The South Limburg candidate site for the Einstein telescope:
Geological and seismotectonic setting

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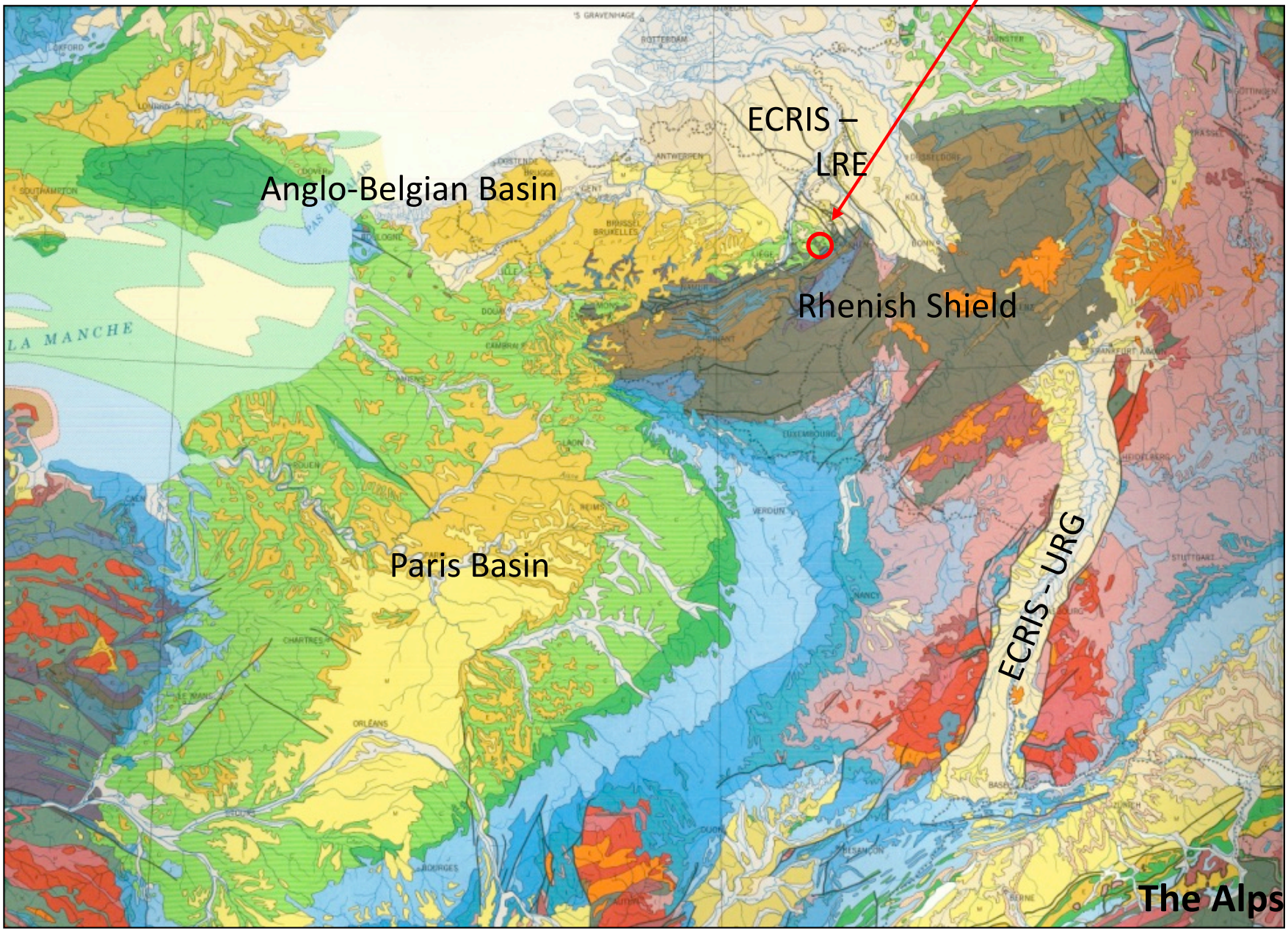
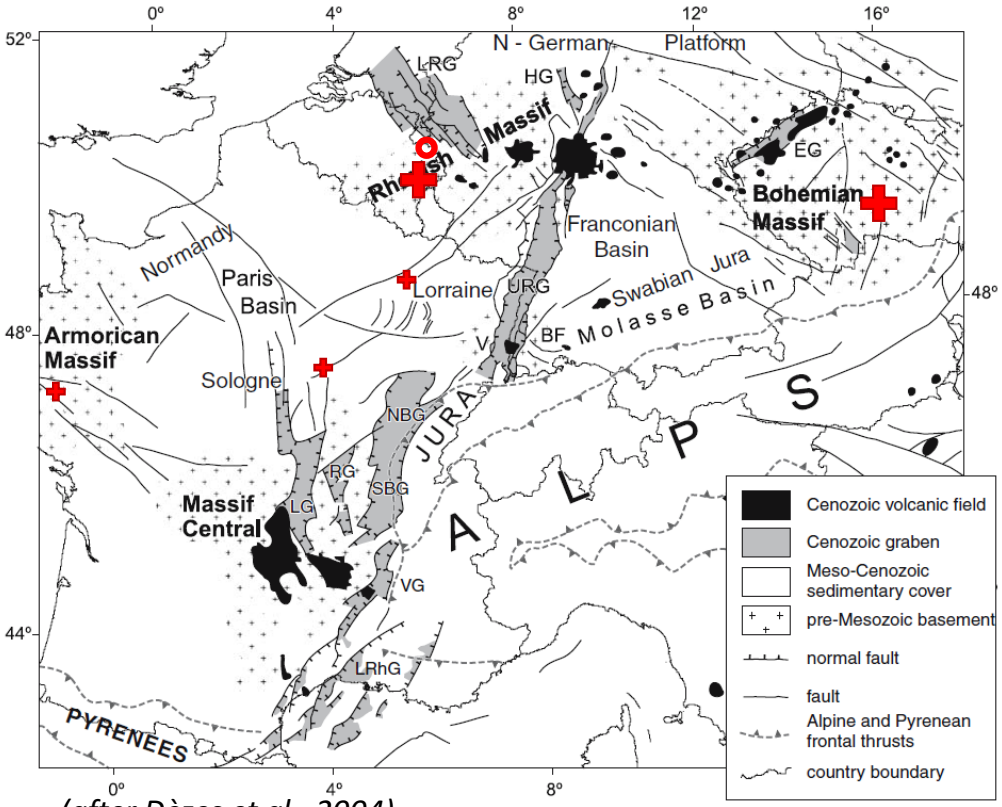
The NW European scale: geological setting

