Simulation of subsea gas hydrate exploitation

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Outline

- Introduction to gas hydrates
- Gas hydrates as an energy source: SUGAR project
- Numerical simulation of hydrate exploitation
  - Simple depressurization
  - CO₂ injection
- Summary
What are gas hydrates?
Stability of gas hydrates

Pressure [bar] vs. Temperature [K] for various gases:
- Nitrogen
- Argon
- Propane
- Carbon dioxide
- Ethane
- Methane
- Xenon
- Hydrogen sulfide
How do gas hydrates look like?
Where you can find hydrates?

Methane (g) + water → Methane hydrate

Water temperature

Seafloor

Water depth [m]

Temperature [°C]

Methane (g) + water

Methane hydrate

Geothermal gradient

BSR

M. Haeckel, IFM-GEOMAR
Where you can find hydrates?

- Canada
- USA
- Japan
- China
- Taiwan
- S. Korea
- India
Gas hydrates and carbon matter

Gas hydrates and carbon matter

- Oxygen hydrates: 10,000 Gt
- Soil: 1,400 Gt
- Atmosphere: 6,6 Gt
- Peat: 500 Gt
- Terrestrial biosphere: 830 Gt
- Dissolved organic matter: 980 Gt
- Organic matter: 60 Gt
- Oil, coal, gas: 5,000 Gt

Fossil fuel reserves and submarine gas hydrates

- Coal: 6,6 Gt
- Oil: 1,400 Gt
- Gas: 830 Gt
- Hydrates: 10,000 Gt


Simulation of natural gas hydrate exploitation

- CO₂ hydrate stable at lower pressure / higher temperature
- CO₂ higher stability
- Replacing CH₄ by CO₂
- Simultaneous production of CH₄ and storage of CO₂
- Sustainable energy supply system
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Case study - Ulleung Basin, South Korea

Water depth: 2153 m,
Salinity: 34,
Geotherm: 0.2 °C + 112 °C/km

Seafloor

Quaternary turbidites,
$S_{GH}: < 1$ Vol%

135 mbsf

Quaternary turbidites
Gas hydrates in sand-dominated layers

167 mbsf (BGHS)

Quaternary turbidites,
Mass flow deposits
Free gas/water in sand-dominated layers

400 mbsf

Lee et al., 2011; Bahk et al., 2011; Moridis et al., 2009; Kim et al., 2011

Clay:
$\phi$: 0.5
$K_v$: 1 mD
$K_s$: 2 mD
$S_{GH}$: < 1 Vol%
$\lambda$: 0.3 W/m/K

Sand:
$\phi$: 0.3
$K$: 1000 mD
$S_{GH}$: 40 Vol %
$\lambda$: 1.3 W/m/K
Simulation of depressurization of a deposit

$t = 1$ month
Heat transport within layered deposits

→ Fingering effect increases production rates

hydrate saturation after 3 years
Case study II – Ulleung Basin, Site UBGH 2.6

Methane Production Rates

- Blue line: Hydrate layer thermally closed
- Red line: Hydrate layer thermally open

Methane Production Rate (Nm³/h)

Time (days)
Gas production
2-well approach
Summary

- Immense amount of natural gas hydrates is presumed
- Simulation with commercial code (CMG STARS) and in-house development (implemented in COMSOL Multiphysics)
- Case studies
  - in general: depressurization, CO\textsubscript{2} injection
  - specific: South Korea (Ulleung basin), Black Sea (in future)
- Simultaneous or stepwise CH\textsubscript{4} production and CO\textsubscript{2} injection is possible with acceptable rates
- Results strongly depend on deposit conditions
  - multiphase flow is dominating: Permeability controls production rates
  - heat transport within layered deposits
- Large potential but need for further research to understand the occurring mechanisms and development of applicable technologies
Thank you for your attention!

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