Thermo-mechanical structure of the European Lithosphere:
a common perspective for ENGINE and Topo-Europe

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ENGINE final meeting

13 februari 2008

TOPO-EUROPE

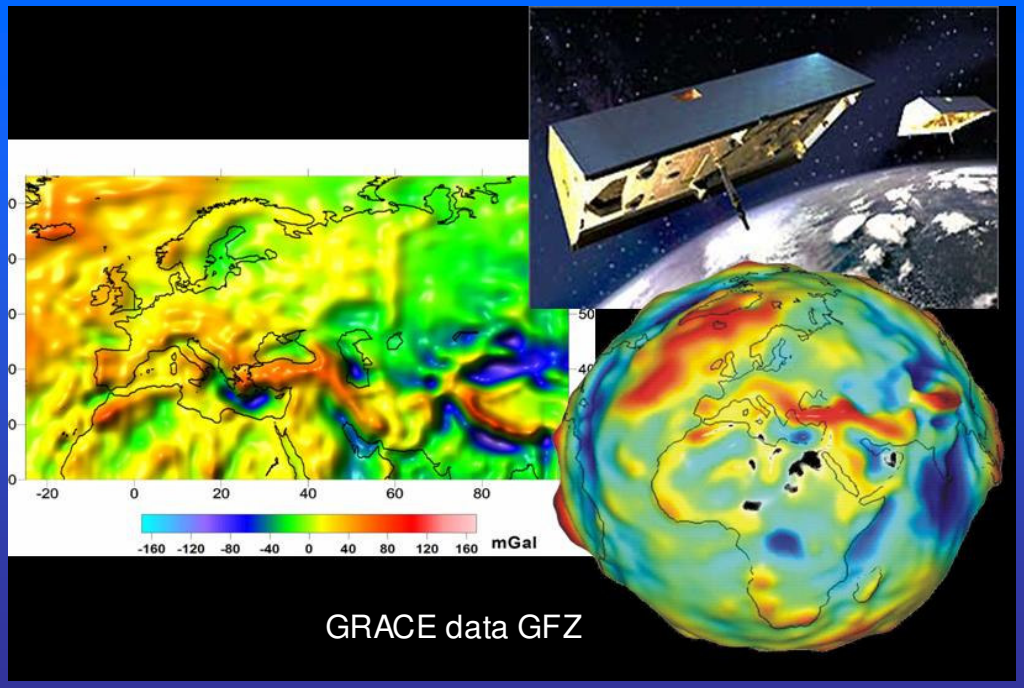
ISES

EUROPEAN SCIENCE FOUNDATION

Academia Europaea

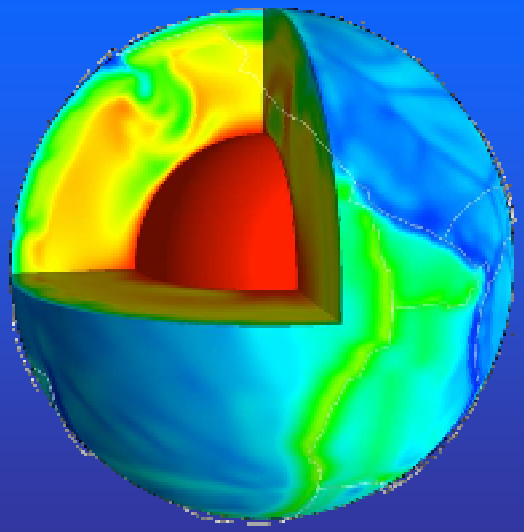
- **Scope:**
  - Coupled deep Earth – surface processes
  - Topography and natural hazards

- **Scientific approach (funding >50 PhD):**
  - Monitoring, imaging, reconstruction, process modelling in Europe's natural laboratories



GRACE data GFZ

Convection model

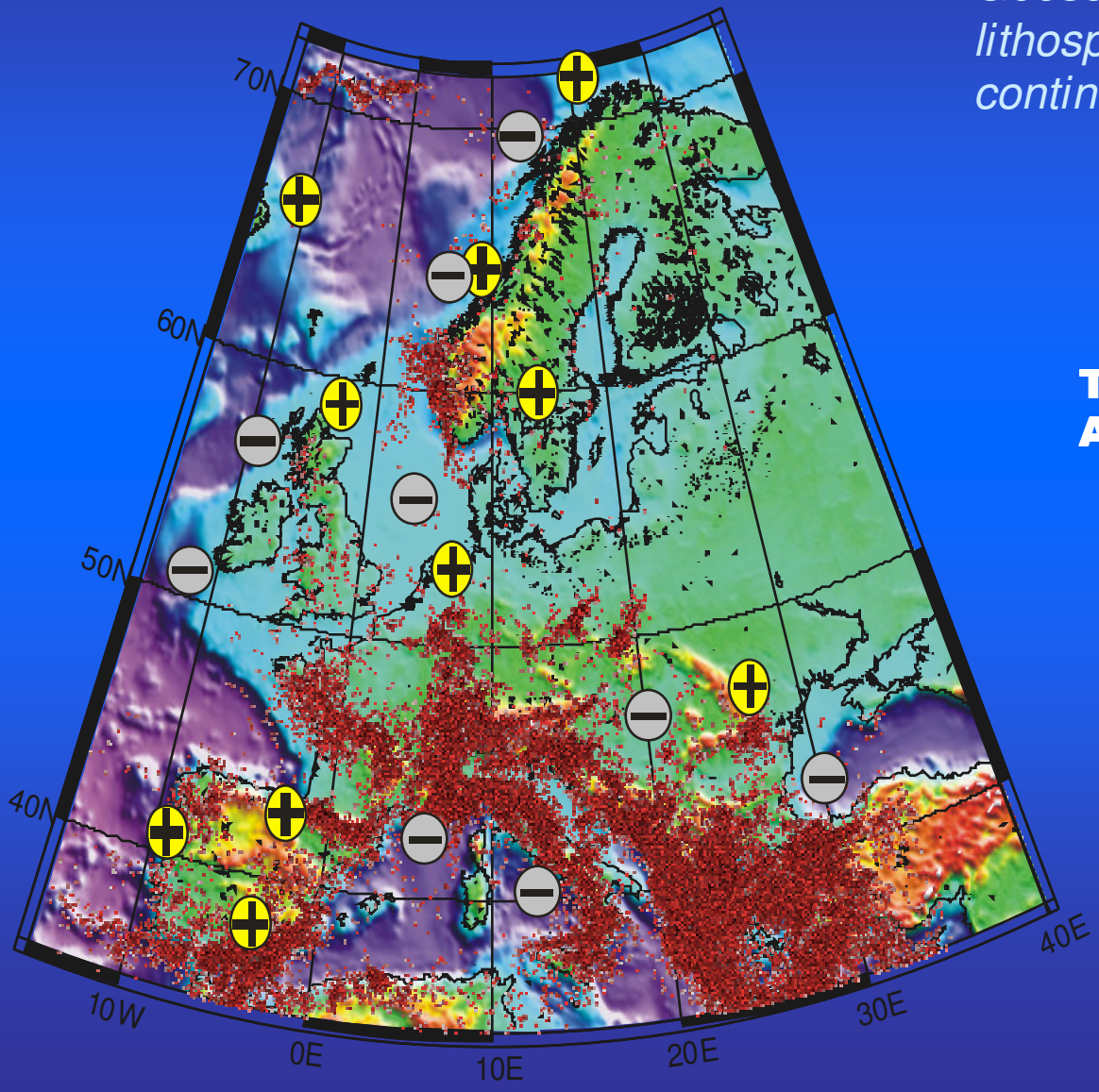


Courtesy Bunge

Societal Relevance of TOPO-EUROPE

Courtesy GeoMotion

TOPO-EUROPE:
Geoscience of coupled surface and lithosphere & mantle processes of continental Europe and its margins



Thermo-mechanical structure And dynamics

Temperature
rheology
Stress
Fault-fracture prediction

Earthquakes

Areas going up

Areas going down

Points to make

General

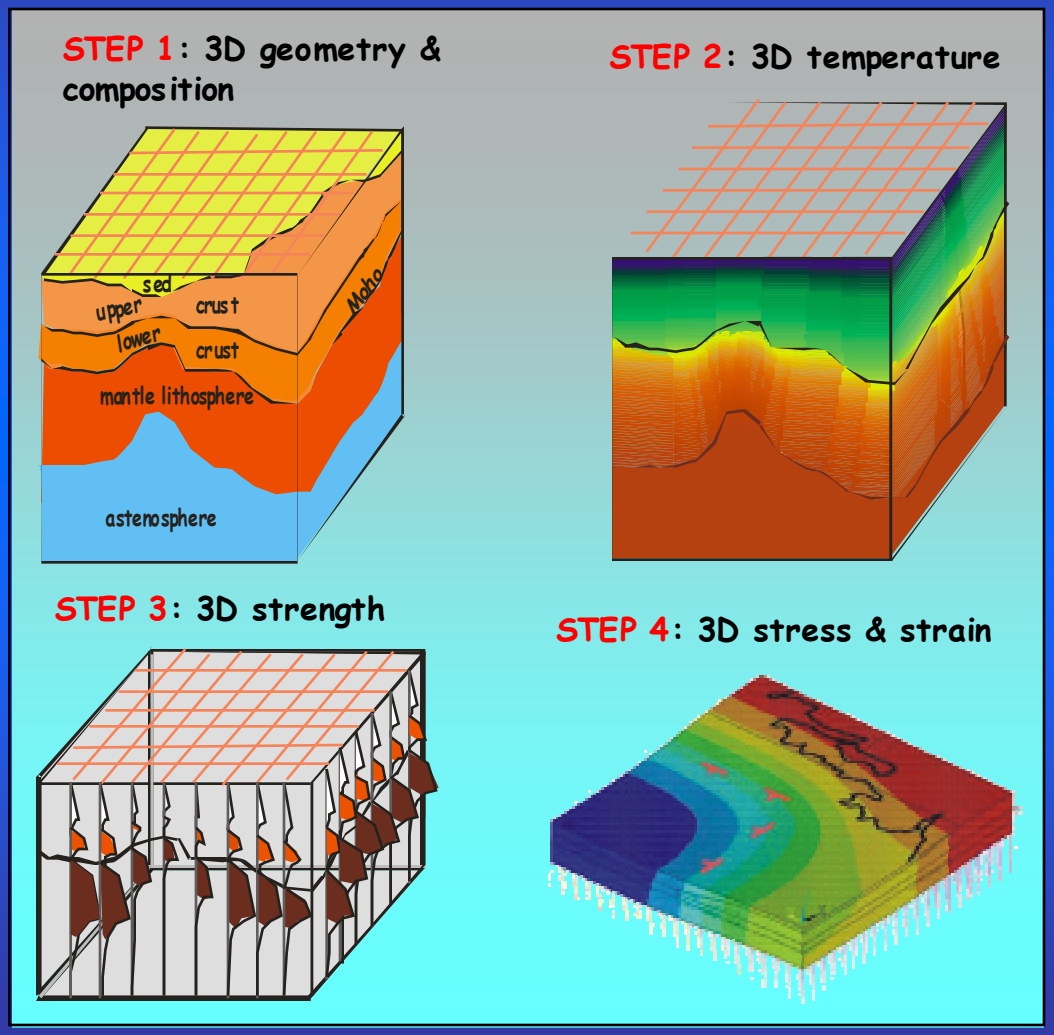
- Thermo-mechanical lithosphere structure ←→ tectonic stress/deformation (tectonics) much interrelated
- Much of temperature structure (<10 km) can be learned from lithosphere studies on these relationships and insight-knowledge on crustal heterogeneous properties

Impact for Europe/ENGINE

Europe is marked by active tectonics, having a strong effect on

- Temperature distribution
- Mechanical properties
- Tectonic deformation and intraplate stress

