Technology Trends and Needs in Enhanced Oil Recovery (EOR)

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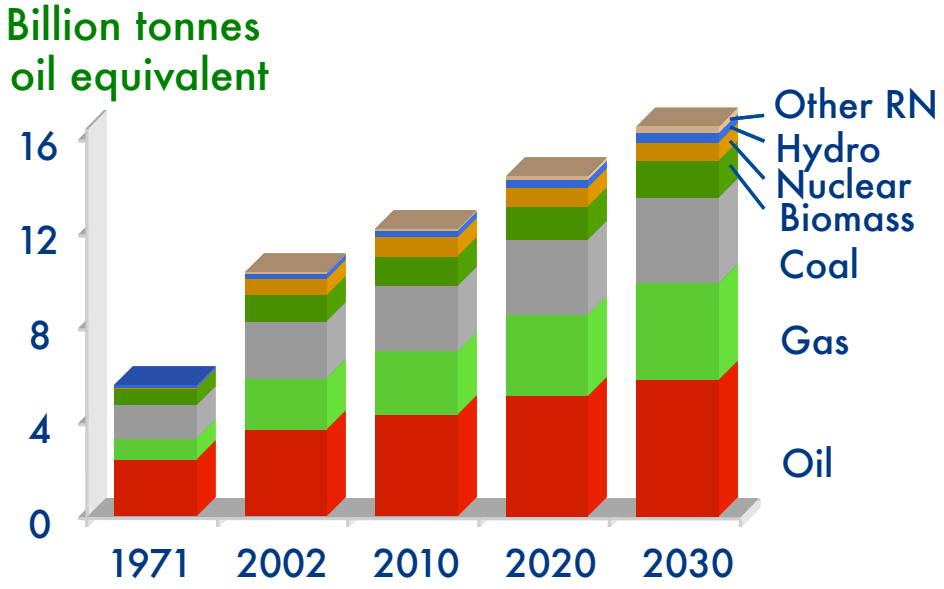
The World's Energy Challenge

Improved access to modern energy for the world

Growing demand for energy

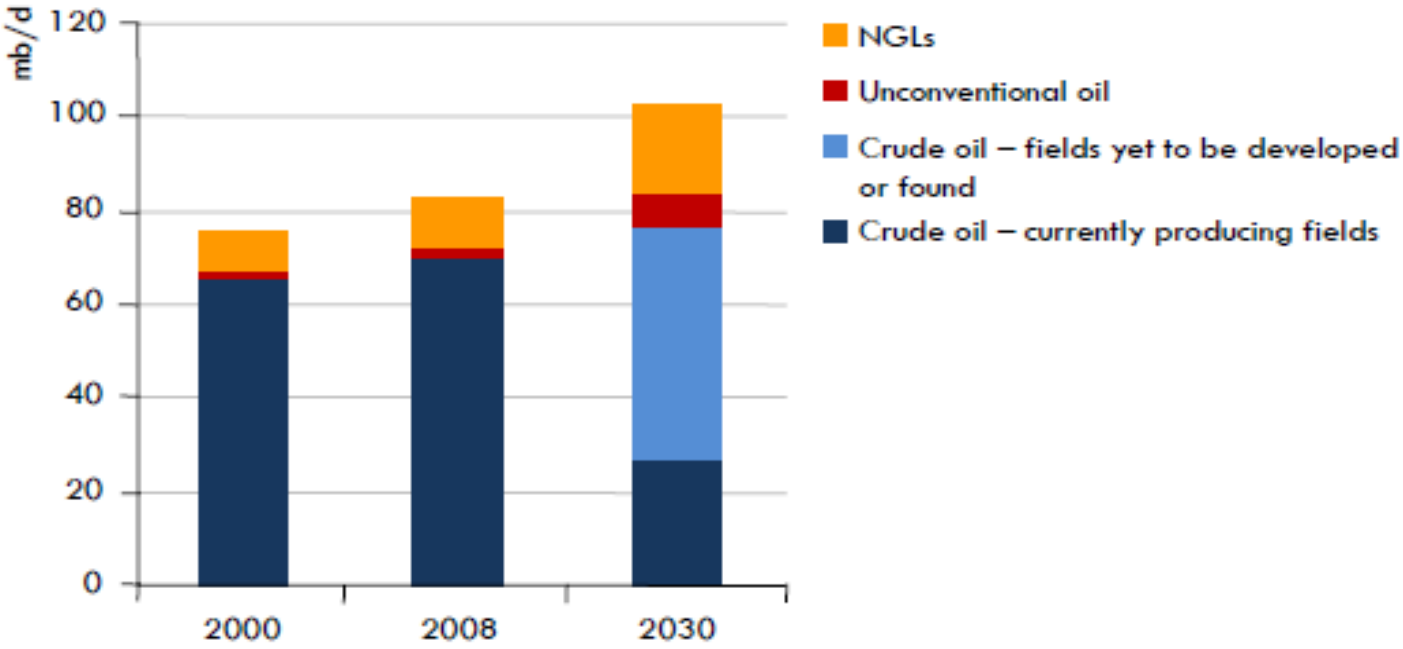
to be met by fossil fuels in the short term

Low-carbon energies sustainable carbon sequestration options



Source: IEA

Demand Keeps Growing

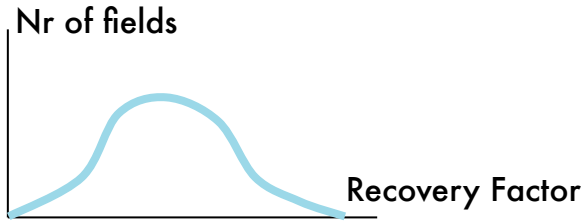


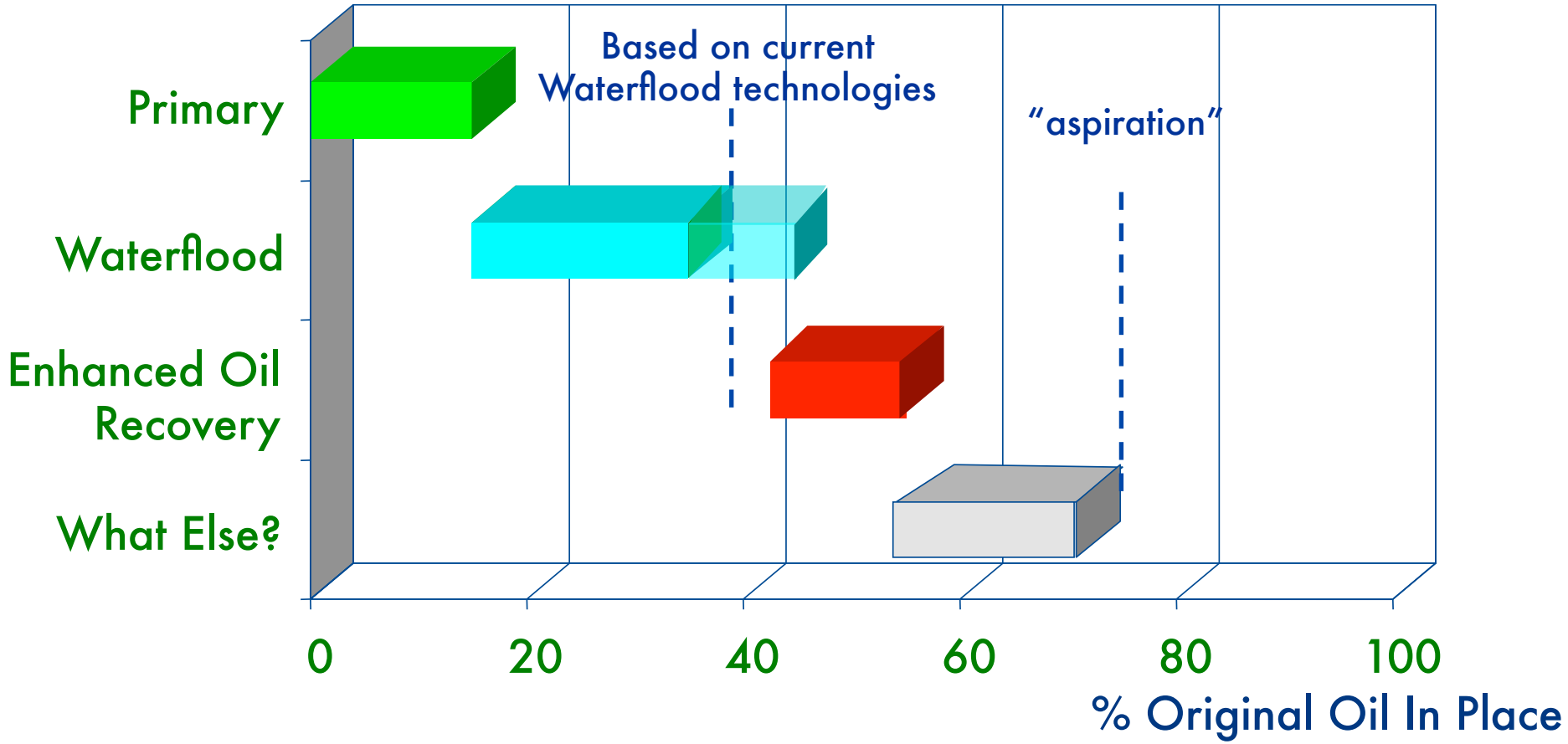
Sustained investment is needed mainly to combat the decline in output at existing fields, which will drop by almost two-thirds by 2030

