

FORCE, Joining Forces Seminar, 22<sup>nd</sup> and 23<sup>rd</sup> of May 2013

# Exploration Technologies at SINTEF Petroleum Research

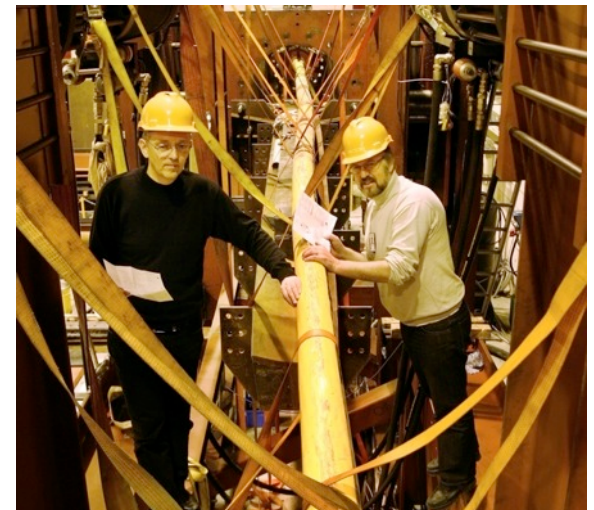
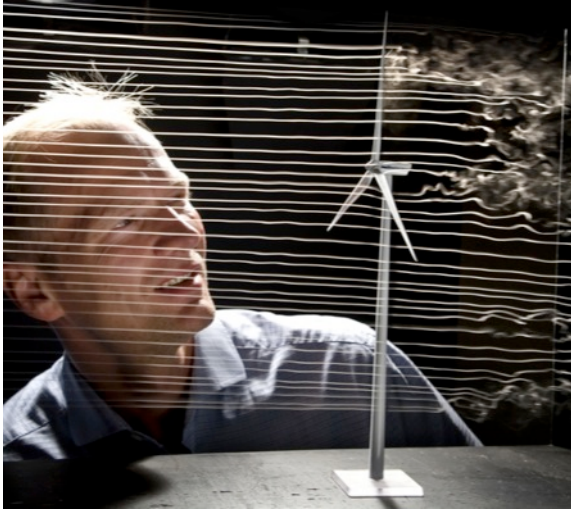
Ane Lothe (PhD), Research Director, Basin Modelling Department



# SINTEF

is the largest independent research organisation in Scandinavia

- Leading expertise in the natural sciences and technology, environment, health and social science
- 2100 employees from 68 countries
- Annual sales of NOK 2.8 billion – customers in 61 countries

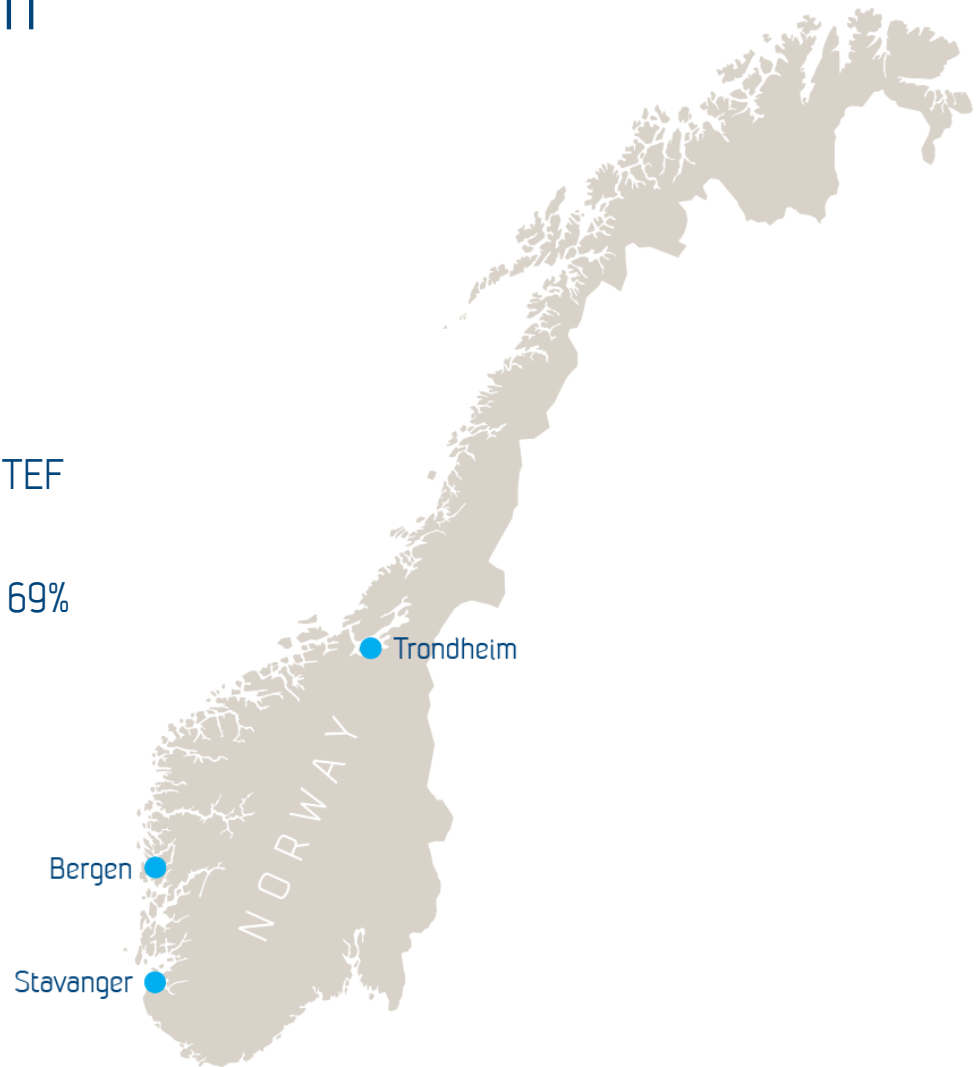


# SINTEF Petroleum Research

## Our vision:

Technology for a better society.

