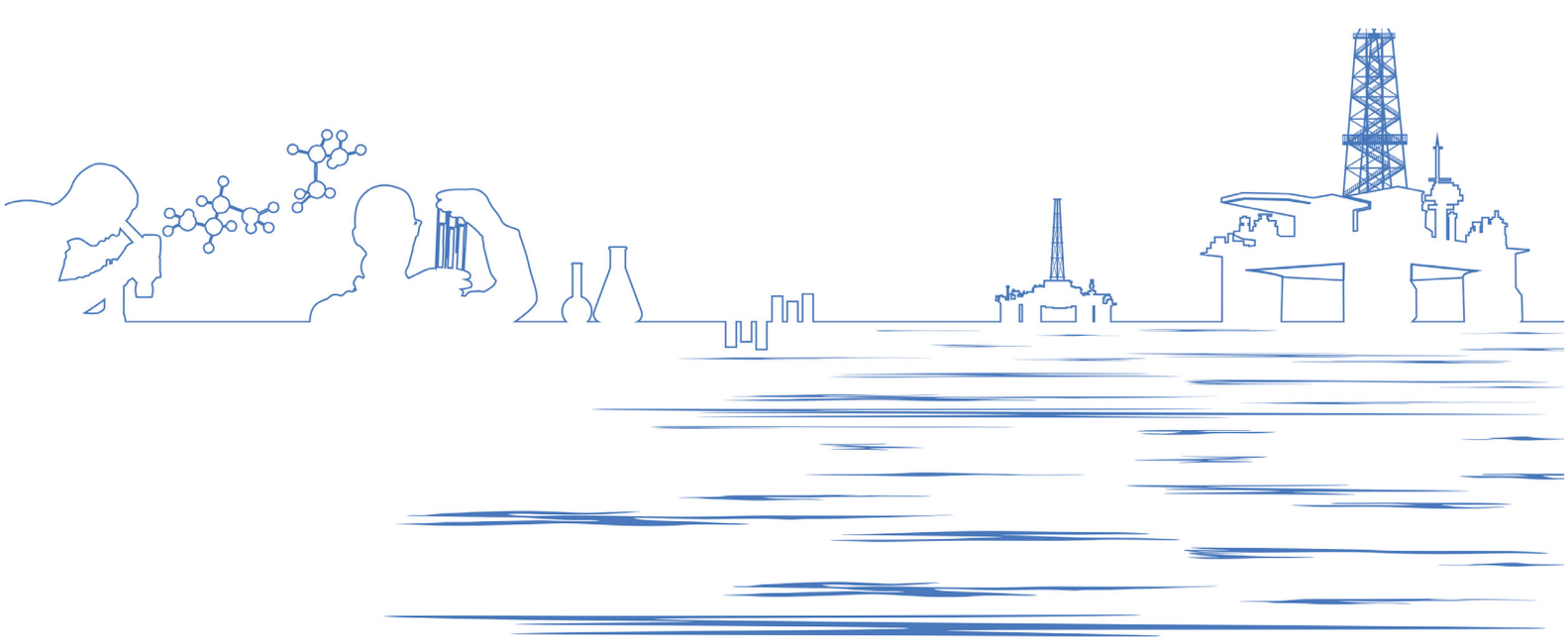
DHRTC Research

Poster Abstracts



Danish Hydrocarbon Research and Technology Centre
Technology Conference 2017

Poster abstracts from Work Programme

Advanced Water Flooding 1

Development of Ekofisk

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Untangling The Chemical Knot of Crude Oil

Jonas Sundberg, DHRTC

A detailed knowledge of the molecular composition of crude oil and reservoir fluids is fundamental to understand its formation, physical properties and macroscopic behavior. However, even when coupling chromatography with state of the art high-resolution-accurate-mass mass spectrometry (MS), the complexity of crude oil presents difficulties in obtaining full molecular coverage. Chemical features become "hidden", and the detection of certain compounds is discriminated in favor of others. In practice, only a small part of the picture is seen.

Our aim is to develop advanced analytical workflows, from sample preparation to data analysis. By using multi-dimensional separation techniques and complementary MS-ionization sources, we wish to improve the overall resolving power. This will allow the assignment of elemental compositions with increased coverage. Using these methods, we will characterize crude oil that has been sampled from the Danish North Sea. The data will provide spatial and temporal information of geochemical, petrochemical and environmental importance. Secondly, they will be applied to follow the compositional change of reservoir fluids during enhanced oil recovery (EOR) experiments. A deeper understanding of the underlying processes at a molecular level will ultimately aid in the development of more efficient recovery methods.

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The Effect of Reservoir Pressure Depletion on Well Productivity in Fractured Reservoirs

Teeratorn Kadeethum, Saeed Salimzadeh, Hamid M. Nick

Danish Hydrocarbon Research and Technology Centre, Technical University of Denmark, Lyngby, Denmark

Many production wells in North Sea reservoirs suffer from intense productivity reduction during primary production. These reservoirs are naturally fractured reservoirs; hence, fractures probably take main responsibilities for this decline. During a primary recovery, pressure-depletion increases effective stresses; and increases contact stresses on the fracture surfaces, subsequently reduces a fracture aperture and the fracture hydraulic conductivity. The objective of this study is to investigate the extent of mechanical effects on the fracture closure and corresponding productivity reduction. Flow through fractures are modelled using the cubic law, the fracture stiffness is captured using both linear and classic Barton-Bandis model. The equations are solved both analytically (for simple geometry) and numerically using the finite element code, CSMP (see Figure 1). The production history of a well in the North Sea has been used for benchmarking, and sensitivity analysis is performed to understand the effect of each parameter on the productivity reduction as well as interactions between each variable.

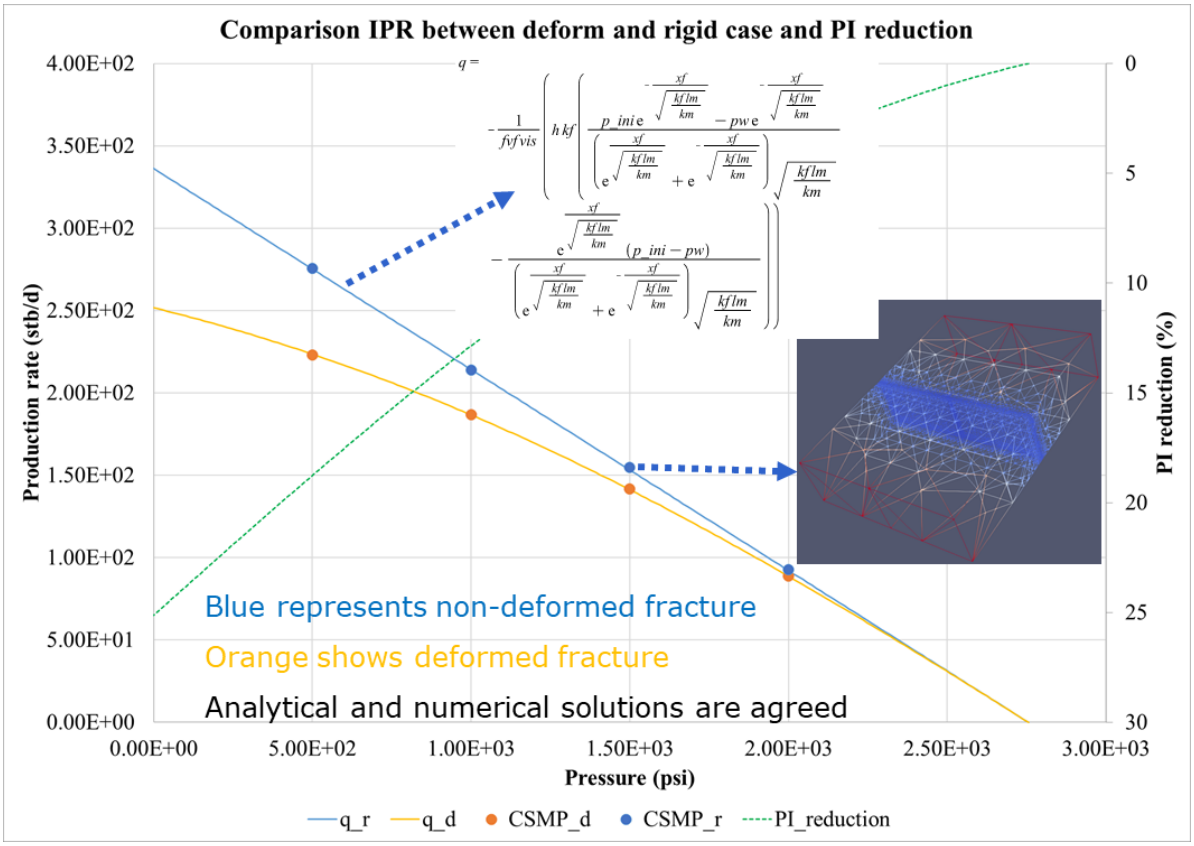

Figure 1 Steady-state production comparison between analytical and numerical solutions

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Infrared Spectroscopy for the Investigation of Molecular Association Mechanisms and the Fast Screening of Petroleum Fluid Constituents

D. Mihrin[1], *C. Hoeck*[2], *J. Andersen*[2], *R. Wugt Larsen*[2] *and K. L. Feilberg*[1]

[1]*The Danish Hydrocarbon Research and Technology Centre (DHRTC), 2800 Kongens Lyngby, Denmark*
[2]*Department of Chemistry, Technical University of Denmark, 2800 Kongens Lyngby, Denmark*

Far-infrared cluster spectroscopy enables a *direct* assessment of the interaction strengths and molecular association mechanisms for dimethyl-ether (DME) with polar petroleum constituents and provides inputs for thermodynamic models of strongly associating DME-fluid mixtures. In a second approach, we are developing a reliable spectroscopic screening approach for the identification of organic acids, which adhere strongly to rock surfaces and are suspected to play a crucial role for oil recovery mechanisms.

Density Measurements of Brine, Oil and DME Mixtures at Dan Field Conditions

S.A. Jones, H. Javanmard and S. Marie Nielsen

Di-Methyl Ether (DME) is a potential EOR fluid that can be used at either the secondary or tertiary EOR stage. The DME is injected in solution in brine, but is preferentially soluble in the reservoir oil, so when it contacts with the oil, it transfers, causing the oil to swell and mobilise. An understanding of the changes, in both the brine and oil, when mixed with DME is therefore very useful in interpreting core flood data.