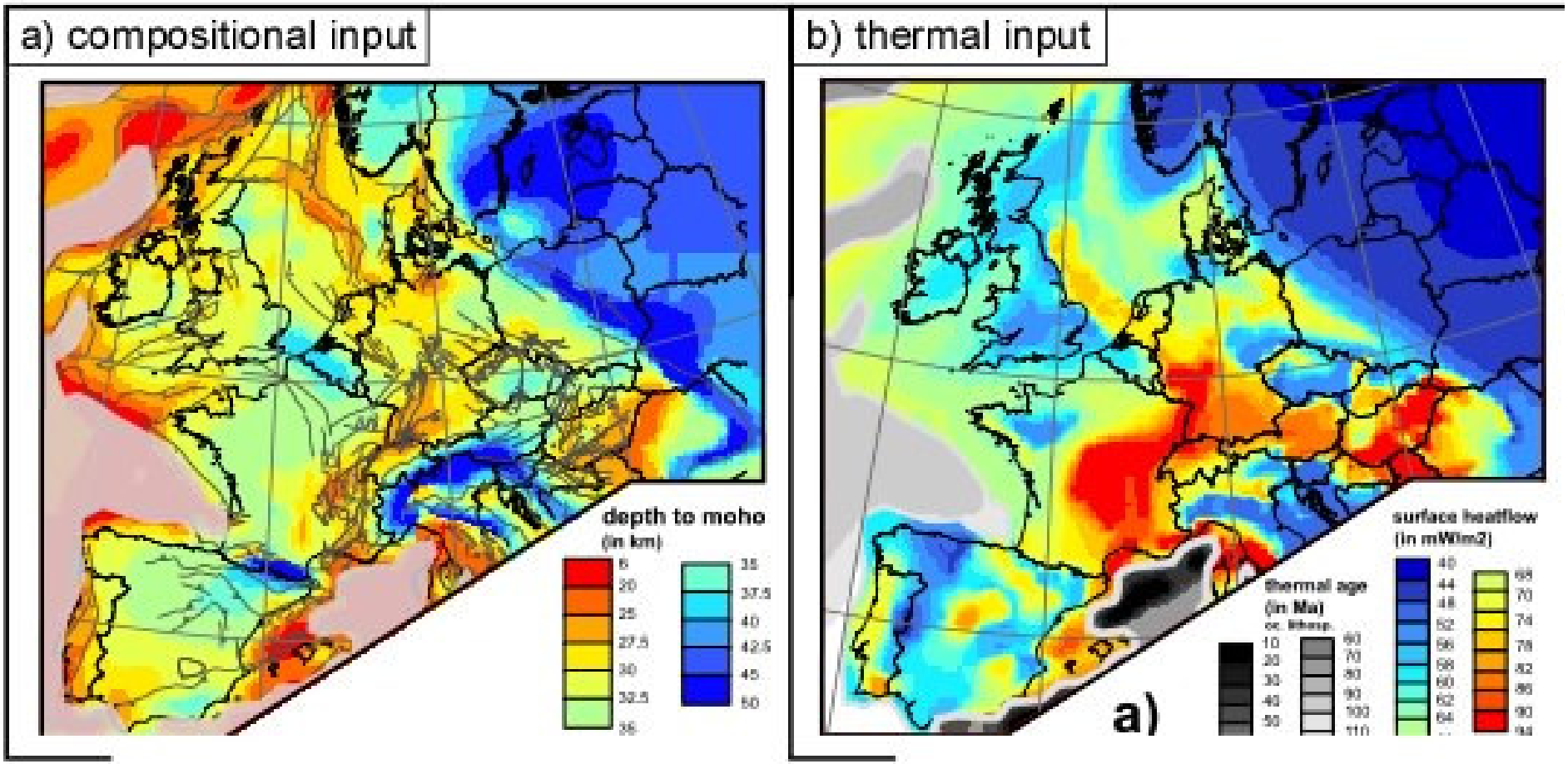
3D models of strength, stress and strain of the European continental lithosphere



Cloetingh et al., 2005, QSR

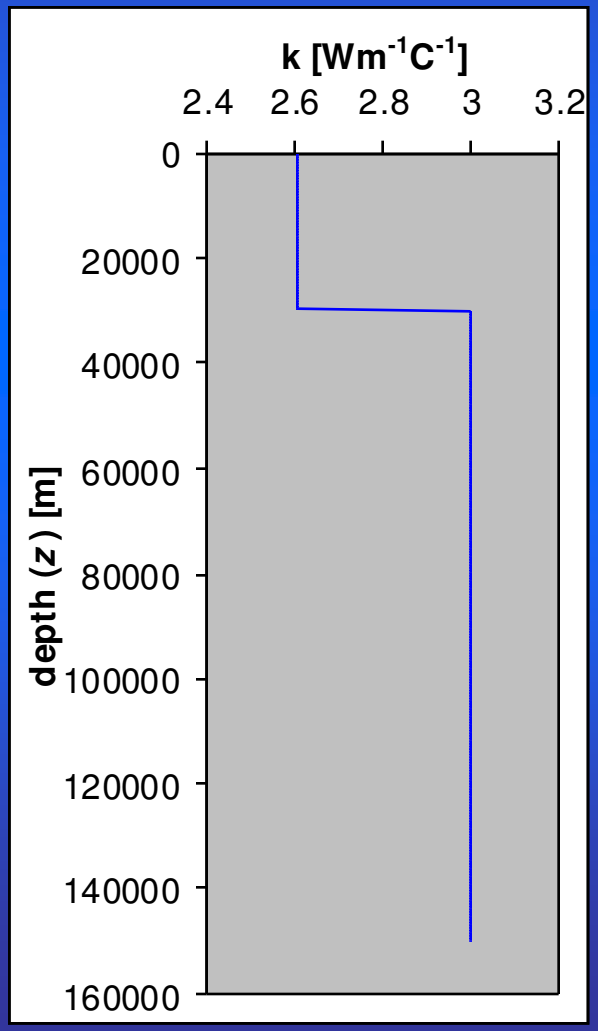
- 3D geometrical & compositional model from digital elevation models, seismic data, gravity, and ENTEC/EUCOR-URGENT/GFZ databases
- Calculations using a mix of in-house developed and commercial software
- Access to LOFAR's "Blue Gene" grid computing network
- Model resolution will increase iteratively during the project
- Grid cells may have a different size
- Final size of the grid cells will depend on the quality of the (geological) input data

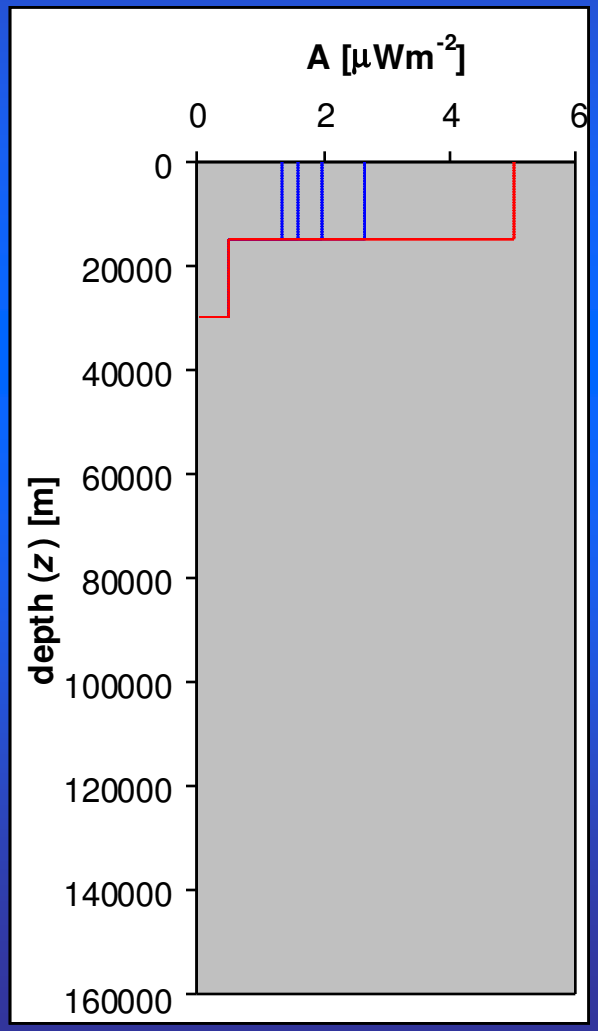
Construction of the temperature

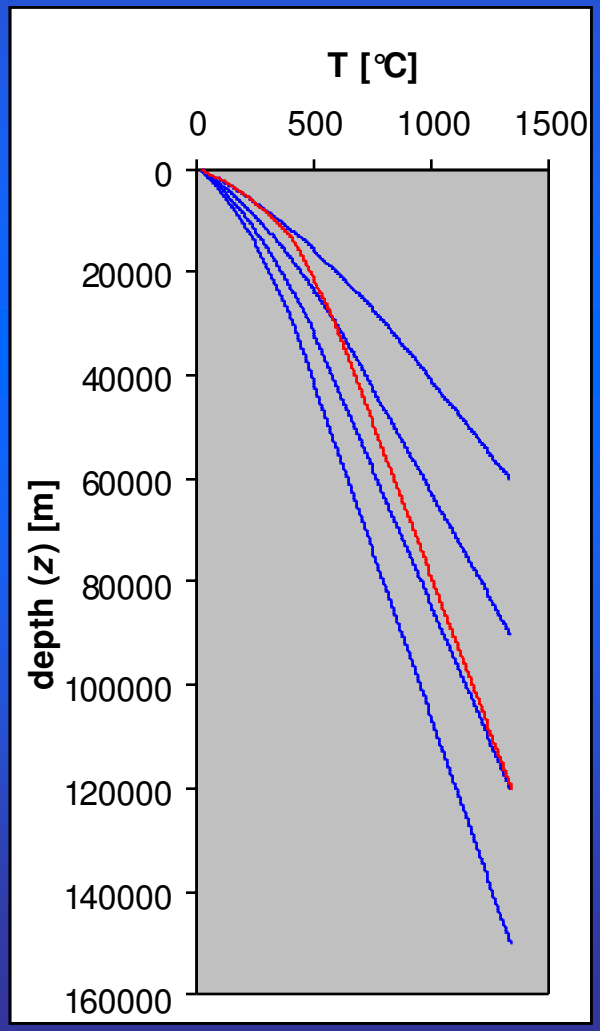


Hardebol et al., 2006

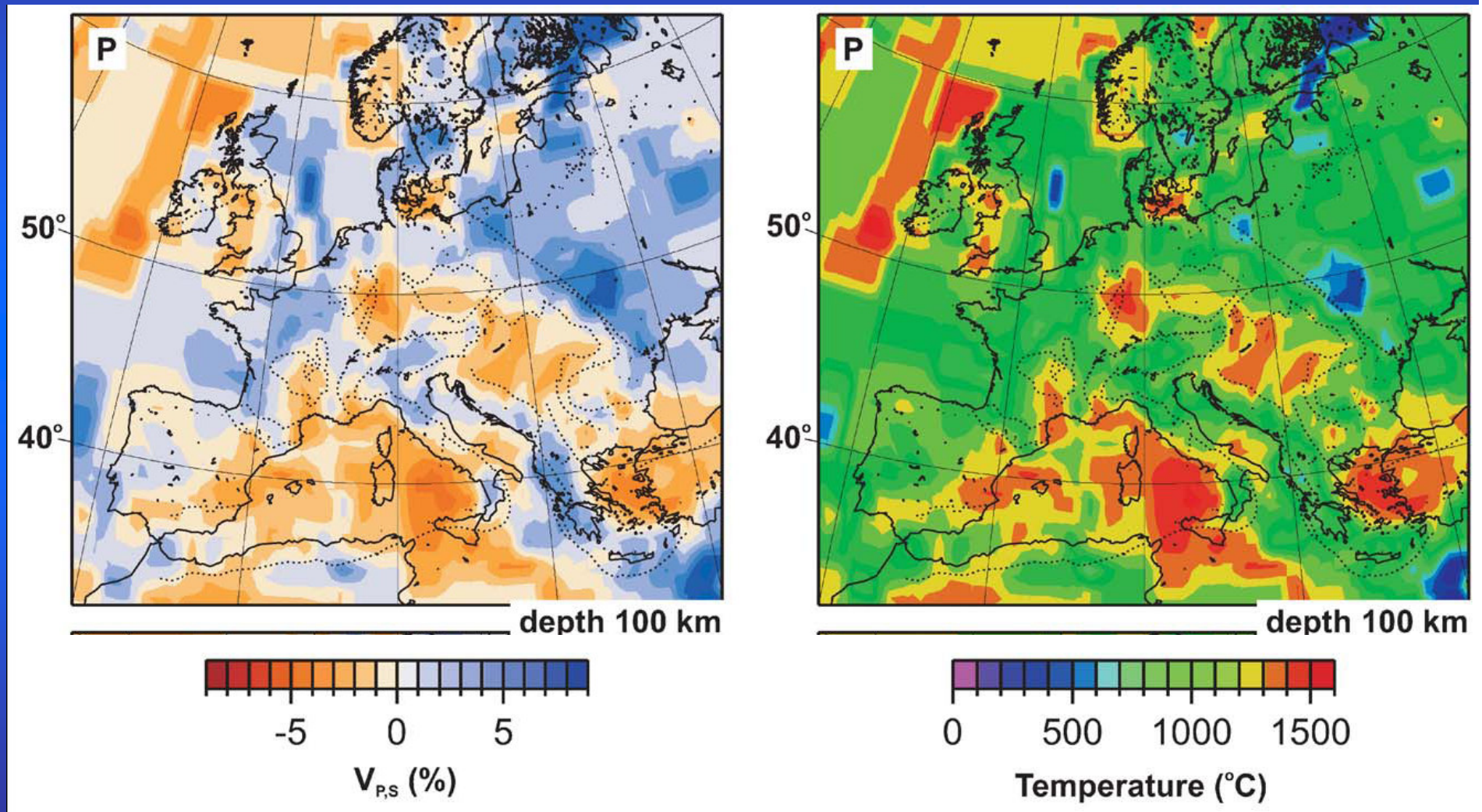
- 40% of heat flow from heat production in upper crust
- Lithosphere thickness related to Surface heat flow and Crustal Temperature gradient
- Strong effect of heat production (e.g. granites)



