

New approach to link depletion and induced seismicity in Lower Saxony gas fields

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5th GSSPE YOUNG PROFESSIONALS
WORKSHOP – LÜNEBURG – 18/19 SEP 2019

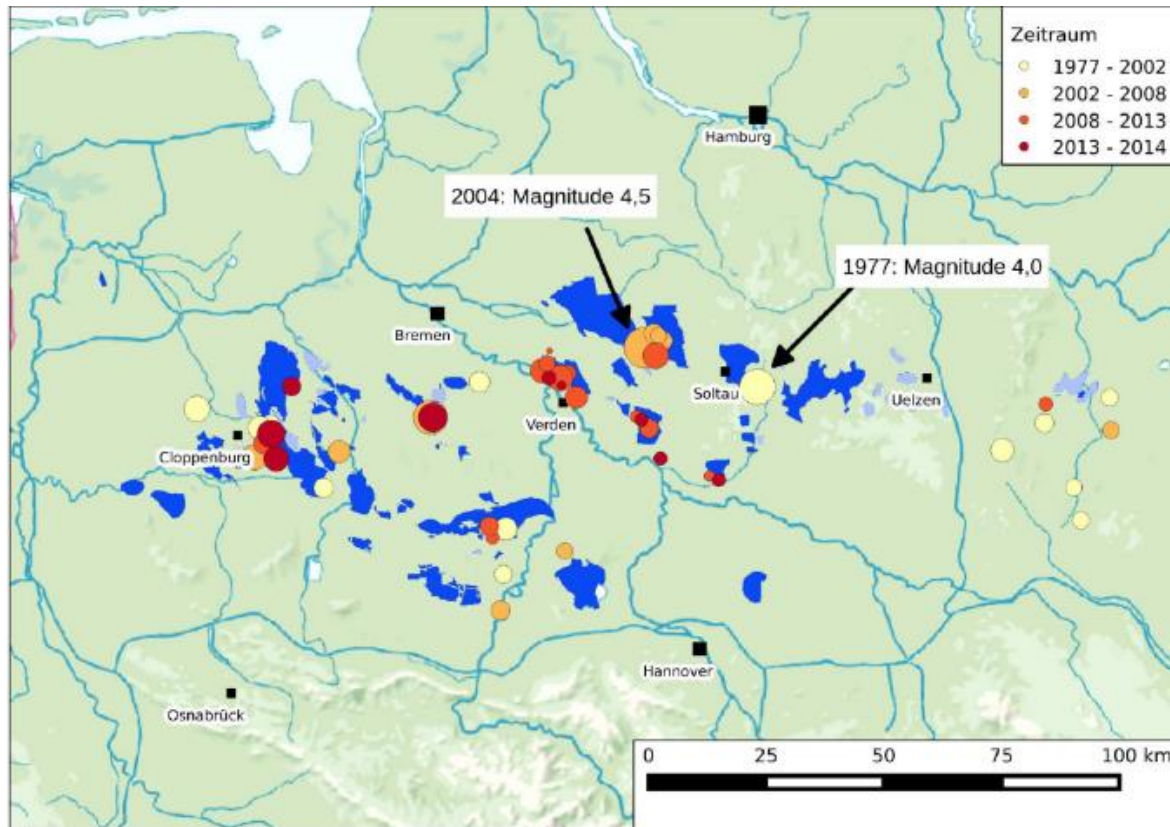
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Outline

- Problem setting
- Geology and seismicity of Northern Germany
- Digitalization of gas extraction
- Digitalization of gas fields
- Calculation of pore pressure
 - Sensitivity analysis
- Correlation with earthquakes
- Discussion
- Conclusion / Outlook



Problem setting



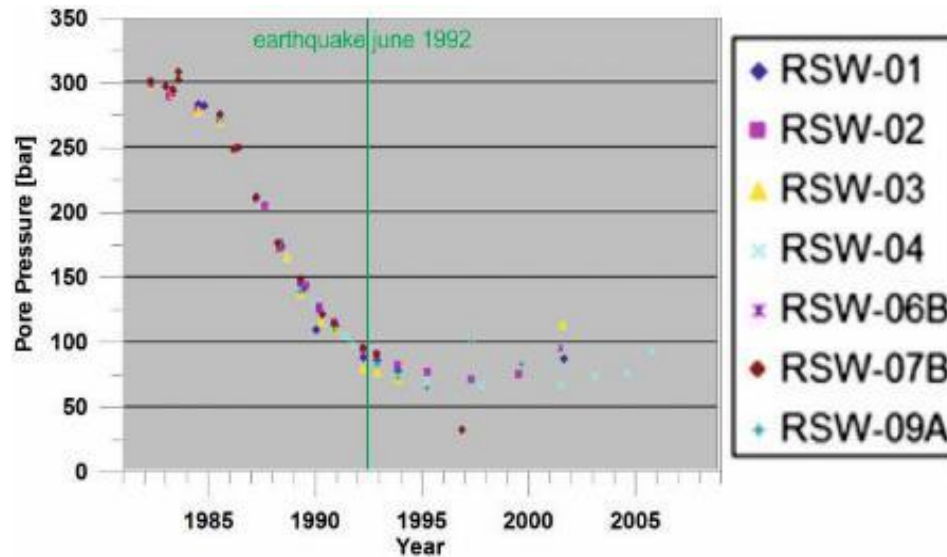
- Gas extraction since 1949
- Only a few tectonic earthquakes
- Increase of seismic activity since begin of gas extraction

Joswig et al. (2015)



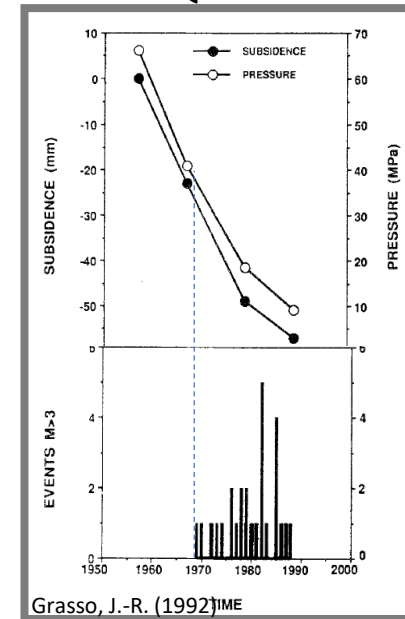
Time shift of seismicity onset

Correlation between gas extraction and seismicity



Pressure History of the Roswinkel gas field between 1981 and 2009.

