Source Rocks of the Norwegian Barents Sea I

Jon H. Pedersen[1], Dag A. Karlsen[1], Harald Brunstad[2] and Jan E. Lie[2]

[1]Department of Geosciences, University of Oslo, P.O. Box 1047 Blindern, N-0316 Oslo, Norway
[2]RWE Dea Norge AS, P.O. Box 243 Skøyen, N-0213 Oslo, Norway

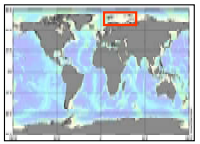
Introduction

The Barents Sea is an ocean area situated between the Norwegian-Russian mainland, the Arctic Ocean margin, the Russian Novaya Zemlya island and the Norwegian-Greenland Sea. In geological terms, the Barents Sea area is a large, intracratonic platform, with several sedimentary basins of Palaeozoic and Mesozoic age. The sedimentary record includes Devonian to Quaternary deposits of dominantly marine types, although continental sediments also occur. Up to 3 km of Cenozoic uplift caused erosion over most of the Norwegian part of the Barents Sea.

The most important source rock in the Norwegian Barents Sea is the Upper Jurassic marine type II Hekkingen Formation. However, several other source rock candidates may exist in the region, both in the Palaeozoic and Mesozoic successions. Palaeozoic source rock systems are known from the Russian Barents Sea, e.g. the Devonian marine Domanik facies in the Timan Pechora area, and oil stains of Carboniferous age are known from onshore areas of Svalbard.

In this study we investigate petroleum potential and thermal maturity of source rock samples from the Norwegian Barents Sea, as well as the properties of oil and gas from discoveries and fields located in this promising region on the Norwegian Continental Shelf.

Study area



Index map.

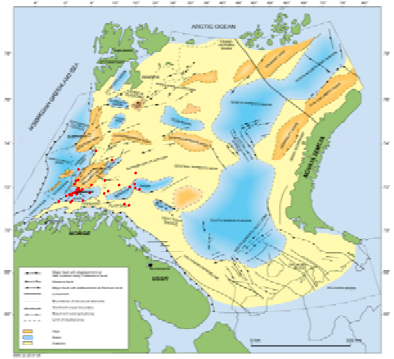


Fig.1. Structural map of the Barents Sea. Red dots indicate well locations. Modified from Johansen et al. (1992).

Stratigraphy

Era	Period		Age	Group	Formation	Source-rock
Cenozoic	Quarternary		1.8 Ma			
	Tertiary	Neo-gene	23.8 Ma	Nordland		
		Paleo-gene	65.0 Ma	Sotbakken	Torsk	
Mesozoic	Cretaceous	Upper	98.9 Ma	Nygrunnen	Kveite/Kviting	
		Lower	142.0 Ma	Nordvest-banken/ Adventdalen	Kolmule	
					Knurr	
	Jurassic	Upper	159.4 Ma	Teisten-grunnen	Hekkingen	
		Middle	180.1 Ma	Realgrunnen/ Kapp Toscana	Fuglen	
		Lower	205.7 Ma		Stø	
					Nordmela	
					Tubåen	
	Triassic	Upper	227.4 Ma	Ingøydjup/ Sassendalen	Fruholmen	
		Middle	241.7 Ma		Snadd	
		Lower	248.2 Ma		Kobbe	
					Klappmyss	
					Havert	
Palaeozoic	Permian	Upper	258.0 Ma	Tempelfjorden	Ørret	
		Lower	290.0 Ma	Gipsdalen	Røye	
					Ørn	
					Falk	
	Carboniferous	Upper	323.0 Ma		Ugle	?
		Lower	354.0Ma	Billefjorden	Tettegras	
					Soldogg	
	Devonian	Upper	370.0 Ma			?
		Lower	417.0 Ma			
	L. Palaeozoic		545.0 Ma			
	Basement					

Fig. 2. Stratigraphy in the Norwegian Barents Sea. Proven source rocks and potential source rock candidates are indicated.

