

19–22 NOVEMBER,  
2018



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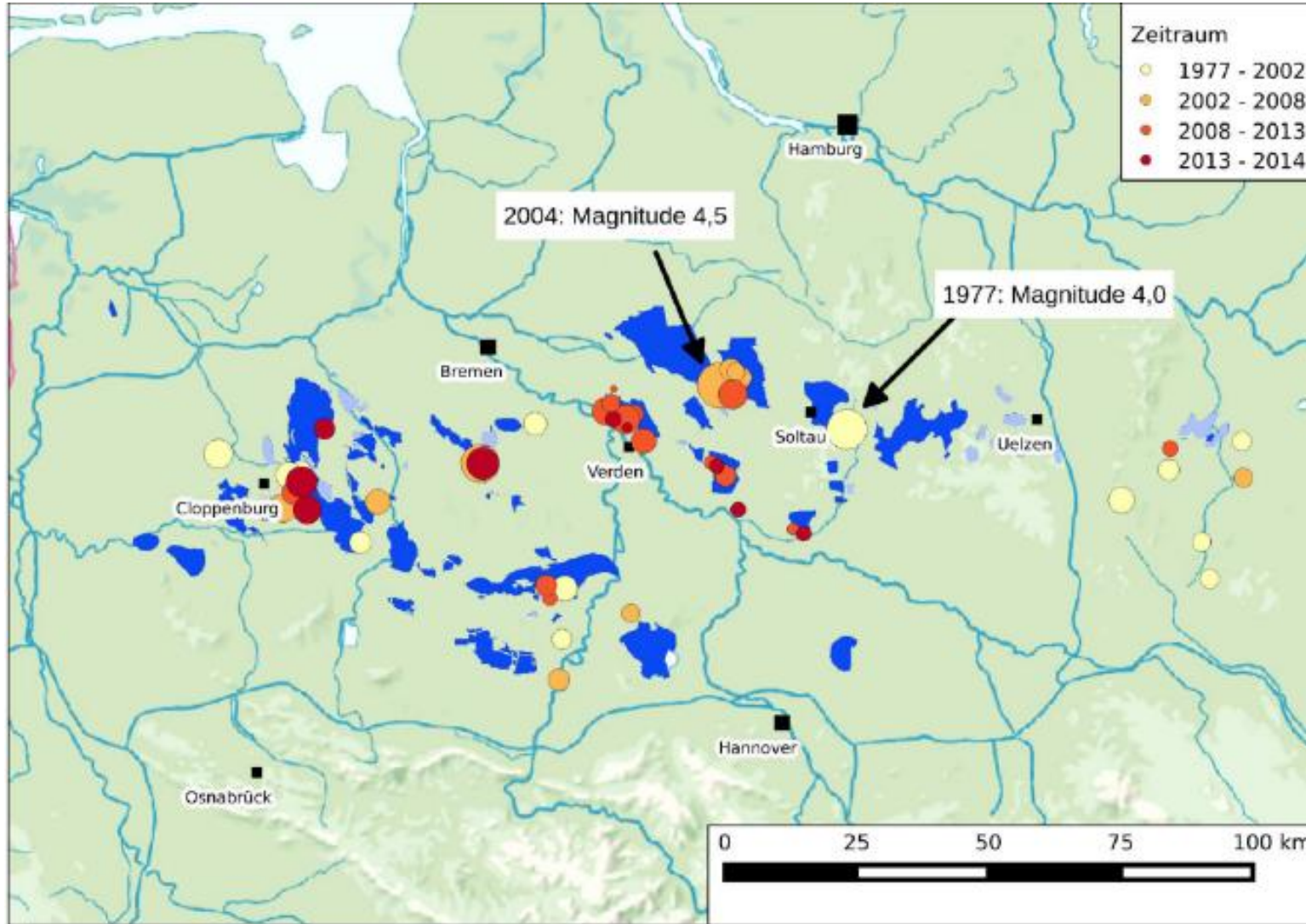
# New approach to link depletion and induced seismicity in Lower Saxony gas fields

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# Problem setting

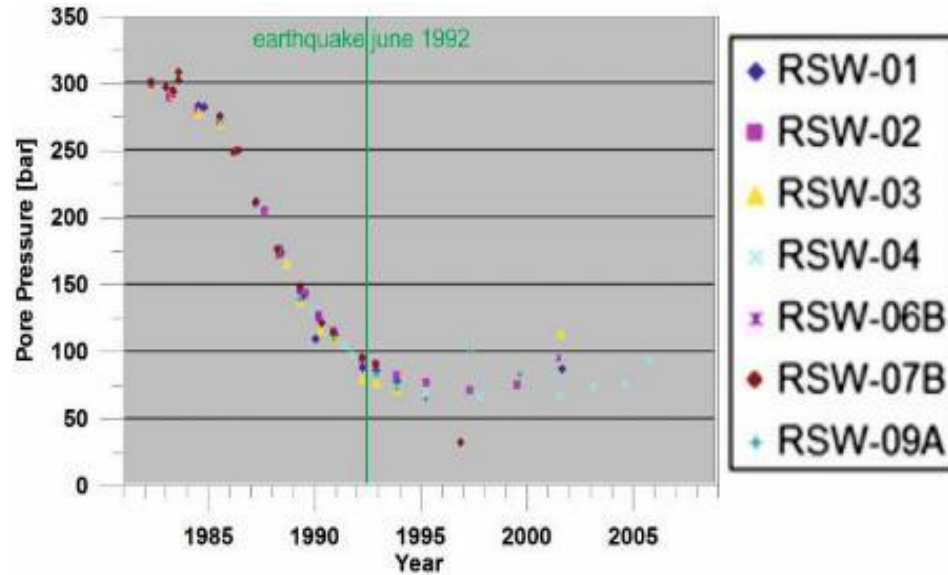


- Gas extraction since 1949
- Only a few tectonic earthquakes
- Increase of seismic activity since begin of gas extraction

