Induced Seismicity at the Natural Gas Fields in Northern Germany

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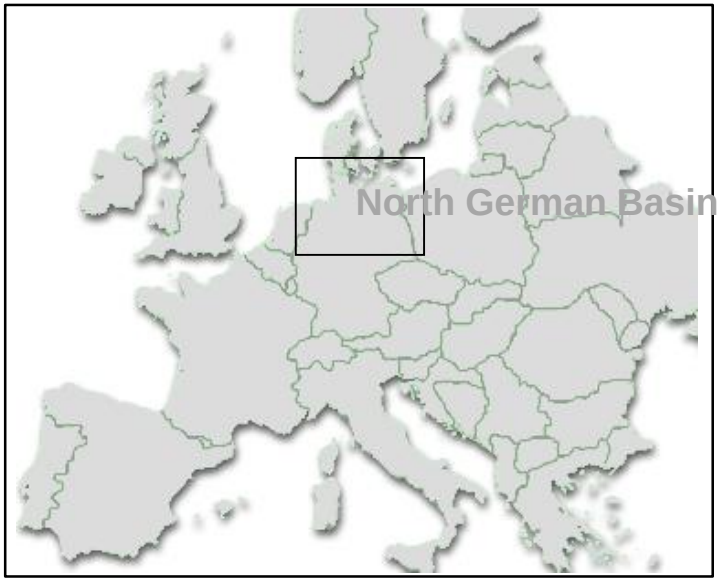
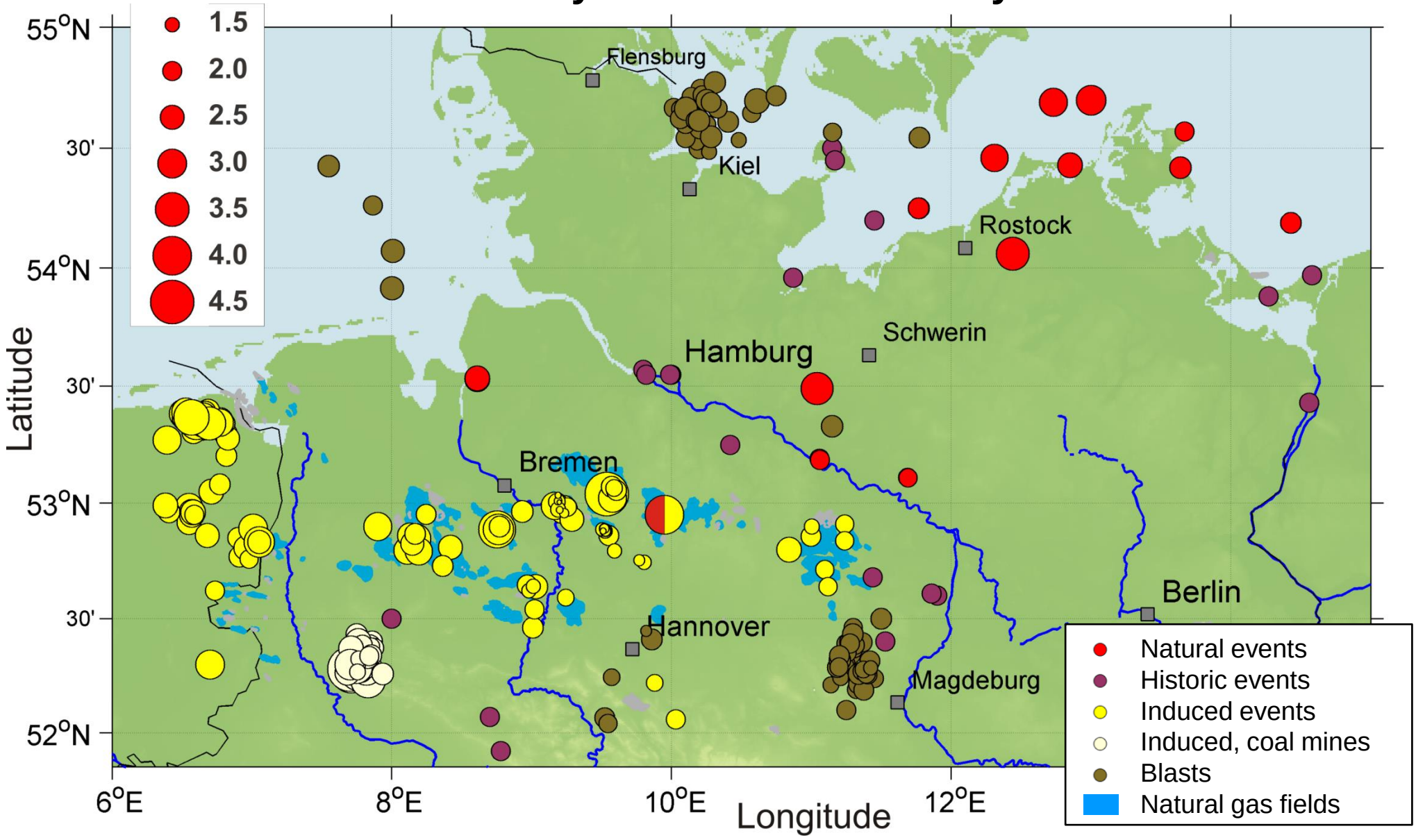
Overview

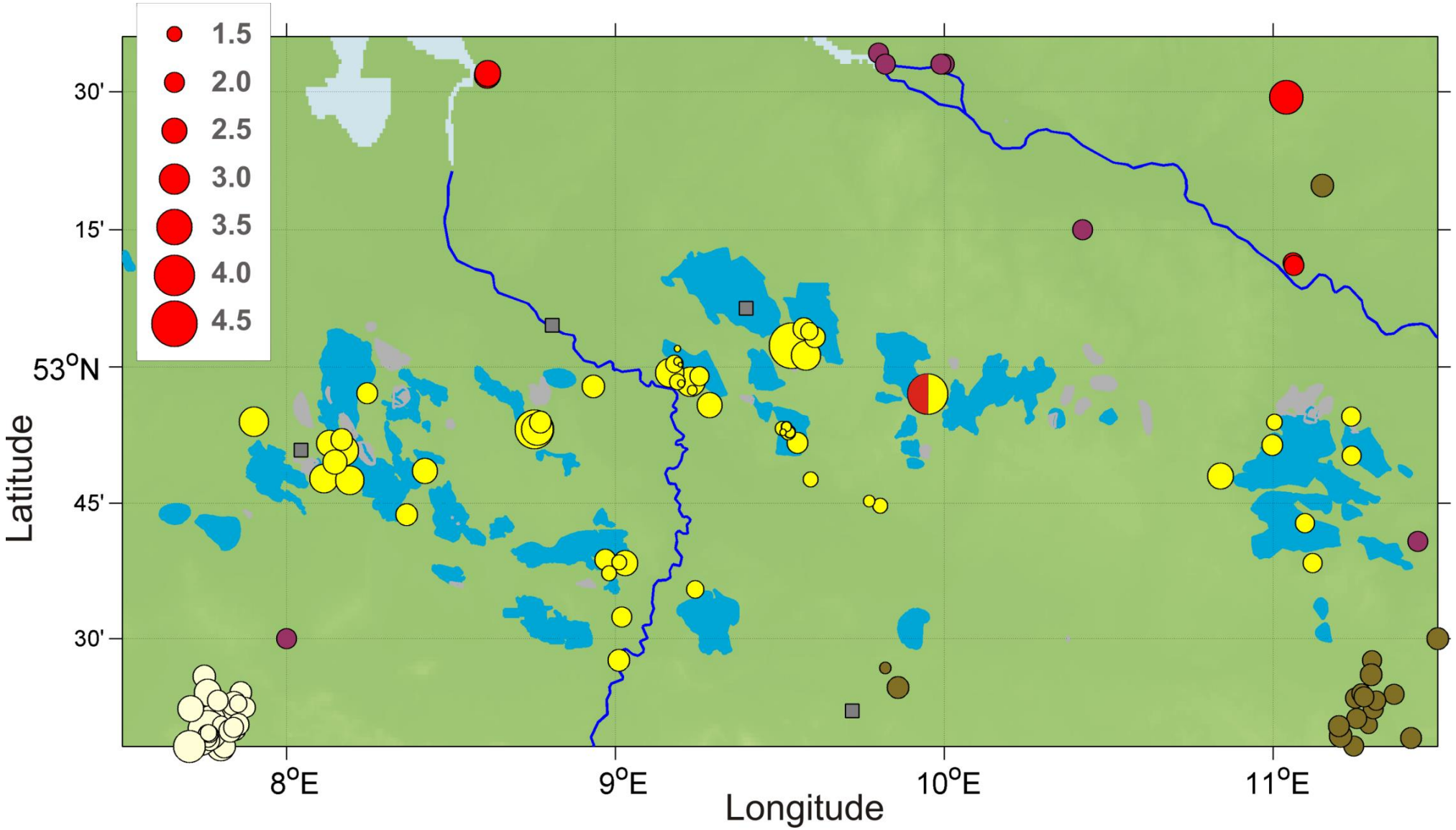
- Seismicity in Northern Germany – Observations
- Natural gas production and induced seismicity
- The role of hydraulic fracturing
- Focal mechanisms and fault zones
- Local hazard potential of seismic events
- Conclusions



