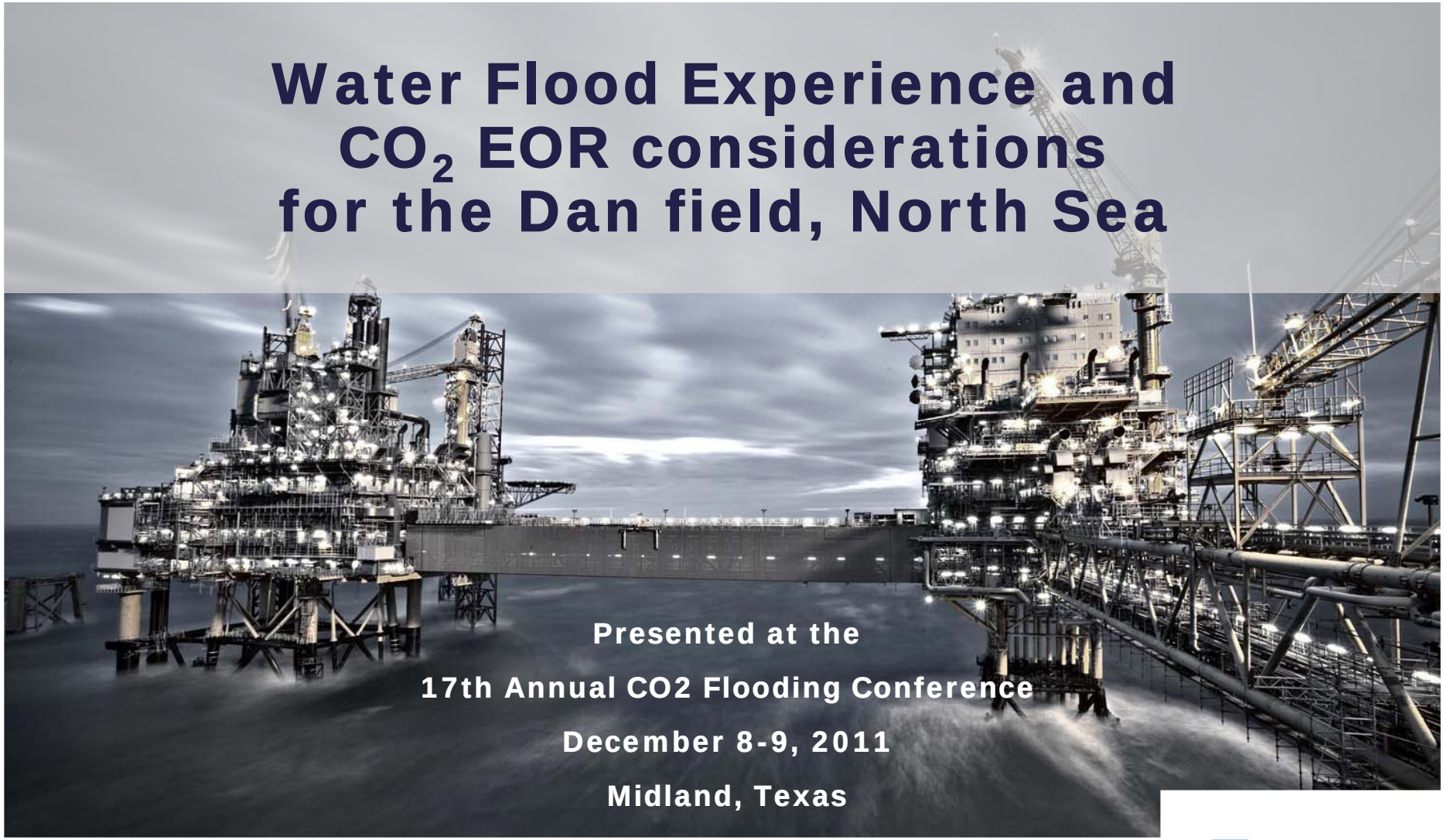
Pepijn Timmermans, MaerskOil

Water Flood Experience and CO_2 EOR considerations for the Dan field, North Sea



Presented at the

17th Annual CO2 Flooding Conference

December 8-9, 2011

Midland, Texas

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Waterflood Experience and CO_2 EOR Considerations for Dan Field, North Sea

- CCS/EOR Project Outline
- Dan Field
  - Geology & Rock
  - Development
  - Waterflood Experience
- CO_2/EOR
  - Sector Modelling
  - Laboratory Experiments
  - Possible Future CO_2 Injection Test

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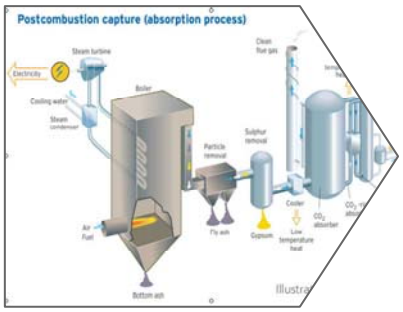
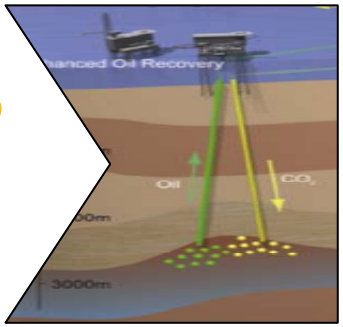
EOR-CCS Value Chain

Capture



Transport

EOR and Storage



- Cost/Risk
  - Capture and transportation cost/risk → Emitter
  - Storage cost/risk → Storage Provider
- Reward
  - CO2 Credits & Funding (during demo phase) → Emitter
  - EOR → Storage Provider

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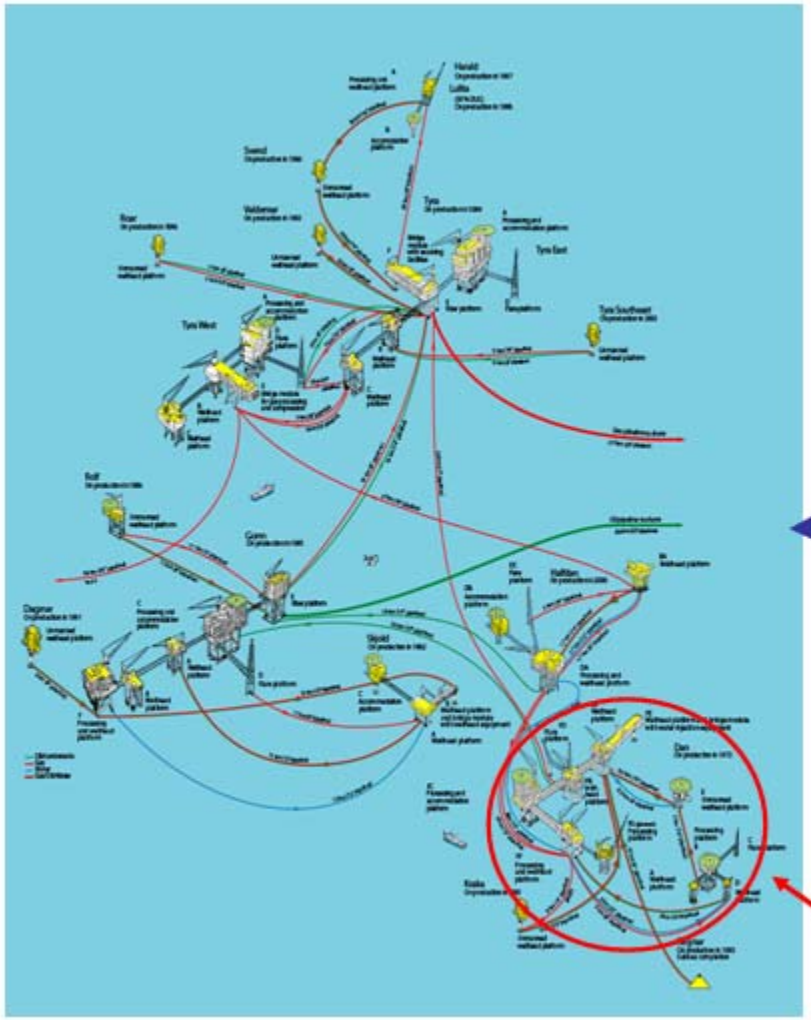
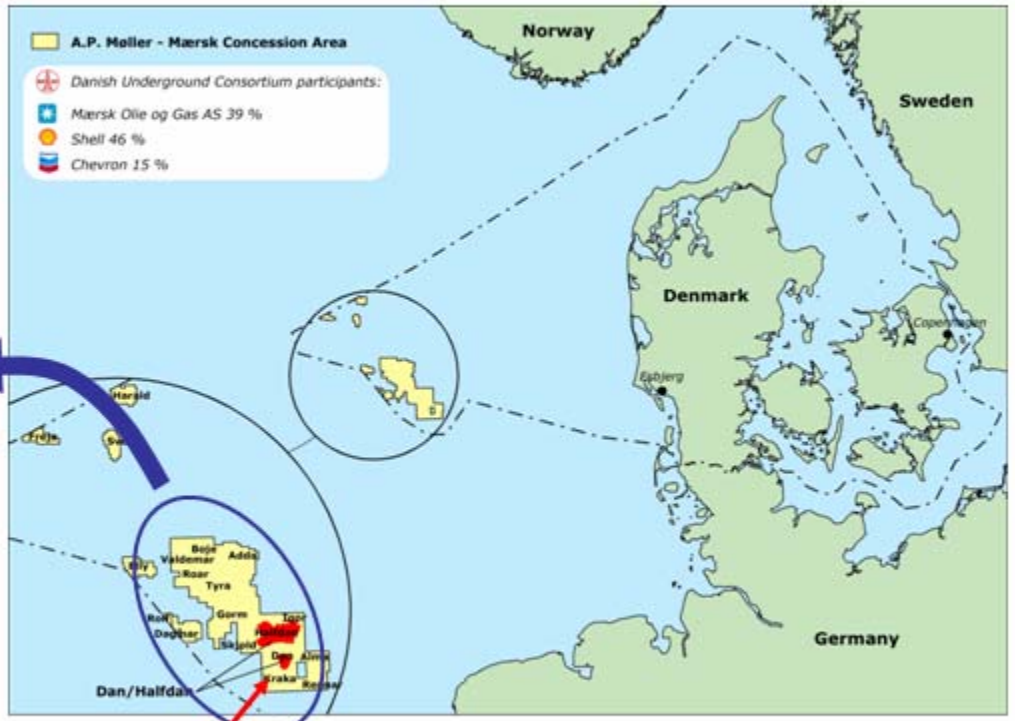
Dan field, one of several in Danish North Sea



