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Migration and Alteration Processes in Barents Sea Oils and Condensates - A Geochemical Appraoch

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SUMMARY

Petroleum systems in the Barents Sea were affected by repeated uplift and erosion processes which had impact on the distribution, alteration and composition of petroleums as well as on cap-rock properties. An important hydrocarbon fraction when evaluating post-emplacement alteration processes such as biodegradation, evaporative fractionation and long-distance migration are light hydrocarbons (LHC), since they make up a significant volume of oils/condensates. This study sheds light on oil-oil and oil-condensate relationships from the Hammerfest Basin and Loppa High. Analyzed condensates are altered by evaporative fractionation but do not show signs of biodegradation. Medium to high toluene contents indicate locally derived LHC with short migration distance. However, analyzed oils show clear indication of biodegradation and some being also altered by evaporative fractionation. Low content of water-soluble aromatic HC imply long-distance migrated LHC. Medium to high gas to oil ratios (GOR) for central basin samples indicate tight sealing cap-rocks, whereas samples with low GOR occur at the northern and southern tectonized basin margins, suggesting leaking cap-rocks. Tight cap-rocks might play a crucial role in the distribution as they hold back gas/condensates and favor the remigration of liquid petroleums, whereas leaking cap-rocks hold back oil and allow the gas/condensate to leak.

Introduction

Biomarkers are commonly used in oil-oil and oil-gas/condensate correlation studies to infer post-emplacement alteration processes or migration induced alteration. However, the concentration of the biomarker compounds decreases with increasing maturity and can be almost absent in high maturity oils and condensates. Here, the use of light hydrocarbons (LHC) is of greatest importance as these make up a significant volume of oils and gas/condensates (England et al., 1987) with up to 16mol% of a standard 0.3kg/kg North Sea oil. The aim of the present study was to delineate post-emplacement alteration such as biodegradation and evaporative fractionation, and indication of long-distance migration based on LHC compounds in the Barents Sea (Hammerfest Basin and Loppa High). Furthermore represent LHC a highly mobile phase, which allows an insight of recent migration processes. Repeated uplift and erosion of the Barents Sea might play a crucial role in the distribution, alteration and composition of accumulated hydrocarbons. In this context, special focus has to be brought on cap-rock properties as they play a critical role in petroleum systems.

Method

Geochemical analysis is based on results obtained from gas-chromatography - flame ionization detection (GC-FID), which allows a near perfect separation of the gasoline range compounds (n-C_4 - n-C_8). Peak areas were determined and LHC parameter ratios were calculated as suggested by Thompson (1987) and Halpern (1995). Thompson (1987) invented two ratios, the paraffinicity (n-heptane/methylcyclohexane) and the aromaticity (toluene/n-heptane) parameters to evaluate samples in respect of their alteration modes, based on the fact that these compounds are characterized by different vapor pressures and variable degree of susceptibility to biodegradation and also solubility in water. Halpern (1995) took advantage of C7 compound ratios (C7 oil transformation star diagram (C7-OTSD)) to infer biodegradation, water-washing and evaporative fractionation. He used the C7 compounds because of their high boiling points compared to other LH that makes them less prone to artificial evaporation effects induced during sampling and storage.

Results – Alteration Effects

Results obtained from the Thompson and Halpern parameters reveal that several oil samples located along the uplifted basin margins as biodegraded. However, condensates and oils from the deeper central and western part of the Hammerfest Basin do not show signs of biodegradation. A representative C7-OTSD of Tornerose field samples is given in (Figure 1b). The most obvious results are the diminished Tr2-Tr8 values for two of the Tornerose samples indicating biodegradation. Two Goliat samples are indicative of biodegradation, and these oils are known to be biodegraded also in the C_{10}+ range, but show a distinctively high toluene values which may be related to a specific source (Figure 1a), albeit benzene is virtually absent. Low Tr1 values for two biodegraded Tornerose samples implicate migration over long-distance, since the water-soluble compound toluene is assumed to be susceptible to get “stripped” out during effective migration in carrier systems. Low Tr1 values are also recorded for oils at the periphery of the basin margins which points towards long-distance migration as well. Evidence of evaporative fractionation is given in the Thompson diagram (Figure 1a). Note that the oil and condensate samples from the Hammerfest Basin plot in the fractionated area, whereas oil samples from the basin margins do not show signs of the same form of fractionation. The gas to oil ratios (GOR) support this observation with low to medium GOR’s at the margins and high GOR’s in the mid basin.