- A non-commercial research subsidiary of SINTEF
- Number of employees: 109
- Proportion of academic staff with doctorates: 69%
- Total number of publications: 141
- Gross turnover: MNOK 199



Facts 2012

# A multidisciplinary research organisation with international top level expertise in specific fields

Basin Modelling  
Drilling and Well  
Formation Physics

Geophysics and Reservoir Technology  
Wellstream Technology

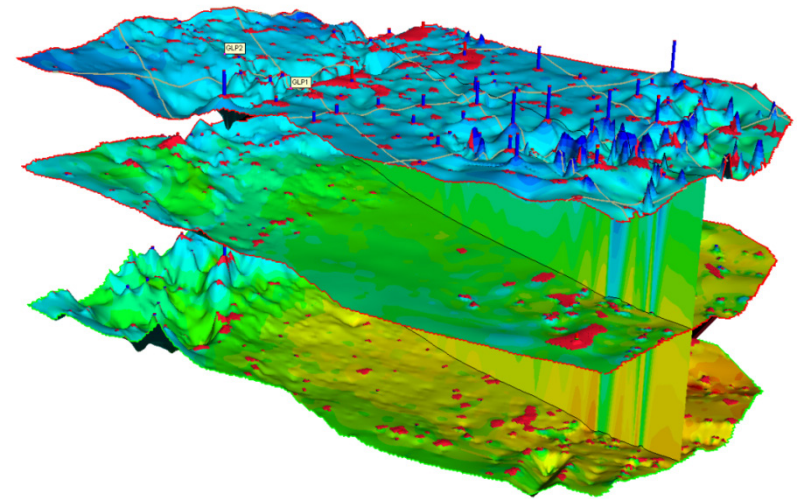




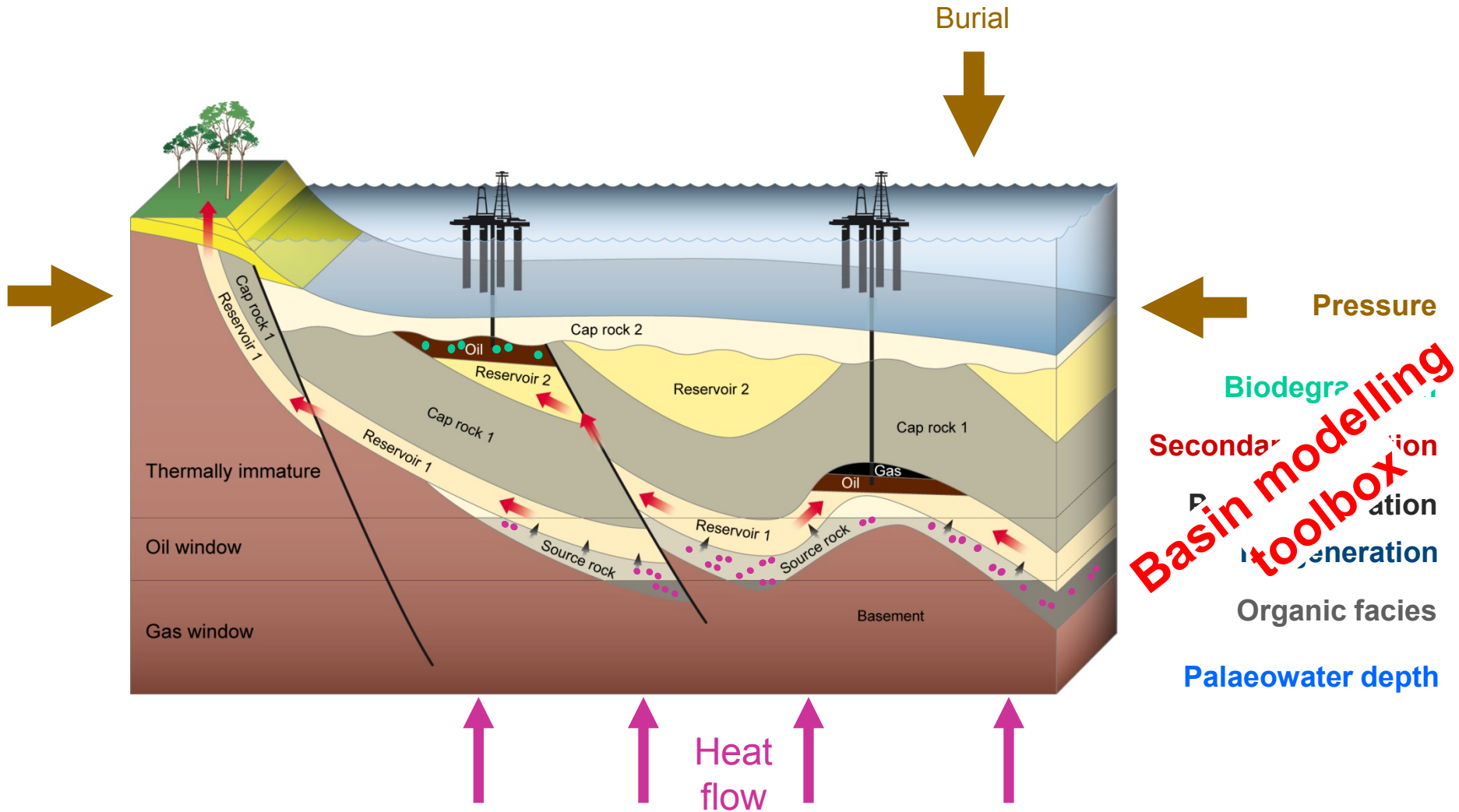
# Basin Modelling Department

## Development and application of mathematical models for intra-basinal processes on geological time scales

- Burial history and palaeobathymetry reconstruction
- Source-rock evaluation and facies prediction
- Hydrocarbon generation and multi-component kinetics
- Expulsion/primary migration
- Secondary migration
- Fault and cap rock leakage
- Pressure and temperature modelling



# Basin modelling / petroleum systems modelling



# Basin Modelling Software Tools

## OF-Mod 1D+3D

predicts organic richness (TOC) and quality (HI) distributions of marine source rocks based on a sedimentation model and process descriptions.