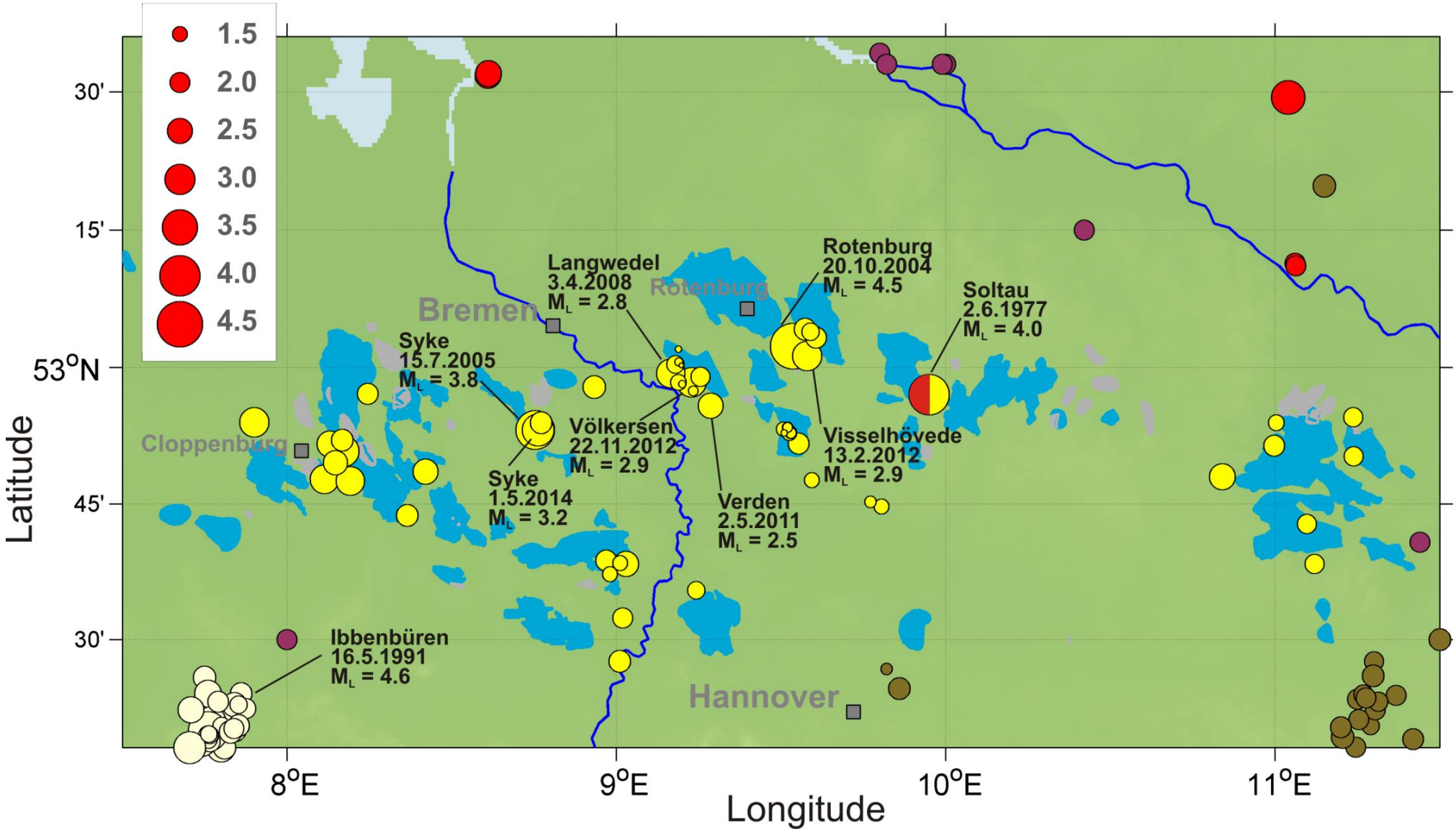
Seismicity in Northern Germany



Seismicity in Northern Germany

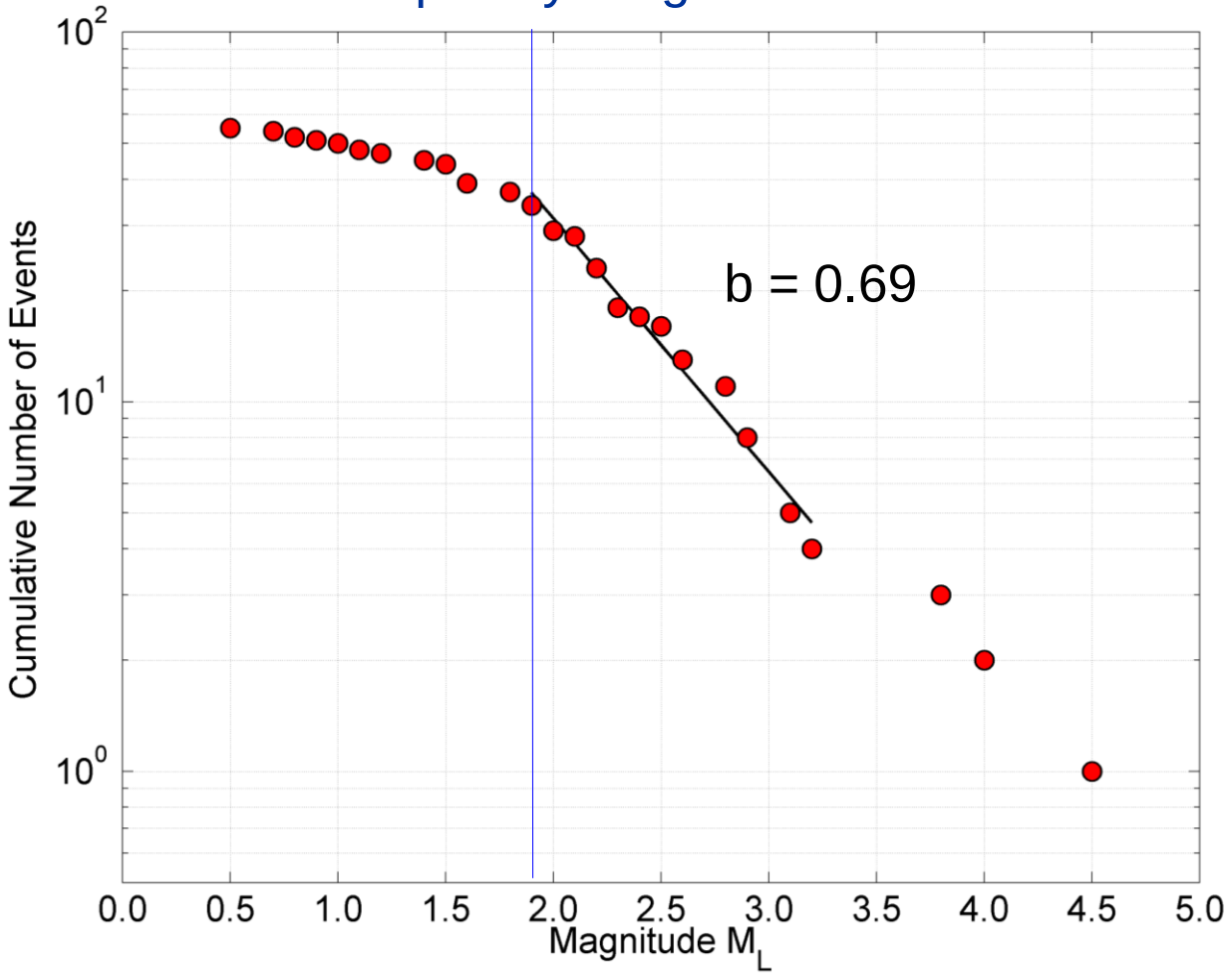


Seismicity in Northern Germany



Seismicity in the Vicinity of the Natural Gas Fields

Frequency-magnitude distribution