Joswig et al. (2015)

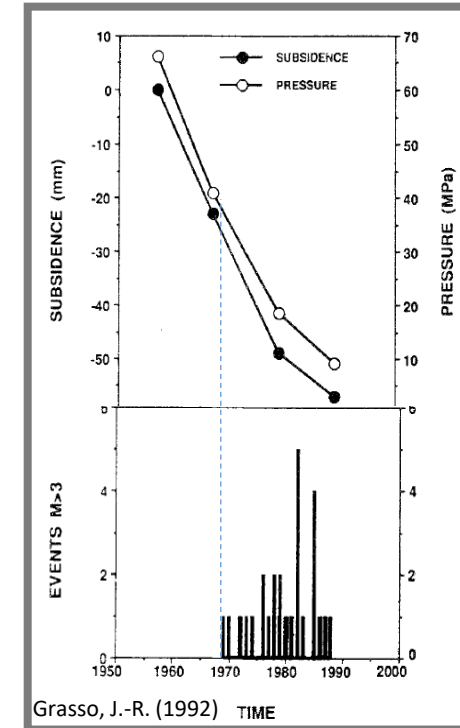
# Time shift of seismicity onset

## Correlation between Gas extraction and Seismicity



*Pressure History of the Roswinkel gas field between 1981 and 2009. The Roswinkel gas field production between 1980 and 2005. After the end of production only two earthquakes were recorded. Since 2006 no more earthquakes in the Roswinkel area were recorded.*

## LACQ, France

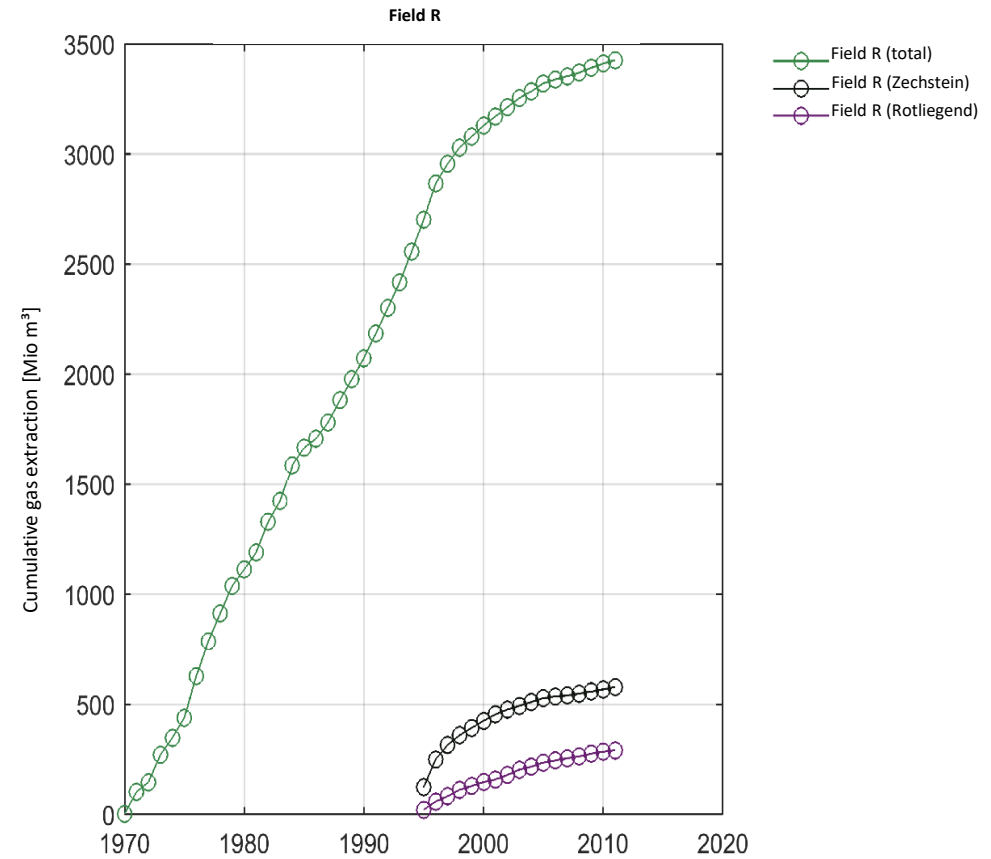
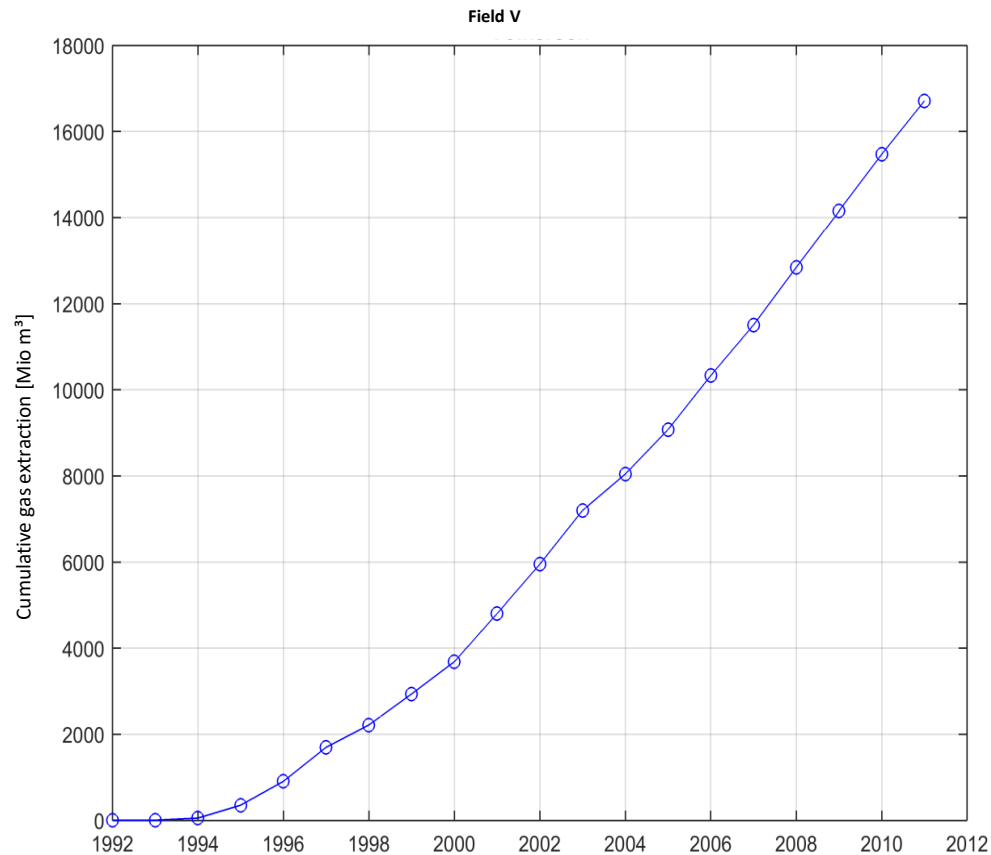