Source IEA 2009

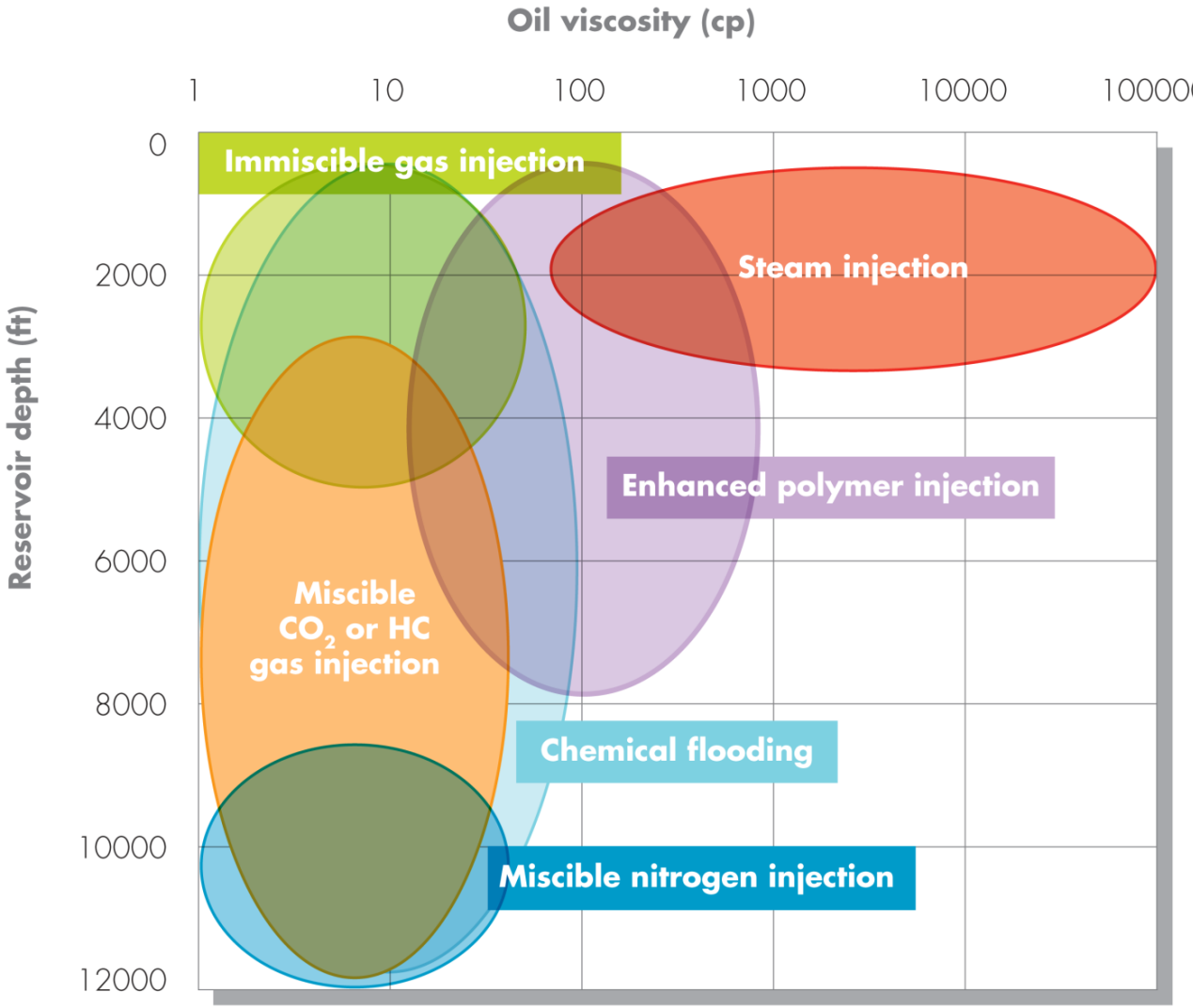
Maximising Recovery

Average RF's: Some fields at 65%
Some fields at 10%





EOR Technologies and Screening

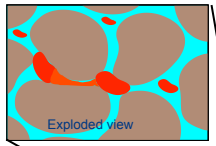


Extracting oil, that would otherwise be left behind

- EOR global potential: ~300 Bbbl

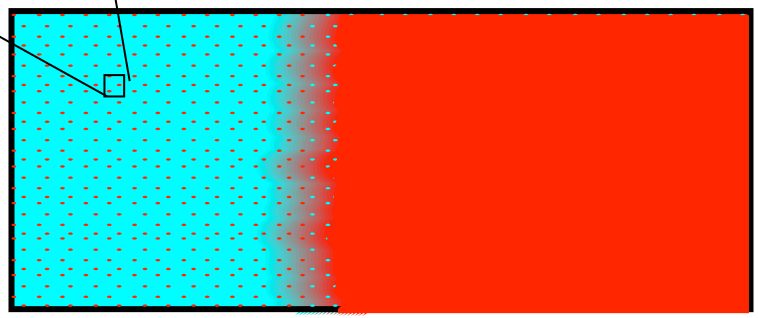
niche role: CO_2 storage

The key issues to be resolved to maximise oil recovery

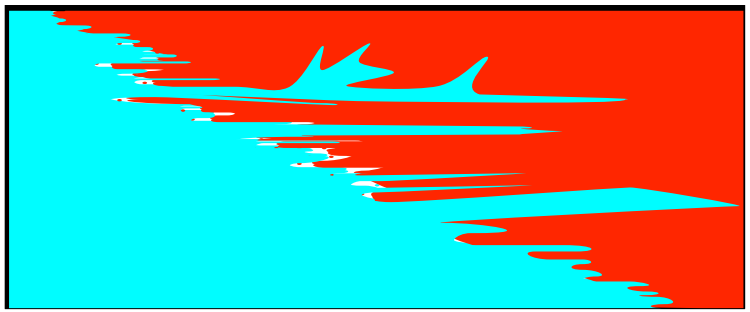


often around 20-30%

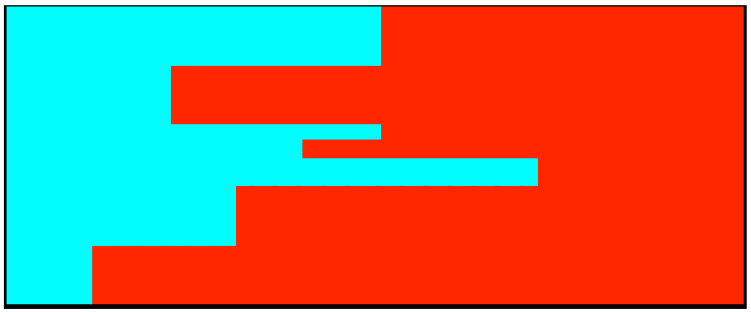
Residual oil saturation



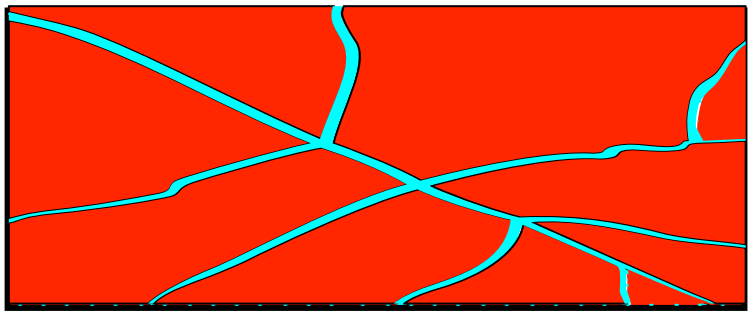