facilities

concession



Dan field

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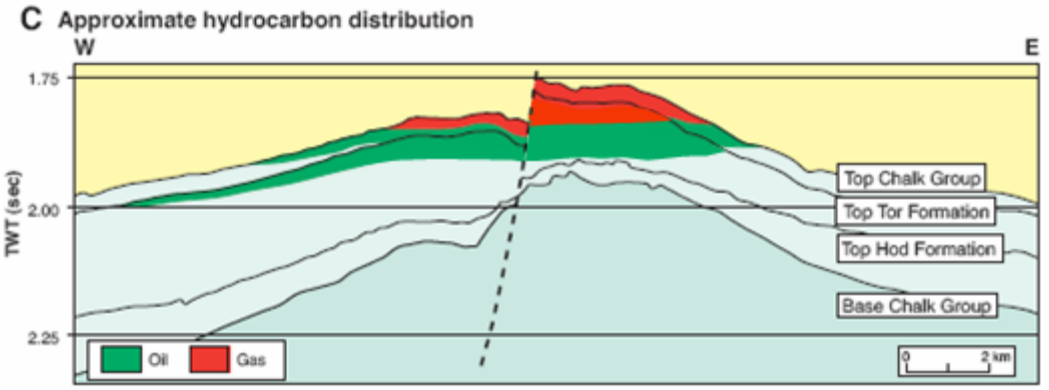
Chalk Rock

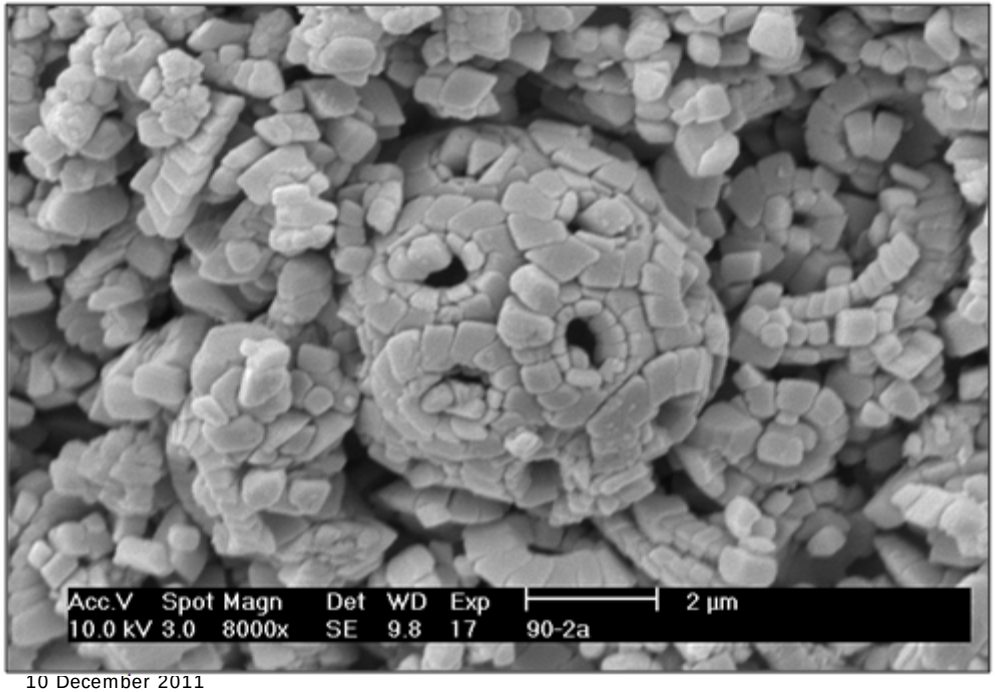
- High porosity (25-35%)
- Low Permeability (2 mD)

- Some natural fracturing
  - Substantial small scale fractures but limited large scale fractures & faults