## SEMI 2.5D

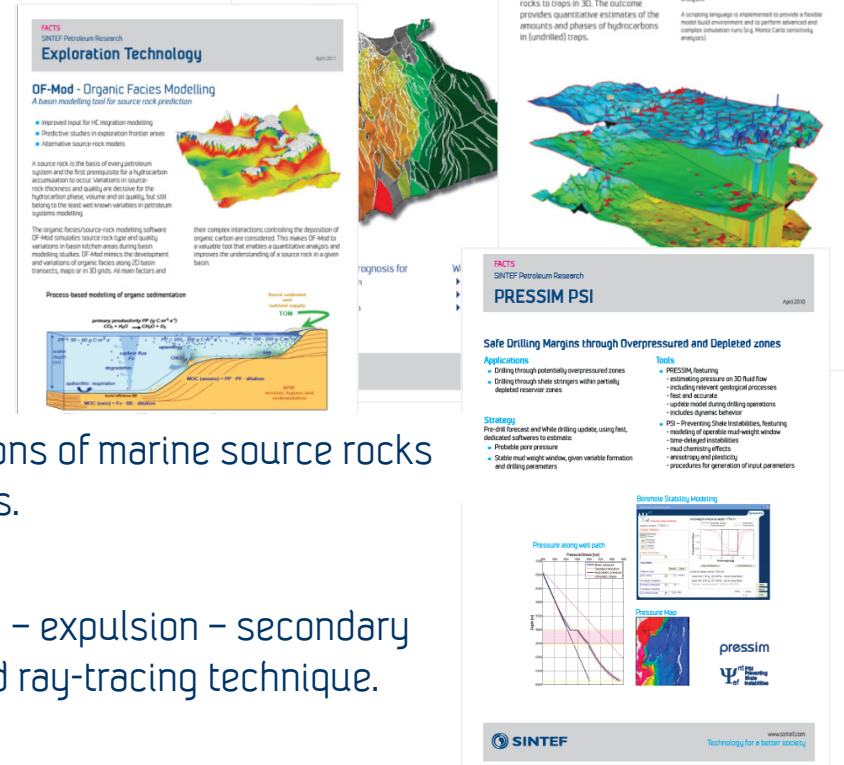
Geo-model framework, models thermal history, generation – expulsion – secondary migration – accumulation of petroleum using a map-based ray-tracing technique.

## SEMI Pressim 3D

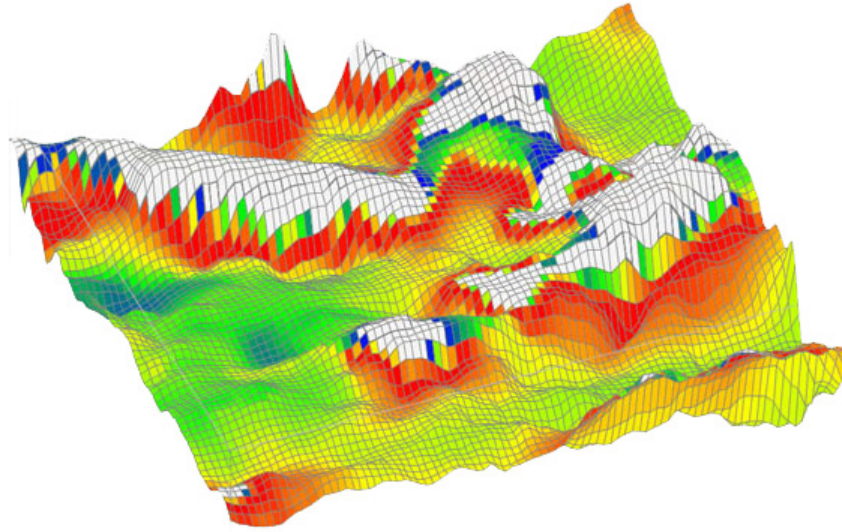
simulates pressure generation and dissipation within fault-bounded compartments based on descriptions of various porosity-influencing processes.

## Presseis 1D+3D

models temperature history by solving a multi-1D heatflow equation, models 3D pressure distribution based on seismic and rock physics data.



# Organic facies modelling with OF-Mod 3D



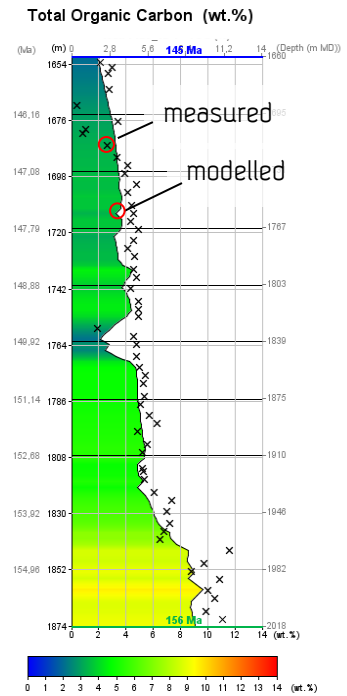
Process-based forward modelling of organic sedimentation allows to predict **pre-burial source-rock potential and -type** away from well control

- Maps generated can be directly imported into the hc migration simulators

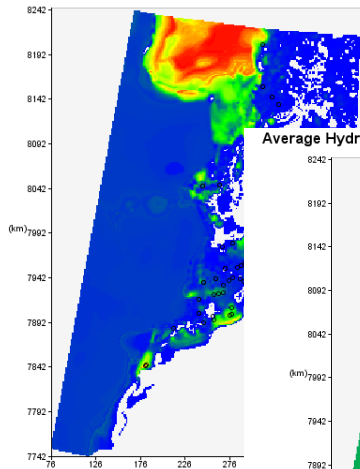


# OF-Mod 3D case studies provide:

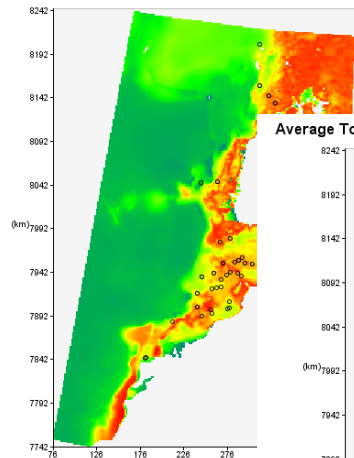
- Calibrated model with analytical data from well samples
- Quantitative prediction of source rock potential and – type away from well control
- Produces 3D grids and thickness maps of different classes SRP
- Produces maps of pre-maturation TOC and HI
- Results can be imported in all secondary migration modelling tools
- Case studies all over the world



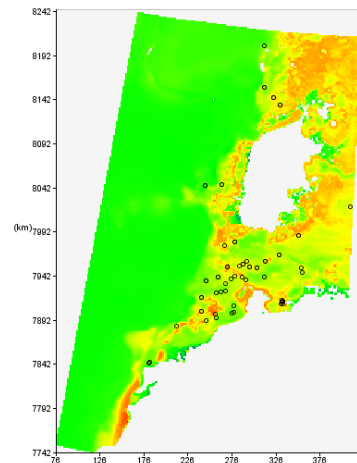
Thickness good SRP (m), period: 156-145 Ma