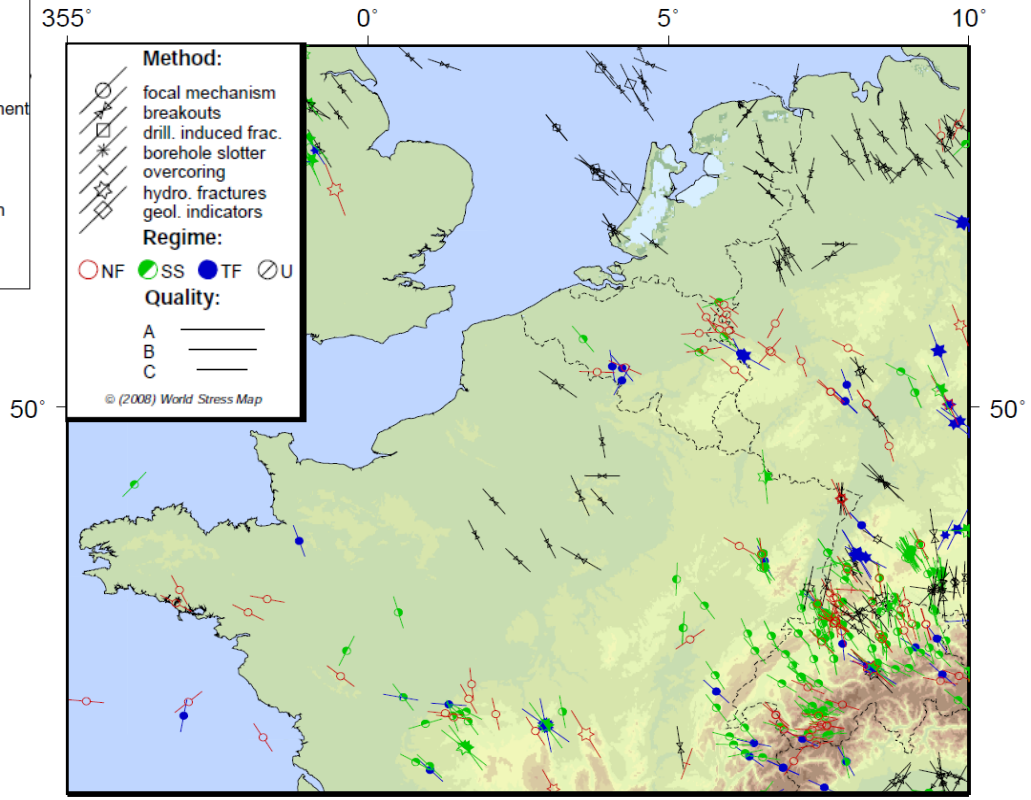


The NW European scale: tectonic setting

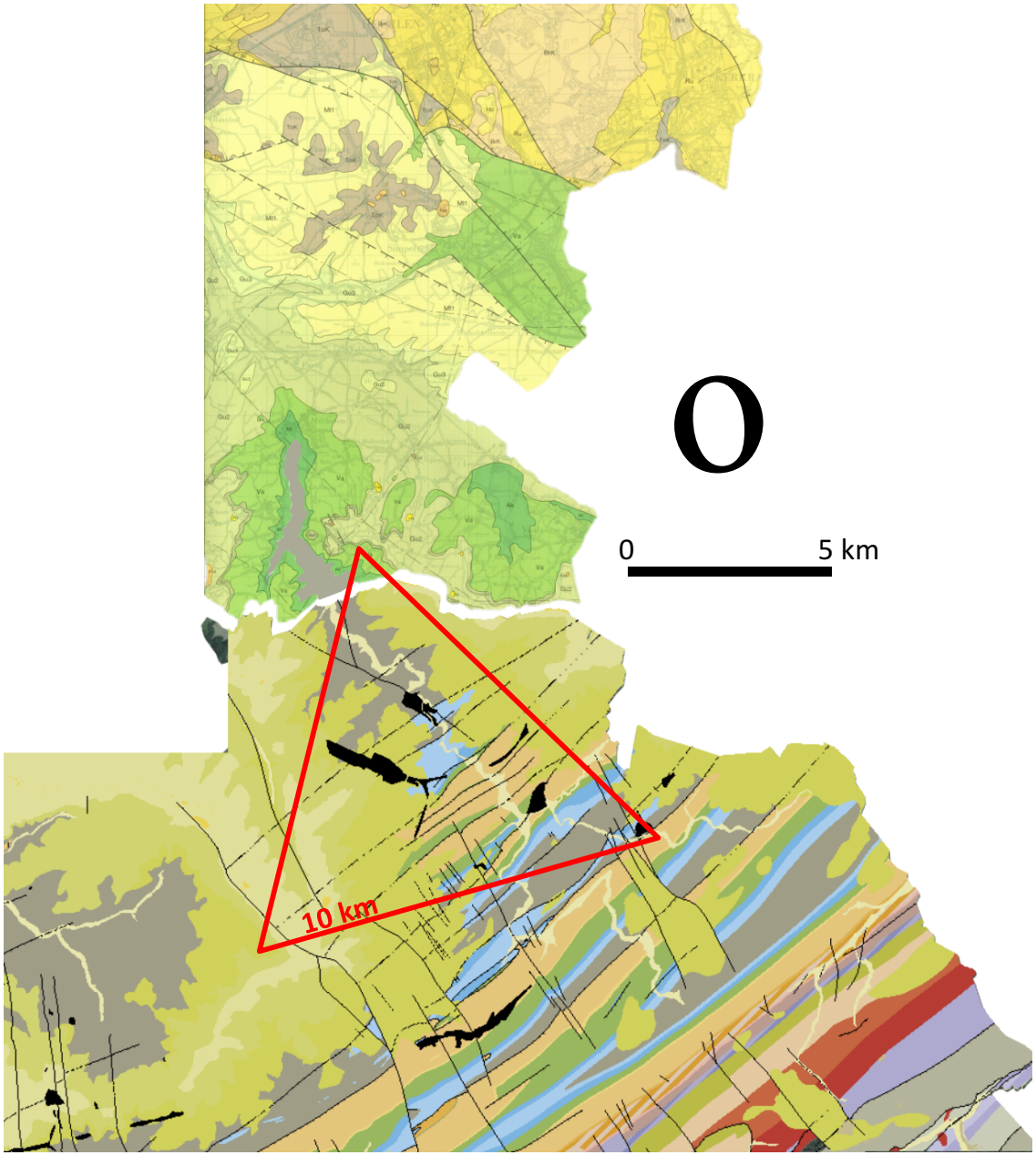


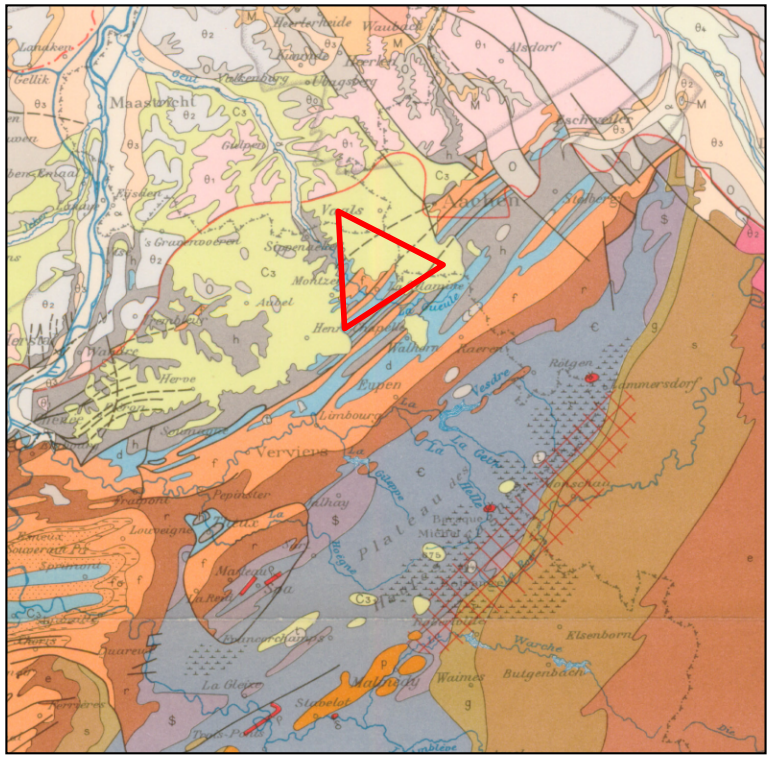
(after Dèzes et al., 2004)

Stress map (*Heidbach et al., 2016*)