Tests have been carried out using a simple flow set-up to determine the density of the fluids at the Dan reservoir conditions of 60°C and 190bar. The density of both the brine and the oil were found to change linearly with DME concentration, although brine tests were limited at 10% maximum solubility.

Fracture Characterization and Modelling in the Kraka Field

T.M. Aabø, M.J. Welch, J.S. Dramsch, M. Lüthje, S. Seyum, F. Amour and C. L. Würtzen

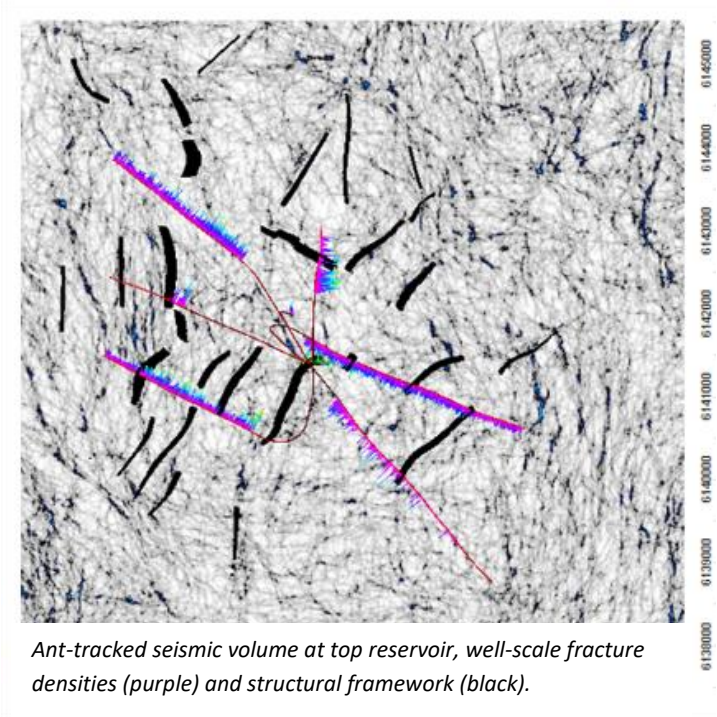
Center for Oil and Gas – DTU

The Kraka Field is an anticlinal structure induced by halokinesis, located in the Danish Central Graben. It is produced through depletion of the naturally fractured Ekofisk Formation of Danian age, which is a widespread chalk reservoir offshore Denmark.

The Kraka fracture pattern has been mapped through borehole images, core- and seismic data prior to upscaling and fracture modelling. Two main fracture trends were identified in the Ekofisk Formation. The first is a NNE/NE trending regional fracture set, which has consistent orientation across the Kraka structure. This trend is parallel or near-parallel to the main fault system, mapped through 3D seismic interpretation, which aligns with the local maximum horizontal stress. The second set consists of fractures trending parallel or perpendicular to contours of the Kraka dome. This fracture set is therefore thought to have formed during halokinesis, and it is expected to follow the strain evolution of the Kraka chalk. Both sets occur as fracture swarms and as isolated features.

High resolution lineations mapped on two ant-tracked cubes (generated through RGB-image processing of the 3D seismic volume and through a variance cube, respectively) shows a good correlation with the well-scale fracture trends and with the structural framework in Kraka. Moreover, an additional structural trend related to the domal structure was identified in the lineations: shallow dipping faults (<30°) dipping away from the contours of the dome. These faults are likely related to an E-W compressional event, which occurred during inversion phases in the Late Cretaceous evolution of the Central Graben.
Localized variations in the fault pattern occur due to re-activation of older, Mesozoic structures.

The Kraka fracture pattern established during the reservoir characterization of the field was successfully reproduced in terms of main orientations in an industry-standard discrete fracture network model (DFN). Resultant fracture parameters (e.g. apertures and length), are however associated with a larger degree of uncertainty. This demonstrates the need for geomechanically based DFNs, to achieve an improved understanding of the fracture distribution in the chalk reservoir.

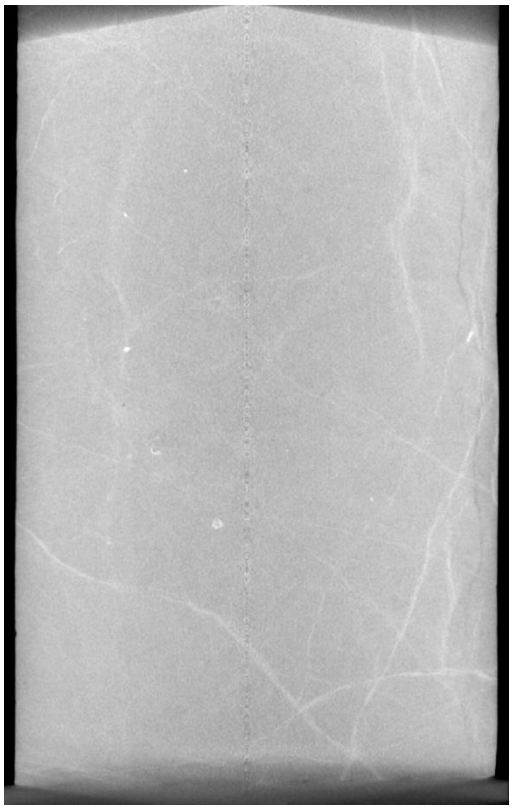


Ant-tracked seismic volume at top reservoir, well-scale fracture densities (purple) and structural framework (black).

Porosity variability in chalk and the scale of variations

Peter Frykman (GEUS), Anders Nymark Christensen (DTU-Compute)

The project has applied novel techniques to image and analyse porosity variations of sub-mm to dm scale in chalk material of decimetre dimensions. The advanced high energy CT-scanning applied for high-resolution imaging of chalk rock requires development of a scanning and reconstruction procedure to account for artefacts, calibration, and treatment of positioning requirements. The first scanning attempts with the advanced equipment reveal important internal heterogeneity features such as very thin fractures, healed-hairline fracture sets, trace-fossils and mineralisations, some of which cannot be detected on the core surface. The application on high-porosity outcrop chalk allows absolute quantification of porosity by exploiting difference-images (saturated and unsaturated) in order to display the porosity variations at very high resolution.



Core 12 cm diameter showing healed hairline fracture network

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Characterization of chalk reservoir analogues using seismic shear waves

Janina Kammann[(1,)], Carsten Albrechtsen[(1)], Alireza Malehmir[(2)] and Lars Nielsen[(1)]*

(1) Department of Geosciences and Natural Resource Management, University of Copenhagen, Copenhagen Denmark

(2) Department of Earth Sciences, Uppsala University, Uppsala, Sweden

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Characterization of onshore chalk reservoir analogues using high-resolution shear wave seismic data has a great potential to add new, detailed understanding of changes in petrophysical parameters and their direct impact on the observed seismic reflectivity. Here, we mainly present shear-wave data examples in order to illustrate the quality and difficulties that can occur during acquisition. The shown data sections are from two field sites in Denmark: (1) Stevns Klint and (2) the Rordal chalk quarry.

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Influence of clay on Chalk diagenesis

Tagliavento, Mattia [1], Stemmerik, Lars [1]*
1) Natural History Museum, University of Copenhagen, Denmark
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In the present study we investigate these intervals in a shallow core, Dalbyover-1, drilled in the central axis of the Danish-Norwegian basin in northern Jylland. Visual inspection of the core have been supplemented by X-Ray Diffractometry (XRD) analysis of the insoluble residues in order to determine the exact mineralogy of the clay; ^{13}C and ^{18}O isotope geochemistry to highlight differences between the layers; isotopic value of ^{34}S and its concentration to evaluate the presence of bacterial activity during the sediment burial, porosity and permeability data and extensive investigations of the microfabric using Scanning Electronic Microscopy (SEM) on non-polished rock surfaces. The integrated dataset allowed us to propose a model where $CaCO_3$ was exported from the marls and partly reprecipitated in the chalk during early burial. This process, correlated with changes in the mineralogical phases present (i.e. clay, pyrite, dolomite) lead to change in petrophysical property.

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Comparing porous plate saturation with evaporation saturation in core-flooding experiments

Hanne Dahl Holmslykke (GEUS)

Dan Olsen (GEUS)

The porous plate method is compared with the evaporation method as means for establishing the initial saturation state in core-flooding experiments. Porous plate drainage typically takes 4 to 8 weeks, but it may take 12 weeks or more for tight rocks or low target Sw. Using the evaporation method (Springer et al. 2003), the initial saturation state may be established in 2-3 weeks. The present work intend to investigate whether the two methods are interchangeable in the sense that the choice of method do not influence (1) the recovery in core-flooding experiments, and (2) the fluid distribution within the samples.

Two plus two chalk samples are used in similar core-flooding experiments after preparation with, respectively, the porous plate method and the evaporation method. After the first series of experiments the sample sets are swapped and the experiments are repeated. The experiments are compared with respect to recovery profiles, ultimate recovery, and homogeneity in CT scanning.

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Relationships between reservoir properties and production-related changes in effective vertical stress (the Kraka Field, Danish North Sea)

F. Amour, M. Welch, S. Seyum and E. Galdal

Flow properties of chalk reservoirs can significantly evolve through time due to rock deformation caused by pressure depletion, involving challenges during hydrocarbon production and enhanced oil recovery. The present study aims at identifying the relationships between petrophysical and mechanical compartments in chalk reservoirs, and recognizing which compartments are likely to deform appreciably due to production-related increase in effective vertical stress.

Based exclusively on subsurface data, we use visual inspection of cores, well correlation, and X-ray diffraction (XRD) and well log analyses to provide information on the rock fabric and stratigraphy. Mechanical properties values of chalk are derived from iso-frame conceptual models and triaxial test results, and fluid pressure data are used to estimate effective vertical stress at reservoir conditions. Well correlation indicates that the Kraka reservoir consists of petrophysical and mechanical units that vary vertically and laterally. While chalk porosity is mainly controlled by the amount of non-calcite residue, mechanical behaviour of chalk likely results from the degree of lithification.

Changes in estimated effective vertical stress due to pressure depletion over a 25 years production history led to brittle deformation of high porous chalk compartments initiated between 1991 and 1997. Such partitioning in flow and mechanical behaviour across a reservoir needs to be assessed in order to enhance our ability to predict the evolution of the network of flow conduits and baffles over a field's lifetime and, thus, optimise hydrocarbon sweep efficiency.

