Victoria
Modelling of a tight gas reservoir

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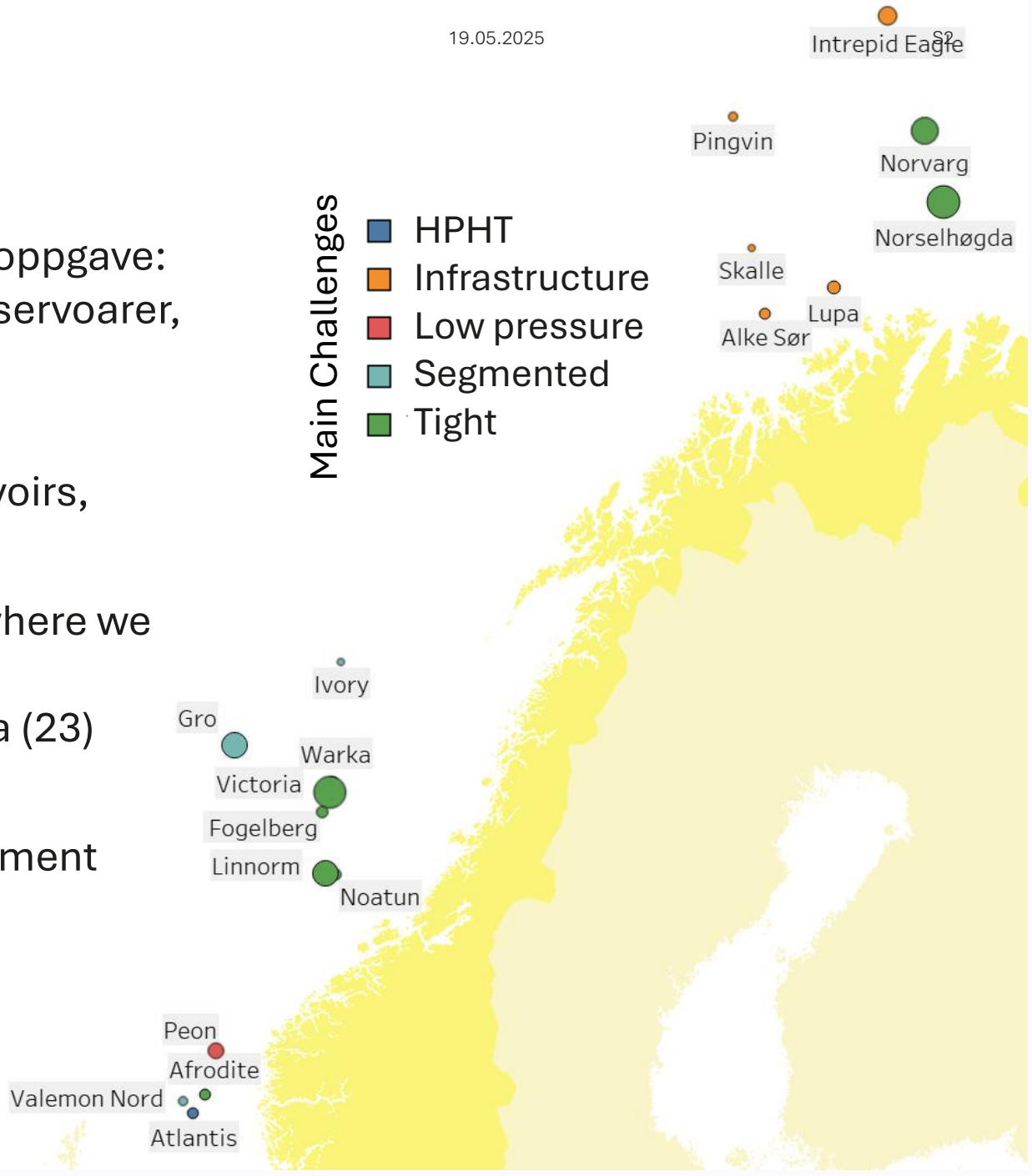
Motivation for study

- ED tildelingsbrev 2025 – særskilt prioritere følgende oppgave:
  - «Bidra til å realisere lønnsom utvinning fra tette reservoarer, herunder bidra til samarbeid og samordning i petroleumsnæringen»
- NOD has done an inventory of challenging gas reservoirs, both licensed and relinquished
- In the Norwegian Sea there are several discoveries where we plan to focus attention
  - Relinquished (GIIP): Victoria (144), Gro (92), Warka (23)
  - Early phase: Linnorm, Fogelberg, Noatun
- What technology exists to enable economic development
  - Hydraulic fracturing is the focus of this study



Background on the Victoria discovery

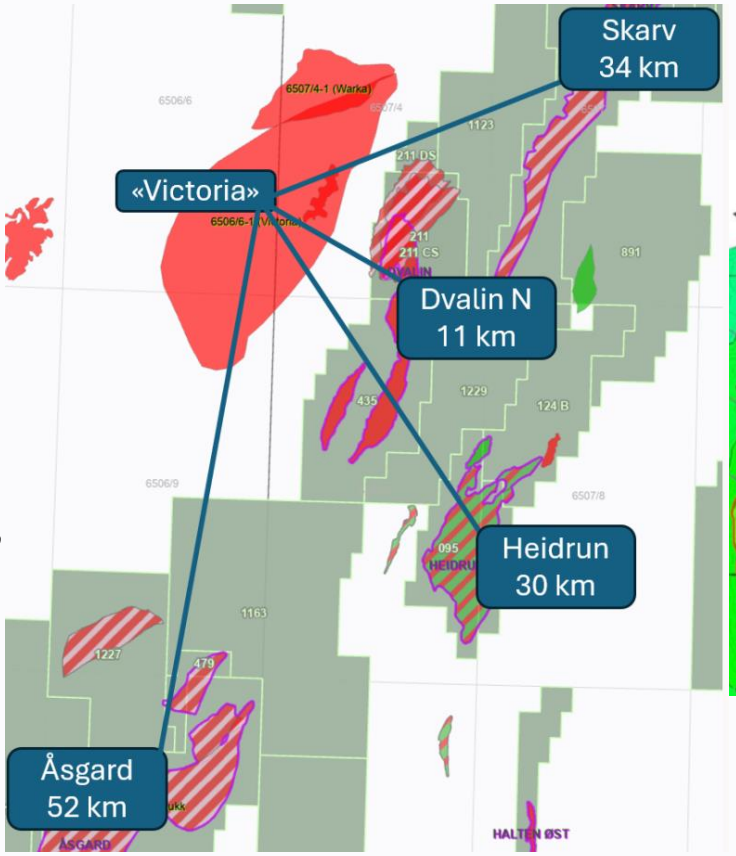
2000 : Discovered by Exxon (6506/6-1)

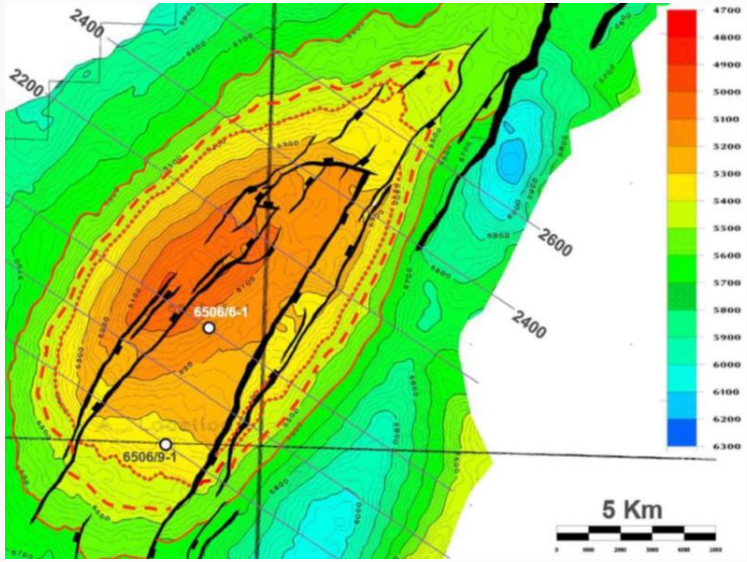
2006 : Operatorship transferred to Total

2009 : Appraisal well (6509/9-1)

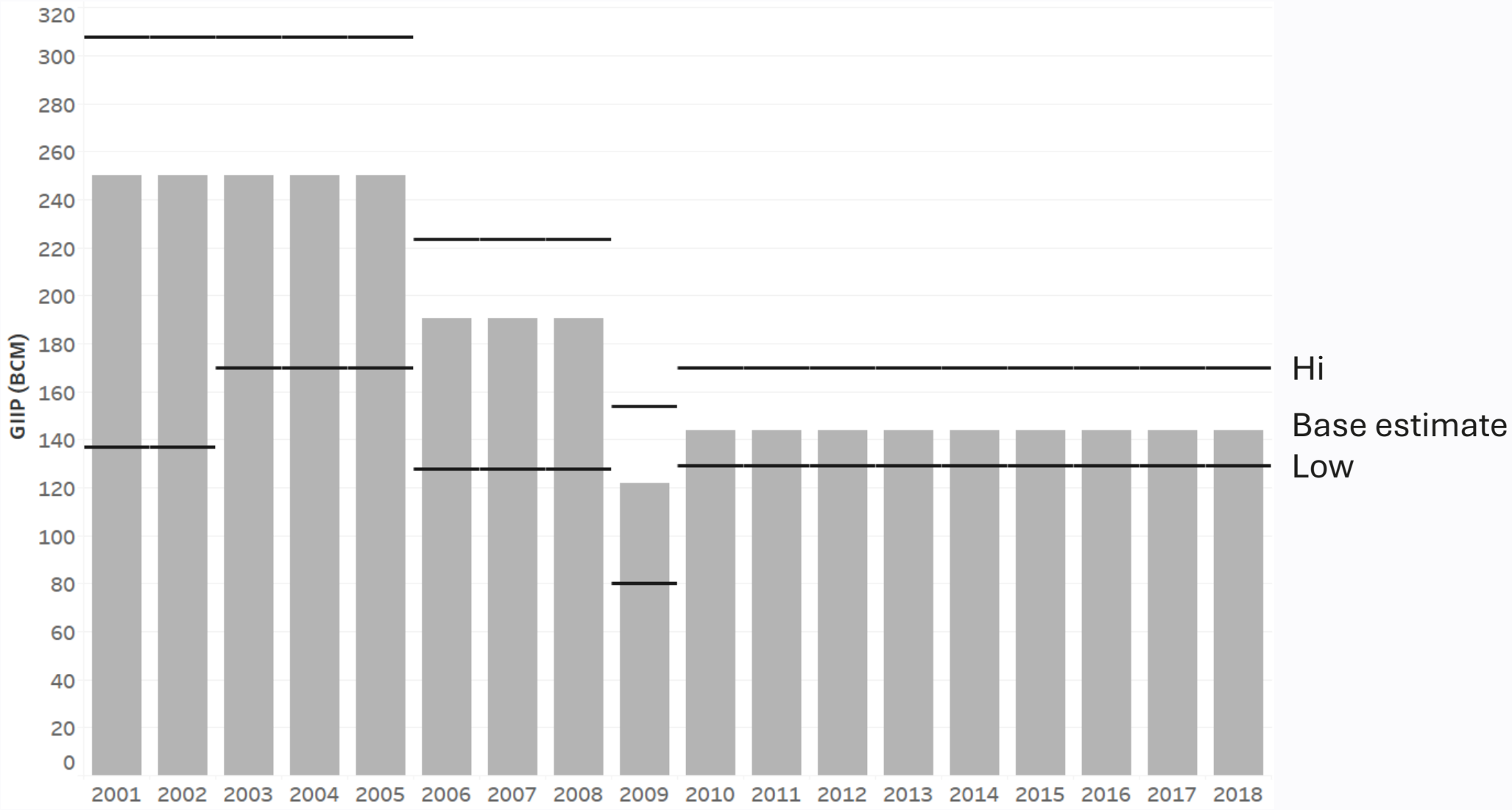
2018 : Victoria discovery relinquished

- Water depth: 420 meters
- Reservoir crestal depth: 4820 m TVD
- Reservoir conditions (@ 5400 m): 820 bar, 190 C
- CO_2 content: 8-10%
- 460 m gas column
- In place gas volumes: ~140 GSm^3



