3D Source Rock Modelling of the Late Jurassic Voring Basin off Mid-Norway

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An underexplored petroleum province
The greater Voring Basin off mid-Norway, close to the well-established petroleum plays of the Danna and Halten Terraces, has high potential for petroleum prospectivity. It remains underexplored, although several discoveries of mainly gas but also oil were made in the last few years. One important risk-factor for the area is the presence or absence of an effective source rock.

Spekken Formation source rock
- Equivalent to the Kimmeridge Clay and Draupne formations of the North Sea
- Only source rock off mid-Norway proven capable of generating significant quantities of oil
- Covered by 9000 to 13000 m of Cretaceous and Tertiary sediments in the central parts of the Voring Basin (Brekke, 2000) > overmature
- Higher chances for prospectivity suggested at local highs and at the western flank of the basin where the overburden is less - but there covered by Tertiary lava drapes and invisible to seismic

There is no direct information on quality and distribution of the Spekk Fm in the deeper Voring Basin available

Well data collection and interpretation
- No well ever reached Late Jurassic rocks in the deeper Voring Basin
- Therefore, well data from the eastern and western margin of the Jurassic rift zone (Halten Terrace, Danna Terrace, Trøndelag Platform, East Greenland) were analysed
- Data from 28 wells in the Norwegian Sea comprising 1077 Spekk Fm samples were compiled

High source rock potential
- The Late Jurassic rift zone between Norway and Greenland represents a marine basin with anoxic deep waters and deposition of organic matter rich clays
- Input of terrigenous organic matter is significant as indicated by bulk organic, maceral and biomarker data
- Kerosene composition and petroleum potential of the Spekk Fm vary significantly over short lateral distances
- Most samples from the Spekk Fm. represent a mixture of type II and type III kerogens
- High content of pyrolytically "dead" organic carbon (inertinite)
- The results indicate that the eastern part of the Norwegian Sea represented a shallow shelf environment

Organic facies modelling
We applied SINTEF's process-based source rock modelling tool OF-MOD 3D to form a spatial picture of TOC and HI distribution during the Late Jurassic in the entire rift area between mid-Norway and East Greenland. Based on the data interpretation, a detailed palaeo-water depth reconstruction, structural and seismic information and general process-understanding a 3D model was developed, on which several conceptual settings were tested.

Generally good fit of modelled TOC and HI with the calibration data
- Some strong deviations close to morphological highs because of local patterns of organic matter input and distribution with currents
- Source Rock potential
  - poor
  - fair
  - good
  - very good

In the basins:
- High source rock potential
- Dominance of marine organic matter
- Good preservation of OM in anoxic bottom waters

Increasing potential with increasing distance to coast
- Distribution and quality of the source rock are highly dependent on palaeo-water depth
- In the basins, organic matter of marine origin dominates, but the overall volume of high quality source rock is limited as primary production and sedimentation rates are low
- At morphological highs already existing in the Jurassic, potential is reduced (2-4 wt% TOC, HI of 100-200 mgHC/gTOC) because of high content of terrigenous organic matter
- Current and wave action provide good oxygenation reducing preservation of organic matter
- Special local patterns of sediment input (rivers) and transport close to the coast of the Norwegian mainland and the local highs resulted in rather strong variation in source rock quality over small lateral distances and can not be matched by the model
- In anoxic bottom water conditions comparatively low marine primary production (50 to 100 µgC/m²·yr) is sufficient to support high organic matter content and hydrocarbon potential of the sediments as preservation is rather good.

Conclusions
- Our modeling results indicate very good source rock potential of the Spekk Fm over large parts of the Voring Basin area (5-7 wt% TOC, HI of 250-300 mgHC/gTOC)
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Geoseismic section through the working area

Hydrogen Index (mg HC/g TOC)

Increasing potential with increasing distance to coast

In morphological highs:
- Low thickness or even absence (low sedimentation /winnowing)
- Strongly varying TOC over small lateral distances (terrigenous input)
- Low HI (little marine OM, oxic bottom water)

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