- >10 years production
- > 250 bar pressure reduction
- till events M>3

# Excel spreadsheet: Gas extraction

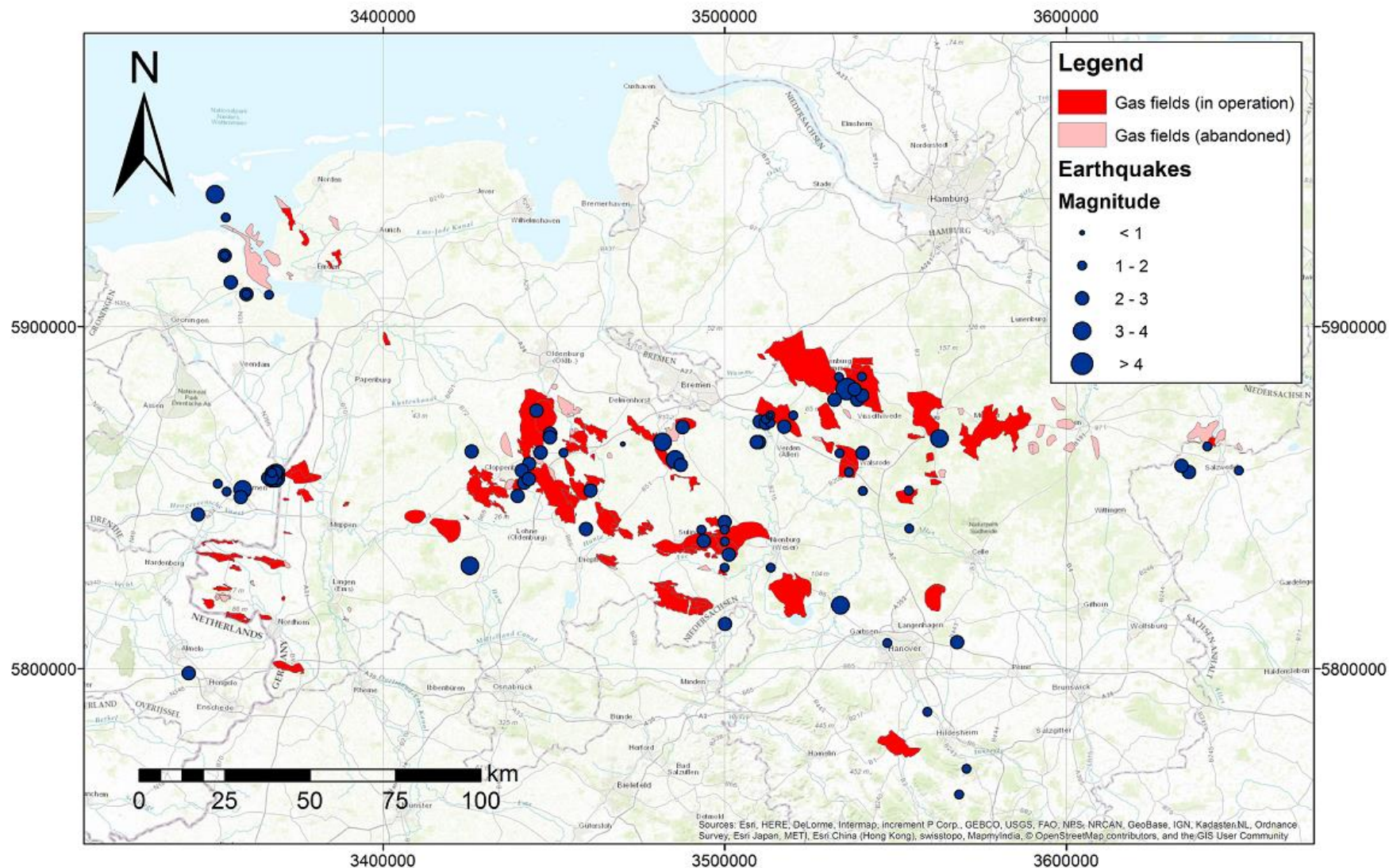
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Feldname	Testfeld	Adorf-Dalu	Adorf(Bunts	Adorf(Zechs	Ringe	Ringe (Karl	Ringe(Zech	Ahlhorn	Alfeld-Eize	Annaveen	Apeldorn	Bahnsen	Bahrenbors
2	Top			2150	2780			3000	3725	1200	3725	2100	4200	
3	Bottom			2275	3000			3100	3875	1457	3975	2145	4250	
4	Mächtigkeit [m]		50	125	220		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 [m]	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(Zech	Ahlhorn	Alfeld-Eize	Annaveen	Apeldorn	Bahnsen	Bahrenbors	
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	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



