



UNIVERSITY
OF OSLO

Atypical source rocks and petroleum of the Norwegian Continental Shelf I

Jon H. Pedersen¹, Dr. Dag A. Karlsen¹, Dr. Jan E. Lie² and Harald Brunstad²

¹Department of Geosciences, University of Oslo, P.O. Box 1047 Blindern, N-0316 Oslo, Norway

²RWE Dea AS, P.O. Box 243 Skøyen, N-0213 Oslo, Norway

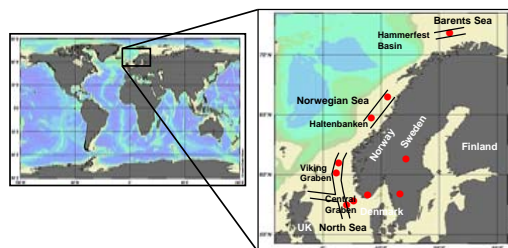


Fig. 1. Map showing the study area, main structural elements and sample locations.

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.

Introduction

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 petroleum 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 petroleum, and to show the variation in NOCS source rock depositional facies and maturity.

Era	Period	Group	Formation	Source	Reservoir	Cap
Cretaceous	Upper	Shetland	Utsikten		✓	
			Åmøyfjellet			
	Lower	Cromer Knoll	Martholmen			✓
			Åsund			✓
Jurassic	Upper	Viking	Drønesen/Mandal	◆	✓	✓
	Middle	Brent	East/Brent Høgland	✓	✓	
			Mossneset	✓	✓	
			Ellev	✓	✓	
			Flåmoen	✓	✓	
Lower	Dunlin	Mattjord		✓	✓	
Triassic	Middle	Hegre	Lunde/Skagestak			
			Lunde			
Lower			Foss/Sandnes			

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)
- ¹³C 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).

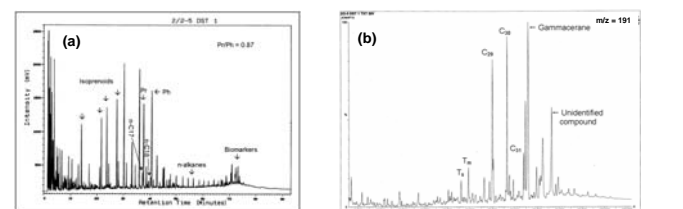


Fig. 3. A GC-FID (a) and GC-MS (b) chromatogram of a highly atypical North Sea oil. Note the isoprenoid over n-alkane relationship and low Pr/Ph ratio, suggesting an anoxic depositional facies. The high abundance of gammacerane indicates a hypersaline facies.

Composition of oils and extracts

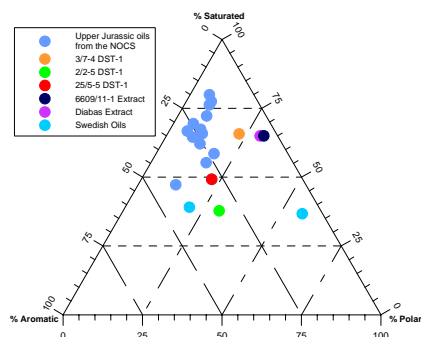


Fig. 4. The bulk composition of the C₁₅₊ fraction of the sample set expressed as a ternary plot. The oils and rock extracts considered to be atypical are enriched in polar compounds and asphaltenes, compared to the set of Upper Jurassic North Sea oils.

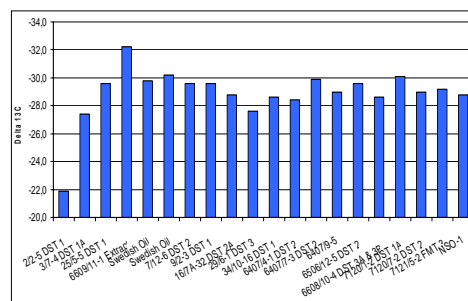


Fig. 5. The ¹³C values for the sample set. An oil from North Sea well 2/2-5 are abnormally enriched in ¹³C, while a rock extract from Mid Norway well 6609/11-9 is clearly depleted in ¹³C. These deviations in ¹³C values from the rest of the sample set are believed to be inherited from the depositional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

Thermal maturity

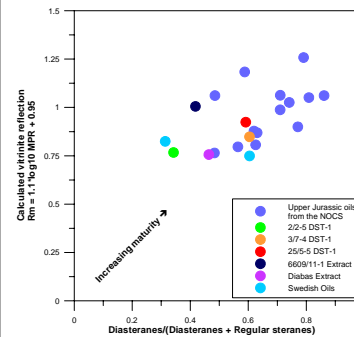


Fig. 6. Thermal maturity of the samples expressed by steranes and methylphenanthrenes. The samples regarded as atypical are seen to be of relatively low maturity compared to typical NOCS oils.