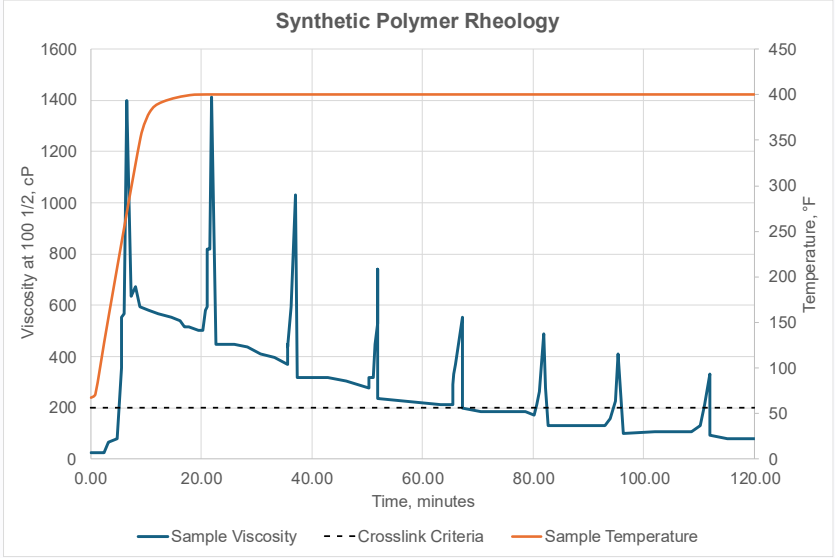


Gas inplace as reported to NOD through RNB



Biggest Industry Advancements Applicable to Victoria

- Use of drill pipe to manipulate frac sleeves
  - This removes the need for coiled tubing interventions between stages
  - System allows for quick transition between zones
  - Screen-out recovery is quick, and simply requires the sleeve to be closed, followed by reverse circulation of any proppant laden fluids
  - Delivery of 1 fracture per day, even with a screen-out occurrence
- Availability of high temperature and environmentally compliant fluids



Example of synthetic polymer rheology

Geomechanics Modelling done by Opecs

1. Build a detailed geomechanics model with minimum assumptions.

Logs QC for input to MEM

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Estimate rock mechanics properties with sonic

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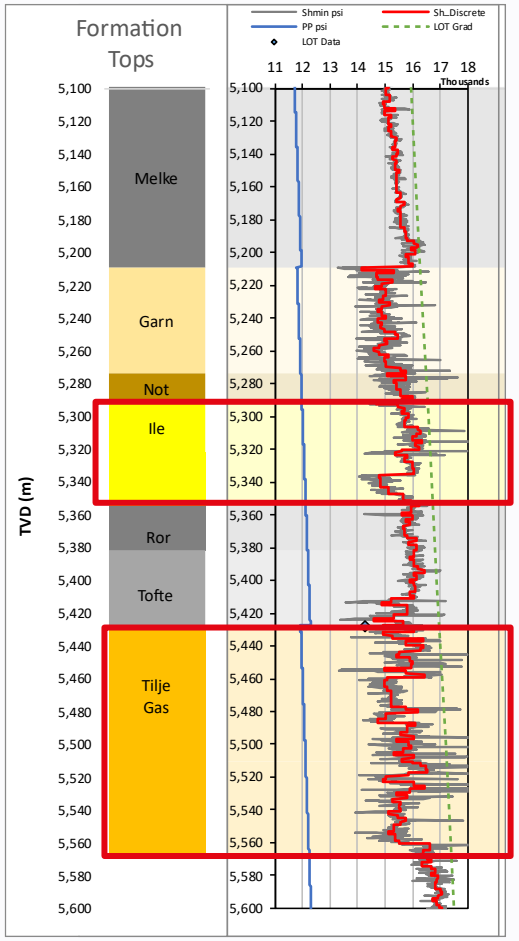
Estimate static rock properties

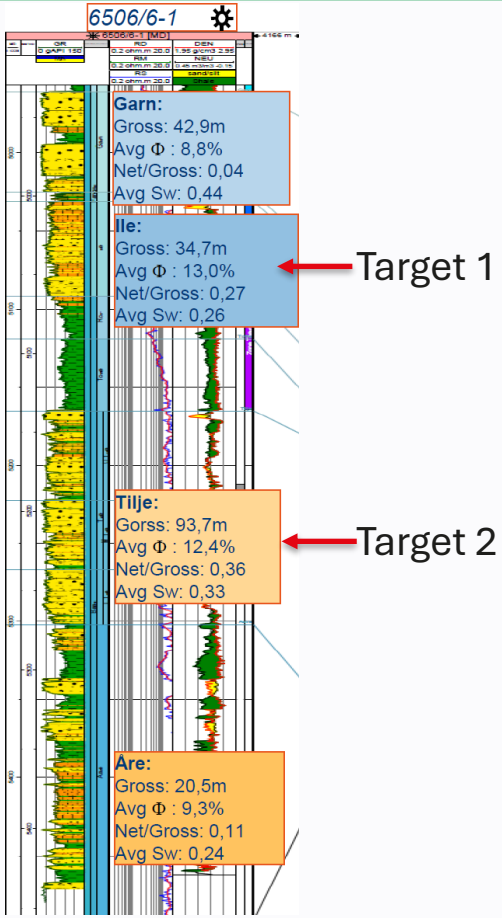
↓

Calculate lithostatic load with rock properties and pore pressure

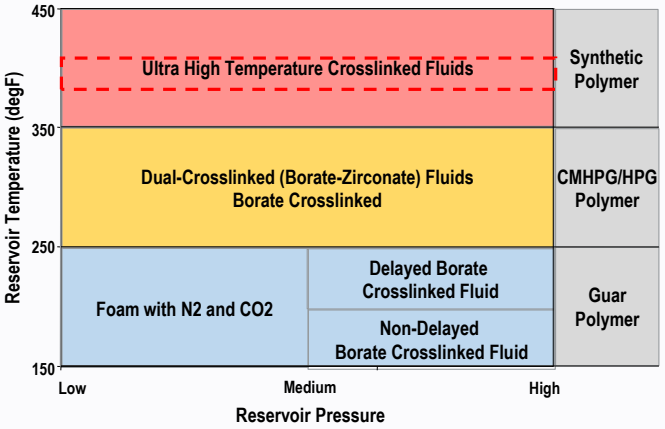
2. Calibrate the geomechanics model with available data.



3. Define any sensitivities that need to be considered.

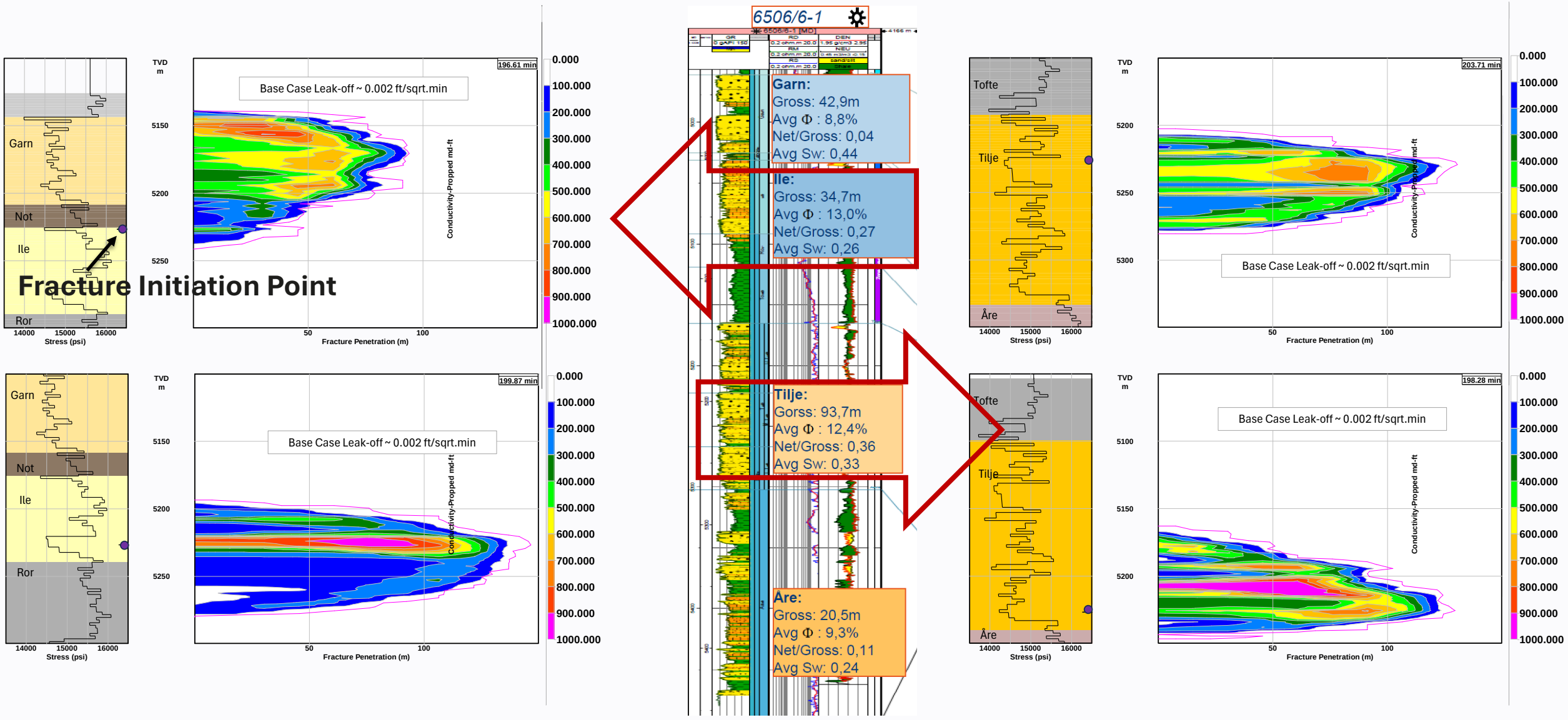


4. Determine appropriate materials for fracturing



Fluids: sophisticated crosslinked system to or synthetic polymers.
Proppant: HSP

Fracture Simulation Results

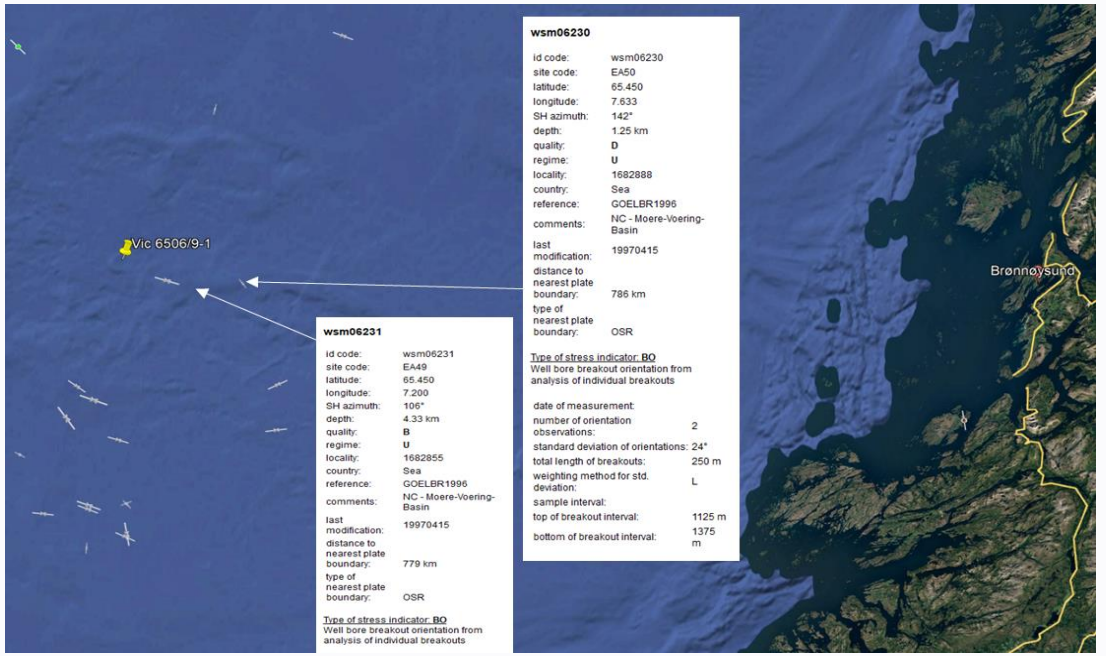


Fracturing Input to Detailed Reservoir Model

- **Fracture properties:**
  - Reasonable properties achieved when initiated in the **Tilje**, covering around 70% of the interval.
  - Effective fracture properties modelled, as a conservative approach, to not under design the fracture.

- **Fracture Direction:**
  - The maximum stress azimuth is between 100 – 145 deg at depths similar to the Victoria 6506/9-1 well.
  - In low permeability reservoirs, multiple transverse fractures in a horizontal well increases the reservoir contact and thus increases productivity.
  - Orienting the wellbore parallel to the minimum stress will increase chance of transverse fractures.