LACQ France



- >10 years production
- > 250 bar pressure reduction
- till events M>3



Connection to seismicity

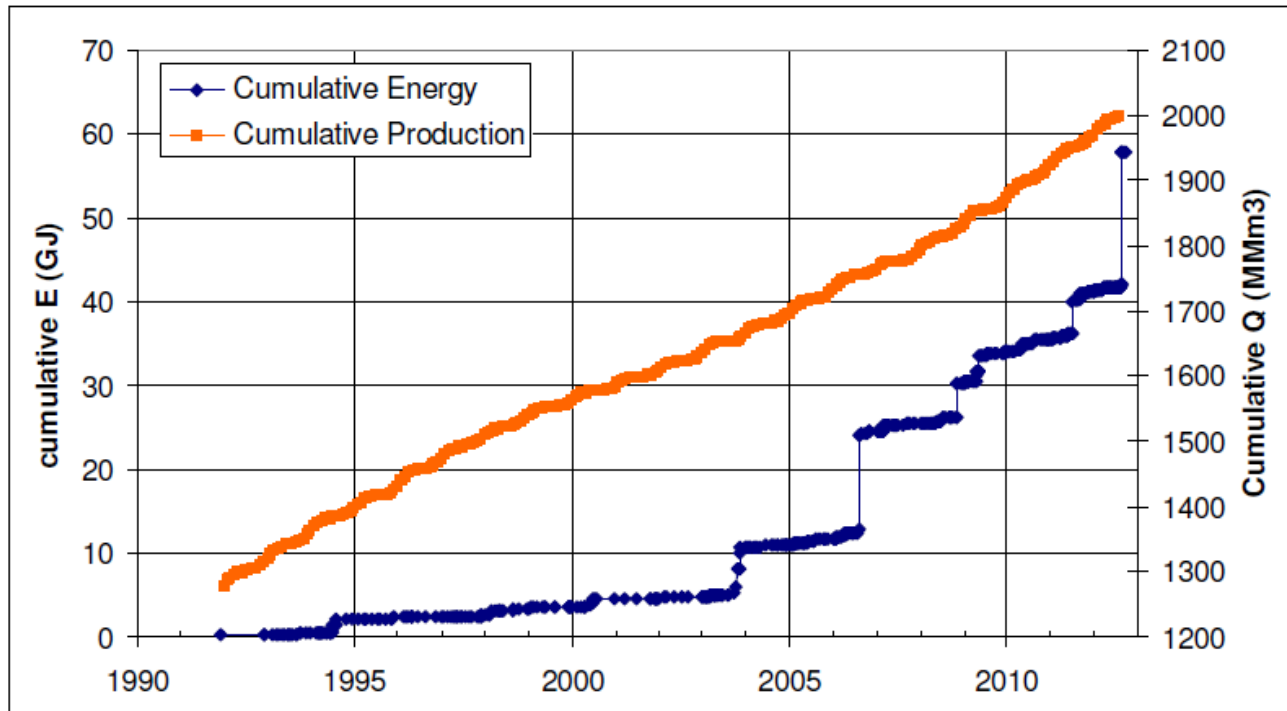
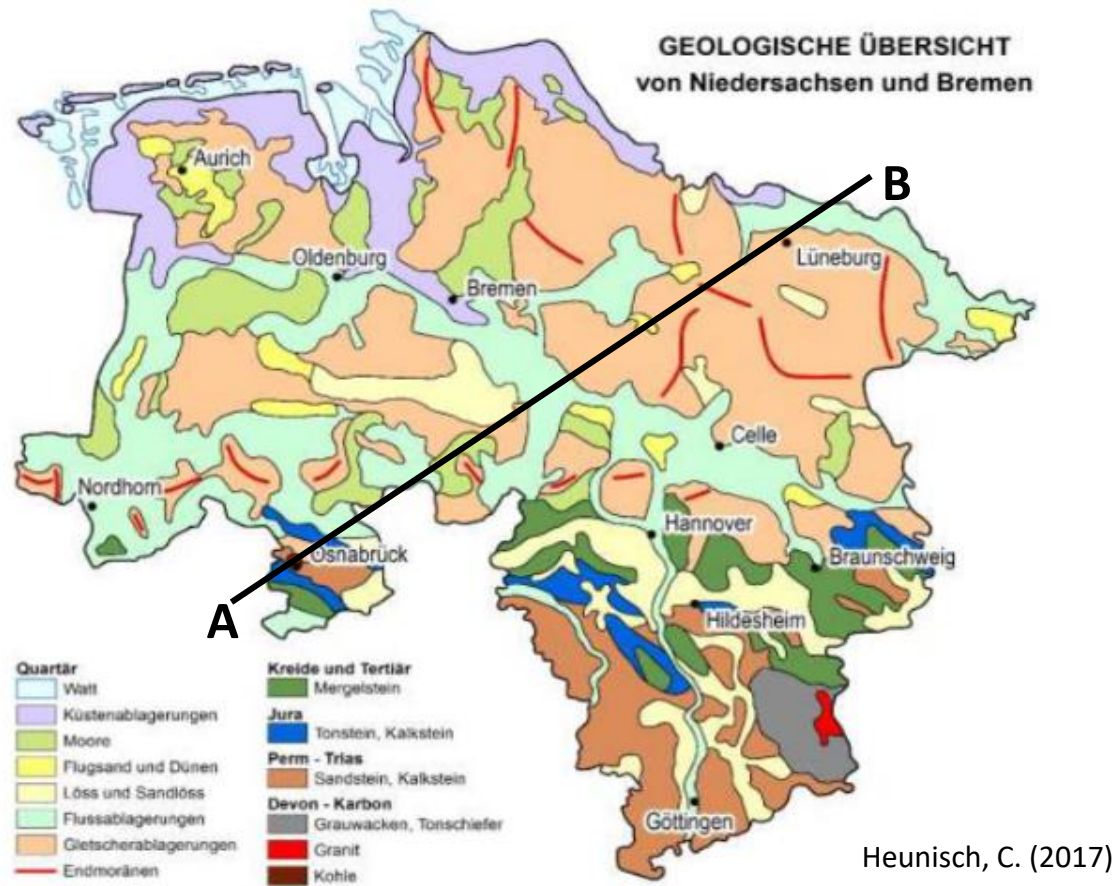