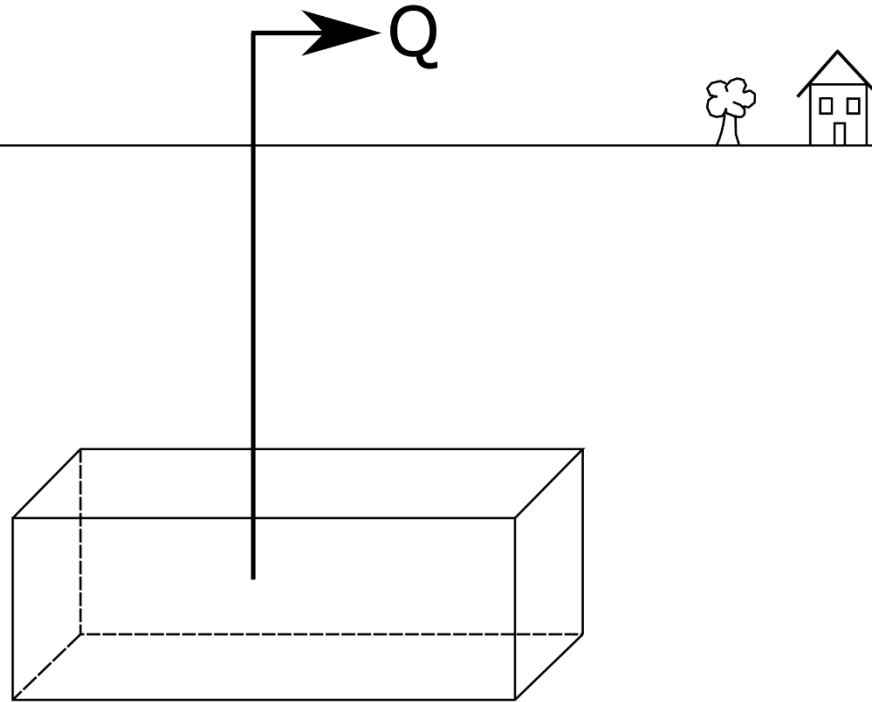


# Digitalization of gas fields and earthquakes



# Calculation of pore pressure

1. Assumption: Closed system



# Calculation of pore pressure (2)

## 1. Assumption: Closed system

→ Flux of formation water into the reservoir is neglected

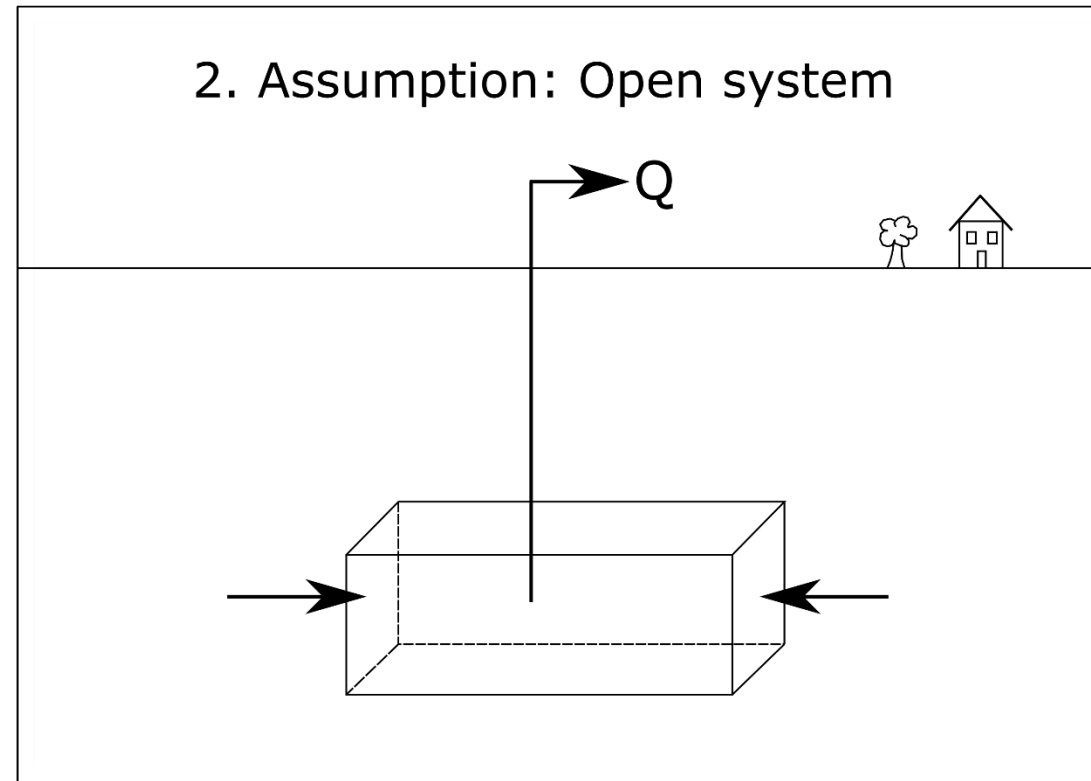
- Ideal gas equation:  $P_{reservoir} * V_{pore} = R * n * T$