Mobility control



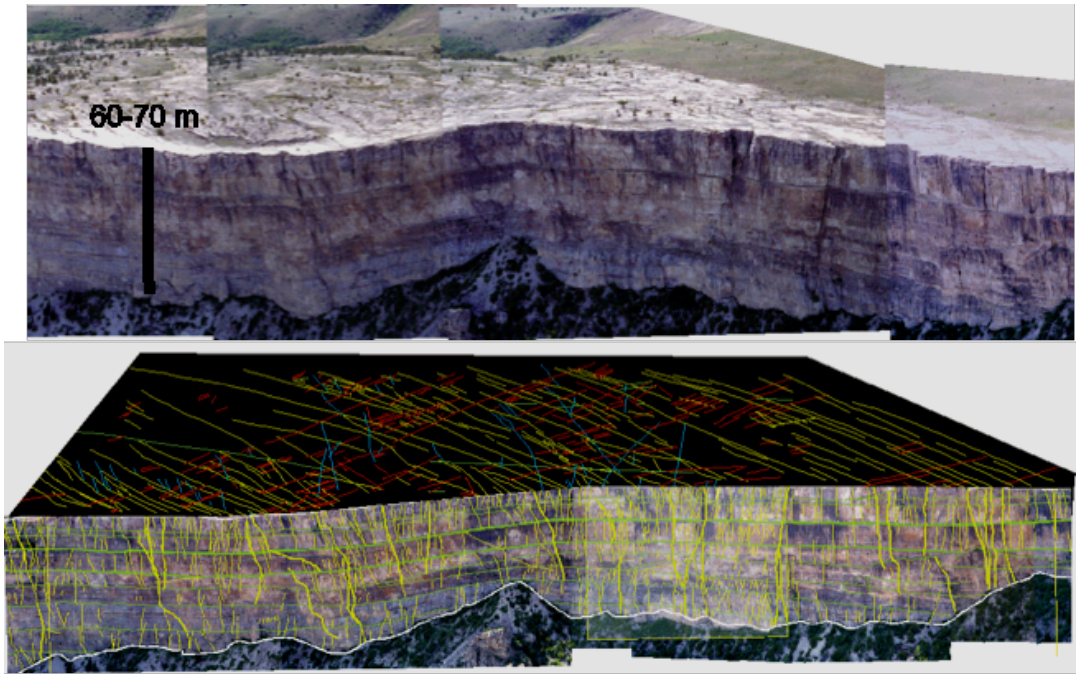
Thief zones



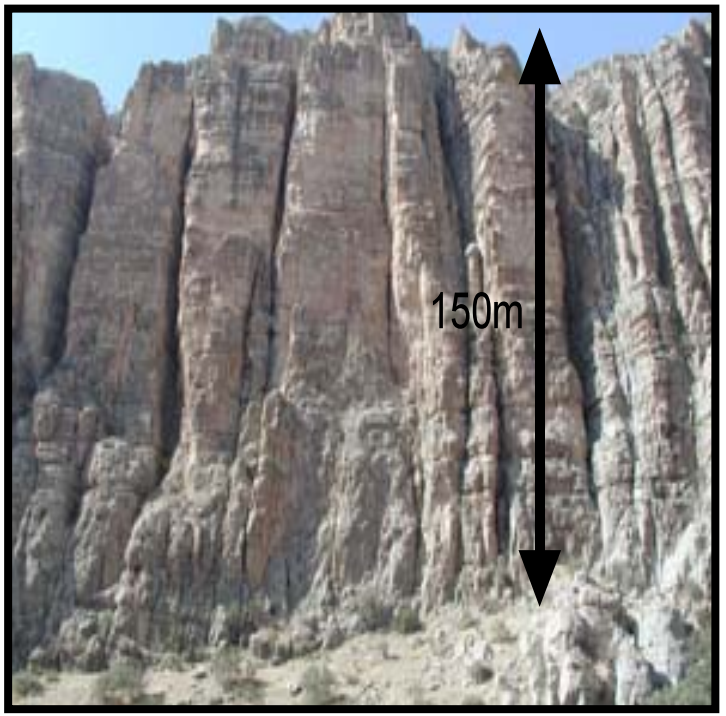
Oil wet fractured carbonates



Geology: Fracture connectivity



(Rocky Mountains, Martin de Keijzer)

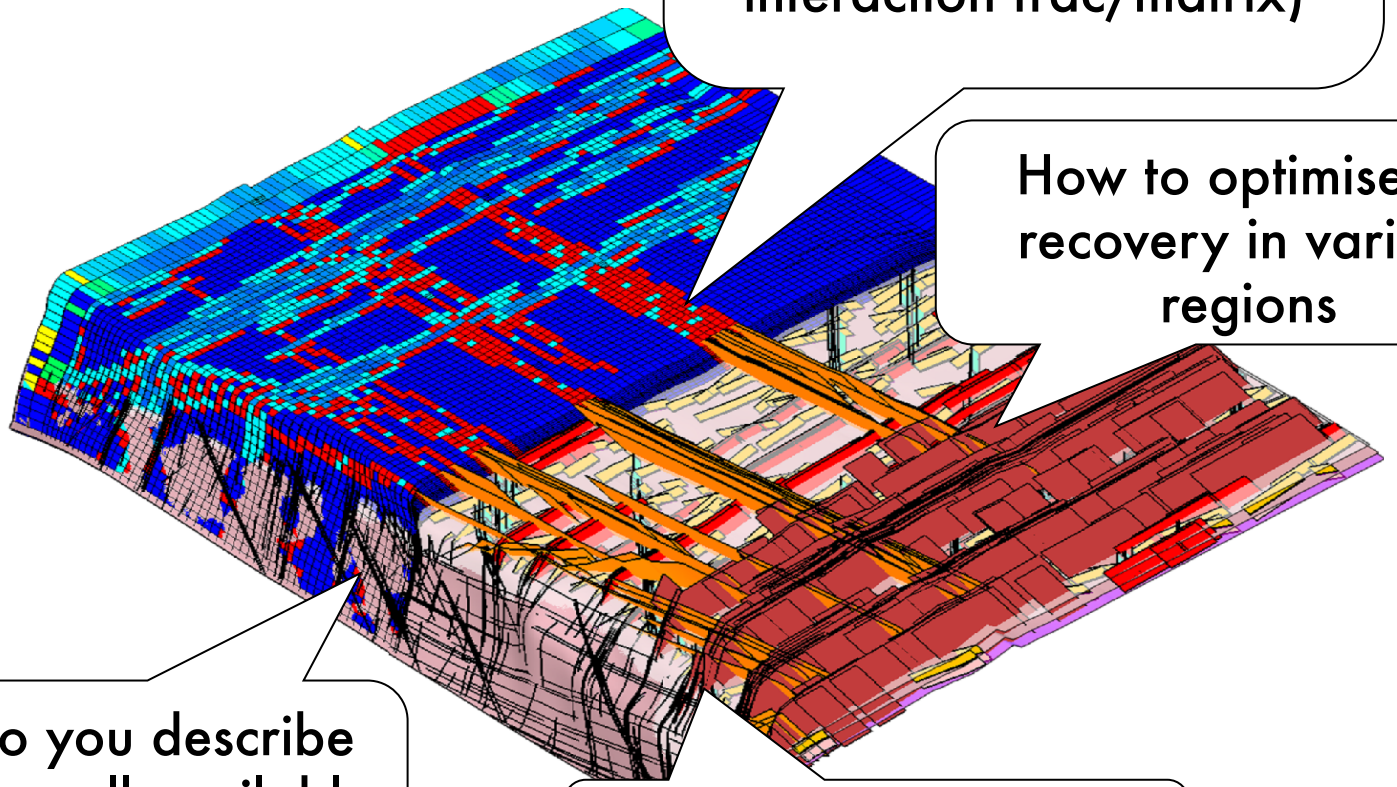


(Zagros Mountains, Ben Stephenson)

Fractured Carbonates
- Characterization
- Modeling

What are the key displacement processes in various regions (role of wettability, interaction frac/matrix)

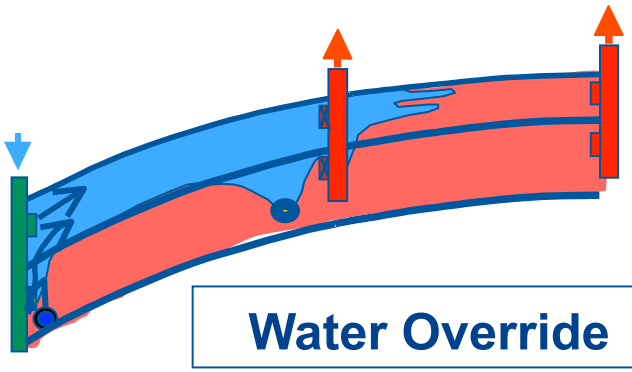
How to optimise oil recovery in various regions



How do you describe this, using all available data.