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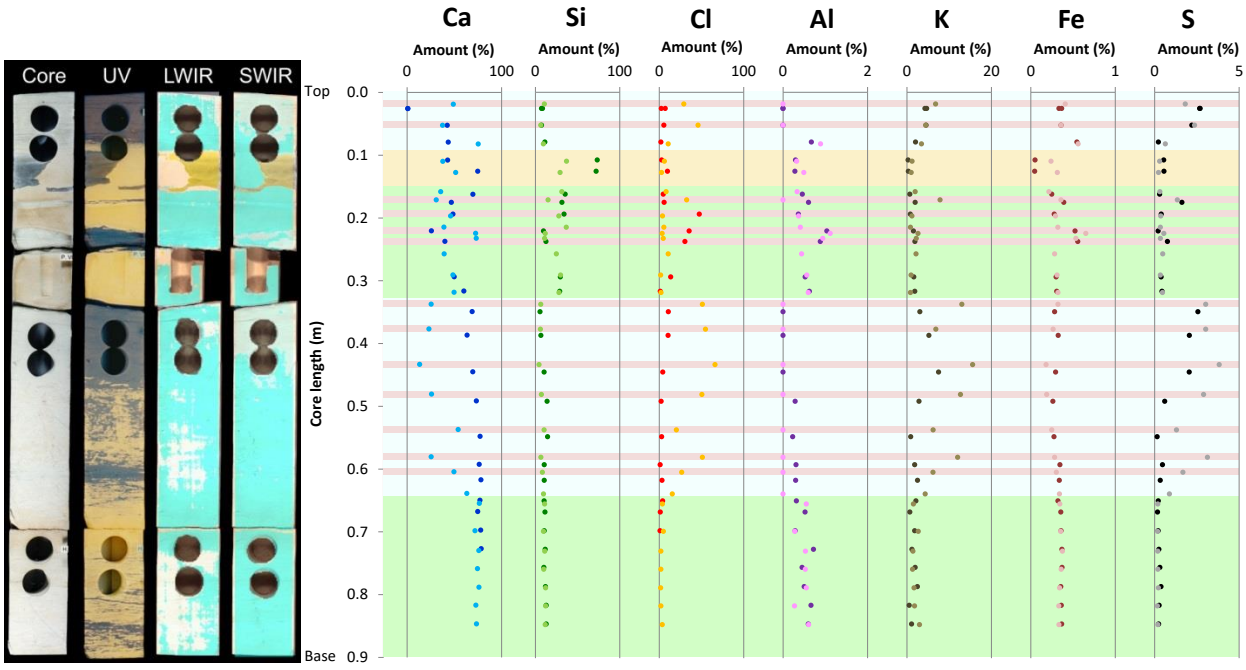
Hyperspectral scanning of chalk cores for efficient facies/lithology mapping

Morten L. Hjuler[1], Finn Jakobsen[1], Niels Schovsbo[1], Rikke Weibel[1] & Paul Linton[2]

[1] Geological Survey of Denmark and Greenland (GEUS), Øster Voldgade 10, DK-1350 København K, Denmark
[2] TerraCore, Wits University, George Area, South Africa

Hyperspectral Imaging of rock surfaces within the near-infrared - shortwave infrared (VNIR-SWIR) spectra and the longwave infrared (LWIR) spectra have been used to characterize mineralogical and textural differences in silicified chalk from a cored interval of a North Sea well. First step is to calibrate obtained spectra to actual core mineralogy. This will be done by performing SEM, XRD and insoluble residue (IR) analyses and using the obtained mineralogical data as reference for the spectral data. Further, a comparison to hand-held XRF (*hh*-XRF) is performed. After calibration of the spectral data, the efficiency of hyperspectral imaging as a lithological tool is evaluated. The mineralogy of the core material will be identified and various degrees of silicification of the chalk will be evaluated. As a first conclusion, hyperspectral imaging provides a fast and cost-efficient method of mapping continuous lithological and facies variations in core material.

Core photos	Hyperspec. imaging	*hh*-XRF



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Effect of temperature and potential ions on North Sea chalk wettability

*Adeel Sohal, Erica Godinho, Geoffrey Thyne, Kasper Steffensen & Erik G.Søgaard**
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More oil can be recovered from mature oil fields like Ekofisk by adjusting the wettability to optimum conditions. The Modified Flotation Test (MFT) method was used to understand the significance of the potential scale forming ions (PSFI's) present in the formation water (FW) and the potential determining anions (PDA's) on chalk wettability. A comparison between wettability measurement by flotation and contact angle demonstrate flotation produces very similar results, although different crude oil-brine-rock system (CBR) were used in both techniques. The absence of PSFI's in FW led to an overestimation of chalk water-wetness, and exclusion of these ions from laboratory brines (*s.l.*) may produce unrealistic results regarding the wetting conditions in the real reservoir system. It was also observed that the system became more oil-wet as temperature and concentration of the sulfate ion in injected brine increased.

The poster belongs to Advanced Water Flooding 1 – Development of Ekofisk.

UNDERSTANDING THE DANIAN

Bodil W. Lauridsen, Kasper Blinkenberg and Lars Stemmerik, KU

The Danian chalk deposits occur from the North Sea reservoirs in the Ekofisk Formation to the various facies in the shallower onshore part of the basin. The difference in reservoir properties compared to the Upper Maastrichtian Tor Formation and the common occurrence of silica in various forms still poses questions to the optimal exploitations of hydrocarbon resources. Recent work on middle Danian chalk localities in the northwestern part of the Danish Basin where it is developed as a chalk mudstone, as opposed to the otherwise common bryozoan wackestones, shows new aspects of the Danian chalk environment. Here the chalk is soft, with a low diversity benthic fauna and a relatively large amount of unevenly distributed flint and silicified chalk. All the recorded species in the fauna show special adaptations to survival in this relatively deep and nutrient poor setting. Many species are Mesozoic survivors from the Late Cretaceous chalk sea. By studying the fauna and the diagenesis from the onshore middle Danian localities, we improve our understanding of the Danish Basin, the hydrodynamic patterns, distribution of nutrients and taphonomic processes. These detailed studies are significant contributions to a further understanding of Danian chalk in the North Sea.

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Chalk porosity and improved hand-held X-ray fluorescence spectrometry (HH-XRF) for cuttings and core

Christian J. Bjerrum and Emma R. Haxen, KU

Department of Geosciences and Natural Resource Management, University of Copenhagen

Hand-held X-ray fluorescence spectrometry (HH-XRF) is a fast and non-destructive method for the chemical analysis of cuttings and core. However, understanding interference from matrix effects is crucial for data quality. We quantify the porosity-based error for different elements and improve calibration procedures. Based on preliminary results, we also explore the possibility of developing an HH-XRF-based porosity proxy. Potentially, industrial application of the method could be developed towards offshore deployment for near real-time characterization of the porosity and chemical composition of reservoir rocks.

Category: Advanced Water Flooding 1

Hydrocarbon Fingerprinting of Kraka and neighboring oil fields - Tracking temporal changes in oil and core samples during long term production and EOR experiments

Kristoffer G. Poulsen [a], *Karen Louise Feilberg* [b] *and Jan H. Christensen* [a]

[a] *University of Copenhagen, Plant and Environmental Sciences, Thorvaldsensvej 40, 1871 Frederiksberg, Denmark.*

[b] *Danish Hydrocarbon Research and Technology Centre – DTU, Elektrovej Bygning 375, 2800 Kgs. Lyngby, Denmark.*

Presenter: Kristoffer Gulmark Poulsen: employed as Project leader at Research center for Advanced Analytical ChEmistry (RAACE). Email: krgp@plen.ku.dk

Temporal characterization of the hydrocarbon composition for relevant DUC oil fields during long term oil production and core-flooding experiments. Oil and core samples are analyzed using state-of-the-art analytical platforms (e.g. GC-MS, GCxGC-HRTOFMS and LC-HRTOFMS) coupled with chemometric data treatment in order to describe the polar and non-polar hydrocarbon fraction with respect to geochemical properties (e.g. source rock, thermal maturity, biodegradation) and enhanced oil recovery (EOR).

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Cementation features in fractured chalk: A petrographic study based on optical microscopy, the Kraka Field (Danish North Sea)

Aslaug C. Glad[1] and Frédéric Amour[1]
[1]Danish Hydrocarbon Research and Technology Centre, DTU, Denmark

The Kraka Field in the southeastern part of the Danish Central Graben is an anticlinal structure induced through several phases of halokinesis spanning from the early Late Cretaceous to Paleocene. The Kraka reservoir consists of the Ekofisk Formation of Danian age, a naturally fractured and overpressured chalk interval, subdivided into the upper Danian Porous and the lower Danian Tight units. Average matrix permeability of pure chalk is 0.88mD and the fracture network is the main driving factor of fluid flow within the reservoir. The orientation, distribution, density and origin of faults and fractures were previously investigated using core, borehole imaging, and seismic data. However, petrographic studies on the type, distribution, and geometry of cements precipitating along fractures are still missing. Characterizing the cement optically will significantly strengthen the work with identifying phases of fracturing and cementation filling the fractures during burial, their relative timing, and impact on effective rock permeability.

The present study aims at characterizing the types and phases of cements that precipitates along fractures. Visual inspection of cores provides information on fracture geometries and changes in cement filling at a macro-scale. Seventeen thin-sections are studied petrographically using optical microscopy in order to identify cement phases. The fractures are locally folded and show signs of brittle deformation along the vertical axis. The occurrence of clay-rich laminae influence fracture propagation. In addition, fractures are categorized into two groups according to the types of cement observed. The first set of fractures shows an early, polyphase quartz cementation followed by a calcite cementation. The second set of fractures suggests two successive calcite cementation phases separated by a period during which fractures may have remained open.
Isotopic analyses of calcite cement precipitating along fractures and bulk rock adjacent to fault planes (wells A2, A3 and A-5P) are compared to the petrographic findings to identify the origin of the brines from which calcite cement precipitated and better constrain the relative timing between different cementation phases during burial of chalk in the Kraka reservoir.

Analysis of Reservoir Water Samples and Injection Water for Enhanced Oil Recovery

Sofie Nitsche Gottfredsen and Karen Louise Feilberg, Centre for Oil and Gas – DTU.
Presented by PhD student Sofie Nitsche Gottfredsen

To improve existing enhanced oil recovery (EOR) techniques it is important to understand the underlying mechanisms that take place in the reservoir. Evidence exists that lower total salinity and higher content of certain divalent ions including sulphate (SO_4^{2-}) and magnesium (Mg^{2+}) can in some cases lead to higher recovery. The effect on North Sea chalk is being investigated by analyzing the ionic composition and the changes herein in different fluid samples that has been in contact with chalk. For this Inductively Coupled Plasma – Optical Emission Spectroscopy (ICP-OES) and Ion Chromatography (IC) is used. Analysis of produced water samples will be compared to laboratory experiments and data from e.g. flooding experiments and models. From this, we will investigate the effect of salinity on recovery.