  - Pressure:  $P_{reservoir} = \rho * g * h * overpressure (1,2)$
  - T is given by geothermal gradient 30°C/km
- Calculation of amount of substance in porespace
- Change of amount of substance by gas extraction → Back calculation of reservoir pressure



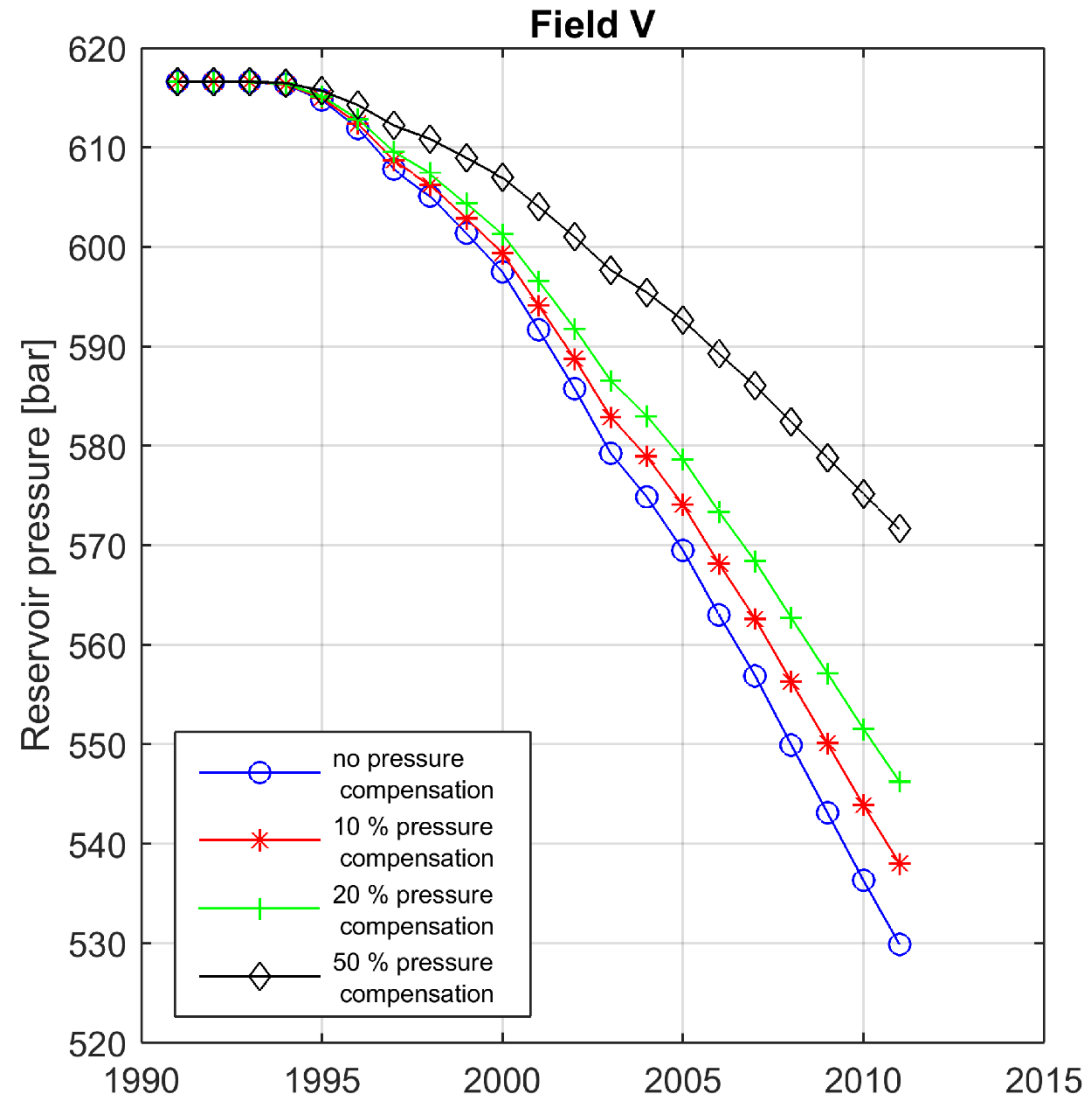
# Calculation of pore pressure (3)