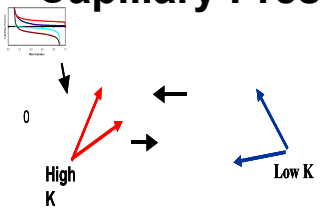
How do you model this

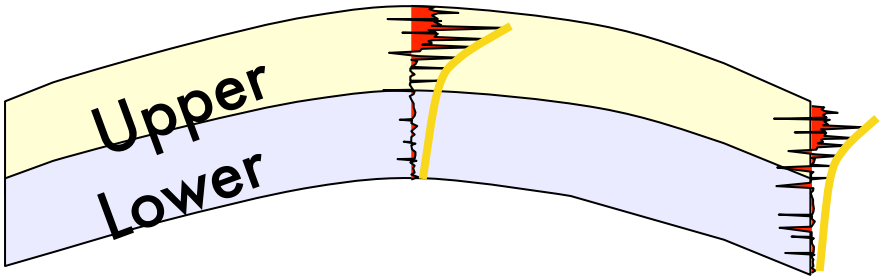
Carbonates - Geology + Flow Physics



Water Override

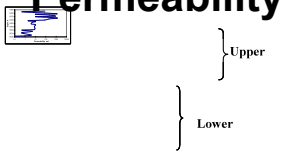
Capillary Pressure & Hysteresis



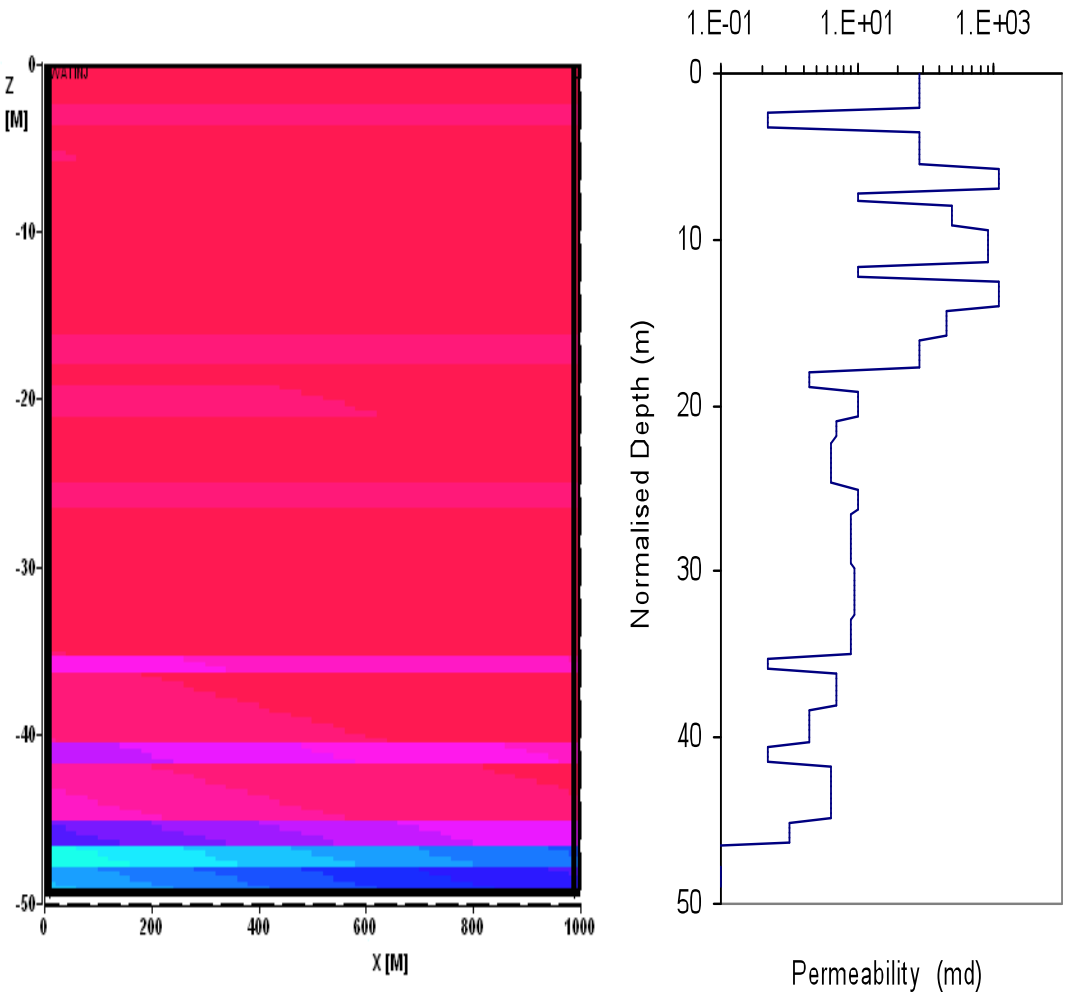


Reservoir Architecture

Permeability Trend



Impact on Waterflood Remaining Oil Saturation Predictions:

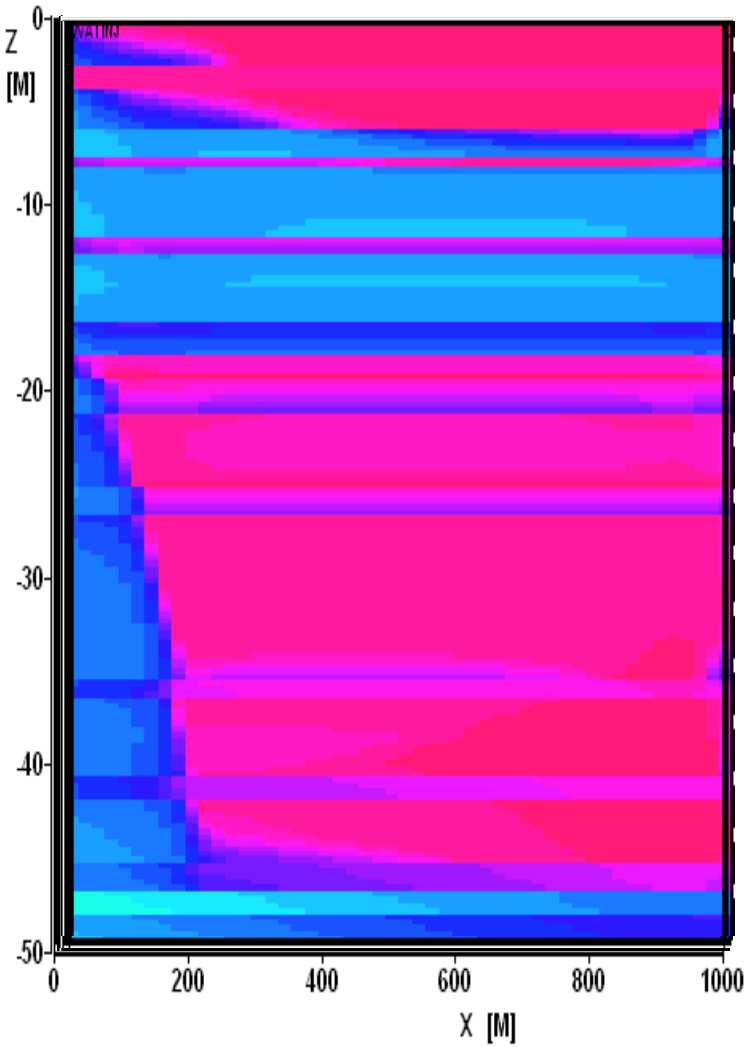


2D cross sectional model, number grid blocks 50 X 160, grids size 20 m X 30 cm

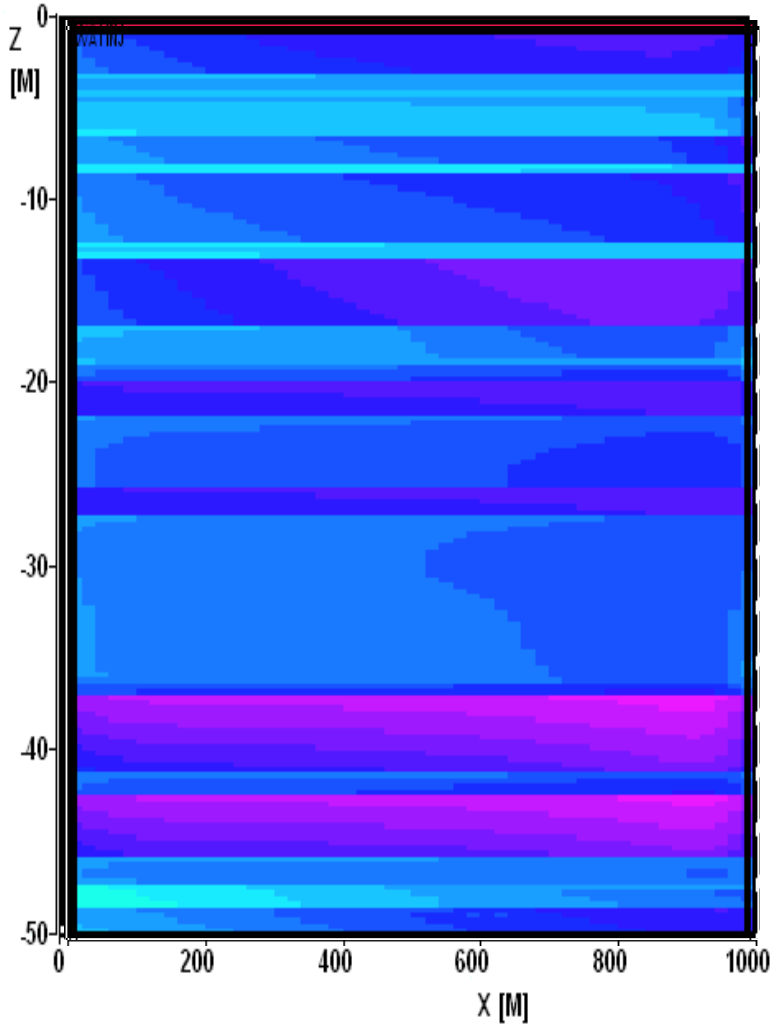
Waterflooding injector/ producer pair, Heterogeneous carbonate oil-wet reservoir, light oil, matrix dominated