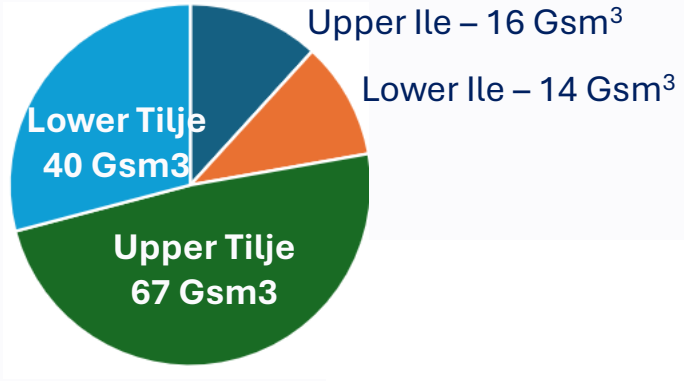
Fracture Parameter	Range from Simulations
Propped length (m)	107 – 137
Effective Half-Length (m)	**80 – 103**
Average Conductivity (md-ft)	**336 – 570**
Max Fracture Height (m)	72 – 94
Avg width at end of pumping (in)	0.4 – 0.6

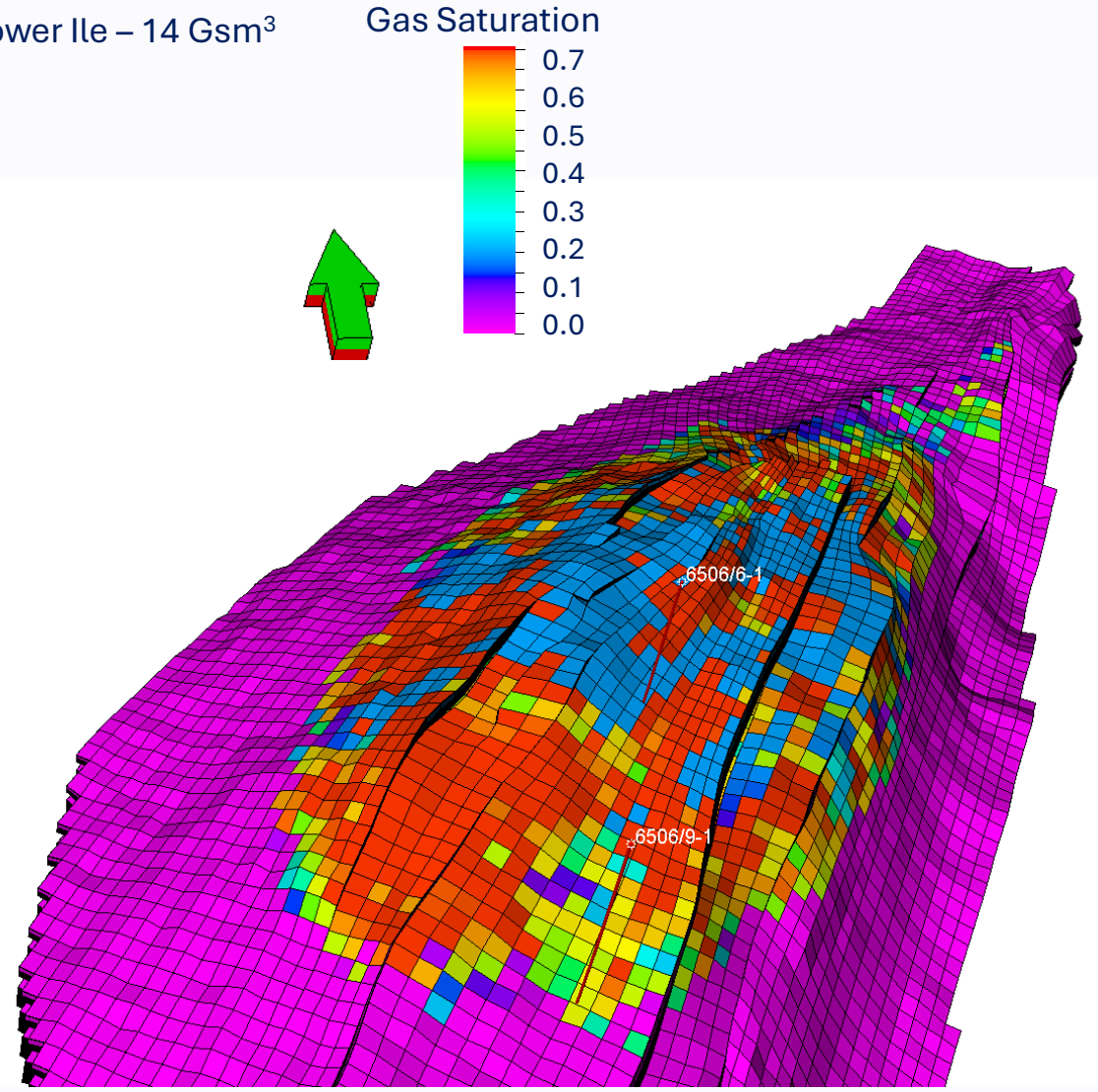


Victoria Model

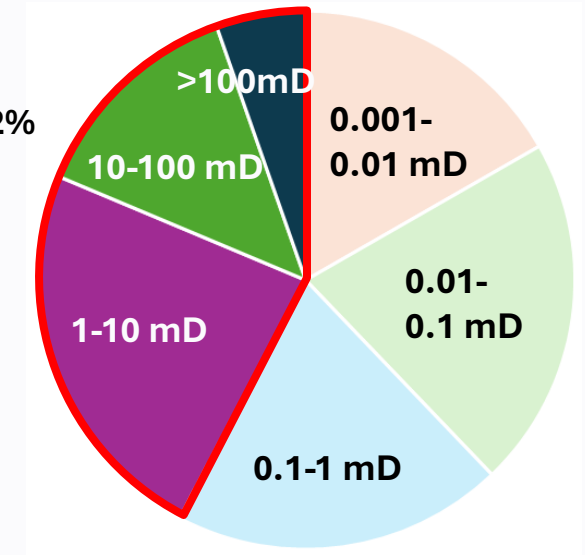
- 54 x 119 x 175 Grid
  - 766k active cells
- GIIP 137 GSm^3
  - 107 GSm^3 in Tilje formation
  - 58 GSm^3 in permeability > 1mD
  - Low vertical connectivity

GIIP by formation

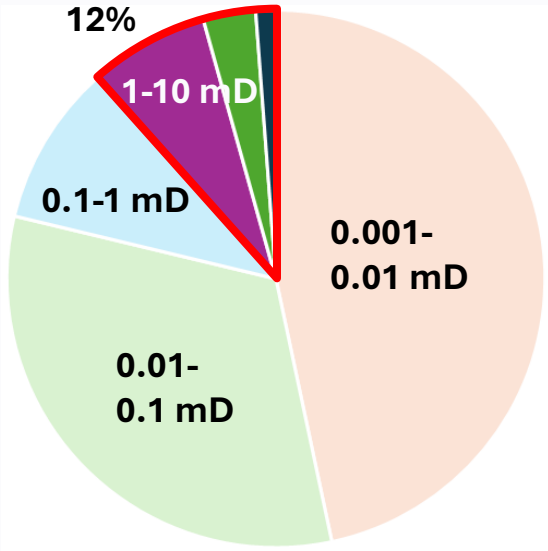




Distribution of GIIP

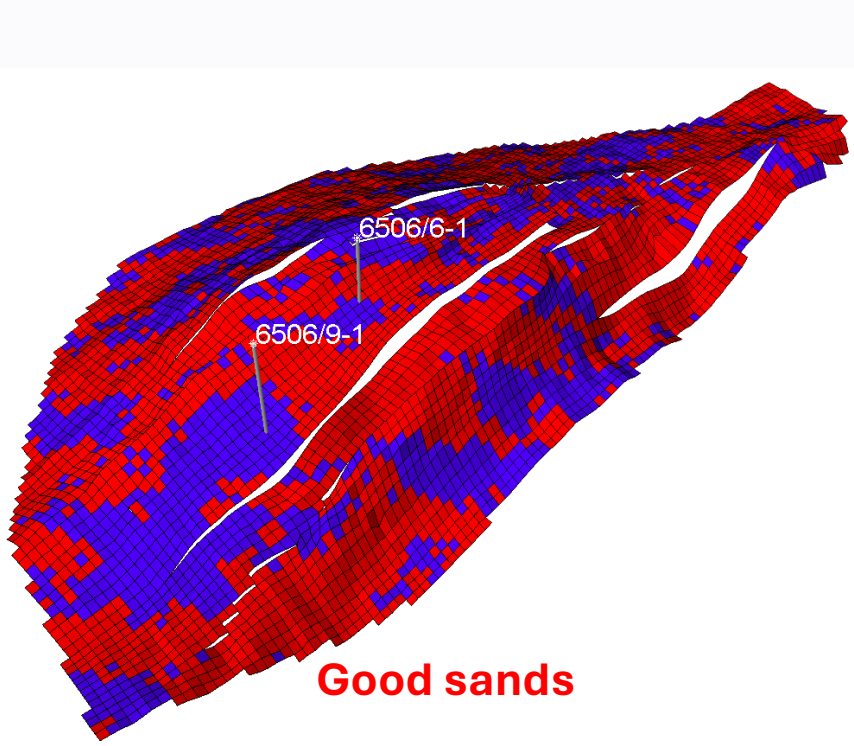


Distribution of Permeability

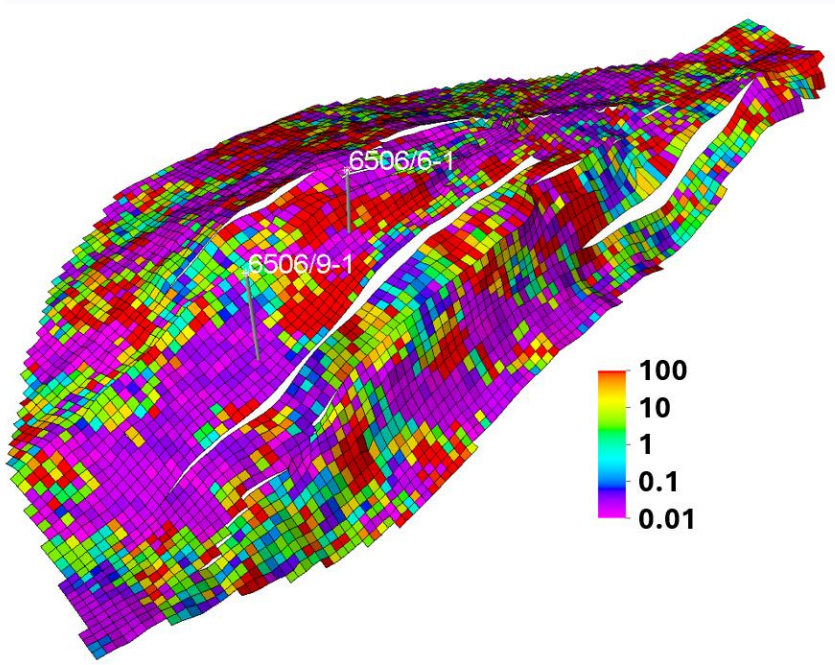


Permeability Distribution

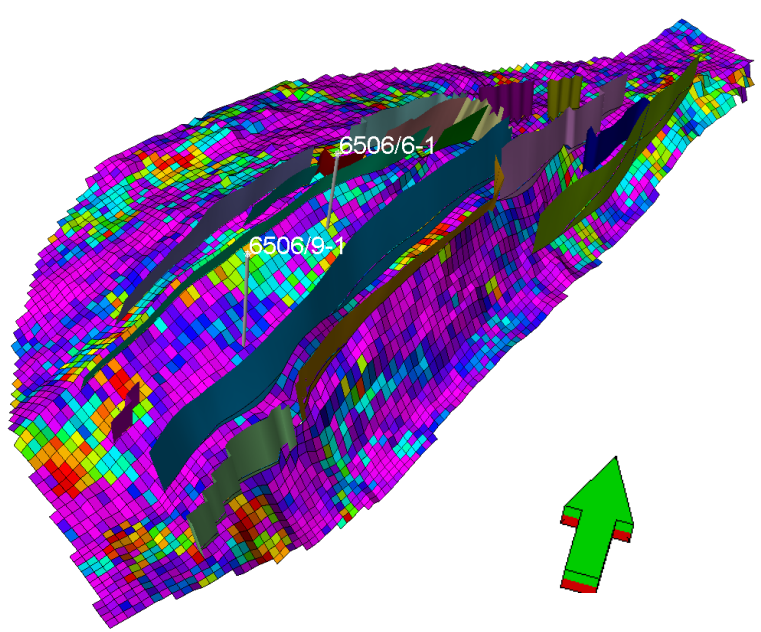
- “Good” sands have permeability greater than 1mD and KvKh of 0.1
- Background has permeability less than 0.1 mD and KvKh of 0
- Faults trend is mostly NE-SW

