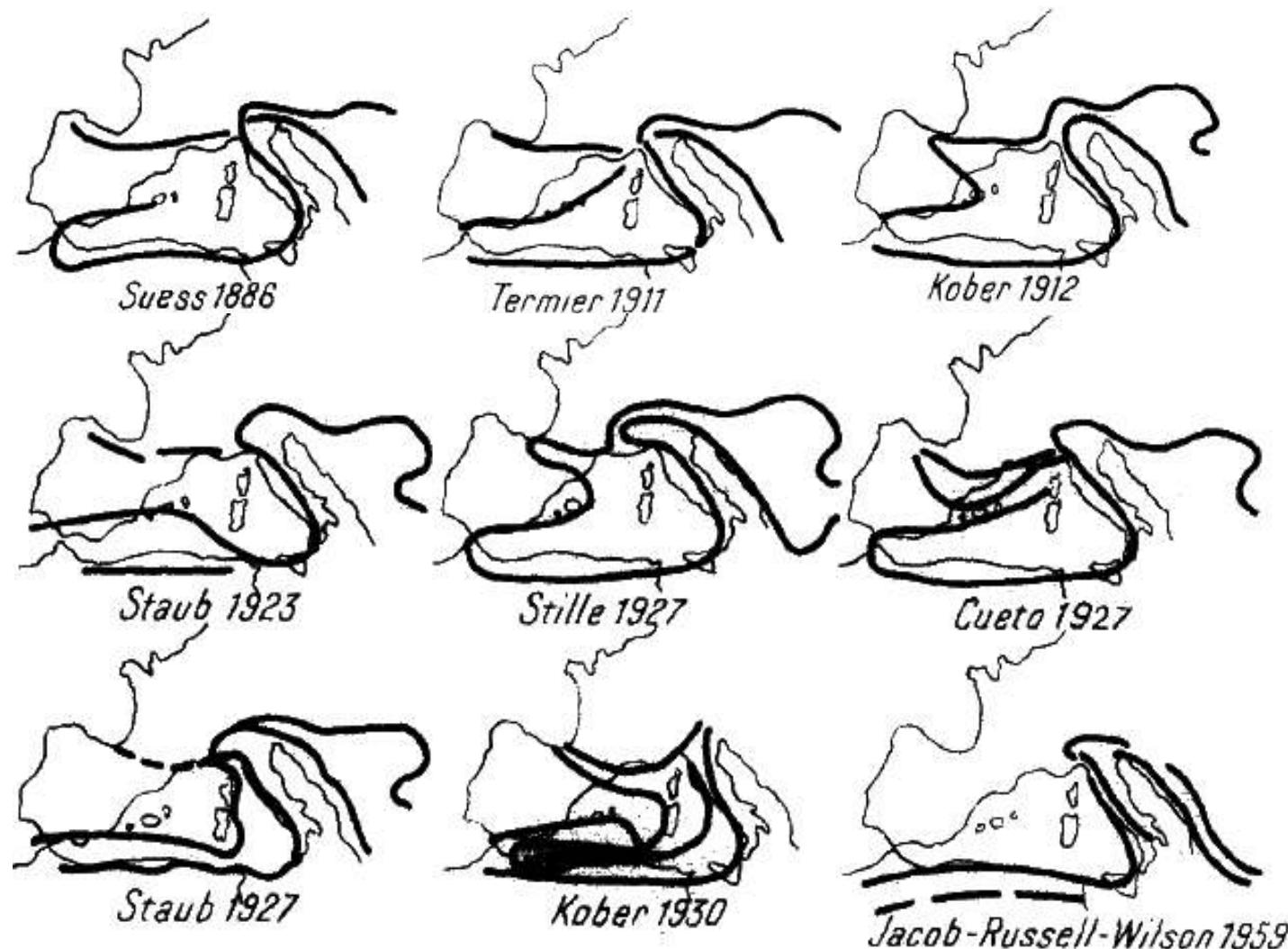
“....the great ocean that once stretched across Eurasia” whose “folded and crumpled deposits stand forth to heaven in Tibet, Himalaya and the Alps”

(E. Suess 1893)

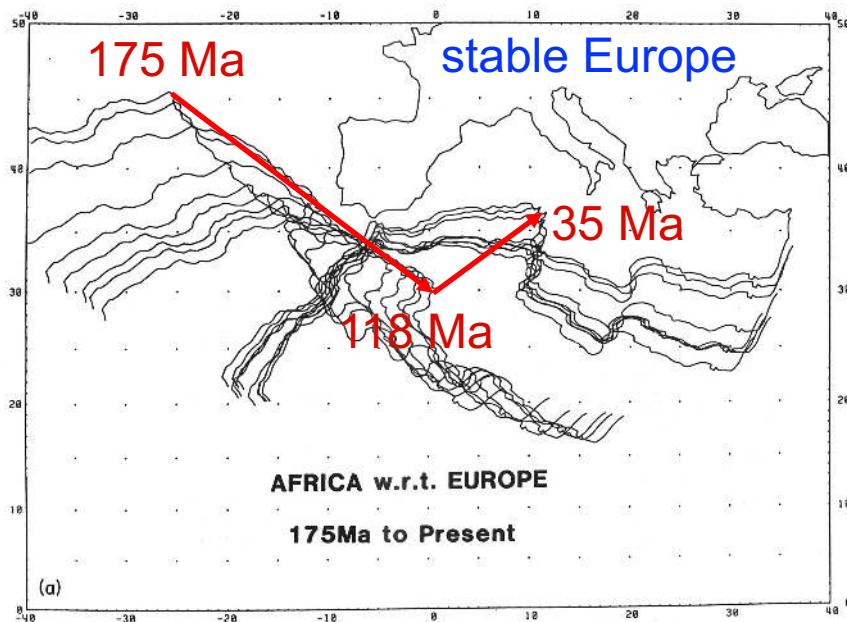
# Past & present ocean basins and sutures



