[PS]Burial, Thermal and Maturation History in the Northern Viking Graben (North Sea)*

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Abstract

In this research study burial, thermal, and maturation reconstruction have been carried out using seismic and exploration wellbore data from the northern part of the Viking Graben. The study area can be found eastward from the Statfjord Field in the 35/8 section.

The best source rocks located in the northern part of the Viking Graben subsided in the late Jurassic. These source rocks represented by the Kimmeridge Shale (also called Drauphne Shale) and the Heather Shale Formations of the Viking Formation Group can be found in the depth of 3000-3500 m underlain by the delta-plain deposits of the middle Jurassic Brent Group, which also have a moderate petroleum generation potential in this area. The deposition of the above-mentioned source rocks and the reservoir rocks of the northern Viking Graben are connected with the extensional event of the Pangea supercontinent in the late Jurassic - early Cretaceous. The Triassic terrestrial, alluvial, and lithoral sandstones of the Statfjord Group and the middle Jurassic river bed, shoreface, and delta-bar developments of the Brent Group are the primary reservoir rocks in this area. The main seal rocks of the Viking Graben are the Jurassic shales and the Cretaceous pelites.

The Jurassic organic-rich source rocks have generated hydrocarbons since the late Cretaceous. The recent thermal maturity measurements (Rock Eval analysis, vitrinite reflection measurement) on the samples from the exploration wells provided good verifying information during the modeling of the history of the thermal maturation of the source rocks and the generation of the hydrocarbons.

The source rocks of the Kimmeridge Shale, Heather Shale Formations, and the Brent Group containing predominantly type II and type III kerogene have generated mainly gas in the modelling. These source rocks became mature in the late Cretaceous and have generated hydrocarbons since then, and are having petroleum generation potential now. The gas generally migrated upward and sidelong. The migrating gas has reached the base of the Oligocene sandstones. Gas accumulates in stratigraphic traps in the Brent Group sandstones and in the Eocene sandstones.

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Website

Norwegian Petroleum Directorate, Stavanger, Norway: www.npd.no/

BURIAL, THERMAL AND MATURATION HISTORY IN THE NORTHERN VIKING GRABEN (NORTH SEA)

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1. Introduction

The Noth Sea is the 4th biggest hydrocarbon province on Earth. Several giant oil and gas fields can be found in the North Sea Rift System. The adjacent Troll gas giant is the second biggest gas field in Europe after the Groningen gas field in The Netherlands.The study area can be found eastward from the Statfjord oil field and northward from the Troll gas field in the 35/8 norwegian section of the North Sea. The Viking Graben is a deep Cretaceous basin. In the Viking Graben we can find everything we need: perfect source rocks, for example the Late Jurassic Kimmeridge Shale, perfect reservoir rocks, for example the Triassic alluvial and eolian red sandstone or the Brent delta facies sandstones and shales, those can function as seals over the reservoir rocks. In the Viking Graben source rocks are mature enough to generate both oil and gas. This research is going to represent a small part of the North Sea Rift System at the junction of Viking Graben and Sogn Graben (Fig. 1). The study wants to show the petroleum generation potential of the Jurassic source rocks in the northern Viking Graben. All of the modellings were carried out by IES Petromod Software.
On Fig. 2. we can sea the shematic W-E geological buildup of the northern Viking Graben. The extremely thick Triassic sandstones are targets in the North Sea hydrocarbon exploration thanks to the high reservoir capacity of the eolian, alluvial, fluvial sandstones. The Jurassic rocks are the main source rocks and the Jurassic deep-marine sandstones are excellent reservoirs.
On Fig. 3. the shematic stratigraphical column of the Norther Viking Graben can be observed. The Late Jurassic organic rich shales are worth cathing attention interbedded by deep marine sandstones.

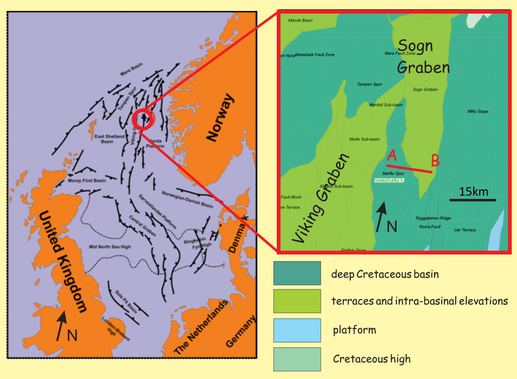


Fig. 1. The location of the study area and the 2D section used in the modeling at the junction of the deep Cretaceous Viking Graben and Sogn Graben (www.npd.no)

