Datashare 126

Timing and origin of multiple petroleum charges in the Solveig oil field, Norwegian North Sea: A rhenium-osmium isotopic study

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Table S1. Analytical Results: Bitumen Content, Asphaltene-Maltene Separation, Re-Os Isotopes, Rock-Eval Data, and Trace Metal Concentration (Excel spreadsheet)

Table S2. Studied Bitumen and Oil Intervals and Their Asphaltene and Maltene Contents

Well/Sample	Depth in Well, m	Bitumen, wt. %	ASPH Measured, wt. %	MALT Measured, wt. %	MALT-Missing Calculated, wt. %	MALT Calculated, wt. %
Well 16/4-8S						
Crude oil	–	–	5.5	72.7	21.8	94.5
Well 16/4-6S						
Crude oil (A)	1960.6–1980.6	–	0.8	61.1	38.1	99.2
Crude oil (B)	1960.6–1980.6	–	0.7	59.0	40.3	99.3
Oil leg 2	1958.135–1958.260	0.53	2.0	96.4	1.6	98.0
Oil leg 1	1962.575–1962.593	0.36	–	–	–	–
Transition 1	1979.637–1979.670	0.59	13.1	85.7	1.1	86.9
Tar mat 1	1987.255–1987.278	2.74	65.1	42.5	–7.6	34.9
Tar mat 2	1992.506–1992.638	3.63	57.9	38.2	3.9	42.1
Residual 4	2001.480–2001.395	0.65	15.7	81.6	2.8	84.3
Residual 2	2012.760–2012.862	0.74	12.2	85.8	2.0	87.8
Residual 1	2012.862–2012.880	0.75	–	–	–	–
Residual 3	2016.75–2016.83	0.70	13.6	86.9	–0.5	86.4

Dichloromethane-methanol–extracted bitumen content expressed as weight percent of the rock. Asphaltene (ASPH) and maltene (MALT) fractions, separated by n-heptane, are expressed as weight percent from the oils and bitumens. Missing MALT are material lost/evaporated during sample handling calculated as 100% – (ASPH + measured MALT). ASPH were separated from two bottles of crude oil from well 16/4-6S labeled A and B, respectively. Long dashes (–) in the data table mark data that are not applicable or not available for specific samples.

Table S3. Rhenium-Osmium Regressions for Solveig Samples

Material/ Interval	Age, Ma	2σ	Initial $^{187}Os/^{188}Os$	2σ	Age Model	MSWD	*n*
Well 16/4-8S – crude oil							
Crude oil	−227	110	0.5919	0.0068	3	11.7	11
Well 16/4-6S – crude oil							
Bottle A	−1	46	0.6199	0.0050	1	0.46	5
Bottle B	−29	48	0.6210	0.0055	1	0.22	3
***Both bottles	−18	33	0.6209	0.0037	1	1.4	8
Well 16/4-6S – bitumen							
Oil leg 2	−18	16	0.6124	0.0061	1	0.29	5
***Oil leg 2 and 1	−8	12	0.6134	0.0055	1	0.34	6
***Transition 1	40	10	0.6008	0.0044	1	2.0	4
Tar mat 1	149	180	0.602	0.043	3	51	7
Tar mat 2	89	66	0.620	0.012	3	22	9
Tar mat 1 and 2	100	64	0.617	0.013	3	35	16
Residual 4	13	21	0.598	0.014	3	8.4	7
Residual 2	64	30	0.549	0.014	3	19	7
Residual 3	23	20	0.573	0.012	3	6.2	8
***Residual 4, 2, 1, and 3	39	23	0.569	0.013	3	59	23

Model 1 ages are calculated when assigned errors for individual data points accommodate all analytical scatter (Ludwig, 2003). Model 3 ages assume that scatter is because of a combination of assigned uncertainties plus an unknown but normally distributed variation in the initial $^{187}Os/^{188}Os$ (Ludwig, 2003). The four representative isochrons discussed in the main text are marked by ***.

Abbreviations: MSWD = mean square of weighted deviates; *n* = number of Re-Os analyses used for a particular regression.