## 2. Assumption: Flux of water into the reservoir

→ Pressure compensation in the reservoir

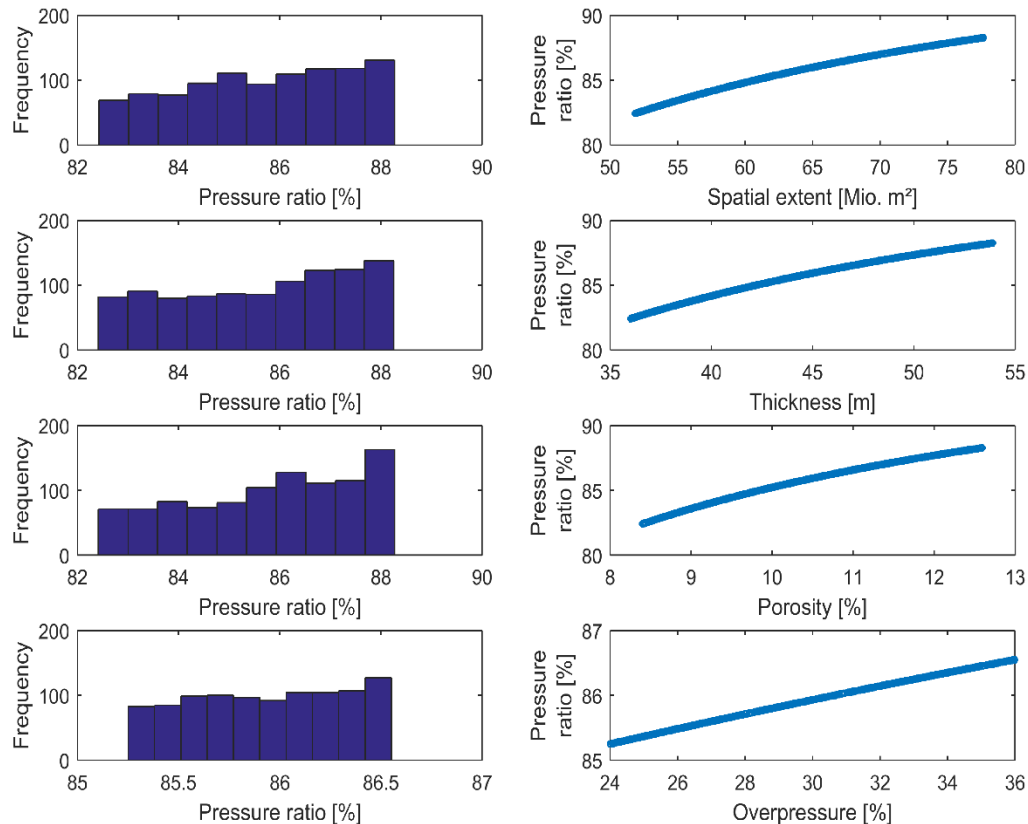


# *Pressure reduction of field V*

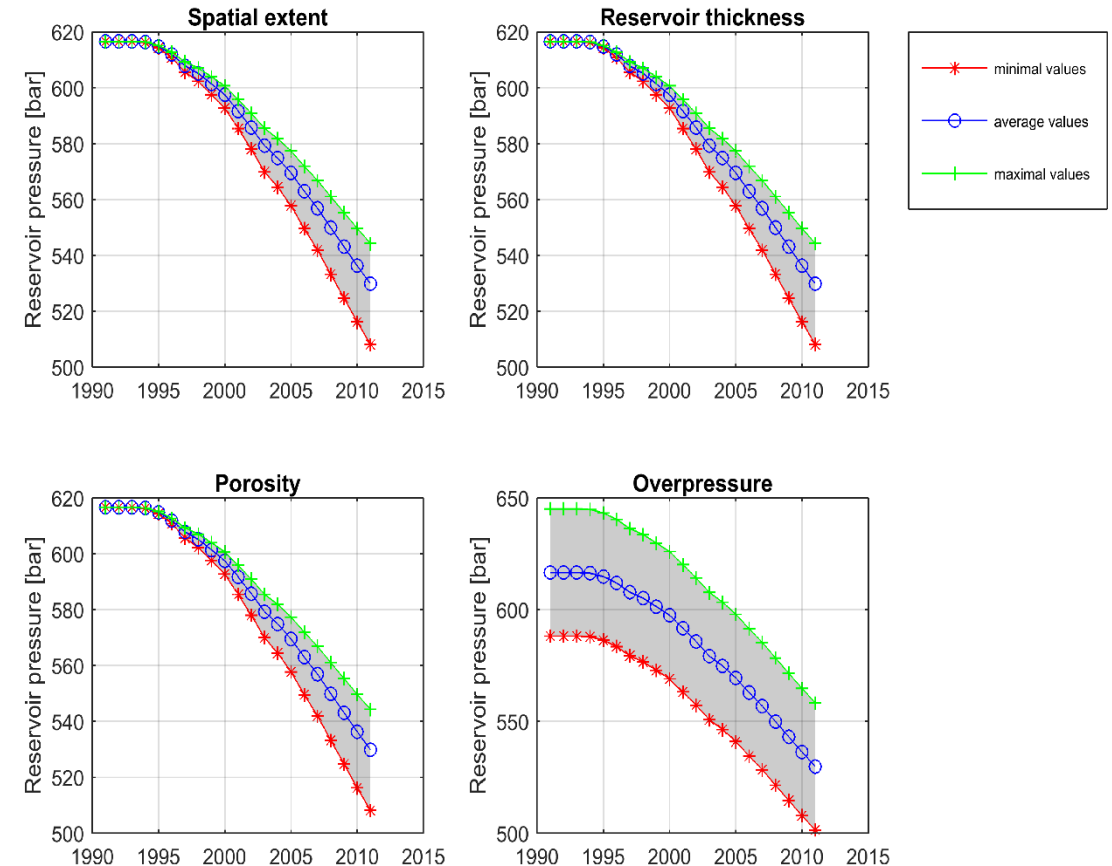


