BACK-CALCULATED PETROLEUM GENERATION POTENTIAL OF JURASSIC MARINE SHALES THROUGH TIME AND SPACE IN THE DANISH NORTH SEA

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Introduction

Oil and gas geochemistry shows that the primary source rock in the Danish Central Graben (DCG), North Sea, is the U. Kimmeridgian–Ryazynian marine shales of the Farsund Fm. Potential additional marine source rocks are the shales of the Oxfordian–L. Kimmeridgian Lola Fm and the relatively poorly known L. Jurassic Fjerritslev Fm. The shales of the Farsund Fm show significant lateral and stratigraphic variations in source rock quality (Petersen et al., 2010, 2013; Ponsaing et al., 2018). These organofacies variations are recorded in the oil geochemistry. To obtain higher granularity and capturing these variations the U. Jurassic shales were subdivided into seismic units (Lola Fm: pre-FSU1; Farsund Fm: FSU1 to FSU6) delineated by regional mappable seismic markers (FSM). The uppermost FSU6 contains the Bo Member (‘Hot Unit’) that has normally been considered the most oil-prone section characterized by elevated TOC contents and HI values. The depositional area of the units varied through Late Kimmeridgian to Volgian times.

Calculated average source rock properties (TOC and HI) for the entire formation are strongly affected by these variations as high-quality intervals will be ‘diluted’ by poor organic-lean intervals. Further, measured source rock properties (TOC, HI, S2) represent present-day potential and do not consider the natural depletion in quality associated with thermal maturation and petroleum generation. However, a basin model with the purpose to estimate the amount of generated hydrocarbons and hydrocarbon phases requires original source rock properties as input parameters.

The present study reports the original source rock properties (TOCo, S2o, HIo) and estimation of reactive and inert TOC of Jurassic marine shales through time and space in the DCG. Back-calculation of measured source rock values applied an empirical relationship between T\text{max} and HI derived by Banerjee et al. (1998, 2000) to determine the transformation ratio \( f \) for each sample.

Results

Dead carbon \[\text{TOCo(inert)}\] content is relatively constant in the shales, including assumed inert back-ground TOC that only varies from c. 0.3-0.55 wt% throughout Late Jurassic time. The Lower Jurassic Fjerritslev Fm contains highly reactive kerogen, but mean \text{TOCo(reactive)} is very low and the liquid generation potential is thus limited. Most of the oil-prone kerogen has HIo from 350-500 mg HC/g TOC and only a small part has HI >500 mg HC/g TOC. The potential of the highly reactive kerogen is likely suppressed/masked by the relative dominance of inert, non-generative kerogen. The pre-FSU1 contains good quality oil-prone kerogen but the amount is on average negligible and overall pre-FSU1 is gas-prone. FSU6 contains the highest proportion of reactive TOCo and highly oil-prone kerogen and where mature FSU6 is the primary oil-prone source rock unit in the DCG. FSU4/FSU5 contains also highly oil-prone kerogen, but the mean \text{TOCo(reactive)} content is fairly low. The observed decrease in mean HIo(reactive) from FSU1 to FSU3 result in relatively gas-prone and gas/oil-prone units.
However, the combination of a higher TOCo content and the presence of good quality kerogen indicates that FSU3 can be a good source interval in the deeper part of the Farsund Fm. The general maximum source rock quality of all Jurassic units seems to be just above 675 mg HC/g TOC which thus marks the absolute highest generation capacity the marine sapropelic kerogen can reach. This must be related to the type of algae that thrived in the Early and Late Jurassic seas in the North Sea area.

Conclusions

Back-calculated source rock properties demonstrate that the quality varied through time and space in the DCG. The primary source rock is the upper part of the Farsund Fm included in FSU6, but deeper intervals may as well be oil-prone in restricted areas (Fig. 1).

![Figure 1 Source rock quality based on original HI values through Late Jurassic time.](image)

References