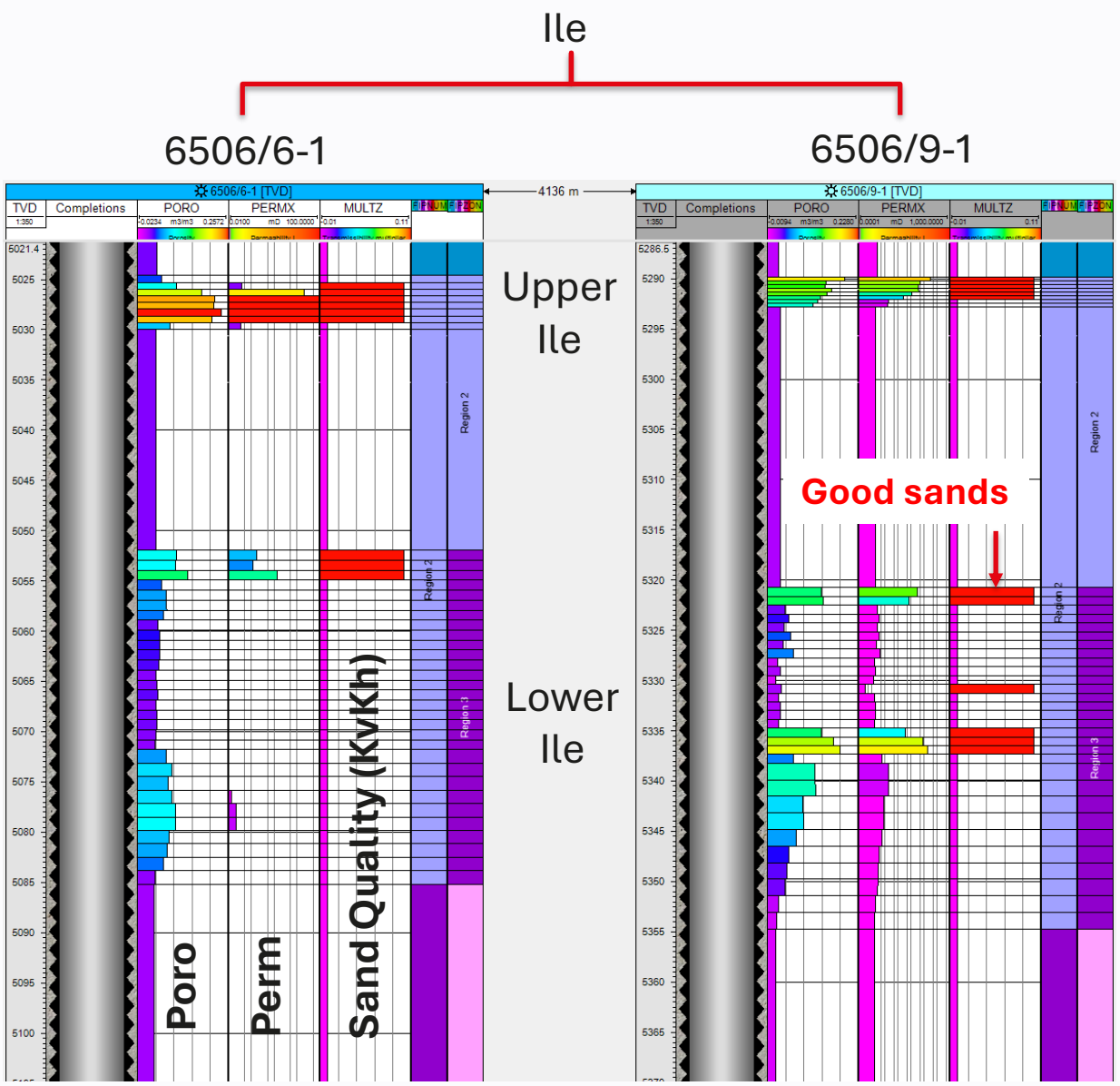


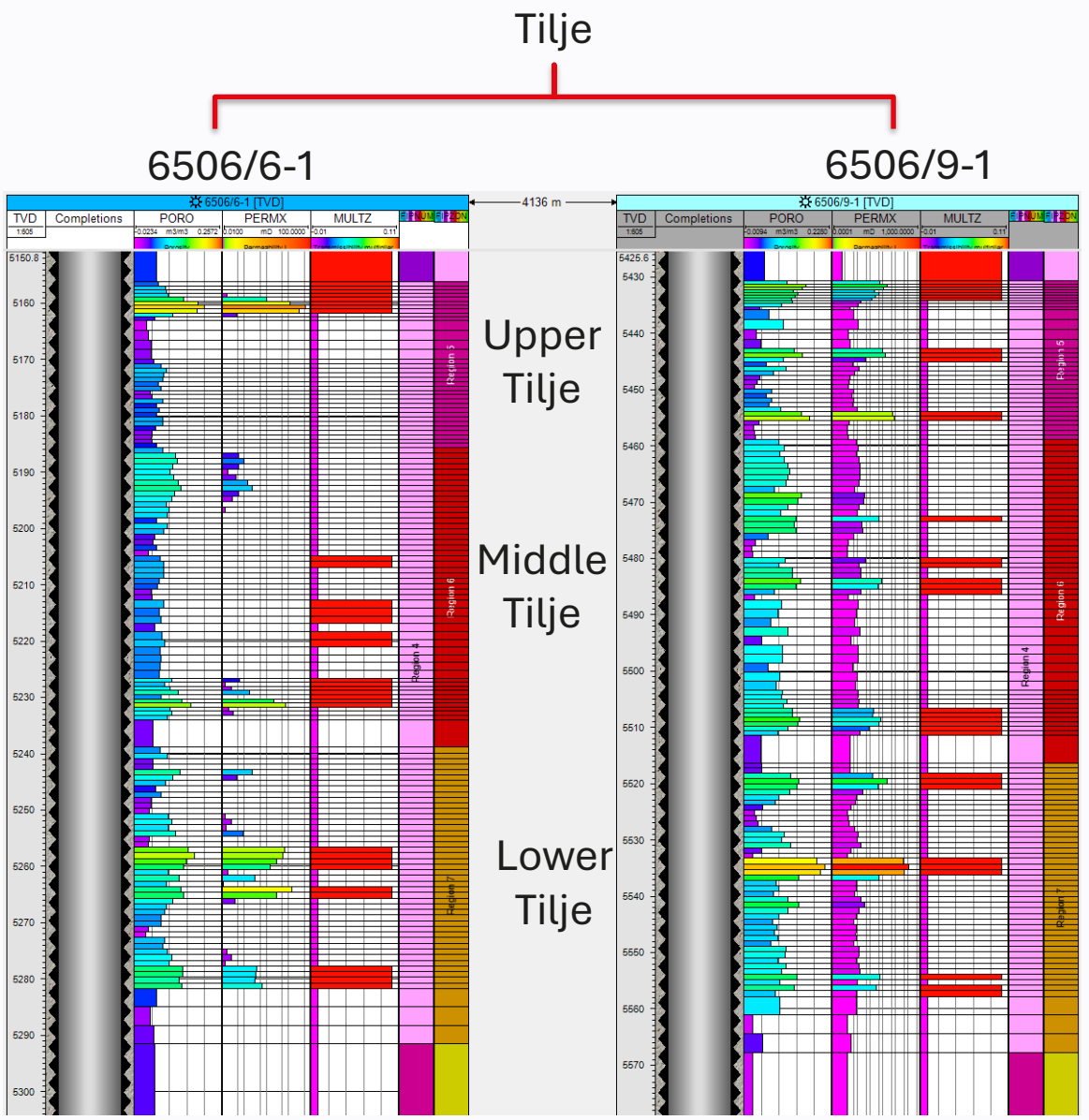
Upper Ile



Lower Ile

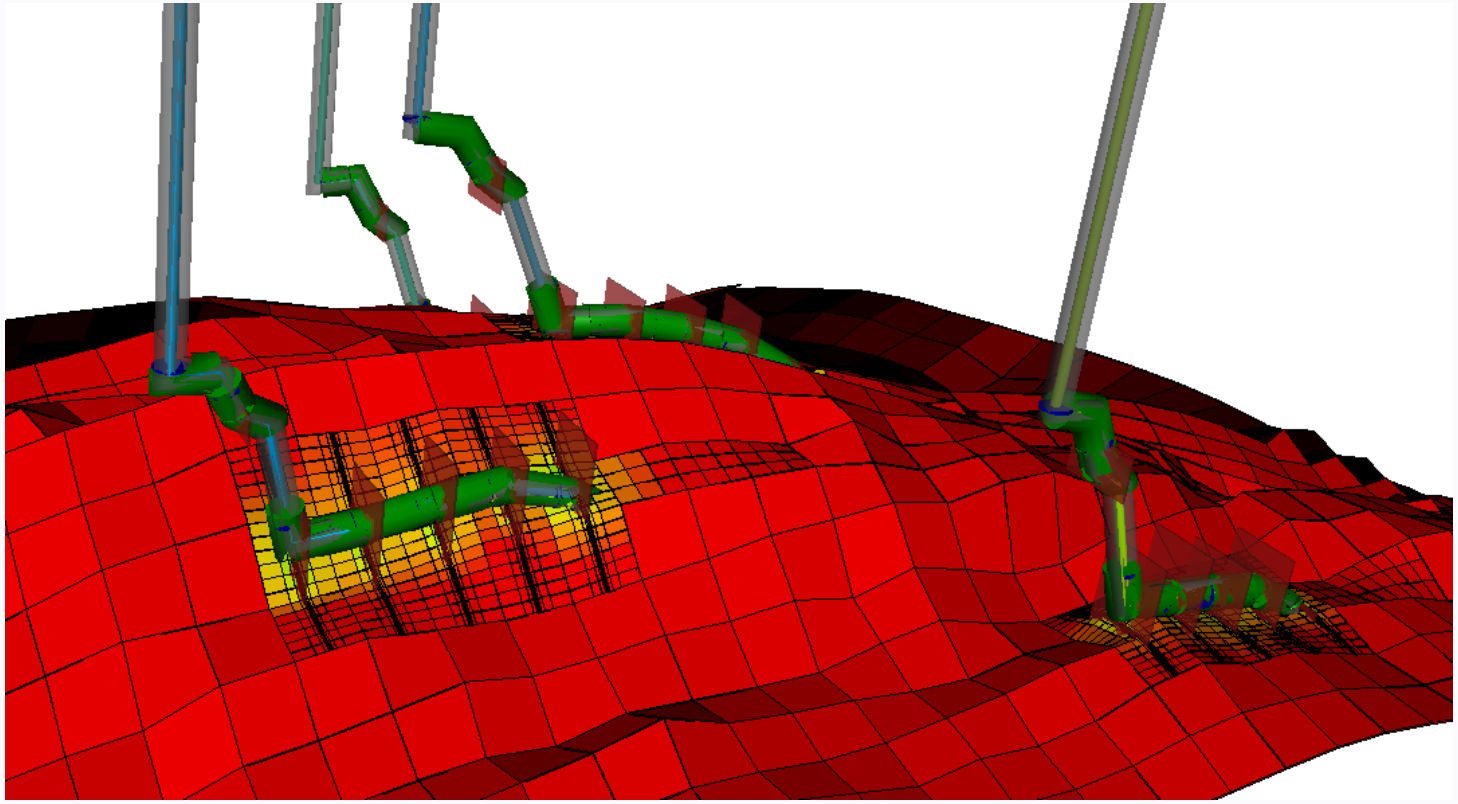



Ile
6506/6-1
6506/9-1
4136 m
Upper Ile
Lower Ile
Good sands
Poro
Perm
Sand Quality (KvKh)


Tilje
6506/6-1
6506/9-1
4136 m
Upper Tilje
Middle Tilje
Lower Tilje

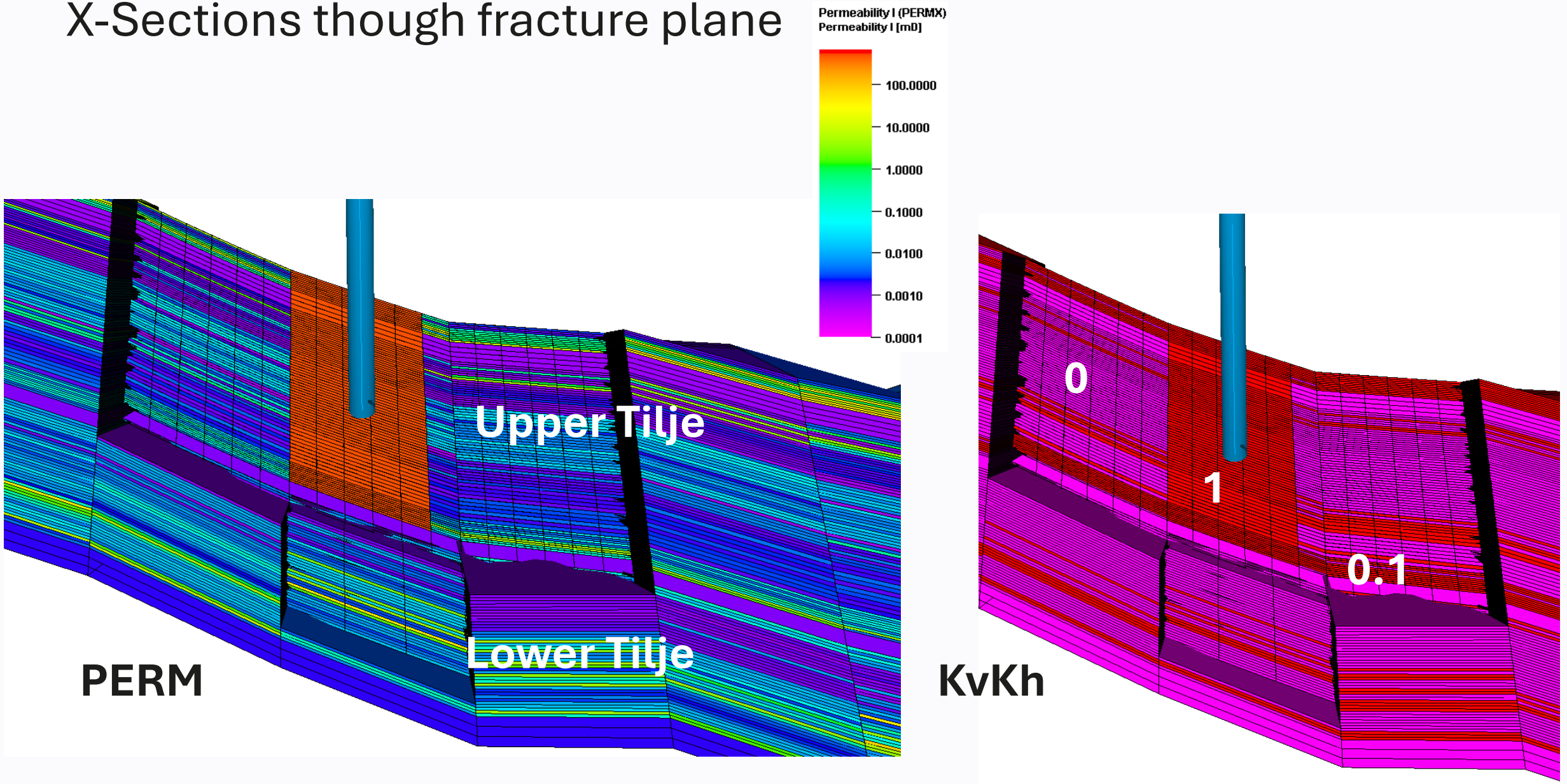
Fracture Modelling

- Fractures are modelled explicit with LGR
  - Transverse fractures along horizontal section
  - Matching conductivity, but with 1ft width and ~500mD perm
  - Host cells refined 6x13x1
  - Few numerical problems in IX