Source rocks

Jurassic

Fig. 3. Upper Jurassic marine shales of the Hekkingen Formation from well 7219/8-1. The source rock interval has TOC 4.2 to 8.8 wt%.

Triassic

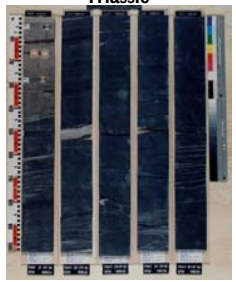


Fig. 4. Upper Triassic marine shales of the Fruholmen Formation from well 7124/3-1. The source rock interval has TOC 11.4 to 15.7 wt%.

Permian

Fig. 5. Upper Permian marine limestone of the Røye Formation from well 7128/6-1. The source rock interval has TOC 1.4 to 2.0 wt%.

Carboniferous

Fig. 6. Lower Carboniferous coals, mudstones and sandstones of the Soldogg Formation from well 7128/6-1. The coals have TOC 34 to 80 wt%, the mudstones have TOC 1.5 to 4.8 wt%.

Source rock database

Well	Age at TD	TVD (m)	Top Jurassic (m)	Top Triassic (m)	Top Permian (m)	Top Carboniferous (m)
7019/01-01	Lower Jurassic	2998	2345			
7120/01-01	Permian	3134		692	2403	
7120/02-01	Pre-Devonian	3484		613	1945	2024
7120/09-02	Upper Permian	5069	1906	2290	4844	
7120/12-02	Pre-Devonian	4667	1700	2334	3657	4558
7120/12-04	Upper Carboniferous	2199		435	1366	2118
7122/02-01	Middle Jurassic	2120	1955			
7122/06-01	Middle Triassic	2710	1931	2063		
7122/07-01	Triassic	1523	1022	1125		
7124/03-01	Upper Carboniferous	4727	1233	1305	3475	4271
7125/01-01	Middle Triassic	2199	1344	1521		
7128/04-01	Pre-Devonian	2528		494	1569	1820
7128/06-01	Pre-Devonian	2543		468	1623	1834
7219/09-01	Upper Triassic	4286	1893	2305		
7224/07-01	Lower Triassic	3064	792	931		
7226/11-01	Pre-Devonian	5200	1147	1234	3877	4334
7228/02-01	Lower Triassic	4000	1168	1404		
7228/07-01	Lower Permian	1987	1314	1480	1712	
7228/09-01	Lower Permian	4477	1030	1140	3884	
7229/11-01	Upper Carboniferous	4628	1212	1323	3879	4282
7321/08-01	Upper Permian	3482	1383	1467	3398	
7324/10-01	Lower Triassic	2919	561	577		

Table 1. Norwegian Barents Sea wells relevant for this source rock study.

Petroleum database

Well	Sample depth (m)	Sample	Field	Year	Age of reservoir	Reservoir Formation
7019/01-01	2246-2550	Gas	-	2000	Middle Jurassic	Stø
7119/12-03	3184-3195	Condensate, oil	-	1983	Middle Jurassic	Stø
7120/01-01	2607-2665	Gas	-	1988	Upper Permian	Røye
7120/01-02	1887-1943	Oil	-	1989	Upper Jurassic	Hekkingen
7120/02-01	1944-2031	Oil	-	1985	Upper Permian	Ørn
7120/06-01	2386-2436	Condensate, oil	Snøhvit	1985	Middle Jurassic	Stø
7120/07-01	2415-2435	Oil	Snøhvit	1982	Middle Jurassic	Stø
7120/07-02	2149-2228	Condensate, oil	Snøhvit	1983	Middle Jurassic	Stø
7120/08-01	2092-2172	Condensate	Snøhvit	1981	Middle Jurassic	Stø
7120/08-02	2092-2097	Condensate, oil	Snøhvit	1982	Middle Jurassic	Stø
7120/09-01	1869-1877	Condensate, oil	Snøhvit	1982	Middle Jurassic	Stø
7120/12-01	1985-1991	Gas, condensate, oil	-	1981	Middle Triassic	Snadd
7121/04-01	2420-2471	Condensate, oil	Snøhvit	1984	L + M Jurassic	Nordmela + Stø
7121/04-02	2484-2493	Oil	Snøhvit	1985	L + M Jurassic	Tubåen + Stø
7121/05-01	2802-2825	Oil	-	1988	Lower Jurassic	Nordmela
7121/05-02	2323-2346	Oil	-	1986	Middle Jurassic	Stø
7121/07-01	2415-2435	Oil	Snøhvit	1982	Middle Jurassic	Stø
7121/07-02	1881-1898	Oil	Snøhvit	1986	Middle Jurassic	Stø
7122/02-01	1874	Gas	-	1992	Lower Cretaceous	Knurr
7122/06-01	2424-2434	Condensate, oil	-	1987	Middle Triassic	Snadd
7122/07-01	1106-1140	Oil	Goliat	2000	Lower Jurassic	Tubåen
7124/03-01	1289-1298	Gas, oil	-	1987	Lower Jurassic	Tubåen
7125/01-01	1403-1406	Oil	-	1988	Middle Triassic	Kobbe
7128/04-01	1577-1586	Oil	-	1984	Upper Permian	Røye
7224/07-01	2352	Gas	-	1988	Middle Triassic	Kobbe

