Multiscale petroleum research at IRIS

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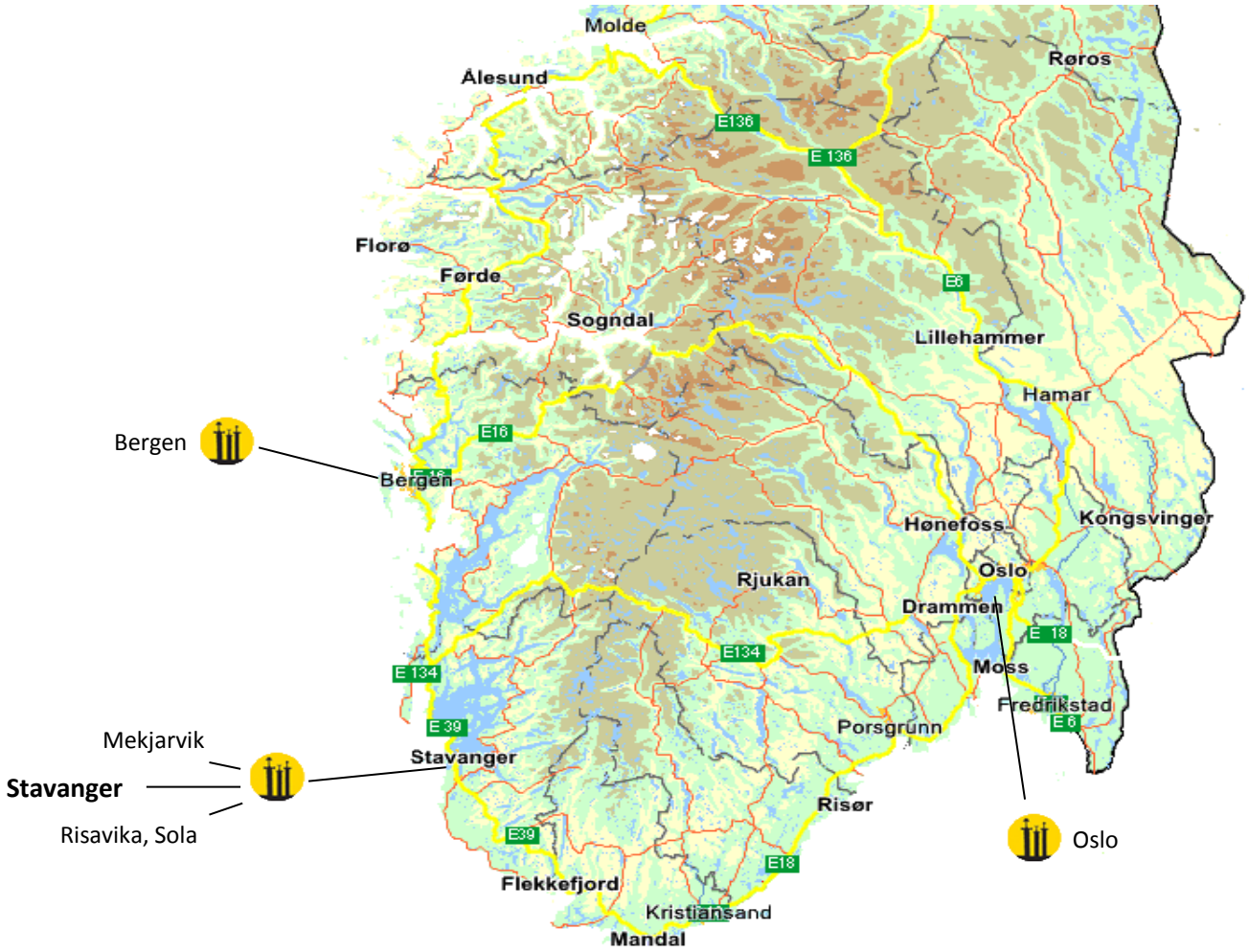
Outline

- IRIS – Overview
- IOR research at IRIS
  - COREC – Centre for Oil Recovery
  - SBBU – Center for Drilling and Wells for Improved Recovery
  - Application: National IOR Centre
- Reservoir-scale research at IRIS