Work Programme: Advanced Water Flooding 1 – Development of Ekofisk
(with relevance to Cost Transformation 2 - Transformation of Asset Cost)

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Mechanical effect of chert nodules in chalk on fracture lengths, apertures, and spacing

Solomon Seyum

Interactions of fractures with chert nodules in chalk are described in core from Ekofisk and Tor Fms., and compared to measurements in chalk at Stevns Klint. In large-scale models of flow through fractures, chert nodules are ignored because their impact on fracture lengths, spacing, and apertures controlling permeability, is not well known despite their notable presence in chalk. Key geometric quantities of fractures from measurements are used to build and constrain numerical, fracture mechanics models to evaluate the effect of mechanical quantities on fracture geometries. Fracture development is affected by chalk-chert elastic stiffness contrasts, fracture positions relative to chert, chert/fracture length ratios, and remote stress magnitudes and orientations.

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Phase Equilibrium Modeling for the DME Enhanced Water-flooding

Christos Tsanas, Erling H. Stenby, Wei Yan

Center for Energy Resources Engineering (CERE), Department of Chemistry, Technical University of Denmark, 2800 Kongens Lyngby, Denmark, email: weya@kemi.dtu.dk

Dimethyl ether (DME) has recently emerged as a novel-solvent in water-flooding enhanced oil recovery (EOR), because it can be dissolved in both the oil and the water/brine phase. DME dissolves preferentially in the oil phase (first contact miscible), causing swelling and reducing the viscosity of the oil, thus improving its mobility. Dynamic modeling and DME enhanced water flood simulations require accurate phase description. The purpose of this work is to provide satisfactory modeling of the DME partitioning between the oil and the water/brine phases. Two models were used: the Cubic Plus Association (CPA) equation of state (EoS) and cubic EoS (CEoS) with Huron-Vidal (HV) mixing rules. Parameters for CPA and CEoS-HV were regressed for binary systems of DME with water, several HCs, carbon dioxide and nitrogen. Overall the results were satisfactory. Finally, predictions with CPA were made in ternary mixtures of DME/water/HC. DME/water required temperature dependent parameters to capture sufficiently the experimental data, whereas the rest of the systems needed only one temperature independent parameter. Analysis of the modeling results can provide beneficial information to the planning of core flood experiments.

Category: Advanced Water Flooding 1 – Development of Ekofisk

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Spatial distribution of porosity in North Sea Chalk, Denmark

Aurelien Meyer, Lars Stemmerik and Meysam Nourani , KU

Abstract: This study elaborates an innovative approach to investigate the spatial variability of porosity in chalk using outcrop plug data and SEM images of polished thin sections. Chalk porosity reveals to be more complex and heterogeneous than usually assumed. Unexpectedly, spatial variability increases as the observation scale decreases. Pore volumes in outcrop plug samples may vary by 10 % over decimetres although no change in microfacies, grain size or diagenetic overprint is discernible. Porosity distribution within "homogeneous" thin sections commonly varies by a factor of 2-3.

Modelling of Modified Salinity Waterflooding: A Comparison between the Mechanistic and Empirical Models

Hadise Baghooee, Ali A. Eftekhari, Hamid M. Nick

Water flooding is the most widely applied method of improved oil recovery. The majority of the studies show that lowering or modifying the salinity of the injected water seems to alter the wettability towards more water-wet conditions and increases the displacement efficiency of water-flooding. Different mechanistic and empirical models have been suggested to investigate the effect of modified-salinity water flooding on the production history and the ultimate oil recovery. In this study, we model a set of core flooding experiments on the Stevns Klint chalk samples using empirical models and compare the results with an in-house mechanistic model. We first obtain the relative permeability parameters by fitting (history-matching) a two-phase flow model to the reported core flooding recovery data in different formation brine and injection brine compositions. For the empirical group of models, we assume that salt is transported as a pseudo-component in the aqueous phase with/without adsorption on the rock, and we assume that the relative permeabilities are a function of the total salinity. The results show different saturation fronts when the adsorption is included in the model.

Experimental Study of the Potential of Dimethyl Ether EOR in North Sea Chalk Reservoirs

Hoda Javanmard, Mojtaba Seyyedi, Sian Jones, Sidsel Marie Nielsen

The present study aims at quantifying, at the laboratory scale, the potential of Dimethyl Ether (DME) Enhanced Oil Recovery (EOR) technology to improve oil recovery in North Sea chalk reservoirs. In DME EOR, the DME is dissolved into the brine and injected into the reservoir. The DME is mutually soluble in the water and oil phases with documented strong partitioning into the oil phase. Thus the DME migrates from the water phase to the oil phase, leading to oil swelling and mobilization of residual oil.

A series of core flood experiments have been carried out at reservoir conditions on aged core plugs from a North Sea chalk reservoir. The results reveal the significant potential of DME-saturated brine injection in improving oil recovery, with the secondary scenario giving a better performance than the tertiary. The results also show that the saturation condition of DME-brine mixture has a direct impact on the additional oil recovery obtained.

Chemistry at the pore – fluid interface

A look into the electrical double layer

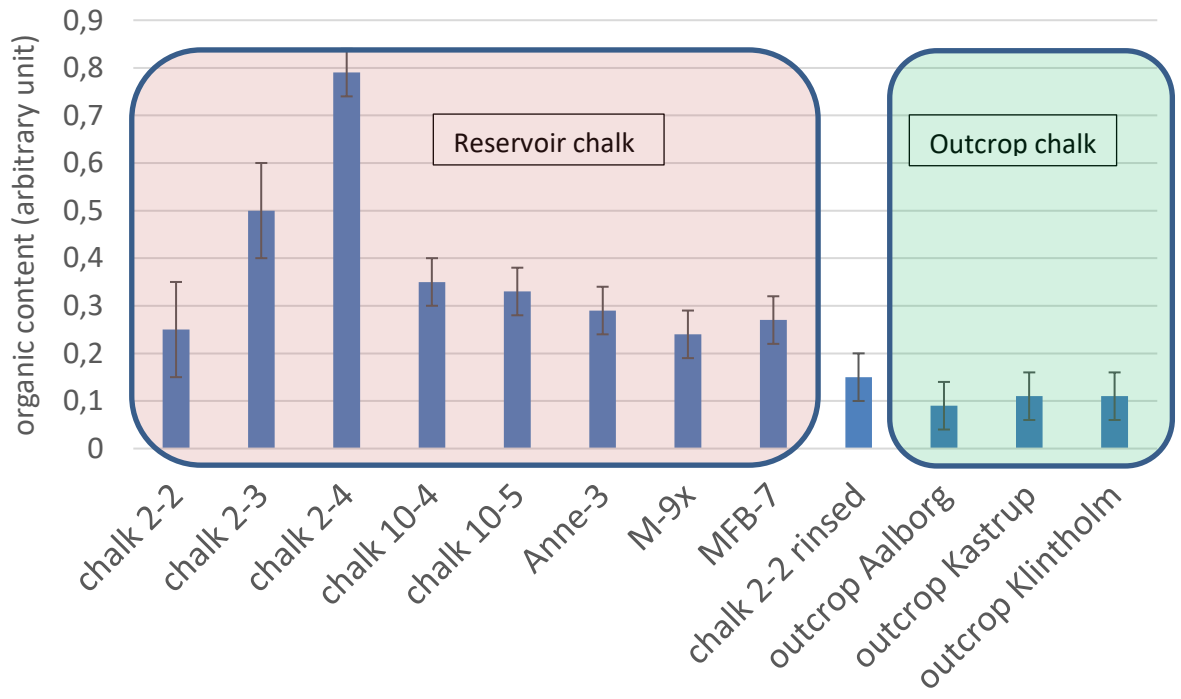
Nicolas Bovet (University of Copenhagen)

The reactivity of pore surfaces is governed by the composition of the pore – fluid interface. Physical properties such as wettability, surface energy and the ability to adsorb or desorb organic molecules are dependent on nanoscale mechanisms happening at this pore – fluid interface. We are using X-ray photoelectron spectroscopy (XPS), a technique that can '*see*' at the nanometer scale, to obtain chemical information about the pore surfaces, thus getting insights on the composition of the few nanometers of fluids in contact with the rocks.

In the first Sprint project "Surface Chemistry of Chalk", we have shown that the surface of chalk from reservoir and chalk from outcrop location do not have the same surface composition. In particular, the amount of organic molecules at the surface is different (Figure 1). This difference should be taken into account when probing the reactivity of the surface, from experiments looking at nanometer scale mechanisms to core plug tests.

In our current project "Wettability Modification of Chalk", we plan to match small changes in surface composition to macroscopic measurements of contact angle, a classical measure of wettability. We will exposed calcite and various chalk samples to ions and monitor change in wettability, is order to show that we can predict and therefore screen in the future possible candidates ions for advanced water flooding.

Figure 1: organic content of chalk samples



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Numerical modelling of two-phase flows in discrete fracture-matrix models

Nikolai Andrianov, Hamid M. Nick
Centre for Oil and Gas – DTU

The state-of-art numerical models for detailed resolution of fracture-matrix flows are the discrete fracture-matrix models (DFM). The DFM models explicitly represent the fracture network as lower-dimensional objects embedded in the matrix grid, and the flow is considered to occur both in the fracture network and in the surrounding rock matrix. Numerical simulation of DFM models is typically faster than a detailed flow simulation, where the fracture is discretized in transversal direction. One of the challenges with DFM models is how to properly account for fracture-matrix interaction.

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Hydrodynamical and data-driven modelling of unsteady multiphase flows in pipes

Nikolai Andrianov
Centre for Oil and Gas – DTU

Multiphase flow occurs in almost all producing wells and production gathering facilities on the surface. Traditionally, such flows are modelled using hydrodynamical approach, which consists in numerical solution of phase conservation equations. As a result, one can estimate a large number of parameters at arbitrary point of the flow. However, there are serious limitations due to complexity of mathematical models which makes the hydrodynamical models difficult to build and to deploy. An alternative approach is to use a machine learning methodology to estimate key parameters of the flow. We demonstrate how a regression neural network can be used as a virtual flow meter for a synthetic severe slugging case.