Cap-Rock Properties

Cap-rock properties play a critical role in the distribution and composition of the investigated petroleum phases. The uplift of the Barents Sea lead to tectonized and brittle cap-rocks on the basin margins (proximal parts), whereas cap-rocks in the deeper distal center of the Basin were unaffected or healed. Cap-rocks in the central part of the Hammerfest Basin tend to hold back gas/condensates, which through expansion push the liquid phases down-dip below closure, allowing remigration. Seals

on the basin margins leak gas/condensates and hold back oil according to the model outlined in (Karlsen and Skeie, 2006; and Ohm et al., 2008).

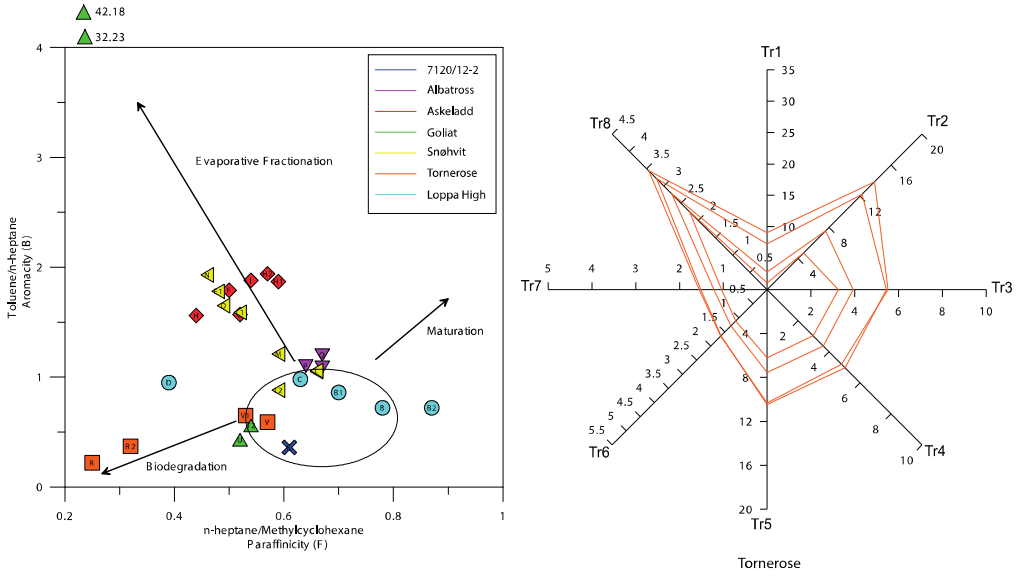

Figure 1 *a) Plot of paraffinicity (F) vs. aromaticity (B) after Thompson (1987) illustrating post-emplacement transformation processes b) Representative C7-OTSD comparing samples from the Tornerose fields. Eight transformation ratios are indicated at the apex of the axes after Halpern (1995).*

Conclusion

LHC alteration parameters are a powerful geochemical tool to reveal post-emplacement alteration. Our study manifests that samples from the proximal margins of the Hammerfest Basin are biodegraded, whereas samples from the distal mid-part of the Basin seem to be unaffected by biodegradation. Locally derived oils and condensates in the Hammerfest Basin are characterized by medium to high toluene contents whereas oils with low toluene content are long-distance migrated in effective carrier systems. The GOR is an efficient tool in determining the composition of petroleums and thus assists in the assessment of cap-rock properties and in-reservoir alteration processes.

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