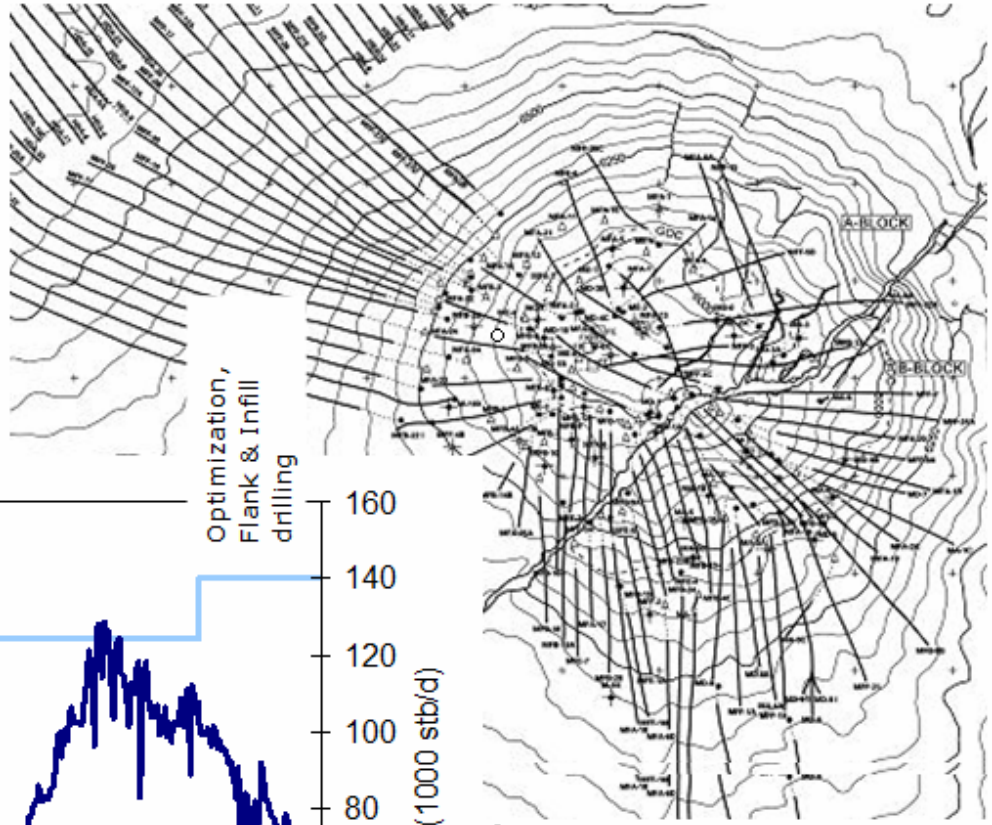
Cross section across Dan field

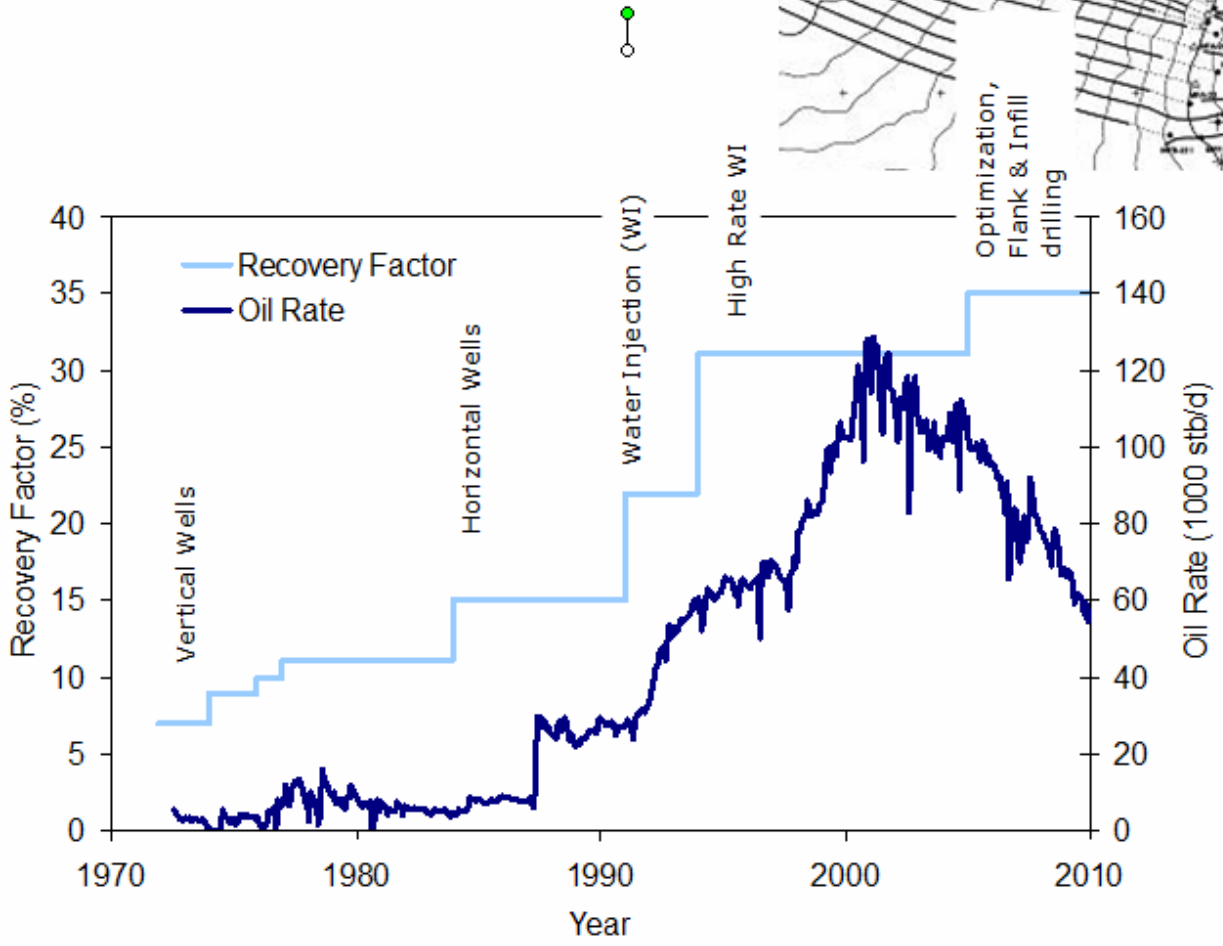


Microscopic Photo of Chalk

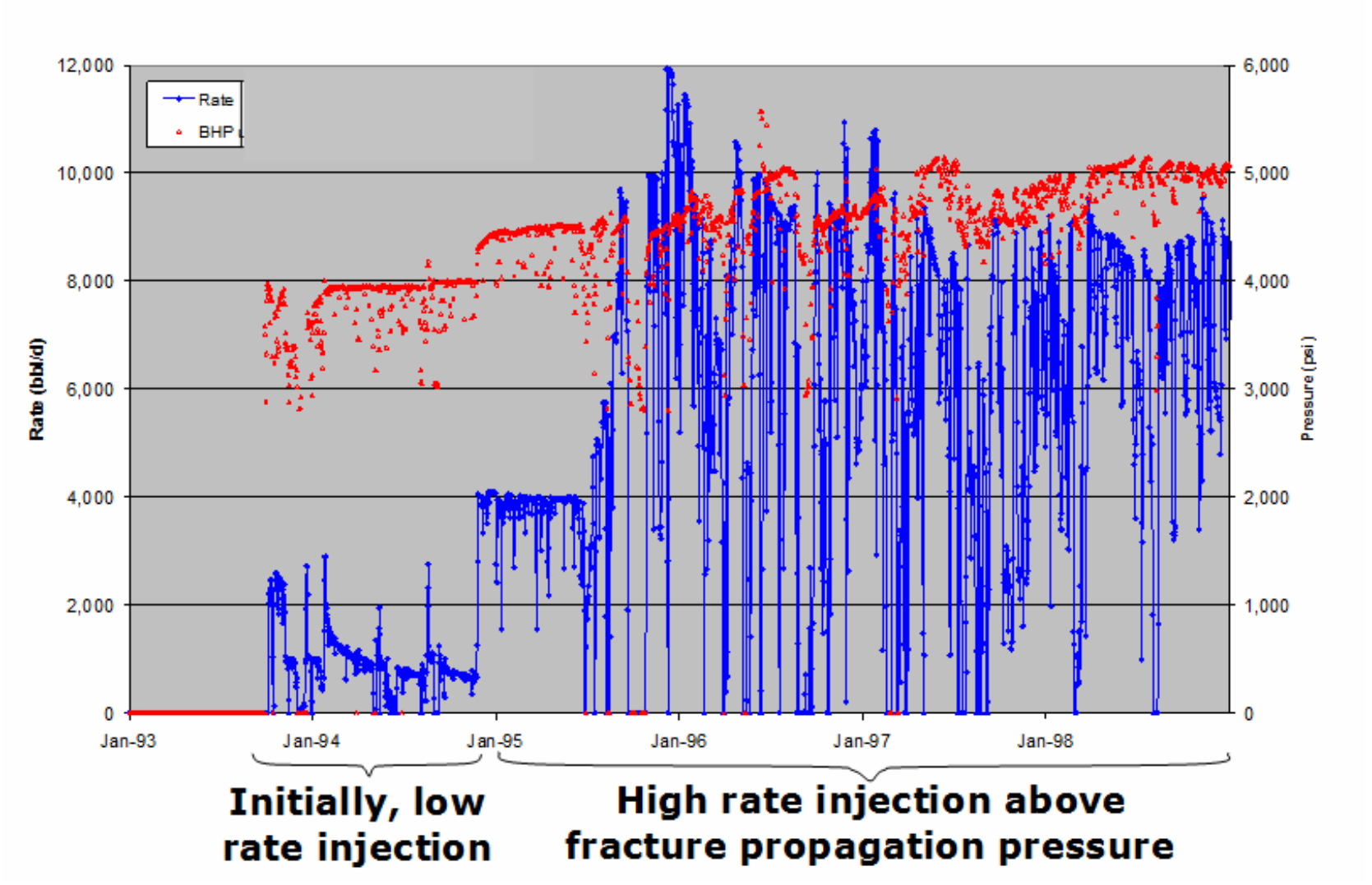


Dan Development

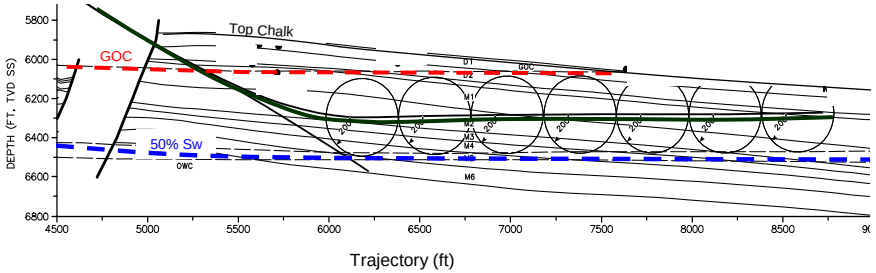


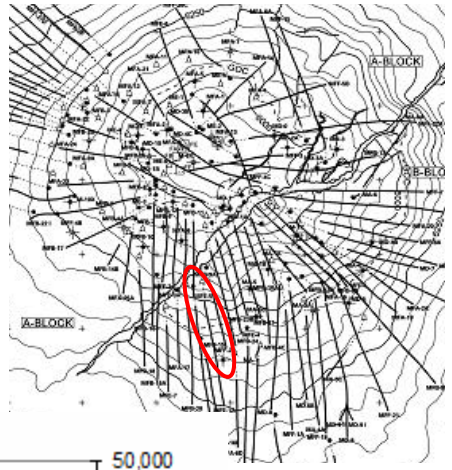


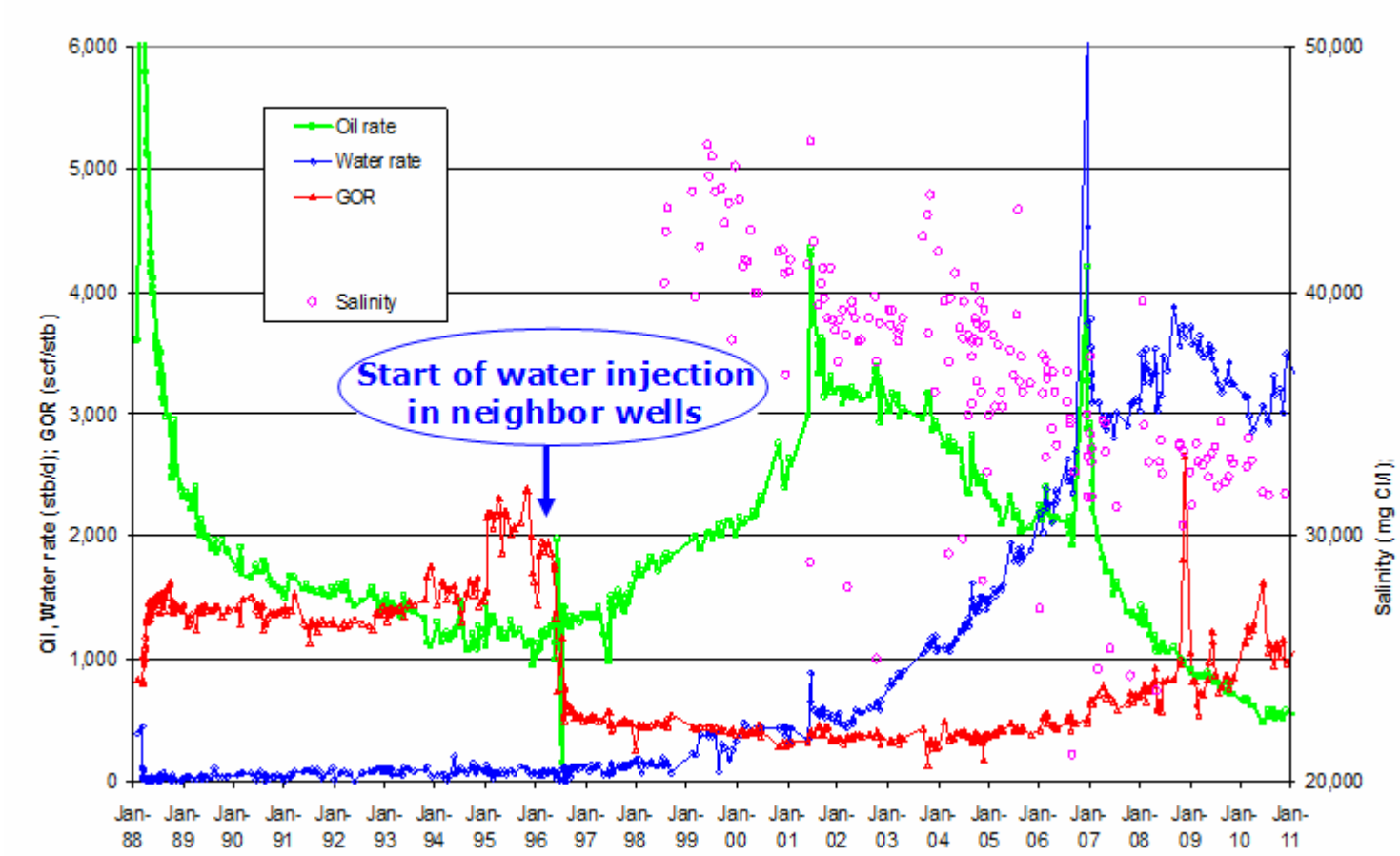
Injection Performance, example



Production Performance, example







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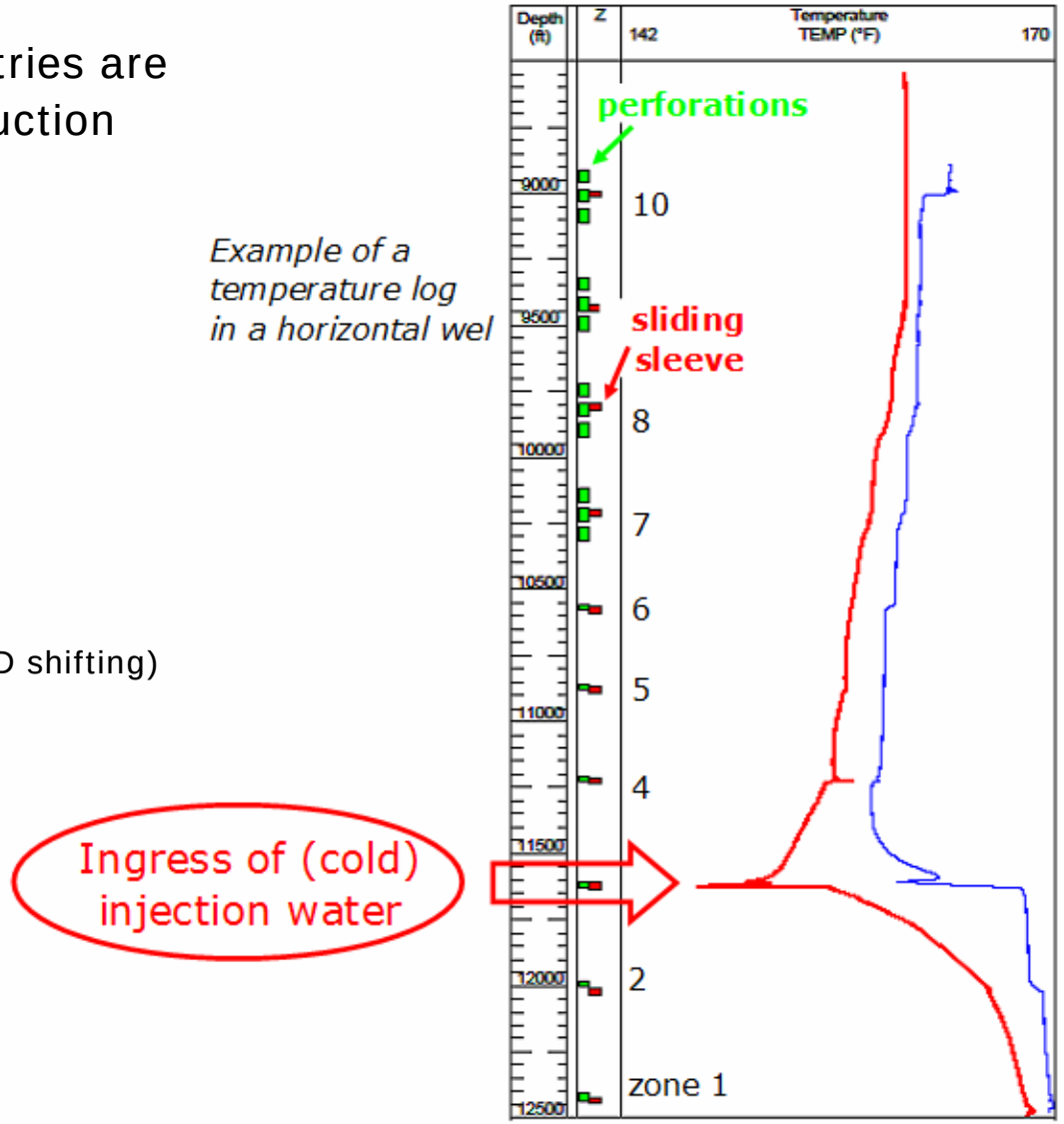
Production Logs
to indication of water breakthrough location