# Past tectonic approaches to the “ocean problem”



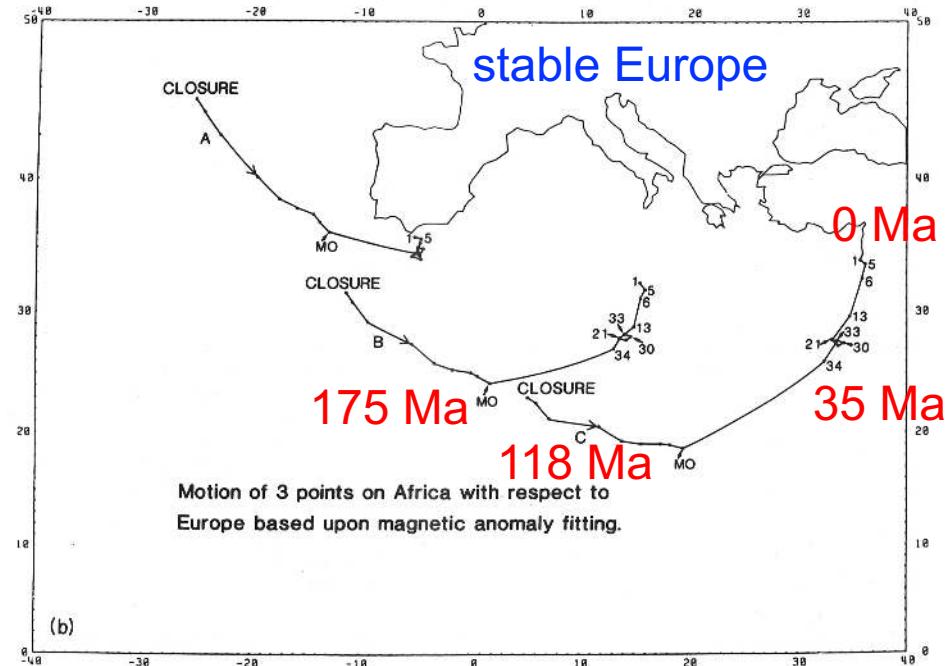
# The Alps as the product of changing plate motion



Dewey et al. 1989

Africa (here includes Adria) moved sinistrally with respect to Europe from 175 to 130-118 Ma, then moved northwards while rotating counterclockwise.

In many models,  
**Adria** considered  
part of Africa from  
175 Ma – Present



# Past oceans – paleogeography

## Alpine Tethys

- Valais
- Piemont
- Liguria

Iberia

future Alps-Carpathians

Dercourt et al. 1986

Neotethys (south)  
• Ionian Sea

future Apennines

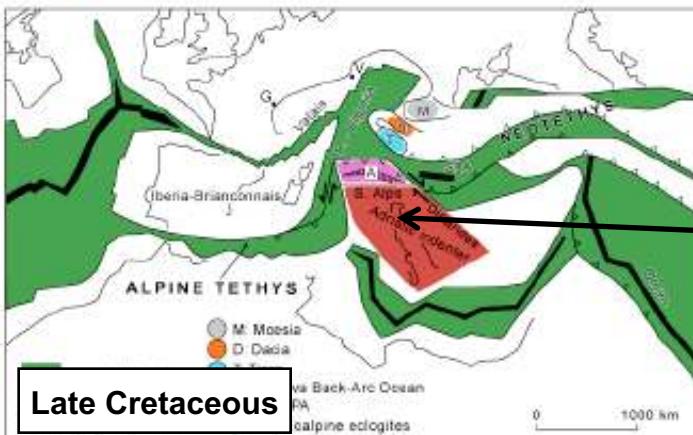
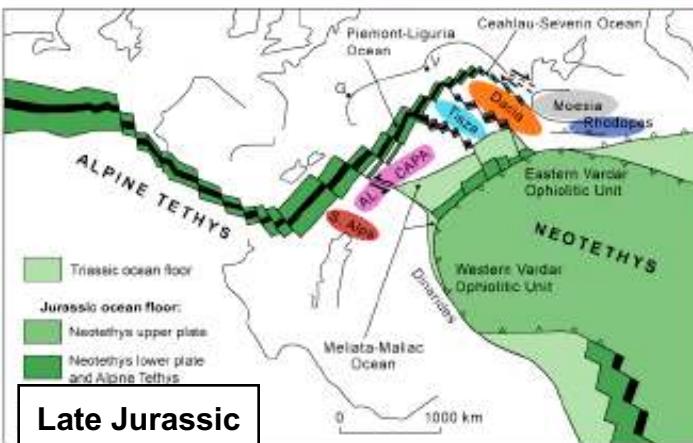
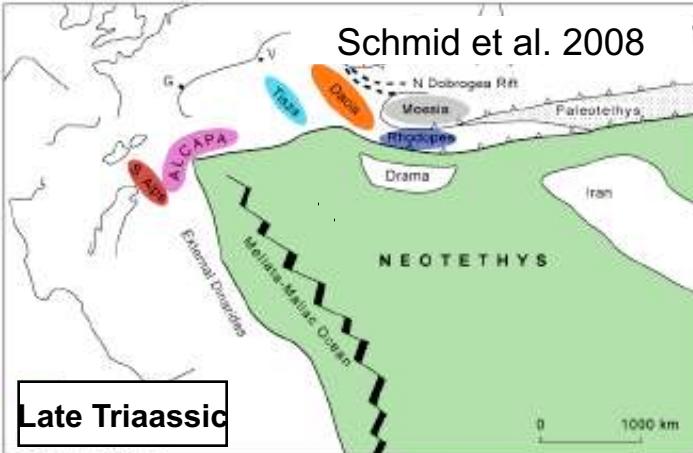
future Dinarides

