Atypical source rocks and petroleums of the Norwegian Continental Shelf I

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Introduction

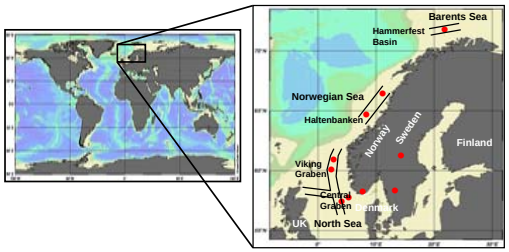

Fig.1. Map showing the study area, main structural elements and sample locations.

In one of the world's most important oil and gas provinces, the North Sea and NE Atlantic margin of the NW Europe, the dominating source rock is the Upper Jurassic marine Kimmeridge Clay. Up to 1 km of this excellent source rock was deposited in extensive Jurassic rift systems developed along almost the entire Norwegian continental shelf from the Central Graben in the south to the Barents Sea in the north.

21 hydrocarbon samples, including some highly atypical oils, were analysed geochemically to determine their source rock facies and maturity relationships. While most of the samples are from the Norwegian Offshore Continental Shelf (NOCS), oils and condensates from onshore Scandinavia are also analysed, debated and attempted interpreted in relation to source facies and thermal maturity.

It was hoped that this work might help in providing evidences that the NOCS and neighbouring regions may contain additional source rocks besides the widespread Upper Jurassic Kimmeridge Clay formation and its equivalents.

Another goal was to seek out and point to potential atypical petroleums and bitumens on and offshore Norway and Fennoscandia, by using organic geochemical analytical procedures and parameters obtained from these. The molecular parameters are used to illustrate the differences between the typical and atypical petroleums, and to show the variation in NOCS source rock depositional facies and maturity.

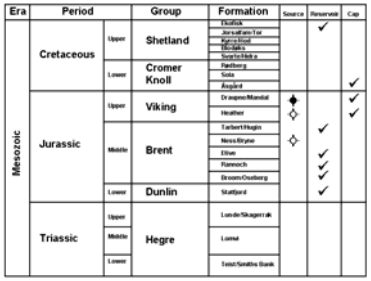

Fig. 2. Mesozoic stratigraphy for the North Sea.

Methodology

The analytical procedures in this study included the following:

- TLC-FID (Thin Layer Chromatography-Flame Ionization Detection, (Iatroscan))
- GC-FID (Gas Chromatography-Flame Ionization Detection)
- GC-MS (Gas Chromatography-Mass Spectrometer)
- ^{13}C isotopic analysis

Both isoprenoids, n-alkanes and selected biomarkers and aromatic compounds were studied in order to understand the organic facies and thermal maturity of the samples.

As a reference oil, the North Sea Oil 1 (NSO-1) from the Oseberg field was used. The NSO-1 oil is sourced from the Upper Jurassic Kimmeridge Clay (Dahl & Speers, 1985).

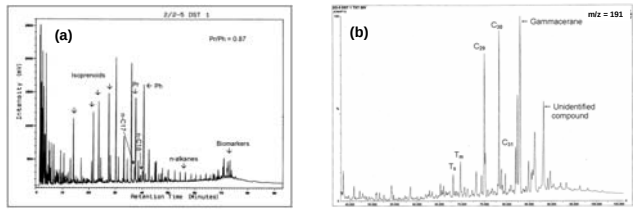

Fig. 3. A GC-FID (a) and GC-MS (b) chromatogram of a highly atypical North Sea oil. Note the isoprenoid over n-alkane relationship and low Pr/Ph ratio, suggesting an anoxic depositional facies. The high abundance of gammacerane indicates a hypersaline facies.

Composition of oils and extracts

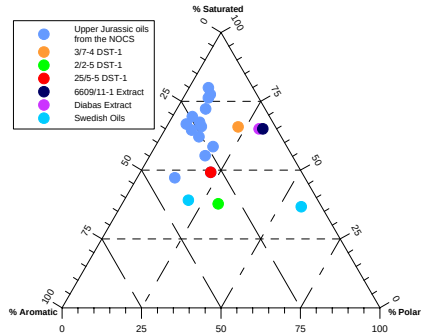

Fig. 4. The bulk composition of the C_{15+} fraction of the sample set expressed as a ternary plot. The oils and rock extracts considered to be atypical are enriched in polar compounds and asphaltenes, compared to the set of Upper Jurassic North Sea oils.

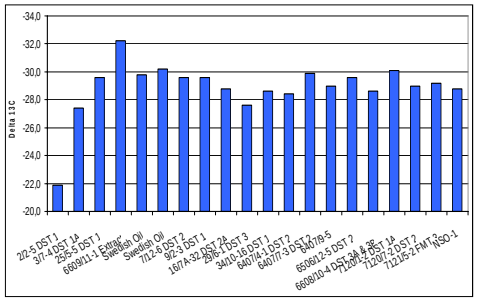

Fig. 5. The ^{13}C values for the sample set. An oil from North Sea well 2/2-5 are abnormally enriched in ^{13}C, while a rock extract from Mid Norway well 6609/11-9 is clearly depleted in ^{13}C. These deviances in ^{13}C values from the rest of the sample set are believed to to be inhereted from the depositional environment.

Thermal maturity

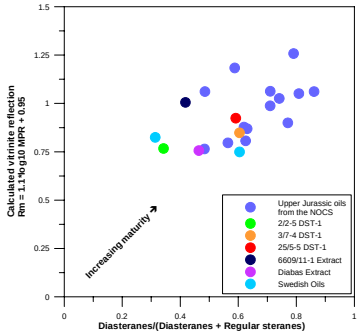

Fig. 6. Thermal maturity of the samples expressed by steranes and methylphenanthrenes. The samples regarded as atypical are seen to be of relatively low maturity compared to typical NOCS oils.

