CASE STUDY

HALLIBURTON

North Sea

Integrated SCAL accelerates reservoir insight for revised depletion strategy

Digital and physical core analysis improves confidence in relative permeability for a complex chalk reservoir

CHALLENGE

- Heterogeneous chalk with high porosity, low permeability, and complex pore structures
- Long turnaround times and high uncertainty in physical SCAL tests
- Difficult to capture wettability effects and representative flow behavior

SOLUTION

- Developed 3D digital rock models with FIB-SEM and micro-CT imaging
- Simulated capillary pressure and relative permeability with DRP
- Benchmarked digital results against physical SCAL data for validation

RESULT

- Delivered relative permeability curves one year ahead of lab data
- Achieved good agreement between digital and physical Kr curves
- Allowed for early decision-making and improved reservoir modeling for Hod formation

Overview

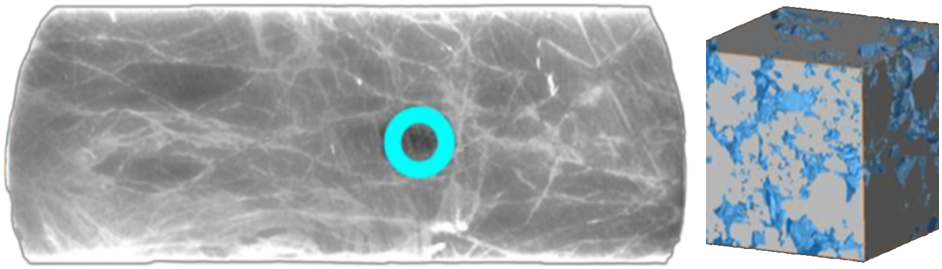
A North Sea operator and Halliburton collaborated to evaluate the relative permeability (Kr) of the Hod formation in the Valhall field, a mature chalk reservoir in the Norwegian North Sea. The Hod formation, though less developed than the overlying Tor formation, holds significant untapped potential. However, its heterogeneity and low permeability posed challenges for traditional core analysis workflows.

To address these issues, the team implemented an integrated approach that combined physical steady-state Special Core Analysis (SCAL) with digital rock physics (DRP). This integrated strategy allowed for early delivery of key reservoir properties and provided a robust framework to reduce subsurface uncertainty.

Challenge

The Hod formation exhibited complex heterogeneity, which included brecciated and cemented features that complicated core preparation and testing. Traditional SCAL methods, particularly steady-state relative permeability measurements, proved time-consuming and sensitive to sample quality and wettability conditions.

Additionally, the nano-scale pore environment of chalk made it difficult to obtain representative flow data. These limitations threatened the ability to generate reliable Kr curves in time to support a revised depletion plan for the field.



Micro-CT of one rock sample showing extensive fractures (left) and the segmented FIB-SEM volume of the matrix and pore (right).

Solution

To overcome these challenges, the team implemented a comprehensive workflow that included:

- Core selection and imaging: Whole-core CT scans and seal-peel imaging guided the selection of representative plugs. The team used multi-resolution Micro-CT and FIB-SEM imaging to construct high-resolution 3D digital rock volumes.
- Digital SCAL simulations: The team used the Lattice Boltzmann method to perform digital simulations of capillary pressure (Pc) and relative permeability (Kr) under various wettability scenarios. The team then calibrated these simulations with MICP data and validated them against physical measurements.
- Physical SCAL benchmarking: The team conducted steady-state Kr experiments on carefully prepared plugs. In situ saturation monitoring (ISSM) and bump floods provided high-quality data for comparison.

Result

The digital SCAL workflow delivered a complete set of relative permeability curves approximately one year ahead of the physical lab results. The digital and physical Kr curves showed strong agreement, particularly for oil-relative permeability underwater-wet conditions. This early insight allowed the operator to confirm the viability of water injection in the Hod formation, improve the accuracy of dynamic reservoir models, and reduce uncertainty in residual oil saturation estimates.

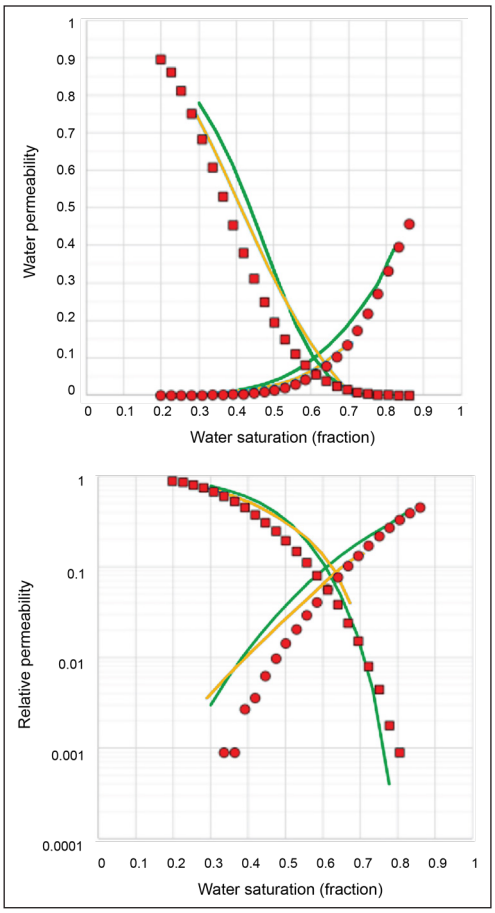


Figure 1

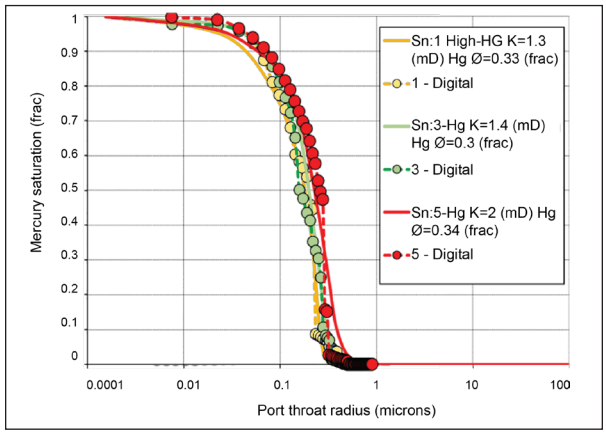


Figure 2

» **FIGURES -** A comparison of physical (dots) and digital (solid lines) relative permeability (figure 1) and capillary pressure (figure 2) results showing good agreement between the digital and physical flow experiments and underlining the value of Digital Rock Physics in delivering data nearly one year ahead of the physical results.

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