## Neotethys (north)

- Meliata-Maliac
- W. Vardar

Early Cretaceous, 130 Ma

# Past ocean basins

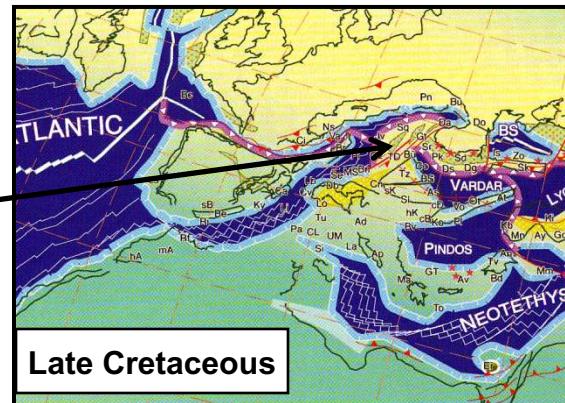
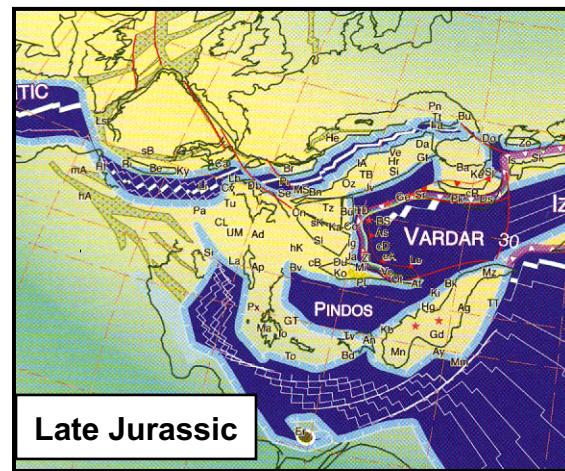
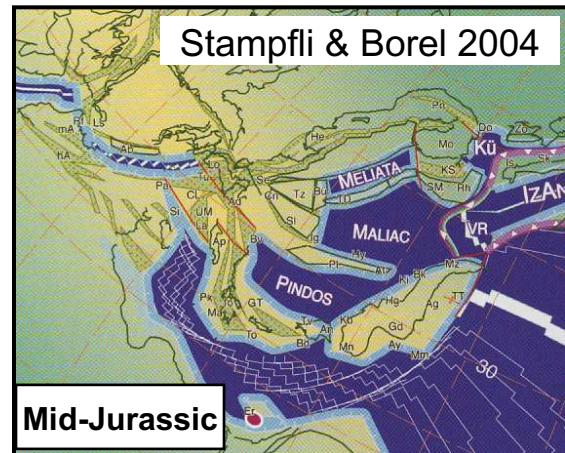