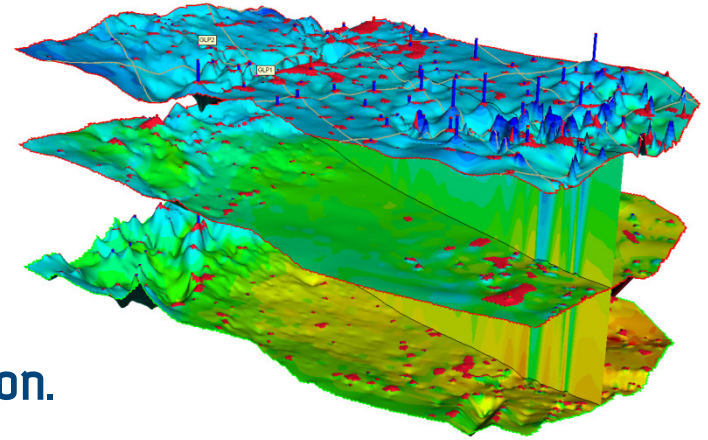
Average Hydrogen Index (mg HC/g C), period: 156-145 Ma



Average Total Organic Carbon (wt.%), period: 156-145 Ma



# SEMI - Secondary migration modelling



- The secondary migration modelling tool SEMI is our **central** basin modelling application.
- It uses a **ray-tracing** scheme and **parallel computing** techniques to model petroleum migration within stacked carrier rock sequences at high resolution.
- It also handles the processes that cause hydrocarbons to **migrate out of traps** and provides advanced methods for predicting and accounting for **fault seal capacities** in migration modelling.

# Products – regional integrated studies



## Integrated Geological

This integrated and comprehensive study includes some of the most comprehensive geochemical, thermal and pressure data currently available for the region. These data, combined with public seismic and re-evaluated formation tops from the geometrical framework. These datasets will form the framework for base-case models of palaeo-water depth, source-rock quality, burial and thermal histories (considering fission-track results), organic matter maturation, formation pressure, hydrocarbon expulsion and secondary migration. Particular attention was paid to identifying and incorporating the timing and extent of geological events (e.g. erosion events) that exert a profound influence on petroleum generation, migration and entrapment.

The study also provides evaluations at a prospective

The results are summarized in the following:

- Maps of timing of key geological events (e.g. erosion events) that exert a profound influence on petroleum generation, migration and entrapment.
- Depth and time floor to Base Quaternary
- Palaeo-water depth for Cretaceous and Palaeogene
- Timing and quality of source rocks
- Temperature at different geological horizons
- Geochemical data for 2300 vitrinite reflectance samples which have been analysed specifically for this study
- Identification and geochemical characterisation of potential source rocks
- Source-rock property maps (thickness, TOC and HI) for potential Jurassic, Triassic and Permian age, based on organic facies modelling
- Detailed geochemical correlation between oils, gases and show units of different ages identified in the Norwegian and Russian Barents Sea
- Assessment of seal integrity based on headspace gas analyses



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SINTEF Petroleum Research



## Integrated Barents Sea Study Basin Modelling Upgrade 2008



- completed -

The Integrated Barents Sea Study provides a highly successful overview of petroleum systems in the Barents Sea to include an extensive modelling upgrade 2008. This study combines an extensive modelling upgrade 2008. This study combines an extensive modelling upgrade 2008. This study combines an extensive modelling upgrade 2008.

### A Basin Modelling

- improved seismic
- increased grid resolution
- eight instead of five
- updated erosion a (co-operation with APT)
- improved and extended
- consideration of fault
- improved calibration



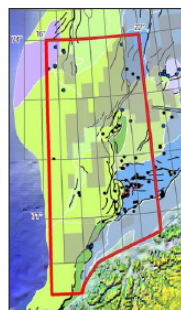
www.sintef.no



## Invitation to participate in the Western Barents Sea Study 2012 (WBS 2012) Mesozoic play types: evaluation and uncertainty

The continuation of the recent exploration success in the Norwegian Barents Sea will require sophisticated analysis of petroleum systems and play types. SINTEF Petroleum Research has started a petroleum systems modelling study that focuses on the evaluation and uncertainty analysis of selected Mesozoic play types in the western Norwegian Barents Sea. AGR (assisted by APT), Geotrack and Fugro Geolab Nor contribute as co-operation partners.

The study will integrate comprehensive geochemical, thermal, and pressure databases provided by our co-operation partners and from public sources. All depth maps and fault structures will be derived from a consistent interpretation of the latest released public seismic and re-evaluated formation tops. These datasets will form the framework for base-case models of palaeo-water depth, source-rock quality, burial and thermal histories (considering fission-track results), organic matter maturation, formation pressure, hydrocarbon expulsion and secondary migration.



Project area (red), blocks nominated for the 22nd licensing round (grey), exploration blocks (black), and shallow stratigraphic correlates (blue).

Monte-Carlo-type simulations will be performed to characterize uncertainties and variations in the Mesozoic play-type models. Statistical analyses of the results will be used to identify key risk factors for petroleum generation, secondary migration and trapping in this tectonically strained area. Particular attention will be laid on the representation of the complex geological history (e.g. erosion events) in the model.

We plan to release the study in late summer 2012, in time for the 22<sup>nd</sup> licensing round.

### Deliverables

- Maps of statistical analysis of most likely petroleum entrapments in 3 carrier-rock units
- Uncertainty analysis of key parameters in secondary petroleum migration models
- Maps of the base-case model scenarios for
  - thermal histories (all horizons),
  - erosion maps for selected time steps,
  - burial histories for source- and carrier rocks,
  - fluid pressure histories in the carrier rocks,
  - petroleum generation and expulsion histories from the source rocks, and
  - petroleum migration and trapping in carrier rocks.
- Source-rock property maps (thickness, TOC, HI) for 2 Mesozoic source rocks, based on organic facies modelling
- Maps of modelled palaeo-water depth for Lower Triassic to Base Quaternary
- Depth maps from Lower Triassic to sea floor for 19 horizons (6 interpreted, 13 constructed, <500 m x <500 m grid)
- Temperature, pressure and geochemical databases (Excel)
- Report (paper and PDF)

All maps will be delivered in a consistent Petrel project or as grids. Other formats (ESRI shape files, Kingdom, Landmark) can be made available on request.