Data set

- 02.06.1977 - 19.12.2014
- 55 events
- M_L min = 0.5
- M_L max = 4.5

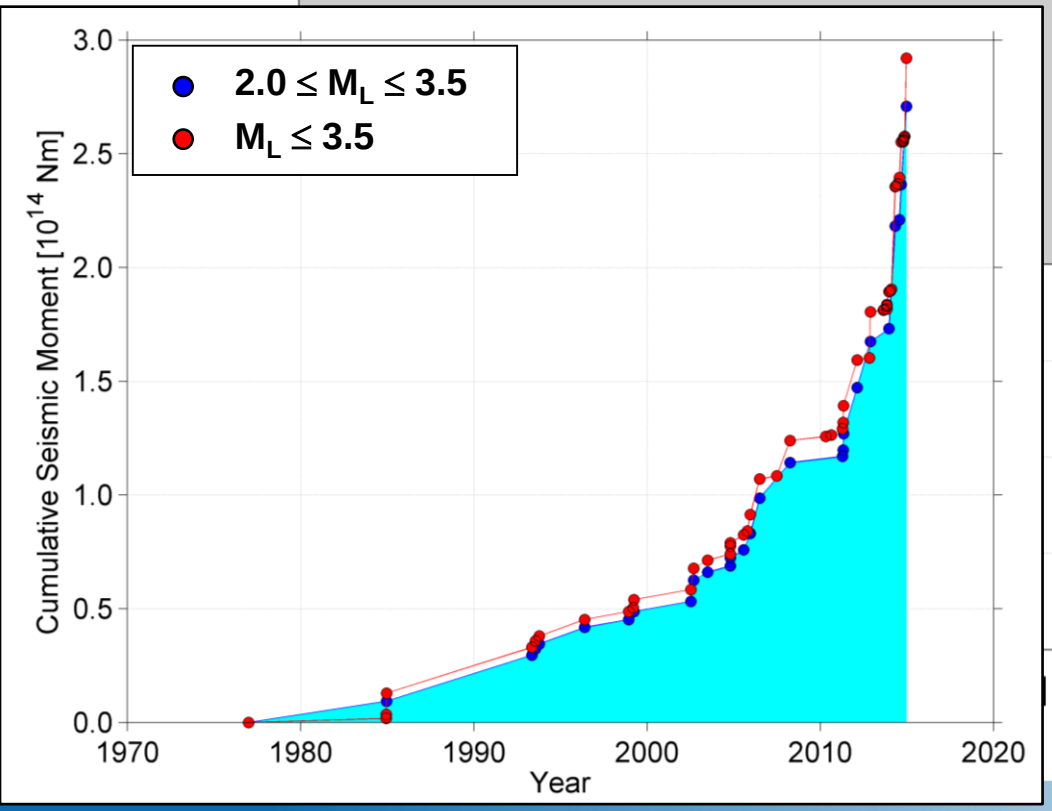
Limitations

Data set is too small

Time interval is too small

What do we expect from area with anthropogenic activities?