Figure 3: Cumulative seismic energy release and cumulative production through time. The higher magnitude earthquakes ($M \geq 3.0$) release the most energy (10 times more than a magnitude 2.5 earthquake), which introduces the steps observed in the figure.

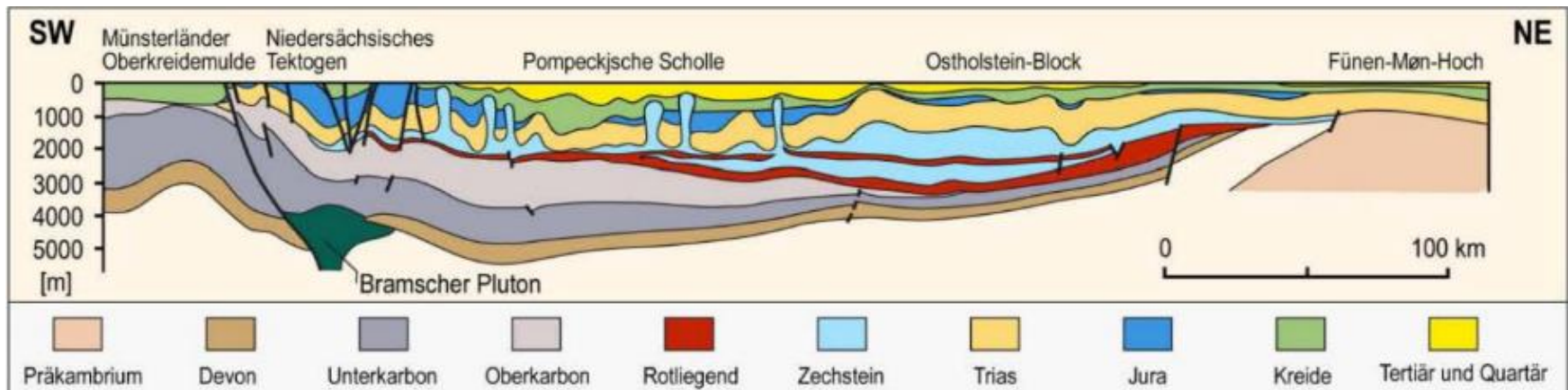
Muntendam-Bos & Wal (2013)



Geological map of Lower Saxony



Geology of Northern Germany – profile section



Stratigraphy	Lithology	Reservoir?
Bedrock	Magmatic & metamorphic rocks	-
Silurian and Devonian	Tectonically undisturbed sediments	-
Carboniferous	Coal formations	Reservoir rocks (Upper C.)
Permian	Salt domes in Rotliegend and Zechstein	Reservoir rocks
Triassic	Red sandstone + Keuper	Reservoir rocks
Jurassic	Limestone	Source rock for crude oil

Rothe, P. (2009)



German Section

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7

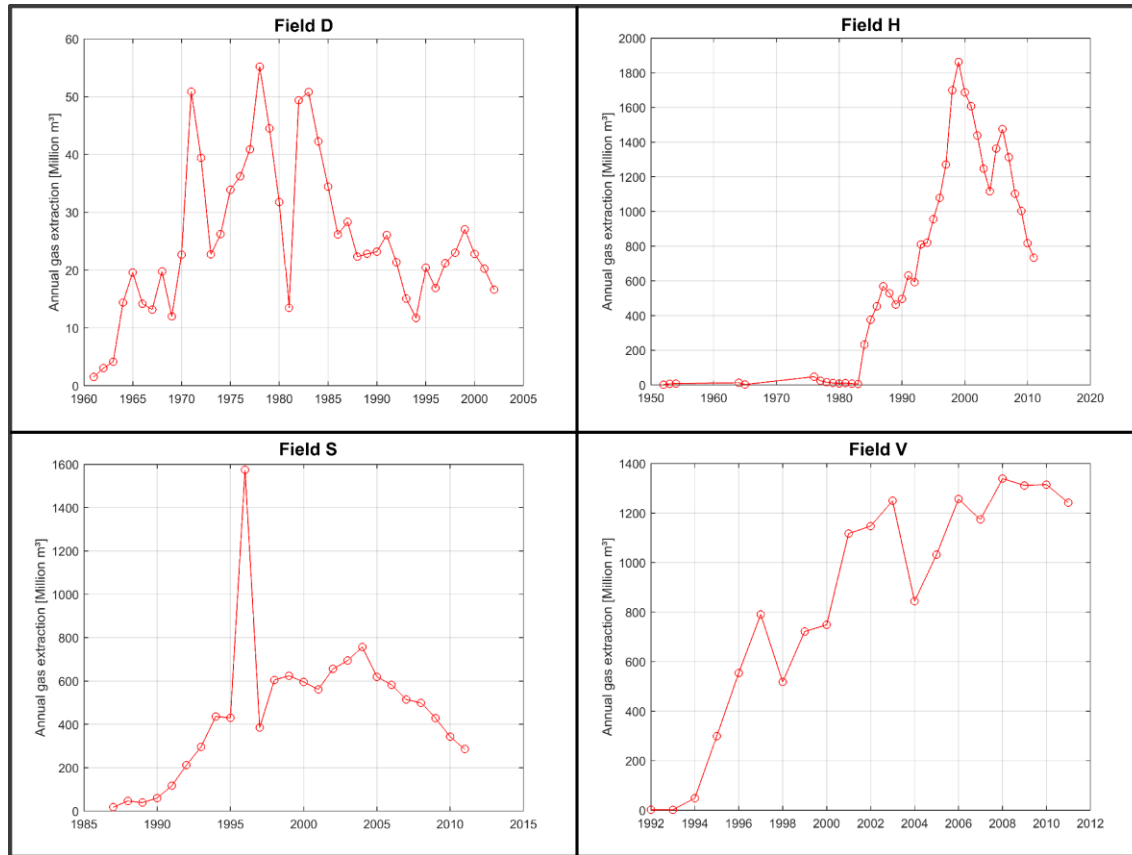
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Excel spreadsheet: Gas extraction