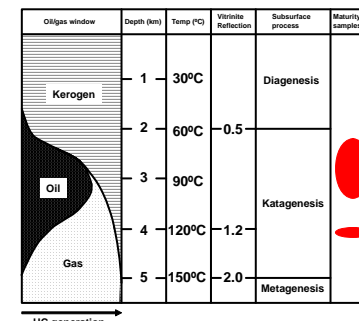


Fig. 7. The majority of samples in this study have maturities corresponding to the upper to middle part of the oil window. The maturity is calculated from aromatic compounds in oils and extracts. (Modified from Bjerlykke, 1989)



UNIVERSITY
OF OSLO

Atypical source rocks and petroleum of the Norwegian Continental Shelf II

Jon H. Pedersen¹, Dr. Dag A. Karlsen¹, Dr. Jan E. Lie² and Harald Brunstad²
¹Department of Geosciences, University of Oslo, P.O. Box 1047 Blindern, N-0316 Oslo, Norway
²RWE Dea Norge AS, P.O. Box 243 Skøyen, N-0213 Oslo, Norway

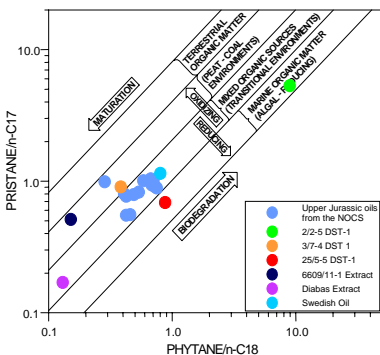


Fig. 8. A cross plot of isoprenoid/n-alkane ratios describing the maturity and source rock facies of the petroleum samples. North Sea oil 2/2-5 is believed to have an anoxic, hypersaline origin, while an extract from Mid-Norway well 6609/11-1 is believed to have a pre-Jurassic, non-marine origin. An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

Organic facies

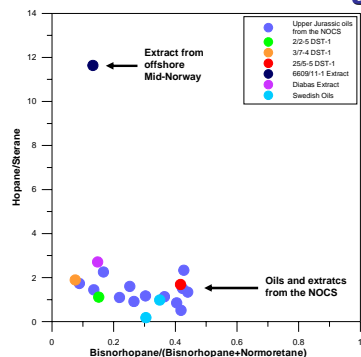


Fig. 9. A cross plot of two biomarker parameters sensitive to facies. Note how the extract from Mid-Norway (Helgeland Basin) deviates from the rest of sample set. This extract is believed to originate from pre-Jurassic source rocks, and to be affiliated with source rocks dominated by humic organic matter.

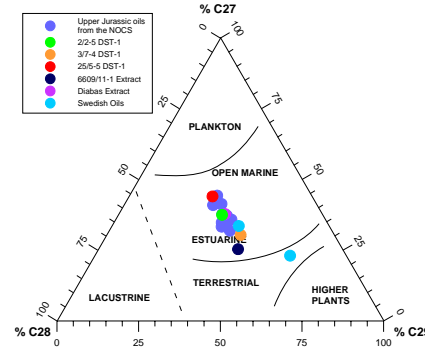


Fig. 10. A ternary plot of the percentages of regular steranes describing the samples affinity to different organic facies. The majority of samples appear to have a marine origin, but North Sea oil 3/7-4, Mid-Norwegian extract 6609/11-1 and a Swedish onshore oil have a higher terrestrial derived component.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

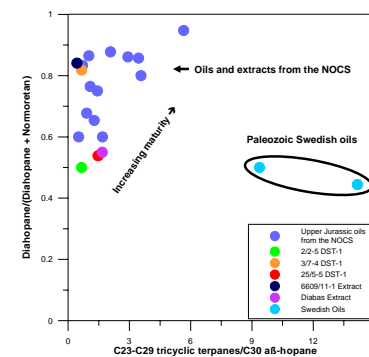


Fig. 11. A cross plot of two maturity parameters. The characteristic lack of correlation between these parameters for the two Swedish oils, compared to oils from the NOCS, may be due to a special, Palaeozoic organic facies.

Conclusions

Oils from the Norwegian offshore areas varies in maturity from early to late oil generation, with calculated vitrinite reflection ($R_m = 0.073 \cdot MDR + 0.51$) 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 ¹³C 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 Palaeozoic or Triassic age.

Two low-mature, black oils of Lower Palaeozoic age from onshore Sweden are most likely derived from the Ordovician organic rich Fjåcka/Tretaspis shale. These oils are characterised by being enriched in C₂₃-C₂₉ 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.