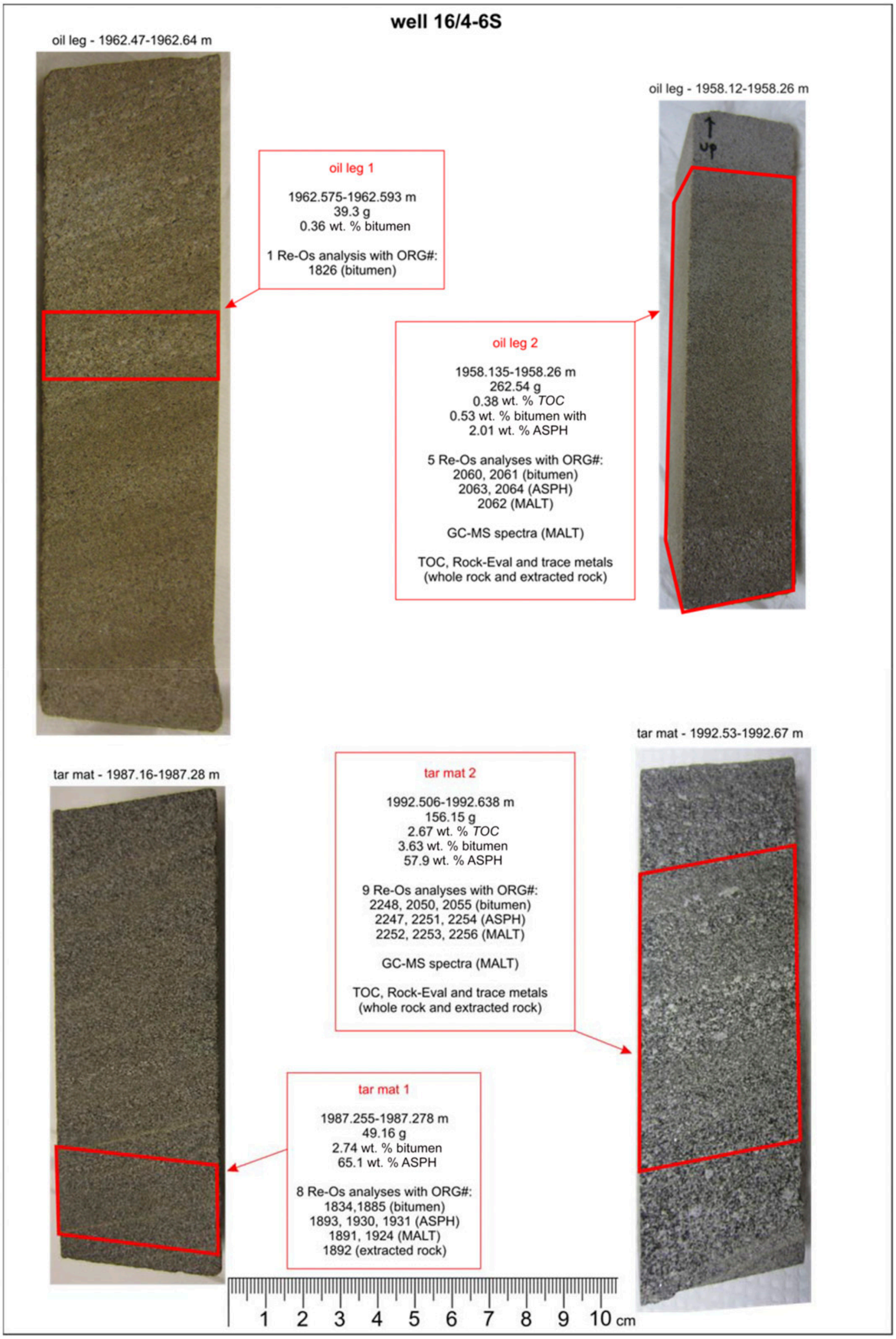
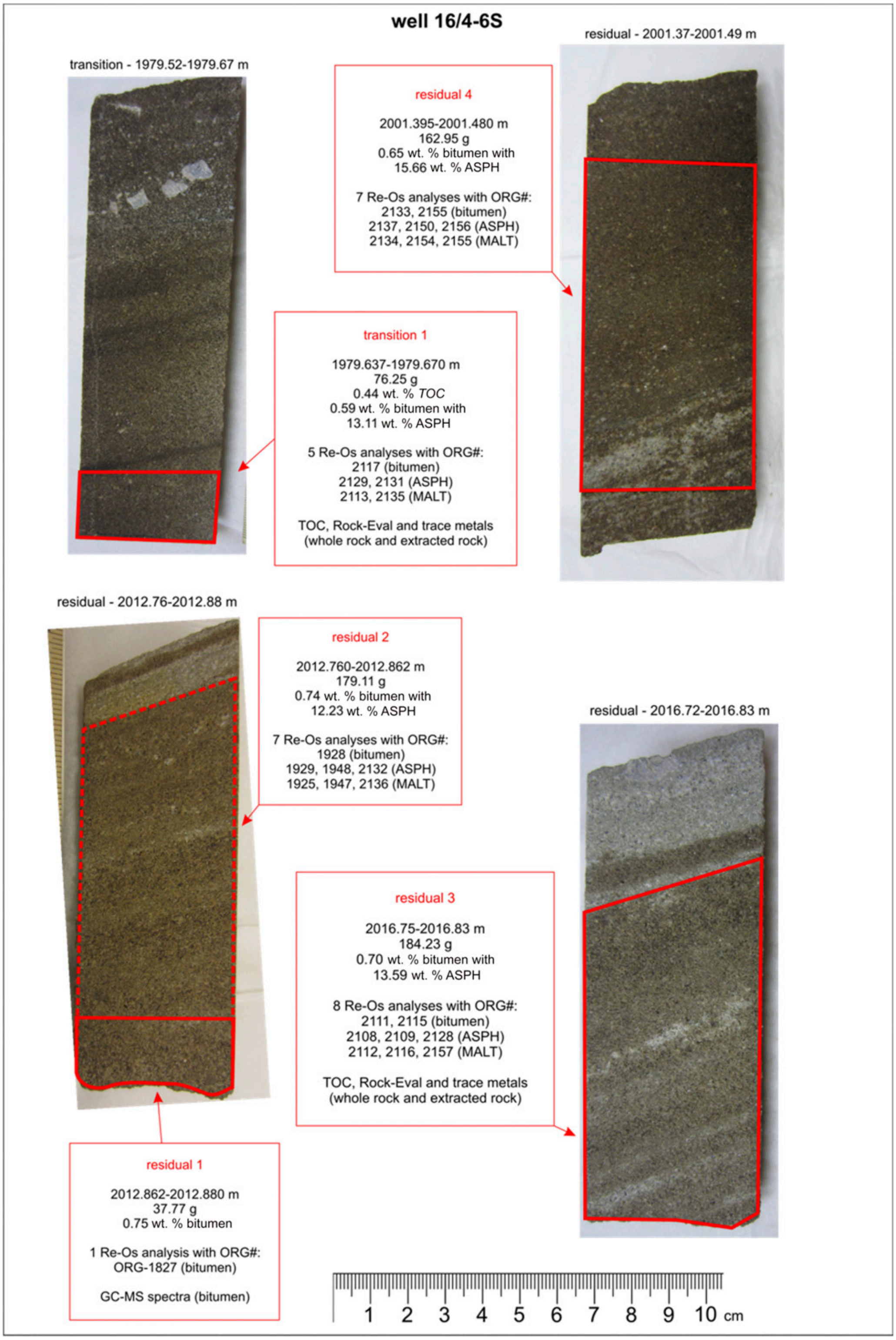