- Frequent coil tubing well entries are performed to optimise production performance

- Production Logging
  - Spinner
  - Temperature
  - Density
  - through casing saturation log
- Curing
  - Zone shut-off or reopening (SSD shifting)
  - Selective re-stimulation

Example of a temperature log in a horizontal wel



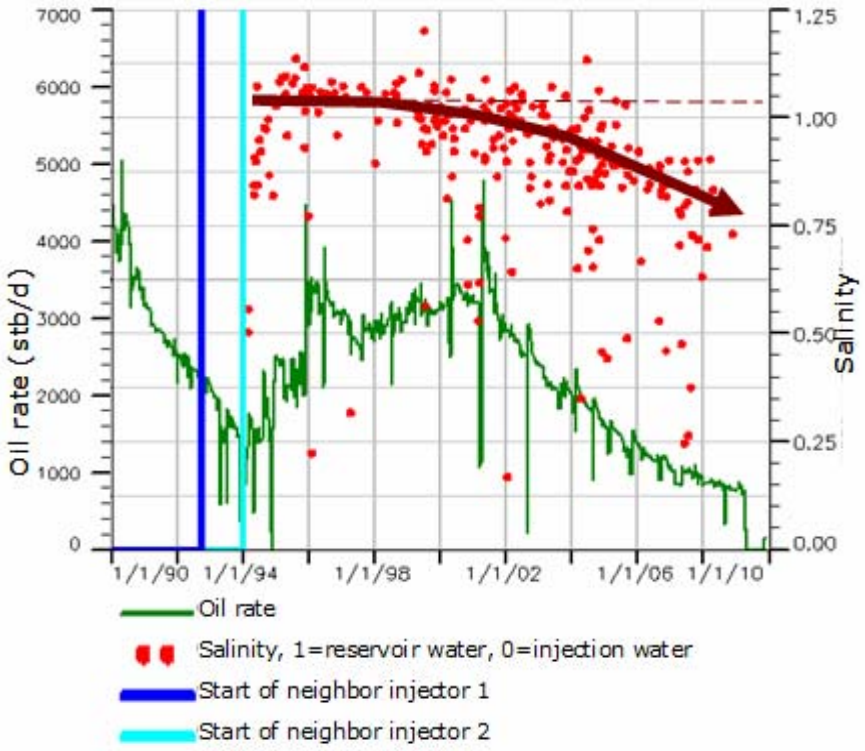
Produced Salinity as indicator for Injection / Prod Communication

Water breakthrough experience due to many measurements of a.o. produced salinity

2 examples:

- Gradual breakthrough

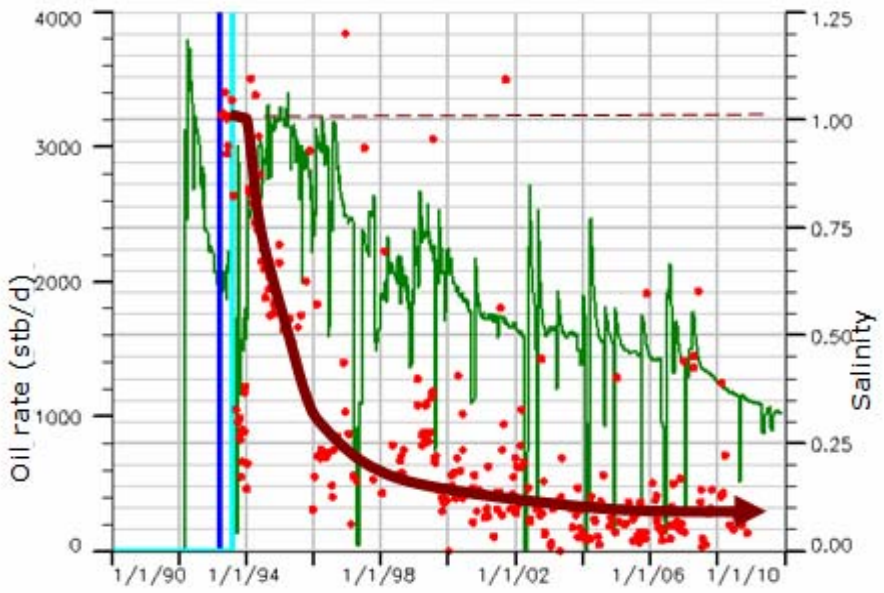
  Possible candidate for CO2 injection!