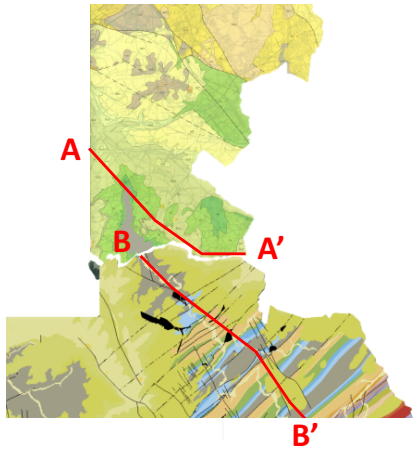
The regional scale: lithology

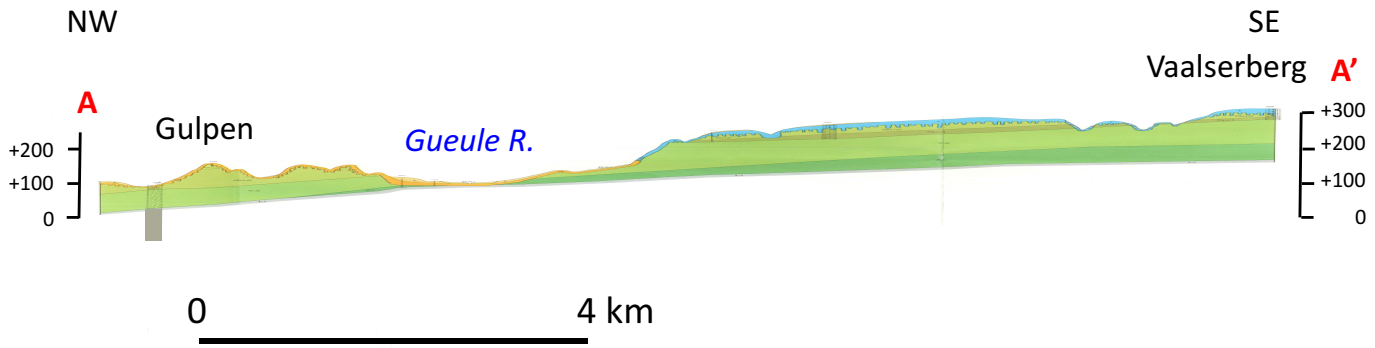


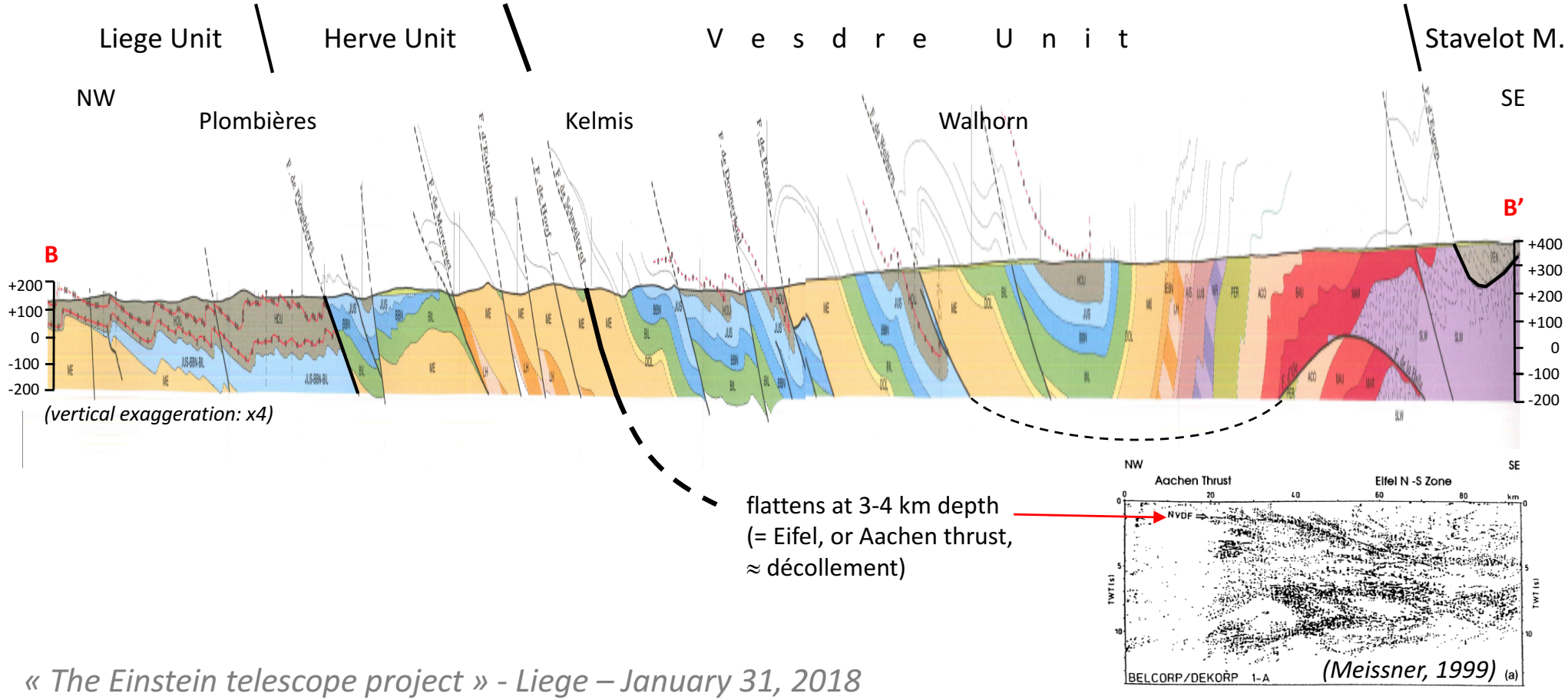


(geological map of Wallonia, http://geoportail.wallonie.be/walonmap)

The regional scale: structural/lithologic cross-section



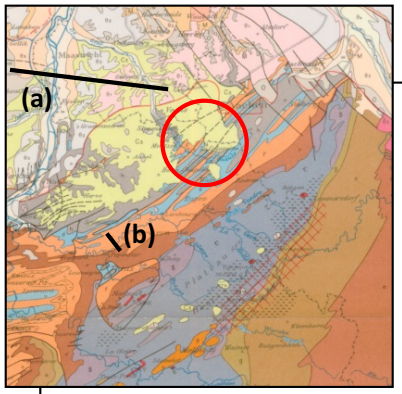




Plio-Quaternary tectonics – regional uplift and subsidence

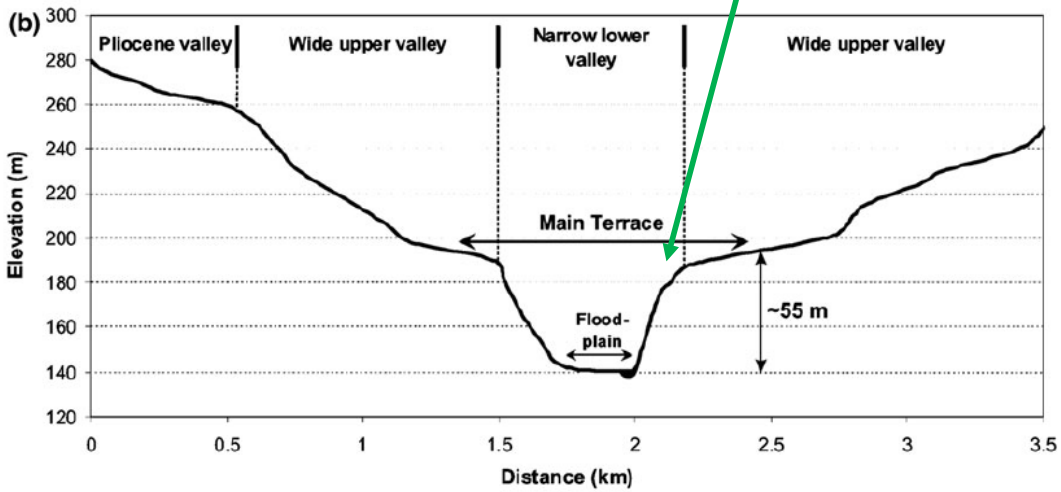
Geomorphic indicators of tectonic deformation:

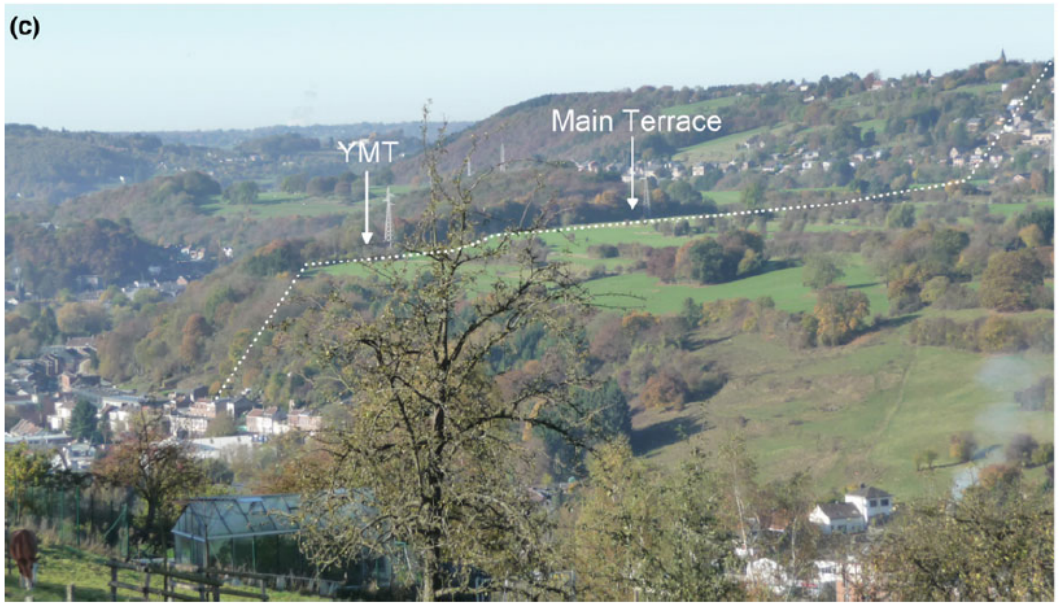
- incised valleys and river terrace staircases



(Van den Berg, 1996)

