DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 2005/29

Ophelia-1 well: Petroleum Geochemistry

Rock-Eval/TOC screening and vitrinite reflectance data from the Mesozoic succession of the Ophelia-1 well, Danish Central Graben

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Released 27.04.2006

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Introduction

The Ophelia-1 well was drilled by DONG E&P a/s in the Danish North Sea (N 56°05'47.97" E 03°59'53.04") in 2003 (fig. 1).

The well was spudded on August 16th 2003, plugged and abandoned with oil shows on October 28th 2003. The well reached its total depth in Rotliegend strata at 4977m TVD bRT (loggers depth).

The well was drilled using Versavert® drilling mud additive, which is known to cause problems for geochemical analyses, in particular if the samples have been stored for some time after drilling. The present study was carried out to test if useful petroleum geochemistry data could be obtained from Versavert®-contaminated wells if samples were analysed shortly after collection.

Methods

All samples analysed were wet ditch cuttings (bagged cuttings). In order to ease removal of drilling mud and additives, samples were left to soak in water plus detergent (standard perfume-free dish-washing detergent) for up to several days, and subsequently rinsed under lukewarm water on a 63 micron brass sieve. The samples were left to dry at room temperature in a fumehood. Obvious contaminants and bit chips (magnetic) were removed manually and by magnet, respectively, and the 1-4 mm cutting fraction was collected for further treatment. Sample aliquots for vitrinite reflectance analysis were collected directly from 1-4 mm fraction, whereas aliqouts for Rock-Eval/TOC screening were ground to <250 micron, and extracted for 2*8h using soxhlet instrumentation and dichloromethane+methanol (93+7 vol./vol.) as solvent.
Samples for vitrinite reflectance were mounted in epoxy resin, ground, polished and measured following standard procedures.
Rock-Eval screening pyrolysis was carried out using a Rock-Eval 6 instrument, following standard procedures. Total Carbon (TC) and Total Sulphur (TS) as well as Total Organic Carbon (TOC) contents were determined using a LECO CS-200 instrument. TOC was determined after removal of carbonates by HCl-treatment.

Results

All results are listed in table 1. A scrutiny of individual pyrograms shows that the S1 fraction, roughly corresponding to free hydrocarbons, is more or less absent, and with the exception of a few samples, S2-peaks are regular and unimodal, indicating that the cleaning procedure has been effective and that the contamination has been removed or at least reduced beyond direct recognition, albeit along with any indigenous hydrocarbons present. Hence, the data produced are judged to be largely reliable, although minor amounts of contaminant may still remain in some samples, potentially resulting in slightly elevated S2 recordings.

Plots of TOC, TS, S2 and Hydrogen index versus depth are shown in fig 2. High values of Hydrogen Index in the Cromer Knoll Group are technical artifacts arising from coinciding low, and thus poorly defined, values of TOC and S2. The Farsund Formation generally show high values of both TOC (up to 7.7%) and S2 (up to 35 kg/T), and consequently, high Hydrogen Indices, up to 618, however with the majority of the samples yielding values in the range 200-300. The sulphur content is somewhat higher than expected, probably caused by abundant pyrite. The Bo Member of the Farsund Formation (previously known as the ”hot unit”) can be clearly identified by elevated levels of TOC and S2 in the interval 4422-4455 m.

Maturity assessment using both vitrinite reflectance and Tmax, consistenty indicate that the Farsund Formation is well within the oil window (fig. 3). Vitrinite reflectance data show slightly higher values than expected. Both sample preparation and measurement proved very difficult due to a combination of contaminants and very small drill cutting size produced by the bit and drilling technique used, and some data scatter is not surprising. The data show a rather poorly constrained slightly increasing trend through the succession deeper than the Cromer Knoll Group, with values increasing from app. 0.80 to slightly more than 1.0 at TD. Over the same interval Tmax data show a very slightly increasing, or nearly constant but poorly constrained trend with values generally beween 440°C and 448°C, pointing to active generation (fig. 4). A few samples show outlying low values of Tmax, probably indicating the presence of residual Versavert®. Based on the S2 and Hydrogen Index values recorded, the Farsund Formation in the Ophelia-1 well retains some petroleum generation potential, despite relatively high levels of thermal maturity indicated by both vitrinite reflectance and Tmax data.