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Poster abstracts from Work Programme

Advanced Water Flooding 2

Improved Sweep in Deep Tor

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Hydraulic Fracturing in Layered Media

Saeed Salimzadeh, Teeratorn Kadeethum, Hamid M. Nick

Danish Hydrocarbon Research and Technology Centre, Technical University of Denmark, Lyngby, Denmark

Hydraulic fracturing has been proven as an efficient method to improve recovery from unconventional reservoirs and also a potential method for improving the sweep in the North Sea chalk reservoirs. While the majority of the published research focus on a single (or multiple) fracture(s) in a homogenous, single layer rock, it is evident that the real reservoirs are consisted of multiple, soft and stiff layers, which makes the hydraulic fracturing process more complex (Figure 1). When a hydraulic fracture hits an interface, it can be arrested at the interface, or the new layer can act as a favourable medium for the fracture to grow in. In this study, hydraulic fracturing process through multiple layers is investigated using a robust finite element code, CSMP. Different layers in the model have different mechanical properties, thus the stress distribution is not continuous across interfaces and that discontinuity affects the growth direction and the size of the hydraulic fracture in each layer. The hydraulic fractures are assumed to propagate under toughness regime, so the fracture toughness of each layer is also affecting the propagation direction and the shape of the induced fracture. A sensitivity analysis on the governing parameters is performed and the results are presented. The outcomes of this research can be instrumental in designing the hydraulic fractures in the chalk reservoirs in the Danish North Sea.

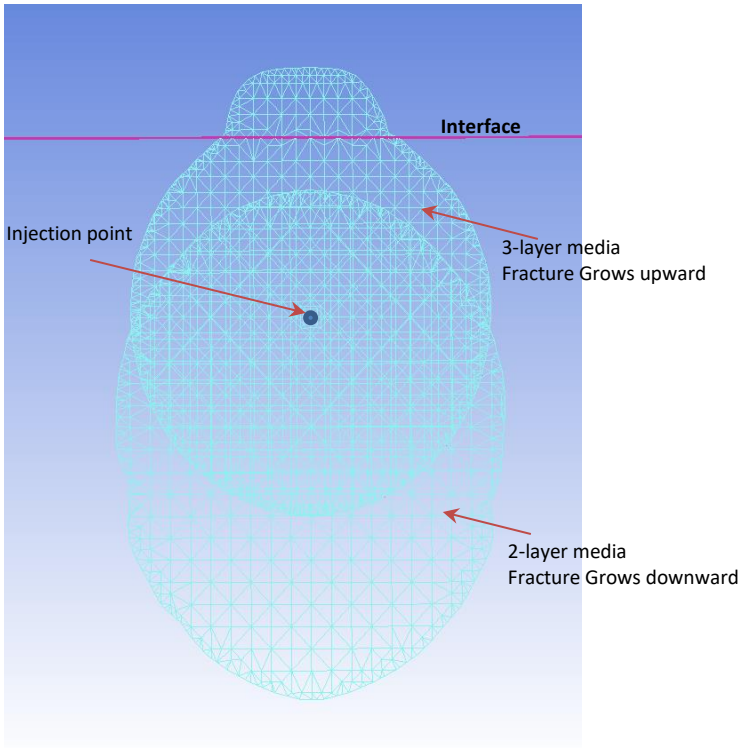

Figure 1- The shape of the hydraulic fracture is affected by the layers' thickness

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Poster abstracts from Work Programme

Cost Transformation 1

Increased Water Injection Availability

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VBA-CUSTOMIZATION OF ASPEN HYSYS FOR ADVANCED PROCESS ANALYSIS OF OIL AND GAS SEPARATION TRAIN

Bence Vizi, György Imrényi, Marco Maschietti
Aalborg University Esbjerg, Department of Chemistry and Bioscience, Niels Bohrs Vej 8, 6700 Esbjerg, Denmark

A customization based on Visual Basic for Applications (VBA) of Aspen HYSYS, aimed at process analysis and optimization of gas-oil-water separation train, is presented and preliminary tested on multistage gas-oil separation. The program maps a user-defined objective function by varying the operating pressures of the separators of the train. The generated map allows locating optimal operating conditions of the train, as well as evaluating the profit losses due to discrepancies from the optimal conditions. In this work, the objective function accounts for the revenues of the sales of oil and gas and the expenditure for gas re-compression and pumping of cooling water. The test of the program of the present study covers two typical feed compositions (light oil and gas condensate) at two different feed pressures (30 bar and 60 bar) and temperatures (48°C and 58°C), for separation trains ranging from 1 to 4 stages.

Presenter: Bence Vizi (Research Assistant)

Work Programme: Cost Transformation 1 - Increased Water Injection Availability

EFFECT OF CORROSION INHIBITORS ON OIL IN WATER DEMULSIFICATION IN TOPSIDE SEPARATORS

Mathias Kjeldahl Jørgensen, Nikolaos Montesantos, Marco Maschietti

Aalborg University Esbjerg, Department of Chemistry and Bioscience, Niels Bohrs Vej 8, 6700 Esbjerg, Denmark

Corrosion inhibitors used in Oil & Gas production end up to some extent in topside separators, where they can hinder the oil in water demulsificaton process. The aim of this project is to study experimentally the separation kinetics of oil in water at operating conditions typically applied in topside separators, with the focus on how different oil and brines interact with corrosion inhibitors and demulsifiers.

Experimental tests are based on a procedure developed in a DHRTC Sprint Project and recently presented in the literature [1]. The procedure includes dispersion of oil in synthetic brines, gravity settling laboratory experiments at different residence times, and analysis of the aqueous phase by means of an OSPAR inspired method. Preliminary results concern two different aqueous phases (distilled water and seawater), one type of oil, and two settling temperatures (23.5°C and 50°C). Upcoming experiments will concern the addition of corrosion inhibitors and demulsifiers.

Presenter: Mathias Kjeldahl Jørgensen (Master Thesis student)

Work Programme: Cost Transformation 1 - Increased Water Injection Availability

References:

[1] N. Montesantos, M. Maschietti, Preliminary evaluation of the impact of modified injection water composition on the oil/water separation in produced water treatment facilities, Chemical Engineering Transactions 57 (2017) 559-564.

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Cost Transformation 2

Transformation of Asset Cost

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Self-Healing Cement

Søren D. Nielsen (presenter and PhD-student), Kasper U. Kjeldsen and Hans Røy
Aarhus University, Center for Geomicrobiology

The aim of my PhD-project is to adapt the microbial self-healing cement approach already in use in surface environments to facilitate the use of microbial self-healing cements in subsurface off shore oil and gas production facilities. The deep subsurface cement-installations are characterized by a lack of oxygen, high temperature, high pH and high pressure. Combined these four stressors challenge bacterial growth, yet we need to identify endospore-forming bacterial cultures able to metabolize under such extreme conditions. For this, we have cultivated and tested axenic strains of endospore-forming anaerobes and found a strain with the right physiological traits. We will embed the endospores in millimeter-sized capsules of super absorbent polymers together with the necessary nutrients and incorporate them into the cement during the mixing and casting processes. When small cracks occur in the cement the capsules will hydrate and expand inducing the endospores to germinate, grow and precipitate calcium carbonate thereby effectively healing the cracks. We will present the results of a proof-of-concept experiment using an aerobe endospore forming strain capable of precipitating $CaCO_3$ inside the superabsorbent polymer.

Mechanical evaluation of self-healed cementitious material

Elisa Cristinelli, Victor Marcos Meson, research assistants, DTU BYG

Gregor Fischer, Associate Professor, DTU BYG

Ieva Paegle, Postdoc, DHRTC

The research within self-healing cement materials is addressing challenges which could extend the life-time of oil wells and the potential for increased recovery by enhanced well conformance treatment. The main objective of this project is to develop a suitable and mechanically realistic mechanical evaluation method to characterize the functionality of self-healing of cementitious materials in Oil & Gas wells. The test methods developed should be able to determine:

- The degree of healing the crack – can fluids and gas flow through the healed crack?
- The strength of the healed crack,
- The stress-crack opening behavior of the healed crack vs original material.

Category*:* CTR.2, results of 2 sprint projects

Development of Value of Information Tool for Inspection Planning

Arifian Agusta Irman, DTU Civil Engineering

Inspection planning is an integral part of offshore structure asset management. As consequence of the low price of oil, inspection planning has again become the focus of structural reliability research. The decision theory, especially Value of Information (VoI) theory, has been widely applied to optimize inspection planning to lower the service life costs. However, utilization of VoI theory can be computationally demanding due to exponential growth of the decision tree. With this poster, an efficient VoI analysis tool called VoICalc is introduced. The tool is able to solve moderately complex decision problem and schedules inspection time efficiently. Demonstration of the VoI analysis with an example in inspection planning is presented.

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The 3D Geotechnical Model

Incorporating geology and engineering geophysics

Lasse Krogsgaard Prins, Katrine Juul Andresen, Ole Rønø Clausen – Aarhus University

The Danish Central Graben has been subject to extensive seismic surveying (both 2D and 3D) during the past four decades. In the last decade, these data sets have proven very useful for investigating the Quaternary sediments and especially erosional channels. The present study combines extensive mapping of these channels with detailed seismic analyses of high-resolution 2D seismic site surveys in order to validate the mapping from 3D timeslice analyses. This gives us a better understanding of the sediment distribution in the different channels and their relative age. By including geotechnical data from the site surveys we create a geotechnical stratigraphy for the area that will be of great value when designing new installations, optimizing the position of satellite platforms and assessing potential differentiated production induced subduction etc. This poster will visualize some of the hazards and interpretational pitfalls we face in the generation of the geotechnical model as well as some of our results.

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Composite Coil Tubing Design

Andrei Costache, Mohsen Rezaei *, *Christian Berggreen*

Researcher, DTU-Department of Mechanical Engineering

Conventional steel coiled tubing cannot reach along the entire length of very long horizontal oil wells. A lighter and more buoyant coiled tube is made possible using composite materials. The high stiffness to weight ratio of fiber reinforced polymers, coupled with a lower coefficient of friction, has the potential of greatly extending the reach in horizontal oil wells. This study shows how to design composite coiled tubing and gives a comprehensive discussion about the most influential parameters. Several solutions, using glass-fiber and carbon are considered. Finite element models are used to calculate the buckling loads and the corresponding interlaminar stresses. The very positive results obtained during this study show that composite coiled tubing systems are vastly superior to their steel counterparts, and that in the future, these will become the new industry standard.