Impact on Waterflood Remaining Oil Saturation Predictions in a Carbonate

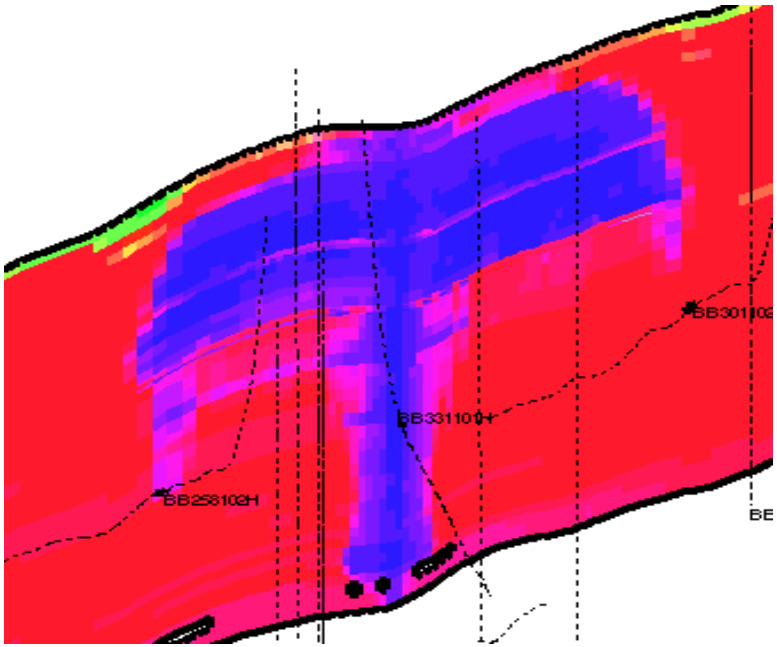
Oil-Wet Pc



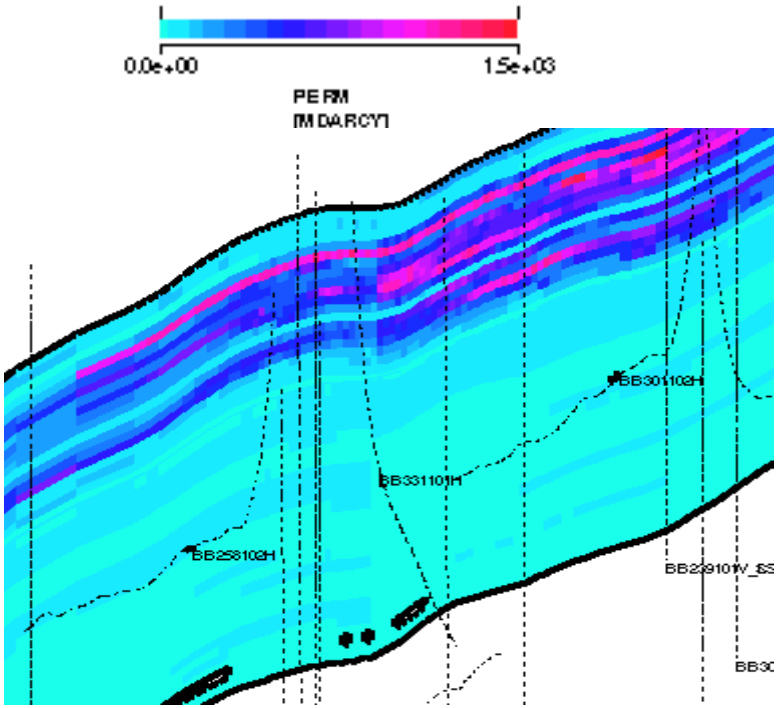
Water-Wet Pc



Field Case: Waterflood in a carbonate reservoir
What next to improve recovery?



Saturation Distribution at the end of history match run

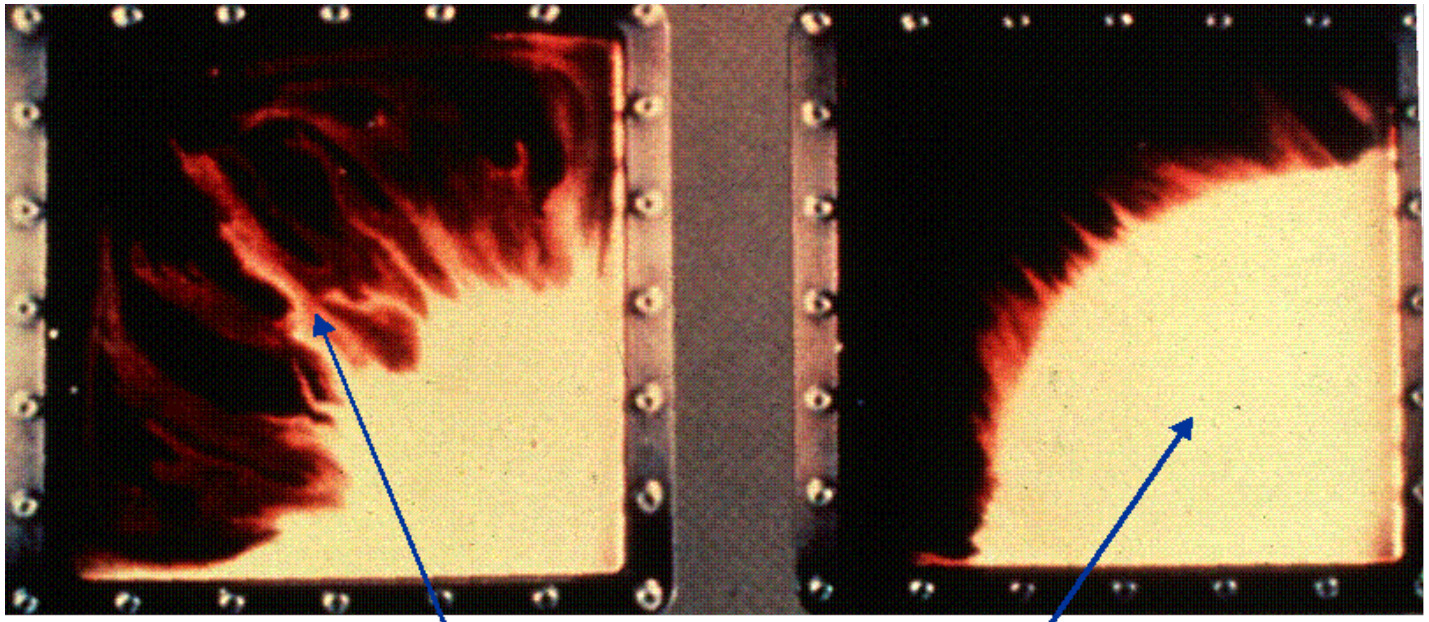


Perm Profile

Polymer flooding

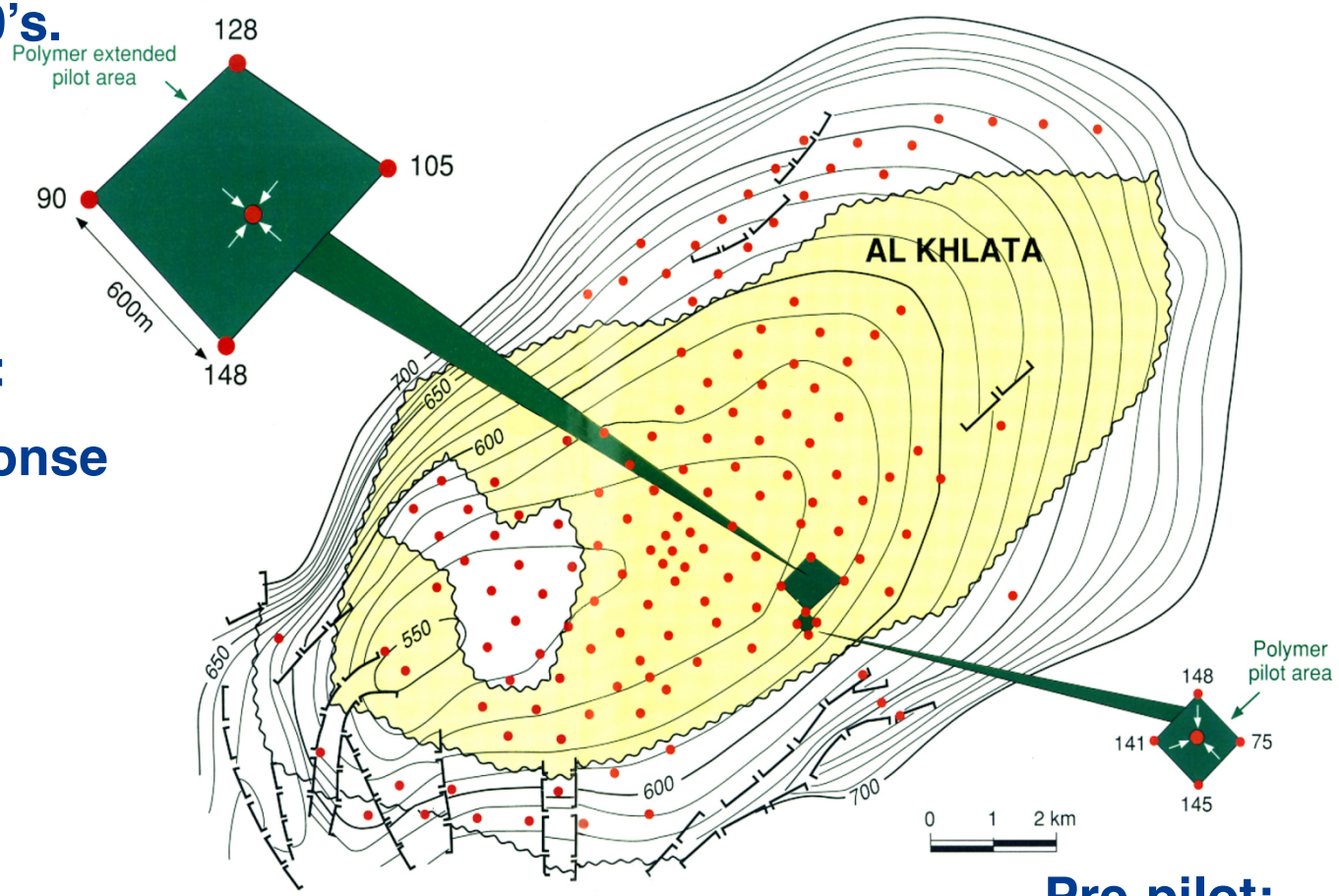
Problem: **Water flooding of oil with a viscosity > 10 cP results in a poor displacement efficiency due to fingering**

Objective: **Increase the displacement efficiency by reducing the mobility of the injected water by adding polymer**



Oman: Large scale polymer project

Extensive piloting end 80's and early 90's.