Contact persons: Matthias C. Daszinnies, matthias.c.daszinnies@sintef.no  
Hermann M. Weiss, hermann.weiss@sintef.no

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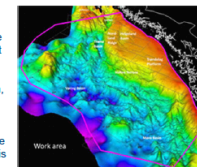
January 2012



## Integrated Norwegian Sea Study - INS 2010 Geological history and petroleum system evolution

SINTEF Petroleum Research, together with its cooperation partners AGR Petroleum Services, Fugro Geolab Nor and Geotrack International, has completed a regional overview study covering most of the Norwegian Sea.

This integrated basin modelling study comprises some of the most comprehensive geochemical, thermal, and pressure databases currently available in the region. Depth maps derived from a consistent interpretation of public seismic and re-evaluated formation tops from the geometrical framework. These data were used to model palaeo-water depth, source-rock quality, burial and thermal history (considering fission-track results), organic matter maturation, formation pressure, hydrocarbon expulsion and migration. Various petroleum systems were characterized and key risk factors identified within this large and geologically complex area.



3D depth map of a key horizon showing the approximate extent of the work area.

Particular attention was paid to identifying and incorporating the timing and extent of geological events (e.g. thermal and erosion events) that exert a profound influence on petroleum generation, migration and entrapment.

### Deliverables

- Report (paper and PDF)
- Maps of petroleum generation and expulsion from source rocks
- Maps of petroleum migration and entrapment in carrier rocks
- Maps showing the modelled thermal and fluid pressure history
- Source-rock property maps (thickness, TOC, HI) for marine Mesozoic potential source-rocks, based on organic facies modelling (Åre Fm. coal conceptual)
- Maps of modelled palaeo-water depth for Intra Upper Permian to Base Quaternary



November 2010

SINTEF Petroleum Research

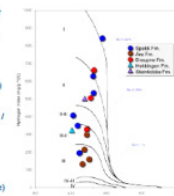


## KinLib A library of multicomponent kinetic models

Any hydrocarbon generation model requires kinetic data for generation of petroleum components from the modelled source rocks.

SINTEF Petroleum Research offers kinetic models of four petroleum components for core samples from all major source rocks of the Barents Sea, the Norwegian Sea and the North Sea, presently including:

- Draupne Formation, claystone (3 samples representing kerogen types I, II, III-IV, N Viking Graben)
- Spekk Formation, claystone (6 samples representing kerogen types I to III, Trøndelag Platform / Frøan Basin)
- Hekkingen Formation, claystone (1 sample representing kerogen type III-II, Nordkapp Basin)
- Åre Formation, coal and coaly shale (4 samples representing kerogen types III-II and III, Halten Terrace)
- Steinkobbe Formation, claystone (1 sample representing kerogen type II, Svalis Dome)

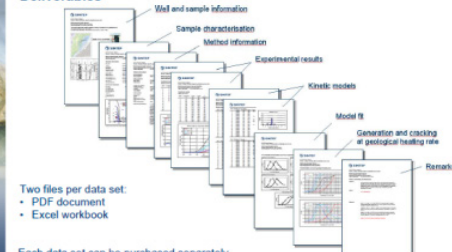


Rock-Eval hydrogen index vs. Time, indicating the wide range of kerogen types covered.

Further extensions will follow.

The four components represent the following carbon number ranges: C<sub>1</sub> (methane, dry gas), C<sub>2</sub> to C<sub>2</sub> (wet gas), C<sub>3</sub> to C<sub>14</sub> (light oil) and C<sub>15</sub> to C<sub>35</sub> (heavy oil). The models are derived from MSSV-GC-FID data obtained at two different heating rates.

### Deliverables



Two files per data set:  
• PDF document  
• Excel workbook

Each data set can be purchased separately.

Contact persons: Hermann M. Weiss, hermann.weiss@sintef.no, phone +47 73 59 12 28  
Joachim Røva, joachim.rova@sintef.no, phone +47 73 59 12 41

www.sintef.no/petroleumbasin



# preDrill

Simulation and analysis for verification and decision support in well and drilling planning