## Neotethys

- Meliata-Maliac
- Vardar

## Alpine Tethys

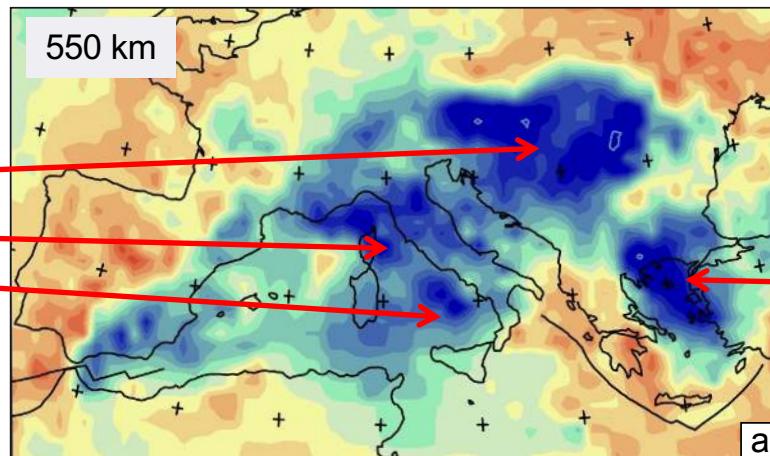
- Piemont-Liguria
- Valais



Adria

# Past oceans & continental margins buried as slabs

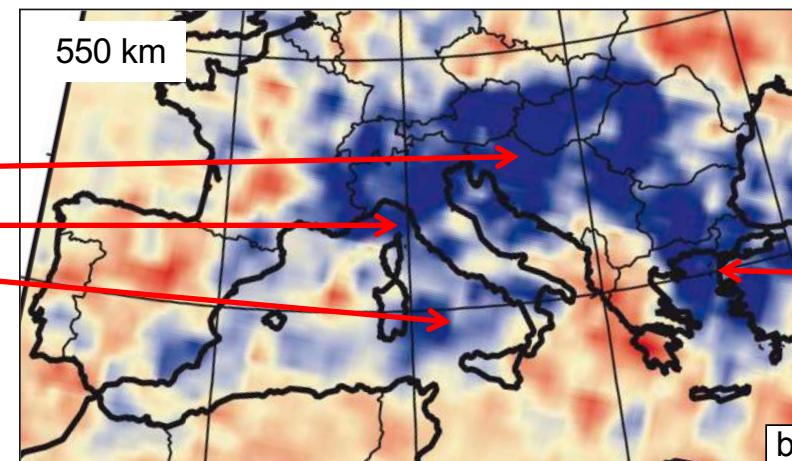
Alpine  
Tethys



P-wave teleseismic  