- Direct & substantial breakthrough

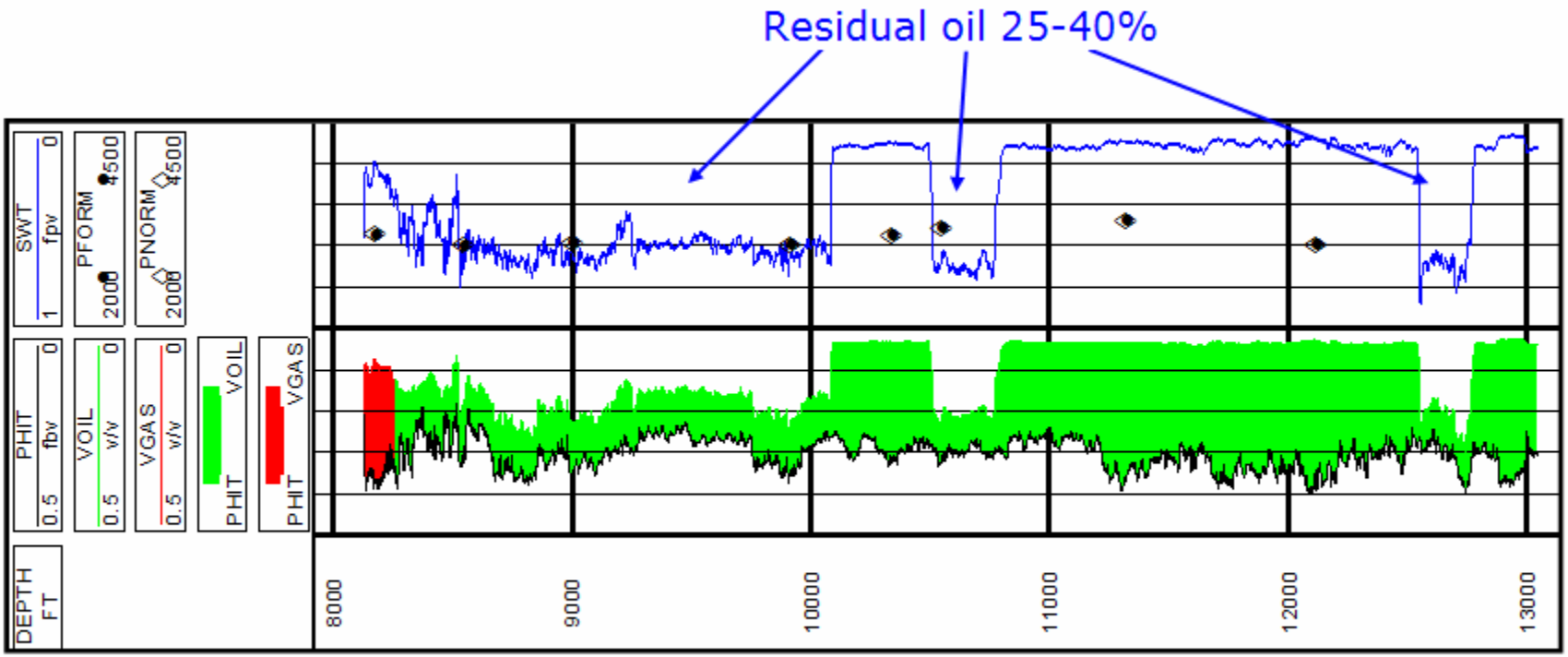
  Water Flood works, however

  No candidate for CO2 injection

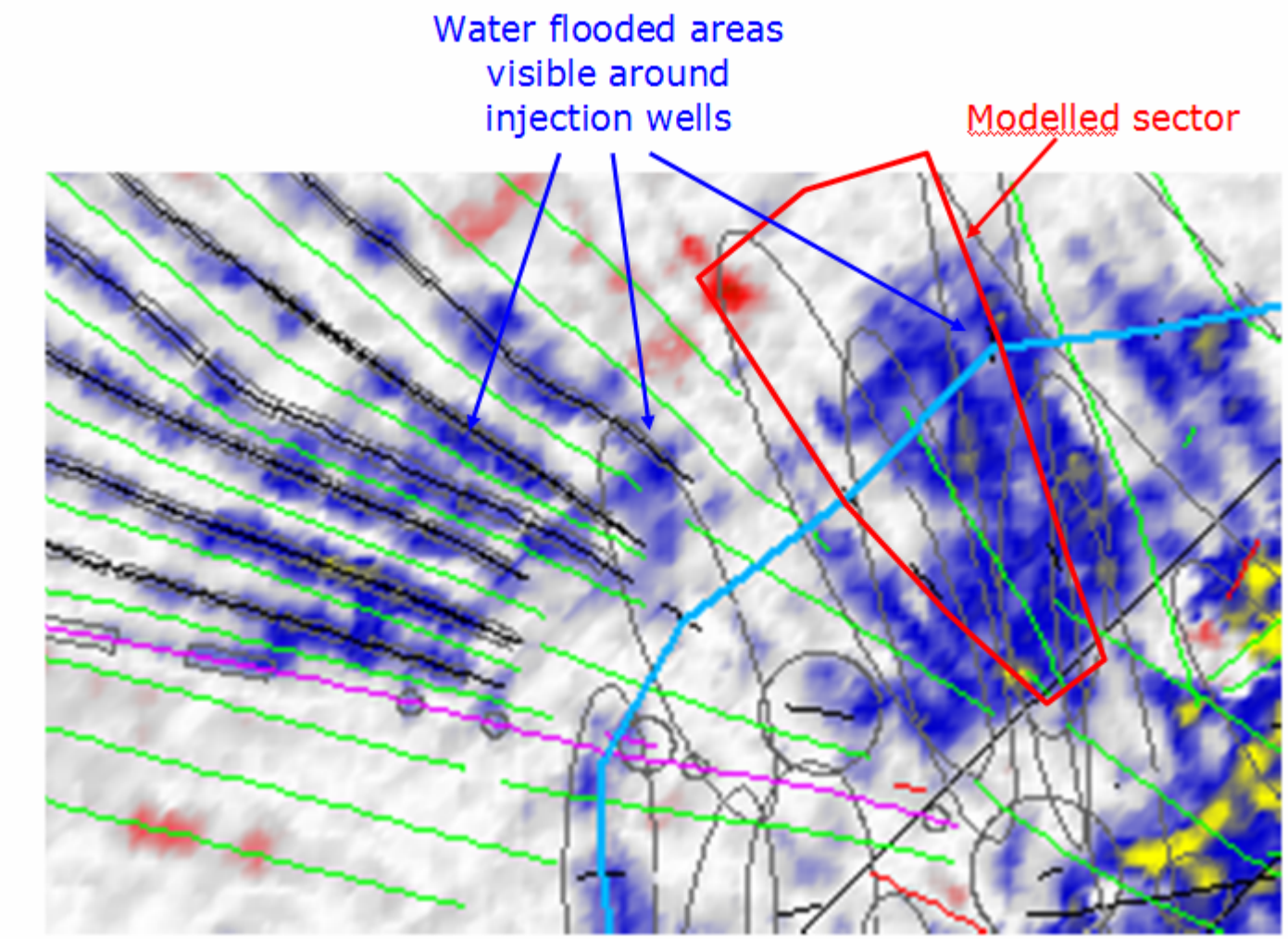


Residual Oil after Water Flood measured from Well Logs

Example: Log of horizontal well drilled through water flooded areas



4D Seismic
to Indicate Water Flooded Areas



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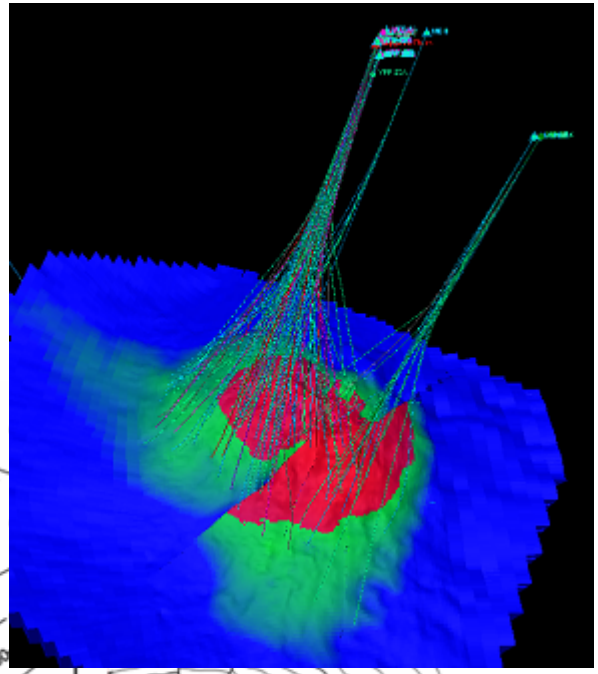
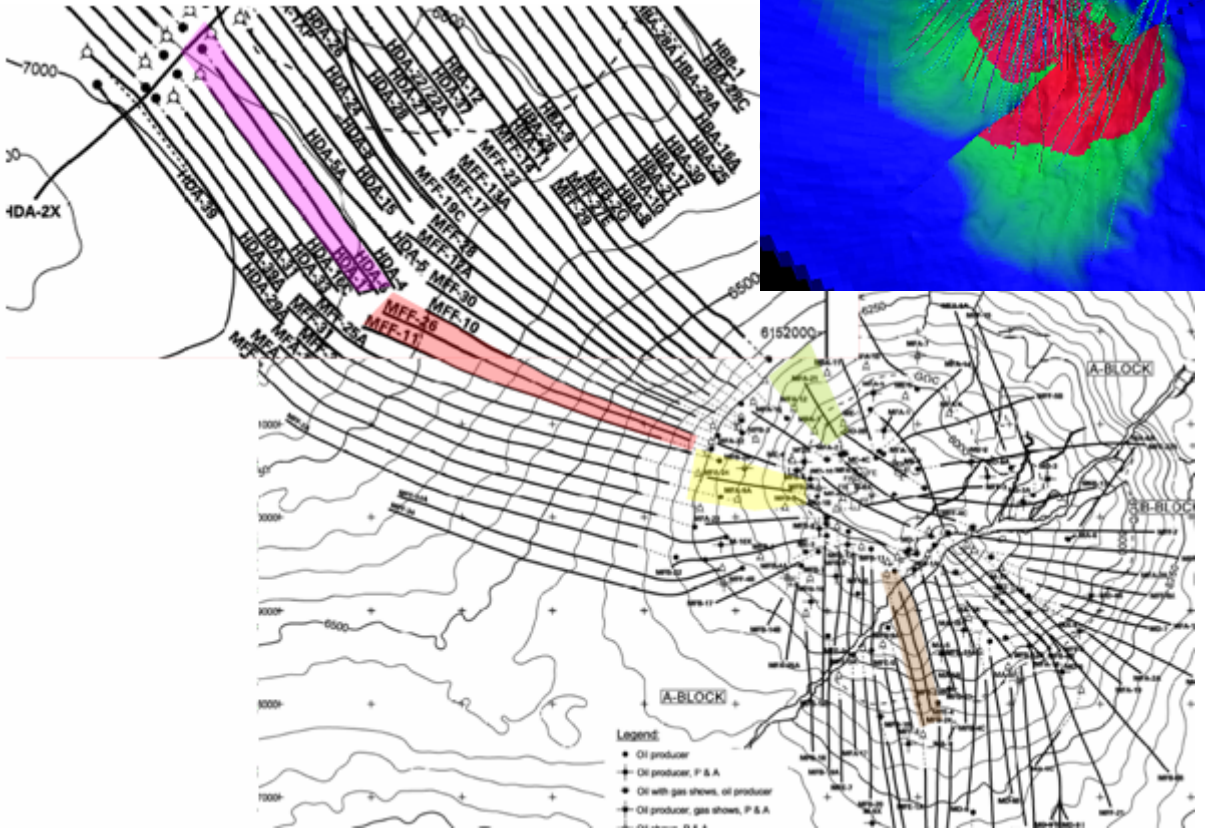
Sector Models to Forecast CO2 Flood