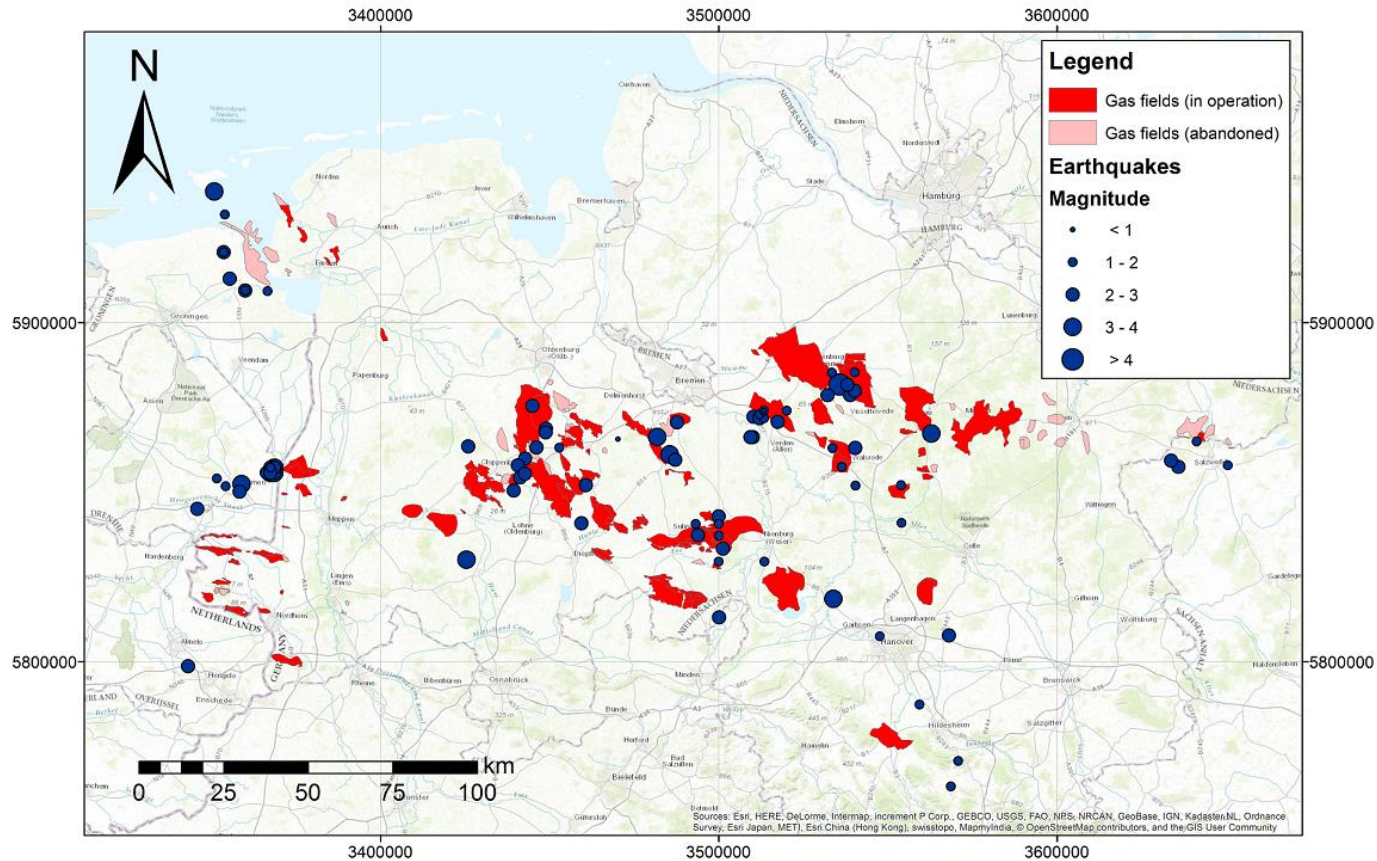
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Feldname	Testfeld	Adorf-Dalu	Adorf(Bunts Adorf(Zechst Ringe			Ringe (Karl Ringe(Zechst Ahlhorn			Alfeld-Eize Annaveen	Apeldorn	Bahnsen	Bahrenbor	
2	Top			2150	2780			3000	3725	1200	3725	2100	4200	
3	Bottom			2275	3000			3100	3875	1457	3975	2145	4250	
4	Mächtigkeit [m]		50	125	220		50	100	150	257	250	45	50	50
5	mittlere Tiefe [m]	5000	4000	2212,5	2890	4000	4000	3050	3800	1328,5	3850	2122,5	4225	4000
6	Mächtigkeit Rechnung [rr	50	50	50	50	50	50	50	50	50	50	50	50	50
7	Überdruck	0,2	0,2	0,5	0,25	0,2	0,2	0,25	0,25	0,3	0,5	0,5	0,3	0,2
8	Porosität	0,1	0,1	0,25	0,1	0,1	0,1	0,1	0,1	0,1	0,25	0,1	0,1	0,1
9	Fläche [m²]	25000000	19658498	4591311	15067187	25000000	25000000	451462	9502713,5	46103183	3482383,5	1522372,2	5984777,2	62568324
10	ID	-1	-1	78	12	-1	13	-1	113	69	14	19	137	-1
11	Volumen [m³]			5,74E+08	3,31E+09		1,25E+09	4,51E+07	1,425E+09	1,18E+10	8,71E+08	6,85E+07	2,99E+08	3,13E+09
12	angenommene Werte			angenommen: Bentheimer SST						angenommen: Bentheimer SST				
13	Verdacht auf Erdölfeld													
14						7uz 6								
15	Jahre	Testfeld	Adorf-Dalu	Adorf(Bunts Adorf(Zechstein)			Ringe(Zechst Ahlhorn			Alfeld-Eize Annaveen	Apeldorn	Bahnsen	Bahrenbor	
16			in 1000 cbm	in 1000 cbm	in 1000 cbm		in 1000 cbm	in 1000 cbm	in 1000 cbm	in 1000 cbm	in 1000 cbm	in 1000 cbm	in 1000 cbm	
17	1949													
18	1950													
19	1951													
20	1952													
21	1953													
22	1954		154											
23	1955		486,1											
24	1956		19919											
25	1957		36502											
26	1958		11817											
27	1959		1003											
28	1960		19537											
29	1961		11316											
30	1962		7633											
31	1963		85270											
32	1964		136514										2402	
33	1965		179959								38892		4779	
34	1966		184519								37124		6509	
35	1967		162637								28654		26035	
36	1968		149277								26675		121959	
37	1969		164333								35017		80427	
38	1970		154022								36845		126193	
39	1971		134184								60886		141301	
40	1972		119123								34574		156629	
41	1973		165726					30533			40546		143007	
42	1974		140733					85456	2475		43590		174453	