International Research Institute of Stavanger – Offices in Norway



40 years of Research and Development

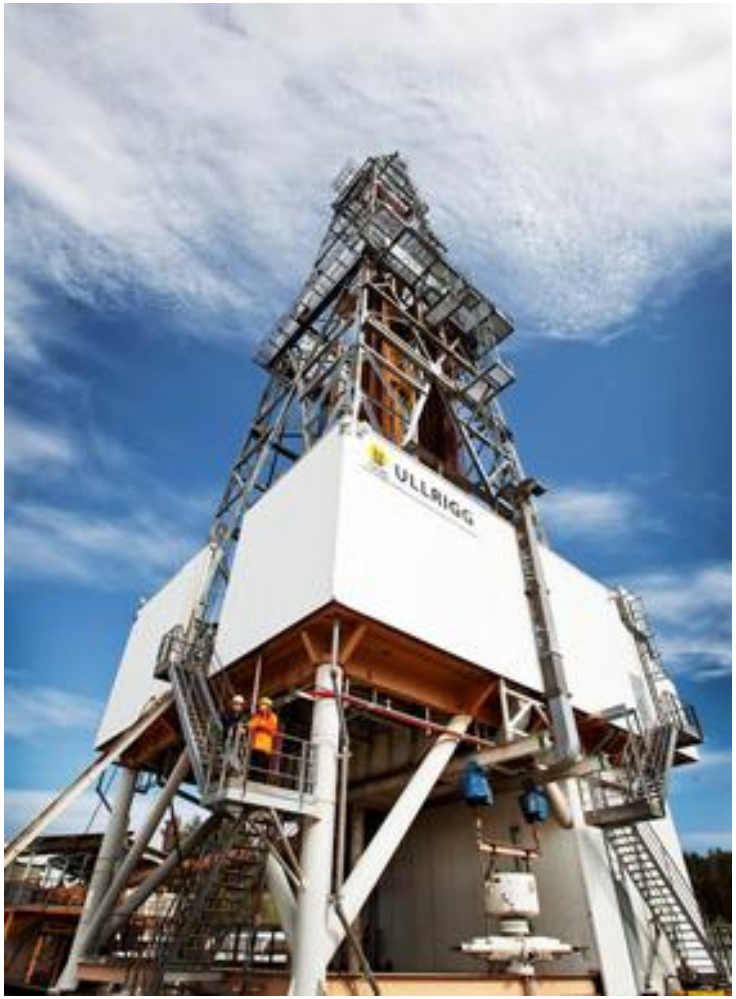
- IRIS is a client-oriented research institute
- Owned equally by the University of Stavanger and the regional foundation Rogalandsforskning
- In 2006, IRIS replaced Rogaland Research (established in 1973)

- Research and development within:
  - ENERGY
  - ENVIRONMENT (marine biology and biotechnology)
  - SOCIETY (social science and business development)

- Clients:
  - Oil and service companies, public sector (esp. Research Council of Norway)
  - National and international

- 210 employees, and 85 of the researchers hold a PhD degree

IRIS ENERGY: contributing to efficient and safe energy production



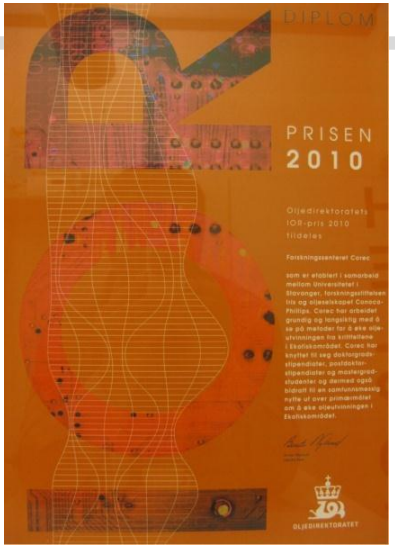
Research

- Reservoir technology
- Improved Oil Recovery
- Drilling and well technology
- CO_2 storage
- Renewable energy

Resources

- Staff of 120
- Facilities
  - Ullrigg drilling facility (full-scale offshore type drilling rig with access to seven wells)
  - Virtual rig (realistic real time well modelling)
  - Petroleum laboratory (Special Core Analyses, petrophysical measurements, experiments at reservoir conditions)

IRIS ENERGY: cooperations for research and education



- Close cooperation with the University of Stavanger
  - Education of bachelor, master, and PhD students
  - Common research projects
- Close cooperation with industry partners
  - Understanding of basic mechanisms
  - Tools for improved oil recovery
  - Assisting in performing field pilots
  - Center for Oil Recovery – initiated by ConocoPhillips, IRIS, and the University of Stavanger in 2003
    - Several industry partners as well as public funding (Research Council of Norway)
    - Research with focus on fractured chalk reservoirs
      - Understanding and optimising water injection
      - Potential for CO_2 injection at Ekofisk
      - Interaction of CO_2 and seawater with chalk
    - COREC received the IOR-prize for 2010 from the Norwegian Petroleum Directorate, NPD

IRIS IOR group: ca. 25 researchers

IRIS

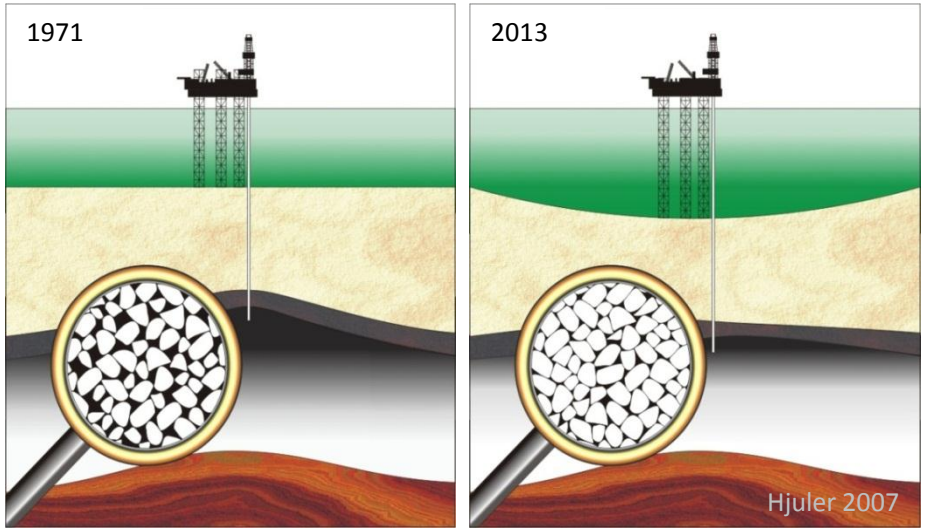
- Understanding of basic mechanisms:
  - Pore-scale mechanisms, e.g., for CO_2-storage and EOR applications
  - Rock–fluid interactions, e.g., water weakening of chalk, relative permeability and capillary pressure curves
  - Different EOR technologies, e.g., effects of wettability, water chemistry, polymer and surfactant flooding
- Tools for:
  - Optimising multiphase reservoir flow
  - Improving macroscopic reservoir sweep efficiency and water production management
  - Improving microscopic sweep efficiency
- Pore-, core-, and reservoir-scales