tomography

Neotethys

a Spakman & Wortel 2004



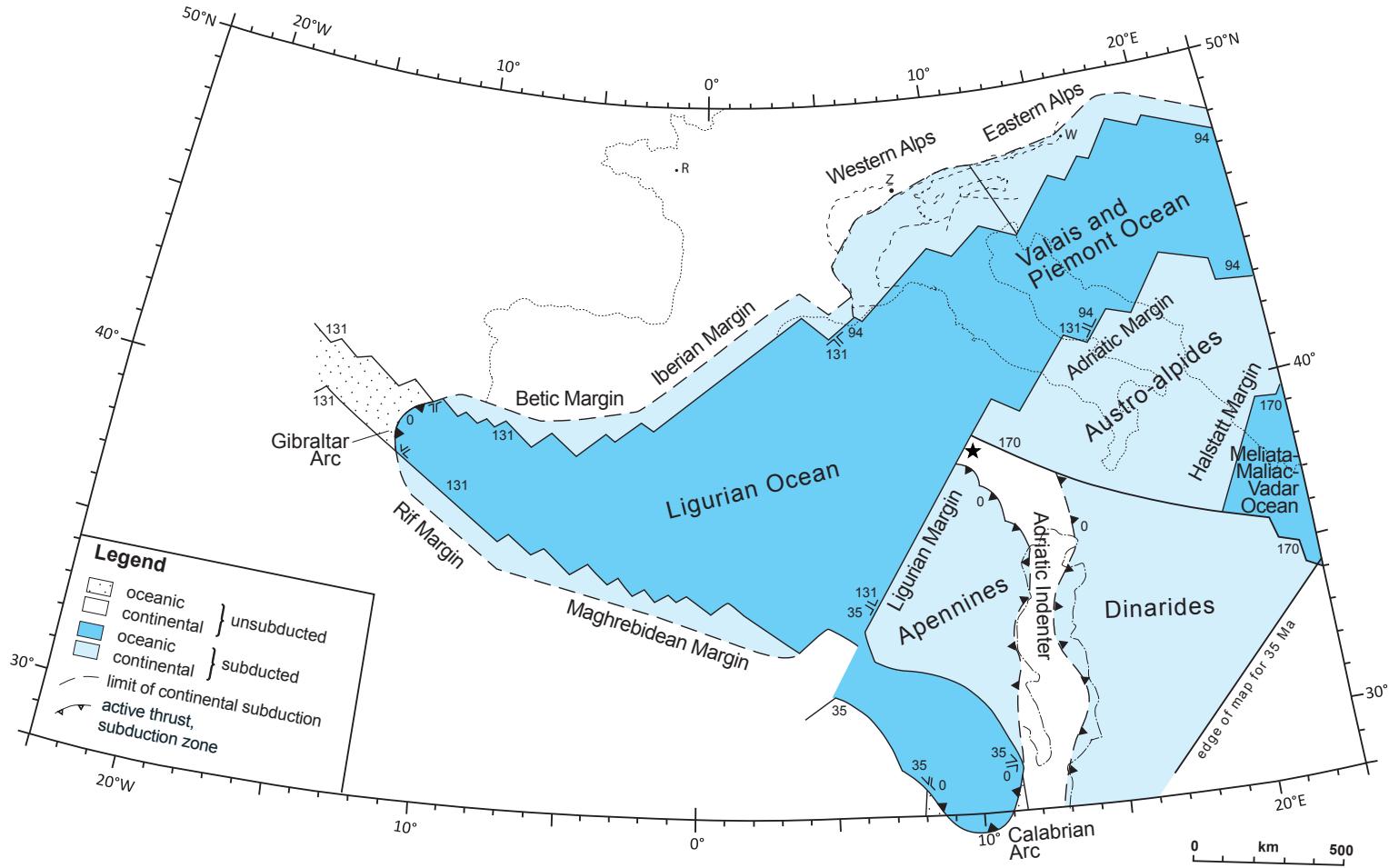
Alpine  
Tethys

Neotethys

b Piromallo & Morelli 2003

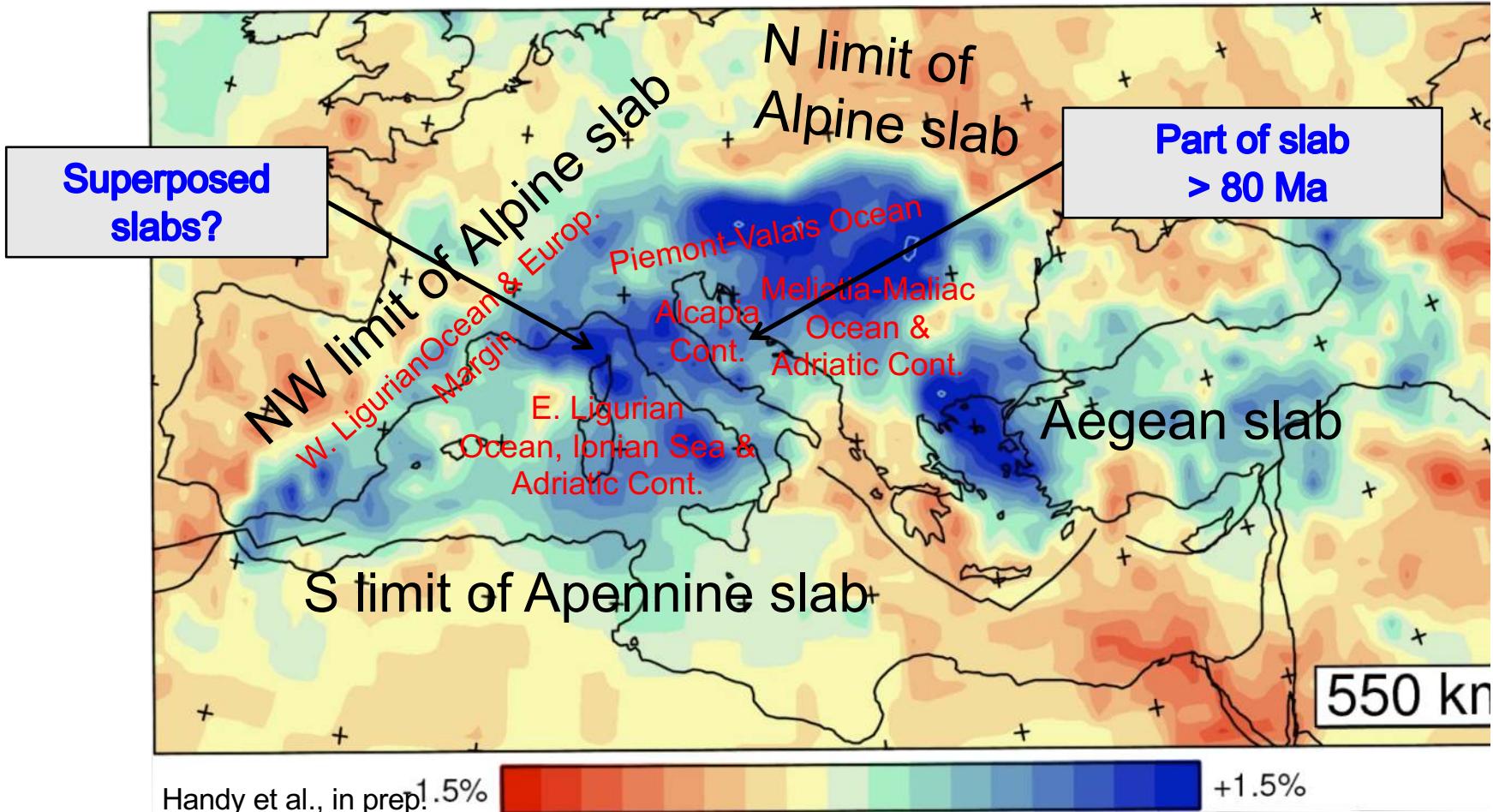
-2% -1 0 1 2%

# Area of subducted lithosphere from plate motion