SELF-HEALING CEMENT PROJECT: APPLICATION OF HYDROSTATIC PRESSURE AND TEMPERATURE ENHANCES BACTERIAL CAPACITY TO GROW AND PERFORM AT DEEP SUB-SEAFLOOR CONDITIONS

Scoma Alberto, Hans Røy and Kasper Kjeldsen

The *Self-healing cement* project aims to apply a microbially-engineered system for $CaCO_3$ precipitation in deep sub-seafloor environments to fix cracks formed in concrete structures around oil wells and boreholes. At these locations microbes must withstand high pH (>10), hydrostatic pressure (HP; up to 30 MPa) and temperature (up to 75°C). One candidate is the polyextremophilic bacterium *Clostridium paradoxum*, known to grow best at pH 10, 50°C and ambient pressure (0.1 MPa) although HP application- as for most microbes- is unknown. In our cultivation system, the maximum temperature for growth was extended from 63 to 70°C. At 0.1 MPa, growth linearly decreased from 50 to 70°C. However, application of 15 MPa (equivalent to 1.5 km below surface) enhanced bacterial growth at 60°C, with yields 2.5 times higher than the optimal conditions known so far (50°C, 0.1 MPa). At 30 MPa, growth was observed up to 60°C. Such positive interaction of HP and temperature likely applies to many microbial processes within reservoirs, including souring, corrosion and microbially-enhanced oil recovery. Specifically, the present information will facilitate the design of protocols for $CaCO_3$ precipitation agents.

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DTU Msc. Thesis:
Data-driven modular optimization of well maintenance at Maersk Oil

Front-loading of activity modules in workover operations

Andreas Peter Rafn & Peter Bjerrum

This thesis suggest a new way to plan the Workover activities at Maersk Oil in the North Sea.

By introducing the theory of modularization to the service regime in Well Service activities, this thesis indicates that a novel way of planning workovers can be established and give a potential activity cost reduction and increased workover capacity.

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Cost Transformation 3

Extend life of Potential Hub Structures

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Actual Stress Estimation

Bruna Nabuco, Marius Tarpø, Sandro Amador, Rune Brincker

The entire design process of offshore structures is based on risk assessments due to high amounts of uncertainties related to the environmental conditions and the material properties which affect the estimated lifetime of the structure.

The purpose is to apply the Operational Modal Analysis (OMA) technique to estimate the actual stress of fixed offshore structures aiming to reduce the uncertainties and extend the lifetime of these platforms.

Robust Identification

Tobias Friis, Karsten Krautwald Vesterholm, Evangelos Katsanos, Rune Brincker

Current methods for identification of dynamic behavior have certain limitations in relation to the actual behavior of offshore platforms. The limitations are mainly related to the basic assumptions of linearity and stationarity when Operational Modal Analysis (OMA) is applied. However, the majority of the structures are highly non-linear and time varying, e.g. in cases of non-linearities from friction and in case of time varying systems when emptying and filling tanks on the topside. The research project is focused at adjusting existing OMA procedures so that the mechanical characteristics of the platform can be identified under the mentioned real conditions. With the ability to identify the real dynamic behavior, the life time prediction and structural health monitoring can carried out with far greater precision.

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Tight Reservoir Development

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Phase Behaviour in Tight Lower Cretaceous Formation

*Diego Sandoval[1], Teresa Regueira[1], Erling Stenby[1], Wei Yan[1]**

[1]Technical University of Denmark, Department of Chemistry, Kgs. Lyngby, Denmark

**(weya@kemi.dtu.dk)*

The influence of porous media on phase behaviour is a topic of interest driven by the shale gas boom because many field observations suggest the saturation pressure in tight shale formation may change dramatically. It is also expected that the extremely low permeable Lower Cretaceous (LC) rock may influence the phase behaviour of the reservoir fluid. However, the extent of the influence needs to be estimated. In this work, we plan to study the influence of the capillary pressure on phase behaviour for fluids of interest to the LC formation using PVT modeling tools that will be validated experimentally. Bubble point measurements at different pressures inside Controlled Pore Glass (CPG) samples will be performed for pure components and hydrocarbon mixtures using calorimetry techniques. The validated model will then be used to evaluate the impact of the phase behaviour in a real production scenario using customized reservoir simulation tools.

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New Framework for Multiphase Flash in Compositional Simulation

Duncan Paterson, Christos Tsanas, Michael L. Michelsen, Erling H. Stenby, Wei Yan
Technical University of Denmark, Building 206, DK 2800, Denmark, email: weya@kemi.dtu.dk

Compositional simulation of many underground processes, such as gas injection, thermal recovery with solvent, and CO_2 sequestration, requires robust and efficient multiphase flash calculation. For a system of *C* components and *F* phases , the conventional approach solves *C*(*F*-1) equations where the dependent variables need to be updated dynamically. We propose a modified RAND method which solves *E*+*F* equations (*E* is the number of independent elements) for reactive systems and *C*+*F* equations for non-reactive systems. The RAND-based flash formulation has several advantages: (1) It provides quadratic convergence; (2) All phases and components are treated in the same manner and no complicated bookkeeping is needed for multiphase flash; (3) Chemical reactions can be easily included (useful for CO_2 sequestration, for example); (4) Various flash specifications can be used; (5) Volume-based formulation makes calculation using complicated EoS more affordable; (6) The RAND formulation satisfies the material balance during iteration, meaning that Gibbs-energy can be used to monitor convergence in isothermal flash. It is worthwhile to consider the RAND-based formulation as new multiphase flash framework for future compositional simulation.

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Gas Injection in Lower Cretaceous Reservoirs

Duncan Paterson, Wei Yan, Erling H. Stenby
Center for Energy Resources Engineering, Department of Chemistry, DTU

The lower cretaceous reservoirs in the Valdemar field are low permeable chalk which are generally under-exploited. It is clear that to improve recovery additional energy must be added to the reservoir. Gas injection is preferred to water injection due to the low permeability nature of the reservoirs, and high injectivity of gas. With careful selection of the injection gas it is possible to reduce the residual oil saturation, and in the case of complete miscibility achieve 100% recovery of oil on the microscopic scale. Gas injection is considered as the only viable technical EOR technique for DUC reservoirs (according to the DUC EOR Screening Study 2013).

We will present a study into the various methods of gas injection that have been carried out in the North Sea. Along with this we will describe how the gas injection can be tuned using various injection gases to further improve the recovery.

The role of DTU-BYG (Section for Geotechnics and Geology) and GEO in the LOCRETA Consortium

Ivanka Orozova-Bekkevold, Senior Scientist, DTU-BYG - Presenter
Helle F. Christensen, Chief Engineer, GEO
Jeppe Regel, Engineer, GEO
Einar Storebø, Ph.d. student, DTU-BYG
Katrine Andreassen, Assistant Professor, DTU-BYG
Ida Fabricius, Professor, DTU-BYG

The LOCRETA Consortium (GEUS, AU, KU, DTU, DHRTC) is established with the purpose of studying the Lower Cretaceous Reservoirs in the North Sea with the scope of improving recovery.

Our research will be focused on the determination and analysis of rock physics and rock mechanics properties of the Lower Cretaceous Chalk formations. Accurately determined rock physics & rock mechanics properties are essential to evaluate reservoir quality and in the modeling of compaction, fracture initiation& distribution, geomechanics (stress/strain) evolution, as well as in seismic modelling and inversion studies. Based on experimental work and logging data, we will establish a petrophysical model for the hydraulic properties of the Lower Cretaceous Chalk.

The work will be carried out in close cooperation between the Section for Geotechnics and Geology at DTU-BYG and GEO, and will include a PhD (combining rock mechanics and rock physics) project.

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Poster abstracts from DHRTC Sprint

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Linking facies and petrophysics in the Lower Cretaceous Valdemar Field –

Facies characterisation predicts reservoir properties

Morten Bjerager, Peter Frykman, Jon Ineson, Finn Jakobsen, Lars Kristensen
GEUS, Geological Survey of Denmark and Greenland, Øster Voldgade 10, 1350 Copenhagen K

A core interval from Lower Cretaceous Valdemar Field covering the Lower Tuxen-3, Munk Marl and Middle Tuxen-1 reservoir zones was logged sedimentologically. The interval comprises a heterogeneous interbedded succession of structureless chalk mudstone, bioturbated chalk mudstone, and bioturbated slightly marly and marly chalk mudstones and marl that represent different reservoir properties. The studied interval shows a consistent link between the detailed geological facies description and the porosity-permeability properties from conventional core analysis and petrophysical log values. These results indicate that petrophysical reservoir properties can be assigned to uncored sections based on the log:facies relationships derived in this study.

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Membrane crystallization for recovery of salts from produced water

Cejna A. Quist-Jensen[1], Henriette C. Jensen[1], Aamer Ali[2], Morten L. Christensen[1]*

[1] Department of Chemistry and Bioscience, Aalborg University, Fredrik Bajers Vej 7H, 9220 Aalborg East, Denmark

[2] Institute on Membrane Technology – National Research Council (ITM-CNR), Via P. Bucci 17C, 87036 Rende (CS), Italy

[*] Presenting author – cejna@bio.aau.dk

Membrane Crystallization (MCr) is a novel technology able to recover freshwater and high-purity salts from complex solutions and therefore, is suggested for a better exploitation of wastewater streams. Unlike other membrane processes, MCr is not limited by high concentrations and, therefore, the solutions can be treated to achieve saturation level. Hereby different salts can be precipitated and directly recovered from various streams. In this study, it is shown that MCr is able to treat produced water by producing clean water and simultaneously NaCl crystals. The recovered crystals exhibited high purity. Moreover, the MCr process showed excellent stability in terms of trans-membrane flux during 20 hours of operation. At moderate feed temperature of 47.2 ± 1.7 °C, transmembrane flux of 0.49 ± 0.08 L/(h·m^2) was obtained by using commercial hollow fiber membrane module. Throughout the experiments, the membrane maintained its hydrophobic nature despite that produced water contained oil residues. Conductivity and HPLC was utilized to analyze the quality of the permeate stream.

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Matrix properties in the Lower Cretaceous Valdemar Field

Hanne Dahl Holmslykke, Finn Jakobsen, Morten Bjergager, Peter Frykman

Geological Survey of Denmark and Greenland

The evaluation of the stratigraphic interval from Middle Tuxen-1 to Lower Tuxen-3 in two selected wells from the Valdemar area indicates similar facies types and petrophysical properties in the reservoir units. The interval has a heterogeneous facies distribution and consequently a wide range of petrophysical parameters. Three samples representing different reservoir properties and different facies have been analysed, and naturally cannot be considered as general representatives for equivalent reservoir intervals. The results from the advanced pore system analysis of 3 samples indicate a slightly larger pore throat and pore diameter in the samples from the southern well compared to the sample from the northern part.