Table 2. Norwegian Barents Sea wells relevant for this petroleum study.

References

Radke, M. (1988) Application of aromatic compounds as maturity indicators in source rocks and crude oils. *Marine and Petroleum Geology*, 5, 1998, 224-236.

Schoell, M. (1983) Genetic characterisation of natural gases. *AAPG Bulletin*, 67, 2225-2238.

Shanmugam, G. (1985) Significance of coniferous 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.

Whiticar, M. J. (1994) Correlation of natural gases with their sources. Magoon, L. B. and Dow, W. G. (eds.): The Petroleum system - from source to trap. *AAPG Memoir*, 60.

Johansen, S. E., Ostisby, B. K., Birkeland, Ø., Fedorovsky, Y. F., Martirosjan, V. N., Christensen, O. B., Cheredeev, S. I., Ignatenko, E. A. & Margulis, L. S. (1992) Hydrocarbon potential in the Barents Sea region: play distribution and potential. Vorren, T. O., Bergsager, E., Dahl-Stamnes, Ø. A., Holter, E., Johansen, B., Lie, E. & Lund, T. B. (eds) Arctic Geology *and Petroleum Potential*, NPF Special Publication 2, 273-320.

Source Rocks of the Norwegian Barents Sea II

Jon H. Pedersen[1], Dag A. Karlsen[1], Harald Brunstad[2] and Jan E. Lie[2]

[1]Department of Geosciences, University of Oslo, P.O. Box 1047 Blindern, N-0316 Oslo, Norway
[2]RWE Dea Norge AS, P.O. Box 243 Skøyen, N-0213 Oslo, Norway

Petroleum potential

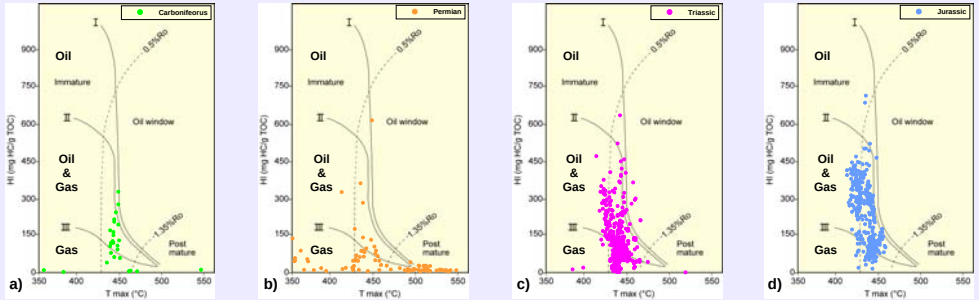


Fig. 1. T_{max} vs Hydrogen Index (HI) plots indicate petroleum potential and thermal maturity for selected source rock samples (TOC > 1wt%) from the Norwegian Barents Sea. Carboniferous samples, Fig. 1 a), have in general potential for gas, but oil prone shales also occur. The samples appear mid-mature with respect to the oil window. Most Permian source rock candidates, Fig. 1 b), have only gas potential, although a few oil prone Upper Permian samples are found in two wells. Maturity for Permian samples ranges from early- to post-mature. Numerous Triassic and Jurassic samples, Fig. 1 c) and d), show both oil and gas potential, and thermal maturities generally corresponding to the upper - middle part of the oil window.