reconstruction



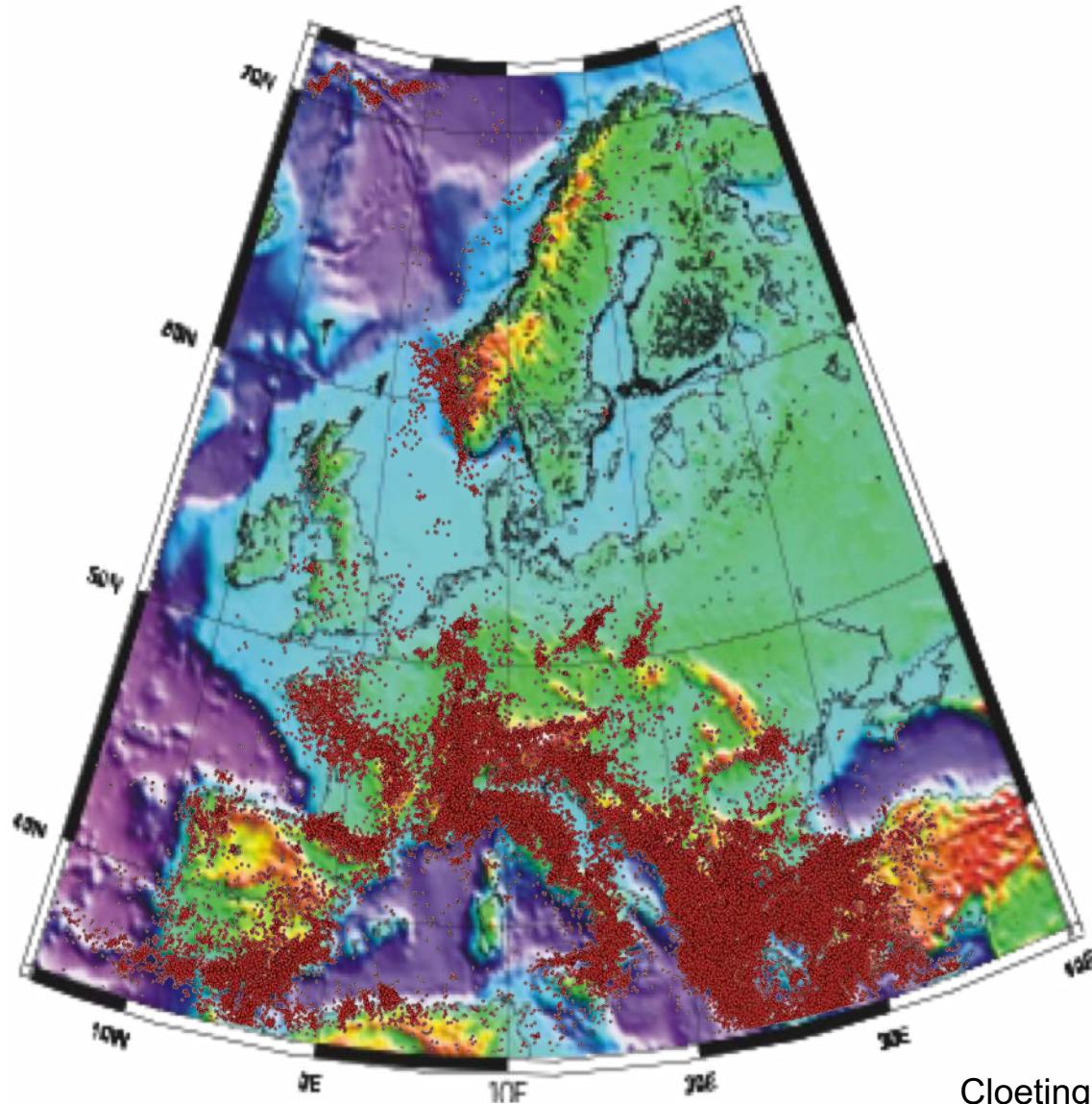
Handy et al. 2010

# Sites of subducted Tethyan lithosphere



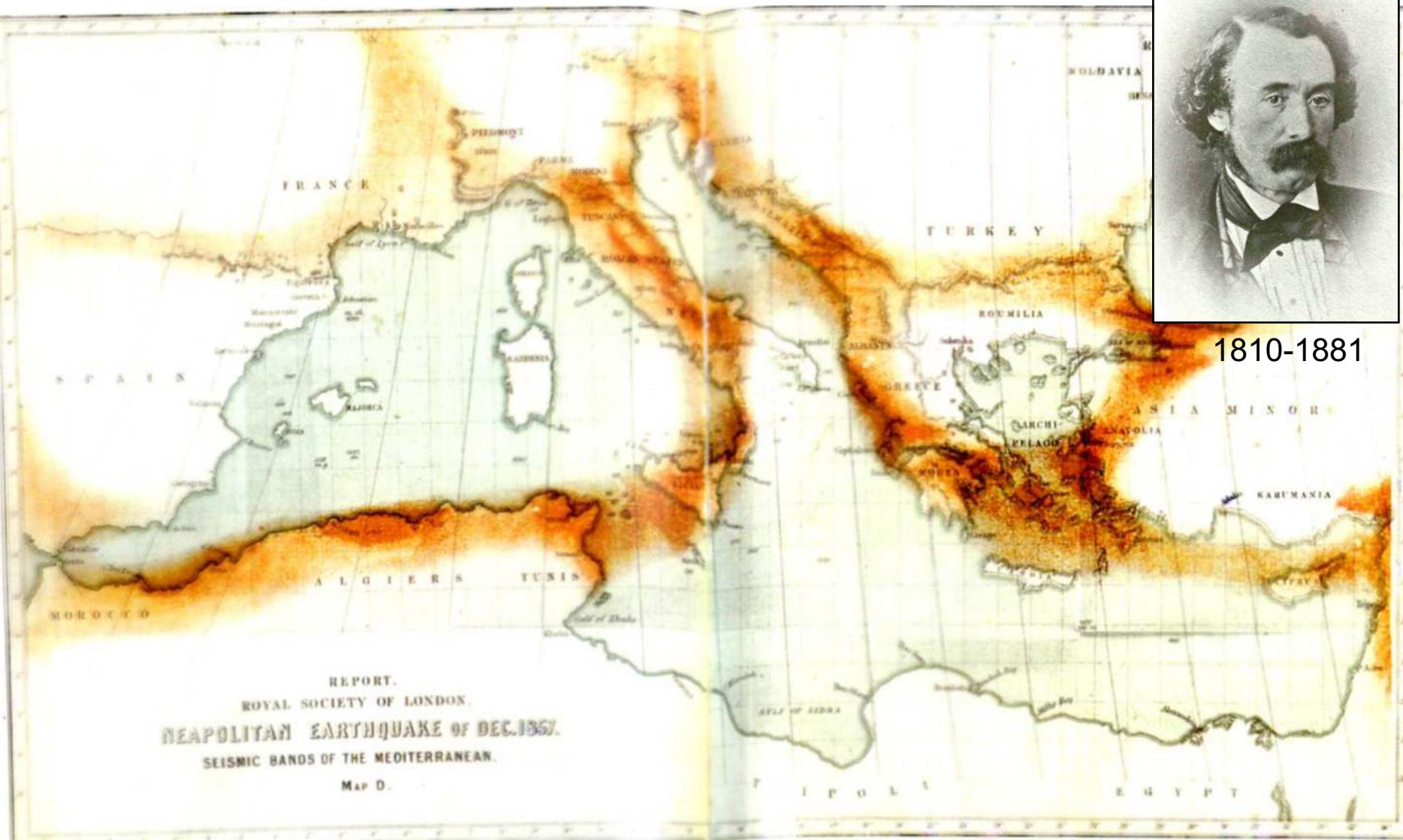
Note - minor S or E displacement of European lithosphere with respect to the mantle transitional zone