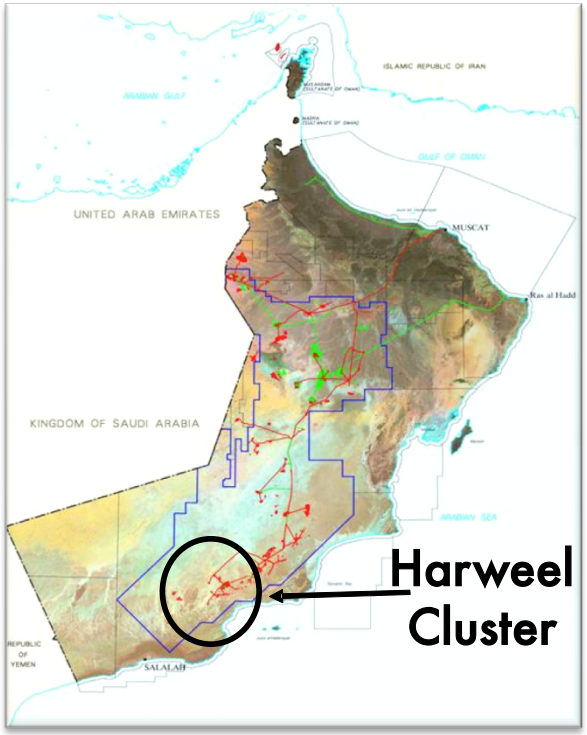
Extended pilot:

Expected response

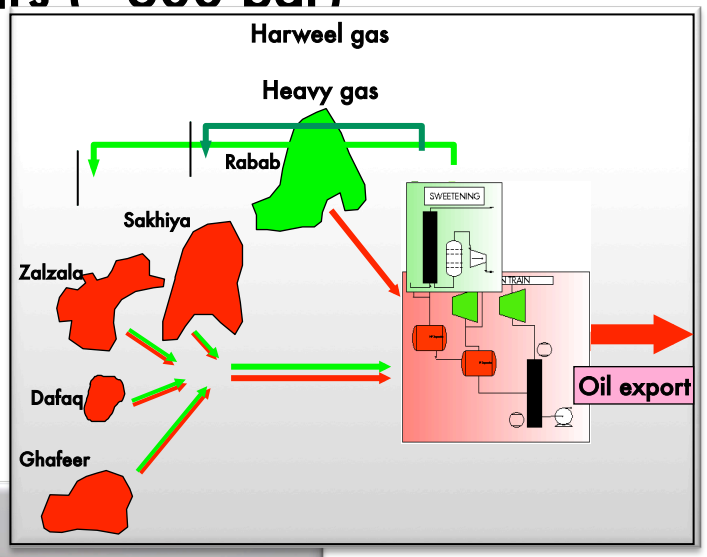
Pre-pilot: Excellent response

When oil price increased, the decision made to go ahead

Miscible Gas Flood

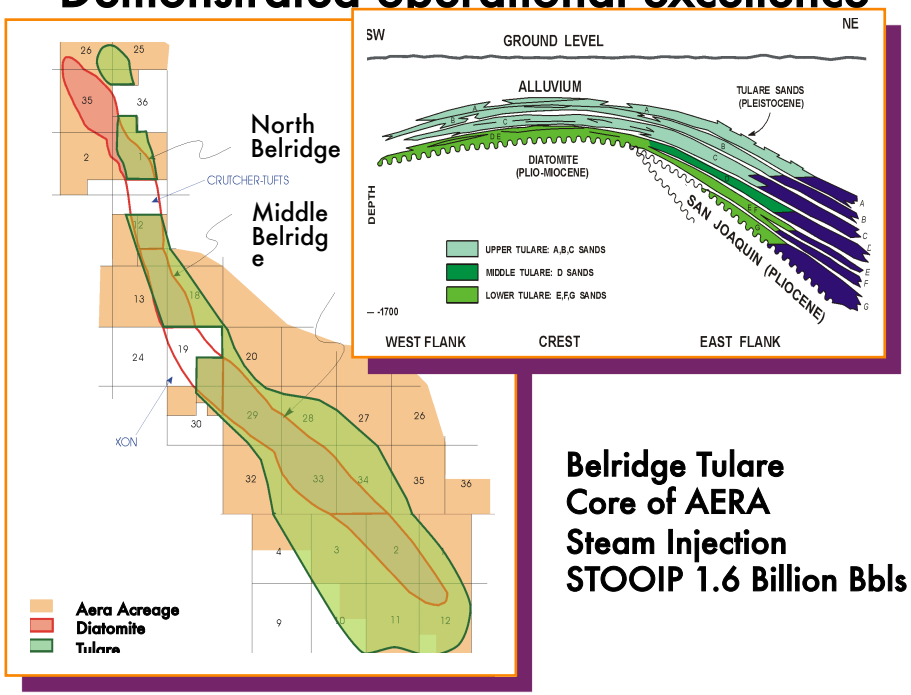


- 7 fields / 9 reservoirs discovered in 1997-2002
- Light oil, sour gas in 3-5 km deep high pressure reservoirs (~600 bar)

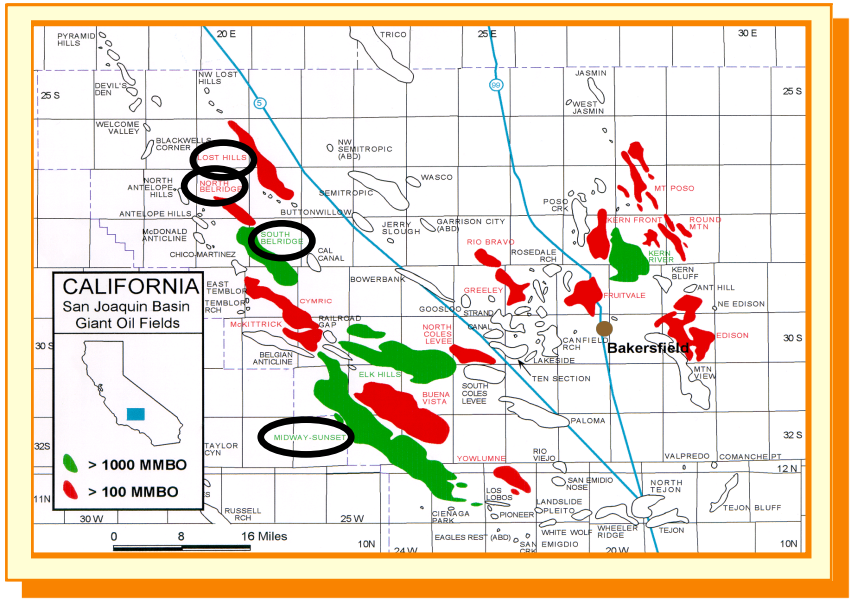


Steam Injection – Belridge Example

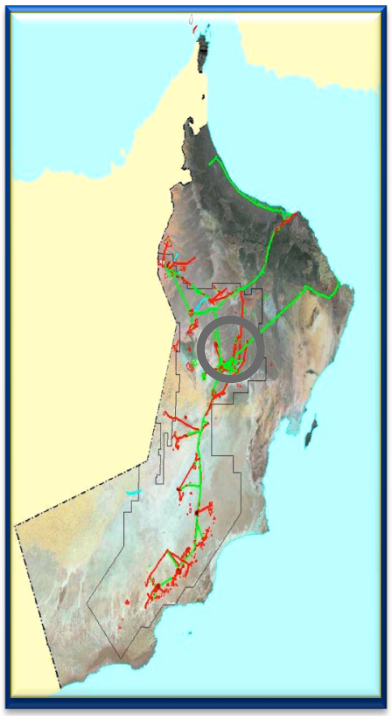
- Operated by Aera, a Shell JV
- Produces 235,000 b/d from 15,000 wells
- Headquarters in Bakersfield, California (1150 employees)
- Demonstrated operational excellence