Cumulative gas extraction



Digitalization of gas fields and earthquakes



Calculation of pore pressure

1. Assu

→ Flux

• Ideal

• Press

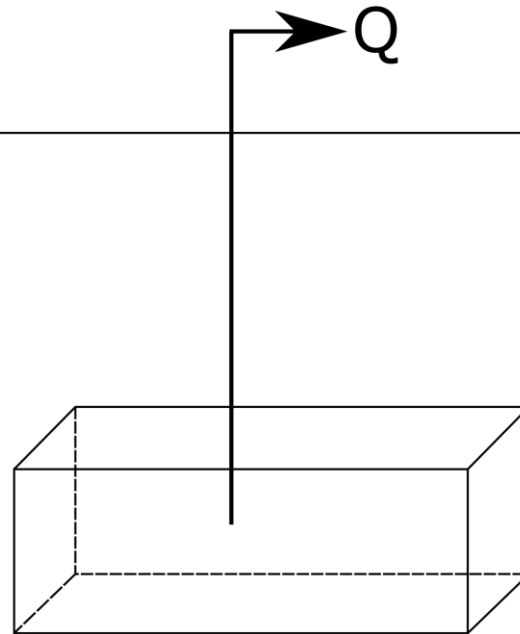
• T is g

→ Calc

→ Cha

Back

1. Assumption: Closed system



lected

(1,2)

e

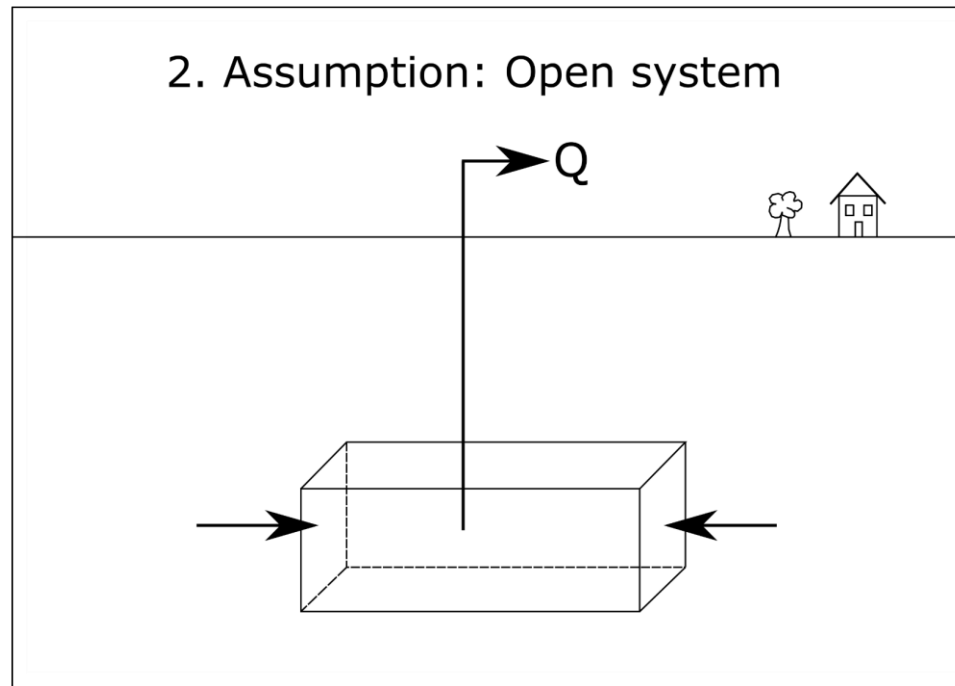
n →



Calculation of pore pressure (2)