# Sensitivity analysis of pressure reduction

Sensitivity analysis of field V



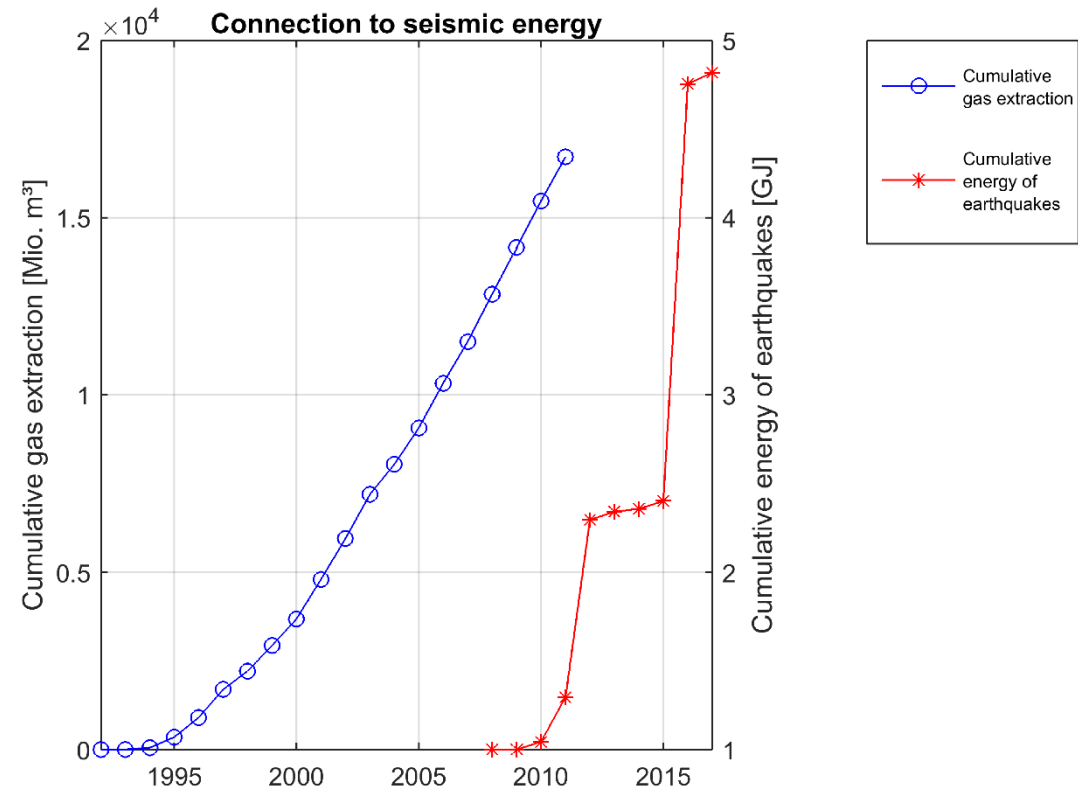
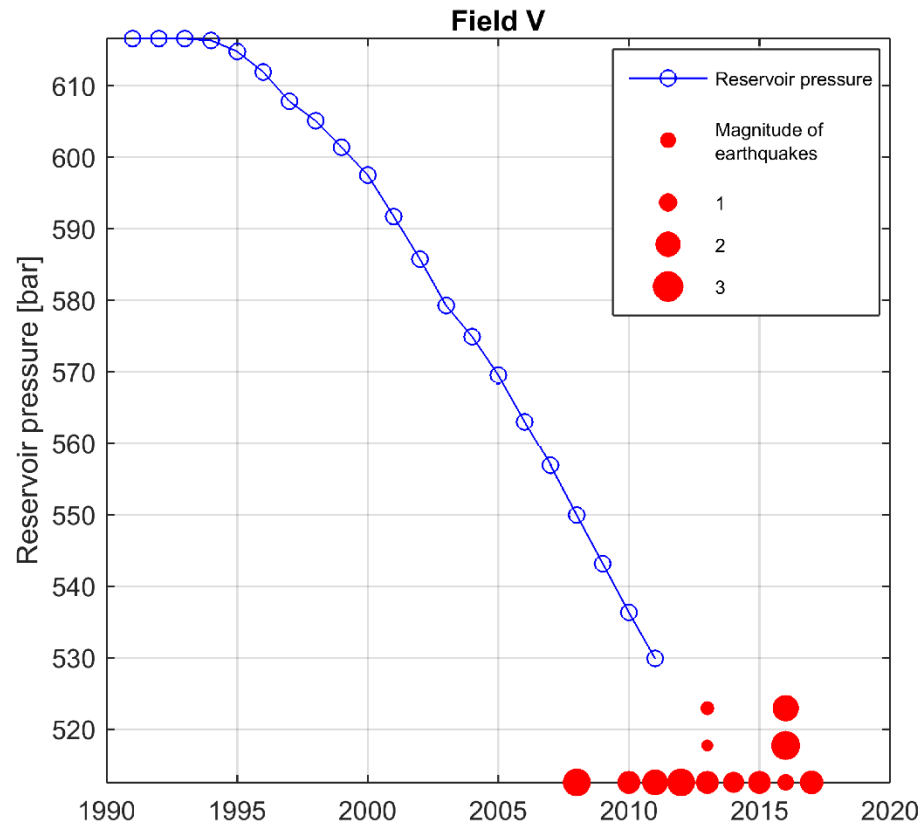
Sensitivity analysis of field V



