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

Kai Stricker*, Kristina Krasnonosov, Nadine Wittmann (Karlsruhe Institute of Technology)

Mentor: Dr. Birgit Müller (Karlsruhe Institute of Technology)

*kai.stricker@student.kit.edu
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.

- >10 years production
- > 250 bar pressure reduction
- till events M>3
### Excel spreadsheet: Gas extraction

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<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
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</table>

X Oil and Gas Horizons | Moscow, Russia
Cumulative gas extraction
Digitalization of gas fields and earthquakes

Legend
- Gas fields (in operation)
- Gas fields (abandoned)

Earthquakes
- Magnitude
  - < 1
  - 1 - 2
  - 2 - 3
  - 3 - 4
  - > 4
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: $P_{reservoir} \times V_{pore} = R \times n \times T$
   • Pressure: $P_{reservoir} = \rho \times g \times h \times overpressure \ (1,2)$
   • $T$ 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

2. Assumption: Open system
Pressure reduction of field V
Sensitivity analysis of pressure reduction
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

Criteria:
- Pressure reduction
- Distance
- Extraction period
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

<table>
<thead>
<tr>
<th>Gas field</th>
<th>Distance [m]</th>
<th>Period of production</th>
<th>Pressure ratio</th>
<th>Assignment parameter (AP)</th>
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<tbody>
<tr>
<td>Goldenstedt/Visbek</td>
<td>1837</td>
<td>1971 - today</td>
<td>0.83</td>
<td>2.79</td>
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<td>Cappeln</td>
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<td>1970 – today</td>
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<td>Hengstlage</td>
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<td>Ahlhorn</td>
<td>696</td>
<td>1972 – 1998</td>
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</table>
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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GUBKIN UNIVERSITY, MOSCOW

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Kai Stricker
kai.stricker@student.kit.edu