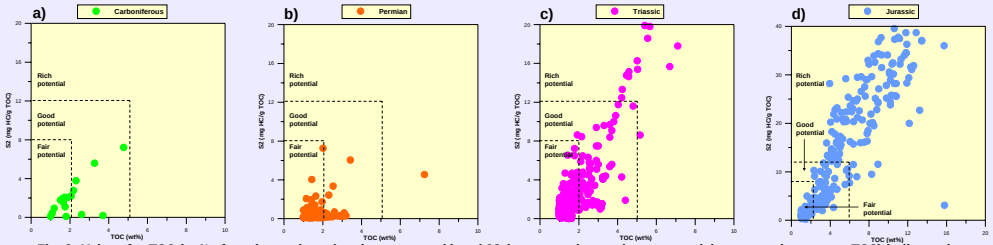


Fig. 2. Values for TOC (wt% of total organic carbon in source rock) and S2 (source rock petroleum potential, mg petroleum per g TOC) indicate the richness and quality of source rock candidates. Only samples with TOC > 1wt% are regarded as source rock candidates. Carboniferous and Permian samples, Fig. 2 a) and b), have fair to good potential. Triassic samples, Fig. 2 c), have good to rich potential. Jurassic samples, Fig. 2 d), have by far the best petroleum potential of the investigated samples. Note that increased maturity of a source rock sample decreases the petroleum potential.

Thermal maturity

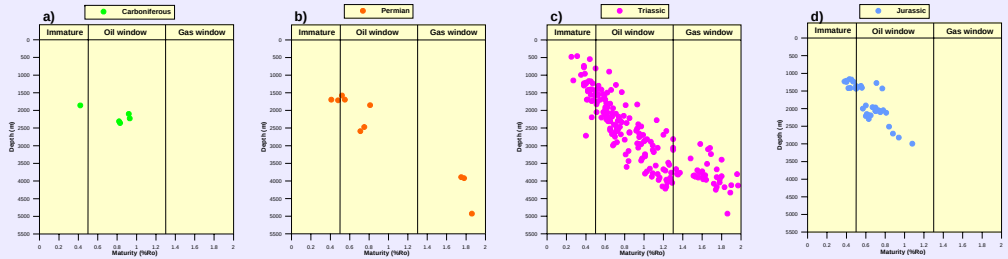


Fig. 3. The vitrinite reflectivity (%Ro) of source rocks increases with burial and subsequent heating. Fig. 3. shows vitrinite reflectivity measurments of Norwegian Barents Sea source rock samples collected at various depths in a number of wells. From this study, it appears that the oil window lies between 1500 to 4000 meters. However, since the Barents Sea area has experienced as much as 3000 m of uplift during the Cenozoic, the oil window is more likely to exist between 2500 to 5000 meters. Note that the majority of samples, regardless of age, are within the oil window in terms of thermal maturity.

Conclusions

- We have indentified Lower Carboniferous, Upper Permian, Upper Triassic and Upper Jurassic petroleum source rocks from the Norwegian Barents Sea
- Carboniferous source rocks are gas prone coals and mudstones, and to a lesser extent, oil prone shales
- Carboniferous samples have a fair to good petroleum potential
- Upper Permian source rock samples from two wells are oil prone, with fair to good potential
- Triassic marine source rocks are oil and gas prone, with good petroleum potential
- Jurassic marine source rocks are oil and gas prone, with excellent petroleum potential
- The majority of the samples have thermal maturities within the range of the oil window (0.6 to 1.3 %Ro)
- The oil window in the Norwegian Barents Sea is located approx. between 2500 to 5000 meters (8200-16400 feet)