Conclusions

- The Farsund Formation in the Ophelia-1 well is mature and well within the oil generative window.
- Despite the relatively high levels of thermal maturity, some petroleum generation potential remains
- It is possible to eliminate most contamination arising from the use of Versavert® additives to the drilling mud, and to obtain useful organic geochemical screening data if sample storage time is keeps minimal.
- The cleaning procedure is however very labour-intensive and time consuming
- From previous studies it is, however, known that the use of Versavert® is absolutely detrimental to biological marker studies.

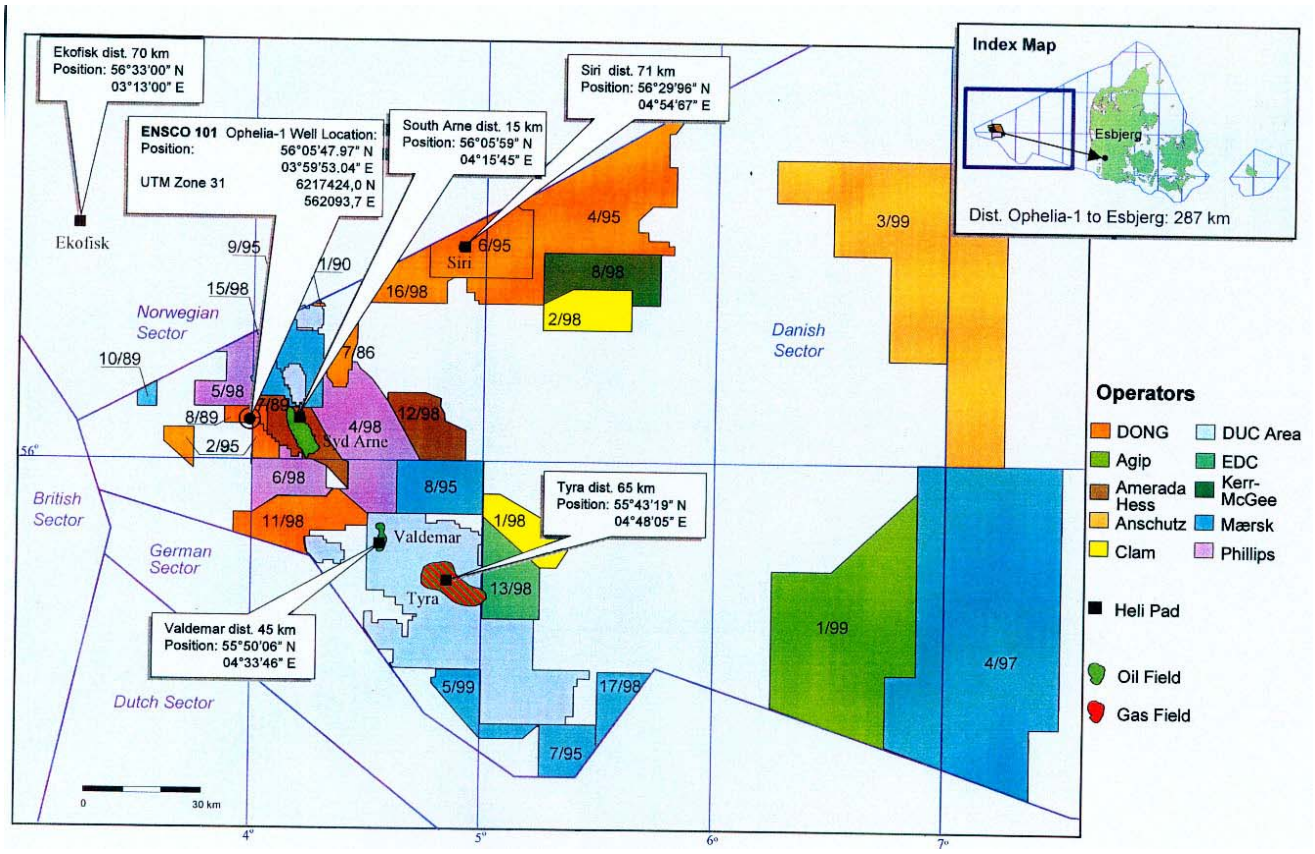

Fig. 1 Location map

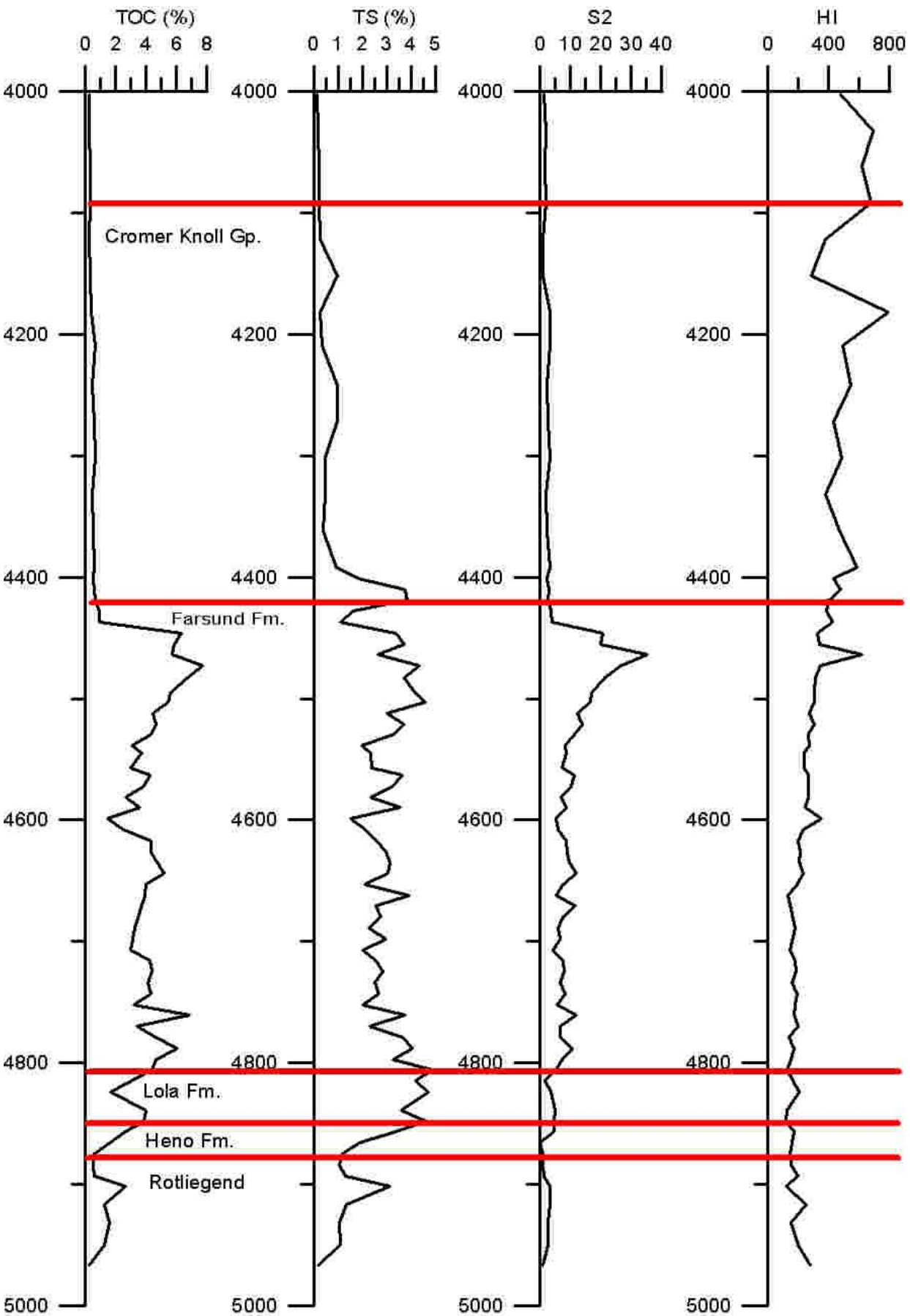
TOC (%)
0 2 4 6 8
TS (%)
0 1 2 3 4 5
S2
0 10 20 30 40
HI
0 400 800
4000
4200
4400
4600
4800
5000
Cromer Knoll Gp.
Farsund Fm.
Lola Fm.
Heno Fm.
Rotliegend