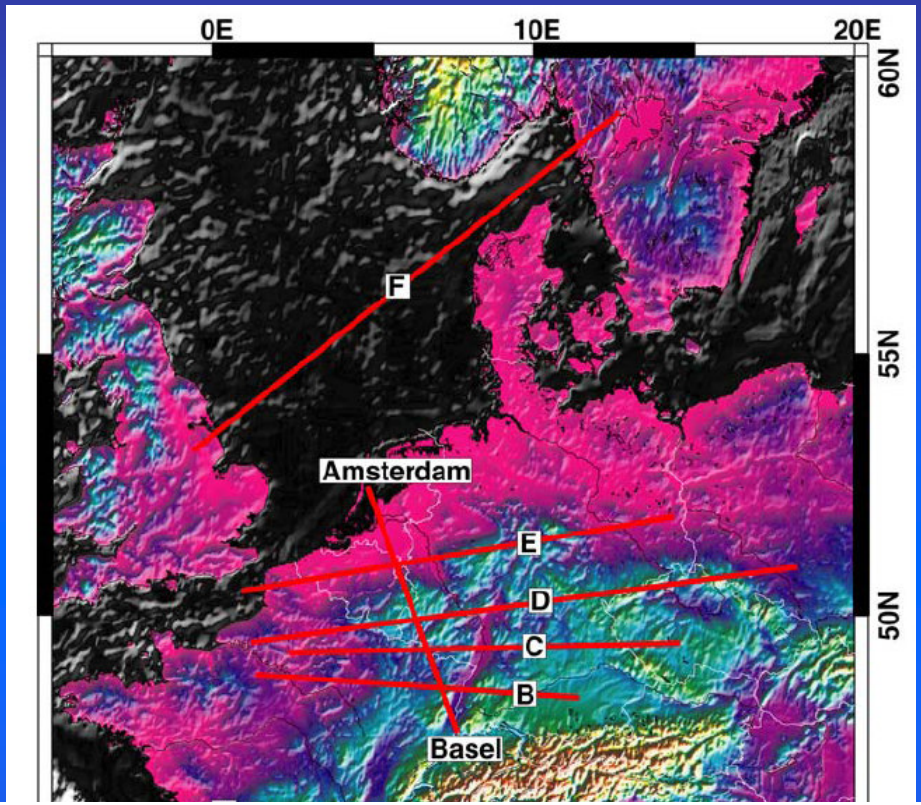


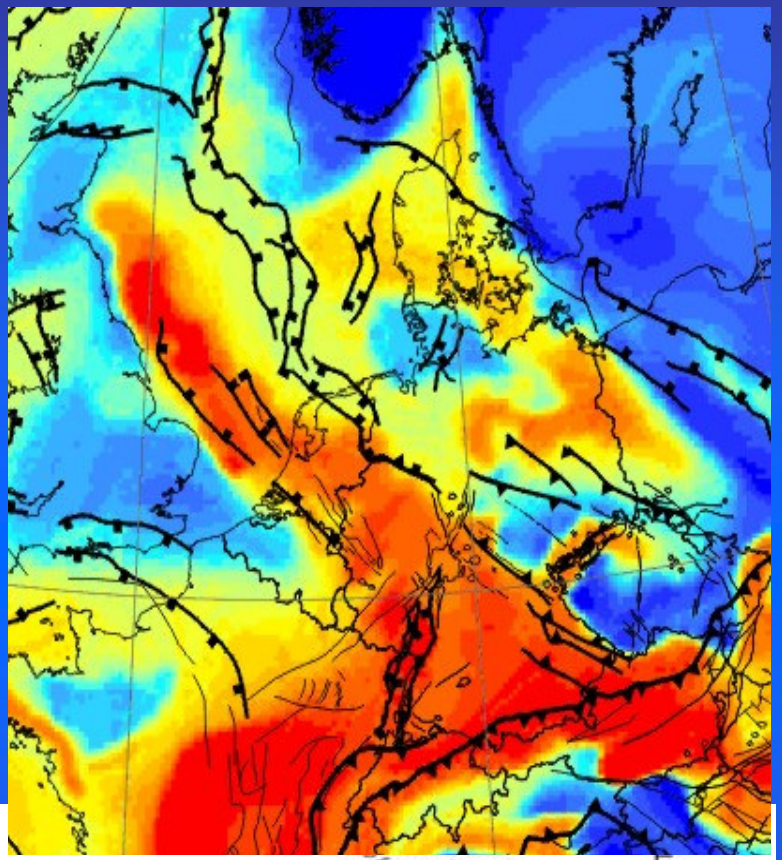


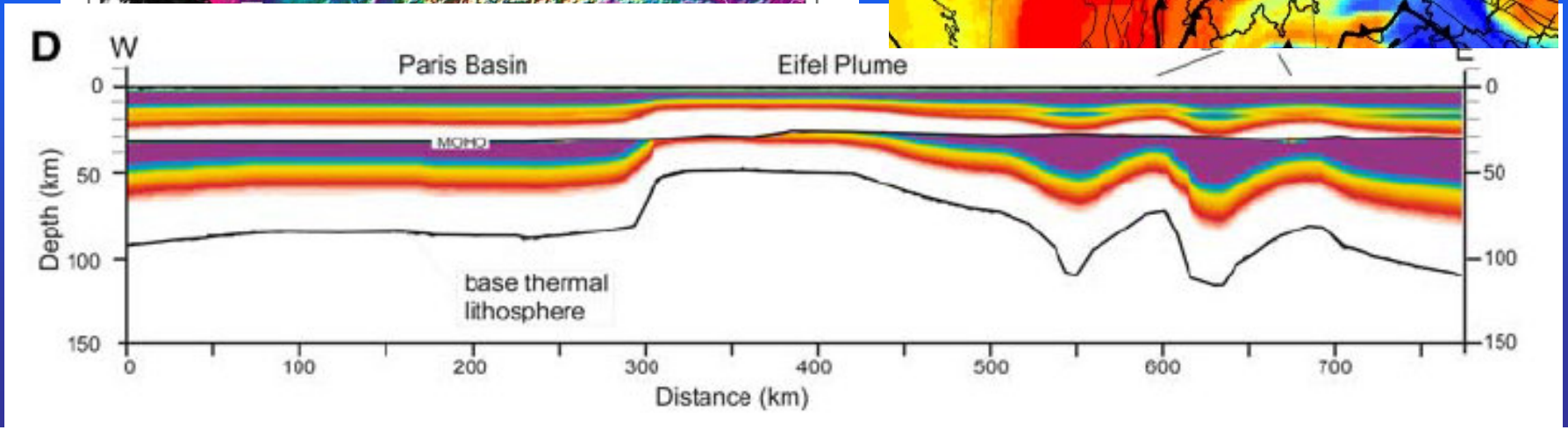
Lithosphere temperature from Seismic tomography