A 3D compositional simulation model of 4 sectors in the Dan Field was constructed

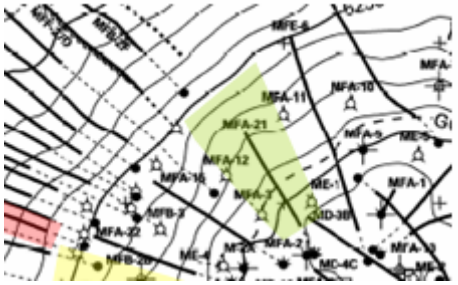
- Based on full field model
- Smaller grid size
- PVT model



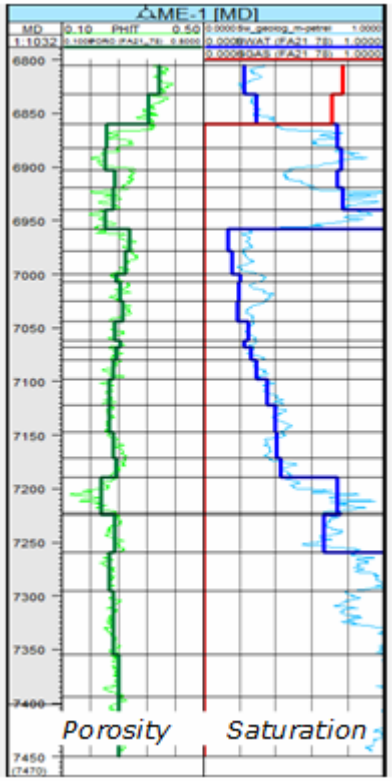


Example: MFA-21 Sector Model

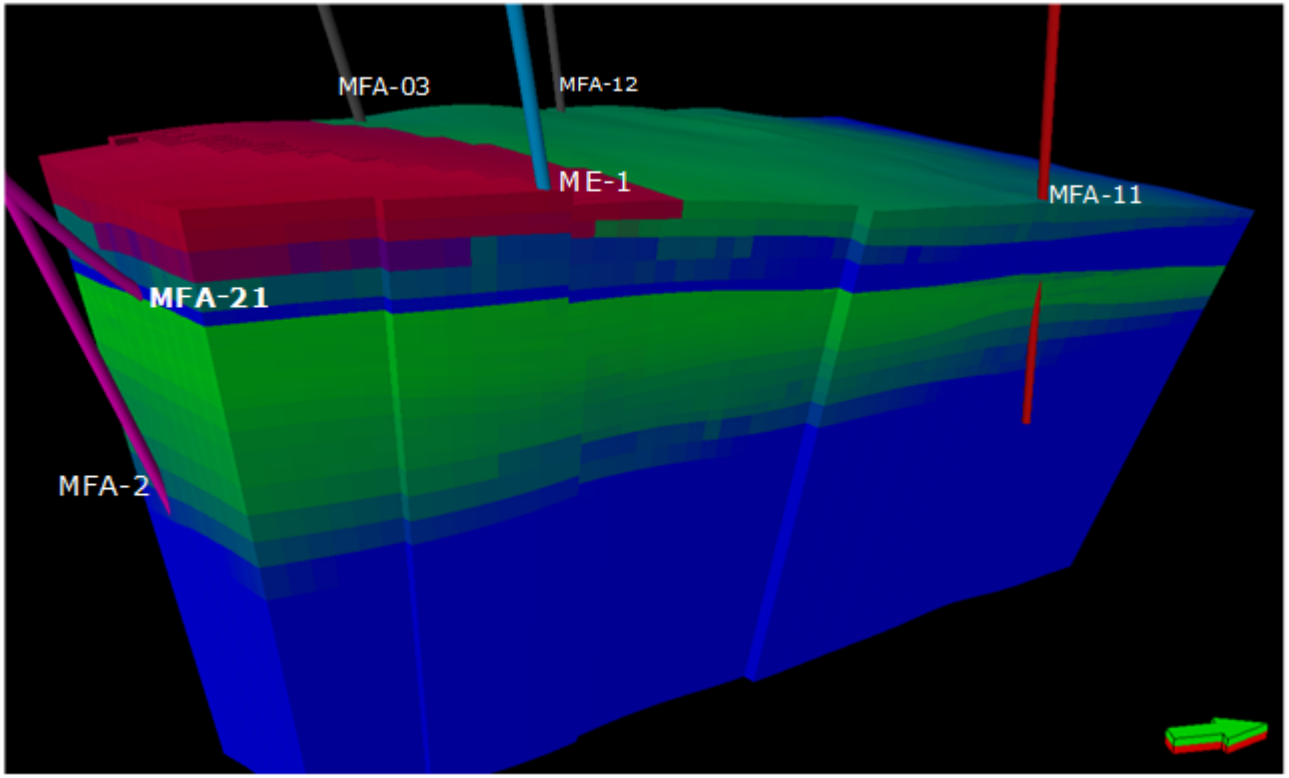
- Initial volumes are well defined based on well logs



Example of modelled and measured logs of a deviated well



3D view of wells and sector with ternary phases (oil, gas, water)



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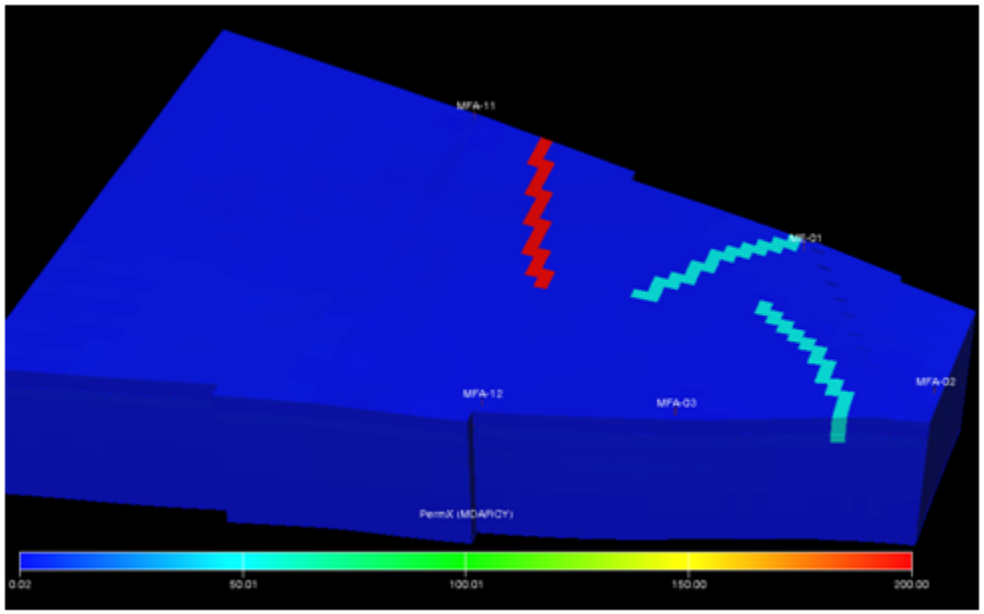
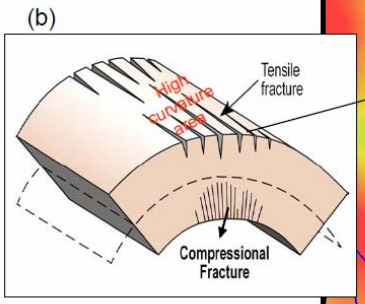
Modelled Faults/Fractures