Fig. 2

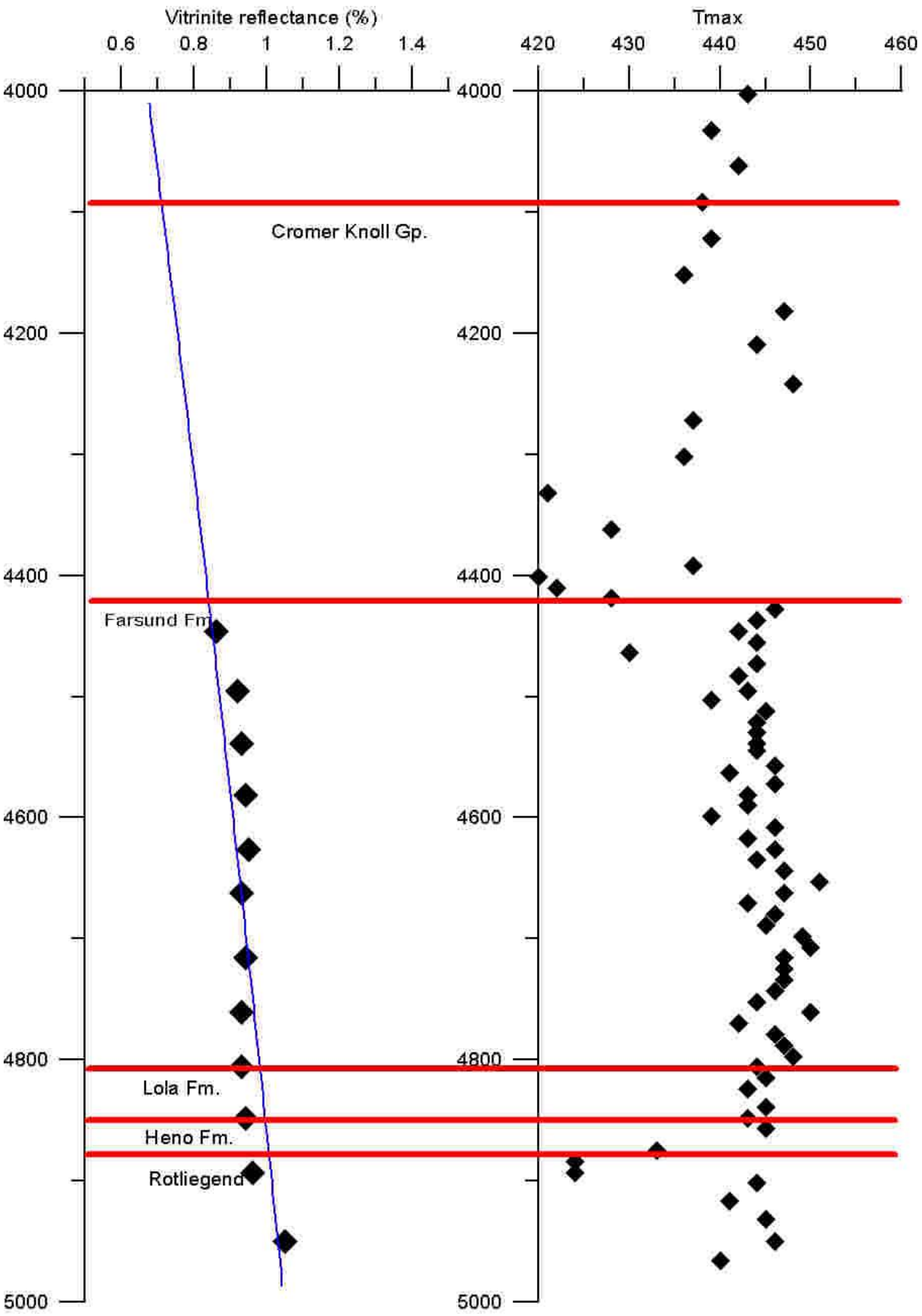
Vitrinite reflectance (%)
0.6
0.8
1
1.2
1.4
Tmax
420
430
440
450
460
4000
4200
4400
4600
4800
5000
Cromer Knoll Gp.
Farsund Fm.
Lola Fm.
Heno Fm.
Rotliegend