Water weakening of chalk

- Oil production from chalk fields (Ekofisk, Valhall)
  - → pore pressure depletion
  - → increase in effective stresses
  - → reservoir compaction

- Seawater injection
  - → reservoir pressure stabilised
  - → subsidence rate decreased

  <u>BUT:</u>
  - → water weakening effect on chalk
  - → continued reservoir compaction



Rock–fluid interactions in laboratory experiments

IRIS

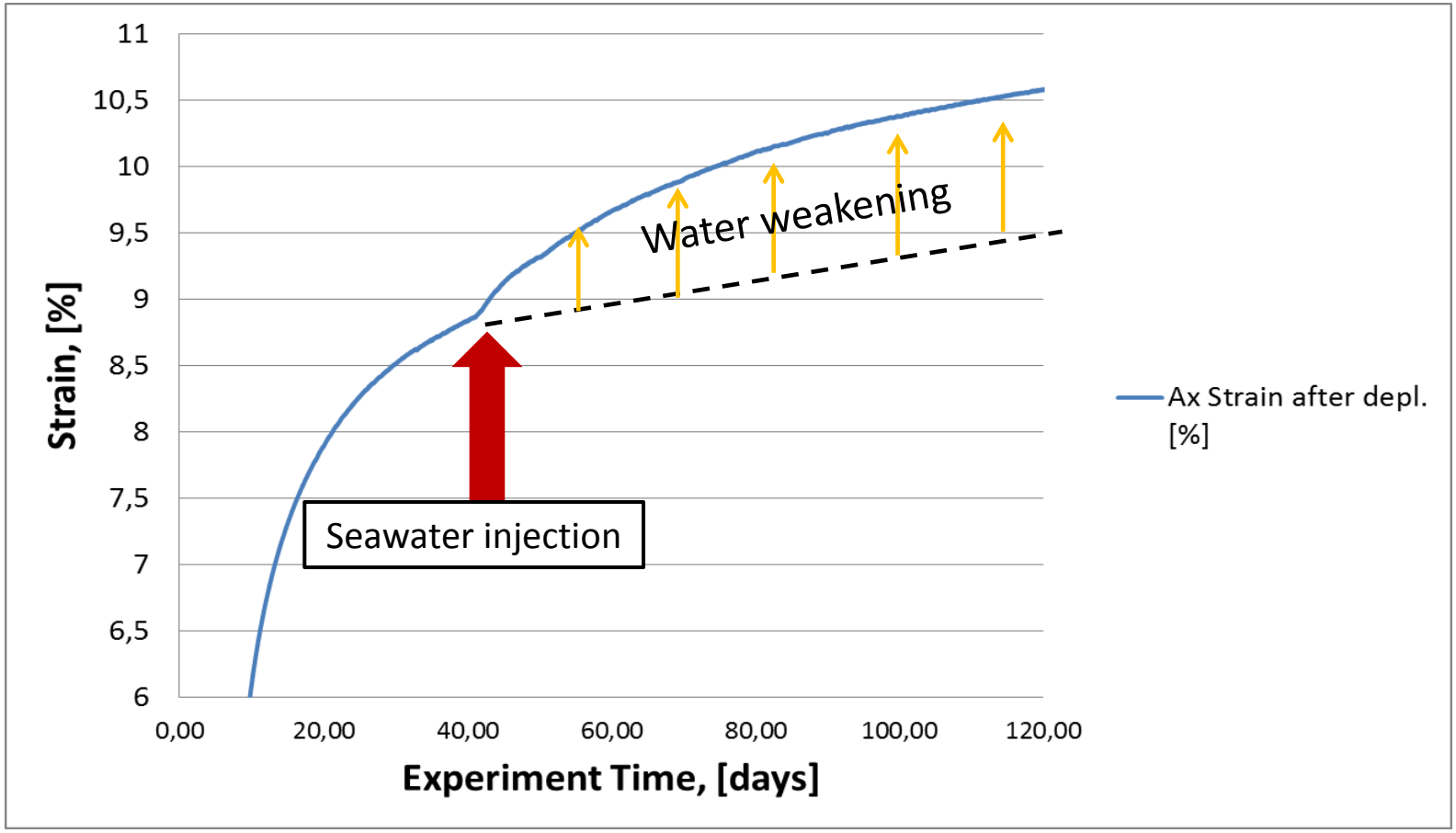
- Rock mechanical experiments with water flooding
  - Measurement of deformation
- Effluent analyses
  - Monitoring changes in water chemistry
- Comparison of cores prior to and after waterflooding
  - Textural and mineralogical alterations
- Geochemical modelling
  - Prediction of mineral under- or supersaturations, i.e., mineral dissolution and precipitation