2. Assumption: Flux of water into the reservoir

→ Pressure compensation in the reservoir



Example for pressure calculation

Researched parameters for gas field V:

Parameter	Researched value
Porosity	10,5 %
Overpressure	30 %
Thickness	45 m
Depth	4835 m
Spatial extent	Digitized data

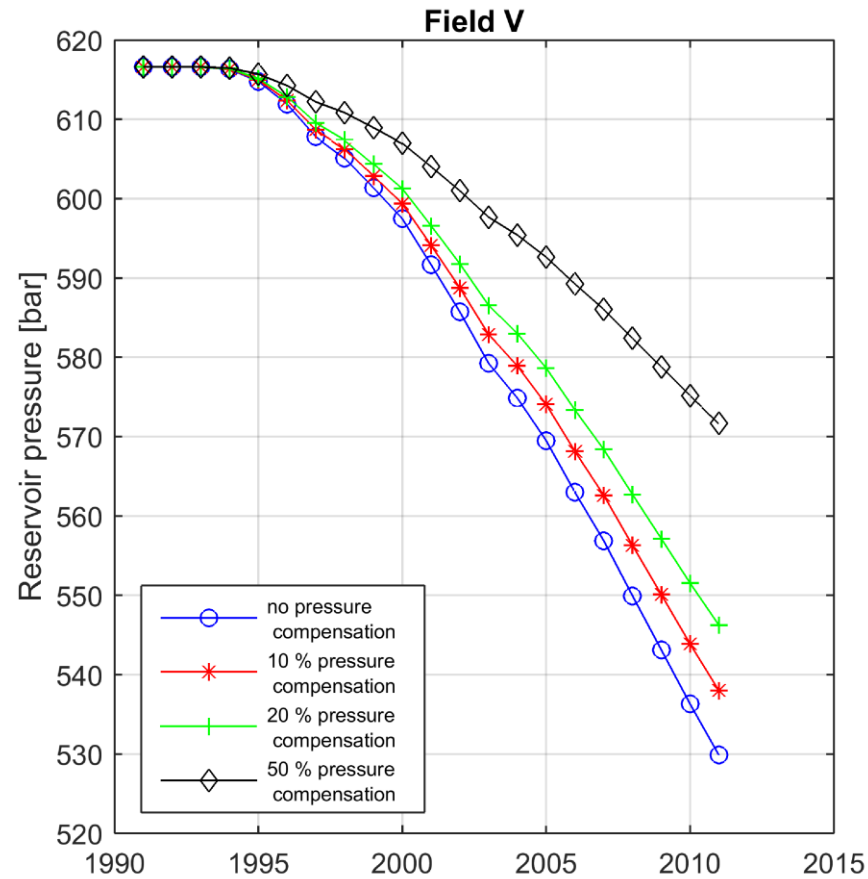
Sauerland & Schneider (1997)

Lithology	Overpressure [%]
Buntsandstein	50
Jura + Keuper	10
Oberkarbon	20
Rotliegend	30
Unterkreide	5
Zechstein	25

Pasternak (2017)