References

- Berglund, L. T., Augustsson, J., Færøsh, R., Øjilberg, J. & Ramberg-Moe, H. (1986) The evolution of the Hammerfest Basin. *Spencer, A. M. et al. (eds) Petroleum Geology of the North European Margin*, Norwegian Petroleum Society, Graham & Trotman, p.319-338
- Sjøyakke, K. (1989) *Sedimentology and petroleum geology*. Springer-Verlag Berlin Heidelberg
- Chung, H. M., Winger, W. S. & Claypool, G. E. Geochemistry of oils in the Northern Viking Graben, p.277-292
- Corford, C. (1998) Source rocks and hydrocarbons of the North Sea. *Olsson, K. W. (ed) Petroleum Geology of the North Sea 4th Edition*, Blackwell Science Ltd., 371-462
- Dahl, B. & Speers, G. C. (1995) Organic geochemistry of the Oseberg field (3). From: *Norwegian geochemistry in exploration of the Norwegian Shelf*, Norwegian Petroleum Society, Graham & Trotman, p.185-195
- Garard, J., Whalley, T. J., Ritchie, J. S., Sullivan, M. & Baskett, M. D. (1995) Permian-Carboniferous and older plays, their historical development and future potential. *Parker, J. R. (ed) Petroleum Geology of Northwest Europe: Proceedings of the 4th Conference*, The Geological Society, London, 641-650
- Hunt, J. M. (1996) *Petroleum geochemistry and geology* (2nd edition). W. H. Freeman & Company, New York
- Karlsen, D. A. & Larner, S. R. (1991) Analysis of petroleum fractions by TLC-FID: applications to petroleum reservoir description. From: *Organic Geochemistry* vol. 17 n.5. Pergamon Press plc, p.603-617
- Karlsen, D. A., Nedviltne, T., Larner, S. R. & Sjøyakke, K. (1993) Hydrocarbon composition of authigenic inclusions: Application to elucidation of petroleum reservoir filling history. *Geochimica et Cosmochimica Acta*, 57, 3641-3659
- Karlsen, D. A., Nyland, B., Flood, B., Ohm, S. E., Brakke, T., Olsen, S. & Backer-Owe, K. (1995) Petroleum geochemistry of the Haltenbanken continental shelf. *The Geochemistry of Reservoirs, Geological Society Special Publication* no. 86, 205-256
- Khoshrak, P. (2001) Variations in source facies and maturity in Central Graben Oils, Norwegian Continental shelf. *Canad. Scienc. thesis*, Department of Geology, University of Oslo, Norway
- Longman, M. W. & Palmer, S. E. (1987) Organic geochemistry of mid-continent Middle and Late Ordovician oils. *American Association of Petroleum Geologists Bulletin*, 71, p.939-950
- Miller, R. G. (1996) A paleoceanographic approach to the Kimmeridge Clay Formation. *Huc, A. Y. (ed) Deposition of organic facies*, American Association of Petroleum Geologists, Studies in Geology 30, p.13-26
- Mills, N., di Primio, R., Hvoslov, S., Stoddart, D., Thronsen, I. & Whitaker, M. (2000) From seismic to biomarkers - the value of additional data in continually refining geological models. *Ofstad et al. (eds) Improving the Exploration Process by Learning from the Past*, Norwegian Petroleum Society Special Publication 9, Elsevier Science B.V., Amsterdam, p.203-229
- Norheim, M. A. (1988) Correlation of Northern North Sea oils: the different facies of their Jurassic source. *Petroleum Geochemistry in Exploration of the Norwegian Shelf*, Norwegian Petroleum Society, Graham & Trotman, 95-99
- Pedersen, J. H. (2002) *Atypical Oils and Condensates of the Norwegian Continental Shelf - an Organic Geochemical Study*. Cand. Scient. thesis in Geology, University of Oslo, Norway
- Peters, K. E. & Moldovan, J. M. (1993) The biomarker guide - Interpreting molecular fossils in petroleum and ancient sediments. Prentice Hall, Englewood Cliffs, New Jersey 07632, p.1-363
- Radke, M. (1988) Application of aromatic compounds as maturity indicators in source rocks and crude oils. From: *Marine and Petroleum Geology*, 5, 1998, p.224-236
- Shanmugam, G. (1985) Significance of continuous rain forests and related organic matter in generating commercial quantities of oil, Gippsland Basin, Australia. *American Association of Petroleum Geologists Bulletin*, 69, p.1241-1254
- Skånes, E. (1993) *Geochemistry and filling history of the Hild Field, Viking Graben, Norwegian Continental Shelf*. Cand. Scient. thesis, Department of Geology, University of Oslo, Norway
- Thomas, S. M., Møller-Pedersen, P., Whitaker, M. F. & Shaw, N. D. (1985) Organic facies and the hydrocarbon distributions in the Norwegian North Sea. *Petroleum Geochemistry in exploration of the Norwegian Shelf*, Norwegian Petroleum Society, Graham & Trotman, p.2-26
- Tissot, B. P. & Welte, D. H. (1984) *Petroleum formation and occurrence*. Springer-Verlag Berlin Heidelberg, p.1-699
- Vilferboom, F., Cortini, B. & Zumberge, J. E. (1986) The occurrence of petroleum in sedimentary rocks of the meteor impact crater at Lake Siljan, Sweden. *Organic Geochemistry* 10, Pergamon Journals Ltd., p.153-161
- Vobes, S. J. (1996) An organic geochemical study of oils and condensates from the Hammerfest, Southern Norwegian Barents Sea. *Canad. Scienc. thesis*, Department of Geology, University of Oslo, Norway, 1-152

Acknowledgements

For supplying samples:
Norwegian Petroleum Directorate
Sven Dahlgren (state geologist in Telemark og Buskerud counties, Norway)

For funding:
RWE Dea Norge AS
Statoil AS
The Pennsylvania State University's Energy Institute