Assessment of hydrate-related geohazards: The Black Sea Case study

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Gas hydrates as a hazard potential

- Solid phase of gas (mostly methane) in crystalline cage structure
- Sometimes considered as next generation unconventional gas resource
- Gas hydrates exist in continental margin sediments worldwide as well as permafrost areas
- BUT .... **Hazard potential** for deep sea resource exploitation

*Figure 2.4* - Gas hydrates resource potential by global regions. This figure includes only that subset of global in-place gas hydrates that appear to occur at high concentrations in sand-rich reservoirs, the most likely candidates for development. Source: Johnson 2011.

Sources: USGS, RCMG, IODP, Frozen Heat, NETL
Hazard related to hydrate exploitation

- Phase of hydrate changes to Gas from Solid -> Weakening/softening formations

Gas production by depressurization

- Production induced subsidence

Water + Gas

- Pressure diffusion
  - > consolidation in overburden

Hydrate reservoir

- Reservoir compaction

- Potential slip surface
- Gas leakage
- MH dissociation zone
- Oil and Gas production
- Well
Hydrate melting around hot well

- Hot well (deeper reservoir, e.g., conventional reservoir)
  - Typically low hydrate saturation and large temperature contrast
  - Relatively slow process
  - Well integrity (uncontrolled fluid release, fracturing, loss of capacity)?

DSS tests on samples subjected to gas exsolution (NGI, Yang et al., 2015)

Strength loss about 15% for samples subjected to severe gas exsolution
Hydrate melting due to temperature change in sea-bed

Temperature change in seabeed by global warming or seabeed installation can cause hydrate melting (and increase of in situ pore pressure, thus lower resistance)

Q1: Does dissociation cause a failure to create leakage pathway?
Q2: Does it become a potential hazard to marine slide?

Weaken zone by hydrate dissociation due to changed GHSZ

The gas bubble observed in Western Svalbard are likely caused by hydrate dissociation due to bottom water warming last 30 to hundreds years

(Berndt et al. 2014)
Objective and scope

- Improve our understanding of the hazard potential and consequences of deep-sea hydrate exploitation,
- Investigation through element technology for stream-line geo-hazard analyses
- Applied to the Black Sea (MIDAS area)
Workflow to assess gas hydrate exploitation related geohazard

- Preliminary screening
  - Geophysical/geotechnical survey

- 2D slope stability analysis
  - Static analysis
  - EQ analysis

- Hydrate geomechanics analysis
  - Vertical displacement
  - Shear strain after full depletion

- Evaluating consequence
  - (Run-out analysis)
  - (Sand production /leakage potential)
Preliminary screening using topography

- Slope inclination can be a good index to screen critical areas

Potential hydrate reservoir
Quantified assessment for static screening analysis

1D infinite slope stability model

Potential hydrate reservoir
Preliminary screening: effect of earthquake

- One-dimensional (1D) infinite pseudo-static slope stability analyses

European Seismic Hazard Map

Potential hydrate reservoir

Blacksea

(Giardin et al, 2013)
2D slope stability analysis (static analysis)

- Static FoS for the initial phase is 1.266.
- The slip zone is much shallower than the depth of hydrate reservoir.
2D slope stability analysis (pseudo-static analysis)

- Landslide is likely by peak ground acceleration of $0.1g$ ($FoS = 1.014$)
- Slip plane lies deeper, thus landslide volume larger compared to static case
Consequence evaluation: run-out analysis (static case)

- Run-out may be several hundreds of metres long. The mass could reach to middle of channel bed and hit the offshore installation.
Consequence evaluation: run-out analysis (Earthquake case)
Consequence evaluation: run-out analysis (Velocity of debris flow)
Shear failure induced leakage/sand production

- Depressurization can cause a shear failure in reservoir and overburden

(Schlumberger, 1992)
Summary and Conclusion

This study focused on geohazard potential of hydrate exploitation for the Black Sea.

- Direct effect of strength reduction of dissociated zone (i.e. hydrate reservoir) appears small, as the depth of commercially feasible hydrate reservoirs is generally deeper than the potential failure depth of critical slopes.
- Mechanical consequence of hydrate dissociation (i.e. deformation or mechanical failure due to stress redistribution) may contribute as a secondary factor to trigger slope failure (oversteepening due to subsidence).
- Run-out analysis shows that enough set-back distance should be applied for the production planning to avoid damage to seabed installation or pipe/flow line by potential slope slides. Run-out may be 800 m long. Flow velocities is ~10 m/s.
- Possibility of sand production/leakage should be considered if high depressurization scenario is planned.
Thanks for your kind attention!

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Tensile failure induced leakage in shallow subsurface

- In shallow surface, temperature-induced dissociation can cause excess pore pressure in impermeable clay section.
- Shallow section have a low effective confining stress and easily become tensile failure zone by dissociation-induced excess pore pressure.

(NGI, Yang et al., 2015)
FE analysis for western Svalbard margin (on-going)

- When the initial saturation of hydrate is assumed as 5%, the dissociation generate less than 10 kPa of excess pore pressure. (Thatcher et al., 2013)
- Tensile failure (fracturing) is likely to major mechanism of leakage

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