Triaxial cell, 130 °C, ca. 12 MPa stress

Rock mechanics

IRIS

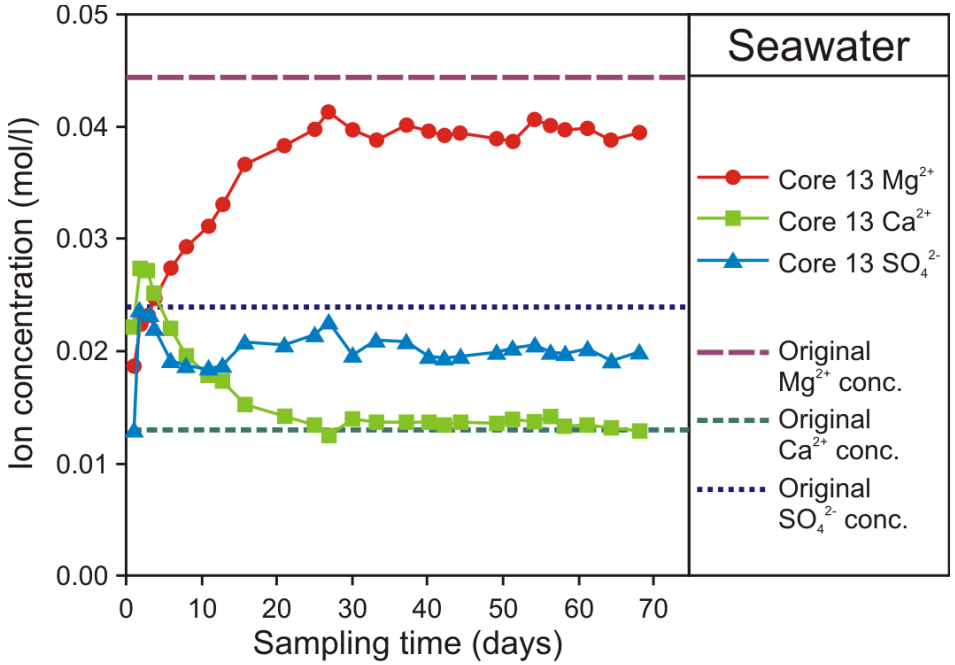
Increased deformation of a chalk core due to seawater injection



Effluent analysis

IRIS

Changes in water chemistry indicate chalk–seawater interaction



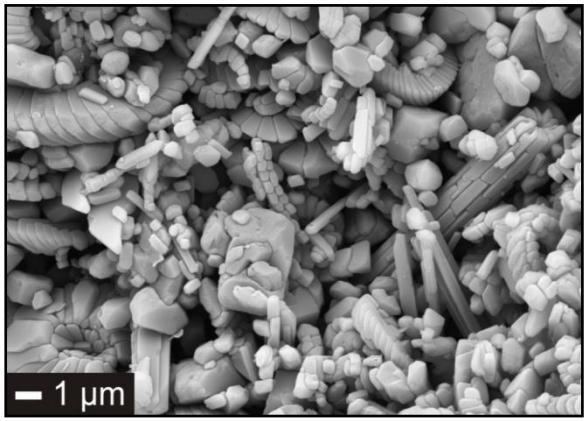
- More Ca^{2+} in effluent → calcite dissolves
- Less Mg^{2+} & SO_4^{2-} in effluent → magnesium and sulphate are retained in the core

Chalk cores prior to and after seawater flooding

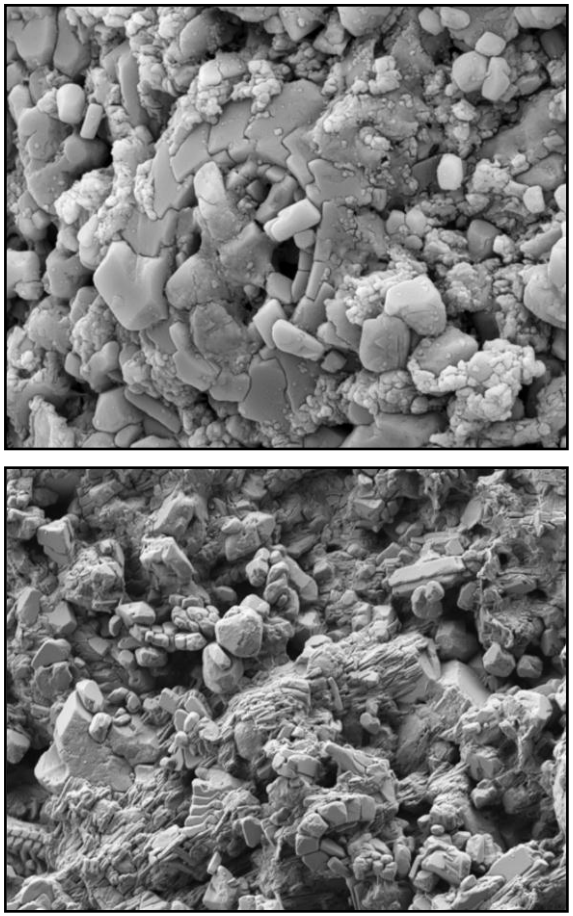
IRIS

› Chalk dissolution and secondary mineral formation

Before



After



Granular magnesite precipitates

Bladed-massive anhydrite precipitates

Geochemical modelling

- Simulation of seawater injection into chalk at high temperature and pressure predicts:
  - Precipitation of minerals (dolomite, huntite, brucite, magnesite, anhydrite, talc)
  - Dissolution of calcite and silicate minerals
- Successful matching of effluent profile
- Location of alteration in complex pore geometries can be predicted
- Upscaling of modelling results to field scale
- Comparison with produced water composition