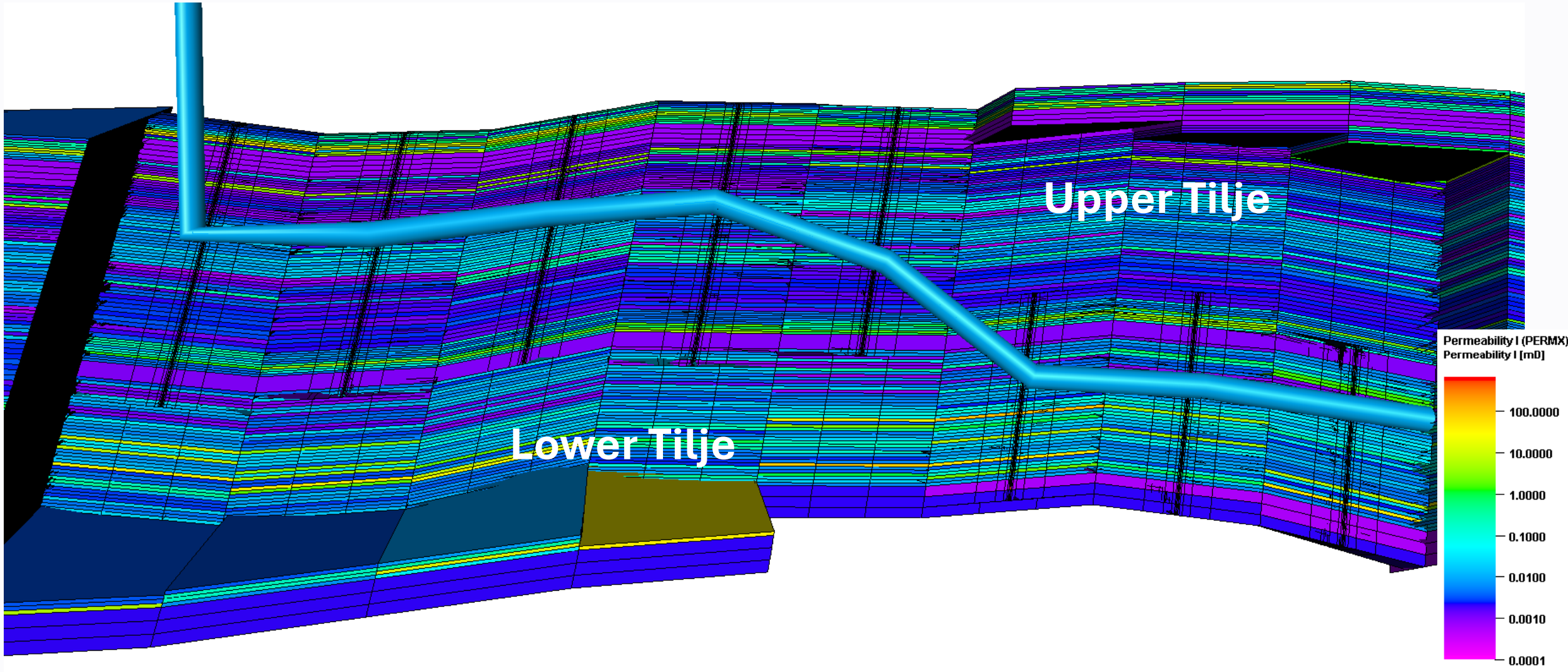


Mid Ile

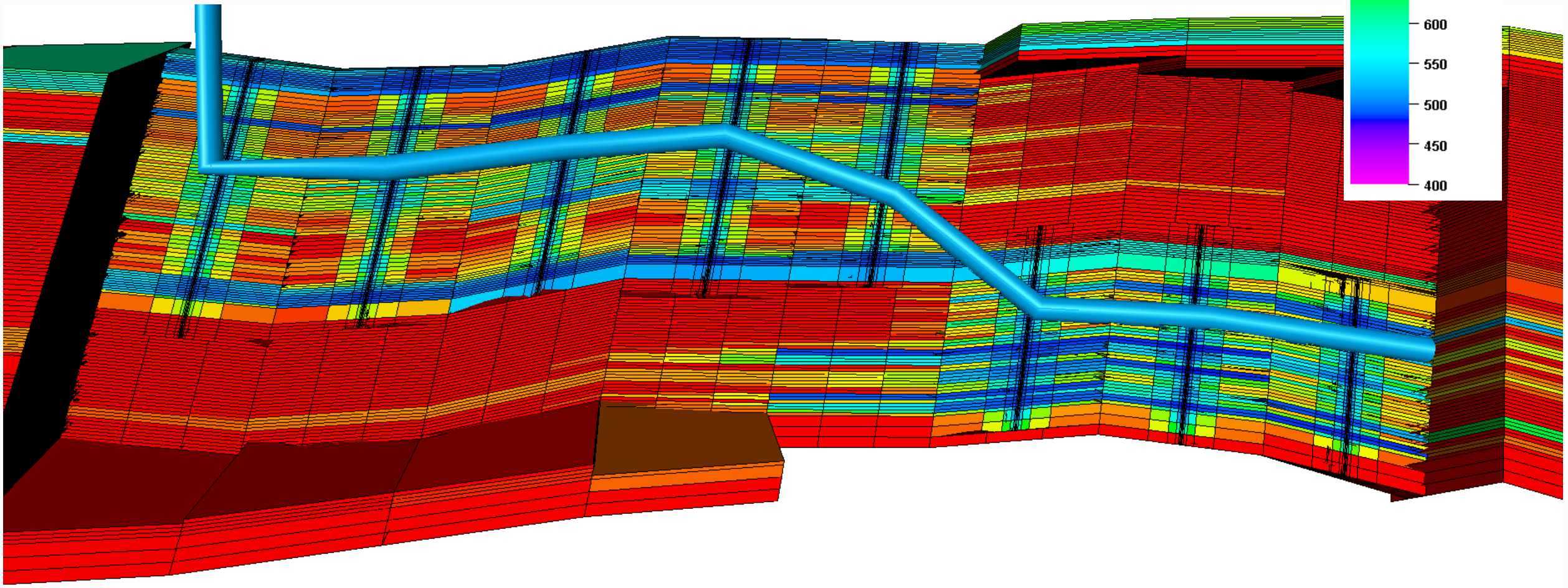
X-Sections though fracture plane



X-Sections along well path (Permeability)

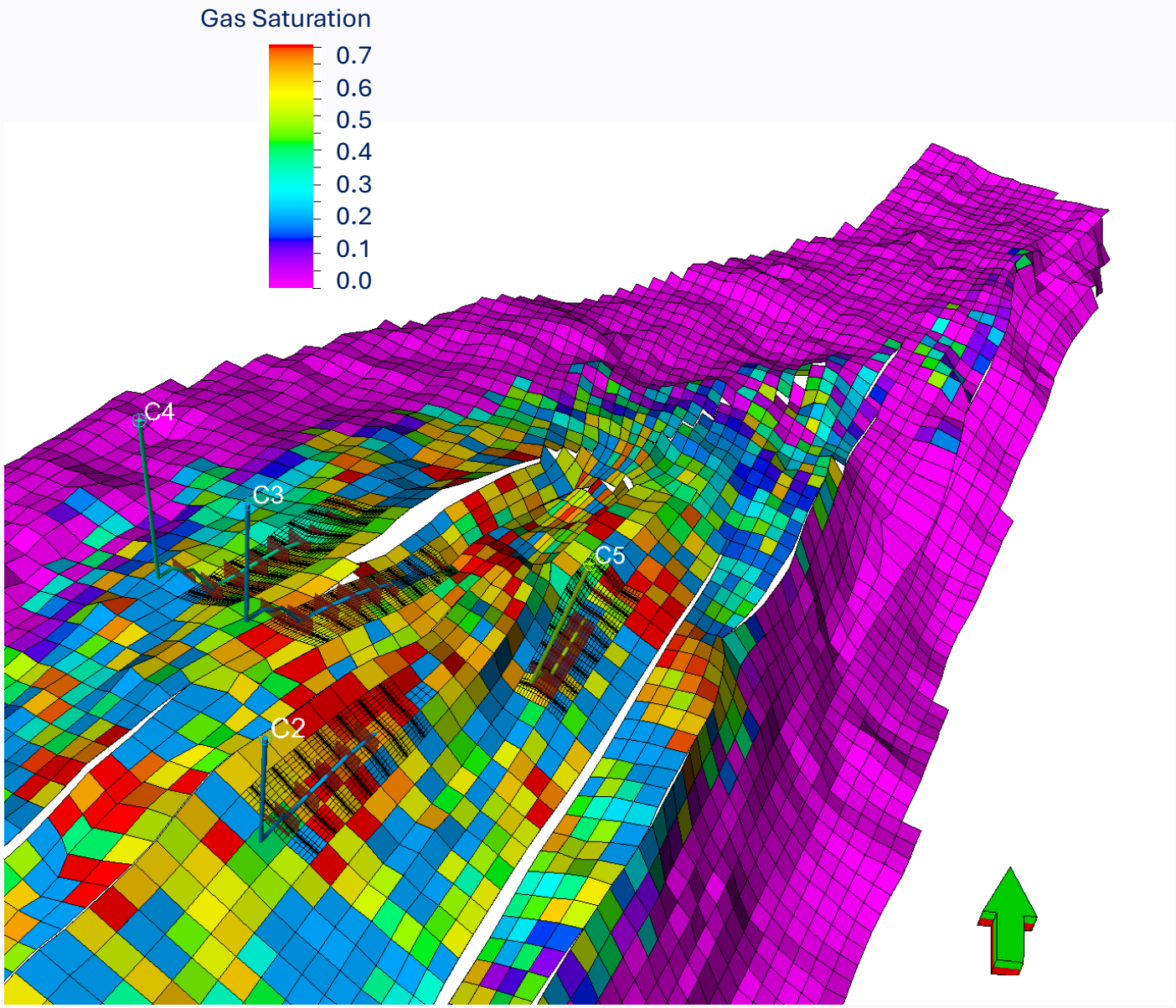


Pressure (1 year production)



