Untangling the Details of North Sea Crude Oil

Sundberg, Jonas Folke; Jensen, Annette Eva; Feilberg, Karen L.

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Jonas Sundberg, Annette Eva Jensen, Karen L. Feilberg

Reservoir Fluid Characterization

A detailed knowledge of the molecular composition of crude oil and reservoir fluids is fundamental to understand its formation, physical properties and macroscopic behavior. Our objective is to study compositional changes that occur during recovery processes, and gain a better understanding of the underlying mechanisms on a molecular level. Additionally, parameters that correlate to maturity, biodegradation and oil genetics are employed to understand migration patterns. The results will provide input for computational models that links laboratory-scale enhanced oil recovery (EOR) experiments to theory, and ultimately field applications.

Sample Set

Geological parameters were determined for a sample set consisting of 5 oils and 2 condensates from different fields and wells in the Danish North Sea. The condensates are visually distinguishable based on colour, and are lighter than the crude oils which also is evident in the data.

Group-type Analysis

The crude oil samples show typical distributions of saturates and aromatics, with OilS4 having slightly higher content of polar components than the others. The two condensates show a high concentration of light hydrocarbons and monoaromatics, however full SARA distribution was not determined due to lack of method specificity for this type of samples. The oils have low asphaltene content, and due to the high uncertainty associated with asphaltene precipitation at these levels, values are reported as +/-0.5% without further specification. The percentage of resin is back-calculated.

Maturity and Biodegradation

Semi-quantitative parameters used for maturity, biodegradation and oil source correlation are based upon peak area ratios and should be used with care. Issues such as co-elution, and integration parameters affect the data and interpretation and the values must be used in relation with others and as indications, not absolute facts. Compounds were identified by a combination of deconvolution of high-resolution mass data and comparison of retention using a reference sample (NISS N0-1) from known composition.

The alkane distribution is noticeable different between OilS1 and the other samples. Maturity parameters indicate that these oils are of similar thermal maturity, and the difference is likely due to slight biodegradation. Ratios of Pristane/C17 and Phi/C18 add further evidence, as biodegradation affects linear hydrocarbons before branched. OilS2 and OilS3 are the most affected samples. For the condensates, the distribution is shifted towards lighter hydrocarbons as expected. Only very low levels of saturated biomarkers were detected in the condensates, which indicates that evaporative fractionation / gas-condensate migration in the source has taken place.

Geochemical Parameters

The crude oils were separated into saturated and aromatic hydrocarbons using Parametric Split RFN split-phase extraction columns. The RFN columns were conditioned with CH2Cl2, and in fractions, aromatic fractions were combined with identical standards and cleaned over the columns. Isolation was done with a normal boiling range of saturates, using CH2Cl2. Isolated fractions were re-dissolved in pentane or CH2Cl2, avoiding exposure to oxygen in low temperature of −30°C. Each sample was processed and analyzed in two two replicates.

Experimental Details

Solid Phase Extraction

Crude oils and condensates were fractionated into saturated and aromatic hydrocarbons using Parametric Split RFN split-phase extraction columns. The RFN columns were conditioned with CH2Cl2, and in fractions, aromatic fractions were combined with identical standards and cleaned over the columns. Isolation was done with a normal boiling range of saturates, using CH2Cl2. Isolated fractions were re-dissolved in pentane or CH2Cl2, avoiding exposure to oxygen in low temperature of −30°C. Each sample was processed and analyzed in two two replicates.

NMR

More contemporary analysis was carried out using an Agilent 500 MHz spectrometer at a steady 500.13 MHz, 15 cm probe, 5 mm broad band probe using a temperature-gated proton decoupled pulse sequence, condensates were separated in 30 min at 0.0002 / -0.002 ppm. Solid-state spectra were acquired using a Hahn enhancement sequence. Spectra and integrals are presented using an ‘average’ number of scans. Samples were heated to 150°C in a probe. Prior to analysis, samples were degassed under a vacuum for 24 h, then transferred to an NMR probe head, heated to 150°C, then cooled to 90°C. Spectra were collected after 1 h. Spectra were post-processed using Astra software.

GC-MS (HRAM)

All samples were analyzed on a Thermo Trace GC ultrastar with splitless inlet and a TSQ Quantum Ultra mass spectrometer. Samples were analyzed at 250°C using a CP-Sil 88 column (0.25 mm x 30 m, 0.25μm). The oven temperature was increased from 40°C to 300°C at 10°C/min. The total time was 5 min. Samples were injected using a splitless injection method. The GC-MS was operated in electron impact mode and the mass spectrometer was operated in the full-scan mode with a scan range of m/z 29 to 500. Quantitation was done using a sequence of standard solutions, each with a different concentration. The concentrations were determined from the difference between the areas of the parent and daughter ions. The response factors were determined using a series of polynuclear hydrocarbons and polycyclic aromatic hydrocarbons. Samples were analyzed under headspace analysis of crude oil. The GC-MS sample was operated at a temperature of 270°C and 140°C.

Quality Control

The crude oil of Inner Moray Field (0001B-01 in UKCS STM 275) was used as internal quality control during the isolation and analysis.