## Pressim

-Pore pressure estimate

## PSI

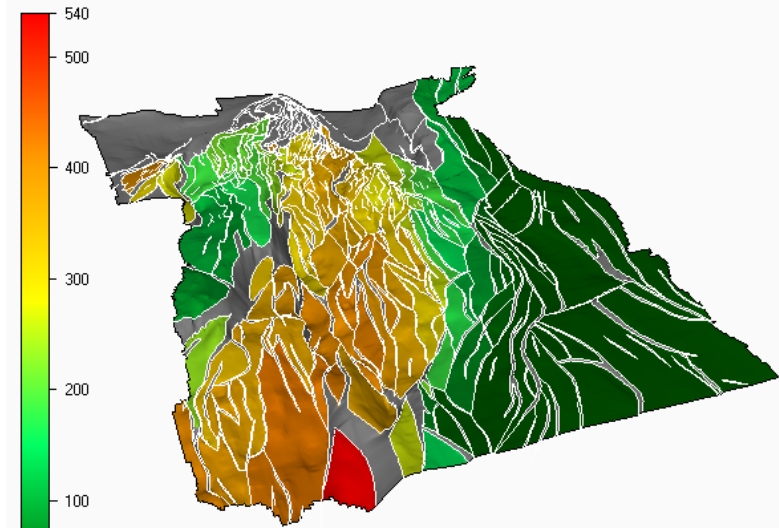
-Prevent shale instability

## Flow Model

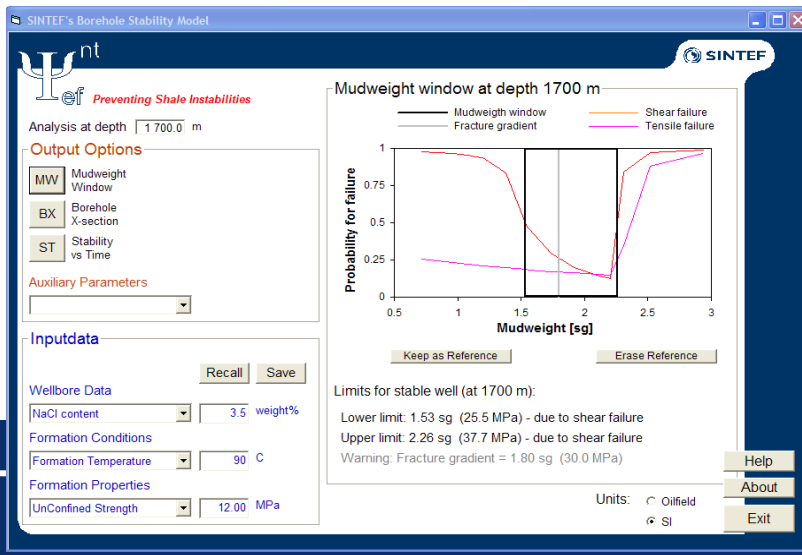
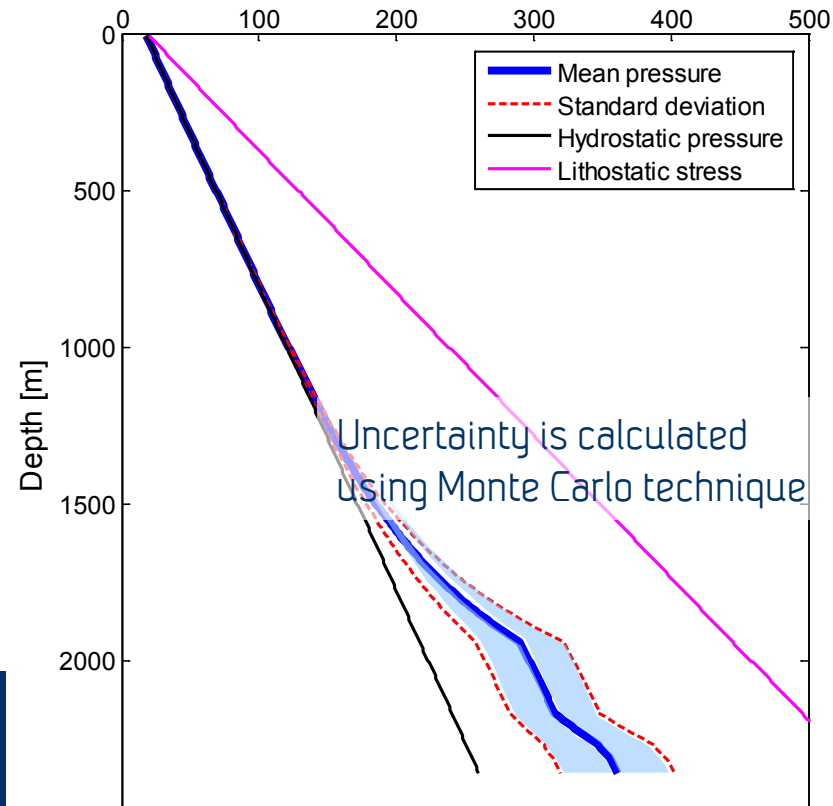
-Estimation of hydraulics and flow during drilling

## Torque & Drag Model

-Estimation of forces during drilling



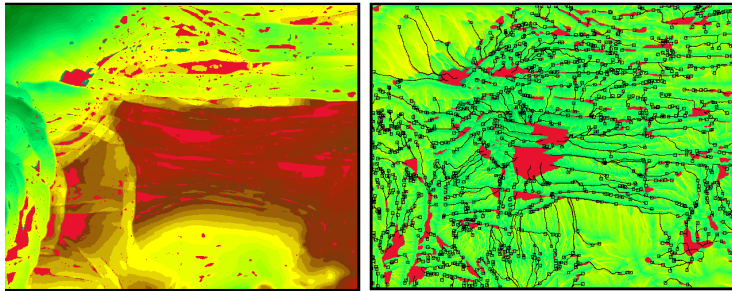
Pressure/Stress [bar]



# Some selected R&D projects

## Impact of Cenozoic structural development and glacial erosion on gas expansion, hydraulic fracturing and leakage

- Start 2013 to 2016
- ENI
- One PhD student



Oil and gas pools

Active spill points

(Figures from another study)

## BASE -Deep Weathering -JIP

Start late 2013 together with NGU

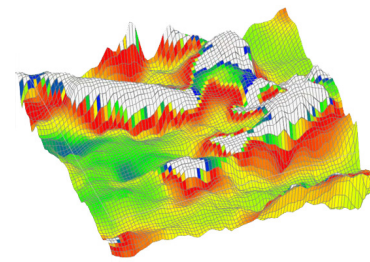
## Migration and risk modelling for CO<sub>2</sub> storage



[www.sitechar-co2.eu](http://www.sitechar-co2.eu)

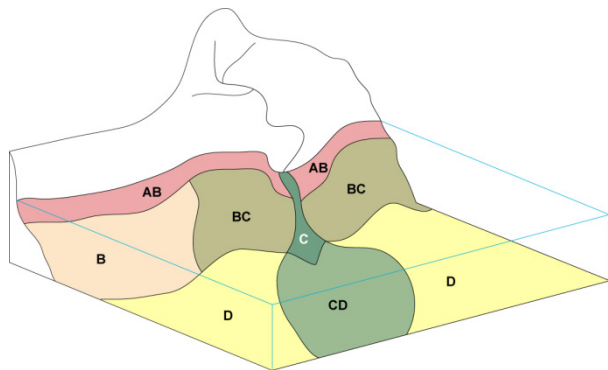


# OF-Mod 3D Facies - JIP



## Modelling linked sedimentary and organic facies for the prediction of source rock deposition

- Geologically-informed lithology model, improved stratigraphy model,
- Modelled constraints by input data
- Uncertainty analysis of the organic deposit simulation results
- Easily extendable for future use  
(different depositional environments, different types of uncertainty, ...)



Project duration 3 years, 2010 -2013  
4 participants



# OF-Mod 3D Facies - JIP

## Modelling linked sedimentary facies for the prediction of source rock

- Geologically-informed lithology
- Modelled constraints from stratigraphy model, sedimentation rates
- Uncertainty analysis of simulation results
- Easily extended to different basins, different types of uncertainty, ...)