Belridge Tulare
Core of AERA
Steam Injection
STOOIP 1.6 Billion Bbls

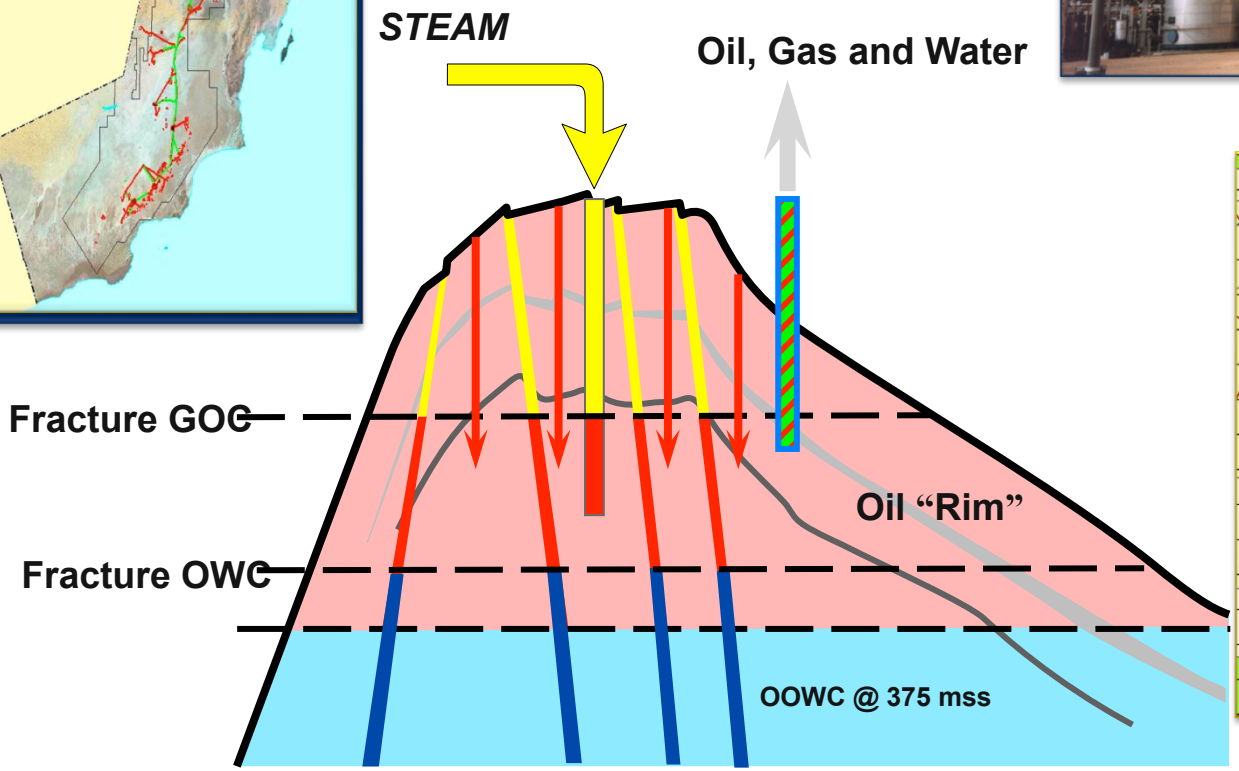


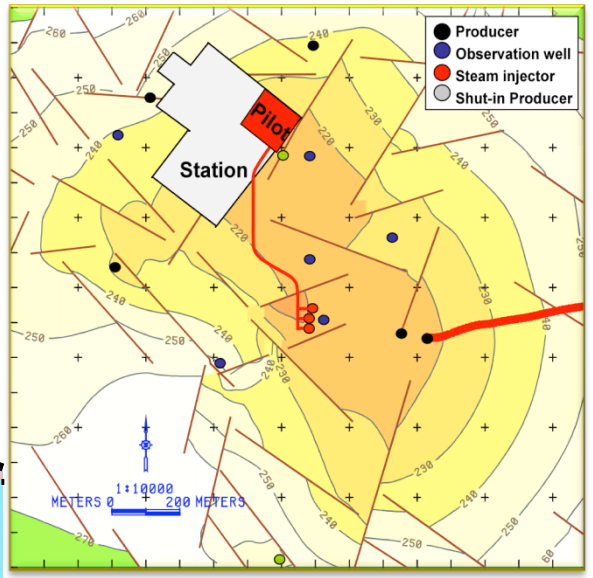
Qarn Alam Steam Injection – Steam-Assisted Gravity Drainage



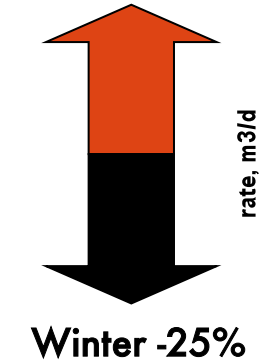
Fractured Carbonate

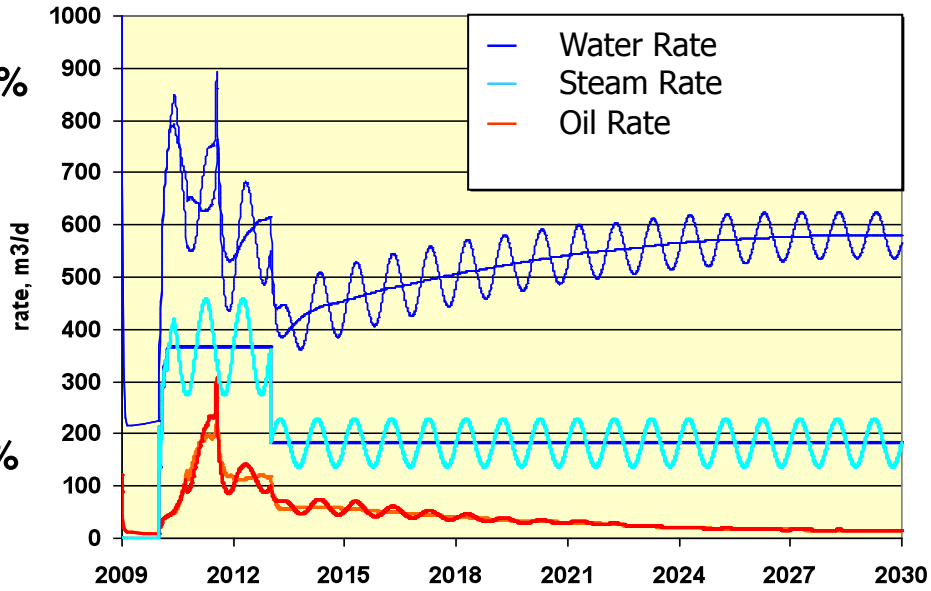
Viscous Oil





Energy Efficient EOR : Solar Steam Generation

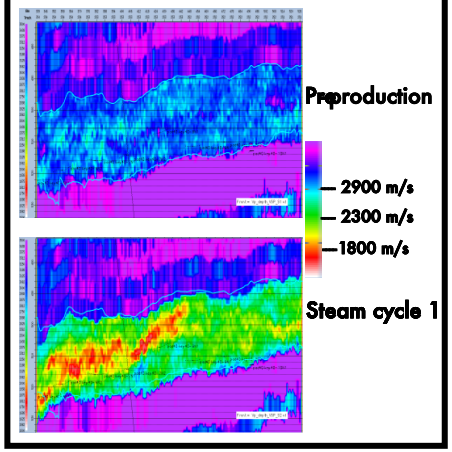


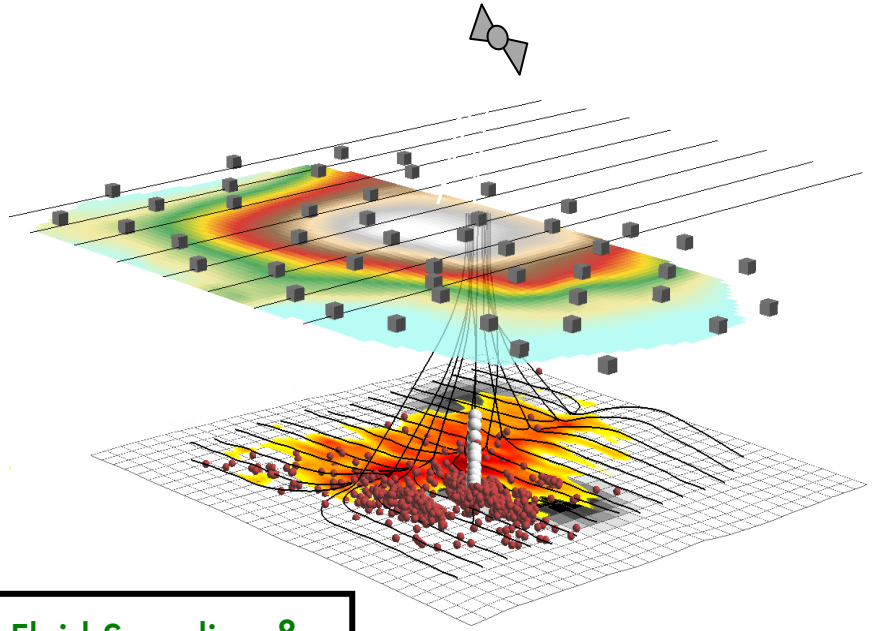


- Oil recovery primarily driven by cumulative steam injection
  - Daily cycles have no impact on oil rate or recovery
  - Yearly cycles show up in oil production rates
- Demonstration in Oman

Surveillance is key for EOR

4D Seismic





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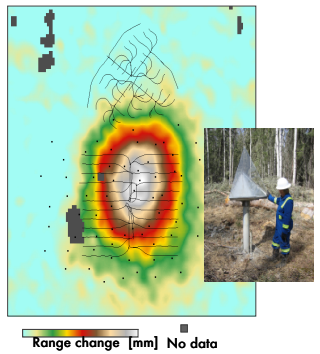
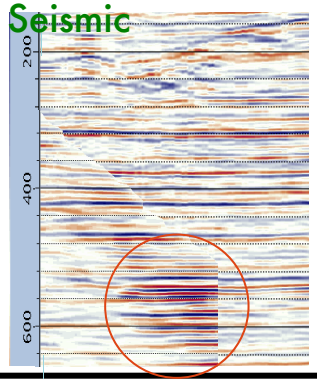
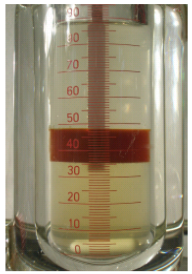