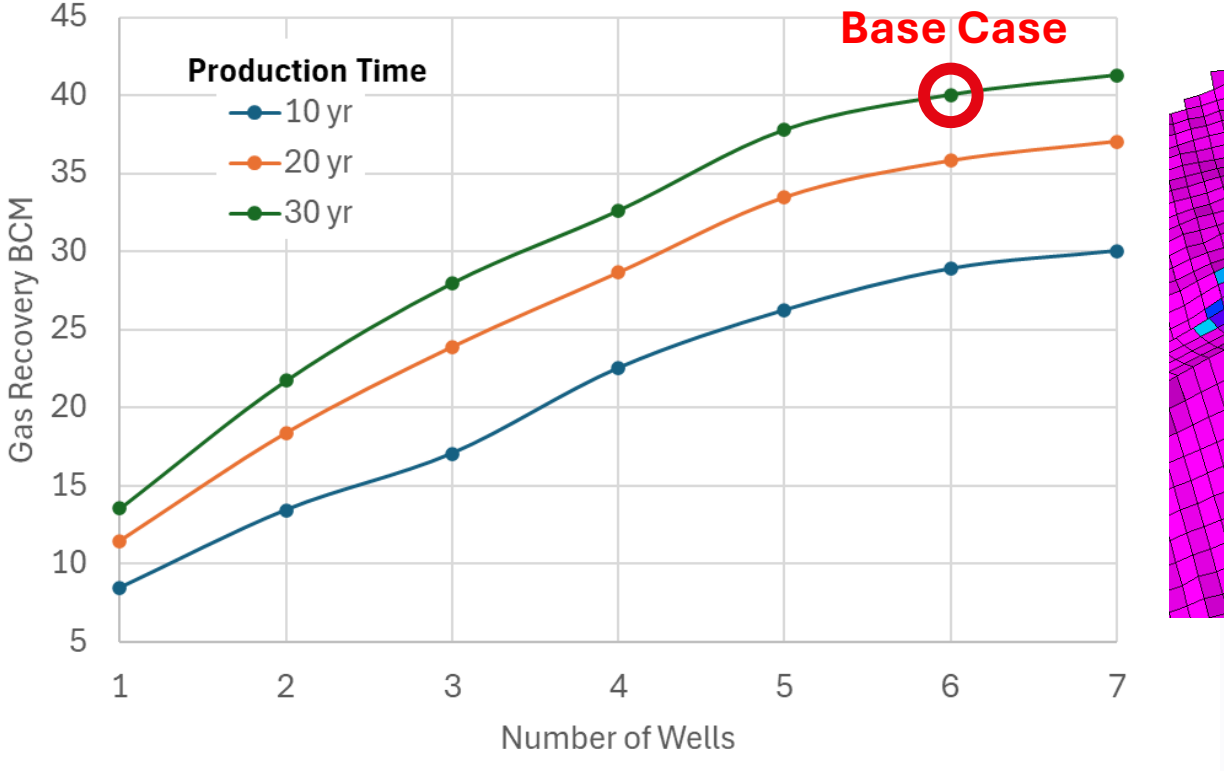
Development Scenario

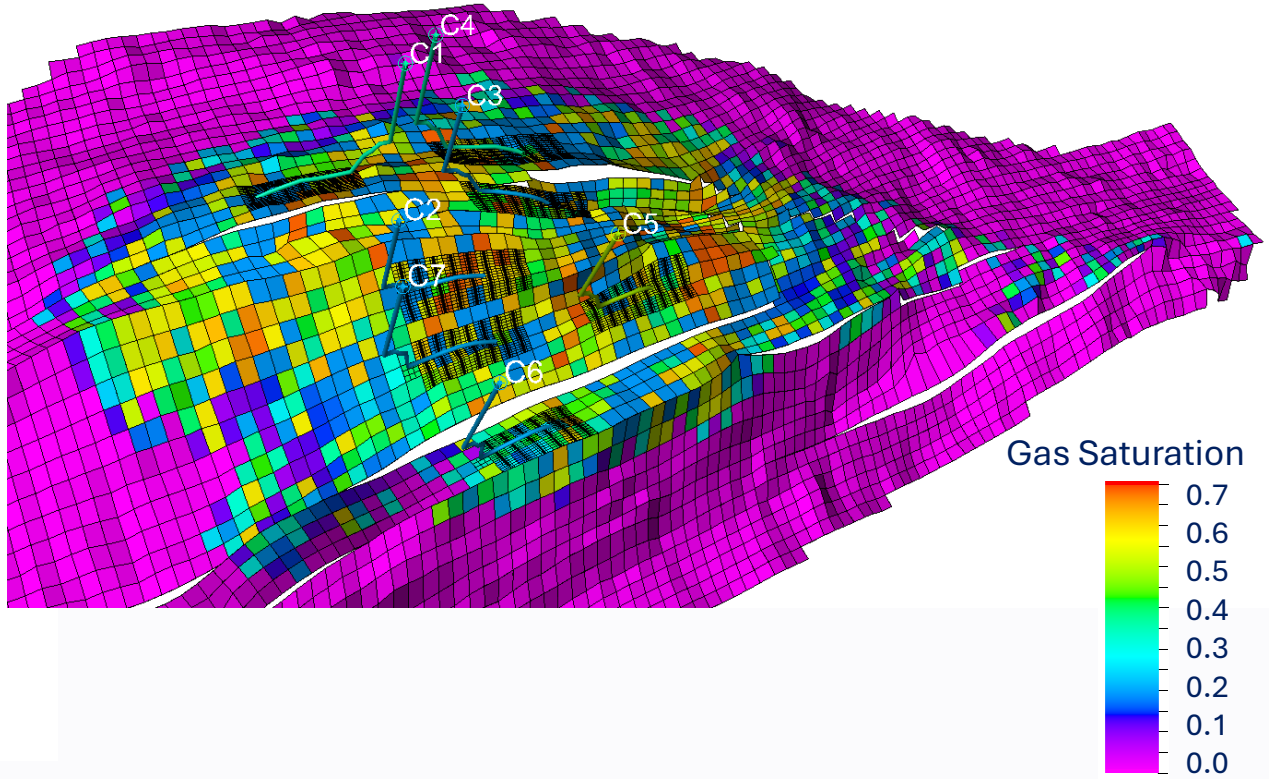
- Multi-stage fractured horizontal wells
  - About 2000m horizontal section
  - Targeting both Ile and Tilje
  - 9 transverse fractures
    - 1 Lower Ile, 4 Upper Tilje, 4 Lower Tilje
    - Openhole Upper Ile
    - Fractures explicitly modelled using LGR
    - 766k active cells (1.91M w/LGR)
- Up to 30-year production period
- 10 MSm^3/d plateau rate
- 90 bar THP constraint
- Compared to regular openhole completion



Development Scenario – Number of Wells

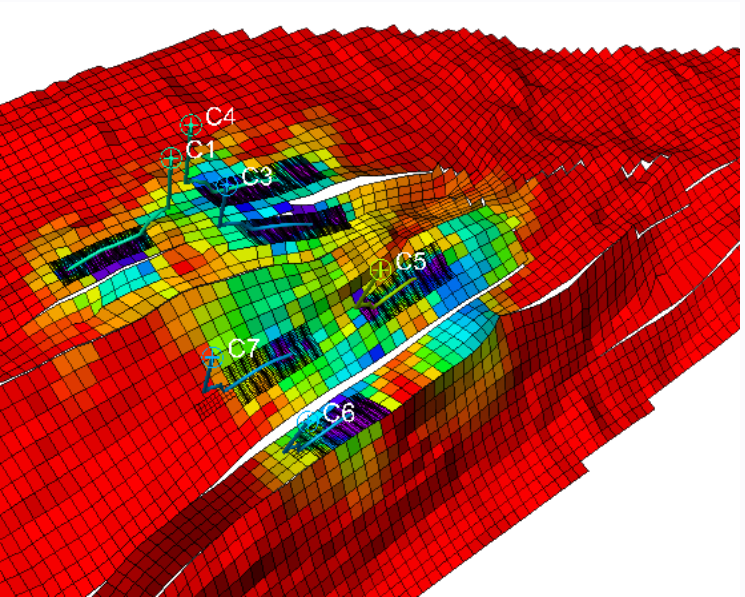
- Recovery starts to level off after 6 wells
- Still close to 5 BCM recovery after 20 years
- Selected base case is 6 well development with 30-year production period
  - Wells in all major fault blocks

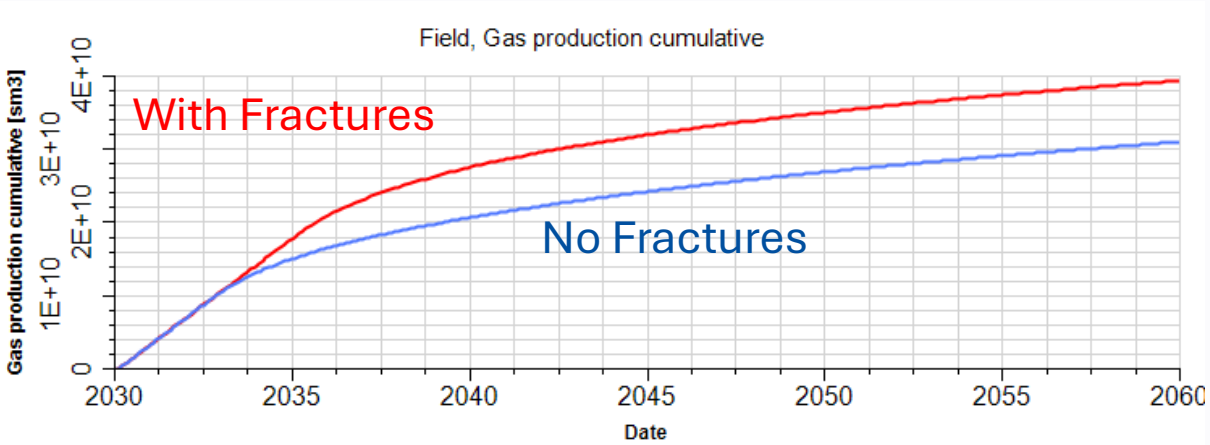


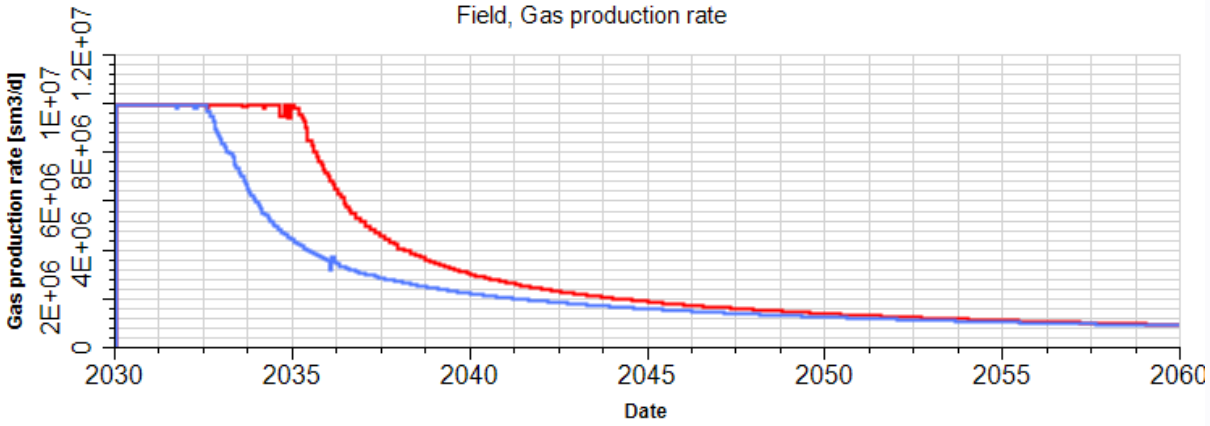


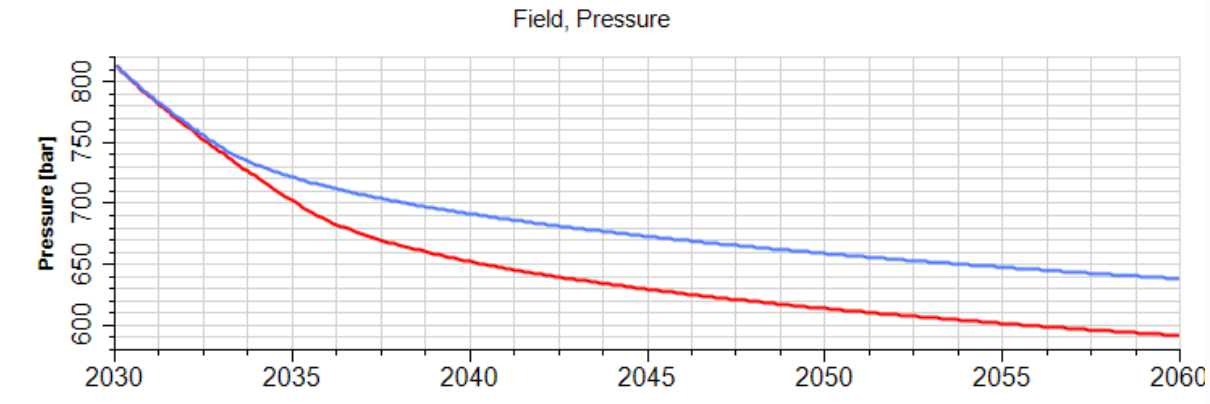
Production

- 40 BCM total production
  - Almost 5-year plateau at 10 MSm^3/d (2 year at 15 MSm^3/d)
  - Well cumulative production between 4 and 9 BCM
    - 3 MSm^3/d individual well constraint
- 31 BCM without fracturing
- Pressure depletion varies greatly vertically