Seismicity of the North German Basin

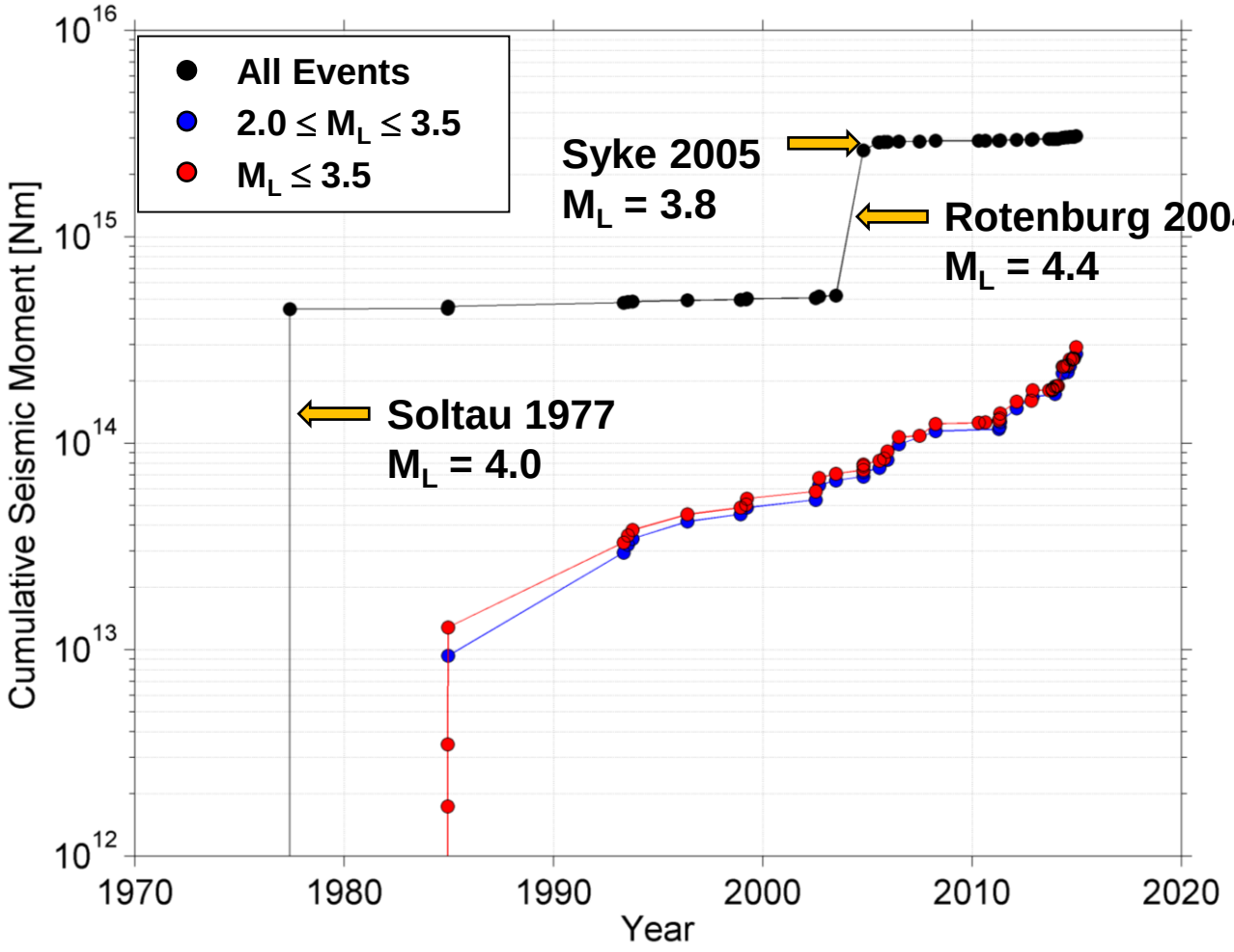


Seismic events in the vicinity of the natural gas fields in Northern Germany

Detection Threshold ≤ 2.0 M_L

Seismicity of the North German Basin

Energy release from earthquakes



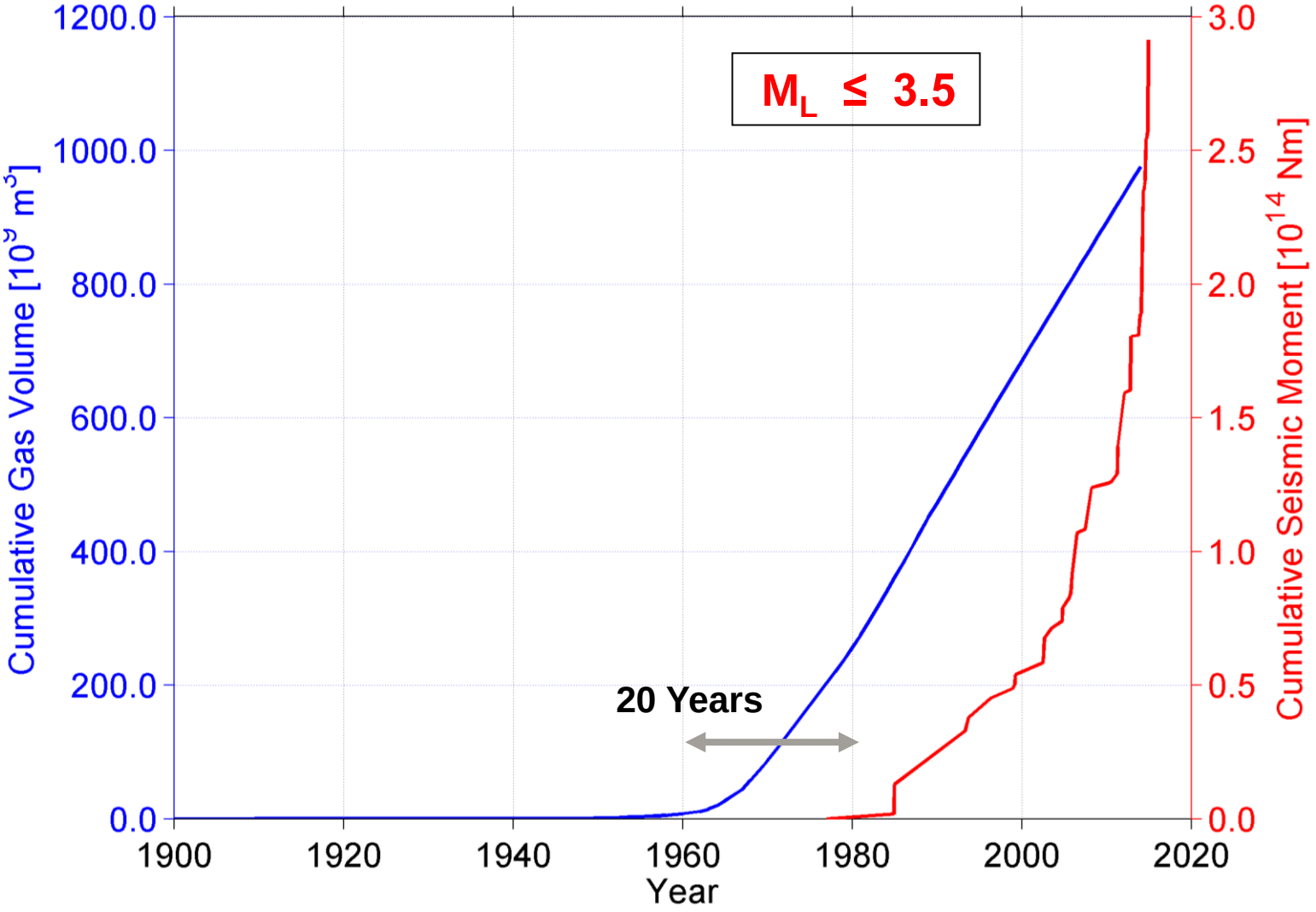
55 Seismic Events

2.6.1977 – 19.12.2014

Seismic Moment M_0 [Nm]

All Events	3.1×10^{15}	
$2.0 \leq M_L \leq 3.5$	2.7×10^{14}	8.8%
$M_L \leq 3.5$	2.9×10^{14}	9.5%
Soltau (1977)	4.5×10^{14}	14.5%
Rotenburg (2004)	2.1×10^{15}	**68.0%**
Syke (2005)	2.5×10^{14}	8.0%
		90.5%