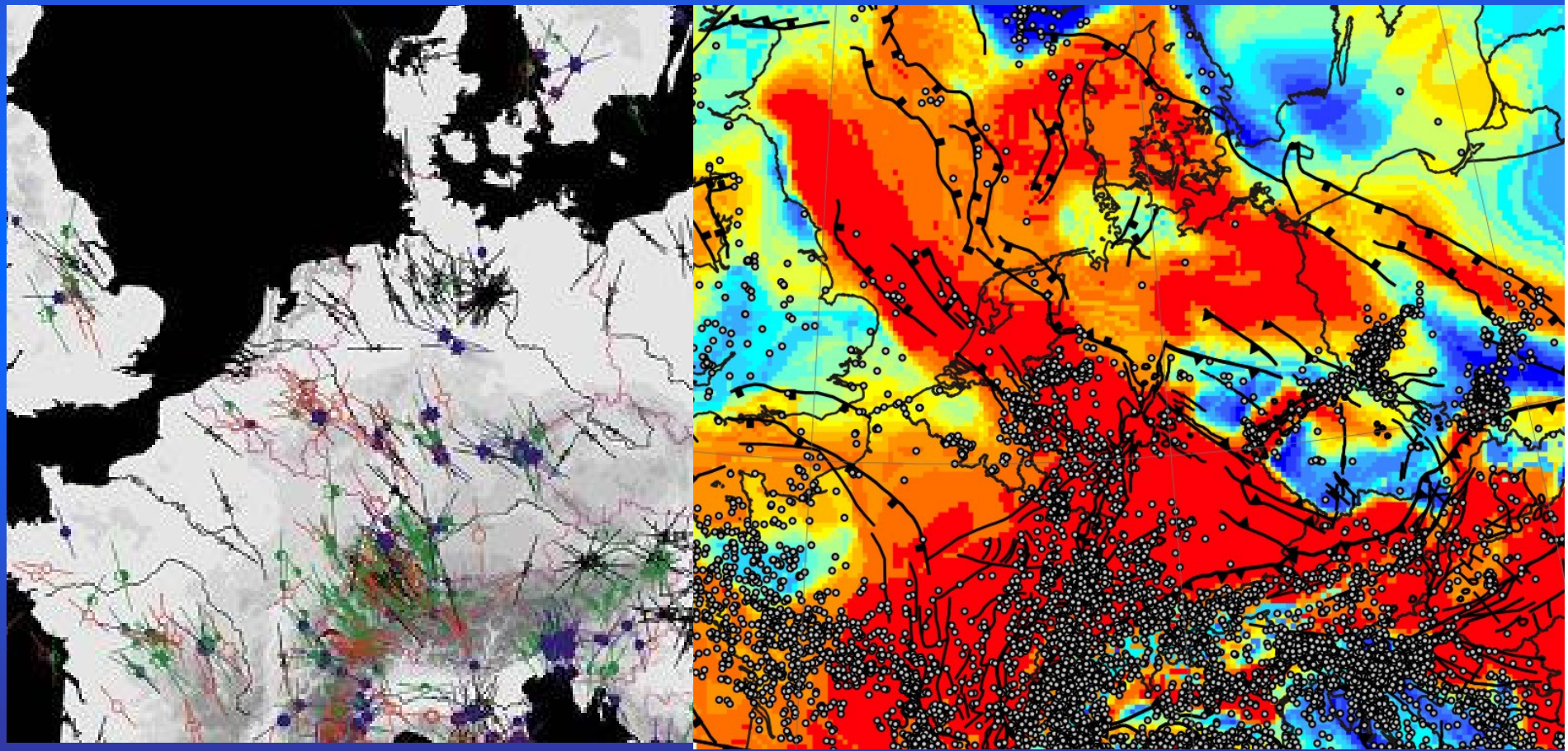
Lithospheric strength





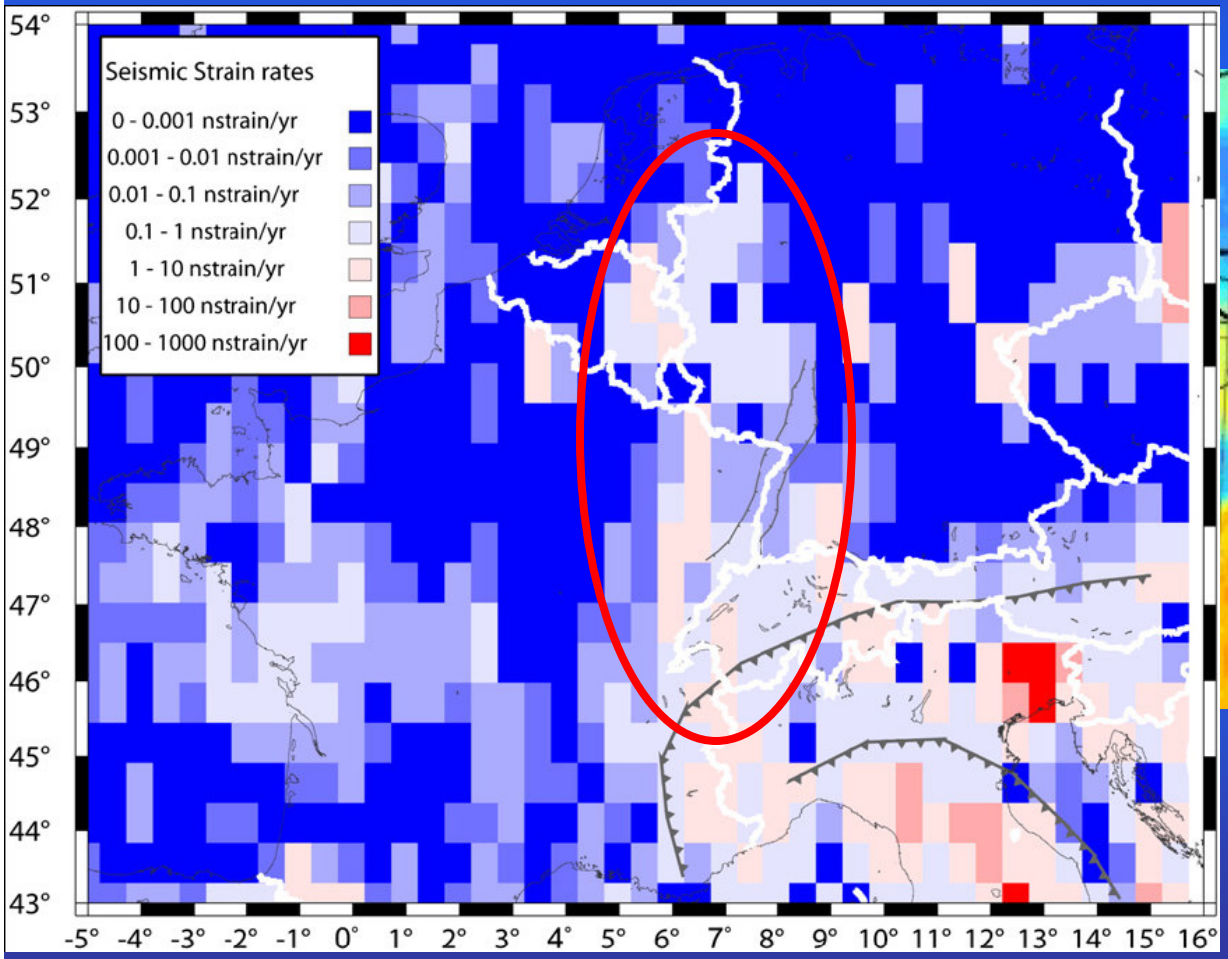


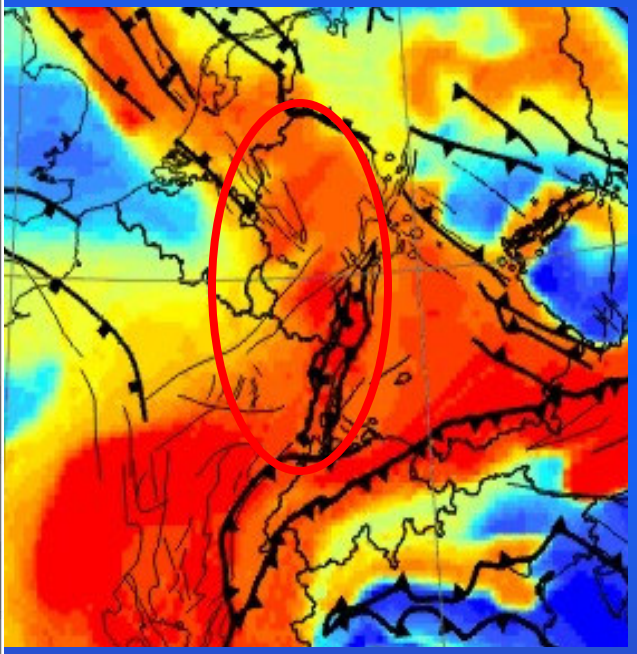
Relationschip between crustal stress and seismicity/crustal strength



Cloetingh et al., 2006, ESR

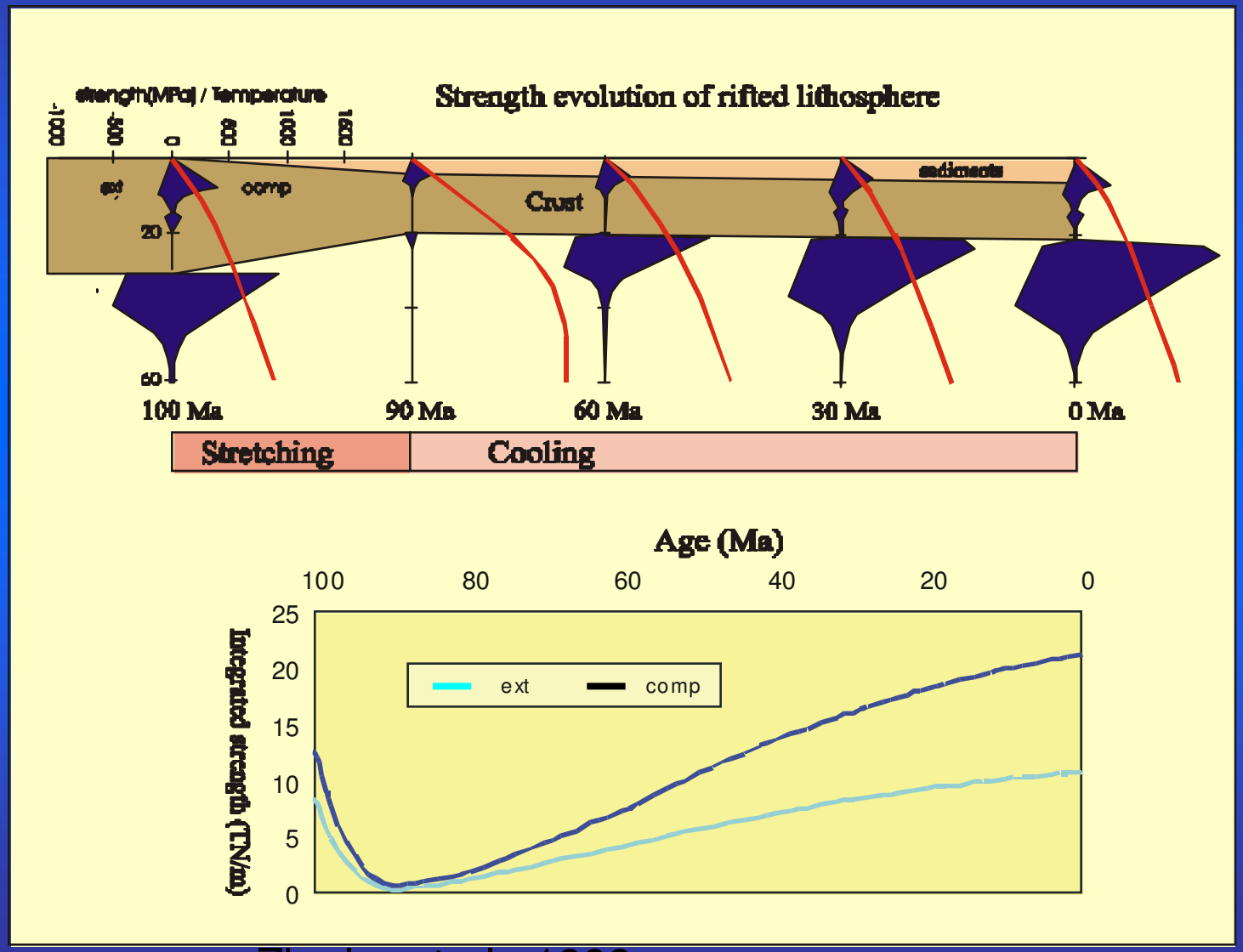
Relationschip between crustal strength and geodetically derived strain localization