Fig. 3

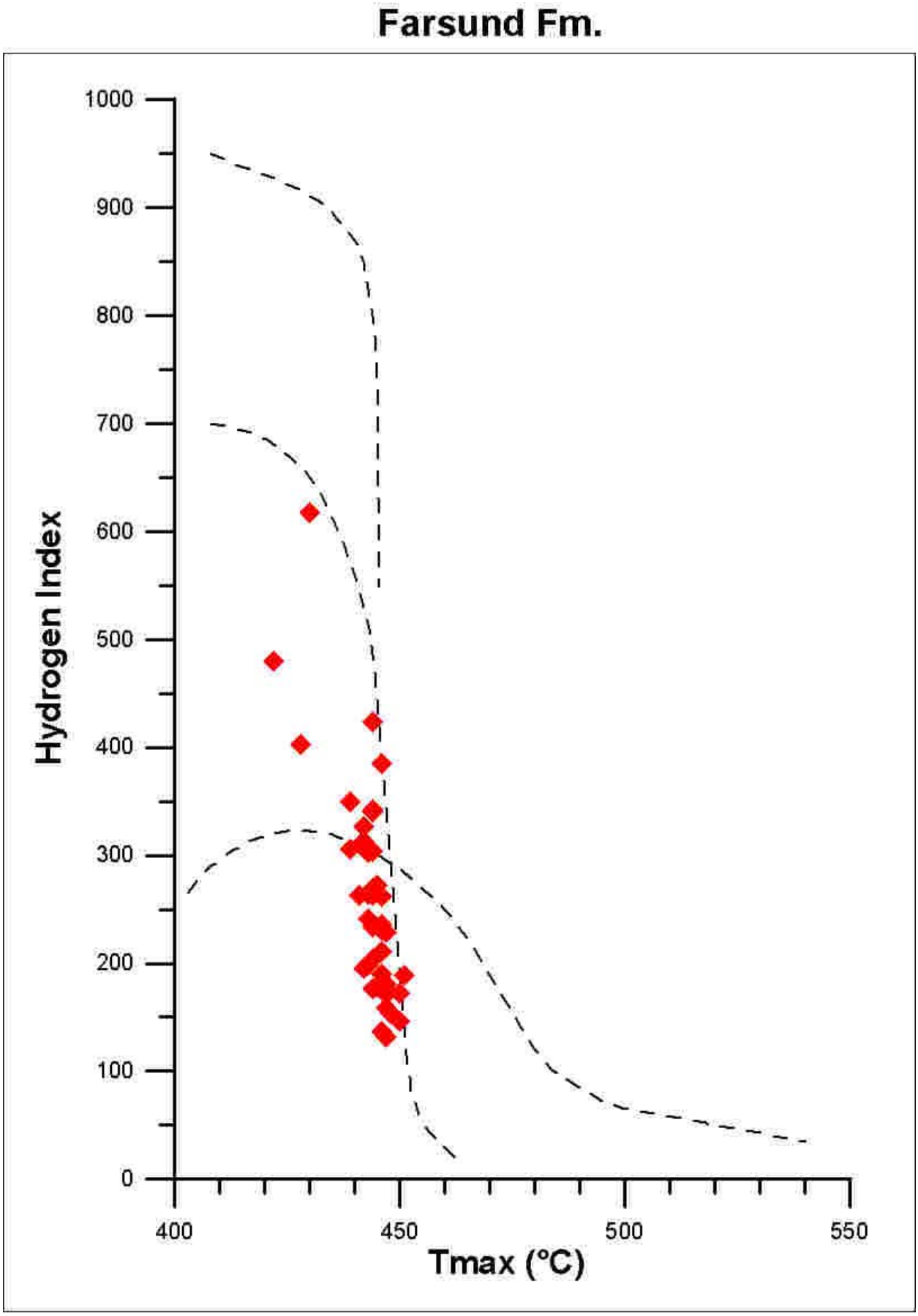
Farsund Fm.
Hydrogen Index
1000
900
800
700
600
500
400
300
200
100
0
400
450
500
550
Tmax (°C)