**New phase - Carbonates**  
• Include carbonate mud environments  
• This is where highest organic carbon concentrations are found

Project duration 3 years, 2010 -2013  
4 participants

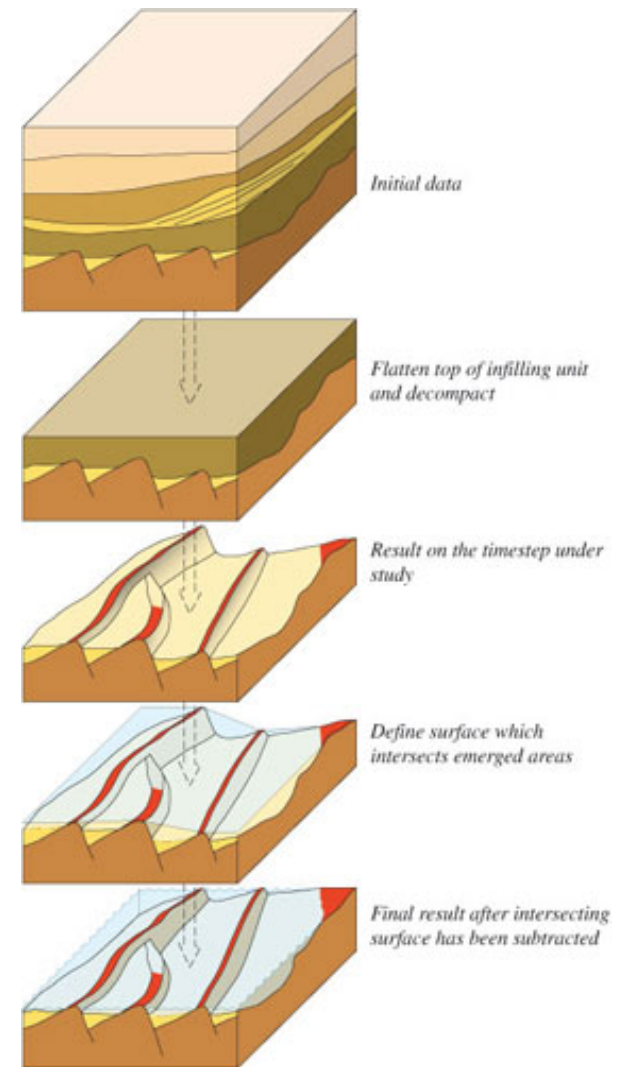


# Project proposal : **Uncertainty in 3D palaeobathymetry reconstruction**

- Uncertainty to be determined for
  - seismic depth interpretation that will influence decompaction
  - lithology variations
  - lithospheric stretching
  - restoration of erosion
- Not a full tectonic reconstruction

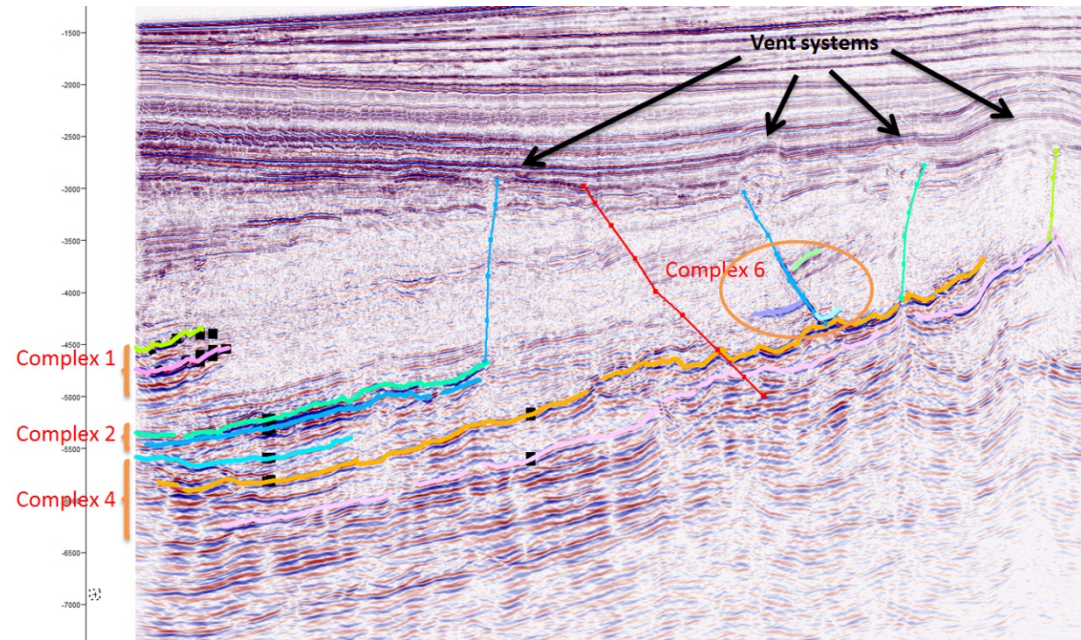
## Deliverables

- Quantifying the uncertainties in 3D
- Better geomodels that can be used as input into
  - source rock modelling
  - migration modelling
  - sedimentation modelling



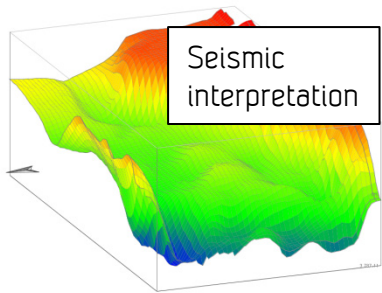
# The effect of sill intrusions on the Petroleum system

- On-going JIP project with Tector and Royal Holloway University
- Motivation:
  - Thermal effects of the sill emplacement on maturation of hydrocarbons
  - Identify under which circumstances a sill may act as a reservoir and/or as a top seal

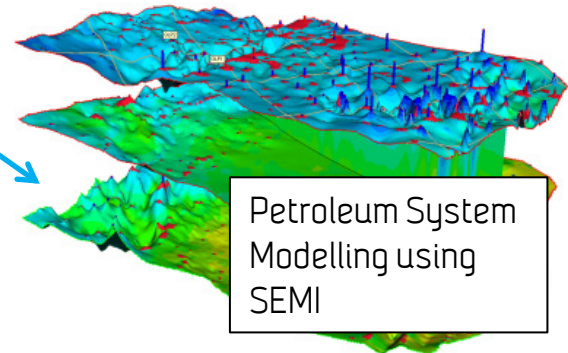
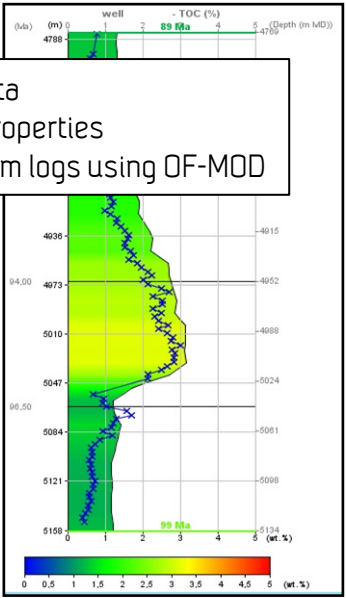