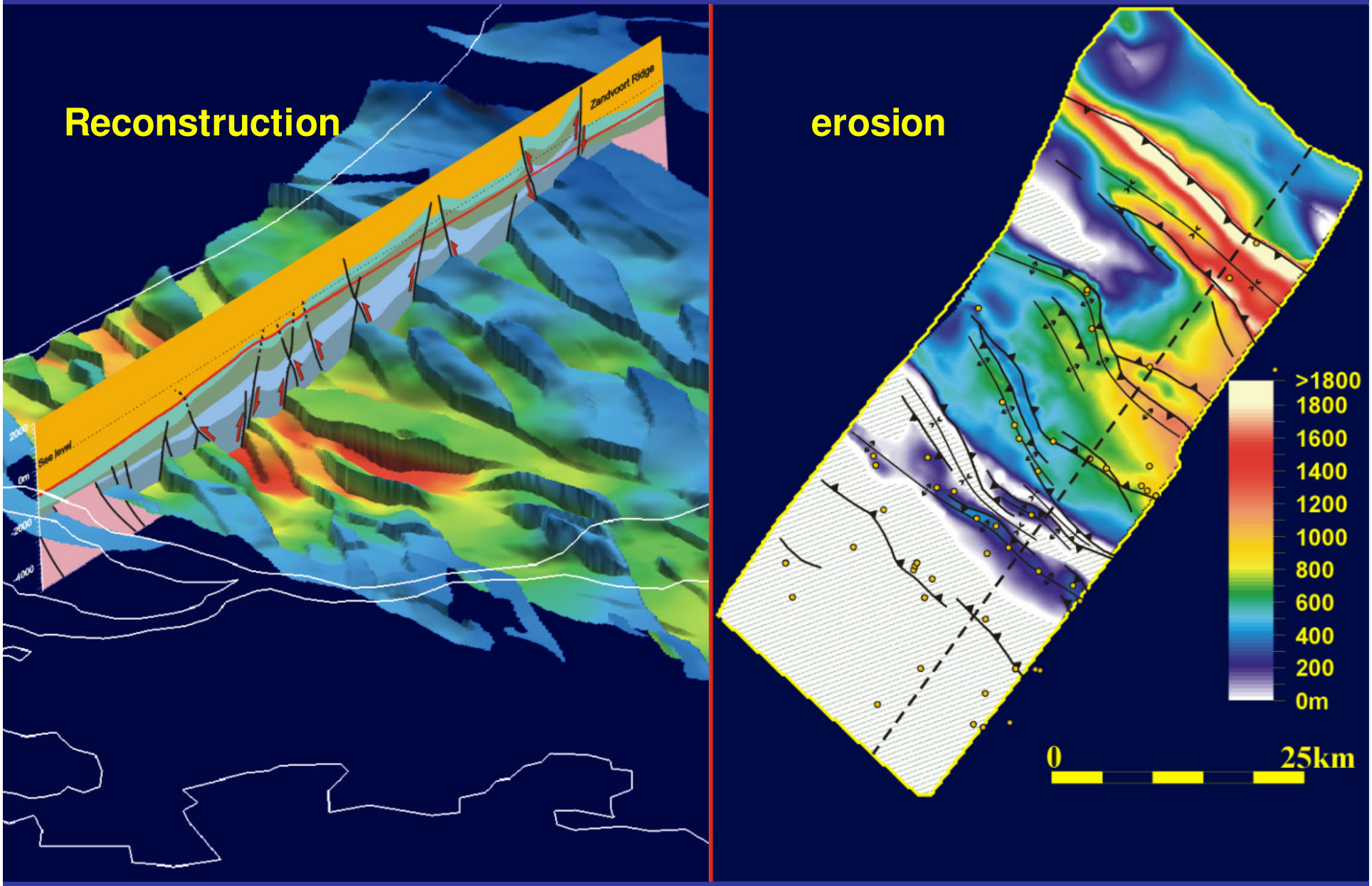
Tesauro et al., 2007, EPSL

Lithosphere memory → reactivation of faults



Ziegler et al., 1998

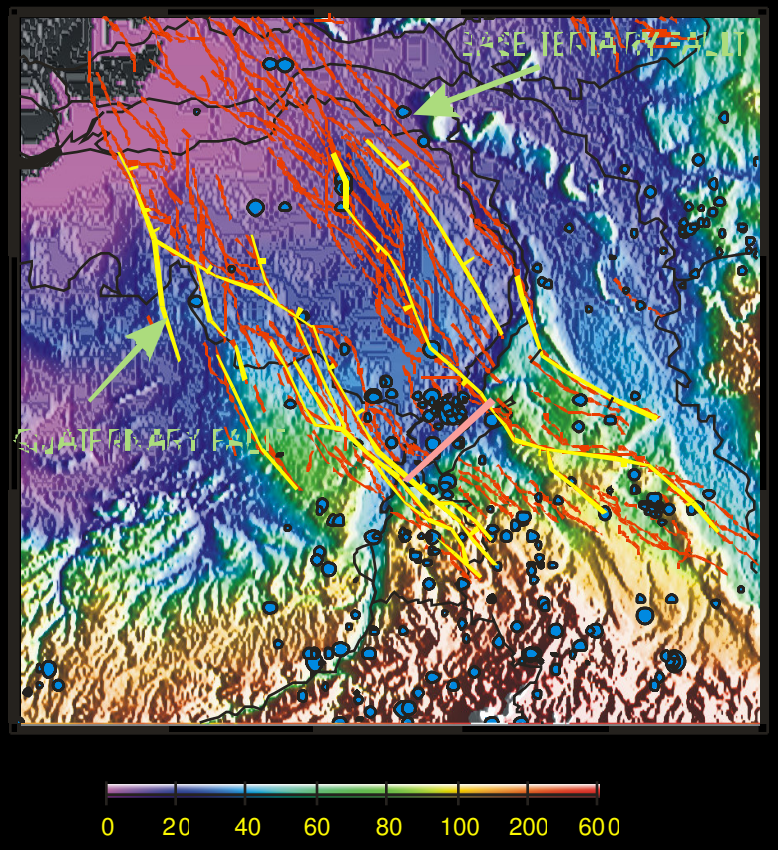
bekkenreactivation (>70 Ma) -> weak fault fabric