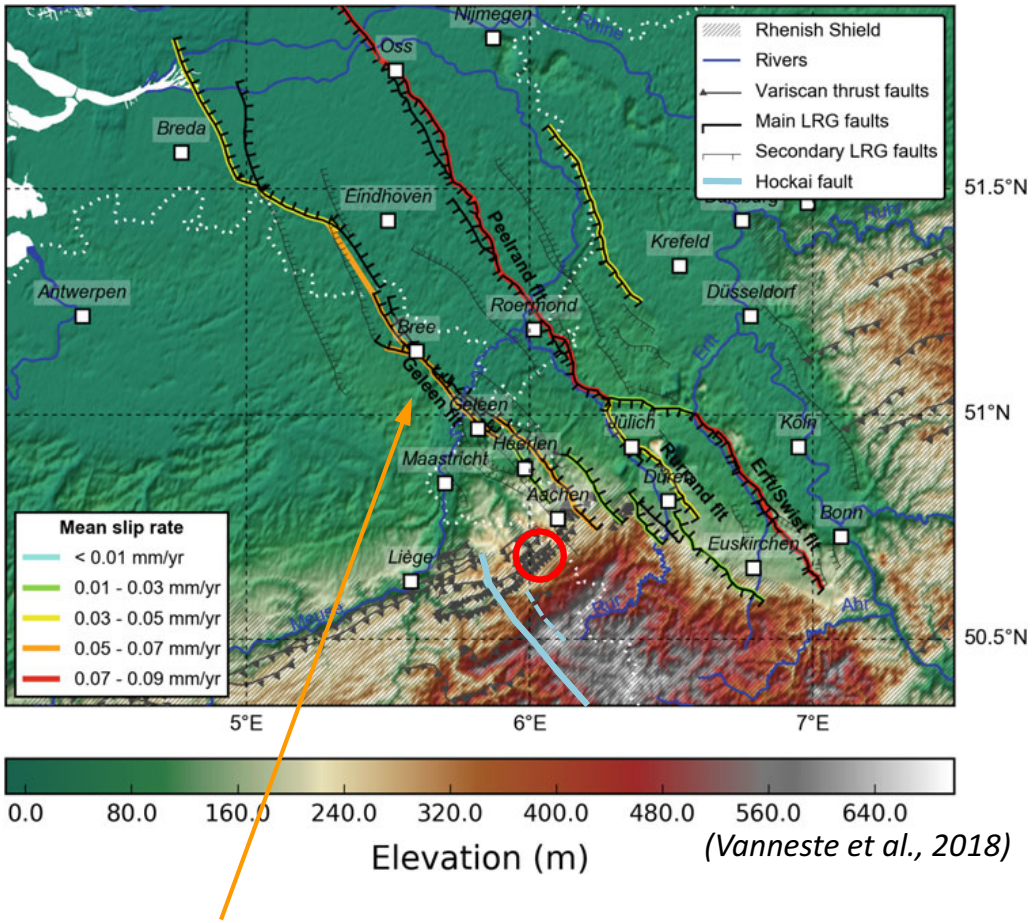
increased incision rate = response to a pulse of accelerated uplift at ~0.7 Ma





(Rixhon & Demoulin, 2018)

Plio-Quaternary tectonics – active faulting



(Vanneste et al., 2018)

1. Fault slip rates

Mean long-term (up to 1 My) fault slip rates are inferred from deformed geomorphic features and stratigraphic data:

- displaced river terraces
- offset in the base of alluvial deposits
- tectonic scarps

2. Seismic vs aseismic fault motion

Predominant seismic behaviour is indicated by:

- morphotectonic and sedimentary features at fault traces
- the correspondence between long-term geologic and shorter-term (10^4 y) paleoseismic slip rates

Bree segment of the Geleen fault:

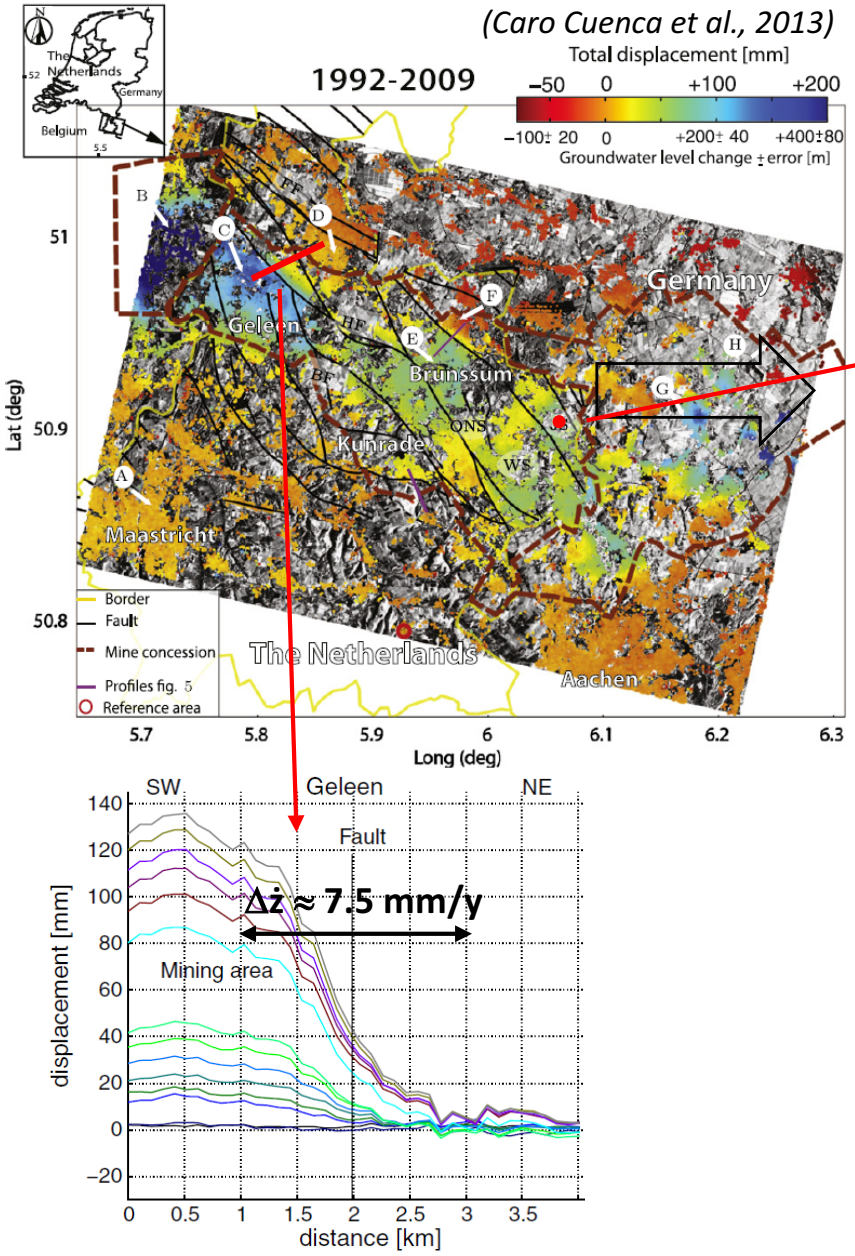
- displaced base of the ~740-ky-old Meuse terrace
*→ geologic slip rate of **0.04-0.07 mm/y***

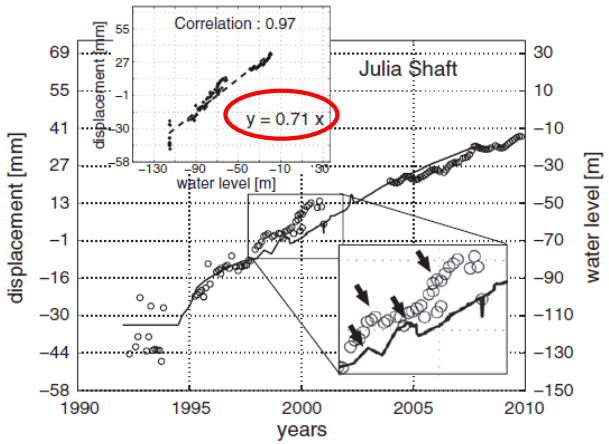
- paleoearthquake record of the last ~100 ky
*→ paleoseismic slip rate of **0.03-0.06 mm/y***

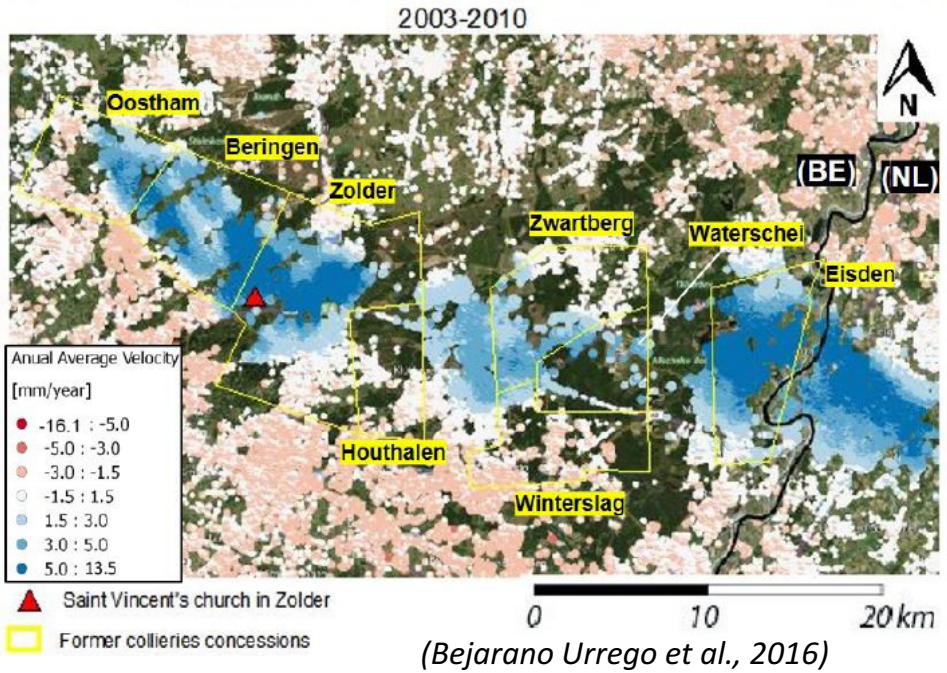
Present-day ground deformation – geodetic data