Seismicity and gas production of North German Basin



North German Basin

Natural gas production

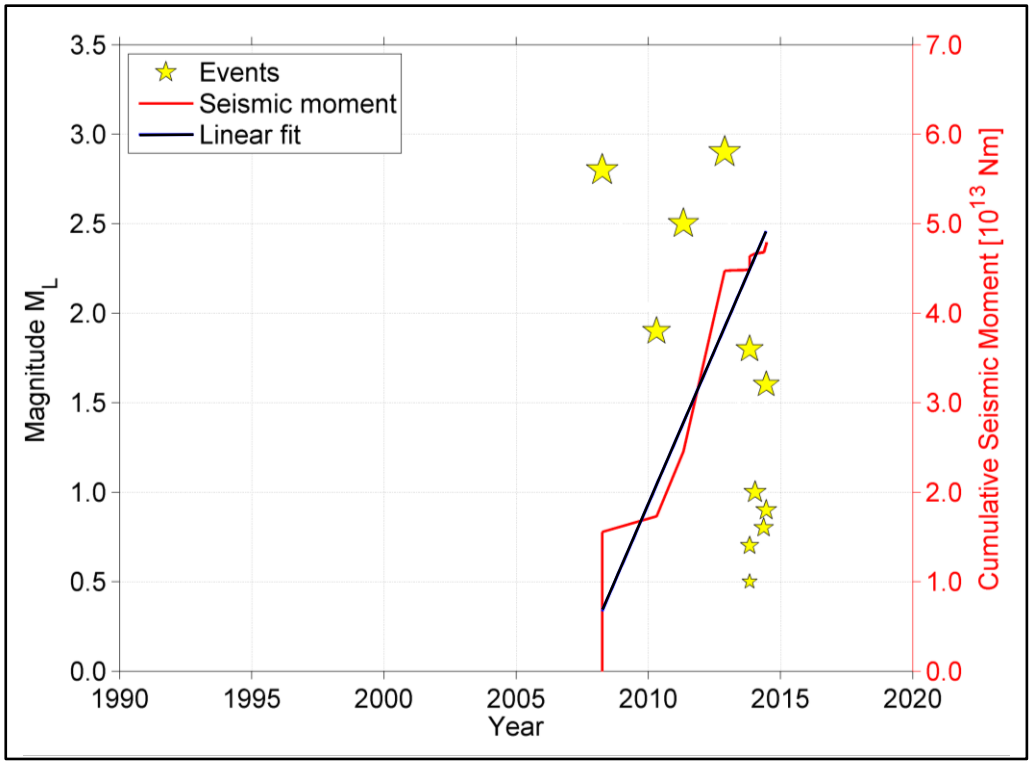
-

Energy release from earthquakes

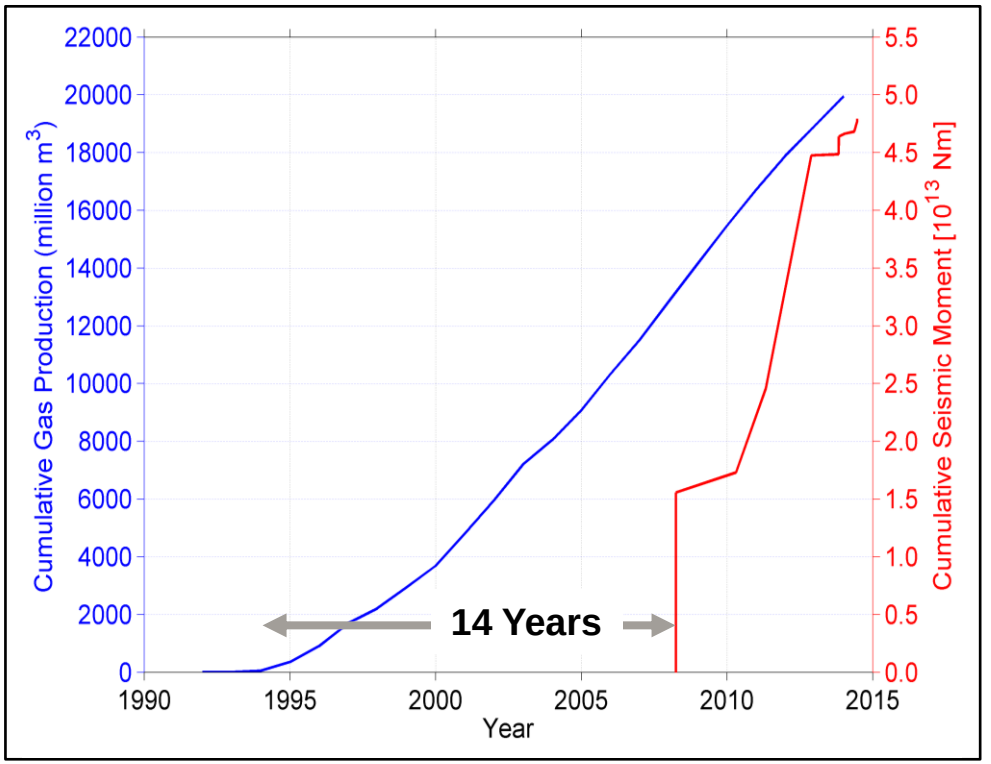
Delay ≈ 20 years

Natural Gas Field Völkersen

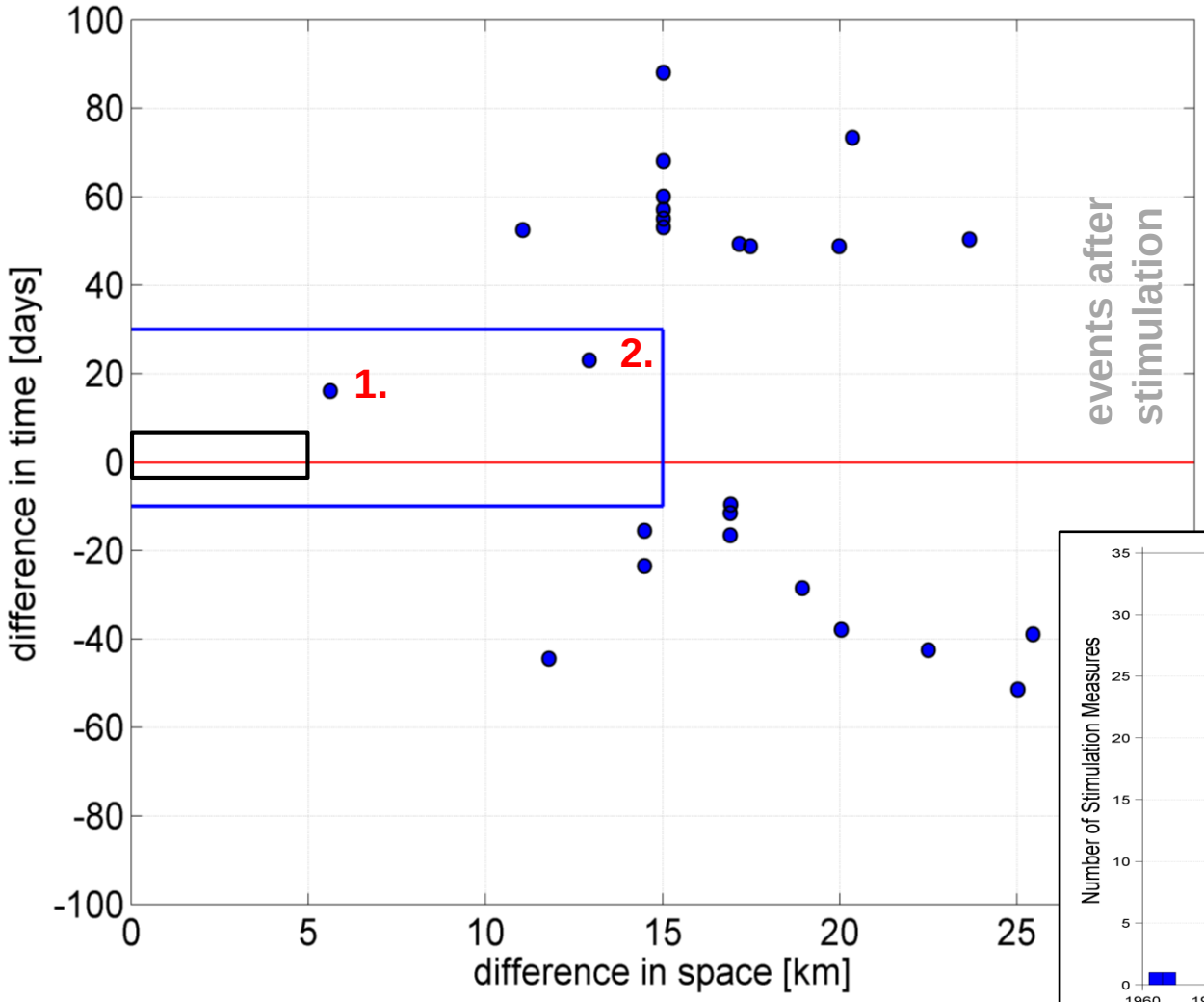
Seismic events and cumulative seismic moment



Cumulative natural gas production and seismic moment



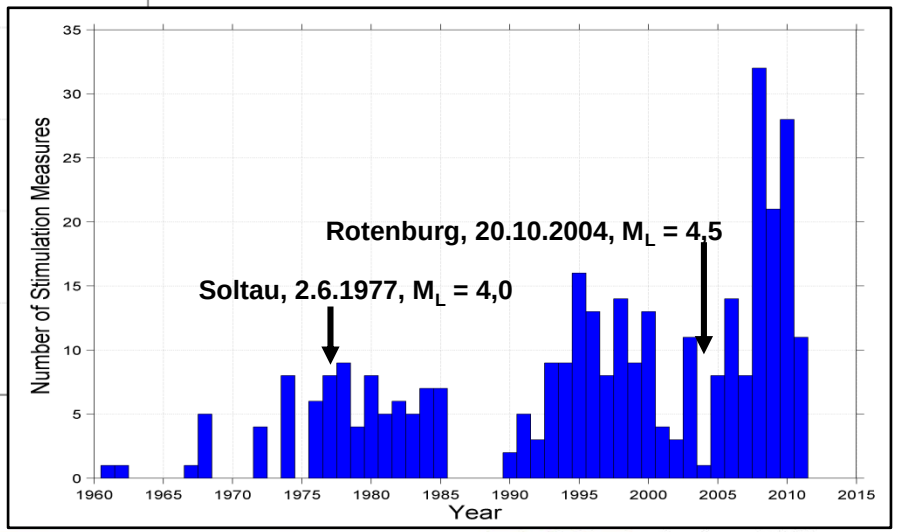
Seismicity and Hydraulic Fracturing (Tight Gas)