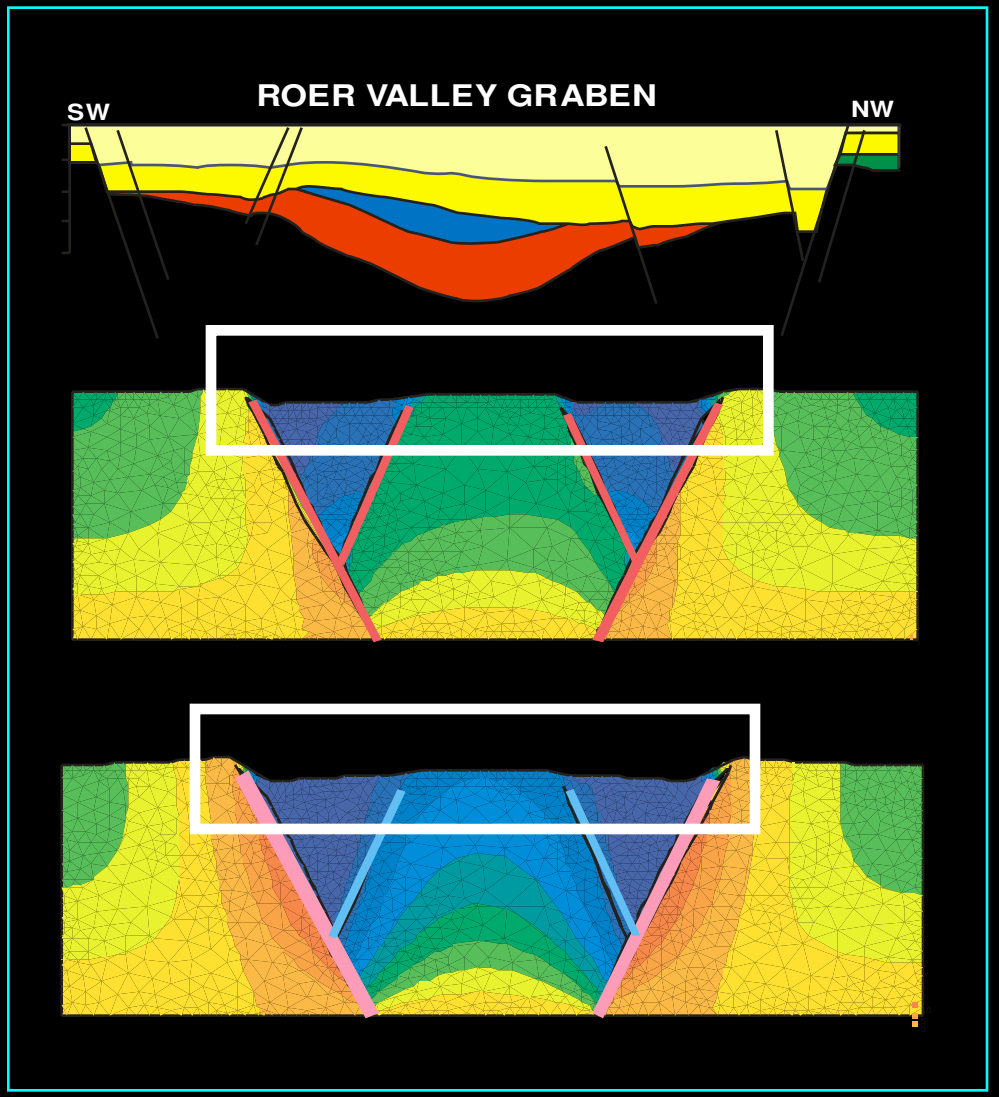


Worum and Van Wees, submitted

Lithosphere Memory - Faults

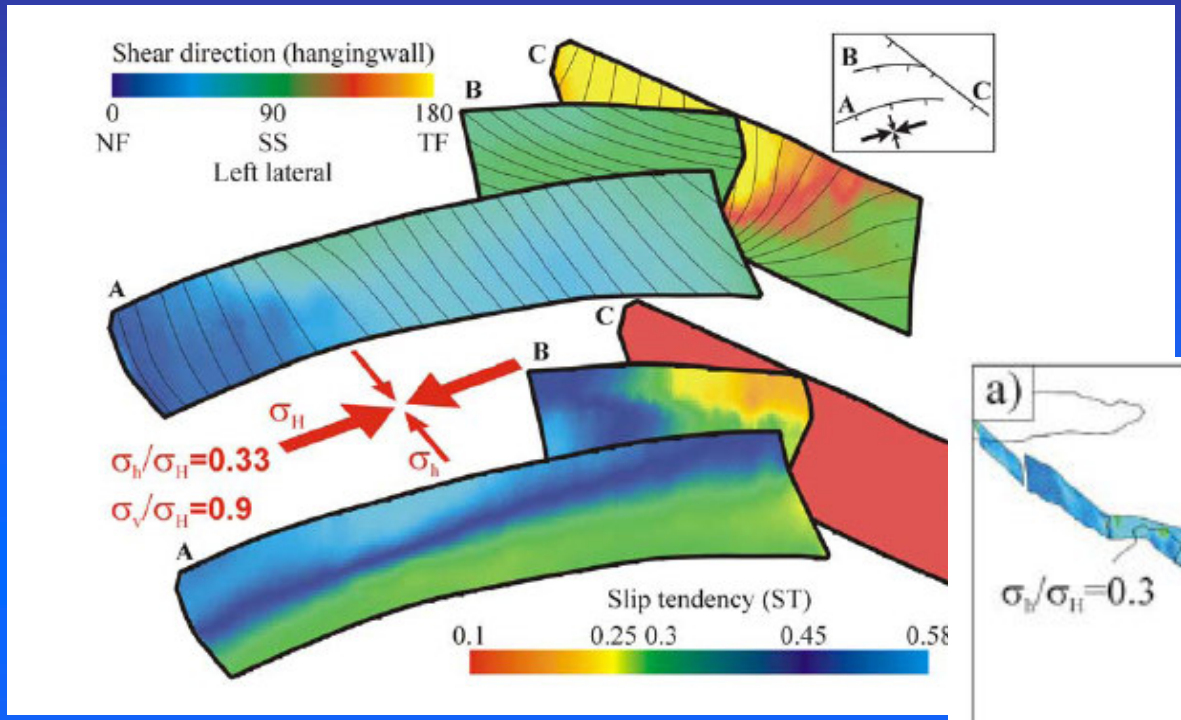
SE-NETHERLANDS

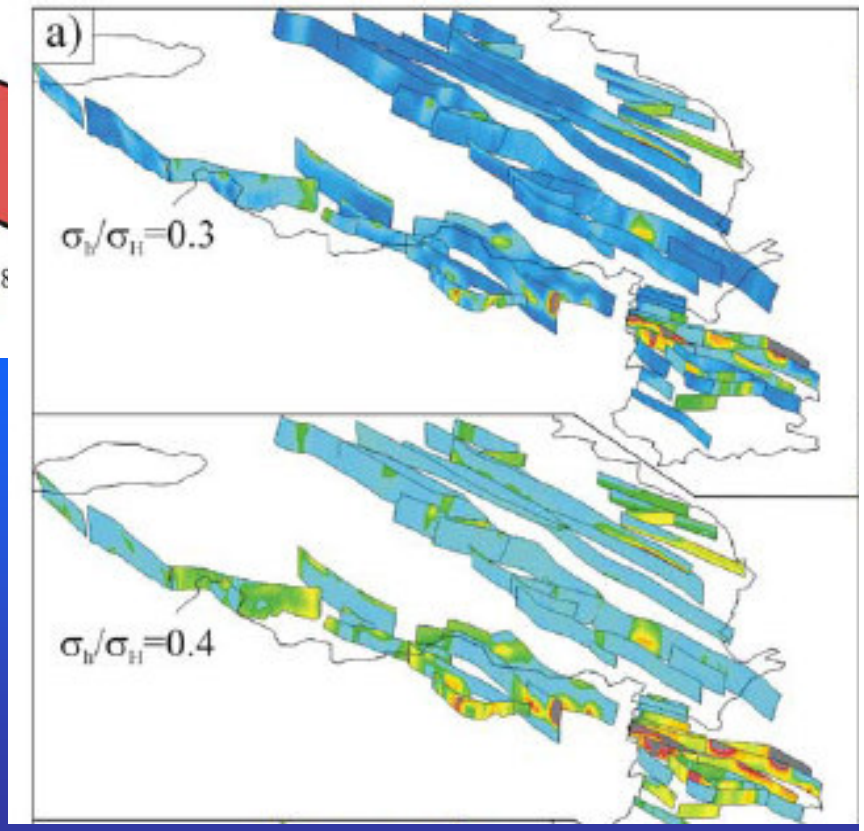




Dirkzwager et al., 2001

Lithopshere memory- active faults -seismicity

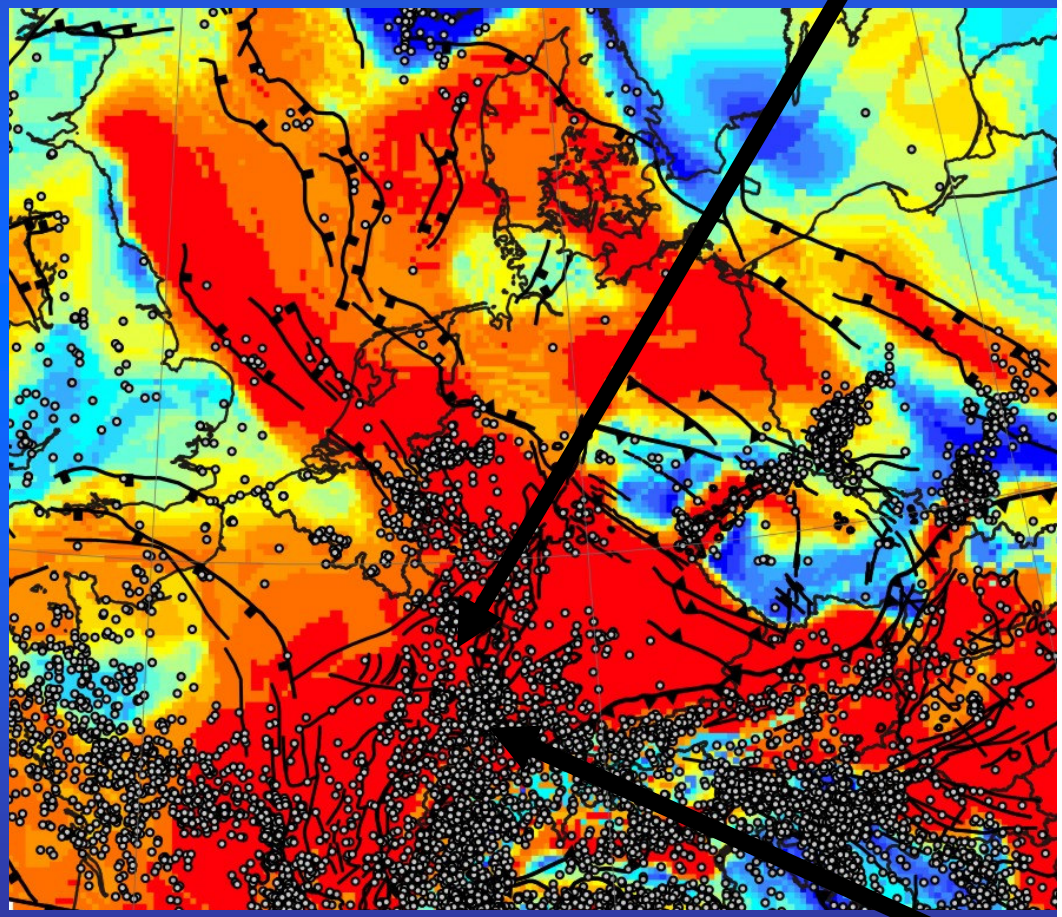




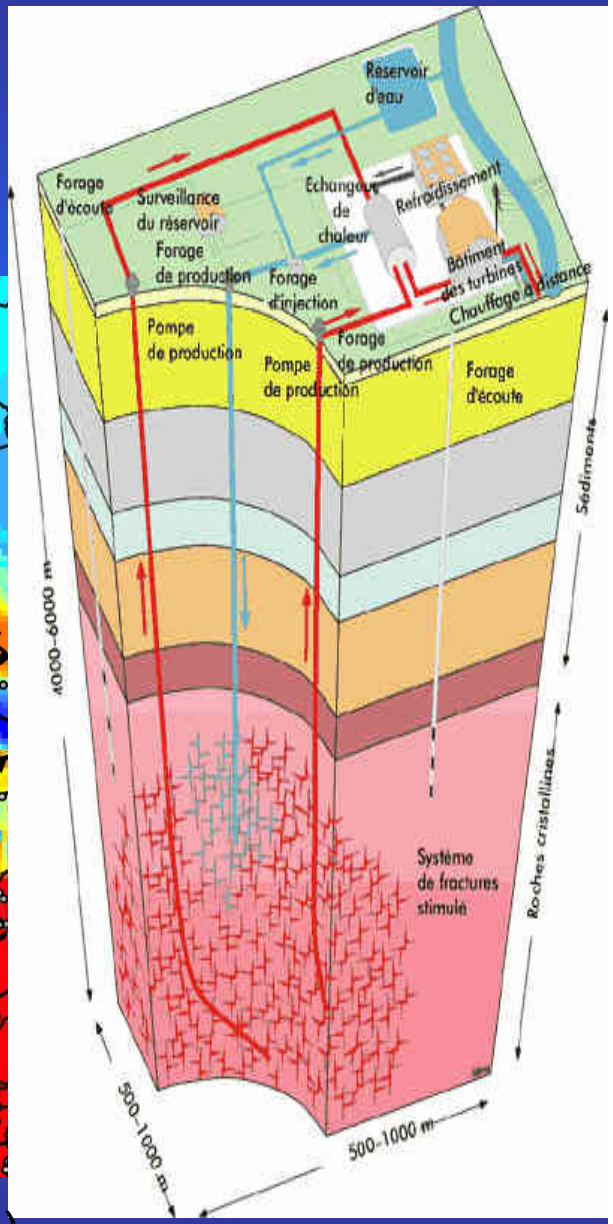
Slip Tendency (Worum et al., 2004)

Lithosphere memory – risk for induced and triggered earth-quakes

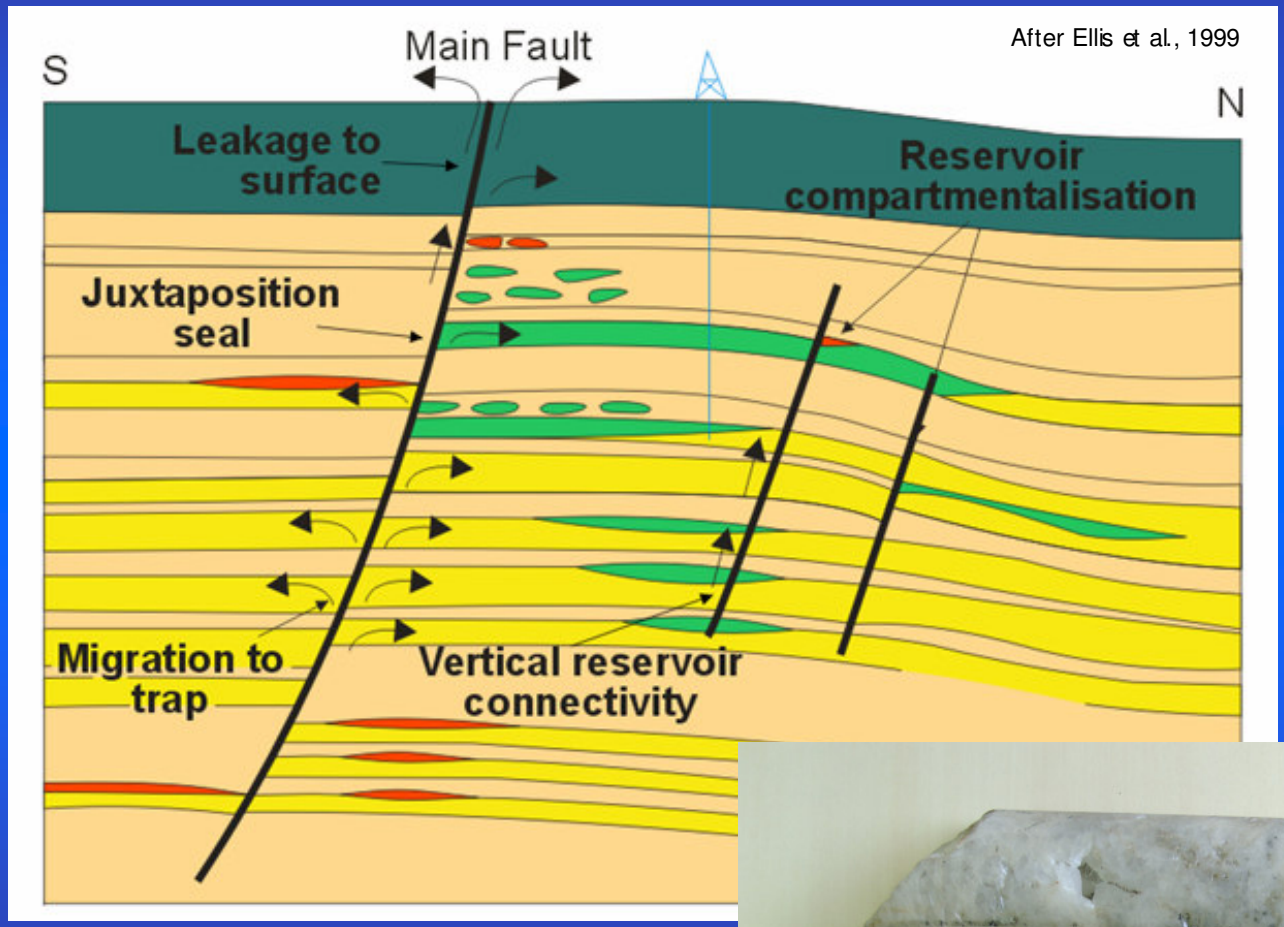
Soultz (2.5)



Basel (3.4)