Fig. 4

Table 1

Screening data

Arbejdsnummer **2004026**

Materiale: cuttings ekstraherede prøver

Lokation: Ophelia-1

Dato: 12-05-2005

Laboratorienummer	Dybde bund (m)	TOC %	TC %	TS %	Tmax (°C)	S1 (mg/g)	S2 (mg/g)	HI	PI	PC	Ro	n
10109	4002	0,25	8,61	0,12	443	0,25	1,21	478	0,17	0,12	n.d.	0
10110	4032	0,27	8,01	0,18	439	0,21	1,84	694	0,10	0,17		
10111	4062	0,27	8,23	0,21	442	0,25	1,67	621	0,13	0,16		
10112	4092	0,30	9,61	0,23	438	0,10	2,01	674	0,05	0,18	n.d.	0
10113	4122	0,27	8,20	0,25	439	0,08	1,00	375	0,07	0,09		
10114	4152	0,29	5,75	0,95	436	0,09	0,81	283	0,10	0,07		
10115	4182	0,40	9,86	0,25	447	0,11	3,19	790	0,03	0,27	n.d.	0
10116	4209	0,64	9,46	0,33	444	0,09	3,13	489	0,03	0,27		
10117	4242	0,41	8,17	0,96	448	0,08	2,25	545	0,03	0,19		
10118	4272	0,55	6,77	0,96	437	0,11	2,37	430	0,04	0,21	n.d.	0
10119	4302	0,64	7,42	0,45	436	0,14	3,12	488	0,04	0,27		
10120	4332	0,45	8,25	0,46	421	0,08	1,70	379	0,04	0,15		
10121	4362	0,49	7,48	0,37	428	0,09	2,31	471	0,04	0,20	n.d.	0
10122	4392	0,56	8,04	0,93	437	0,12	3,26	583	0,04	0,28		
10123	4401	0,53	6,40	1,84	420	0,10	2,28	432	0,04	0,20		
10124	4410	0,60	4,79	3,77	422	0,14	2,86	480	0,05	0,25	n.d.	0
10125	4419	0,61	6,86	3,83	428	0,10	2,44	403	0,04	0,21		
10126	4428	0,88	8,32	1,63	446	0,09	3,40	386	0,03	0,29		
10127	4437	0,93	9,36	1,09	444	0,10	3,96	424	0,02	0,34		
10128	4446	6,30	6,76	3,38	442	0,13	20,59	327	0,01	1,72	0,86	59
10129	4455	5,84	6,50	3,73	444	0,14	19,87	340	0,01	1,66		
10130	4464	5,69	7,38	2,62	430	2,12	35,12	618	0,06	3,09		
10131	4473	7,72	8,44	4,34	444	0,63	26,39	342	0,02	2,24		
10132	4483	6,74	7,62	3,72	442	0,21	21,08	313	0,01	1,77		
10133	4495	5,58	7,30	4,17	443	0,23	16,90	303	0,01	1,42	0,92	33
10134	4503	5,42	6,53	4,57	439	0,33	16,55	305	0,02	1,40		
10135	4512	4,44	5,64	3,03	445	0,17	12,08	272	0,01	1,02		
10136	4521	4,61	6,00	3,72	444	0,16	13,98	303	0,01	1,17		
10137	4530	4,28	5,63	3,27	444	0,11	11,25	263	0,01	0,94		
10138	4539	3,06	6,86	1,98	444	0,12	8,24	269	0,01	0,69	0,93	19
10139	4545	3,69	4,88	2,32	444	0,11	8,64	234	0,01	0,73		
10140	4557	2,98	5,35	2,38	446	0,09	7,03	236	0,01	0,59		
10141	4563	4,21	5,33	3,63	441	0,15	11,05	263	0,01	0,93		
10142	4572	3,85	5,10	3,28	446	0,14	10,09	262	0,01	0,85		
10143	4581	2,64	5,51	2,35	443	0,12	6,99	265	0,02	0,59	0,94	13
10144	4590	3,60	5,18	3,54	443	0,15	8,69	242	0,02	0,73		
10145	4599	1,44	7,96	1,49	439	0,15	5,03	349	0,03	0,43		
10146	4608	2,49	6,28	2,15	446	0,08	5,73	230	0,01	0,48		
10147	4617	4,28	5,96	2,60	443	0,10	8,47	198	0,01	0,71		
10148	4626	4,27	6,17	2,98	446	0,09	9,01	211	0,01	0,76	0,95	26
10149	4635	4,73	7,21	3,11	444	0,10	9,61	203	0,01	0,81		
10150	4644	5,17	7,72	3,06	447	0,12	11,85	229	0,01	0,99		
10151	4653	3,95	5,94	2,10	451	0,06	7,45	189	0,01	0,62		
10152	4662	3,92	5,04	3,92	447	0,07	5,19	132	0,01	0,44	0,93	17
10153	4671		6,09	2,55	443	0,60	11,59		0,05	1,01		
10154	4680		5,41	2,76	446	0,07	7,43		0,01	0,62		
10155	4689	3,24	4,93	2,24	445	0,05	5,80	179	0,01	0,49		