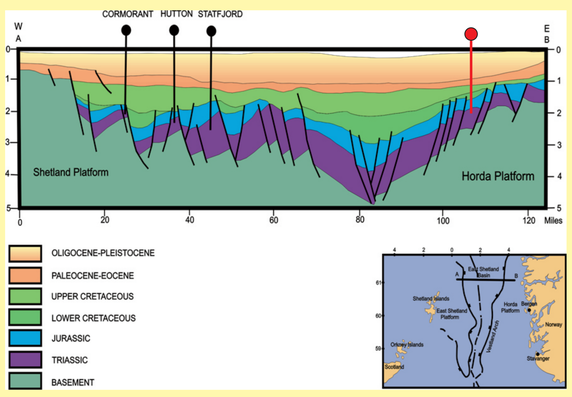


Fig. 2. W-E geological build up of the Northern Viking Graben after Kirk, R. H. (1979). The red spike shows the location of the study area

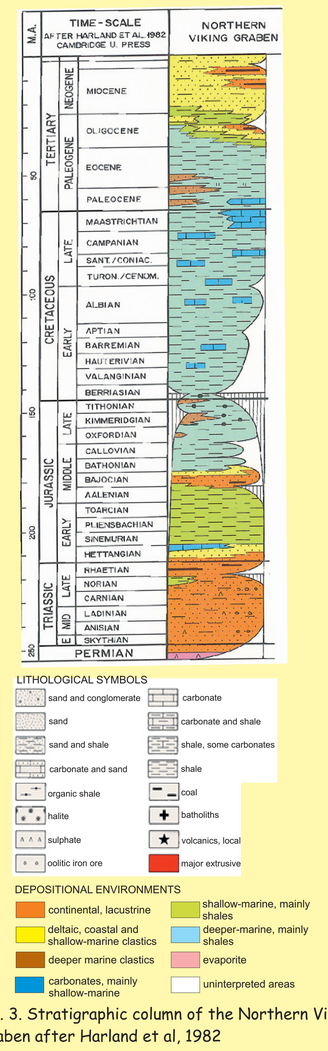


Fig. 3. Stratigraphic column of the Northern Viking Graben after Harland et al, 1982