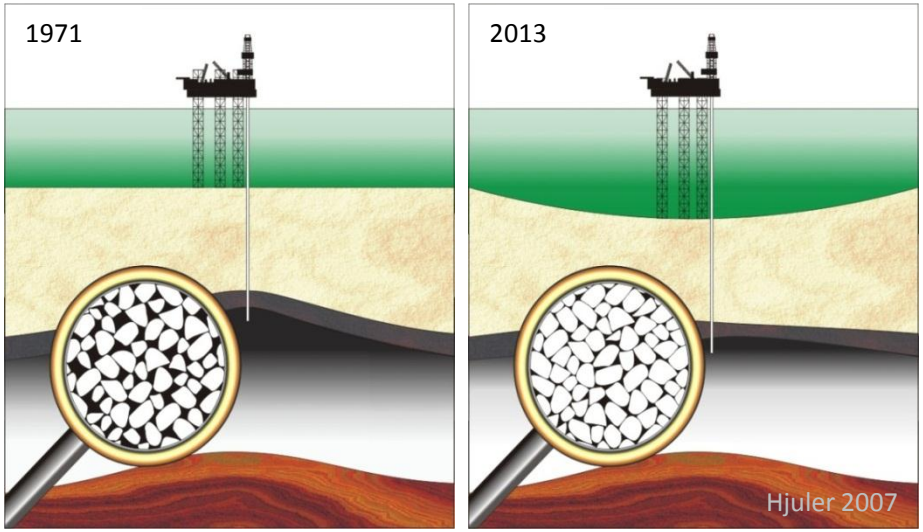
Water weakening of chalk

- Main conclusion:

  Precipitation–dissolution processes represent an important contributor to the water weakening of chalk — and the seabed subsidence at the Ekofisk field

- ”Geo” competency at IRIS proven indispensable for understanding the chalk–water interactions at Ekofisk

- Example for a multiscale, multidisciplinary project that benefits from the joint efforts of academia and industry



Centres at IRIS

IRIS

- COREC = Center for Oil Recovery
  - Increase oil recovery from producing fields by understanding the reservoirs and the relevant methods

corec
Center for Oil Recovery

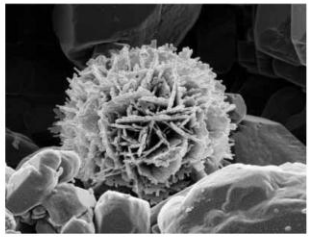
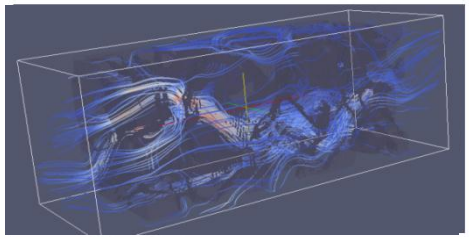
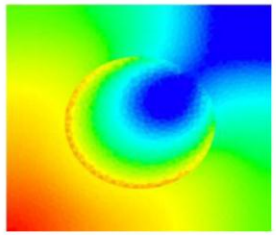
- SBBU = Center for Drilling and Wells for Improved Recovery (SBBU)
  - Unlock petroleum resources through better drilling and well technology

sfi
SBBU - CENTRE FOR DRILLING AND WELLS FOR IMPROVED RECOVERY

Joint application: National IOR Centre

University of Stavanger

IRIS

Research Centre for improved recovery of petroleum resources on the Norwegian Continental Shelf

«Stavanger is the place!»

University of Stavanger

IRIS

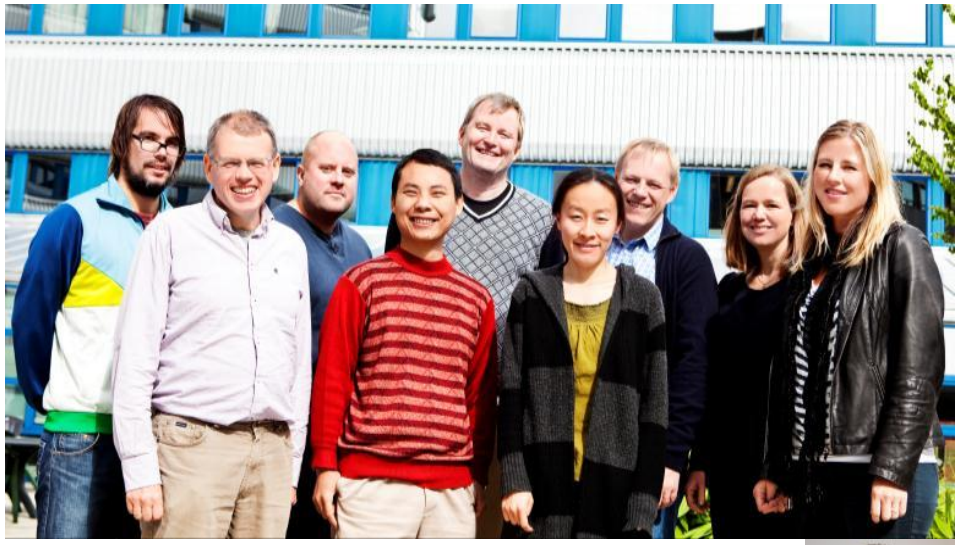
- 70+ researchers (UiS-IRIS) with unique knowledge and expertise within IOR and reservoir characterisation
- Strong competence in petroleum economics and environmental preservation
- Proximity between industry, petroleum authorities, and academia/research in Stavanger
- Competence from large research programmes and COREC are crucial