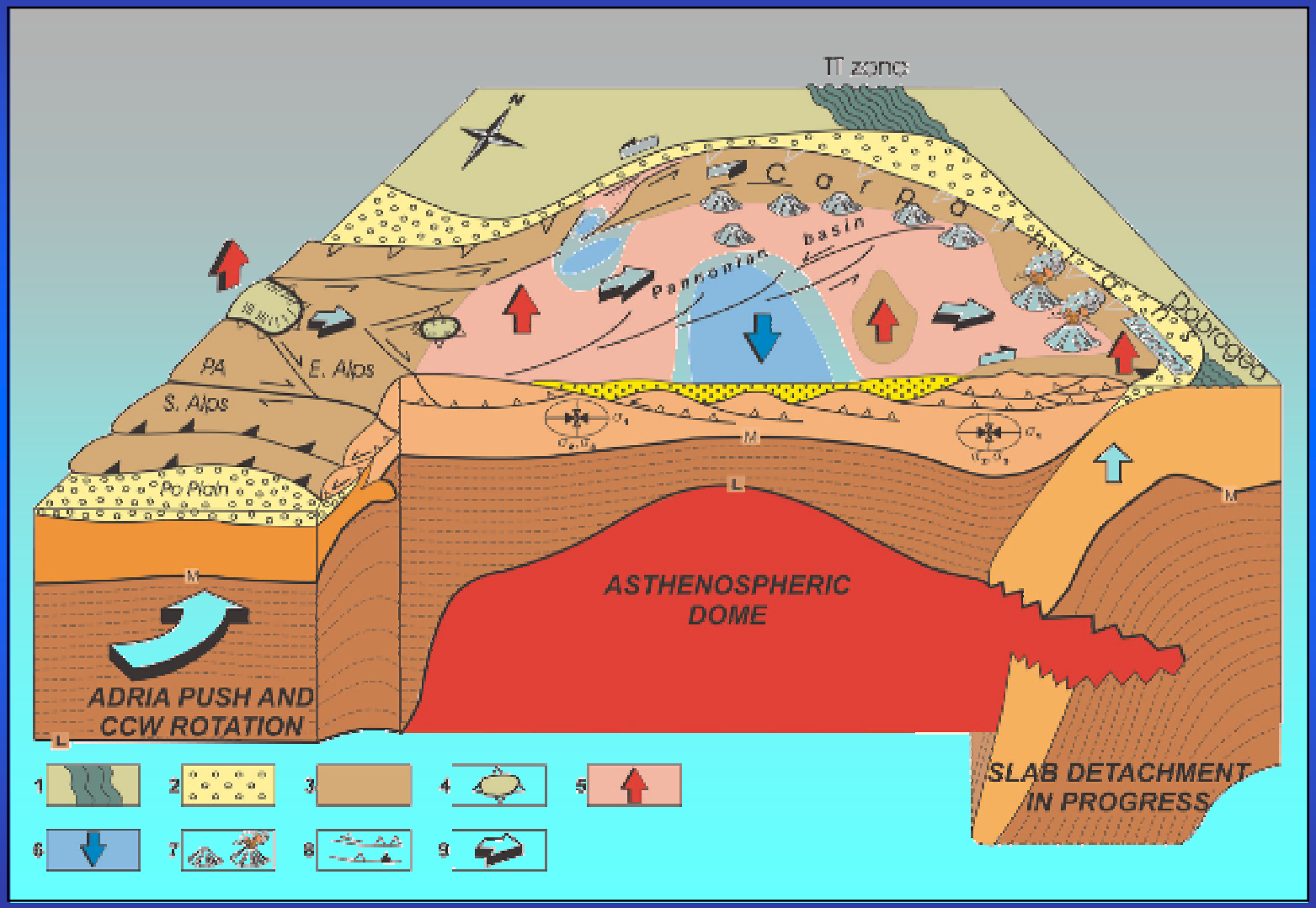


Lithopshere memory- active faults allow hydro-thermal conduit zones



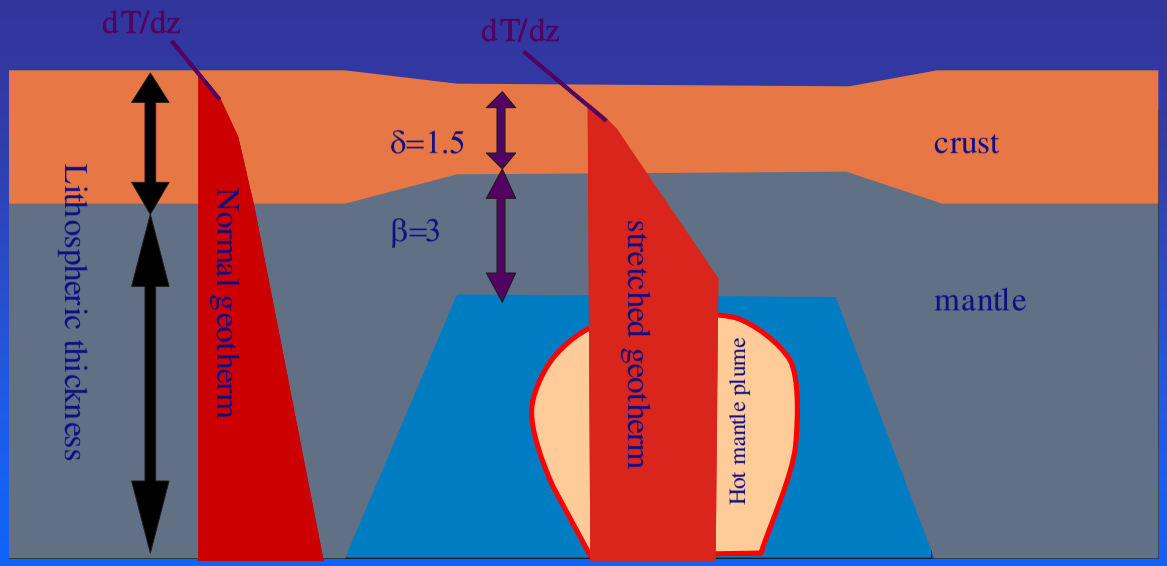
Soultz

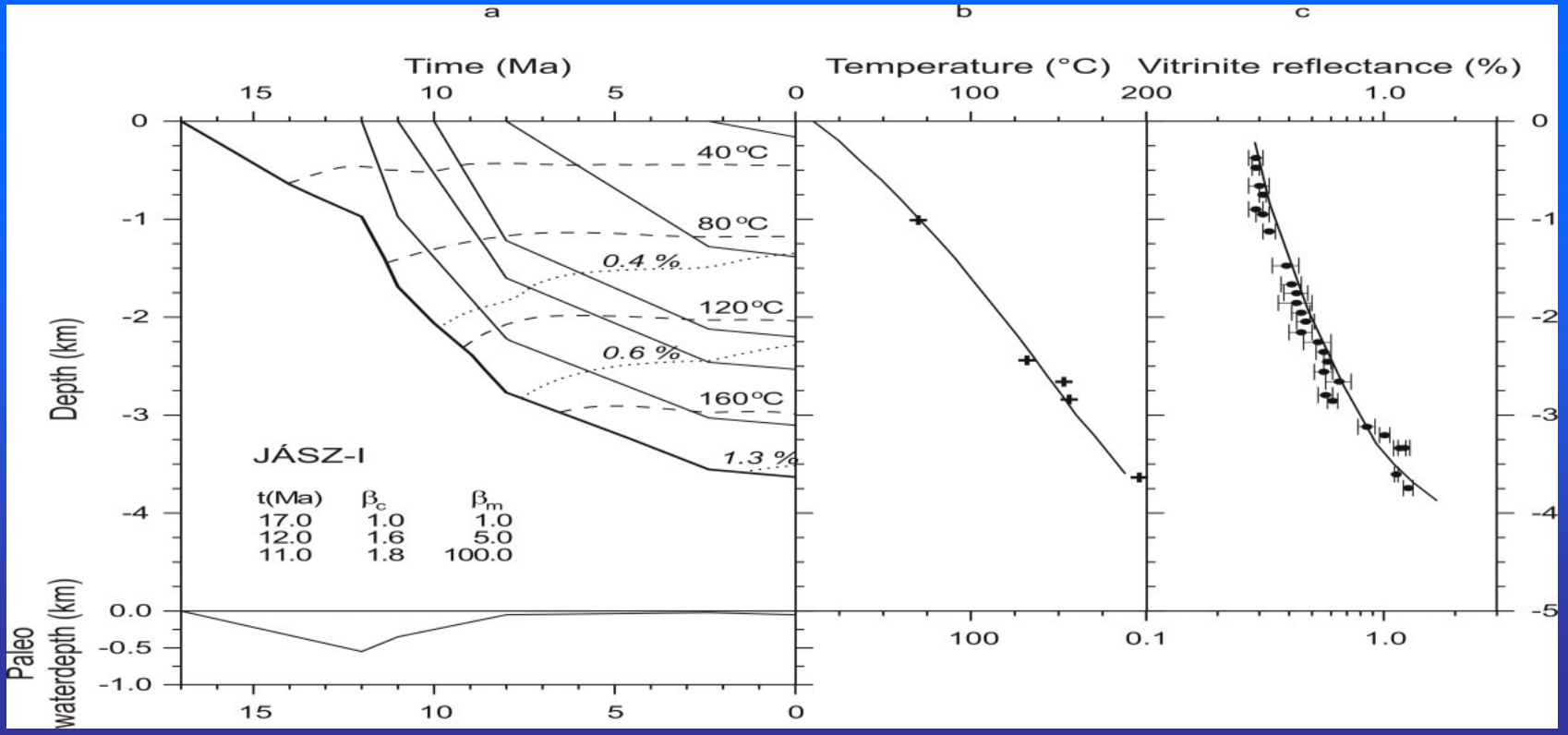
Active deformation and the thermal field