2. Burial history

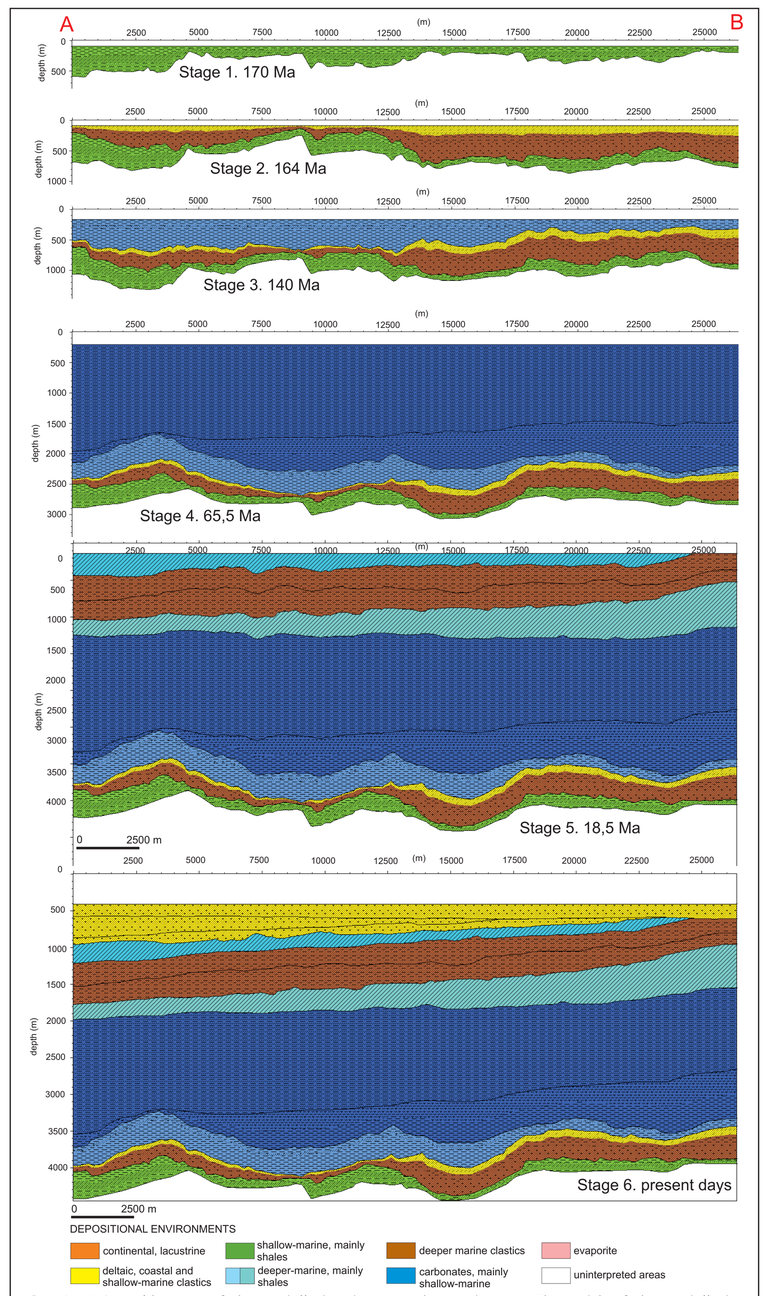


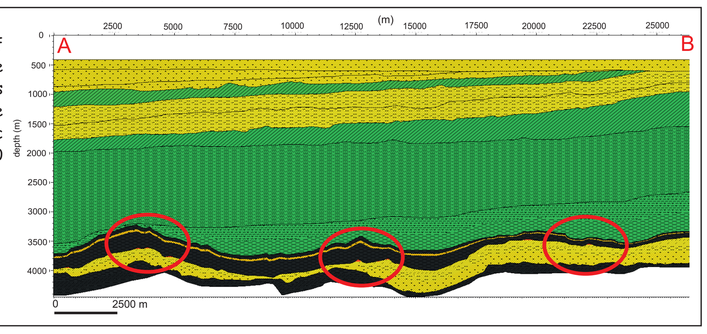
Fig. 4. 2D burial history of the modelled sedction in the study area. The width of the modelled section is 27 km, the depth is around 4500 m

The basement of the modelling is the Triassic fluvial, alluvial red sandstone. After the deposition of the above mentioned sandstones, Dunlin Group deposited containig shallow marine mudstones and deltaic sandy mudstone layers (Stage 1). The Dunling Group mudstones contain an average of 2-3 % TOC. This amount of organic carbon is highly noticeable. Uplift at the triple junction of Central, Viking and Witch Ground Graben from late Toarcian to Callovian caused significant erosion of underlying sequences (Underhill and Partington, 1993) and supplied erosional products to be redeposited in deltaic complexes (Stage 2), such as the Brent Delta (Graue et al., 1987).Establishment of the rift system in the Late Jurassic coupled with eustatic sea level rise led to widespread transgression and deep-water sedimentation (Ziegler, 1988). Under these conditions the Kimmeridgian organic-rich shales were deposited. The Middle-Jurassic sandstones are important reservoir targets (Stage 3). The Cretaceous sediments are deep marine shales interbedded by calcareous strata (Stage 4). The dominant Tertiary event was the deposition of Paleocene and lower Eocene deep-marine sandstones (Stage 5). Uplift, related to the development of the Iceland plume in the earliest Tertiary (Nadin and Kusznir, 1995), caused significant erosion and supplied large quantities of clastic sediments (Jenssen et al., 1993; Jordt et al., 1995). After decay of the uplift in the Eocene, three significant phases of post-Eocene uplift of the Shetland Platform, the Northern North Sea Basin and Southern Fennoscandinavia resulted in erosion and subsequent deposition of sand-rich sediments in the Oligocene and Miocene (Rundberg and Eidvin, 2005). The Pleistocene (Stage 6) was governed by glacially induced subsidence, isostatic adjustments (Riis and Fjeldskaar, 1992; Jordt et al., 1995) and a sharp acceleration in sedimentation rates (Ziegler, 1990).

3. Petroleum system

The best source rocks located in the northern Viking Graben subsided in the late Jurassic. These source rocks represented by the Kimmeridge Shale (also called Drauphne Shale) and the Heather Shale Formations can be found in the depth of 3000-3500 m in the study area. The coaly beds in the Brent Sandstones are also good source rocks and the Early Jurassic shallow-marine shales also(under 4000 m). The best reservoirs are the the Late Jurrassic delta Brent sandstones, and the deep-marine sandstones interbedding the organic rich Heather Formation (with yellow colour in the depth between 3300-4500 m). The seal rocks of the study area are the Jurassic deep marine shales. As the result of the modelling accumulations can be observed in the Brent sandstones sealed by the Jurassic Heather shales. Fig. 5. shows the petroleum system across the study area.