Figure S1. Photographs of drill core intervals from well 16/4-6S, showing the type and number of analyses for each studied vertical interval from the four main reservoir zones (oil leg, transition, tar mat, and residual; see also Figure 2 in the main text), the weight percent of total organic carbon (*TOC*), the amount of hydrocarbons (bitumen) extracted with dichloromethane-methanol, and the asphaltene (ASPH) and maltene (MALT) contents of extracted bitumen. All numerical data (Re-Os, Rock-Eval, bitumen content, ASPH-MALT content, and trace metals) are provided in the supplementary Excel data table. GC-MS = gas chromatography–mass spectrometry; ORG = sample label (e.g., ORG-1834 and ORG-1885 are two different samples).


well 16/4-6S

transition - 1979.52-1979.67 m

residual - 2001.37-2001.49 m

residual 4

2001.395-2001.480 m
162.95 g
0.65 wt. % bitumen with
15.66 wt. % ASPH

7 Re-Os analyses with ORG#:
2133, 2155 (bitumen)
2137, 2150, 2156 (ASPH)
2134, 2154, 2155 (MALT)

transition 1

1979.637-1979.670 m
76.25 g
0.44 wt. % *TOC*
0.59 wt. % bitumen with
13.11 wt. % ASPH

5 Re-Os analyses with ORG#:
2117 (bitumen)
2129, 2131 (ASPH)
2113, 2135 (MALT)

TOC, Rock-Eval and trace metals
(whole rock and extracted rock)

residual - 2012.76-2012.88 m

residual 2

2012.760-2012.862 m
179.11 g
0.74 wt. % bitumen with
12.23 wt. % ASPH

7 Re-Os analyses with ORG#:
1928 (bitumen)
1929, 1948, 2132 (ASPH)
1925, 1947, 2136 (MALT)

residual - 2016.72-2016.83 m

residual 3

2016.75-2016.83 m
184.23 g
0.70 wt. % bitumen with
13.59 wt. % ASPH

8 Re-Os analyses with ORG#:
2111, 2115 (bitumen)
2108, 2109, 2128 (ASPH)
2112, 2116, 2157 (MALT)

TOC, Rock-Eval and trace metals
(whole rock and extracted rock)

residual 1

2012.862-2012.880 m
37.77 g
0.75 wt. % bitumen

1 Re-Os analysis with ORG#:
ORG-1827 (bitumen)

GC-MS spectra (bitumen)

Figure S1. Continued.