- We have a consortium of the two core partners UiS and IRIS, additional corporative partners, and research partners
- UiS is the host institution

BERGEN Reservoir Group

Geir Nævdal, Chief Scientist

Kristin Flornes, Research Director



11 researchers with background in
- Applied Mathematics
- Physics
- Reservoir Engineering
- Geology

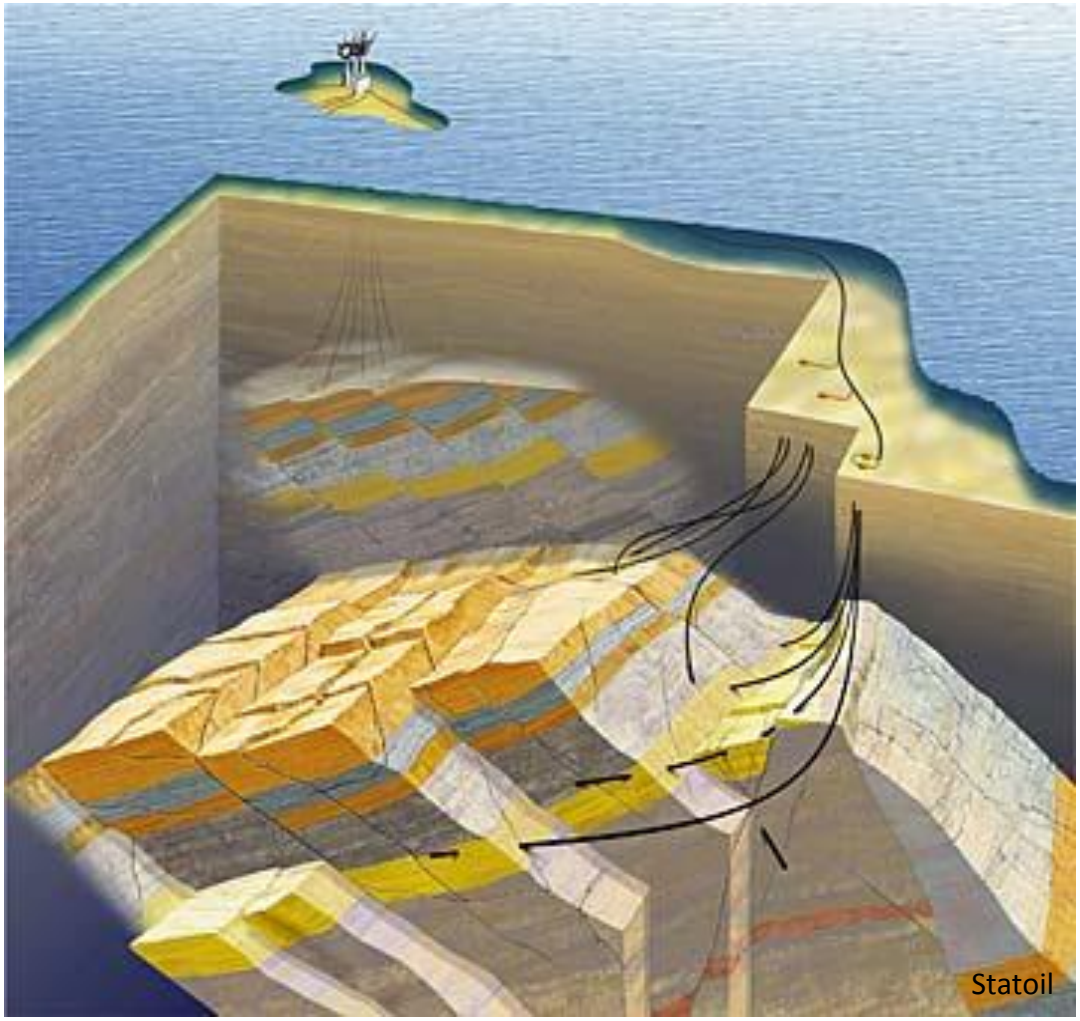
Experts in
- Improved reservoir management
- Data assimilation and inverse modelling
- Dynamic reservoir and well flow modelling
- History matching and ensemble based methods (EnKF)
- Production optimization
- Sedimentology and Diagenesis

Based in Bergen at Høyteknologisenteret

Background - The inverse problem

IRIS

- Inverse problem: Adjust reservoir flow model so that model output match measurements (history matching).
- Our measurements are production and log data at the wells and seismic data.
- The production data: Uncertain rates (oil, gas, water) and pressure data.