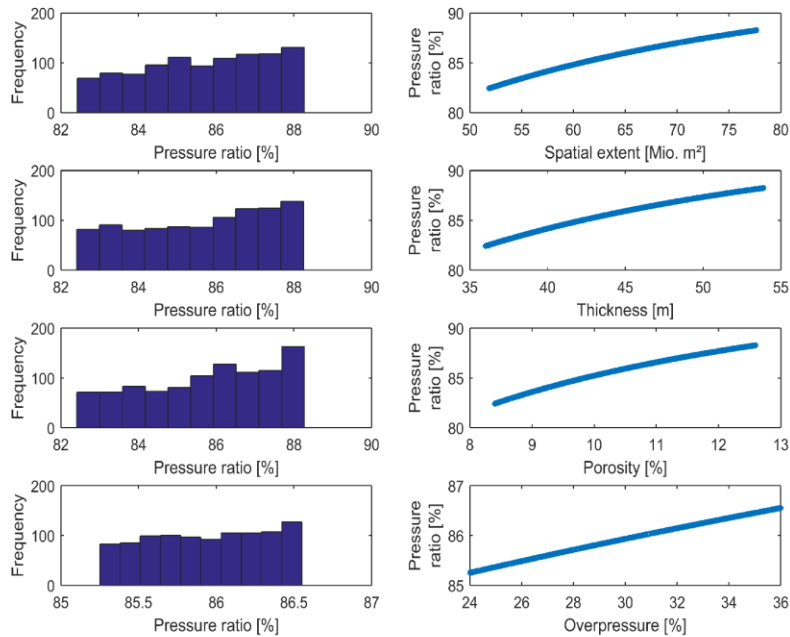


Pressure reduction of field V

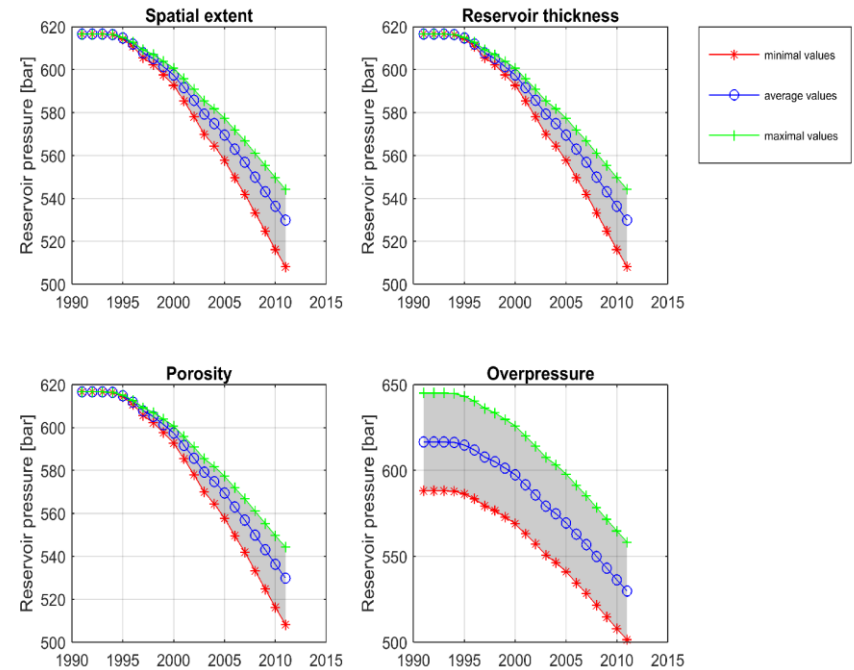


Sensitivity analysis of pressure reduction

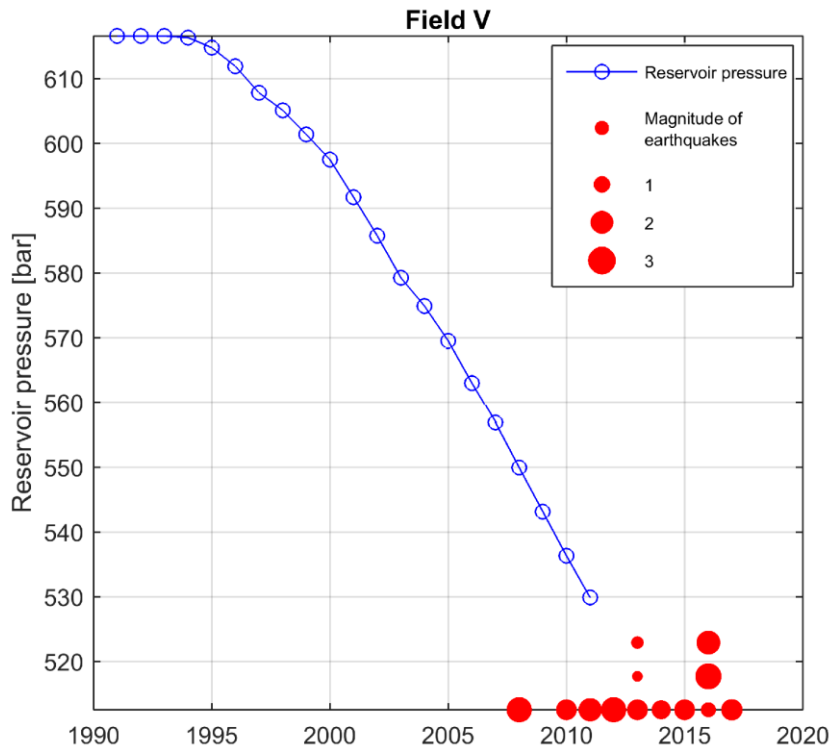
Sensitivity analysis of field V



Sensitivity analysis of field V

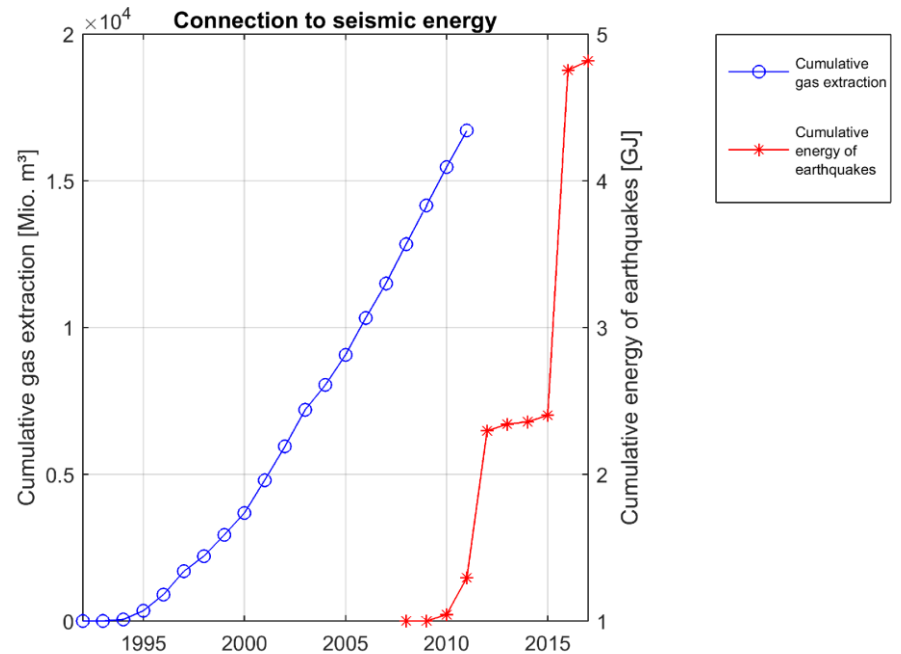


Correlation to seismicity

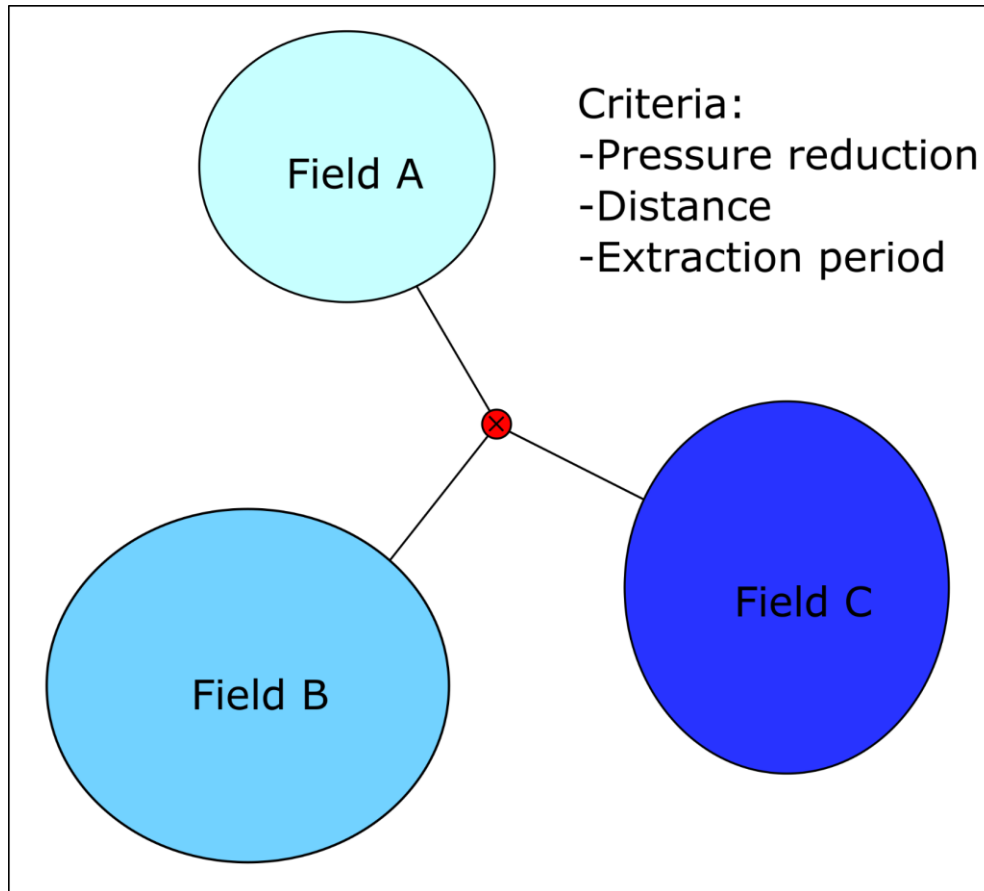


$$\log(E_S) = 1,5 \cdot M_S + 4,8$$

Hanks & Kanamori (1979)



Assignment of earthquakes to gas fields



- Derivation of assignment parameter (AP) based on these criteria



Discussion

- Assignment
- Comparison of earthquakes

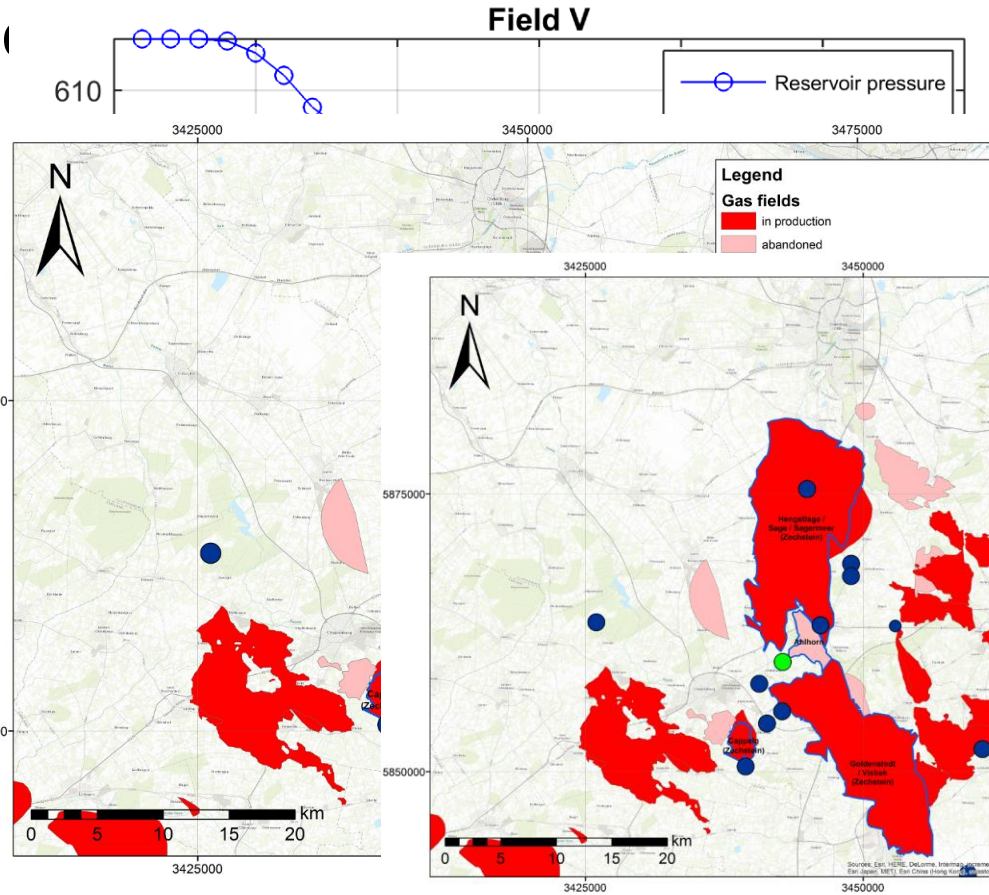
Gas field

Goldenstedt/Visk

Cappeln

Hengstlage

Ahlhorn



(e.g. L5))



Conclusion / Outview

- Compilation and digitalization of gas extraction, gas field extents as well as earthquake data into two excel spreadsheets
- Development of a MATLAB tool
 - Calculate pressure reduction of gas fields (including sensitivity analysis)
 - Correlation to earthquakes (with the aid of ArcGIS)
- ➔ Possibility for companies, authorities etc. to use the tool with supplementary data
- ➔ Additional calculations including multiple wells per gas field



Thank you for your attention!



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20

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Literature

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