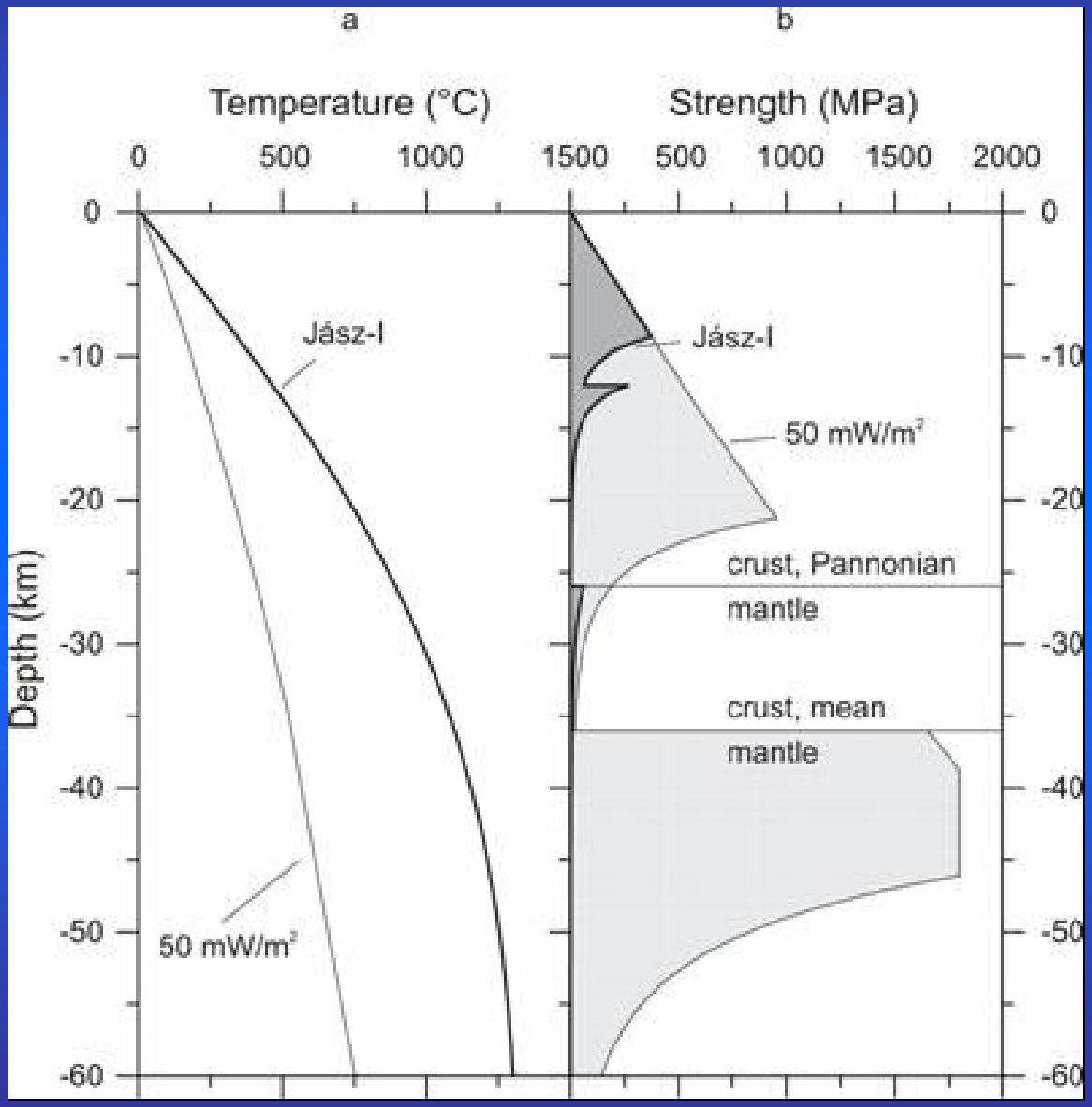
Horvath et al. 2006

Panonian Basin

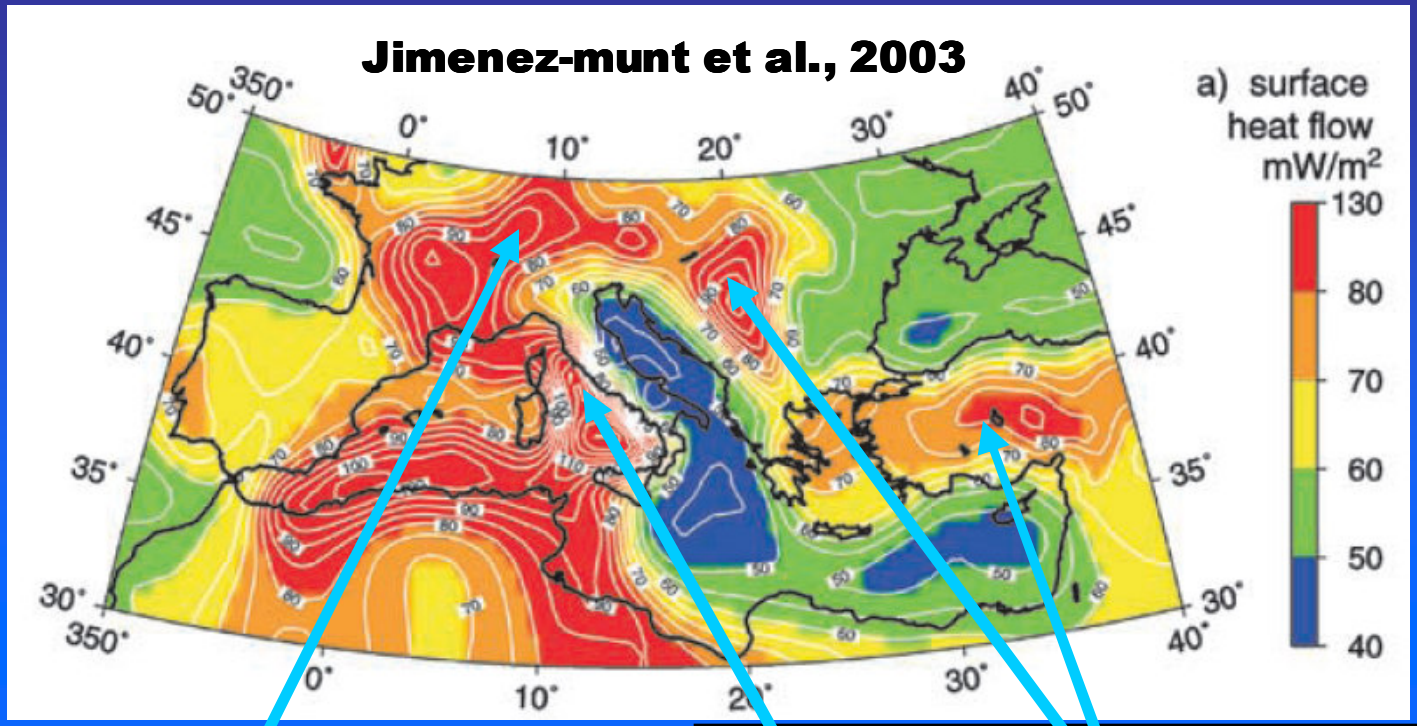


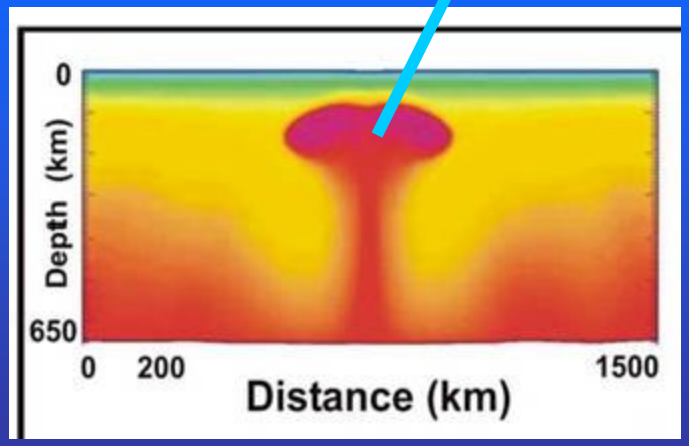


Elevated heat flow- reduced strength

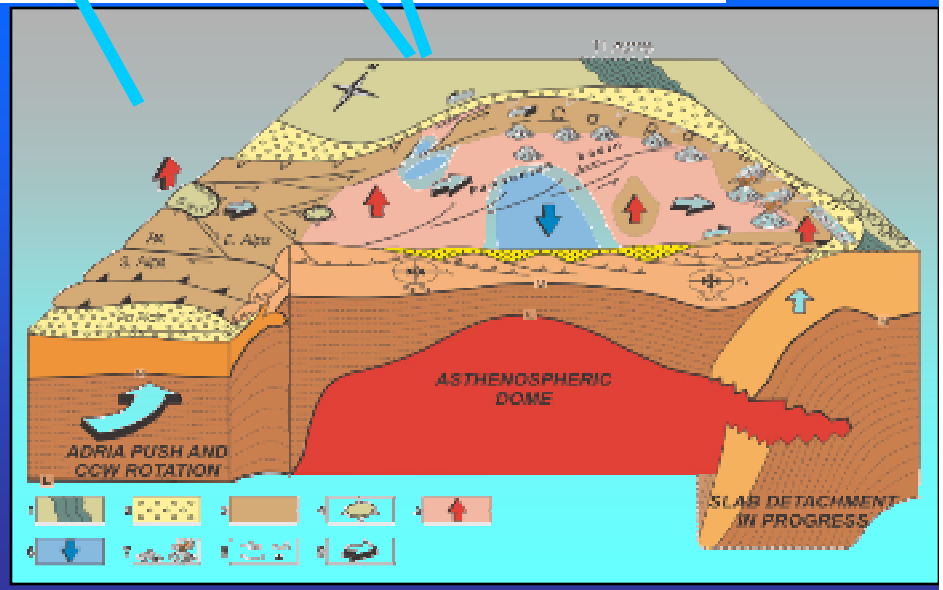


Jimenez-munt et al., 2003

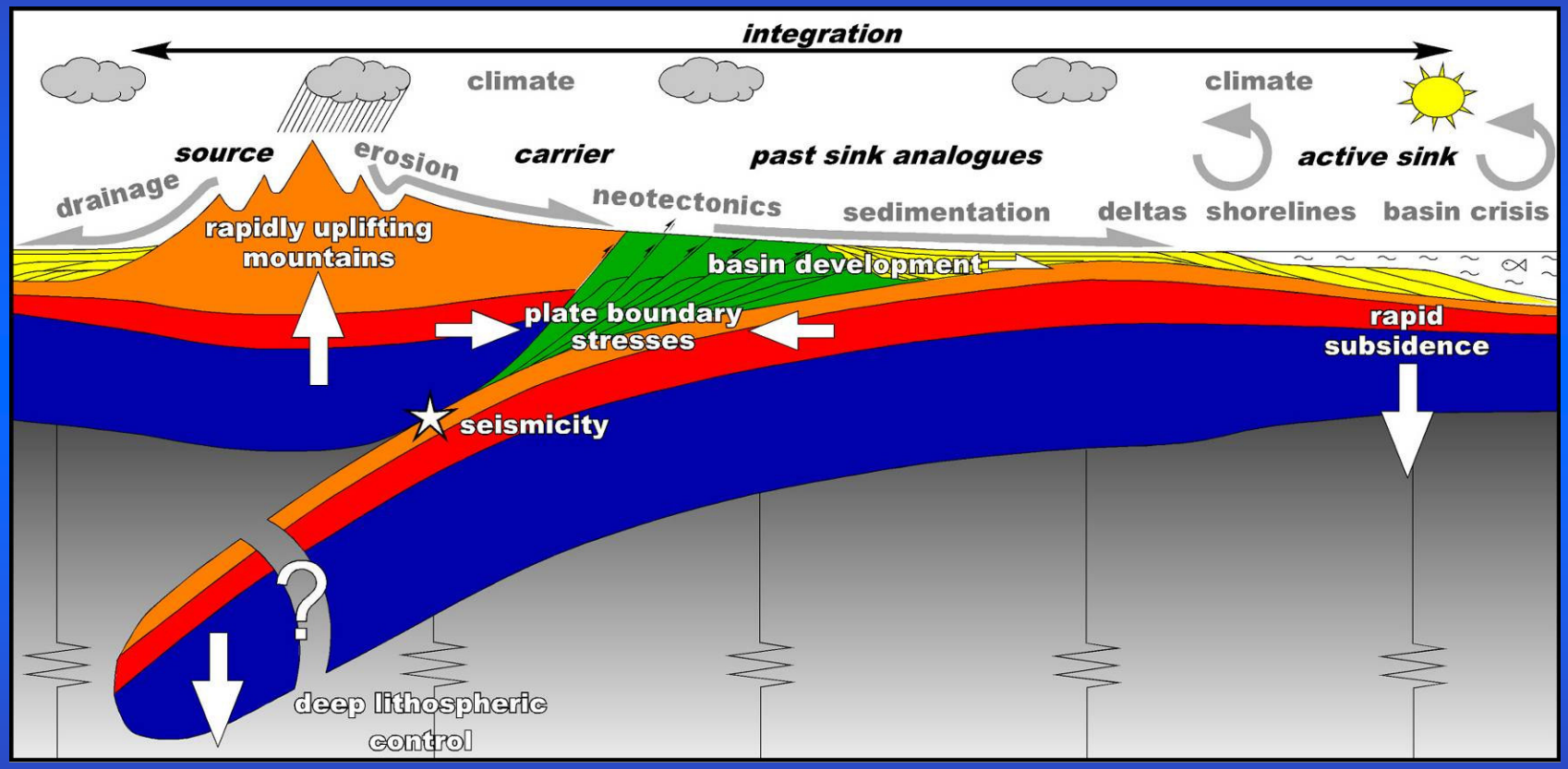




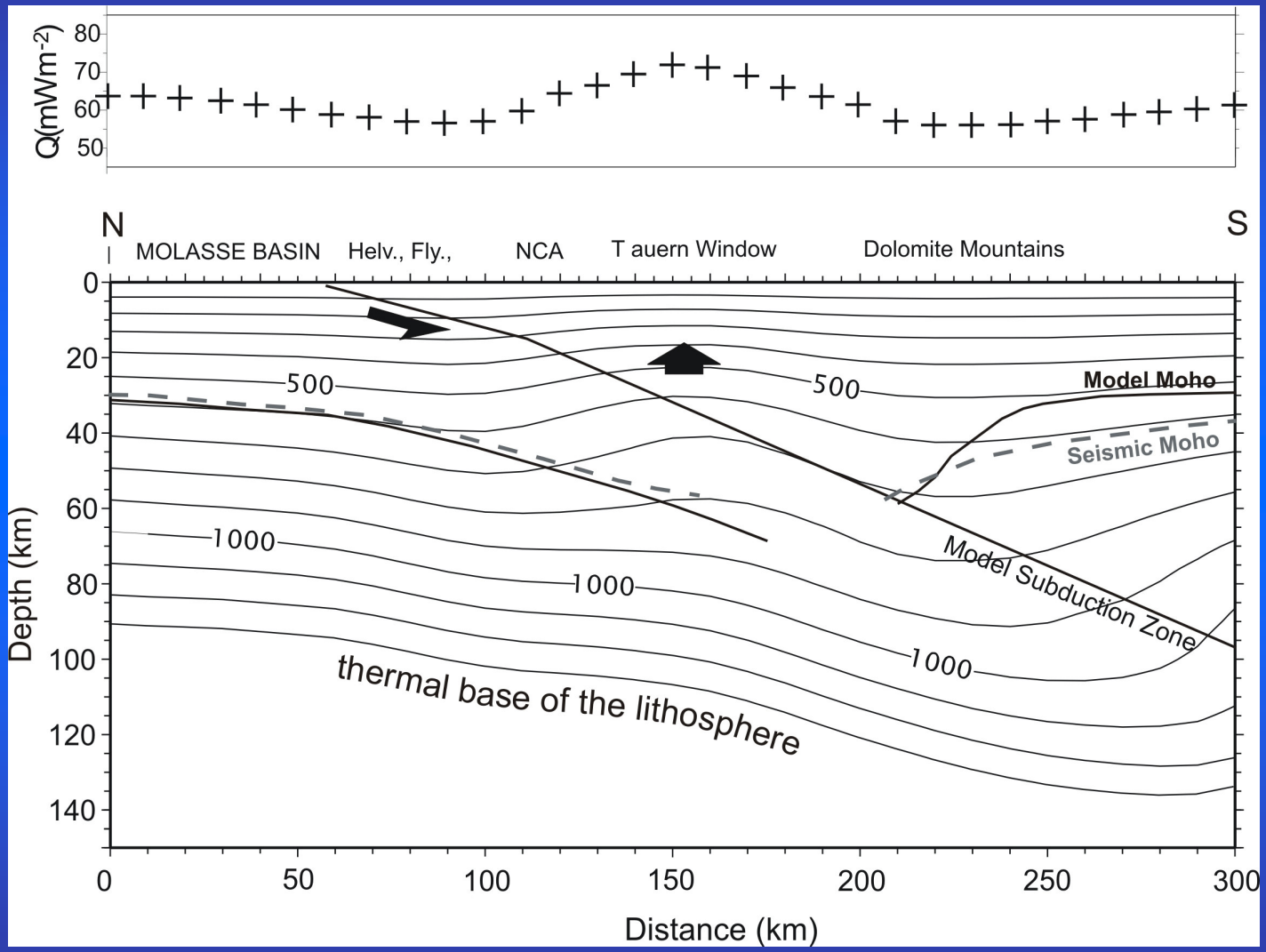
Guillou-Frottier et al., 2007



TOPO-EUROPE: From Source to Sink



Alpine tectonics and present thermal structure



Willingshofer and Cloetingh, Tectonics 22, 2003

Conclusions and Perspectives

- Tectonic modelling provides key constraints on crustal stress and temperature, helpful for geothermal exploration beyond well control
- Late Tertiary tectonics have strong influence on spatial variation of crustal heat flow and stress→ much more heterogeneous than to be expected from first order maps (properties , processes and fabric)
- Interplay of lithospheric and surface processes operating at multiple scales need to be taken into account for understanding and prediction of crustal stress and heat flow
- Analogue-numerical modelling applied in natural laboratories provide a set of world class opportunities to develop a new generation of models for crustal stress and heat flow evolution