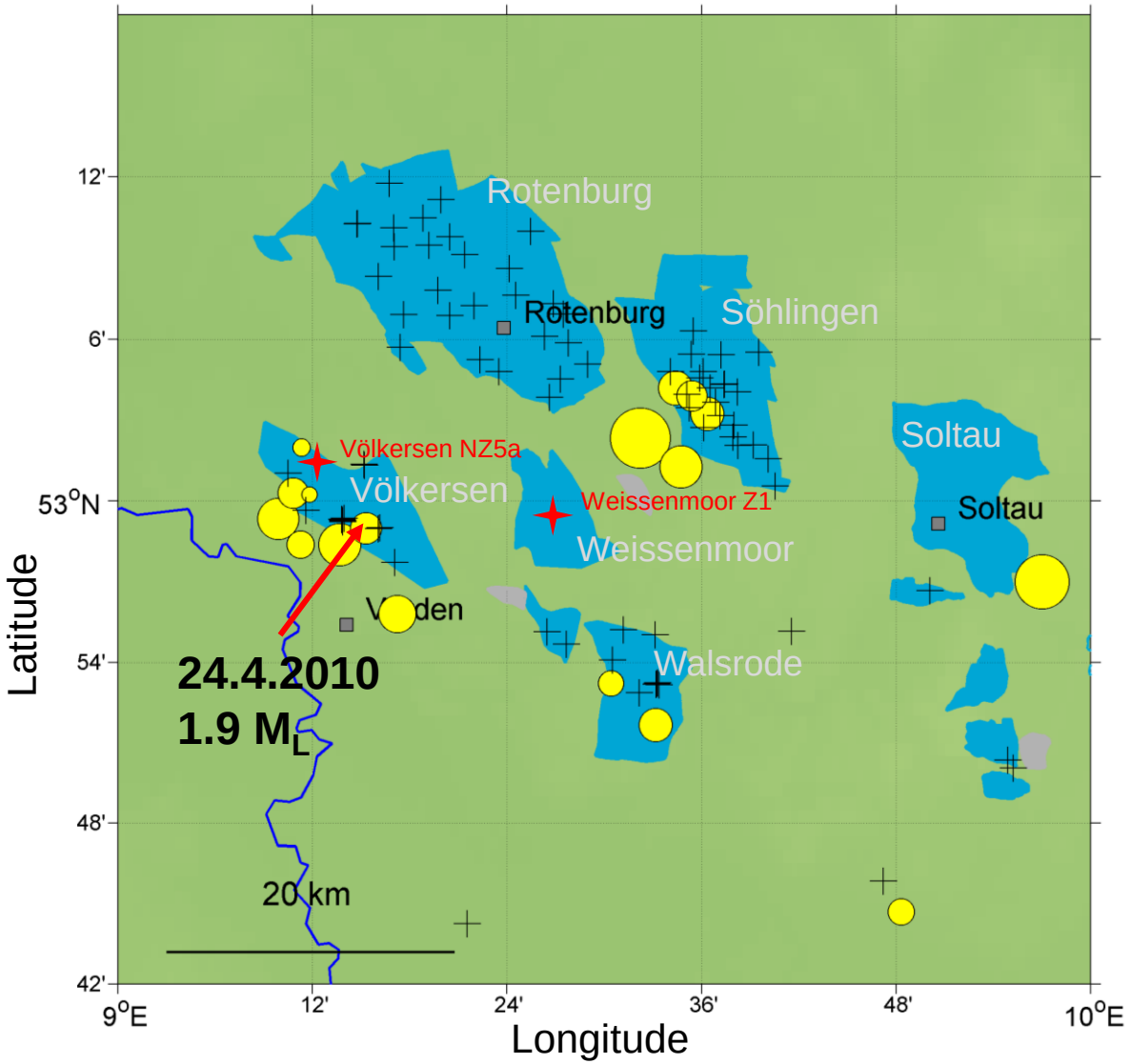
Data Set

327 Hydraulic Fracturing measures (tight gas) (Source: LBEG)

55 Seismic Events (BGR-Bulletin)



Seismicity and Hydraulic Fracturing



Best correlation in time and space

Seismic event

24.4.2010 1.9 M_L

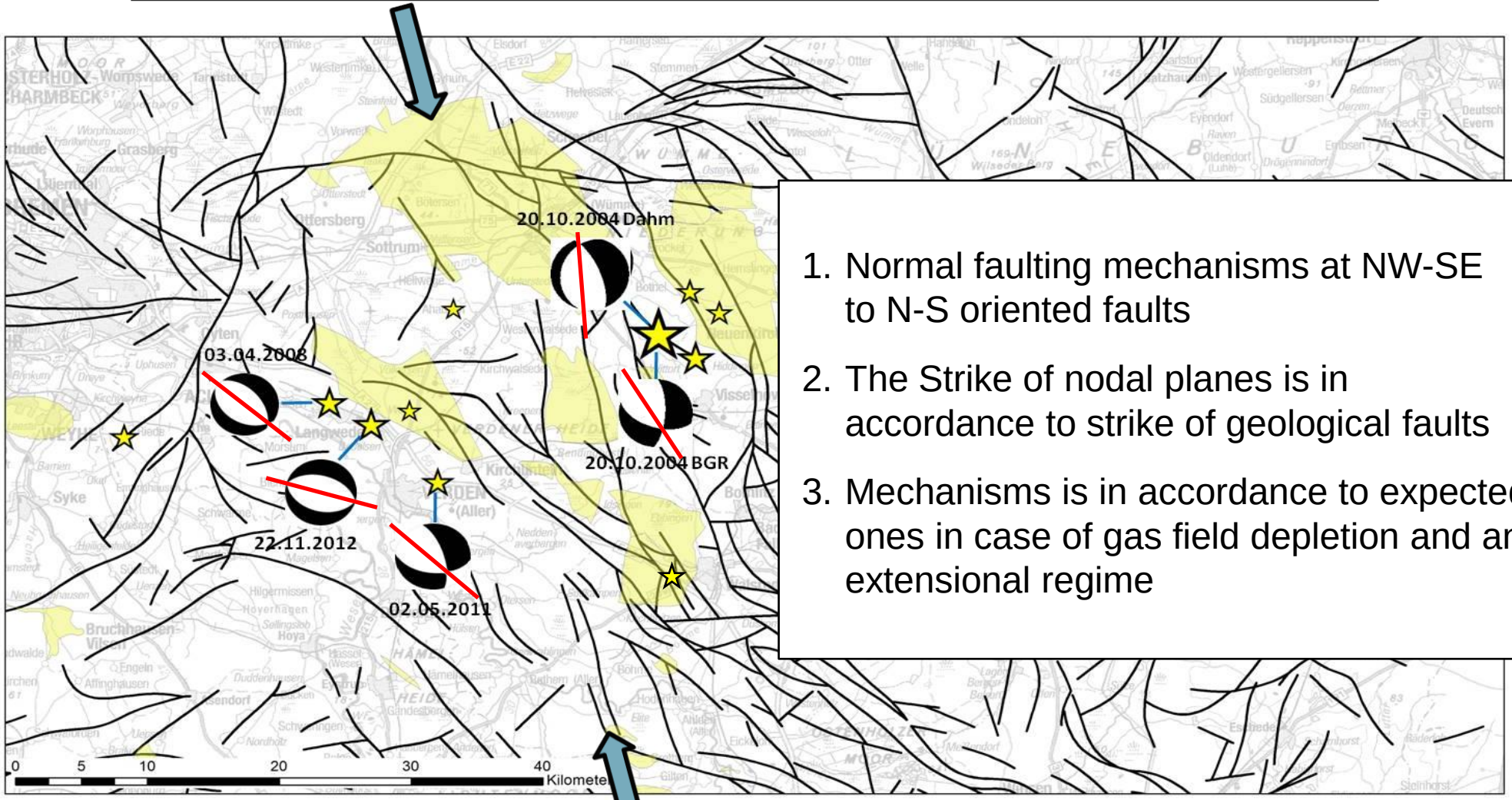
Natural gas field Völkersen

Hydraulic fracturing

1. Field Völkersen 8.4.2010
   Well: Völkersen N Z5a
   Difference: 16 days, 6 km
2. Feld Weissenmoor 1.4.2010
   Well: Weissenmoor Z1
   Difference: 23 days, 13 km