Virtual Source Seismic



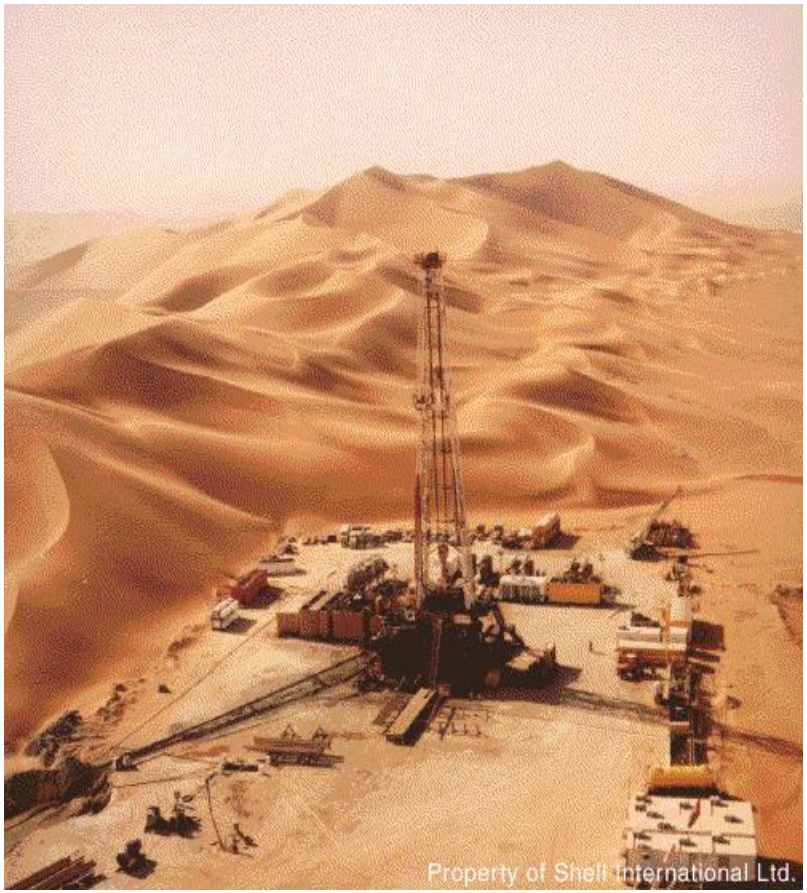
Fluid Sampling & chemical an



Are we making full use of all data

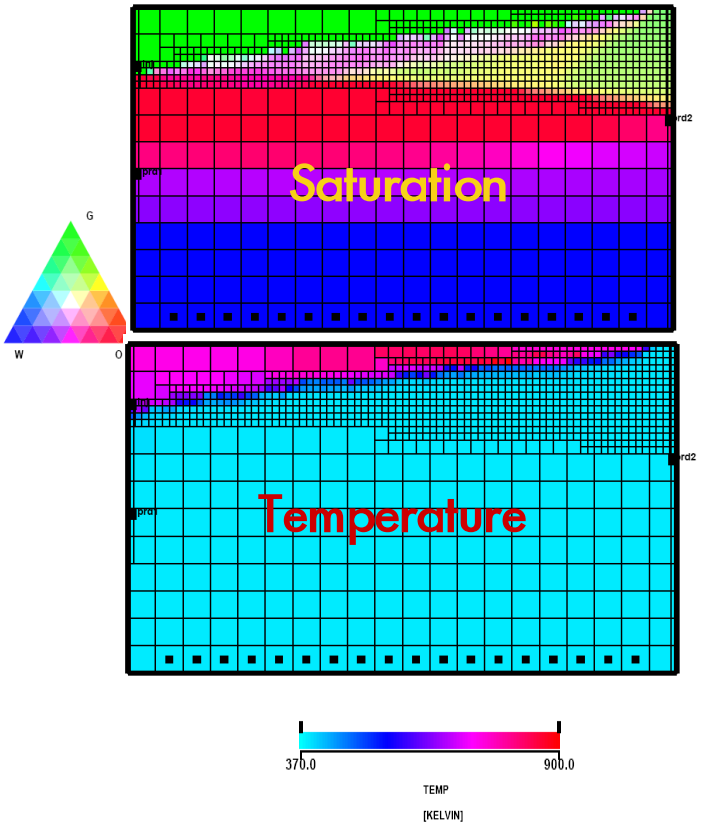
Are there novel options for surveillance

Moving EOR Offshore - Challenges

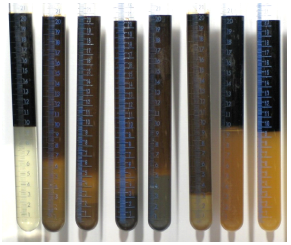


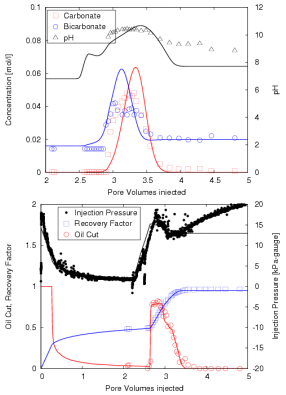
New EOR Modelling Capability

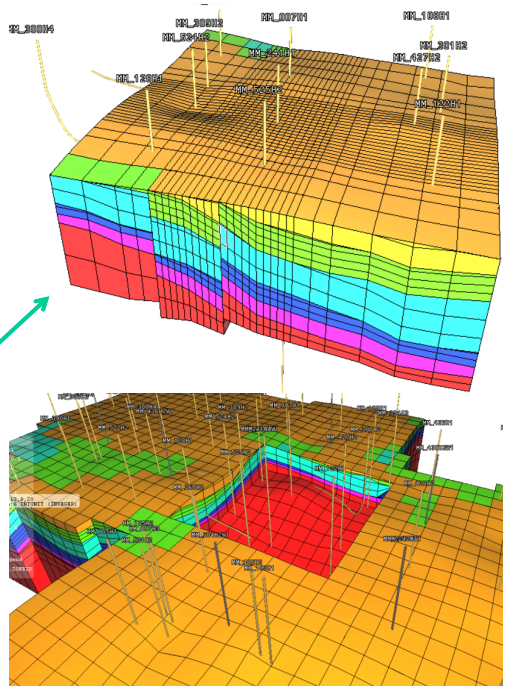
High Pressure Air Injection (Thermo Gas EOR)



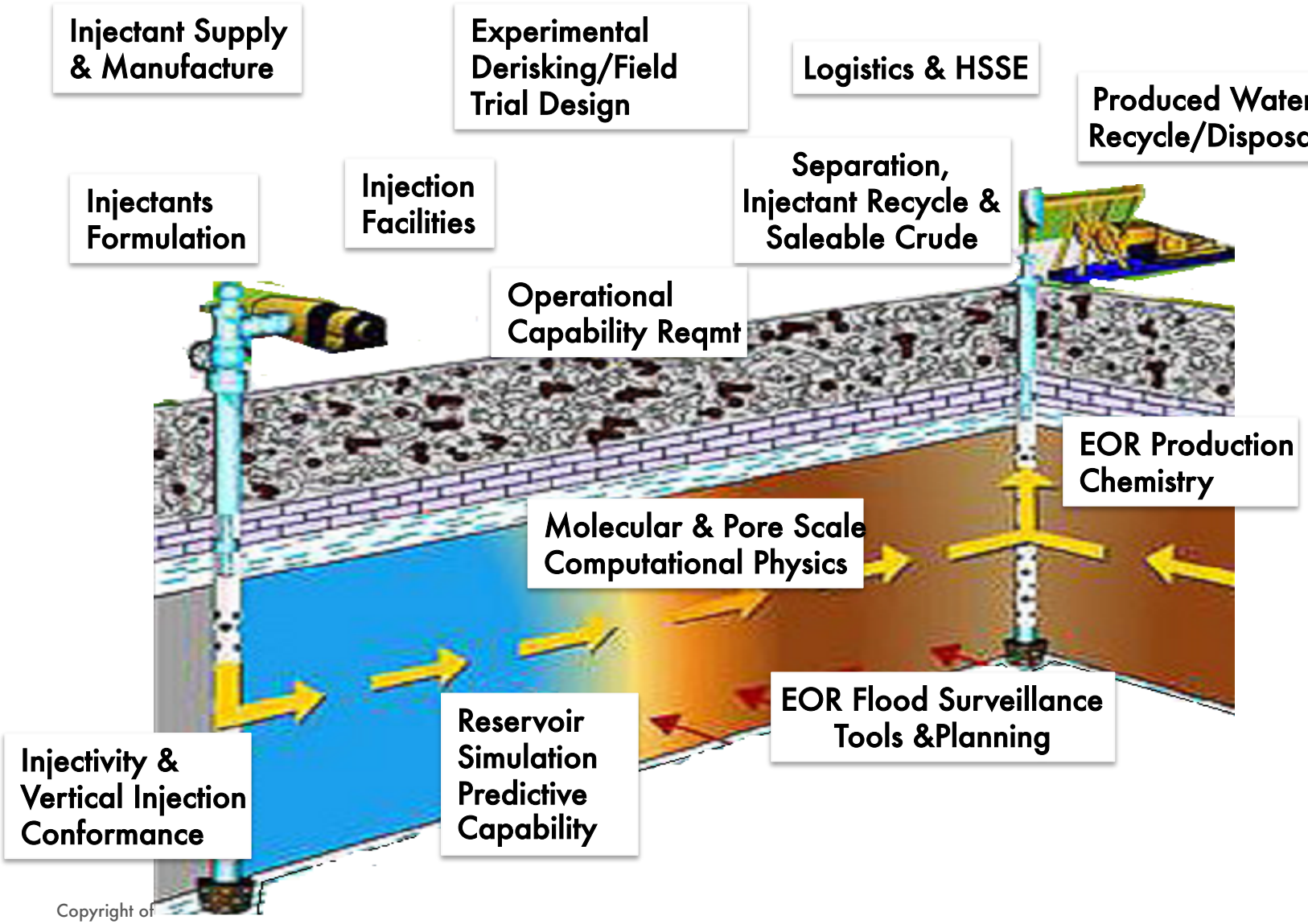
Alkaline Surfactant Polymer







EOR Capability Requirements & Deployment Elements



EOR Challenges, Experiences and Opportunities

- Life Cycle View – A plan for maximizing recovery
- Selection from Full Toolkit – Right technology for the reservoir
- Cost reduction – Technology, design & operating model
- Fiscal Terms – Enabling commercial environment
- EOR Well and Reservoir Management – Data analysis & response
- Energy Efficiency & CO2 Footprint – Novel ways to generate steam
- Integration & Implementation – Integrated technology solutions

- People – New skills and more integrated ways of working

Common Challenge: Coupled processes with complex geology and complex wells