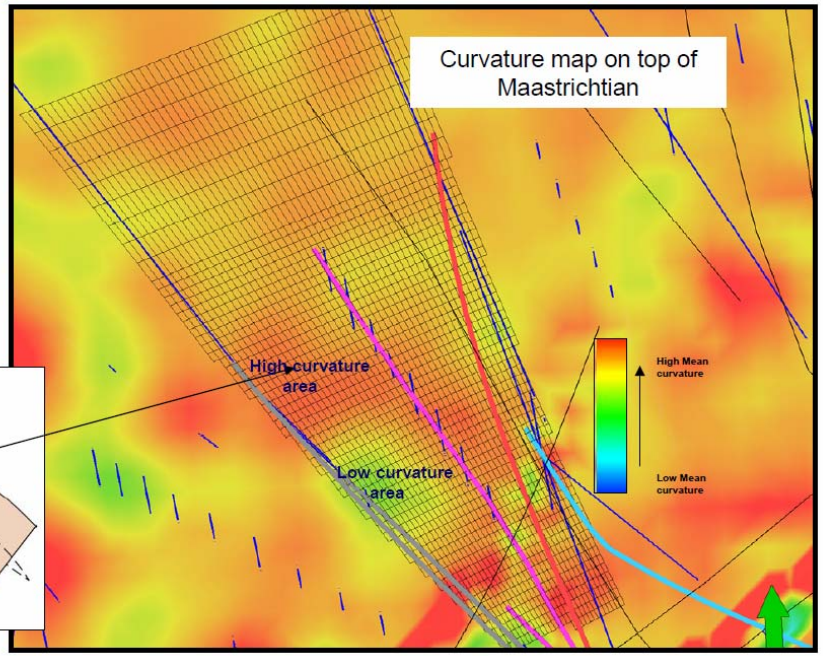
Permeability enhancement to model natural faults/fractures at high curvature areas



Fault model details:

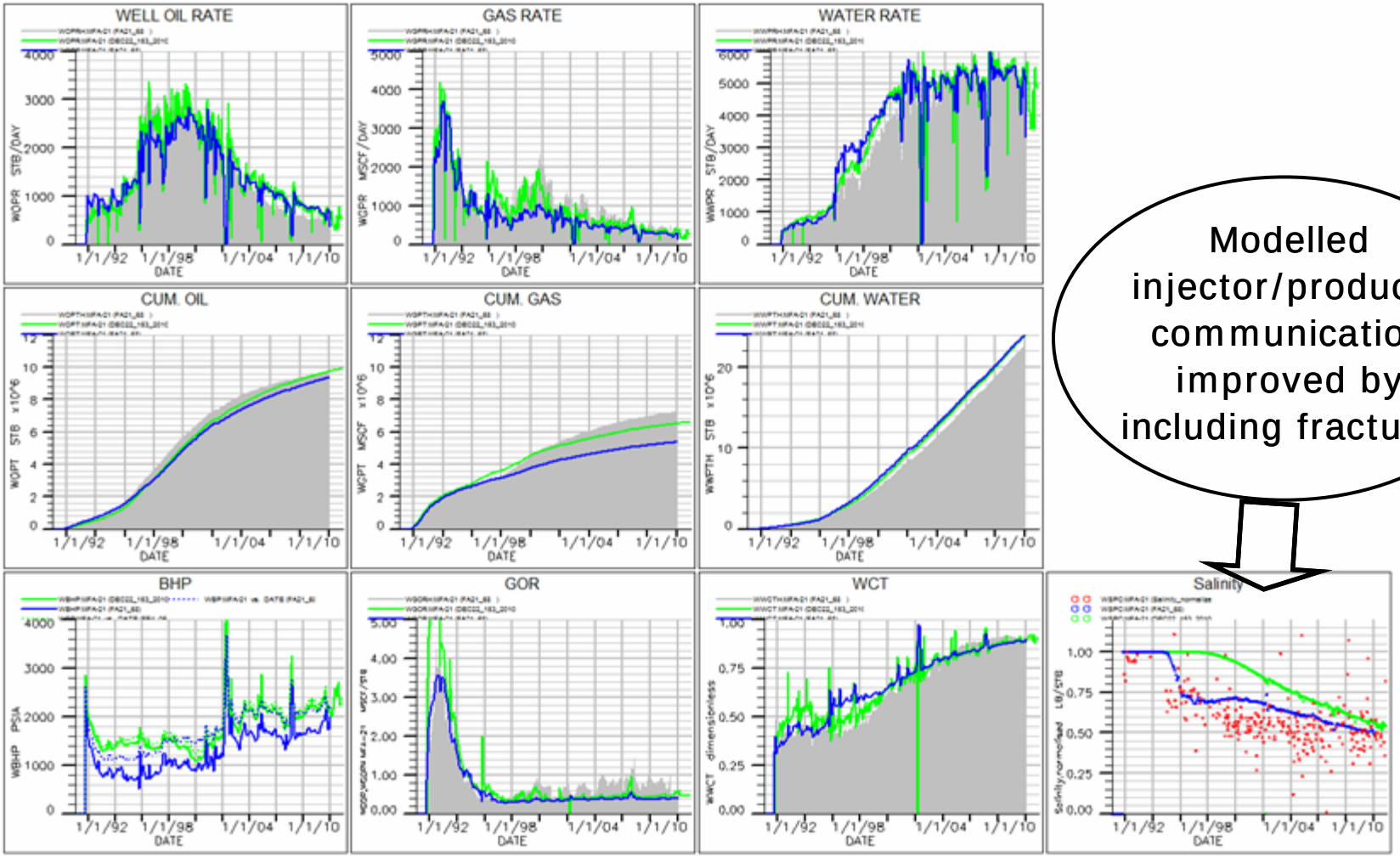
- Permeability 50-200 mD
- Porosity 1%
- Straight line rel.perms





Improved History Match including Fractures

MFA-21 Well performance, Sector Model with conductive faults vs Full Field Model



Modelled injector/producer communication improved by including fractures

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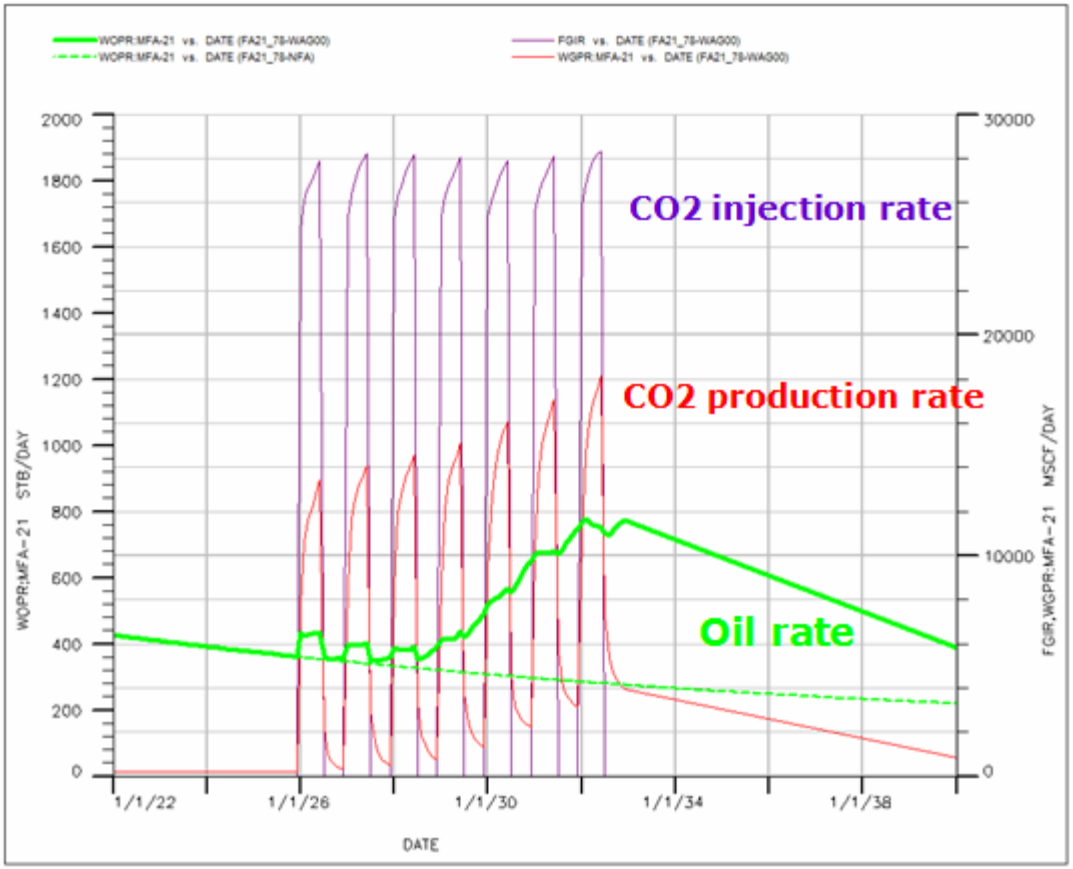
Incremental Oil due to CO2 Flood

sector model

- CO2 Injection Modeled
  - Viscous displacement
  - First contact miscibility
  - Water Alternating Gas
    - 1-year slugs
  - Reinjection of produced CO2



Laboratory Core Testing

Ongoing

- 3-phase core flooding tests
  - reservoir conditions
  - composite core plugs
  - provide input to reservoir simulations
- Geochemical core flooding tests
  - gain an understanding of the chemical reaction caused by the CO2 in the reservoir
- Geomechanical tests
  - in a tri-axial Hoek cell to estimate the effect of CO2 on the mechanical properties of the chalk
- Cap rock characterization tests
  - estimate the risk of CO2 leaking from the reservoir