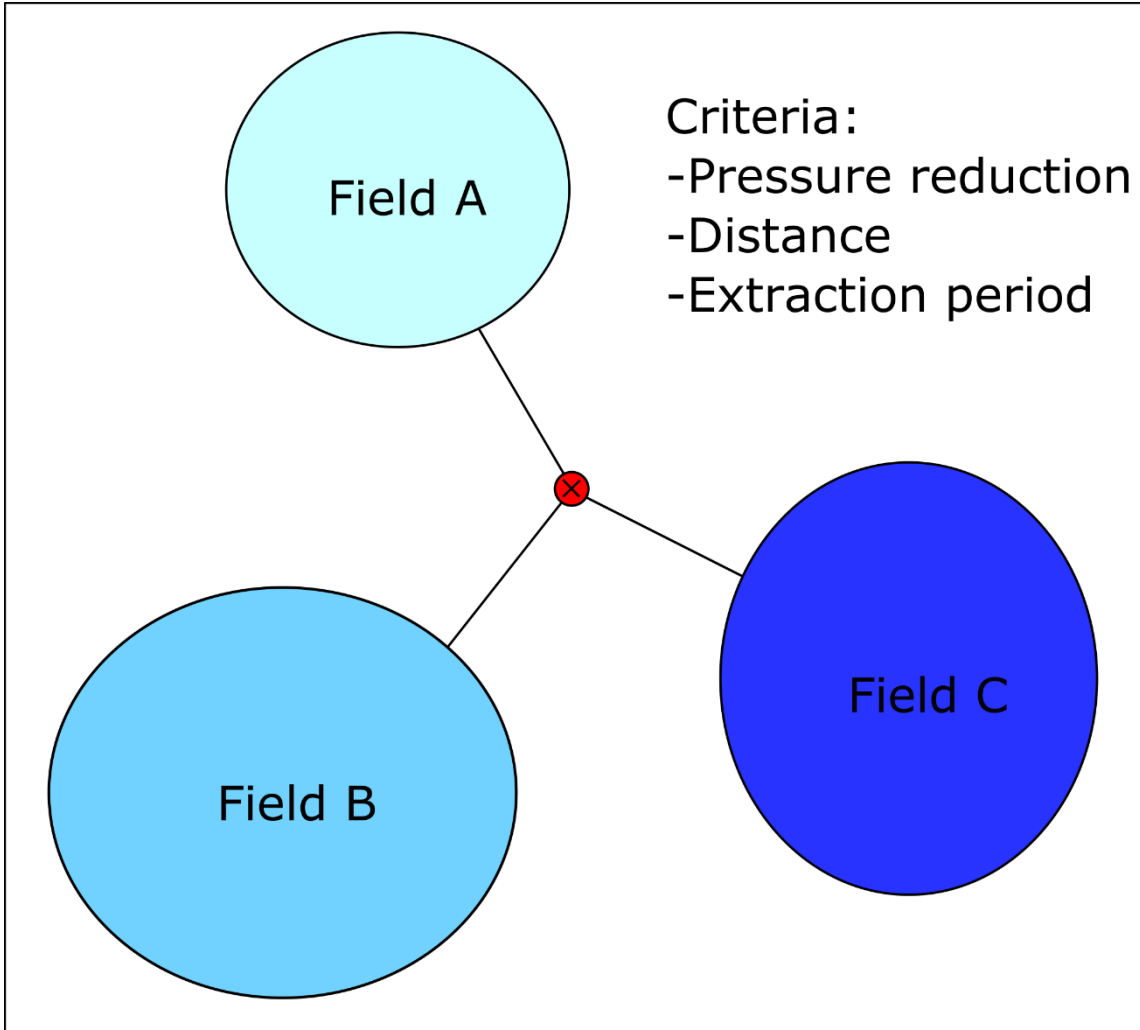
# Correlation to seismicity

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

Hanks & Kanamori (1979)



# Assignment of earthquakes to gas fields



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



# Discussion

- Assignment of earthquakes to gas fields
  - Comparison of assignment with literature (e.g. earthquake of 02.09.2014; Bischoff et al. (2015))
- Time shift between onset of seismicity and begin of gas production
  - Accordance with literature

Gas field	Distance [m]	Period of production	Pressure ratio	Assignment parameter (AP)
Goldenstedt/Visbek	1837	1971 - today	0,83	2,79
Cappeln	6380	1970 – today	0,86	34,83
Hengstlage	976	1968 – today	0,90	0,86
Ahlhorn	696	1972 – 1998	0,96	0,47

# 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 attention!***

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