# Seismicity

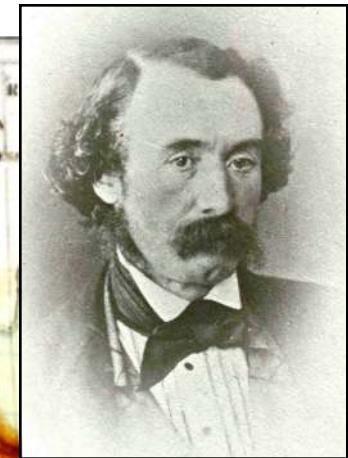


Cloetingh et al. 2007

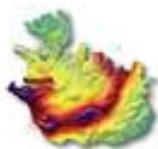
# Part of Robert Mallet's map of global seismicity



1857

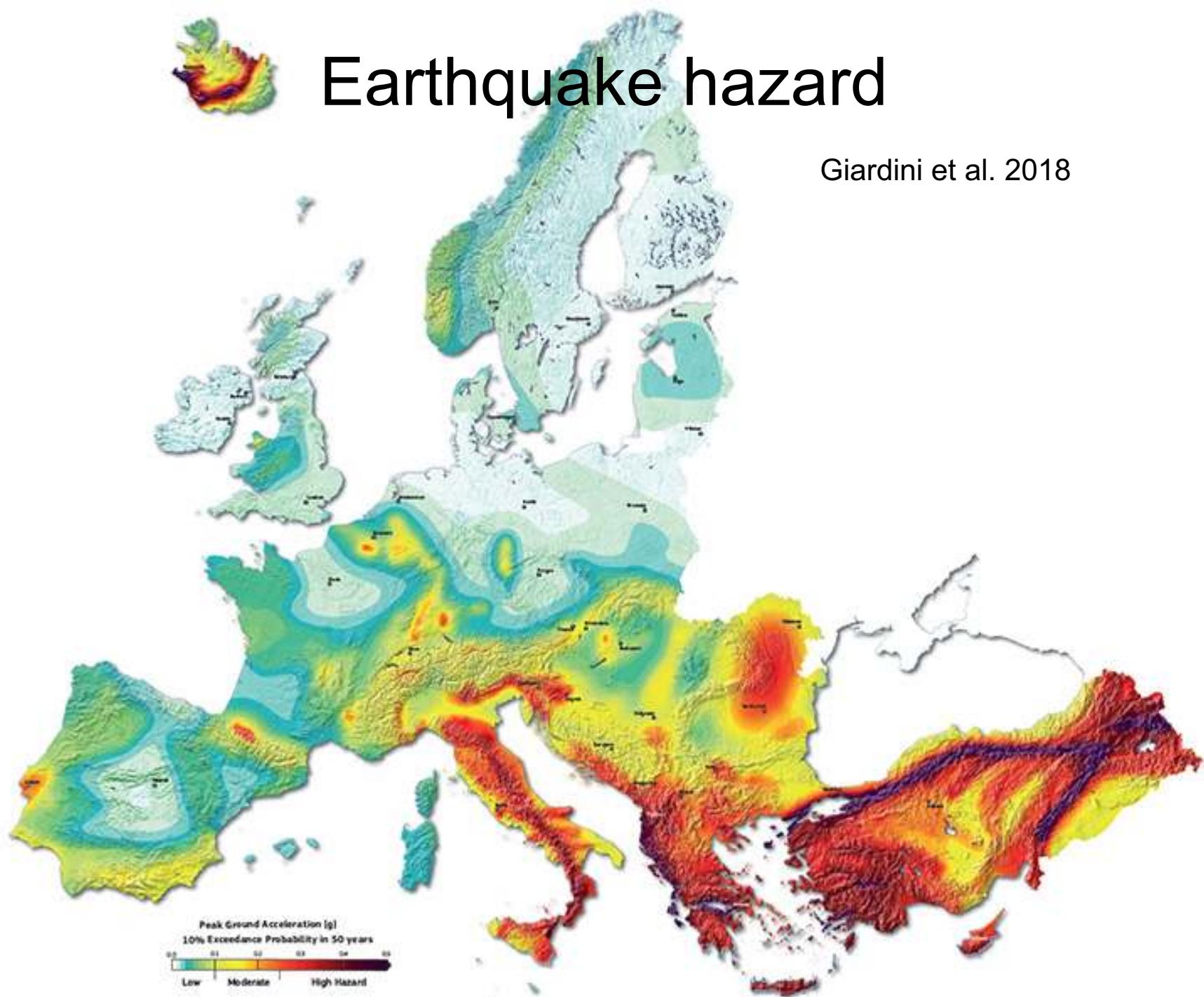


1810-1881

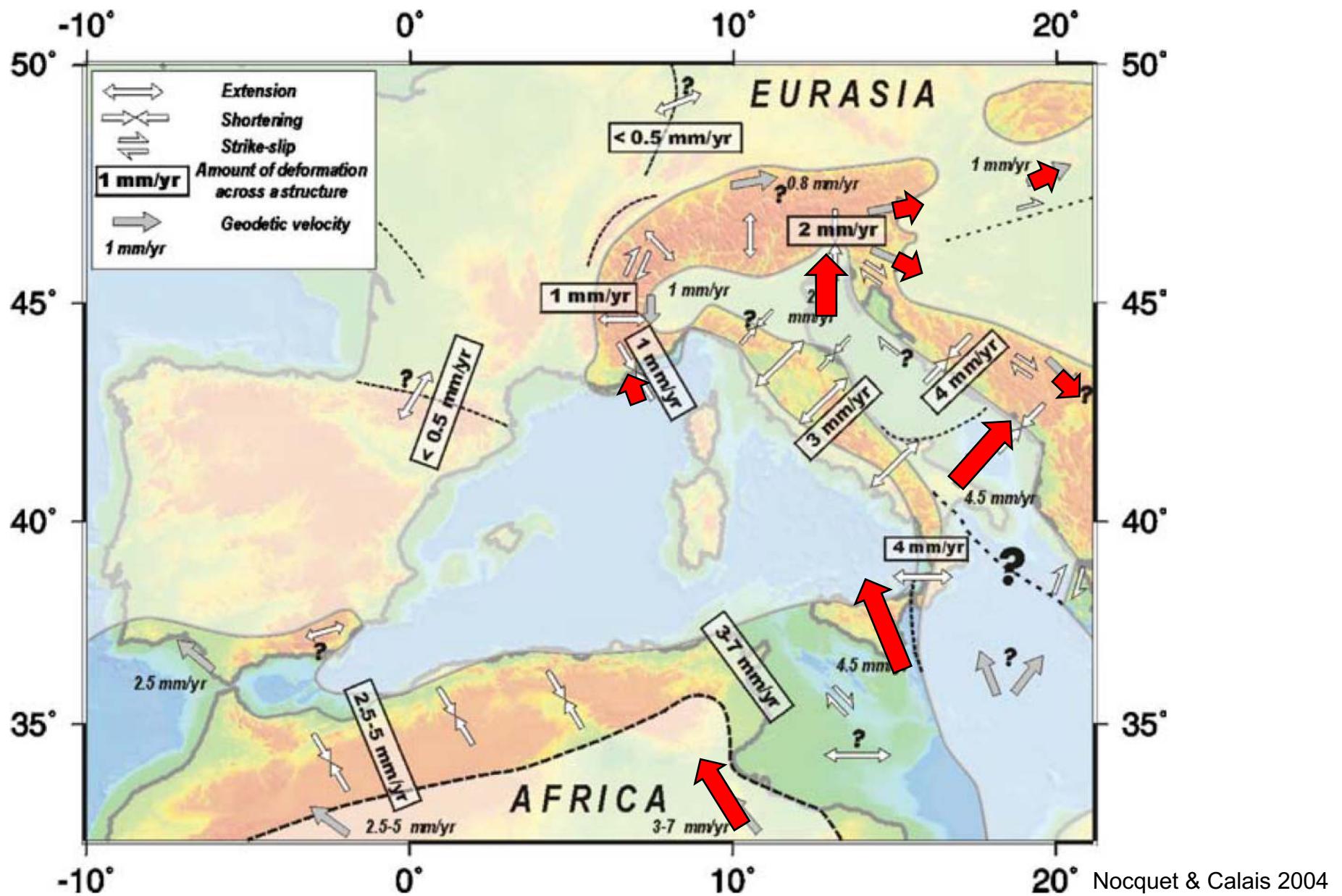


# Earthquake hazard

Giardini et al. 2018



# Present plate motions



# Literature

## Used in this lecture

Abatte, E., Bortolotti, V., Passerini, P., Sagri, M., 1970. Introduction to the geology of the Northern Apennines. *Sedimentary Geology*, 4, 3-4, 207-249.

Cloetingh, S.A.P.L., P.A. Ziegler, P.J.F. Bogaard, P.A.M. Andriessen, I.M. Artemieva, G. Bada, R.T. van Balen, F. Beekman, Z. Ben-Avraham, J.-P. Brun, H.P. Bunge, E.B. Burov, R. Carbonell, C. Facenna, A. Friedrich, J. Gallart, A.G. Green, O. Heidbach, A.G. Jones, L. Matenco, J. Mosar, O. Oncken, C. Pascal, G. Peters, S. Sliaupa, A. Soesoo, W. Spakman, R.A. Stephenson, H. Thybo, T. Torsvik, G. de Vicente, F. Wenzel, M.J.R. Wortel, TOPO-EUROPE Working Group, 2007. TOPO-EUROPE: The geoscience of coupled deep Earth-surface processes. *Global and Planetary Change* 58, 1–118.