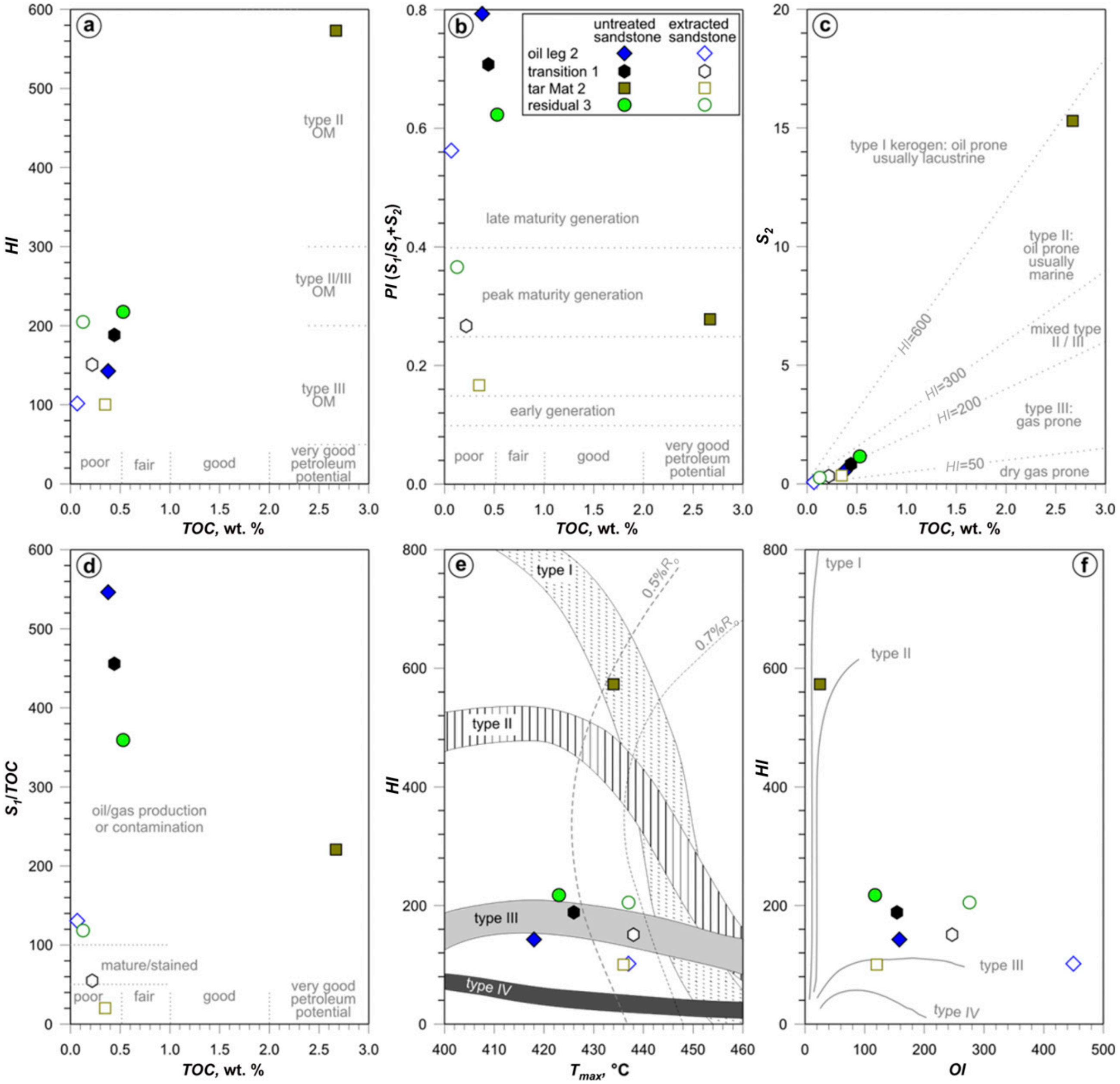


Figure S2. (A–F) Key Rock-Eval parameters describing the quantity, quality, and thermal maturation of organic matter (OM) in untreated reservoir sandstones and extracted reservoir sandstones (bitumen removed by dichloromethane-methanol [DCMM]) from well 16/4-6S, Solveig oil field. Rock-Eval parameters include S_1 (milligrams of free hydrocarbons per gram of rock), S_2 (milligrams of hydrocarbons produced during thermal cracking of kerogen per gram of rock), S_3 (milligrams of CO_2 per gram of rock), temperature of maximum hydrocarbon generation during pyrolysis (T_{max}), and key derivative ratios such as the hydrogen index (*HI*) (milligrams of S_2 per gram of total organic carbon [*TOC*]), oxygen index (*OI*) (milligrams of S_3 per gram of *TOC*) and production index (*PI*) $S_1/(S_1 + S_2)$. Oil and bitumen infiltration is marked by high S_1 and high S_1/TOC ratios. See discussion in Demaison et al. (1983), Peters and Cassa (1994), Cornford (1998), and Jarvie (2012) for a more-detailed description of these parameters and the significance of boundaries between fields on the