No relation between earthquakes and hydraulic fracturing

Focal Mechanisms and Fault Zones



1. Normal faulting mechanisms at NW-SE to N-S oriented faults
2. The Strike of nodal planes is in accordance to strike of geological faults
3. Mechanisms is in accordance to expected ones in case of gas field depletion and an extensional regime

(Faults of Zechstein basis from 3D-Model of Lower Saxony)

Natural gas fields

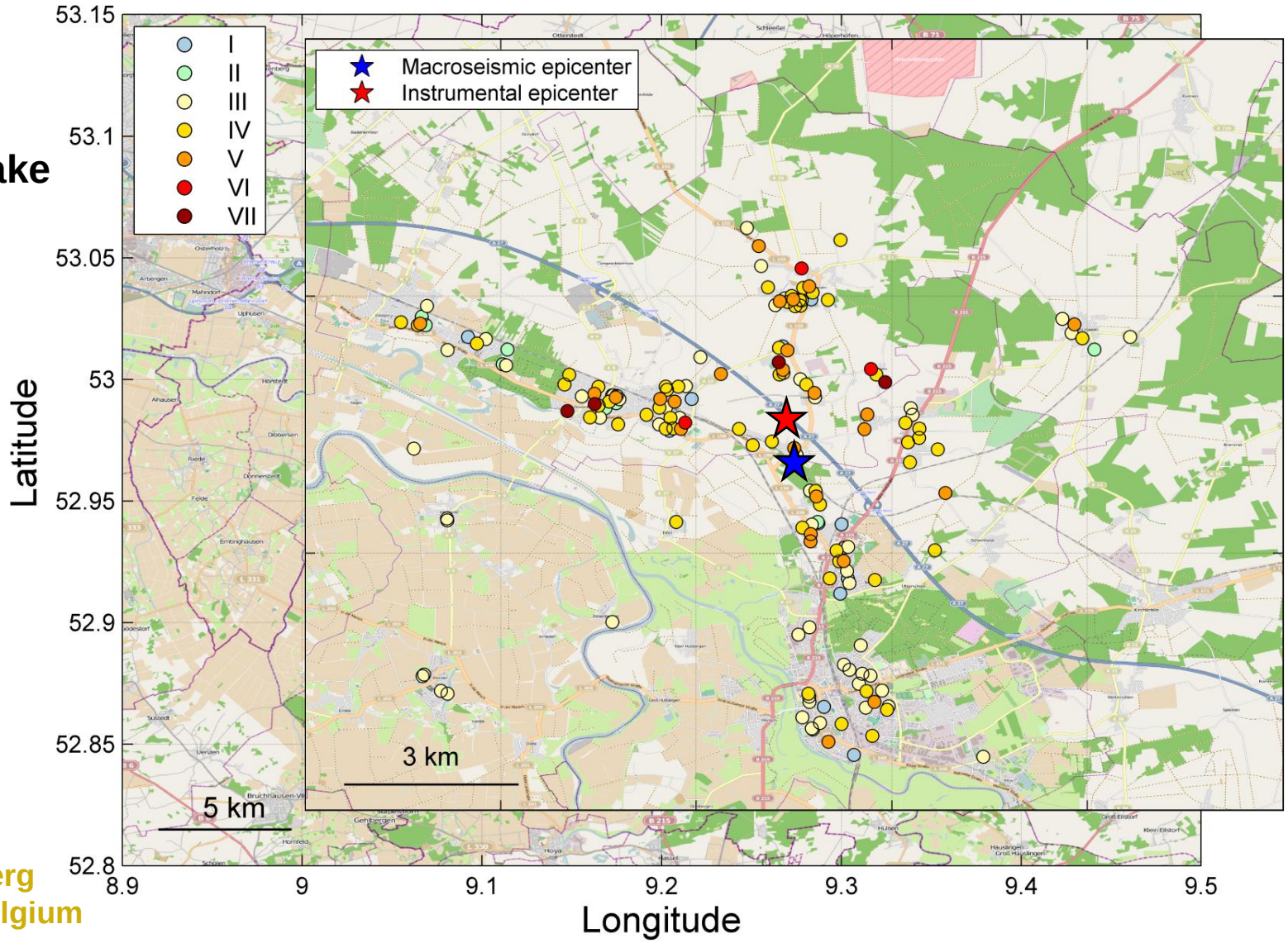
Macroseismic Investigation

Völkersen Earthquake
22. November 2012

M_L = 2.9
Intensity V

184 Observations

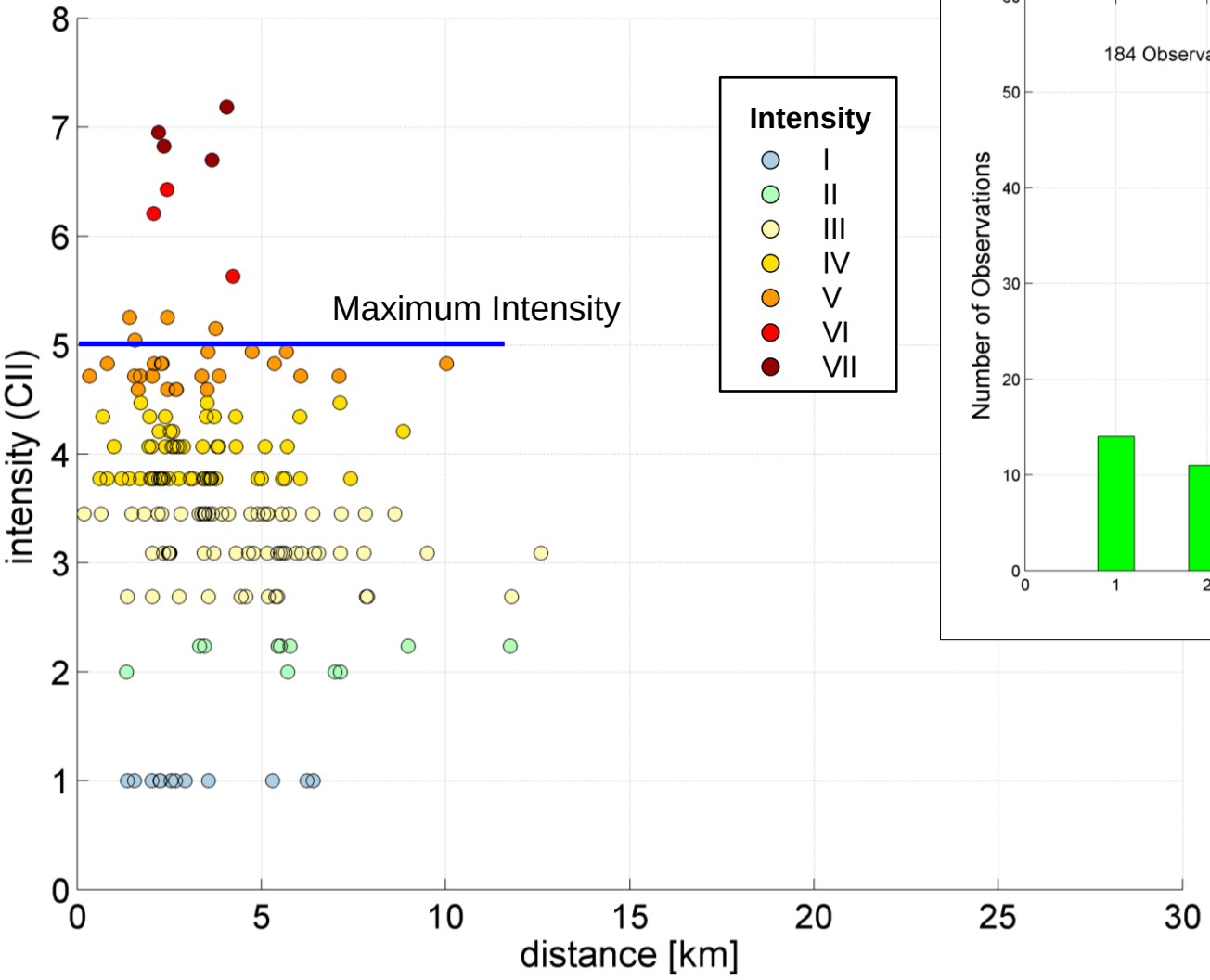
***Individual Internet Intensity* (III)**