10156	4698		4,32	2,95	449	0,06	6,49		0,01	0,54		
10157	4707	2,96	5,37	2,00	450	0,04	4,33	146	0,01	0,36		
10158	4716	4,24	6,36	2,55	447	0,09	7,50	177	0,01	0,63	0,94	17
10159	4725	4,39	7,09	2,85	447	0,09	7,93	181	0,01	0,67		
10160	4734	4,11	6,81	2,52	447	0,08	6,50	158	0,01	0,55		
10161	4743	4,31	7,66	2,69	446	0,12	8,18	190	0,01	0,69		
10162	4752	3,16	7,59	2,03	444	0,11	5,58	176	0,02	0,47		
10163	4761	6,86	9,05	3,75	450	0,14	11,80	172	0,01	0,99	0,93	10
10164	4770	3,40	8,74	2,31	442	0,28	6,63	195	0,04	0,57		
10165	4779	4,65	7,51	3,67	446	0,08	6,36	137	0,01	0,53		
10166	4788	6,06	8,97	4,04	447	0,35	10,35	171	0,03	0,89		
10167	4797	4,65	8,17	3,25	448	0,17	7,12	153	0,02	0,61		
10168	4806	4,36	7,11	4,89	444	0,10	5,26	121	0,02	0,44	0,93	14
10169	4815		6,48	4,18	445	0,03	1,57		0,02	0,13		
10170	4824	1,67	7,14	4,70	443	0,12	3,40	204	0,03	0,29		
10171	4839	3,96	8,54	3,57	445	0,08	4,86	123	0,02	0,41		
10172	4848	3,82	6,69	4,62	443	0,07	4,43	116	0,02	0,37	0,94	27
10173	4857	2,61	6,81	3,37	445	0,05	4,47	171	0,01	0,38		
10174	4866		6,32	1,86		0,23	0,00			0,02		
10175	4875	0,57	2,05	1,17	433	0,05	0,81	142	0,06	0,07		
10176	4884	0,51	2,70	1,07	424	0,03	0,76	149	0,04	0,07		
10177	4893	0,59	1,95	1,30	424	0,09	1,17	198	0,07	0,10	0,96	3
10178	4902	2,66	7,68	3,12	444	0,13	3,18	119	0,04	0,27		
10179	4917	1,24	5,04	1,33	441	0,13	3,10	251	0,04	0,27		
10180	4932	1,58	5,47	1,06	445	0,07	2,41	153	0,03	0,21		
10181	4950	1,27	6,00	1,07	446	0,05	2,51	198	0,02	0,21	1,05	26
10182	4966	0,30	3,13	0,23	440	0,05	0,82	270	0,06	0,07		