FracRisk

Assessment of deep subsurface hydro-mechanical and transport processes for reducing the environmental footprint of shale gas development.

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Key aspects of FracRisk

• Multiscale data sets
• Risk analysis
  – scenario based quantification of risks involved
• Numerical modelling
  – process oriented approach
  – forward modelling approach
  – integration of relevant components
• Monitoring and mitigation
• Legislation
Project Information Flow

Selected sites across Europe & USA
- Generic Hydro-Geo-Chemical-Mechanical Facies
- Baseline Data
- Features / Events / Processes

Risk Register

Model development

Risk reduction
Uncertainty reduction

Increase certainty

Static and dynamic modelling of scenarios

Mitigation and monitoring strategies

Knowledge base, scientific recommendations, legislation

Determine cost effective data requirements to increase certainty
Risk Based Approach
Source Pathway Target

- Common language
- Common concepts
- Characterisation
Shale Gas in the EU

- Selection of basins in EU with different settings, characterisation of source.

<table>
<thead>
<tr>
<th>Basin</th>
<th>Tectonic setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bowland - 1</td>
<td>Rift basin</td>
</tr>
<tr>
<td>Paris - 2</td>
<td>Cratonic sag basin</td>
</tr>
<tr>
<td>Lublin - 3</td>
<td>Flexural foredeep basin</td>
</tr>
<tr>
<td>Carpathian-Balkan - 4</td>
<td>Rift basin</td>
</tr>
<tr>
<td>Pannonian - Transylvanian - 5</td>
<td>Extensional basin</td>
</tr>
<tr>
<td>North Sea - Germany - 6</td>
<td>Epicontinental sag basin</td>
</tr>
<tr>
<td>Baltic - 7</td>
<td>Foreland basin</td>
</tr>
</tbody>
</table>
Compartmentalisation of Subsurface

Key natural features characterised under FEATURES of FEP list.

- Near Surface Environment
  - Marine Environment
  - Terrestrial Environment

- Overburden

- Hydrocarbon bearing formation

- Underburden
Approach to Risk Assessment

Natural System

Natural System Close Up

Natural System in FEP’s

High Risk Combination

Combinations of FEP’s

Consequence

Receptor

Undesirable Event

CAUSE to EFFECT

EFFECT to CAUSE
**FEPs appraisal, example for Processes**

1. 14 participants assigned an importance value (from 1 to 5) for each focused scenario.
2. Performed an average calculation of the 14 rankings, for each item in the list.
3. Listed the FEPs which received an average grade of 4 or 5 (highest importance value).
4. Calculated the standard deviations of these grades (results range from 0.5 to 1.8) which indicate that some FEPs are more agreeable between the respondents, than others.

### List of Processes

<table>
<thead>
<tr>
<th>Number</th>
<th>Process Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Thermal effects on the borehole</td>
</tr>
<tr>
<td>1.1</td>
<td>Thermal effects on borehole and seal integrity.</td>
</tr>
<tr>
<td>1.2</td>
<td>Thermal effects on the injection point</td>
</tr>
<tr>
<td>2</td>
<td>Hydraulics / Fluid Pressure Dominated</td>
</tr>
<tr>
<td>2.1</td>
<td>Fluid pressure exceeds rock fracking pressures generating new fractures</td>
</tr>
<tr>
<td>2.2</td>
<td>Fluid exceeds fault sealing pressures</td>
</tr>
<tr>
<td>2.3</td>
<td>Fluid pressure exceeds stability of part of the plant construction</td>
</tr>
<tr>
<td>2.4</td>
<td>Displacement of surrounding formation fluids</td>
</tr>
<tr>
<td>2.5</td>
<td>Buoyancy-driven flow</td>
</tr>
<tr>
<td>2.6</td>
<td>Advection and co-migration of other gas</td>
</tr>
<tr>
<td>2.7</td>
<td>Formation of gas hydrates</td>
</tr>
<tr>
<td>2.8</td>
<td>Fluid pressure exceeds stability of part of the plant construction</td>
</tr>
<tr>
<td>2.8.1</td>
<td>Advection</td>
</tr>
<tr>
<td>2.8.2</td>
<td>Dispersion</td>
</tr>
<tr>
<td>2.8.3</td>
<td>Diffusion</td>
</tr>
<tr>
<td>2.9</td>
<td>Hydraulic and production fluids and the associated contaminants release processes</td>
</tr>
<tr>
<td>3</td>
<td>Chemical</td>
</tr>
<tr>
<td>3.1</td>
<td>Corrosive mixture attacks plant</td>
</tr>
<tr>
<td>3.2</td>
<td>Corrosive mixture attacks geology</td>
</tr>
<tr>
<td>3.3</td>
<td>Sorption and desorption</td>
</tr>
<tr>
<td>3.4</td>
<td>Mineral dissolution</td>
</tr>
<tr>
<td>3.5</td>
<td>Heavy metal release</td>
</tr>
<tr>
<td>4</td>
<td>Mechanical</td>
</tr>
<tr>
<td>4.1</td>
<td>Soil and rock deformation around boreholes</td>
</tr>
<tr>
<td>4.2</td>
<td>Evidence of ground related to gas extraction</td>
</tr>
<tr>
<td>4.3</td>
<td>Soil and rock deformation around boreholes</td>
</tr>
<tr>
<td>4.4</td>
<td>Fault valving</td>
</tr>
<tr>
<td>4.5</td>
<td>Generation of excavation disturbed zone around well</td>
</tr>
<tr>
<td>4.6</td>
<td>Micro-cracking in the casing cements</td>
</tr>
</tbody>
</table>