Fig. 5. Petroleum system of the study area.The possible accumulations (red colour) can be observed in the deltaic sandstones between 3500 and 4000 meters



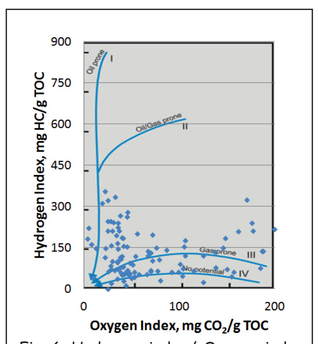


Fig. 6. Hydrogen index/ Oxygen index diagram of the Jurassic source rocks from a wellbore data in the study area

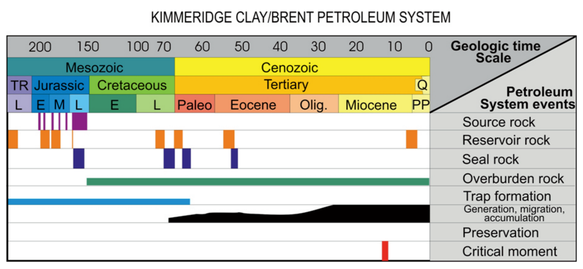


Fig. 7. Event chart of the Kimmeridge Clay/Brent Petroleum System. Jurassic source formations: coaly sediments (Hettangian-Bajocian) and anoxic marine shales (Bathonian-Berriasian) and T3, J, C2, Pc, E, M reservoir

4. Thermal, maturation history, migration

The source rocks are the Early Jurassic shallow marine coaly mudstones, the Late Jurassic Kimmeridge Clay and Heather Shale Formations. The source rocks became mature (> 0,6 % R_o) in the late Cretaceous (Fig. 9). The source rocks became gas-mature around the beggining of Neogene (27 Ma years ago). Active generation continues at present. The migrating gas has reached the base of the Oligocene sandstones. (Fig. 8.) Gas accumulations can be expected in the Brent Group Jurassic deltaic sandstones and in the Eocene deep marine sandstones. The source rocks of the Kimmerdige Shale, Heather Shale Formations, Brent Formation coaly beds and the Dunlin Group containing predominantly type II and type III kerogene have generated mainly gas in the modelling (Fig. 6 and fig. 8.).

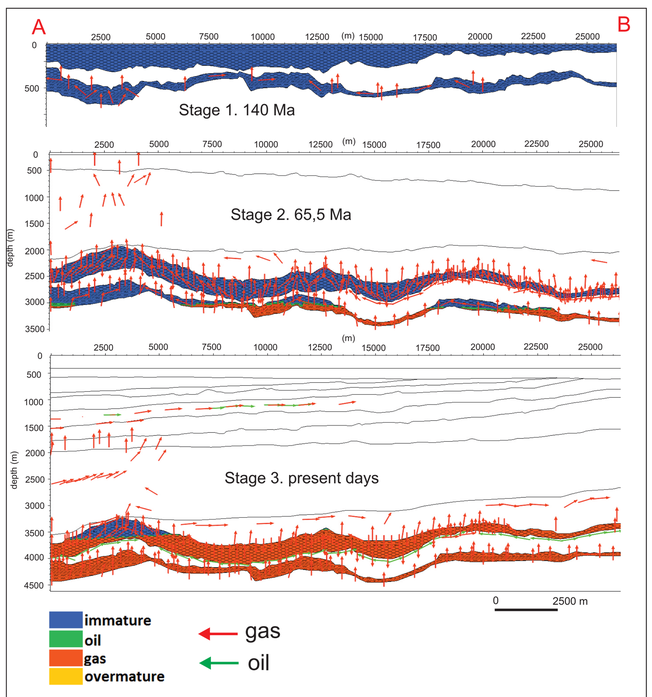


Fig. 8. Maturation history of the Jurassic source rocks; the maturity zones, the generated hydrocarbons and migration pathways are shown with the coloured arrows

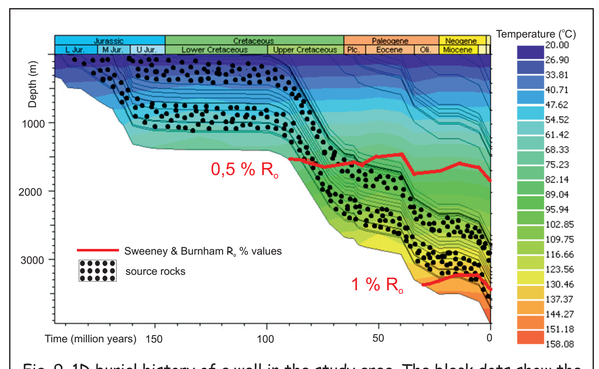


Fig. 9. 1D burial history of a well in the study area. The black dots show the Jurassic source rocks. The red lines show the major vitrinite-reflectance values.The colors from blue to red show the temperature in Celsius scale

5. Conclusion

- The source rocks of the study are mature and generated oil and gas from the Late Cretaceous
- Hydrocarbons are generated in the the study at present days
- The sandstones, i.e. the Brent Sandstones and Heather Sandstones can function as reservoirs
- The modelling shows possible accumulations in the Brent Sandstones, however exploration wells penetrated the Brent Sandstones at the anticlines in the study area and found gas
- A new possible accumulation can be observed at the modelled section
- Further 3D modellings would be necessary to understand the migration in the whloe study area

Acknowledgment

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