Reservoir data assimilation: Integrated workflow & realistic geology

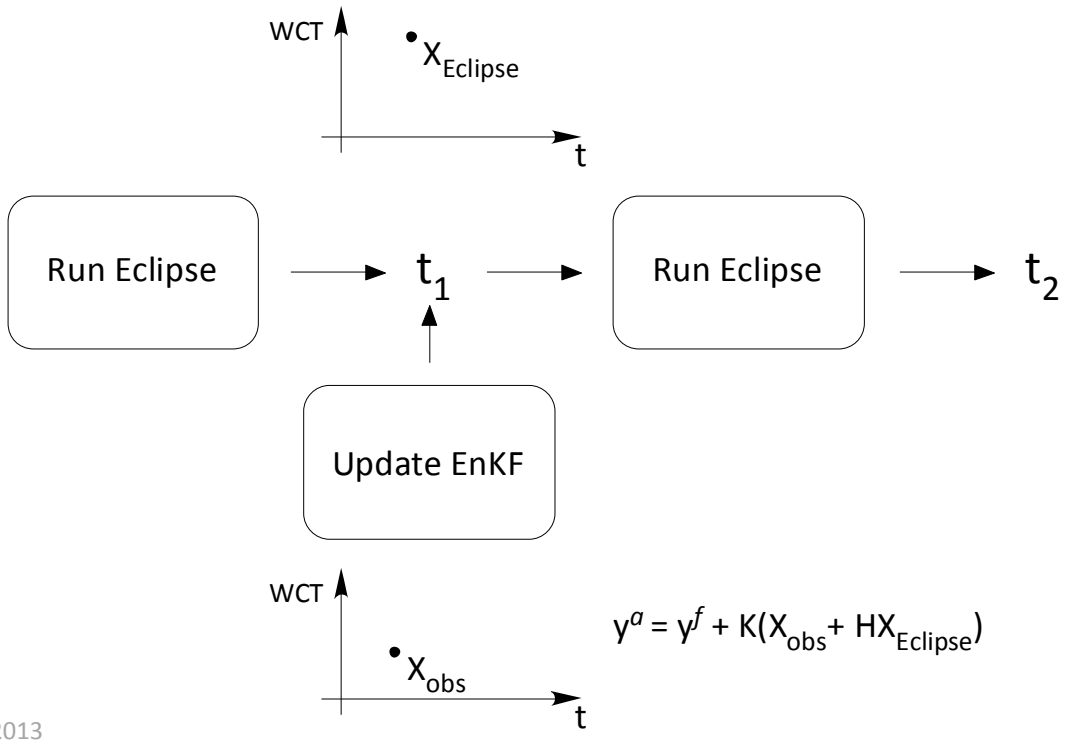
IRIS

- Provide reservoir models honoring:
  - Geological interpretation/ geostatistics
  - Seismic
  - Production data
  - Other data: 4-D seismic, Gravity, …

Reservoir model and update

1. Geomodel (e.g. Petrel)

2. Decide what is to be estimated
   Initial parameterization
   Make ensemble (100 realizations)
   } y^f

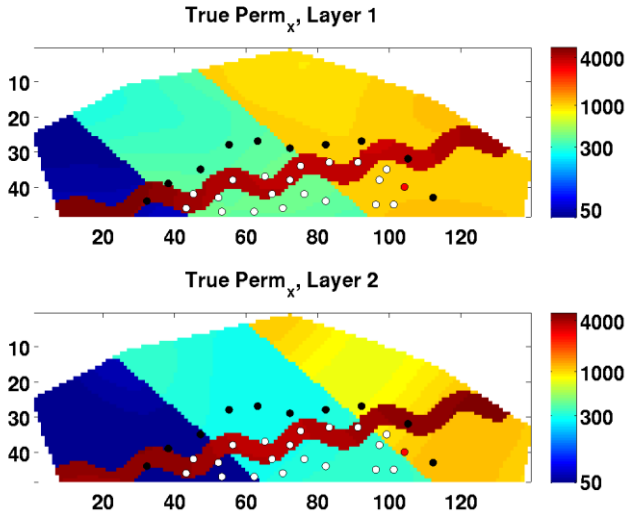
3. 

Facies model updating

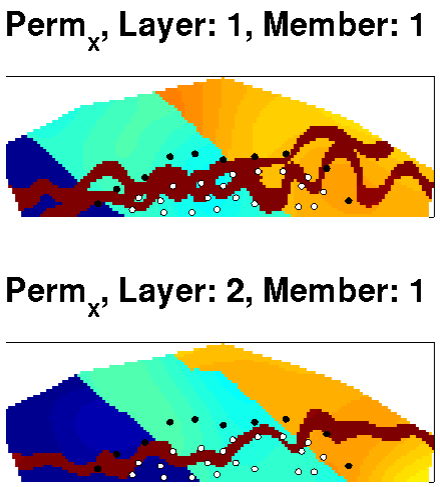
IRIS

› Problem:

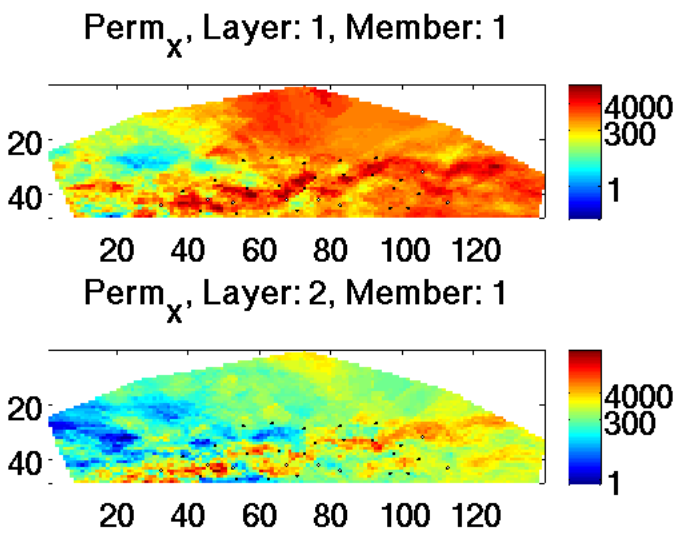
True



Initial



Estimated



› Shallow-marine environment: coarse-sand/sand/fine–sand/shale

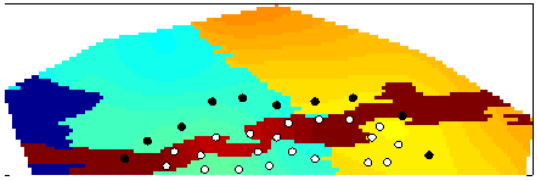
› Using the EnKF to update the permeability directly smears out the channel

› We would like to preserve the channel shape

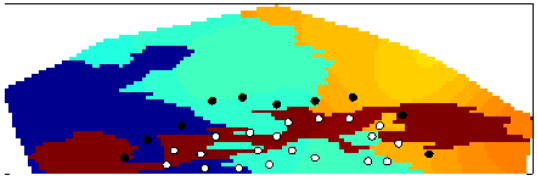
Facies model updating and multi level methods

- Combine truncated Gaussian field modeling of background with level set approach to model channel
- Improve shape preservation of channel
- More effective representation of internal heterogeneities

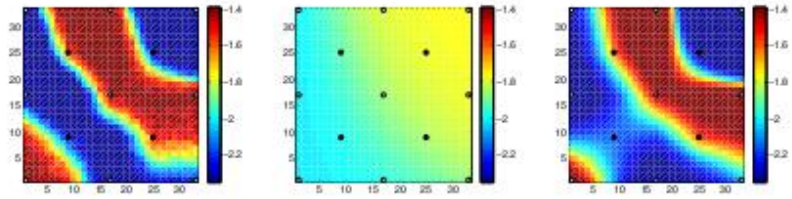
Perm$_x$, Layer: 1, Member: 1



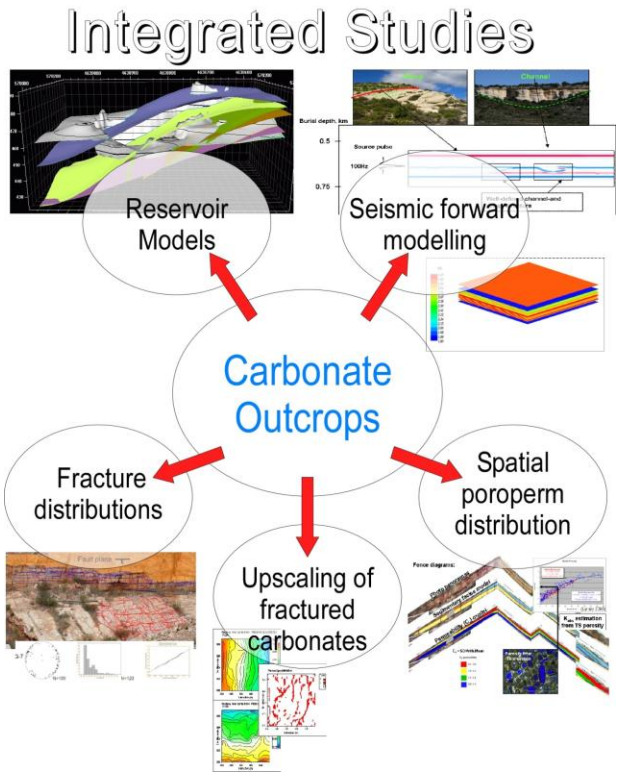
Perm$_x$, Layer: 2, Member: 1



Multiscale LSE



Carbonate Reservoir Geomodels



- Database of samples and reservoir properties from a range of carbonate rocks
  - More than 500 core plugs
  - Sedimentary logs
  - Fracture measurements in 3D
  - Several hundred Gamma-ray measurements
  - Thin-sections
  - Poro-perm measurements
  - Velocity and density measurements
  - Diagenesis analysis
  - LIDAR and Georadar datasets
  - Synthetic seismics
- Build reservoir models by integrating a range of different datasets
- Education of 11 MSc and 3 PhD students
- Publications

Reservoir studies

- Recent projects
  - CO_2 Storage Potential of the Dunlin Group (CLIMIT/Gassnova)
  - Petrographic Study of Dunlin Group (Gassnova/Ross Offshore)
  - Fluid inclusion study of the Johansen Fm (Gassnova/Ross Offshore)
  - Review on current available knowledge and thinking regarding rates of loss of CO_2 from sub-sea geological formations (CLIMIT)

IRIS ENERGY: ”geo” competencies and research

- Research at pore-, core-, and reservoir-scales
- Laboratory experiments and modelling approaches
- Reservoir and outcrop rock characterisation
  - Petrography and thin section analysis
  - Mineralogy and diagenesis
  - Fluid inclusion studies
- Reservoir characterisation and field scale simulation
  - Well test analysis and estimation of reservoir properties
  - Thermal conductivity measurements
  - Temperature history modelling
  - Flow modelling

Thank you for your attention!

Contact IRIS

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