A. Feldbiss fault zone – PS-InSAR analysis – the aftermath of coal mining + GW seasonal oscillations

(Caro Cuenca et al., 2013)



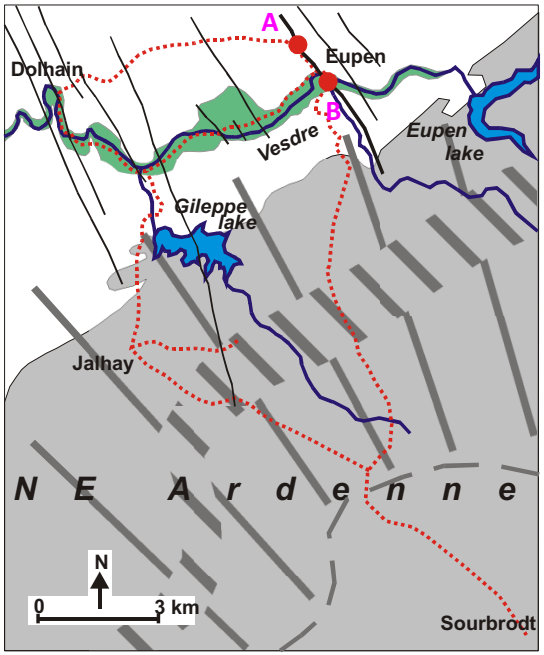




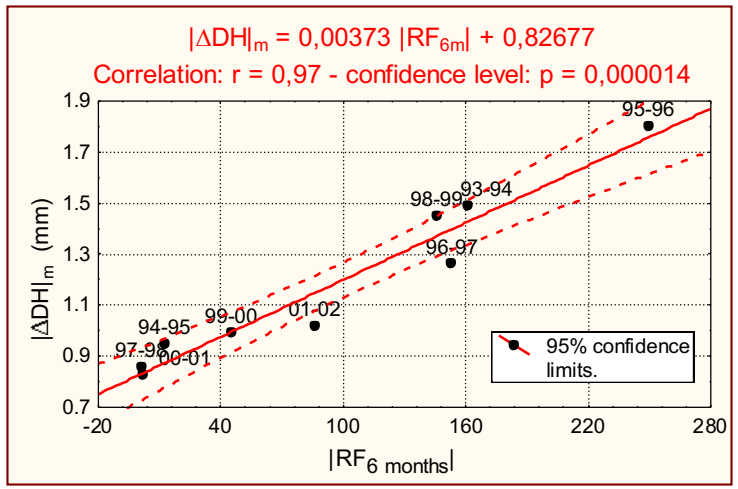
(Bejarano Urrego et al., 2016)

Present-day ground deformation – geodetic data

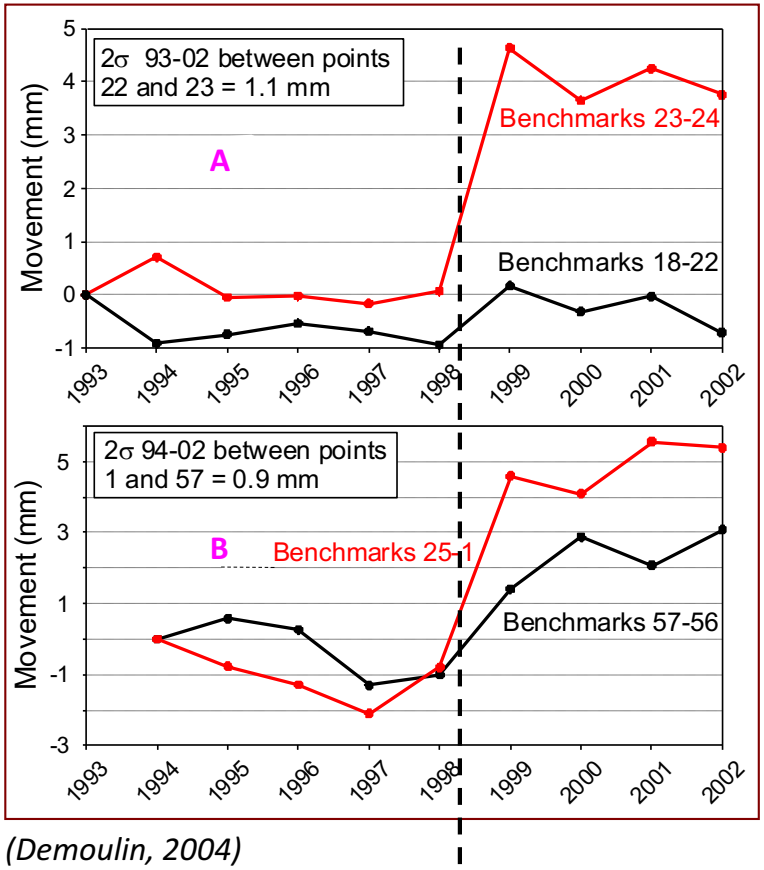
A. Levelling across the N margin of the Hautes Fagnes uplift – random fault creep event



(1) Groundwater level variation effect



(2) Random fault creep event



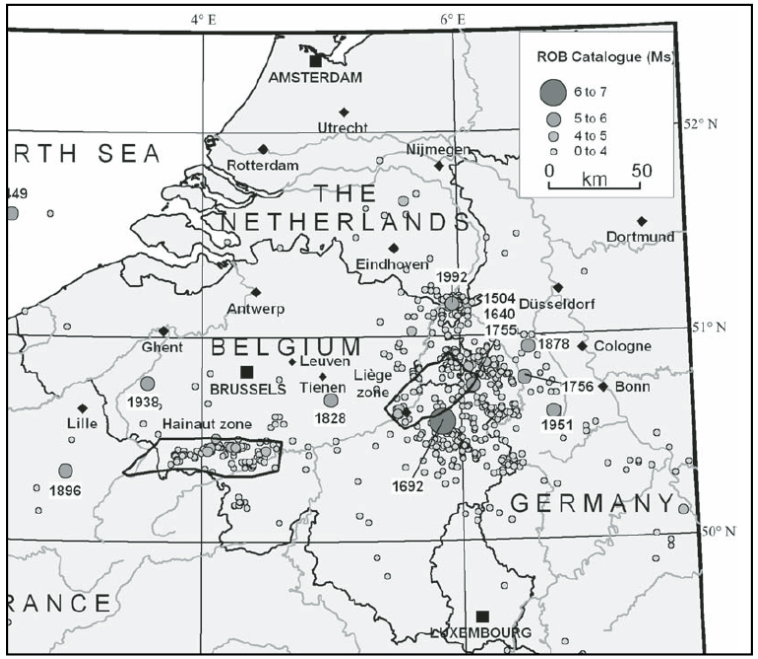
(Demoulin, 2004)

Stockem fault

A Δz(1998-99) 3.5 mm ≈ Δ_mz(<1998->1999) 3.6 mm

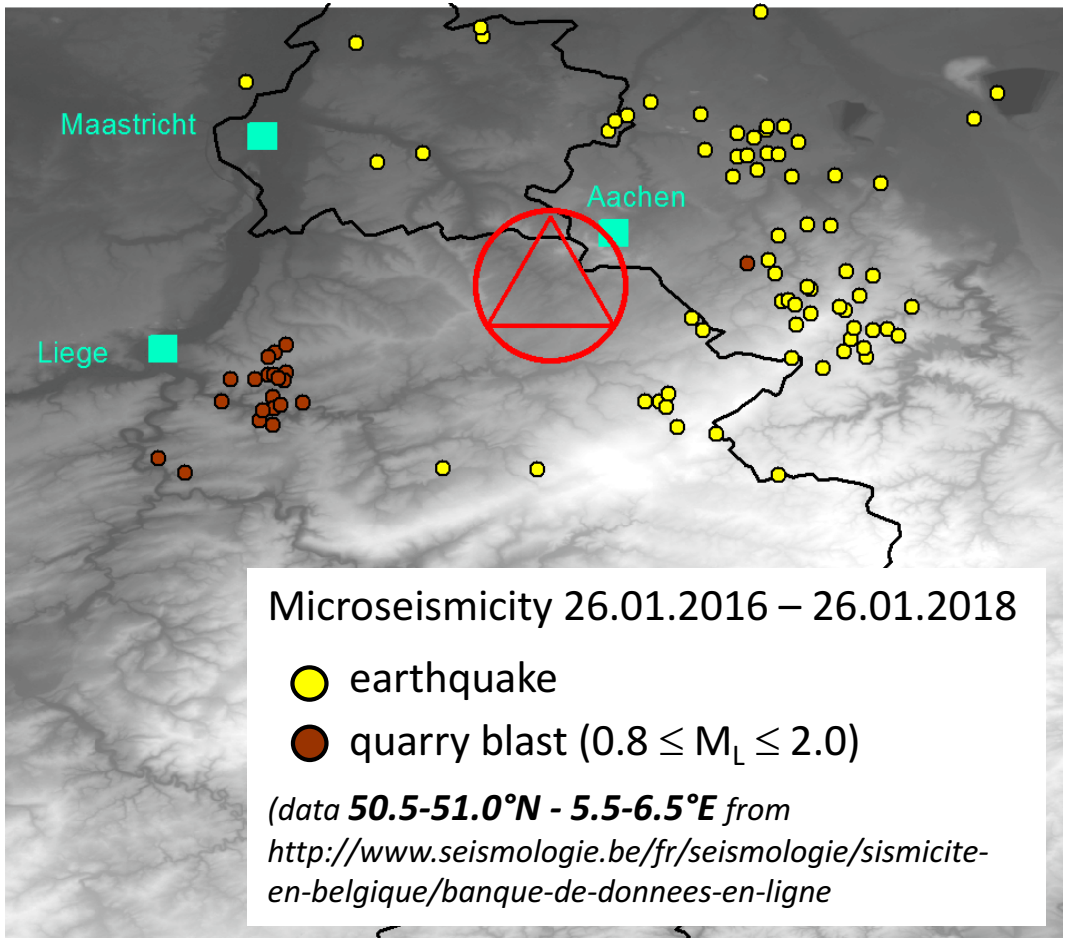
B Δz(1998-99) 3.0 mm ≈ Δ_mz(<1998->1999) 3.2 mm