diagrams. Maturation trends for the four main types of OM (E) and the T_{max}-*HI*-vitrinite reflectance (%R_o) relations are typical for source rocks from the North Sea (Cornford, 1998). The low amount of hydrocarbons in two DCMM-extracted rocks from the oil leg and residual intervals did not allow accurate T_{max} measurements; T_{max} values for these two samples were arbitrarily set to 437°C (E).

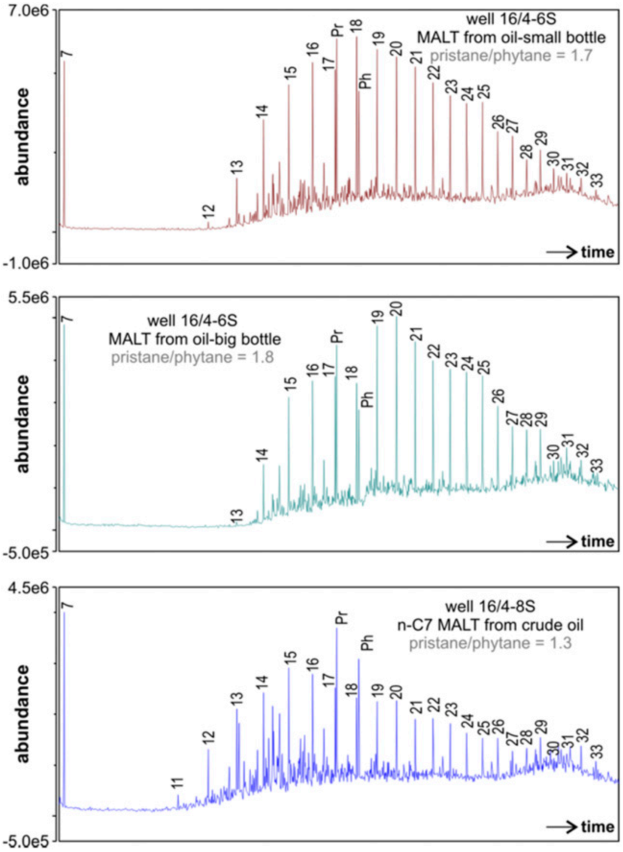


Figure S3. Additional gas chromatography–mass spectrometry (GC-MS) profiles for maltene (MALT) samples from crude oils from wells 16/4-6S and 16/4-8S, with carbon numbers of the n-alkanes indicated above their respective peaks. Peak ratios are calculated from integrated background corrected peak areas. Evaporation during prolonged asphaltene precipitation procedures explains the depletion of lighter compounds compared with the corresponding crude oil spectra presented in the main manuscript. The presence of n-heptane (n-C7) in these MALT samples reflects incomplete evaporation of the n-heptane solvent used for asphaltene precipitation.

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