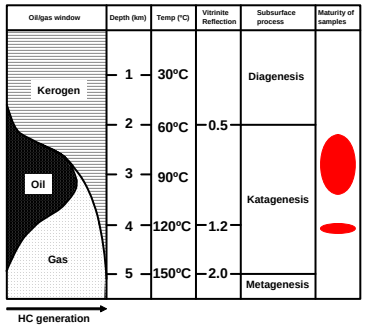

Fig. 7. The majority of samples in this study have maturities corresponding to the upper to middle part of the oil window. The maturity is calculated from aromatic compounds in oils and extracts. (Modified from Bjørlykke, 1989)

Atypical source rocks and petroleums of the Norwegian Continental Shelf II

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Organic facies

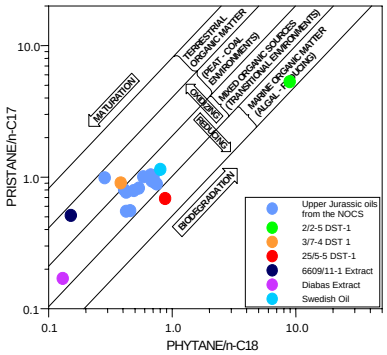

Fig. 8. A cross plot of isoprenoid/n-alkane ratios describing the maturity and source rock facies of the petroleum samples. North Sea oil 2/2-5 is believed to have an anoxic, hypersaline origin, while an extract from Mid-Norway well 6609/11-1 is believed to have a pre-Jurassic, non-marine origin. An extract from a volcanic intrusion may have a Lower Palaeozoic origin. (Modified from Shanmugam, 1985).

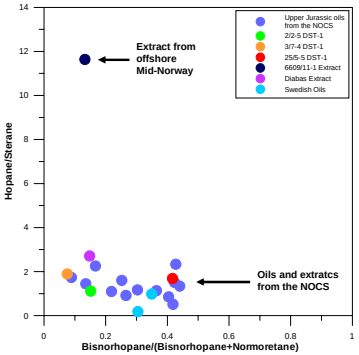

Fig. 9. A cross plot of two biomarker parameters sensitive to facies. Note how the extract from Mid-Norway (Helgeland Basin) deviates from the rest of sample set. This extract is believed to originate from pre-Jurassic source rocks, and to be affiliated with source rocks dominated by humic organic matter.

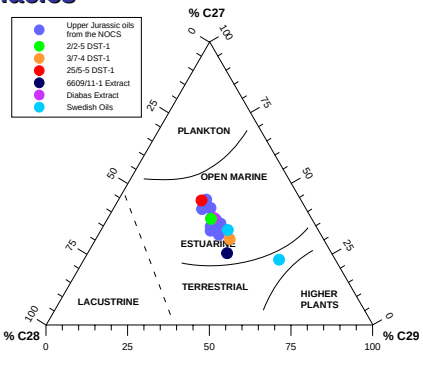

Fig. 10. A ternary plot of the percentages of regular steranes describing the samples affinity to different organic facies. The majority of samples appear to have a marine origin, but North Sea oil 3/7-4, Mid-Norwegian extract 6609/11-1 and a Swedish onshore oil have a higher terrestrial derived component. (Modified from Shanmugam, 1985).

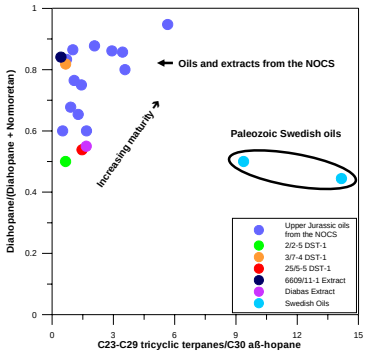

Fig. 11. A cross plot of two maturity parameters. The characteristic lack of correlation between these parameters for the two Swedish oils, compared to oils from the NOCS, may be due to a special, Palaeozoic organic facies.

Conclusions

Oils from the Norwegian offshore areas varies in maturity from early to late oil generation, with calculated vitrinite reflection (Rm = 0.073*MDR + 0.51) ranging from 0.6% to 1.7%.

Oils from the Norwegian North Sea and the Haltenbanken area (Mid-Norway) are in general black oils derived from a marine type II source rock, the Upper Jurassic Mandal/Draupne/Spekk Formation.

A black, low-mature North Sea oil (well 2/2-5) is enriched in isoprenoids, gammacerane and ^{13}C isotopes, and is believed to origin from an anoxic, hypersaline environment.

A light, medium mature, terrestrial influenced North Sea oil (well 3/7-4) is most likely sourced from lacustrine shales and coals of the Middle Jurassic Bryne Group.

A black North Sea oil (well 25/5-5) may have been generated from a local carbonate dominated variety of Upper Jurassic marine shales.

A sandstone extract from well 6609/11-1 in the Helgeland Basin, Mid Norway, shows terrestrial/lacustrine properties. The source rock is proposed to be lacustrine, and of Upper Palaeozioc or Triassic age.

Two low-mature, black oils of Lower Palaeozoic age from onshore Sweden are most likely derived from the Ordovician organic rich Fjäcka/Tretaspis shale. These oils are characterised by being enriched in C_{23}-C_{29} tri- and tetracyclic terpanes.

A moderate mature, light oil depleted in isoprenoids occurs in a Permian volcanic intrusive on the south coast of Norway. The source rocks of this oil are marine, and of Lower Palaeozoic or Jurassic age.

Two samples in this study, a black North Sea oil (UK well 16/7A-32) and a black oil from onshore Sweden, are clearly biodegraded.

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