Dercourt, J., Zonenshain, L.P., Ricou, L.-E., Kazmin, V.G., Le Pichon, X., Knipper, A.L., Grandjaquet, C., Sbortshikov, I.M., Geyssant, J., Lepvrier, C., Pechersky, D.H., Boulin, J., Sibuet, J.-C., Savostin, L.A., Sorokhtin, O., Westphal, M., Bazhenov, M.L., Lauer, J.P., Bijou-Duval, B., 1986. Geological evolution of the Tethys belt from the Atlantic to the Pamirs since the Lias. *Tectonophysics* 123, 241–315.

Handy, M.R., Schmid, S.M., Bousquet, R., Kissling, E., Bernoulli, D. 2010. Reconciling plate-tectonic reconstructions with the geological-geophysical record of spreading and subduction in the Alps. *Earth Science Reviews*, 102, 121-158.

# Literature

Nocquet, J.-M., Calais, E. 2004. Geodetic Measurements of Crustal Deformation in the Western Mediterranean and Europe. *Pure Applied Geophysics*, 161, 661–681. DOI 10.1007/s00024-003-2468-z

Schmid, S.M., Fügenschuh, B., Kissling, E., Schuster, R., 2004a. Tectonic Map and overall architecture of the Alpine orogen. *Eclogae Geologicae Helvetiae* 97, 1, 93–117.

## **Historical literature**

Mallet, R. 1847. The Dynamics of Earthquakes. *Proceedings of the Royal Irish Academy. Royal Irish Academy*, **XXI**, 51.