## New software development phase:

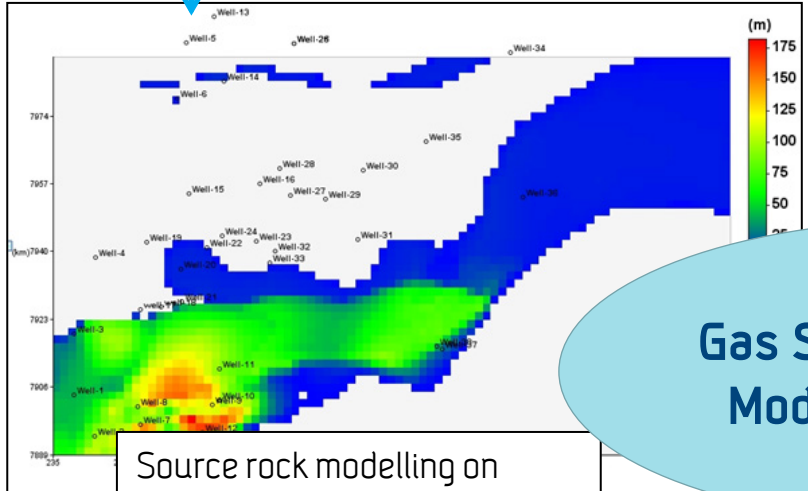
- Integrating hydrocarbon migration and entrapment within the sill intrusions



Well data  
Rock properties  
TOC from logs using OF-MOD



Natural fracturing and pressure modeling in shale gas: reconstruction of geopressure using SEMI-Pressim



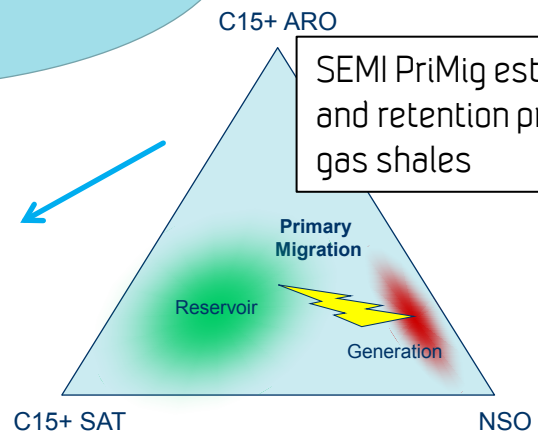
# Gas Shale Exploration Modelling Workflow

Source rock modelling on basin scale using OF-MOD, output maps:

- Total organic carbon (TOC)
- Hydrogen index (HI)
- Accu. thickness (m) of organic facies classes

Sensitivity and risk Analysis

SEMI PriMig estimate expulsion and retention processes of HC in gas shales





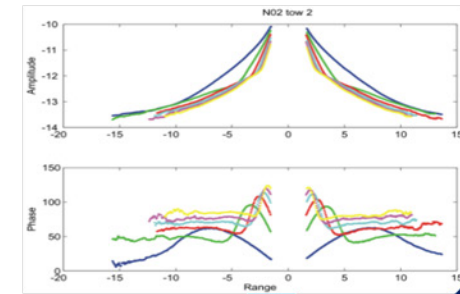
# Thank you!

More information:

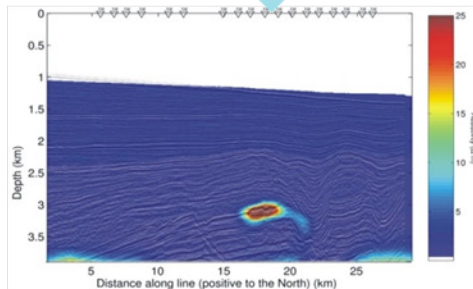
[www.sintef.no/petroleum](http://www.sintef.no/petroleum)

or

ane.lothe@sintef.no

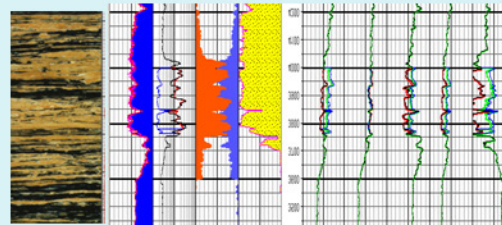


CSEM inversion



## Rock physics driven integration

### Core and Well data

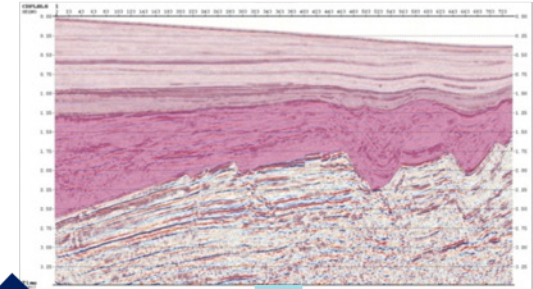
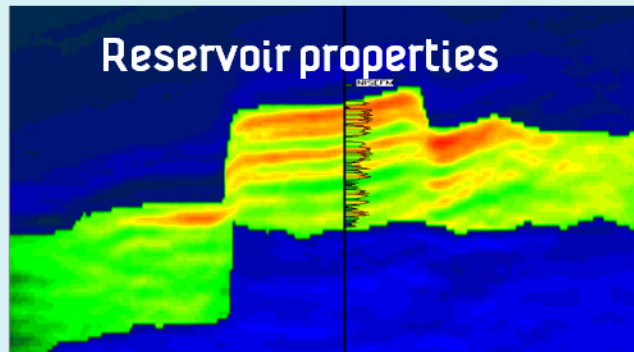


Rock Physics properties,  
hydrocarbon volumes,  
phases,  
*uncertainties*

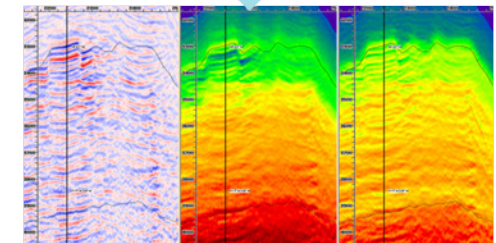
Cross-  
calibration

Basin modelling:  
hydrocarbon volumes,  
phases,  
*uncertainties*

## Reservoir properties



Seismic inversion



Close collaboration from  
Seismic, FP and BM  
departments.

Provide oil and gas industry not only higher resolution geophysical structural models but also the important reservoir information what the model means in terms of hydrocarbons.