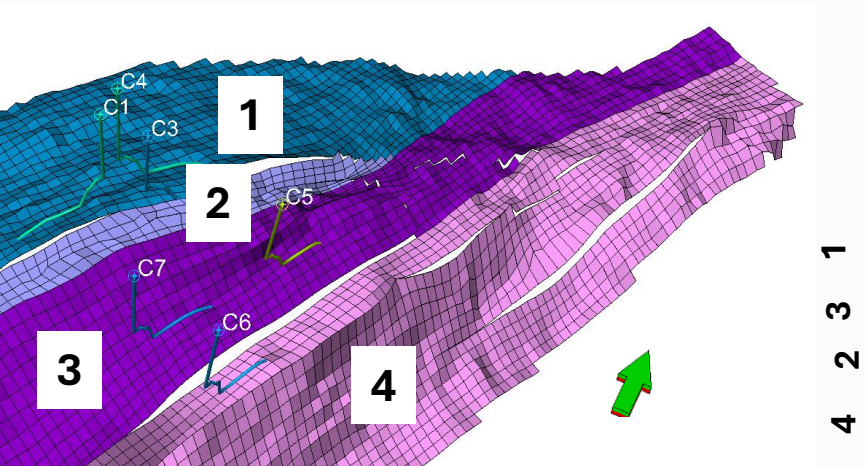




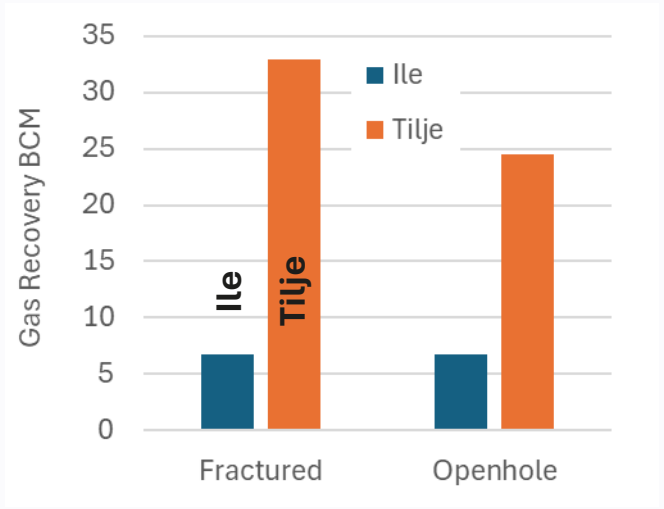


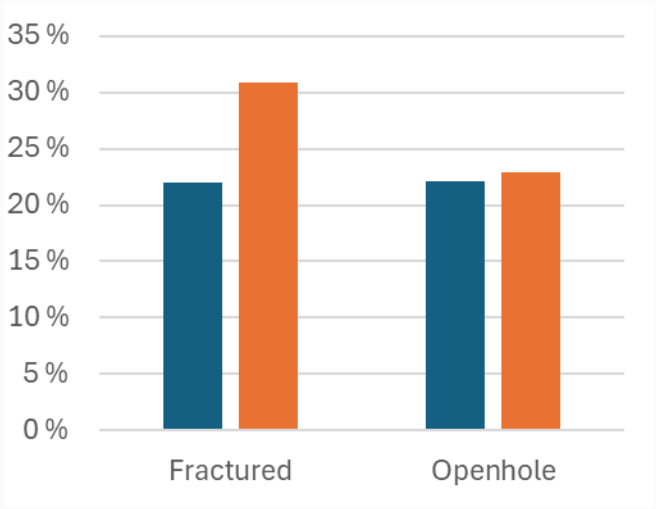
Recovery by Zone

- Ile recovery is largely the same if fractured or not
- Almost 10% improved recovery in Tilje from fracturing
- 6 wells manage to drain all regions

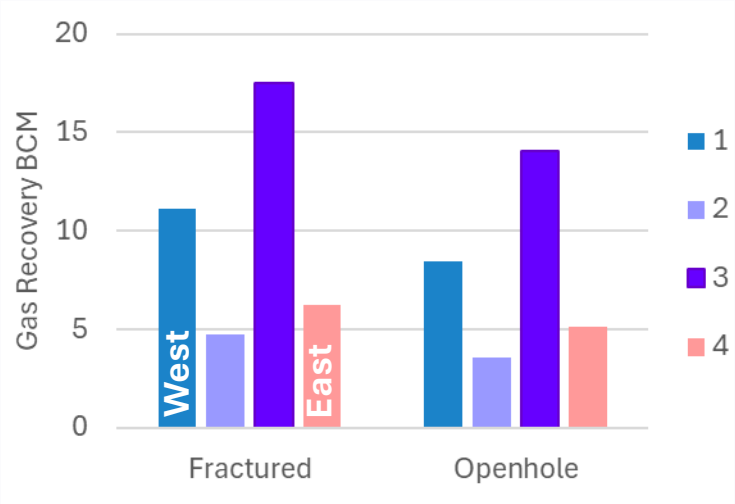


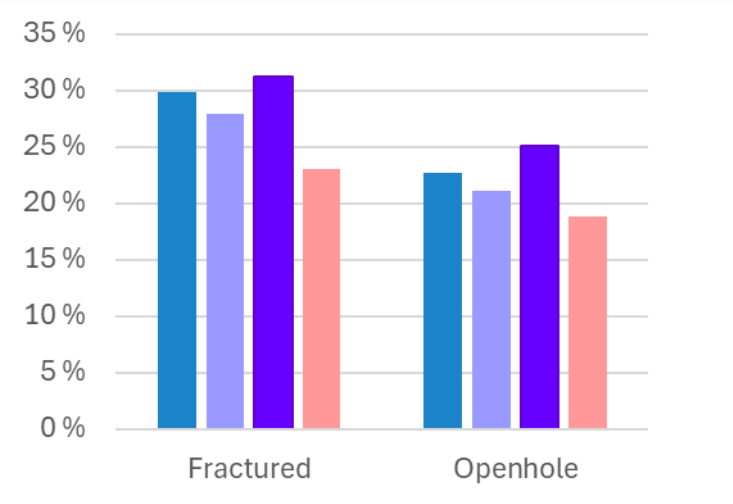
By Formation





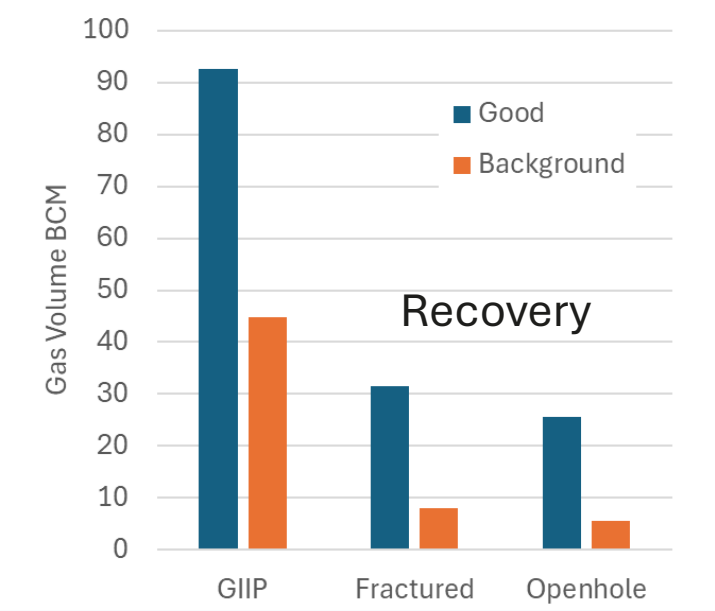
By Region

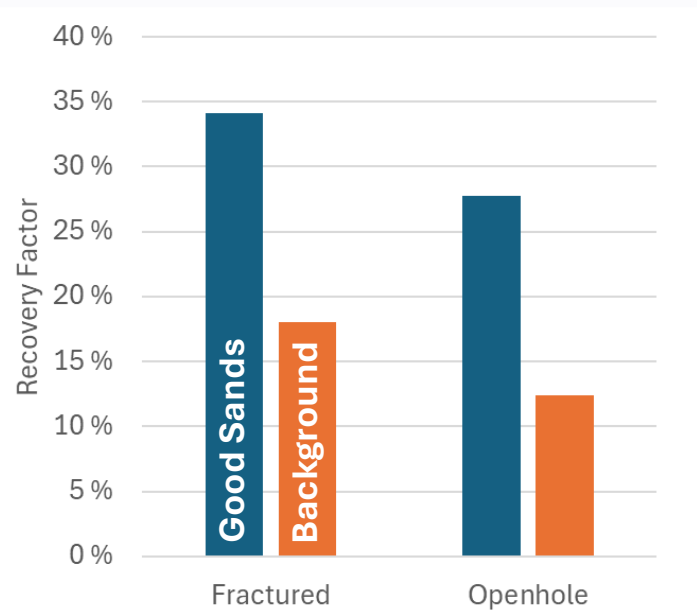




Recovery by sand type

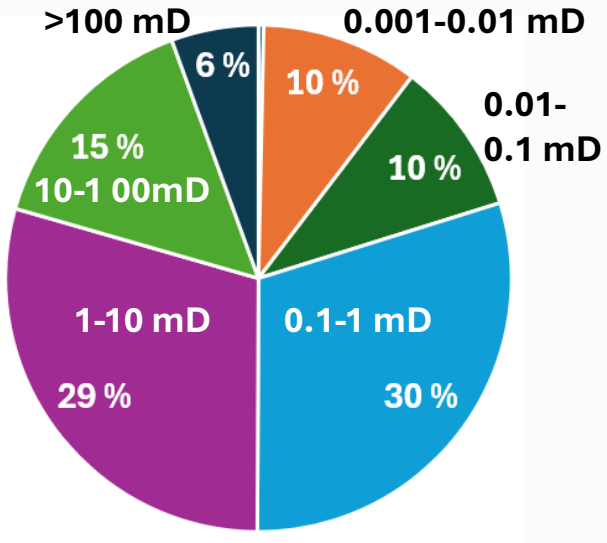
- Good sand fraction of total:
  - 20% of gross rock volume
  - 34% of pore volume
  - 67% of GIIP
  - 80% of recovery (82% openhole)



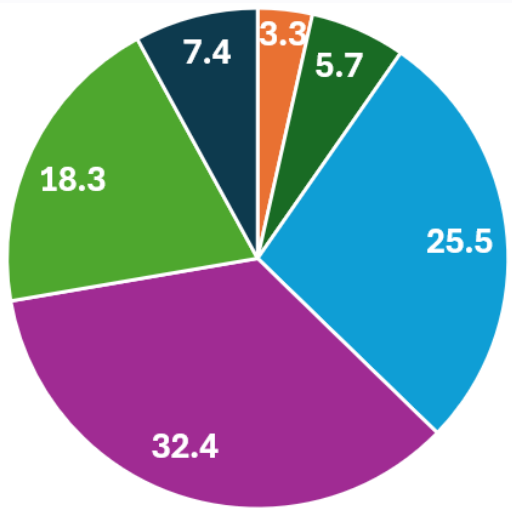


Properties of good sands by permeability classes

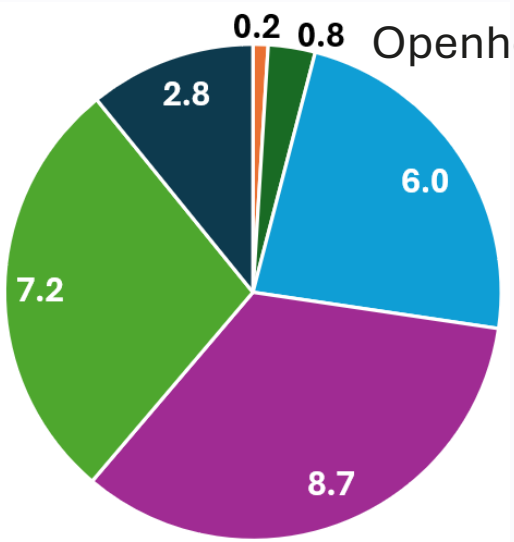
Pore volume



GIIP (BCM)

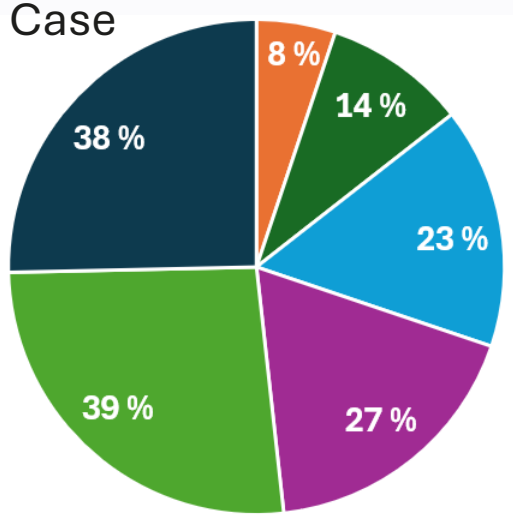


Recovery (BCM)