ShipNet

Cosmin Avasalcai and Prof. Paul Pop

Description: The goal of this project is to perform a research study on how to solve the problem of offshore platform connectivity. Our idea is to use supply vessels to implement a seamless high-bandwidth communication link for old Oil and Gas offshore platforms. The Oil and Gas industry must take advantage of all the modern technologies risen with Industry 4.0, such as the Internet of Things and Industrial Internet of Things. This idea will enable to use efficiently Cloud Computing to better store and analyze the collected data, offering at the same time a safe and reliable data backup solution and provide a fast and dependable approach to transfer the data to the Cloud.

Forward seismic modelling for understanding reservoir characteristics in the Valdemar field area

The importance of the Vp/Vs ratio

Rasmus Rasmussen (GEUS)

Seismic response resulting from heterogeneity in the Lower Cretaceous thin-bedded Sola and Tuxen Formation reservoir zones in the Valdemar Field Area has been evaluated by a preliminary forward modelling study.

The Sola and Tuxen Formations comprise a succession of interlayered pelagic/hemipelagic chalks, marly chalks, marlstones and claystones. The high quality reservoir zones are located in the high porosity zones of the chalks and in the high porosity zones of the marly chalks. The acoustic response from these high quality reservoir zones is characterized by a relatively low P-velocity and a low Vp/Vs ratio in comparison to the marlstones, claystones and lower porosity marly chalks, which indicates a seismic mapping potential of the best reservoir rock.

The differences in reservoir quality are not fully resolved by P-velocities alone. The generally lower Vp/Vs ratio from the Sola and Tuxen high quality reservoir zones compared to the low quality zones indicates that the seismic AVO response is essential for the mapping of the reservoir quality in the Valdemar Field Area.

The use of seismic forward modelling for analysing reservoir architecture must incorporate the Vp/Vs characteristics described here.

The number of wells with S-velocity measurements is limited, and extension of S-velocity estimates must be based on correlation towards the P-velocities and other logs.

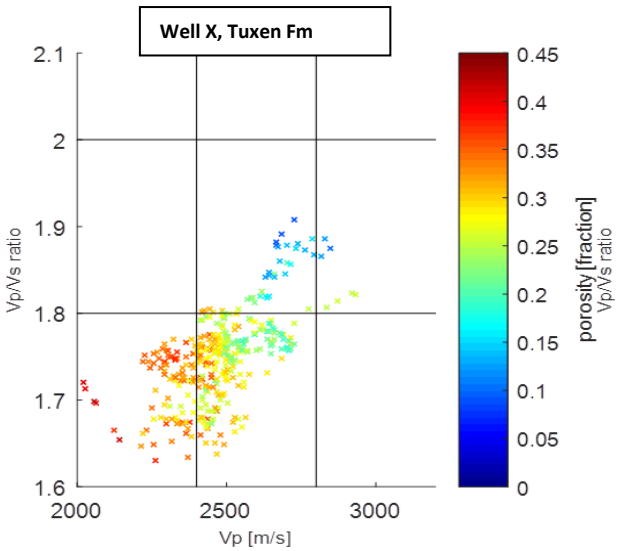

Figure 1. Cross plot correlation for the Tuxen Fm for well X.

Deep Reach Through Acid Encapsulation and Wormhole Propagation

Sprint Project - DHRTC

Jyoti Shanker Pandey (Research Assistant, CERE) (& Main Presenter) Prof Nicolas von Solms (Associate Professor-CERE)

Acid Injection into carbonate reservoirs is a popular well stimulation method to improve the formation permeability and enhance oil production. Acid injection leads to wormhole creation and propagation which can bypass the damage zone. Wormhole creation and propagation depends on the acid injection rate and dissolution rate of the rock in acid. At an optimal injection rate, dominant wormholes are formed which correspond to a minimum volume of acid required. Lower dissolution rates lead to deeper acid penetration into the formation.

The main objective of the project is to compare acid penetration and wormhole propagation in chalk samples (with and without cavity) using 3 different acidizing fluids (15% HCl, 10% Acetic Acid & Mixture of 15% HCl & 10% Acetic Acid). Initial test are carried out at normal temperature and pressure conditions. Key experiments performed are a soaking experiment, where acid is left stationary in a core and an acid injection experiment using a core flooding setup. Experiments are followed by CT Scanning, in order to elucidate the results.

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Monitoring Seabed Subsidence with Optical Fiber Sensing – A Feasibility Study

Eyal Levenberg, Associate Professor, DTU Civil Engineering (presenter)

Ivanka Orozova-Bekkevold, Senior Scientist, DTU Civil Engineering (presenter)

Kristian Nielsen, Development Engineer, DTU Photonics Engineering (not participating)

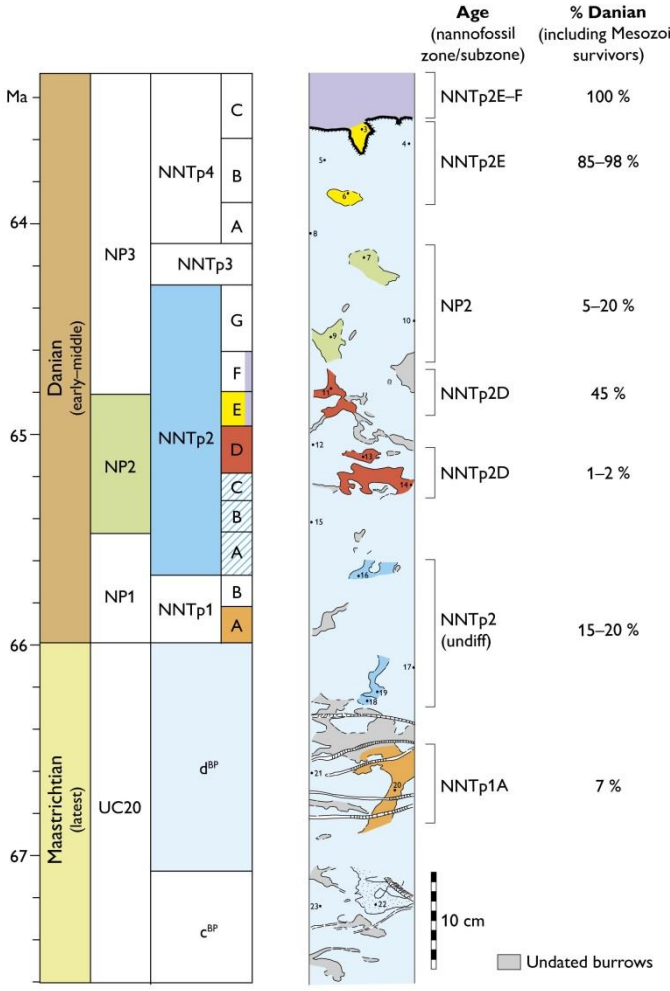
The work aimed at assessing whether readings from a deployed mesh of fiber optic sensors, coupled to the seabed, can detect useful information with regard to: (i) production-induced subsidence, and to (ii) operational functionality of a producer-injector array. The poster presents results from an in silico investigation involving the application of an existing analytic technique for computing seabed subsidence due to imposed subterranean deformations.

Radical Innovation Sprint 2017

HIATUS DEVELOPMENT AT THE TOR/EKOFISK BOUNDARY – FORMATION OF A RESERVOIR BARRIER

Sarah Møller (Copenhagen University), Jon Ineson, Emma Sheldon (GEUS)

The Cretaceous–Palaeogene boundary in the chalk of the Central Graben, North Sea, is commonly represented by a hardground on cored structural highs. This cemented layer contributes to a barrier/baffle between the Tor Formation and Ekofisk Formation chalk hydrocarbon reservoirs. A biostratigraphic hiatus of up to five early Danian nannofossil subzones (*c*. 1 million years) is commonly reported at this level. Detailed biostratigraphic and geochemical investigation of a core from the Halfdan Field (Danish Central Graben) to better characterize this low-permeability layer, revealed that much of the 'missing time' is recorded in *Thalassinoides* burrow fills beneath the top-Tor hardground surface. Isotopic geochemical data ($\delta^{13}C$, $\delta^{18}O$) suggest that despite early cementation/impregnation of the hardground surface, the burrow systems remained open in the earliest Danian and their eventual permeable fill provided a complex corridor for subsequent fluid migration. Understanding the temporal and spatial development of this layer, in conjunction with rock mechanics and fracture studies, will contribute to quantification of the variable transmissivity of this layer – of benefit to production/waterflooding strategies.



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Micro-texture and mineral mapping in fine-grained reservoirs in the Valdemar Field

Results from Qemscan analysis

Christian Knudsen, GEUS

Seven samples of drill-core from North Jens–1 and three from Bo-2-X have been analysed using Qemscan to describe the content of minerals, texture and structure in fine-grained reservoir rocks in the Valdemar Field. The main conclusion is that the Qemscan method will be very useful in understanding the differences in reservoir properties across the Valdemar field. The main geological findings are: Silica is precipitated in the chalk and common in the matrix in both wells and silica is precipitated in fractures in the chalk. There is diagenetic calcite in the matrix. Calcite is also precipitated along fractures in the chalk. Ankerite is a common diagenetic mineral in the chalk matrix. There are different clay minerals in the chalk, textural relations can be identified and the clay has been affected by diagenesis and precipitated e.g. in fractures during the diagenetic and tectonic evolution of the chalk.

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OptiProbe: Possible use of optical probes for real time, in situ measurement of pH and dissolved oxygen during oil production

Knud Dideriksen and Thomas Just Sørensen*

Affiliation: *Nano-Science Center, Department of Chemistry, University of Copenhagen, Universitetsparken 5 ,DK-2100 Copenhagen Ø, Denmark. *Presenting author: knud@nano.ku.dk*

pH and redox are two of the most important variables for understanding reactions in water. However, in situ measurement over extended periods is very complicated. Optical probes based on fluorescence overcome most critical limitations. A pH and DO optical probe has already been developed by Thomas Just Sørensen for biotech application. In this project, we have modified them by grafting the fluorescent molecule directly to the optical fibres, simplifying probe geometry and making them more robust. For competing probes, fluorescent molecules decay extensively in response to excitation by light. We have demonstrated that the fluorescent in our probes can be excited above 400.000 times without deterioration of probe performance. We will now 1) perform measurements in seawater and produced water, and 2) estimate the cost/benefit of using the probes at the various water streams of oil recovery.