Present-day crustal deformation and ground motion – microseismicity



(Camelbeeck et al., 2007)

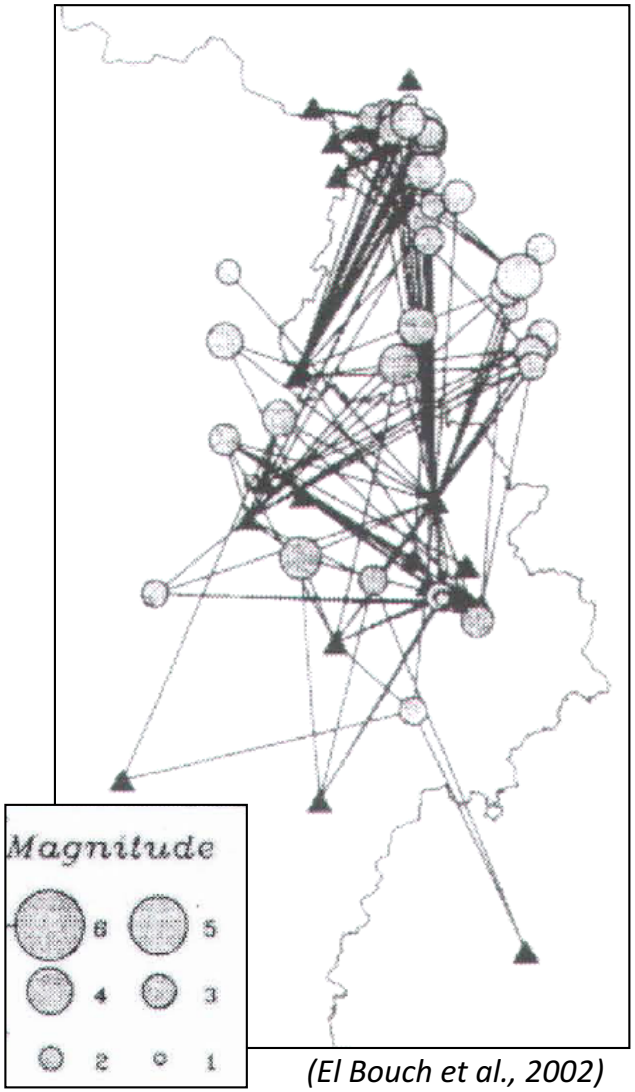
(SPWallonie -DGO4 - SDER) – active quarries



	$M_L = 0.0$	$M_L = 2.0$
At 10 km distance	$A_{max} \approx 32$ µm	$A_{max} \approx 3.2$ mm
30 km	$A_{max} \approx 8$ µm	$A_{max} \approx 0.8$ mm

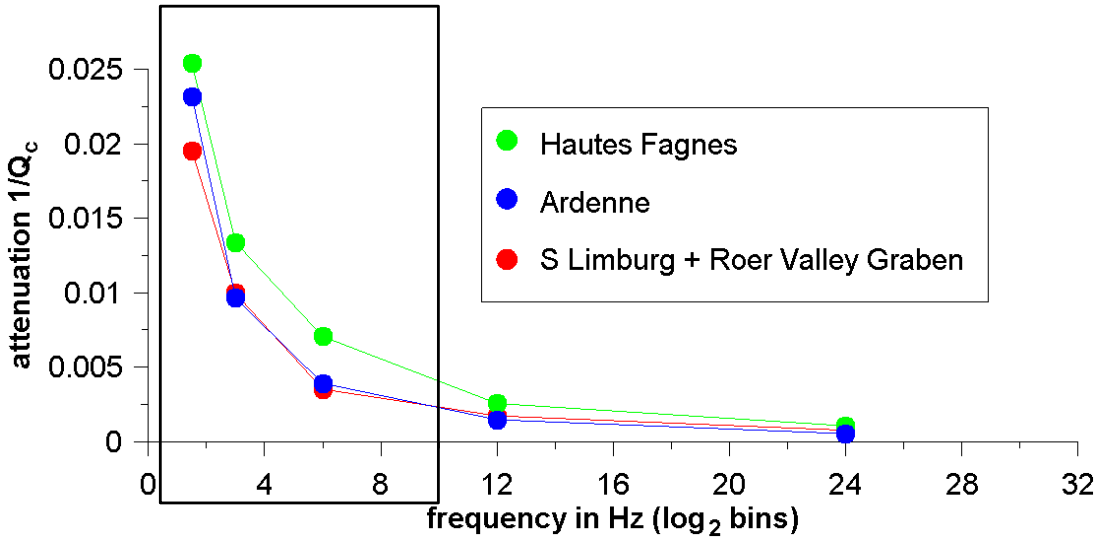
Ground motion – seismic attenuation - the geological as primary seismic isolator?

Source-station couples used for Q_c estimates in E Belgium and S Limburg

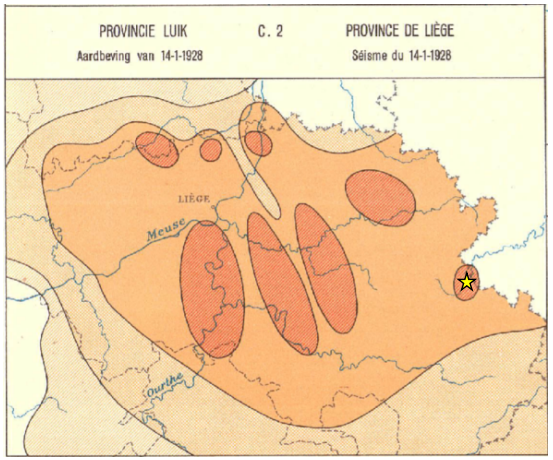


(El Bouch et al., 2002)

Hautes Fagnes: $Q_c = 17.0\ f^{1.16}$
Ardenne: $Q_c = 21.2\ f^{1.37}$
S Limburg – RVG: $Q_c = 26.9\ f^{1.2}$



Ground motion – seismic shaking and site effects



(1st Atlas of Belgium, 1950-72)

KALTERHERBERG (D) - 1928-01-14 00:17:35

DERNIÈRE MISE-À-JOUR : 2010-06-07 17:09:57 HEURE BELGE

Paramètres au foyer

Date et heure	**1928-01-14 00:17:35 T.U.** 1928-01-14 00:17:35 Heure belge
Type	**Tremblement de terre**
Magnitude	**M_L 4.4** M_S 3.7
Maximal intensity	**VI**
Région	**KALTERHERBERG (D)**
Coordonnées de l'épicentre	**50.500° N, 6.100° E**

Source de données : ROB (Royal Observatory of Belgium)

http://www.seismologie.be/fr/seismologie/tremblements-de-terre-en-belgique/ny2rwlmq4

+ soft-sediment to moderately indurated Cretaceous cover

+ propagation of surface waves along the numerous thrust faults

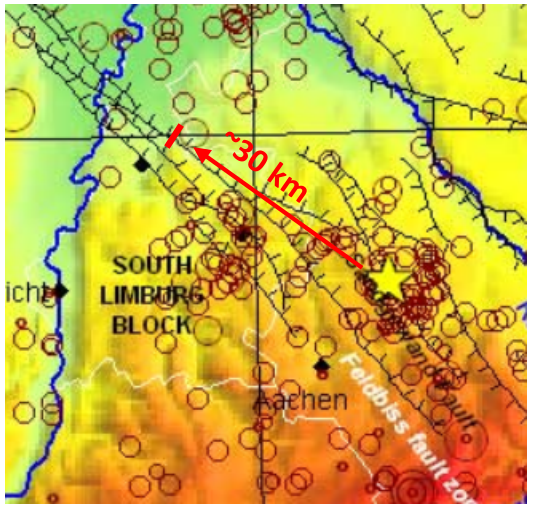
+ vulnerability of abandoned mines to seismic shaking