Recovery Factor

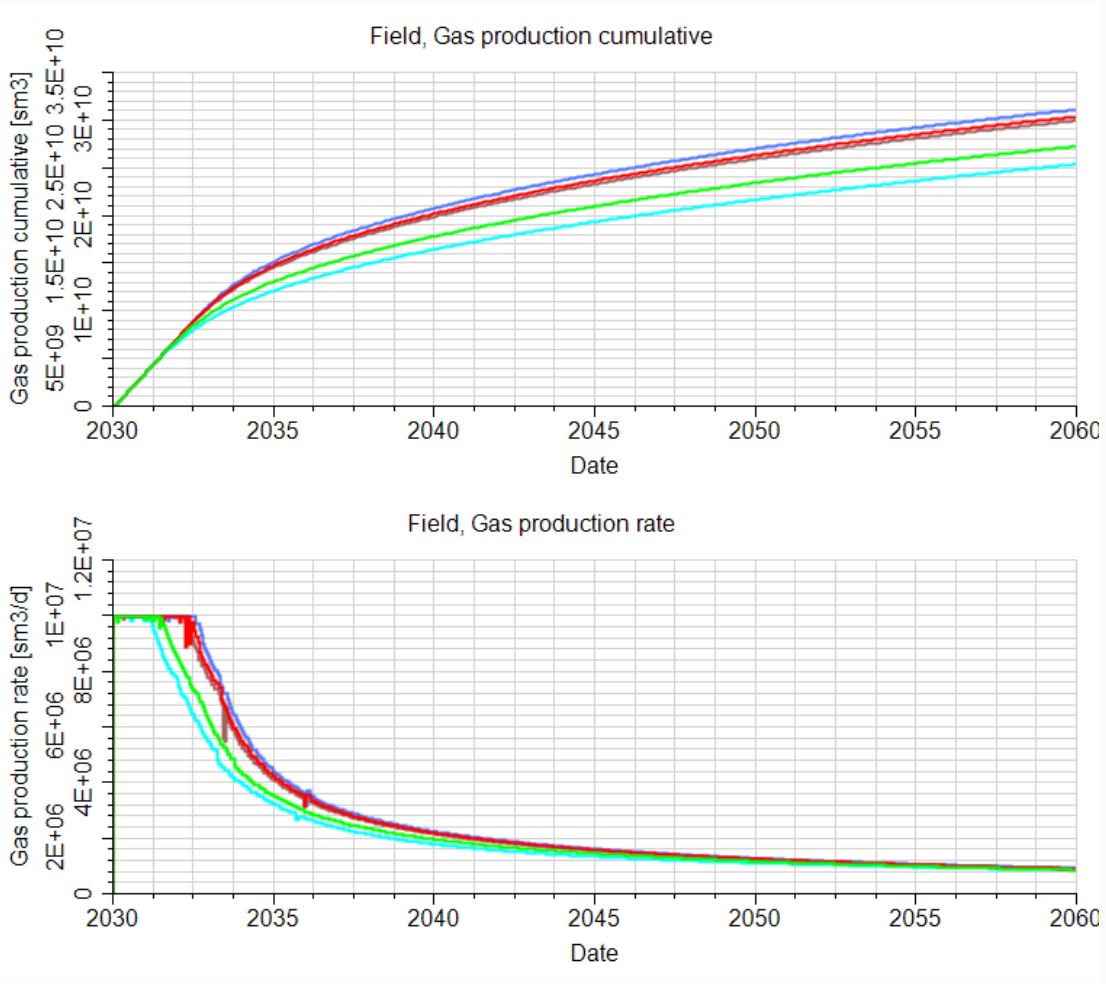
Openhole Case



Openhole completion

- How realistic is the recovery from openhole completion
  - 75% of the fractured scenario
- Sensitivity with respect to skin, non-Darcy skin and PI multiplier
- Fractured case is less sensitive
  - Less than 1 BCM reduction, 1-year shorter plateau

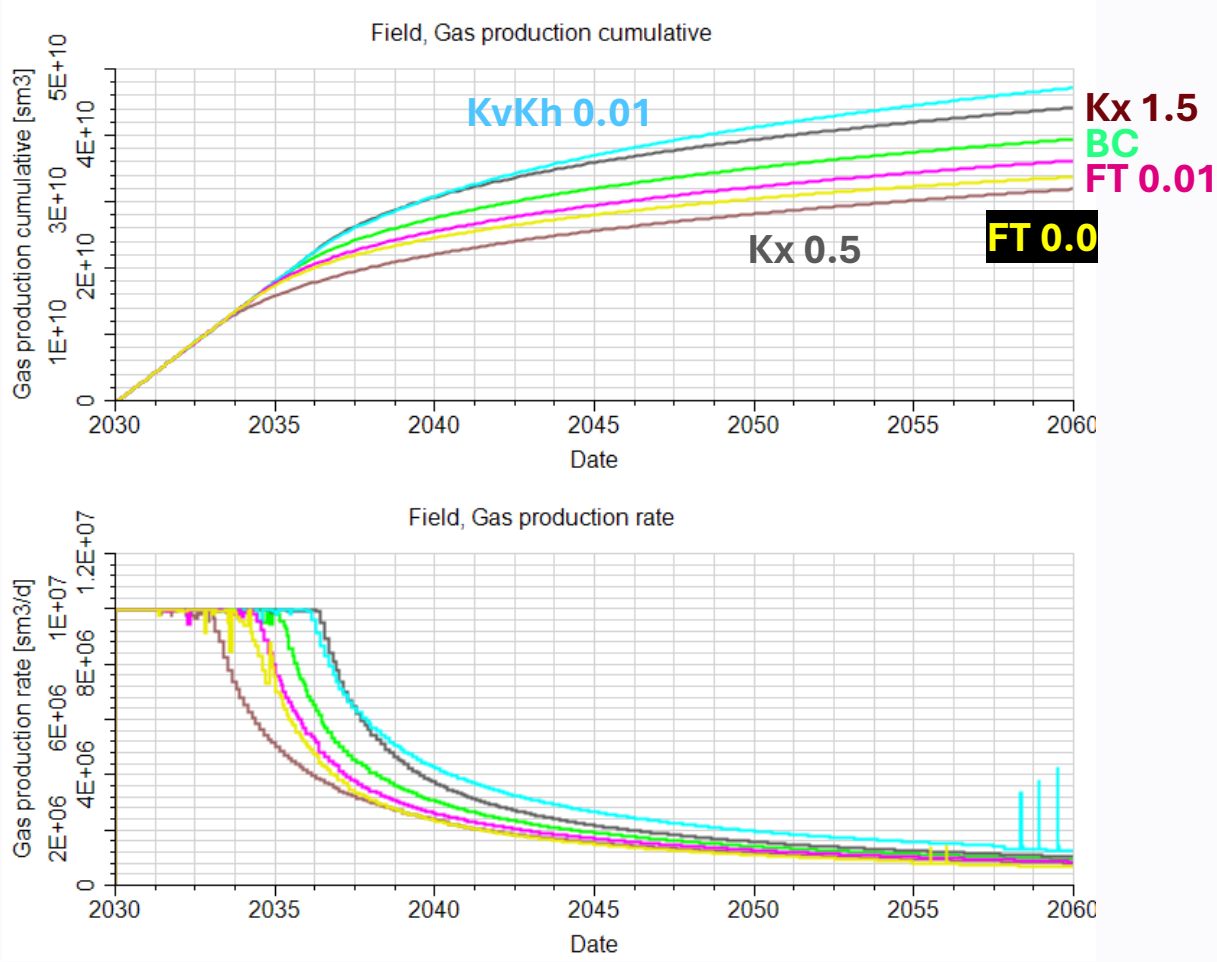
Sensitivity	Recovery (BCM)
Base case	31
Skin 10	30
PI multiplier 0.5	30.5
PI multiplier 0.1	27
Non-Darcy skin (WDFAC) 3E-5 d/sm^3	25



Geological Uncertainty

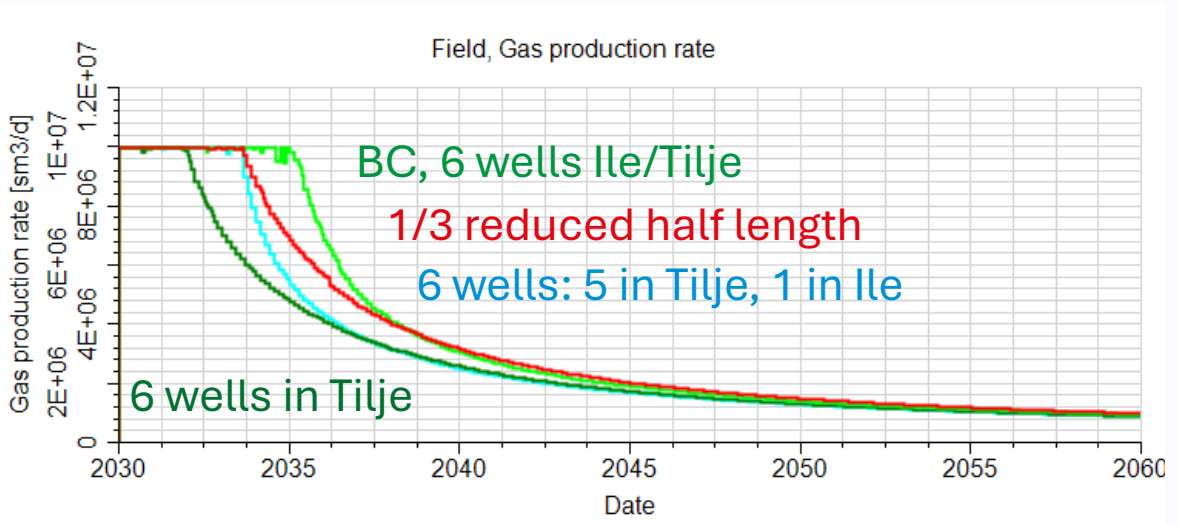
- Distribution and connectivity of good sands is outside the scope of this study
  - Ensemble based modelling should be used
- Have looked at some sensitivities
  - Vertical communication, uniform KvKh of 0.01
  - Fault transmissibility 0.5 (BC), 0.01 and 0
  - Permeability multiplier in good sands (1.5 and 0.5)

Sensetivity	Recovery (BCM)
Base case, fault T 0.5, KvKh 0.1/0.0	40
Fault transmissibility 0.01	36
Fault transmissibility 0	34
KvKh 0.01 everywhere	47
KvKh 0.01 in good sands, 0 otherwise	39
Permeability multiplier 1.5	44
Permeability multiplier 0.5	32



Well Configuration

- What is effect of shorter wells and only completing in Tilje
  - About 1500m reservoir section
  - 2 fewer fractures per well, 7 rather than 9
- Fractured wells in Tilje can possibly be combined with separate well in Ile
  - Single well near crest with 600m horizontal section
  - 5 fractured wells in Tilje and 1 horizontal well in Ile
- Reduce fracture half length by 1/3

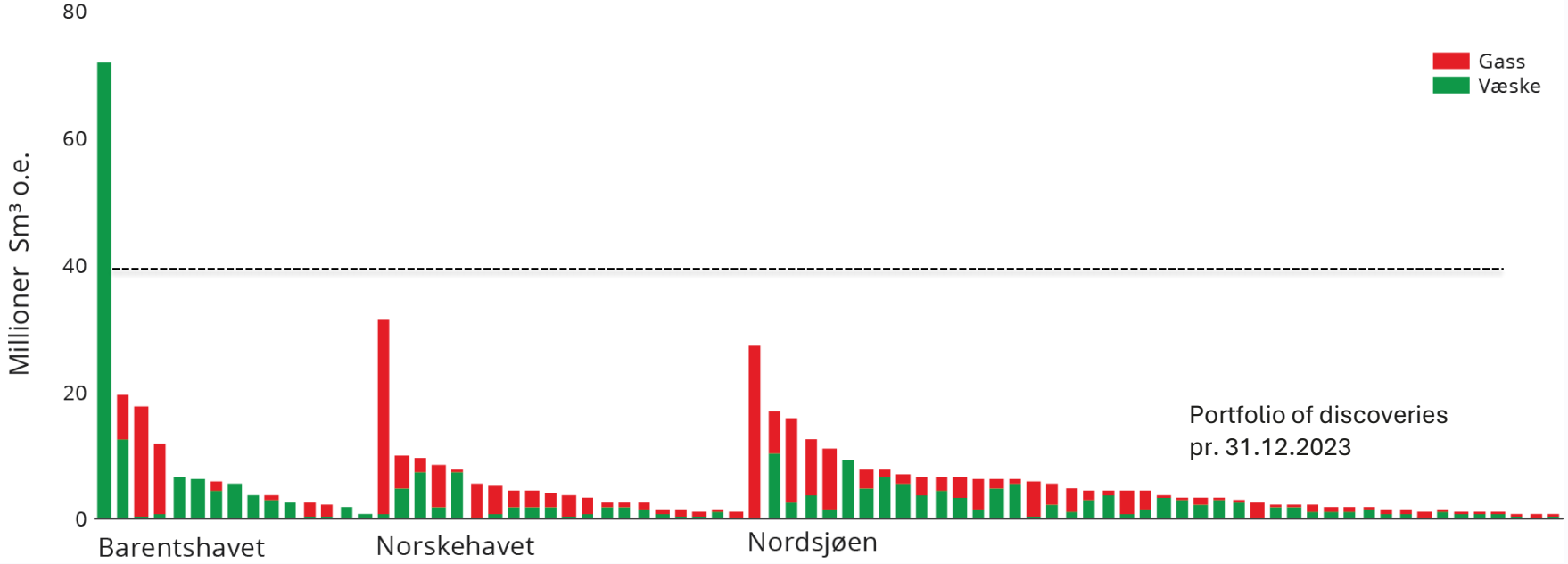


Sensetivity	Recovery (BCM)
Base case, Ile-Tijle	40
Shorter 1500m wells, Tilje only	32
Single 600m horizontal well in Ile	3.4
5 fractured wells in Tilje, 1 well in Ile	34
1/3 reduced fracture half length	38

Recovery by zone	Ile	Tilje
Base case, Ile-Tijle	6.7	33.0
Shorter 1500m wells, Tilje only	0.3	31.6
Single 600m horizontal well in Ile	3.4	0
5 fractured wells in Tilje, 1 well in Ile	3.7	30.2

Conclusions

- Multistage fracturing is feasible in HPHT conditions like Victoria
  - Significant advancements in both equipment and fracturing fluids
  - Detailed geomechanics and fracture modelling indicate that most of Tilje can be covered
- 40 BCM production with 6 wells appear to be a feasible development scenario
  - Multistage fracturing give substantial benefit over regular openhole completion
  - This would be among the largest remaining resources on NCS
- Is there interest in a dedicated FORCE network group on tight reservoirs? We can help…



Thank you

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