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Smart-Spider: Autonomous self-driven robot for cost-effective in-line inspection of subsea pipeline integrity

Ying Qu *(Research Assistant)*, *Petar Durdevic Løhndorf (assistant Professor)*, *Zhenyu Yang (Associate Professor)*

DHRTC Contactor: Kristine Wille Hilstrøm

Affiliations: Department of Energy Technology, *Aalborg University*

Abstract: Bearing in the mind of an ultimate objective to propose an alternative/complementary solution to traditional pig system of subsea pipeline inspection, by deploying a set of small, flexible, modularized, autonomous self-driven, in-line robot systems, for which we call as "**smart-spider**", this print project focuses on the conceptual development of a prototyped smart-spider system, which will equip with fundamental functionalities as motion & position control, path navigation planning & control, inspection data storage, self-condition monitoring & self-rescue strategy.

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Radical Innovation – Concept and Projects

Lene Hjelm Poulsen, Kristine Wille Hilstrøm, DHRTC

Establishing a functional radical innovation sprint concept in a network organization as DHRTC is not an easy task. Radical Innovation, i.e. research with a very high risk of failure is not common within oil and gas industry research nor is the model of a three months research sprint. The concept consists of a 5 step process with strong emphasis on culture, people and behaviour: the initial planning phase, a call for radical ideas, an assessment and selection phase, a three month research sprint phase on the selected ideas and finally an evaluation and close out phase of the concept. Currently (November 17) the first three phases of the 2017 radical sprint has been completed and out of a bulk of incoming 53 ideas 13 ideas has been assessed as potential radical. Research on those ideas are currently being conducted. The two posters present the Radical Innovation concept and the 13 radical ideas.

Radical innovation sprint: New tools for well control and sampling (WASP)

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During oil and gas production on an unmanned platform, the offshore production supervisor (OSV) is in control of produced well fluids. Currently it can be difficult to continuously monitor the individual oil:water:gas well ratio. There could be a great potential to shut in wells which has a too high water-cut, but the OSV only has limited tools to pinpoint well stream composition.

The objective is to create a tool to reduce the water production and maximize oil production. It is intended for both manned and unmanned platforms. It must give on-line readings of oil/gas/water production rations and it must be able to automatically take consistent high pressure samples on demand, which can be used for understanding of the well conditions. *The device we call WASP* (well analysis + sampler). The information coming from the device is vital to the production. It forms the whole basis for the offshore production control and it feeds into reservoir models etc.

The auto-sampler will address the need for the operator to undertake more in-depth analysis and research of the well fluids. An added value could be that less water is produced which may lead to less corrosion and scaling by applying the WASP.

The objectives are reached by a design study which includes the following tasks: Design and development of 2D and 3D illustrations of the equipment, construction of Standard Operating Procedures for installing and operating the WASP and finally estimating the total prize of constructing the equipment.

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Next generation liquid-repelling surfaces for improved oil flow

Johannes Franz, Post Doc

Oil flow within pipelines is determined by friction at the material surface. Inspired by nature, we develop next generation liquid-repelling surfaces to optimize oil flow by drag reduction. Here we show how confocal imaging was used to determine the optimal surface structure size for the formation of a stable lubricant layer during oil flow. Moreover, we provide an overview about the surface science approach we use to look at surfaces exposed to oil flow.

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Poster abstracts

Relevant research from DHRTC partner institutions

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UNIVERSITY OF COPENHAGEN
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Application of natural antimicrobial compounds for reservoir souring and MIC prevention in offshore oil and gas production systems

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Offshore oil production facilities are subjectable to internal corrosion, potentially leading to human and environmental risk and significant economic losses. Microbiologically influenced corrosion (MIC) and reservoir souring - sulphide production by sulfate reducing microorganisms in the reservoir - is believed to be an important factor in these major problems in the petroleum industry (1,2). The sulphide-producing microorganisms can be Bacteria (SRB) or Archaea (SRA) with the main focus in the literature being on SRB (4-7). The SRB most frequently reported in literature to be responsible for souring are: *Desulfovrio, Desulfobacter, Desulfomonas, Desulfotomaculum, Desulfobacterium, Desulfobotulus* and *Desulfotignum* (3, 7). Souring occurs mainly as a result of water flooding during secondary oil recovery, where the seawater used can contain large amounts of sulfate (up to 25-30 mM (4)). Although SRB can use a variety of organic electron donors, including low-molecular-weight aliphatic and aromatic hydrocarbons, alcohols, and carboxylic acids, volatile fatty acids (VFA) are considered important electron donors in oil fields (4). MIC is often seen as localized pitting attack that is generally associated with the presence of microbial communities embedded in a matrix (often with bioinorganic matrixes) referred to as biofilms.

Halophytes are plants that can grow in seawater. They have been shown to produce a wide variety of very active phytochemicals including strong antimicrobial compounds (8). In our previous studies, we have extracted and enhanced these natural halophyte antimicrobials for efficient use as contamination control in anaerobic fermentations (ethanol fermentation with yeast) where they were shown to significantly inhibit methanogens and VFA producing bacteria (9). The halophytes have specialized in thriving in the very competitive aquatic environment, protecting themselves from attacks by seawater bacteria and archaea, and hence our hypothesis is that the natural antimicrobials produced by halophytes can act as natural and safe MIC and reservoir souring inhibitors. This poster discusses the potential benefits of tailoring natural antimicrobial mixtures based on plant extract compositions for reservoir souring and MIC prevention in offshore oil and gas production systems.

Presenter: Mette Hedegaard Thomsen (Assistant Professor)

Work Programme: Relevant research from DHRTC partner institution

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Innovative Pipeline Concepts for North Sea applications

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Jens Vinge, Associate professor, Department of Engineering - Biomechanics and Mechanobiology
Anne Ladegaard, Associate professor, DTU Chemical Engineering

Challenges for the conventional offshore Carbon Steel (CS) welded pipelines are seen as:

Up to 40% of failures in CS pipelines are related to problems with corrosion
If scale potential exists, CS pipelines are prone to build up scale

The innovative polypropylene pipeline with an added weight coat for on bottom stability is seen as an alternative solution, offering a corrosion free pipeline less prone scale than CS for costs similar or less than a CS welded pipeline.

Stochastic Greybox Modeling of Slugging Flows

Goran Goranović, Jan Kloppenborg Møller, Thomas Martini Jørgensen, Henrik Madsen

Air/gas is often entrapped in water delivery pipes of petrochemical rigs, blocking the flow and thereby increasing operational energy demands or idle downtimes. Hence, the efficient liquid transport that minimizes the blockage through long pipelines would reduce costs in oil industry. The entrapment belongs to the category of two- (e.g. air/water) or multi-phase (e.g. air/oil/water) flows, the difficult and well-studied topics. The long bubbles on top of thin water layers, known as slugging flow, are particularly relevant in oil recovery.

We present a stochastic grey-box model which combine the physical (mechanistic) knowledge with the (incomplete) measurements of an actual, experimental slugging flow. In particular, stochastic (random) component is introduced to quantify both the missing information and the statistical nature of the complicated flow data.

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Optimal Control of Compositional and Thermal Recovery Processes

A C/C++ Simulator with Capabilities for Gradient Computations

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We develop numerical algorithms for optimal control of oil and gas recovery. The algorithms combine simulations of the subsurface reservoir flow with a numerical optimization algorithm. The optimization algorithm iteratively improves the production strategy until an optimal strategy is reached.

The optimization requires a number of simulations, each of which is computationally expensive. We therefore use efficient optimization algorithms combined with an adjoint method to compute gradients, which requires significantly fewer simulations compared to simpler gradient-free optimization algorithms.

We present a numerical example of optimal control of compositional and thermal reservoir flow. The example is based on a recently developed C/C++ code, and the implementation uses a cubic equation of state to evaluate thermodynamic properties of the fluid.

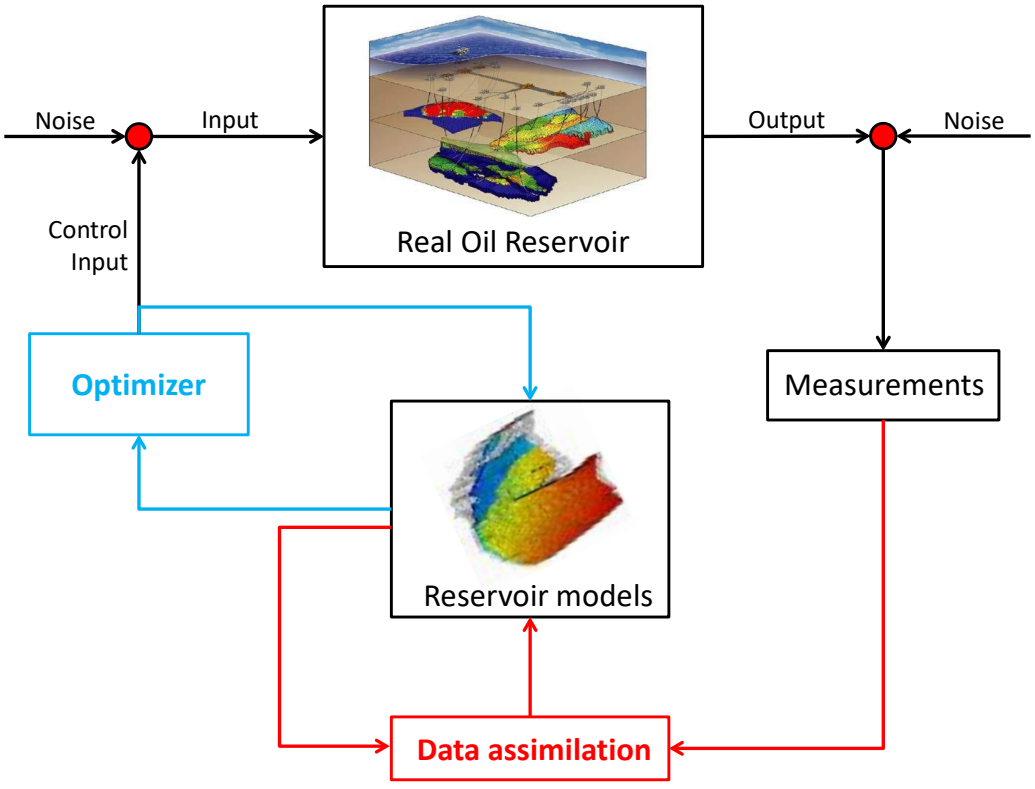

Fig. 1: Diagram illustrating the role of optimal control (the blue loop) in a production optimization workflow (known as closed-loop reservoir management).

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