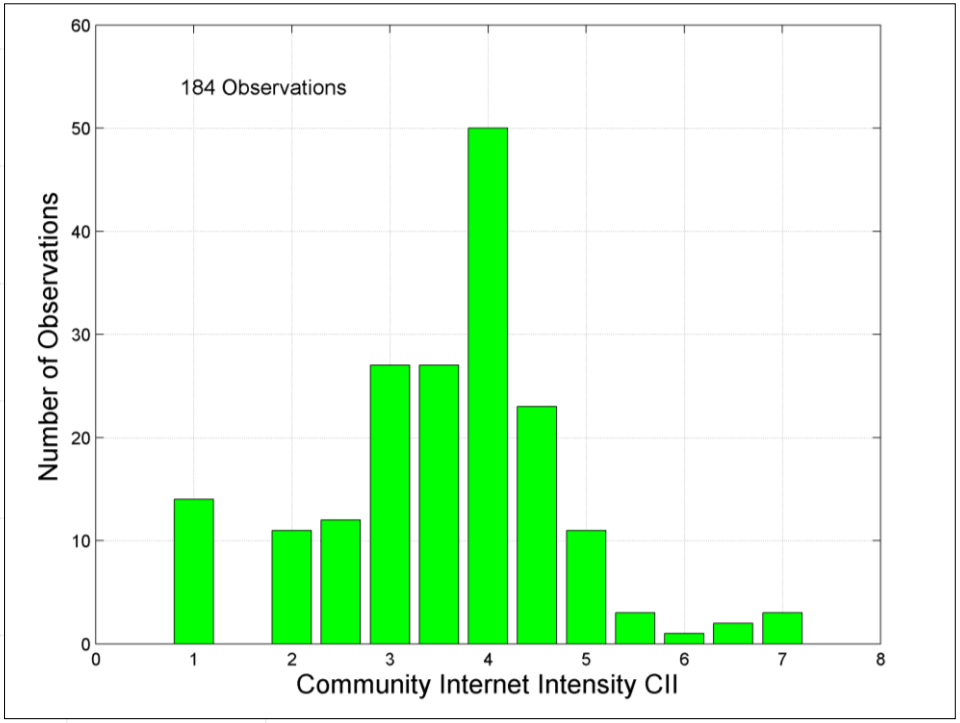


Source:
Erdbebenstation Bensberg
Royal Observatory of Belgium

Macroseismic Investigation

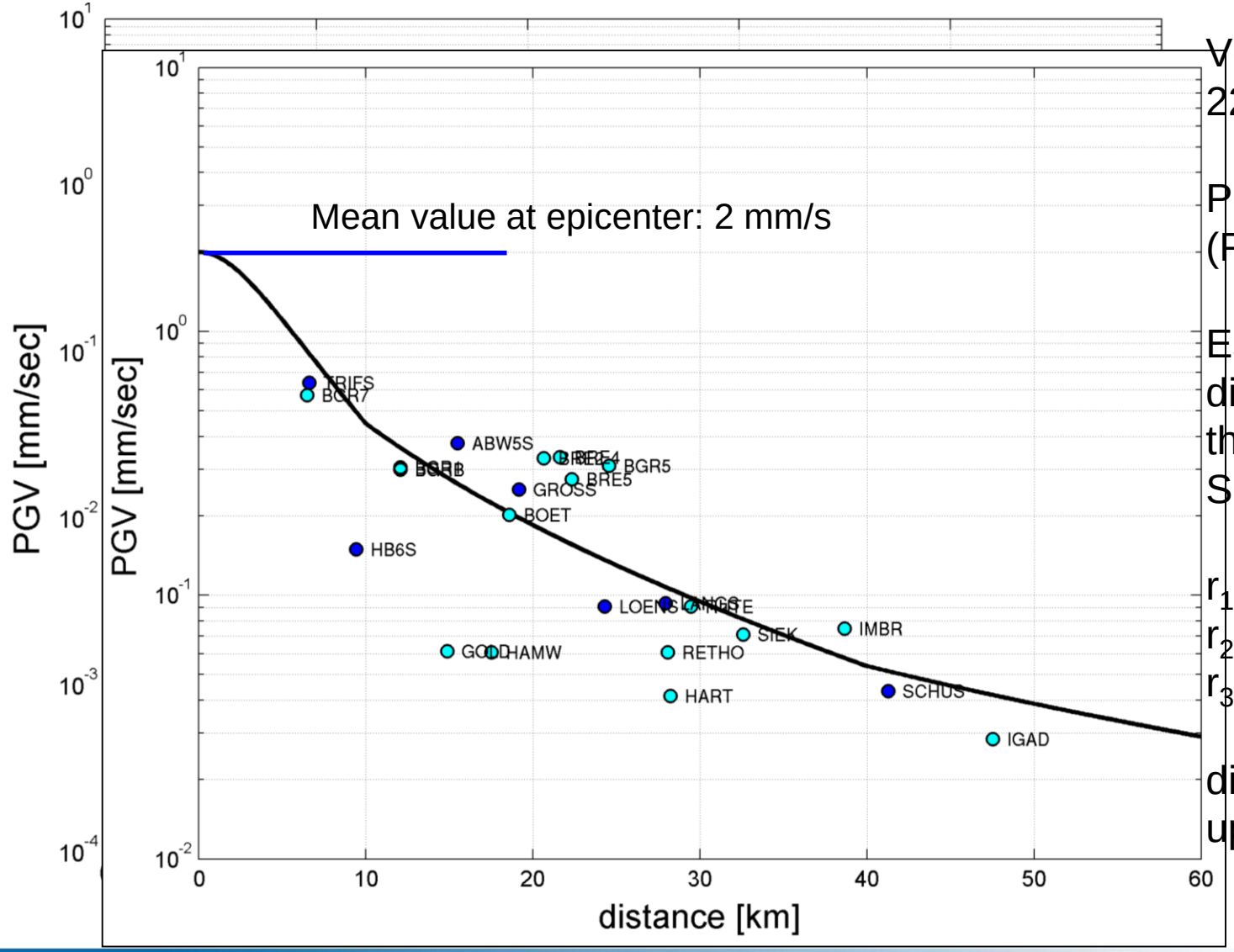
Reported Intensity values as a function of distance





Intensity distribution

Surface Effects



Völkersen earthquake
22.11.2012 2.9 M_L

Peak-Ground-Velocity (PGV)

Estimation of PGV – distance relation for three distance Segments

$r_1 < 10$ km ($Q_S = 80$)
$r_2 < 40$ km ($Q_S = 250$)
$r_3 \geq 40$ km ($Q_S = 500$)

distance range up to 250 km

Conclusions

- The characteristics of seismicity in the area of the natural gas fields indicate that events are induced or triggered from natural gas production.
- The maximum magnitude (4.5 M_L) is unexpected high compared to the background seismicity.
- Despite several stronger events low magnitude seismicity is missing for some areas
- The process of earthquake generation or trigger mechanism is still not well understood
- One relevant factor seems to be the level of depletion which correlates with the decrease in pressure within the reservoir
- For most natural gas fields relevant seismicity starts with a delay of 10 to 20 years after start of gas production
- No relationship between seismicity and hydraulic fracturing