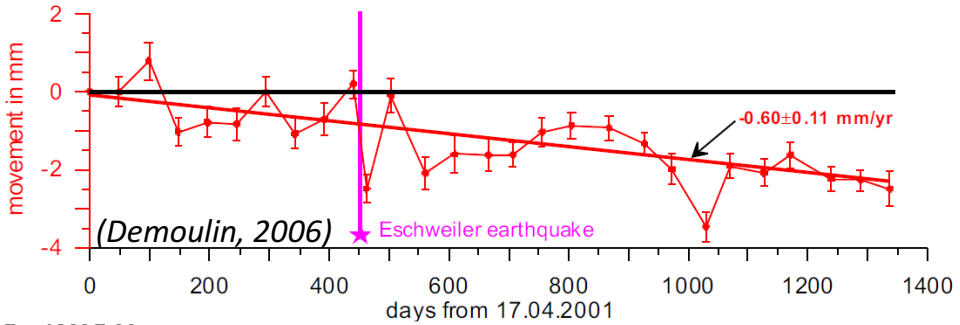
Seismic wave amplification in the damage zone of NNW-SSE faults

Date et heure	**2002-07-22 05:45:04 T.U.** 2002-07-22 07:45:04 Heure belge
Type	**Tremblement de terre**
Magnitude	**M_L 4.9** M_W 4.6
Maximal intensity	**VI**
Région	**ESCHWEILER - ALSDORF (DE)**
Coordonnées de l'épicentre	**50.886° N, 6.207° E** **Incertitude ± 0.8 km**
Profondeur de l'hypocentre	**16.4 ± 0.7 km**

Source de données : ROB (Royal Observatory of Belgium)

http://www.seismologie.be/fr/seismologie/tremblements-de-terre-en-belgique/vw15qky10





(Demoulin, 2006)

Conclusion: South Limburg versus other nearby potential ET sites

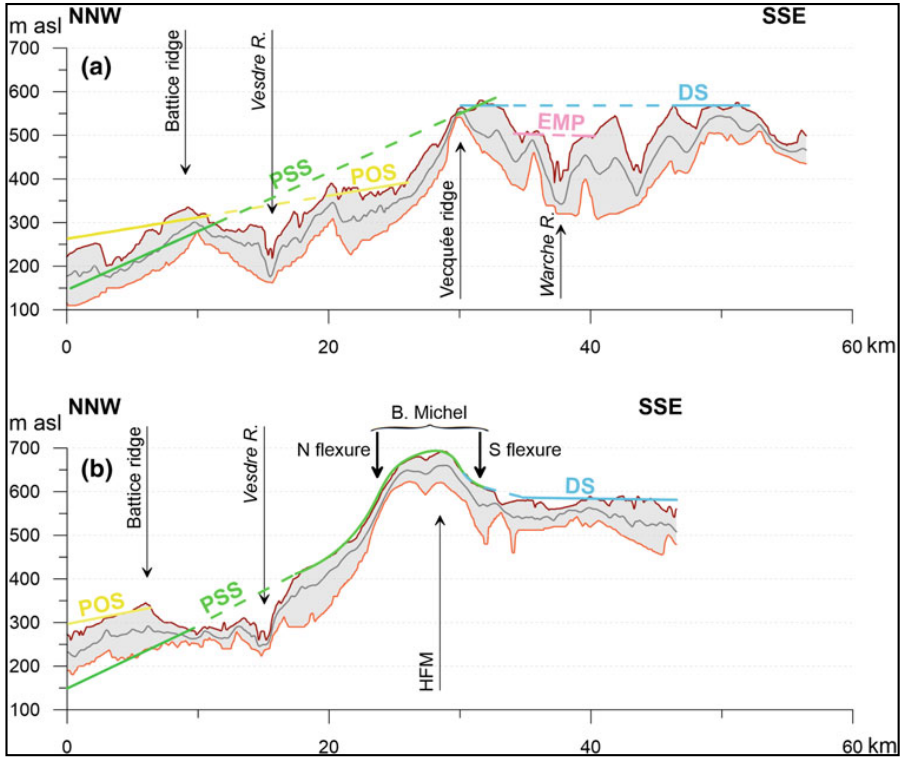
	S Limburg	Mol (Campine)	Hautes Fagnes	Redu (central Ardenne)	Famenne
high-tech environment	+	+	0	+	0
building cost	-	+	-	-	0
active fault density	- -	-	0	+	+
(micro)seismicity level	-	-	-	+	+
human-induced seismicity (quarries)	0	++	0	+	0
other human seismic noise (big cities, industry)	-	-	++	++	++
seismic attenuation	-	?	+	0	?
thrust faults as propagators of surface noise	-	+	+	+	+
lithologic/structural uniformity allowing simpler noise modelling	- -	0	0	+	+
mine GW-induced ground deformation	-	-	+	+	+
seasonal GW-induced ground deformation	0	0	-	0	0
ground deformation from load variations (open pit mines in Germany, lakes)	-	+	-	+	+

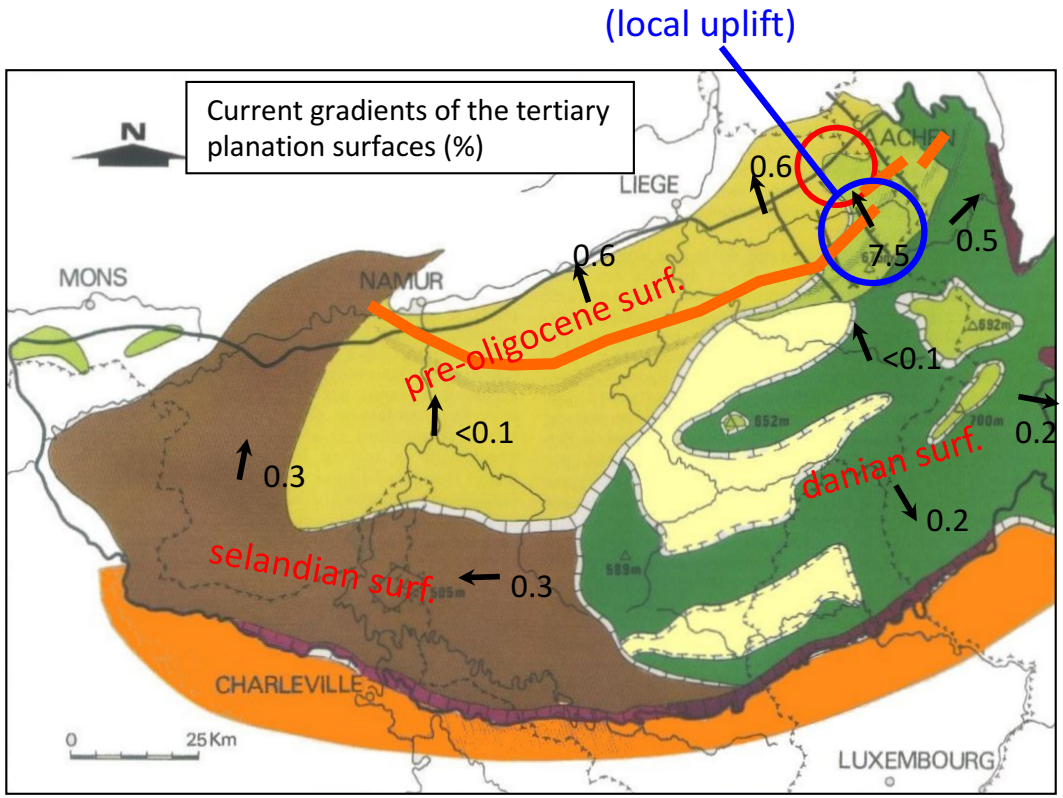
Thank you

Plio-Quaternary tectonics – regional uplift and subsidence

Geomorphic indicators of tectonic deformation:

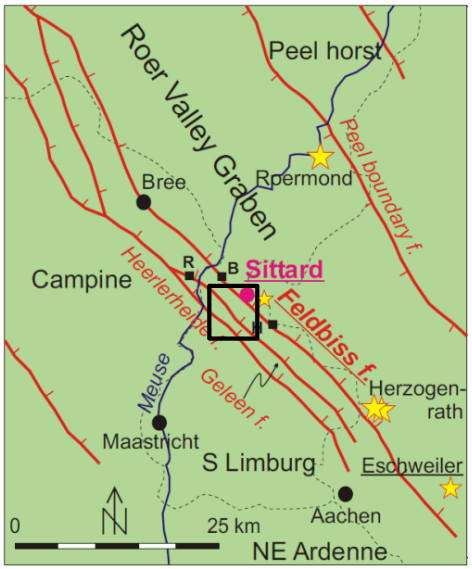
- tilted surfaces

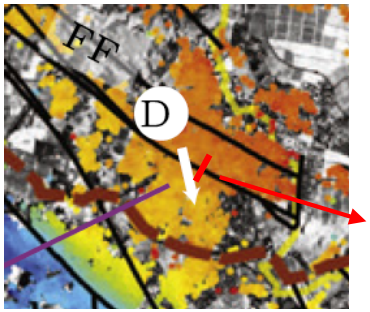




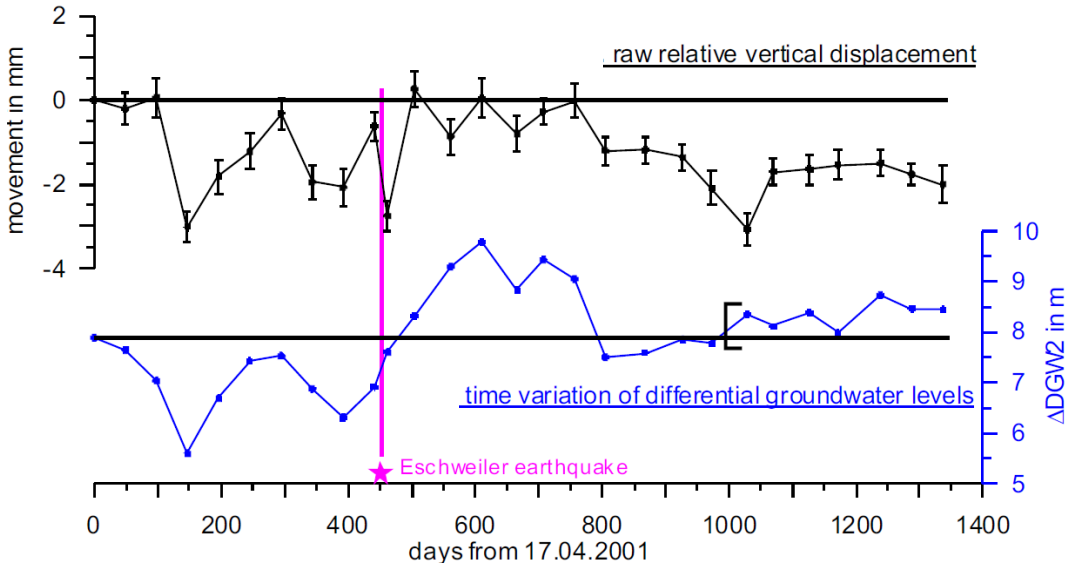
Present-day ground deformation – geodetic data

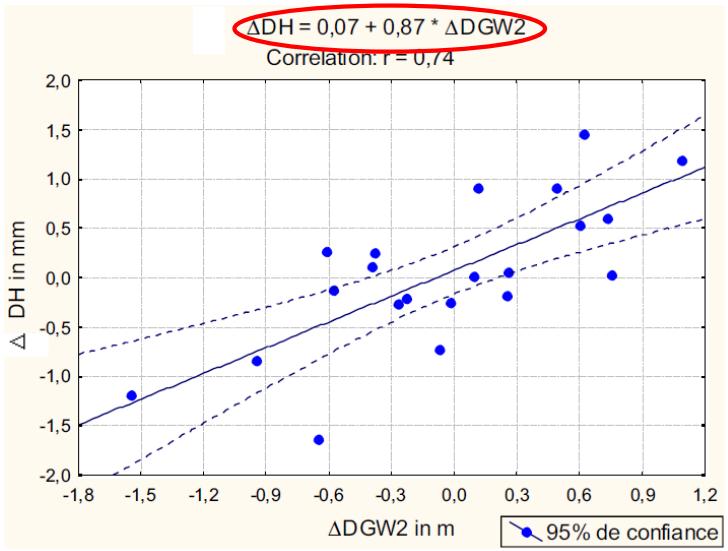
A. Feldbiss fault zone – levelling at Sittard (NL) – seasonal groundwater perturbation + tectonic trend (?)

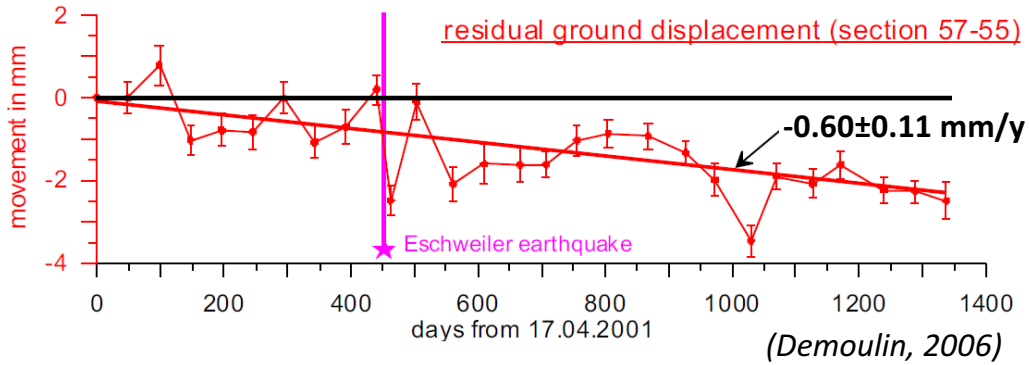




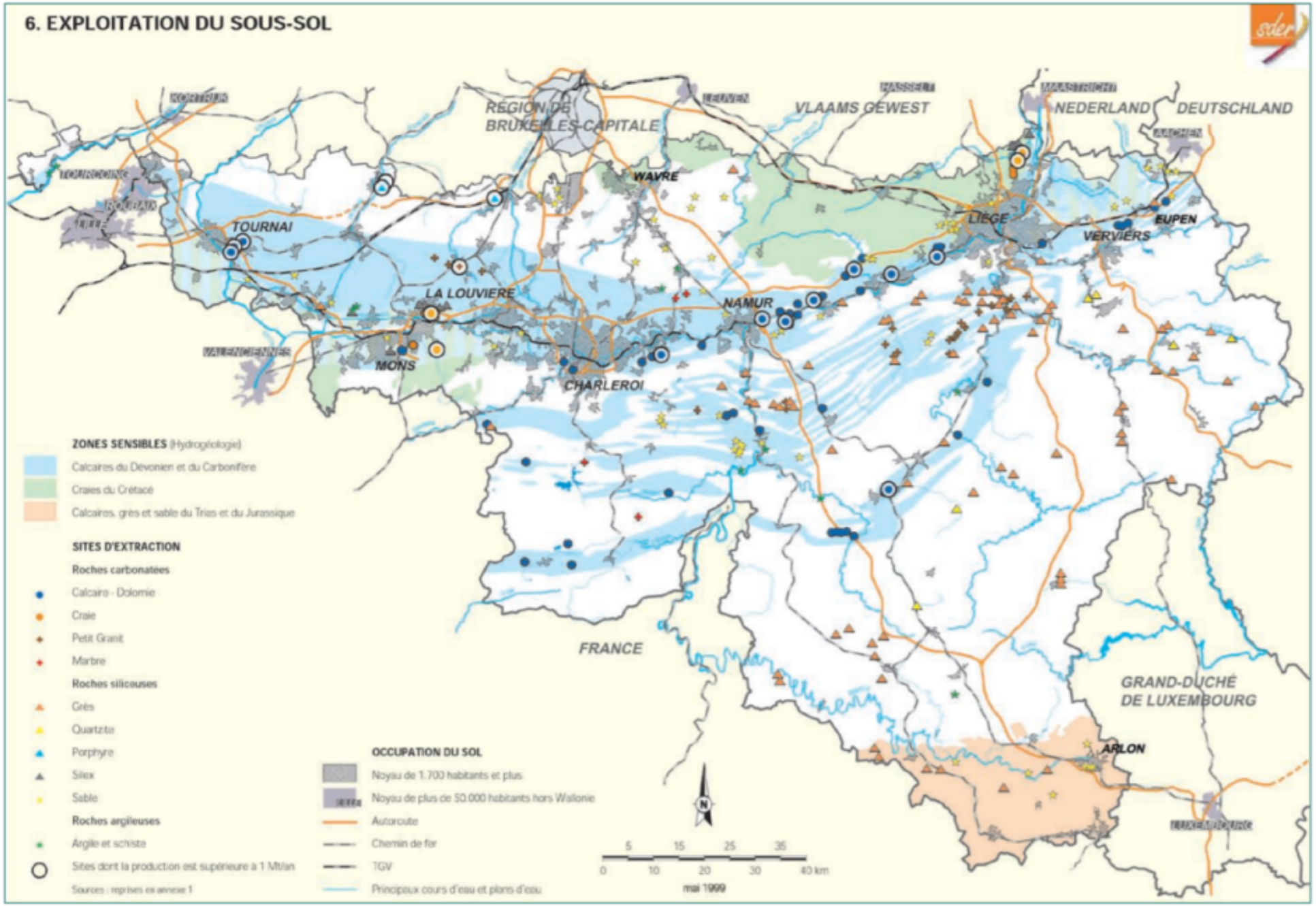
1992-2009







(Demoulin, 2006)



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