### Relevance to Scenario

<table>
<thead>
<tr>
<th>Relevance to Scenario</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most Critical</td>
<td>5</td>
</tr>
<tr>
<td>Least Critical</td>
<td>1</td>
</tr>
</tbody>
</table>

### Correlation between the processes’s average grade and STDEV

- The average grade and standard deviation (STDEV) for each process are calculated.
- The diagram illustrates the correlation between the average grade and STDEV for each process.
- An average grade of 4 or 5 indicates that the process is considered highly critical.
Highest ranked Processes for FS1

All items presented, have an average grade of 4. The standard deviation indicates that there was consensus on the score of *Propagation of fractures beyond the target zone* (0.9) whereas on *Fluid pressure exceeds stability of part of the plant construction, Fault valving and Micro-cracking in the casing cements*, there was less agreement (1.7 for the last three).
Combining FEP’s, Top Down Hazard Assessment and Bow Tie Diagrams

**BOTTOM UP**

- FEP’s
  - THREAT

**PREVENTION**

- INJECTION PROCEDURE
- PRESSURE MONITORING

**HAZARD**

- HIGH PRESSURE OPERATIONS
- WELL CASING RUPTURES

**LOSS OF CONTROL**

**RECOVERY**

- LEAK DETECTION SYSTEM
- ISOLATION VALVES

**TOP DOWN**

- EXTRACT

**CONSEQUENCES**

- POLLUTION OF SURFACE ENVIRONMENT
- TRANSPORT of FRACKING FLUID into GROUNDWATER AQUIFER
- LOSS OF FRACTURING FLUIDS
- MICRO SEISMICS

Undesirable Event
Focussed Modelling Scenarios to Delimit Possible Threats, Prevention Methods, Recovery Methods and Consequences

- Geomechanics of frack development
- Hydro-mechanics and geo-seismicity
- Driving forces (e.g. gravity, capillarity, diffusion, initial pressure, pressure gradient).
- Time scale (2h for the fracking process, 100 years for methane migration).
- Spatial scale (near field and far field).
- Fluid (fracking fluids or methane).
Closer look at the focused modelling scenarios

- **Regional fluid flow**
  - Diffuse source
  - Natural background

- **Faults**
  - Fracking

- **Rapid transport**
  - Faults
  - Abandoned wells

- **Chemical transport**
  - Baseline geochemistry
  - Flowback composition

- **Pressure migration**
  - Fluid flow

- **Hydro mech. behaviour**
  - Fracking models
  - Micro-seismics
  - Baseline seismics
Several threats will be analysed by the same scenario.
Example of intended impact of modelling and risk work

- **IMPROVED UNDERSTANDING** of HAZARDS viz FRACKING
- **IMPROVED OPERATION**
- **FOCUSED MONITORING**

- **IMPROVED PROCEDURES**
- **IMPROVED REGULATION**
RBCA helps you to:
- Categorize sites according to risk
- Allocate resources
- Provide appropriate oversight
- Identify pathways and receptors
- Determine the level and urgency
- Cost-effective action
Model Data, Tier 2

Some generic parameters for all scenarios, and some scenario specific
Model Data Interpreted Using Polynomial Functions (Emulator)

Some generic parameters for all scenarios, and some scenario specific
Interpreted Surface for RBCA

\[ \% = f(a, b, c, d, e, f, g, h, i, j) \]

Some generic parameters for all scenarios, and some scenario specific
Integrating Science, Best Practice and Legislation

Major Basins

North Sea
German
Baltic
Lublin
Carpathian
Balkanian
Pannonian
Transylvanian

Legislative Review

UK
Germany
Poland
Rumania
Hungary
Austria
France
Spain

Output

Nomenclature
Instruments
Common approaches
Key differences
Recommendations based on highest risk hazards
Summary

Key Features of Focussed Scenarios

Source
- Hydro mech. behaviour
- Fracking models
- Micro-seisics
- Baseline seismic

Pathway
- Pressure migration
- Fluid flow
- Chemical transport
- Baseline geochemistry
- Flowback composition
- Faults
- Abandoned wells

Target
- Regional fluid flow
- Local “fracked” source
- Long term transport
- Natural background

WP5 MODELLING and MODELLING DEVELOPMENT

Application of standard industry codes & research codes
- Identification of key deficits and development of code

Static and dynamic modelling of scenarios
- Model development

WP4 ENVIRONMENTAL IMPACT and RISK ASSESSMENT

Increase certainty

Risk Register

Risk reduction
- Uncertainty reduction

Mitigation and monitoring strategies

WP6 MONITORING and MITIGATION of KEY EVENTS

Identification of required data density

Identification of events and monitoring thereof

WP7 DISSEMINATION, KNOWLEDGE BASE, SCIENTIFIC RECOMMENDATIONS, LEGISLATION, BEST PRACTISE