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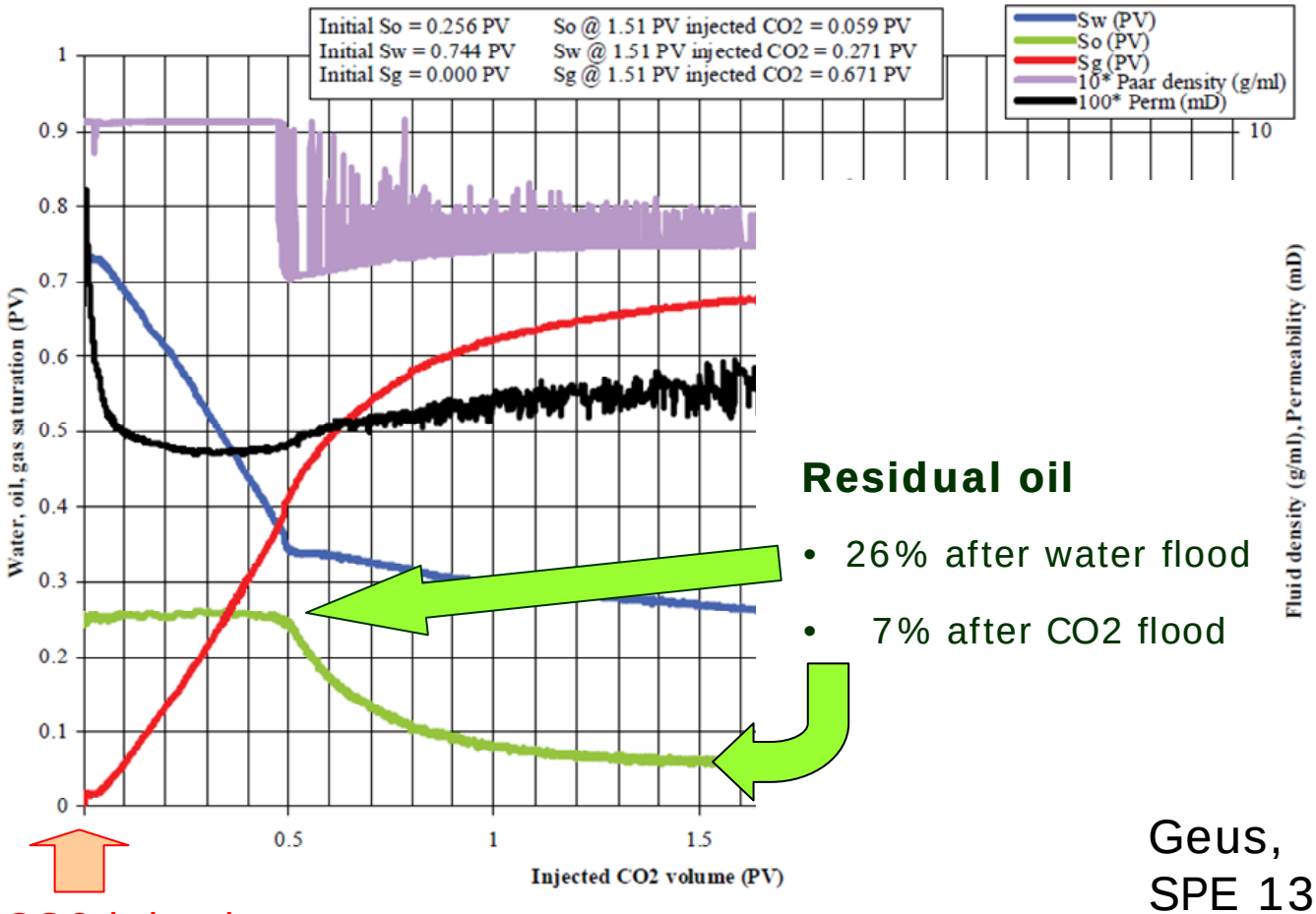
Core Flood Tests at reservoir conditions



Residual oil

- 26% after water flood
- 7% after CO2 flood

Start CO2 injection
(after waterflood)

Geus,
SPE 131516

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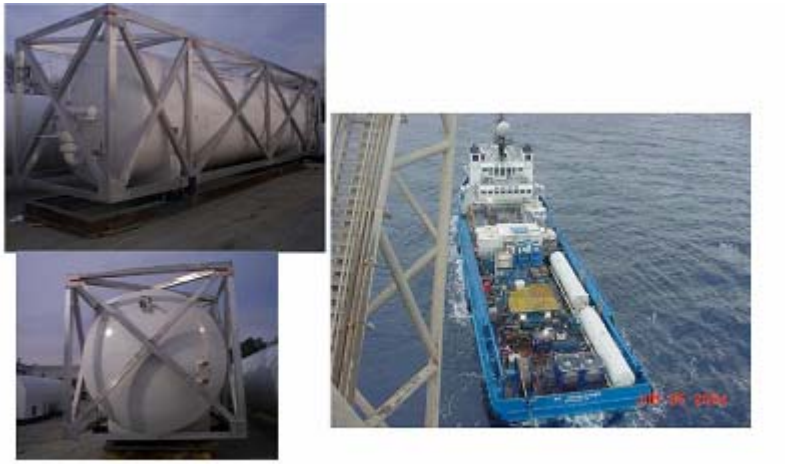
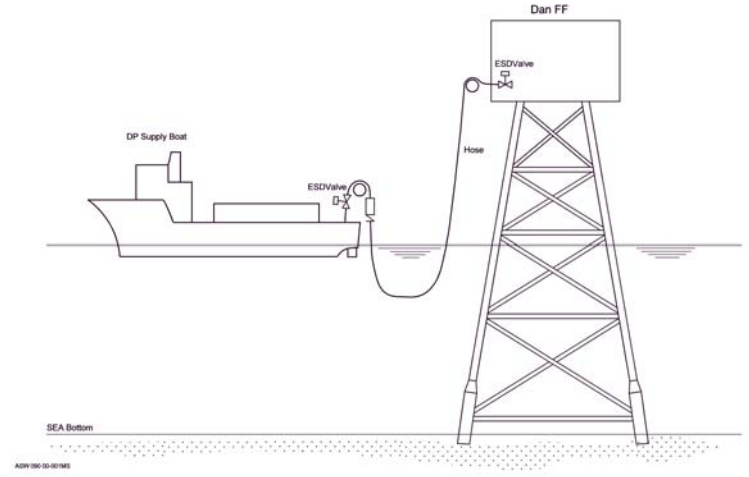
Possible Future Injection Test

- Aim of CO2 injection test
  - gain operational experience
  - reduce uncertainty of
    - CO2 injectivity
    - rock conformance

- Two wells selected for test
  - one well with known communication between water injector and producer
  - Tracer test CO2 injection

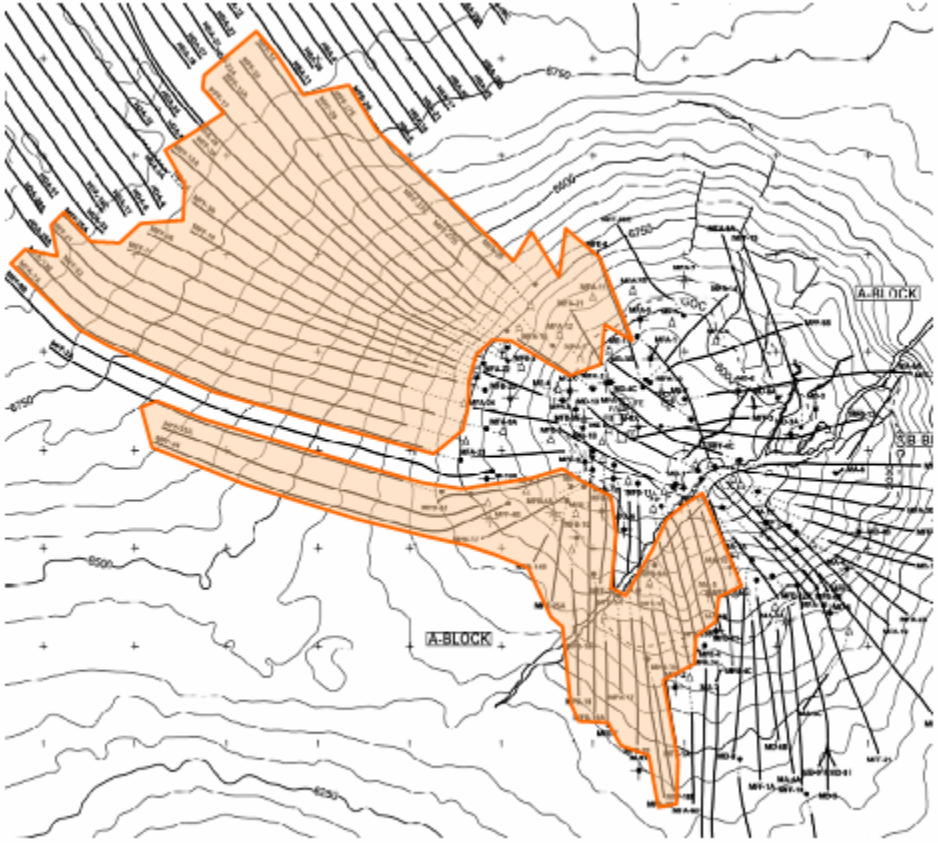
    and compare with tracer test result of water injection





Possible CO2 Flood Scenario

- A possible CO2 flood only in part of the Dan field due to:
  - Platform space availability
  - Water flood experience
- Roll-up of sector models
- Approximately 80 MMscf/d CO2
  - for 6-10 years
- Main subsurface risks:
  - CO2 leak outside designated area
  - Long horizontal wells have limited control options
  - (Chalk dissolution)



Thank you!

Questions?